AIR SILENCER

In-Line and 6V Engines

The air silencer (Fig. 1) is attached to the intake side of the blower housing to reduce the sound level of the air entering the blower.

A perforated sheet metal partition divides the silencer into two sections. The engine side of the partition and the outer shell forms an air duct the entire length of the silencer. Air enters this duct from both ends and flows to the blower intake opening at the center. The area between the partition and the outer side of the silencer is filled with sound absorbent, flame-proof, felted cotton waste.

An air intake (blower) screen is used between the air silencer and the blower housing to prevent foreign objects from entering the blower.

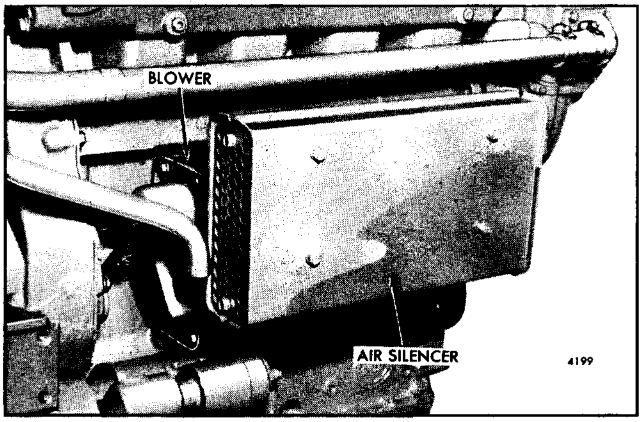

Fig. 1 - Air Silencer Mounted on In-Line Engine

Remove and Install Air Silencer

While no servicing is required on the air silencer, it may be necessary at times to remove it to clean or replace the blower screen or to perform other service operations.

1. Support the silencer and remove the attaching bolts and lock washers. Then remove the silencer and the blower screen. On the 6V engine, the air silencer adaptor must be removed to gain access to the blower screen.

2. Clean the blower screen with fuel oil and dry it with compressed air.

3. Place the blower screen on the 6V engine blower housing and install the air silencer adaptor.

4. Place the lock washers over the bolts and slide the bolts through the bolt holes in the silencer.

5. Place the blower screen (In-line engines) over the projecting bolts and position the silencer against the blower housing. Then tighten the bolts.

8V Engine

The air silencer (Fig. 2) is mounted on a support attached to the flywheel housing. The air outlet end is attached to the air inlet housing with a hose and clamps. An air filter element of polyurethane foam is used on the current air silencer inlet screen.

Remove Air Silencer

While no servicing is required on the air silencer, it may be necessary to remove it to perform other service operations.

1. Remove the air filter element, if used.

2. Loosen the clamps and slide the hose back on the air inlet housing.

3. Loosen the lower bolts which secure the mounting straps to the silencer support bracket. Then, while holding the silencer, remove the bolts and washers. Remove the silencer.

4. If necessary, remove the breather pipe clip from the silencer mounting strap. Then remove the bolts and washers and remove the mounting straps.

Install Air Silencer

1. If previously removed, attach the mounting straps to the top of the silencer support bracket with two 7/16" -14 bolts, washers and nut (one bolt threads into the flywheel housing). Do not tighten the bolts at this time.

2. Position the air silencer under the mounting straps and install the 3/8" -16 bolts, lock washers, washers and nuts. Do not tighten the bolts at this time.

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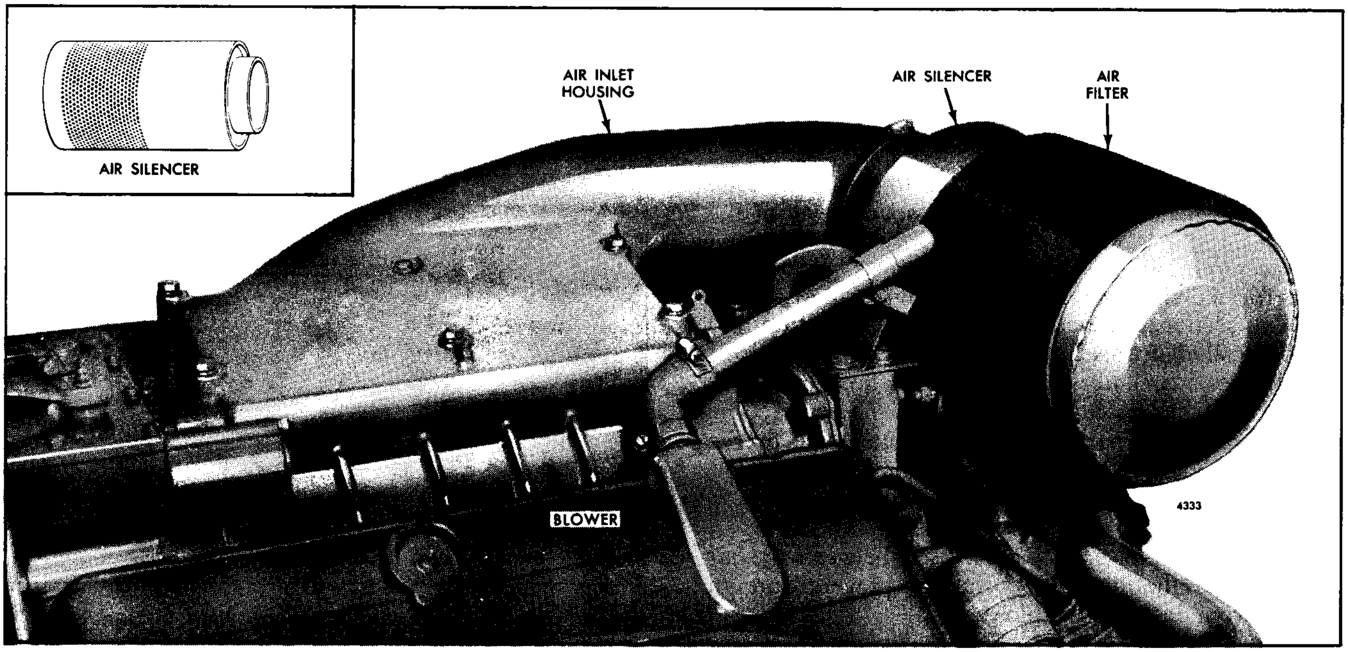

Fig. 2 - Air Silencer Mounted on 8V Engine

3. Align the silencer with the air inlet housing, slide the hose in place and tighten the clamps.

4. Tighten the mounting strap bolts at this time.

5. Install the breather pipe clip.

6. Slide the air filter element (if used) over the silencer air inlet screen.

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AIR SHUTDOWN HOUSING

The air shutdown housing on the In-line engine is mounted on the side of the blower, while the V-type engine has the air shutdown housing mounted on the top of the blower. The housing serves as a mounting for the air cleaner or the ducting for an air cleaner mounted away from the engine. The air shutdown housing contains an air shutoff valve that shuts off the air supply and stops the engine whenever abnormal operating conditions require an emergency shut down.

Remove Air Shutdown Housing

1. Disconnect and remove the air ducts between the air cleaner and the air shutdown housing.

2. Disconnect the control wire from the air shutoff 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.

> **NOTE:** The bolts that retain the air inlet housing to the blower are of different lengths. Mark the location of each bolt to insure proper installation later.

4. Cover the blower opening to prevent dirt or foreign material from entering the blower.

Disassemble Air Shutdown Housing

Refer to Fig. 1 and disassemble the air shutdown housing as follows:

1. Remove the pin from the end of the shutdown shaft. Then, remove the washer from the shaft and the seal ring from the housing.

2. Remove the two pins that secure the air shutoff valve to the shaft.

3. Remove the bolt, lock washer and plain washer which attach the latch to the housing. , Then remove the latch, latch spring and spacer.

4. Note the position of the air shutoff valve spring and the valve (Fig. 2). Then, withdraw the shaft from the housing to release the valve and the spring. Remove the valve and spring and the seal ring from the housing.

5. Remove the cam pin handle and withdraw the cam from the shaft.

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 shutoff 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, using a 1/8" diameter drill, at the time a new service shaft or air shutoff valve(s) is assembled. The valve(s) must be in the same plane within .030" when in the stop position (flush with the housing face). Refer to Figs. 1 and 2 and proceed as follows:

1. Place the valve(s) and spring in position in the housing and slip the shaft in place (Fig. 2. The shaft must extend .700" from the side of the housing where the shutdown latch is assembled.

2. Install a new seal ring at each end of the shaft. Be sure the seals are seated in the counterbores of the housing.

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 (bushing), spring and latch to the shutdown housing with the 1/4"-20 bolt, lock washer and plain washer.

   a. Align the notch on the bushing with the notch on the latch and lock the bushing in this position.

   b. Install the pins in the valve(s) to retain it to the shaft with the cam release latch set and the valve(s) in the run position.

   c. Level the valve(s) in the shutdown position.

   d. Adjust the bushing so the valve(s) contacts the housing when the cam release latch is set.

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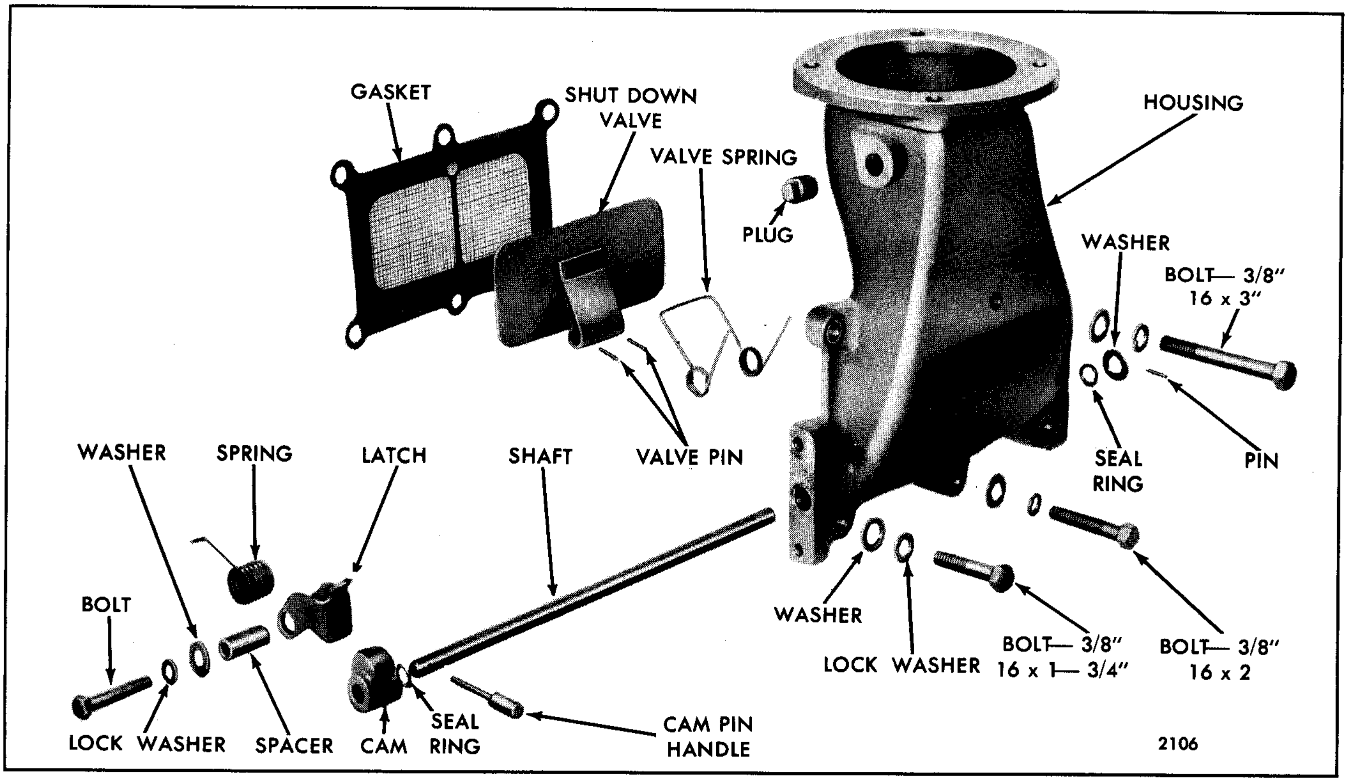

Fig. 1 - Typical In-Line Engine Air Shutdown Housing Details and Relative Location of Parts

Install Air Shutdown Housing

(In-line Engines)

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.

2. Refer to Figs. 1 and 3 and secure the air shutdown housing to the blower with bolts, washers and lock washers as follows:

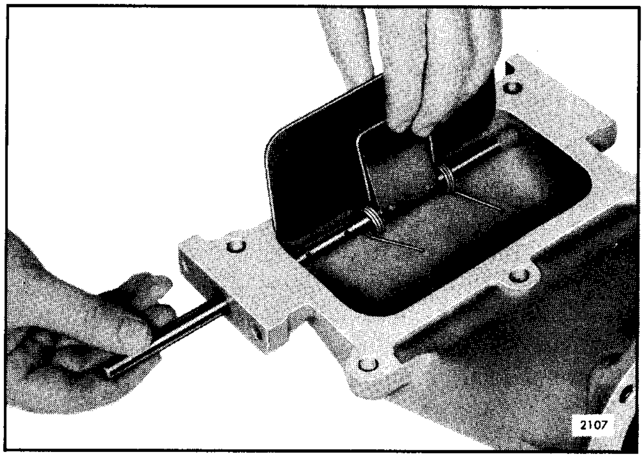

Fig. 2 - Installing Air Shutoff Valve Spring and Valve

a. Install and finger tighten the six attaching bolts (Fig. 3).

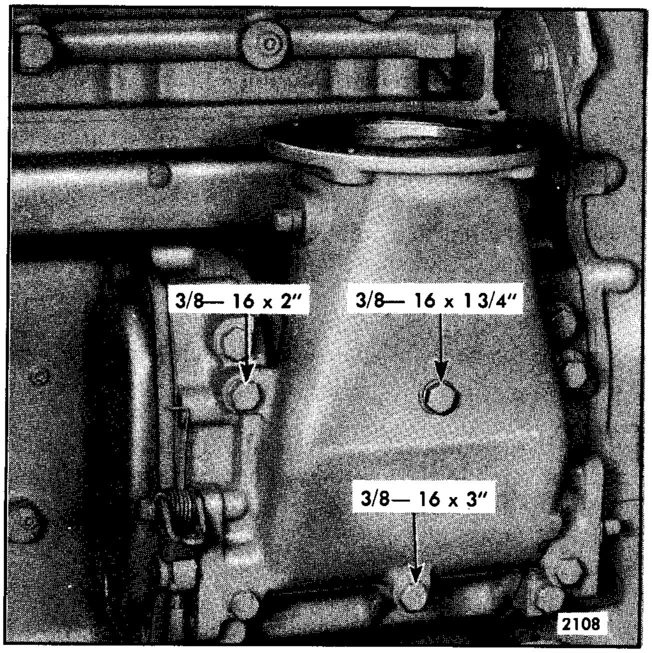

Fig. 3 - Location of Air Shutdown Housing Mounting Bolts (In-Line Engines)

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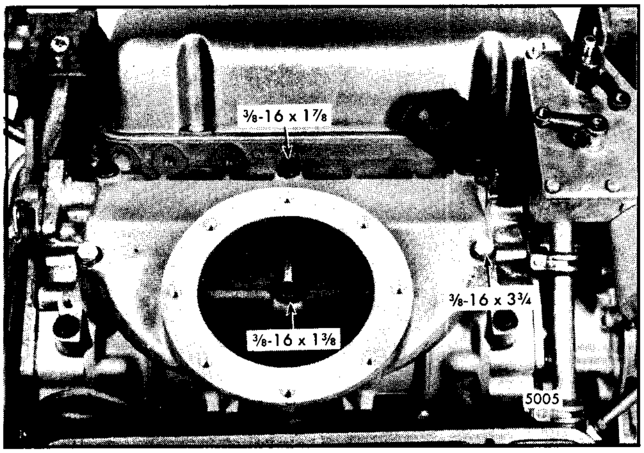

Fig. 4 - Location of Air Shutdown Housing Mounting Bolts (6V-53 Engines)

b. Tighten the two center bolts to 16-20 lb-ft (22-27 Nm) torque.

c. Then, tighten the four corner bolts to 16-20 lb-ft (22-27 Nm) torque.

NOTE: A power wrench should not be used to tighten the above bolts.

3. Reset the air shutdown to the run position.

4. Start and run the engine at no-load idle speed. Then, increase the engine no-load speed to 900-1100 rpm. Next, trip the air shutdown. If the engine does not stop, check it for air leakage between the valve and the gasket. If necessary, reposition the valve.

Install Air Shutdown Housing (6V-53 Engines)

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward 2. Refer to Fig. 4 and mount the air inlet housing on the blower and secure it with bolts, washers and lock washers. Tighten the bolts to 16-20 lb-ft (22-27 Nm) torque.

3. Reset the air shutdown to the run position.

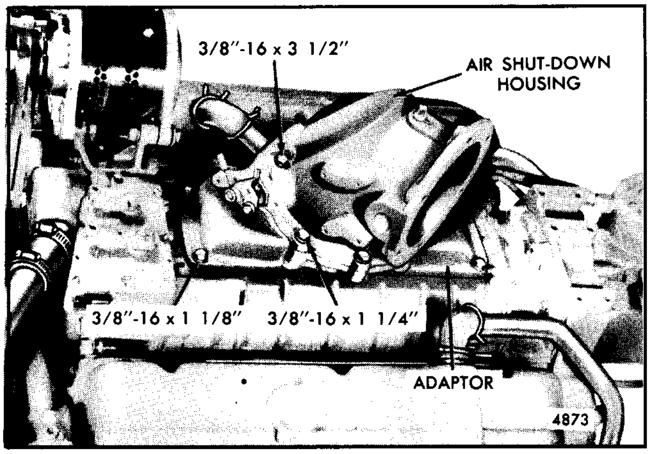

Fig. 5 - Location of Air Shutdown Housing and Adaptor Mounting Bolts (8V-53 Engines)

4. Start and run the engine at no-load idle speed. Then, increase the engine no-load speed to 900-1100 rpm. Next, trip the air shutdown. If the engine does not stop, check it for air leakage between the valves and the gasket. If necessary, reposition the valves.

Install Air Shutdown Housing and Adaptor (8V-53 Engines)

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.

2. Refer to Fig. 5 and install the air shutdown housing adaptor on the screen and gasket assembly. Install the six bolts and lock washers and tighten them to 16-20 lb-ft (22-27 Nm) torque.

3. Affix a new gasket on the top of the air inlet housing adaptor, then place the air shutdown housing on top of the gasket. Install the six bolts and lock washers and tighten them to 16-20 lb-ft (22-27 Nm) torque.

4. Reset the air shutdown to the run position.

5. Start and run the engine at no-load idle speed. Then, increase the engine no-load speed 900-1100 rpm. Next, trip the air shutdown. If the engine does not stop, check it for air leakage between the valves and the gasket. If necessary, reposition the valves.

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BLOWER

IN-LINE AND 6V ENGINES

The blower supplies the fresh air required for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow double-lobe rotors revolve in a housing bolted to the side of the In-line engines (Fig. 1) or on top of the cylinder block between the cylinder banks on the 6V engine (Fig. 2). The revolving motion of the rotors provides a continuous and uniform displacement of air.

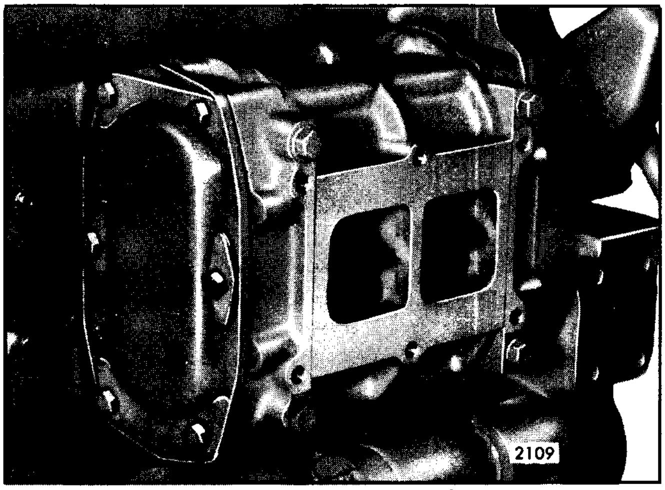

Fig. 1 - Blower Mounting (3-53 Engine)

The blower rotors are pinned to the rotor shafts. The rotor shafts are steel and the blower end plates are aluminum, providing for a compatible bearing arrangement.

Gears located on the splined end of the rotor shafts space the rotor lobes with a close tolerance. Since the lobes of the two rotors do not touch at any time, no lubrication is required.

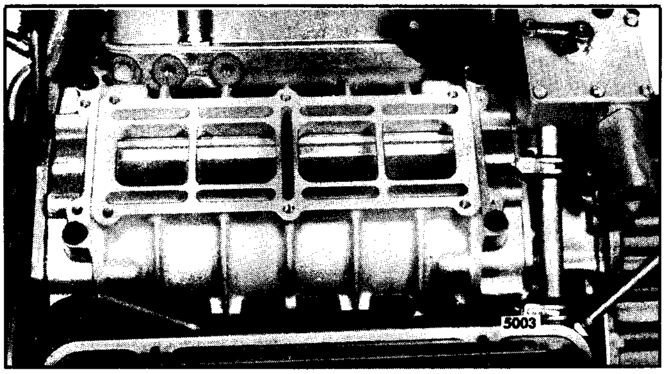

Fig. 2 - Blower Mounting (6V Engine)

The blower upper rotor gear of the 2-53 and 3-53 engines meshes with either the camshaft or balance shaft gear. The 4-53 and 6V engines have a blower drive gear.

Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage. The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616. When replacing the former blower drive gears with the new, both gears must be changed.

Lip type oil seals are used in both the front and rear end plates on current engines. The seals prevent air leakage past the blower rotor shaft bearing surfaces and also keep the oil, used for lubricating the blower rotor gears, from entering the rotor compartment. Former blowers used a ring type oil seal consisting of a fiber washer, "O" ring, retainer and seal spring in each end of the blower rotors.

The Brazilian built engines used a blower assembly with a shorter housing and rotors for reduced capacity. Turbocharged engines use the Teflon® oil seal while the naturally aspirated engines built in Brazil used the polyacrylic oil seal. Only the Teflon® blower oil seal is serviced. An oversized lip type oil seal and a blower rotor shaft sleeve are available to increase life on the sealing surface of the blower rotor shaft.

Effective with engine serial numbers 4D-201579 and 6D-220736, new carbonitride-hardened blower drive shaft and a new steel induction-hardened blower coupling cam are being used in naturally aspirated and turbocharged engines. Carbontride hardening results in added resistance to shaft and coupling spline wear. To distinguish the new shafts from the former, one end of each new shafts is stamped with the letter "H". The non-counterbored face of the new cam is stamped with the letter "S". The former and the new components are not interchangeable, and only the new components will be serviced.

Effective with engine serial numbers 3D-191032, 4D-204949 and 6D-225858, bypass blowers are used on all Series 53 turbocharged industrial engines.

A spring-loaded bypass relief valve is positioned in a passage in the front (3-53 and 4-53 engines) or rear (6V engines) blower end plate (Figs. 21 and 22). This valve is closed at start-up and during low rpm/light load operation. However, as engine speed and load increase, turbocharger speed also increases until the turbocharger provides sufficient boost pressure for scavenging and charging the engine cylinders. At 10″ Hg (34 kPa) airbox pressure the valve in the passage begins to open and is fully open at 13″ Hg (44 kPa). With the valve in the *open* position, incoming air is allowed to flow through the lobes of the blower and through the end plate to the airbox. The blower continues to operate with the valve open, but requires less engine power because the pressure rise across the blower is greatly reduced. This results in decreased

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brake specific fuel consumption and increased fuel economy.

The bypass blower valve is externally vented back into the crankcase by means of a small hose and tube through the blower end plate. A very small amount of air bleeds past the valve and psses through the hose to help keep the valve clean and functioning properly. This has no effect on crankcase pressure.

Inspect Blower (Attached to Engine)

The blower may be inspected without removing it from the engine. However, the air cleaner and the air inlet housing must be removed.

CAUTION: To avoid personal injury when inspecting the blower with the engine running, keep your 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. Burrs around such abrasions may cause interference between the rotors or between the rotors and the blower housing.

Leaky oil seals are usually indicated by the presence of oil on the blower rotors or inside surfaces of the blower housing. Run the engine at low speed and direct a light into the rotor compartment and toward the end plates and the oil seals. A thin film of oil radiating away from a seal indicates an oil leak.

A worn blower drive resulting in a loose, rattling sound within the blower may be detected by running the engine at approximately 500 rpm.

Loose rotor shafts or worn rotor shaft bearing surfaces will result in contact between the rotor lobes, the rotors and the end plates, or the rotors and the housing.

Excessive backlash between the blower rotor gears usually results in the rotor lobes rubbing throughout their entire length.

Remove Blower

Before removing the blower from the engine, remove the air shutdown housing as outlined in Section 3.3.

2-53 and 3-53 ENGINE BLOWER

1. Remove the six bolts, special washers and reinforcement plates which secure the blower to the engine end plate and the flywheel housing. *Note the location of the two shorter bolts.* Then, remove the front end plate cover and gasket from the blower.
2. Remove the four blower-to-block bolts and special washers and lift the blower away from the engine.

4-53 ENGINE BLOWER

1. Loosen the clamp retaining the cover-to-support seal.
2. Remove the four blower-to-block bolts and special washers and lift the blower away from the engine, being careful not to damage the serrations on the blower drive shaft.

6V-53 ENGINE BLOWER

1. Disconnect the linkage to the governor control levers.
2. Remove the screws and lock washers which attach the governor cover to the governor housing. Remove the cover and gasket.
3. Remove the two bolts and lock washers which hold the spring housing to the governor housing. Remove the spring housing and gasket.
4. Remove the spring assembly from the governor.
5. Loosen the hose clamps and slide the hoses back on the fuel rod covers.
6. Clean and remove the valve rocker cover from each cylinder head. Discard the gaskets.
7. Disconnect the lower fuel rod from each injector control tube lever and also from each upper fuel rod.
8. Remove the threaded pins connecting the fuel rods to the control link lever. Remove the upper fuel rods.
9. Remove the blower drive cover plate. Remove the snap ring and withdraw the blower drive shaft from the housing.
10. Remove the two bolts and copper washers securing the blower drive support assembly. Then, withdraw the drive assembly until the splined end of the drive shaft is free from the drive plate (Fig. 3). Turn the drive assembly slightly so the serrated end of the governor weight shaft will pass around the governor operating fork. Remove the drive support from the engine.

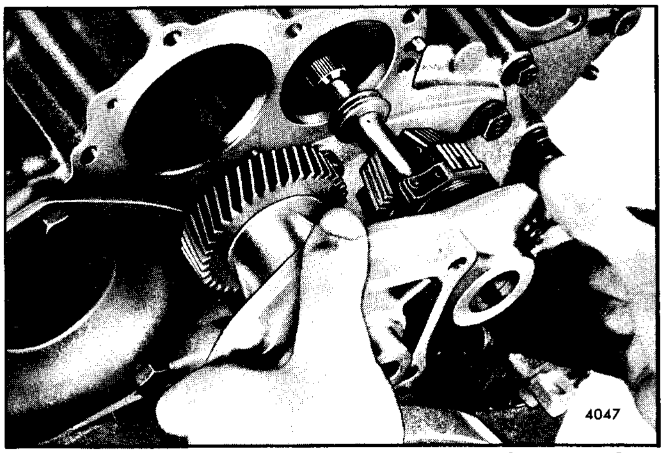

Fig. 3 - Removing/Installing Blower Drive Support (6V Engine)

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11. The governor is doweled to the cylinder block rear end plate. Use a suitable tool to press or drive the dowel pin from the end plate.
12. Remove the four bolts and flat washers which attach the blower to the top face of the cylinder block. Lift the blower and governor assembly from the engine (Fig. 4).

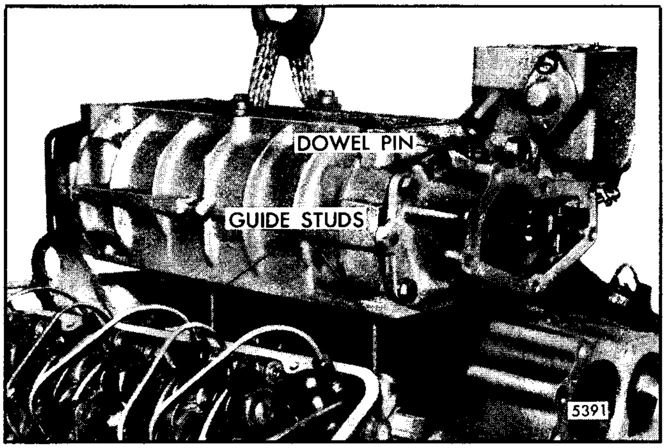

Fig. 4 - Removing/Installing Blower (6V Engine)

13. Remove the six bolts and lock washers which attach the governor housing to the blower rear end plate. Remove the governor and gasket.

Disassemble Blower

2-53 and 3-53 ENGINE BLOWER

1. Wedge a clean cloth between the rotors to prevent their turning. Then, remove the blower gear retaining bolts and washers.
2. For identification, mark the R.H. helix gear. Then, remove the gears with pullers J 28483 as follows:
   a. With the pullers in place under the gears (Fig. 5), place a brass bar, approximately 1" long and 5/8" diameter, between the point of each puller bolt and blower rotor shaft.

NOTICE: If the brass bar is larger than 5/8" diameter, the serrations in the blower drive gear may be damaged.

   b. Alternately turn the bolt in each puller until the gears are off the shafts.
3. Remove the rotor shims and the gear spacers and place them with their respective gears to ensure correct reassembly.
4. At the other end of the blower, remove the three thrust plate bolts, the thrust plate and three spacers from the front end plate. Remove the bolts and thrust washers (refer to Fig. 6).
5. Remove the two screws that retain the end plate to the blower housing. Tap the end plate off of the dowel pins and housing with a soft (plastic) hammer, being careful not to damage the mating surfaces of the end plate and the housing.

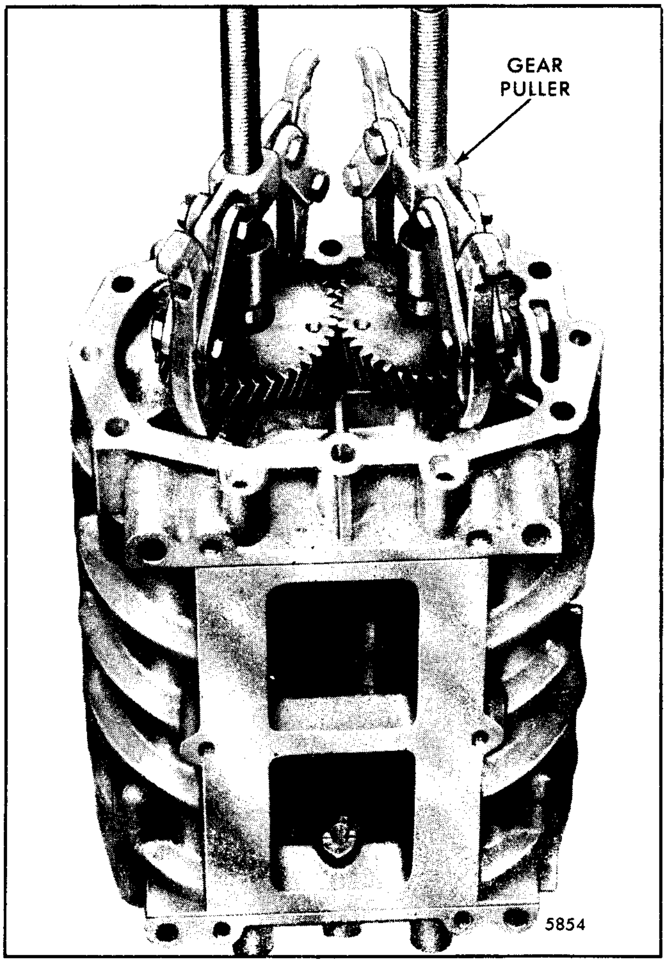

Fig. 5 - Removing Blower Rotor Gears

6. Remove the rotors from the blower housing.
7. Remove the retaining screws and remove the rear end plate as in Step 5.
8. Remove and discard the lip type oil seals from the end plates on current blowers. Remove the seal washer, "O" ring, retainer and retainer spring from each rotor shaft on former blowers.
9. If a bypass valve is used in the front end plate, disconnect the hose from the end plate. Remove the two belts which secure the bypass valve in the end plate, then remove the bypass valve.
10. Clamp the bypass valve between the soft jaws of a vise and loosen the nut in the end of the valve. Remove the nut, spring and valve.

4-53 and 6V-53 ENGINE BLOWERS

1. Refer to Fig. 7 and remove the six bolts, special washers and reinforcement plates which secure the front end plate cover and the front end plate to the blower housing. Then, remove the end plate cover and gasket from the end plate.

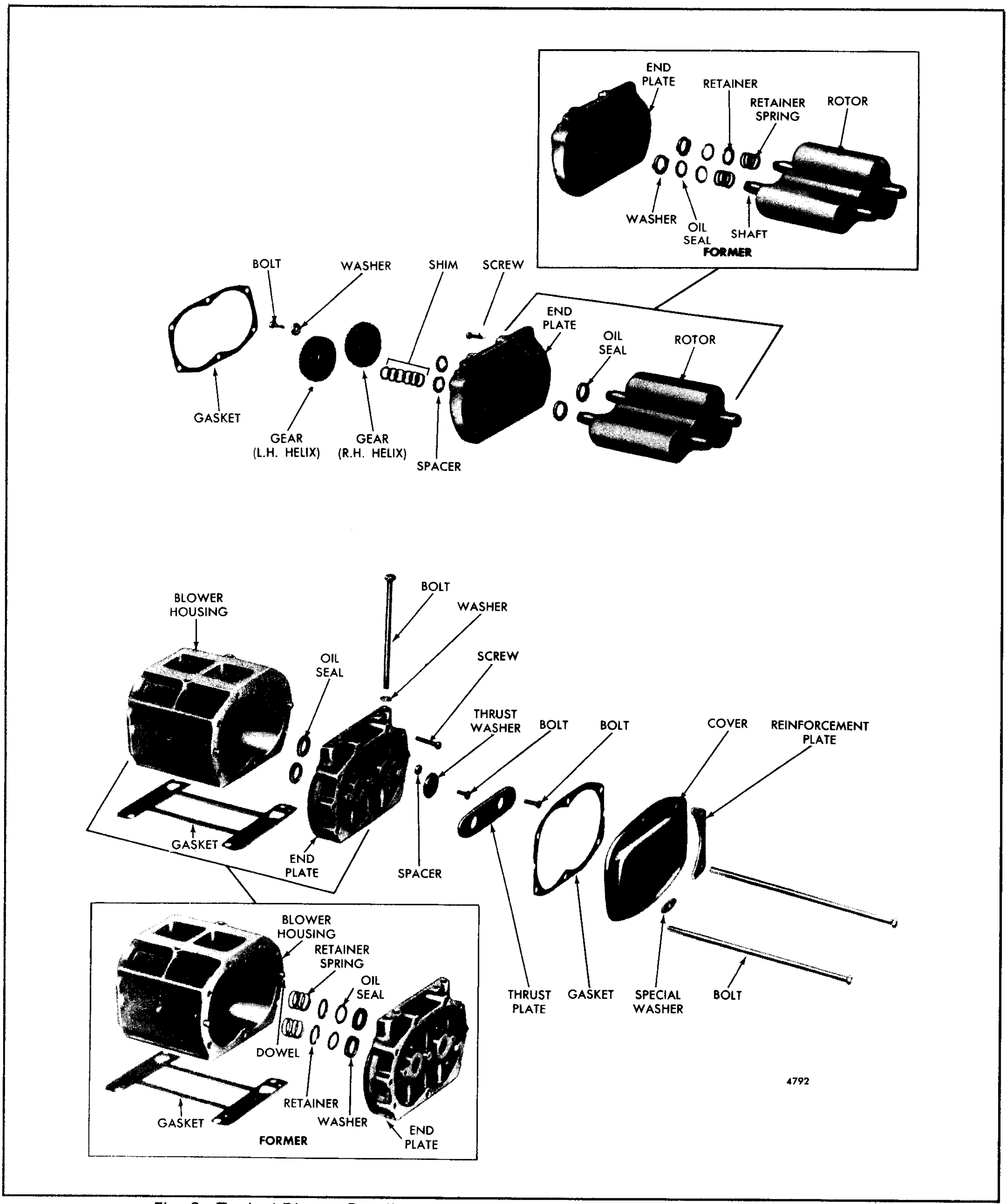

Fig. 6 - Typical Blower Details and Relative Location of Parts (3-53 Engine Blower)

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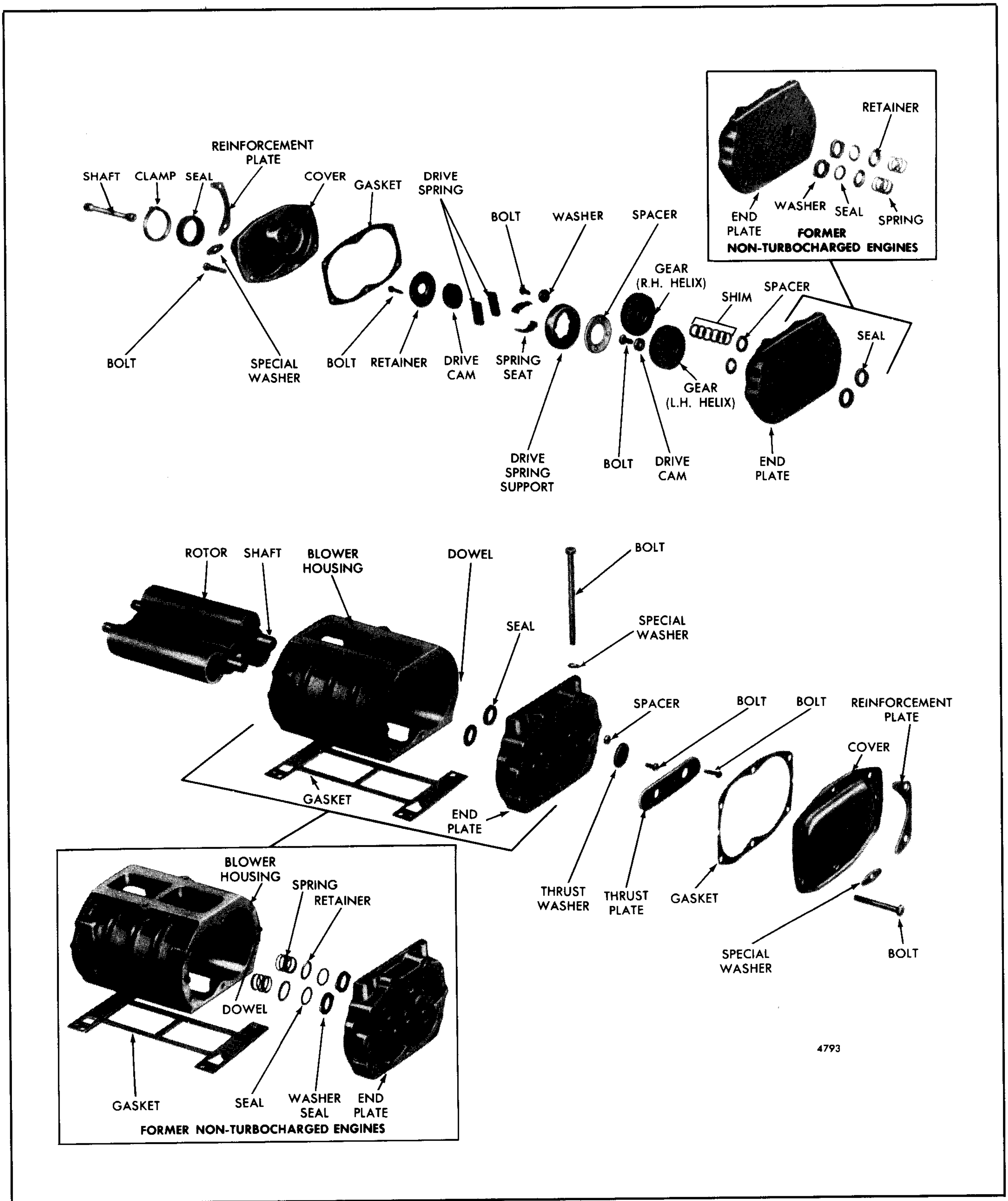

Fig. 7 - Typical Blower Details and Relative Location of Parts (4-53 Engine Blower)

2. On a 4-53 engine blower, remove the six bolts, special washers and reinforcement plates which secure the rear end plate cover and the rear end plate to the blower housing. Then, remove the

end plate cover and gasket from the end plate. On the 6V engine, this step is accomplished by removing the governor.

3. Wedge a clean cloth between the rotors to prevent their turning and remove the four bolts that hold the blower drive cam retainer and blower drive spring support to the gear. Separate the retainer, support and spacer from the gear. On the 6V engine, the governor drive plate must also be removed from the opposite gear.
4. On a 4-53 engine blower, remove the retaining bolts and the washer and the blower drive cam pilot from the blower gears. On the 6V engine blower, a cam pilot is used on both gears.
5. For identification, mark the upper gear on the 4-53 blower or the left-hand gear on the 6V blower.
6. Use two pullers J 28483 to remove the two gears simultaneously.
7. Remove the rotor shims and the gear spacers and place them with their respective gears to ensure correct reassembly.
8. At the other end of the blower, remove the three thrust plate bolts, the thrust plate and three spacers from the front end plate. Remove the bolts and thrust washers.
9. Tap the end plate off of the dowel pins and housing with a soft (plastic) hammer, being careful not to damage the mating surfaces of the end plate and the housing.
10. Remove the rotors from the blower housing.
11. Remove the rear end plate as in Step 9.
12. Remove and discard the lip type oil seals from the end plates on current blowers. Remove the seal washer, "O" ring, retainer and retainer spring from each rotor shaft on former blowers.
13. If required, disassemble the blower drive spring support by driving the cam from the support with a brass drift, permitting the springs and spring seats to fall free.
14. If a bypass valve is used in the front end plate, disconnect the hose from the end plate. Remove the two belts which secure the bypass valve in the end plate, then remove the bypass valve.
15. Clamp the bypass valve between the soft jaws of the vise and loosen the nut in the end of the valve. Remove the nut, spring and valve.

Inspection

Clean and dry all of the parts thoroughly.

The finished inside face of each end plate must be smooth and flat. Slight scoring may be cleaned up with a fine grit emery cloth. If the surface is badly scored, replace the end plate.

Inspect the surfaces of the rotors and the blower housing. Remove burrs or scratches with an oil stone.

Examine the rotor shaft, gear or drive coupling for burred or worn serrations.

Inspect the blower gears for excessive wear or damage.

Check the bearing and oil seal contact surfaces of the rotor shafts and end plates for scoring, wear or nicks.

If an oversize oil seal is required, a sleeve on the rotor shaft can be replaced as follows:

a. Place sleeve remover J 23679-2 over the rotor shaft and behind the oil seal sleeve.
b. Back out the center screw of one gear puller J 21672-4 and attach the puller to the sleeve remover with three 1/4"-20 x 3" bolts and flat washers.
c. Turn the puller screw clockwise and pull the sleeve off of the shaft.
d. Support the rotor, gear end up, on the bed of an arbor press.
e. Start a new sleeve straight on the shaft.
f. Place sleeve installer J 23679-1 on top of the sleeve and press the sleeve on the shaft until the step in the installer contacts the shoulder on the shaft. The step in the sleeve installer properly positions the sleeve on the shaft.

The rotor assemblies for the 6V engine blower have been revised to permit the use of longer (1-3/4") gear retention bolts. The former bolts were 7/8" long. If a former blower is removed for repair or overhaul, rework the rotor shafts as illustrated in Fig. 8.

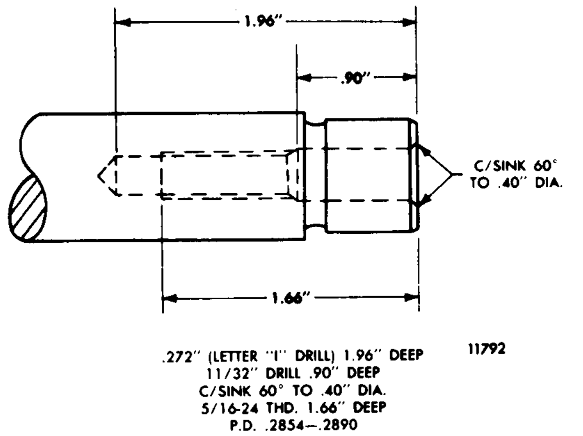

Fig. 8 - Dimensions for Reworking 6V Blower Rotor Shafts

Assemble Blower

Current front and rear blower end plates can now be identified either of two ways:

Knowing the machining differences, such as thrust washer drilling, governor hole drilling, counterbores drilled, etc. (Fig. 9).

End plates are stamped with the last digit of its part number (Fig. 10). The end plate with a part number ending in 99 will have both numbers stamped in the plate.

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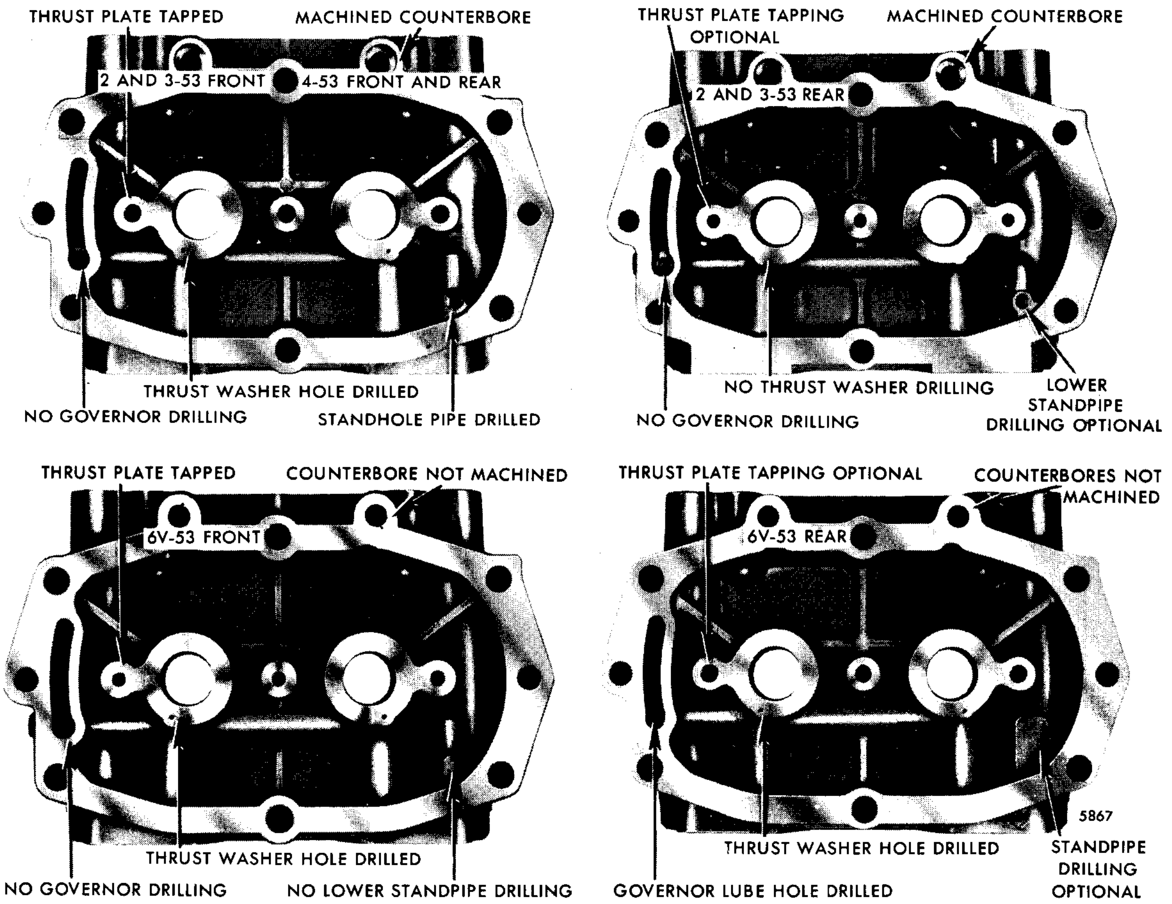

Fig. 9 - End Plate Machining Differences

Refer to Figs. 6 and 7 and assemble the blower as follows:

1. Install new lip type oil seals in each end plate in *current blowers* as follows:
   a. Place the end plate on the bed of an arbor press.
   b. Lubricate the outer diameter of the seal and, using installer J 22576, press the seal (lip facing down) into the counterbored hole until the shoulder on the installer contacts the end plate (Fig. 11). A step on the seal installer will position the oil seal below the finished face of the end plate within the .002" to .008" specified.

No seal leakage should occur after the blower housing end plate Teflon oil seals are installed. If leakage does occur, the cause may be:

(1) Failure to install the seal dry. Blower end plate oil seals *must* be installed dry, without any prelubing.

(2) Previous deposits of P.T.F.E. (graphite-filled Teflon) on the blower rotor shaft. A certain amount of material transfer onto the blower rotor shaft has occurred, the *interface* (the area of material transfer between the lip of the new seal and the shaft) may not conform. This may prevent the new seal from seating properly.

If the blower housing end plate oil seal continues to leak after proper installation, replacement with service sleeve and seal may be required.

2. Install the ring type oil seals on the rotor shafts of *former blowers* as follows:
   a. Install a retainer spring on each shaft of each rotor. Then, place an "O" ring retainer (dished side up) on each spring.
   b. Lubricate the "O" rings with clean engine oil, then slide one ring on each shaft.
   c. Lubricate and place a seal on each shaft. Note that the tangs on each seal are flush with one side of the seal; this side of the seal must face toward the rotor.
3. Two 5/16" x 5/16" steel plugs are used in the blower end plates of all *turbocharged* engines to ensure that a full-pressure flow of lubricating oil is supplied to the engine and to the oil galleries in the turbocharger center housing. The plugs (if removed) must be installed in the diagonally drilled orifices which supply additional

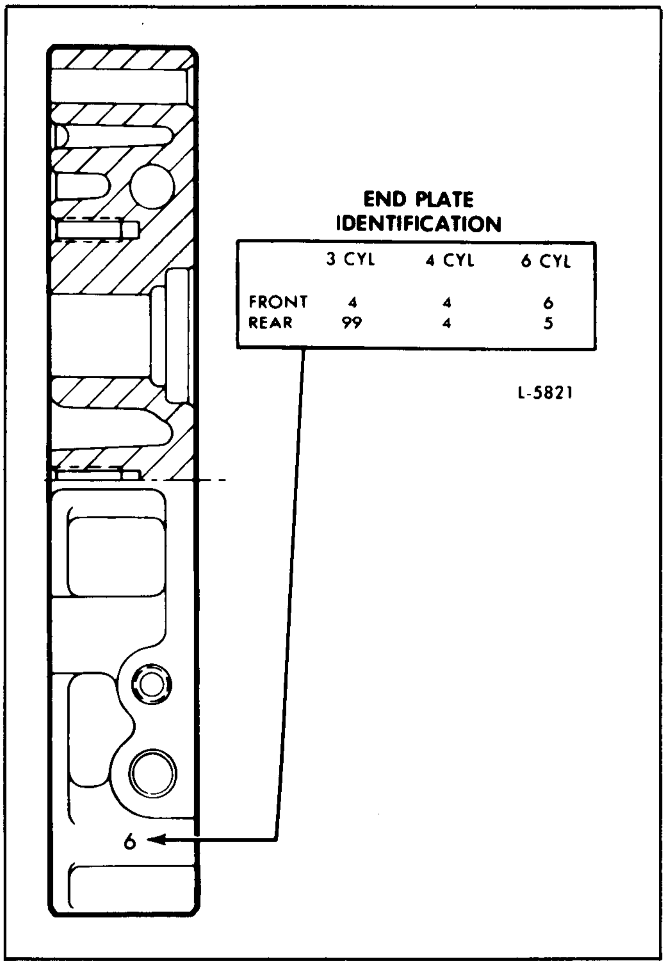

Fig. 10 - End Plate Identification

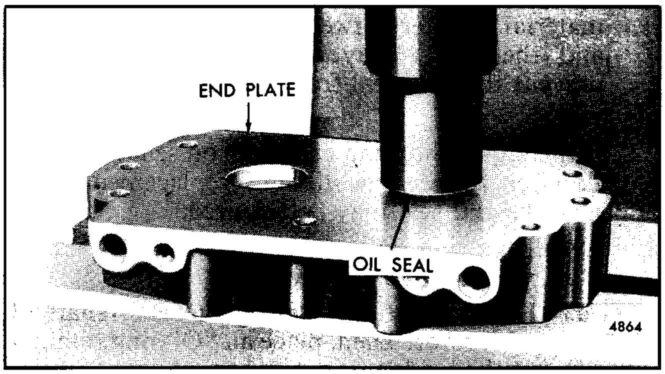

Fig. 11 - Installing Lip Type Oil Seal in End Plate with Tool J 22576

lubrication to the blower drive gears. Plugs are pressed flush to .03″ below the surface of the end plates and staked in three places (Fig. 12). The plugs are not installed in the blower end plates of naturally aspirated engines.

NOTICE: Failure to install the plugs in the blower end plates of *turbocharged* engines can result in low engine oil pressure, inadequate turbo shaft bearing lubrication and serious engine or turbocharger damage.

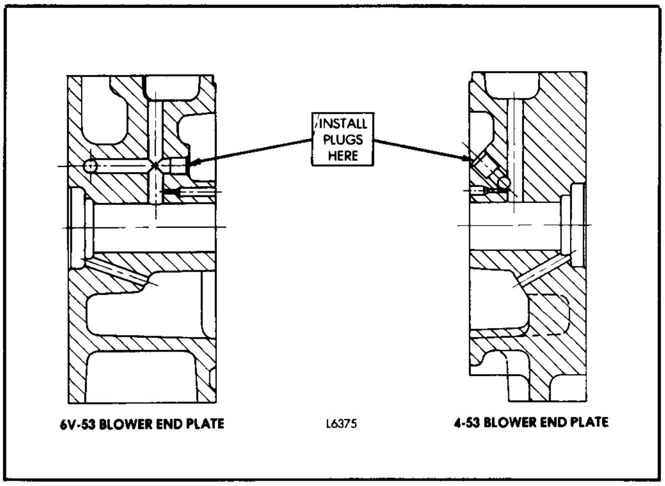

Fig. 12 - Location of Holes to be Plugged - Blower End Plates

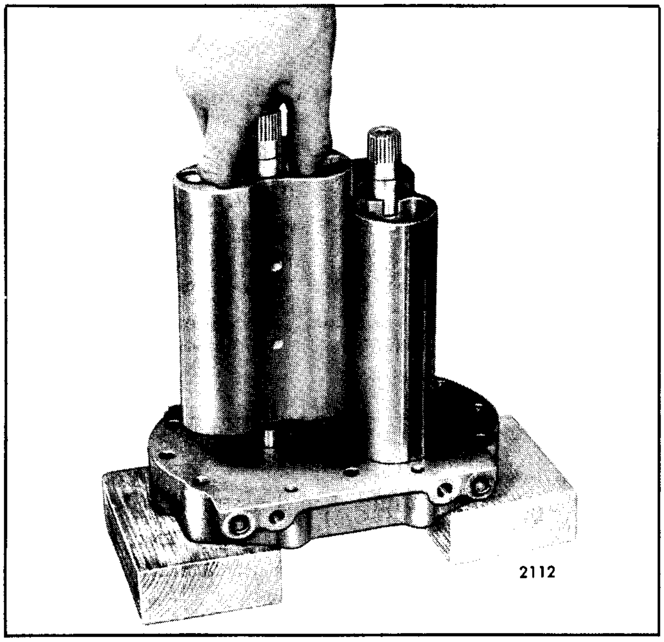

Fig. 13 - Installing Blower Rotors in Front End Plate

4. Place the front end plate on two wood blocks. Then, install the rotors, gear end up, on the end plate (Fig. 13). On the former blowers, be sure that the ring type oil seals are properly positioned on the rotors.
5. Install the blower housing over the rotors (Fig. 14).

NOTICE: To prevent inadequate lubrication or low oil pressure, care must be exercised in the assembly of the front and rear blower end plates to the blower housing. The rear end plate for the *2-53 and 3-53 blower* does not have tapped holes for the thrust washer plate bolts and no thrust washer lubricating oil holes. The rear end plate for the *6V blower* does not have tapped holes for the thrust washer plates and is the only cover that has the horizontal oil passage drilled through into the pocket on the left

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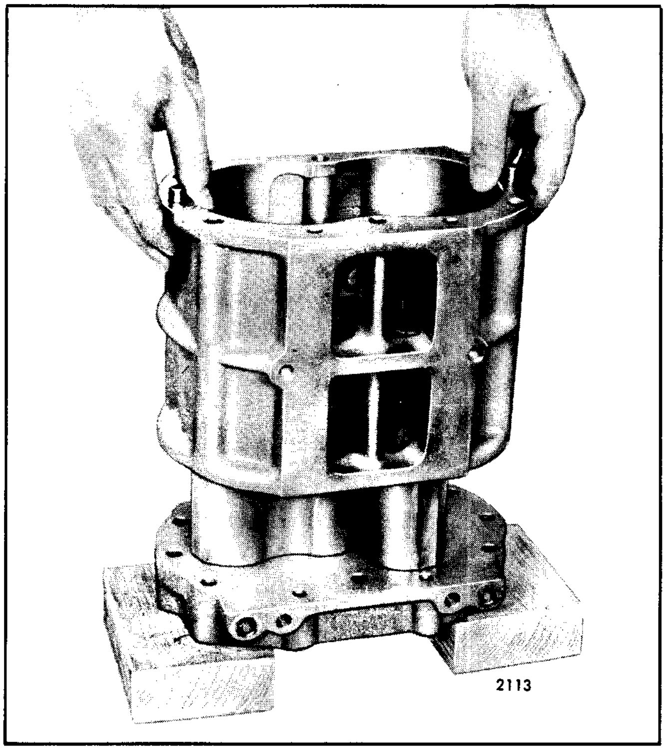

Fig. 14 - Installing Blower Housing Over Rotors

side of the end plate for supplying oil to the blower drive gear support bearing.

6. Place the rear end plate over the rotor shafts (Fig. 15). On the former blowers, be sure that the ring type oil seals are properly positioned on the rotors. Then, secure each end plate to the 3-53 blower housing with two end plate retaining screws and two cover bolts and plain washers. Secure each end plate to the 4-53 or 6V blower with four end plate cover bolts and plain washers.

Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than .001" above to .004" below the end plate. Excessive protrusion could distort the housing when the end plate to cylinder block bolts are tightened and cause rotor-to-housing interference.

7. Attach the two thrust washers to the front end of the blower with the washer retaining bolts. If 5/16"-24 bolts are used, tighten them to 25-30 lb-ft (34-41 N·m) torque; if 3/8"-24 bolts are used, tighten them to 54-59 lb-ft (73-80 N·m) torque.
8. Attach the three spacers and the thrust plate to the front end of the blower. Tighten the three bolts to 7-9 lb-ft (10-12 N·m) torque. Then, check the clearance between the thrust plate and the thrust washers. The specified clearance is .001" to .003" (In-line engine blower) or .0025" to .0050" (6V engine blower).

The current thrust plate is .260" thick. The former plate was .180" thick.

9. Position the rotors so that the missing serrations on the gear end of the rotor shafts are 90° apart. This is accomplished by placing the rotors in a "T" shape, with the missing serration in the upper rotor facing to the left and the missing serration in the lower rotor facing toward the bottom (Fig. 16). Install the shims and spacers in the counterbore in the rear face of the rotor gears. Then, place the gears on the ends of the shafts with the missing serrations in alignment with the missing serrations on the shafts.
10. Tap the gears lightly with a soft hammer to seat them on the shafts. Then, rotate the gears until the punch marks on the face of the gears match. If the marks do not match, reposition the gears.
11. Wedge a clean cloth between the blower rotors. Use the gear retaining bolts and plain washers to press the gears on the rotor shafts (Fig. 17). Turn the bolts uniformly until the gears are tight against the shoulders on the shafts.
12. Remove the gear retaining bolts and washers. Then, proceed as follows:

2-53 and 3-53 Blower -- Place the gear washers on the gears and start the gear retaining bolts in the rotor shafts. Tighten the bolts to 25-30 lb-ft (34-41 N·m) torque.

4-53 Blower -- Place the blower drive cam pilot in the counterbore of the upper gear and start the gear retaining bolt in the rotor shaft. Place the gear washer on the face of the lower gear and start the gear retaining bolt in the rotor shaft. Tighten the bolts to 25-30 lb-ft (34-41 N·m) torque.

6V-53 Blower -- Place a pilot in the counterbore of each gear and start the 12-point bolt in the right-hand rotor shaft and start the hex head bolt in the left-hand rotor shaft. Tighten the bolts to 25-30 lb-ft (34-41 N·m) torque.

13. Check the backlash between the blower gears, using a suitable dial indicator. The specified backlash is .0005" to .0025" with new gears or a maximum of .0035" with used gears.
14. Time Blower Rotors:

After the blower rotors and gears have been installed, the blower rotors must be timed. When properly positioned, the blower rotors run with a slight clearance between the rotor lobes and with a slight clearance between the lobes and the walls of the housing.

The clearances between the rotors may be established by moving one of the helical gears out or in on the shaft relative to the other gear by adding or removing shims between the gear hub and the rotor spacers.

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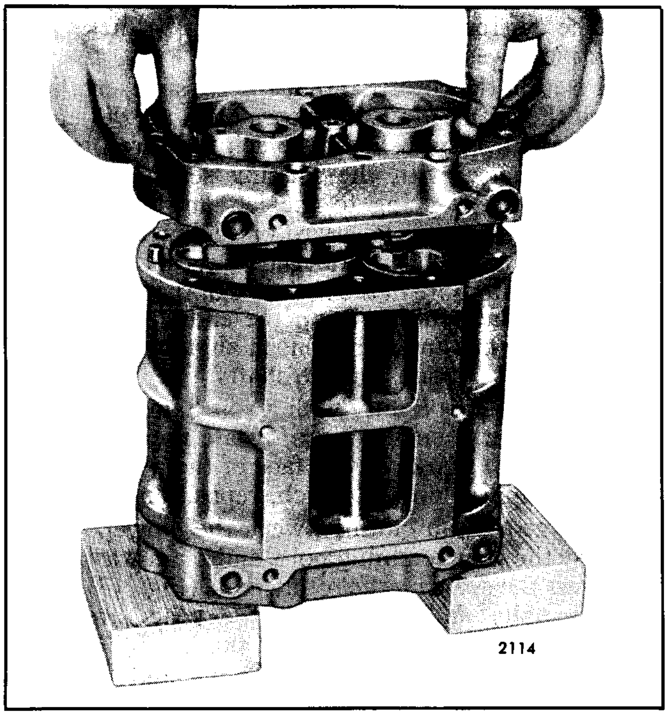
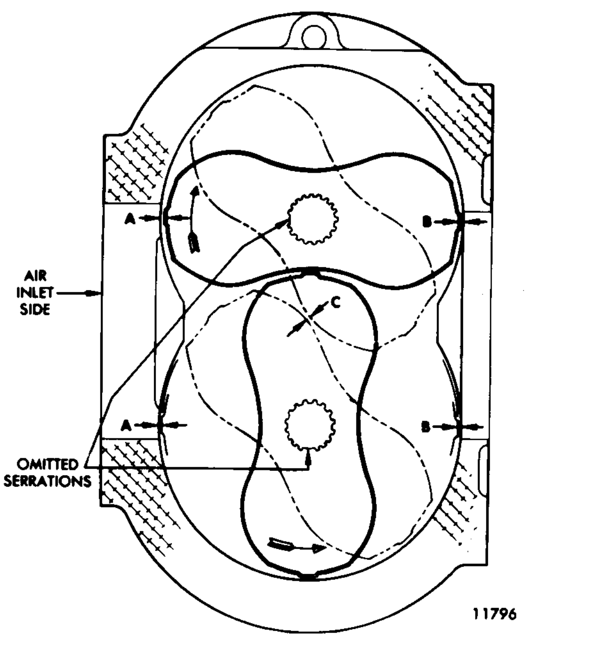


Fig. 15 - Installing Rear End Plate



	A	B	C
3-53	.010"	.004"	.010"
3-53T	.012"	.006"	.012"
4-53	.0075"	.004"	.010"
4-53T	.0075"	.007"	.010"
6V-53	.010"	.004"	.009"
6V-53T	.010"	.004"	.009"

Fig. 16 - Minimum Blower Rotor Clearance

It is preferable to measure the clearances with a feeler gage comprised of two or more feelers, since a combination is more flexible than a single feeler gage. A specially designed feeler gage set

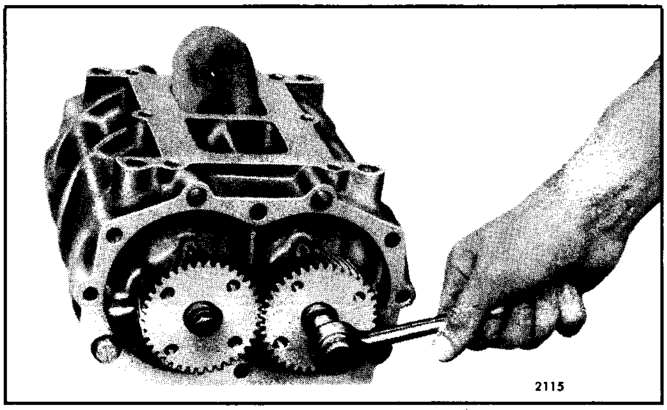


Fig. 17 - Installing Blower Rotor Gears

J 1698-02 for the blower clearance operation is available. Take measurements from both the inlet and outlet sides of the blower.

a. Measure the clearance between the rotor lobes and the housing (Fig. 18). Take measurements across the entire length of each rotor lobe to be certain that a minimum clearance of .004" exists at the *air outlet side* of all blowers and a minimum clearance of .0075" (In-line engine blower) or .010" (6V engine blower) exists at the *air inlet side* of the blower (Fig. 16).

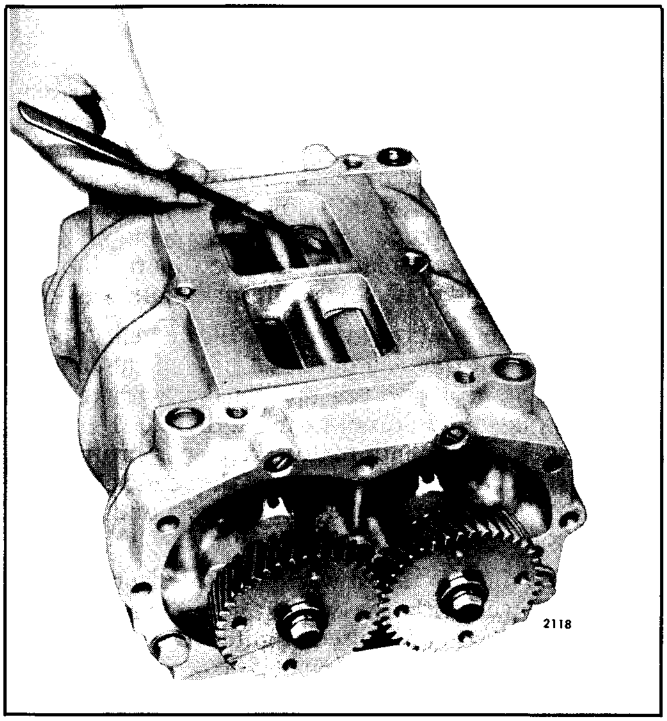


Fig. 18 - Measuring Rotor Lobe to Housing Clearance

b. Measure the clearance between the rotor lobes, across the length of the lobes, in a similar manner. By rotating the gears, position the lobes so that they are at their closest relative position (Fig. 16).

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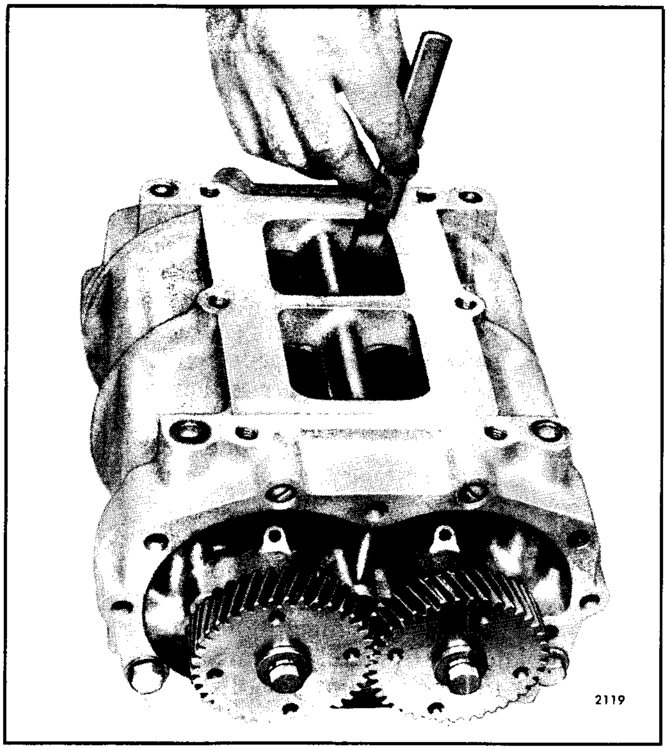

Fig. 19 - Measuring Rotor Lobe to End Plate Clearance

c. Measure the clearance between the end of the rotor and the blower end plate (Fig. 19). Refer to Table 1 for the required minimum clearances. Push and hold the rotor toward the end plate at which the clearance is being measured.

BLOWER ROTOR END CLEARANCES (Minimum)		
Engine	Front End Plate	Rear End Plate
3-53	.006"	.008"
3-53T	.008"	.009"
4-53	.006"	.009"
4-53T	.008"	.010"
6V-53	.008"	.010"
6V-53T	.010"	.012"

TABLE 1

After timing the rotors, complete assembly of the blower.

15. Remove the bolts and washers used to temporarily secure the front end plate to the housing. Then, install the front end plate to the blower with six bolts and special washers and two reinforcement plates and tighten the bolts to 20-25 lb-ft (27-34 N·m) torque.

Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than .001" above to .004" below the end plate. Excessive protrusion could distort the housing when the end plate to the cylinder block bolts are tightened and cause rotor to housing interference.

The current front and rear end plate gaskets on the 4-53 engine blower are identical and may be used in either position. Formerly, these gaskets were not interchangeable. The gasket used between the blower and the governor housing on the 6V engine is not interchangeable with the front end plate cover gasket.

16. Assemble the blower drive spring support as follows:
   a. Place the drive spring support on two blocks of wood (Fig. 20).

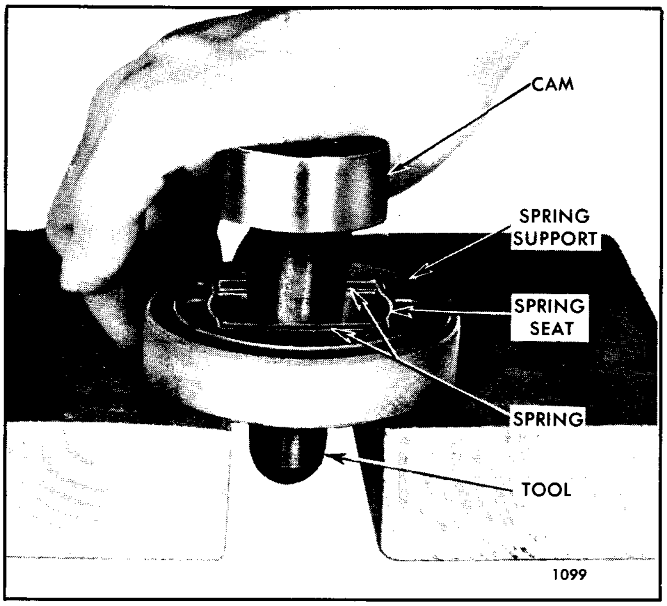

Fig. 20 - Inserting Cam in Blower Drive Support with Tool J 5209

   b. Position the drive spring seats in the support.
   c. Apply grease to the springs to hold the leaves together, then slide the two spring packs (15 leaves per pack) in place.
   d. Place the blower drive cam over the end of tool J 5209, insert the tool between the spring packs and press the cam in place.

17. Install the drive spring support coupling on the rotor gear at the rear end of the blower.

Effective with engine serial number 4D-14120, the blower assembly for the 4-53 engine has been revised by the use of a new longer drive gear pilot and the addition of a drive coupling spacer (Fig. 21). Tighten the 5/16"-24 drive gear pilot bolt to 25-30 lb-ft (34-41 N·m) torque. Prior to the above change, a shorter drive coupling was used and no spacer was required.

The coupling is placed on the upper rotor gear on the In-line engine blower and on the left-hand gear on the 6V engine blower. A spacer is placed between the gear and the coupling on the 6V engine blower.

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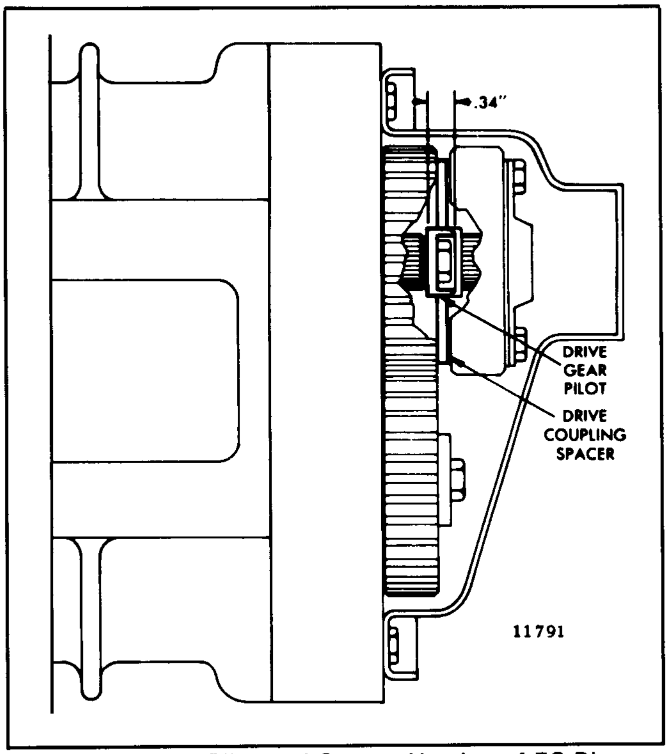

Fig. 21 - Current Pilot and Spacer Used on 4-53 Blower

18. Secure the cam retainer to the coupling with four 1/4"-28 bolts and tighten them to 14-18 lb-ft (19-24 N·m) torque.
19. On the 6V engine blower, install the governor drive plate on the right-hand rotor gear with four bolts and tighten them to 8-10 lb-ft (11-14 N·m) torque.
20. Remove the bolts and washer used to temporarily secure the rear end plate to the 4-53 engine blower. Then, install the rear end plate cover and gasket and secure the cover and end plate to the blower with six bolts and special washers and two reinforcement plates and tighten the bolts to 20-25 lb-ft (27-34 N·m) torque.

This step is accomplished on the 6V engine blower by securing the governor to the end plate with six bolts.

- Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than .001" above to .004" below the end plate. Excessive protrusion could distort the housing when the end plate to cylinder block bolts are tightened and cause rotor-to-housing interference.

Install Blower

Examine the inside of the blower for any foreign material. Also, revolve the rotors by hand to be sure that they turn freely. Then, install the blower on the engine as follows:

2-53 and 3-53 ENGINE BLOWER

1. Affix a new blower-to-block gasket on the side of the cylinder block. Use Scotch Grip Rubber Adhesive No. 1300, or equivalent, only on the block side of the gasket.
2. Position the blower front end plate and gasket on the end of the blower and install six bolts with two special washers on the center bolts and the reinforcement plates on the two top and two bottom bolts. Install a new engine end plate to blower gasket over the threaded ends of the bolts. Apply Scotch Grip Rubber Adhesive No. 1300, or equivalent to the engine end plate side of the gasket. The current front and rear end plate gaskets are identical and may be used in either position. Formerly, these gaskets were not interchangeable due to a difference in thickness.
3. Place the blower on the cylinder block locating flanges and, while holding the blower in place, thread the six bolts finger tight in the rear engine end plate and flywheel housing. Then, install the blower-to-block mounting bolts and washers and tighten them to 10-15 lb-ft (14-20 N·m) torque.
4. Tighten the center blower-to-end plate bolts first, and then the top and bottom bolts to 20-25 lb-ft (27-34 N·m) torque. Then, tighten the blower-to-block bolts to 55-60 lb-ft (75-81 N·m) torque.
5. Check the backlash between the upper rotor gear and the camshaft or balance shaft gear. The backlash should be .003" to .007".
6. Install the air shutdown housing (Section 3.3).
7. If used, assemble and install the blower bypass valve as follows:
   a. Install the valve in the bypass valve body with the open end facing out. Then, install the spring and nut.
   b. Clamp the bypass valve body between the soft jaws of a vise and tighten the nut to 95-105 lb-ft (129-143 N·m).
   c. Install the bypass valve assembly in the blower end plate and connect the hose.
   d. Secure the bypass valve to the blower with clamps and bolts (Fig. 22).

4-53 ENGINE BLOWER

1. Affix a new blower-to-block gasket on the side of the cylinder block. Use Scotch Grip Rubber Adhesive No. 1300, or equivalent, only on the block side of the gasket.
2. Install the seal and clamp on the blower rear end plate cover.
3. Slide one end of the blower drive shaft into the drive cam.
4. Position the blower on the side of the cylinder block. Use care so that the blower gasket is not

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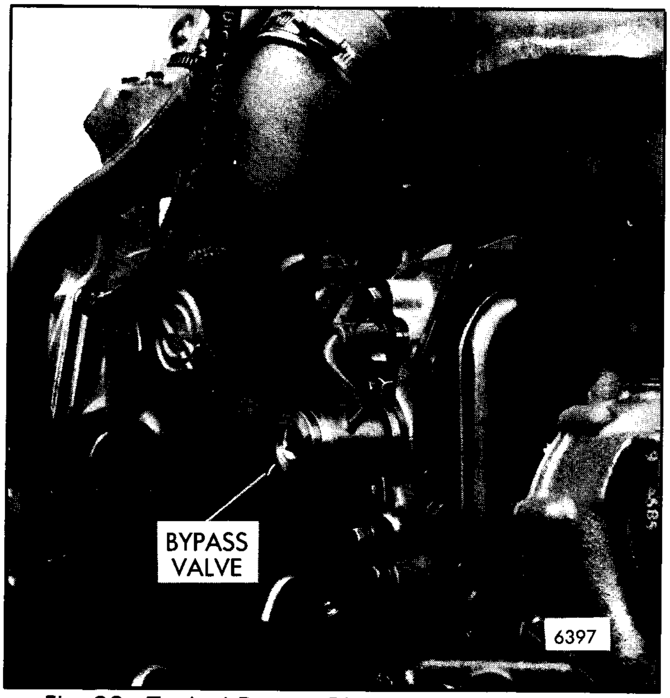

Fig. 22 - Typical Bypass Blower Valve Installation (In-Line Engine)

damaged or dislocated during installation of the blower.

5. Secure the blower to the cylinder block with bolts and washers. Tighten the bolts to 55-60 lb-ft (75-81 N·m) torque.
6. Slide the seal and clamp back against the blower drive gear support and tighten the clamp to hold the seal in place.
7. Check the backlash between the blower drive gear and the camshaft gear. The backlash should be .003" to .007".
8. Install the air shutdown housing (Section 3.3).
9. If used, assemble and install the blower bypass valve as follows:
   a. Install the valve in the bypass valve body with the open end facing out. Then, install the spring and nut.
   b. Clamp the bypass valve body between the soft jaws of a vise and tighten the nut to 95-105 lb-ft (129-143 N·m).
   c. Install the bypass valve assembly in the blower end plate and connect the hose.
   d. Secure the bypass valve to the blower with clamps and bolts (Fig. 22).

6V-53 ENGINE BLOWER

1. Install a new blower-to-block seal ring and two new blower-to-block gaskets. Affix the gaskets to the cylinder block and engine end plate with Scotch Grip Rubber Adhesive No. 1300, or equivalent.
2. Install the blower and governor assembly on the engine as follows:

NOTICE: Improper bolt down sequence can cause severe stresses which could result in failure of the main governor housing.

   a. To install the blower and governor on the engine without disturbing the gaskets and seal, use guide studs (Fig. 4). Install the guide studs in the end blower bolt holes in the cylinder block.
   b. While lowering the blower and governor assembly over the guide studs, push the blower away from the governor housing gasket attached to the rear end plate.
   c. Remove the guide studs and install the blower to block bolts and flat washers. Tighten the bolts finger tight only.
   d. Press or drive the governor housing dowel pin into the rear end plate with a suitable tool.
3. Secure the blower to the block with bolts and flat washers. Tighten the bolts to only 10-15 lb-ft (14-20 N·m) torque at this time.
4. Install the blower drive support as follows:
   a. Affix a new gasket to the blower drive support.
   b. Position the light governor weights (high-speed limiting-speed governor) in a horizontal position to provide clearance (Fig. 3). Turn the operating shaft fork away from the blower, if necessary, for additional clearance.
   c. Move the blower drive assembly into the openings in the flywheel housing until the blower drive gear enters the housing. Then, turn the drive assembly slightly so that the serrated end of the governor weight shaft may pass around behind the governor operating fork, permitting the fork to slip into place between the serrated end of the shaft and the riser bearing.
   d. Push the drive support assembly up against the flywheel housing; the serrations in the governor weight shaft and in the governor drive plate on the blower timing gear must mesh. The blower drive gear must also mesh with the mating gear.
5. Secure the small end of the blower drive support to the flywheel housing with two 3/8"-16 bolts and copper washers. Tighten the bolts to 20-24 lb-ft (27-33 N·m) torque.
6. Insert the blower drive shaft into the blower gear shaft. If necessary, turn the crankshaft so that the serrations on the blower drive shaft register with the serrations in the blower drive cam and the blower drive gear shaft.
7. Install the snap ring in the blower drive gear shaft to secure the blower drive shaft. The blower drive support and attaching accessories must be secured to the governor housing before final torque of the blower-to-block bolts.

8. Attach a new gasket to the blower drive support cover. Then, secure the cover to the support with four 3/8"-16 bolts and lock washers. Tighten the bolts to 20-24 lb-ft (27-33 N·m) torque.
9. Tighten the blower-to-block bolts to 55-60 lb-ft (75-81 N·m) torque.
10. If used, assemble and install the blower bypass valve as follows:
    a. Install the valve in the bypass valve body with the open end facing out. Then, install the spring and nut.
    b. Clamp the bypass valve body between the soft jaws of a vise and tighten the nut to 95-105 lb-ft (129-143 N·m).
    c. Install the bypass valve assembly in the blower end plate and connect the hose.
    d. Secure the bypass valve to the blower with clamps and bolts (Fig. 23).
11. Insert the upper fuel rods through the fuel rod covers and attach the rods to the governor control link lever.
12. Attach the lower fuel rods to the injector control tube levers and upper fuel rods.
13. Use new gaskets and reinstall the valve rocker covers.
14. Slide the fuel rod cover hoses in place and secure them with hose clamps.

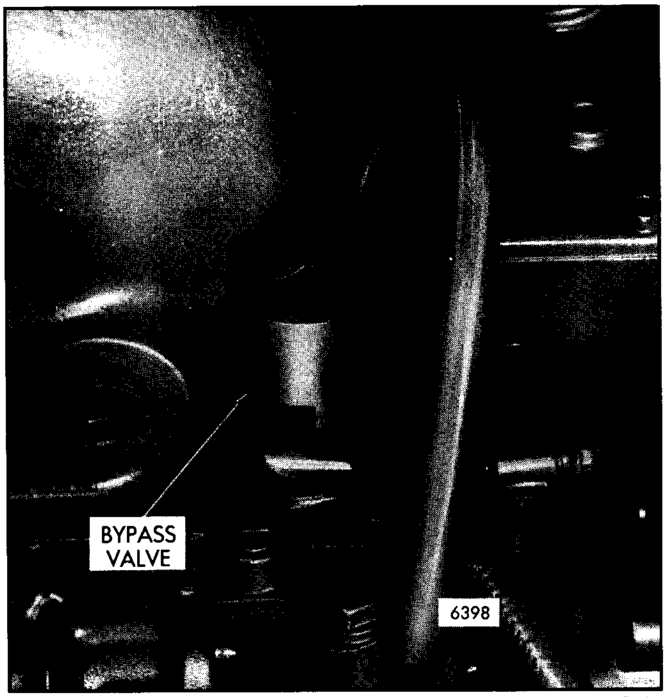

Fig. 23 - Typical Bypass Blower Valve Installation (6V Engines)

15. Install the spring assembly in the governor.
16. Install the air shutdown housing (Section 3.3).

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BLOWER (8V)

The blower, designed especially for efficient diesel operation, supplies the fresh air needed for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow three-lobe rotors revolve with very close clearances in a housing mounted between the two banks of cylinders and bolted to the top deck of the cylinder block. To provide continuous and uniform displacement of air, the rotor lobes are made with a helical (spiral) form (Fig. 1).

Two rotor gears, located on the drive end of the rotor shafts, space the rotor lobes with a close tolerance; therefore, as the lobes of the two rotors do not touch at any time, no lubrication is required.

Lip type oil seals located in the blower end plates prevent air leakage and also keep the oil, used for lubricating the rotor gears and rotor shaft bearings, from entering the rotor compartment.

Effective with engine serial number 8D-4508, new blowers are used on the 8V engines. The current blowers differ from the former blowers in that the double-row ball bearings are now in the rear end plate (gear end) rather than the front end plate and the roller bearings are in the front end plate.

On the current blower, new rotors are used which have a counterbore for a cup plug in the balance holes to increase blower efficiency. Each rotor is supported in the end plates by a roller bearing in the front end plate and a two-row ball bearing at the gear end. The oil seal sleeves have been discontinued in the rear position of the non-turbocharged engine blower. The same oil seal is now used in both the front and rear end plates. The oil seal sleeves will continue to be used in both the front and rear end plates (four positions) in the turbocharged engine blower.

The right-hand helix rotor of an 8V blower is driven at approximately twice (2.205:1) engine speed by the blower drive shaft. The blower drive shaft is splined at one end to two flexible couplings attached to the blower drive gear and at the other end to a hub attached to the left-hand helix rotor drive gear. The mating right-hand helix rotor driven gear drives the left-hand helix rotor.

A flexible coupling, formed by an elliptical cam driven by four bundles of leaf springs which ride on four spring seats, is attached to the rear face of the blower drive gear and prevents the transfer of torque fluctuations to the blower.

The blower rotors are timed by the two rotor gears at the rear end of the rotor shafts. This timing must be correct, otherwise the required clearance, obtained by

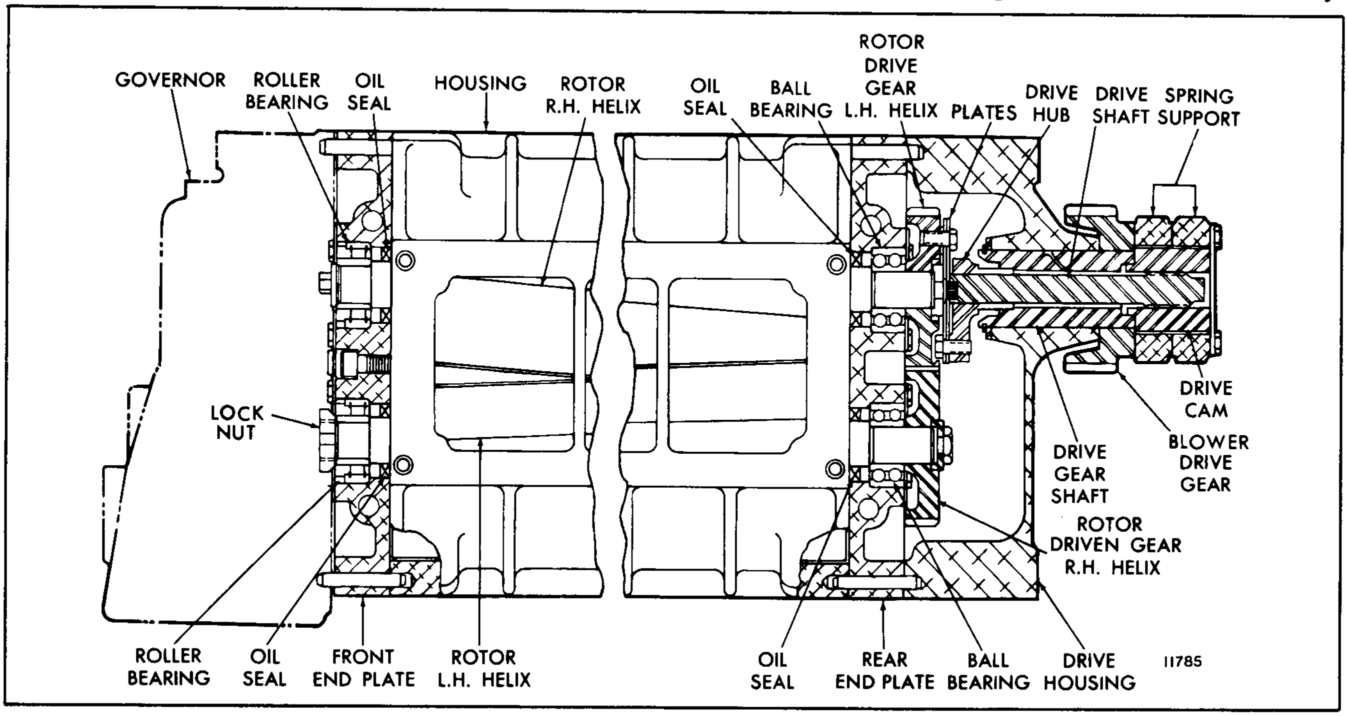

Fig. 1 - Current Blower and Drive Assembly

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the use of shims behind the rotor gears, between the rotor lobes will not be maintained.

Normal rotor gear wear causes a decrease of rotor-to-rotor clearance between the leading edge of the right-hand helix (drive) rotor and the trailing edge of the left-hand helix (driven) rotor. Clearance between the opposite sides of the rotor lobes is increased correspondingly.

While the rotor lobe clearance may be corrected by adjustment, rotor gear backlash cannot be corrected. When rotor gears have worn to the point where the backlash exceeds .004", replace the gears.

Lubrication

The blower bearings, rotor gears and governor drive mechanism are pressure lubricated by means of oil passages in the top deck of the cylinder block which lead from the main oil galleries to an oil passage in each blower end plate (Fig. 2). The oil flows upward to the horizontal oil passage in the end plate and leaves through a small orifice just below each bearing bore in the end plate. The oil is ejected from these orifices against the rotor gears at the rear end of the blower and the governor weights at the front end of the blower.

The bearings are splash lubricated by oil thrown by the rotor gears and governor weights. Oil which collects at the bottom of each end plate overflows into two drain passages which lead back to the crankcase via oil passages in the cylinder block.

The blower drive support bearing receives oil under pressure from the horizontal oil passage in the blower rear end plate (Fig. 2) which leads to the oil passage in the blower drive support housing.

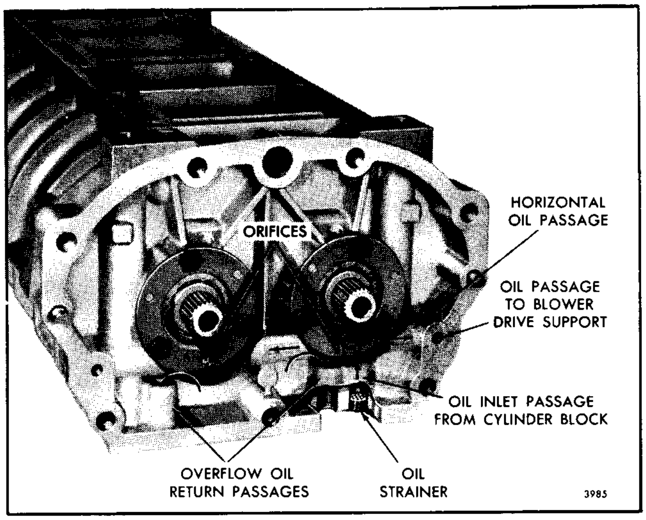

Fig. 2 - Blower Lubrication

Inspection

The blower may be inspected without being removed from the engine. However, the air silencer and adaptor, or the air inlet housing, air shutdown housing and adaptor must first be removed.

> **CAUTION:** 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 remove the burrs to eliminate the interference, or replace the rotors if they are badly scored.

Leaky oil seals are usually manifest by the presence of oil on the blower rotors or the inside surfaces of the housing. This condition may be checked by running the engine at low speed and directing a light into the rotor compartment at the end plates and the oil seals. A thin film of oil radiating away from the seals is indicative of an oil leak.

A worn blower drive usually results in a rattling noise inside the blower and may be detected by grasping the right-hand helix 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. The drive

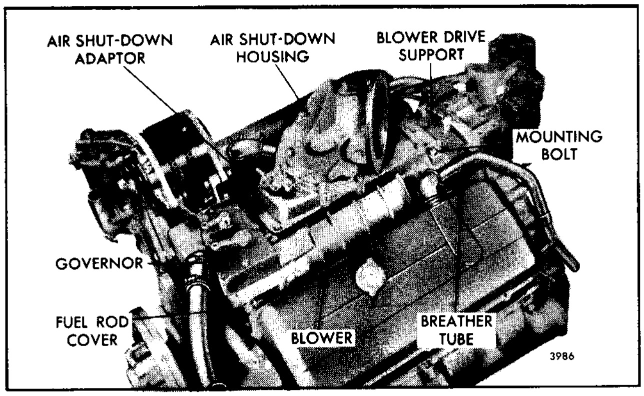

Fig. 3 - Typical Blower Mounting

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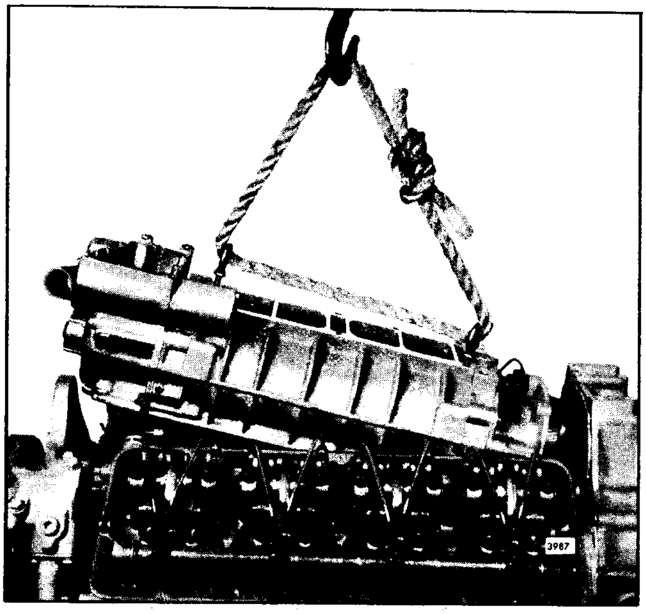

Fig. 4 - Removing Blower From Engine

coupling is attached to the left-hand helix rotor drive gear.

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 rotor gears usually results in rotor lobes rubbing throughout their entire length.

Inspect the blower inlet screen periodically for 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 it with a stiff brush until the screen is free of all dirt deposits.

To correct any of the above conditions, remove the blower from the engine and either repair or replace it.

Remove Blower

The engine governor components are assembled in a combination governor housing and blower front end plate cover. The blower drive components are assembled in a combination blower drive housing and blower rear end plate cover. Therefore, when removing the blower assembly from the engine, the governor and blower drive support assemblies will also be removed at the same time. Refer to Fig. 1 and proceed as follows:

1. Disconnect the throttle control rods from the governor levers.

2. Remove the six bolts and lock washers securing the air shutdown housing to the air inlet adaptor. Remove the shutdown housing and gasket.

3. Remove the six bolts and lock washers securing the air inlet adaptor to the blower housing. Remove the air inlet adaptor and blower screen and gasket assembly.

4. Loosen the battery-charging generator adjusting strap bolt. Also loosen the nuts on the bolts securing the generator to its mounting bracket. Then remove the generator drive belts from the generator pulley.

5. While supporting the generator, remove the two nuts, lock washers and bolts securing the generator to the generator mounting bracket. Then lift the generator off the engine.

6. Remove the four bolts and lock washers securing the generator mounting bracket to the governor housing.

7. Loosen the governor housing breather tube hose clamp at the forward face of the governor and the breather tube clamp at the water pump attaching bolt. Remove the tube, hose and hose clamps from the governor and the engine.

8. Remove the four bolts and lock washers securing the water by-pass tube to the thermostat housing. Slide the

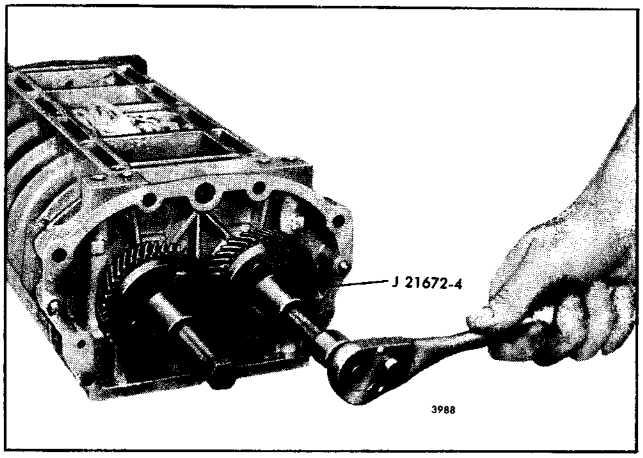

Fig. 5 - Removing Rotor Gears

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tube back on one of the thermostat housings, then lift the opposite end of the tube up and remove it from the thermostat housing.

9. Disconnect and remove the fuel oil supply and return lines connecting the fuel manifolds and the cylinder heads.

10. Remove the valve rocker cover breather tube hose clamp on each rocker cover and the tube clamp attached to the rear face of the flywheel housing; then remove the breather tubes from the engine.

11. If an air compressor is attached to the rear face of the flywheel housing, it may be removed as follows:

a. Disconnect the air compressor water inlet and outlet tubes from the air compressor. Then disconnect the oil supply line from the air compressor.

b. While supporting the air compressor, remove the four bolts and lock washers securing the air compressor to the rear face of the flywheel housing. Then remove the air compressor and gasket. If necessary, remove the air compressor drive coupling.

12. Remove the five bolts and lock washers securing the blower drive hole cover to the flywheel housing. Remove the cover and gasket.

13. Remove the two bolts securing the blower drive shaft retainer to the blower drive coupling support, then remove the retainer.

14. Pull the blower drive shaft out of the blower drive

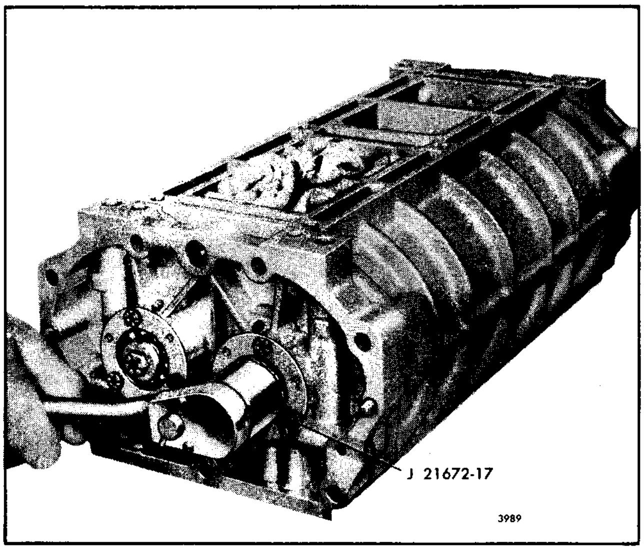

Fig. 6 - Removing Rotor Bearing Retaining Nut

hub and cam. If necessary, use a pair of small nose pliers.

15. Remove the two remaining bolts and flat washers securing the blower drive couplings to the blower drive gear, then remove the blower drive couplings.

16. Remove the five bolts, lock washers and one plain washer securing the blower drive support housing to the engine end plate.

17. Disconnect and remove the fuel oil supply line between the fuel oil pump and the fuel oil filter.

18. Clean and remove the valve rocker cover from each cylinder head.

19. Remove the eight screws and lock washers securing the governor cover to the governor housing.

20. Disconnect the fuel rods from the injector rack control tube levers and the governor and remove the fuel rods.

21. Loosen the hose clamps and slide the fuel rod cover hose down against each cylinder head.

22. Remove the two 7/16"-14 x 7/8" bolts, lock washers and plain washers securing the governor housing to the cylinder block.

23. Remove the two bolts and special washers from each blower end plate securing the blower assembly to the cylinder block.

24. Thread eyebolts in diagonally opposite air inlet adaptor-to-blower bolt holes. Attach a rope sling and a chain hoist to the eyebolts. Then lift the blower assembly, at an angle, from the cylinder block as shown in Fig. 4 and place it on a bench.

Remove Accessories from Blower

Remove the accessories from the blower as follows:

1. Remove the six bolts, lock washers, plain washers and one socket head bolt securing the blower drive support housing to the blower rear end plate.

2. Tap each end of the blower drive support housing with a plastic hammer to loosen it from the gasket and dowel pins. Then remove the drive support assembly and gasket.

3. Remove the three self-locking bolts (current blowers) or four self-locking bolts (former blowers) securing the blower drive hub to the left-hand helix rotor drive gear.

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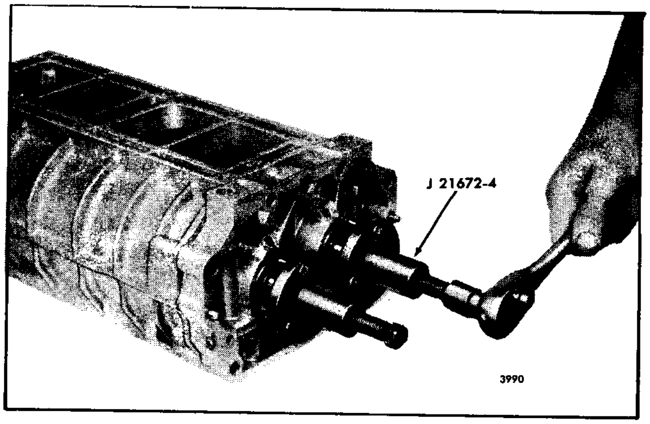

Fig. 7 - Removing Blower Rotors from Front End Plate Ball Bearings (Former Blower)

4. Remove the seven bolts and lock washers securing the breather body to the governor housing. Remove the breather body and gasket.

5. Remove the seven bolts and copper washers, two inside and five outside, securing the governor assembly to the blower front end plate.

6. Tap the governor housing with a plastic hammer to loosen it from the gasket and dowel pins. Then remove the governor assembly and gasket.

Disassemble Blower

Cover the air inlet and outlet openings and clean the exterior of the blower with fuel oil and dry it with compressed air.

Refer to Figs. 3 and 10 and disassemble the blower as follows:

1. Place a clean folded shop towel between the rotors and a towel between the rotor and housing to prevent the rotors from turning.

2. Remove the two bolts and pilots (43) securing the blower rotor gears to the blower rotor shafts.

3. Remove the blower rotor gears with pullers J 21672-4 (Fig. 5). Both rotor gears must be pulled at the same time as follows:

   a. Back the center screws out of both pullers, then place the flange end of the pullers against the rotor gears. Align the large holes in the puller flanges with the 3/8"-24 tapped holes in the gears. Secure the pullers to the gears with four 3/8"-24 x 1" bolts.

   b. 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 as shown in Fig. 5.

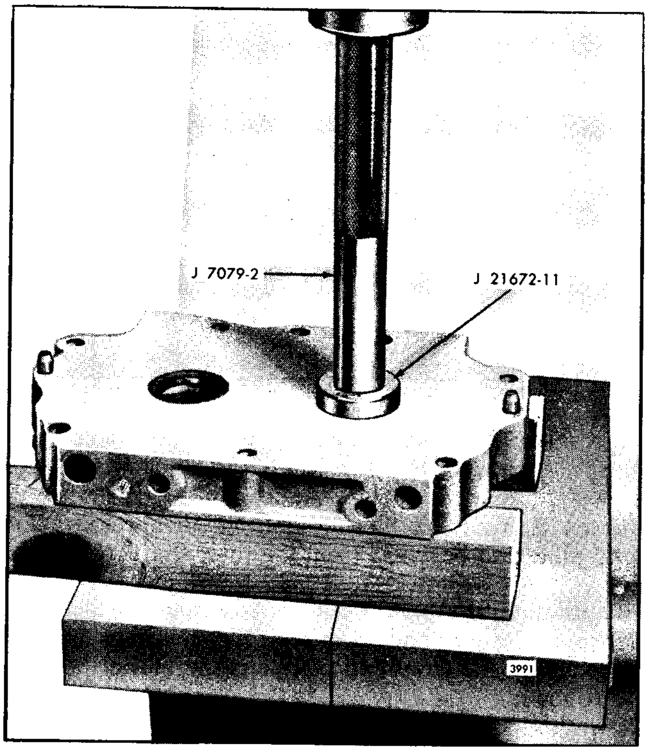

Fig. 8 - Removing Oil Seal and Roller Bearing from Rear End Plate (Former Blower)

4. Remove the shims from the rotor shafts and note the number and thickness of the shims on one or both of the rotor shafts.

5. Remove the bolts securing the rotor shaft bearing retainers (71) to the rear end plate, then remove the retainers.

6. Remove the bolt and special washer (80) securing the ball bearing (former blower) or roller bearing (current blower) on the right-hand helix rotor shaft at the front end of the blower.

7. Bend the tang of the bearing retainer nut lock washer (81) up out of the notch in the bearing lock nut (82). Then remove the bearing lock nut with spanner wrench J 21672-17 as shown in Fig. 6.

8. Remove the bolts securing the rotor shaft bearing retainers to the front end plate, then remove the retainers.

9. Remove the socket head bolt (50) securing the blower rear end plate to the blower housing. Tap each end of the rear end plate with a plastic hammer to

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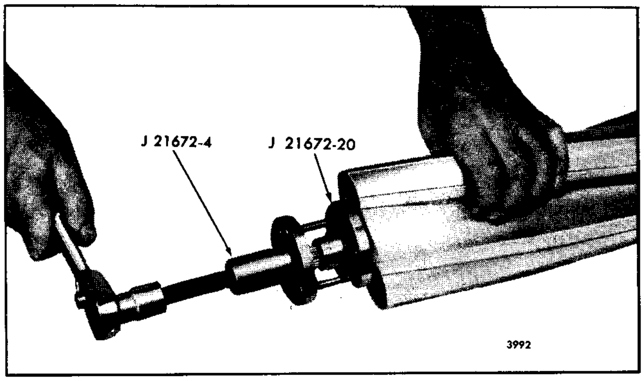

Fig. 9 · Removing Oil Seal Sleeve and Roller Bearing Inner Race from Rotor Shaft

loosen it from the blower housing, then remove the end plate and bearings from the rotor shafts.

10. Remove the blower rotors from the ball bearings (former blowers) and from the roller bearings (current blowers) in the front end plate and the blower housing as follows:

a. Back the center screw out of both pullers J 21672-4, then attach the pullers to the blower front end plate with six 1/4″-20 x 1-1/2″ or longer bolts as shown in Fig. 7.

b. Remove the shop towels from between the blower rotors and the housing.

c. Turn the puller screws uniformly clockwise and push the rotor shafts out of the ball bearings (former blower) or roller bearings (current blower) in the end plate. Then slide the rotors out of the blower housing.

d. Remove the pullers from the blower front end plate.

11. Remove the socket head bolt securing the blower front end plate to the blower housing. Tap each end of the front end plate with a plastic hammer to loosen it and remove it from the blower housing.

12. Inspect the rotor shaft oil seals. If the seals are scored or hard, remove the bearings and oil seals from the blower end plates as follows:

a. Support the blower end plate, inner face up, on two wood blocks on the bed of an arbor press as shown in Fig. 8.

b. Place the oil seal remover J 21672-11 with handle J 7079-2 on top of the oil seal and under the ram of the press, then press the oil seal and bearing out of the end plate as shown in Fig. 8. Discard the oil seal.

c. Remove the remaining oil seals and bearings from the end plates in the same manner as outlined in items "a" and "b" above.

NOTE: When the roller bearings are removed from the rear end plate, each bearing must be tagged to be sure it will be installed in the same bearing bore in the end plate that it was removed from.

NOTE: Oil seal sleeves have been discontinued in the rear position of the current non-turbocharged engine blower. The oil seal sleeves will continue to be used in both the front and rear end plates (four positions) in the turbocharged engine blower.

13. If the roller bearings or the oil seal sleeves are to be replaced, the roller bearing inner races and oil seal sleeves may be removed from the rotor shafts as follows:

The roller bearing inner race may be removed separately or the oil seal sleeve and inner race may be removed together.

a. Place the roller bearing inner race and oil seal sleeve remover J 21672-20 over the rotor shaft behind the oil seal sleeve as shown in Fig. 9.

b. Back out the center screw of one gear puller J 21672-4, then attach the puller to the oil seal sleeve remover with three 1/4″-20 x 3″ bolts and flat washers as shown in Fig. 9.

c. Turn the puller screw clockwise and pull the roller bearing inner race and oil seal sleeve off of the rotor shaft.

d. Remove the roller bearing inner race and oil seal sleeve from the remaining rotor shaft.

NOTE: Be sure and tag or place each roller bearing inner race with its mating roller bearing. Do not intermix the inner races and roller bearings.

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

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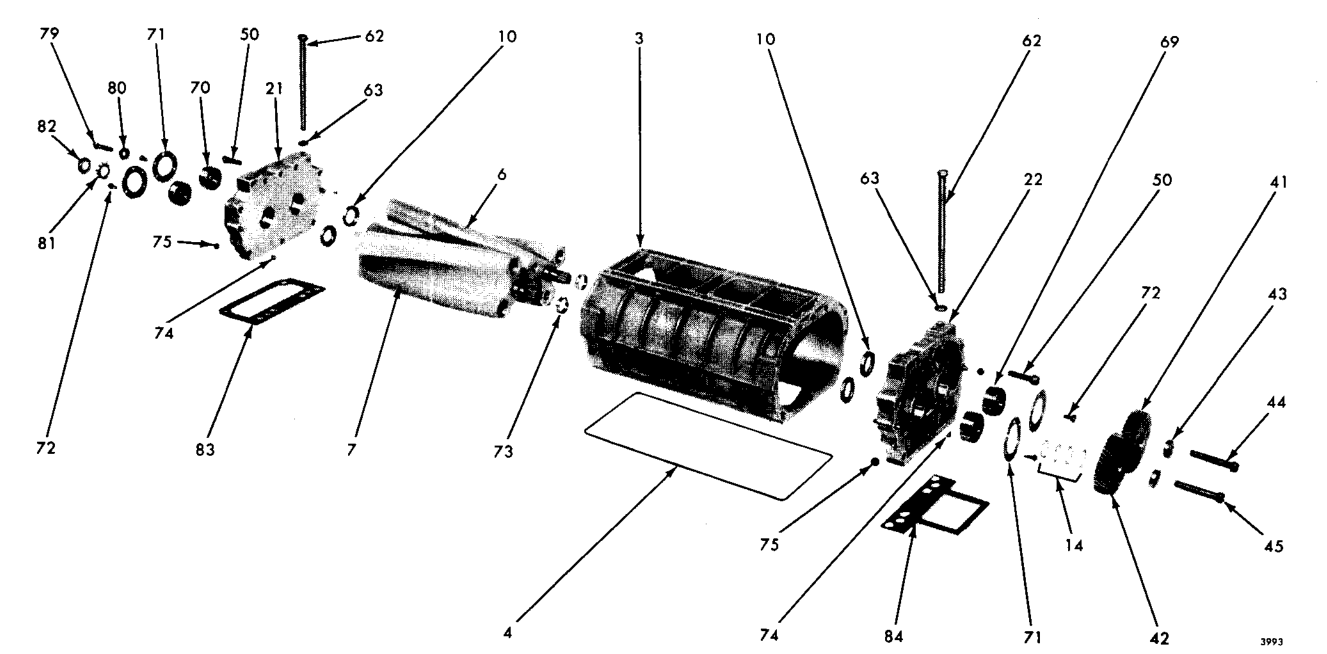

3. Housing--Blower	42. Gear--Rotor Driven R.H. Helix	69. Bearing--Rotor Rear (Roller)	74. Strainer--End Plate Oil Passage
4. Gasket	43. Pilot--Rotor Gear	70. Bearing--Rotor Front (Ball)	75. Plug--Pipe
6. Rotor Assy.--R.H. Helix	44. Bolt--Drive Gear	71. Retainer--Bearing	79. Bolt
7. Rotor Assy.--L.H. Helix	45. Bolt--Driven Gear	72. Bolt--Bearing Retainer	80. Washer
10. Oil Seal--Rotor Shaft	50. Bolt--Socket Head	73. Sleeve--Oil Seal	81. Lock Washer
14. Shims	62. Bolt--Blower-to-Block		82. Nut
21. Plate--Front End	63. Washer--Special		83. Gasket
22. Plate--Rear End			84. Gasket
41. Gear--Rotor Drive L.H. Helix			

Fig. 10 - Blower Details and Relative Location of Parts (8V-53) (Former Blower)

no end play. A new double-row bearing will seem to have considerable resistance to motion when revolved by hand.

Examine the rotor shafts and the oil seal sleeves (used on former blowers and turbocharged engine blowers) for wear.

Inspect the blower rotor lobes, especially the sealing ribs, for burrs and scoring. 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 contact surfaces of the shafts for wear and scoring.

Inspect the inside surface of the blower housing for burrs and scoring. If the inside surface of the housing is slightly scored or burred, it may be cleaned up with emery cloth.

Check the finished ends of the blower housing for flatness and burrs. The end plates must set flat against the blower housing.

The finished inside face of each end plate must be smooth and flat. If the finished face is slightly scored or burred, it may be cleaned up with emery cloth.

Examine the serrations in the blower rotor 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.

NOTE: The left-hand helix rotor drive gear in the current blower has three bolt holes. The gear in the former blower has four bolt holes. This is due to the bolting arrangement (three bolt holes current drive hub, four bolt holes former drive hub) of the drive hub.

Check the blower drive shaft serrations for wear or peening. Replace the shaft if it is bent.

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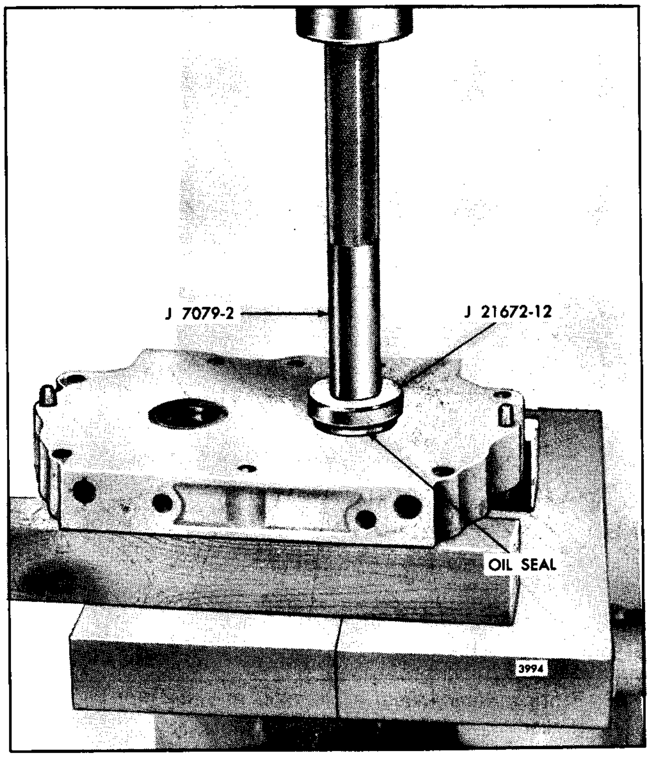

Fig. 11 - Installing Oil Seal in Rear End Plate (Former Blower)

Inspect the blower drive coupling springs (pack) and the cam for wear.

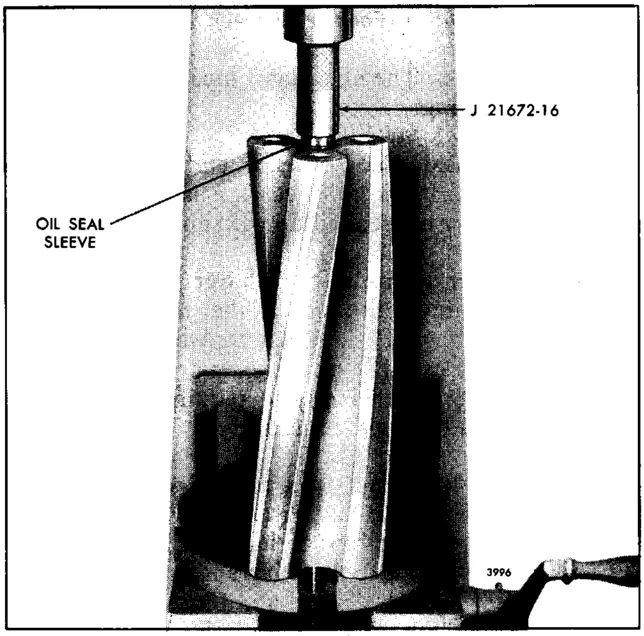

Fig. 12 - Installing Oil Seal Sleeve on Rotor Shaft (Former Blower)

Replace all worn or excessively damaged blower parts.

Clean the oil strainer in the vertical oil passage at the bottom of each blower end plate and blow out all oil passages with compressed air.

Assemble Blower

The lobes on the *driving* blower rotor form a right-hand helix and the teeth on its gear form a left-hand helix while the lobes on the *driven* blower rotor form a left-hand helix and the teeth of its gear form a right-hand helix. Hence, a rotor with right-hand helix lobes must be used with a gear having left-hand helix teeth and vice versa.

> **NOTE:** New rotors with a different helix angle have been incorporated in the 8V engine blowers. The former and new rotors must not be mixed in a blower assembly. The proper clearances cannot be obtained in a mix of the former and new rotors.

With this precaution in mind, proceed with the blower assembly, referring to Figs. 10 through 20 as directed in the text:

1. If removed, press a new oil strainer into the vertical oil passage at the bottom of each end plate from flush to .015" below the bottom surface (Fig. 2). Also, if removed, install a pipe plug in the horizontal oil passage at each end of both end plates.

2. Install new oil seals in the blower end plates as follows:

   a. Support the blower rear end plate, finished surface facing up, on wood blocks on the bed of an arbor press.

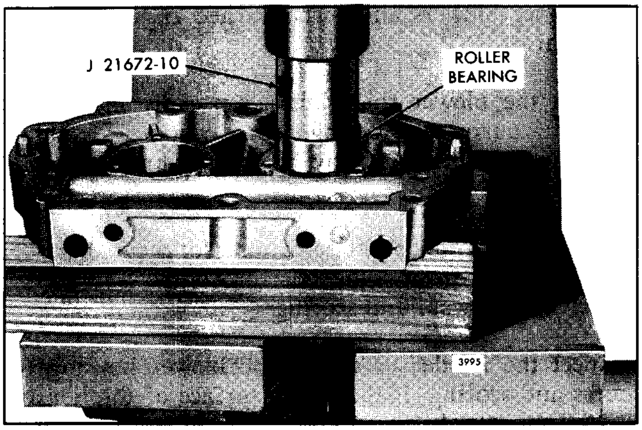

Fig. 13 - Installing Roller Bearing in Rear End Plate (Former Blower)

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NOTE: The rotor shaft oil seals used in the former blower end plates have two different inside diameters. Install the oil seal with the largest inside diameter in the former blower rear end plate. On current blowers, the oil seal sleeves have been discontinued in the rear position, therefore the same oil seal is now used in both the front and rear end plates.

NOTE: The rear end plate may be identified by the bolt guide sleeve pressed into the right-hand bolt hole in the bottom of the end plate.

b. Start the large inside diameter oil seal straight into the bore in the rear end plate with the lip of the seal facing down (toward the bearing bore).

c. Place the oil seal installer J 21672-12 with handle J 7079-2 on top of the oil seal as shown in Fig. 11. Then press the oil seal straight into the end plate until the shoulder on the installer contacts the end plate.

d. Install the second oil seal in the rear end plate and the oil seals in the front end plate in the same manner.

NOTE: The oil seals must be flush to .010" below the finished surface of the end plate.

3. If removed, install the rear end plate oil seal sleeve and the roller bearing inner race on the gear end of each blower rotor shaft as follows:

a. Support the blower rotor, gear end up, on the bed of an arbor press as shown in Fig. 12.

b. Start the oil seal sleeve straight on the sleeve surface of the shaft.

c. Place the oil seal sleeve installer J 21672-16 on top of the oil seal sleeve. Then press the sleeve on the shaft until the step in the installer contacts the shoulder on the shaft.

NOTE: The step in the installer properly positions the oil seal sleeve on the rotor shaft.

d. Install the remaining oil seal sleeve on the shaft of the second blower rotor.

e. Press a roller bearing inner race on the gear end of each blower rotor shaft with installer J 21672-16.

NOTE: When installing a roller bearing inner race, note the tags previously placed on the bearings and races at the time of removal and install the bearing inner races, numbered end up, on the rotor shafts in their original positions. Do not intermix the races and bearings.

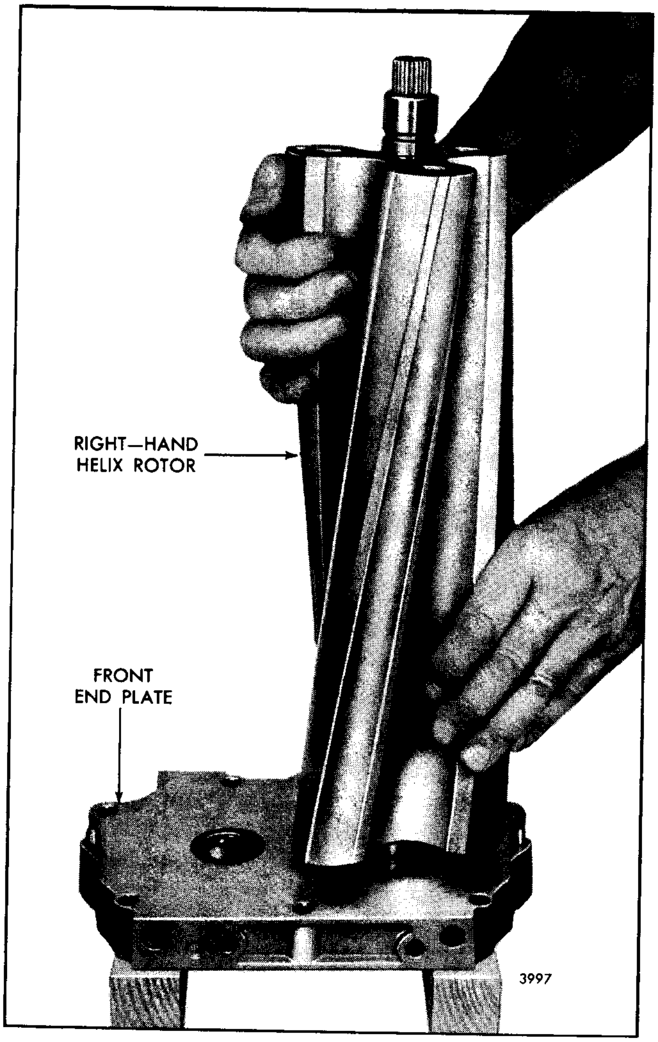

Fig. 14 - Installing Blower Rotor in Front End Plate

4. Install the roller bearings in the rear end plate as follows:

a. Support the rear end plate (inner face down) on two wood blocks on the bed of an arbor press as shown in Fig. 13.

NOTE: The rear end plate may be identified by the bolt guide sleeve pressed into the right-hand bolt hole in the bottom of the end plate.

b. Lubricate the outside diameter of a roller bearing with engine oil. Note the tag previously placed on the bearing at the time of removal, then start the bearing, numbered end up, straight into the bearing bore in the end plate.

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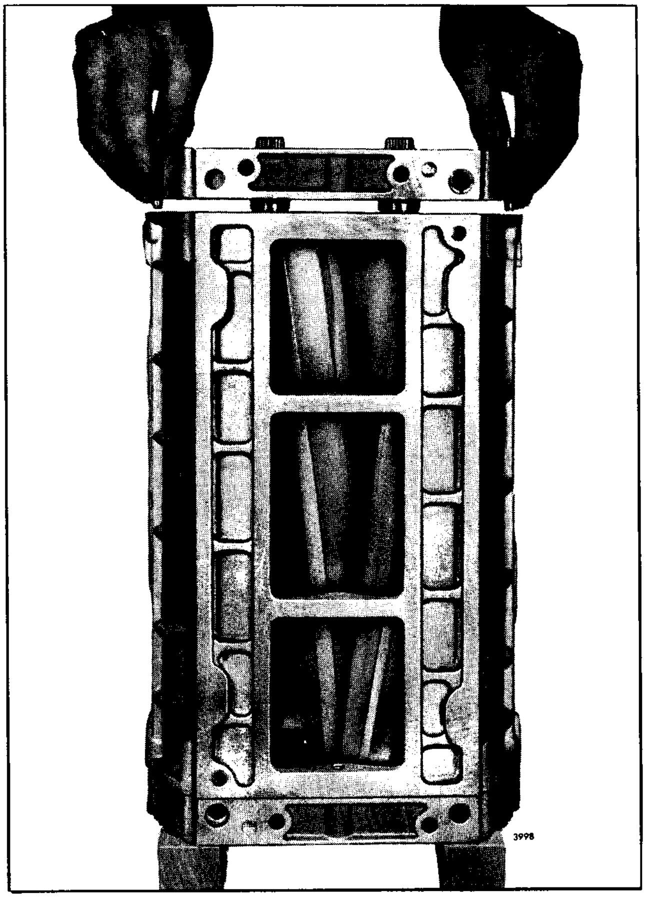

Fig. 15 - Installing Rear End Plate on Blower Rotors and Housing

NOTE: Be sure the bearing installed in the end plate will mate with its inner race on the rotor shaft.

c. Place the bearing installer J 21672-12 on top of the roller bearing, then press the bearing straight into and against the shoulder in the end plate.

d. Install the remaining roller bearing in the rear end plate in the same manner.

5. Install the blower rotors in the front end plate.

The rotors must be assembled in the blower housing with the omitted serrations in the rotor shafts aligned as shown in Fig. 20.

The front end plate should be attached to the front end of the blower housing first. The rear end plate is attached to the blower housing after the rotors are in place. The front end plate does not incorporate the bolt guide sleeve in the counterbored bolt hole in the bottom of the end plate. Install the blower rotors in the front end plate as follows:

a. Check the dowel pins. The dowel pins must project .380″ from the flat inner face of the front end plate to assure proper alignment of the end plate with the housing.

b. Hold the right-hand helix rotor in a vertical position, gear end up, with the omitted serration in the splines of the shaft facing to the right as shown in Fig. 20. Then start the end of the shaft straight into the oil seal in the right-hand shaft opening in the end plate as shown in Fig. 14 and lower it until the lobes of the rotor contact the end plate.

c. Position the left-hand helix rotor so the lobes of the rotors are in mesh and the omitted serration in the splines of the rotor shaft is facing in the same direction as the omitted serration in the right-hand helix rotor shaft. Then start the end of the shaft straight into the oil seal in the left-hand shaft opening in the end plate and lower it until the lobes contact the end plate.

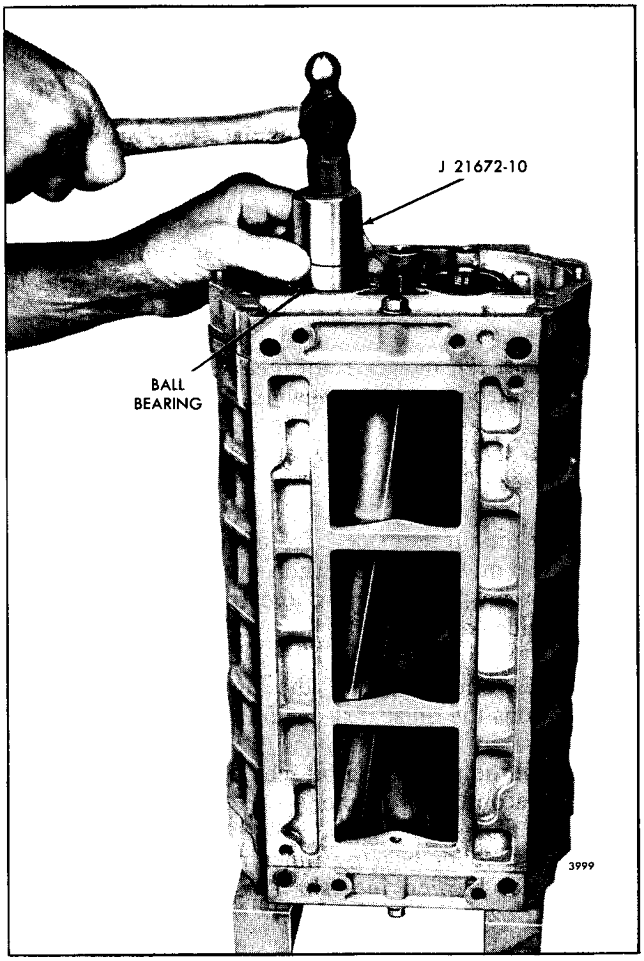

Fig. 16 - Installing Ball Bearings on Rotor Shafts and in Front End Plate (Former Blower)

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6. Position the blower housing over the rotors, rear end of housing up, with the bottom of the housing facing toward the bottom of the end plate (Fig. 15). Lower the housing over the rotors and start it straight on the dowel pins in the front end plate, then push it down tight against the end plate. If necessary, tap the housing lightly with a plastic hammer.

NOTE: The blower housing is marked **REAR** near the top on the outside face of the housing and must be at the gear end of the rotors when assembled to the front end plate.

7. Install the blower rear end plate on the rotor shafts and housing as follows:

a. Check the dowel pins. The dowel pins must project .380″ from the flat inner face of the rear end plate to assure proper alignment of the end plate with the housing.

b. Lubricate the inside diameter of the roller bearings with engine oil.

c. Position the rear end plate over the top of the rotor shafts with the inner face of the end plate facing the rotors and the **TOP** side of the end plate facing the top side of the blower housing.

d. Lower the end plate straight over the rotor shafts until the dowel pins in the end plate contact the blower housing (Fig. 15), then carefully work the dowel pins into the dowel pin holes in the housing and push the end plate tight against the housing. If necessary, tap the end plate lightly with a plastic hammer.

e. Install the 3/8″-16 socket head bolt in the counterbored bolt hole at the top of the end plate. Then install a 3/8″-16 hex head bolt with a flat washer in the center bolt hole at the bottom of the end plate.

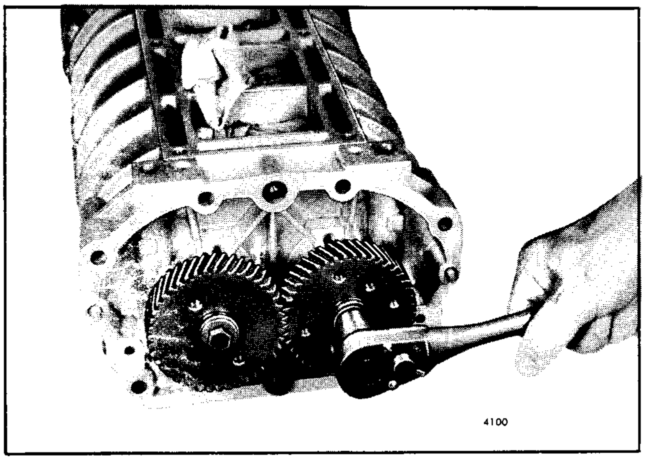

Fig. 17 - Installing Blower Rotor Gears

f. Place the bearing retainers on top of the bearings and the end plate, then install the retainer bolts. Tighten the bolts to 7-9 lb-ft (10-12 Nm) torque.

8. Reverse the blower housing, rotors and end plates on the wood blocks.

9. Install a 3/8″-16 socket head bolt in the counterbored bolt hole at the top of the end plate. Then install a 3/8″-16 hex head bolt with a flat washer in the center bolt hole at the bottom of the end plate.

10. Install the ball bearings on the blower rotor shafts and in the front end plate as follows:

a. Lubricate one of the ball bearings with light engine oil. Start the bearing, numbered end up, straight on one of the rotor shafts.

b. Place installer J 21672-10 on top of the bearing and tap the bearing straight on the shaft and into the front end plate as shown in Fig. 16.

c. Install the second ball bearing on the remaining rotor shaft in the same manner.

d. Place the bearing retainers on top of the bearings and the end plate, then install the retainer bolts. Tighten the bolts to 7-9 lb-ft (10-12 Nm) torque.

11. Place the blower assembly on a bench and 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. 21. Refer to Fig. 19 for minimum blower clearances.

12. Install the blower rotor gears on the rotor shafts as follows:

a. Place the blower assembly on the bench, with the top of the housing 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 to the right (Fig. 20).

c. Install the same number and thickness of shims on the rotor shafts that were removed at the time of disassembly.

d. Lubricate the serrations of the rotor shafts with light engine oil.

e. Place the teeth of the rotor gears in mesh so that

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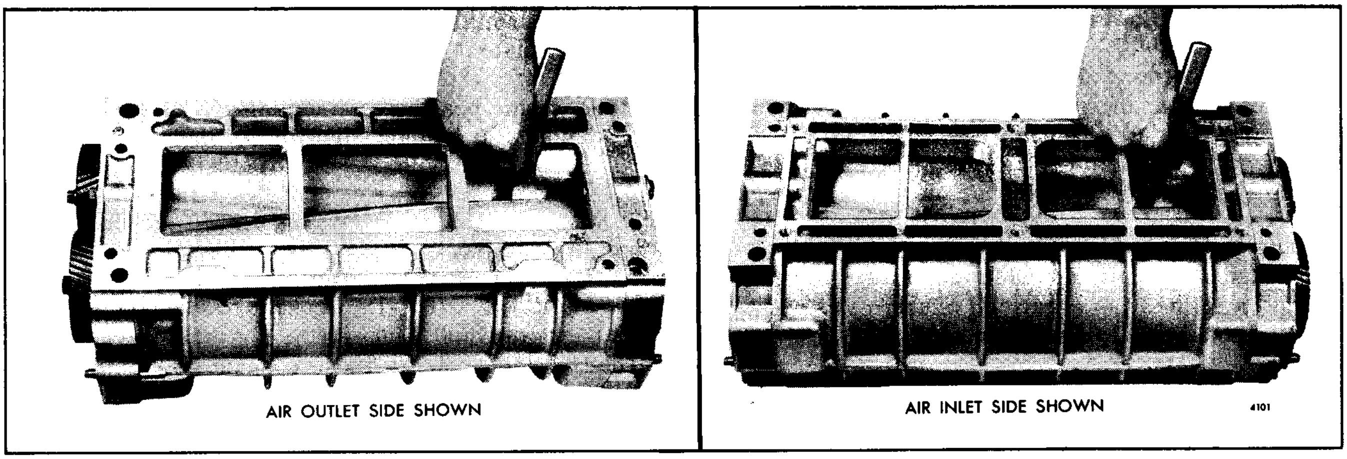
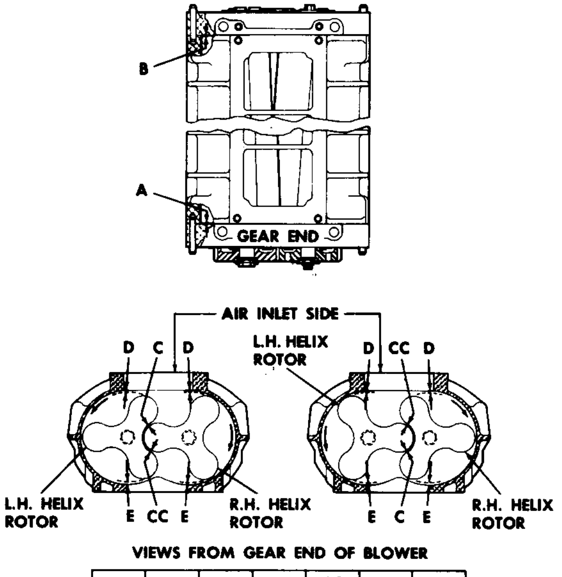


Fig. 18 - Measuring Clearance Between Blower Rotor Lobes

the omitted serrations inside the gears are in alignment and facing the same direction as the serrations on the shafts.

NOTE: A center punch mark placed in the end of each rotor shaft at the omitted serrations will assist in aligning the gears on the shafts.



	A	B	C	CC	D	E
MIN.	.007"	.017"	.018"	.008"	.017"	.005"
* MIN.	.014"	.007"	.018"	.008"	.017"	.005"

11794

NOTE: Time rotors to dimensions on above chart for clearance between trailing side of R.H. Helix Rotor and leading side of L.H. Helix Rotor (cc) from both inlet and outlet side of blower.

***Use these clearances for blowers with ball bearings at the front and the roller bearings at the (rear) gear end.**

Fig. 19 - Chart of Minimum Blower Clearances

f. Start the left-hand helix gear on the right-hand helix rotor and the right-hand helix gear on the left-hand helix rotor, with the omitted serrations in the rotor gears in line with the omitted serrations on the rotor shafts.

g. Place the rotor gear pilots (43) on two 3/8"-24 x 2-3/4" bolts, then thread a bolt into the end of each rotor shaft. Place a clean shop towel between the rotors and one between the rotor and the housing (Fig. 17) to prevent the gears from turning. Then draw the gears approximately half-way on the rotor shafts.

h. Remove the two bolts and pilots that were used to draw the rotor gears half-way on the rotor shafts.

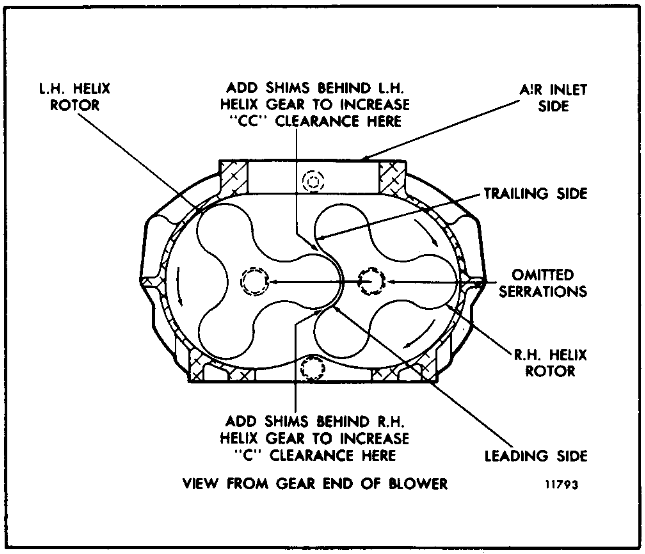


Fig. 20 - Diagram Showing Proper Location of Shims for Correct Rotor Lobe Clearances

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i. Lubricate the threads of the rotor gear retaining bolts with engine oil.

j. Place a pilot on each rotor gear retaining bolt with the counterbored side facing away from the bolt head.

k. Thread the hex head bolt in the left-hand helix rotor shaft and the twelve point head bolt in the right-hand helix rotor shaft and draw the rotor gears into position tight against the shims and the bearing inner races as shown in Fig. 17. Tighten the bolts to 50-55 lb-ft (68-75 Nm) torque.

l. Check the backlash between the rotor gears. The backlash should be .0005" to .0025" with new gears. Replace the gears if the backlash exceeds .0035".

13. Install the 3/8"-24 x 2" bolt with special flat washers in the right-hand helix rotor shaft at the front end of the blower. Tighten the bolt to 50-55 lb-ft (68-75 Nm) torque.

14. Place the bearing retainer nut lock washer over the end of the left-hand rotor shaft with the tang in the inner diameter of the washer in the notch in the shaft. Then thread the bearing lock nut on the shaft. Tighten the lock nut to 50-60 lb-ft (68-81 Nm) torque with spanner wrench J 21672-17.

15. Bend the tang of the lock washer over the notch of the bearing retainer nut.

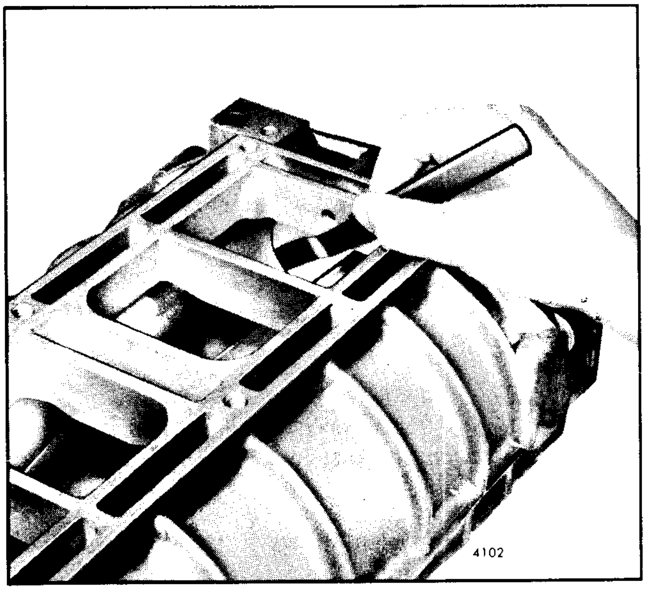

Fig. 21 - Measuring End Clearance Between Blower Rotors and End Plate

Timing Blower Rotors

After the blower rotors and rotor gears are installed, the blower rotors must be timed.

1. The blower rotors, when properly positioned in the housing, run with a slight clearance between the lobes. This clearance may be varied by moving one of the helical gears in or out on the shaft relative to the other gear.

2. If the left-hand helix gear is moved out, the right-hand helix rotor will turn clockwise when viewed from the gear end. If the right-hand helix gear is moved out, the left-hand helix rotor will turn counterclockwise 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.

3. Moving the gears *out* or *in* on the rotor shafts is accomplished by adding or removing shims between the gears and the bearings.

4. The clearance between the rotor lobes may be checked with 1/2" wide feeler gages in the manner shown in Fig. 18. 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.

5. A specially designed feeler gage set J 1698-02 for the blower clearance operation is available. Time the rotors as follows:

a. Time the rotors to pass an .008" feeler gage at the closest point between the *trailing* edge of the right-hand helix rotor and the *leading* edge of the left-hand helix rotor ("CC" clearance) measured from both the inlet and outlet sides as shown in Figs. 18 and 21.

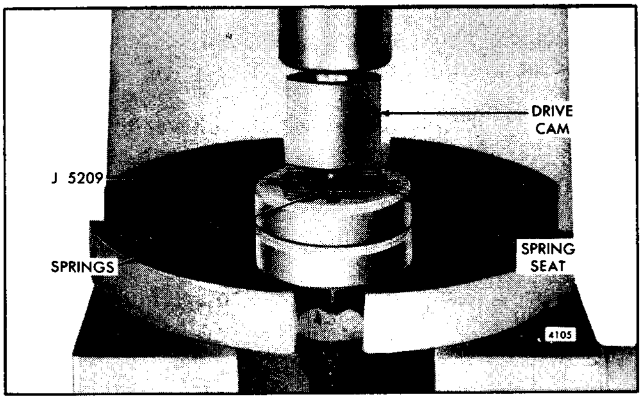

Fig. 22 - Inserting Blower Drive Cam in Springs

b. Then check the clearance between the *leading* edge of the right-hand helix rotor and the *trailing* edge of the left-hand helix rotor ("C" clearance) for the minimum clearance of .018". Rotor-to-rotor measurements should be taken 1" from each end and at the center of the blower.

6. After determining the amount one rotor must be revolved to obtain the proper clearance, add shims back of the proper gear as shown in Fig. 20 to produce the desired result. When more or less shims are required, both gears must be removed from the rotors. Placing a .003" shim in back of a rotor gear will revolve the rotor .001".

7. Install the required thickness of shims back of the proper gear and next to the bearing inner race and reinstall both gears. Recheck the clearances between the rotor lobes.

8. Determine the minimum clearances at points "A" and "B" shown in Fig. 19. Insert the feeler gages, as shown in Fig. 21, between the end plates and the ends of the rotors. This operation must be performed at the ends of each lobe, making 12 measurements in all. Refer to Fig. 19 for the minimum clearances.

9. Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side -- 12 measurements in all. Refer to Fig. 19 for the minimum clearances.

Attach Accessories to Blower

On the former blowers, the drive hub is attached to the left-hand helix gear with four bolts. On the current blowers, a new drive hub is used with three bolt holes and utilizing two steel plates. The plates are bolted between the left-hand helix rotor drive gear and the drive hub to provide a flexible drive connection. On former blowers, the right-hand helix rotor gear is separately interchangeable, but the current drive hub and attaching parts must be included to replace the left-hand helix rotor gear.

1. On the former blower, attach the blower drive hub to the left-hand helix rotor gear with four bolts. On the current blower, bolt two steel plates between the left-hand helix rotor drive gear and the drive hub. Tighten the bolts to 15-19 lb-ft (20-26 Nm) torque.

2. If removed, install a new blower drive hub oil seal (former blower) in the groove in the outside diameter of the drive hub.

3. Attach the blower drive support assembly to the blower assembly as follows:

a. Affix a new gasket to the blower rear end plate. Then place the blower drive support assembly over the two dowel pins in the rear end plate and against the gasket.

b. Attach the blower drive support assembly to the rear end plate with six bolts, lock washers, plain washers and one socket head bolt. Tighten the bolts to 20-24 lb-ft (27-33 Nm) torque.

4. Attach the governor assembly to the blower assembly as follows:

a. Affix a new gasket to the blower front end plate.

b. Position the governor assembly in front of the blower, then start the weight shaft straight into the end of the rotor shaft. If necessary, rotate the weight shaft or rotor shaft to align the splines. Now push the governor assembly on the dowel pins in the end plate and against the gasket.

c. Attach the governor to the front end plate with seven bolts and copper washers (two bolts inside and five outside). Tighten the bolts to 20-24 lb-ft (27-33 Nm) torque.

Install Blower

1. Affix a new governor housing gasket (83), Fig. 10, to the cylinder block.

2. Affix a new blower drive support housing gasket (84) to the cylinder block. Also affix a new gasket to the cylinder block rear end plate.

> **NOTE:** Use Scotch Grip Rubber adhesive No. 1300, or equivalent, on the governor housing and blower drive support housing gaskets to prevent them from slipping when the blower assembly is lowered into position.

3. Place the blower housing-to-cylinder block seal ring in the groove in the top of the cylinder block.

4. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at the side of each cylinder head.

5. Thread eyebolts in two diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and a chain hoist to the eyebolts as shown in Fig. 4.

6. Lift the blower assembly at a slight angle and position it over the top of the cylinder block. Then lower the assembly on the cylinder block and mesh the blower drive gear with the camshaft gear.

7. Install two 7/16"-14 x 7-1/2" bolts and special

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washers in each blower end plate. Tighten the bolts to 55-60 lb-ft (75-81 Nm) torque.

8. Install the two 7/16″-14 x 7/8″ governor housing-to-cylinder block bolts and copper washers. Tighten the bolts to 46-50 lb-ft (62-68 Nm) torque.

9. Install the five blower drive support housing-to-engine end plate bolts, lock washers and one plain washer. Tighten the bolts to 20-24 lb-ft (27-33 Nm) torque.

10. If disassembled, install the springs and blower drive cam in the two blower drive coupling supports as follows:

a. Place the drive spring supports on a bench. Then place the drive spring seats inside the support.

b. Lubricate the springs with engine oil. Then place the spring packs, consisting of 15 leaves per pack, in between the spring seats as shown in Fig. 22.

c. Place the second drive spring support on top of the first drive spring support, then install the spring seats and spring packs in the second support as outlined in Steps "a" and "b" above.

d. Place the two drive spring supports, with springs, over a small opening in the bed of an arbor press so the spring seats and the ends of the spring packs will rest on the bed of the arbor press.

e. Place the blower drive cam, the protruding end of the cam down, over the end of the installer J 5209. Insert the tapered end of the installer in between the spring packs and under the ram of the press, then press the cam into place between the spring packs as shown in Fig. 22. Catch the installer by hand after it passes through the spring packs.

11. Attach the blower drive coupling supports to the blower drive gear as follows:

a. Insert the blower drive coupling supports through the opening in the rear face of the flywheel housing, with the protruding end of the drive cam facing the drive shaft (Fig. 1).

b. Align the bolt holes in the supports with the holes in the blower drive gear, then thread two bolts with flat washers in two diametrically opposite holes, finger tight only. Install the two remaining bolts finger tight only.

c. Insert the blower drive shaft, flat end first, through the blower drive cam and into the blower drive hub. Then tighten the two bolts with the flat washers to 8-10 lb-ft (11-14 Nm) torque.

d. Check the blower drive shaft for alignment and freeness by sliding the shaft in and out of the splines in the drive hub and cam. If the drive shaft binds, loosen the two bolts with flat washers and move the blower drive support coupling slightly and retighten the bolts.

e. Remove the two bolts without the flat washers. Place the blower drive shaft retainer against the end of the blower drive support, then install the two bolts and tighten them to 8-10 lb-ft (11-14 Nm) torque.

12. Affix a new gasket to the blower drive gear hole cover, then place the cover in position against the flywheel housing and install the five bolts and lock washers. Tighten the 5/16″-18 bolts to 13-17 lb-ft (18-23 Nm) torque and the 3/8″-16 bolt to 20-24 lb-ft (27-33 Nm) torque.

13. Slide the fuel rod cover tube hoses up on the cover tubes in the governor housing and tighten the hose clamps.

14. Install the governor fuel rods and connect them to the governor and injector rack control levers.

15. Place the governor cover on the governor housing and secure it in place with eight screws and lock washers.

16. Connect the fuel oil supply line to the fuel oil pump and the fuel oil filter.

17. Connect the fuel oil supply and return lines to the fuel manifold fittings in the cylinder heads.

18. Place the water by-pass tube with seal rings and flanges in between the two thermostat housings and secure it in place with four bolts and lock washers. Tighten the bolts to 7-9 lb-ft (10-12 Nm) torque.

19. Connect the blower housing breather tube and hose to the breather housing with a hose clamp, then attach the tube clamp at the lower end of the tube to one of the water pump attaching bolts.

20. Attach the air compressor (if used) to the engine flywheel housing as follows:

a. Affix a new gasket to the bolting flange of the air compressor.

b. Install the air compressor drive coupling in the drive plate attached to the rear face of the camshaft gear.

c. Place the air compressor in position at the rear of the flywheel housing and guide the teeth on the drive coupling into the teeth in the drive plate on

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the air compressor, then push the air compressor against the flywheel housing. If necessary, rotate the crankshaft to align the teeth of the drive coupling and the drive plate.

d. Install the four bolts and lock washers and tighten them to 71-75 lb-ft (96-102 Nm) torque.

e. Connect the water inlet and outlet tubes to the air compressor. Then connect the oil supply line to the air compressor and the cylinder block.

21. If removed, attach the battery-charging generator mounting bracket to the top of the governor housing with four bolts and lock washers. Tighten the bolts to 30-35 lb-ft (41-47 Nm) torque.

22. Attach the battery-charging generator to the mounting bracket. Install the generator drive belts, then tighten the generator mounting bolts and adjust the drive belt tension.

23. Use new gaskets and install a valve rocker cover on each cylinder head.

24. Attach a valve rocker cover breather tube to each rocker cover with a hose clamp, then secure the breather tube clamp at the lower end of each tube to the flywheel housing.

25. Place the blower screen and gasket assembly in position on top of the blower, with the screen side of the assembly toward the blower. Then place the air inlet adaptor on the blower screen. Install the six bolts and lock washers and tighten them to 16-20 lb-ft (22-27 Nm) torque.

26. Affix a new gasket to the top of the air inlet adaptor, then place the air shutdown housing on top of the gasket. Install the six bolts and lock washers and tighten them to 16-20 lb-ft (22-27 Nm) torque.

27. Connect the throttle control rods to the governor levers.

28. Attach any other accessories that were removed from the engine.

29. Adjust the governor and injector rack control levers as outlined in Section 14. Check for and repair any coolant or oil leaks detected when performing the tune-up.

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TURBOCHARGER (Airesearch)

TE0675 TURBOCHARGER

The TE0675 turbocharger (Figs. 1 and 2) is designed to increase engine efficiency and power output. Power to drive the turbocharger is extracted from the waste energy in the engine exhaust gas.

The turbocharger consists of a radial inward flow turbine wheel and shaft, a centrifugal compressor wheel, and a center housing which serves to support the rotating assembly, bearings, seals, turbine housing and compressor housing. The center housing has connections for oil inlet and outlet fittings.

The turbine wheel is located in the turbine housing and is mounted on one end of the turbine shaft. The compressor wheel is located in the compressor housing and is mounted on the opposite end of the turbine wheel shaft to form an integral rotating assembly.

The rotating assembly consists of the turbine wheel and shaft assembly, piston ring(s), thrust spacer, compressor wheel and wheel retaining nut. The rotating assembly is supported on two pressure lubricated bearings which are retained in the center housing by retaining rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings and thrust collar, thrust bearing, piston ring(s) and thrust spacer.

The oil is sealed off from the compressor and the, turbine by seal arrangements at both ends of the center housing. Oil drains from the center housing by gravity.

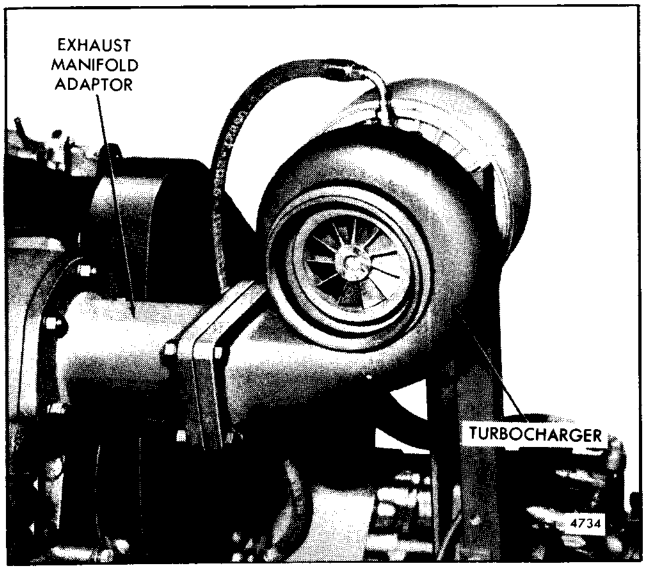

Fig. 1 - Turbocharger Mounting

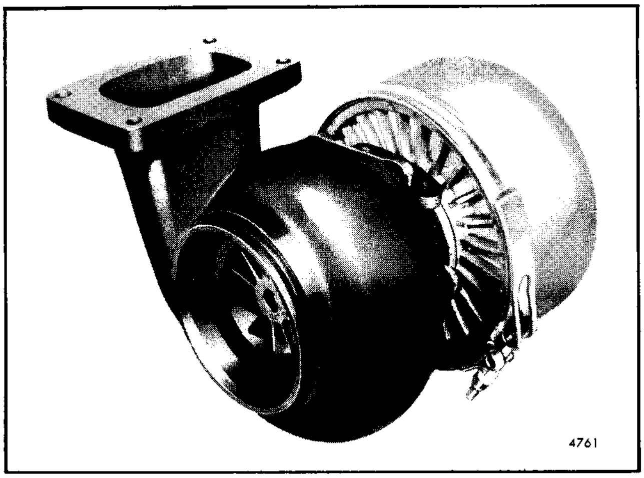

Fig. 2 - Turbocharger Assembly

The turbine housing is a heat resistant alloy casting which encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially-located turbocharger exhaust gas outlet. The turbine housing is bolted to the turbine end of the center housing, thus providing a compact and vibration free assembly.

The compressor housing which encloses the compressor wheel provides an ambient air inlet and a compressed air discharge outlet. The compressor housing is bolted to the compressor end of the center housing backplate assembly with a "V" band coupling.

Operation

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flowing from the engine and through the turbine housing cause the turbine wheel and shaft to rotate (Fig. 3). The gases are discharged into the atmosphere after passing through the turbine housing.

The compressor wheel, which is mounted on the opposite end of the turbine wheel shaft, rotates with the turbine wheel. The compressor wheel draws the ambient air into the compressor housing, compresses it and delivers it to the engine blower.

During operation, the turbocharger responds to the engine load demands by reacting to the flow of the engine exhaust gases. As the engine power output increases or decreases, the turbocharger responds to

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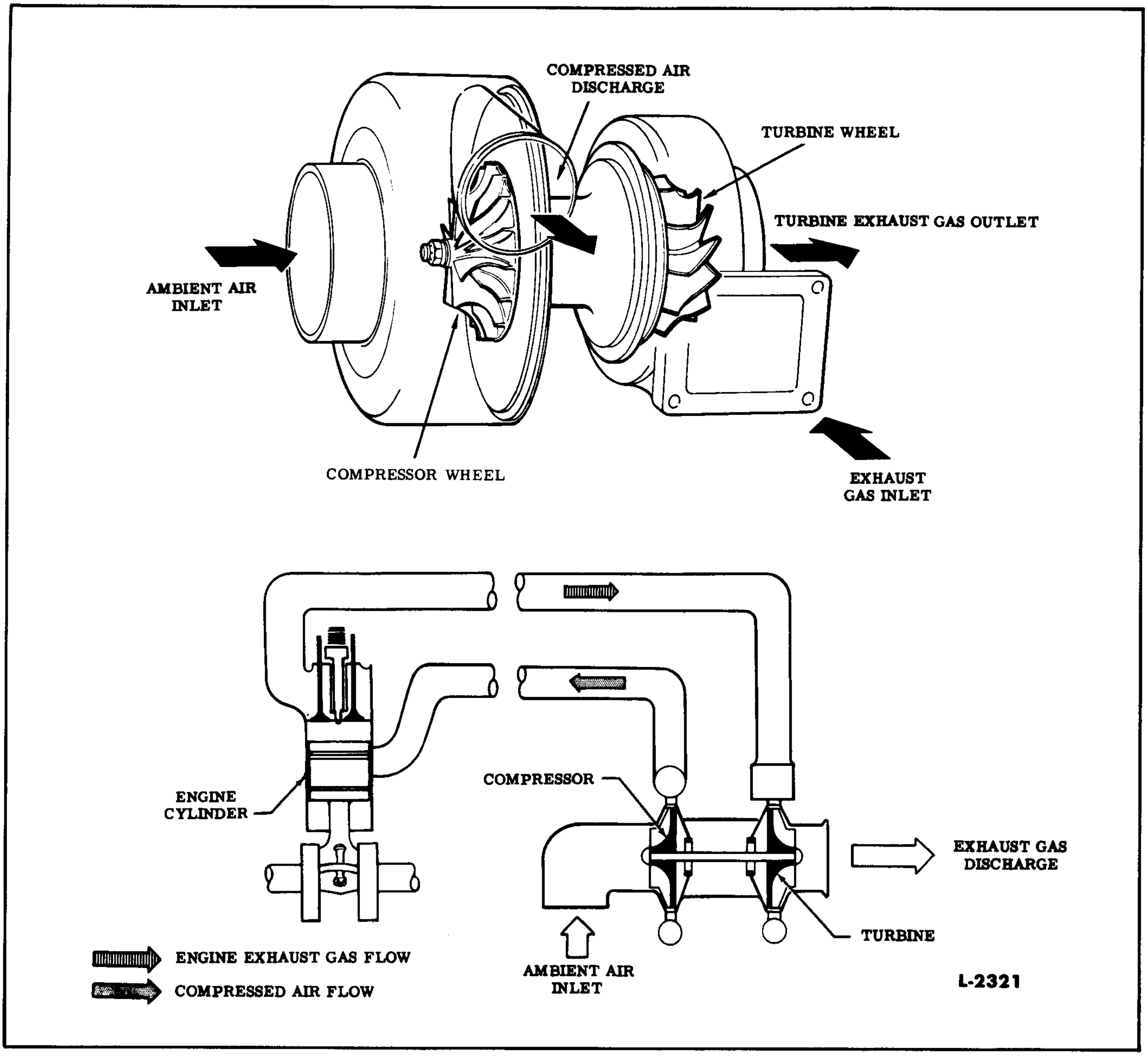

Fig. 3 - Schematic Flow Diagram

the engine's demand to deliver the required amount of air under all conditions.

Certain engines are equipped with an intercooler to reduce the temperature of the discharge air from the turbocharger before it enters the engine blower (Section 3.5.2).

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust ring, thrust bearing and backplate. The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the side of the cylinder block.

Minimum oil flow to the turbocharger with the engine at idle speed is achieved at 10 psi (69 kPa) with an oil temperature of 200 °F (93 °C).

Before the initial engine start, when a new or overhauled turbocharger is installed, the turbocharger must be pre-lubricated as outlined under *Install Turbocharger*.

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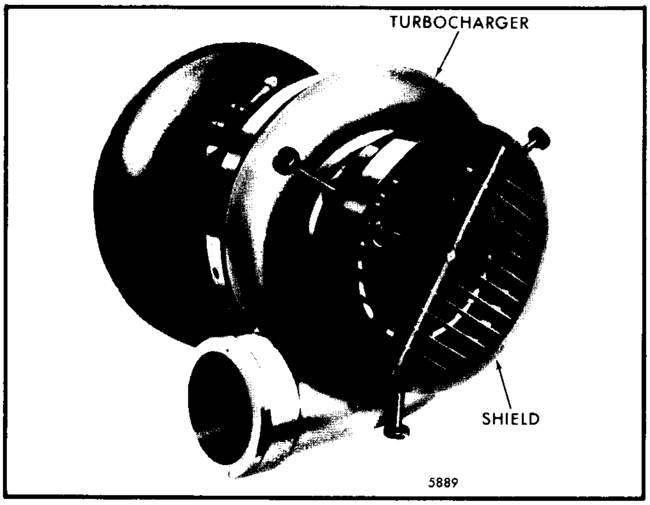

Fig. 4 - Inlet Shield (J 26554-A)

NOTE: Failure to perform the prelubrication procedure may result in premature bearing failure due to "oil lag" or lack of lubrication.

Periodic Inspection

NOTE: A turbocharger compressor inlet shield, J 26554-A, is available for use anytime the engine is operated with the air inlet piping removed (Fig. 4). The shield helps to prevent foreign objects entering the turbocharger and prevents a serviceman from touching the moving impeller. The use of this shield *does not* preclude any other saftey practices contained in this manual.

Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits (refer to Section 13.2).

A periodic inspection of the turbocharger should be made along with an engine inspection.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connection, the turbine inlet and exhaust manifold gasket.

NOTE: Do not operate the engine if leaks are found in the turbocharger ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.

Remove the inlet duct to the turbocharger compressor housing and check for carbon or dirt buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air filtering system. Remove all such accumulations and determine and correct the cause. Refer to *Trouble Shooting Charts* (Fig. 5). Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

NOTE: Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. The blades on the wheels must be thoroughly cleaned. If chunks of carbon are left on the blades, an unbalanced condition would exist and subsequent failure of the bearings would result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt and dust buildup.

For proper operation, the turbocharger rotating assembly must turn free. Whenever the exhaust ducting is removed, spin the turbine wheel by hand. If it does not spin freely, refer to Chart 1 of Fig. 5. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

Inspect the oil inlet and oil return lines to make certain all of the connections are tight and that the lines are not dented or looped so that oil flow to and from the center housing is restricted. Looping the oil return lines disrupts gravity flow of the oil back to the engine.

NOTE: Be sure the oil inlet lines are filled with oil and that they are clear of the turbine housings.

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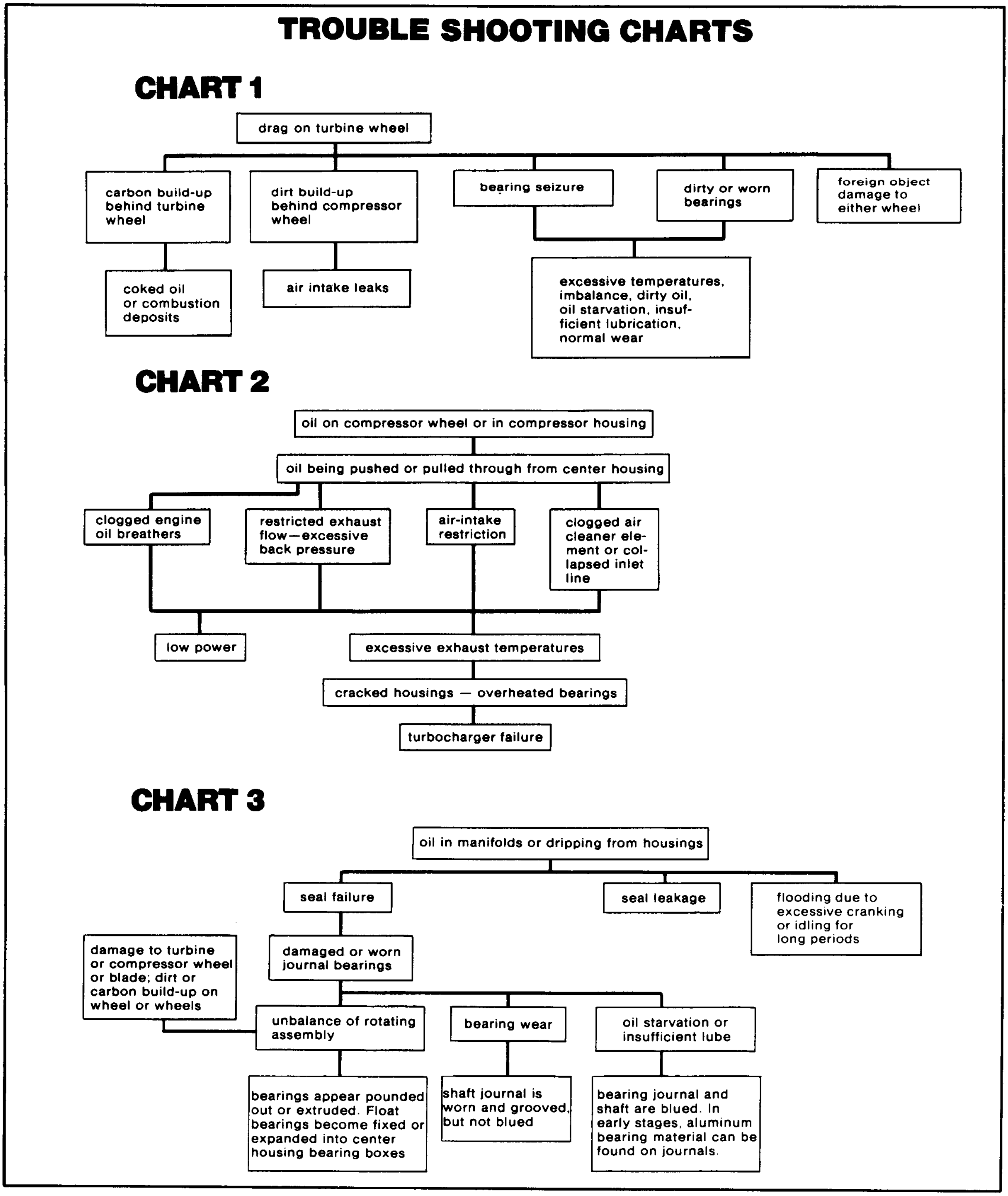

Fig. 5 - Inspection Checks for Turbocharger

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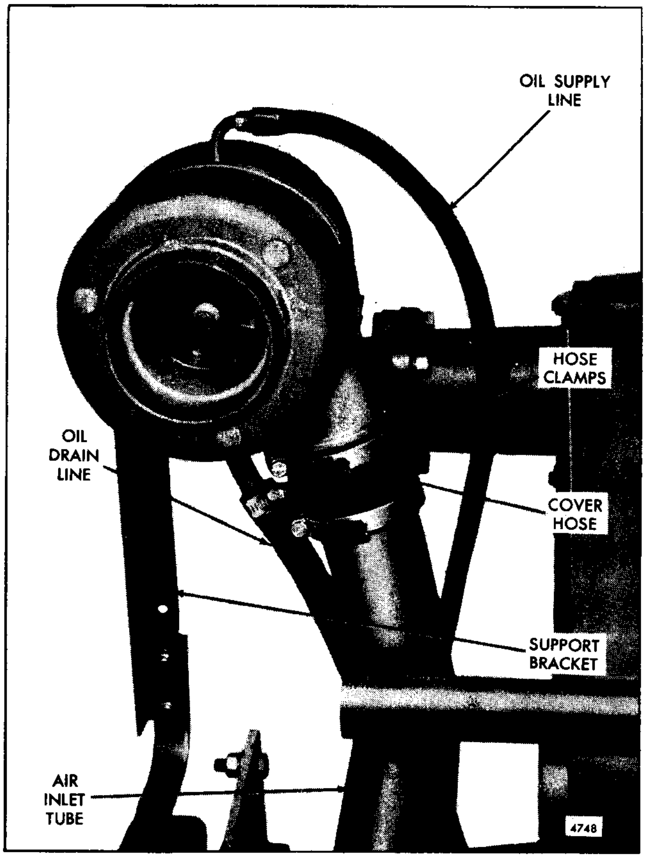

Fig. 6 - Turbocharger Support Bracket, Oil Lines and Air Inlet Tube

Check for signs of oil leaking from the turbocharger housings.

Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, oil in these sections should disappear. If the oil does not disappear, refer to Chart 2 of Fig. 5.

Oil pull-over from an oil bath type air cleaner can also cause oil to enter the compressor housing. Check for a dirty air cleaner element or for too low viscosity oil in the air cleaner. Also, too small an air cleaner could create excessive air flow velocity and result in oil pullover.

Evidence of oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that will require overhaul of the turbocharger. Refer to Chart 3 of Fig. 5.

Tests show there are three conditions that contribute to oil seal leakage at the internal turbocharger oil seal.

1. A worn or defective oil seal, which must be replaced.

2. High air inlet restriction (above specified limits). This will cause oil to be pulled past the oil seal.

3. Long periods of operation where the engine is being motored (using the engine as a braking device when going down a long hill). This can also cause oil to pass by the oil seal.

To confirm oil leakage from one or more of these conditions, remove the compressor housing and inspect the backplate. If the surface is wet with oil, it indicates leakage.

If this test does not show leakage patterns, the oil seal assembly is good for normal operation. This simple test will allow some positive testing on each engine in all cases.

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure:

1. Determine that air inlet restriction is within the Detroit Diesel maximum limit. Refer to Section 13.2.

2. Be certain that the turbocharger oil drain line is unrestricted.

3. Be certain that the turbocharger has not obviously been damaged and in need of major repair.

4. Remove air intake ducting. Inspect inside of ducting for evidence of oil. If oil is found in the intake system, determine the source before proceeding with compressor seal test and also thoroughly remove oil from the intake. Some external sources of oil are oil bath air cleaners, air compressor line, or a leak near an oil source such as an engine breather, etc.

5. Remove the compressor housing from the turbocharger.

6. Thoroughly clean the internal surfaces of the compressor housing, impeller cavity behind the impeller, and the backplate annulus with suitable solvent spray and then dry completely with shop air.

7. Spray the backplate annulus with a light coating of "Spot-Check" developer type SKD-MF, or equivalent.

8. Install the compressor housing on the turbocharger and reconnect the inlet and outlet connections.

9. Warm up the engine to normal operating temperature.

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10. Operate the engine at no load at the governor limited high speed for approximately five minutes.

11. Return the engine to low idle and then stop it.

12. Remove the intake duct and outlet hose and then remove the compressor housing. Evidence of compressor end shaft seal oil leakage will be observed as oil streaks in the "Spot-Check" developer on the backplate annulus. This surface should be completely free of oil streaks after the test.

13. If leakage is detected, and oil is positively not entering through the intake duct, then the turbocharger may be removed from the engine and inspected for damaged components.

Remove Turbocharger

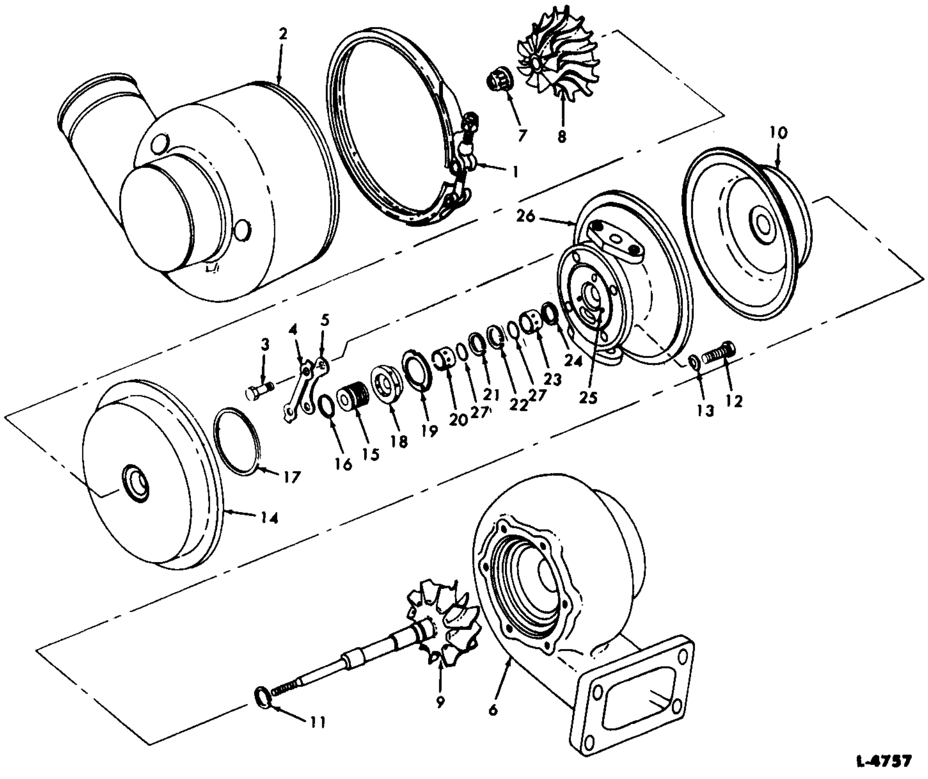
1. Refer to Fig. 6 and remove the turbocharger support bracket.

2. Disconnect the oil supply line and the oil drain line from the turbocharger.

3. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entrance of foreign material.

4. Loosen the two hose clamps securing the cover hose to the turbocharger and the air inlet tube and slide the cover hose down over the inlet tube.

5. Remove the four bolts, nuts and lock washers securing the turbocharger to the exhaust manifold adaptor and remove the turbocharger and gasket. Refer to Fig. 1.



1. Coupling--"V" Band
2. Housing--Compressor
3. Bolt
4. Lockplate
5. Clamp--Turbine Housing
6. Housing--Turbine
7. Nut--Self-Locking
8. Wheel--Compressor
9. Shaft--Turbine Wheel Assembly
10. Shroud--Turbine Wheel
11. Ring--Piston
12. Screw
13. Lockplate
14. Backplate Assembly
15. Spacer--Thrust
16. Ring--Piston
17. Ring--Seal
18. Collar--Thrust
19. Bearing--Inboard Thrust
20. Bearing
21. Ring--Retaining
22. Ring--Retaining
23. Bearing
24. Ring--Retaining
25. Pin--Groove
26. Housing--Center
27. Spacer

Fig. 7 - Model TE0675 Turbocharger Details and Relative Location of Parts

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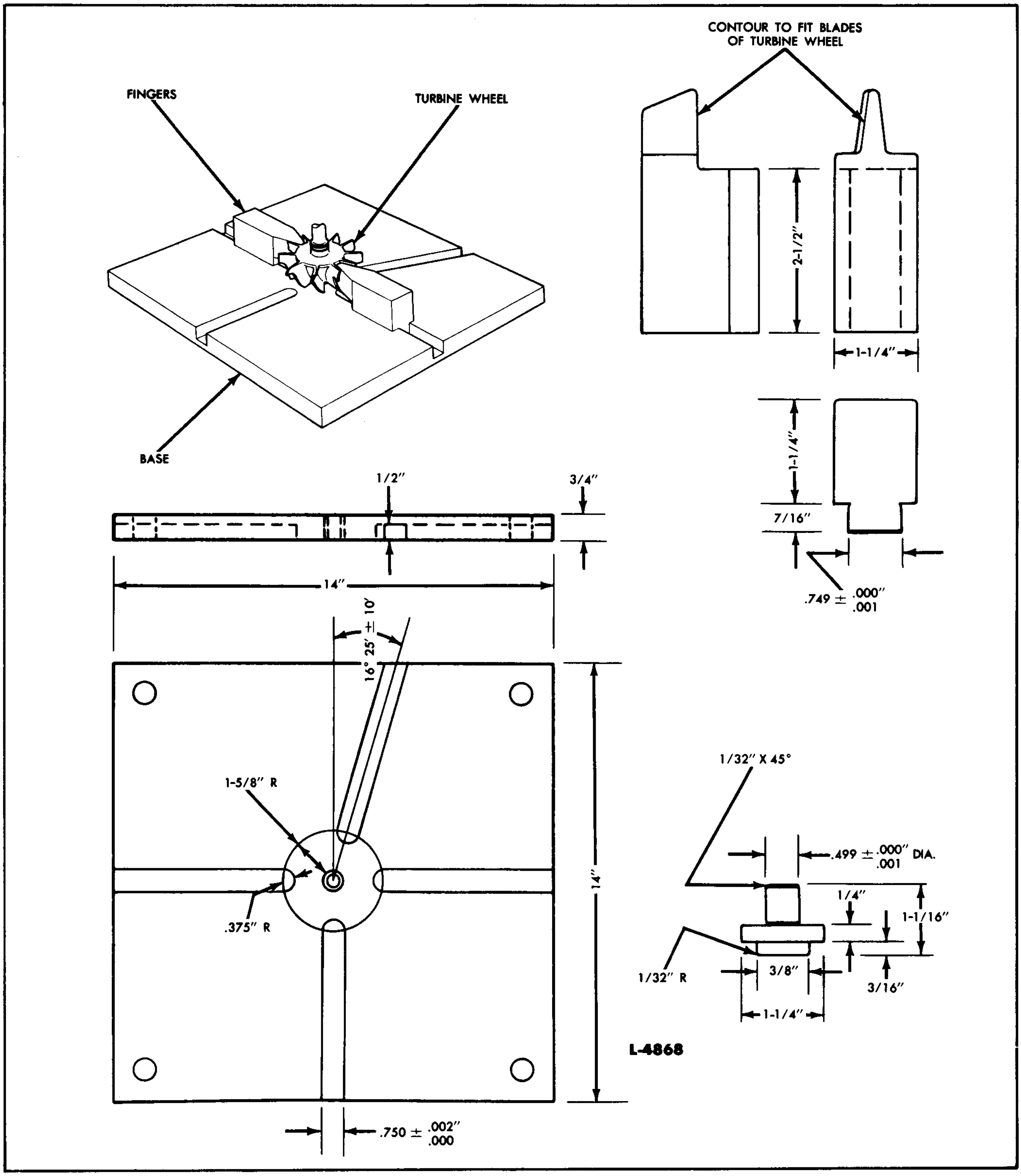

Fig. 8 · Turbocharger Holding Fixture

Disassemble Turbocharger

Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly and proceed as follows:

NOTE: Mark related positions of the compressor housing, center housing and turbine housing with a punch or scribe prior to disassembly to assure reassembly in the same relative position.

1. Loosen the "V" band coupling (1) securing the compressor housing (2) to the backplate assembly (14) and remove the compressor housing and "V" band.

NOTE: Exercise care when removing the center and turbine housings to prevent damage to the compressor or turbine wheel.

2. Bend down the ends of the lockplates and remove the eight bolts (3) securing the four lockplates (4) and turbine housing clamps (5) to the center housing (26) and turbine housing (6). Remove the turbine housing from the center housing.

NOTE: Tap the housing with a soft headed hammer if force is needed for removal.

3. Position the turbine wheel (9) of the center housing assembly in a suitable holding fixture (Fig. 8). Remove the wheel nut (7) from the shaft.

NOTE: To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.

4. Place the center housing and rotating assembly in a oven, furnace or hot oil bath that has been preheated to 350-375 °F (177-190 °C) for no longer than ten minutes.

5. Press the compressor wheel (8) from the wheel shaft assembly (9).

6. Withdraw the wheel shaft assembly (9) and wheel shroud (10) from the center housing. The wheel shroud (10), which is not retained, will fall free when the wheel shaft is removed.

7. Remove the piston seal (11) from the wheel shaft assembly (9).

8. Bend down the lock tabs and remove the four bolts (12) and lockplates (13) securing the backplate assembly (14) to the center housing (26) and remove the backplate assembly.

NOTE: Tap the backplate lightly to remove it from the center housing recess.

9. Remove and discard the seal ring (17) from the groove in the center housing.

10. Remove the thrust spacer (15) and piston ring(s) (16) from the backplate assembly. Discard the piston ring(s).

11. Remove the thrust collar (18), inboard thrust bearing (19), bearing (20), spacer (27) if used, and retaining ring (21) from the center housing. Discard the bearing and retaining ring.

12. Remove the retaining ring (22), spacer (27) if used, bearing (23) and retaining ring (24) from the center housing. Discard the retaining ring and bearing.

Cleaning

Before cleaning, inspect all of the parts for signs of burning, rubbing or other damage which might not be evident after cleaning.

Soak all of the parts in a non-caustic cleaning solvent for about 25 minutes. After soaking, use a stiff bristle brush and remove all dirt particles. Dry all of the parts thoroughly.

CAUTION: Never use a caustic cleaning solution for cleaning as this will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean the parts.

Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.

Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air.

Clean the oil passage in the center housing thrust plate with dry compressed air.

Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out. An oil line that is dented or crimped enough to restrict the flow of oil must be replaced.

Inspection

Inspect all of the parts for signs of damage, corrosion or deterioration. Check for nicked, crossed or stripped threads.

Visually check the turbine wheel for signs of rubbing.

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For shaft bearing journal dimensions and wear limits, refer to Section 3.0.

Inspect the shaft for signs of scoring, scratches or bearing seizure.

Check the compressor wheel for signs of rubbing or damage from foreign material. Check to see that the wheel bore is not galled. The wheel must be free of dirt and other foreign material.

Inspect the seal parts for signs of rubbing or scoring of the running faces.

Inspect the housing for contact with the rotating parts. The oil and air passages must be clean and free of obstructions.

Minor surface damage may be burnished or polished. Use a Silicone Carbide abrasive cloth for aluminum parts or a crocus abrasive cloth for steel parts.

It is recommended that piston ring(s), thrust washers, bearings, bearing washers and retaining rings be replaced at time of disassembly.

Assemble Turbocharger

Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.

Refer to Fig. 7 for parts orientation and proceed as follows:

1. Lubricate the new bearings (20 and 23) with clean engine oil.

2. Install a new retaining ring (24), bearing (23), spacer (27) and retaining ring (22) in the turbine housing end of the center housing (26).

3. Install a new retaining ring (21), spacer (27) and bearing (20) in the center housing.

4. Install a new piston ring(s) (16) on the thrust spacer (15) and gently insert the spacer into the backplate assembly (14).

The current thrust spacer has two grooves. When replacing the former one groove spacer with the two groove spacer, be sure and include two piston rings.

> **NOTE:** Do not force the piston rings into place.

5. Position the inboard thrust bearing (19) flat against the center housing with the hole and cut-outs in the bearing in alignment with the pins (25) in the center housing.

6. Install the thrust collar (18) snugly against the thrust bearing (19). Lubricate the thrust collar and bearing with clean engine oil.

7. Install a new seal ring (17) in the groove in the backplate assembly (14).

8. Align the oil feed holes in the center housing (26) and the backplate assembly and install the backplate, using four bolts (12) and new lockplates (13). Tighten the bolts to 75-90 **lb-in** (8-10 Nm) torque and bend the lockplate tangs up against the side of the bolt heads.

9. Install a new piston seal (11) on the wheel shaft assembly (9).

10. Position the wheel shroud (10) against the center housing (26) and insert the wheel shaft assembly (9) through the wheel shroud and into the center housing.

> **NOTE:** Be careful not to scuff or scratch the bearings when installing the shaft. Do not use force to compress the piston ring into place. A gentle rocking and pushing action will allow the piston ring to seat and the shaft to bottom. A thin tool may be used as an aid in compressing the piston ring if difficulty is encountered.

11. Heat the compressor wheel in an oven or hot oil bath to 325-375 °F (163-190 °C) for no more than ten minutes.

12. Position the turbine wheel (9) of the center housing assembly in the holding fixture (Fig. 8).

13. Position the compressor wheel over the shaft and install the wheel retaining nut. Tighten the nut to 120 **lb-in** (14 Nm) torque. After the compressor wheel has cooled to room temperature, remove the retaining nut.

14. Check the face of the retaining nut and the wheel face to make sure they are smooth and clean. Lightly oil the shaft threads and washer face and reinstall the nut. Tighten the nut to 18-20 **lb-in** (2 Nm) torque. Continue to tighten until the shaft increases in length .008 ″-.009 ″.

> **NOTE:** Tighten the retaining nut in such a manner so as not to impose a bending load on the shaft.

15. Check the bearing axial end play:

a. Clamp the center housing assembly in a bench vise equipped with soft jaws as shown in Fig. 9.

b. Fasten the dial indicator and magnetic base

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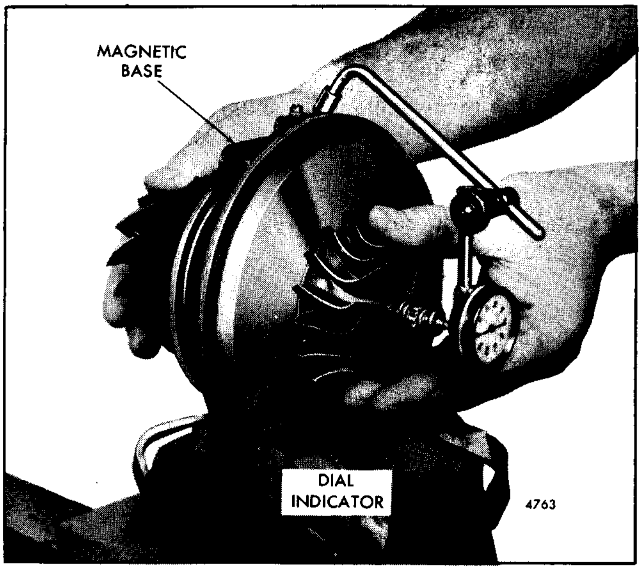

Fig. 9 - Checking Bearing Axial End Play

(J 7872) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side.

c. Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be between .004 ″ and .007 ″. If the dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

16. Position the turbine housing (6) as marked at disassembly against the center housing (26) and secure it in place with four clamps (5), four lockplates (4) and eight bolts (3). Tighten the bolts to 160-190 **lb-in** (18-22 Nm) torque. Bend the lockplate tabs up against the flat on the bolt heads.

17. Position the compressor housing (2) against the backplate assembly (14) and secure it in place with the "V" band coupling (1). Lightly lubricate the threads of the toggle bolt with engine oil and tighten the nut on the coupling to 30-45 **lb-in** (3-5 Nm) torque.

18. After assembly, push the rotating assembly as far as possible from the turbine end. Then rotate the assembly and check for bind. Push the rotating assembly in the opposite direction and repeat the check.

19. Check the shaft radial movement:

a. Position the magnetic base J 7872-2 with the swivel adaptor J 7872-3 on the flat surface of the turbine housing inlet flange as shown in Fig. 10.

b. Fasten the dial indicator extension rod J 7057 to the dial indicator J 8001-3 and attach the dial indicator to the swivel adaptor.

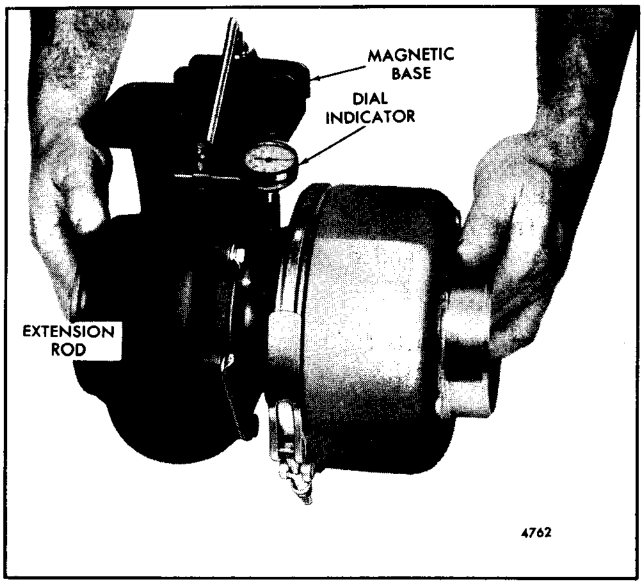

Fig. 10 - Checking Shaft Radial Movement

c. Insert the extension rod into the oil drain tube mounting pad opening so that it is against the wheel shaft and is perpendicular to the shaft.

NOTE: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

d. Grasp each end of the rotating assembly and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between .003 ″ and .007 ″. If the displacement does not fall within the specified limits, disassemble and repair or replace the rotating assembly.

20. If it is to be stored, lubricate the turbocharger internally and install protective covers on all openings.

21. Stamp the letter "R" in the lower left-hand corner of the name plate to identify that the turbocharger has been reworked.

Install Turbocharger

If a turbocharger is to be installed on a new or overhauled engine, operate the engine for approximately one hour *before* the turbocharger is installed. This must be done to ensure that no foreign material is carried from the engine into the turbocharger lubrication system.

1. Position the turbocharger, using a new gasket,

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against the exhaust manifold adaptor and secure it in place with four bolts, lock washers and nuts (Fig. 1).

2. Slide the cover hose (Fig. 5) over the end of the turbocharger air outlet opening and tighten the two hose clamps.

3. Install the turbocharger support bracket.

4. Install the oil drain line from the opening in the bottom side of the center housing (Fig. 5) to the cylinder block.

5. Attach the oil inlet line at the cylinder block.

6. After installing a rebuilt or new turbocharger, it is very important that all of the moving parts of the turbocharger center housing be lubricated as follows:

a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing (Fig. 3).

b. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

c. Add additional clean engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig or 69 kPa at idle speed).

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

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

7. Check all ducts and gaskets for leaks.

8. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, stop the engine immediately and correct the cause.

NOTE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

TO4B AND TV61 TURBOCHARGERS

The turbocharger (Figs. 11 and 12) is designed to increase engine efficiency and power output. Power to drive the turbocharger is extracted from the waste energy in the engine exhaust gas.

The turbocharger consists of a turbine wheel and shaft, a compressor wheel, a center housing which serves to support the rotating assembly, bearings, seals, a turbine housing and a compressor housing. The center housing has connections for oil inlet and outlet fittings.

The turbine wheel is located in the turbine housing and is mounted on one end of the turbine shaft. The compressor wheel is located in the compressor housing and is mounted on the opposite end of the turbine wheel shaft to form an integral rotating assembly.

The rotating assembly consists of the turbine wheel and shaft assembly, piston ring, thrust collar, thrust bearing, compressor wheel and wheel retaining nut. The rotating assembly is supported on two pressure lubricated bearings which are retained in the center housing by retaining rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings and thrust bearing, piston ring and thrust collar.

The oil is sealed off from the compressor and the turbine by seal arrangements at both ends of the center housing. Oil drains from the center housing by gravity.

The turbine housing is a heat resistant alloy casting which encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially-located turbocharger exhaust gas outlet. The TO4B turbine housing is bolted to the turbine end of the center housing and the TV61 turbine housing is secured to the center housing with a "V" band coupling.

The compressor housing, which encloses the compressor wheel, provides an ambient air inlet and a compressor air discharge outlet. The compressor housing is bolted to the backplate assembly. The TO4B backplate assembly is bolted to the compressor end of the center housing. The TV61 backplate assembly is secured to the compressor end of the center housing with a "V" band coupling.

Operation

The TO4B turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold (Fig. 11). The TV61 turbocharger is mounted between the air

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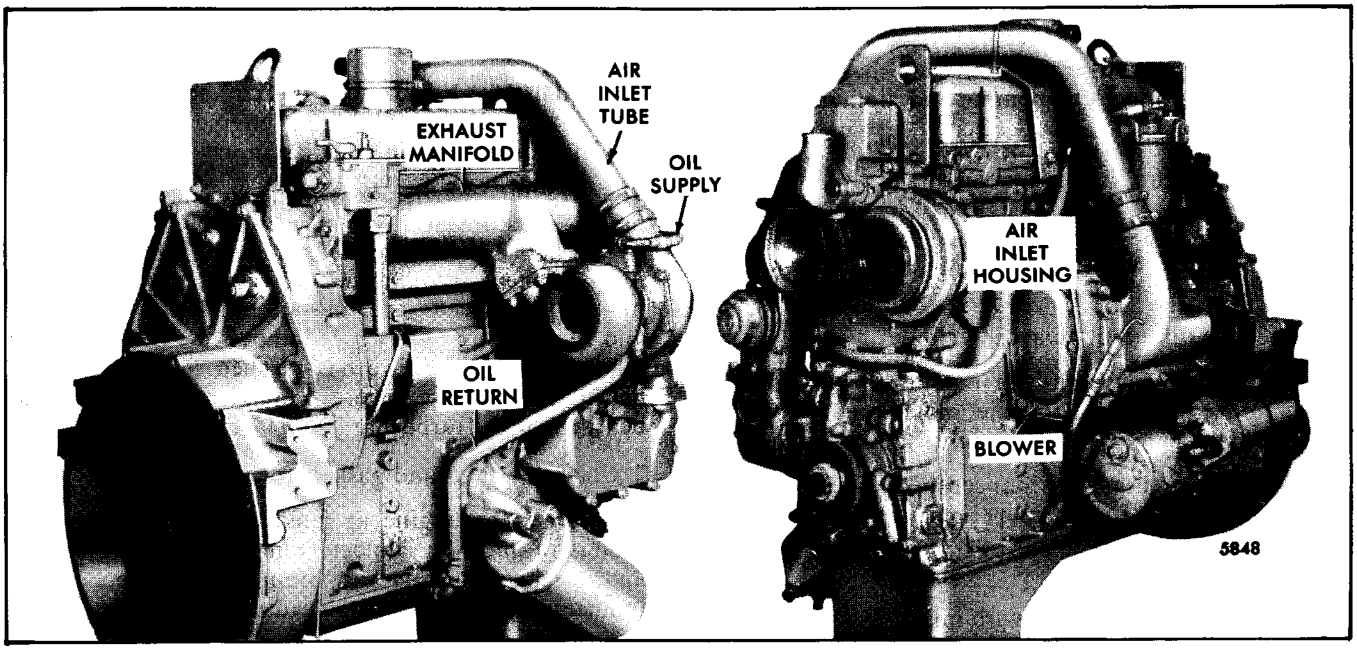

Fig. 11 - T04B Turbocharger Mounting (In-Line Engine)

inlet housing and the air outlet tube adaptor. The air inlet housing is mounted on the blower. The air outlet tubes are clamped to the exhaust outlet flange of each engine exhaust manifold and the air outlet tube adaptor (Fig. 12).

After the engine is started, the exhaust gases flowing from the engine and through the turbine housing cause the turbine wheel and shaft to rotate (Fig. 13). The gases are discharged into the atmosphere after passing through the turbine housing.

The compressor wheel, which is mounted on the opposite end of the turbine wheel shaft, rotates with the turbine wheel. The compressor wheel draws the ambient air into the compressor housing, compresses the air and delivers it through the blower to the engine cylinders.

During operation, the turbocharger responds to the engine load demands by reacting to the flow of the engine exhaust gases. As the power output of the engine increases, the flow of exhaust gases increases and the speed and output of the rotating assembly increases proportionately, delivering more air to the engine blower.

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust collar and thrust bearing (Fig. 14). The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block.

Before the initial engine start, when a new or overhauled turbocharger is installed, the turbocharger must be pre-lubricated as outlined under *Install Turbocharger*.

> **NOTE:** Failure to perform the pre-lubrication procedure may result in premature bearing failure due to "oil lag" or lack of lubrication.

Periodic Inspection

> **NOTE:** A turbocharger compressor inlet shield, J 26554-A, is available for use anytime the engine is operated with the air inlet piping removed (Fig. 4). The shield helps to prevent foreign objects entering the turbocharger and prevents a serviceman from touching the moving impeller. The use of this shield *does not* preclude any other safety practices contained in this manual.

Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits (refer to Section 13.2).

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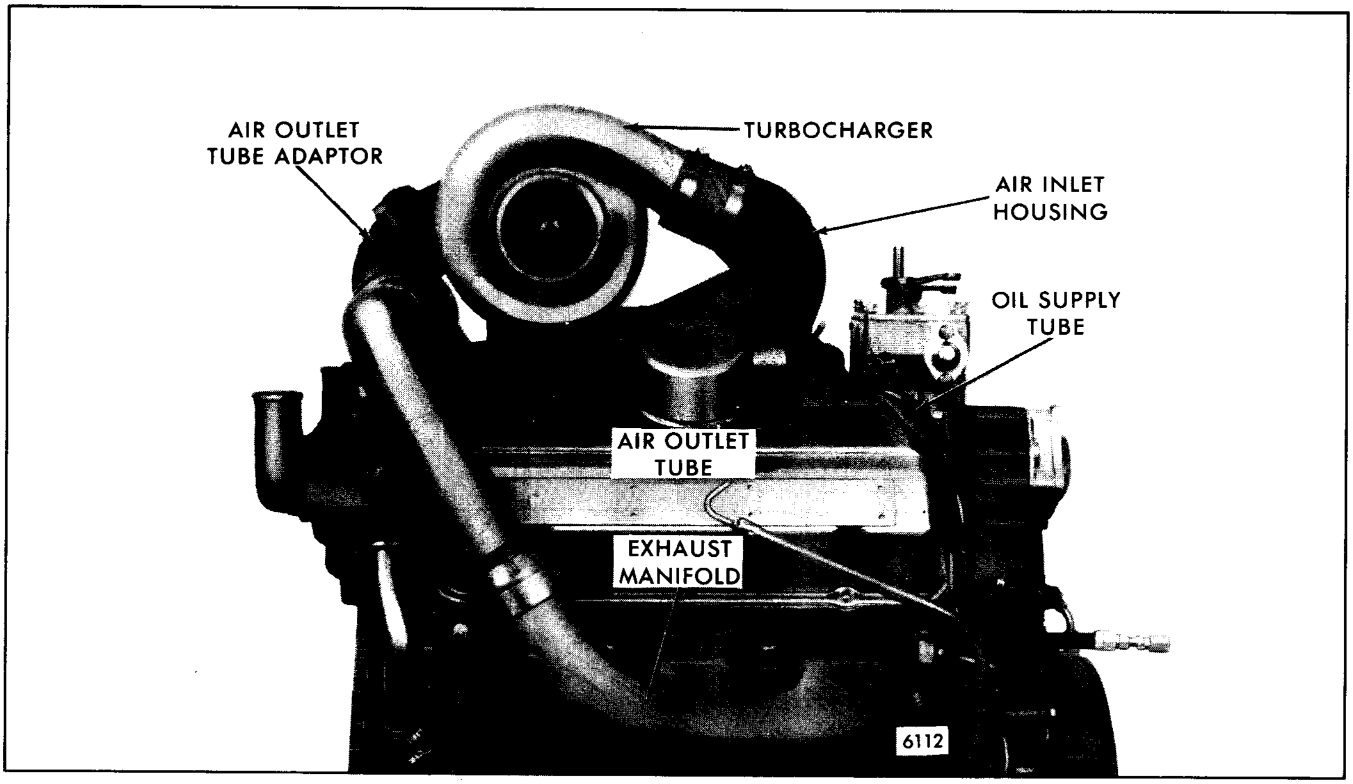

Fig. 12 - TV61 Turbocharger Mounting (6V Engine)

A periodic inspection of the turbocharger should be made along with an engine inspection.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connection, the turbine inlet and exhaust manifold gasket.

NOTE: Do not operate the engine if leaks are found in the turbocharger ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.

Remove the inlet duct to the turbocharger compressor housing and check for carbon or dirt buildup on the

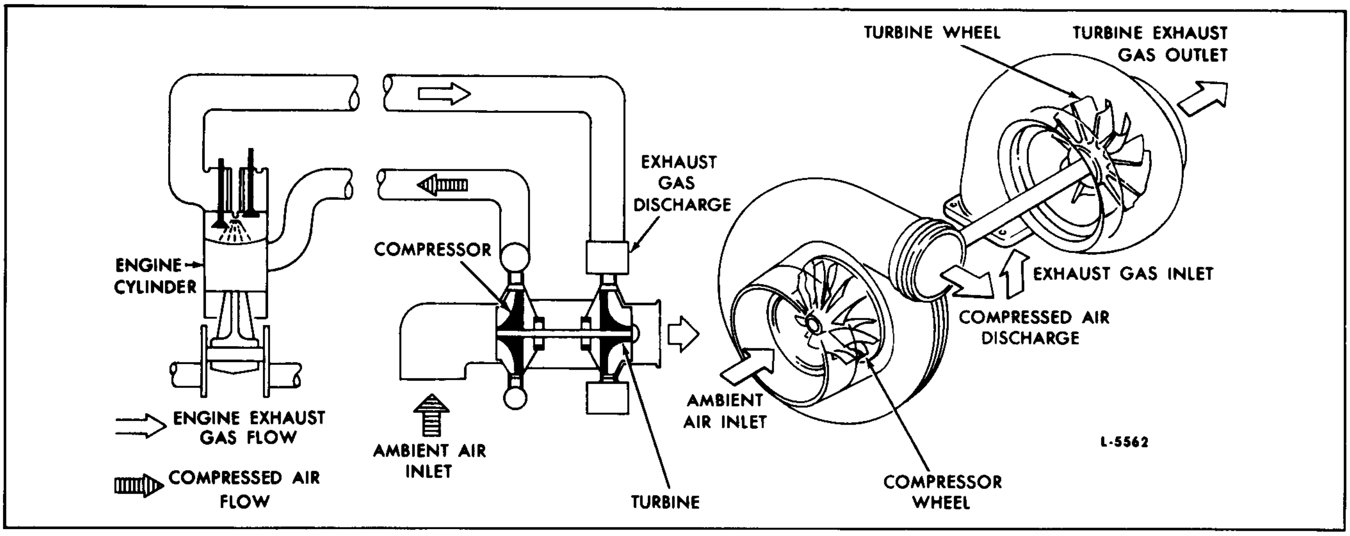

Fig. 13 - Schematic Air Flow Diagram

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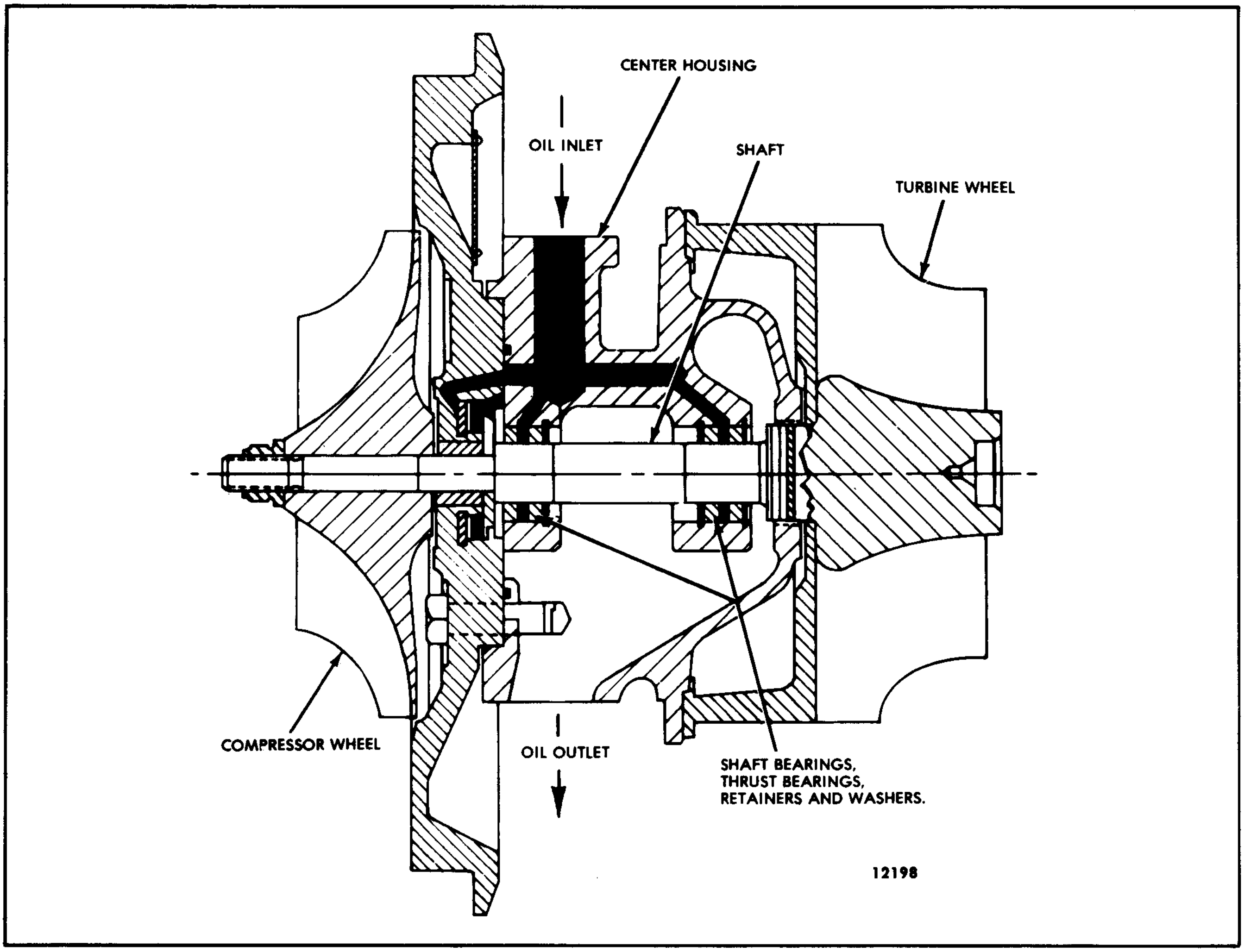

Fig. 14 - Turbocharger Oil Flow Diagram

impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air filtering system. Remove all such accumulations and determine and correct the cause. Refer to *Trouble Shooting Charts* (Fig. 5). Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

NOTE: Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. The blades on the wheels must be thoroughly cleaned. If chunks of carbon are left on the blades, an unbalanced condition would exist and subsequent failure of the bearings would result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt and dust buildup.

For proper operation, the turbocharger rotating assembly must turn free. Whenever the exhaust ducting is removed, spin the turbine wheel by hand. If it does not spin freely, refer to Chart 1 of Fig. 5. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

Inspect the oil inlet and oil return lines to make certain all of the connections are tight and that the lines are not dented or looped so that oil flow to and from the center housing is restricted. Looping the oil return lines disrupts gravity flow of the oil back to the engine.

NOTE: Be sure the oil inlet lines are filled with oil and that they are clear of the turbine housings.

Check for signs of oil leaking from the turbocharger housings.

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Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, oil in these sections should disappear. If the oil does not disappear, refer to Chart 2 of Fig. 5.

Oil pull-over from an oil bath type air cleaner can also cause oil to enter the compressor housing. Check for a dirty air cleaner element or for too low viscosity oil in the air cleaner. Also, too small an air cleaner could create excessive air flow velocity and result in oil pull-over.

Evidence of oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that will require overhaul of the turbocharger. Refer to Chart 3 of Fig. 5.

Tests show there are three conditions that contribute to oil seal leakage at the internal turbocharger oil seal.

1. A worn or defective oil seal which must be replaced.

2. High air inlet restriction (above specified limits). This will cause oil to be pulled past the oil seal.

3. Long periods of operation where the engine is being motored (using the engine as a braking device when going down a long hill). This can also cause oil to pass by the oil seal.

To confirm oil leakage from one or more of these conditions, remove the compressor housing and inspect the backplate. If the surface is wet with oil, it indicates leakage.

If this test does not show leakage patterns, the oil seal assembly is good for normal operation. This simple test will allow some positive testing on each engine in all cases.

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure:

1. Determine that air inlet restriction is within the Detroit Diesel maximum limit. Refer to Section 13.2.

2. Be certain that the turbocharger oil drain line is unrestricted.

3. Be certain that the turbocharger has not obviously been damaged and in need of major repair.

4. Remove the air intake ducting. Inspect the inside of the ducting for evidence of oil. If oil is found in the intake system, determine the source before proceeding with the compressor seal test and also thoroughly remove oil from the intake. Some external sources of oil are oil bath air cleaners, air compressor line, or a leak near an oil source such as an engine breather, etc.

5. Remove the compressor housing from the turbocharger.

6. Thoroughly clean the internal surfaces of the compressor housing, impeller cavity behind the impeller, and the backplate annulus with suitable solvent spray and then dry completely with shop air.

7. Spray the backplate annulus with a light coating of *Spot-Check* developer type SKD-MF, or equivalent.

8. Install the compressor housing on the turbocharger and reconnect the inlet and outlet connections.

9. Warm-up the engine to normal operating temperature.

10. Operate the engine at no load at the governor limited high speed for approximately five minutes.

11. Return the engine to low idle and then stop it.

12. Remove the intake duct and outlet hose and then remove the compressor housing. Evidence of compressor end shaft seal oil leakage will be observed as oil streaks in the *Spot-Check* developer on the backplate annulus. This surface should be completely free of oil streaks after the test.

13. If leakage is detected, and oil is positively not entering through the intake duct, then the turbocharger may be removed from the engine and inspected for damaged components.

Remove Turbocharger

1. Remove the TO4B turbocharger support bracket.

2. Disconnect the oil supply line and the oil drain line from the turbocharger.

3. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entrance of foreign material.

4. Loosen the two hose clamps securing the cover hose to the turbocharger and the air inlet tube and slide the cover hose down over the inlet tube.

5. Remove the four bolts, nuts and lock washers securing the turbocharger to the exhaust manifold adaptor or exhaust outlet flange and remove the turbocharger and gasket.

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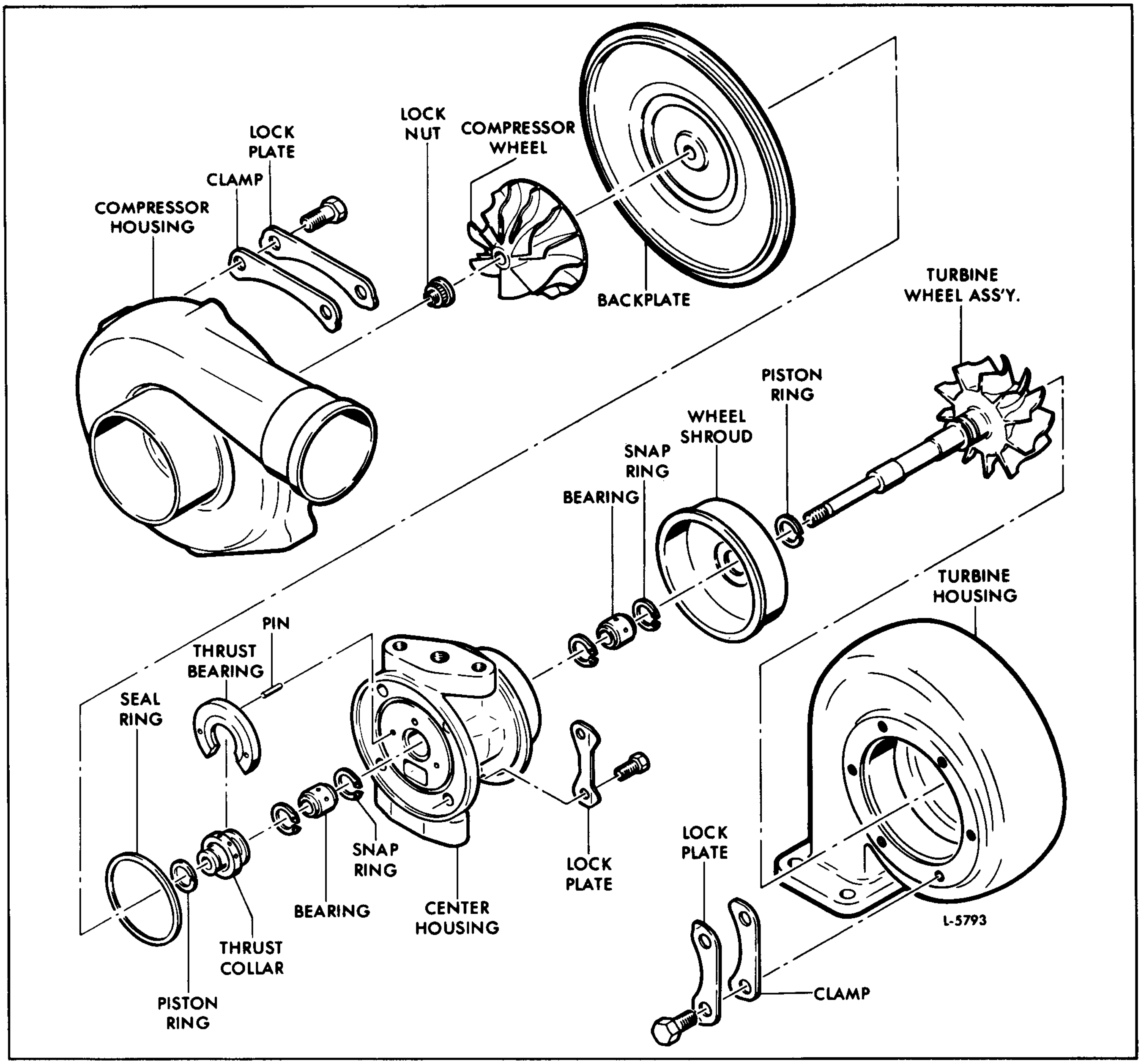

Fig. 15 - TO4B Turbocharger Details and Relative Location of Parts

Disassemble Turbocharger

Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembling and proceed as follows:

> **NOTE:** Mark related positions of the compressor housing, center housing and turbine housing with a punch or scribe prior to disassembly to assure reassembly in the same relative position.

TO4B Turbocharger - Fig. 15

1. Bend the lock tabs of the lock plates down and remove the bolts which hold the lockplates and clamps securing the compressor housing and turbine housing.

> **NOTE:** Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels. Tap the housing with a soft hammer if force is needed for removal.

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2. Position the turbine wheel of the center housing assembly in a suitable holding fixture (Fig. 8). Remove the wheel nut from the shaft. If a holding fixture is not available, clamp a suitable socket or box end wrench in a vise and place the extended hub on the shaft in the socket or wrench. Hold the center housing upright and remove the wheel nut from the shaft.

NOTE: To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.

3. Lift the compressor wheel off of the turbine wheel shaft assembly.

4. Invert the center housing and turbine wheel assembly and remove the turbine wheel assembly (with piston ring) from the center housing. Remove the piston ring from the wheel assembly.

5. Bend the lock tabs down and remove the bolts and lockplates securing the backplate assembly to the center housing. Remove the backplate assembly.

NOTE: Tap the backplate lightly to remove it from the center housing recess.

6. Do not disassemble the backplate assembly. Also, do not remove the pins from the center housing, unless it is necessary to replace the pins.

7. Remove and discard the seal ring from the groove in the center housing.

8. Remove the thrust bearing and piston ring from the backplate assembly. Discard the piston ring.

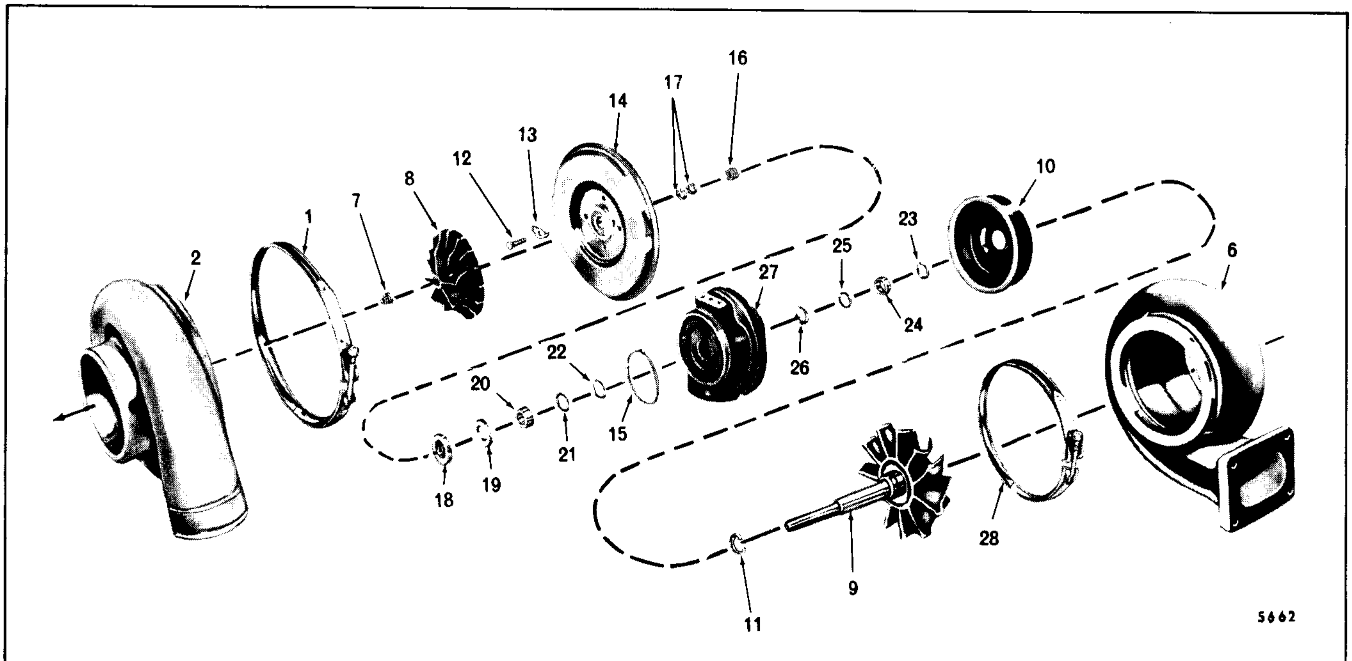
9. Remove the thrust collar, bearing and snap ring from the center housing. Discard the bearing and snap ring.

10. Remove the snap ring, bearing and snap ring from the opposite end of the center housing. Discard the snap rings and bearing.

TV61 Turbocharger - Fig. 16

1. Loosen the "V" band coupling securing the compressor housing to the backplate assembly and remove the compressor housing and "V" band.

NOTE: Exercise care when removing the compressor housing and turbine housing to



1. Coupling--"V"Band
2. Housing--Compressor
6. Housing--Turbine
7. Nut--Self-Locking
8. Wheel--Compressor
9. Shaft--Turbine Wheel Assy.
10. Shroud--Turbine Wheel
11. Ring--Turbine Piston
12. Screw
13. Lockplate
14. Backplate Assy.
15. Ring--Seal
16. Spacer--Thrust
17. Ring--Piston
18. Collar--Thrust
19. Washer--Inboard Thrust
20. Bearing
21. Washer--Bearing
22. Ring--Snap
23. Ring--Snap
24. Bearing
25. Washer--Bearing
26. Ring--Snap
27. Housing--Center
28. Coupling "V"Band

Fig. 16 - TV61 Turbocharger Details and Relative Location of Parts.

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prevent damage to the compressor and turbine wheels.

2. Loosen the "V" band coupling securing the turbine housing to the center housing. Remove the turbine housing from the center housing.

NOTE: Tap the housing with a soft hammer if force is needed for removal.

3. Position the turbine wheel of the center housing assembly in a suitable holding fixture (Fig. 8). Remove the wheel nut from the shaft. If a holding fixture is not available, clamp a suitable socket or box end wrench in a vise and place the extended hub on the shaft in the socket or wrench. Hold the center housing upright and remove the wheel nut from the shaft.

NOTE: To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.

4. Press the compressor wheel from the wheel shaft assembly.

5. Withdraw the wheel shaft assembly from the center housing. The wheel shroud, which is not retained, will fall free when the wheel shaft is removed.

6. Remove and discard the turbine piston ring from the wheel shaft.

7. Bend down the lock tabs and remove the four bolts and lockplates securing the backplate assembly to the center housing and remove the backplate assembly.

NOTE: Tap the backplate lightly to remove it from the center housing recess.

8. Remove and discard the seal ring from the groove in the center housing.

9. Remove the thrust spacer and piston ring(s) from the backplate assembly. Discard the piston ring(s).

10. Remove the thrust collar, inboard thrust washer, bearing, bearing washer and snap ring from the center housing. Discard the thrust washer, bearing, washer and snap ring.

11. Remove the snap ring, bearing, bearing washers and snap ring from the opposite end of the center housing. Discard the snap rings, bearing and washers.

Cleaning

Before cleaning, inspect all of the parts for signs of burning, rubbing or other damage which might not be evident after cleaning.

Soak all parts in a non-caustic cleaning solvent for about 25 minutes. After soaking, use a stiff bristle brush and remove all dirt particles. Dry all of the parts throughly.

CAUTION: Never use a caustic cleaning solution for cleaning as this will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean the parts.

Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.

Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air.

Clean the oil passage in the center housing thrust plate with dry compressed air.

Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out. An oil line that is dented or cramped enough to restrict the flow of oil must be replaced.

Inspection

Inspect all of the parts for signs of damage, corrosion or deterioration. Check for nicked, crossed or stripped threads.

Visually check the turbine wheel shroud and turbine wheel for signs of rubbing.

Inspect the shaft for signs of scoring, scratches or bearing seizure.

Check the compressor wheel for signs of rubbing or damage from foreign material. Check to see that the wheel bore is not galled. The wheel must be free of dirt and other foreign material.

Inspect the seal parts for signs of rubbing or scoring of the running faces.

Inspect the backplate for wear or damaged bore (piston ring groove).

Inspect the housing for contact with the rotating parts.

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The oil and air passages must be clean and free of obstructions.

Minor surface damage may be burnished or polished. Use a Silicone Carbide abrasive cloth for aluminum parts or a crocus abrasive cloth for steel parts. It is recommended that the seal ring, piston rings, bearings, snap rings, lockplates and bolts be replaced at time of disassembly.

Inspect the exhaust outlet elbow seal ring for signs of wear or breakage.

Assemble Turbocharger

Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.

TO4B Turbocharger - Fig. 15

1. Lubricate the new bearings with clean engine oil.

2. Install a new snap ring, bearing and snap ring in the turbine end of the center housing, using snap ring pliers J 28507.

3. Install a new snap ring, bearing and snap ring in the compressor end of the center housing, using snap ring pliers J 28507.

4. Fill the piston ring groove in the turbine wheel shaft assembly with high vacuum silicone grease. Then install the piston ring on the wheel assembly.

5. Position the wheel shroud on the wheel of the shaft assembly and insert the shaft assembly into the center housing as far as it will go.

NOTE: Be careful not to scuff or scratch the bearings when installing the shaft and do not force the piston ring into the center housing bore.

6. Place the turbine wheel shaft assembly, shroud and center housing upright in a suitable holding fixture as shown in Fig. 8.

NOTE: If a holding fixture is not available, clamp a suitable socket or box wrench in a vise and place the extended hub on the shaft in the socket or wrench.

7. Lubricate the thrust collar and thrust bearing with clean engine oil and install the thrust collar on the shaft of the turbine wheel assembly. Then install the thrust bearing in the groove of the collar and slide the assembled parts down against the center housing so that the pins engage the holes in the thrust bearing.

8. Install a new piston ring on the thrust collar.

NOTE: To avoid breakage, do not force the piston ring into place.

9. Install a new seal ring in the groove at the compressor end of the center housing.

10. Install the backplate assembly over the shaft and carefully guide the piston ring on the shaft into the backplate bore, ring gap first.

11. Align the oil feed holes in the center housing and the backplate assembly and attach the backplate to the center housing with bolts and new lockplates. Tighten the bolts to 75-90 **lb-in** (8-10 Nm) torque and bend the lockplate tabs up against the side of the bolt heads.

NOTE: If a new backplate with a warning plate is inadvertently installed, *the warning plate must be removed and the three drive screw holes plugged to prevent air leakage.*

12. With the compressor wheel at room temperature, position it over the shaft.

13. Lightly lubricate the shaft threads and wheel face that will be under the nut with engine oil and install the locknut on the shaft. Tighten the nut to 18-20 **lb-in** (2 Nm) torque above the drag torque required to bottom the locknut.

NOTE: Bottoming of the locknut will be indicated by the sharp increase above the drag torque observed while running the nut down.

14. Retighten the locknut through an angle of 90°. This additional tightening will result in stretching the shaft .0055" to .0065" in length.

NOTE: Tighten the retaining nut in such a manner as not to impose a bending load on the shaft.

15. Check the bearing axial end play:

a. Clamp the center housing assembly in a bench vise equipped with soft jaws as shown in Fig. 9.

b. Fasten the dial indicator and magnetic base (J 7872-2) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side (Fig. 9).

c. Move the shaft axially back and forth by hand. The total indicator reading should be between .004" and .009". If the total dial indicator

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readings do not fall within the specified limits, repair or replace the rotating assembly.

16. Position the turbine housing as marked at disassembly against the center housing and secure it in place with clamps, new lockplates and bolts. Tighten the bolts to 100-130 **lb-in** (11-15 Nm) torque and bend the tabs of the lockplates up against the bolts.

17. Position the compressor housing as marked at disassembly against the center housing and secure it in place with clamps, new lockplates and bolts. Tighten the bolts to 100-130 **lb-in** (11-15 Nm) torque and bend the tabs of the lockplates up against the bolts.

18. Check the shaft radial movement:

a. Position the magnetic base J 7872-2 with the swivel adaptor J 7872-3 on the flat surface of the turbine housing inlet flange as shown in Fig. 10.

b. Fasten the dial indicator extension rod J 7872-1 to the dial indicator J 8001-3 and attach the dial indicator to the swivel adaptor.

c. Insert the extension rod J 7872-1 into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft.

NOTE: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

d. Grasp each end of the rotating assembly (Fig. 10) and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between .003" and .007". If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.

19. If it is to be stored, lubricate the unit internally and install protective covers on all openings.

20. Stamp the letter "R" in the lower left-hand corner of the name plate to identify that the turbocharger has been reworked.

TV61 Turbocharger - Fig. 16

1. Lubricate the new bearings with clean engine oil.

2. Install a new snap ring, bearing washer, bearing and snap ring in the turbine end of the center housing.

3. Install a new snap ring, bearing washer and bearing in the compressor end of the center housing.

4. Install new piston rings on the thrust spacer and gently insert the spacer into the backplate assembly.

NOTE: Do not force the piston into place.

5. Make sure the compressor bearing is in place, then position the inboard thrust washer flat against the center housing with the hole and cutout in the thrust washer in alignment with the pins in the center housing.

6. Install the thrust collar snugly against the thrust washer. Lubricate the thrust collar and thrust washer with clean engine oil.

7. Install a new seal ring in the groove at the compressor end of the center housing.

8. Align the oil feed holes in the center housing and the backplate assembly and attach the backplate to the center housing with four bolts and new lockplates. Tighten the bolts to 80-100 **lb-in** (9-11 Nm) torque and bend the lockplate tangs up against the side of the bolt heads.

NOTE: If a new backplate with a warning plate is inadvertently installed, *the warning plate must be removed and the three drive screw holes plugged to prevent air leakage.*

9. Install a new piston ring on the turbine wheel shaft assembly.

NOTE: Before installing the piston ring, fill the piston ring groove with Dow Corning High Vacuum Silicone grease, or equivalent.

10. Position the wheel shroud against the center housing and insert the wheel shaft assembly through the wheel shroud and into the center housing.

NOTE: Be careful not to scuff or scratch the bearings when installing the shaft.

11. Place the turbine wheel shaft assembly, shroud, center housing and backplate upright in a suitable holding fixture as shown as Fig. 8.

NOTE: If a holding fixture is not available, clamp a suitable socket or box wrench in a vise and place the extended hub on the shaft in the socket or wrench.

12. With the compressor wheel at room temperature, position it over the shaft.

13. Lightly lubricate the shaft threads and wheel face

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that will be under the nut with engine oil and install the retaining nut. Tighten the nut to 125-150 **lb-in** (14-17 Nm) torque to seat the compressor wheel against the thrust spacer.

14. Loosen the nut and inspect the nut face and front face of the compressor wheel to be sure they are smooth and clean.

15. Retighten the nut to 35-55 **lb-in** (4-6 Nm) torque.

16. Continue to tighten the retaining nut until the shaft increases in length .009"-.010". Tighten the nut in such a manner as not to impose bending loads on the shafts.

NOTE: If equipment is not available to measure the shaft stretch, tighten the wheel retaining nut to 35-55 **lb-in** (4-6 Nm) torque. Then continue to tighten the nut through an angle of 120-130° turn (90° is 1/4 turn).

17. Check the bearing axial end play:

a. Clamp the center housing assembly in a bench vise equipped with soft jaws as shown in Fig. 9.

b. Fasten the dial indicator and magnetic base (J 7872-2) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side (Fig. 9).

c. Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be between .003" and .010". If the total dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

18. Position the turbine housing as marked at disassembly against the center housing and secure it in place with the "V" band coupling. Position the "V" band coupling between the turbine housing and center housing so that the bolt end does not interfere with the turbine housing. Failure to properly orient the "T" bolt end of the clamp can result in an exhaust leak and/or turbine wheel damage. Tighten the toggle nut as follows:

a. Lubricate the toggle bolt threads with a high temperature anti-seize compound, such as Jet Lube (Mil Spec A-907D), or equivalent.

b. Tighten the nut on the "V" band toggle bolt to approximately 160 **lb-in** (18 Nm) torque.

NOTE: Do not pull a misaligned turbine housing into alignment with the "V" band coupling. The parts must be aligned and seated first.

c. Loosen the "V" band coupling nut to approximately 50 **lb-in** (6 Nm) torque, then retorque the nut to 152-168 **lb-in** (17-19 Nm) torque.

19. Position the compressor housing as marked at disassembly against the backplate and secure it in place with the "V" band coupling. Lightly lubricate the threads of the toggle bolt with engine oil and tighten the nut to 110-130 **lb-in** (12-15 Nm) torque.

20. Check the shaft radial movement.

a. Position the magnetic base J 7872-2 with the swivel adaptor J 7872-3 on the flat surface of the turbine housing inlet flange as shown in Fig. 10.

b. Fasten the dial indicator extension rod J 7872-1 to the dial indicator J 8001-3 and attach the dial indicator to the swivel adaptor.

c. Insert the extension rod J 7872-1 into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft.

NOTE: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

d. Grasp each end of the rotating assembly (Fig. 10) and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between .003" and .007". If the displacement does not fall within these limits disassemble and repair or replace the rotating assembly.

21. If it is to be stored, lubricate the unit internally and install protective covers on all openings.

22. Stamp the letter "R" in the lower left-hand corner of the name plate to identify that the turbocharger has been reworked.

Install Turbocharger

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

2. Remove the covers from the air inlet and exhaust outlet openings on the engine that were placed over the openings when the turbocharger was removed.

3. Place the turbocharger assembly into position. Use a

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new gasket between the exhaust manifold adaptor or exhaust outlet flange and the turbine housing flange.

NOTE: When attaching the exhaust flange or adaptor to the turbine housing, be sure the inner diameter of the adaptor or flange is the same as the turbine inner diameter. The turbine opening in a T04B turbocharger is 2.581" and the TV61 turbocharger is 3.100".

4. Secure the T04B turbocharger to the mounting bracket with bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbocharger tight against the bracket.

NOTE: When self-locking nuts are used to secure the turbocharger to the mounting bracket, be sure there is full thread engagement (at least one full thread above the nut) of the self-locking nuts on the bolts.

5. Slide the blower air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps.

6. Tighten the turbocharger to exhaust manifold adaptor (T04B) or exhaust outlet flange (TV61) bolts securely. Then remove the chain hoist and lifting sling from the turbocharger.

7. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block.

8. Attach the oil inlet line to the cylinder block.

9. After installing a rebuilt or new turbocharger, it is very important that all of the moving parts of the turbocharger center housing be lubricated as follows:

a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing (Fig. 14).

b. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

c. Add additional engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig - 69 kPa at idle speed).

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

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

10. Check all connections, ducts and gaskets for leaks.

11. Operate the engine at rated output and listen for sound of metallic contact from the turbocharger. If any such noise is apparent, stop the engine immediately and correct the cause.

NOTE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

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TURBOCHARGER (Schwitzer)

The Schwitzer turbocharger, Model 3LM (2.7 square inches), (Figs. 1 and 3) is comprised of a centrifugal compressor which shares a bearing system and rotor shaft with an exhaust gas driven turbine. The turbocharger boosts the blower intake pressure of an engine above that which would prevail if the engine were naturally aspirated. The rotating assembly is supported radially by a free-floating, pressure lubricated, sleeve type bearing. Axial end play is controlled by a stationary pressure lubricated thrust bearing, with attendant hardware in the compressor end of the bearing housing.

The oil cavity is separated from the air and exhaust chambers by piston type seal rings located in the cylindrical bores at both axial extremities of the bearing housing.

The external configuration of both the Schwitzer and the Airesearch turbochargers are identical and hardware connections will not change. However, the internal components are different.

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearing, thrust bearing and thrust sleeve. The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block.

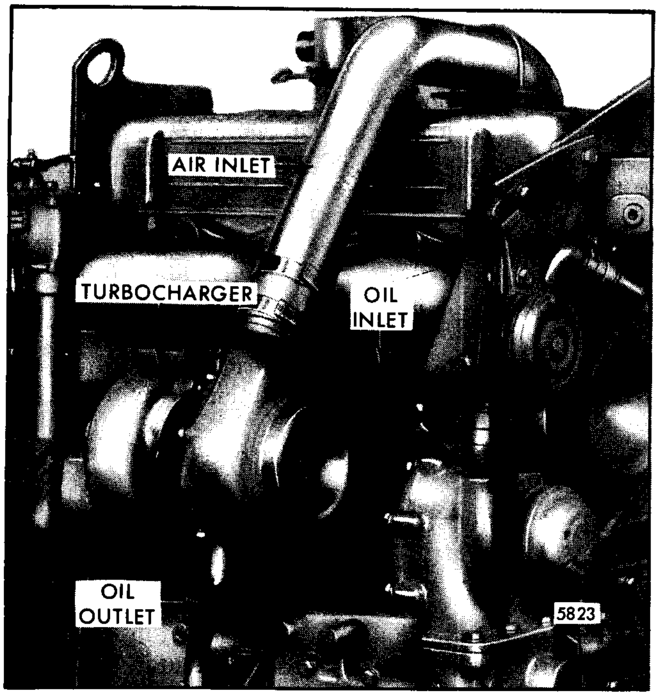

Fig. 1 - Model 3LM Turbocharger Assembly

Before the initial engine start, when a new or overhauled turbocharger is installed, the turbocharger must be pre-lubricated as outlined under *Install Turbocharger*.

> **NOTE:** Failure to perform the pre-lubrication procedure may result in premature bearing failure due to "oil lag" or lack of lubrication.

Periodic Inspection

> **NOTE:** A turbocharger compressor inlet shield, J 26554-A, is available for use anytime the engine is operated with the air inlet piping removed (Fig. 2). The shield helps to prevent foreign objects entering the turbocharger and prevents a serviceman from touching the moving impeller. The use of this shield *does not* preclude any other saftey practices contained in this manual.

Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits (refer to Section 13.2).

A periodic inspection of the turbocharger should be made along with an engine inspection.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connection, the turbine inlet and exhaust manifold gasket.

> **NOTE:** Do not operate the engine if leaks are found in the turbocharger ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.

Remove the inlet duct to the turbocharger compressor housing and check for carbon or dirt buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air filtering system. Remove all such accumulations and determine and correct the cause. Refer to *Trouble*

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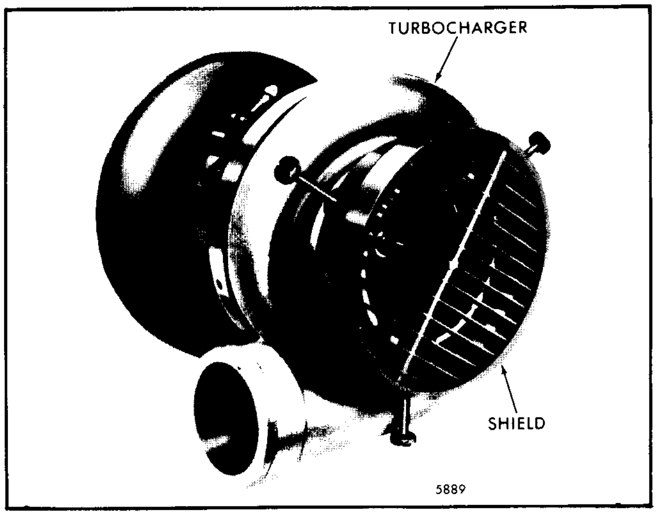

Fig. 2 - Inlet Shield (J 26554-A)

Shooting Turbocharger in Section 3.0. Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

> **NOTE:** Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. The blades on the wheels must be thoroughly cleaned. If chunks of carbon are left on the blades, an unbalanced condition would exist and subsequent failure of the bearings would result if the turbocharger is operated.

For proper operation, the turbocharger rotating assembly must turn free. Whenever the exhaust ducting is removed, spin the turbine wheel by hand. If it does not spin freely, refer to Chart 1, Fig. 3. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

Inspect the oil inlet and oil return lines to make certain all of the connections are tight and that the lines are not dented or looped so that oil flow to and from the center housing is restricted. Looping the oil return lines disrupts gravity flow of the oil back to the engine.

> **NOTE:** Be sure the oil inlet lines are filled with oil and that they are clear of the turbine housing.

Check for signs of oil leaking from the turbocharger housing. Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, oil in these sections should disappear. If the oil does not disappear, refer to Chart 2, Fig. 3.

Oil pull-over from an oil bath type air cleaner can also cause oil to enter the compressor housing. Check for a dirty air cleaner element or for too low viscosity oil in the air cleaner. Also, too small an air cleaner could create excessive air flow velocity and result in oil pull-over.

Evidence of oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that will require overhaul of the turbocharger. Refer to Chart 3, Fig. 3.

Tests show there are three conditions that contribute to oil seal leakage at the internal turbocharger oil seal.

1. A worn or defective oil seal, which must be replaced.

2. High air inlet restriction (above specified limits). This will cause oil to be pulled past the oil seal.

3. Long periods of operation where the engine is being motored (using the engine as a braking device when going down a long hill). This can also cause oil to pass by the oil seal.

To confirm oil leakage from one or more of these conditions, remove the compressor housing and inspect the backplate. If the surface is wet with oil it indicates leakage.

If this test does not show leakage patterns the oil seal assembly is good for normal operation. This simple test will allow some positive testing on each engine in all cases.

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure:

1. Determine that air inlet restriction is within the Detroit Diesel maximum limit. Refer to Section 13.2.

2. Be certain that turbocharger oil drain line is ununrestricted.

3. Be certain that the turbocharger has not obviously been damaged and in need of major repair.

4. Remove the air intake ducting. Inspect inside of the ducting for evidence of oil. If oil is found in the intake system, determine the source before proceeding with the compressor seal test and also thoroughly remove oil from the intake. Some external sources of oil are

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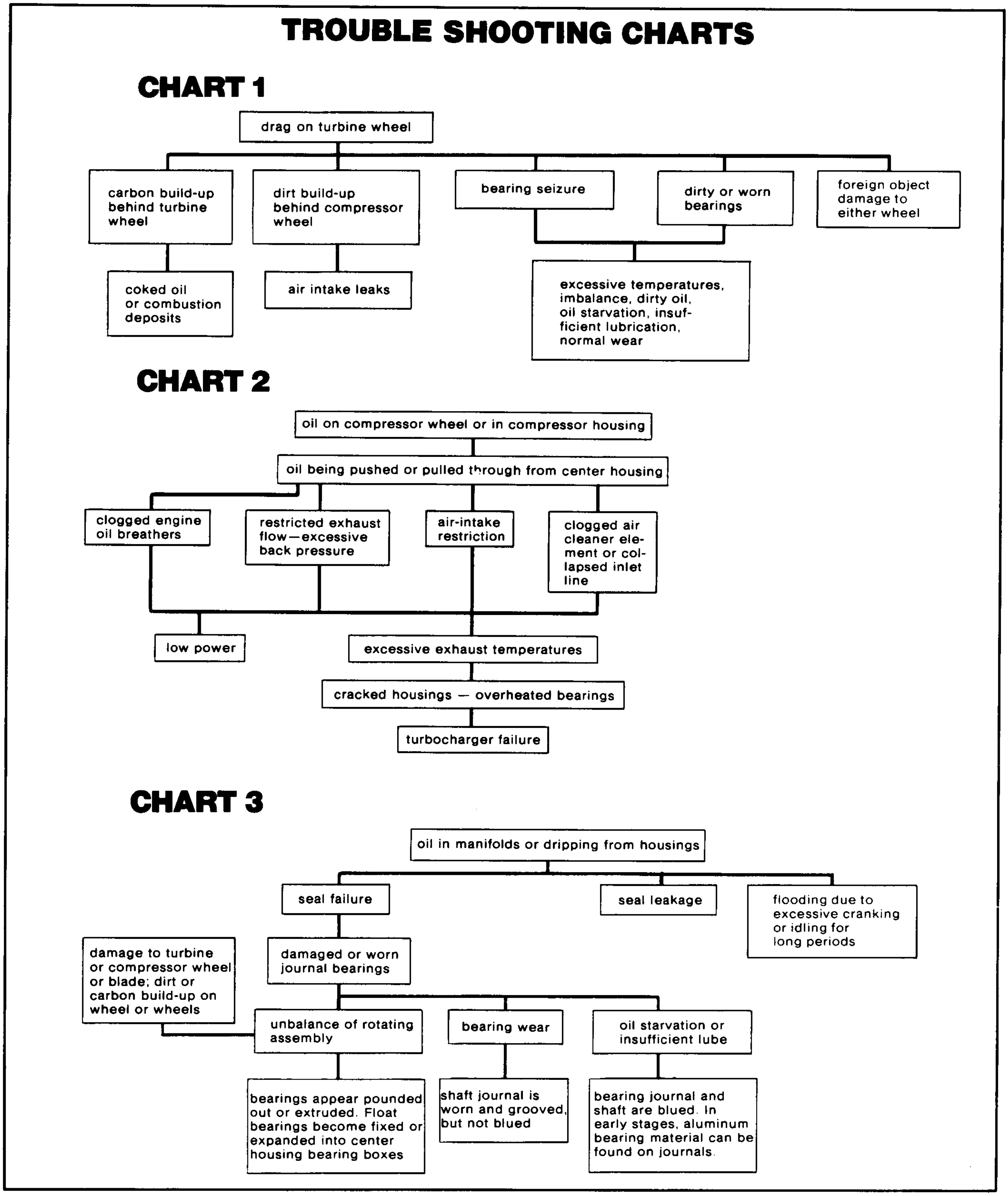

Fig. 3 - Inspection Checks for Turbocharger

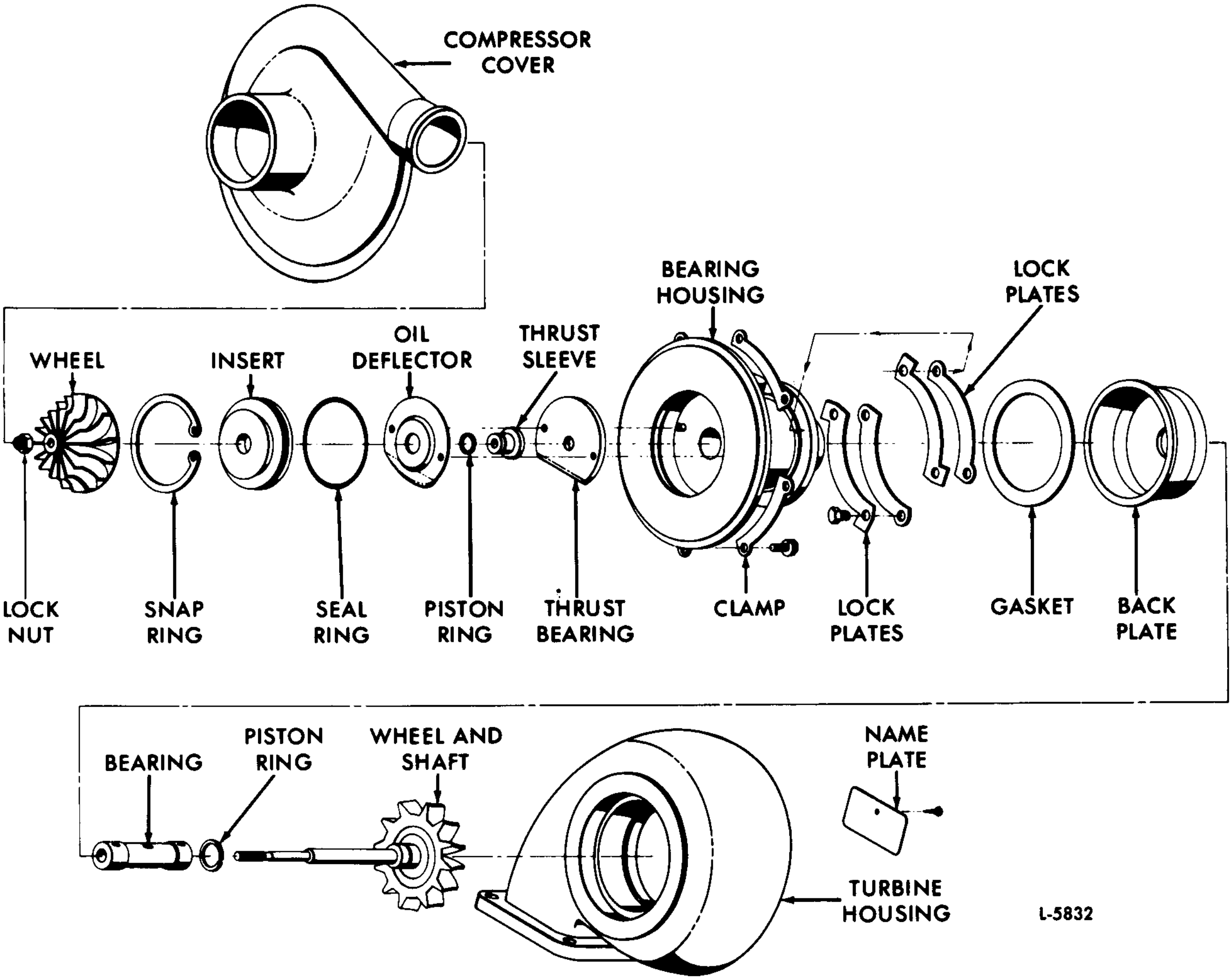

Fig. 4 - Model 3LM Turbocharger and Relative Location of Parts

oil bath air cleaners, air compressor line, or a leak near an oil source such as an engine breather, etc.

5. Remove the compressor housing from the turbocharger.

6. Thoroughly clean the internal surfaces of the compressor housing, the impeller cavity behind the impeller, and the backplate annulus with a suitable solvent spray and then dry completely with shop air.

7. Spray the backplate annulus with a light coating of "Spot-Check" developer type SKD-MF, or equivalent.

8. Install the compressor housing on the turbocharger and reconnect the inlet and outlet connections.

9. Warm-up the engine to normal operating temperature.

10. Operate the engine at no load at the governor limited high speed for approximately five minutes.

11. Return the engine to low idle and then stop it.

12. Remove the intake duct and outlet hose and then remove the compressor housing. Evidence of compressor end shaft seal oil leakage will be observed as oil streaks in the "Spot-Check" developer on the backplate annulus. This surface should be completely free of oil streaks after the test.

13. If leakage is detected, and oil is positively not entering through the intake duct, then the turbocharger may be removed from the engine and inspected for damaged components.

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Remove Turbocharger

1. Disconnect the air inlet connection and the exhaust outlet connection from the compressor housing and turbine housing respectively. This will permit inspection of the compressor and turbine wheels. Spin and wobble the rotor assembly variously by hand for evidence of wheel to turbine housing and impeller to compressor housing contact.

2. Remove the oil inlet and outlet lines from the top and bottom of the bearing housing.

3. Attach a suitable lifting sling to the turbocharger.

4. Remove the nuts and lock washers securing the turbocharger to the mounting bracket. Lift the turbocharger from the engine.

5. Cover the oil inlet and outlet openings and the air inlet and exhaust openings on the engine to prevent the entry of foreign material.

Disassemble Turbocharger

> **CAUTION:** During disassembly it is recommended that safety glasses be used.

1. Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly and proceed as follows:

> **NOTE:** Exercise care when removing the compressor housing and turbine housing from the bearing housing to prevent damage to the compressor and turbine wheels.

2. Secure the turbine housing mounting flange in a vise and bend back the lock tabs on the lock plates. Then remove the four screws, two lock plates and two clamps.

3. Remove the rotating assembly and compressor cover as an assembly out of the turbine housing and invert it and place it on a work bench with the turbine wheel facing up.

4. Remove the eight screw and lock washer assemblies and four clamps. Then remove the rotating assembly from the compressor cover.

5. With the turbine wheel lug of the rotating assembly in a 1″ wrench (Fig. 5), remove and discard the compressor wheel lock nut.

6. Remove the compressor wheel from the turbine shaft assembly by hand (Fig. 6). The wheel is a slip fit on the shaft.

7. Remove the external snap ring from the compressor end of the bearing housing (Fig. 7). Use medium size internal snap ring pliers and restrain the ring with a shop cloth to prevent injury, in the event the ring goes astray.

8. Remove the compressor insert from the bearing housing by prying evenly and gently with screw drivers placed under the lip of the insert (Fig. 8).

> **IMPORTANT:** If the insert tilts and binds, tap it back into place and repeat the procedure. *Do not force* the insert from the bearing housing.

9. Remove the oil deflector, outer piston ring, thrust sleeve, thrust bearing (discard) and inner piston ring from the cavity in the bearing housing.

> **NOTE:** Do not remove the dowels from the bearing housing.

10. Tap the turbine shaft assembly gently with a plastic faced mallet to release it from the bearing housing (Fig. 9).

11. Remove the turbine wheel and shaft assembly. The shaft should slip freely out of the bearing after the initial release by tapping.

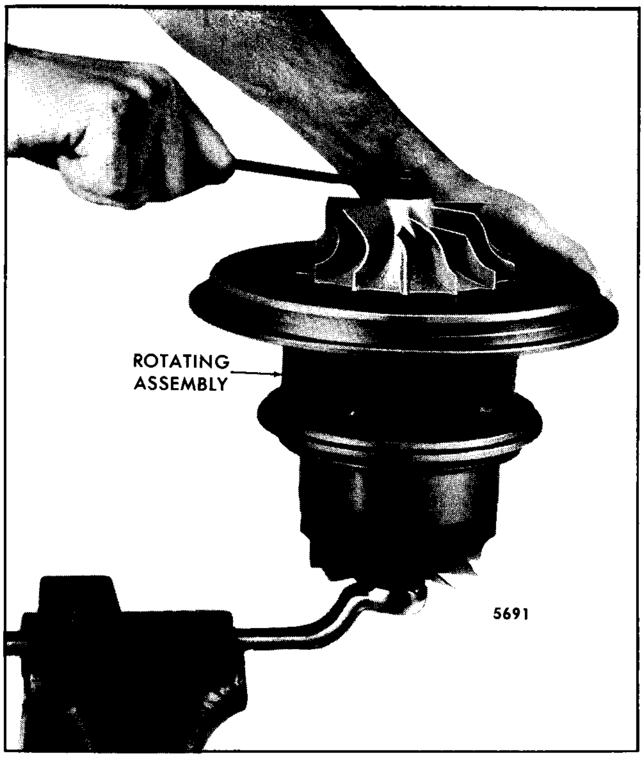

Fig. 5 - Removing Compressor Wheel Lock Nut

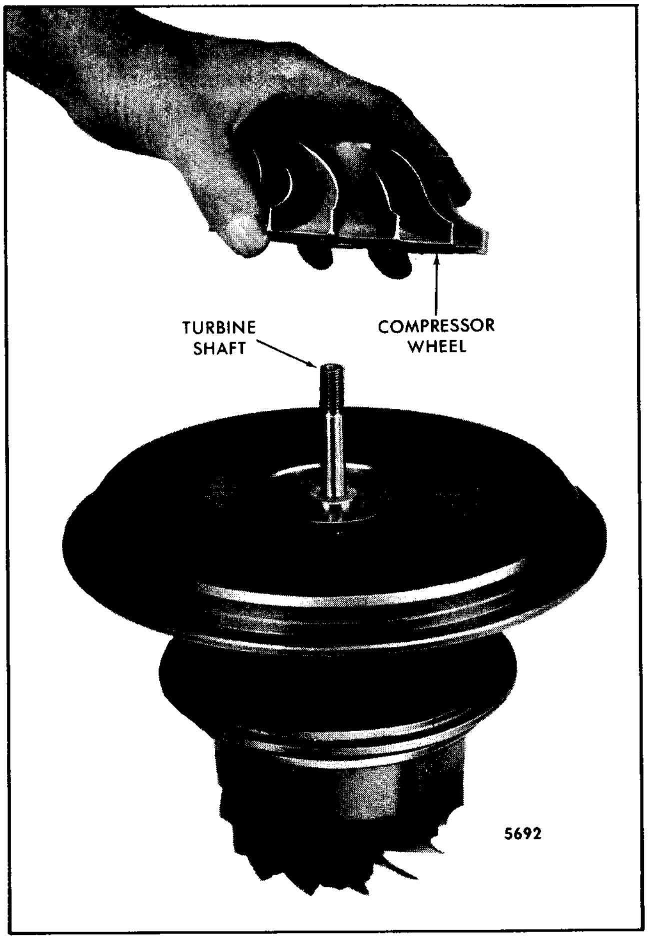

Fig. 6 - Removing Compressor Wheel from Turbine Shaft

12. Remove and discard the turbine shaft bearing from the bearing housing bore (Fig. 10).

13. Separate the backplate and gasket from the bearing housing. Discard the gasket.

NOTE: If the seal ring bore in the bearing housing is encrusted with carbon, preventing removal of the bearing components, scrape away the carbon with a sharp-edged tool. Do not scratch or gouge the seal ring bore surface.

14. Remove and discard the seal ring from the turbine wheel-and-shaft by prying and breaking with a screw driver. Take care not to mar the hub or groove surfaces of the turbine wheel.

Cleaning Procedures

1. Bearing Housing and Dowel Assembly:

a. Scrape or wipe appropriately any loose or heavy

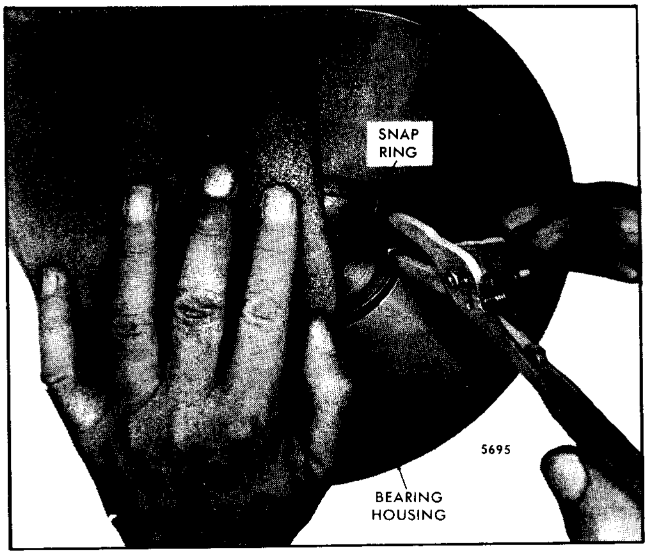

Fig. 7 - Removing External Snap Ring from Bearing Housing

foreign material accumulations from the exterior surfaces.

b. Immerse briefly in safety solvent to remove any traces of oily residue.

c. Dry with clean compressed air, again taking care that all drilled oil passages are thoroughly cleaned.

d. Oil all interior and exterior surfaces to prevent rust and *immediately* wrap in a clean, dry plastic bag until inspection and reuse.

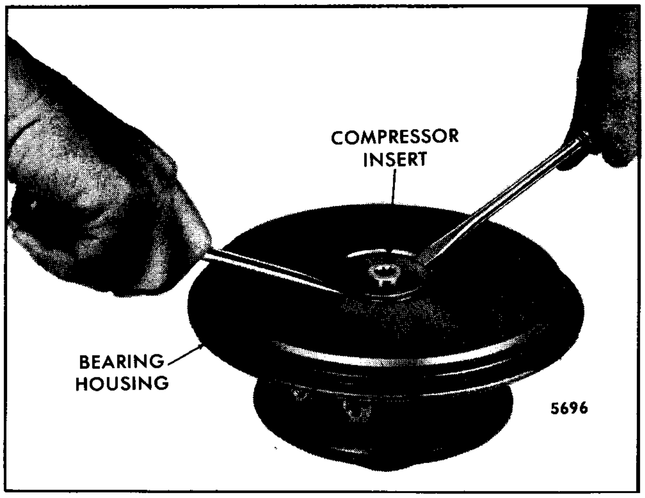

Fig. 8 - Removing Compressor Insert from Bearing Housing

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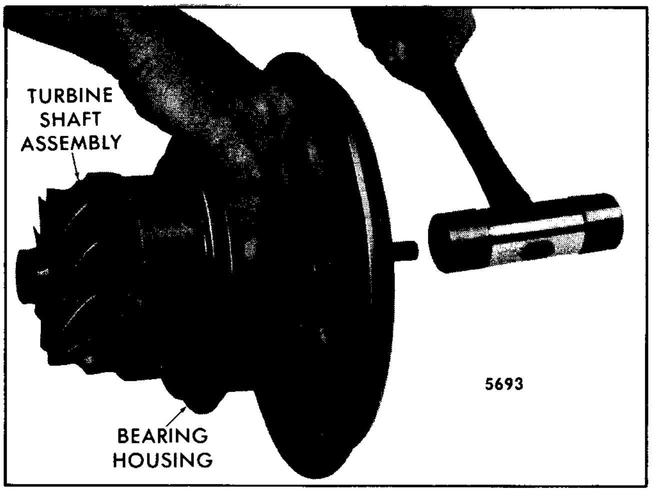

Fig. 9 - Tapping Turbine Shaft Assembly from Bearing Housing

2. Compressor Wheel:

a. Immerse briefly in safety solvent to remove any traces of oily residue.

b. Dry with clean compressed air.

c. *Immediately* wrap in a clean, dry plastic bag until inspection and reuse.

3. Turbine Wheel-and-Shaft Assembly:

a. Immerse briefly in safety solvent to remove any traces of oily residue.

b. Dry with clean compressed air.

c. Mask the entire shaft section with either appropriately sized rubber hose or adhesive backed cloth tape.

d. Vapor blast or dry hone the entire turbine wheel and the hub to total cleanliness, taking care not to concentrate on the seal ring groove.

e. Remove the masking material.

f. Mount the small diameter shaft section in a lathe chuck, taking care not to mar the shaft surface. *Lightly* polish the bearing journal section of the shaft, at 300 to 600 rpm, with 400 grit abrasive paper and clean engine oil.

g. Reimmerse briefly in clean safety solvent, agitating moderately by hand to help loosen any remaining particles of foreign material.

h. Dry with clean compressed air.

i. Oil the shaft surfaces liberally to prevent rust and *immediately* wrap in a clean, dry plastic bag until inspection and reuse.

4. Compressor Housing:

a. Scrape or wipe appropriately any loose or heavy foreign material accumulations from the exterior surfaces.

b. Immerse briefly in safety solution to remove any traces of oily residue.

c. Dry with clean compressed air.

d. *Immediately* wrap in a clean, dry plastic bag until inspection and reuse.

5. Turbine Housing and Turbine Backplate:

a. Immerse briefly in safety solvent to remove any traces of oily residue.

b. Dry with clean compressed air.

c. Oil all interior and exterior surfaces to prevent rust and *immediately* wrap in a clean, dry plastic bag until inspection and reuse.

6. Clamp Bands:

a. Immerse in safety solvent until foreign material deposits have been softened or dissolved, agitating moderately and occasionally by hand.

b. Dry with clean compressed air.

c. Wrap *immediately* in a clean, dry plastic bag until inspection and reuse.

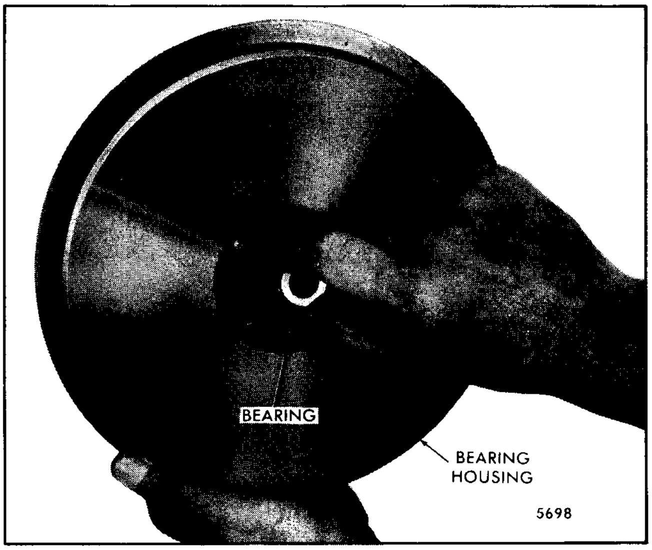

Fig. 10 - Removing Turbine Shaft Bearing from Bearing Housing

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7. Small Internal Parts:

a. Immerse briefly in clean safety solvent to remove any traces of oily residue.

b. Wipe dry with a clean shop rag.

c. Oil liberally to prevent rust and wrap *immediately* in a clean, dry plastic bag until inspection and reuse.

Inspection

1. Bearing Housing and Dowel Assembly:

NOTE: The installation of the two groove pins into the bearing housing of Schwitzer 3LM turbocharger used on 4-53 engines is an extremely critical operation requiring special tools not generally available to the service technician. Since improper assembly of the pins into the housing can result in high turbocharger oil flow, seal leakage and serious turbocharger damage, the service technician should not attempt to replace them when worn or damaged. Instead, the bearing housing assembly incorporating the factory-installed pins should be used. Only the bearing housing assembly with factory-installed pins will be serviced.

a. Inspect visually for evidence of cracks and fractures, pitting (as from corrosion or hot gas erosion) of gasket and other machined surfaces, and warpage of the turbine end flange. Replace if any of the above conditions are excessive.

b. Closely inspect the bearing bore visually for evidence of surface distress. The condition of the bearings that were removed during disassembly will serve as a good indicator of probable bore condition. Replace if the bore condition is substandard. The maximum bore diameter is .7505".

c. Install the turbine seal ring in its bore, inspect visually for full circle contact, and measure the ring gap with a feeler gage (Fig. 11). The gap range is .002" to .007". Replace if the ring fit is faulty.

NOTE: Do not attempt to restore the bore condition by reaming or honing.

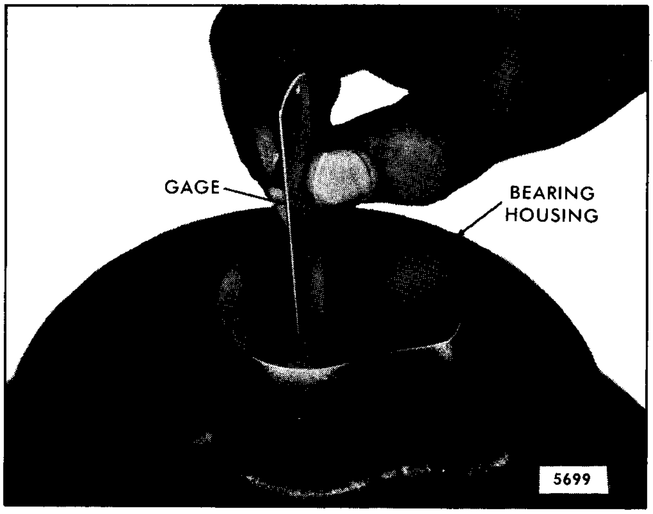

Fig. 11 - Checking Turbine Seal Ring Gap in Bearing Housing

2. Compressor Wheel:

Inspect visually for evidence of bent, burred or eroded vanes and for evidence of scuffing on the backplate. Replace if this damage is present. Slightly nicked vanes are acceptable.

NOTE: Do not attempt to straighten bent vanes.

3. Turbine Wheel and Shaft Assembly:

a. Inspect the wheel visually for evidence of bent, burred or eroded vanes and for evidence of scuffing on the back face. Replace if damaged.

NOTE: Do not attempt to straighten bent vanes.

b. Inspect the hub visually for evidence of smearing (as from high speed contact with the bearing housing bore) and for deterioration of the seal ring groove. Replace if damage is excessive.

c. Inspect bearing journals visually for evidence of other than superficial deterioration (as from a bearing failure). Replace if journal condition is sub-standard. The minimum journal diameter is .5611".

d. Measure the concentricity between the large and small turbine shaft diameters with a dial test indicator and vee-block (Fig. 12). Limit of eccentricity is .0006" total indicator reading. Replace if the measurement is excessive.

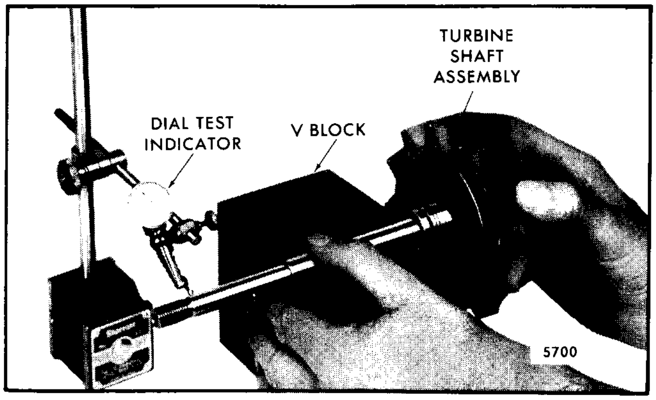

Fig. 12 - Measuring Concentricity Between Large and Small Turbine Shaft Diameters

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NOTE: Do not attempt to straighten a bent shaft.

4. Compressor Housing:

Inspect visually for evidence of contour damage (as from high speed wheel contact). Replace if damaged.

5. Turbine Housing and Backplate:

Inspect visually for evidence of contour damage (as from high speed wheel contact) and for evidence of excessive heat damage, to internal and flanged surfaces, such as cracking, pitting or warpage. Replace if damaged.

6. Small Internal Parts:

a. Install the compressor seal ring in the insert bore, inspect visually for full circle contact and measure the ring gap with a feeler gage. Gap range is .002 " to .007 ". Replace the insert if the ring fit is faulty.

NOTE: Do not attempt to restore bore condition by reaming or grinding.

b. Inspect both thrust rings visually for evidence of wear and scratching. Replace if damaged.

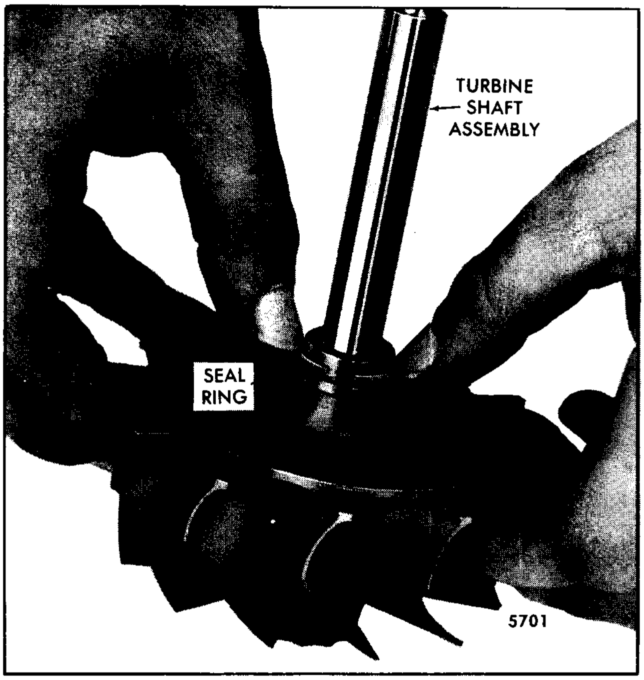

Fig. 13 - Installing Seal Ring on Turbine Shaft

Assemble Turbocharger

1. Place the turbine housing in a vise with the four threaded holes facing up.

2. Lubricate a new piston ring with clean engine oil and install it in the ring grooves of the wheel and shaft assembly (Fig. 13).

NOTE: Do not over expand the ring.

3. Position the bearing housing, turbine end up (Fig. 14). Then install a new gasket and the turbine backplate.

NOTE: The backplate has no attachment to the bearing housing. Its position is fixed when the bearing housing and turbine housing are clamped together.

4. Lubricate the piston ring area of the shaft and wheel assembly with clean engine oil and install it through the backplate and into the bearing housing (Fig. 15).

NOTE: Be careful and avoid damage to the piston ring.

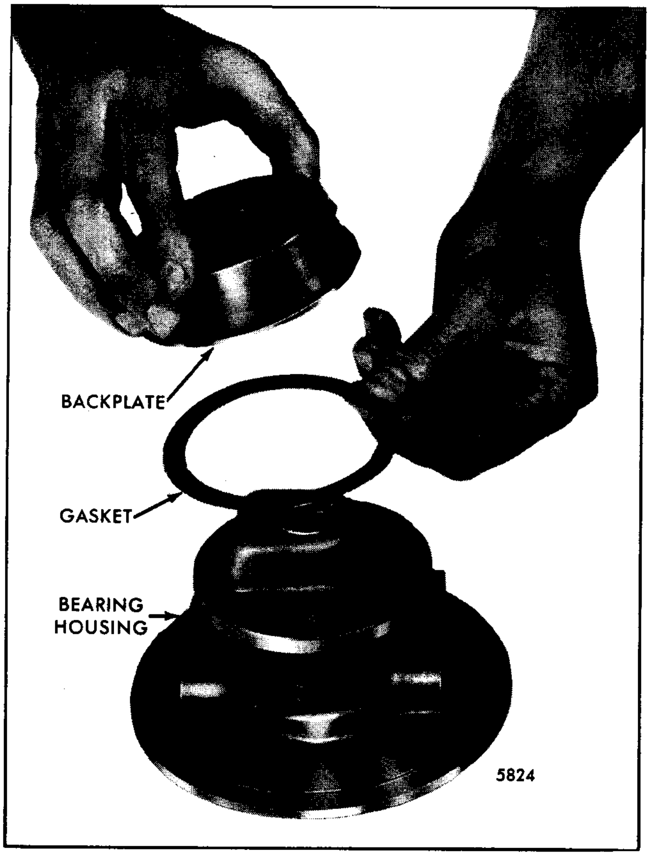

Fig. 14 - Assembling Bearing Housing, Gasket and Backplate

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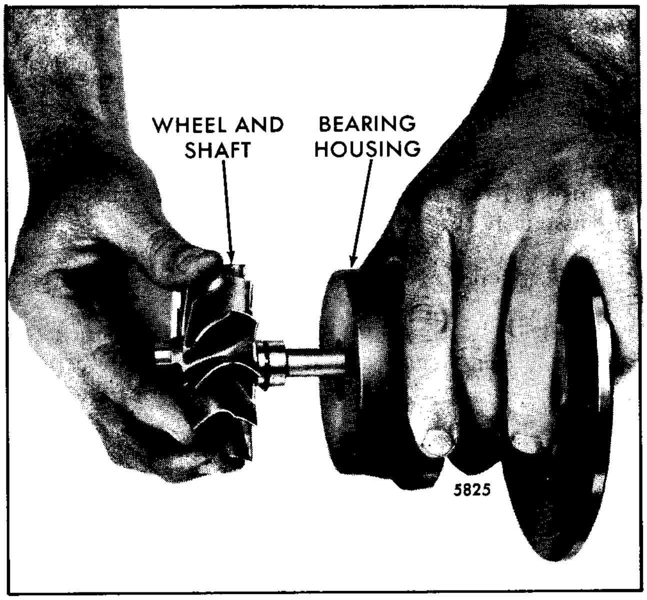

Fig. 15 - Installing Shaft and Wheel Assembly Through Back Plate into Bearing Housing

5. Holding the end of the shaft, to prevent the shaft and wheel assembly from falling out of the bearing housing, install the assembly in the turbine housing wheel end down.

6. Lubricate the inner and outer diameter of the bearing. Then install the bearing down over the shaft and into the bearing housing bore.

7. Lubricate the thrust faces on both side of the thrust bearing and install the bronze side of the bearing over the shaft and groove pins, engaging the pins to the holes in the thrust bearing (Fig. 16).

8. Install the oil deflector on the thrust sleeve.

9. Lubricate a new piston ring and install it on the thrust sleeve.

NOTE: Do not over expand the piston ring.

10. Lubricate a new seal ring and install it in the groove on the insert.

11. Lubricate the thrust sleeve and install the small end into the hole of the insert from the concave side of the insert. Be careful to avoid damage to the piston ring.

12. Lubricate the thrust cavity in the bearing housing and install the insert, oil deflector and thrust sleeve assembly over the shaft and into the bearing housing (Fig. 17). Align the oil deflector to mate with the oil drain cavity in the bearing housing.

NOTE: It may be necessary to tap the insert

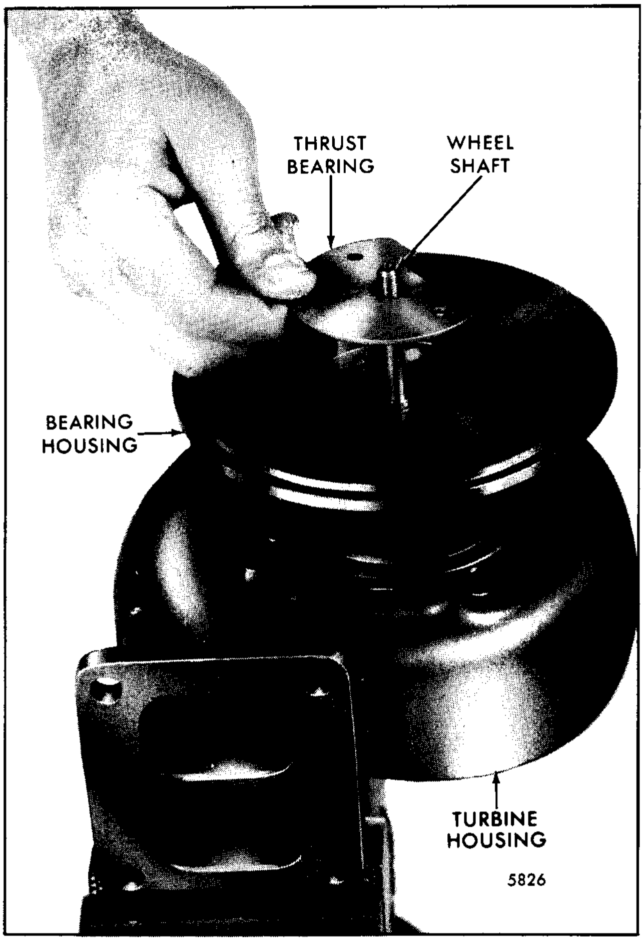

Fig. 16 - Install Thrust Bearing in Bearing Housing

with a soft hammer to seat it completely. Do not damage the seal ring.

13. Install the external snap ring in the compressor end cavity of the bearing housing. Be sure the ring seats fully in the groove, by twist-prying against the insert rim with a screw driver.

CAUTION: To prevent eye or facial injury, use a rag to snub the ring should it slip from the pliers during compression (Fig. 7).

14. Mount a dial indicator on the bearing housing with the stem resting on end of the shaft. Make sure that the turbine end of the bearing housing is properly seated in the turbine housing. Then move the shaft vertically to determine turbine wheel contour clearance. It must be .018 " to .049 ". If the clearance is not within these tolerances, disassemble the unit to determine the cause. Look for burrs, dirt particles or incorrectly assembled parts. Reassemble and check the

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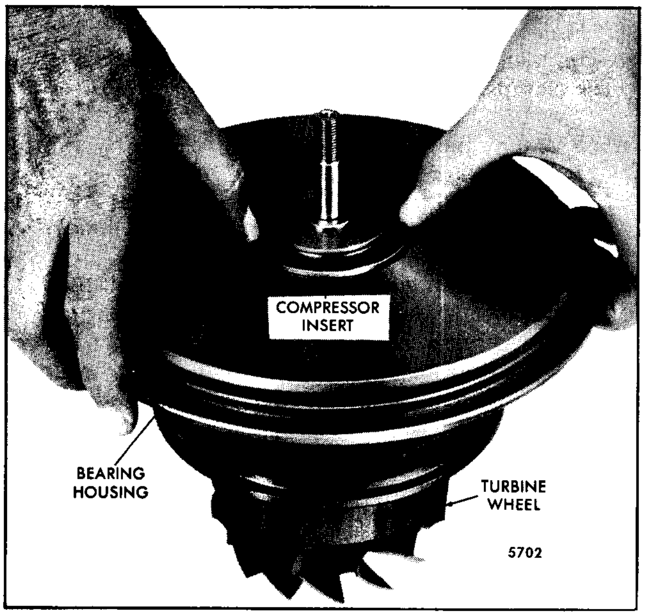

Fig. 17 - Installing Compressor Insert in Bearing Housing

contour clearance. If it is still out of tolerance, do not attempt to use.

15. Install the compressor wheel on the shaft.

16. Lubricate the back face and threads of the lock nut with anti-seize compound. Install the lock nut on the shaft finger tight (until elastic of nut engages shaft threads) and place an 11/16 " socket on the turbine wheel lug to prevent the shaft from turning. Use a torque wrench to tighten the lock nut to 13 lb-ft (18 Nm) torque (Fig. 18).

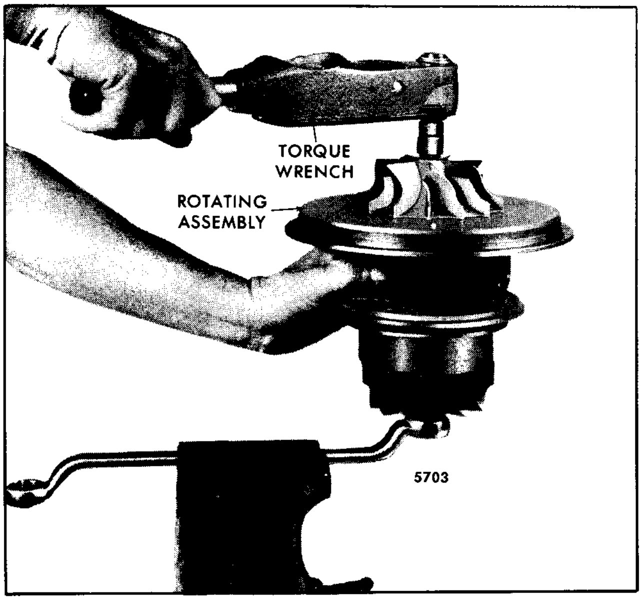

Fig. 18 - Tightening Compressor Locknut

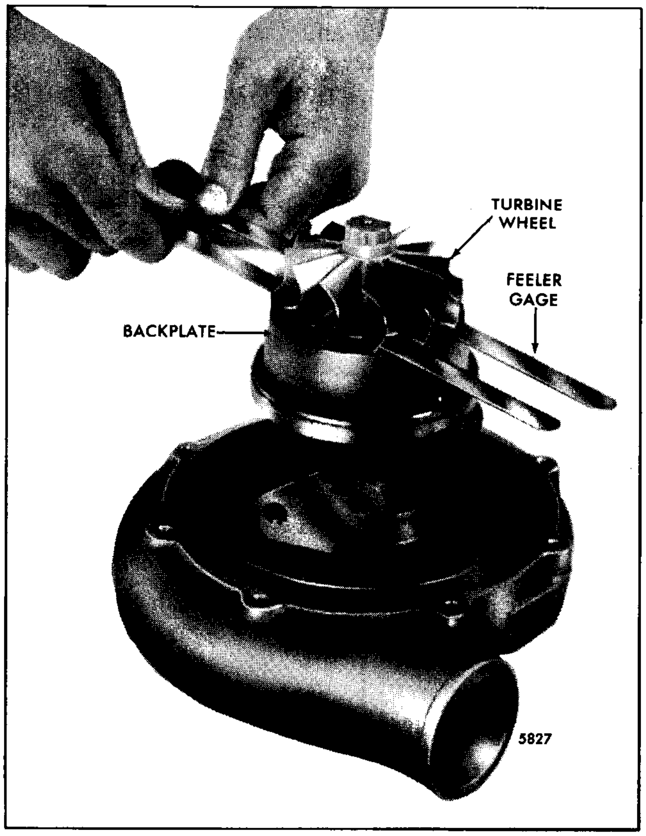

Fig. 19 - Checking Turbine Wheel to Backplate Clearance

17. Mount the dial indicator on the bearing housing with the stem resting on the end of the shaft to check end play. Total movement must be .002 " to .005 ". If not within these tolerances, proceed as in Step 14 above.

18. Place the compressor cover on a work bench with the wheel cavity up. Lubricate the pilot diameter with grease or oil and place the rotating assembly in the compressor cover with the turbine wheel up.

19. Check the turbine wheel back clearance by placing two equal feeler gage stacks between the back face of the turbine wheel and the backplate on the opposite sides of the shaft (Fig. 19). Clearance must be .017 " to .049 ". If clearance is not within limits, proceed as in Step 14 above.

20. Install four clamp plates and eight screw and lock washer assemblies. Tighten the screws to 5 lb-ft (7 Nm) torque. Use care not to overtighten the screws.

NOTE: If the compressor cover needs to be re-oriented upon installation on the engine, do not tighten the screws at this point.

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21. Turn the unit over and install it in the turbine housing. Apply anti-seize compound to the threads of the four screws. Install the two clamps, two lock plates and four screws. Tighten the screws to 12 lb-ft (16 Nm) torque.

22. Bend the tabs of the lock plates up against one flat of each screw.

> **NOTE:** If the turbine housing needs to be re-oriented upon installation on the engine, do not tighten the screws or bend the lock plate tabs at this point.

23. Inject approximately 1/4 ounce of clean engine oil into the oil inlet port of the bearing housing.

24. Spin the rotating assembly by hand to assure smooth and free rotation.

25. Seal the completed unit in a clean, dry plastic bag until installed on the engine.

Install Turbocharger

1. Inspect the intake and exhaust systems leading to the turbocharger to ensure absence of foreign material (even small particles can cause severe damage to the rotating assembly when inducted at high speeds).

2. Use *new* gaskets at all of the air, oil and exhaust connections to the turbocharger.

> **IMPORTANT:** Do not use joint compound at the oil inlet and exhaust connections.

3. Use anti-seize thread compound on all threaded fasteners used to mount the turbocharger.

4. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

5. Position the turbocharger so that it aligns with all corresponding connections on the engine.

6. Tighten the compressor housing and turbine housing clamp band retaining nuts to 10 lb-ft (14 Nm) torque.

7. Secure the turbocharger to the mounting bracket with bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbocharger tight against the brackets.

> **IMPORTANT:** When self locking nuts are used to secure the turbocharger to the mounting bracket, be sure there is full thread engagement (at least one full thread above the nut) of the self locking nuts on the bolts.

8. Slide the blower air inlet tube hose over the compressor housing outlet and secure it in place with hose clamps.

9. Tighten the turbocharger to exhaust manifold adaptor bolts securely.

10. Connect the oil inlet line to the cylinder block.

11. After installing a rebuilt or new turbocharger, it is very important that all of the moving parts of the turbocharger center housing be lubricated as follows:

   a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing.

   b. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

   c. Add additional engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

   d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig - 69 kPa at idle speed).

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

The free floating bearing in the turbocharger bearing housing requires positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed,* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearing can cause severe damage to the shaft and bearing of the turbocharger.

12. Check all connections, ducts and gaskets for leaks.

13. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, shut the engine down immediately and correct the cause.

> **NOTE:** After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

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TURBOCHARGER INTERCOOLER

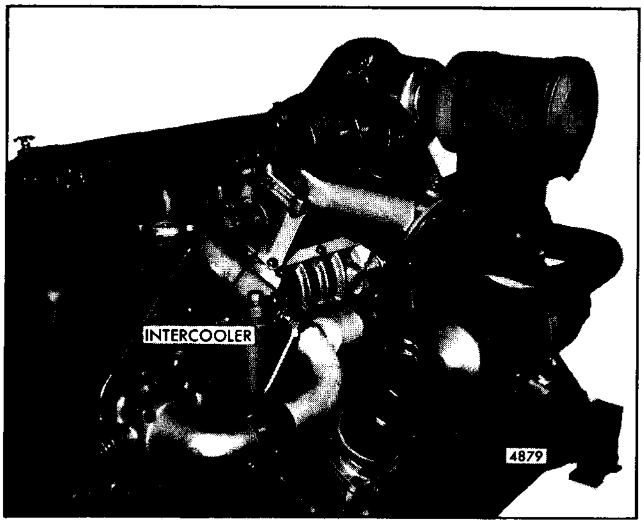

Fig. 1 - Turbocharger Intercooler Mounting

The turbocharger intercooler is mounted on the air inlet side of the engine blower and is used to reduce the temperature of the compressed air from the turbocharger before the air enters the engine blower. This permits a more dense charge of air to be delivered to the engine. The cooling is accomplished by the raw water from the heat exchanger passing through the cells of the intercooler core. The compressed air enters the intercooler via the air inlet housing and circulates past the cooler core of the intercooler.

Remove Intercooler

1. Drain the raw water system.

2. Loosen the two hose clamps on the hose connecting the raw water inlet tube to the inlet end of the intercooler (Fig. 1).

3. Remove the four 5/16"-18 x 1" bolts and lock washers that retain the air inlet tube flange to the air inlet housing.

4. Disconnect the connection between the outlet end of the intercooler and the raw water discharge line.

5. Disconnect the manual shutdown, if used.

6. Remove the six bolts, nuts, washers and lock washers that retain the air inlet housing to the intercooler and remove the air inlet housing and the screen and gasket assembly.

NOTE: The bolts are not all the same length and their location should be noted during removal to facilitate installation.

7. Remove the six bolts and lock washers that retain the intercooler to the blower and remove the intercooler. Note the location of the two shorter bolts.

8. Remove the gasket from the side of the blower.

Clean Intercooler

Check all of the intercooler tubes to be sure they are free of obstructions.

If the tubes contain dirt or any other foreign material, they can be cleaned with a small brush or by use of a suitable solvent cleaning solution. Flush the core thoroughly with water to remove any foreign material and the solvent.

Install Intercooler

1. Affix a new gasket to the side of the blower.

2. Mount the intercooler assembly to the blower with the six bolts and lock washers and tighten the bolts to 16-20 lb-ft (22-27 Nm) torque.

3. Affix a new air inlet screen and gasket assembly on the intercooler.

4. Mount the air inlet housing to the intercooler with the six bolts, nuts, washers and lock washers and tighten the nuts to 35-39 lb-ft (47-53 Nm) torque.

5. Affix a new gasket on the air inlet housing flange and secure the air inlet tube flange to the air inlet housing with the four 5/16"-18 x 1" bolts and lock washers. Tighten the bolts to 13-17 lb-ft (18-23 Nm) torque.

6. Connect the raw water inlet tube to the inlet end of the intercooler with the hose and clamps. Tighten the clamps securely.

7. Connect the raw water discharge line to the outlet end of the cooler.

8. Connect the manual shutdown, if used.

9. Fill the raw water system. Then start the engine and check for air or water leaks.

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SHOP NOTES - TROUBLESHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

REWORKING BLOWER FRONT END PLATES - 6V-53 ENGINES

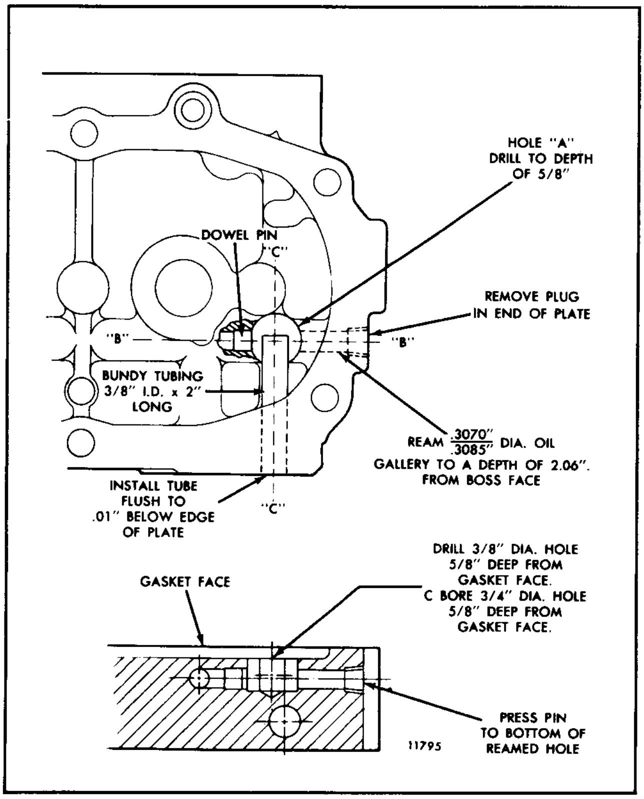

Fig. 1 - Dimensions for Reworking Front End Plate (6V-53 Engine)

When rebuilding a 6V-53 blower assembly in the field, the front end plate can be reworked to provide improved lubrication, when desirable, in the area of the thrust washers. The rework procedure is as follows:

1. Remove the pipe plug from the horizontal oil gallery (B-B) of the end plate. Place a reamer in the chuck of the drill press and ream a .3070" - .3085" diameter hole 2.060" deep from the boss face (Fig. 1). Remove the metal cuttings from the hole.

2. Install the copper-plated dowel pin to the full depth of the reamed portion of the horizontal oil gallery.

3. Locate and mark the center of hole "A" (Fig. 5). The center of hole "A" is where the center line (B-B) of the horizontal oil gallery intersects with the center line (C-C) of the drain hole. Clamp the end plate on the bed of the press and center drill at the location marked. Then, drill a 3/8" diameter hole 5/8" deep from the gasket face of the end plate. Lubricate the drill and the area of the end plate that is being reworked with mineral spirits or fuel oil.

4. Place either an end mill or a 3/4" counterbore reamer (remove the pilot from the reamer) in the chuck of the drill press and counterbore a 3/4" diameter hole 5/8" deep from the gasket face of the end plate.

5. Wash the end plate in clean fuel oil to remove the metal cuttings and dry it with compressed air.

6. Cut a piece of 3/8" I.D. Bundy tubing 2.00" long. Coat the tubing with Gasola or an equivalent type sealant. Press the tubing into the oil drain hole in the end plate flush to .010" below the edge of the plate. It is important that the area around the tube be oil tight.

7. Reinstall the pipe plug in hole (B-B).

8. When assembling the blower, apply a liberal amount of Lubriplate, or equivalent, on the surfaces of the thrust washers. This will provide lubrication of the thrust washers during initial start-up of the engine.

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TROUBLESHOOTING

TURBOCHARGER

CONDITION	PROBABLE CAUSE	SUGGESTED REMEDY
NOISY OPERATION OR VIBRATION	WHEEL SHAFT BEARINGS ARE NOT BEING LUBRICATED	Locate cause of loss of oil pressure and repair. Remove, dis-assemble and inspect turbocharger for bearing damage.
	IMPROPER CLEARANCE BETWEEN TURBINE WHEEL AND HOUSING	Remove, disassemble, and inspect turbocharger.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or replace exhaust manifold gaskets as necessary.
ENGINE WILL NOT DELIVER RATED POWER	CLOGGED AIR INTAKE SYSTEM	Check air cleaner and clean air intake ducts.
	FOREIGN MATERIAL LODGED IN COMPRESSOR OR TURBINE WHEELS	Remove, disassemble and clean turbocharger.
	EXCESSIVE DIRT BUILD-UP IN COMPRESSOR	Thoroughly clean compressor assembly. Clean air cleaner and check for leaks.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or replace exhaust manifold gaskets as necessary.
	ROTATING ASSEMBLY BEARING SEIZURE	Remove and overhaul turbocharger.

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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 PART (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Blower			
Backlash--rotor gears (all)	.0005″	.0025″	.0035″
Backlash between upper rotor and camshaft or balance shaft gear (2-53 and 3-53)	.0030″	.0070″	
Backlash between blower drive gear and camshaft gear	.0030″	.0070″	
Oil seal (below end plate surface) (In-line and 6V-53)	.0020″	.0080″	
Oil seal (below end plate surface) (8V-53)	flush	.0100″	
Oil strainer (below end plate surface) (8V-53)	flush	.0150″	
Pin--dowel (projection beyond inside face of front or rear end plate) (8V-53)	.3800″		
Clearances:			
Thrust plate and thrust washer (In-line)	.0010″	.0030″	
Thrust plate and thrust washer (4-53T and 6V-53)	.0025″	.0050″	
Rotor to air outlet side of housing:			
In-line and 6V-53	.0040″		
8V-53	.0050″		
3-53T	.0060″		
4-53T	.0070″		
Rotor to air inlet side of housing:			
In-line	.0075″		
6V-53	.0100″		
3-53T	.0120″		
8V-53	.0170″		
Rotor to front end plate:			
In-line	.0060″		
3-53T, 4-53T and 6V-53	.0080″		
+8V-53 (former)	.0070″		
6V-53T	.0100″		
†8V-53 (current)	.0170″		
Rotor to rear (gear) end plate:			
2-53	.0060″		
3-53	.0080″		
4-53 and 3-53T	.0090″		
4-53T and 6V-53	.0100″		
6V-53T	.0120		
+8V-53 (former)	.0140″		
†8V-53 (current)	.0070″		

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ENGINE PART (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Rotor-to-rotor clearance:			
In-line	.0100″		
3-53T	.0120″		
6V-53	.0090″		
6V-53T	.0130″		
Trailing edge of R.H. helix rotor to leading edge of L.H. helix rotor (8V-53)	.0080″		
Leading edge of R.H. helix rotor to trailing edge of L.H. helix rotor (8V-53)	.0180″		
Turbocharger (TE0675)			
Rotating shaft axial end play	.0040″	.0070″	
Rotating shaft radial movement	.0030″	.0070″	
Turbine wheel rotor shaft journal bearing:			
Inside diameter	.6268″	.6272″	
Outside diameter	.9780″	.9785″	
Turbine wheel shaft journal diameter	.6251″	.6254″	
Bearing bore diameter in center housing	.9827″	.9832″	
Turbocharger (T04B and TV61)			
Rotating shaft axial end play	.0040″	.0090″	
Rotating shaft radial movement	.0030″	.0070″	

+This clearance applies to former blowers with the ball bearings in the front end plate and roller bearings in the rear end plate.

†This clearance applies to current blowers with the roller bearings in the front end plate and ball bearings in the rear end plate.

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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 1 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

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EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)	TORQUE (Nm)
Blower drive coupling to rotor gear bolt (In-line and 6V-53)	1/4 -28	14-18	19-24
Blower drive gear pilot bolt (In-line and 6V-53)	5/16-24	25-30	34-41
Blower thrust washer retaining bolt (In-line and 6V-53)	5/16-24	25-30	34-41
Blower timing gear-to-rotor shaft bolts (In-line and 6V-53)	5/16-24	25-30	34-41
Air inlet adaptor-to-blower bolts	3/8 -16	16-20	22-27
Air inlet housing-to-adaptor or blower housing bolts	3/8 -16	16-20	22-27
Blower drive gear cover bolt	3/8 -16	20-24	27-33
Blower drive support-to-blower rear end plate bolts	3/8 -16	20-24	27-33
Blower-to-engine rear end plate and flywheel housing bolts (2-53 and 3-53)	3/8 -16	20-25	27-34
Flywheel housing-to-blower drive support bolts	3/8 -16	20-24	27-33
Front end plate cover bolts (4-53 and 6V-53)	3/8 -16	20-25	27-34
Governor-to-blower front end plate bolts	3/8 -16	20-24	27-33
Blower thrust washer retaining bolt (In-line and 6V-53)	3/8 -24	54-59	73-80
Blower timing gear-to-rotor shaft bolts (8V-53)	3/8 -24	50-55	68-75
Rotor shaft ball bearing retaining bolt (8V-53)	3/8 -24	50-55	68-75
Blower end plate-to-block bolts	7/16-14	55-60	75-81
Rotor shaft ball bearing retaining nut (8V-53)	.781"-32	50-60	68-81

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SERVICE TOOLS

TOOL NAME	TOOL NO.
Blower	
Blower clearance feeler gage set	J 1698-02
Blower drive cam installer	J 5209
Blower gear puller (part of J 23679)	J 28483
Blower service tool set (except 8V-53)	J 23679-A
Blower service tool set (8V-53)	J 21672
Handle	J 7079-2
Turbocharger	
Extension rod (2.500")	J 7057
Magnetic base indicator set	J 7872
Turbocharger inlet shield	J 26554-A

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SECTION 4

LUBRICATION SYSTEM

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Lubricating Oil Pressure Regulator	4.1.1
Lubricating Oil Filters	4.2
Lubricating Oil Cooler	4.4
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LUBRICATION SYSTEM

IN-LINE AND 6V-53 ENGINES

The engine lubrication systems, illustrated in Figs. 1 and 2, include an oil intake screen and tube assembly, an oil pump, an oil pressure regulator valve, a full flow oil filter with a bypass valve, an oil cooler and oil cooler bypass valve.

The rotor type oil pump is bolted to the back of the engine lower front cover and is driven directly by the crankshaft. The pump width varies for the In-line engines and the 6V-53 engine, but otherwise is of identical design. By rotating the pump 180°, it can be used for either right-hand or left-hand rotation engines.

Lubricating oil from the pump passes from the lower front engine cover through short gallery passages in the cylinder block. From the block, the oil flows to the full flow filter, then through the oil cooler and back into the front engine cover and cylinder block oil galleries for distribution to the various engine bearings. The drain from the cylinder head and other engine parts leads back to the oil pan.

Clean engine oil is assured at all times by the use of a replaceable element type full flow filter. With this type filter, which is installed between the oil pump and the oil cooler, all of the oil is filtered before entering the engine. Should the filter become plugged, the oil will flow through a bypass valve, which opens at approximately 18-21 psi (124-145 kPa) directly to the oil cooler. Bypass filters are used in certain applications when additional filtration is required (Section 4.2).

On current engines, the oil cooler bypass valve is located on the right-hand side of the engine front cover and the oil pressure regulator valve is located on the left-hand side as viewed from the rear of the engine (Figs. 1 and 2). On former engines, both valves were located on the right-hand side of the cover (Figs. 1 and 2).

If the cooler becomes plugged, the oil flow will be to a bypass valve in the lower engine front cover and then to the cylinder block oil galleries. The bypass valve opens at approximately 52 psi (359 kPa) in the current In-line engines and 6V-53 engines. In the former In-line engines, the bypass valve opens at approximately 30 psi (207 kPa).

NOTE: The bypass valve opens at approximately 32 psi (221 kPa) on 6V-53 marine engines prior to engine number 6D-11074 and all 6V-53 engines prior to engine number 6D-17960.

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a regulator valve located in the lower front engine cover. The regulator valve, located in the pump outlet passage, opens at the

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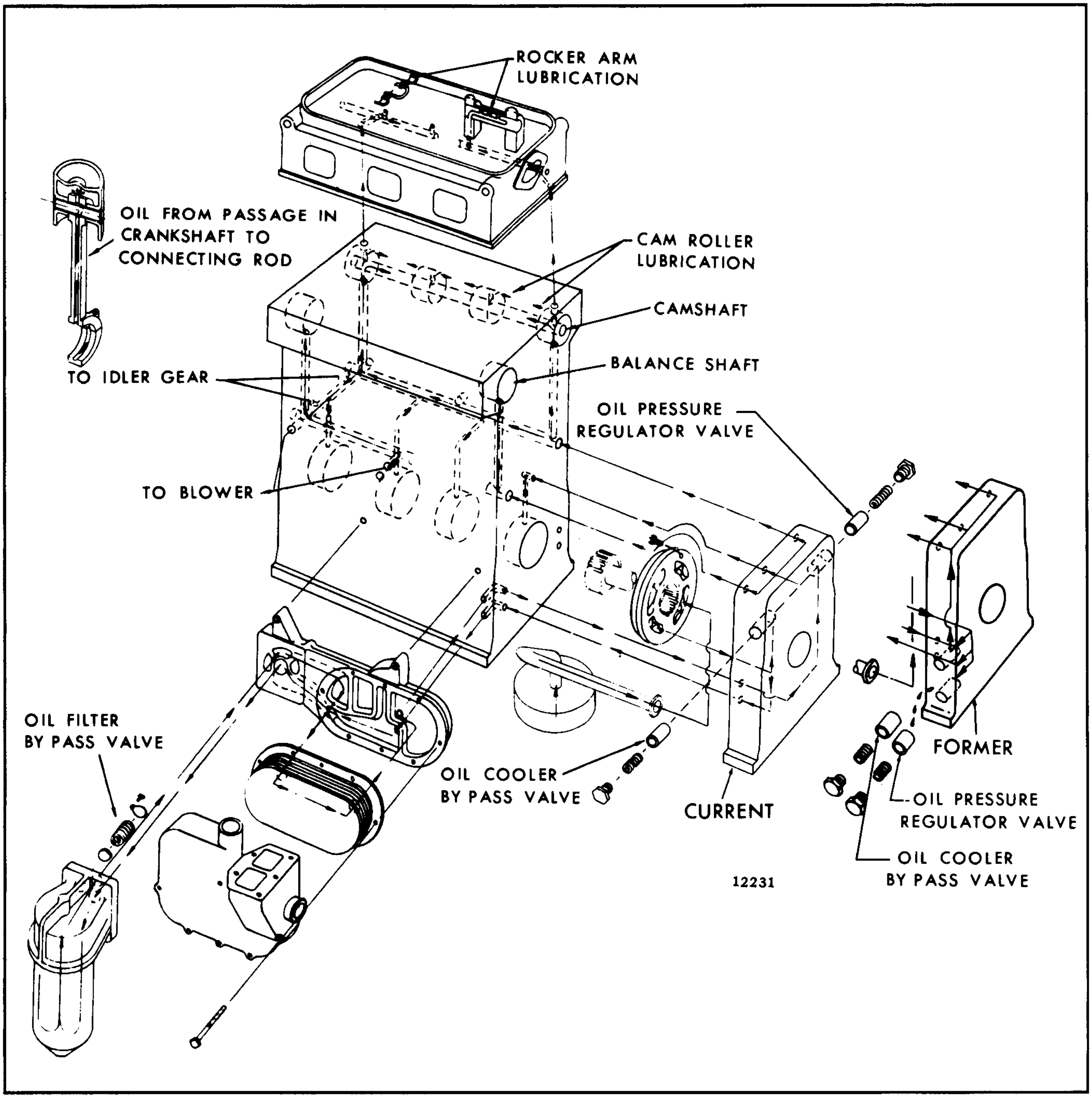

Fig. 1 - Schematic Diagram of Typical In-line Engine Lubrication System

pressure shown in the Table in Section 4.1.1 and returns excess oil directly to the crankcase.

Lubricating Oil Distribution

Oil from the oil cooler on the In-line engine is directed to the lower engine front cover and then to a longitudinal main oil gallery in the cylinder block. This gallery distributes the oil, under pressure, to the main bearings and to a horizontal transverse passage at one end of the block and to vertical passages at each corner of the block which provide lubrication for the balance shaft and camshaft bearings (Fig. 1). The camshaft bearings incorporate small slots through which lubricating oil is directed to the cam follower rollers.

On a 6V-53 engine, oil from the pump enters a passage in the cylinder block and flows under pressure to the

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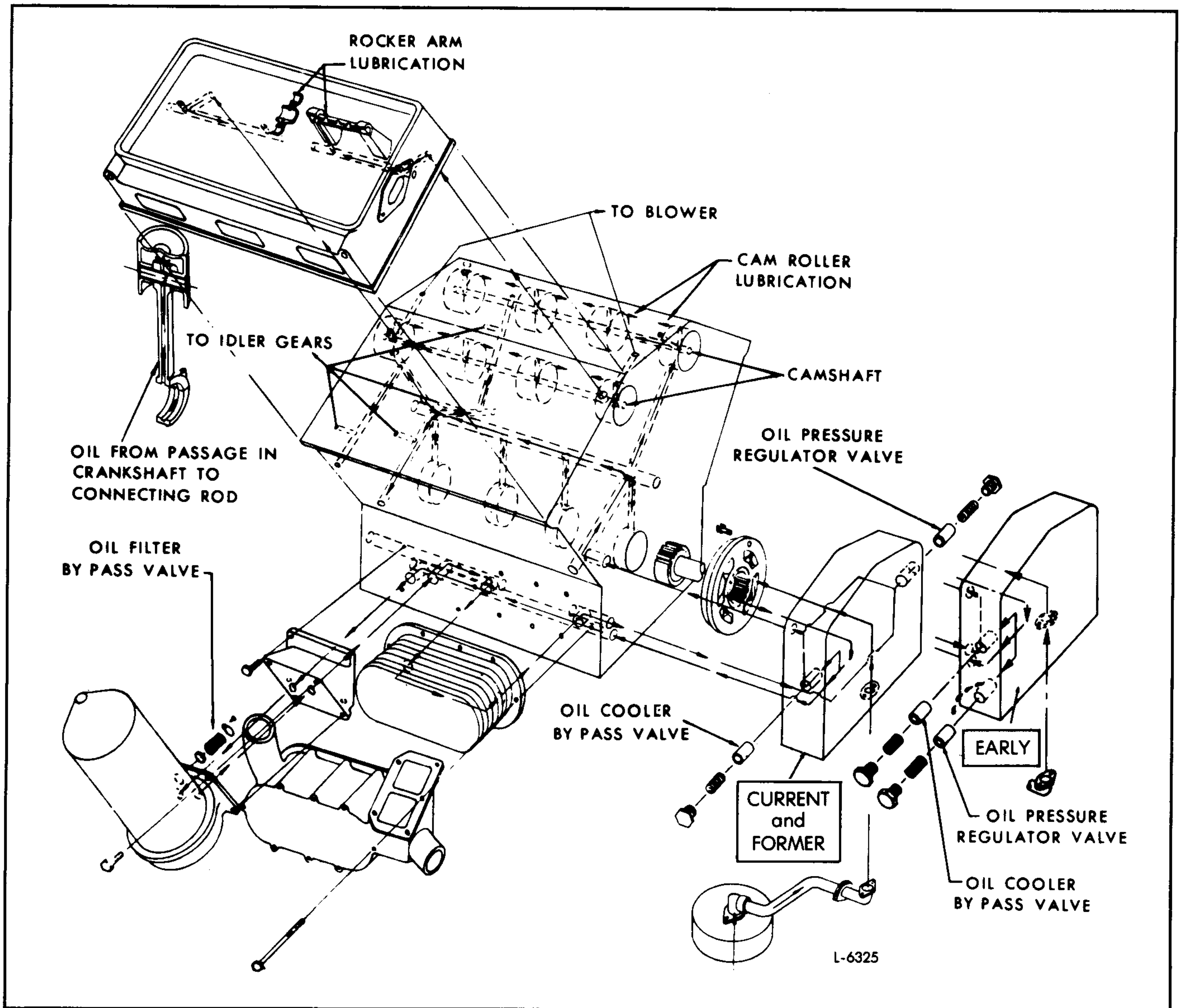

Fig. 2 - Schematic Diagram for 6V-53 Engine Lubrication System

filter and oil cooler and returns through a passage in the block to the lower engine front cover. From a passage in the cover, the oil flows to the longitudinal main oil gallery in the block which distributes the oil, under pressure, to the main bearings. Oil passages branching off from the main oil gallery direct oil to the camshaft end bearings, idler gear and accessory drive gear bearings, blower, and cylinder heads.

In addition, oil is forced through an oil passage in each camshaft which lubricates the camshaft intermediate bearings. All of the camshaft bearings incorporate small slots through which lubricating oil is directed at the cam follower rollers.

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 camshafts, balance shaft (In-line engine), idler gears and accessory drive gears (6V-53 engine).

Drilled oil passages on the camshaft side of the cylinder head (Figs. 1 and 2) are supplied with oil from the bores located at each end of the cylinder block. Oil from these drilled passages enters the drilled rocker shaft brackets at the lower ends of the drilled bolts and lubricates the rocker arm bearings and push rod clevis bearings.

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Excess oil from the rocker arms lubricates the lower ends of the push rods and cam followers, then drains to cam pockets in the top of the cylinder block, from which the cams are lubricated. When these pockets are filled, the oil overflows through holes at each end of the cylinder block and then through the flywheel housing and front cover to the crankcase.

The blower bearings are pressure lubricated by oil from drilled passages in the cylinder block which connect matching passages in the blower end plates which, in turn, lead to the bearings. On current 6V-53 engines (built Jan. 77 and after) the lubricating oil is supplied from the main oil gallery to the right rear camshaft bushing (Fig. 2). This oil is forced through an oil passage in the camshaft and lubricates all camshaft bushings on the right bank as well as the blower. The left front bank camshaft bushing is supplied pressurized oil directly from the main oil gallery (Fig. 2). This oil then flows through the left bank camshaft and lubricates all left bank camshaft bushings as well as the blower. On former engines, the blower bearings received lubrication indirectly via the right rear camshaft end bearing only. Excess oil returns to the crankcase via drain holes in the blower end plates which lead to corresponding drain holes in the cylinder block (In-line engines) or the governor housing (6V-53 engines).

The blower drive gear hub in a 6V-53 engine is pressure lubricated through a connecting passage from the rear blower end plate, through the governor housing and into the blower and governor drive support.

Four tapped oil pressure take-off holes (three at the rear and one at the front) are provided in a 6V-53 cylinder block.

One tapped oil pressure take-off hole is provided in the lower engine front cover on some In-line engines. In addition, tapped oil holes in the cylinder block, on the side opposite the blower, are also provided as follows: three holes in the four-cylinder block and two holes in the three-cylinder block when the blower is on the left side of the engine or three holes when the blower is on the right side of the engine.

Lubricating System Maintenance

Use the proper viscosity grade and type of *heavy duty* oil as outlined in the *Lubrication Specifications* in Section 13.3. 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 and 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 ten 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 it to the proper level 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 Section 5 for the recommended cleaning procedure.

8V-53 ENGINE

The 8V-53 engine lubrication system, illustrated in Fig. 3, includes an oil intake screen and tube assembly, an oil pump with a relief valve, an oil pressure regulator valve, a full flow oil filter with a bypass valve, an oil cooler and an oil cooler bypass valve.

The oil is circulated by a gear-type oil pump mounted on the number 4 and 5 main bearing caps and is driven by the crankshaft timing gear.

Lubricating oil is drawn by suction from the oil pan through the inlet screen and pipe to the pump where it is pressurized. The oil then passes from the pump to a gallery in the cylinder block, to the full-flow filter adaptor, through the filter, then through the oil cooler and into the engine front cover and cylinder block oil galleries for distribution to the various engine bearings, including the outboard bearing in the front cover. The oil drains from the cylinder head and other engine parts back to the oil pan.

A spring-loaded relief valve, located in the oil pump outlet pipe, bypasses excess oil back into the crankcase when the engine is cold or when the pressure in the engine oil gallery exceeds approximately 120 psi (827 kPa).

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of an oil pressure regulator valve in the engine front cover which opens at approximately 52 psi (359 kPa).

Clean engine oil is assured at all times by the use of a replaceable element type full-flow filter which is installed between the oil pump and the oil cooler. All

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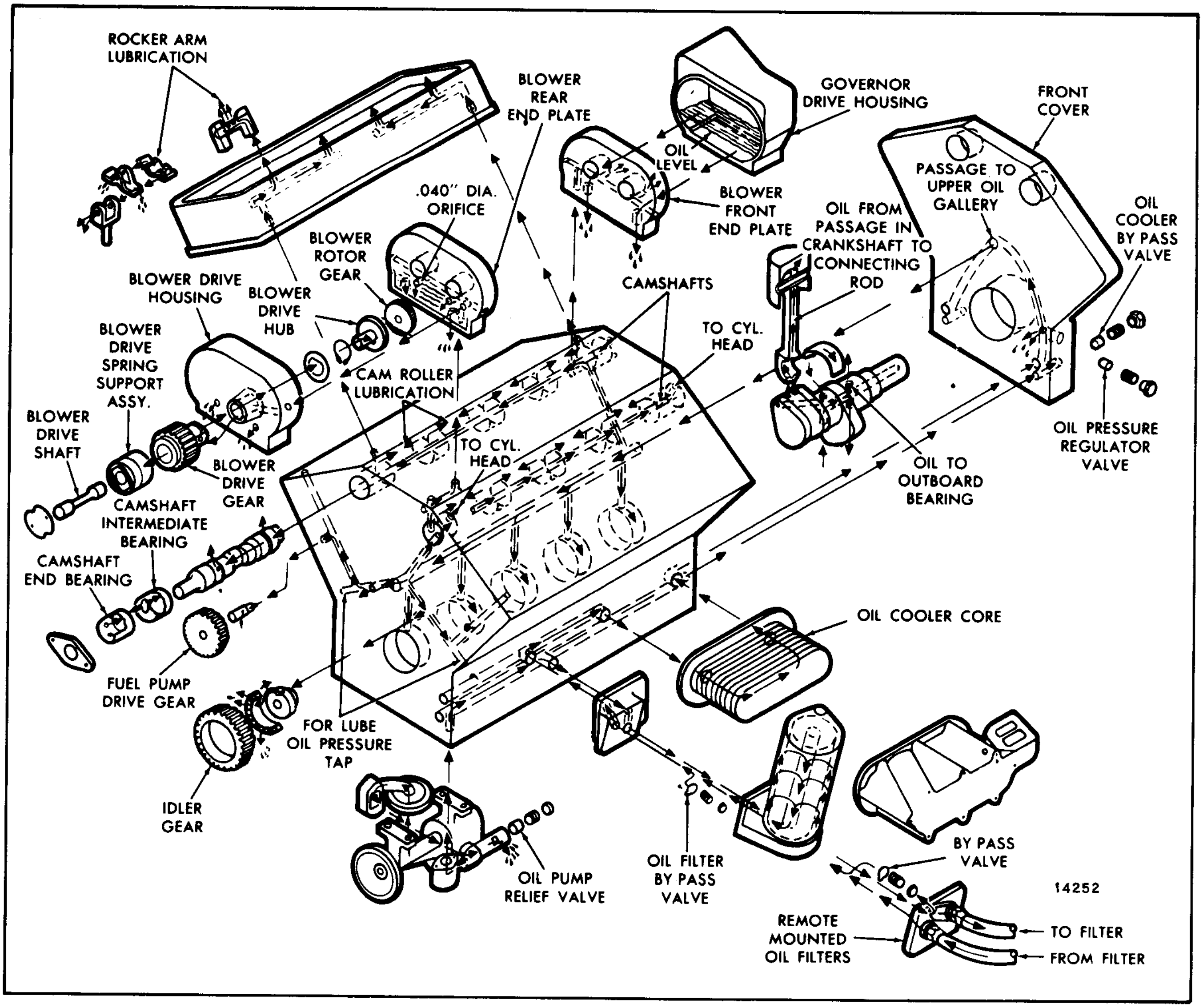

Fig. 3 - Schematic Diagram of Typical 8V-53 Engine Lubrication System

of the oil is filtered before entering the engine. Should the filter become plugged or before the engine is at operating temperature, the oil will flow through a bypass valve, which opens at approximately 18-21 psi (124-145 kPa), directly to the oil cooler.

The oil cooler bypass valve, which opens at approximately 52 psi (359 kPa), is located in the engine front cover. If the cooler becomes clogged or before the engine reaches operating temperature, the oil flow will be to the bypass valve, then through the engine front cover oil passage and the cylinder block oil galleries.

Lubricating Oil Distribution

Oil from the pump enters a passage in the cylinder block and flows under pressure to the filter and oil cooler, then through a passage in the cylinder block to the engine front cover. From a passage in the cover, the oil flows to the longitudinal main oil gallery which distributes the oil, under pressure, to the main bearings and the outboard bearing. Oil passages branching off from the main oil gallery direct oil to the camshaft end bearings, idler gear and fuel pump drive gear bearings, blower and cylinder heads.

In addition, oil is forced through an oil passage in each camshaft which lubricates the camshaft intermediate bearings. All of the camshaft bearings incorporate small slots through which lubricating oil is directed to the cam follower rollers.

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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 pockets through a communicating passage into the flywheel housing. Some oil spills into the flywheel housing from the camshaft end bearings, idler gear, and fuel pump drive gear.

Drilled oil passages on the camshaft side of the cylinder heads (Fig. 3) are supplied with oil from the bores located at each end of the cylinder block. Oil from these drilled passages enters the drilled 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 lower ends of the push rods and cam followers, then drains to cam pockets in the top of the cylinder block, from which the cams are lubricated. When these pockets are filled, the oil overflows through holes at each end of the cylinder block and then drains back through the flywheel housing and front cover to the crankcase.

Oil is forced through drilled oil passages in the cylinder block to the blower. The oil level in the blower and the governor drive is maintained by two .040 " diameter orifices in the blower end plates. Thus the rotor timing gears and the governor weights turn in oil.

The splash of the oil and the vapor created lubricate the blower bearings and supplies oil to the blower drive gear, spring pack and drive shaft. Oil is returned to the blower drive support by a groove in the drive gear hub. Excess oil helps lubricate the gear train before returning to the crankcase. Two tapped oil pressure take-off holes are located at the rear of the cylinder block.

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 Section 5 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.

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OIL PRESSURE TAKE-OFF LOCATIONS

The cylinder block illustrations in Fig. 4 show the main oil gallery pressure locations that are available for supplying oil under pressure to oil gages, Jacobs engine brake or other accessories.

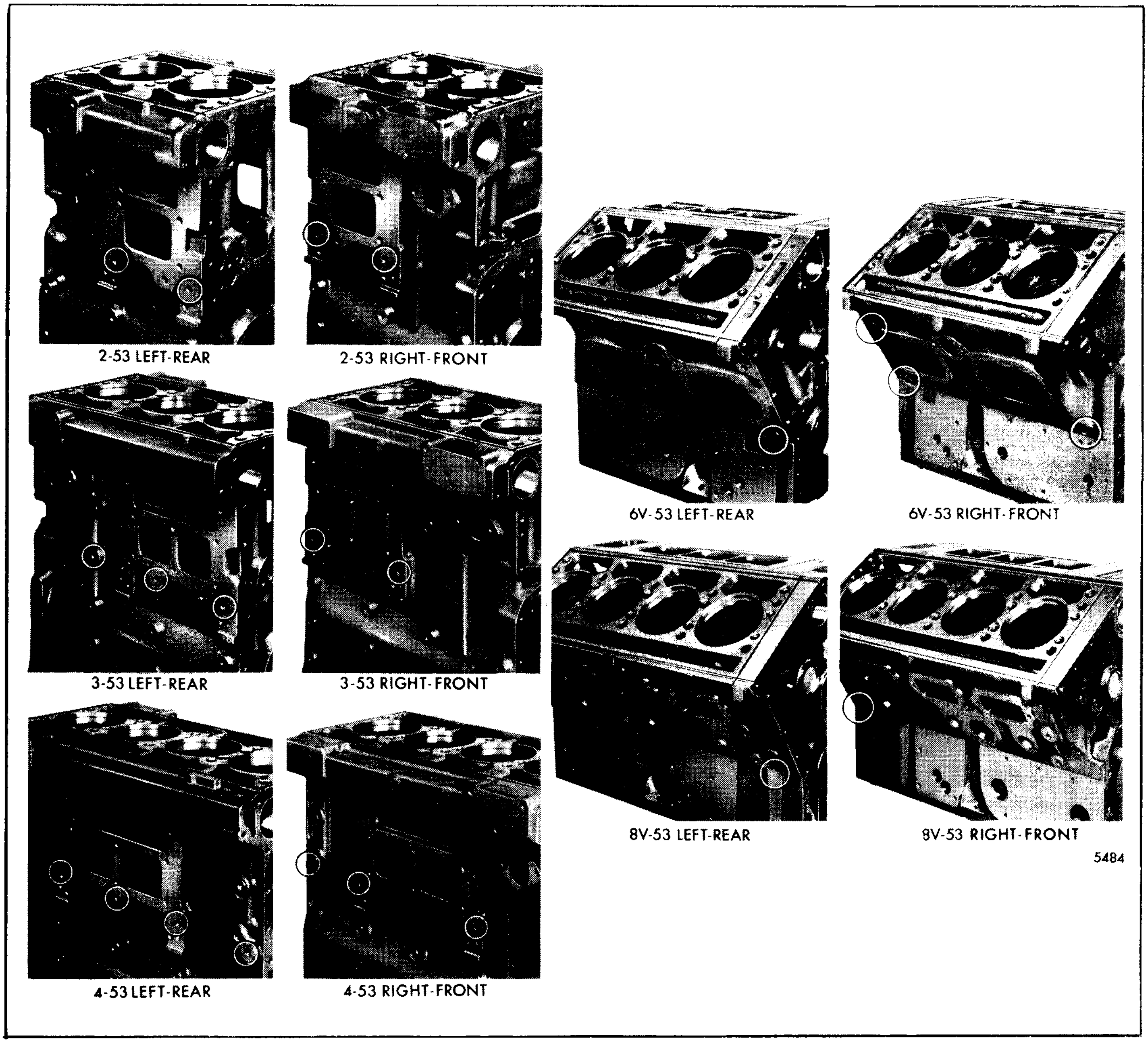

Fig. 4 - Oil Pressure Take-Off Locations

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LUBRICATING OIL PUMP

IN-LINE AND 6V ENGINES

The lubricating oil pump, assembled to the inside of the lower engine front cover as illustrated in Fig. 1, is of the rotor type in which the inner rotor is driven by a gear pressed on the front end of the crankshaft. The outer rotor is driven by the inner rotor. The bore in the pump body, in which the outer rotor revolves, is eccentric to the crankshaft and inner rotor. Since the outer rotor has nine cavities and the inner rotor has eight lobes, the outer rotor revolves at eight-ninths crankshaft speed. Only one lobe of the inner rotor is in full engagement with the cavity of the outer rotor at any given time, so the former can revolve inside the latter without interference.

The pump width varies for the 2, 3 and 4 cylinder In-line and 6V-53 engines, but otherwise is of identical design. By rotating the pump 180°, it can be used for either a right-hand or left-hand rotation engine.

The 3, 4 and 6V-53 turbocharged engines use a higher capacity oil pump (which includes thicker inner and outer rotors) than the naturally aspirated engines.

Operation

As the rotors revolve, a vacuum is formed on the inlet side of the pump and oil is drawn from the crankcase, through the oil pump inlet pipe and a passage in the front cover, to the inlet port and then into the rotor compartment of the pump. Oil drawn into the cavities between the inner and outer rotors on the inlet side of the pump is then forced out under pressure through the discharge port into a passage in the front cover, which leads to the lubricating oil filter and cooler, and is then distributed throughout the engine.

If a check of the lubrication system indicates improper operation of the oil pump, remove and disassemble it as outlined below.

Remove Oil Pump

1. Drain the oil from the engine.

2. Remove the crankshaft pulley, fan pulley, support bracket and any other accessories attached to the front cover.

3. Remove the oil pan.

4. Refer to Fig. 2 and remove the four bolts which attach the oil pump inlet pipe and screen assembly to the main bearing cap and engine front cover or oil pump inlet elbow. Slide the flange and the seal ring on the inlet pipe and remove the pipe and screen as an assembly. Remove he oil pump inlet elbow (if used) and gasket from the engine front cover.

5. Remove the lower engine front cover.

6. Remove the six bolts and lock washers (if used) which attach the pump assembly to the engine front cover and withdraw the pump assembly from the cover (Fig. 1).

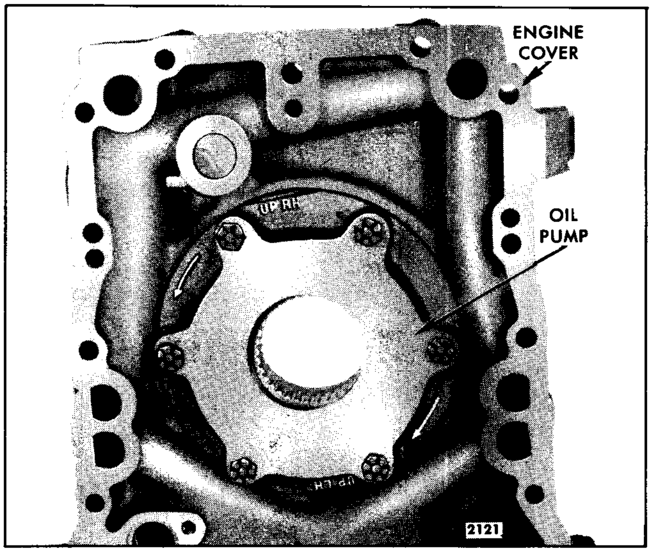

Fig. 1 - Typical Right-Hand Rotation Oil Pump Mounting

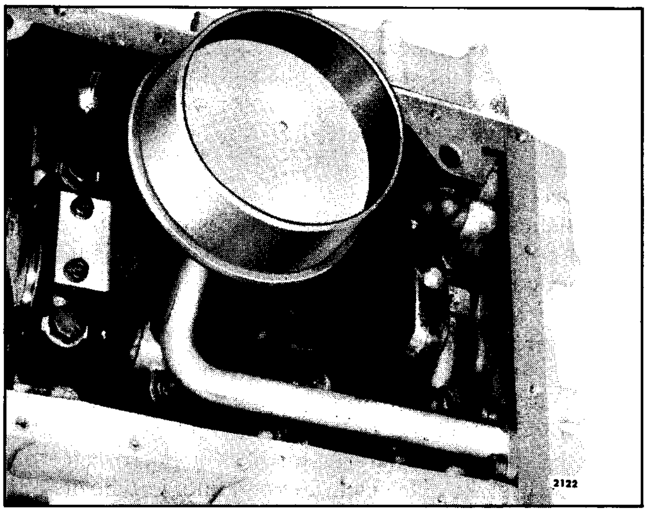

Fig. 2 - Typical Oil Pump Inlet Pipe and Screen Mounting

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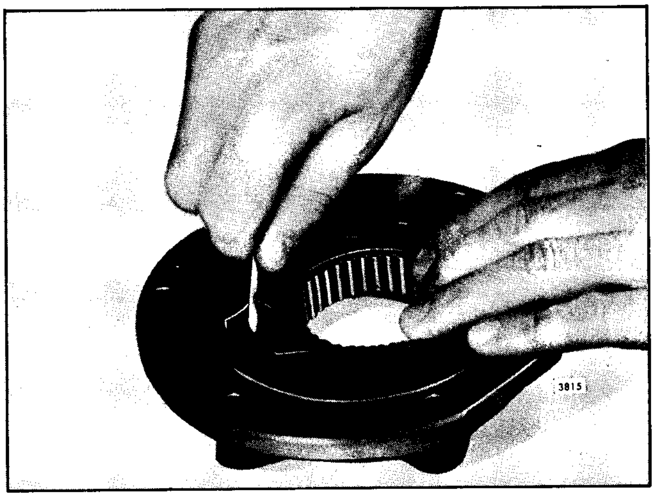

Fig. 3 - Measuring Rotor Clearance

Disassemble Oil Pump

If the oil pump is to be disassembled for inspection or reconditioning, proceed as follows:

1. Refer to Fig. 5 or 6 and remove the two drive screws holding the pump cover plate to the pump body. Withdraw the cover plate from the pump body.

2. Remove the inner and outer rotors from the pump housing.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

The greatest amount of wear in the oil pump is imposed on the lobes of the inner and outer rotors.

This wear may be kept to a minimum by using clean oil. If dirt and sludge are allowed to accumulate in the lubricating system, excessive rotor wear may occur in a comparatively short period of time.

Inspect the lobes and faces of the pump rotors for scratches or burrs and the surfaces of the pump body and cover plate for scoring. Scratches or score marks may be removed with an emery stone.

Measure the clearance between the inner and outer rotors at each lobe (Fig. 3). The clearance should not be less than .004" or more than .011". Measure the clearance from the face of the pump body to the side of the inner and outer rotor with a micrometer depth gage (Fig. 4). The clearance should not be less than .001" or more than .0035".

Inspect the splines of the inner rotor and the oil pump drive gear. If the splines are excessively worn, replace the parts. The rotors are serviced as matched sets, therefore, if one rotor needs replacing, replace both rotors.

Remove the oil inlet screen from the oil inlet pipe and clean both the screen and the pipe with fuel oil and dry them with compressed air. Replace the inlet pipe flange seal ring with a new seal ring.

Assemble Oil Pump

After the oil pump parts have been cleaned and inspected, refer to Fig. 5 or 6 and assemble the pump as follows:

1. Lubricate the oil pump outer rotor with engine oil and place it in the pump body.

2. Lubricate the oil pump inner rotor with engine oil and place it inside of the outer rotor.

3. Place the cover plate on the pump body and align the drive screw and bolt holes with the holes in the pump body. Since the holes are offset, the cover plate can be installed in only one position.

4. Install two new drive screws to hold the assembly together.

Remove Pump Drive Gear From Crankshaft

With the lower engine front cover and the lubricating oil pump removed from the engine, the oil pump drive gear may, if necessary, be removed from the end of the crankshaft as follows:

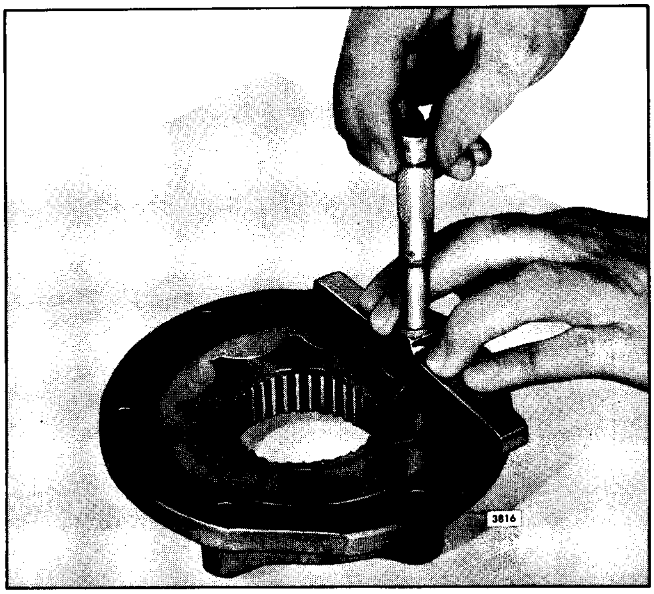

Fig. 4 - Measuring Clearance from Face of Pump Body to Side of Rotor

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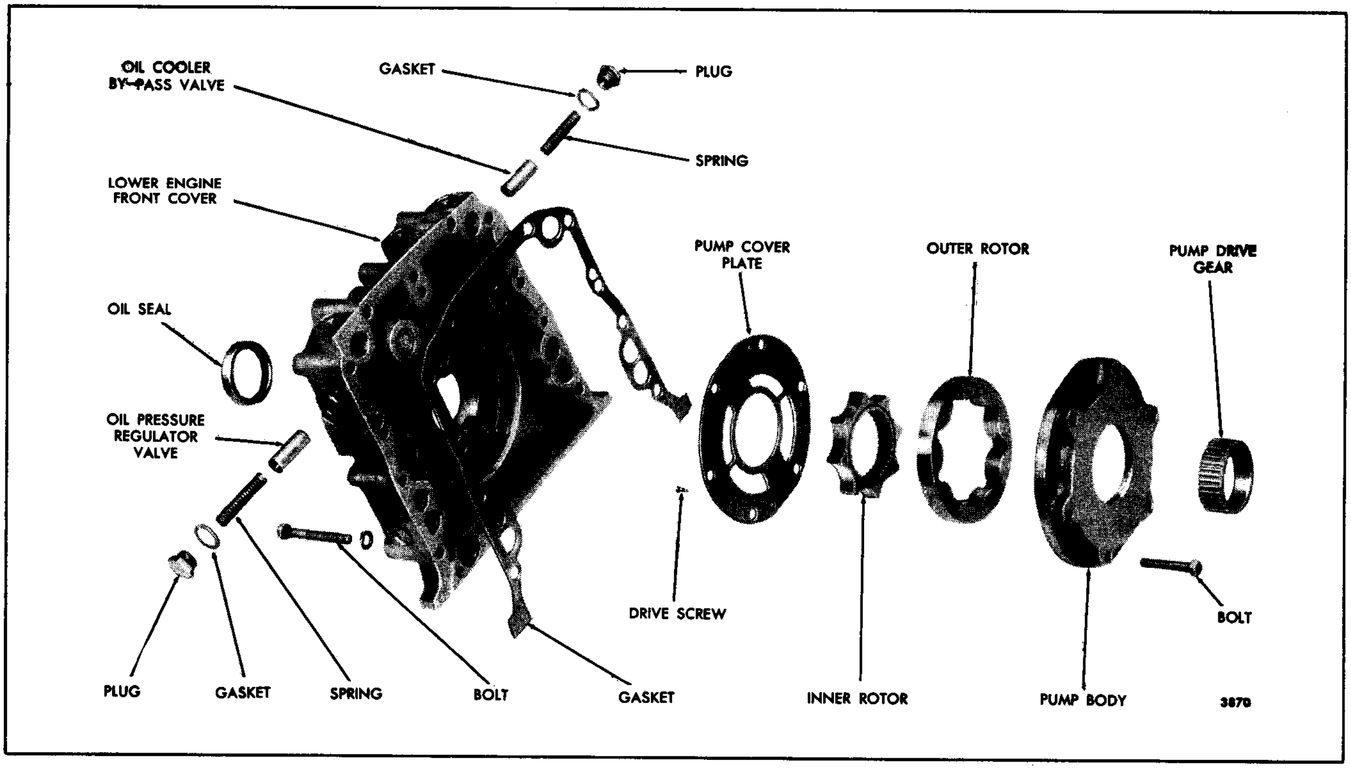

Fig. 5 - Oil Pump Details and Relative Location of Parts (Current)

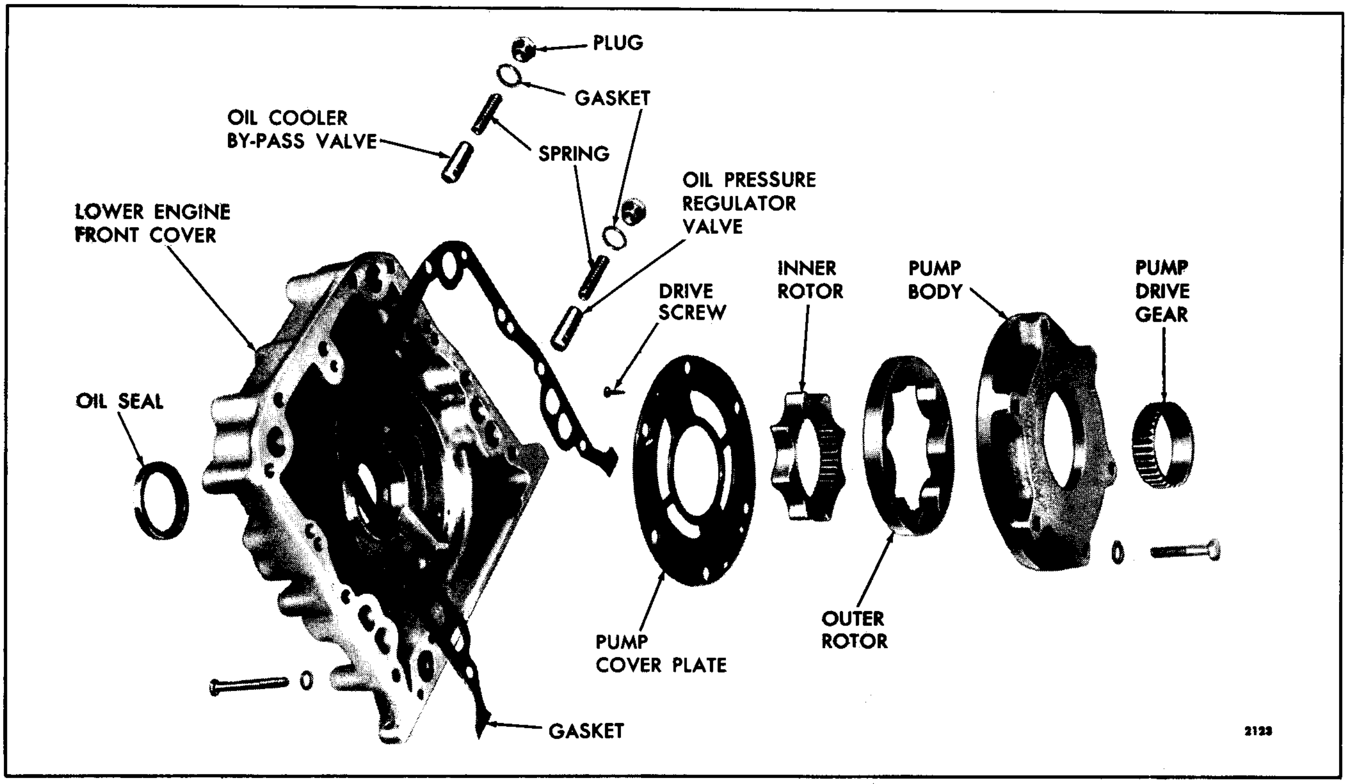

Fig. 6 - Oil Pump Details and Relative Location of Parts (Former)

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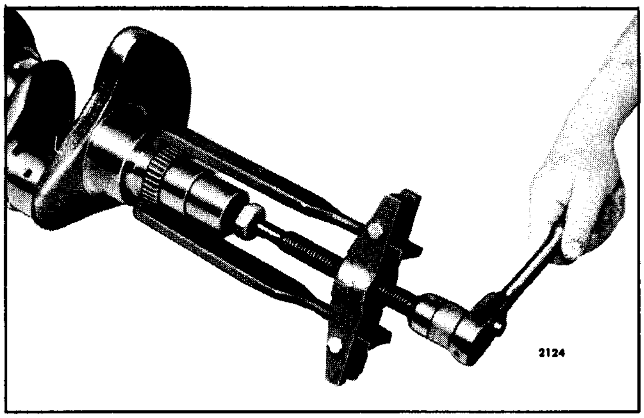

Fig. 7 - Removing Oil Pump Drive Gear

1. Thread the crankshaft pulley retaining bolt in the end of the crankshaft (Fig. 7).

2. Attach the jaws of a suitable gear puller behind the gear and locate the end of the puller screw in the center of the pulley retaining bolt.

3. Turn the puller screw clockwise to remove the gear from the crankshaft.

Install Pump Drive Gear on Crankshaft

1. Lubricate the inside diameter of a new oil pump drive gear with engine oil. Then start the gear straight on the crankshaft with the chamfered edge of the gear toward the butt end of the crankshaft. Re-installation of a used gear is not recommended.

2. Position the drive gear installer J 8968-01 over the end of the crankshaft and against the drive gear and force the gear in place as shown in Fig. 8. When the end of the bore in the tool contacts the end of the crankshaft, the drive gear is correctly positioned (2.680 " from the front end of the crankshaft to the forward face of the gear).

3. It is important that the press fit of the drive gear to

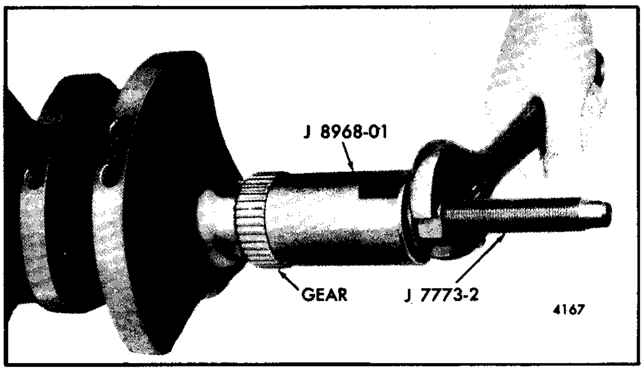

Fig. 8 - Installing Oil Pump Drive Gear

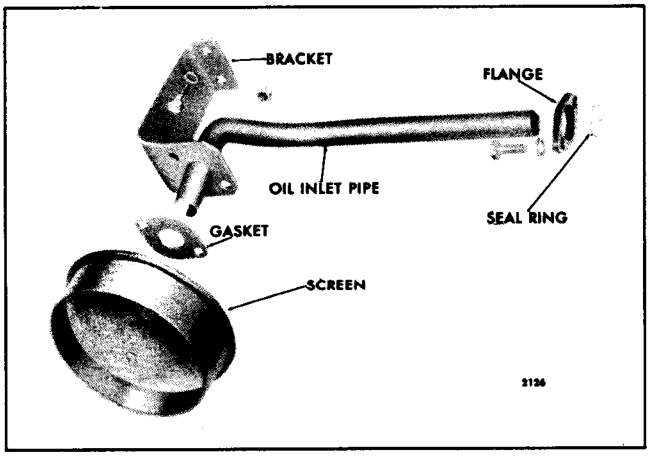

Fig. 9 - Oil Pump Inlet Pipe and Screen Details and Relative Location of Parts (In-Line Engine)

the crankshaft be checked to be sure that the gear does not slip on the crankshaft. It is recommended that the press fit (slip torque) be checked with tool J 23126. On in-line or 6V engines, the drive gear should not slip on the crankshaft at 100 lb-ft (136 Nm) torque.

NOTE: Do not exceed this torque. If the gear slips on the shaft, it is suggested that another oil pump drive gear be installed.

Install Oil Pump

1. The markings on the pump body indicate the installation as pertaining to left or right-hand crankshaft rotation. Be sure that the letters "UP R.H." (right-hand rotation engine) or "UP L.H." (left-hand rotation engine) on the pump body are at the top (Fig. 1).

2. Insert the six bolts with lock washers (if used) through the pump body and thread them into the engine front cover. Tighten the bolts to 13-17 lb-ft (18-23 Nm) torque.

3. Install the lower engine front cover and pump assembly on the engine as outlined in Section 1.3.5.

4. Attach the oil inlet screen to the oil inlet pipe support with two lock nuts (6V engine) or two bolts and lock washers (Fig. 9).

5. Use a new gasket and attach the oil pump inlet elbow (6V engine) to the underside of the engine front cover with the two bolts and lock washers.

6. Place the oil pump inlet pipe and screen assembly in position and fasten the support to the main bearing cap with the two bolts and lock washers.

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7. Slide the inlet pipe flange and seal ring against the engine front cover (or oil pump inlet elbow on the 6V engine) and secure them with the two bolts and lock washers.

NOTE: On In-line engines, the oil pump inlet tube and water by-pass tube seals are the same size but of different material. *Be sure that the correct seal is used.* A new oil pump inlet tube seal may be identified by its white stripe.

8. Install the oil pan and refill the crankcase to the proper level.

9. Install the crankshaft pulley, fan pulley, support bracket and any other accessories that were attached to the front cover.

8V ENGINE

The oil pump (Fig. 10) on an 8V engine is mounted on the No. 4 and No. 5 main bearing caps. The oil pump is driven by the crankshaft timing gear.

A spring-loaded relief valve, which is located in the oil pump outlet pipe assembly, by-passes excess oil back to the crankcase when the pressure in the engine oil gallery exceeds approximately 120 psi (827 kPa).

Effective with engine 8D-174, a new lubricating oil pump and inlet tube is used on the 8V engine. The pump has a new cover which supports the ends of the drive and driven shafts. The new drive shaft is longer and larger in diameter and the new drive gear has a larger inside diameter. When replacing an old oil pump with a new pump on an engine that has the inlet tube assembled to the pump cover, it will be necessary to install a new oil pump inlet system.

Effective with engine 8D-4611, a new high capacity oil pump with longer drive and driven gears is used on the 8V engines. The high capacity pump must be used in combination with the seven hole upper main bearing shells (Section 1.3.4).

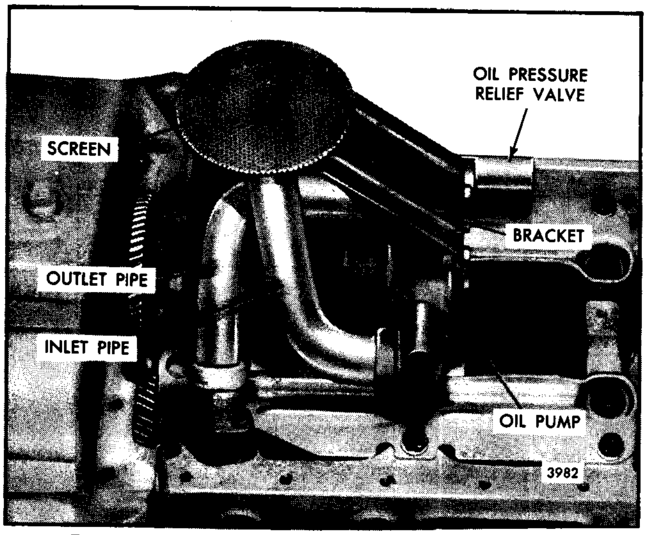

Fig. 10 - Lubricating Oil Pump Mounting (8V Engine)

NOTE: The new pump can be used with the former one hole upper main bearing shells.

Remove Oil Pump

1. Remove the bolts and lock washers securing the inlet pipe and the bracket to the oil pump. Then remove the inlet pipe, screen and bracket as an assembly from the pump.

2. Remove the two bolts and lock washers securing the oil pressure relief valve to the oil pump.

3. Remove the oil pump outlet pipe-to-cylinder block bolts. Then remove the relief valve and outlet pipe as an assembly from the engine.

4. Remove the oil pump-to-bearing cap attaching bolts and lock washers and remove the pump assembly from the engine.

NOTE: Shims are used between the oil pump mounting feet and the main bearing caps. Whenever the original pump from such an engine is re-installed, the same shims or an equal number of new (identical) shims must be placed under both the front and rear mounting

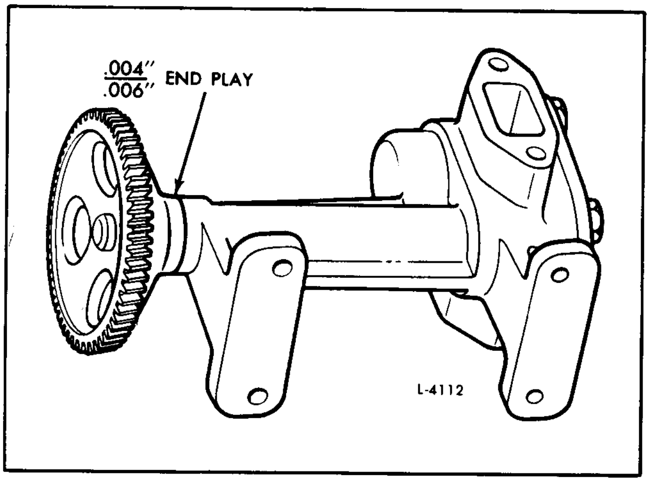

Fig. 11 - Oil Pump Gear End Play

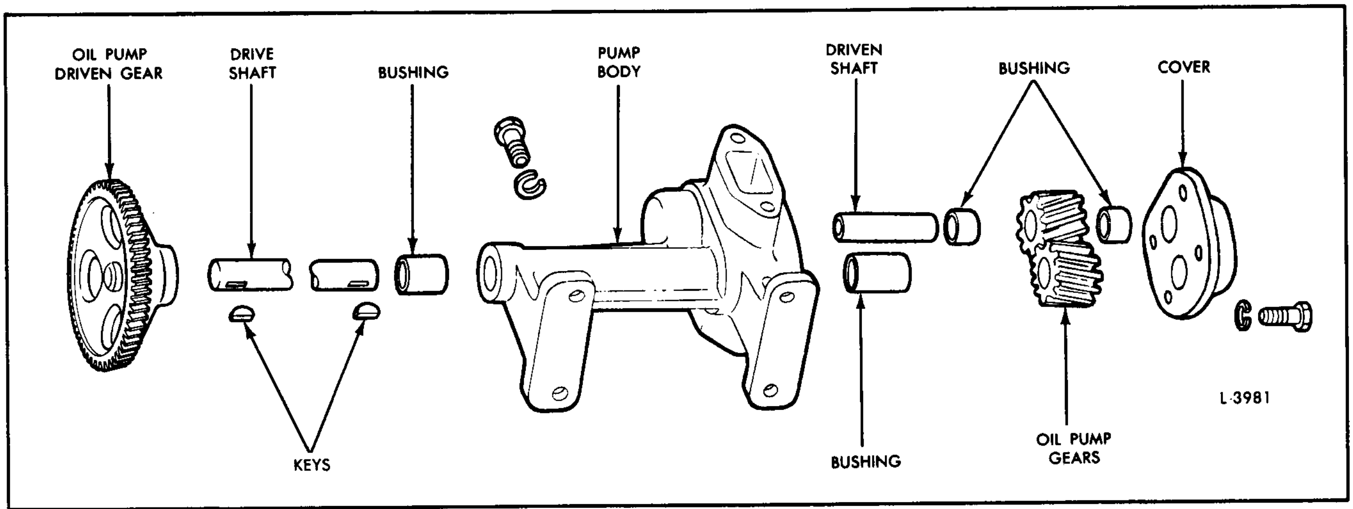

Fig. 12 - Lubricating Oil Pump Details and Relative Location of Parts (8V Engine)

feet and the number then adjusted to obtain the proper clearance between the gears.

Disassemble Oil Pump

Remove the four bolts and lock washers and pull the cover off of the shafts. Slide the pump gear from the pump body cavity.

Remove the oil pump driven gear by pressing the drive shaft through the gear.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

The greatest amount of wear in the oil pump is imposed on the internal drive and driven gears. This wear may be kept to a minimum by keeping the lubricating oil clean and acid-free. If dirt and sludge are allowed to accumulate in the lubricating system,

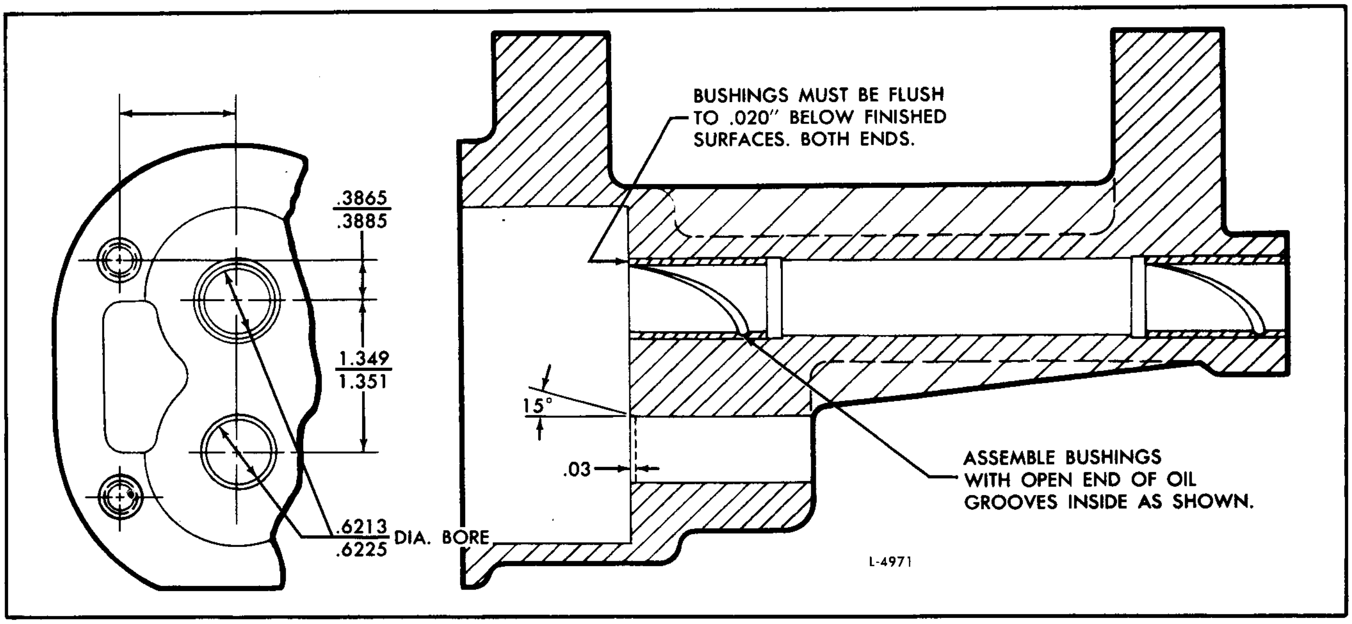

Fig. 13 - Diameter and Location of Bushings in Oil Pump Body

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pronounced gear wear may occur in a comparatively short period of time. Proper servicing of oil filters will increase the life of the gears.

Examine the internal gear cavity of the pump body and scavenger pump, if used, for wear or scoring. Also inspect the pump cover, or the spacer between the pump and scavenger bodies, for wear. Replace parts if necessary.

Inspect the bushings in the pump body and cover (or scavenging pump body). If the bushings are worn excessively, replace the pump and cover (or scavenging pump body) unless suitable boring equipment is available for finishing the new bushings. When installing new bushings, replace all of the bushings in the pump bodies. The bushings must be located and positioned as shown in Fig. 13. Also, the gear bore and the bushing bore in both the pump body and scavenging pump body must be concentric within .001 " total indicator reading. The shaft-to-cover or scavenging pump body to bushing clearance with new parts is .001 " to .0027 ".

> **NOTE:** When installing the spacer between the oil pump body and the scavenging pump body, be sure the bleed hole is located on the discharge side of the oil pump assembly.

If the driven gear bushings are worn, replace the bushings. Then ream the bushings to .625 " ±.0005 " diameter after assembly.

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 external pump drive-driven gear for wear and replace it, if necessary.

Inspect the pump shafts for wear and check the keyways. Replace the shafts if necessary.

Check to be sure the pressure relief valve moves freely in the valve housing. Replace it if necessary.

Replace a pitted or fractured spring.

Assemble Oil Pump

Install the oil pump driven shaft and pump gear in the pump body. Install the other pump gear on the shaft in the pump cavity (Fig. 12).

Mount the cover on the two shafts, and fasten the cover on the pump with four bolts and lock washers.

Install a Woodruff key, if previously removed, in the shaft. Press the drive gear over the key on the shaft and place .006 " feeler stock between the gear and the pump body. Press the gear on the shaft until the clearance between the gear and the pump body is .004 " to .006 " (Fig. 11).

Install Oil Pump

1. Place the pump on the No. 4 and No. 5 main bearing caps and, with shims in place, fasten the pump to the main bearing caps with four bolts and lock washers. Proper gear clearance is from .005 "-.007 ".

> **NOTE:** Always check the clearance between the crankshaft gear and the oil pump driving gear with the engine in the upright or running position.

2. Attach new gaskets to the oil pressure relief valve housing and fasten it to the pump and cylinder block with four bolts and lock washers.

3. Place a new gasket under the oil pump inlet pipe and fasten it to the pump body with two bolts and lock washers.

4. Fasten the oil pump screen bracket to the oil pump cover with two bolts, lock washers and nuts.

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LUBRICATING OIL PRESSURE REGULATOR

IN-LINE AND 6V ENGINES

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by an oil pressure regulator valve installed in the engine lower front cover (Figs. 1 and 2).

The oil pressure regulator consists of a hollow piston-type valve, a spring, gasket and plug. The valve is located in an oil gallery within the lower front cover and is held tight against a counterbored valve seat by the valve spring and plug. When the oil pressure exceeds a given value (Table 1), the valve is forced from its seat and the lubricating oil is bypassed into the engine oil pan.

Engine	Plug Marks	Front Cover	Valve Opening Pressure	
			psi	kPa
In-line		Former	78	538
		Current	51	352
6V	None	Early	32	221
	R	Former	52	359
	X	Current	62	427

TABLE 1

Under normal conditions, the pressure regulator valve should require very little attention. If sludge accumulates in the lubrication system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure.

Whenever the lubricating oil pump is removed for inspection, the regulator valve and spring should also be removed, thoroughly cleaned in fuel oil and inspected.

Remove Oil Pressure Regulator

1. Remove the plug and washer from the engine lower front cover.

2. Withdraw the spring and the valve from the cover.

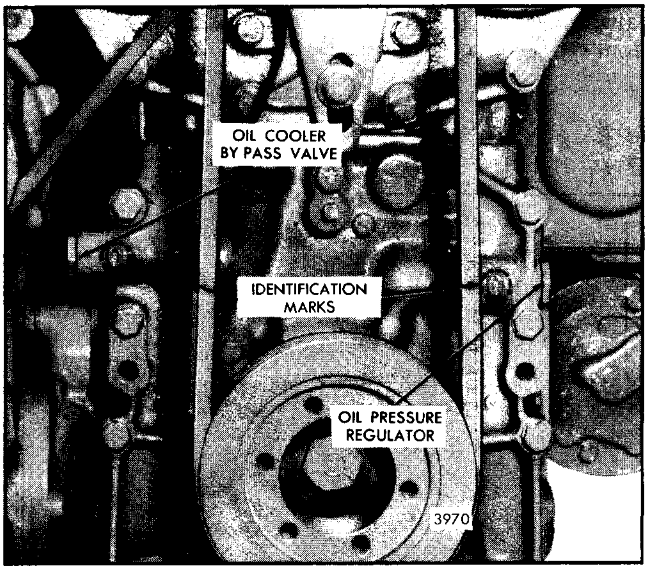

Fig. 1 - Location of Current Oil Pressure Regulator Valve (In-line Engine)

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 bore. If the valve is scored and cannot be cleaned up with crocus cloth, it must be replaced.

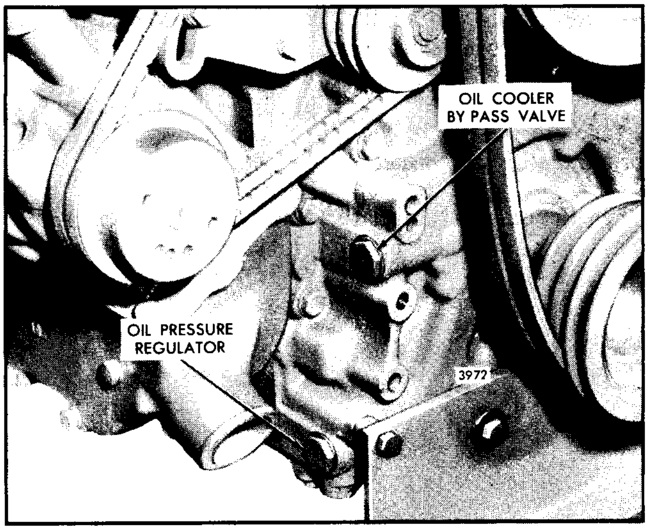

Fig. 2 - Location of Former Oil Pressure Regulator Valve (6V Engine)

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Replace a fractured or pitted spring.

Install Oil Pressure Regulator

1. Apply clean engine oil to the outer surface of the valve and slide it into the opening in the engine lower front cover, closed end first.

2. Install a new copper gasket on the plug.

3. Insert the spring in the valve.

4. While compressing the spring, start the plug in the side of the cover, then tighten the plug.

8V ENGINE

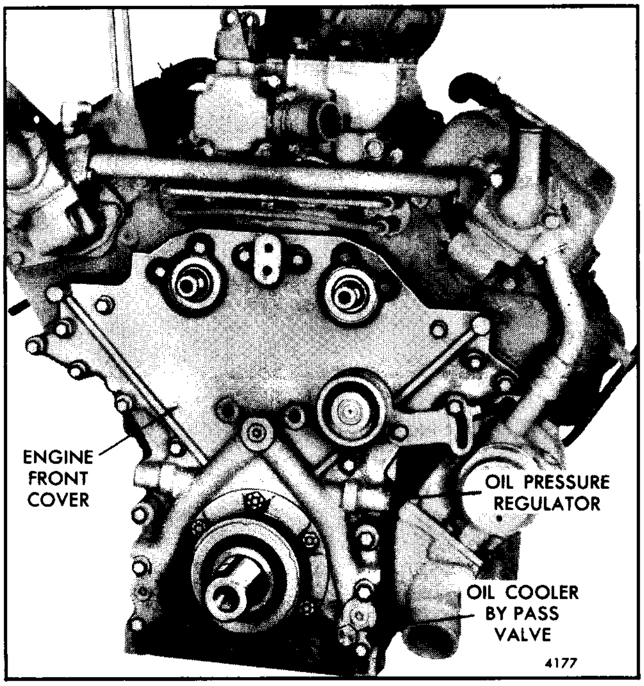

Fig. 3 - Location of Oil Pressure Regulator (8V Engine)

The lubricating oil pressure regulator is located in the engine front cover (Fig. 3).

A regulator assembly consists of a piston-type valve, a spring, a plug and gasket.

When the oil pressure at the valve exceeds 52 psi (359 kPa), the valve is forced from its seat and oil from the gallery passage in the front cover is bypassed to the crankcase.

Whenever the lubricating oil pump is removed for inspection, the regulator valve and spring should also be removed, thoroughly cleaned in fuel oil and inspected.

Remove Oil Pressure Regulator

1. Remove the plug and gasket from the engine front cover.

2. Withdraw the spring and valve from the cover.

Inspection

Clean the parts thoroughly in fuel oil, dry them with compressed air and inspect them.

Check to be sure the regulator valve moves freely in the engine cover valve bore. If the valve is scored and cannot be cleaned up with crocus cloth, it must be replaced.

Replace a pitted or fractured spring.

Install Oil pressure Regulator

1. Apply clean engine oil to the outer surface of the valve and slide it into the opening in the engine front cover, closed end first.

2. Install a new copper gasket on the plug.

3. While compressing the spring, start the plug in the side of the cover, then tighten the plug.

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LUBRICATING OIL FILTERS

Series 53 engines are equipped with a full-flow type lubricating oil filter. A bypass type oil filter may be used in addition to the full-flow type filter when additional filtration is desired.

Full-Flow Oil Filter

The full-flow type lubricating oil filter is installed ahead of the oil cooler in the lubrication system (Fig. 1). On the two and three cylinder models, the oil filter shell is mounted in a downward or rearward position unless it has an adaptor to provide optional mounting positions. On the four cylinder models, the oil filter may be mounted with the filter shell up, down or toward the rear, except when on the blower side of the engine where the down and rearward positions are optional. On V-type engines, the filter is mounted at an angle down and towards the rear of the engine.

NOTE: Do not reverse the flexible oil filter hoses at the filter hose adaptor on 6V and 8V marine engines equipped with a remote mounted lubricating oil filter. Refer to Fig. 2 for the proper installation of the hoses.

If the oil filter adaptor is removed from the engine for any reason, it must be reinstalled with the open half of the casting toward the top of the block. The word **TOP** is cast into the upper right corner of the adaptor. If installed in any other way, engine oil will not flow through the filter and may cause serious engine damage (Fig. 3).

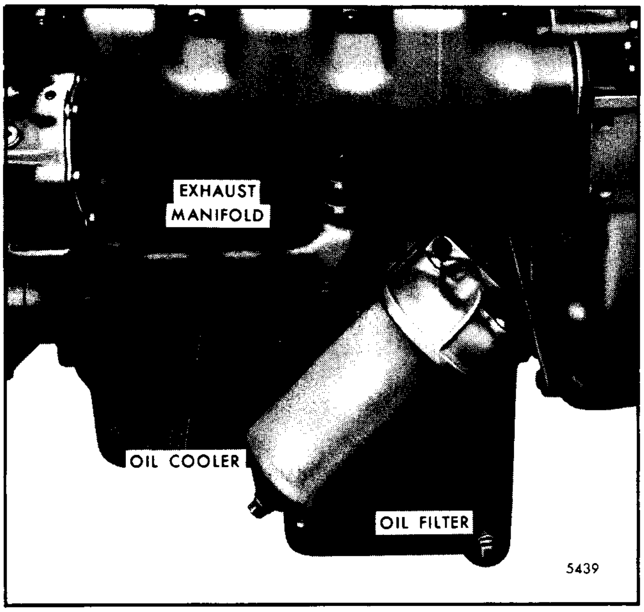

Fig. 1 - Typical Full-Flow Oil Filter Mounting (6V Engine Shown)

The filter assembly consists of a replaceable element enclosed within a shell which is mounted on an adaptor or base. When the filter shell is in place, the element is restrained from movement by a coil spring.

All of the oil supplied to the engine by the oil pump passes through the filter before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter base to the space surrounding the filter element. Impurities are filtered out as the oil is forced through the element to a central passage surrounding the center stud and out through another passage in the filter base and then to the oil cooler.

A valve, which opens at approximately 18-21 psi (124-145 kPa), is located in the filter base on engine mounted filters or in the hose adaptor (7/8" hoses) with a remote mounted filter and will bypass the oil directly to the oil cooler should the filter become clogged.

The spin-on lubricating oil filter (throw-away type) and mounting adaptor are now being installed on certain engines. The spin-on oil filter requires a new mounting adaptor which in some cases is part of the oil cooler cover. The oil filter assembly is serviced in a package which consists of an element and gasket (seal).

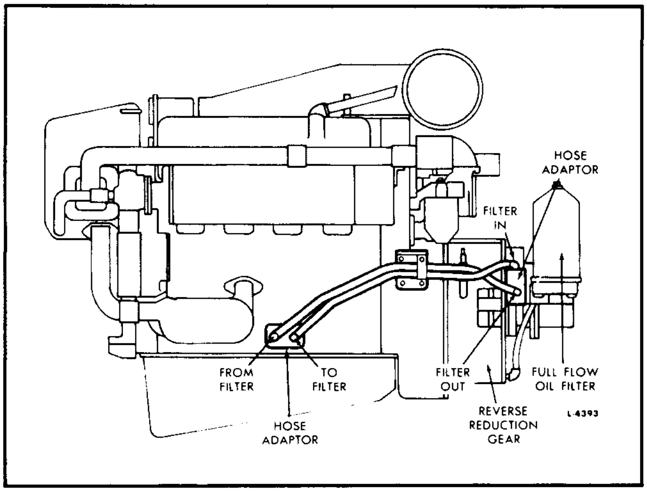

Fig. 2 - Proper Installation of Flexible Oil Filter Hoses

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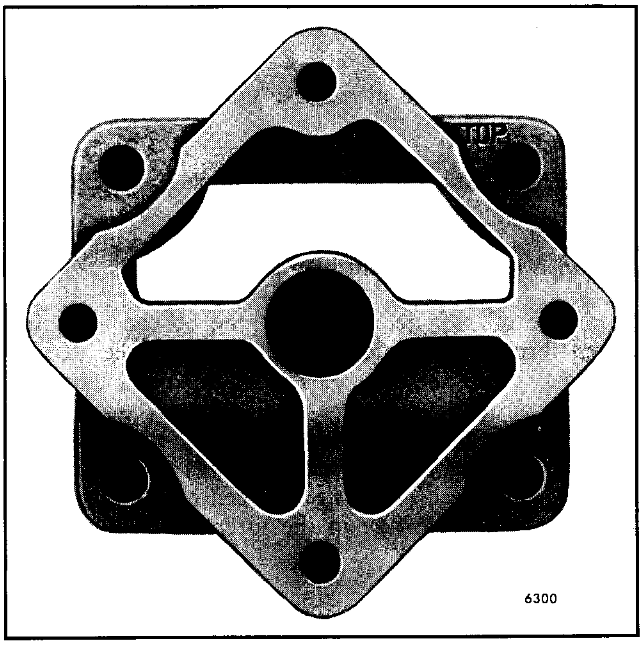

Fig. 3 - Proper Installation of Oil Filter Adaptor

Bypass Oil Filter

When additional filtration is desired, an oil filter of the bypass type may also be installed on the engine (Fig. 4). However, *the size of the orifice on the discharge side of the filter must not exceed .062"* to control the oil flow rate and to provide sufficient oil pressure when the engine is running at idle speed.

When the engine is running, a portion of the lubricating oil is bled off the oil gallery and passed through the bypass filter. Eventually all of the oil passes through the filter, filtering out fine foreign particles that may be present.

The bypass filter assembly consists of a replaceable element contained in a shell mounted on a combination base and mounting bracket. When the shell is in place, the filter element is restrained from movement by a coil spring at the top. A hollow center stud serves as the outlet passage from the filter as well as securing the shell to the base.

On certain models, the filter assembly consists of a replaceable element contained in a shell and sealed in place by a cover. This type of filter assembly incorporates a mounting bracket attached to the filter shell. A hollow center stud serves as the outlet passage from the filter as well as positioning the filter element.

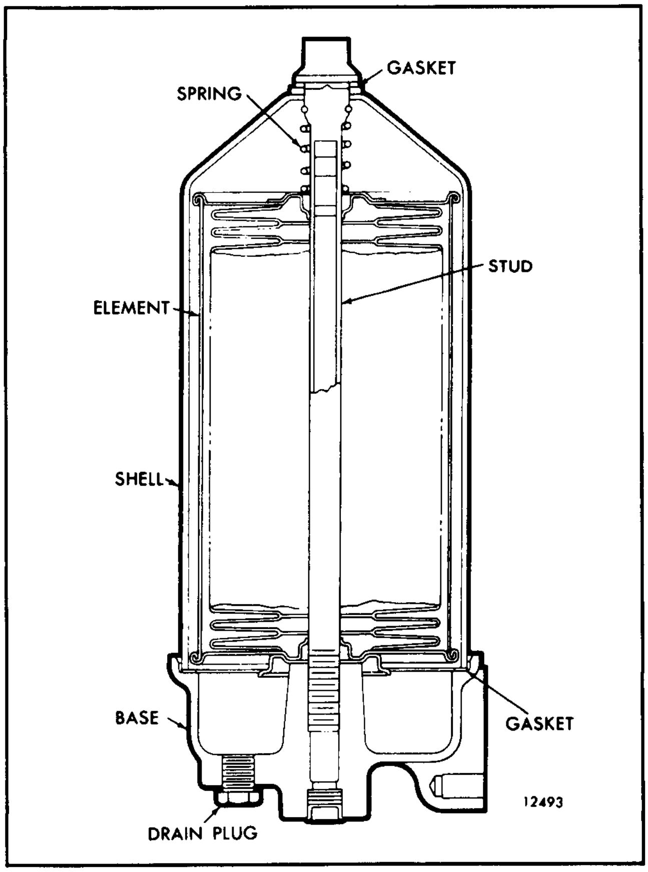

Fig. 4 - Bypass Oil Filter Details

Oil Filter Maintenance

With the use of detergent lubricating oils, the color of the lubricant has lost value as an indicator of oil cleanliness or proper filter action. Due to the ability of the detergent compounds to hold minute carbon particles in suspension, heavy duty oils will always appear dark colored on the oil level dipstick.

Heavy sludge deposits found on the filter elements at the time of an oil change must be taken as an indication that the detergency of the oil has been exhausted. When this occurs, the oil drain interval should be shortened. The removal of abrasive dust, metal particles and carbon must be ensured by replacement of the oil filter elements at the time the engine oil is changed.

Selection of a reliable oil supplier, strict observation of his oil change period recommendations and proper filter maintenance will ensure trouble-free lubrication and longer engine life.

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Replace Oil Filter Element

Replace the element in either the full-flow or bypass type oil filter assembly (Figs. 4 and 5) as follows:

1. Remove the drain plug from the filter shell or the filter adaptor or base and drain the oil. If a type S-6 filter assembly is used, oil may be removed with a sump pump after the cover and element are removed.

2. Back out the center stud or the cover nut and withdraw the shell, element and stud as an assembly. Discard the element and the shell gasket.

3. Remove the center stud and gasket. Retain the gasket unless it is damaged and oil leaks occurred.

4. Remove the nut or snap ring on the full-flow filter center stud.

> **NOTE:** The center stud on the current full-flow oil filter has been revised by removing the snap ring groove and increasing the 5/8″-18 thread length approximately 1/2″. To conform with this change, a 5/8″-18 nut replaces the snap ring formerly used to retain the filter spring and seal.

5. Remove and discard the element retainer seal (Fig. 4). Install a new seal.

6. Clean the filter shell and the adaptor or base.

7. Install the center stud gasket and slide the stud (with the spring, washer, seal and retainer installed on the full-flow filter) through the filter shell.

8. Install a new shell gasket in the filter adaptor or base.

> **NOTE:** Before installing the filter shell gasket, be sure all of the old gasket material is removed from the filter shell and the filter adaptor or base. Also, make sure the gasket surfaces of the shell and the adaptor or base have no nicks, burrs or other damage.

9. Position the new filter element carefully over the center stud and within the shell. Then, place the shell, element and stud assembly in position on the filter adaptor or base and tighten the stud to 50-60 lb-ft (68-81 Nm) torque.

10. Install the drain plug.

11. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected and the engine has been stopped long enough (approximately ten minutes) for the oil from various parts of the engine to drain back to the crankcase, add sufficient oil to bring it to the proper level on the dipstick.

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.

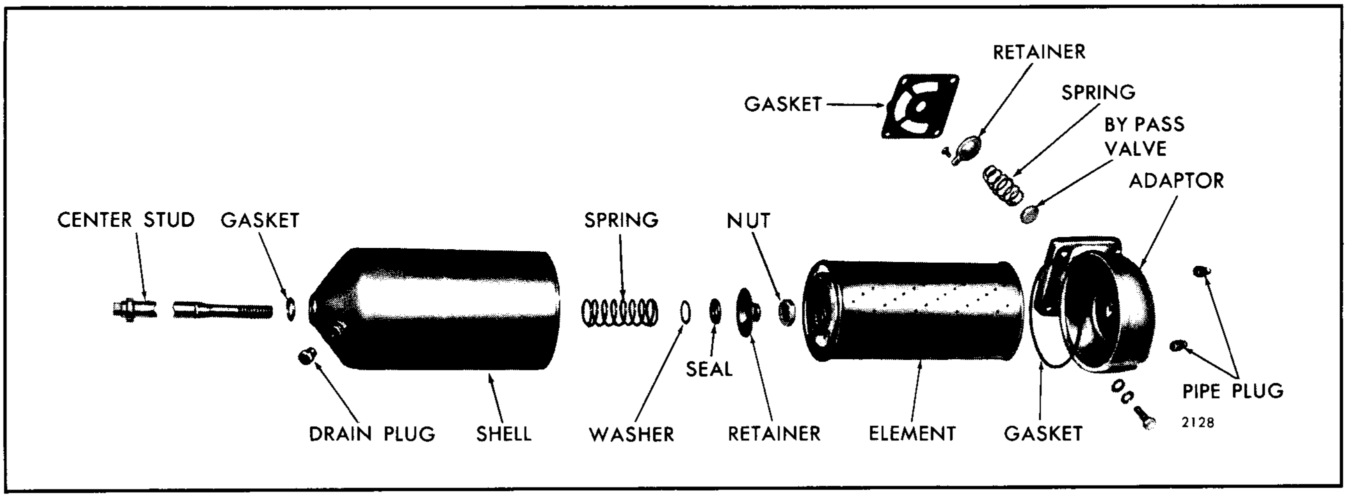

Fig. 5 - Full Flow Oil Filter Details and Relative Location of Parts

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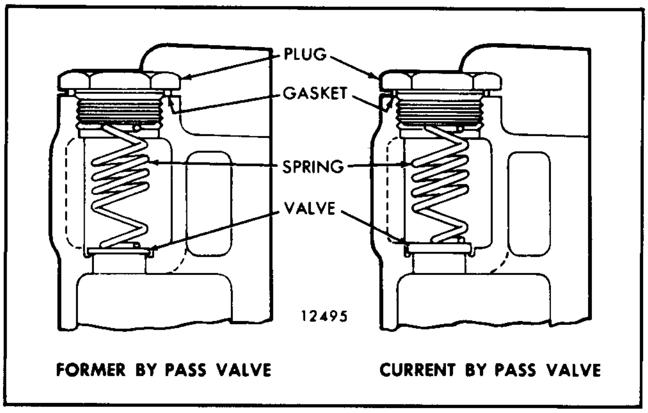

Fig. 6 - Bypass Valve Assembly Secured by Plug

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.

NOTE: 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 ten minutes), add sufficient oil to raise the oil level to the proper mark on the dipstick.

Remove and Install Bypass Valve

1. Remove the four bolts and washers and detach the filter adaptor or filter junction housing from the oil cooler adaptor (Fig. 5).

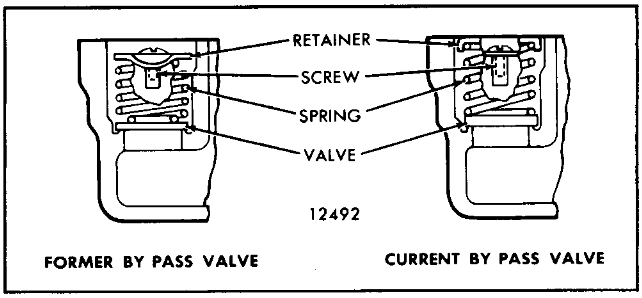

Fig. 7 - Bypass Valve Assembly Secured by Retainer and Screw

2. Remove the plug and gasket (Fig. 6) or the screw and retainer (Fig. 7) and withdraw the spring and bypass valve.

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. 6). The current thicker valve and stiffer spring increase the bypass pressure from 13-18 psi (90-124 kPa) to 18-21 psi (124-145 kPa) to permit more efficient filtration. A thicker valve, stronger spring, heavier retainer and a longer retaining screw are currently used in the bypass valve assembly shown in Fig. 7. The filter adaptors and filter junction housings have been revised by deepening the valve cavity to accommodate the thicker valve and related parts.

6. Use a new gasket and install the filter adaptor or filter junction housing.

NOTE: The small protrusion on the gasket must mate with the boss on the filter adaptor regardless of the position in which the filter is assembled. If the gasket is not correctly positioned, the flow of oil will be obstructed.

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LUBRICATING OIL COOLER

Engine oil coolers are provided for all engines with the exception of certain 2-cylinder models which do not include or require an oil cooler. The oil cooler is mounted on the side of the cylinder block (Fig. 1).

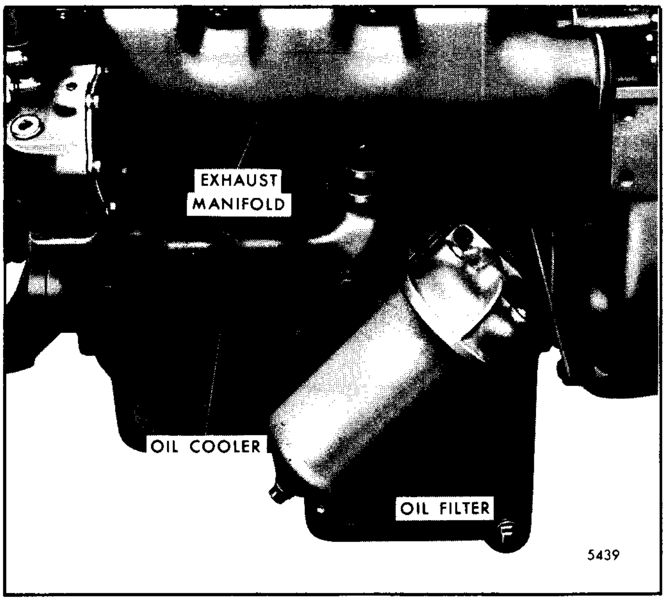

Fig. 1 - Typical Oil Cooler Mounting (6V-53 Engine Shown)

To assure engine lubrication should the oil cooler become plugged, a bypass valve located near the top of the lower engine front cover bypasses oil from the oil pump discharge port directly to the oil galleries in the cylinder block. The bypass valve opens at approximately 52 psi (359 kPa) (current In-line engines), 30 psi (207 kPa) (former In-line engines) or 52 psi (359 kPa) (6V and 8V engines). The valve components are the same as and serviced in the same serviced in the same manner as the oil pressure regulator valve in Section 4.1.1.

The bypass valve opens at approximately 32 psi (221 kPa) on 6V marine engines prior to engine number 6D-11074 and all 6V engines prior to engine number 6D-17960.

Coolant circulated through the oil cooler completely surrounds the oil cooler core. Therefore, whenever an oil cooler is assembled, special care must be taken to have the proper gaskets in place and the retaining bolts tight to assure good sealing.

The oil cooler housing on an In-line engine is attached to an oil cooler adaptor which, in turn, is attached to the cylinder block. The flow of oil is from the oil pump through a passage in the oil cooler adaptor to the full flow oil filter, which is also mounted on the oil cooler adaptor, and then through the oil cooler core and the cylinder block oil galleries.

The oil cooler housing on a V-type engine is attached directly to the cylinder block.

In order to standardize, a new aluminum oil cooler cover has replaced two cast iron covers. The new oil cooler cover has two inlet holes (to filter) and two outlet holes (from filter). One each of these holes must be plugged when the new cover is used (Fig. 2). Different attaching bolts are required because of varying cover flange thicknesses. Only the new aluminum oil cooler cover will be serviced.

Effective with engine serial number 4DB-48774 the 4-53 turbocharged engine uses a 12 plate oil cooler with a reinforced oil cooler core. When replacing an oil cooler on a 4-53 turbocharged engine built prior to the above serial number use the reinforced oil cooler assembly.

Remove Oil Cooler Core

1. Drain the cooling system by opening the drain cock at the bottom of the oil cooler housing.
2. Remove any accessories or other equipment necessary to provide access to the cooler.
3. On In-line or 6V engines, loosen and slide the clamps and hose back on the water inlet elbow on the cylinder block. On 8V engines, remove the bolt and lock washer attaching the water outlet flange and seal ring to the cylinder block.
4. Loosen and slide the clamps and hose back on the tube leading from the thermostat to the water pump.
5. Remove the bolts and lock washers which attach the water pump to the oil cooler housing.
6. Matchmark the end of the oil cooler housing, cooler core and adaptor with a punch or file so they can be reinstalled in the same position.
7. Remove the bolts and lock washers which attach the oil cooler housing to the adaptor or cylinder block and remove the housing and core as an assembly. Be careful when withdrawing the assembly not to drop or damage the cooler core.
8. If the adaptor (In-line engine) is to be removed, the oil filter must first be removed. Then, remove the bolts and lock washers which attach the adaptor to the cylinder block. Withdraw the adaptor and gaskets.
9. Remove all traces of gasket material from the cylinder block and the oil cooler components.

Clean Oil Cooler Core

1. *Clean oil side of Core* - Remove the core from the oil cooler. Circulate a solution of 1,1,1 tricholorethane through the core passages with a force pump to remove the carbon and sludge.

CAUTION: To avoid personal injury, perform this operation in the open or in a well ventilated area. Avoid breathing the fumes or direct contact of the chemicals with your skin. Use recommended safety equipment as required.

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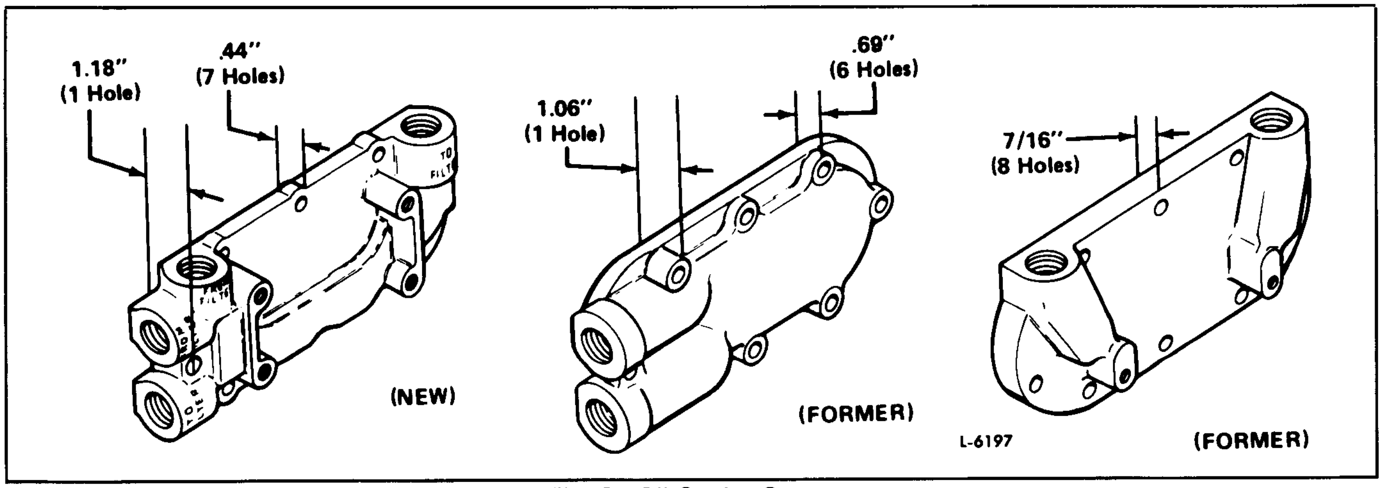

Fig. 2 - Oil Cooler Cover

Clean the core before the sludge hardens. If the oil passages are badly clogged, circulate a cleaning solution through the core and flush thoroughly with clean, hot water.

2. *Clean water side of Core* - After cleaning the oil side of the core, immerse it in the following solution:

Add one-half pound of oxalic acid to each two and one-half gallons of solution composed of one third muriatic acid and two-thirds water. The cleaning action is evidenced by bubbling and foaming.

CAUTION: To avoid personal injury, perform ths operation in the open or in a well ventilated area. Avoid breathing the fumes or direct contact of the chemicals with your skin. Use recommended safety equipment, as required.

Watch the process carefully and, when bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution and thoroughly flush it with clean, hot water. After cleaning, dip the core in light oil.

NOTICE: 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. Replace the oil cooler core.

Pressure Check Oil Cooler Core

After the oil cooler core has been cleaned, check for leaks as follows:

1. Make a suitable plate and attach it to the flanged side of the cooler core. Use a gasket made from rubber to assure a tight seal. Drill and tap the plate to permit an air hose fitting to be attached at the inlet side of the core (Fig. 3).
2. Attach an air hose, apply approximately 75-150 psi (517-1034 kPa) air pressure and submerge the oil cooler core and plate assembly in a container of water heated to 180°F (82°C). Any leaks will be indicated by air bubbles in the water. If leaks are indicated, replace the core.

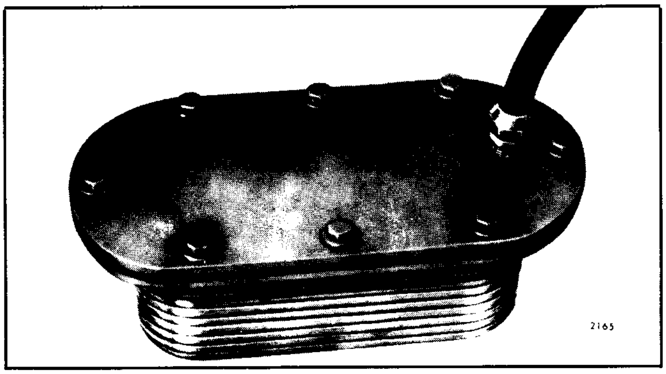

Fig. 3 - Preparing Oil Cooler Core for Pressure Test

CAUTION: When making this pressure test, be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose or the oil cooler core.

3. After the pressure check is completed, remove the plate and air hose from the cooler core, then dry the core with compressed air.

NOTICE: Where a leaking oil cooler core has caused contamination of the engine, the engine must be immediately flushed to prevent serious damage (refer to Section 5).

Install Oil Cooler Core

To provide increased oil cooler capacity, an 18-plate oil cooler is being used in all 6V-53T units with engine-mounted oil coolers. DDA recommends replacing the former 16-plate core with the 18-plate core at time of engine overhaul or if the former core is damaged.

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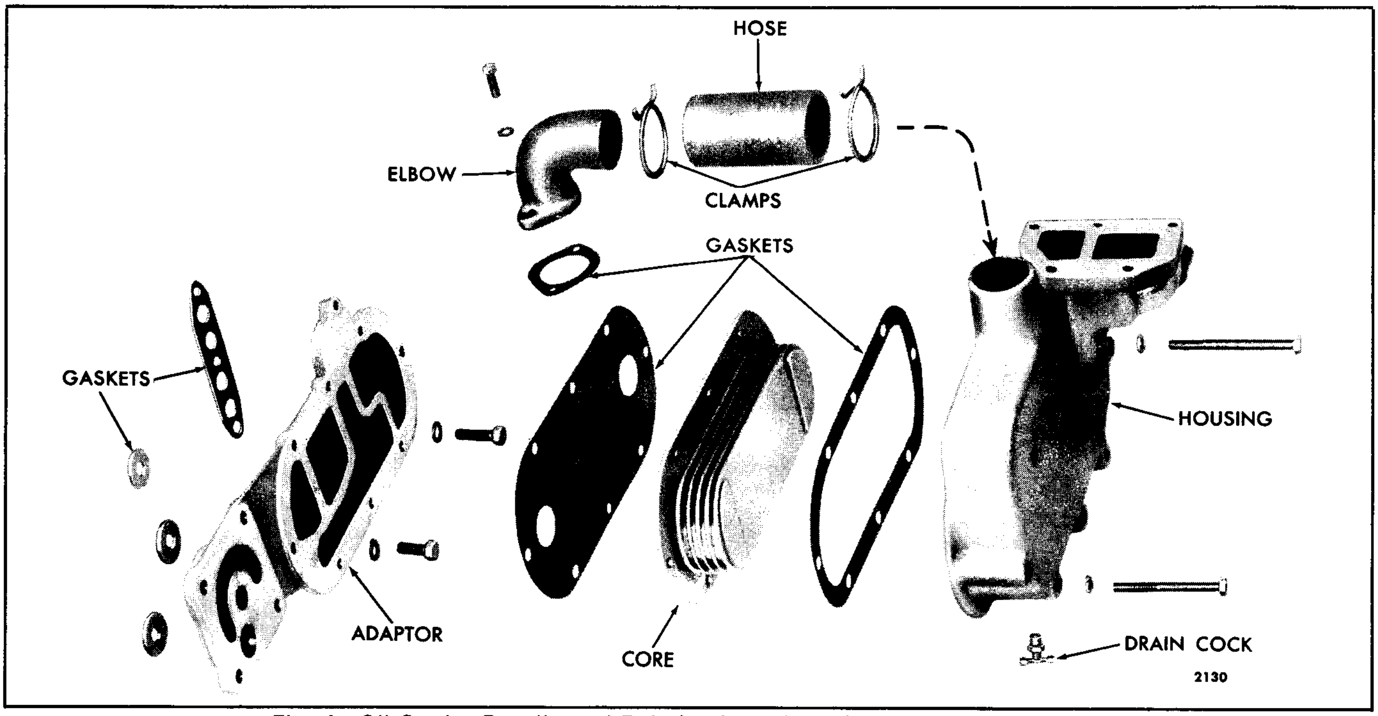

Fig. 4 - Oil Cooler Details and Relative Location of Parts (In-Line Engine)

1. If the oil cooler adaptor (In-line engines) was removed from the cylinder block, remove the old gasket material from the bosses where the adaptor sets against the block. Affix new adaptor gasket and shims (Fig. 4), then secure the adaptor to the cylinder block with five bolts and lock washers. A nitrile base oil cooler to adaptor gasket is currently used on vehicle engines equipped with the AT540 transmission. The new gasket (charcoal colored) is more compatible with transmission fluid than the former gasket (beige color).

2. Clean the old gasket material from both faces of the core flange and affix new gaskets to the inner and outer faces (Figs. 4 and 5). Insert the core into the cooler housing.

NOTICE: The inlet and outlet openings in the oil cooler core are stamped *in* and *out* . It is very important that the core be installed in the correct position to prevent any possibility of foreign particles and sludge, which may not have been removed in cleaning the fins of the core, entering and circulating through the engine.

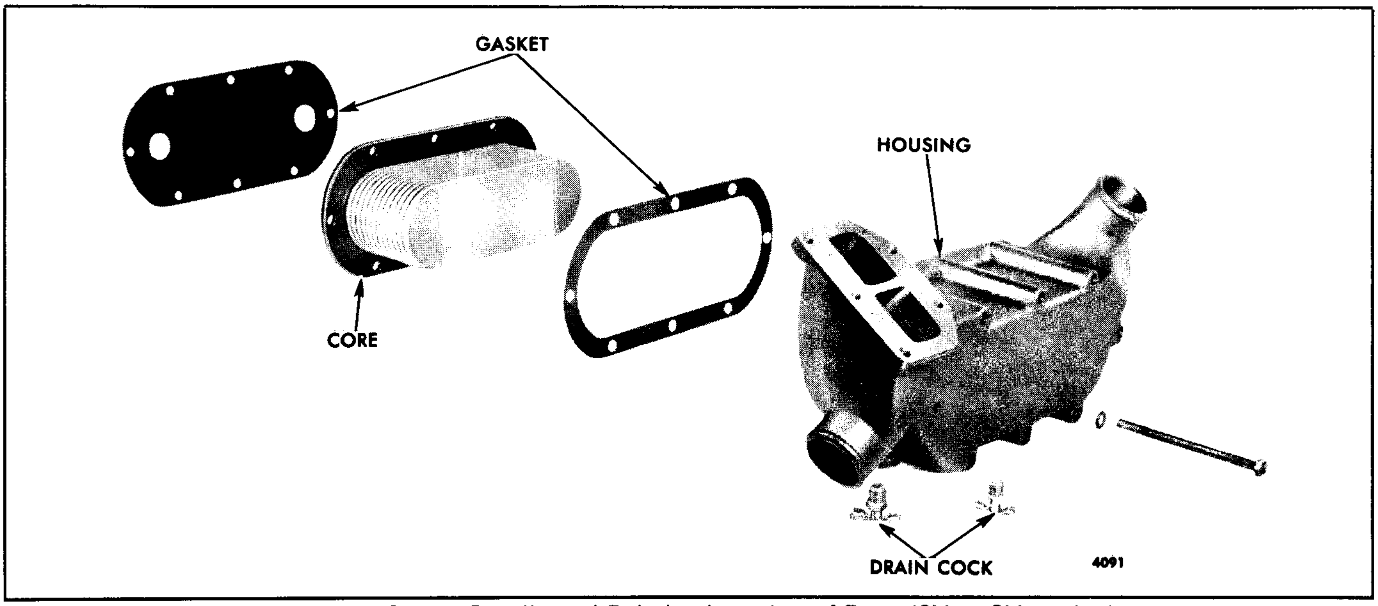

Fig. 5 - Oil Cooler Details and Relative Location of Parts (6V or 8V engine)

3. Align the matchmarks previously placed on the core and housing and install the oil cooler core in the oil cooler housing.
4. With the matchmarks in alignment, place the oil cooler housing and core against the oil cooler adaptor (In-line engines) or cylinder block (6V or 8V engines). On 8V engines, slide the water outlet flange and a new seal ring over the outlet. Then, secure the housing in place with bolts and lock washers. Tighten the bolts to 13-17 lb-ft (18-23 N·m) torque. On 8V engines, secure the outlet flange in place with two bolts and lock washers.
5. Slide the hose and clamps in position between the cylinder block water inlet elbow and the oil cooler. Secure the clamps in place.
6. Place a new gasket between the water pump and the cooler housing and secure the pump to the cooler housing.
7. Position the hose and clamps in place between the water pump and the tube to the thermostat housing. Secure the clamps.
8. Install all of the accessories or equipment it was necessary to remove.
9. Reinstall the oil filter (In-line engine).
10. Make sure the draincock in the bottom of the cooler housing is closed. Then, fill the cooling system to the proper level.

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OIL LEVEL DIPSTICK

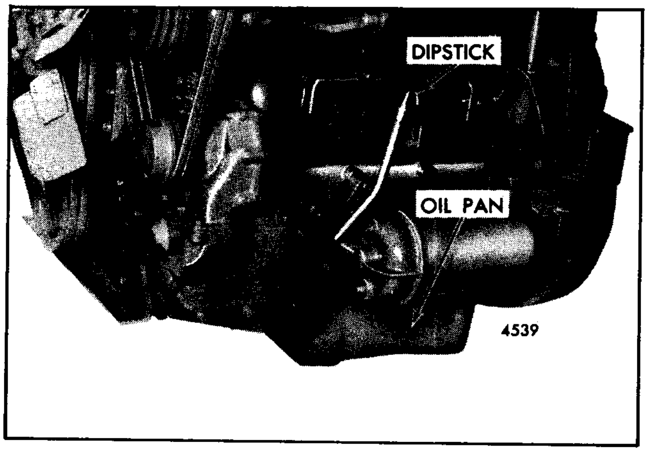

Fig. 1 · Typical Oil Dipstick Mounting

A steel ribbon type oil level dipstick is mounted in an adaptor on the side of the engine (Fig. 1) to check the amount of oil in the engine oil pan. The dipstick has markings to indicate the *Low* and *Full* oil level. Current engines include a 3/4 " long rubber oil seal inside the cap of the dipstick. This prevents the escape of vapors carrying oil from the dipstick tube.

> **NOTE:** On 8V engines, effective with 8D-468, a new dipstick, adaptor and guide combination is used to raise the full mark on the dipstick approximately two quarts (1.893 litres). When replacement of any part of the combination is required on an early engine, the complete new combination is necessary.

Maintain the oil level between the *full* and *low* marks on the dipstick and never allow it to drop below the low mark. No advantage is gained by having the oil level above the full mark. Overfilling will cause the oil to be churned by the crankshaft throws causing foaming or aeration of the oil. Operation below the low mark will expose the pump pick-up causing aeration and/or loss of pressure.

Check the oil level after the engine has been stopped for a minimum of twenty minutes to permit oil in the various parts of the engine to drain back into the oil pan.

Dipsticks are normally marked for use only when the equipment the engine powers is on a level surface. Improper oil levels can result if the oil level is checked with the equipment on a grade.

Fill the crankcase with oil as follows:

1. Fill the oil pan to the full mark on the dipstick.

2. Start and run the engine for approximately ten minutes.

3. Stop the engine and wait a minimum of twenty minutes. Then add the required amount of oil to reach the full mark on the dipstick.

Marine Engines

Dipsticks in marine engines are located and marked to provide the proper oil level at any angle within the recommended maximum installation angle applicable to the specific boat.

In a properly filled crankcase, the oil level must be below the crankshaft rear oil seal when the boat is at rest.

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OIL PAN

The oil pan (Fig. 1) may be made of steel, cast iron or cast aluminum. A shallow or deep sump type oil pan is used, depending upon the particular engine application. A one-piece oil pan gasket is used with stamped steel pans. A four-piece gasket is used with the cast oil pans.

Removing and Installing Oil Pan

On some engine applications, it may be possible to remove the oil pan without removing the engine. It is recommended that if the engine is to be removed, the oil pan be left in place until the engine is removed.

The procedure for removing the oil pan without taking the engine out and after taking the engine out of the unit will vary. However, the following will generally apply.

1. Remove the drain plug and drain the oil.

2. Detach the oil pan; take precautions to avoid damaging the oil pump inlet pipe and screen.

   NOTE: Stamped oil pans used on some marine engines have a layer of lead or cadmium beneath the paint to protect the pans against the salt water atmosphere encountered in some marine applications. If this coating is scuffed or broken unknowingly, corrosion or electrolysis may result. Electrolysis in the form of small holes will eat through the pan at the scuffed area. Therefore, do not rest, slide or rock the engine on its oil pan when removing it. Every precaution should be taken before installation to prevent nicks and scratches on stamped marine oil pans. Also exercise care when performing engine repairs to avoid scratching the outer surface of the oil pan.

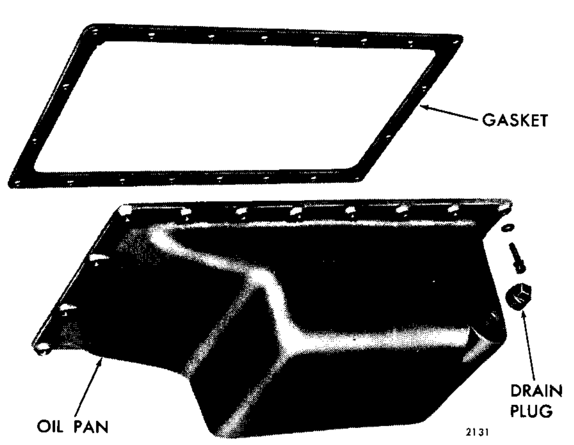

Fig. 1 - Typical Oil Pan

3. Remove the oil pan gasket completely.

4. Clean all of the old gasket material from the cylinder block and the oil pan. Clean the oil pan with a suitable solvent and dry it with compressed air.

5. Inspect a cast oil pan for porosity or cracks. Check a stamped oil pan for dents or breaks in the metal which may necessitate repair or replacement. Check for misaligned flanges or raised surfaces surrounding the bolt holes by placing the pan on a surface plate or other large flat surface.

6. 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 Nm) torque. *Do not overtighten the bolts.* Once the bolts are tightened to the specified torque, do not retighten them as it could be detrimental to the current type gaskets. If a leak should develop at the oil pan, check if the lock washer is compressed. If not, the bolt may be tightened. However, if the lock washer is compressed and leaking occurs, remove the oil pan and determine the cause of the leakage.

   NOTE: Current oil pan bolts (stamped metal pans) are coated with a locking material. To reactivate the locking ability of the bolts, apply a drop or two of Loctite J 26558-242, or equivalent, to the threads of the bolts at reassembly.

7. On 8V engines, if the oil pan and flywheel housing include outriggers for the installation of reinforcement bolts, be sure the oil pan butts up against the flywheel housing before tightening the oil pan bolts. Install and tighten the 1/2 "-13 reinforcement bolts.

8. Install and tighten the oil drain plug. Tighten the plug (with nylon washer) to 25-35 lb-ft (34-47 Nm) torque.

9. Fill the oil pan with new oil (refer to Sections 4.6 and 13.3) to the full mark on the dipstick. Then start and run the engine for ten minutes and check for oil leaks.

10. Stop the engine and, after approximately twenty minutes, check the oil level. Add oil if necessary.

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VENTILATING SYSTEM

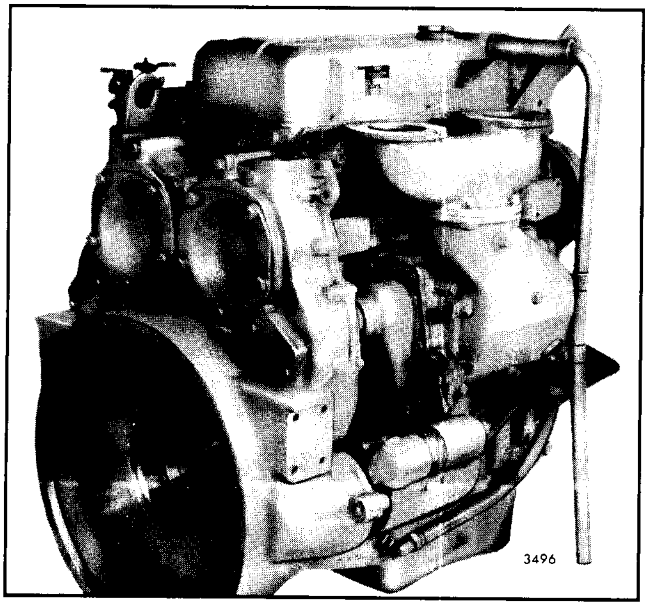

Fig. 1 - Typical Crankcase Breather Mounting (In-Line Engine)

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train and valve compartment by a continuous pressurized ventilating system.

A slight pressure is maintained in the engine crankcase by the seepage of a small amount of air from the airbox past the piston rings. This air sweeps up through the engine and is drawn off through a crankcase breather.

In-line engines are equipped with a breather assembly attached to the valve rocker cover (Fig. 1) or a breather assembly mounted on the flywheel housing (Fig. 2).

On 6V engines, a breather assembly is mounted on the upper engine front cover (Fig. 3) or the rocker cover (Fig. 4).

The 8V engines have a breather tube attached to the valve rocker cover (Fig. 5) and a breather (with a filter pad) mounted on the governor. However, the marine engines did not include a filter pad until engine number 8D-2701. Early 8V engines were equipped only with a breather assembly mounted on the governor housing.

Service

It is recommended that the breather tube be inspected and cleaned, if necessary, to eliminate the possibility of clogging. This can best be done by removing the tube from the engine, washing it with a suitable solvent and drying it with compressed air.

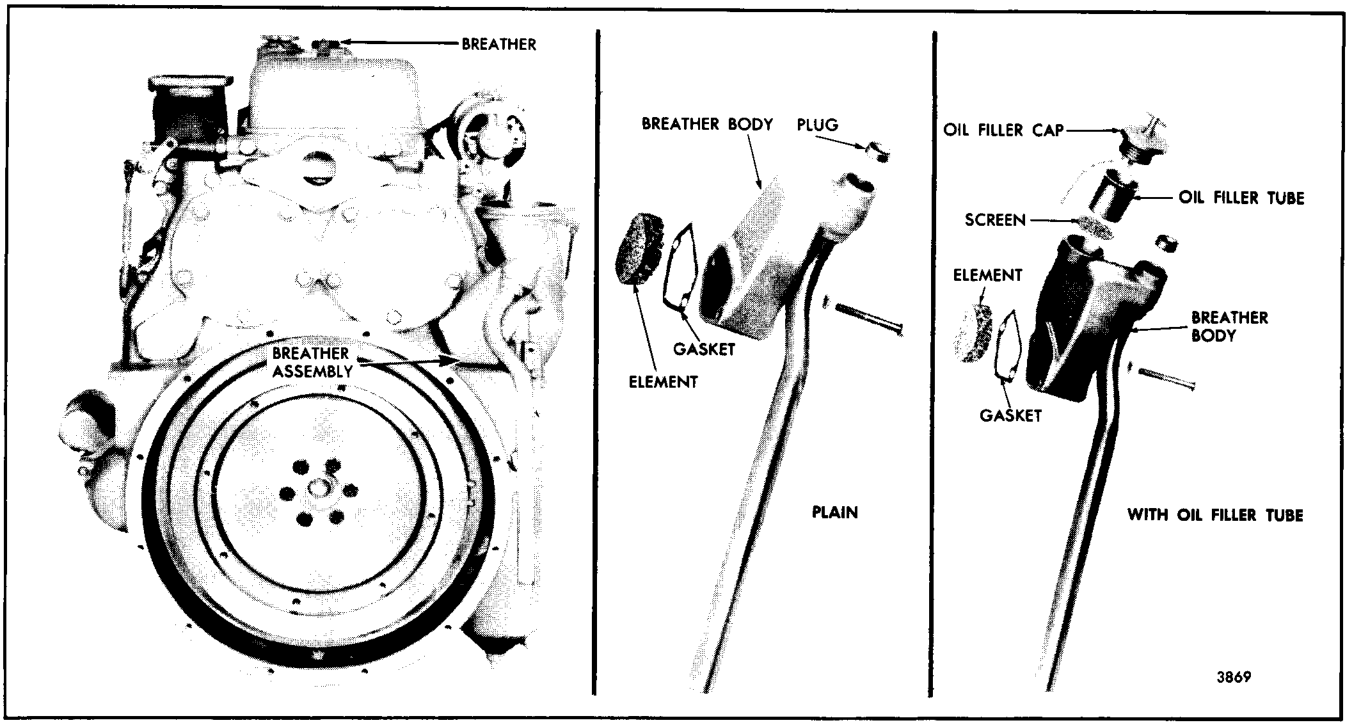

Fig. 2 - Crankcase Breather Mounting and Details (In-Line Engine)

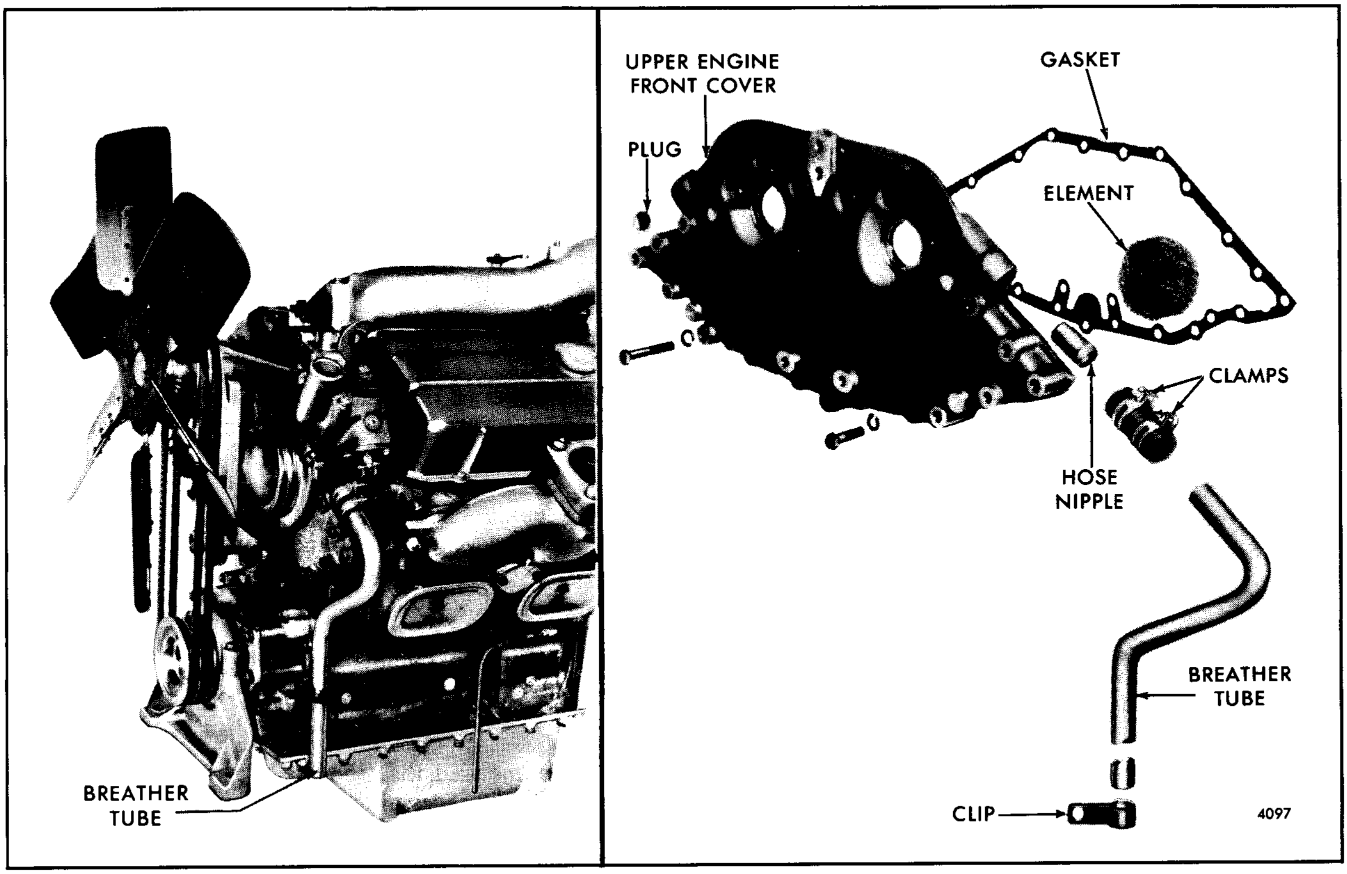

Fig. 3 - Typical Crankcase Breather Mounting and Details (6V-53 Engine)

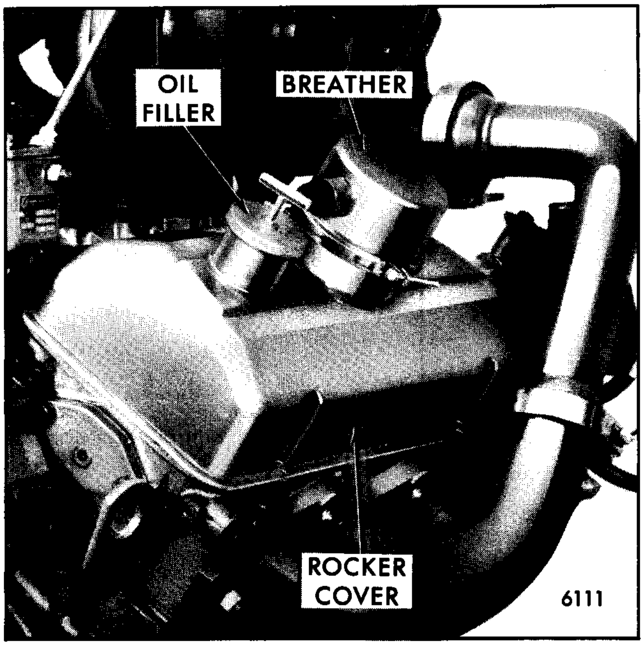

Fig. 4 - Rocker Cover Breather Mounting (6V-53 Engine)

The wire mesh pad (element) in the breather assemblies should be cleaned if excessive crankcase pressure is observed.

If it is necessary to clean the element, remove the breather housing from the flywheel housing (In-line

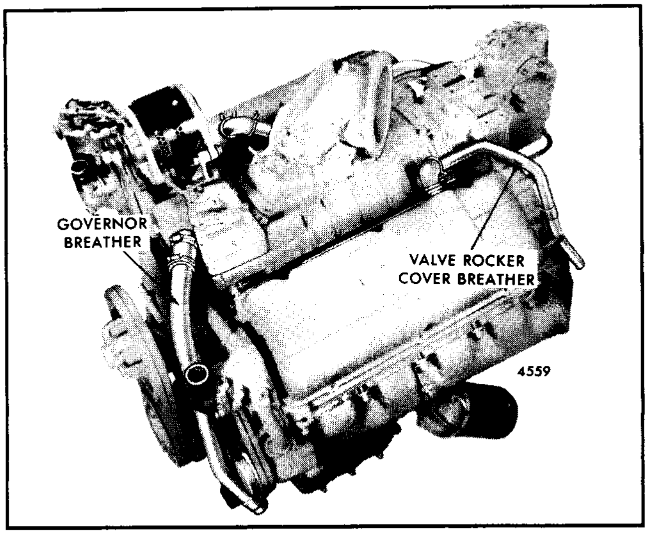

Fig. 5 - Typical Breather Mountings (8V-53 Engine)

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engines), the the upper front cover (6V engines), the rocker cover (6V engines) or the governor housing and/or valve rocker cover (8V engines).

Wash the element in fuel oil and dry it with compressed air.

Reinstall the element in the breather housing, the upper front cover or the governor housing and/or the valve rocker cover and install them by reversing the procedure for removal.

NOTE: When the limiting speed governor assembly or the governor housing is replaced on an early 8V engine, it will be necessary to include the current thicker breather element.

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SHOP NOTES - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

REWORK INSTRUCTIONS FOR 6V-53 OIL PUMP INLET TUBE SUPPORTS

When replacing the cylinder block or main bearing caps on an early engine, it will be necessary to either replace the oil inlet tube support or elongate the bolt holes in the support (Fig. 1) and use new support attaching parts.

In the old bearing caps, the holes were tapped 5/16 ″-18 with 1.680 ″ between centers. In the new bearing caps, the holes are tapped 3/8 ″-16 with 2.240 ″ between centers.

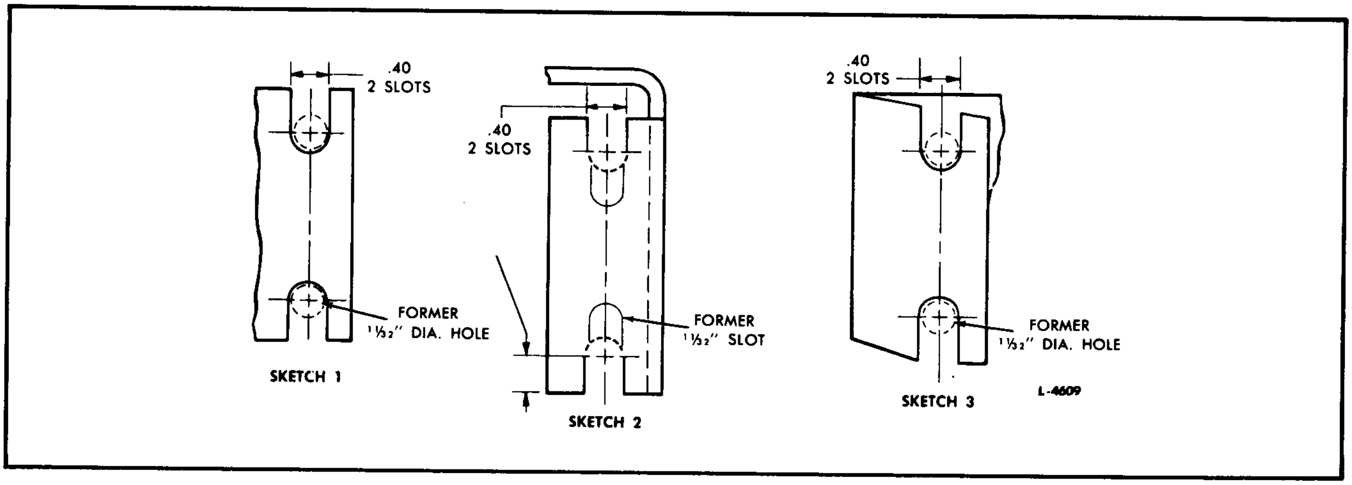

Fig. 1 - Oil Inlet Tube Supports

REWORKING 6V-53 CAST IRON OIL PAN FOR USE WITH CURRENT OIL PUMP INLET TUBE

When the seven hole upper main bearing shells (Section 1.3.4) are used in 6V marine engines prior to 6D-11074 and all 6V engines prior to 6D-17960, a 1-3/8 ″ diameter lubricating oil pump inlet tube must be used rather than the former 1 ″ diameter inlet tube. To conform with the increased diameter of the oil pump inlet tube, the cast iron oil pan must be reworked to provide installation clearance by reducing the height of the integral cast baffle approximately .440 ″ (Fig. 2).

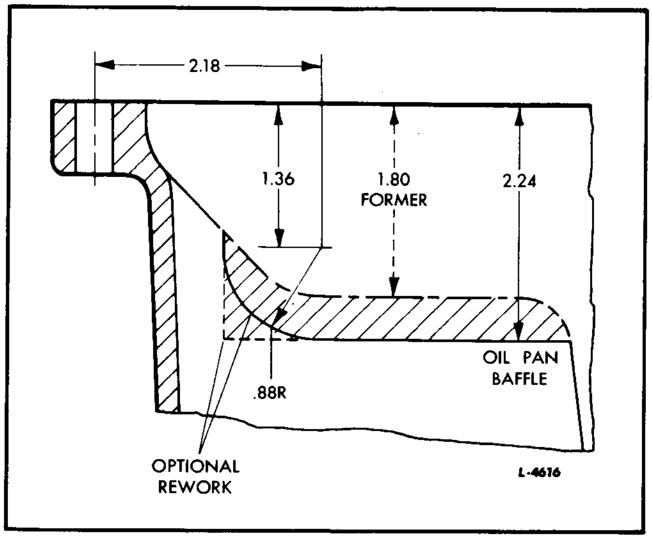

Fig. 2 - Rework Sketch for a Cast Iron Oil Pan

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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 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 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

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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 filter center stud	5/8 -18	50-60	68-81
Oil pan drain plug (Nylon washer)	18 mm	25-35	34-47

SERVICE TOOLS

TOOL NAME	TOOL NO.
Crankshaft pulley installer set	J 7773
Oil pump drive gear adaptor	J 23126
Oil pump drive gear installer	J 8968-01
Strap wrench (spin-on filter)	J 24783
Universal puller (4 " diameter range)	J 24420
Universal puller (13 " diameter range)	J 8190

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SECTION 5

COOLING SYSTEM

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COOLING SYSTEM

To effectively dissipate the heat generated by the engine, one of three different types of cooling systems is used on a Series 53 engine: radiator and fan, heat exchanger and raw water pump, or keel cooling. A centrifugal type water pump is used to circulate the engine coolant in each system. Each system incorporates thermostats to maintain a normal engine operating temperature (refer to Section 13.2). Typical In-line and V-type engine cooling systems are shown in Figs. 1 and 2.

Radiator and Fan Cooling System

The engine coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler and into the cylinder block.

From the cylinder block, the coolant passes up through the cylinder head(s) and, when the engine is at normal operating temperature, through the thermostat(s) and into the upper portion of the radiator. The coolant passes down a series of tubes where the coolant temperature is lowered by the air stream created by the revolving fan.

Upon starting a cold engine or when the coolant is below operating temperature, the coolant is restricted at the thermostat(s) and a bypass provides water circulation within the engine during the warm up period.

Heat Exchanger Cooling System

In the heat exchanger cooling system, the coolant is drawn by the engine water pump from the lower portion of the expansion tank through the engine oil cooler, then through the engine the same as in the radiator and fan system. Upon leaving the thermostat housing, the coolant either passes through the heat exchanger core or bypasses the heat exchanger and flows directly to the water pump, depending on the coolant temperature.

While passing through the core of the heat exchanger, the coolant temperature is lowered by raw water, which is drawn by the raw water (sea water) pump from an outside supply. The raw water enters the heat exchanger at one side and is discharged at the opposite side.

To protect the heat exchanger element from electrolytic action, a zinc electrode is located in both the heat exchanger inlet elbow and the raw water pump inlet elbow and extends into the raw water passage.

Keel Cooling System

The keel cooling system is similar to the heat exchanger system, except that the coolant temperature is reduced in the keel cooler. In this system the coolant is drawn by the fresh water pump from the lower portion of the expansion tank through the engine oil cooler. From the

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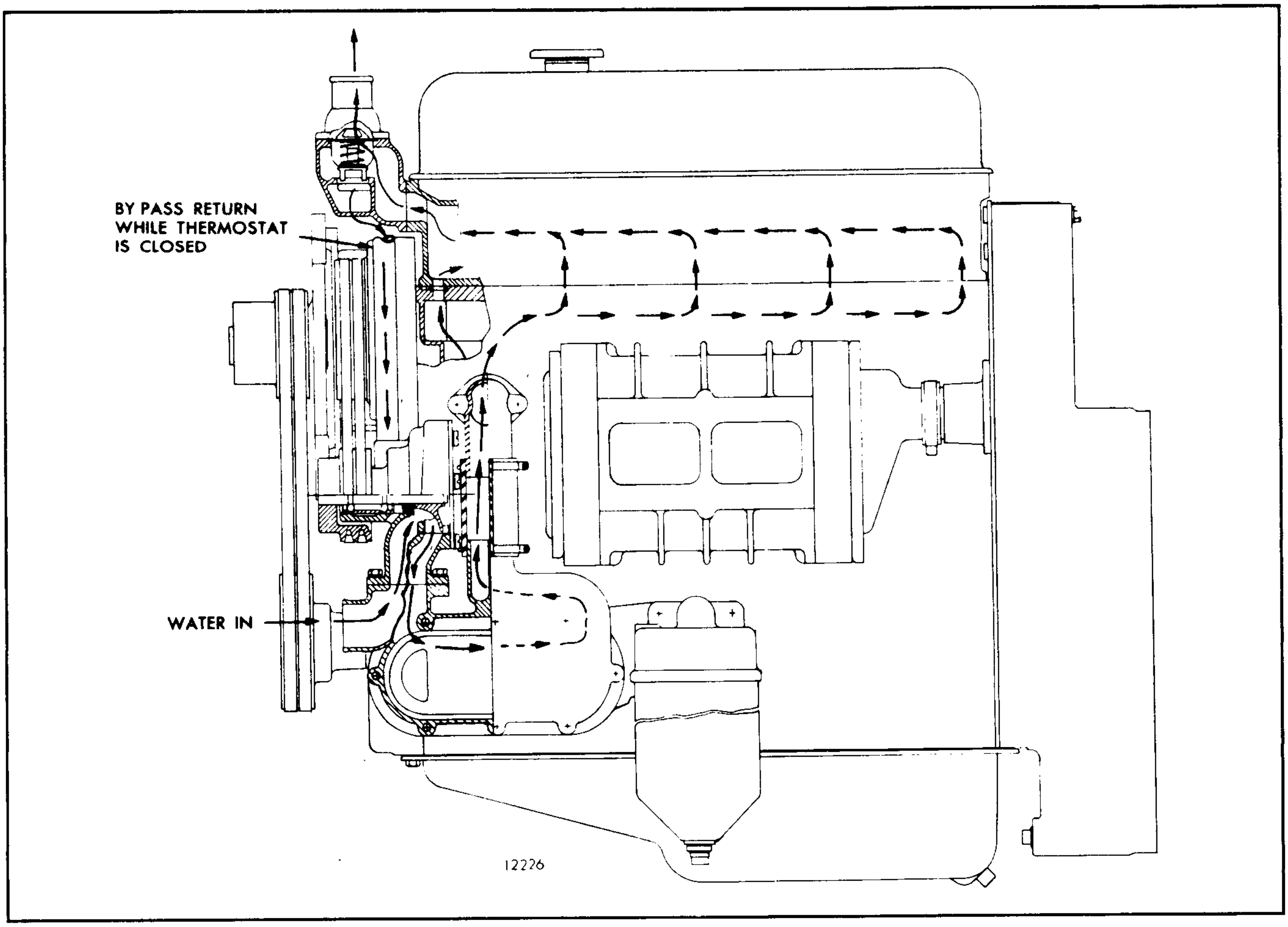

Fig. 1 - Typical Cooling System for an In-Line Engine

cooler the flow is the same as in the other systems. Upon leaving the thermostat housing, the coolant is bypassed directly to the lower portion of the expansion tank until the engine operating temperature, controlled by the thermostat, is reached. As the engine temperature increases, the coolant is directed to the keel cooler, where the coolant temperature is reduced before flowing back to the expansion tank.

ENGINE COOLING SYSTEM MAINTENANCE

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from components of the engine such as exhaust valves, pistons and cylinder liners which are surrounded by water jackets. In addition, heat absorbed by the oil is also removed by the engine coolant when oil to water oil coolers are used. When operating within the proper temperature range and not exceeding the recommended horsepower output of the unit, all engine parts will be within their design operating temperature range and at their proper operating clearances. Coolant must be properly selected and maintained (refer to Section 13.3).

Cooling System Capacity

COOLING SYTEM CAPACITY (BASIC ENGINE)		
ENGINE	CAPACITY	
	GALLONS	LITERS
2-53	1-1/2	5.7
3-53	2	7.6
4-53	2-1/4	8.5
6V-53	3-1/2	13.2
8V-53	5	18.9

TABLE 1

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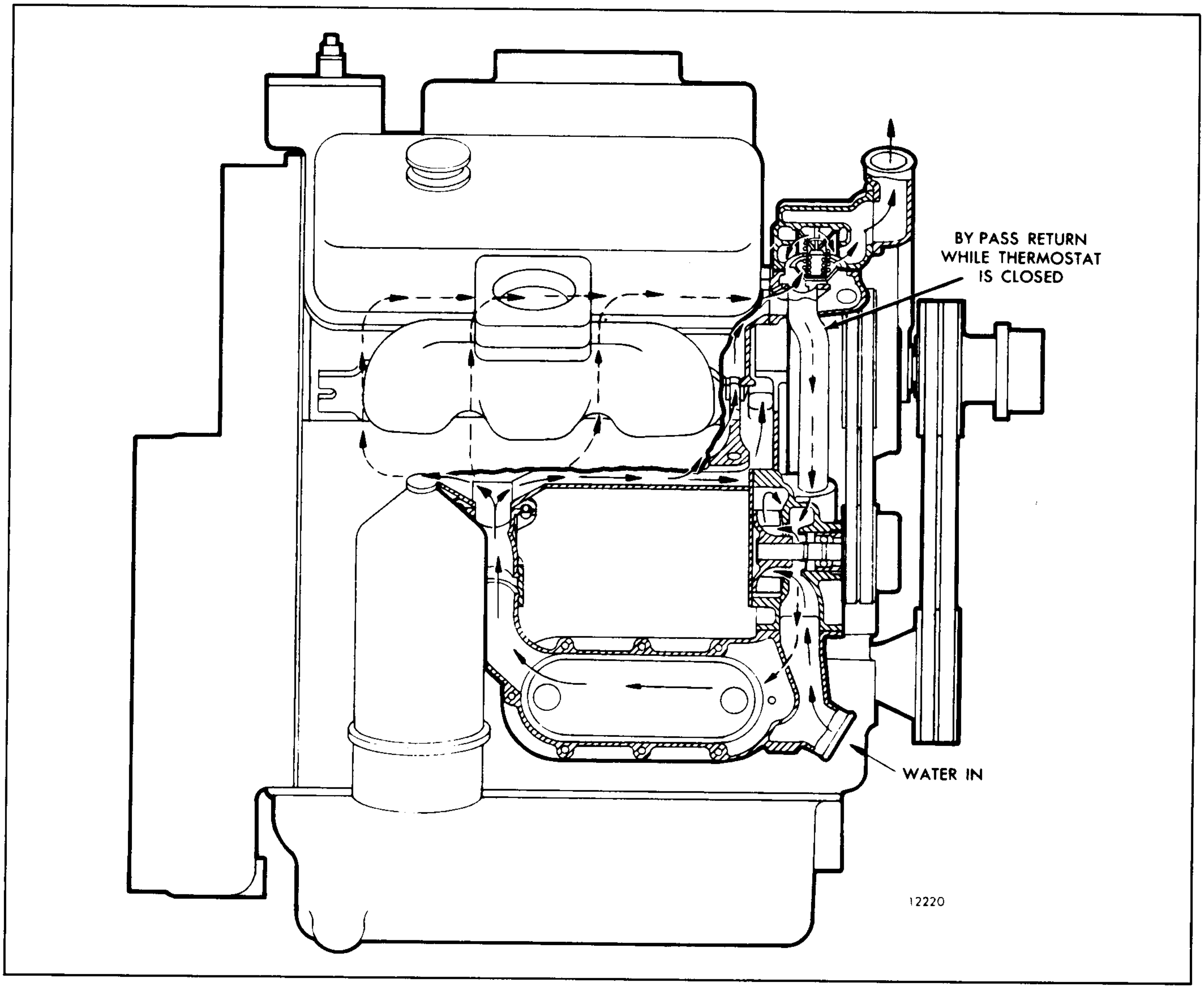

Fig. 2 - Coolant Flow Through a 6 or 8V Engine

The capacity of the basic engine cooling system (cylinder block, cylinder head, water manifold, thermostat housing(s) and oil cooler housing) is shown in Table 1.

These quantities do not include the capacity of the radiator, hoses or related equipment.

Fill Cooling System

Before starting the engine, close all of the drain cocks and fill the cooling system with coolant (see Section 13.3). If the unit has a raw water pump, it should be primed, since operation without water may cause impeller failure.

Start the engine and, after normal operating temperature has been reached, check the coolant level. The coolant level should be within two inches of the top of the filler neck.

Excessive amounts of air in the cooling system may hinder the flow of water due to pump cavitation or result in hot spots when air collects at low velocity points in the water passages. Therefore, whenever the cooling system is filled or make-up water is added, the air must be thoroughly vented from the system. The thermostat housing(s) on the Series 53 engines provides a vent hole to release the air to the atmosphere while the cooling system is being filled. In addition, the cooling system should be vented at the time normal operating temperature is reached after starting the engine and again after the engine has been in operation for 30 to 45 minutes.

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Should a daily loss of coolant be observed, and there are no apparent leaks, there is a possibility that gases are leaking past the cylinder head water seal rings into the cooling system. The presence of air or gases in the cooling system may be detected by connecting a rubber tube between the overflow pipe and a container of water. Bubbling in the water in the container during engine operation will indicate leakage. Another method for observing air in the cooling system is by inserting a transparent tube in the engine coolant outlet line.

Drain Cooling System

Drain the cooling system by opening the cylinder block and radiator (or heat exchanger) drain cocks and removing the cooling system filler cap. Removal of the filler cap permits air to enter the cooling passages and the coolant to drain completely from the system.

Drain cocks are located as indicated in Table 2. Radiators that do not have a drain cock are drained through the oil cooler housing drain.

If freezing weather is anticipated and the engine is not protected by antifreeze, drain the cooling system completely when the engine is not in use. Leave all of the drain cocks open until the cooling system is refilled. Should any entrapped water in the cylinder block, radiator or other engine parts freeze, it will expand and may result in damage to the engine.

COOLANT DRAIN VALVES		
Engine	Oil Cooler or Coolant Inlet Side of Block	Side of Block Opposite Oil Cooler or Coolant Inlet
2-53	Bottom of oil cooler or coolant inlet	*Water hole cover near front of block
3-53	Bottom of oil cooler and coolant inlet	Just forward of blower mounting pad
4-53	Bottom of oil cooler, coolant inlet, and behind blower drive or governor near rear of block	Behind blower drive or governor near rear of block
6V-53	Bottom of oil cooler, coolant inlet, and side of block near rear end	Water hole cover between hand hold covers and side of block near rear end
8V-53	Bottom of oil cooler, and side of block near rear end	Side of block near front end and below center of air box cover

*Most industrial units contain a 1/8" pipe plug at this location.

TABLE 2

Marine engine exhaust manifolds are cooled by the same coolant used in the engine. Whenever the engine cooling system is drained, open the exhaust manifold drain cocks.

Raw water pumps are drained by loosening the cover attaching screws and tapping the cover gently to loosen it. After the water has drained, tighten the screws.

Flushing

If a coolant filter or a corrosion inhibitor supplement is used and properly maintained, the cooling system need not be flushed. However, if the cooling system was not properly protected, drain and flush the cooling system each fall. Examine the cooling system for contamination and if necessary, chemically clean it. Perform the flushing operation as follows:

1. Drain the coolant from the engine.

2. Refill with soft clean water.

   NOTE: 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 fifteen minutes to thoroughly circulate the water.

4. Drain the engine completely.

5. Refill with the solution required (refer to Section 13.3).

Cooling System Cleaners

If the engine overheats, and the fan belt tension and coolant level have been found to be satisfactory, it may be necessary to clean and flush the entire cooling system. Remove scale formation by using a reputable and safe de-scaling solvent. Immediately after using the de-scaling solvent, neutralize the system with the neutralizer. It is important that the directions printed on the container of the de-scaler be thoroughly read and followed.

After the solvent and neutralizer have been used, completely drain the engine and radiator and reverse flush, as outlined below, before filling the system.

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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 by hot water, under air pressure, being forced through the cooling system in a direction opposite to the normal flow of coolant, loosening and forcing scale deposits out.

The radiator is reverse flushed as follows:

1. Remove the radiator inlet and outlet hoses and replace the radiator cap.

2. Attach a hose at the top of the radiator to lead 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, allowing the radiator to fill between air blasts.

> **NOTE:** Apply air gradually. Do not exert more than 20 psi (138 kPa) air pressure. Too great a pressure may rupture a radiator tube.

6. Continue flushing until only clean water is expelled from the radiator.

The cylinder block and cylinder head water passages are reverse flushed as follows:

1. Remove the thermostats and the water pump.

2. Attach a hose to the water inlet of the cylinder block to drain the water away from the engine.

3. Attach a hose to the water outlet at the top of the cylinder block and insert the flushing gun in the hose.

4. Turn on the water and, when the water jackets are filled, turn on the air in short blasts, allowing the engine to fill with water between air blasts.

5. Continue flushing until the water from the engine runs clean.

If scale deposits in the radiator cannot be removed by chemical cleaners or reverse flushing as outlined above, it may be necessary to remove the upper tank and rod out the individual radiator tubes with flat steel rods. Circulate water through the radiator core from the bottom to the top during this operation.

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 cooling system hoses, thermostats and radiator pressure cap should be checked and replaced if found to be defective.

When water connection seals and hoses are installed, be sure the connecting parts are properly aligned and the seal or hose is in its proper position before tightening the clamps.

> **NOTE:** In order to assure the integrity of the cooling system, it is recommended that a periodic cooling system pressure check be performed. Pressurize the cooling system (15-20 psi or 103-138 kPa) using radiator cap and cooling system tester J 24460-01. *Do not exceed 20 psi (138 kPa).* Any measurable drop in pressure may indicate an external/internal leak. Whenever the oil pan is removed, the cooling system should be pressure checked as a means of identifying any coolant leaks.

The fan belts must be checked and adjusted, if necessary, to provide the proper tension. The fan shroud must be tight against the radiator core to prevent recirculation of air which may lower the cooling efficiency.

Contaminated Engines

When the engine cooling 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. With a cracked oil cooler core, oil will be forced into the cooling system while the engine is operating, and when it is stopped, coolant will leak into the lubricating system.

Coolant contamination of the lubricating system is especially harmful to engines when the cooling system is filled with an ethylene glycol base antifreeze solution. When mixed with the oil in the crankcase, this antifreeze forms a varnish which can cause the engine to seize or result in severe bearing wear.

Make certain that the cause of the internal coolant leak has been corrected before flushing the contaminated systems.

Contaminants may be flushed from the engine systems as follows:

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Cooling System

If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, the following procedure is recommended.

1. Prepare a mixture of Calgon (a low sudsing dish-washer detergent), or equivalent, and water at the rate of two ounces (dry measure) to one gallon of water.

2. Remove the engine thermostats to permit the Calgon and water mixture to circulate through the engine and the radiator or heat exchanger.

3. Fill the cooling system with the Calgon solution.

4. Run the engine for five minutes.

5. Drain the cooling system.

6. Repeat Steps 1 through 5.

7. Fill the cooling system with clean water.

8. Let the engine run five minutes.

9. Drain the cooling system completely.

10. Install the engine thermostats.

11. Close all of the drains and refill the cooling system with fresh coolant (refer to Section 13.3).

Lubrication System

When the engine lubricating system has been contaminated by an ethylene glycol base antifreeze solution or other water soluble material, the following cleaning procedure, using Butyl Cellosolve, or equivalent, is recommended.

CAUTION: Use extreme care in the handling of these chemicals to prevent serious injury to the person or damage to finished surfaces. Wash off spilled fluid immediately with clean water.

1. Drain all of the lubricating oil.

2. Remove and discard the oil filter element. Clean and dry the filter shell and replace the element.

3. Mix two parts of Butyl Cellosolve, or equivalent, with one part SAE 10 engine oil. Fill the engine crankcase to the proper operating level with the mixture.

4. Start and run the engine at a fast idle (1,000 to 1,200 rpm) for thrity 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. Replace the drain plug and refill the crankcase with SAE 10 oil and run the engine at the same fast idle for ten or fifteen minutes and again drain the oil thoroughly.

7. Remove and discard the oil filter element, clean the filter shell and install a new element.

8. Replace the drains and fill the crankcase to the proper level with the oil recommended for normal engine operation.

9. To test the effectiveness of the cleaning procedure, it is recommended that the engine be started and run at a fast idle (1,000 to 1,200 rpm) for approximately thirty minutes. Then stop and immediately restart the engine. There is a possibility that the engine is not entirely free of contaminant deposits if the starting speed is slow.

10. If the procedure for cleaning the lubricating oil system was not successful, it will be necessary to disassemble the engine and to clean the affected parts thoroughly.

Make certain that the cause of the internal coolant leak has been corrected before returning the engine to service.

MAXIMUM ENGINE COOLANT TEMPERATURE

The heat-dissipating capacity of the engine cooling systems and related components must be sufficient to prevent the coolant temperature from rising above 210° F (99° C). This temperature must not be exceeded under any engine operating condition, regardless of altitude, type of coolant used or cooling system condition. Exceeding this limit can result in malfunction or serious engine damage.

TEMPERATURE CONTROL COMPONENTS

These engines are designed to operate with 170° F (77° C) or 180° F (82° C) thermostats which, combined with a radiator or heat exchanger, regulate coolant temperature within a range of 170° F-187° F (77° - 86° C) or 180° -197° F (82° -92° C). Many engines also use radiator shutters, clutch fans or conbinations of both to help control coolant temperature. These "add on" cooling system components must operate in proper sequence to prevent coolant temperature instability and/or engine overheating.

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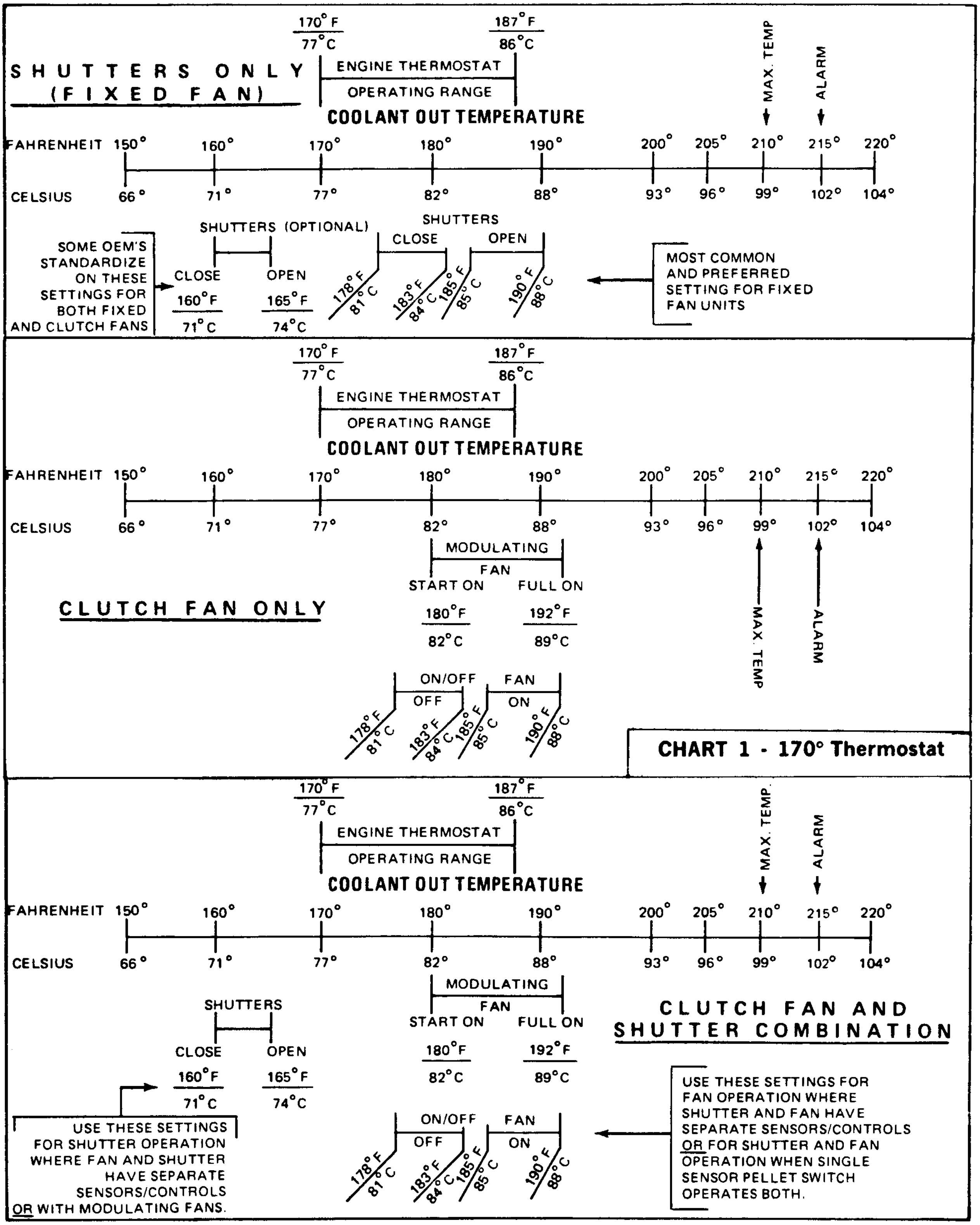
A badly adjusted operating sequence can also have a detrimental effect on the life of the "add on" components as well.

The following charts give the recommended normal temperature settings for various coolant temperature control devices. These settings should not be exceeded, since this will unnecessarily increase the engine coolant and lubricating oil temperature, possibly resulting in serious engine damage.



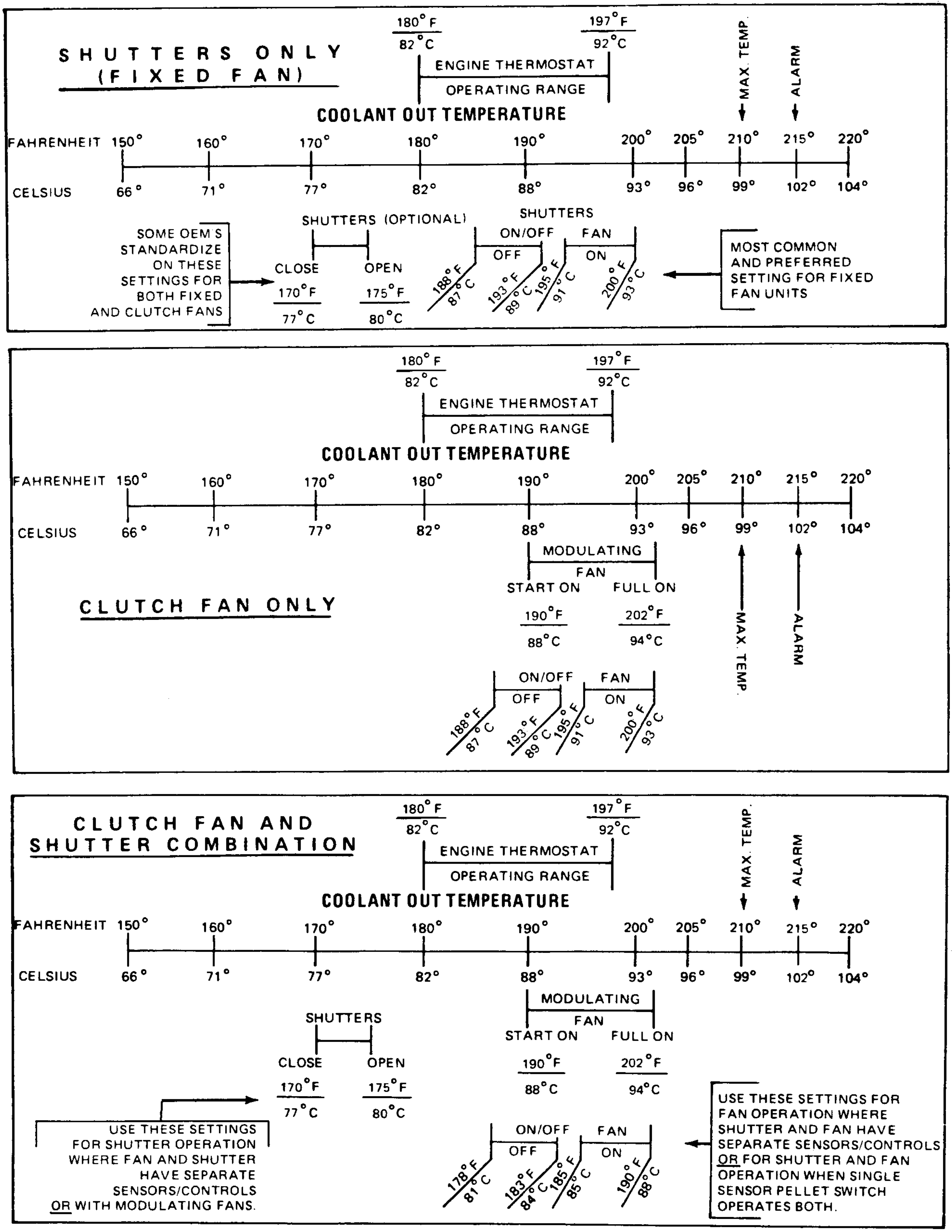


CHART 2 - 180° Thermostat

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Water Pump

A centrifugal-type water pump (Figs. 1 and 2 or 3 and 4) is mounted on top of the engine oil cooler housing (Fig. 5). It circulates the coolant through the oil cooler, cylinder block, cylinder head(s) and radiator.

The pump is belt driven by either the camshaft or balance shaft (In-line engines) or by one of the camshafts (V-type engine).

An impeller is pressed onto one end of the water pump shaft, and a drive pulley is pressed onto the opposite end. The pump shaft is supported on a sealed double-row combination radial and thrust ball bearing. Coolant is prevented from creeping along the shaft toward the bearing by a seal. The shaft and bearing constitute an assembly, and are serviced as such, since the shaft serves as the inner race of the ball bearing. The sealed water pump shaft ball bearing is filled with lubricant when assembled. No further lubrication is required.

Effective with engine serial numbers 2D-27598, 3D-64888, 4D-66635, 6D-66897 and 8D-3815, the water pump assemblies include an impeller and ceramic insert combination (Figs. 3 and 4).

A new seal has been released for the fresh water pumps, effective with engine serial numbers 3D-189023, 4D-202708 and 6D-223092. The new seal has a high grade carbon face, a stainless steel case and a shroud. The former seal had a phenolic face, brass case and no shroud. Because of its design, the new seal provides improved resistance to leakage even after high engine hours or mileage. The former seal and the new seal are completely interchangeable and only the new seal will be available to service fresh water pumps.

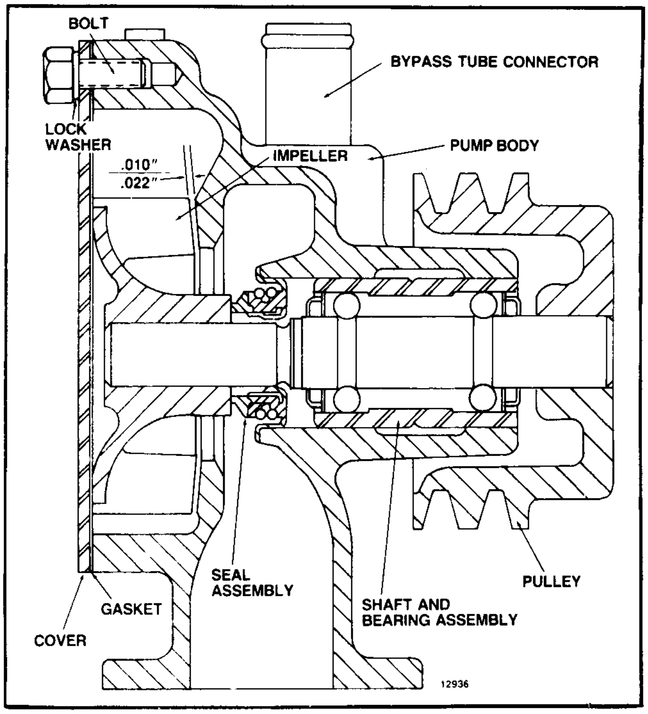

Fig. 1 - Former Water Pump Assembly

Remove Water Pump

1. Remove the radiator cap, open the block and radiator drain cocks, and drain the cooling system.

2. Loosen and remove the water pump belts.

NOTE: An idler pulley is used on some engines to adjust the water pump drive belt tension.

3. Loosen the hose clamps and slide the hose up on the water bypass tube.

4. Remove the five bolts securing the water pump to the oil cooler housing and take off the pump.

Disassemble Pump

1. Note the position of the pulley on the shaft so that the pulley can be reinstalled in the same position when the pump is reassembled. Remove the water pump pulley (Fig. 6).

2. Remove the pump cover and discard the gasket.

3. Press the shaft and bearing assembly, seal and impeller out of the pump body as an assembly, by applying pressure on the bearing outer race with remover J 1930.

NOTE: The bearing will be damaged if the pump is disassembled by pressing on the end of the pump shaft.

4. Use plates J 8329 and holder J 358-1 to press the shaft out of the impeller (Fig. 7).

5. Remove and discard the seal assembly from the pump shaft.

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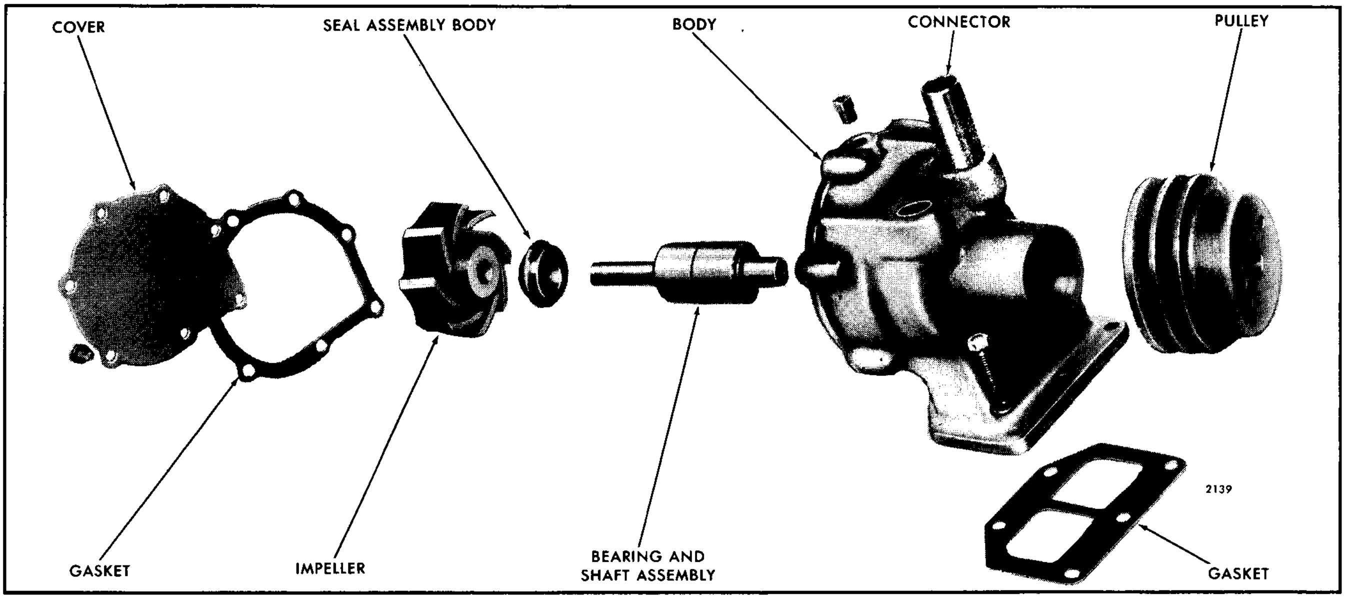

Fig. 2 - Water Pump Details and Relative Location of Parts

Inspection

Wash all of the pump parts, except the bearing and shaft assembly, in clean fuel oil and dry them with compressed air.

> **NOTE:** A permanently sealed and lubricated bearing is used in the bearing and shaft assembly and should not be washed. Wipe the bearing and shaft assembly with a clean lintless cloth.

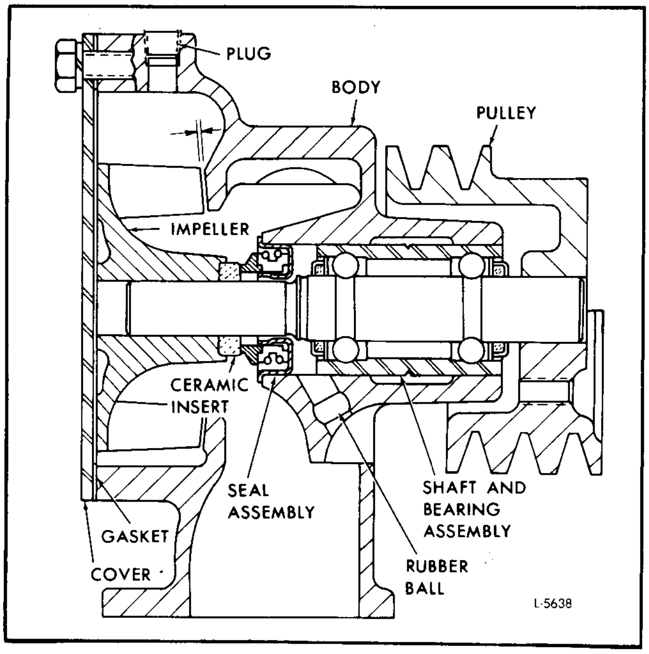

Fig. 3 - Current Water Pump Assembly

Always replace the ceramic insert and bond it to the impeller at overhaul.

Inspect the ceramic insert for cracks, scratches and bond to the impeller. A new ceramic insert must be used if a new seal is installed. If the insert is dmaaged or a new seal is used bond the ceramic insert to the impeller 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 of a buffing wheel to remove the old adhesive, oxide, scale, etc.

2. Wet a clean cloth with a suitable solvent such as alcohol and thoroughly clean the impeller insert area and the grooved side of a new ceramic insert. Then, wipe the parts with a clean, dry cloth.

3. Place the adhesive washer in the impeller bond area with the ceramic insert on top. The polished face of the ceramic insert should be visible to the assembler. Clamp the ceramic 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.

4. 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.

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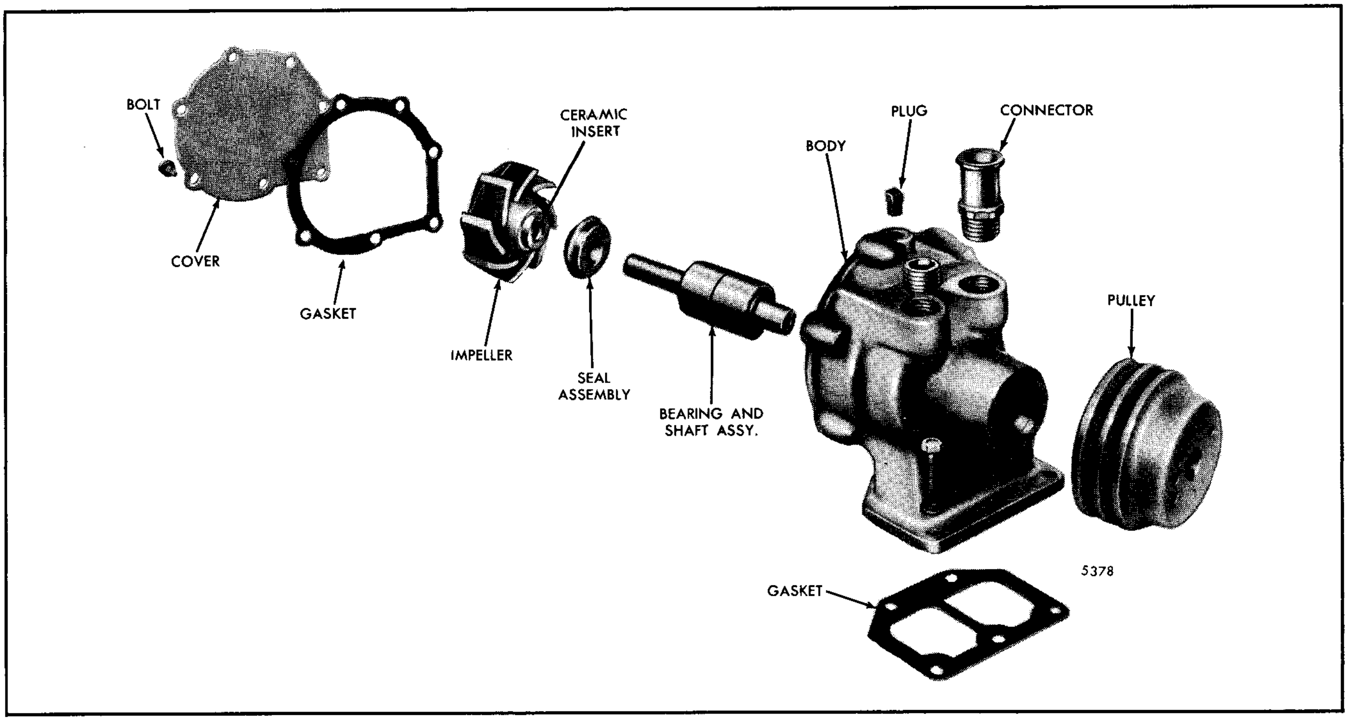

Fig. 4 - Details of Current Water Pump Assembly with Ceramic Seal

NOTE: The face of the ceramic insert must be square with the axis of the tapered bore within .004". The pump shaft may be used as a mandrel for inspection.

5. Remove the impeller from the oven and, after it has cooled to room temperature, install it in the pump. Do not loosen the clamping bolt until the assembly cools. Make sure the mating surfaces of the water seal and the ceramic insert are free of dirt, metal particles and oil film.

Discard the bearing if it has a general feeling of roughness, is tight or has indications of damage.

Examine the 7/16" diameter rubber ball in the current water pump weep hole (Fig. 3). Replace if damaged or deterriated.

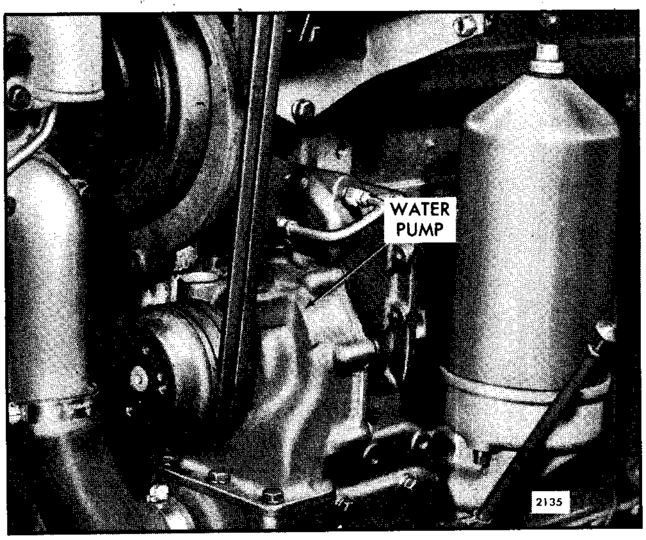

Fig. 5 - Typical Water Pump Mounting

Assemble Pump

1. Use installer J 1930 to apply pressure to the outer race of the bearing (Fig. 8) and press the shaft and bearing assembly into the pump body until the outer race of the bearing is flush with the outer face of the body.

NOTE: The bearing will be damaged if the bearing and shaft assembly is installed by applying pressure on the end of the shaft.

2. To reduce possible coolant leakage, apply a light coat of non-hardening sealant on the outside of a new seal. Then, with the face of the pump body and the bearing outer race supported, install the seal by applying pressure on the seal outer flange only, until the flange contacts the pump body (Fig. 1 or 3). Wipe the face of

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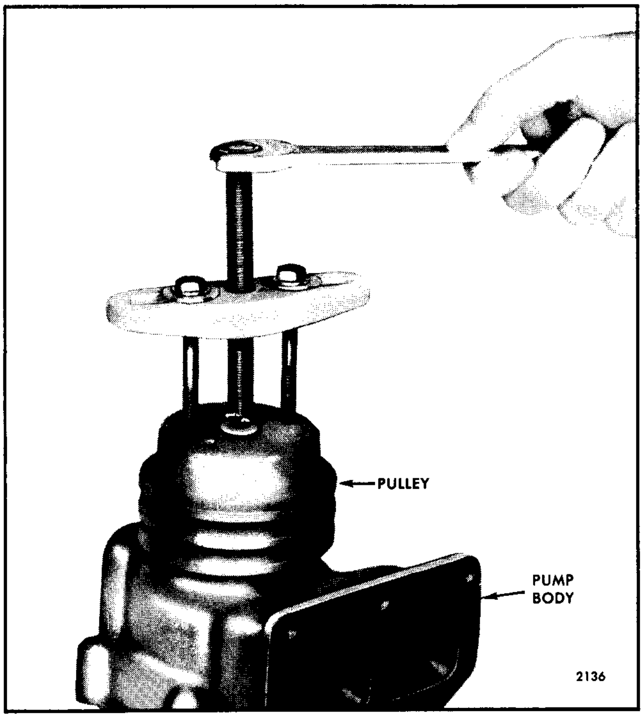

Fig. 6 - Removing Pulley using Puller J 24420-A

the seal with a chamois to remove all dirt and metal particles.

3. Support the pulley end of the shaft on the bed of an arbor press and press the impeller on the shaft until the impeller is flush with the large end of the body.

4. Place the pulley on the bed of an arbor press. Place a suitable rod between the ram of the press and the impeller end of the shaft, then press the shaft into the pulley until the pulley is in its original position on the shaft.

5. Install the cover and a new gasket on the pump body. Tighten the cover bolts to 6-7 lb-ft (8-9.5 Nm) torque.

6. Run the pump dry at 1200 rpm for a minimum of 30 seconds, or as required, to assure satisfactory seating of the seal.

Install Water Pump

1. Affix a new gasket to the flange of the water pump body.

2. Secure the water pump to the oil cooler housing with the five bolts and lock washers.

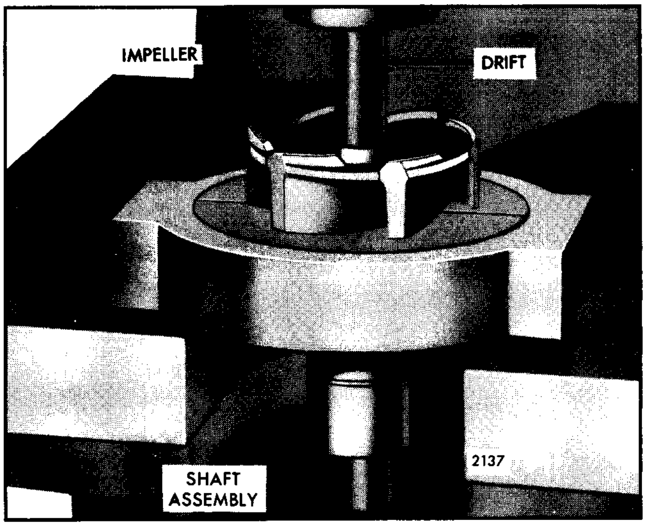

Fig. 7 - Removing Shaft from Impeller with Tools J 8329 and J 358-1

3. Install the hose between the water pump and water bypass tube and tighten the hose clamps.

4. Install and tighten the belts.

NOTE: An idler pulley is used on some engines to adjust the water pump drive belt tension.

5. Close all of the drain cocks and refill the cooling system.

6. Start the engine and check for leaks.

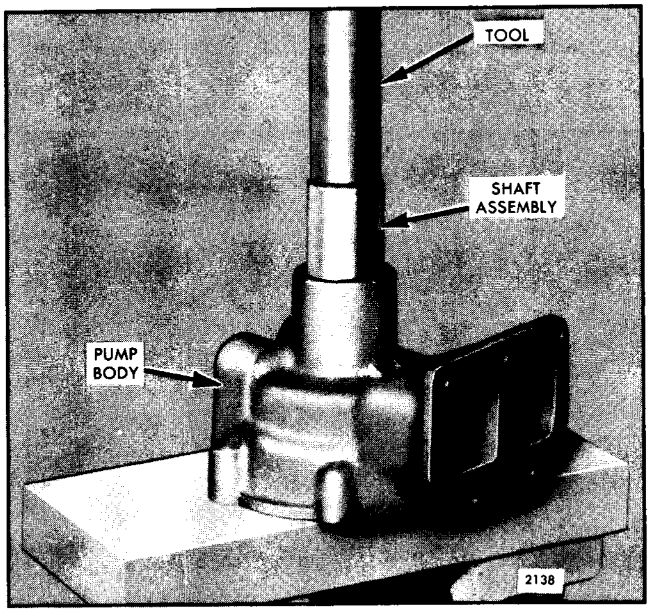

Fig. 8 - Pressing Shaft Assembly into Water Pump using Tool J 1930

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FRESH WATER PUMP IDLER PULLEY ASSEMBLY

The fresh water pump idler pulley assembly is mounted on the upper engine front cover (Fig. 1).

Remove Idler Pulley Assembly

Remove the two attaching bolts and lift the pulley assembly away from the front cover and drive belts.

Disassemble Idler Pulley Assembly

1. Support the pulley, then press the shaft and bearing assembly and bracket from the pulley by applying pressure to the outer race of the bearing (Fig. 2).

2. Support the bracket, then press the shaft and bearing assembly from the idler pulley bracket by applying pressure on the shaft only.

Inspection

Wash the idler pulley bracket and pulley in clean fuel oil and dry them with compressed air. The idler pulley shaft and bearing assembly must not be washed in fuel oil. If the bearing is immersed in cleaning fluid, dirt may be washed in and the fluid and dirt could not be entirely removed from the bearing.

Examine the bracket and pulley for excessive wear or cracks.

Revolve the shaft slowly in the bearing by hand. If rough or tight spots are detected, the bearing and shaft assembly must be replaced.

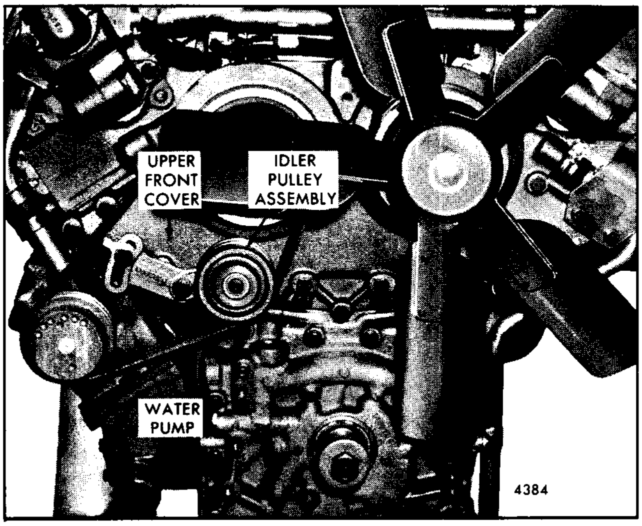

Fig. 1 - Typical Fresh Water Pump Idler Pulley Mounting

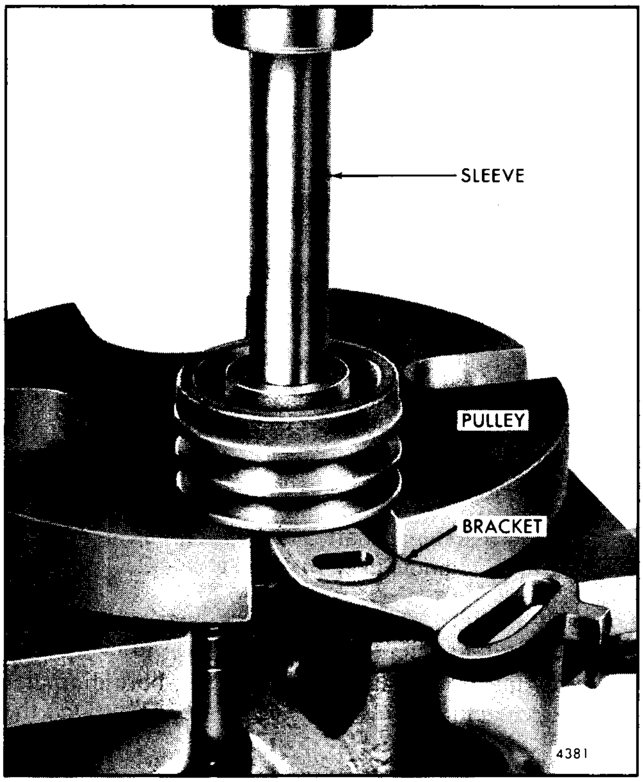

Fig. 2 - Removing Shaft and Bearing Assembly and Bracket from Idler Pulley

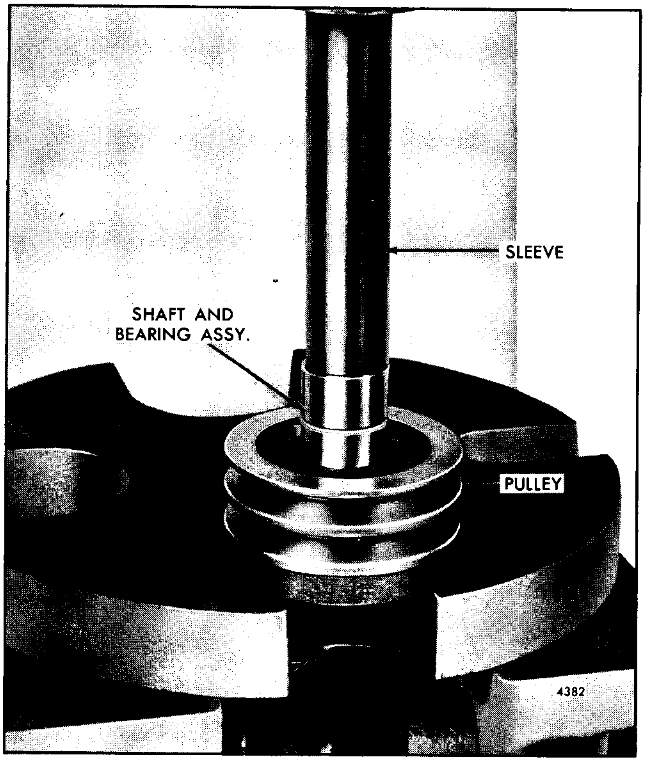

Fig. 3 - Installing Shaft and Bearing Assembly in Idler Pulley

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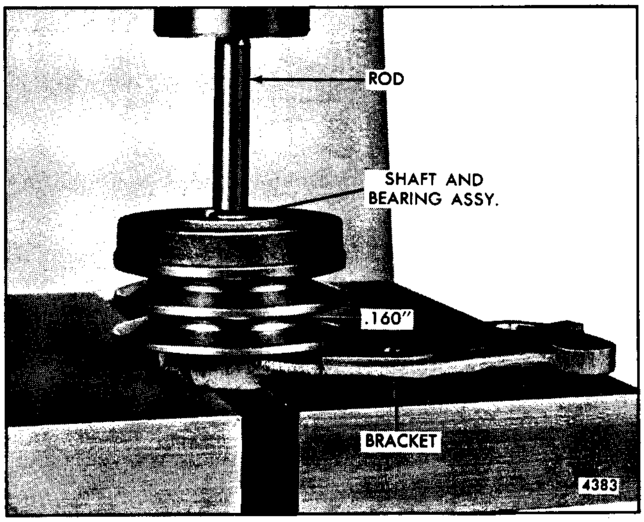

Fig. 4 - Installing Shaft and Bearing Assembly and Pulley in Bracket

On early engines, if the bracket or bearing assembly requires replacement, the complete idler pulley assembly must be replaced. The bearing bore diameter on the current bracket is .6237" -.6247". On the former bracket, the bearing bore diameter is .6242" - .6252".

Assemble Idler Pulley Assembly

1. Apply a minimum of 2500 lbs pressure only on the outer race of the bearing as shown in Fig. 3 and press the bearing and shaft assembly into the idler pulley until the outer race of the bearing is flush with the inside surface of the pulley.

2. With a short rod, apply pressure on the shaft only (Fig. 4) and press the shaft and bearing assembly with the pulley into the idler pulley bracket. The distance between the outer edge of the pulley and the bracket must be .160".

Install Idler Pulley Assembly

1. Attach the idler pulley assembly to the front cover with two bolts and lock washers.

2. Install the water pump drive belts.

3. Adjust the idler pulley assembly so that the drive belts have the proper tension and tighten the bolts.

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THERMOSTAT

The temperature of the engine coolant is automatically controlled by a blocking type thermostat located in a housing attached to the water outlet end of the cylinder head. A single thermostat is used in the In-line engines; the V-type engines use two thermostats, one at each cylinder head.

The bypass system on the V-type engine consists of a crossover tube connecting the two thermostat housings and an outlet tube attached between one thermostat housing and the water pump (Fig. 1). On the In-line engines, a bypass tube is attached between the thermostat housing and the water pump.

At coolant temperatures below approximately 170°F (77°C), the thermostat valve remains closed and blocks the flow of coolant through the radiator or heat exchanger. During this period, the coolant circulates through the cylinder block and head and then back to the suction side of the pump via the bypass tube. As the coolant temperature rises, the thermostat valve begins to open, restricting the bypass system and permits the coolant to circulate through the radiator or heat exchanger. When the valve is fully open, the bypass system of the V-type engine is completely blocked off and all of the coolant circulates through the radiator. However, with the valve fully opened in the In-line engine, a very small portion of the coolant will continue to circulate through the bypass tube, while the major portion will pass 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 (see Section 13.2), remove and check the thermostat(s).

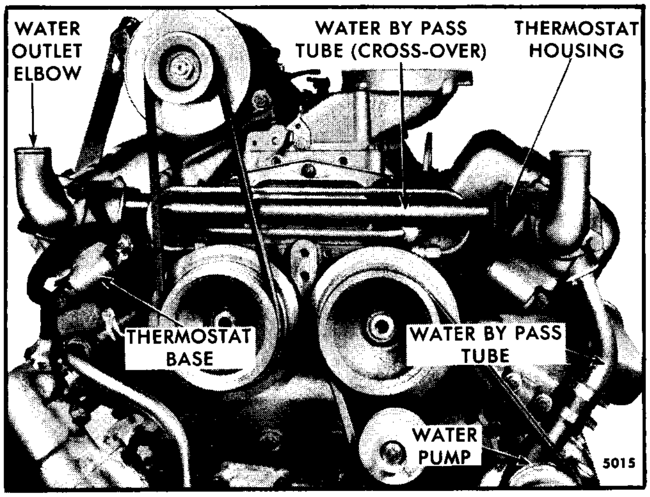

Fig. 1 - Thermostat Housings (6V Engine)

NOTE: There are areas where approved fuel (less than 0.5% sulfur) is not commercially available or economically feasible to obtain. It is important to keep the engine cooling system temperature of these engines on the high side of normal to prevent the condensation of sulfur trioxide gas, which combines with combustion water to form sulfuric acid. Therefore, install a 180°or 190°F (82°or 88°C) temperature thermostat and modify the cooling system to provide rapid warm-up in order to maintain coolant temperature at a minimum of 175°F (80°C).

Remove Thermostat

1. Drain the cooling system to the necessary level by opening the drain valves.

2. Remove the hose connections between the thermostat housing water outlet elbow and the radiator or heat exchanger.

3. Loosen the bolts and remove the water outlet elbow from the thermostat housing on the In-line engine (Fig. 2). Take out the thermostat.

4. On the V-type engine, remove the crossover bypass tube which is located between the thermostat housings. Also disconnect the bypass tube between the water pump and the thermostat housing (Fig. 3). Remove the gaskets. Then loosen the bolts and remove the thermostat housings from their bases. Remove the thermostats and remove and discard the thermostat seals.

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 water, overheating of the engine will result. A thermostat which is stuck in a 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 a build-up of carbon deposits on the pistons, rings and valves.

The operation of the thermostat may be checked by immersing it in a container of hot water (Fig. 4). Place a thermometer in the container, but do not allow it to touch the bottom. Agitate the water to maintain an even temperature throughout the container. As the

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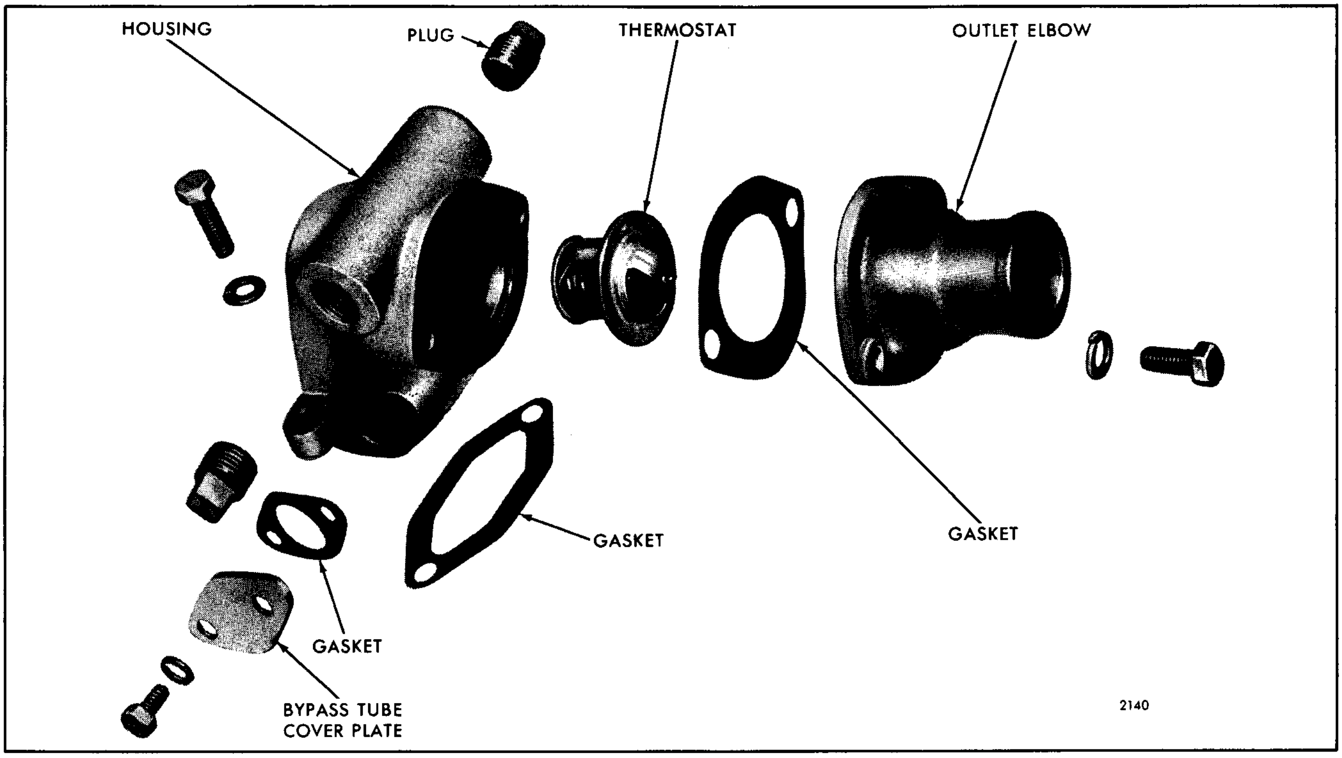

Fig. 2 - Thermostat Housing Details and Relative Location of Parts (In-Line Engine)

water is heated, the thermostat valve should begin to open when the temperature reaches the opening temperature stamped on the thermostat.

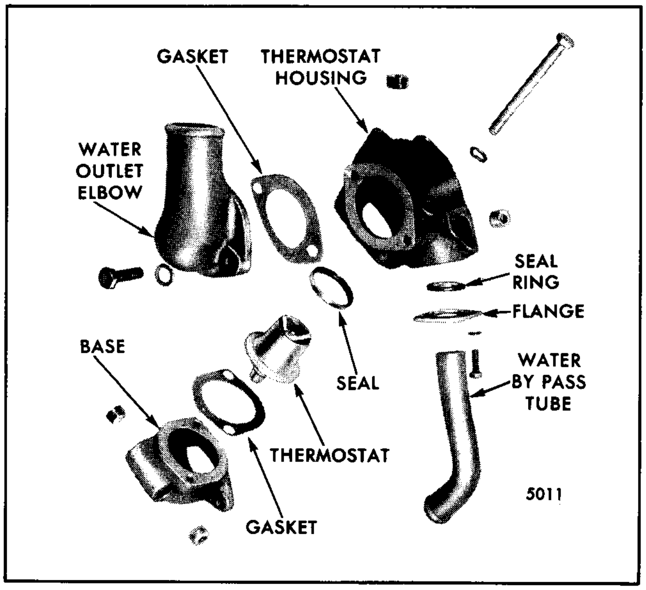

Fig. 3 - Thermostat Housing Details and Relative Location of Parts (V-Type Engine)

NOTE: Current 6V-53 automotive engines use thermostats with a range of 180-190°F (82-88°C). Interchangeability with the former 170-190°F (77-88°C) thermostats is not affected. However, the higher range of the new thermostats may affect operation of shutters where used.

Clean the thermostat seating surface in the thermostat housing and base or the water outlet elbow.

Check the bleed hole in the thermostat housing to be sure it is open (Fig. 5).

NOTE: The early 6V-53 thermostat housing had three bleed holes. Current housings have one bleed hole. If an excessively long warm up period is encountered with the former thermostat housing (three bleed holes), plug two of the bleed holes with No. 4 drive screws.

Drill a 3/32" diameter hole in the thermostat housing used on In-line industrial engines built prior to serial number 2D-603, 3D-011 or 4D-094 (refer to Fig. 6). This will provide a coolant drain hole for the bypass cavity in the housing.

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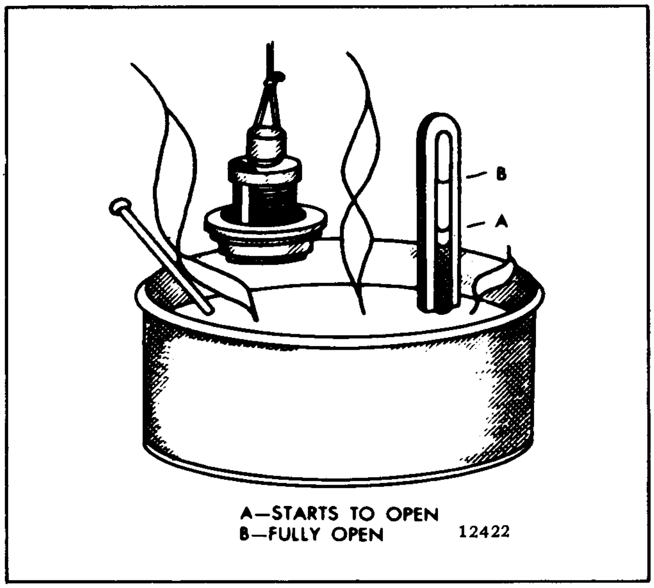

Fig. 4 - Checking Thermostat Operation

Install Thermostat

Refer to Figs. 2 and 3 and install the thermostat(s) as follows:

IN-LINE ENGINE:

1. Place a new gasket on the thermostat housing.

2. Insert the thermostat into the housing.

3. Install the water outlet elbow and secure it to the housing with two bolts and lock washers.

4. Connect the hose from the radiator or heat exchanger to the water outlet elbow, align and tighten the hose clamps.

V-TYPE ENGINE:

1. Install new seals in the thermostat housings. Position the seals so the lips face away from the thermostats. Press the seals in with seal installer J 22091 and handle J 7079-2.

2. Place a new gasket on each thermostat housing base.

3. Insert a thermostat in each base.

4. Install the thermostat housings and secure the housings with bolts and lock washers.

NOTE: Exercise care to prevent damage to the thermostat seals.

5. Place new seals on the crossover bypass tube, then reinstall the tube.

6. Use new gaskets and attach the water outlet elbows to the thermostat housings. Secure the elbows with bolts and lock washers.

7. Place a new seal ring on the upper end of the bypass tube and install the tube between the thermostat housing and the water pump.

8. Install the hoses between the radiator or heat exchanger and the water outlet elbows and secure them with the hose clamps.

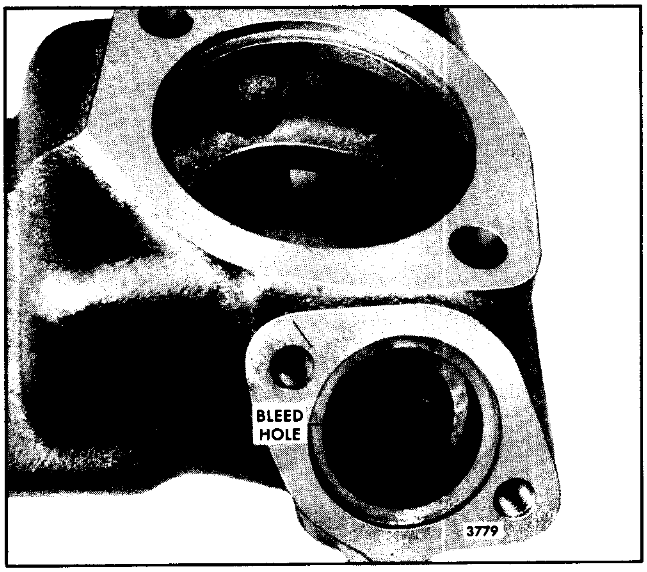

Fig. 5 - Bleed Hole in Thermostat Housing (V-Type Engine)

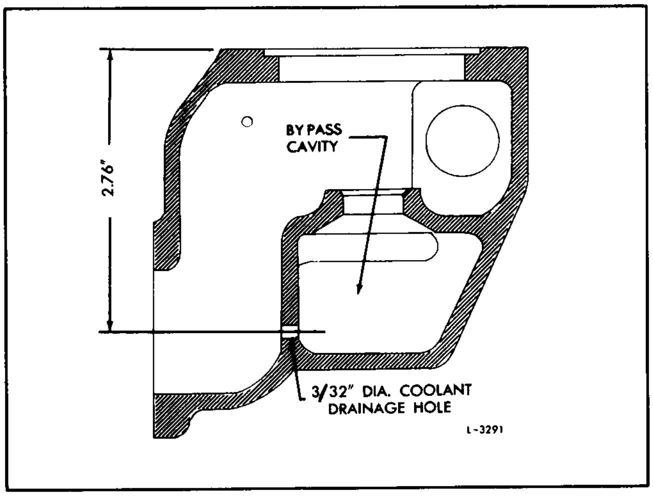

Fig. 6 - Cross-Section of Thermostat Housing (Early Industrial In-line Engine)

After the thermostats have been installed, close all of the drain cocks and fill the cooling system. Vent the system as outlined in Section 5. Then start the engine and check for leaks.

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RADIATOR

On some engines 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 (Fig. 1) 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 a recommended type coolant is used (refer to Section 13.3).

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

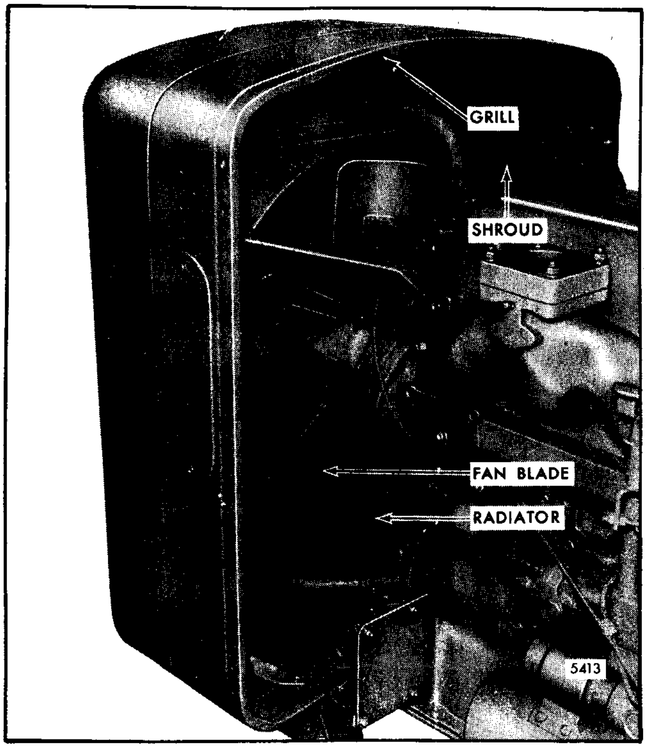

Fig. 1 - Typical Radiator Mounting (In-Line Engine)

should be checked periodically (refer to *Preventive Maintenance,* Section 15.1). A faulty fan, inoperative or misadjusted shutterstats could also cause an engine to overheat.

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 the 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 gasoline, 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. To avoid damage to the radiator fins, do not use high air or water pressure.

> **CAUTION:** 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

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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.

To remove the hardened scale, a direct chemical action is necessary. A flushing compound such as sal-ammoniac, 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 fifteen 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 a recommended coolant (refer to *Engine Coolant* in Section 13.3). 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

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 bolts, lock washers and nuts which attach the fan guards to the fan shroud.

3. Loosen the hose clamps at the radiator inlet hose and remove the hose.

4. Loosen the hose clamps at the radiator outlet hose and remove the hose.

5. Use a chain hoist and a suitable lifting device (through the filler neck or otherwise) and draw the hoisting chain taut to steady the radiator.

6. Remove the bolts, lock washers, plain washers, nuts and bevel washers (if used) which attach the radiator shell to the engine base.

NOTE: Since the shroud is very close to the tips of the fan blades, to prevent damage to these parts great care must be exercised whenever the radiator is removed.

7. Lift the radiator enough to clear the engine base and move it directly away from the engine.

8. Remove the fan shroud and the radiator core by removing the bolts securing them in place.

Inspection

Clean all radiator parts thoroughly, removing dirt, scale and other deposits.

Examine the radiator for cracks or other damage. The core fins should be straight and evenly spaced to permit a full flow of cooling air. The core tubes should be clean inside and outside and have no leaks.

If repainting the radiator core becomes necessary, it is recommended that a thin coat of dull black radiator paint or another high quality flat black paint be used. Ordinary oil paints have an undesirable glossy finish and do not transmit heat as well.

Check all radiator hoses and clamps. Replace cracked and deteriorated hoses and damaged clamps.

Install Radiator

Assemble the radiator, grill and shroud. Then mount the assembly on the engine base by reversing the procedure given for removal.

Check for clearance between the tips of the fan blades and radiator shroud after the radiator is in place. There must be sufficient clearance or damage to the fan and shroud will result when the engine is started. Use shims between the radiator and base, if necessary, to obtain the proper clearance.

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CROSS-FLOW DESIGN RADIATOR

Certain 6V-53 on-highway vehicle engines incorporate a cooling system radiator of a cross-flow design rather than the conventional down-flow design.

As the name implies, a cross-flow radiator has a core of horizontally positioned tubes and coolant flow moves across rather than down the radiator.

Two reasons for using the cross-flow design radiator are:

1. The reduced height of the radiator permits a lower hood line design, thus providing better road visibility.

2. The area ahead of the engine crankshaft and below the radiator is open for mounting a power take-off unit, if desired.

The intent here is to describe briefly how the cross-flow radiator functions and to identify some of the components unique in the cross-flow system.

One such component is a Y-shaped device called an aspirator (Fig. 2) which is mounted externally on the filler cap side of the radiator and serves to rid the cooling system of air. The aspirator directs coolant under pressure through a venturi where entrapped air inside the radiator is picked up and moved to the supply chamber of the radiator where it is vented. The coolant line providing the drive flow originates at the engine thermostat housing. This hookup provides a flow of coolant to the aspirator regardless of whether the thermostat is open or closed. As the coolant flow passes through the aspirator, its action pulls coolant and any air that is present from the top of the radiator core outlet chamber into an internal "U" tube which vents near the filler cap inside the radiator supply chamber to complete the deaeration process. This "U" tube insures that the entire cooling circuit, other than the supply chamber, remains completely full when the engine is stopped. Also, it keeps the coolant from seeking a common level throughout the system and, thereby, eliminates an aerated system at the next engine start-up.

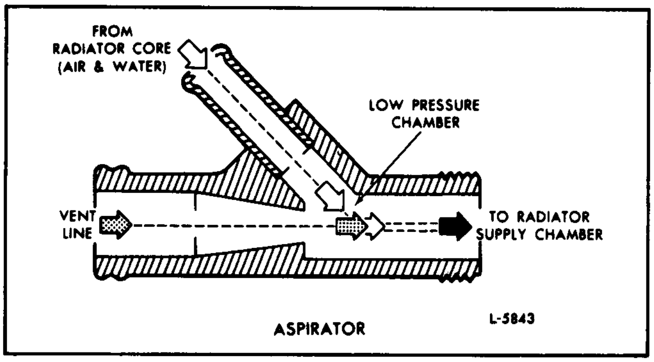

Fig. 2 - Aspirator for Cross-Flow Design Radiator

In order to provide adequate coolant flow through the engine deaeration line when the thermostat is closed, a restricting orifice is used in the engine water pump bypass (Fig. 3). This orifice is 5/8" I.D. and is brazed into the upper end of the water bypass tube that connects the right-hand thermostat housing to the water pump; thus, it becomes a permanent part of the water bypass tube assembly and *must* be used for adequate system performance.

Properly installed hose connections are required for adequate cross-flow radiator efficiency. Figure 3 illustrates the proper hose connections for the 6V-53 installation.

The cross-flow cooling system should always be drained at the radiator drain cock. This will insure that both the radiator and internal "U" tube is empty. If the "U" tube is not emptied, refilling the system will prove difficult.

Due to the design of the cross-flow radiator, air may be trapped inside of the radiator during the fill process resulting in a false coolant level reading. Therefore, after filling the cooling system, the engine should be run approximately ten minutes at 1200-1400 rpm so that any entrapped air can be vented. Generally, additional coolant (approximately 3 to 4 quarts or 2.8 to 3.8 liters) will be required to bring the coolant to the proper level.

For efficient operation of the cross-flow radiator system, it is important that no leak exists between the radiator core and the supply tank. If an internal leak

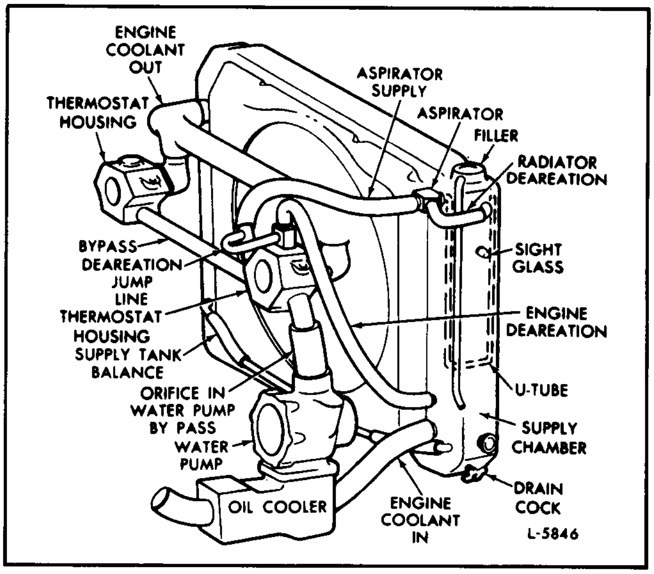

Fig. 3 - Cross-Flow Design Radiator

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has developed between the radiator core and the supply tank, it can cause the cooling system to become aerated at low speed and following engine shut down. The radiator should be tested periodically for possible internal leaks. To determine if a leak is present, proceed as follows:

1. Remove the radiator cap and run the engine for approximately ten minutes at high idle to completely deaerate the cooling system. While the engine is running, add additional coolant to the supply chamber to bring the coolant level to the bottom of the filler neck.

2. Stop the engine and drain 4 quarts (3.8 liters) of coolant from the radiator.

3. Start and run the engine at high idle for approximately ten minutes and observe the coolant level.

4. Stop the engine and again observe the coolant level. If the coolant rises substantially in the supply tank, an internal leak is present and immediate corrective action should be taken to repair the leak. If the coolant level remains constant or falls, the system is satisfactory.

5. After the test is completed, refill the cooling system to the proper coolant level.

If the leak situation is not corrected, the engine will be operating with an aerated coolant for abnormal periods of time which could lead to an engine failure.

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COOLANT PRESSURE CONTROL CAP

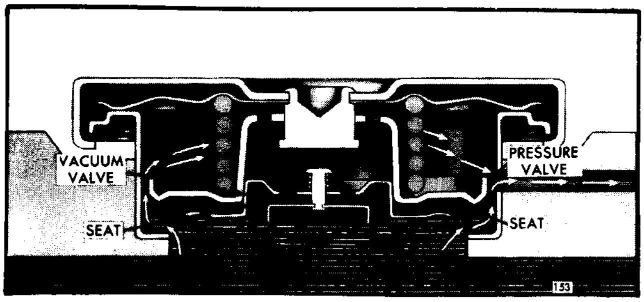

Fig. 1 - Pressure Control Cap (Pressure Valve Open)

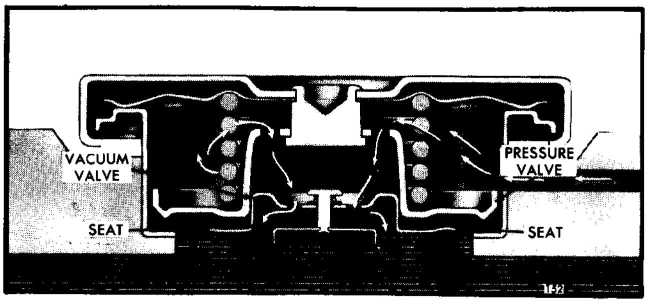

Fig. 2 - Pressure Control Cap (Vacuum Valve Open)

The radiator (or expansion tank) has a pressure control cap with a normally closed valve. The cap, with a number 7 stamped on its top, is designed to permit a pressure of approximately seven pounds (48 kPa) in the system before the valve opens. The cap with a number 9 stamped on tis top, is designed to permit a pressure of approximately nine pounds (62 kPa) 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.

CAUTION: Use extreme care while 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 with tester J 22460-01 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 is not open at .625 psi (4.3 kPa) - (differential pressure), replace the pressure control cap.

It is recommended that all 53 on-highway vehicle engines use a minimum 9 psi (62 kPa) pressure control cap. If the pressure valve does not open between 8 psi (55 kPa) and 10 psi (69 kPa) or the vacuum valve does not open at .625 psi (4.3 kPa) - (differential pressure), replace the pressure control cap.

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ENGINE COOLING FAN

The engine cooling fan is driven by a pair of V-drive belts from the crankshaft pulley (Fig. 1) or driven directly by the crankshaft (Fig. 2). Because of high vibration loads on certain applications, a new 22 " five blade type fan with a thicker spacer is now being used on the In-Line 53 engines as required. This is effective with engine serial number 4D-154007. The former and new fan assemblies are interchangeable on an engine, but only the new fan assembly is serviced.

Effective with engine serial numbers 2D-28185, 3D-66957 and 4D-68816, new fan hub assemblies are being used on the In-line engines. The new assemblies are similar to the integral cast shaft and bracket design, with tapered roller bearings, currently used on the V-type engines (Fig. 5). A new pulley hub assembly similar to the present hub assembly is now being used on certain four and six cylinder 53 Series engines to extend operational life under severe dirt conditions. It includes a front ball bearing and a rear roller bearing along with a hub cap (with relief valve), a dust cap and a grease fitting in the fan pulley hub (Fig. 8).

The belt-driven fan is bolted to a combination fan hub and pulley which turns on a sealed ball bearing assembly (former In-Line engines), two tapered roller bearings (present V-type and In-Line engines) or a front ball bearing and a rear roller bearing (new 4-53 and 6V-53 engines). The crankshaft driven fan is bolted to the crankshaft pulley.

Lubrication

The sealed ball bearing, used in the fan hub assembly shown in Fig. 3, is pre-lubricated and requires no further lubrication.

Tapered roller bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled. Refer to Section 15.1 for the maintenance schedule.

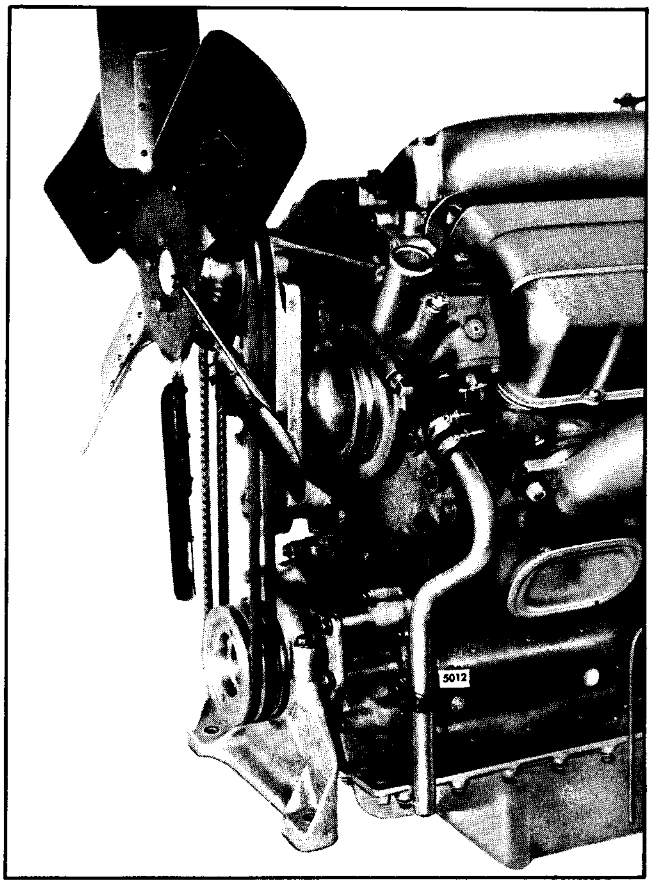

Fig. 1 - Belt-Driven Fan Mounting (V-Type Engine)

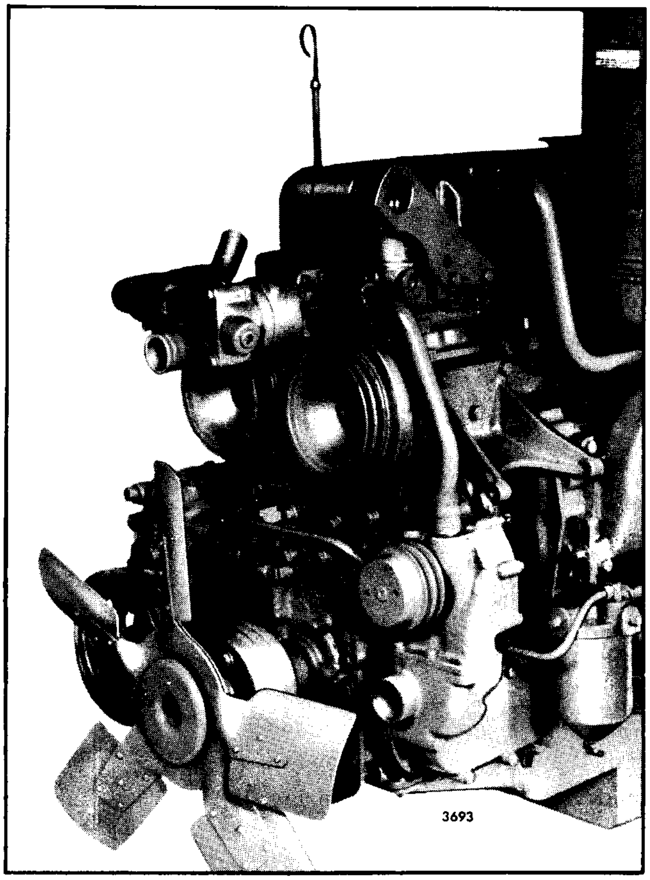

Fig. 2 - Crankshaft-Driven Fan Mounting (In-Line Engine)

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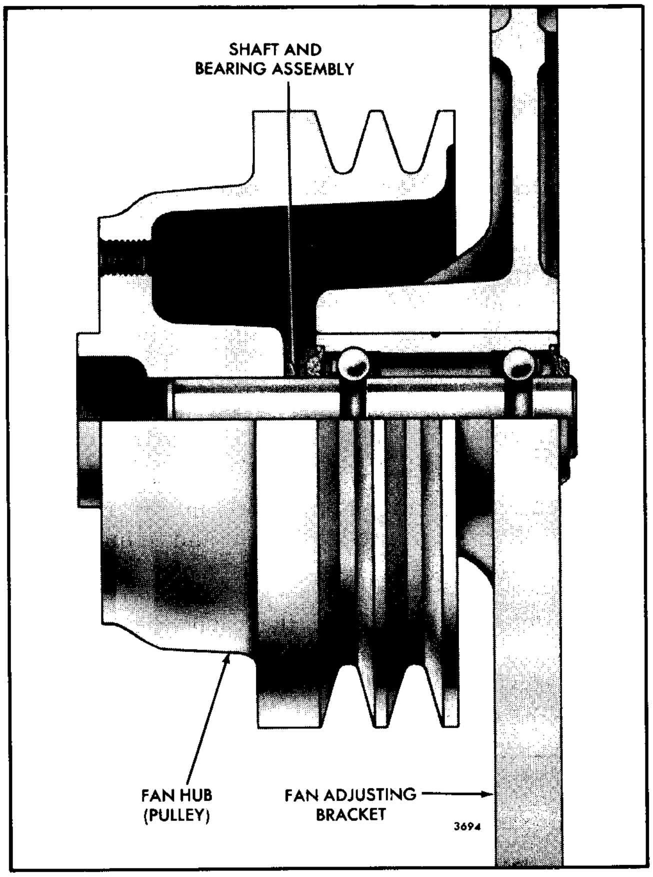

Fig. 3 · Ball Bearing Type Fan Hub Assembly (In-Line Engine)

Fan Belt Adjustment

Adjust the fan belts periodically as outlined in Section 15.1.

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 fan belts and fan guards.

2. Remove the attaching bolts and lock washers and remove the fan and spacer (if used).

NOTE: If insufficient clearance exists between the fan and radiator, remove the fan, hub and adjusting bracket as an assembly.

3. Loosen the fan hub adjusting bracket bolts and

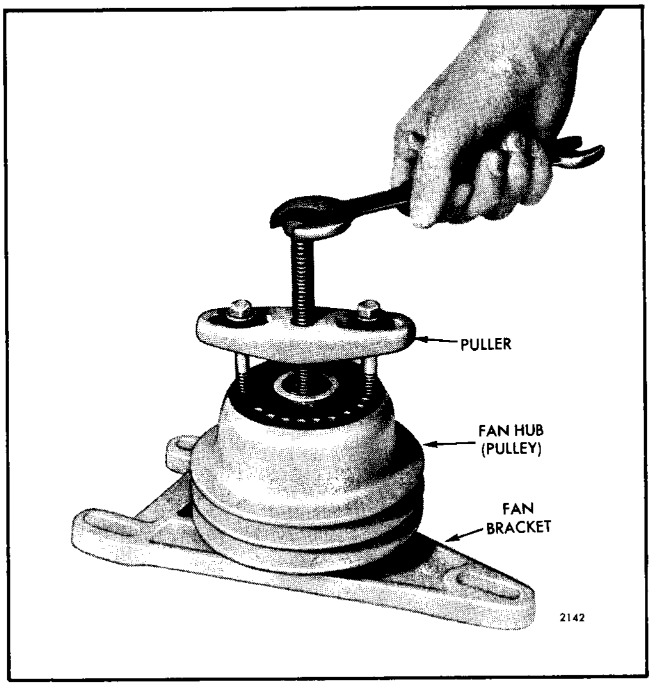

Fig. 4 · Removing Fan Hub (Pulley)

remove the drive belts. Then withdraw the bolts and washers and remove the hub and bracket assembly from the engine.

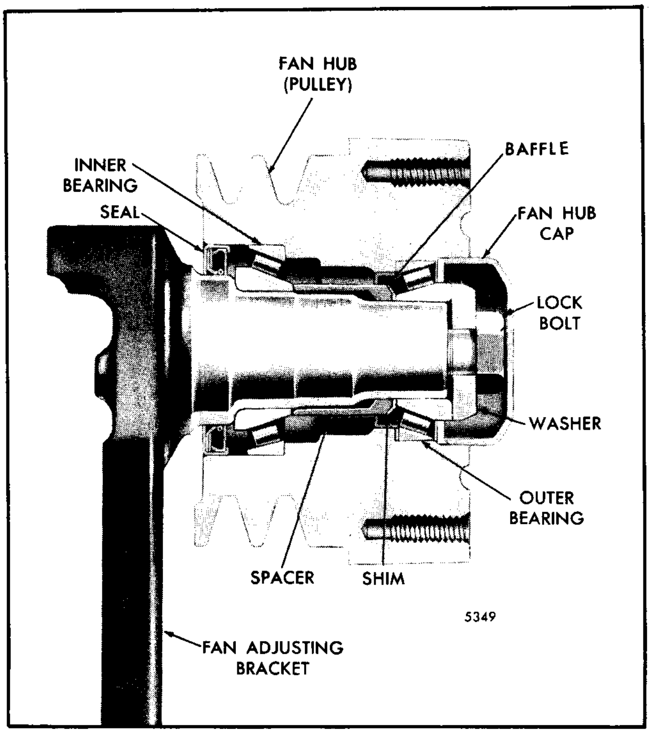

Fig. 5 · Roller Bearing Type Fan Hub Assembly (In-Line Engine)

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Disassemble Hub and Adjusting Bracket

IN-LINE ENGINES (Ball Bearing Type Hub):

1. Refer to Fig. 3 and measure the distance between the rear face of the rim on the pulley and the rear face (machined) of the fan adjusting bracket. Record this measurement for reassembly purposes.

2. Remove the fan hub from the shaft with a puller as shown in Fig. 4.

3. Place the bracket assembly in an arbor press. Then place a suitable sleeve over the shaft and against the outer race of the bearing and press the bearing and shaft assembly from the bracket.

NOTE: Damage to the bearing will result if force is applied to the shaft.

IN-LINE ENGINES (Roller Bearing Type Hub):

1. Refer to Fig. 5 and remove the fan hub cap.

2. Remove the hub bolt and washer.

3. Withdraw the hub and bearing assembly from the shaft. It may be necessary to tap the end of the shaft with a soft hammer to loosen the hub assembly.

4. Remove the oil seal and bearing from the fan hub.

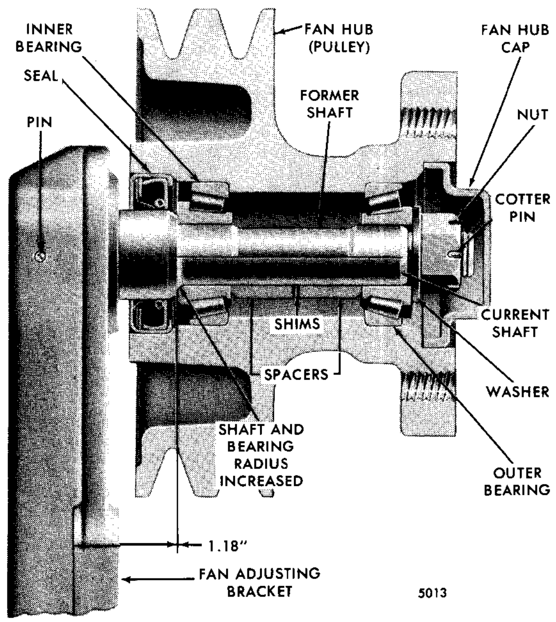

Fig. 6 - Shaft Type Fan Hub Assembly (6V Engine)

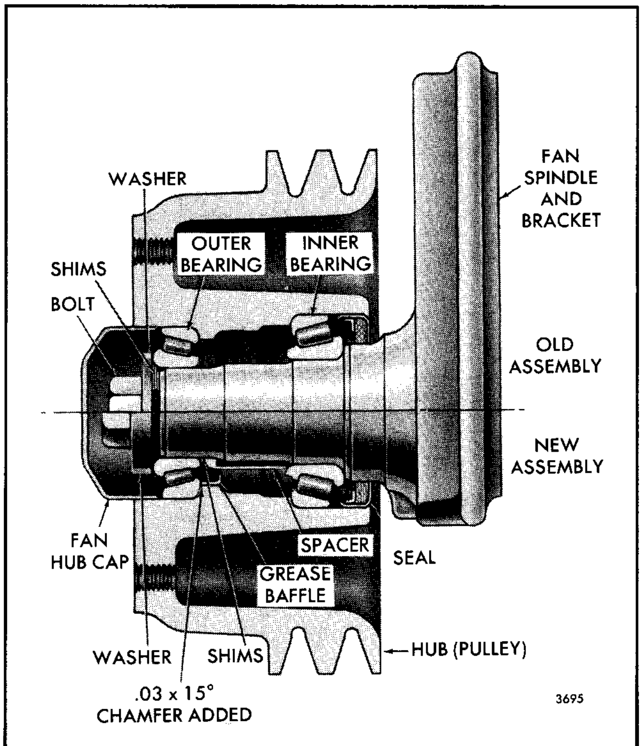

Fig. 7 - Spindle Type Fan Hub Assembly (6V and 8V Engine)

5. Remove the bearing spacer, shims and grease retainer.

4-53 and V-TYPE ENGINES:

1. Remove the fan hub cap (if a spacer and cap assembly were not used).

2. Remove the hub retaining cotter pin, nut and washer (Fig. 6) or the bolt and special washer (Fig. 7 and 8). Also remove the shims if the former type fan hub assembly illustrated in Fig. 7 is used.

3. Withdraw the hub and bearing assembly from the shaft. It may be necessary to tap the end of the shaft with a soft hammer to loosen the hub assembly.

4. Remove the seal and bearings from the fan hub.

5. Remove the bearing spacer (Fig. 7 and 8) and shims (if the current type hub assembly is used).

Inspection

Clean the fan and related parts with clean fuel oil and dry them with compressed air.

NOTE: Do not wash the permanently sealed bearing which is used in the In-line engine

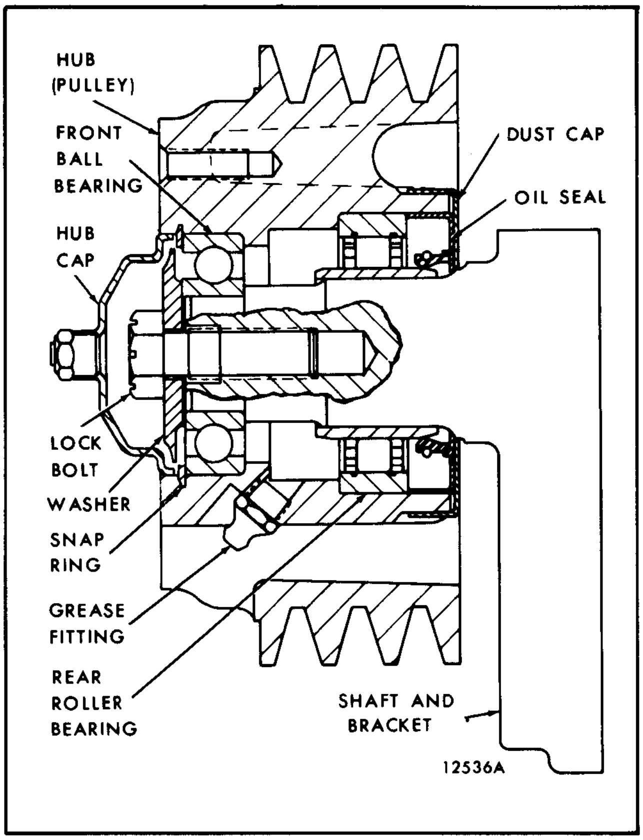

Fig. 8 - Shaft Type Fan Hub Assembly (4-53 and 6V-53 Engines)

roller bearing hub assembly. Wipe the bearing and shaft assembly with a clean lintless cloth.

Hold the inner race (shaft of sealed ball bearing assembly) and revolve the outer race of the bearing slowly by hand. If rough or tight spots are detected, replace the bearing.

The current fan shaft rear bearing inner race should be inspected for any measurable wear. Replace the inner race if the outer diameter is less than 1.7299 ".

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.

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.

New .500 " thick and .800 " thick fan hub spacers and a new fan hub cap replace the former spacer and cap assemblies to provide spacers compatible with the six bolt hole mounting fan hub assemblies. The spacers (individually or in combination) also provide a means for setting the different clearances between the back of the fan blades and front groove of the crankshaft pulley.

The spacers have a flange on one side that serves as a pilot for the fan as well as a spacer pilot for the second spacer when two or more spacers are used together.

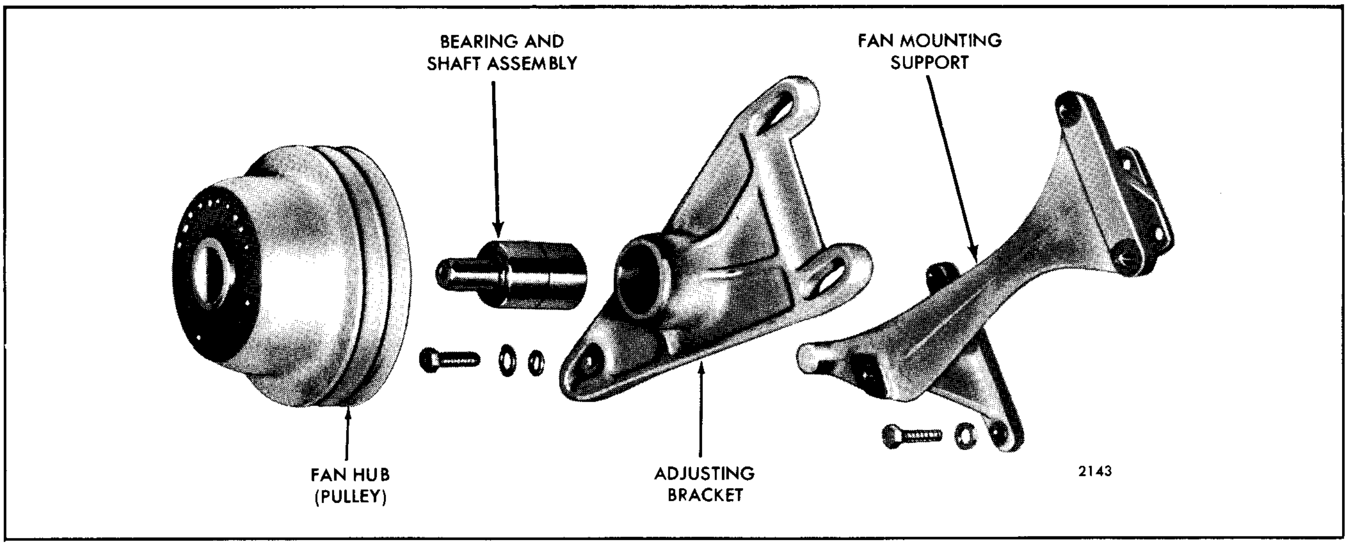

Fig. 9 - Typical Fan Hub and Adjusting Bracket Details and Relative Location of Parts (In-Line Engine)

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EXAMPLE: A former 1.800" thick spacer and cap assembly have been replaced by two .500" thick spacers, one .800" thick spacer and the new fan hub cap.

When replacing the former fan hub spacer, be sure and include the new cap.

The fan hub assembly illustrated in Fig. 6 has been revised. The revisions consist of an increase in the bearing inner race and shaft bearing radii, a hardened hub retaining nut and washer and the addition of spacers and shims on the shaft between the bearings. This type fan hub assembly should be rebuilt with the current parts, especially where the former undercut shaft is used. The current spacers and shims cannot be used with the former shaft.

To replace the shaft, remove the groove pin and press the shaft from the adjusting bracket. Press the new shaft in the bracket to the dimension shown in Fig. 6. Then drill the shaft, using the hole in the bracket as a guide, and install a groove pin.

The spindle-type fan hub assembly illustrated in Fig. 7 has also been revised. A bearing spacer has been added and a new outer bearing, which provides a closer fit on the shaft, replaces the old. A baffle has also been added to retain the grease and assure lubrication at the outer bearing. To facilitate installation of the grease baffle, a .030" by 15° chamfer has been added to the bore in the pulley.

The tapped hole in the end of the shaft has been counterbored and increased in depth from 1.000" to 1.260". A longer hub retaining bolt and a .320" thick washer replaces the former bolt and 1/8" thick washer.

New shims, assembled between the bearing spacer and the inner race of the outer bearing, provide .001" to .006" end play. The former shims, which were assembled between the hub retaining washer and the end of the shaft, provide .002" to .004" end play.

When service is required on the spindle-type shaft, it should be rebuilt with the new components.

Fan hubs equipped with roller bearings (except the sealed type in Fig. 3) may be modified by adding a grease fitting (refer to Section 5.0).

Assemble Hub and Adjusting Bracket

A new, heavy-duty shaft and bearing assembly is now used for high-mounted fan applications. This assembly incorporates both ball and roller bearings (Fig. 11). The former assembly contained two rows of ball bearings. The new shaft and bearing assembly can be identified by the designation "HR-803" stamped on the front of the shaft.

Both former and new shaft and bearing

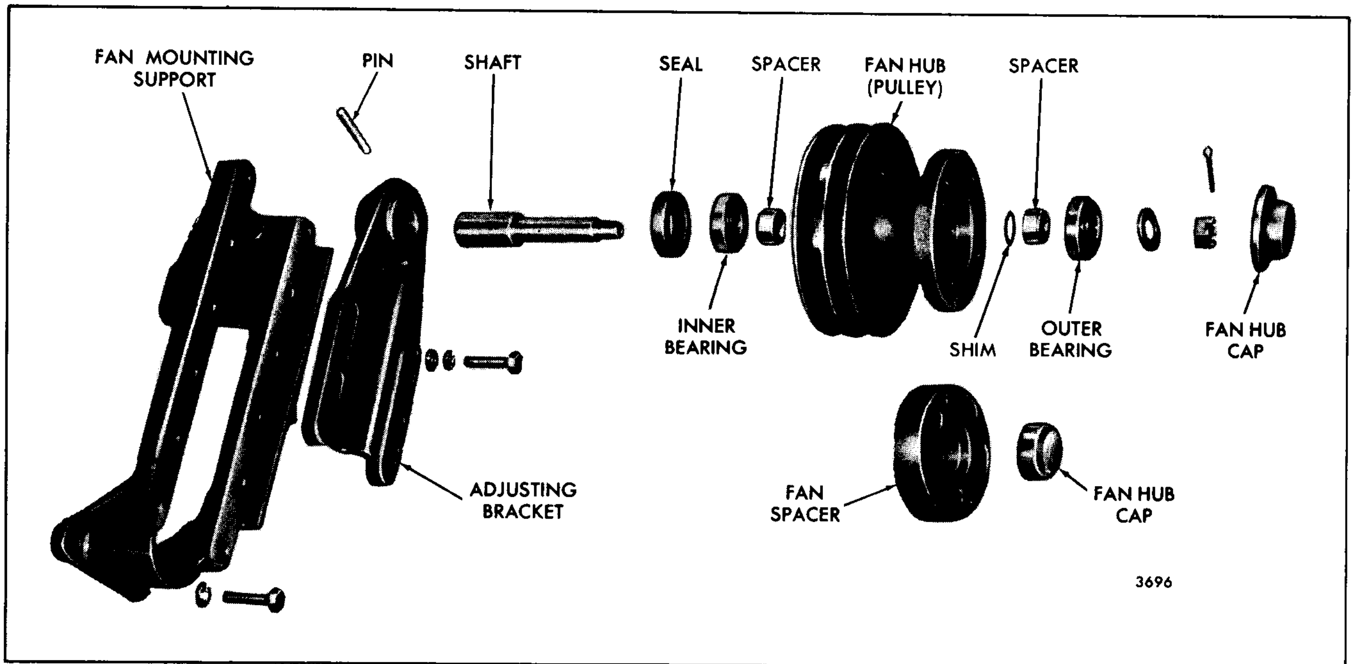

Fig. 10 - Typical Fan Hub, Shaft and Adjusting Bracket Details and Relative Location of Parts (6V Engine)

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assemblies are completely interchangeable, and only the new will be available for service.

Apply Loctite "601" or equivalent to the bearing shaft and the bearing case when rebuilding the fan hub assembly.

IN-LINE ENGINES
(Ball Beaering Type Hub):

Refer to Figs. 3 and 9 and assemble the fan hub and adjusting bracket as follows:

1. Press the shaft and bearing assembly into the adjusting bracket by applying pressure on the outer race of the bearing, using a suitable sleeve, until the bearing is flush with the pulley end of the bracket.

2. Measure the shaft diameter and the pulley bore. It is important that a .001" - .002" press fit be maintained. Then support the bearing end of the shaft and press the fan hub (pulley) on the shaft to the original dimensions taken during disassembly. This will assure proper alignment and clearance of the parts.

The shaft and bearing assembly are permanently sealed and require no lubrication.

IN-LINE ENGINES
(Roller Bearing Type Hub):

Assemble the fan hub and spindle shown in Fig. 5 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 fan hub (pulley).

2. Install the inner bearing with the protruding face of the inner race facing outward from the hub.

3. Install a new seal with the felt-side flush with the outer edge of the hub.

4. Place the hub over the spindle and install the bearing spacer.

5. Pack the cavity approximately 1/4 full with grease and install the grease baffle.

6. Place the shims against the bearing spacer. Then install the outer bearing with the protruding face of the inner race facing outward from the hub.

7. Place the retaining washer with the breakout side toward the bearing. Install and tighten the bolt to 83-93 lb-ft (113-126 Nm) torque while rotating the pulley.

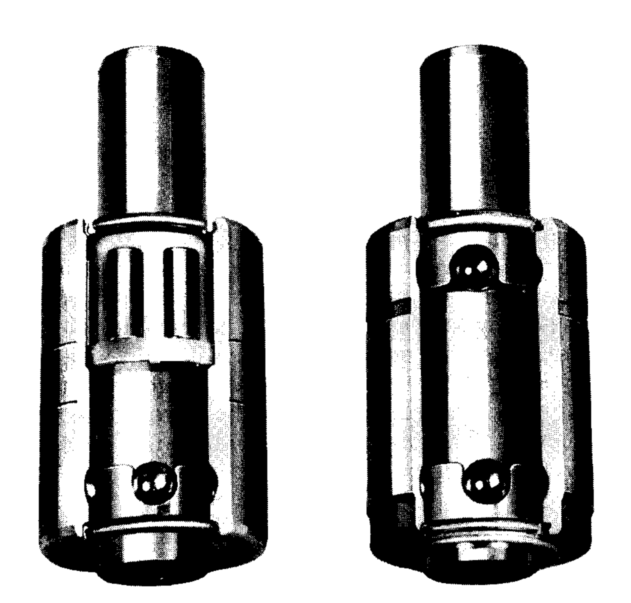

Fig. 11 - Heavy-Duty Shaft and Bearing Assembly

8. Check the end play in the assembly with the spindle (shaft) in a horizontal position. The end play must be within .001" to .006". If necessary, remove the bolt, washer and outer bearing and adjust the number and thickness of shims to obtain the required end play. Shims are available in .015", .020" and .025" thickness. Then reassemble the fan hub and check the end play.

9. Fill a new fan hub cap 3/4 full of grease and install it in the end of the fan hub (pulley).

V-TYPE ENGINE:

Assemble the fan hub, shaft and adjusting bracket shown in Figs. 6 and 10 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 fan hub (pulley).

2. Install the inner bearing with the protruding face of the inner race facing outward from the hub.

3. Install a new seal with the lip of the seal facing toward the bearing. Coat the lip of the seal lightly with grease.

4. Slide the spacers and shims on the shaft (Fig. 6).

NOTE: It may be necessary to install as many as

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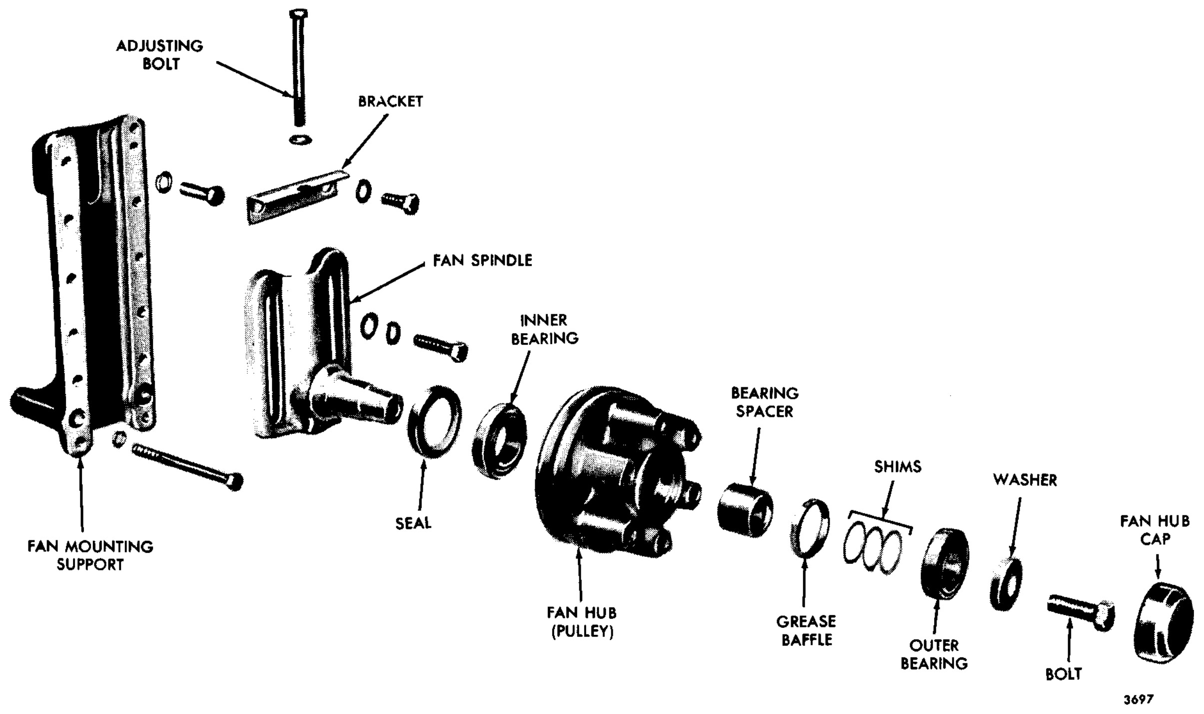

Fig. 12 - Typical Fan Hub and Spindle Details and Relative Location of Parts (6V and 8V Engine)

three .005" and three .010" shims between the spacers on a current shaft incorporated in a former fan hub to achieve the required .001" to .005" end play.

5. Place the hub over the shaft and pack the cavity approximately 1/2 full with grease. Then install the outer bearing with the protruding face of the inner race facing outward from the hub.

6. Secure the hub assembly with the washer and 1/2"-20 nut. Tighten the nut to 35-40 lb-ft (47-54 Nm) torque.

NOTE: Enough shims must be provided to avoid loading directly through the bearing rollers when the nut is torqued. The pulley must turn freely after the nut is tight.

7. Check the bearing end play. If the end play is not within the specified limits (.001" to .005"), remove the hub, add or remove shims and repeat Steps 5 and 6.

8. Fill a new fan hub cap 1/2 full of grease and install it in the end of the fan hub (pulley).

Assemble the fan hub and spindle shown in Figs. 7 and 12 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 fan hub (pulley).

2. Install the inner bearing with the protruding face of the inner race facing outward from the hub.

3. Install a new seal with the felt-side flush with the outer edge of the hub.

4. Place the hub over the spindle and install the bearing spacer.

5. Pack the cavity approximately 1/4 full with grease and install the grease baffle.

6. Place the shims against the bearing spacer. Then install the outer bearing with the protruding face of the inner race facing outward from the hub.

7. Secure the hub with the retaining washer and bolt. Tighten the 1/2"-20 bolt to 83-93 lb-ft (113-126 Nm) torque while rotating the pulley.

8. Check the end play in the assembly with the spindle (shaft) in a horizontal position. The end play must be within .001" to .006". If necessary, remove the bolt,

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washer and outer bearing and adjust the number and thickness of shims to obtain the required end play. Shims are available in .015", .020" and .025" thickness. Then reassemble the fan hub and check the end play.

9. Fill a new fan hub cap 3/4 full of grease and install it in the end of the fan hub (pulley).

4-53 and 6V-53 ENGINES (Front Ball and Rear Roller Bearing):

Assemble the new pulley hub as follows (Fig. 8).

1. Apply Texaco Premium RB grease or an eqivalent Lithium base multipurpose grease to the front ball bearings and the rollers of the rear bearing, before installing them in the pulley hub.

NOTE: Do not overgrease.

2. Install the front ball bearing against the shoulder counterbore in the pulley hub. Then install the snap ring in the pulley hub.

3. Install the rear roller bearing outer ring and roller assembly against the shoulder in the counterbore of the pulley hub.

4. Install a new oil seal with rubber side flush with the outer edge of the hub.

5. Install the dust cap (if used) over the oil seal in the hub.

6. Place the shaft and bracket on wood blocks setting on the bed of an arbor press. Then press the rear bearing inner ring or race onto the fan shaft.

7. Pack the cavity 3/4 full with Texaco Premium RB grease.

8. Install the partially assembled fan hub over the rear bearing inner ring on the shaft and against the shoulder on the pully hub shaft.

9. Secure the hub with the washer and 1/2"-20 lock bolt. Tighten the bolt to 83-93 lb-ft (113-126 Nm) torque while rotating the pulley hub.

10. Fill a new fan hub cap 3/4 full of grease and install it in the end of the pulley hub.

Install Fan, Hub and Adjusting 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 until the fan belts are installed.

2. Install the drive belts and adjust the belt tension as outlined in Section 15.1. If used, install the adjusting bracket, bolt and plain washer shown in Fig. 12.

3. Install the fan (and fan spacer and cap, if used) on the hub and secure it with the 5/16"-18 bolts and lock washers (see Section 5.0).

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HEAT EXCHANGER

The heat exchanger core is mounted inside of the water expansion tank and is sealed at the inlet and outlet ends to prevent the engine coolant from mixing with the raw cooling water.

The heat exchanger core consists of a series of cells through which the engine coolant passes and is cooled by the raw water which is forced between the cells by the raw water pump. However, the core used in the two-cylinder engine models consists of a series of flat tubes through which the raw water passes and cools the engine coolant flowing between the tubes.

To protect the heat exchanger core from the electrolytic action of the raw water, a zinc electrode is located in both the heat exchanger inlet tube and the raw water pump inlet elbow (the two-cylinder engines use only one electrode--at the raw water pump).

That portion of the tank located above the heat exchanger provides a means of filling the engine coolant system as well as space for expansion of the coolant as the temperature rises. An overflow pipe near the top of the water tank vents the tank to the atmosphere.

The length of time a heat exchanger will function satisfactorily before cleaning will be governed largely by the kind of cooling liquid used in the engine and the kind of raw water used.

Clean soft water plus a good commercial rust inhibitor or antifreeze should be used as the engine coolant (refer to Section 13.3) to prevent lime deposits in the heat exchanger core as well as in the engine.

Enough coolant should be maintained in the engine to fill the cylinder block and head and to partially fill the water tank. Allow air space above the coolant in the tank for the increase in volume as the temperature of the coolant rises.

Whenever the heat exchanger fails to cool the engine properly, and the raw water pump is circulating a normal amount of cooling water around the heat exchanger core, the core should be examined for foreign deposits.

Clean Heat Exchanger Core

When foreign deposits accumulate in the heat exchanger to the extent that cooling efficiency is impaired, remove the heat exchanger core and clean it as follows:

Immerse the heat exchanger core in a scale solvent consisting of one-third muriatic acid and two-thirds water to which one-half pound of oxalic acid has been added to each two and one-half gallons of solution. Remove the core when foaming and bubbling stops. This usually takes from thirty to sixty seconds. Flush the core thoroughly with clean hot water under pressure.

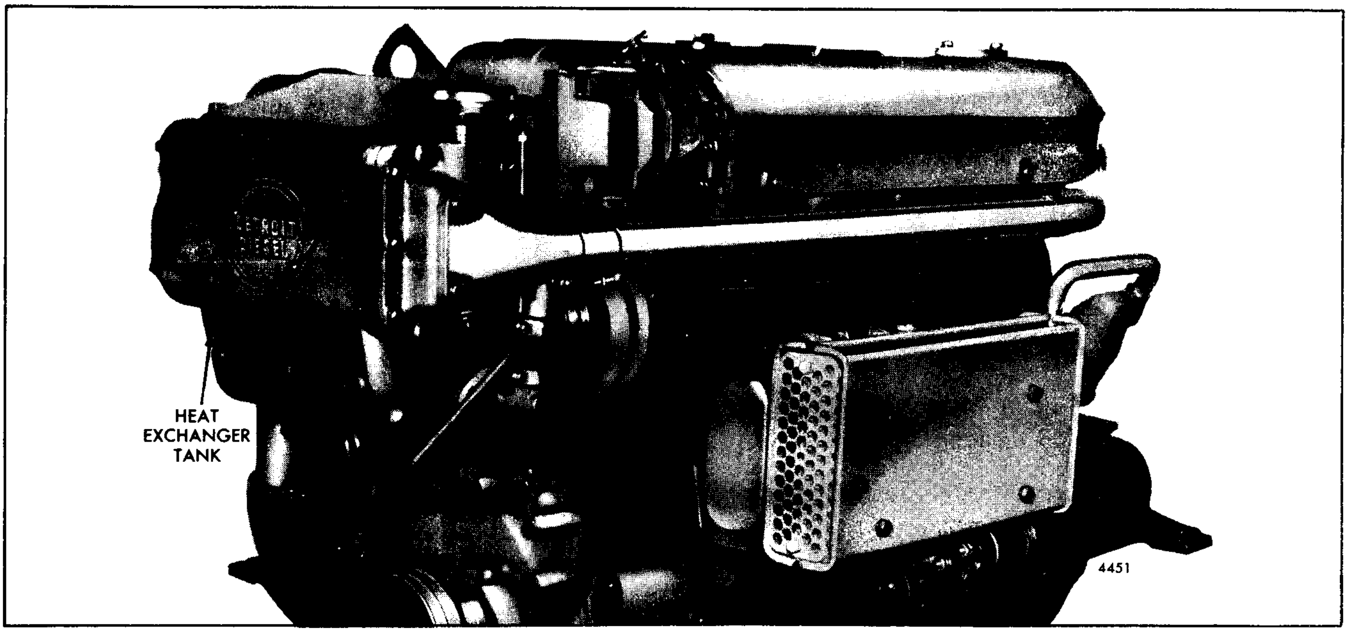

Fig. 1 - Typical Heat Exchanger Mounting In-Line Engine

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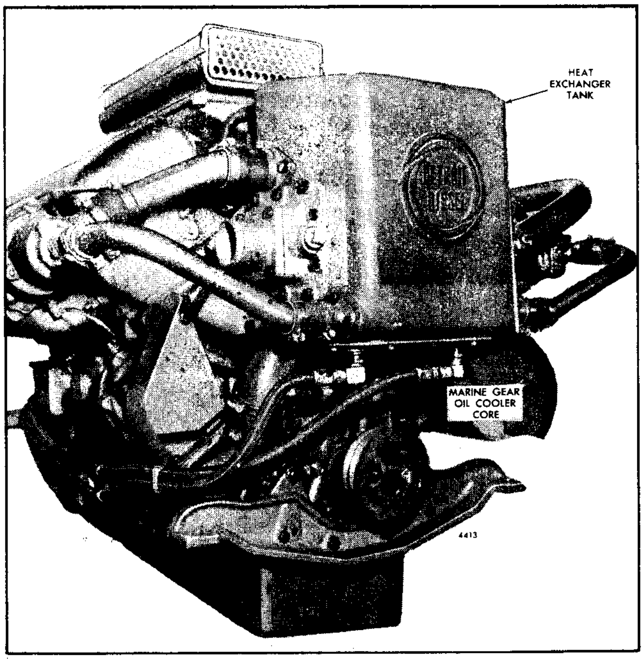

Fig. 2 - Typical Heat Exchanger Mounting
V-Type Engine

To prevent drying and hardening of accumulated foreign substances, the heat exchanger core must be cleaned as soon as possible after removing it from service.

Inspect Zinc Electrode

The zinc electrodes should be examined thirty days after installation. Under normal operating conditions, the electrode will last much longer and need only be examined periodically and replaced when necessary.

Remove Heat Exchanger Core

Remove the heat exchanger core for cleaning and inspection as follows:

1. Drain the engine coolant and raw water system.

2. Remove the heat exchanger core from the two-cylinder engine as follows:

  a. Remove the bolts holding the inlet and outlet covers to the expansion tank and raise the inlet tube away from the tank.

  b. Remove the seal rings from the covers.

  c. Withdraw the heat exchanger core and gasket from the tank.

3. Remove the heat exchanger core from 3, 4, 6, and 8 cylinder engines as follows:

  a. Remove four bolts that hold the inlet tube to the inlet cover. Lower the inlet tube and remove the gasket from the inlet tube flange.

  b. Remove the bolts that hold the inlet cover and heat exchanger core to the tank.

  c. Remove the bolts that hold the outlet elbow to the outlet cover. Lower the outlet elbow and remove the gasket from the flange of the elbow.

  d. Remove the bolts that secure the outlet cover to the tank.

  e. Remove the outlet cover, together with the seals and the seal gland, from the tank.

  f. Withdraw the heat exchanger core and gaskets from the tank.

Install Heat Exchanger Core

After the heat exchanger core has been cleaned and inspected, install it by reversing the sequence of operations given for removal, using new gaskets and seals.

> **NOTE:** To minimize electrolytic action of the raw water, brass pipe plugs are used in the raw water system components wherever pipe plugs are required. Replace any steel plugs that may be found on earlier units with brass plugs.

> **CAUTION:** When installing the heat exchanger core in a two-cylinder engine, the flat sides of the tubes MUST BE in a vertical position to permit uninterrupted flow of engine coolant between the tubes.

Refill the engine coolant fresh and raw water systems. The cooling system must be vented when filling (see Section 5).

Prime the raw water pump, if necessary, then start the engine and check for leaks.

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RAW WATER PUMP (Jabsco)

Raw water for lowering the temperature of the engine coolant is circulated through the heat exchanger by a positive displacement pump (Figs. 1 and 2). The pump is attached to an adaptor which is, in turn, bolted to the flywheel housing. The pump is driven by a gear which meshes with the accessory drive plate mounted on the camshaft gear.

The pump drive shaft is supported by a pre-lubricated, shielded double-row ball bearing. An oil seal prevents oil leakage from the bearing compartment and a rotary type seal prevents water leakage along the shaft.

The current face-type water seal used in In-line engine pumps rides on its own mating surface. The former lip type seal rides on the shaft (Fig. 1).

An impeller splined to the end of the drive shaft is self-lubricated by the water pumped and should not be run dry longer than normally required for the pump to prime itself.

A wear plate in the impeller compartment prevents pump housing wear. This plate may be reversed if wear on the impeller side becomes excessive.

The raw water pump has been revised with the use of a new cam and wear plate assembly to improve the pump priming capabilities. The wear plate is round and conforms with the inside contour of the housing. A slot in the periphery of the wear plate registers with a dowel pin in the end of the cam, which assures a good fit and prevents the rotation of the wear plate with the pump shaft.

The top of the former wear plate was contoured to fit under the cam to prevent its rotation with the shaft.

The current cam and wear plate assembly is interchangeable with the former cam and wear plate and only the current cam and wear plate assembly is serviced.

The pump can be operated in a clockwise or counterclockwise direction. Raw water is drawn into the pump through the inlet opening and discharged through the outlet opening. Both openings are located on the top of the pump housing.

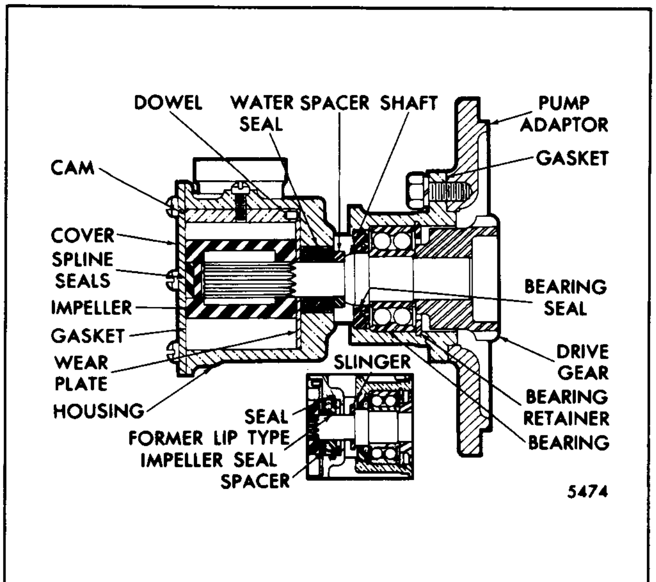

Fig. 1 - Raw Water Pump used on In-Line Engine

Replace Pump Seal

The impeller, cam and wear plate assembly and water seal assembly (Fig. 3) may be serviced without removing the pump from the engine as outlined below:

1. Remove the cover and gasket (Figs. 1 and 2).

2. Note the position of the impeller blades to aid in the reassembly. Then grasp a blade on each side of the impeller with pliers and pull the impeller off of the shaft.

The neoprene spline seal(s) can be removed from the impeller by pushing a screw driver through the impeller from the open end.

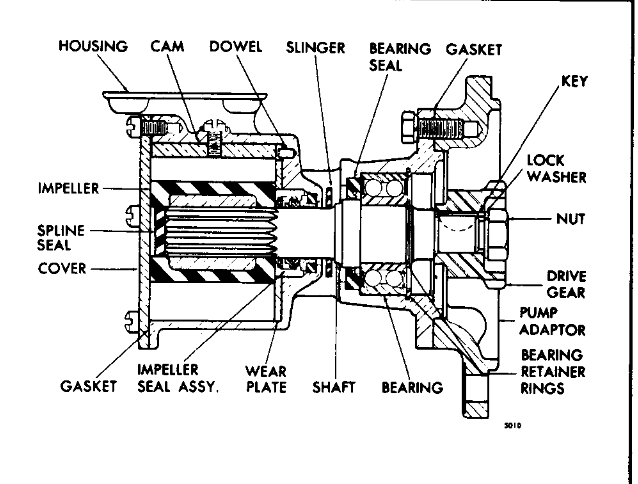

Fig. 2 - Raw Water Pump used on V-Type Engine

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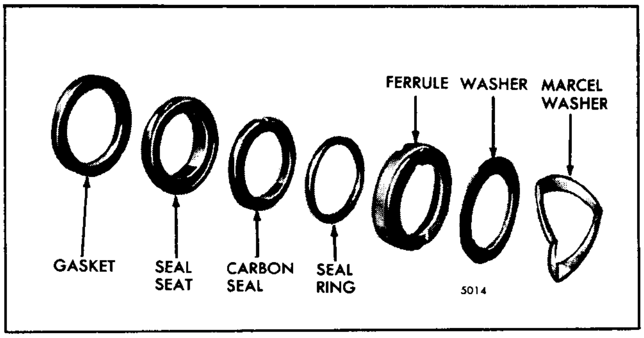

Fig. 3 - V-Type Engine Impeller Seal Detail

CAUTION: If the impeller is reuseable, exercise care to prevent damage to the splined surfaces.

3. Remove the cam retaining screw and withdraw the cam and wear plate assembly.

4. Remove the seal assembly (Fig. 3) from the pump used on the V-type engine by inserting two wires with hooked ends between the pump housing and the seal, with the hooks over the edge of the carbon seal. Remove the seal seat and gasket in the same way.

The seal may be removed from the pump used on the In-line engine by drilling two holes in the seal case and placing metal screws in the holes so that they may be grasped and pulled with pliers. Then remove the rubber seal ring from the groove in the former pump housing.

5. Clean and inspect the impeller, cam and wear plate assembly and water seal. The impeller must have a good bond between the neoprene and the metal. If the impeller blades are damaged, worn or have taken a permanent set, replace the impeller. Reverse the wear plate if it is worn excessively and remove any burrs. Replace the seal, if necessary.

6. Install the seal assembly in the pump used on the V-type engine as follows:

a. If the seal seat and gasket were removed, place the gasket and seal seat over the shaft and press them into position in the seal cavity.

b. Place the seal ring securely in the ferrule and, with the carbon seal and washer correctly positioned against the ferrule, slide the ferrule over the shaft and against the seal seat. Use care to ensure the seal ring is contained within the ferrule so that it grips the shaft.

c. Install the flat washer and then the marcel washer.

Install the face-type water seal and spacer over the shaft in the impeller end of the current pump housing. Push the seal against the spacer. The seal is a snug fit on the shaft.

A lip type seal may be installed in the former pump used on the In-line engine by placing the rubber seal ring in the groove, starting the seal with the lip facing the impeller cavity over the shaft and tapping it into place against the seal spacer.

7. Install the cam and wear plate assembly.

NOTE: Formerly the wear plate was installed separately with the contoured surface fitting under the cam. Currently the wear plate is round and is doweled to the cam. The wear plate must be installed with the cam in the pump housing as an assembly.

8. Apply a non-hardening sealant to the cam retaining screw and the hole in the pump body to prevent any leakage. Then hold the cam with the tapped hole aligned and secure it with the screw.

9. Compress the impeller blades to clear the offset cam and press the impeller on the splined shaft.

10. Install the neoprene spline seal(s) in the bore of the impeller.

11. Turn the impeller several revolutions in the normal direction of rotation to position the blades.

12. Affix a new gasket and install the pump cover.

Remove Pump from Engine

If complete disassembly or replacement of the pump is necessary, it may be removed from the engine as follows:

1. Drain the raw water system.

2. Remove the water inlet and outlet elbows and discard the gaskets.

3. Remove the bolts that secure the pump adaptor to the flywheel housing.

4. Tap the edge of the adaptor with a plastic hammer to loosen the pump.

5. Pull the pump straight out from the flywheel housing so the drive gear will disengage the coupling.

6. Cover the pump opening in the flywheel housing with a clean cloth to prevent the entrance of foreign matter.

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Disassemble Pump

Follow the procedure outlined under *Replace Pump Seal* for the removal of the impeller, cam and wear plate assembly and water seal assembly and then proceed as follows:

1. Mark the pump housing and adaptor to aid in reassembly. Then remove the bolts and separate the housing and adaptor.

2. Clamp the V-type engine pump drive gear and housing assembly in a vise with soft jaws and remove the drive gear retaining nut. Take out the Woodruff key and remove the assembly from the vise.

Use puller J 4794-01 to remove the drive gear from the in-line engine pump.

3. Remove the bearing retainer ring from the groove in the housing.

4. Support the pump body in an arbor press with the splined end of the pump drive shaft under the ram of the press. Place a brass rod on the end of the shaft. Then press the shaft and bearing assembly out of the pump housing.

5. Remove the slinger from the opening in the top of the pump housing, then remove the bearing seal from the inside of the housing.

> **NOTE:** Remove the bearing retainer ring from the groove in the pump shaft on the V-type engine pump.

6. Place a suitable sleeve over the shoulder on the pump drive shaft and against the inner race of the bearing. Place the sleeve, shaft and bearing assembly on the bed of an arbor press with the threaded end of the shaft up. Hold a brass rod on the end of the shaft and under the ram of the press. Then press the bearing off of the shaft.

Inspect Pump Parts

After disassembling the pump, clean all of the parts, except the bearing, and dry them with air. Wipe the bearing with a clean cloth. *The shielded bearing must not be dipped or washed in fluid.*

Hold the bearing inner race and revolve the outer race slowly. Replace the bearing if it has rough spots, corrosion, is worn or does not roll freely.

On the V-type engine pump, inspect the carbon seal components. Replace worn or damaged parts as necessary.

Check the pump drive shaft seal contact surfaces for wear. Remove any scratches with crocus cloth wet with fuel oil.

Refer to Item 5 under *Replace Pump Seal* for the inspection of the remaining parts.

Assemble Pump

Only the current In-line engine pump housing is serviced. When replacing a former housing, it is necessary to include the new face-type water seal and spacer.

> **NOTE:** Stamp the former cover to identify that the pump now has a new housing and water seal.

Use new parts where necessary and assemble the pump as follows:

1. Lubricate the inside diameter of the drive shaft bearing with engine oil and start it, numbered side up, straight on the drive gear end of the shaft. Place a suitable sleeve over the shaft and against the inner race of the bearing. Support the sleeve, bearing and shaft on the bed of an arbor press and press the shaft into the bearing until the shoulder on the shaft is tight against the bearing inner race.

> **NOTE:** On the V-type engine pump, install the bearing retainer ring in the groove on the shaft.

2. Coat the lip of the seal lightly with grease and place it in position in the pump housing with the lip of the seal facing away from the bearing cavity.

3. Start the splined end of the drive shaft into and just through the inner bearing seal in the center of the pump housing from the drive flange end. Place the slinger in the opening in the top of the housing and over the end of the shaft. Carefully push the shaft straight into the housing until the bearing starts into the bearing bore. Use caution to prevent damage to the slinger.

4. Support the impeller end of the housing on the bed of an arbor press. Place a suitable sleeve on the outer race of the bearing and under the ram of the press and press the bearing straight into the bearing cavity in the pump housing.

5. Install the bearing retainer ring in the groove in the housing.

6. Lubricate the bore of the drive gear and start it on the shaft.

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NOTE: A Woodruff key is used with the shaft in the V-type engine pump.

7. Support the in-line engine pump housing and drive shaft assembly on the bed of an arbor press with the splined end of the drive shaft resting on a steel block and the drive gear under the ram of the press. Press the gear on the shaft until it is tight against the shoulder.

Clamp the V-type engine pump drive gear and housing assembly in a vise with soft jaws and install the gear retaining nut and lock washer. Tighten the nut to 25-30 lb-ft torque. Then remove the pump assembly from the vise.

CAUTION: Exceeding the specified torque may cause a pump drive shaft failure.

8. Place a new gasket on the pump adaptor, align the match marks and install the pump housing on the adaptor with the bolts and lock washers. Tighten the bolts to 30-35 lb-ft torque.

9. Follow the procedure outlined under *Replace Pump Seal* for the installation of the impeller, cam and wear plate assembly and water seal assembly.

Install Pump

The raw water pump may be installed on the engine by reversing the procedure for removal.

The pump end cover is marked to indicate the outlet port for a RH rotation and the outlet port for a LH rotation pump installation. These markings are an aid to prevent any difficulty with regard to water flow direction.

After the pump has been installed, prime it before starting the engine.

Draining Pump

The raw water pump is not provided with a drain valve. If freezing temperatures are anticipated and the engine is not going to be operated or the engine is being placed in storage, it is recommended that the raw water pump impeller housing be drained in addition to draining the engine cooling system.

Drain the raw water pump impeller housing by carefully pulling the pump cover away from the housing after loosening the screws. If the gasket is damaged, the cover will have to be removed and the gasket replaced.

After the pump has been drained, replace the cover and tighten the screws.

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COOLANT FILTER AND CONDITIONER

The engine cooling system filter and conditioner is a compact bypass type unit with a replaceable canister type element (Fig. 1), a spin-on type element (Fig. 2) or a clamp-on type element (Fig. 3).

A correctly installed and properly maintained coolant filter and conditioner provides a cleaner engine cooling system, greater heat dissipation, increased engine efficiency through improved heat conductivity and contributes to longer life of engine parts.

The filter provides mechanical filtration by means of a closely packed element through which the coolant passes. Any impurities such as sand and rust particles suspended in the cooling system will be removed by the straining action of the element. The removal of these impurities will contribute to longer water pump life and proper operation of the thermostat.

The filter also serves to condition the coolant by softening the water to minimize scale deposits, maintain an acid-free condition and act as a rust preventive.

Corrosion inhibitors are placed in the element and dissolve into the coolant, forming a protective rustproof film on all of the metal surfaces of the cooling system (refer to Section 13.3). The other components of the element perform the function of cleaning and preparing the cooling passages while the corrosion inhibitors protect them.

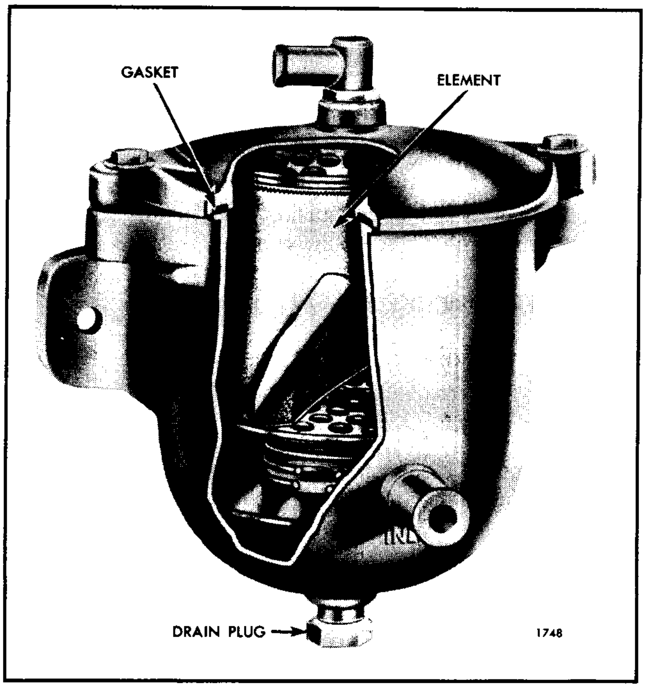

Fig. 1 - Coolant Filter and Conditioner (Canister Type)

Filter Installation

If a coolant filter and conditioner is to be installed on an engine which has been in service, drain and flush the cooling system prior to installation of the filter.

Filter Maintenance

Replace the chemically activated element, following the manufacturer's recommended change periods (refer to Section 15.1). The lower corrosion resistor plate (if used) must be buffed each time (discard the plate, if excessive metal loss or pitting is evident) to ensure effective protection of the cooling system.

If the filter is installed on an engine which has previously been in service, it may be necessary to change the filter element two or three times at intervals of approximately 200 hours or 6,000 miles, or less, to clean-up accumulations of scale and rust in the cooling system. It is advisable to drain and flush the system during these initial change intervals.

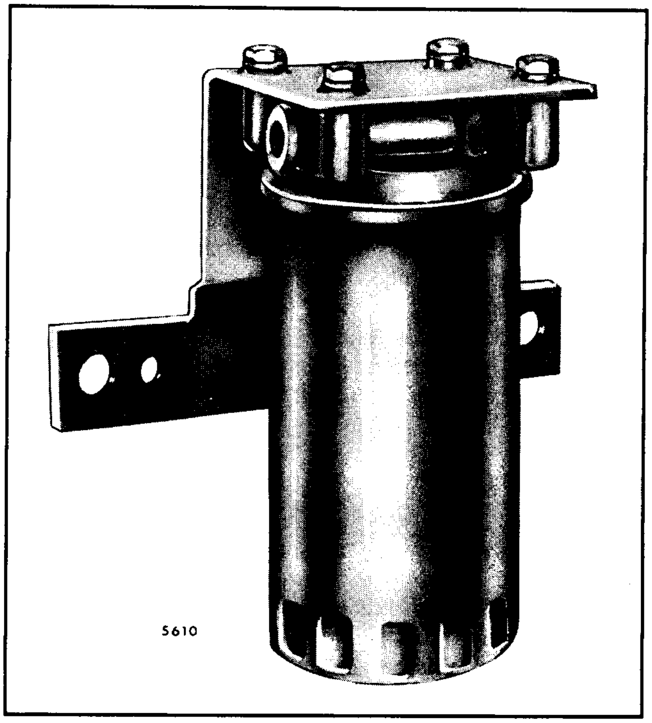

Fig 2. - Coolant Filter and Conditioner (Spin-On Type)

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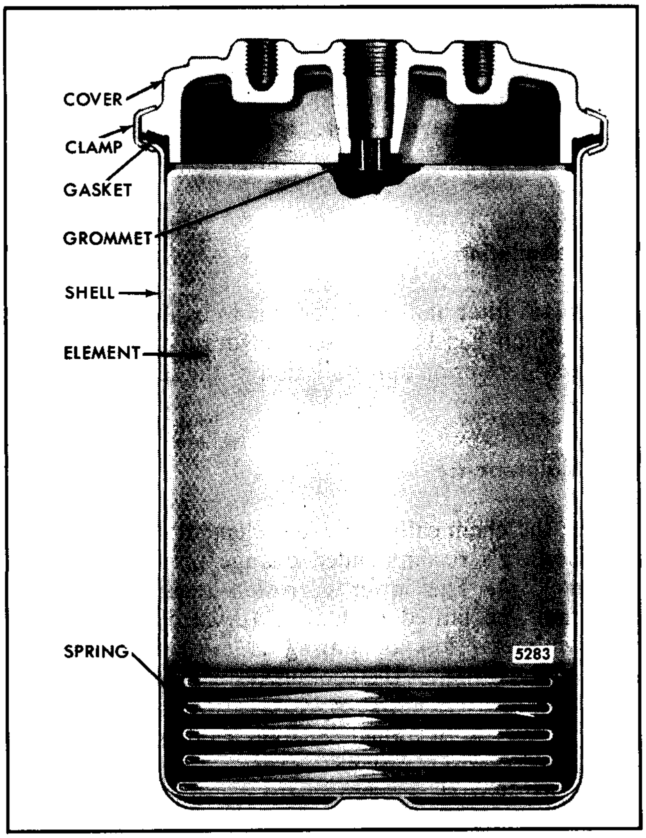

Fig. 3 - Coolant Filter and Conditioner (Clamp-On Type)

Make-up water up to approximately 40% of the total capacity of the cooling system may safely be added before a filter element change is required.

NOTE: Sea water must never be used for make-up water in a marine engine, except under emergency conditions. If it is necessary to use sea water, the cooling system must be completely drained and flushed with fresh water upon reaching port. The filter element must be changed. Filters with resistor plates must be inspected for pitting. *Presence of salt in the coolant results in rapid pitting of the resistor plates.*

If it is necessary for any reason to drain the cooling system before an element change, the treated water should be saved and reused. If the treated water is discarded, a new filter element must be installed since the protective agents in the used filter will have been partially consumed in treating the discarded water.

Service

The coolant filter may be grounded at the option of the user.

The current coolant filter includes a non-chromate type element. This element can be used in place of either of the former filter elements (permanent type antifreeze or plain water type) and thus provides year around cooling system protection. The current and the former filter elements are completely interchangeable in the former filter can (refer to Section 13.3).

Replace the element and service the filter and conditioner as follows:

1. Close the filter inlet and outlet shutoff valves. If shutoff valves are not provided, vise grip pliers can be used to clamp each hose closed during the filter change. Use caution to avoid damaging the hoses with the vise grip pliers.

2. Remove and replace the element.

Canister Type Element - Fig. 1:

a. Remove the drain plug in the bottom of the filter body and let drain.

b. Remove the filter cover-to-filter body bolts.

c. Remove and discard the element.

d. Remove and discard the corrosion resistor plates.

e. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

f. Replace the drain plug in the bottom of the filter.

g. Insert the new element.

h. Use a new filter cover gasket and install the filter cover and tighten the bolts evenly.

Spin-On Type Element - Fig. 2:

a. Remove and discard the element.

b. Clean the gasket seal on the filter cover.

c. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

d. Apply clean engine oil to the filter element gasket and install the new element. A 2/3 turn after gasket contact assures a positive leakproof seal.

Clamp-On Type Element - Fig. 3:

a. Remove the retaining clamp.

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b. Remove and discard the element.

c. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

d. Insert the new element.

e. Secure the filter body in place with the clamp.

3. Open the inlet and outlet lines by opening the shutoff valves or removing the vise grip plier clamps.

4. Operate the engine and check for leaks. The top of the filter and the outlet line should feel warm to the touch with the rise in coolant temperature. If not, disconnect the filter outlet line at the end opposite the filter connection to bleed the air from the system and reconnect the line. Use caution to minimize coolant loss.

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SHOP NOTES - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

FAN HUB SPACER

The new fan hub spacers are similar to the former spacers except for the flange pilot radius and the width of the spacers (Fig. 1). The flange on the spacer serves as a pilot for the fan, as well as a pilot for the second spacer when two or more spacers are used together.

The former and new spacers are interchangeable on a former fan pulley hub assembly and only the new spacers are serviced.

The former .800 " thick spacer must not be used with the current shaft type fan pulley hub assemblies, unless it is reworked (see Service Note).

Use of the former thick spacer will crush the fan hub cap causing the drive to bind.

SERVICE: The former .800 " thick spacer can be reworked into the new .800 " thick spacer by removing materail at the radius (Fig. 1). A reworked spacer should be mated with the fan hub assembly. If a former thin spacer (.500 " thick) is used in conjunction with the reworked thick spacer, it should be positioned against the fan.

NOTE: The .500 " thick spacer cannot be reworked into the new .560 " thick spacer.

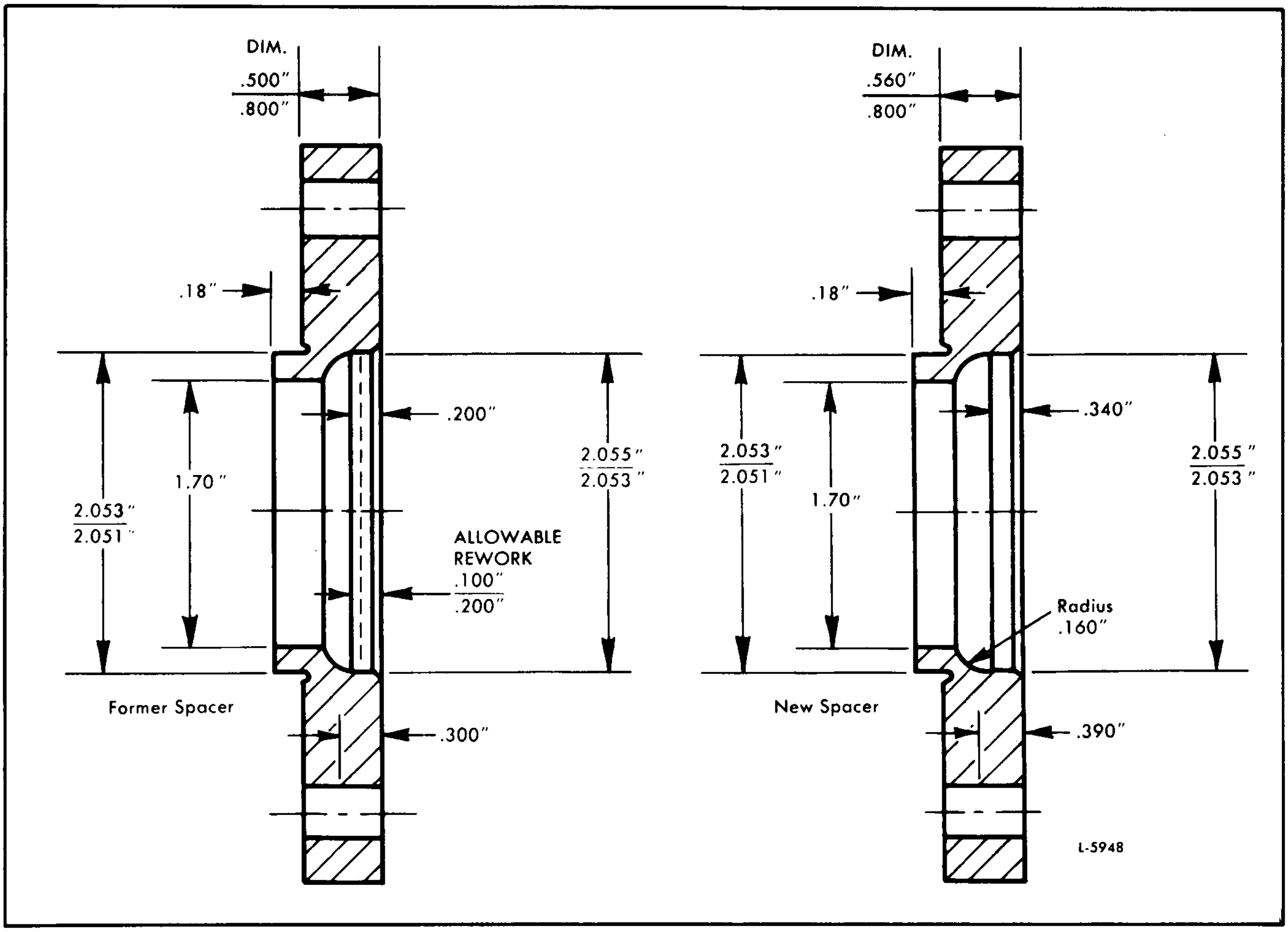

Fig. 1 - Former and New Spacers

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FAN HUB GREASE FITTING

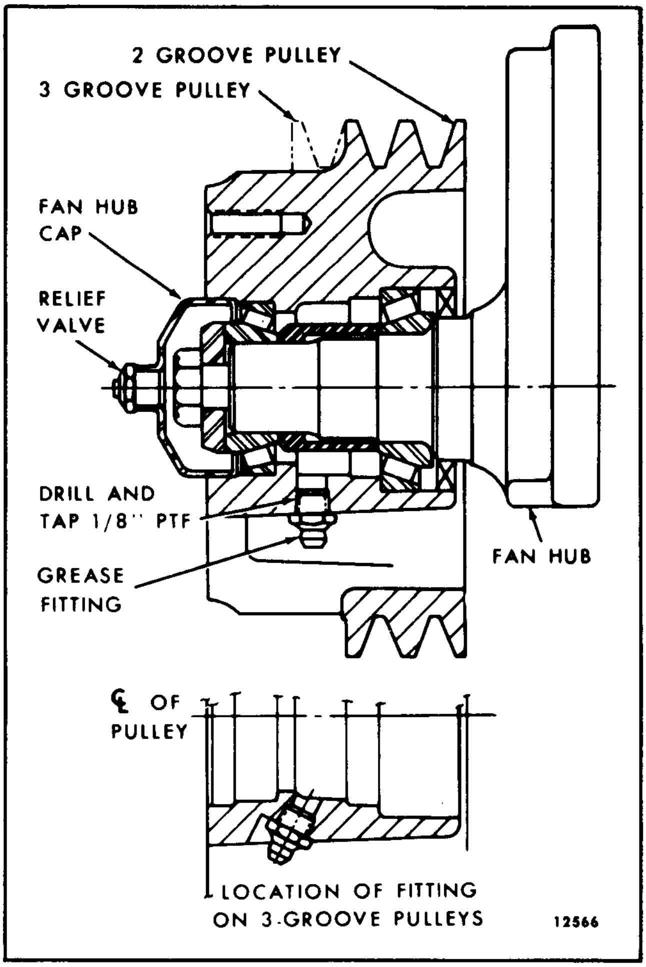

Fig. 2 - Location of Fan Hub Grease Fitting and Relief Valve

A grease fitting may be added to former fan hub assemblies used on vehicle engines to permit periodic lubrication of the bearings.

Re-work the fan hub as follows:

1. Refer to Section 5.4 and dis-assemble the fan hub assembly and clean the parts thoroughly.

2. Drill and tap the fan hub, at the location shown in Fig. 1, to accept a 1/8" PTF x 11/16" threaded lubricator fitting. Clean the hub to remove any metal chips.

3. Refer to Section 5.4 and re-assemble the fan hub. Discard the former grease retainer as it is not required when a grease fitting is used.

4. Install a *new* fan hub cap which is threaded for a relief valve (Fig. 1).

5. Install a grease fitting in the fan hub and a relief valve in the fan hub cap.

Refer to Section 15.1 for the maintenance schedule.

DRAINING JABSCO RAW WATER PUMP

Although all engine units are provided with draincocks for the purpose of draining the cooling system, a small amount of coolant may remain in the impeller housing of a "Jabsco" pump.

Under normal circumstances, there would be no need in completely draining the impeller housing of a raw water pump, therefore, no drain plug has been incorporated at this location. However, certain models employ a raw water pump in conjunction with a fresh water cooling system.

In the event the engine is to be stored in below freezing temperatures, it is suggested that, in addition to draining the cooling system of the engine unit, the impeller housing of the "Jabsco" pump (if so equipped) be completely drained. This may easily be accomplished by loosening the five fillister head screws which attach the end cover to the pump housing, at the impeller end of the pump, then pulling the end cover away from the pump body, while being careful to avoid damage to the gasket. The screws need only be loosened sufficiently to allow complete draining of the impeller housing, then retightened.

RAW WATER PUMP IMPELLERS

The Jabsco raw water pump is equipped with synthetic rubber impellers. Since the synthetic rubber begins to lose its elasticity at low temperatures, impellers made of natural rubber may be installed when it is necessary to pump raw water that has a temperature below 40 °F (4 °C). However, the standard impellers must be used when the pump operates in warmer water.

New service impellers of natural rubber are identified by a stripe of green paint.

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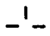
SPECIFICATIONS

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 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 1 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

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EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)	TORQUE (Nm)
Water pump cover bolt	5/16-18	6-7	8.1-9.5
Fan hub retaining nut (6V engines)	1/2 -20	35-40	47-54
Raw water pump drive gear retaining nut	5/8 -18	30-35	41-47

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SERVICE TOOLS

TOOL NAME	TOOL NO.
Handle	J 7079-2
Installer	J 22091
Puller	J 24420-A
Radiator cap and cooling system tester	J 24460-01
Remover and installer	J 1930
Water pump impeller remover set	J 22488

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SECTION 6

EXHAUST SYSTEM

CONTENTS

Exhaust System 6

Exhaust Manifold (Air-Cooled) 6.1
Exhaust Manifold (Water-Cooled) 6.1.1

EXHAUST SYSTEM

Fan and radiator cooled engines are equipped with an air-cooled exhaust manifold. A water-cooled exhaust manifold is provided for engines incorporating a heat exchanger or keel cooling system.

The outlet flange may be located at the end or at the mid-section of the exhaust manifold, depending upon the installation requirements. A flexible exhaust connection or a muffler may be attached to the outlet flange.

The exhaust manifold is attached to studs located between the exhaust ports and the outer side of the two end ports in the cylinder head. Special washers and nuts secure the manifold to the cylinder head.

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EXHAUST MANIFOLD (Air-Cooled)

Two types of exhaust manifolds are used. One type has an outlet to accommodate a square exhaust outlet flange (Fig. 1) and the other has a circular outlet which is connected to the exhaust pipe with a Marmon-type clamp (Fig. 2). Current manifolds, flanges (square) and flange gaskets have SAE standard dimensions.

On engines equipped with a mechanical automatic shutdown system, the exhaust manifold is provided with two 5/16"-18 tapped bolt holes and a 7/8" drilled hole to permit installation of the temperature shutdown valve adaptor and plug assembly.

Remove Exhaust Manifold

1. Disconnect the exhaust pipe or muffler from the exhaust manifold flange.

2. If the engine is equipped with a mechanical automatic shutdown system, remove the two bolts and lock washers and withdraw the shutdown valve adaptor and plug assembly from the exhaust manifold.

3. Loosen, but do not remove, one of the center exhaust manifold nuts. Remove the other nuts and washers.

4. Support the manifold and remove the center nut and washer.

5. Remove the manifold and gasket from the cylinder head.

Inspection

Remove any loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold. Clean the manifold and check for cracks, especially in the holding lug areas.

Clean all traces of gasket material from the cylinder head.

Replace broken or damaged exhaust manifold studs. Apply sealant to the threads and drive new studs to 25-40 lb-ft (34-54 Nm) torque (1.40" to 1.50" height).

Install Exhaust Manifold

1. Place a new gasket over the studs and against the cylinder head.

2. Position the exhaust manifold over the studs and hold it against the cylinder head.

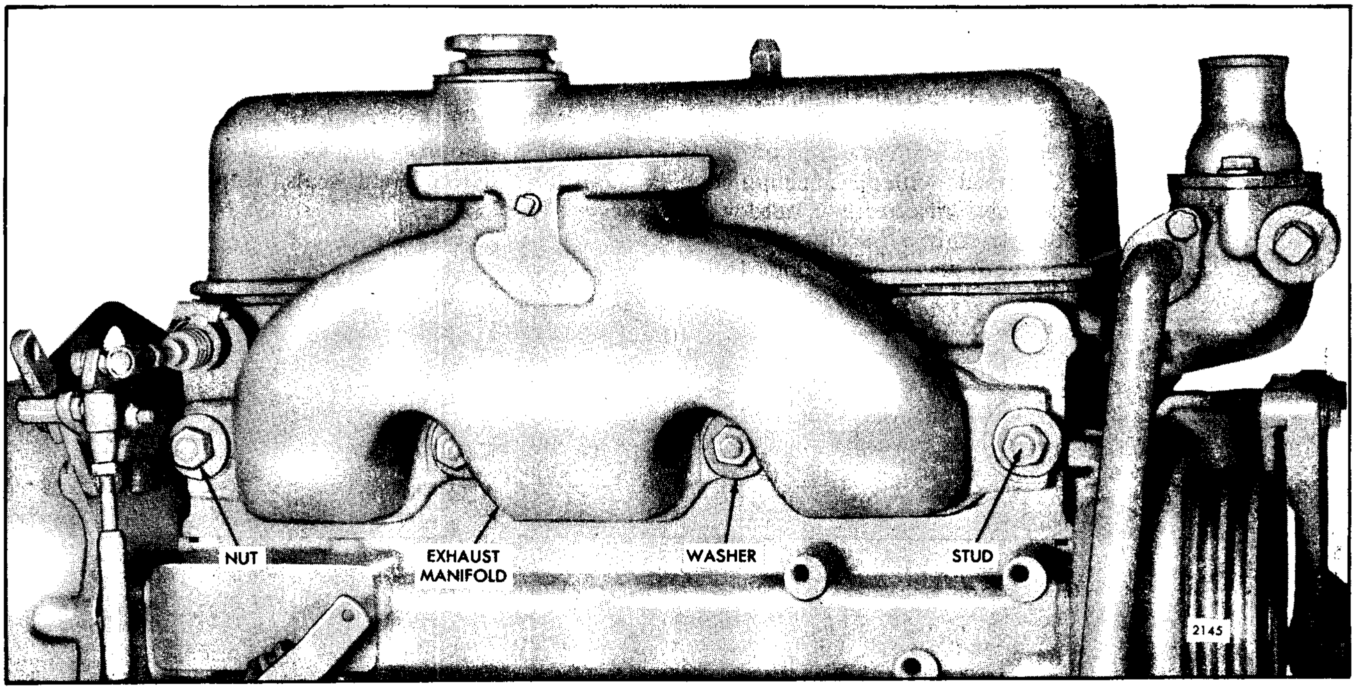

Fig. 1 - Typical Air-Cooled Exhaust Manifold (Square Flange) Mounting

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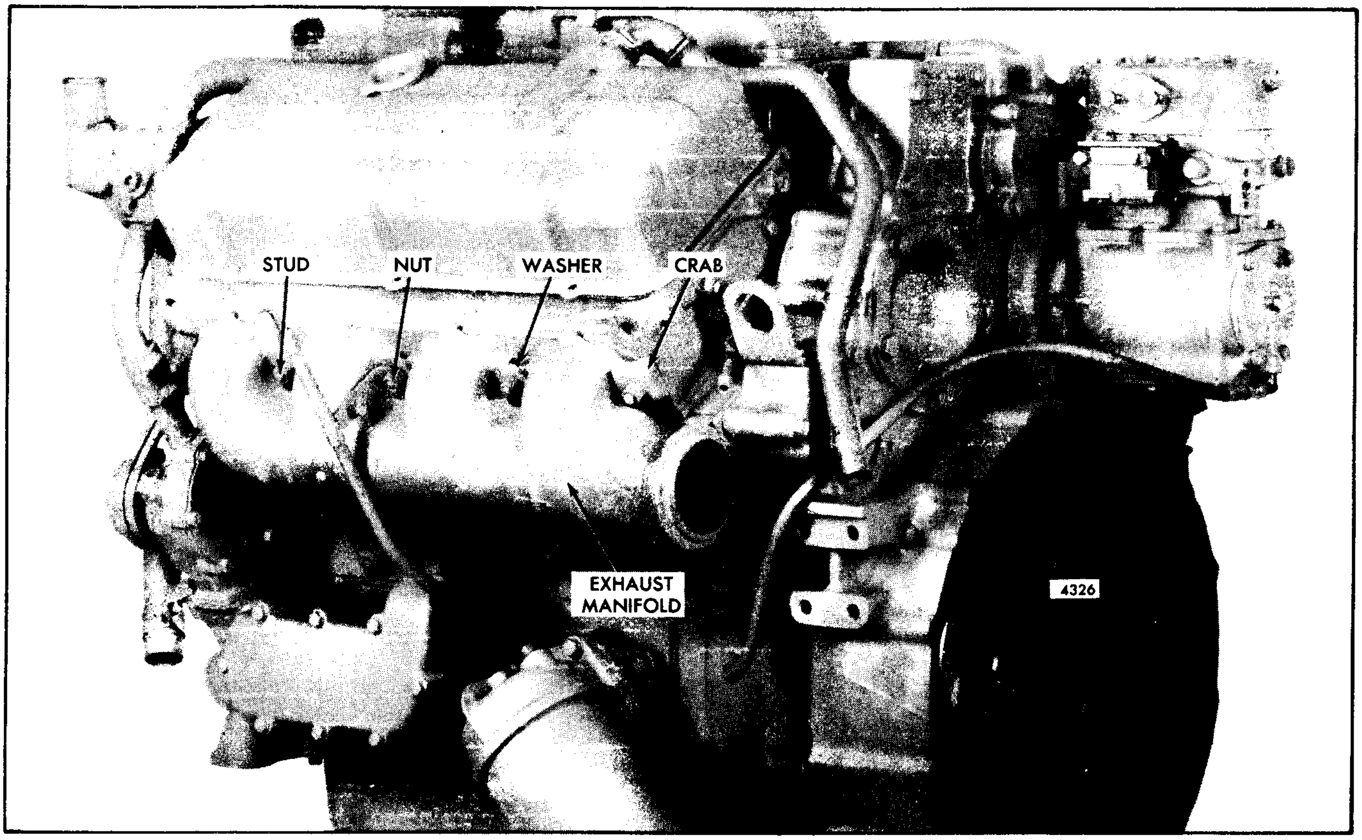

Fig. · Exhaust Manifold with Marmon Flange

3. Install the washers and nuts on the studs. If beveled (dished) washers are used, position them so that the crown side faces the nut. On some engines, crabs are used in place of washers at the end positions (Fig. 2). Beginning with one of the center stud nuts and working alternately toward each end of the manifold, tighten the nuts to 30-35 lb-ft (41-47 Nm) torque.

4. If the engine is equipped with a mechanical automatic shutdown assembly, install the shutdown valve adaptor and plug assembly in the exhaust manifold and secure it with two bolts and lock washers.

5. Connect the exhaust pipe or muffler to the exhaust manifold flange.

NOTE: Do not allow exhaust piping to impose excessive loads on the turbocharger.

6. Inspect the exhaust outlet piping for dents, holes and potential sources of water infiltration such as loose clamps or deteriorated seals. Repair or replace, if necessary.

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EXHAUST MANIFOLD (Water-Cooled)

A water jacket surrounds the exhaust chamber in the cast iron water-cooled exhaust manifold illustrated in Fig. 1. The engine coolant flows from the rear of the cylinder head through the water jacket around the exhaust manifold and through the thermostat housing and the water bypass tube to the water tank.

Remove Exhaust Manifold

1. Remove the water tank filler cap and open the vent valve at the front end of the exhaust manifold.

2. Drain the cooling system.

3. Disconnect the exhaust pipe from the exhaust manifold flange.

4. Loosen the hose clamps and slide the hose back on the water inlet connector attached to the rear end of the cylinder head. On some engines, the connector is a formed hose which can be removed.

5. Disconnect the water tank vent tube, if used, at the exhaust manifold.

6. Loosen the hose clamps and slide the hoses back on the water bypass tube and the heat exchanger water inlet tube or the thermostat housing.

7. If a water filter is used, disconnect the filter hose to the exhaust manifold.

8. Loosen the hose clamps at each end of the raw water pump outlet intermediate tube and slide the hose back on the tube at the curved end, then slide the tube out of the hose at the heat exchanger end.

9. Support the manifold and remove the nuts and washers which secure it to the cylinder head.

10. Remove the manifold and manifold gasket.

11. If necessary, remove the exhaust manifold flange at the rear of the manifold and the water outlet flange at the front.

Inspection

Remove the loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold.

Clean all traces of gasket material from the cylinder head.

Examine the exhaust manifold studs for damage. If necessary, replace the studs. Apply sealant to the threads and drive new studs in to a height of 1.40" to 1.50" or to 25-40 lb-ft (34-54 Nm) torque.

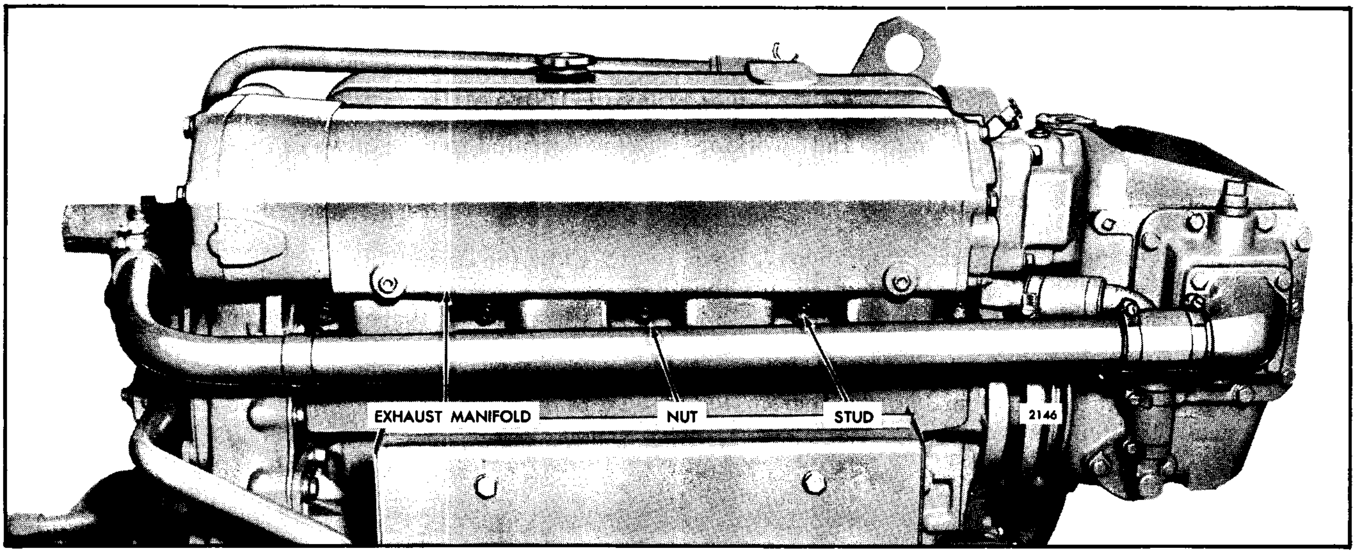

Fig. 1 - Typical Water-Cooled Exhaust Manifold Mounting (In-Line Engine)

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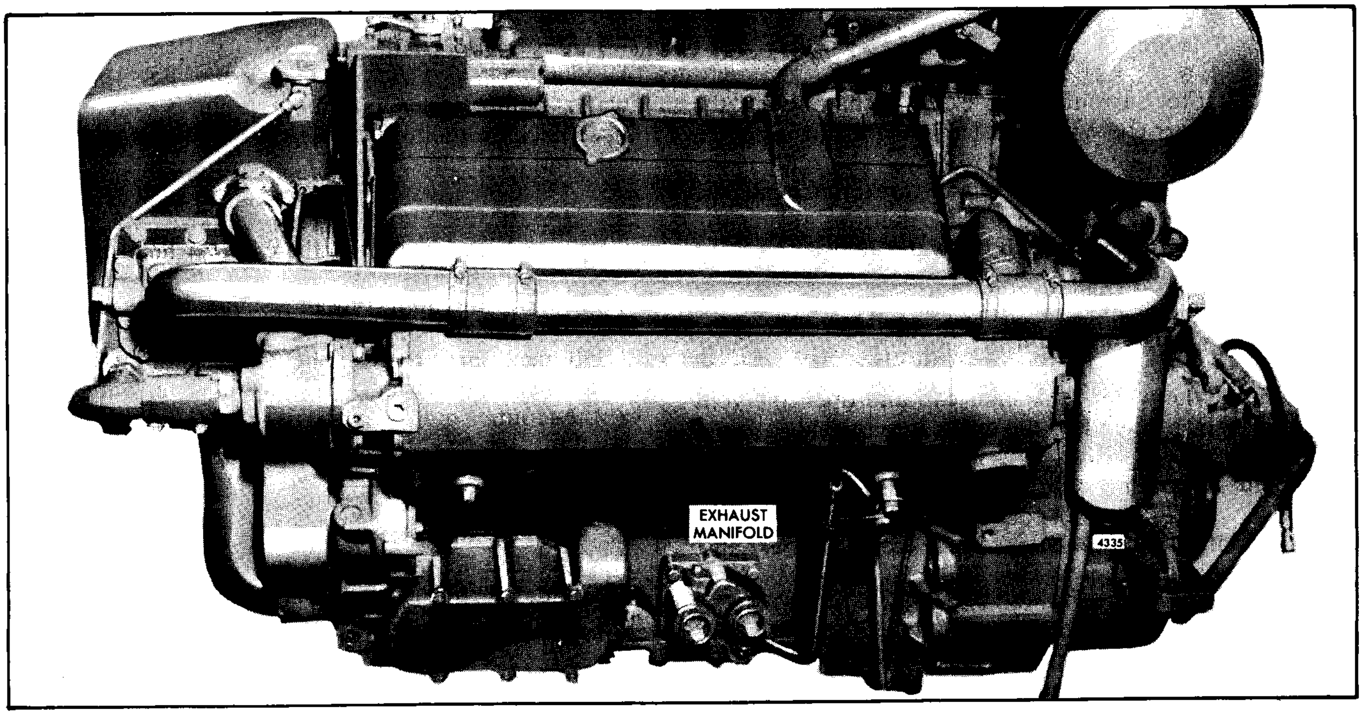

Fig. 2 - Typical Water-Cooled Exhaust Manifold Mounting (8V Engine)

Install Exhaust Manifold

1. If removed, install the exhaust flange and water outlet flange on the exhaust manifold.

2. Place a new gasket over the studs and against the cylinder head.

3. Position the exhaust manifold over the studs and hold it against the cylinder head.

> **NOTE:** Be sure the locating pads on the exhaust manifold rests on the cylinder block locating pads.

4. Install the washers and nuts on the studs. Beginning with one of the center stud nuts and working alternately toward each end of the manifold, tighten the nuts to 30-35 lb-ft (41-47 Nm) torque.

5. Slide the hoses in place on the water bypass tube and the heat exchanger water inlet tube or the thermostat housing and tighten the hose clamps.

6. Install the formed hose or slide the hose in place on the water inlet connector attached to the rear of the cylinder head. Tighten the hose clamps.

7. If used, connect the water tank vent tube to the exhaust manifold.

8. If the engine is equipped with a water filter, connect the filter hose to the exhaust manifold.

9. Install the raw water pump outlet intermediate tube, slide the hoses in place and tighten the hose clamps.

10. Connect the exhaust pipe to the exhaust manifold flange.

> **NOTE:** Do not allow exhaust piping to impose excessive loads on the turbocharger.

11. Inspect the exhaust outlet piping for dents, holes and potential sources of water infiltration such as loose clamps or deteriorated seals. Repair or replace, if necessary.

12. Close the drain valves and fill the cooling system.

13. Close the vent valve at the front end of the exhaust manifold and install the water tank filler cap.

14. Start the engine and check for leaks in the cooling system.

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SECTION 7

ELECTRICAL EQUIPMENT, INSTRUMENTS AND PROTECTIVE SYSTEMS

CONTENTS

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Power Generator and Controls 7.5

Shop Notes - Troubleshooting - Specifications - Service Tools 7.0

ELECTRICAL SYSTEM

CAUTION: Before working on the electrical system, always disconnect the battery ground cable to avoid accidental short circuiting of loose wires.

A typical engine electrical system generally consists of a starting motor, a battery-charging generator or alternator, a transistor combination voltage regulator, current regulator and cutout relay to protect the electrical system, a storage battery and the necessary wiring.

Additional equipment such as an engine protective system may also be included.

Detailed information on maintenance and repair of the specific types of electrical equipment can be found in the service manuals and bulletins issued by the equipment manufacturer. Information regarding equipment manufactured by the Delco-Remy Division of General Motors Corporation may be obtained from their electrical equipment operation and service manuals. The manuals may be obtained from AC-Delco service outlets, or from the Technical Literature Section, Delco-Remy Division of General Motors Corporation, Anderson, Indiana.

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the manufacturer of the equipment. Leece-Neville alternators are serviced locally. 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.

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BATTERY-CHARGING GENERATOR AND ALTERNATOR

The battery-charging circuit consists of a generator or alternator, regulator (Section 7.1.1), battery (Section 7.2) and the wiring. The battery-charging generator (Fig. 1 or 2) or alternator (Fig. 3 or 4) 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 GENERATOR OR ALTERNATOR (Belt-driven)

Direct current generators are manufactured in a wide range of sizes and types, but the basic design of all generators is the same. The size and type of generator applied to a particular engine depends on many factors, including maximum electrical load, type of service, percentage of engine idling to running time, type of drive, drive ratio (engine speed to generator speed), generator mounting and environmental conditions.

The hinge-mounted alternating current self-rectifying alternator is belt driven. The alternator drive pulley is keyed to a shaft which is coupled to the blower drive gear.

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. The alternator is also available in various sizes and types, depending upon the specific application.

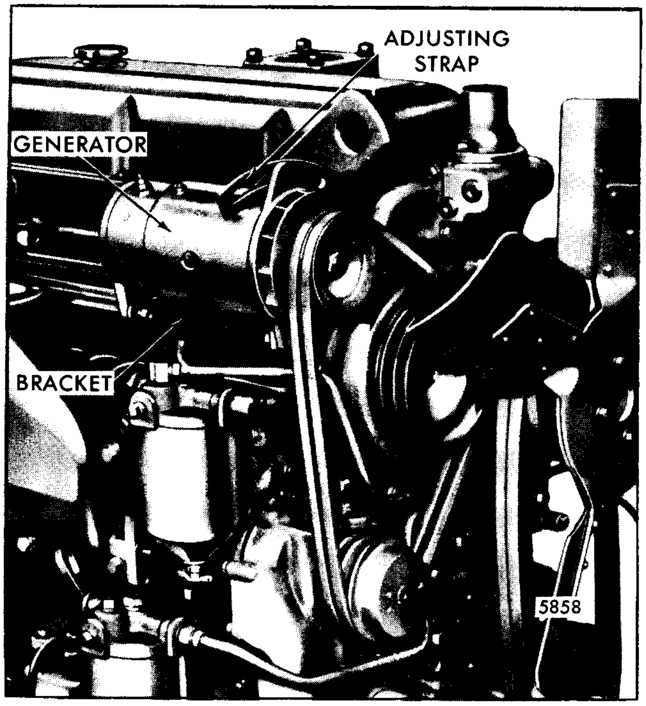

Fig. 1 - Typical Hinge-Mounted Generator (In-line 53)

The SI series alternators have replaced the DN series alternator. With the new alternators, the need for a separately mounted voltage regulator is eliminated.

NOTE: Effective with November, 1979 build engines, the 10SI alternators were converted to metric dimensions, such as the attaching bolts, nuts and lockwashers. Also, hole sizes of some mounting parts will be changed to accommodate the new metric fasteners. The output terminal (BAT) thread will be changed from a 12-24 to a M16X1 thread.

The access hole permitting the external adjustment of the voltage regulator has been eliminated on current alternators. To adjust the voltage setting on the current alternators, remove the rectifier end plate. The voltage regulator circuit board. Refer to the pertinent Delco Service Bulletin for complete adjustment procedure.

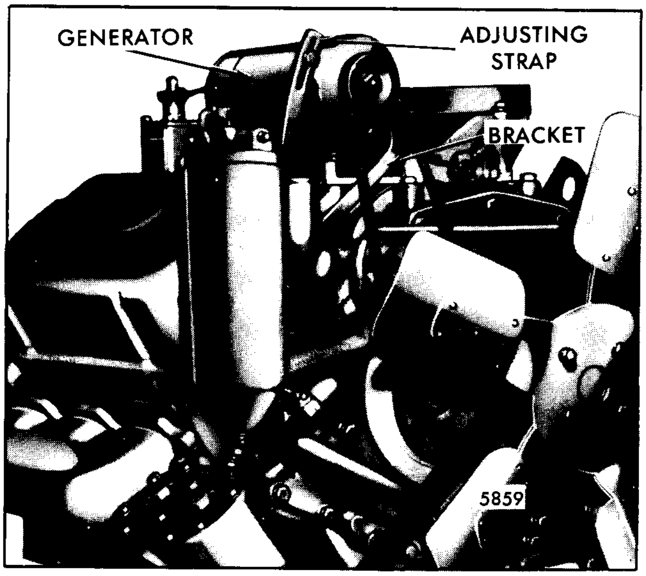

Fig. 2 - Typical Hinge-Mounted Generator (V-53)

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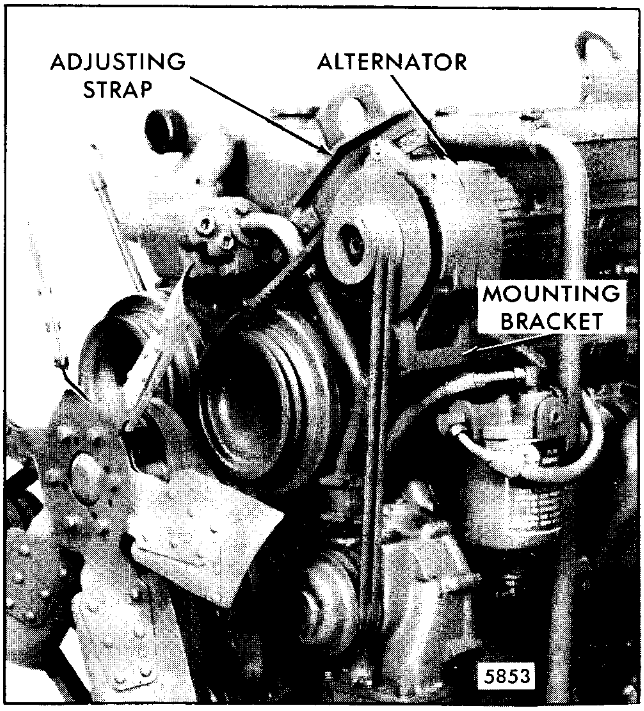

Fig. 3 - Typical Hinge-Mounted Alternator (In-line 53)

The proper selection of a generator or alternator which will meet the needs of the battery-charging circuit on the particular engine is mandatory. This, together with adherence to the recommended maintenance procedures will reduce generator or alternator troubles to a minimum. Since most generators or alternators adhere to the same basic design, the maintenance, removal and installation procedures for all are similar.

Generator or Alternator Maintenance

1. Maintain the proper drive belt tension. Replace worn or frayed belts. Belts should be replaced as a set when there is more than one belt on the generator or alternator drive.

> **NOTE:** When installing or adjusting the drive belt, be sure the bolt at the pivot point is properly tightened, as well as the bolt in the adjusting slot.

2. Lubricate the generator bearings as outlined in the *Lubrication and Preventive Maintenance Chart* in Section 15.1.

3. Alternator bearings are permanently lubricated. There are no external oiler fittings.

Remove Generator or Alternator

1. Disconnect the cables at the battery supply. If the generator or alternator has a separately mounted regulator and field relay, disconnect all other leads from the generator or alternator and tag each one to ensure correct re-installation.

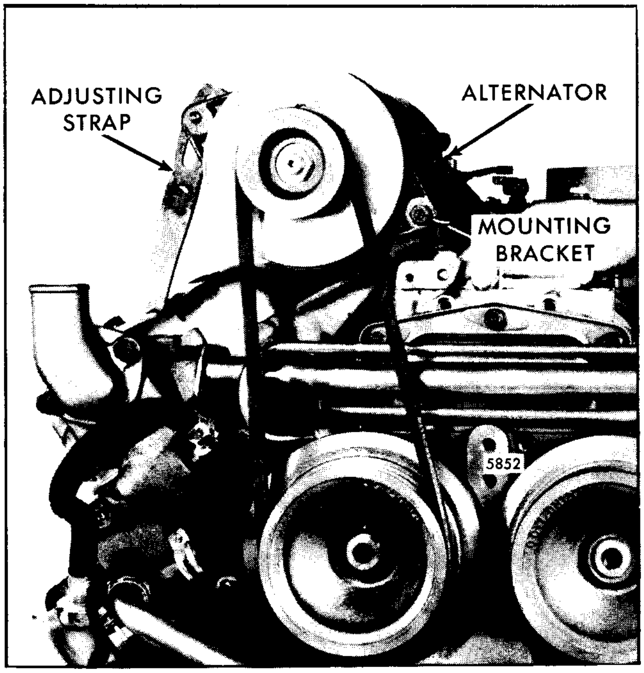

Fig. 4 - Typical Hinge-Mounted Alternator (V-53)

2. Loosen the mounting bolts and the adjusting strap bolt. Then remove the drive belts.

3. While supporting the generator or alternator, remove the adjusting strap bolt and washers. Then remove the mounting bolts, washers and nuts. Remove the generator or alternator carefully and protect it from costly physical damage.

4. Remove the pulley assembly if the generator or alternator is to be replaced.

Generator or Alternator Service

Repairs and overhaul work on generators and alternators should be referred to an authorized repair station of the manufacturer of this equipment. Replacement parts for generators and alternators should be ordered through the equipment manufacturer's outlets. For generators and alternators manufactured by Delco-Remy Division, repair service and parts are available through AC Delco branches and repair stations.

Install Generator or 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. 5).

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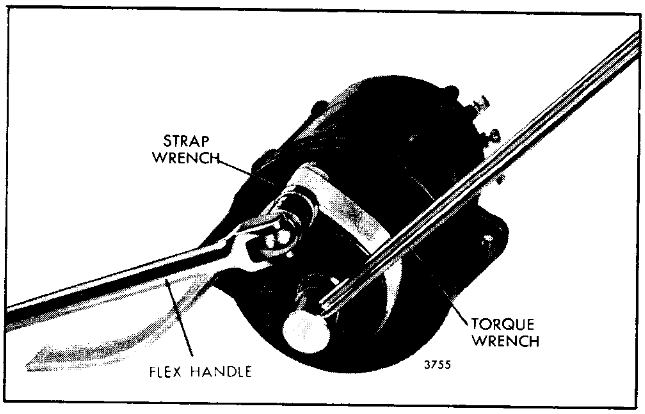

Fig. 5 - Tighten Generator or Alternator Pulley Retaining Nut

NOTE: If the pulley was not removed, check the retaining nut for proper torque.

2. Position the generator or alternator on the mounting brackets and start the bolts, with washers in place, through the bolt holes in the end frames. If nuts are used, insert the bolts through the bolt holes in the mounting bracket and end frame. Make sure that the washers and nuts are in their proper locations.

3. Align the threaded hole in the adjusting lug of the drive end frame with the slot in the adjusting strap. Start the bolt, with the washers, through the slot of the adjusting strap and into the threaded hole in the end frame.

4. Place the drive belts in the grooves of the pulleys.

5. Adjust the belt tension as outlined in Section 15.1. 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 generator or alternator. Keep all connections clean and tight.

POLARIZING GENERATOR

After each check or adjustment of the voltage regulator or generator, particularly after the leads have been disconnected and then reconnected, it is necessary to polarize the generator before starting the engine. This is to ensure correct polarity with respect to the battery.

CAUTION: Never attempt to polarize an alternator.

Failure to polarize a generator will result in burned or stuck cutout relay contact points in the regulator, a rundown battery and damage to the generator.

The procedure for correctly polarizing a generator will vary with the type of electrical equipment installed and upon the generator regulator wiring circuit. If the generator field is grounded through the regulator, it is an "A" circuit; if it is internally grounded, it is a "B" circuit.

If Delco-Remy electrical equipment is installed, reference can be made to the Delco-Remy "Electrical Equipment Manual" and "Test Specifications" (refer to Section 7) to determine the type of circuit applicable to the regulator being used. Since it is possible to have either an "A" or "B" circuit regulator with any given generator, the polarizing procedures must be carefully adhered to. Use of the wrong polarizing procedure or neglecting to polarize will result in reversed generator polarity and serious damage to the electrical components.

After ascertaining the correct circuit used, polarize the generator as outlined below.

1. "A" Circuit:

   Connect a jumper lead momentarily between the "BAT" and "GEN" terminals of the regulator.

2. "B" Circuit:

   Remove the "F" lead from the regulator and momentarily connect it to the "BAT" terminal of the regulator.

A momentary surge of current to the generator correctly polarizes it with respect to the battery.

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ALTERNATOR PRECAUTIONS

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

Avoid grounding or shorting the output wires or the field wires between the alternator and the regulator. Never run an alternator on an open circuit.

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

Accidentally reversing the battery connections must be avoided.

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

In marine applications which have two sets of batteries, switching from one set of batteries to the other while the engine is running will momentarily disconnect the batteries and result in damage to the alternator diodes.

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

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

Never attempt to polarize the alternator.

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

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

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BATTERY-CHARGING GENERATOR REGULATOR

D.C. CHARGING CIRCUIT

To regulate the voltage and current output of the battery-charging generator and to maintain a fully charged storage battery, several protective devices are employed, depending on the type of electrical system. The most representative of these devices is the "three-unit" regulator (Fig. 1).

These regulators are identified as:

a. A "Circuit A" unit in which the generator field circuit is connected to ground within the regulator and is used only with generators having an externally grounded field circuit.

b. A "Circuit B" unit in which the generator field circuit passes through the regulator and returns to ground inside the generator itself. This regulator must be used only with "Circuit B" generators in which the field is internally grounded.

The regulators are dust and moisture-proofed. On most applications, it is necessary to use shock mounts which insulate the regulator against vibration but necessitates the installation of a ground lead.

The three-unit regulator consists of a cutout relay, a voltage regulator and a current regulator mounted in a single assembly as shown in Fig. 1. These three units are basic and generally apply to most regulators in a D.C. generator system.

CUTOUT RELAY

The cutout relay (Fig. 2) has two windings assembled on one core; a series winding of a few turns of heavy wire and a shunt winding of many turns of fine wire. The relay core and windings are assembled into a frame. A flat steel armature is attached to the frame by a hinge so it is centered just above the center of the core. The armature has two or more contact points which are located just above a similar number of stationary contact points.

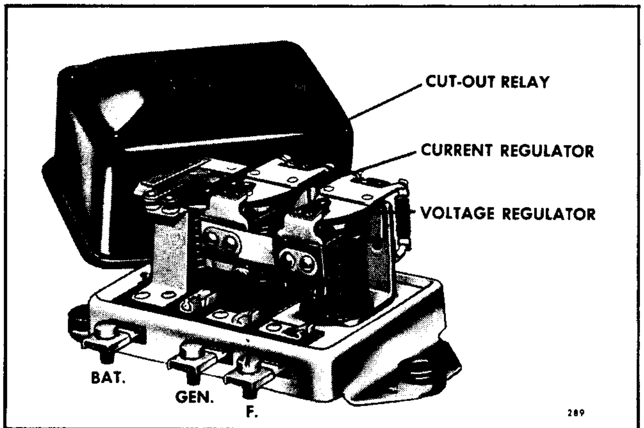

Fig. 1 - Typical Regulator Assembly

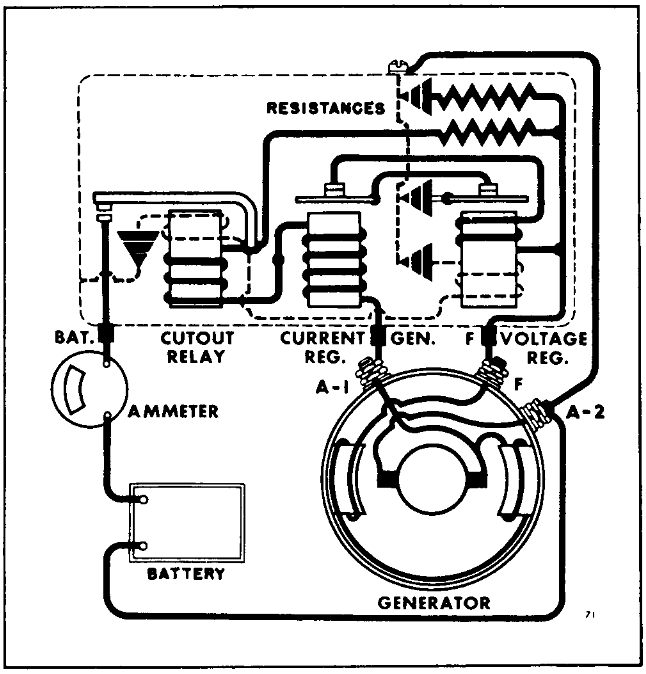

Fig. 2 - Wiring Circuit of Typical Three-Unit Regulator

Operation

When the engine is not running, the armature contact points of the relay are held away from the stationary points by tension of a leaf spring.

As the engine starts and the generator speed increases, the current flowing through the shunt winding builds up until it reaches the value for which the relay has been set. At this point, sufficient magnetism overcomes the armature spring tension, the contact points close and the current flows to the battery. Then the current which flows through the series winding is in the right direction to add to the magnetic force holding the armature down and the points closed.

When the engine is slowed down or stopped, current will begin to flow from the battery to the generator. This reverses the direction of current flow through the

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series winding, causing a reversal of the series winding magnetic field. The magnetic field of the shunt winding does not reverse. Therefore, the two windings now oppose each other magnetically and the resultant magnetic field is not strong enough to hold the armature down. The leaf spring pulls the armature away from the core and the points separate, opening the circuit between the generator and the battery.

CAUTION: The regulator cutout relay contact points must never be closed by hand with the battery connected. This would cause a high current flow through the units and damage them.

VOLTAGE REGULATOR

The voltage regulator (Fig. 2) has two windings on a single core. One is a shunt winding consisting of many turns of fine wire which, in series with a resistor, is shunted across the generator at all times. The second winding is a field current winding which is connected between the generator field circuit and ground whenever the regulator contact points are closed. In addition to the core frame, armature and contact points, the unit has a spiral spring which holds the armature away from the core so the two contact points are touching when the voltage regulator is not operating.

Operation

When the generator voltage reaches the value for which the voltage regulator is adjusted, the combined magnetic field produced by the shunt winding and the field current winding overcomes the armature spring tension, pulls the armature down and separates the voltage regulator contact points. This introduces resistance into the generator field circuit so the generator field current and generator voltage are reduced. The lowering of the output of the generator causes the points to close again, thereby removing the resistance and increasing the generator output. The complete cycle of opening and closing the points and the alternate inserting and removing of the resistance in the generator field circuit is done rapidly, thus limiting the the generator voltage to a predetermined maximum value. With the generator voltage limited, the generator supplies varying amounts of current to meet the requirements of varying states of battery charge and electrical loads.

CURRENT REGULATOR

The current regulator (Fig. 2) contains two windings assembled on one core; a series winding and a field current winding. The series winding, consisting of a few turns of heavy wire, is connected into the charging circuit so that the full output of the generator passes through it. The field current winding is connected in series with the generator field circuit so that the field current flows through the field winding when the regulator contact points are closed.

The outward appearance of the current regulator is similar to that of the voltage regulator.

Operation

The magnetism produced by current flowing through the series winding overcomes the armature spring tension and the contact points open when the current reaches the value for which the current regulator is adjusted. This inserts a resistance into the generator field circuit, resulting in a drop in generator output. Immediately, the magnetic field of the series winding is weakened, the contact points close, the generator output starts to increase and the cycle is repeated. This action prevents the generator from exceeding its rated output.

Therefore, when the load demand is heavy, generator output will increase until it reaches the current value for which the current regulator is set; then the current regulator will begin to operate and pre-regulate the current output from the generator.

After any check or adjustment of the voltage regulator, it is necessary to polarize the generator before starting the engine to assure correct polarity with respect to the battery (refer to Section 7.1).

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BATTERY-CHARGING GENERATOR REGULATOR

A.C. CHARGING CIRCUIT

The alternating current generator regulator is similar in outward appearance to the regulator used with the D.C. generator. The D.C. and A.C. regulators are NOT interchangeable.

The internal wiring circuits of all standard A.C. generator regulators are similar, but the internal connections vary somewhat according to the method used to control the circuit breaker relay.

There are two and three unit standard A.C. generator regulators; the two unit regulators have a circuit breaker relay controlled by a relay rectifier or by an oil pressure switch and the three-unit regulators have a circuit breaker relay controlled by a built-in control relay.

The generator field circuit is insulated in the generator and grounded in the regulator. This type of connection is designated as Circuit "A".

> **NOTE:** Each type of regulator is used with a certain circuit. Do not attempt to interchange regulators.

The two unit A.C. generator regulator has a circuit breaker relay and a voltage regulator unit while the three unit regulator is also equipped with a control relay in addition to the other two units.

CIRCUIT BREAKER RELAY

The circuit breaker relay has a core with the winding made up of many turns of fine wire. This core and winding are assembled into a frame. A flat steel armature is attached to the frame by a hinge and is centered above the core. Two contact points, supported by two flat springs on the armature, are located above two stationary contact points. The upper and lower contact points are held apart by the tension of a flat spring riveted to the top side of the armature.

Operation

When the D.C. voltage reaches the value for which the circuit breaker relay is adjusted, the magnetism induced in the core by current flow in the winding is sufficient to overcome the armature spring tension and the relay points close. Closing of the contact points connects the D.C. side of the power rectifier to the battery so that current will flow to the battery whenever the generator is driven at sufficient speed.

The relay contact points remain closed as long as the D.C. voltage is enough to hold the relay armature against the core. They open when the voltage decreases to a value at which the magnetic pull of the core can no longer overcome the armature spring tension.

VOLTAGE REGULATOR

The voltage regulator unit has a core with a single shunt winding. This winding also consists of fine wire and is connected across the D.C. side of the power rectifier. The assembly and parts are similar to the circuit breaker relay. The matching upper contact point is supported by a detachable contact support insulated from the frame.

Operation

If the voltage regulator unit is not operating, the generator field circuit is completed to ground through the contact points which are held closed by the tension of a spiral spring acting on the armature.

When the D.C. voltage of the A.C. - D.C. system reaches the value for which the voltage regulator is adjusted, the magnetic field produced by the shunt winding overcomes the armature spring tension and pulls the armature down, causing the contact points to separate. When the contact points separate, resistance is introduced into the field circuit. The resistance decreases the field current causing a corresponding decrease in generator voltage and magnetic pull on the regulator armature. This allows the armature spring tension to re-close the contact points. When the voltage again reaches the value for which the voltage regulator is adjusted, this cycle repeats and continues to repeat many times a second, thus limiting the voltage to the value for which the regulator is set.

With the voltage limited in this manner, the generator supplies varying amounts of current to meet the various states of battery charge and electrical load.

Voltage regulators are compensated for variations in temperature by means of a bi-metal thermostatic hinge on the armature. The effect of this hinge causes the regulator to adjust at a higher voltage when cold, which partly compensates for the fact that a high voltage is required to charge a cold battery.

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CONTROL RELAY

In addition to a circuit breaker and a voltage regulator, the three-unit regulator has a control relay unit. This unit has a core with a single shunt winding connected from the "SW" terminal of the regulator to ground. The winding and core are assembled into a frame. A flat steel armature supporting the upper one of two relay contacts is attached to the frame by a hinge and is centered above the core. The lower contact point is supported by a detachable contact support insulated from the frame. An armature stop is assembled above the upper contact.

Operation

When the ignition switch is "OFF", the contact points are held apart by the tension of a spiral spring acting on the armature. When the ignition switch is turned "ON", battery current flows through the control relay winding to ground. The magnetic field produced by the winding overcomes the armature spring tension and pulls the armature down causing the contact points to close. This completes the circuit to ground for the circuit breaker relay winding so that it can operate when the D.C. voltage from the power rectifier reaches the value for which the circuit breaker relay is adjusted. The control relay contact points remain closed until the ignition switch is turned "OFF".

TRANSISTORIZED AND TRANSISTOR REGULATORS

In addition to the standard regulator, there are two other types of regulators being used with the self-rectifying A.C. generators in the battery-charging circuit. One is a transistorized regulator which contains a vibrating voltage regulator unit and a field relay unit. The other is a transistor regulator which contains no moving parts and is used with a separately mounted field relay.

TRANSISTORIZED REGULATOR

The transistorized regulator (Fig. 3), for use on a negative ground circuit, contains a vibrating voltage regulator unit and a field relay unit. The regulator uses a single transistor and two diodes. The transistor works in conjunction with the conventional voltage unit having a vibrating contact point to limit the generator voltage to a pre-set value. A field discharge diode reduces arcing at the voltage regulator contacts by dissipating the energy created in the generator field windings when the contacts separate. A suppression diode prevents damage from transient voltages which may appear in the system.

Certain transistorized regulators are equipped with a choke coil to permit the installation of a capacitor between the regulator and the "BAT" terminal on installations experiencing radio interference. The capacitor suppresses the radio noise and the choke coil

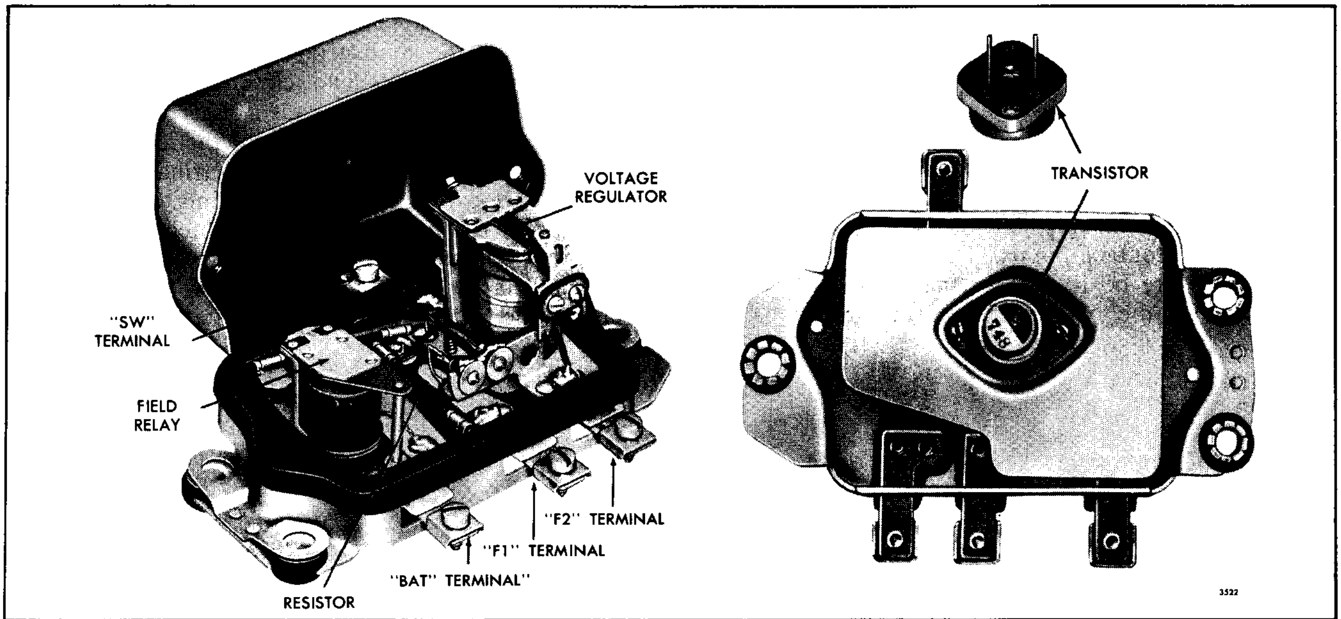

Fig. 3 - Transistorized Regulator

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acts to prevent oxidation of the voltage regulator contacts. Regulators incorporating the choke coil are identified by a spot of green paint on the regulator base, next to the single mounting bolt hole.

CAUTION: A capacitor must not be installed unless the transistorized regulator incorporates the choke coil.

Operation

When the engine starting switch is closed, the field relay winding is energized and causes the contacts to close. Current then flows from the battery through the relay contacts to the regulator "F2" terminal. From this point, the current flows through the generator field winding and then through the transistor and voltage contact points to ground.

As the generator speed increases, the increased voltage from the generator "BAT" terminal is impressed through the field relay contacts across the regulator shunt winding. The magnetism created in the winding causes the voltage contacts to open, thus causing the transistor to shut off the field current. The generator voltage then decreases and the voltage contacts re-close. This cycle repeats many times per second, thereby limiting the generator voltage to the value for which the regulator is set.

The magnetism produced in an accelerator winding, when the voltage contacts are closed, aids the shunt winding in opening the contacts. When the contacts are open, the absence of the magnetism in the accelerator winding allows the spring to immediately re-close the contacts. This action speeds up the vibration of the contacts.

CAUTION: Do not short across or ground any of the terminals on the regulator or the generator and *do not* attempt to polarize the generator.

TRANSISTOR REGULATOR

The transistor regulator is composed principally of transistors, diodes, capacitors and resistors to form a completely static electrical unit containing no moving parts.

The transistor is an electrical device which limits the generator voltage to a pre-set value by controlling the generator field current. The diodes, capacitors and resistors act together to aid the transistor in performing this function, which is the only function that the regulator performs in the charging circuit.

The voltage at which the generator operates is determined by the regulator adjustment. Once adjusted, the generator voltage remains almost constant, since the regulator is unaffected by length of service, changes in temperature or changes in generator output and speed.

A separately mounted field relay connects the regulator "POS" terminal and the generator field windings to the battery when the engine starting switch is closed.

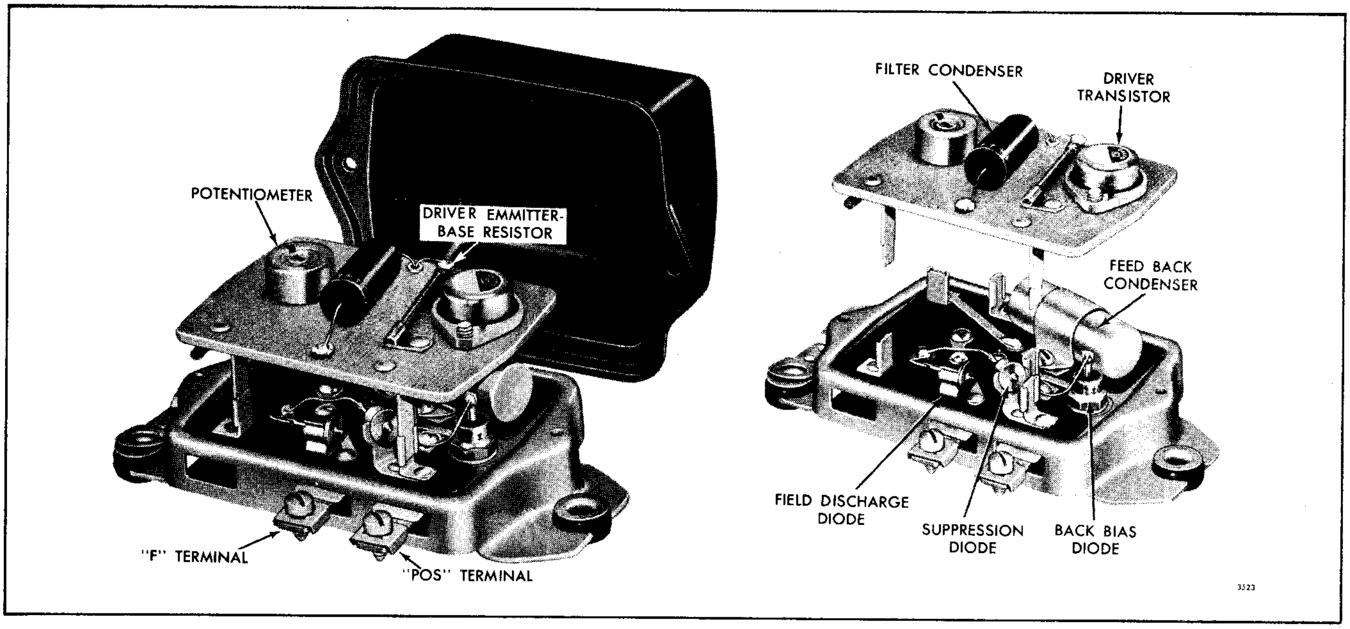

Fig. 4 - Transistor Regulator (Negative Ground Circuits Only)

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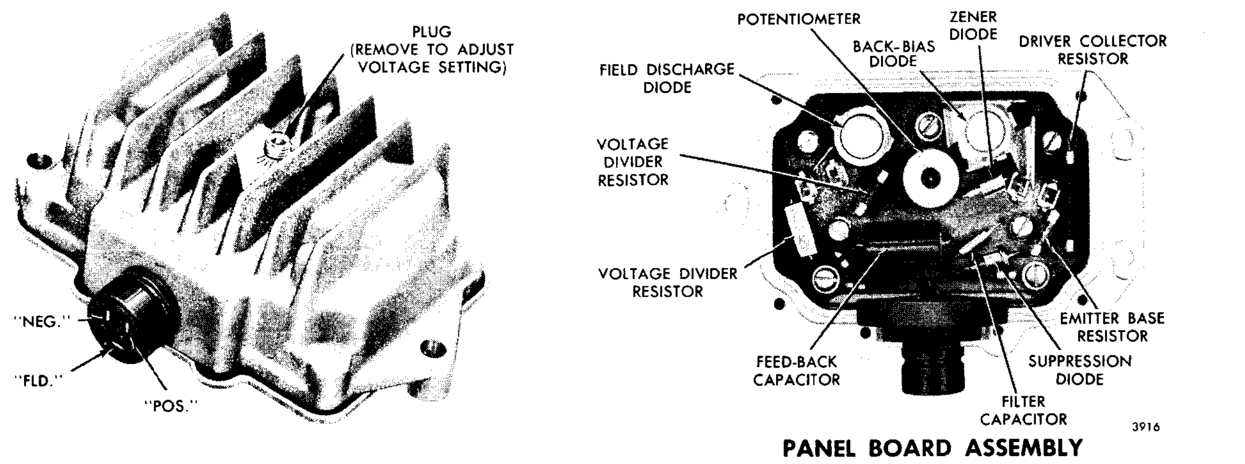

Fig. 5 - Transistor Regulator with Plug-In Connections

The voltage regulator illustrated in Fig. 4 is designed for negative ground battery-charging circuits only. It has two exposed terminals. The voltage setting may be adjusted by relocating a screw in the base of the regulator.

The voltage regulator shown in Fig. 5 has shielded plug-in connections and requires a cable and plug assembly to connect the regulator into the battery-charging circuit. This type of regulator may be used in negative ground, positive ground and insulated charging circuits. The voltage setting may be adjusted by removing a plug in the cover and turning a slotted adjusting button inside the regulator.

Operation

When the engine starting switch is closed, the field relay winding is energized, which causes the relay contacts to close.

In the **negative ground circuit** with the field relay contacts closed and the engine not running, generator field current can be traced from the battery through the relay contacts to the regulator "POS" terminal. Current then continues through the back-bias diode (D-1) and power transistor (TR-1) to the regulator "FLD" terminal, and then through the generator field winding to ground, completing the circuit back to the battery.

When the generator begins to operate, A.C. voltages are induced in the stator windings. These voltages are changed, or rectified, to a D.C. voltage which appears at the output, or "BAT", terminal on the generator. The generator then supplies current to charge the battery and operate vehicle accessories.

As generator speed increases, the voltage reaches the pre-set value and the components in the regulator cause transistor TR-1 to alternately "turn off" and "turn on" the generator field voltage. The regulator thus operates to limit the generator output voltage to the pre-set value.

In the **positive ground circuit**, when the switch is closed and the engine is not running, the field current can be traced from the battery positive ground to generator ground, and then to the regulator "POS" terminal. The current continues through diode D-1 and transistor TR-1 to the regulator "FLD" terminal, and then through the field winding and field relay contacts back to the battery, thus completing the circuit. Except for this primary difference, this circuit operates in the same manner as that described for the negative ground circuit.

REGULATOR PRECAUTIONS

Never short or ground the regulator terminals; *do not attempt to polarize the circuit.*

Make sure all connections in the charging circuit are tight to minimize resistance.

Refer to "A.C. Generator Precautions" in Section 7.1.

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STORAGE BATTERY

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

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 or alternator.

NOTE: In the selection of a replacement battery, it is always good practice to select one of an "electrical size" (refer to chart) 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. 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.

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

Engine	Starting Motor Voltage	Qty.	12 Volt Batteries for 12 or 24 Volt Systems			8 Volt Batteries for 24 or 32 Volt Systems (Marine)			Connect Batteries
			S.A.E. Cold Cranking AMP @ 0°F (-17.8°C) AMP Per Battery	Total S.A.E. Cold Cranking AMP@ 0°F (-17.8°C) AMP Per Bank	Reference S.A.E. 20 AMP Hour Rate Per Bank	Qty.	S.A.E. Cold Cranking AMP@ 0°F (-17.8°C) AMP Per Battery	Total S.A.E. Cold Cranking AMP @ 0°F (-17.8°C) AMP Per Battery	
3, 4-53	12V	1	600	Single Battery	150	—	—	—	Single
	24V	2	600	600	150	—	—	—	Series
6V-53	12V	1	900	Single Battery	205	—	—	—	Single
	24V	2	600	600	150	—	—	—	Series
	32V	—	—	—	—	4	600	600	Series
8V-53	12V*	2	900	1800	410	—	—	—	Parallel
	24V	2	900	900	205	—	—	—	Series
	32V	—	—	—	—	4	750	750	Series

*12 Volt High Output Starter
Note — Bank Refers to the Combined Connected Batteries

BATTERY RECOMMENDATIONS

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regularly. Clean and reapply 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.

> **CAUTION:** 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.

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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 Sprag-type overrunning clutch.

NOTE: See Section 7.0 for the mounting of a Delco-Remy starter auxiliary magnetic switch.

A solenoid switch, mounted on the starting motor housing, operates the Sprag-type overrunning clutch drive by linkage and a shift lever (Figs. 2 and 3). 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 is totally enclosed to protect them from dirt, water and other foreign material.

In the heavy-duty clutch type (Fig. 3), an oil seal, between the shaft and the lever housing, and a linkage seal prevents the entry of transmission oil into the main frame of the starting motor and solenoid case, allowing the motor to be used on wet clutch applications.

The nose housing on the Sprag clutch type starting motor can be rotated to obtain a number of different

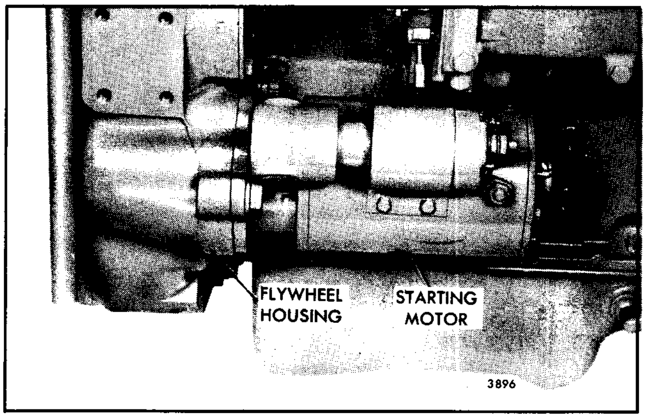

Fig. 1 - Starting Motor Mounting

solenoid positions with respect to the mounting flange. When repositioning of the solenoid is required on a service replacement starting motor, proceed as follows:

Starter with Intermediate-Duty Clutch (In-Line Engines)

The lever housing and the commutator end frame are held to the field frame by bolts extending from the end frame to threaded holes in the lever housing. The nose housing is held to the lever housing by internal attaching bolts extending from the lever housing to threaded holes in the nose housing (Fig. 2). With this arrangement, it is necessary to partially disassemble the motor to provide access to the nose housing attaching bolts. Relocate the nose housing as follows:

1. Remove the electrical connector and the screws attaching the solenoid assembly to the field frame. Then, remove the bolts from the commutator end frame.

2. Separate the field frame from the remaining assembly and pull the armature away from the lever housing until the pinion stop rests against the clutch pinion. This will provide access to the nose housing attaching bolts.

3. Remove the nose housing attaching bolts with a box wrench or open end wrench.

4. Turn the nose housing to the required position.

NOTE: The solenoid must never be located below the centerline of the starter or dust, oil, moisture and foreign material can collect and cause solenoid failures.

5. Reinstall the nose housing attaching bolts and tighten them to 11-15 lb-ft (15-20 Nm) torque.

6. Reassemble the motor.

Starter with Heavy-Duty Clutch (V-Type Engines)

The nose housing, on starters equipped with the heavy-duty clutch (Fig. 3), is attached to the lever housing by six bolts located around the outside of the housing. Relocate the nose housing as follows:

1. Remove the six socket head screws (1 short and 5 long) and six neoprene plugs from the unused holes if a twelve hole starter mounting flange is used.

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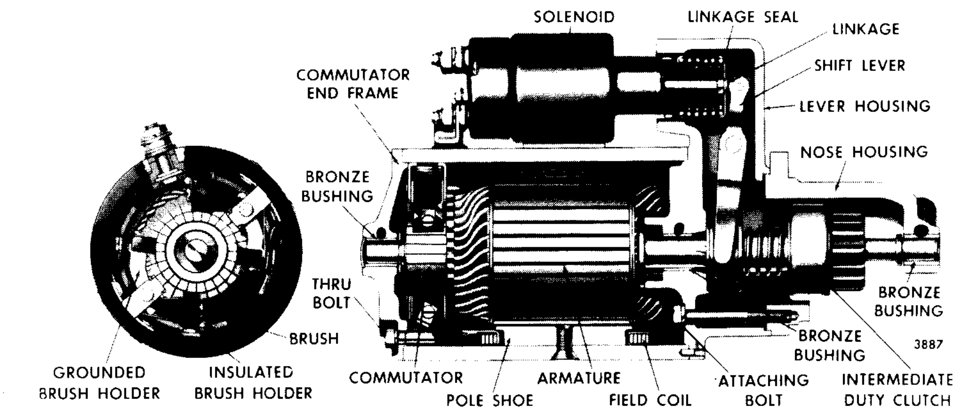

Fig. 2 - Cross-Section of Motor with Intermediate-Duty Clutch

2. Turn the nose housing to the required position.

NOTE: The solenoid must never be located below the centerline of the starter or dust, oil, moisture and foreign material can collect and cause solenoid failures.

3. Install the six socket head screws, with the short screw in the shallow hole nearest the solenoid, and six neoprene plugs, if a twelve hole starter mounting flange is used.

4. Tighten the screws to 13-17 lb-ft (18-23 Nm) torque.

High-Output Starting Motor

A high output 12 volt starting motor, with a Sprag overrunning clutch type drive, is provided for certain vehicle applications which require the equivalent of 24 volts for starting the engine and 12 volts for lighting and operation of electrical accessories. The same total battery capacity recommended for use with a 24 volt starter (two 205 ampere-hour batteries) must be retained and connected in parallel for the high-output 12 volt starter.

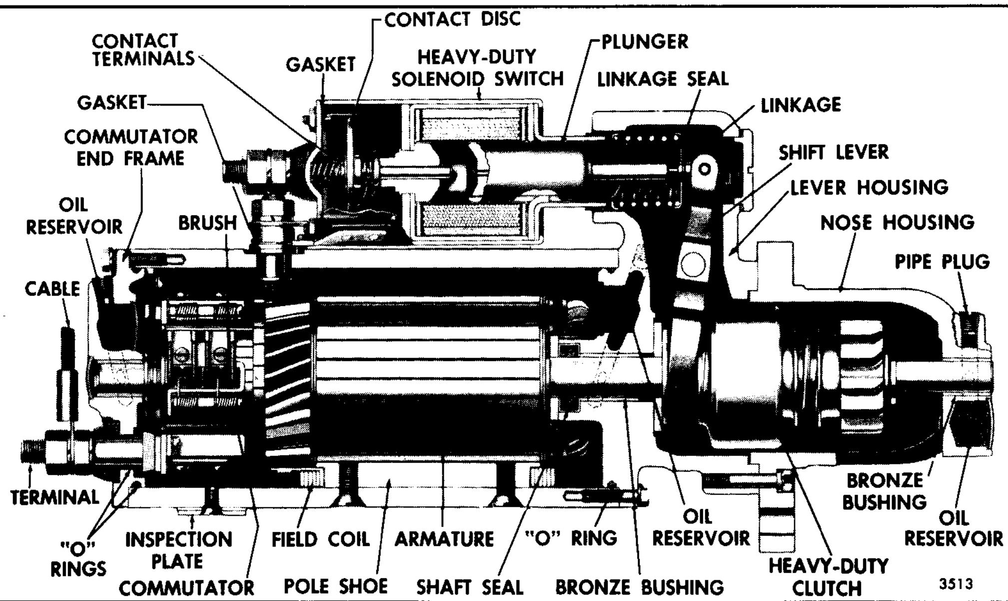

Fig. 3 - Cross-Section of Motor with Heavy-Duty Clutch

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Lubrication

The starting motor bearings (bushings) are lubricated by oil saturated wicks which project through each bronze bushing (one at each end and one at the center) and contact the armature shaft. Oil can be added to each wick by removing a pipe plug which is accessible on the outside of the motor (refer to Section 15.1).

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 gear teeth have either no chamfer or a Bendix chamfer. The Sprag clutch cannot be used with a ring gear with a Dyer chamfer.

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.

NOTE: Before working on the electrical system, disconnect the battery ground cable to avoid accidental short circuiting of any loose wires.

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.

Check the starting motor, if required, in accordance with the Delco-Remy "Cranking Circuit" maintenance handbook.

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 (cast iron flywheel housings) or 95-105 lb-ft (129-143 Nm) torque (aluminum flywheel housings).

Keep all of the electrical connections clean and tight. When installing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10-32 connections to 16-30 **lb-in** (2-3 Nm) torque and the 1/2" x 13 connections to 20-25 lb-ft (27-34 Nm) torque.

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INSTRUMENTS AND TACHOMETER DRIVE

INSTRUMENTS

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 (Fig. 1). Instruments with slotted cases are available for use with lighted dashes. Also, closely related and usually installed in the general vicinity of these instruments are certain controls consisting of an engine starting switch, engine stop knob and an emergency stop knob.

All Torqmatic converters are equipped with an oil pressure gage and, in some instances, with an oil temperature gage. These instruments are mounted on a separate panel.

Instruments, throttle control and engine starting and stopping controls are mounted in various locations depending upon the particular use of the engine.

Marine propulsion engines are provided with an instrument panel which usually includes an engine oil pressure gage, reverse gear oil pressure gage, water temperature gage, ammeter and a tachometer. The instrument panels are generally mounted some distance from the engine. Illuminated instrument panels are provided for marine applications which require night operations.

All illuminated instrument panels are wired for a 12 volt lighting circuit. Therefore, when marine propulsion units incorporate either a 24 or 32 volt electrical system, a 12 volt tap-off from the battery may be made, or resistors (Table 1) may be installed in the circuit to protect the instrument panel bulbs. As indicated in Fig. 2, one resistor is used in the lead for each instrument panel bulb.

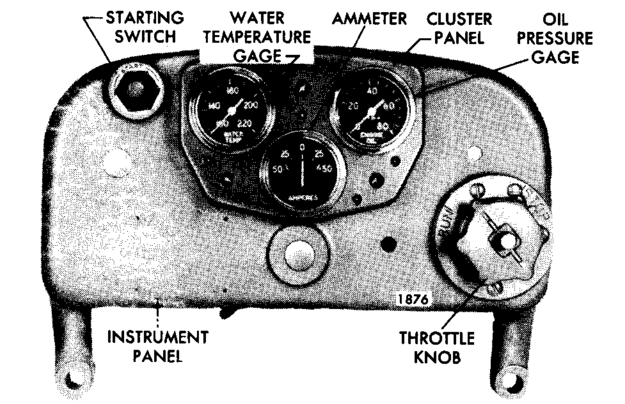

Fig. 1 - Typical Instrument Panel

Resistor Specifications		
Volts	Ohms	Watts
24	50	10
32	100	10

TABLE 1

Whenever performing service or preventive maintenance procedures on marine propulsion engine units which include a 24 or 32 volt electrical system, check the lighting circuit of the instrument panels to determine if either a 12 volt tap-off from the battery or resistors have been installed in the lighting circuit to protect the instrument panel bulbs.

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

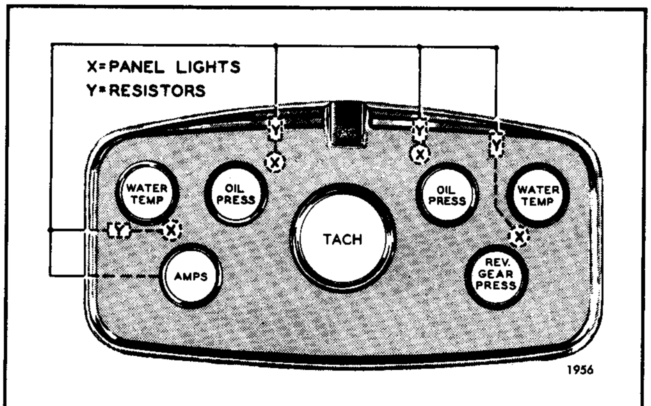

Fig. 2 - Installation of Resistors in Illuminated Instrument Panel

rubber mount 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* in Section 13.2, the engine should be stopped and the cause of the low oil pressure determined and corrected before the engine is started again.

Current oil pressure gages have male threads and require female fittings. When replacing a former gage with female threads, a new mounting clamp and connector must be used.

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. The coils must be located so that they may be securely fastened to prevent vibrating.

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. The small current registered prevents rapid brush wear in the battery-charging alternator. 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

The tachometer, driven by the engine, registers the speed of the engine in revolutions per minute (rpm).

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 is used to energize the starting motor (Fig. 3). 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).

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

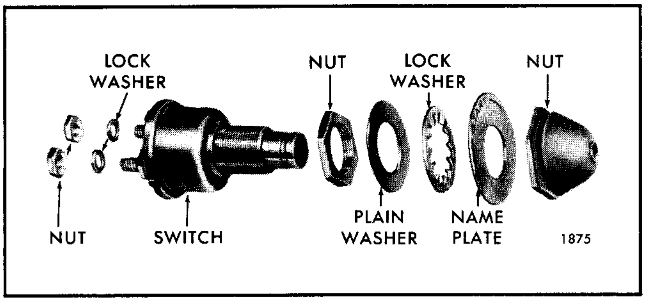

Fig. 3 - Typical Engine Starting Switch

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knob manually places the injector racks in the no-fuel position. Return the stop knob to its original position after the engine stops.

> **NOTE:** When an emergency shutdown is necessary on a current engine with the spring loaded injector control tubes (one adjustment screw) the stop knob should be pulled immediately and held until the engine stops.

Emergency Stop Knob
(Engines with Air Shutdown Valve)

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 shutoff 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 shutoff valve must be reset manually. The cause of the malfunction should be determined before the engine is started again.

TACHOMETER DRIVE

The tachometer drive shaft is pressed into the end of the camshaft, balance shaft or governor drive shaft. On V-type engines, it is pressed into the end of either camshaft, the blower drive shaft or the accessory drive gear.

When required, a tachometer drive cable adaptor is used to change speed or to change direction of rotation, depending upon the location of the tachometer drive. A special key is used to connect the drive shaft to the tachometer drive cable adaptor.

The cable connection at the current tachometer head is a 5/8" threaded connection in place of the former 7/8" connection. To eliminate possible misalignment, the current tachometer angle drive has a short flexible cable and incorporates an integral oil seal. The output shaft key size has been increased from 5/32" to SAE 3/16". New flexible drive cables are also required with the current tachometers and angle drives.

Remove Tachometer Drive Shaft

If threads (5/16"-24 or 3/8"-24) are provided on the outer end of the tachometer drive shaft to accommodate a removing tool, thread remover J 5901-3 on the shaft. Then, attach slide hammer J 23907-1 to the remover. A few sharp blows of the weight against the slide hammer rod will remove the tachometer drive shaft.

If threads are not provided on the outer end of the tachometer drive shaft, or if the end of the shaft is broken off, drill and tap the shaft. Then, thread a stud into the shaft and remove the shaft with the remover and slide hammer.

> **NOTE:** Use adequate protective measures to prevent the metal particles from falling into the gear train and oil pan.

When installing a tachometer drive cover assembly or a drive adaptor, it is important they be aligned properly with the tachometer drive shaft as noted in Section 7.0.

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ENGINE PROTECTIVE SYSTEMS

MANUAL SHUTDOWN

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 an air shutoff 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 connected to thv air shutoff valve shaft lever by a control wire. Pulling the knob all the way out will stop the engine. Push the knob all the way in and manually reset the air shutoff valve before starting the engine again.

Service

For disassembly and assembly of the shutdown device, refer to Section 3.3.

AUTOMATIC MECHANICAL SHUTDOWN

The automatic mechanical shutdown system is designed to stop the engine if an abnormal condition such as high engine coolant temperature, low engine oil pressure or engine overspeeding arises. The components of the shutdown system are schematically illustrated in Fig. 1.

A coolant temperature-sensing valve adaptor and plug assembly is mounted on the exhaust manifold with the plug extending into the manifold. Coolant from the engine is directed through the adaptor assembly, in which the bulb of the temperature-sensing valve assembly is located, to the suction side of the water pump.

Oil under pressure from the engine is directed through a restricted fitting to a "T" connection. One line from the "T" is connected to the temperature-sensing valve assembly and the other line leads to the oil pressure bellows. A line attached to the discharge side of the temperature valve directs any oil that passes through the valve to the engine crankcase. Oil under pressure entering the oil pressure bellows, works through the bellows against a spring, overcomes the spring tension and permits the latch to retain the air shutoff valve assembly in the open position. Should the oil pressure drop below a predetermined value, the spring in the oil pressure bellows will release the latch permitting the air shutoff valve to close, stopping the engine. The oil pressure bellows can be adjusted to release the latch at pressures ranging from approximately 5 to 25 psi (34.5 to 172 kPa).

The overspeed governor, used in some engine applications, consists of a small plunger and valve actuated by a set of spring-loaded weights. The plunger and valve are located in the oil line connecting the oil pressure bellows to the main oil gallery. An outlet in the valve is connected to the engine oil sump. Whenever engine speed exceeds the overspeed governor setting, the valve plunger (actuated by the governor weights) is lifted from its seat and permits oil in the line to flow to the engine sump. This results in a drop of oil pressure to the oil pressure bellows, thus actuating the shutdown mechanism and stopping the engine.

Operation

When starting the engine, it is necessary to first manually open the air shutoff valve and then press the engine starting switch, cranking the engine. As soon as the engine starts, the engine starting switch may be released, but the air shutoff valve must be retained in the open position until the engine oil pressure exceeds the setting of the pressure sensitive device and permits the latch to retain the air shutoff valve in the open position.

During operation, if the oil pressure drops below the setting of the pressure sensitive bellows, the spring within the bellows will release the latch and permit the air shutoff valve to close, stopping the engine.

If the engine coolant overheats during operation, the high temperature will cause the temperature-sensing valve to open and permit the oil to flow to the engine crankcase. The opening of the temperature-sensing valve lowers the oil pressure on the discharge side of

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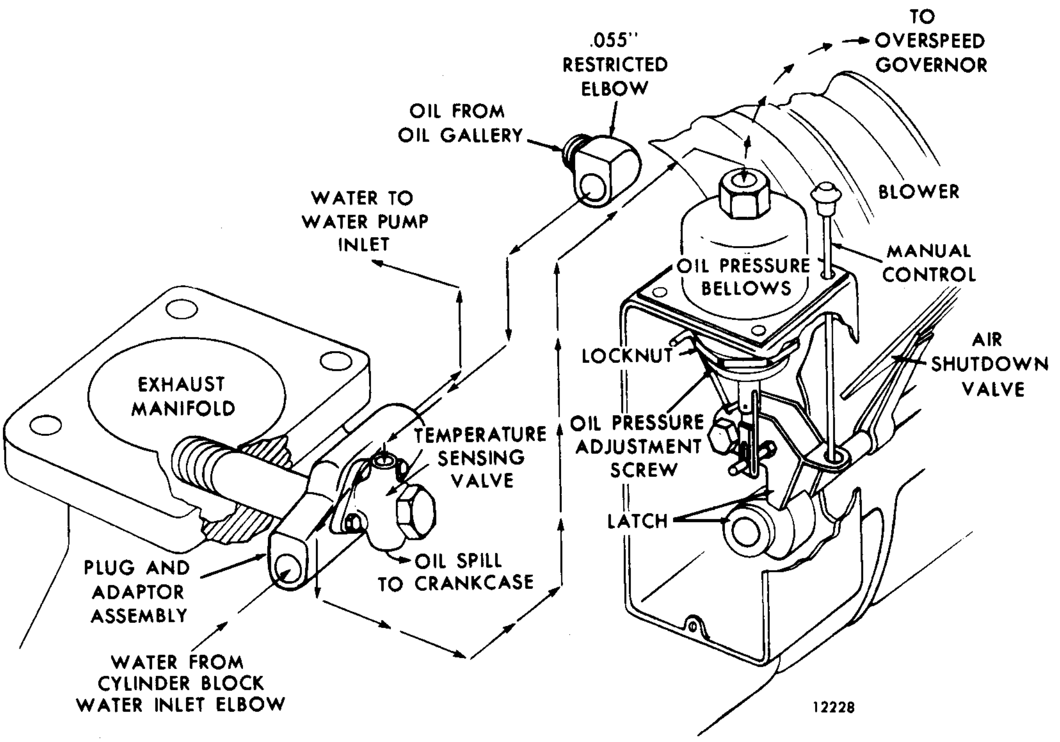

Fig. 1 - Mechanical Shutdown System Schematically Illustrated

the restricted fitting. The spring in the pressure sensitive bellows will release the latch and permit the air shutoff valve to close, stopping the engine.

Should the engine lose its coolant during operation, the copper plug extending into the exhaust manifold will heat up and radiate heat to the temperature-sensing valve which will operate and shut the engine down.

Whenever the engine speed exceeds the overspeed governor setting, the oil in the line flows to the sump, resulting in a decrease in oil pressure. The oil pressure bellows will then release the latch and permit the air shutoff valve to close, stopping the engine.

After the engine has been stopped due to the action of a protective device, it cannot be restarted until the particular device which actuates the shutdown has returned to its normal position. The abnormal condition which stopped the engine must be corrected before attempting to start the engine again.

Adjustment

The only adjustments necessary in the automatic mechanical shutdown system are the low oil pressure setting of the bellows and the overspeed setting of the overspeed governor. Replace the temperature-sensing valve when operation is unsatisfactory.

To adjust the low oil pressure setting of the bellows, run the engine until normal operating temperature has been reached and the oil pressure has stabilized. Then reduce the engine speed slowly until the bellows disengages the latch on the air shutoff valve and stops the engine. Note the oil pressure at which the shut down occurred. For units having a minimum idle speed of 1000 rpm, the recommended oil shutdown pressure is 18 psi (124 kPa); for units having a minimum idle speed of 500 rpm it is 10 psi (69 kPa). If adjustment is necessary, loosen the locknut on the bellows and turn the adjusting screw clockwise to increase the oil pressure setting or counterclockwise to decrease the setting. Hold the adjusting screw and tighten the locknut when the proper setting has been obtained.

Check the operation of the high coolant temperature-sensing valve by placing a cover over the radiator while the engine is operating at 1800 rpm under load. Observe the coolant temperature on a thermometer inserted at the radiator filler hole. An engine shut down should occur when the coolant is 200°to 210°F (93°to 99°C). If shut down does not occur, replace the coolant temperature-sensing valve assembly. If shut down occurs below 200°F (93°C), check the coolant

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flow through the plug and adaptor assembly. If circulation is satisfactory and shut down occurs below 200°F (93°C), replace the coolant temperature-sensing valve assembly. The coolant temperature-sensing valve cannot be adjusted.

NOTE: When removing the temperature-sensing valve or water temperature switch, examine the plunger in the current type copper plug (Fig. 2). If the plunger is not free in the plug and adaptor, install a new plunger, spring, plug and adaptor. Deposits from the engine coolant building up between the plunger, spring and copper plug can cause the plunger to stick. On the former type copper plug, replace the former plug with the new plug, plunger, spring and adaptor when the water holes become plugged with calcium deposits.

When required, the coolant temperature-sensing valve can be bench tested. This can be accomplished by attaching an air hose (40 psi or 276 kPa) to the oil pressure hole and attaching a tube from the spill hole to a can of water. The bulb of the temperature-sensing valve and a thermometer should be emersed in a container of water that is heated and agitated. The valve opening will be indicated by the flow of air when the valve opens (195° to 206°F or 90° to 99°C).

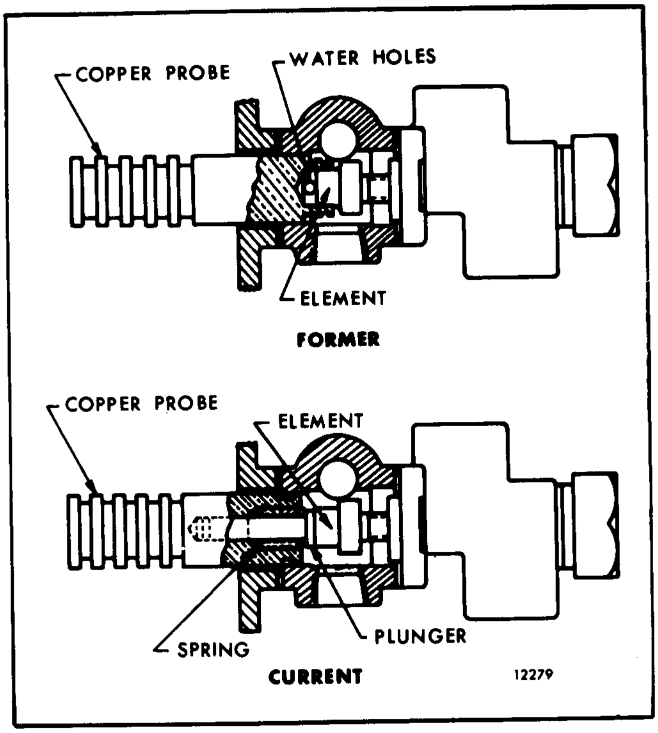

Fig. 2 - Comparison of New and Old Copper Plug

Overspeed Shutdown Adjustment

1. Start the engine and bring it up to operating temperature.

2. Increase the engine speed to the specified overspeed shutdown speed. At this speed the bellow should disengage the air shutdown latch and stop the engine.

3. Adjust the overspeed governor setting, if necessary, by loosening the governor adjusting screw locknut (on the overspeed governor cap), then turning the adjusting screw clockwise to increase the speed at which the air shutdown mechanism is tripped or counterclockwise to decrease the speed at which the latch will trip. Always tighten the locknut after each adjustment.

4. Stop the engine and replace the control shutdown housing cover.

AUTOMATIC ELECTRICAL SHUTDOWN

The automatic electrical shutdown system (Fig. 3) protects the engine against a loss of coolant, overheating of the coolant, loss of oil pressure or overspeeding. In the event one of the foregoing conditions arises, a switch will close the electrical circuit and energize the solenoid switch, causing the shutdown solenoid to release the air shutdown latch and stop the engine.

Operation

The electrical circuit is de-energized under normal operating conditions. When the engine is started, the oil pressure switch opens when the oil pressure reaches approximately 10 psi (69 kPa) and the fuel oil pressure switch closes at approximately 20 psi (138 kPa) fuel pressure. The water temperature switch remains open.

If the oil pressure drops below 10 psi (69 kPa), the oil pressure switch will close the circuit and energize the shutdown solenoid. This will activate the shutdown mechanism and stop the engine.

A loss of coolant or an increase in coolant temperature to approximately 203°F (94°C) will close the contacts in the water temperature switch, thus closing the electrical circuit and activating the shutdown mechanism.

The water temperature switch consists of a temperature-sensing valve and a micro-switch. The valve

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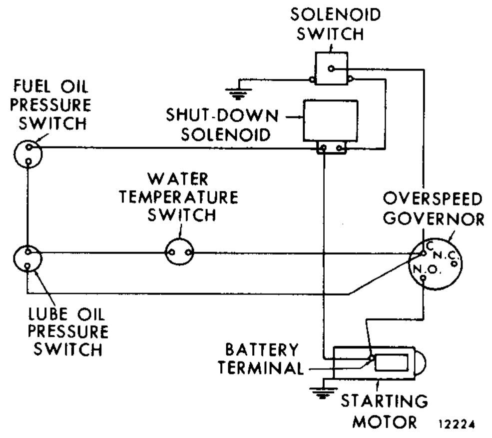

Fig. 3 - Automatic Electrical Shutdown System Diagram

contacts a copper plug (heat probe) which extends into the exhaust manifold outlet. Engine water is directed over the power element of the valve and should the water temperature exceed approximately 203°F (94°C), the valve will close the contacts in the micro-switch and energize the shutdown circuit. If a loss of water occurs, the heat of the exhaust gases will be transmitted through the copper plug to the temperature-sensing valve and cause the shutdown circuit to be activated.

If the engine speed exceeds the high speed setting of the overspeed governor, the governor switch will close and activate the shutdown mechanism.

When the engine is shutdown, the decrease in speed will open the governor switch and the decrease in oil and fuel pressures will close the oil pressure switch and open the fuel pressure switch, thus de-energizing the circuit.

The cause of the abnormal conditions must then be determined and corrected before the engine is started again. Also, the air shutoff valve must be manually reset in the open position before the engine can be started.

Some engines are equipped with an electrically operated automatic shutdown system which incorporates a hot wire relay or solid state time delay switch (Fig. 4).

Since the fuel pressure builds up rapidly, the fuel oil pressure switch could close before the lubricating oil pressure switch opens, thereby effecting a shutdown of the engine. The hot wire relay or time delay switch, however, delays the closing of the fuel oil pressure switch for 3 to 10 seconds to enable the lubricating oil pressure to build-up and open the oil pressure switch contacts.

When the lubricating oil pressure falls below 10 ±2 psi, the contacts in the oil pressure switch used in this system will close and current will flow to the hot wire relay or the time delay switch. The few seconds required to heat the hot wire relay provides sufficient delay to avoid an engine shutdown when low oil pressure is caused by a temporary condition such as an air bubble or a temporary overlap in the operation of the oil pressure switch and the fuel oil pressure switch when starting or stopping the engine.

The high water temperature switch is installed in the side of the thermostat housing. The switch contacts close when the water temperature reaches approximately 205°F (95°C).

Time Delay Switch

The current solid state time delay switch is designed as a direct replacement for the former hot wire relay (Fig. 4).

It is a solid-state time device which effectively withstands shock and vibrations. The switch is polarity-conscious. If a reverse polarity is applied the switch will not work.

The switch has two circuits: a time circuit and an electronic circuit which consists of a silicon control rectifier. The rectifier has sufficient capacity to handle standard loads such as the emergency shutdown solenoid. Abnormal load situations such as a collapsing magnetic field in a coil can damage the rectifier rendering it inoperative. To protect the rectifier a discharge diode is connected across the terminals B and C of the solid state time delay switch.

The time delay switch should be check periodically to be sure that it is operating properly (refer Section 7.0).

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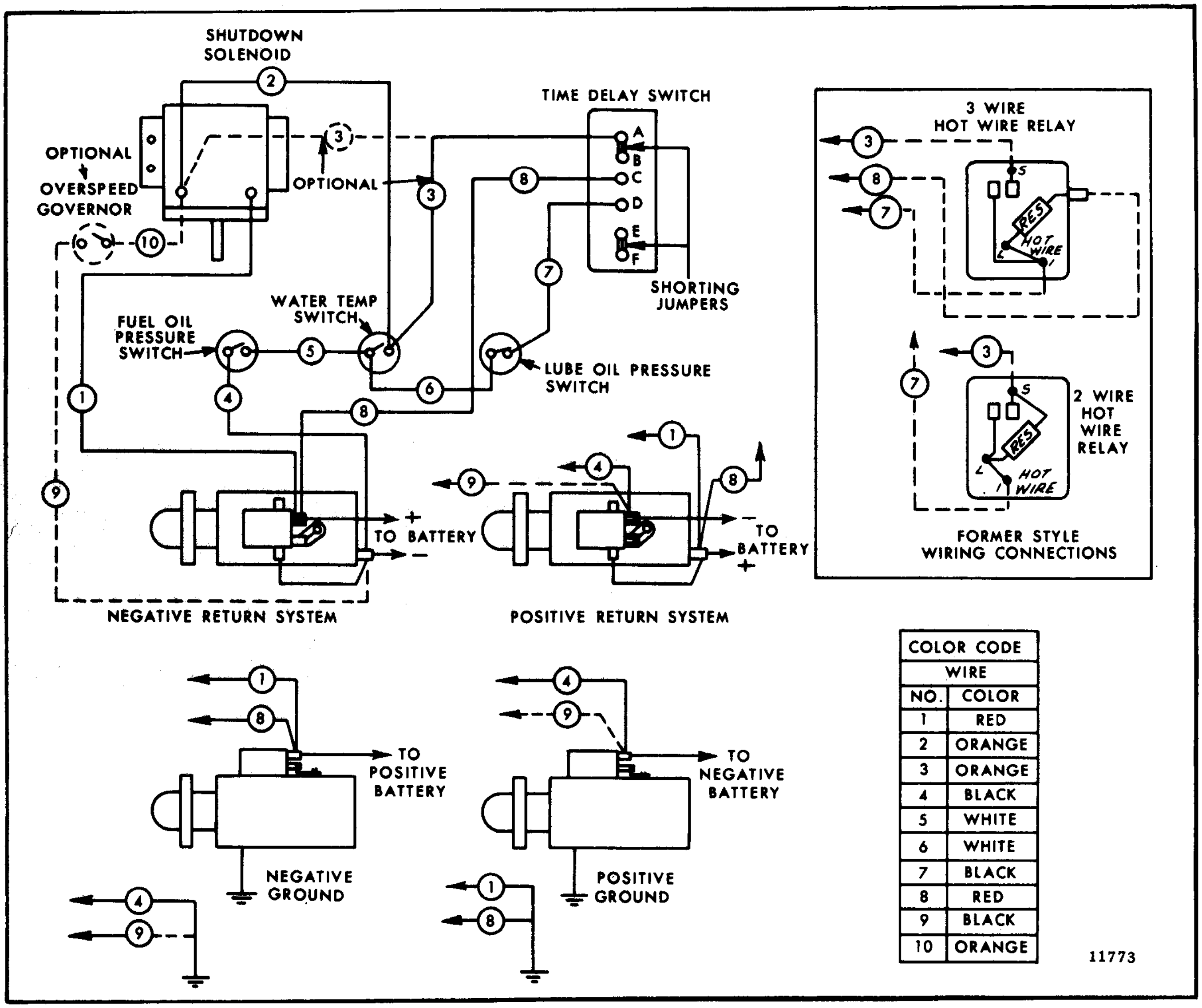

COLOR CODE	
WIRE	
NO.	COLOR
1	RED
2	ORANGE
3	ORANGE
4	BLACK
5	WHITE
6	WHITE
7	BLACK
8	RED
9	BLACK
10	ORANGE

Fig. 4 - Automatic Electrical Shutdown System Incorporating Hot Wire Relay or Time Delay Switch

SHUTDOWN SYSTEM FOR DIRECT MOUNTED TURBOCHARGED ENGINES

With the use of a direct mounted turbocharger and the spring loaded fuel injector control racks, the air shutoff valve was eliminated from the air inlet housing. The spring loaded injector tube control rack enables the engine to come out of any advanced fuel position when an emergency situation arises.

When an engine is operating in an atmosphere subject to volatile fuel and is equipped with an air inlet housing without the air shutoff valve, a customer may request that the engine be equipped with an external or remote mounted emergency air shutdown assembly.

The remote mounted emergency air shutdown assembly that is equipped with the air shutoff valve can be installed upstream of the air inlet side of the turbocharger.

Care should be taken when installing the emergency air shutdown assembly between the turbocharger and the air cleaner. Because the engine shutdown system is activated, all of the piping between the shutdown system and the engine will be subjected to an abnormally high suction which may cause some of the piping components, i.e., rubber hoses and elbows to

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collapse. Therefore, it is recommended that all of these components be designed to withstand the maximum suction without a failure which would allow air to reach the engine air intake.

A 7 to 5 inch diameter reducing 90° rubber hose or a 7 to 5 inch diameter hump hose reducer can be used to adapt the shutdown to the turbocharger.

The rubber elbow can be obtained from the manufacturer; Griffin Rubber Mills in Portland, Oregon under their part number - 51759.

The customer is required to provide the mounting support brackets.

The emergency air shutdown assembly is manually operated. To be an automatic shutdown system, it will be necessary to install a solenoid.

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ALARM SYSTEM

The alarm system is similar in many respects to the automatic shut-down system, but does not include the automatic shut-down feature incorporating the electrical solenoid or the flap valve in the air shut-down housing which is operated by the solenoid. A bell is substituted for the solenoid in the alarm system. The alarm may be substituted for the shut-down solenoid, or it may be added to the automatic shut-down system. In either case, the alarm notifies the operator of a dangerous condition in the engine.

The voltage used through the alarm bell, however, must not exceed 12 volts.

Note that the cranking motor performs no essential function in the circuit.

An oil pressure switch, introduced into the engine oil gallery, is closed when the engine is not running, but opens after starting and remains open while the engine is running. This switch will close only in case of lowered oil pressure, thus causing the alarm to operate, or it will close if the engine is stopped by the operator. A water temperature switch, mounted in the water manifold, always remains open except in case of high water temperature when it closes and operates the alarm.

An automatic fuel oil switch closes after the engine is started and normal fuel oil pressure has been attained.

An optional overspeed switch is sometimes introduced into the system.

The water temperature switch and the oil pressure switch are similar to the same switches used in the automatic shut-down device.

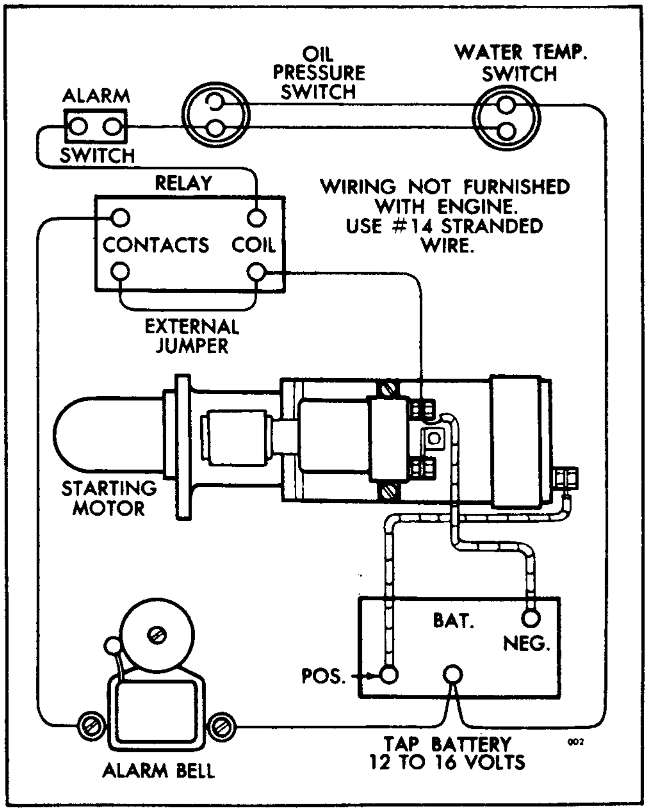

Fig. 1 - Alarm System Wiring Diagram

Service of the alarm system is usually limited to replacement of the alarm bell.

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OVERSPEED GOVERNORS

ELECTRIC (Two Switch)

The series GY-2 Snychro-Start overspeed governor (Fig. 1) contains two separate snap action switches with single-pole double-throw contacts which operate at two different speeds. The governor is adjusted by the manufacturer to trip at the speeds required as indicated on the name plate. Unless otherwise specified, the name plate indicates trip points on increasing speed. The contacts will return to normal when the speed is decreased approximately 100 rpm below the trip speed, except on the high speed switch of those models having a manual reset button. The letter "M" after any model number indicates the high speed switch must be reset manually.

Service

1. The snap action switches may be replaced as follows:

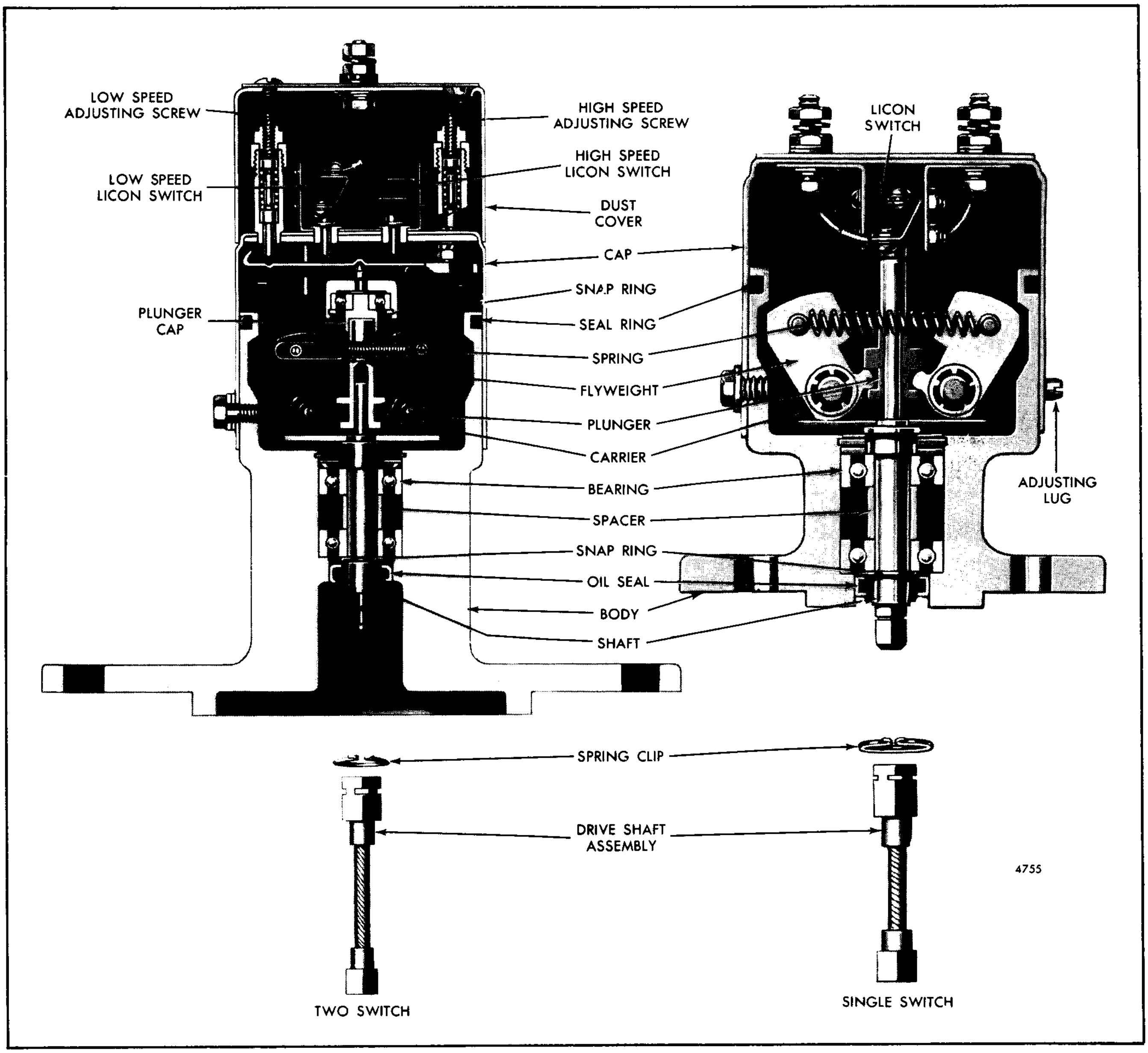

Fig. 1 - Electric Overspeed Governors

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a. Mark the position of the dust cover and remove both hold-down screws.

b. Observe the position of the switches. Usually they are positioned with 1/64" clearance between the switch button and the lifters. If the lifters are replaced, make certain that the long lifter is placed beneath the low speed switch and the short lifter is placed beneath the high speed switch.

c. Install the new switches by reversing the above procedure.

CAUTION: When replacing the dust cover on a governor with a manual reset, make certain the switch wiring does not interfere with the reset mechanism.

d. Adjust the speed as outlined under *Speed Adjustment*.

2. Remove the governor cap as follows:

a. Observe the marking on the cap and the body and remove the three holding screws.

b. Remove the cap assembly, being careful not to damage the seal ring.

c. Replace any internal parts as required and reassemble and return the cap to the original position. A light coat of grease will facilitate assembly of the seal ring to the body.

NOTE: The position of the cap is very critical on governors in which the difference in trip points between the two switches is more than 1000 rpm and the trip point of the high speed switch is above 2100 rpm. These governors use elongated loop flyweight springs. If, after assembly, the No. 1 switch trips at a far higher point than normal, lower the cap position slightly. If the No. 2 switch trips at a very low speed, raise the cap position slightly. If difficulty arises, refer to Step 5 below.

d. Adjust the speed as outlined under *Speed Adjustment*.

3. Replace the speed adjusting springs as follows:

a. Hold the speed adjusting stud with a 5/16" open end wrench and loosen the adjusting stud nut with a 3/8" open end wrench.

b. After the above nut is removed, the adjusting spring and related parts may be removed and replaced as necessary. Exercise care to prevent particles of dirt from accumulating on the parts.

4. Replace the flexible drive shaft as follows:

a. Insert a sharp pointed instrument in the loop of the spring clip and pull it from the shaft as far as possible and remove the shaft assembly.

b. Upon reassembly, first install the spring clip in the groove of the fitting on the end of the governor shaft.

c. Push the shaft assembly into the square end of the governor shaft and the spring clip will snap in place.

NOTE: Check the position of the spring clip. If the clip has sprung out of position, use a small screw driver to push it into place.

5. Adjust the governor cap (with the dust cover in place):

a. Turn the low speed adjusting screw out for minimum speed adjustment. In this position, the top of the adjusting screw is approximately 1/8" from the top of the dust cover.

b. Turn the high speed adjusting screw in for almost maximum speed adjustment. In this position, the top of the adjusting screw is approximately 5/16" from the top of the dust cover.

c. With partial tension on the cap holding screws, turn the governor cap to the maximum extended position.

d. Operate the governor at 200 rpm above the trip point of the low speed switch.

e. Rotate the cap slowly in a clockwise direction until the low speed switch trips, mark the cap position and stop the engine. Then turn the cap another 1/16" and lock the holding screws securely.

f. Complete the operation as outlined under *Speed Adjustment*. Generally, the trip point of the low speed switch will have to be increased and the high speed switch decreased.

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Maintenance

Grease the governor shaft ball bearings every 10,000 hours (every 5,000 hours if the governor speed is above 2500 rpm) as follows:

1. Remove the governor cap.

2. Remove the flexible drive shaft.

3. Remove the retaining ring from the groove in the housing. Then remove the weight and shaft assembly.

4. Inspect the oil seal and, if necessary, replace it as follows:

a. Place the governor body in an arbor press, with the mounting flange toward the bottom, and use a 9/16" diameter rod to press the oil seal out.

b. Press a new seal in place 3/64" from the bottom of the bearing cavity.

5. Fill the grease reservoir between the bearings *only 3/4 full* with Texaco "Unitemp" grease, or equivalent.

6. Reassemble the governor by reversing the procedure for disassembly and adjust the trip speeds as outlined below:

Speed Adjustment

Both switches may be individually adjusted. The dust cover screw marked "1" covers the low speed adjuster; the screw marked "2" covers the high speed adjuster. Proceed as follows:

1. Remove the appropriate dust cover screw. Then insert a 1/16" Allen wrench into the adjusting screw.

2. Turn the screw clockwise to increase the trip speed or counterclockwise to decrease the speed.

CAUTION: If the adjusting screws are turned in too far, the switch will no longer operate. Do not attempt to use the slots in the cap for normal speed adjustments. This position is set and marked by the manufacturer for operation in the speed range required.

ELECTRIC (Single Switch)

Series GWA, GYA and GAA Synchro-Start overspeed governors (Fig. 1) are calibrated by the manufacturer to open or close the switch contacts at the particular speed required. The switch contacts will reset automatically when the speed is reduced approximately 100 rpm below the trip speed.

Service

Grease the governor shaft ball bearings every 10,000 hours (every 5000 hours if the governor speed is above 2500 rpm) as follows:

1. Remove the adjusting screw and the adjusting stud, then remove the governor cap.

2. Insert a sharp pointed instrument in the loop of the spring clip and pull the clip from the flexible shaft as far as possible. Then remove the shaft assembly.

3. Remove the retaining ring from the groove in the housing.

4. Remove the weight and shaft assembly.

5. Inspect the oil seal and, if necessary, replace the seal as follows:

a. Place the governor body in an arbor press with the mounting flange facing down and use a 9/16" diameter rod to press the oil seal out of the body.

b. Press the new oil seal in place, 3/64" from the bottom of the bearing cavity.

6. Fill the grease reservoir between the bearings *only 3/4 full* with Texaco "Unitemp" grease, or equivalent.

7. Reassemble the governor by reversing the procedure for disassembly and adjust the trip speed as outlined below.

Speed Adjustment

Loosen the cap adjusting lock screw and turn the cap until the desired trip speed is reached. Clockwise rotation of the cap lowers the trip speed and counterclockwise rotation increases the trip speed. The total range of adjustment of the particular governor is indicated on the governor name plate. The governor should not be adjusted to trip below 100 rpm above the normal running speed of the governor. Make sure the governor cap locking screw is tightened after the adjustment has been completed.

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CAUTION: Under no circumstances should the governor switch be by-passed to prevent engine shut-down in the event of overspeed, otherwise serious damage to not only the engine, but also to the governor may be incurred since the governor is not designed to operate above its tripping speed.

HYDRAULIC

The hydraulic overspeed governor which contains a set of spring-loaded weights prevents excessive engine speeds.

Figure 2 illustrates the old and new hydraulic overspeed governors. The new governor differs from the old governor in the use of a new housing, cover and speed adjusting screw. The new housing is shorter and the new cover is longer than the old cover. The new adjusting screw differs from the former screw in the width of the seal ring groove which is wider on the new screw.

The overspeed governor is mounted in an adaptor which is mounted on the rear of the flywheel housing. A seal ring in the adpator end of the governor housing prevents oil seepage from the flywheel housing. The governor is driven by a flexible drive assembly from the blower drive shaft. Oil under pressure is supplied to the governor by a tube which is connected to the oil gallery in the cylinder block.

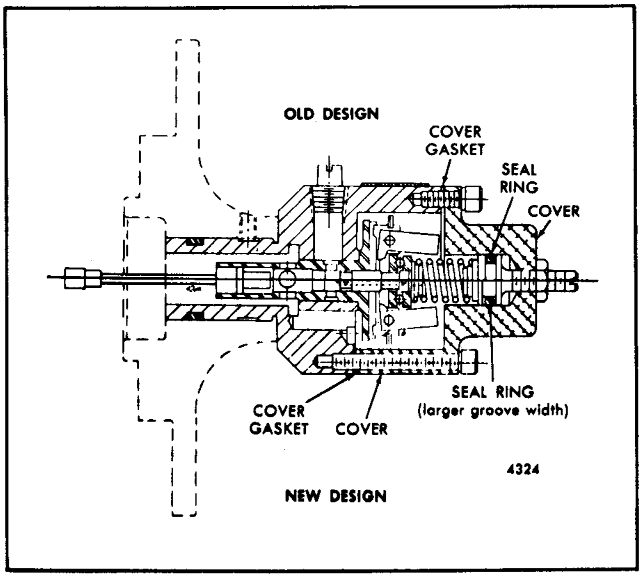

Fig. 2 - Hydraulic Overspeed Governor

Operation

When the engine speed reaches the value for which the overspeed governor is set, the centrifugal force of the weights in the overspeed governor overcomes the spring tension and opens a pilot valve in the governor. The pilot valve dumps oil from the oil tube, lowering the pressure at the engine oil pressure switch, thus closing the switch and energizing the shut-down solenoid and closing the shut-down valve.

Lubrication

The overspeed governor is lubricated by oil from the engine crankcase.

Adjustment

The engine shut-down speed is determined by the position of the adjusting screw in the overspeed governor cover. To change the setting, loosen the lock nut and turn the adjusting screw in to increase the speed or out to decrease the speed. When the proper setting is obtained, tighten the adjusting screw lock nut.

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POWER GENERATOR AND CONTROLS

Detailed information on the maintenance and repair of power generators, control cabinets and component assemblies such as voltage regulators can be found in the service manuals and bulletins issued by the equipment manufacturers.

In many instances, repairs and overhaul work on electrical equipment may be referred to an authorized repair station of the manufacturer of the equipment.

Replacement parts for electrical equipment should be ordered through the equipment manufacturers outlets since these parts are not normally stocked by Detroit Diesel Allison.

For service information regarding Delco Products equipment, direct all requests to the Service Department, Delco Products Division, General Motors Corporation, Dayton, Ohio 45401.

Remove Power Generator From Engine

If required, remove the power generator (Fig. 1) from the engine as follows:

1. If the generator bearing is lubricated by oil, remove the drain plug from the end frame or the bottom of the sight gage and drain the oil.

2. Remove the terminal box cover plate and remove all of the external power leads.

CAUTION: Tag each power lead before disconnecting to ensure correct connections when the generator is reinstalled.

3. If the unit is equipped with a control cabinet, disconnect all of the generator-to-control cabinet power leads at the cabinet. Also disconnect all engine instruments, throttle control linkage, electrical wiring harness or engine shutdown mechanism at the control cabinet.

CAUTION: Tag all electrical leads before disconnecting to ensure correct connections when the unit is reassembled.

4. Remove the control cabinet from the engine base.

5. Loosen the front engine-to-base mounting bolts. Also loosen the upper hose clamps at the radiator to

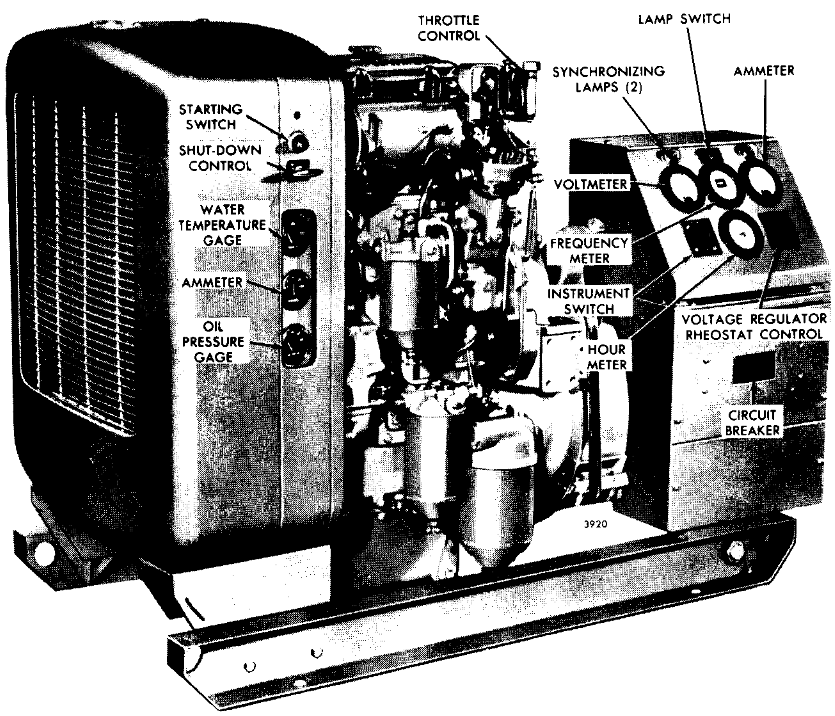

Fig. 1 - Location of Controls on Power Generator Unit

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prevent hose distortion when the flywheel end of the engine is raised.

6. Remove the generator foot-to-engine base mounting bolts and spacers (if used).

7. Attach a chain hoist to the generator eyebolt or lifting ears and raise the generator just enough to allow it to clear the engine base.

8. Place a suitable support under the flywheel housing to support the rear end of the engine before the generator is detached.

9. Remove the generator fan cover retaining bolts and remove the covers.

10. Remove the generator driving disc-to-engine flywheel mounting bolts.

11. With the chain hoist drawn taut, remove the generator frame flange-to-engine flywheel housing mounting bolts.

12. Apply pry bars at opposite sides of the generator to loosen it from the engine flywheel housing.

> **NOTE:** The tenon on the generator frame flange pilots inside of the engine flywheel housing; therefore, the generator must be withdrawn straight back from the engine.

Install Power Generator on Engine

Before installing the generator, the front engine-to-base mounting bolts must be loose and the flywheel end of the engine must be raised and suitably supported.

1. Use a chain hoist to swing the generator in place square against the engine flywheel housing so the pilot of the generator frame enters the flywheel housing.

> **NOTE:** The generator driving disc pilots inside of the engine flywheel with a close tolerance. The driving disc must set flat against the flywheel face when in place, otherwise the generator will be subjected to excessive vibration when placed in service.

2. Align the bolt holes in the generator driving disc with the mating holes in the engine flywheel. Then install the disc retaining bolts and tighten them.

3. Install the generator frame-to-engine flywheel housing bolts and tighten them.

4. Install the generator fan covers.

5. Install the generator foot-to-engine base mounting bolts and spacers (if used). Tighten the bolts.

6. Tighten the front engine-to-base mounting bolts.

7. Position the upper radiator hose and tighten the clamps.

8. Install the control cabinet.

9. Reconnect all power leads.

10. Install the generator terminal box cover plate.

11. Install the oil drain plug and fill the generator bearing oil reservoir, with the same grade of oil as specified for the engine, to the line on the sight gage. Do not overfill.

12. Reinstall and connect all other equipment which was removed during disassembly.

Balance Engine

If proper care is taken in attaching the generator to the engine, the unit should operate smoothly. However, if the unit runs rough (excessive vibration), it must be balanced as follows:

1. Loosen the generator driving disc-to-engine flywheel bolts approximately four turns.

2. Start the engine and run it at a speed not exceeding 600 rpm for approximately one minute. At this speed, the generator armature will tend to center itself with respect to the center line of the engine crankshaft.

3. Stop the engine and tighten the generator driving disc retaining bolts uniformly.

4. Normally, the above procedure will bring the unit into balance for smooth operation. However, if excessive vibration still exists, it may be corrected as follows:

   a. Remove the generator driving disc retaining bolts and rotate the engine flywheel 180 °.

   b. Install the driving disc bolts finger tight.

   c. Repeat Steps 2 and 3 above.

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SHOP NOTES - TROUBLESHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

PROPER OPERATION OF THE SWITCHES OR ALARM SYSTEM FOR TESTING THE ELECTRICAL SHUTDOWN

The protective system is activated whenever low lubricating oil pressure, high coolant temperature, engine overspeed or any other abnormal condition develops that could damage the engine.

In a properly maintained installation, the shutdown system seldom has cause to function. Therefore, it is advisable to check the system periodically to be sure that it will function when needed.

Check each component of the shutdown system as outlined below. It is important to thoroughly warm-up the engine before any component of the shutdown system is checked.

Overspeed Governor

1. Remove the valve rocker cover.

2. Start the engine and move the speed control lever to the full-speed position.

3. While watching a tachometer, manually move the control tube slowly towards the increased fuel position until the air shutoff valve closes, stopping the engine.

NOTE: Do not exceed the engine no-load operating speed by more than 10%.

4. Note the speed at which the engine stops and adjust the overspeed governor, if necessary, as outlined in Section 7.4.3.

5. Replace the valve rocker cover.

Water Temperature Switch

The terminals of the water temperature switch are connected into the shutdown system and when the engine water temperature reaches 200-205° F (93-96° C), the switch closes and completes the circuit in the shutdown or alarm system.

1. Cover the radiator with a sheet of cardboard to prevent circulation of air.

2. Remove the radiator cap, if the engine is operating near sea level, and insert a steel jacketed thermometer.

NOTE: The boiling point of water lowers approximately 2° for each 1,000 foot rise in altitude. As an example, water boils at approximately 203° F (95° C) at 5,000 feet and at 195° F (91° C) at 9,000 feet altitude. It is necessary to retain the radiator pressure cap on engines which operate in excess of 1,000 feet altitude to prevent the coolant from boiling while performing this test. The engine temperature gage, if it is found to be accurate, may be used when performing this test.

Do not exceed 210° F (99° C) when performing this test.

3. Start and run the engine at rated speed and with enough load to raise the water temperature gradually until the air shutoff valve closes. The water temperature switch will usually be set at 200-205° F (93-96° C).

4. Note the temperature at which the air shutoff valve closed.

5. Remove the radiator cover and start the engine without load immediately after the engine stops. This will permit the engine to cool down to normal operating temperature.

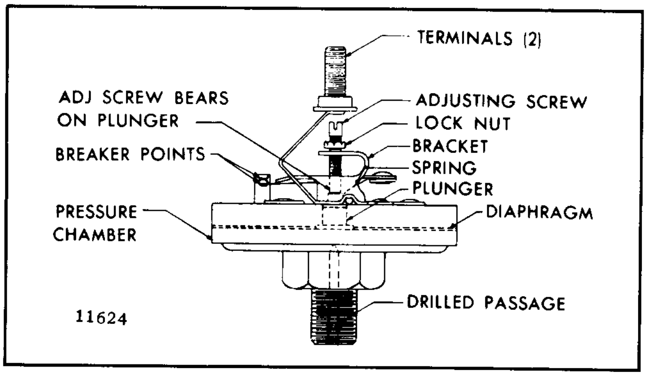

Fig. 1 - Fuel Oil Pressure Switch

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Fuel Oil Pressure Switch

The fuel oil pressure switch is set to make contact at an increasing fuel pressure of 20 psi (138 kPa), and the phrase "20-MAKE" is stamped on the switch cover.

As the fuel pressure increases upon starting the engine, a diaphragm in the switch body expands and forces the plunger upwards (Fig. 1). Since the bottom of the adjusting screw bears against this plunger, the adjusting screw and the lower breaker point are also forced upwards. When the fuel pressure reaches 20 psi (138 kPa), the breaker points close and current flows to the terminals of the lubricating oil pressure switch and the water temperature switch.

When the engine is stopped, the fuel pressure decreases and the diaphragm in the switch body contracts. This action causes the plunger to lower and, when the fuel pressure decreases to 20 psi (138 kPa), permits the lower breaker point arm to lower and break the electrical circuit. The bracket to which the lower breaker point arm and the adjusting screw are attached is spring-loaded, which provides for positive breaking of the connection when the fuel pressure decreases sufficiently.

1. Insert a pressure gage on the discharge side of the fuel strainer.

2. Remove one of the leads from the lubricating oil pressure switch while this test is being performed, to prevent the engine from being shut down.

3. Start and run the engine at idle speed.

4. Slow the engine down by moving the speed control lever towards the *no-fuel* position until the fuel pressure is approximately 15 psi (103 kPa), with the engine barely turning over.

5. Place a jumper wire across the water temperature switch terminals.

6. Raise the engine speed slowly and watch the fuel oil pressure gage until the air shutoff valve closes.

7. Note the fuel pressure at which the air shutoff valve closed and, if necessary, replace the switch.

8. Remove the jumper wire from the water temperature switch and reconnect the lubricating oil pressure switch.

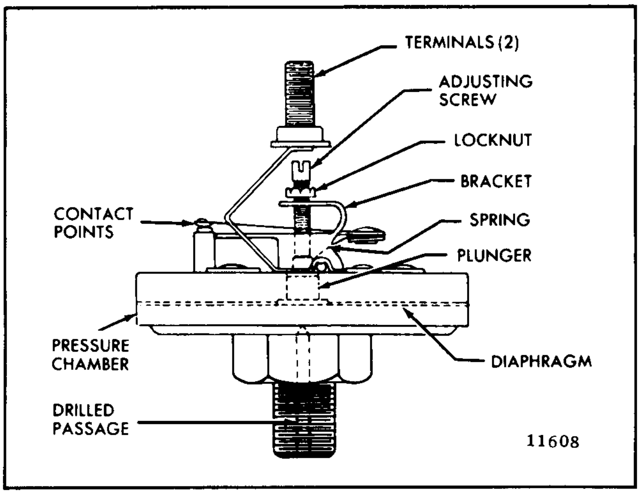

Fig. 2 - Lubricating Oil Pressure Switch

Lubricating Oil Pressure Switch

The construction of the lubricating oil pressure switch is very similar to that of the fuel oil pressure switch, except that the lubricating oil pressure switch is calibrated to break contact when the lubricating oil pressure increases to 10 psi (69 kPa). The phrase "10-BREAK" is stamped on the switch cover.

A 20 psi (138 kPa) break switch is used on some engines whose predominant operation is constant speed.

As the lubricating oil pressure increases upon starting, the diaphragm in the switch body expands and forces the plunger upwards (Fig. 2). Since the bottom of the adjusting screw bears against the plunger, and the adjusting screw is attached to the bracket which controls the upper breaker point arm, the arm is also forced upwards. When the lubricating oil pressure increases to 10 psi (69 kPa), the points separate. Current flows to the lubricating oil pressure switch only after the fuel oil pressure switch closes, at which time the points of the lubricating oil switch are open. Should the lubricating oil pressure decrease to 10 psi (69 kPa) during operation, the breaker point will close and either the alarm bell or shutdown solenoid will be energized.

1. Start and run the engine at idle speed.

2. Place a jumper wire on the hot wire relay between the "1" and "S" terminals.

3. Place a jumper wire across the fuel oil pressure switch terminals.

4. Reduce the engine speed by moving the control lever towards the *no-fuel* position while watching the lubricating oil pressure gage.

5. Note the oil pressure at which the switch stops the engine and, if necessary, replace the switch.

6. Remove the jumper wire.

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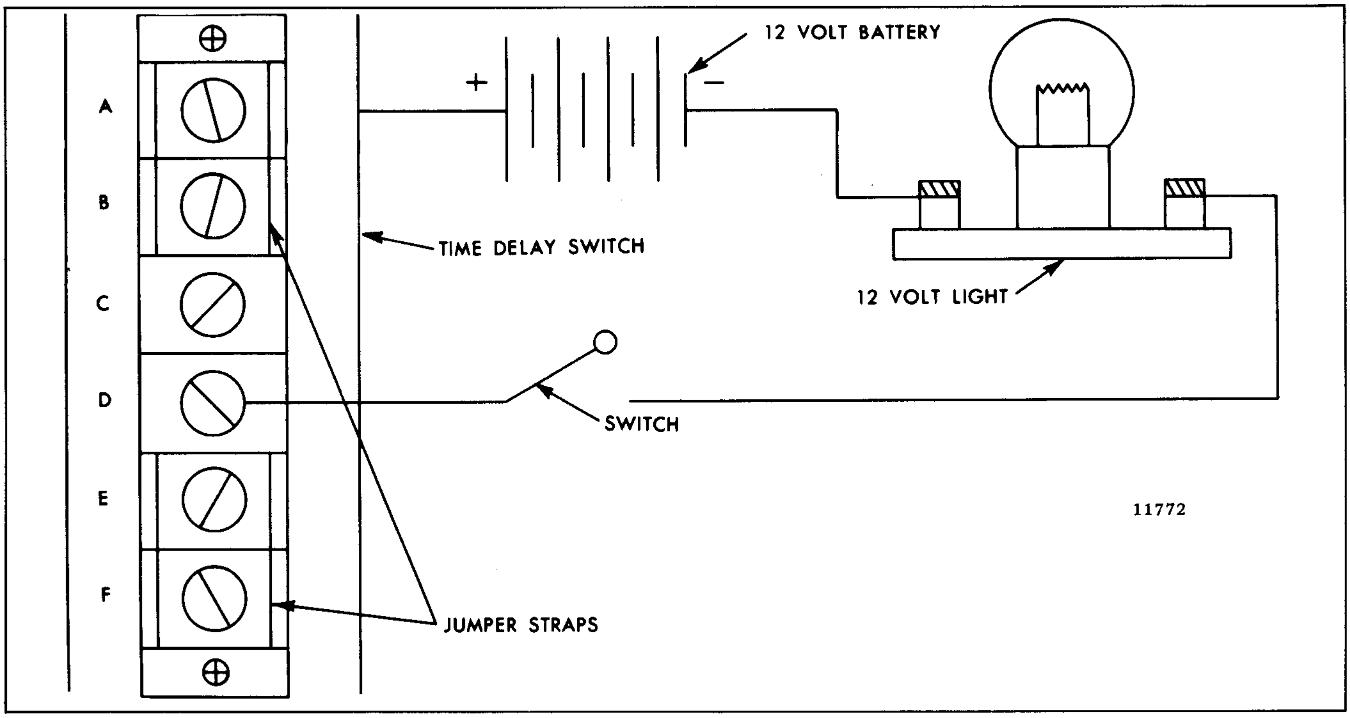

Fig. 3 - Time Delay Switch Testing Diagram

Hot Wire Relay

1. Start and operate the engine at idle speed.

2. Place the jumper wire across the terminals of the lubricating oil pressure switch while watching a second hand of a clock.

3. Not more than three to ten seconds should elapse between the time the jumper wire is placed across the terminals of the lubricating oil pressure switch and the air shutoff valve closes.

The above procedures completely test the normally open electrical shutdown system on an engine.

NOTE: When the engine is operating at idle speed or above, the air shutoff valve will completely close off the air from the engine causing it to stop. However, when the engine is operating at the very low speeds that are necessary when performing the test on the fuel shutdown switch and the lubricating oil shutdown switch, the air damper solenoid will close the air shutoff valve, but the engine may continue to run very slowly. This may be due to insufficient force exerted by the low air flow on the back of the shutoff valve to completely close it.

Solid State Time Delay Switch

A solid state time delay switch is used on current engines in place of the former hot wire relay.

A bench test procedure for the solid state time delay switch is as follows (Fig. 3):

1. Remove the time delay switch from the engine.

2. Install the jumper straps on terminals "A" to "B" and "E" to "F".

3. Install a positive battery lead to terminal "A".

4. Install a negative battery lead to one side of a 12 volt light.

5. Install a lead from the opposite side of the light to terminal "D". A switch may be used in this lead, if desired.

6. After the negative lead is connected to "D" or the switch is closed, the lamp should light in eight to ten seconds. If not, the time delay switch must be replaced.

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CHECK ENGINE STARTING SWITCH

If difficulty in starting motor engagement has been experienced in a vehicle which has been repowered by a diesel engine, check to see if the key-type starting switch on the instrument panel has been retained.

Key-type starting switches are usually not capable of carrying the current required for heavy-duty diesel engine starter solenoids. The excessive voltage drop in the solenoid circuit restricts the solenoid pull and results in failure of the starter to engage and crank. When tooth abutment occurs and the switch is turned off and on several times, breaking of the solenoid current causes burning or welding of the switch contacts.

Install a push button type starting switch which is capable of making, breaking and carrying the solenoid current without damage (refer to *Engine Starting Motor Switch* in Section 7.4). Otherwise, a heavy-duty magnetic switch should be used in the solenoid control circuit in addition to the key-type switch. The magnetic switch must be capable of making and breaking at least 90 amperes in a 12-volt system; the key switch would then carry no more than one ampere, which is sufficient to operate the magnetic switch.

ALIGNMENT TOOLS FOR TACHOMETER DRIVE COVERS AND ADAPTORS

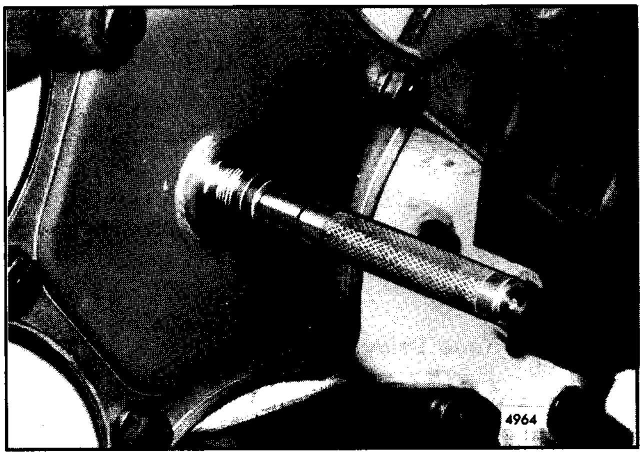

Fig. 4 - Checking Tachometer Drive Shaft Alignment

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.

To establish proper alignment, use one of the three tools in set J 23068. Because of the many different combinations of tachometer drive shafts, covers and adaptors, it is not practical to itemize specific usages for each tool. When confronted with an alignment job, test fit each tool to determine which provides the best fit and proceed to make the alignment with that tool as shown in Fig. 4.

Correct alignment is established when there is no tachometer drive shaft bind on the inside diameter of the tool when one complete hand rotation of the engine is made.

MOUNTING THE STARTER AUXILIARY MAGNETIC SWITCH

On certain railcar and highway units equipped with Detroit Diesel engines and Delco-Remy starter auxiliary magnetic switches, no-start conditions may result from damage to the starter auziliary magnetic switch caused by vibration. The vibration may result from improper mounting of the auxiliary magnetic switch.

The following guidelines should be followed when mounting a Delco-Remy starter auxiliary magnetic switch (Fig. 5):

1. Do not mount the switch on the engine.

2. Position the mounting pads of the switch vertically (one above the other).

3. Mount the switch on a rigid bracket, base rail or fire wall.

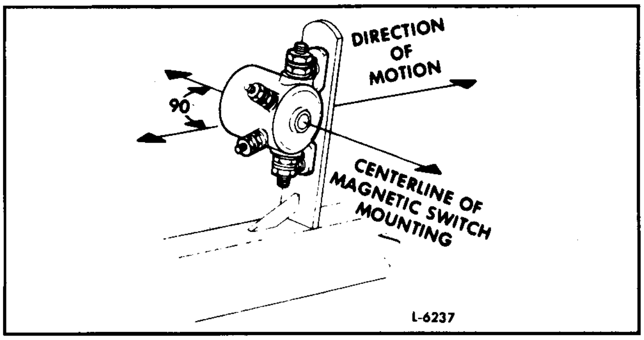

Fig. 5 - Starter Auxiliary Magnetic Switch Mounting

4. Mount the switch on a surface perpendicular (90°) to the forward motion of the vehicle so that contact disc movement is not in line with gravity or vehicle movement.

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TROUBLESHOOTING

CHECKING ENGINE ELECTRICAL GENERATING SYSTEM

Whenever trouble is indicated in the electrical generating system, the following quick checks can be made to assist in localizing the cause.

1. A fully charged battery and low charging rate indicates normal generator-regulator operation.

2. A low battery and high charging rate indicates normal generator-regulator operation.

3. A fully charged battery and a high charging rate condition usually indicates the voltage regulator is set too high or is not limiting the generator output. A high charging rate to a fully charged battery will damage the battery and other electrical components.

4. A low battery and low or no charging rate could be caused by: Loose connections or damaged wiring, defective battery or generator, generator not or improperly polarized, and defective regulator or improper regulator setting.

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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 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 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

12252

BOLT IDENTIFICATION CHART

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EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)	TORQUE (Nm)
Tachometer drive cover bolt	7/16-14	30-35	41-47
Starting motor connector	1/2 -13	20-25	27-34
Tachometer drive cover bolt	1/2 -13	30-35	41-47
Starting motor connector	No. 10-32	*	*
Tachometer drive shaft (blower)	1/2 -20	55-65	75-88
Starting motor attaching bolt (aluminum F/W housing)	5/8 -11	95-105	129-143
Starting motor switch mounting nut	5/8 -32	§	§

*16-30 **lb-in.** (2-3.5 Nm)
§36-48 **lb-in.** (4-5.5 Nm)

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SERVICE TOOLS

TOOL NAME	TOOL NO.
Delcotron tester	J 26290
Puller set	J 5901-01
Slide hammer and shaft	J 23907-1
Tachometer drive shaft remover	J 5901-3
Tachometer drive alignment tool set	J 23068

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SECTION 8

POWER TAKEOFF - TORQMATIC CONVERTER

CONTENTS

Power Takeoff - Direct Drive (Front and Rear Mounted)	8.1
Front Power Takeoff Adaptor and Drive Mechanism	8.1.4
Flywheel Housing Drive Bearing Support Assembly	8.1.5
Torqmatic Converter	*
Shop Notes - Trouble Shooting - Specifications - Service Tools	8.0

*Note: For service and overhaul procedures covering Torqmatic Converters, refer to Allison 200-300 Series Torqmatic Converter Service Manual - Form SA 1099.

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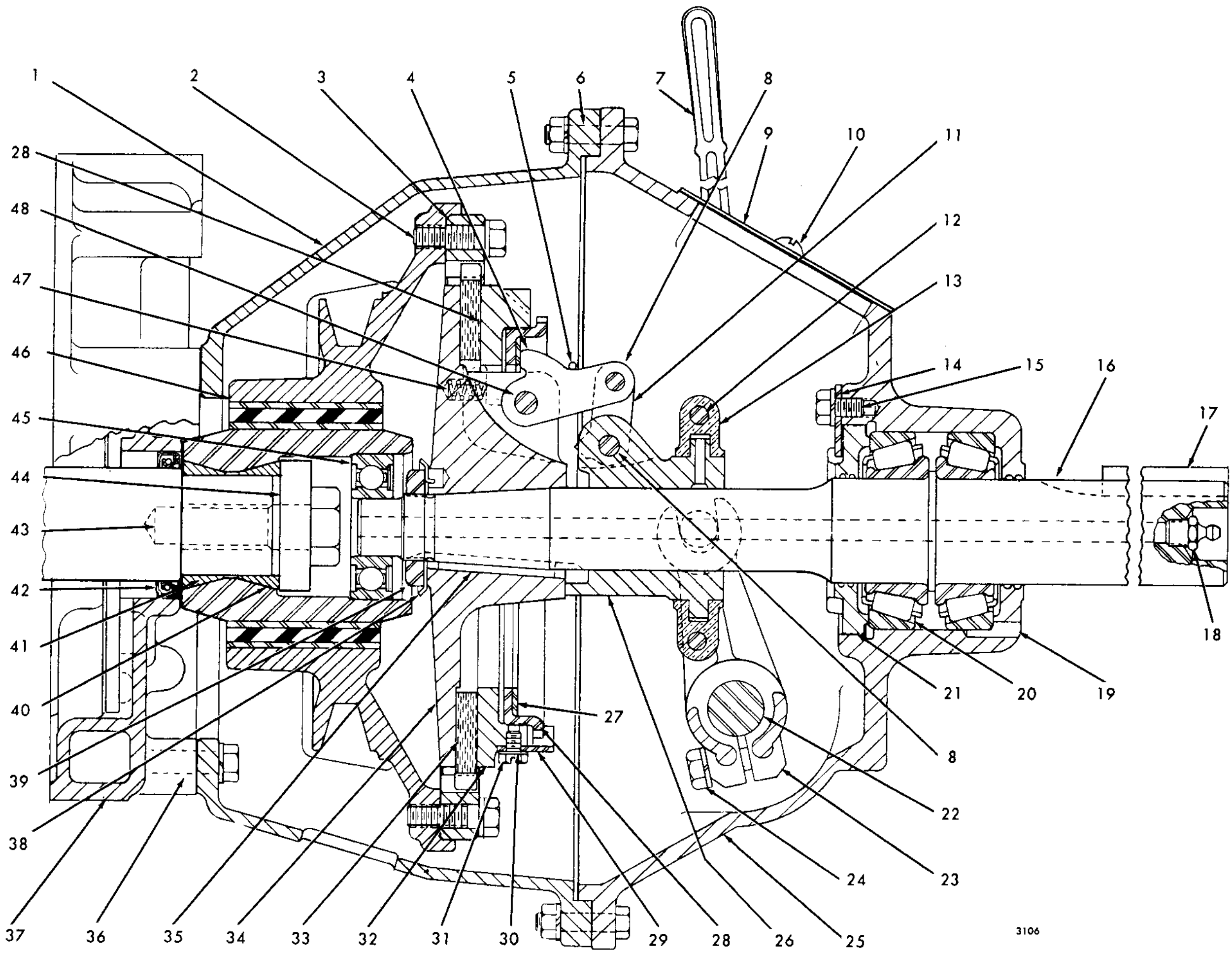
POWER TAKE-OFF - DIRECT DRIVE (Front And Rear Mounted)

The front and the rear power take-off units are basically similar in design, varying in clutch size to meet the requirements of a particular application.



1. Adaptor--Power Take-Off
2. Bolt--Clutch Driving Ring
3. Ring--Clutch Driving
4. Lever--Clutch Release
5. Spring--Clutch Release Lever
6. Bolt--Clutch Housing
7. Lever--Clutch Hand
8. Pin--Release Lever Link
9. Cover--Inspection Hole
10. Screw--Cover
11. Link--Release Lever
12. Bolt--Release Collar
13. Collar--Clutch Release
14. Lock Plate--Bearing Retainer
15. Bolt--Lock Plate
16. Shaft--Clutch Drive
17. Key--Drive Shaft
18. Fitting--Grease
19. Bearing Assy.--Roller (Outer)
20. Bearing Assy.--Roller (Inner)
21. Retainer--Bearing
22. Shaft--Clutch Release
23. Yoke--Clutch Release
24. Bolt--Yoke Clamping
25. Housing--Clutch
26. Sleeve--Clutch Release
27. Plate--Adjusting Ring Wear
28. Ring--Clutch Adjusting
29. Lock--Clutch Adjusting Ring Spring
30. Lock Washer
31. Screw
32. Plate--Clutch Pressure (Inner)
33. Clutch Facing
34. Plate--Clutch Pressure (Outer)
35. Key--Drive Shaft
36. Bolt--Adaptor
37. Cover (Lower)--Engine Front
38. Lock Washer
39. Nut--Drive Shaft
40. Cone (Front)
41. Cone (Rear)
42. Oil Seal--Crankshaft (Front)
43. Bolt
44. Washer
45. Bearing--Clutch
46. Adaptor--Clutch Drive
47. Spring--Pressure Plate Separator
48. Pin--Clutch Release Lever

Fig. 1 - Front End Power Take-Off and Drive Assembly (8 Inch Diameter Clutch)

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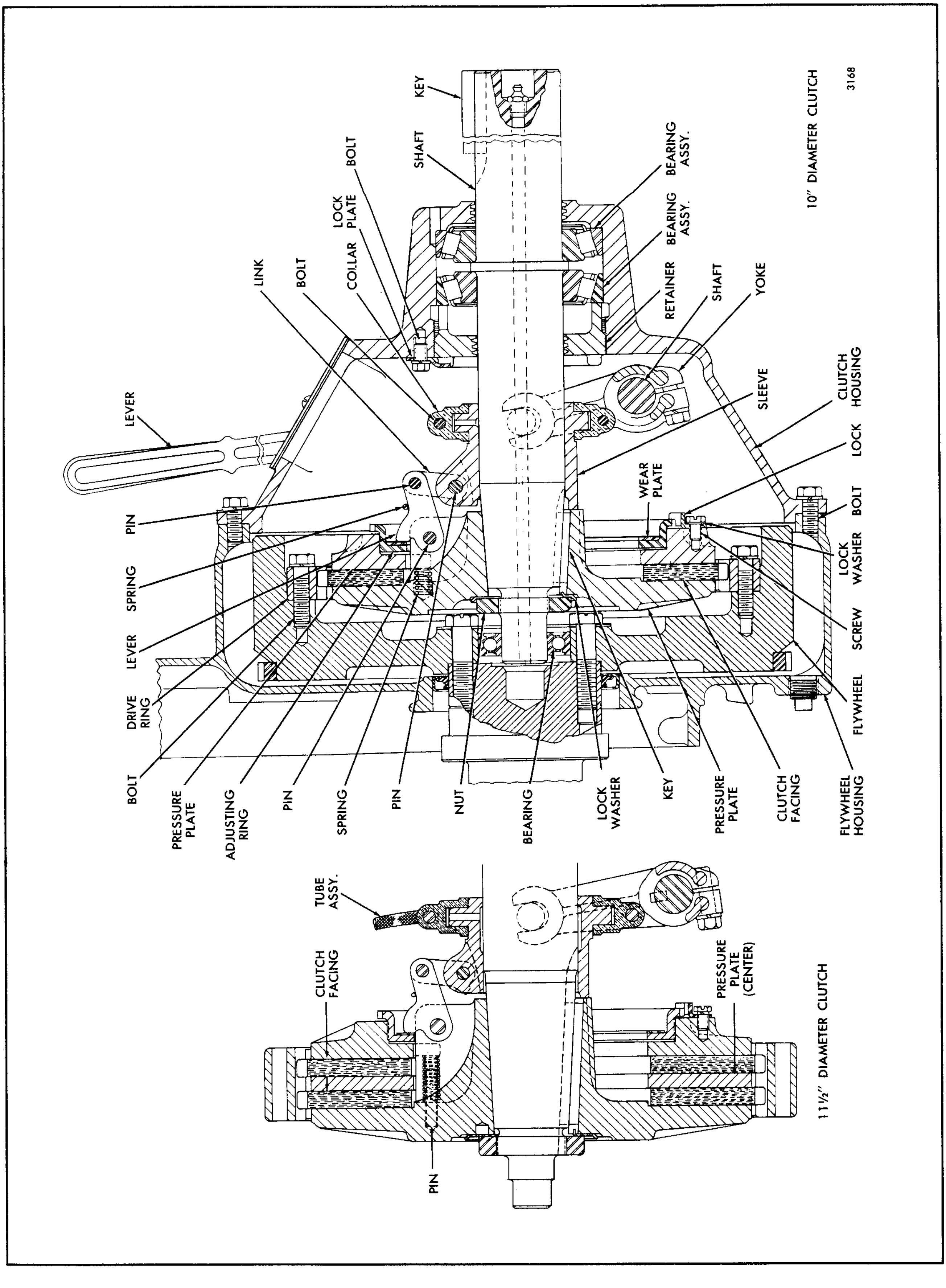

Fig. 2 - Rear Power Take-Off Assembly

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The direct drive power take-off unit is attached to either an adaptor (front power take-off) or the flywheel housing (rear power take-off). The clutch mechanism in the current 8" diameter clutch front power take-off consists of a one-piece dry disc clutch facing (33), Fig. 1. Formerly a three-piece clutch facing was used. The rear mounted power take-offs have either a 10" diameter single or a 11-1/2" diameter double-plate clutch. The clutch mechanism in the 10" diameter clutch consists of a three-piece dry disc clutch facing (Fig. 2). The clutch mechanism in the 11-1/2" diameter clutch consists of two one-piece dry disc clutch facings; formerly it consisted of two three-piece facings.

The forward end of the drive shaft is supported by a single-row ball bearing in the flywheel (Fig. 2) or the clutch drive adaptor (46), Fig. 1. The outer end of the drive shaft is supported by two tapered roller bearings in the clutch housing.

The tapered roller bearings absorb the greatest portion of the thrust and radial load on the drive shaft. An adjustable bearing retainer provides a means of adjusting the tapered roller bearings.

A driving ring, attached to the flywheel or the clutch drive adaptor, drives the power take-off.

Operation

When the hand lever (7) is moved toward the engine, the yoke (23) moves the release sleeve (26) toward the clutch. This movement forces the outer ends of the links (11) away from the axis of rotation causing the levers (4) to contact the face of the adjusting ring (28), which locks the clutch facings (33) between the outer and inner pressure plates (34) and (32). Thus, the power of the engine is transmitted to the drive shaft (16).

When the hand lever (7) is moved away from the engine, the yoke (23) moves the clutch release sleeve (26) away from the clutch, and the springs (47) and (5) return the pressure plate (32) to its released position. Thus, pressure between the pressure plates and clutch facings is relieved, permitting the pressure plates and the clutch drive shaft to cease rotating. Since the clutch facings have external teeth and mesh with the teeth in the inner diameter of the driving ring (3) which is bolted to the flywheel or the clutch drive adaptor, the clutch facings continue to rotate while the engine is running.

Lubrication

The clutch release shaft, clutch release sleeve collar and all bearings are lubricated with grease. Refer to *Lubrication and Preventive Maintenance* in Section 15.1.

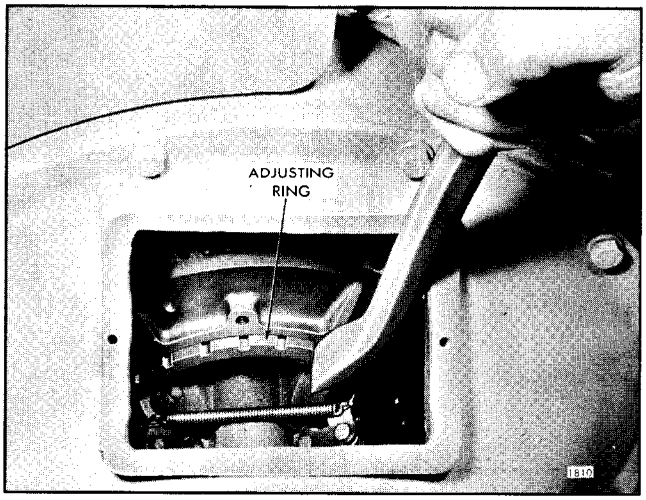

Fig. 3 - Adjusting 8, 10 or 11-1/2 Inch Diameter Power Take-Off Clutch

Clutch Adjustment

These instructions refer to field adjustment for clutch facing wear. Frequency of adjustment depends upon the amount and nature of the load. To ensure longest facing life and best clutch performance, the clutch should be adjusted before slippage occurs.

When the clutch is properly adjusted, a heavy pressure is required at the outer end of the hand lever to move the throwout linkage to the "over center" or locked position.

Adjust 8", 10" and 11-1/2" diameter clutches as follows:

1. Disengage the clutch with the hand lever.

2. Remove the inspection hole cover to expose the clutch adjusting ring.

3. Rotate the clutch, if necessary, to bring the clutch adjusting ring lock within reach.

4. Remove the clutch adjusting ring spring lock screw and lock from the inner clutch pressure plate and adjusting ring. Then, while holding the clutch drive shaft from turning, turn the clutch adjusting ring counterclockwise as shown in Fig. 3 and tighten the clutch until the desired pressure on the outer end of the hand lever, or at the clutch release shaft (Fig. 4) is obtained.

5. When the clutch is properly adjusted, the approximate pressure required at the outer end of the hand lever to engage the various diameter clutches is

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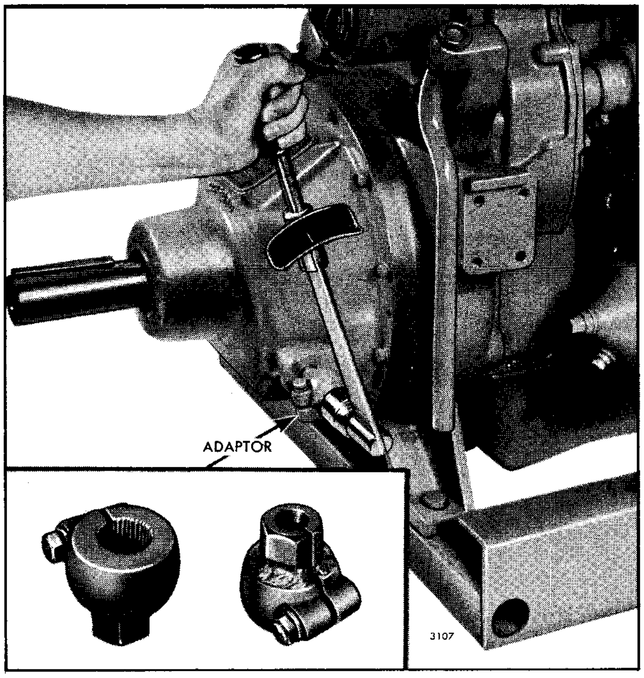

Fig. 4 - Checking Power Take-Off Clutch Adjustment with a Torque Wrench and an Adaptor

shown in the following table. These specifications apply only to the hand lever which is furnished with the power take-off. A suitable spring scale may be used to check the pounds pressure required to engage the clutch.

Clutch Dia.	Hand Lever Length	Pressure Lbs.
8"	15-1/2"	55
10"	15-1/2"	80
11-1/2"	20"	65

However, the most accurate method of checking the clutch adjustment is shown in Fig. 4. To fabricate an adaptor, saw the serrated end off of a clutch hand lever and weld a 1-1/8" nut (across the hex) on it as shown in Fig. 4. Then saw a slot through the nut.

When checking the clutch adjustment with a torque wrench, engage the clutch slowly, noting the torque just before the clutch engages (goes over center). The specified torque is shown in the following table.

Clutch Diameter	Torque Lb-Ft
8"	56-63
10"	88-94
11-1/2"	94-100

6. Install the clutch adjusting ring spring lock. Be sure that the ends of the spring lock register with the notches in the adjusting ring.

7. Install the inspection hole cover.

Replace Clutch Facings

Replace the clutch facings when they become worn to the extent that the clutch adjustment, to prevent slippage, cannot be made with the adjusting ring. When the power take-off assembly is removed from the engine or is being reconditioned, check the clutch facings for wear, burning or scoring. If the clutch facings are burned, scored or worn to or near the minimum facing thickness shown in the following table, they must be replaced.

Clutch Size	Facing Thickness New	Max. Allow. Wear	Min. Thickness of Facing
8"	3/8"	1/8"	1/4"
10"	7/16"	1/8"	5/16"
11-1/2"	7/16"	1/8"	5/16"

The clutch facings on the current 8" diameter single-plate clutch and the 11-1/2" diameter double-plate clutch consists of one piece. When replacing the one-piece clutch facing, the clutch must be removed from the clutch drive shaft and the clutch disassembled. The former 8" diameter single-plate and the 11-1/2" diameter double-plate clutches consisted of three pieces and did not require clutch removal and disassembly. The 10" diameter single-plate clutch facing still consists of three pieces.

The current 8" and 11-1/2" diameter one-piece replacement clutch facings are marked at three places on the side of the facing so they may be cut into three pieces with a 1/8" thick saw to facilitate replacement of the facing (rear mounted power take-offs only) without removing and disassembling the clutch each time a replacement is made.

NOTE: The current one-piece clutch facing should be used on the front mounted power take-off.

Replace the clutch facings in the current 8" diameter single-plate and the 11-1/2" diameter double-plate clutches as follows:

1. Remove the power take-off assembly from the engine as outlined under *Remove Power Take-Off.*

2. Remove the clutch assembly from the clutch drive shaft as outlined under *Disassemble Power Take-Off.*

3. Disassemble the clutch as outlined under *Disassemble Power Take-Off.*

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4. Assemble the clutch as outlined under *Assemble Power Take-Off.*

5. Install the clutch assembly on the clutch drive shaft as outlined under *Assemble Power Take-Off.*

6. Attach the power take-off assembly to the engine as outlined under *Attach Power Take-Off to Engine.*

7. Adjust the power take-off clutch as outlined under *Clutch Adjustment.*

8. Install the inspection hole cover.

Replace the three-piece clutch facings in the former 8" diameter single-plate, 11-1/2" diameter double-plate and the 10" diameter single-plate clutches as follows:

1. Remove the power take-off from the engine as outlined under *Remove Power Take-Off.*

2. Disengage the clutch with the hand lever and the clutch facings will automatically fall out from between the pressure plates.

3. Remove the inspection hole cover to expose the clutch adjusting ring and linkage.

4. Rotate the clutch, if necessary, to bring the clutch adjusting ring lock within reach.

5. Remove the clutch adjusting ring spring lock screw and lock from the inner clutch pressure plate and adjusting ring. On the former clutches, the clutch adjusting ring spring lock did not require removal.

6. While holding the clutch drive shaft to prevent the clutch from turning, back off the adjusting ring by turning it clockwise just enough to permit the new clutch facings to be inserted and locked in position between the pressure plates.

7. Support the power take-off in a vertical position with the clutch assembly up on wood blocks; or, screw two eyebolts in the tapped holes in the flange or the clutch housing and use a rope sling and chain hoist to support the power take-off.

8. Insert the new clutch facings between the pressure plates and center them.

9. Remove the clutch driving ring from the flywheel or the clutch drive adaptor at the front of the engine.

10. Support the clutch driving ring by placing two strips of wood across the top face of the clutch housing, next to the clutch facing, that are just thick enough to permit the driving ring to center over the clutch facings.

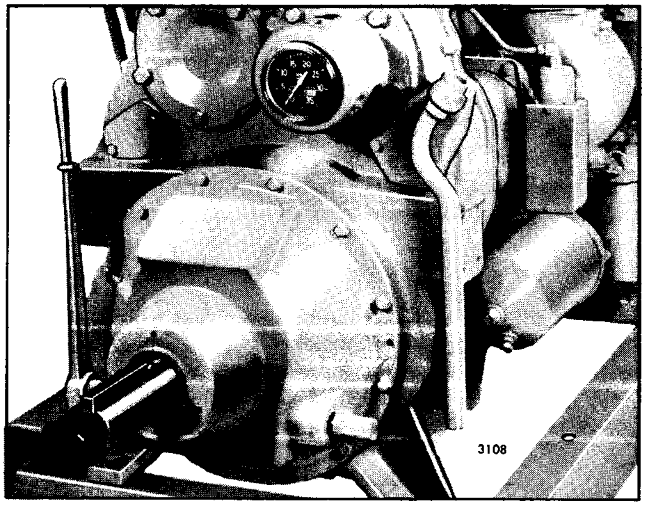

Fig. 5 - Power Take-Off Mounting (Rear)

11. Place the clutch driving ring over the clutch facing, with the teeth in the driving ring in mesh with the teeth of the clutch facings, and locate the driving ring centrally relative to the pressure plates.

NOTE: If the driving ring is not properly located, the clutch cannot be assembled to the flywheel or the clutch drive adaptor because the teeth of the clutch facings will not enter the teeth of the driving ring even though the clutch drive shaft enters the pilot bearing.

12. Engage the clutch with the hand lever and lock the clutch facings between the pressure plates. If the clutch facings are still free to move, disengage the clutch and turn the adjusting ring counterclockwise just enough to lock the clutch facings in place when the clutch is engaged. *Do not disengage the clutch until the power take-off assembly is attached to the engine.*

13. Remove the clutch driving ring from the clutch facing and attach it to the flywheel or the clutch drive adaptor at the front of the engine with bolts and lock washers. Tighten the 3/8"-16 bolts to 30-35 lb-ft torque.

14. Attach the power take-off assembly to the engine as outlined under *Attach Power Take-Off to Engine.*

15. Adjust the power take-off clutch as outlined under *Clutch Adjustment.*

16. Install the inspection hole cover.

Remove Power Take-Off from Engine

If replacement of the clutch facings or reconditioning of the direct drive power take-off assembly becomes

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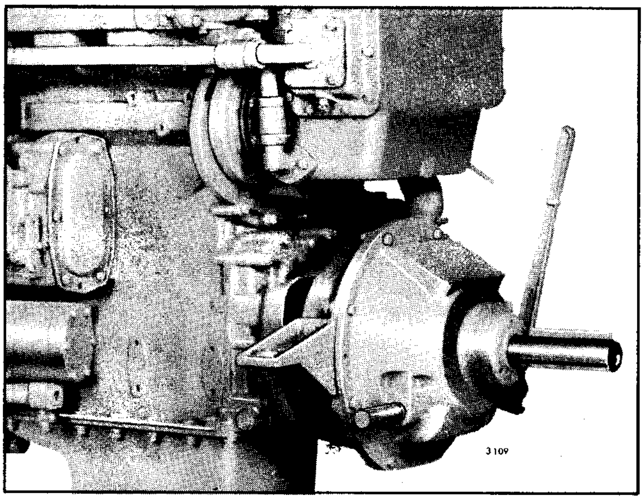

Fig. 6 - Power Take-Off Mounting (Front)

necessary, it must be disconnected and removed from the engine.

With the power take-off disconnected from its driven mechanism, refer to Fig. 5 or 6 and remove the power take-off as follows:

1. Remove the engine accessories, as required, to permit removal of the power take-off.

2. Remove the pulley and key from the drive shaft.

3. Support the weight of the power take-off assembly with a rope sling and chain hoist as shown in Fig. 7. Engage the clutch with the hand lever to hold the clutch facings in place.

4. Refer to Fig. 5 or 6, then remove the bolts and lock washers securing the power take-off assembly to the flywheel housing or bolts, lock washers and nuts to the front end power take-off adaptor.

5. Screw two of the clutch housing attaching bolts into the tapped holes provided in the flange of the clutch housing and push the power take-off assembly away from the flyweel housing or the front end power take-off adaptor. Pull the power take-off assembly straight back away from the engine.

> **NOTE:** Do not permit the outer end of the unit to tip down when being removed from the engine or the clutch pilot bearing may be damaged.

6. If necessary, remove the clutch driving ring from the flywheel on rear mounted or the clutch drive adaptor on front mounted power take-off units.

7. For removal of the front mounted power take-off adaptor, refer to *Remove Power Take-Off Adaptor* in Section 8.1.4.

DISASSEMBLE POWER TAKE-OFF

With the power take-off assembly removed from the engine, it may be disassembled as outlined below:

Remove Clutch Assembly from Clutch Drive Shaft

1. Remove the inspection hole cover and gasket to expose the adjusting ring and linkage.

2. On the 11-1/2" diameter double-plate clutch power take-off unit, hold the outer end of the flexible grease tube from turning (inside the clutch housing) and remove the flexible tube retaining nut. Then pull the outer end of the grease tube inside of the clutch housing and remove the opposite end from the release sleeve collar.

3. Support the power take-off assembly on wood blocks with the clutch drive shaft in a horizontal position. Then bend the edge of the lock washer up off the flat side of the clutch drive shaft nut.

4. Disengage the clutch with the hand lever. On the 10" diameter and the former 8" diameter single and 11-1/2" diameter double-plate clutches equipped with the three-piece clutch facing, the clutch facing will drop out from between the pressure plates.

5. Refer to Fig. 1 or 2 and slide the clutch release

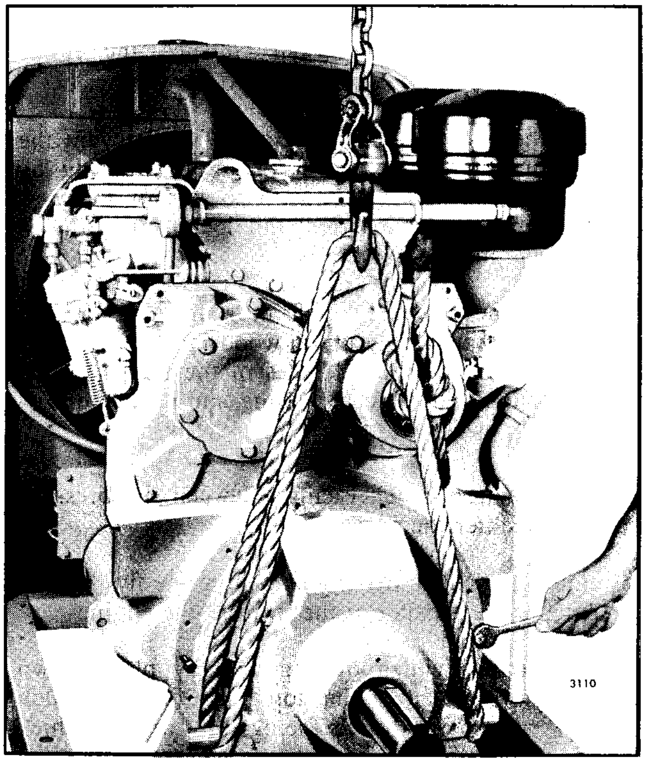

Fig. 7 - Removing Power Take-Off

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lever spring (5) off of the clutch release levers and against the release sleeve collar.

6. Refer to Figs. 1, 2 and 12 and remove the retaining rings from the pins (8); then remove the pins from the links.

7. Install the key in the keyway of the clutch drive shaft. Attach a chain wrench to the drive shaft as shown in Fig. 8 to prevent the drive shaft from turning. Then remove the nut and lock washer from the shaft.

CAUTION: Be sure and place the teeth of the chain wrench on top of the key to prevent damage to the drive shaft while holding the drive shaft from turning. If the key or the drive shaft is damaged and cannot be cleaned up, they must be replaced.

8. Place pry bars behind the inner clutch pressure plate as shown in Fig. 9. While exerting pressure on the outer ends of the pry bars, loosen the clutch assembly from the tapered shaft and key with a brass drift and hammer as shown in Fig. 9.

9. Remove the clutch assembly from the clutch drive shaft and place it on a bench with the forward face down.

10. Remove the chain wrench from the clutch drive shaft.

11. Remove the clutch retaining key from the clutch drive shaft.

12. Slide the clutch release sleeve and release sleeve collar assembly off the clutch drive shaft.

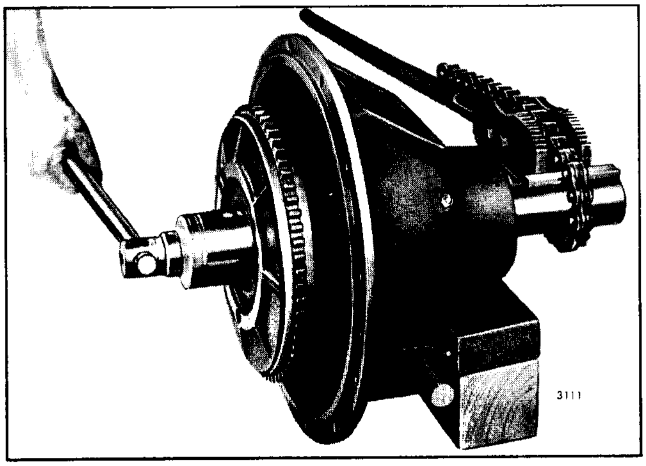

Fig. 8 - Removing Clutch Drive Shaft Nut

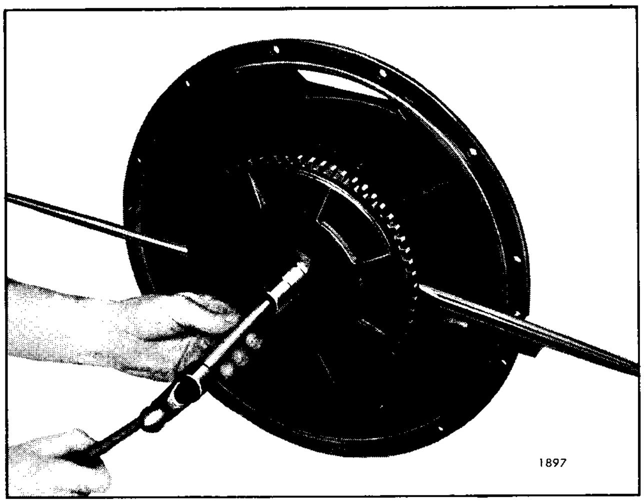

Fig. 9 - Removing Clutch Assembly from Clutch Drive Shaft

Remove Clutch Release Shaft and Yoke from Clutch Housing

1. Loosen the hand lever attaching bolt, then slide the hand lever off of the clutch release shaft.

2. Refer to Fig. 1 or 2 and remove the two clutch release yoke bolts (24) and lock washers from the clutch release yoke (23).

3. Slide the clutch release yoke to the right or left and the clutch release shaft in the opposite direction until the two Woodruff keys are free from the clutch release yoke.

4. Remove the two Woodruff keys from the clutch release shaft; then withdraw the clutch release shaft from the clutch housing and release yoke.

Remove Clutch Drive Shaft from Clutch Housing

With the clutch assembly removed from the clutch drive shaft, refer to Fig. 1 or 2 and remove the clutch drive shaft from the clutch housing as follows:

1. Remove the key from the pulley end of the clutch drive shaft, if not previously removed.

2. Remove the bearing retainer lock plate bolt (15), lock washer and bearing retainer lock plate (14) from the inside of the clutch housing.

3. Remove the bearing retainer (21) from the clutch housing by turning the retainer counterclockwise.

4. Pull the clutch drive shaft and roller bearing cones and one bearing cup from the clutch housing. If the

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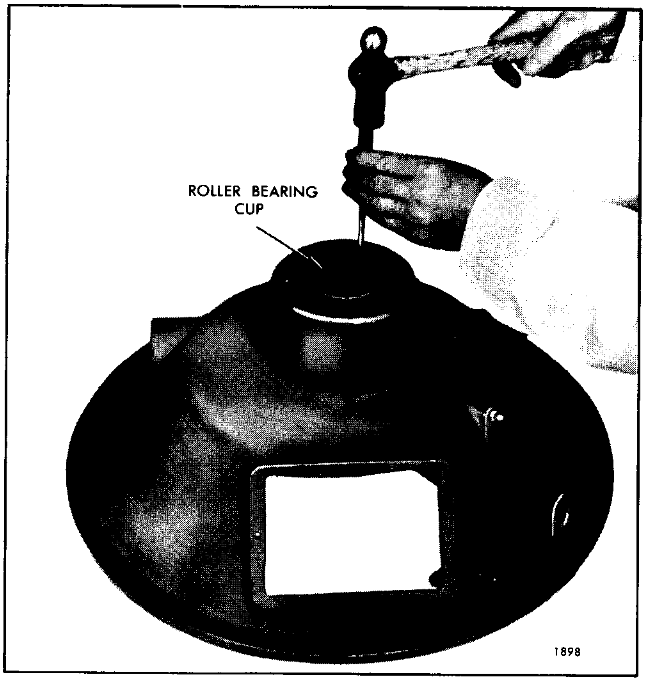

Fig. 10 - Removing Roller Bearing Cup from Housing

bearing cones or cup tend to stick in the clutch housing, tap on the outer end of the clutch drive shaft lightly with a plastic hammer to loosen the bearing cup.

5. The bearing cup of the rear roller bearing cone will remain in the clutch housing when the clutch drive shaft is removed from the clutch housing. It may be removed by inserting a punch in the holes provided at the rear of the clutch housing and tapping the punch alternately at three points as shown in Fig. 10. Do not cock the bearing cup when removing it.

6. If necessary, remove the clutch release sleeve collar grease fitting cover on the side of the clutch housing (8" and 10" diameter clutch power take-offs).

7. Wash the roller bearing cups and cones thoroughly in clean fuel oil, dry them with compressed air and examine them for wear, corrosion or rough spots. If the bearings are unsatisfactory for further use, remove them from the clutch drive shaft.

Remove Roller Bearing Cones from Clutch Drive Shaft

The roller bearing cones may be removed from the clutch drive shaft as follows:

1. Place two split plates (inset in Fig. 11) between the bearing cones; then support the clutch drive shaft and split plates on two steel supports on the bed of the arbor press as shown in Fig. 11.

2. Place wood blocks under the lower end of the clutch drive shaft to prevent the drive shaft from falling and being damaged when it is pressed from the bearing.

3. With the ram of the press resting on the end of the drive shaft, press the shaft out of the roller bearing cone.

4. Reverse the clutch drive shaft on the bed of the press and remove the second bearing cone in the same manner.

Disassemble Clutch

Refer to Figs. 1, 2 and 12 and proceed as follows:

1. Remove the retaining rings (2) from the pins (48) that connect the release levers (4) to the bosses on the outer clutch pressure plate (34). Remove the pins and levers from the outer pressure plate.

2. Remove the clutch adjusting ring spring lock retaining screw (31), lock washer and spring lock (29) from the inner clutch pressure plate (32).

3. On the current 8", 10" and 11-1/2" diameter clutches, remove the clutch adjusting ring wear plate (27) from inside the adjusting ring.

4. Remove the clutch adjusting ring (28) by turning it counterclockwise out of the inner clutch pressure plate.

5. Lift the inner clutch pressure plate straight up off the bosses on the outer clutch pressure plate (34).

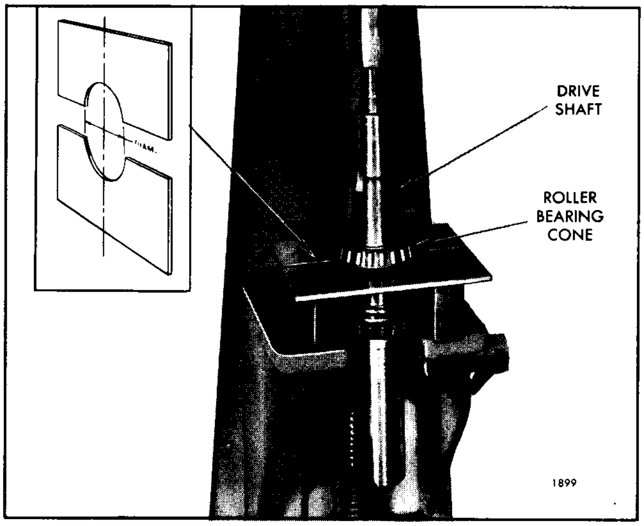

Fig. 11 - Removing Roller Bearing Cone from Clutch Drive Shaft

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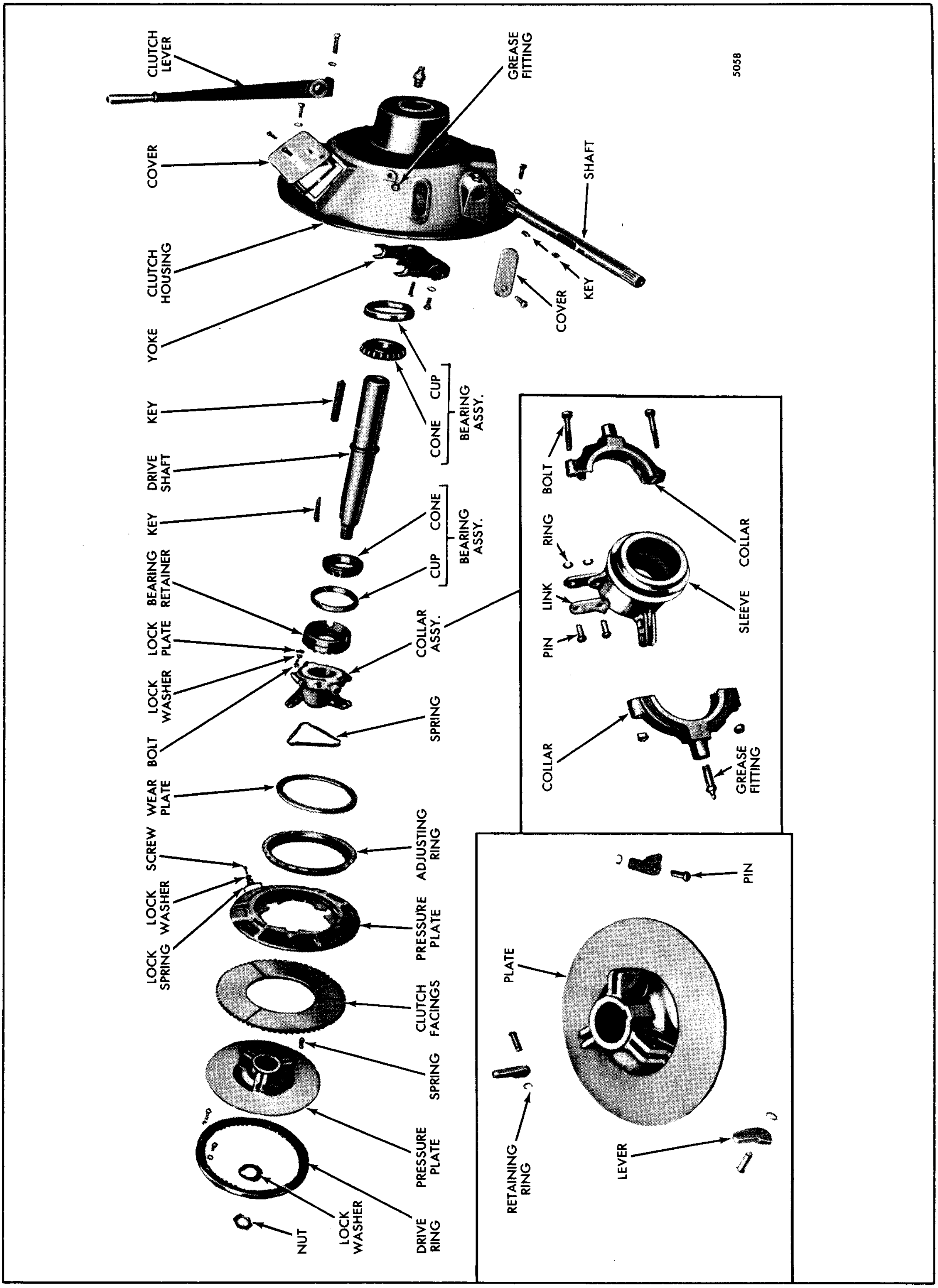

Fig. 12 - Rear Power Take-Off Details and Relative Location of Parts (10 Inch Diameter Clutch Shown)

6. Remove the one-piece clutch facing from the outer clutch pressure plate (8" diameter clutch).

On the 11-1/2" diameter double-plate clutch assembly, remove the one-piece clutch facing from the center pressure plate. Lift the center clutch pressure plate straight off the bosses on the outer pressure plate, then remove the second one-piece clutch facing.

7. Remove the three clutch pressure plate separator springs (47) from the holes (or pins in the 11-1/2" diameter double-plate clutch) in the outer clutch pressure plate.

8. If necessary, on the 11-1/2" diameter double-plate clutch, remove the clutch pressure plate separator spring roll pin (Fig. 2) with a pair of pliers.

9. Remove the clutch release lever spring (5) as an assembly from the clutch release sleeve.

10. Matchmark both halves of the release sleeve collar (13) to assure that they will be assembled in the same position.

11. Remove the two nuts from the bolts (12) securing the two halves of the collar (13) together, then remove the collar from the release sleeve (26).

12. Remove the retaining rings from the pins (8) that connect the links (11) to the release sleeve (26). Remove the pins and links from the release sleeve.

13. If necessary, remove the grease fitting (Fig. 12) from the end of the release sleeve collar trunnion (8" and 10" diameter clutches).

Remove Clutch Drive Shaft Pilot Bearing

If the clutch pilot bearing is worn or damaged, it may be removed as follows:

1. On the front mounted power take-off, remove the pilot bearing from the clutch drive adaptor with slide hammer J 5901-1 and remover adaptor J 5901-2.

2. On the rear mounted power take-offs, remove the pilot bearing from the flywheel as follows:

a. Remove the six flywheel attaching bolts and the bearing retainer or scuff plate, then reinstall one of the attaching bolts to hold the flywheel on the crankshaft.

CAUTION: When removing or installing the flywheel attaching bolts, hold the flywheel firmly against the crankshaft by hand to prevent it from slipping off the end of the crankshaft. The flywheel is NOT doweled to the crankshaft.

b. Remove the pilot bearing from the flywheel with slide hammer J 5901-1 and remover adaptor J 5901-2.

INSPECTION

Wash all of the power take-off parts, except the clutch facings or shielded bearings, in clean fuel oil and dry them with compressed air. *Shielded bearings must not be washed;* dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing.

Examine the ball and roller bearings for corrosion and pitting. Lubricate each bearing with light engine oil; then, while holding the inner race or cone from turning, revolve the outer race or cup slowly by hand and check for rough spots.

Examine the clutch facing for wear, burning or scoring. Also check the teeth for wear or damage and measure the thickness of the facing. Replace the clutch facing if the teeth are worn or damaged, or if the facing is badly burned, scored or worn to the approximate worn thickness shown in the chart under *Replace Clutch Facings*.

Inspect the friction surfaces of the inner, center and outer clutch pressure plates; they should be flat, smooth and free from cracks or heat checks. Also examine the drive bosses, the keyway in the outer pressure plate, the adjusting ring threads and the notches in the inner pressure plate.

Examine all of the release levers, link pins and pin holes in the links, release levers, release sleeve and pressure plate for wear.

On the current clutch adjusting ring, inspect the wear plate and the threads for wear. If the wear plate is worn excessively, reverse the plate. If both sides of the plate are worn excessively, replace it.

NOTE: On the current 8", 10" and 11-1/2" diameter clutches, the wear plate is loose in the adjusting ring.

On the former clutch adjusting ring, inspect the face of the ring where the release levers make contact and the threads for wear. If worn excessively, replace the adjusting ring.

Inspect the fingers of the former adjusting ring lock for wear. If worn excessively or damaged, it must be replaced with the current lock.

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Check for weak and broken pressure plate separator springs. Refer to the following table for the spring specifications. Then check the spring load with spring tester J 9666.

PRESSURE PLATE SEPARATOR SPRING CHART

Clutch Size	Approx. Free Length	Approx. O.D.	Force Exerted by Spring*
8"	7/8"	3/8"	12-15 lbs at 5/8" length
10"	1-1/16"	7/16"	15-20 lbs at 13/16" length
11-1/2"	2"	21/64"	15-20 lbs at 1-3/16" length

*Springs should be replaced when force exerted is less than lowest pressure specified at length indicated.

Examine the wear surface of the clutch release sleeve collar and the mating surface on the release sleeve.

Inspect the mating surface of the clutch release yoke fingers and mating trunnions on the release sleeve collar for wear.

Inspect the keyways in the clutch drive shaft. If the shaft is excessively peened or damaged so that the keys have a tendency to "roll", the drive shaft must be replaced.

Replace all of the power take-off parts that are excessively worn or damaged.

ASSEMBLE POWER TAKE-OFF

With all of the power take-off parts cleaned and inspected and necessary parts on hand, the power take-off may be reassembled,as outlined below.

Assemble Clutches

Refer to Figs. 1, 2 and 12 and proceed as follows:

1. Place the outer pressure plate (Fig. 13) on a bench with the hub end of the pressure plate up.

2. If removed (on the 11-1/2" diameter double-plate clutch), install the pressure plate separator spring roll pins in the holes in the outer pressure plate by driving them straight into the plate until they bottom.

3. Place the pressure plate separator springs in the holes (or on the pins in the 11-1/2" diameter double-plate clutch) in the outer pressure plate.

4. On the 8" diameter clutch, place the one-piece clutch facing on top of the pressure plate.

5. If a one-piece clutch facing is used on the 11-1/2" diameter clutch, place the clutch facing on top of the

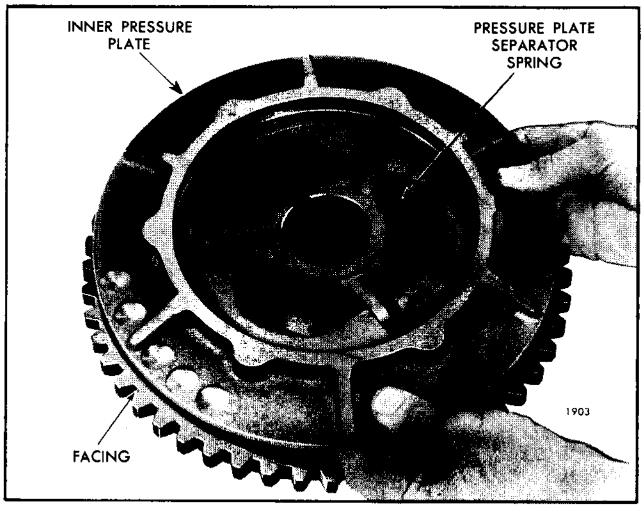

Fig. 13 - Installing Inner Pressure Plate With Springs and Clutch Facing in Plate

pressure plate, followed by the center pressure plate and the second one-piece clutch facing.

NOTE: On the 10" diameter clutch and the former 11-1/2" diameter clutch using a three-piece clutch facing, install the clutch facings after the clutch has been assembled.

6. With the notches in the inner pressure plate aligned with the bosses on the outer pressure plate, place the inner pressure plate over the bosses and rest it on the three pressure plate separator springs.

7. Lubricate the threads of the clutch adjusting ring (28) lightly with engine oil, then thread the adjusting ring into the inner pressure plate until it bottoms.

8. On the current 8", 10" and 11-1/2" diameter clutches, place the clutch adjusting ring wear plate in the cavity in the adjusting ring (Fig. 1 or 2).

The clutch adjusting ring wear plate was not used on the former 8", 10" and 11-1/2" diameter clutches.

9. Install the clutch release levers as shown in Fig. 14.

10. Align the holes in the clutch release levers and the pressure plate; insert the clutch release lever pins through the holes and secure them in place with the retaining rings.

NOTE: Be sure the retaining rings are securely locked in the groove in the release lever pins.

11. Lubricate the inside diameter of the clutch release sleeve collar sparingly with an all purpose grease such as Shell Alvania No. 2, or equivalent. Note the matchmarks previously placed on the collar, then place

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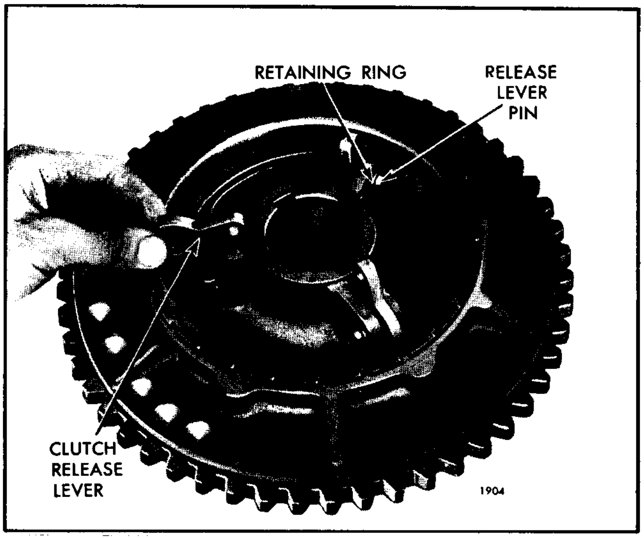

Fig. 14 - Installing Clutch Release Lever

the two halves of the collar over the shoulder on the clutch release sleeve and secure it in place with two bolts and nuts. Rotate the collar on the sleeve to be sure it rotates freely. If necessary, loosen the nuts and tap the edge of the collar lightly with a plastic hammer to free it up, then retighten the nuts.

12. If removed, install the grease fitting (Fig. 12) in the end of clutch release sleeve collar trunnion (8" and 10" diameter clutches).

13. Place the clutch release lever spring (5) over the end of the clutch release sleeve and against the clutch release sleeve collar.

14. Note the position of the stop on the clutch release lever links (11), Fig. 1 or 2. Then attach a pair of release lever links to each ear on the clutch release sleeve with link pins (8) and retaining rings.

NOTE: Be sure the retaining rings are securely locked in the groove in the link pins (8).

15. Place the clutch release sleeve on top of the clutch pressure plates with each pair of release lever links (11) astride the release levers (4). Then connect the release lever links to the release levers with the pins (8) and the retaining rings.

NOTE: Be sure the retaining rings are securely locked in the groove in the link pins.

16. Slide the clutch release lever spring (5) over the end of the release lever links and into place on the clutch release levers (4) as shown in Fig. 1 or 2.

17. On the 10" diameter single-plate clutch, insert the three-piece clutch facing in between the inner and outer clutch pressure plates and center them.

If a three-piece clutch facing is being used on the 11-1/2" diameter double-plate clutch, insert the center two sets of clutch facings in between the pressure plates, with the teeth of both sets of clutch facings in alignment.

18. Lock the clutch facing between the inner and outer pressure plates as follows:

a. With the clutch assembly resting on a bench, forward face down, turn the clutch adjusting ring counterclockwise until the inner pressure plate almost contacts the clutch facing.

b. Place the clutch driving ring over the clutch facing with the teeth in the driving ring in mesh with the teeth on the clutch facing. Then position the driving ring centrally relative to the pressure plates.

NOTE: If the driving ring is not properly located, the clutch cannot be assembled to the flywheel or the clutch drive adaptor because the teeth of the clutch facing will not enter the teeth of the driving ring even though the clutch drive shaft enters the pilot bearing.

c. Lock the clutch facing between the pressure plates by applying pressure on the outer end of the clutch release sleeve and collar assembly. If the clutch facing is still free to move, disengage the clutch and turn the adjusting ring counterclockwise just enough to lock the clutch facing in place when the clutch is engaged. *The clutch must now be kept engaged until the power take-off is assembled and attached to the engine.*

19. Remove the clutch driving ring from the clutch facing and attach it to the flywheel, or the clutch drive adaptor at the front end of the engine, with bolts and lock washers. Tighten the 3/8"-16 bolts to 30-35 lb-ft torque.

20. Attach the adjusting ring spring lock (29) to the inner pressure plate with a bolt (31) and lock washer. Be sure the ends of the spring lock are in the notches in the adjusting ring.

Install Roller Bearing Cones on Clutch Drive Shaft

If the roller bearing cones (Fig. 12) were removed from the clutch drive shaft (16), install them as follows:

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1. Lubricate the inside diameter of the roller bearing cone with engine oil; then start the bearing cone straight on the drive shaft with the wide face of the race facing the shoulder on the drive shaft (Fig. 15).

2. Place a steel ring approximately 1/4" thick over the end of the shaft and rest it on the inner race of the bearing cone.

CAUTION: The steel ring must bear against the inner race of the bearing cone. Do not allow any pressure to be applied against the roller bearing cage or the bearing cone will be damaged.

3. Support the clutch drive shaft, bearing cone and steel ring on the bed of an arbor press with split plates under the steel ring as shown in Fig. 15. Then press the drive shaft straight into the bearing cone until the inner race is tight against the shoulder on the shaft.

4. Install the second roller bearing cone on the clutch drive shaft in the same manner.

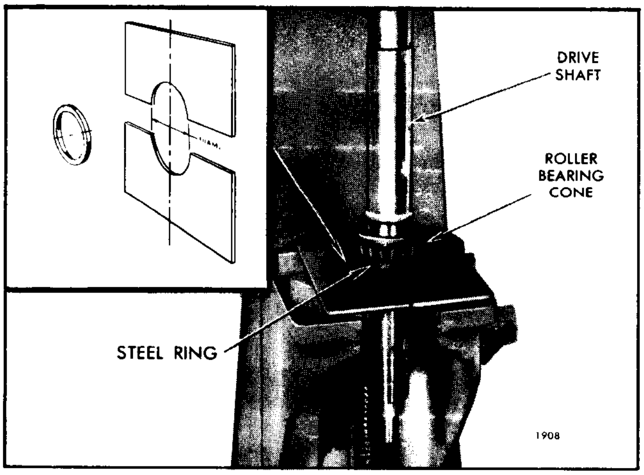

Fig. 15 - Installing Roller Bearing Cones On Clutch Drive Shaft

Install Clutch Drive Shaft in Clutch Housing

With the roller bearing cones installed on the clutch drive shaft, install the shaft as follows:

1. Support the clutch housing on a wood block with the forward (bell) side of the housing up.

2. If removed, lubricate the outside diameter of the rear roller bearing cup with engine oil; then start it straight into the bearing bore in the clutch housing with the tapered inner diameter of the cup facing up.

3. Place a hard wood block (1" O.D. x 15" long) on the top edge of the bearing cup, then use a hammer to tap the bearing cup down in the clutch housing by tapping it alternately at several places.

CAUTION: Do not allow any wood chips off of the wood block to get under the bearing cup.

4. Support the clutch housing on wood blocks in a horizontal position.

5. Lubricate the roller bearing cones with light engine oil; then insert the outer end of the clutch drive shaft through the bearing bore from the forward side of the clutch housing until the bearing cone contacts the bearing cup.

6. Lubricate the outside diameter of the front roller bearing cup with engine oil. Place the cup over the forward end of the clutch drive shaft with the tapered inner diameter of the cup facing the bearing cone.

7. Start the roller bearing cup straight in the bearing bore of the clutch housing. Then tap the cup in against the rollers of the bearing cone by tapping alternately around the cup with a hard wood block and hammer.

8. Lubricate the threads of the roller bearing retainer (21) with engine oil. Place the retainer over the forward end of the drive shaft with the notches in the end of the retainer facing the forward end of the shaft.

9. Thread the bearing retainer into the bearing bore until it is against the bearing cup. Tighten the bearing retainer while rotating the drive shaft until the bearing retainer is tight and the bearing cups are seated. When the bearing cups are seated, it will be noted by the increased effort required to rotate the drive shaft.

10. Back the bearing retainer out 2 or 3 notches.

11. Support the clutch housing and shaft assembly on wood blocks with the outer end of the clutch drive shaft up. Then tap on the outer end of the drive shaft with a plastic hammer to force the roller bearing cup down until the bearing cup seats on the bearing retainer.

Clutch Drive Shaft End Play Adjustment

To check the end play in the clutch drive shaft bearing, the power take-off must be removed from the engine and the clutch assembly removed from the drive shaft to be checked correctly. If the clutch drive shaft and bearing assembly has just been installed in the clutch housing, the end play in the drive shaft

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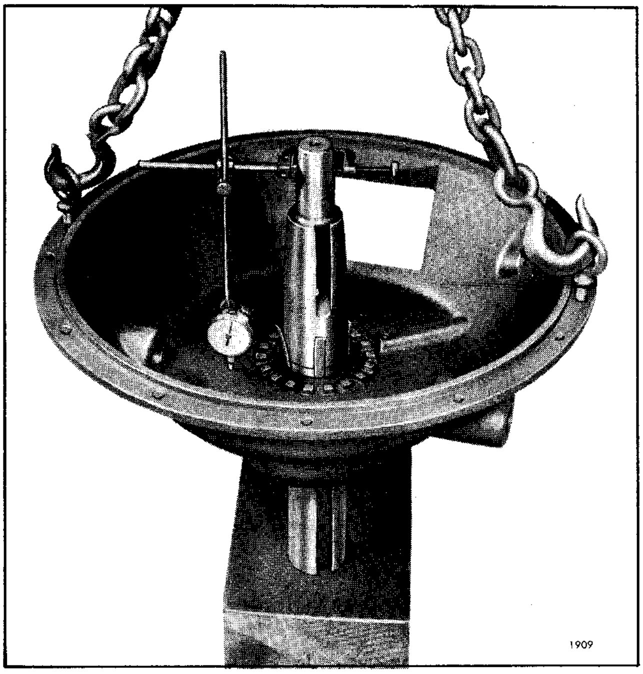

Fig. 16 - Checking Clutch Drive Shaft End Play

bearing must be checked before the clutch is attached to the drive shaft.

Servicing personnel should read the instructions on the clutch housing name plate. Instructions on the name plates are correct for the particular power take-off to which they are attached. If an occasion occurs that a unit does not have the clutch drive shaft end play listed on the clutch housing name plate, the bearing should be adjusted in accordance with the recommendations listed in the following table.

Clutch Sizes	End Play
8", 10" and 11-1/2"	.004" to .006"

With the clutch drive shaft and bearing assembly installed in the clutch housing, the clutch drive shaft bearing end play may be checked as follows:

1. Support the clutch housing with a sling and chain hoist with the drive (pulley) end of the shaft down as shown in Fig. 16.

2. Lower the clutch housing until the end of the drive shaft rests on the wood block.

3. Insert four pieces of shim stock, which are the same thickness, between the bearing retainer and the drive shaft as shown in Fig. 16.

4. Attach a dial indicator to the pilot bearing end of the drive shaft, then position the indicator as shown in Fig. 16. Set the dial indicator at zero.

5. Lift the clutch housing and drive shaft assembly from the wood block.

6. Tap lightly on the pilot bearing end of the drive shaft to move the drive shaft and bearing outer cone assembly against the outer roller bearing cup.

7. Note the reading on the dial indicator. The dial indicator will show the amount of end play in the clutch drive shaft bearing.

8. Lower the clutch housing until the end of the drive shaft rests on the wood block and the weight of the housing is off of the chain hoist.

9. Tap lightly on the inner side of the clutch housing alternately around the bearing retainer to be sure the inner roller bearing cone rests against the bearing cup. The dial indicator should read zero.

10. If necessary, turn the bearing retainer clockwise to decrease or counterclockwise to increase the drive shaft bearing end play.

11. Repeat the above steps to make sure the readings are correct, then install the bearing retainer lock plate, lock washer and bolt.

12. Remove the shim stock and the dial indicator.

13. Support the clutch housing and drive shaft assembly on wood blocks in a horizontal position.

14. Refer to *Lubrication* and fill the roller bearing cavity through the grease fitting, above the bearing, with a grease gun until the grease just starts to seep out around the clutch drive shaft at the bearing retainer or at the rear of the clutch housing.

NOTE: Rotate the clutch drive shaft when filling the bearing cavity to be sure the bearing cavity is full of grease.

Install Clutch Release Shaft and Yoke in Clutch Housing

With the clutch drive shaft and bearings installed in the clutch housing, install the clutch release shaft and yoke in the clutch housing as follows:

1. Squirt engine oil in the clutch release shaft holes in the clutch housing.

2. Slide the clutch release shaft (22) through one of the holes in the side of the clutch housing. Position the clutch release yoke (23) in front of the release shaft inside of the clutch housing so that the heads of the

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clamping bolts (24) will face the forward end of the clutch housing (Fig. 1 or 2). Slide the release shaft through the release yoke and through the hole in the opposite side of the clutch housing.

3. Move the release yoke to one side of the clutch housing to expose the two keyways in the shaft. Then install the two Woodruff keys in the release shaft.

4. Align the keyways in the release yoke with the Woodruff keys in the release shaft; then move the release yoke over the keys until it is centrally located in the clutch housing and each end of the release shaft extends an equal distance outside of the clutch housing.

5. Install the two clamp bolts (24) and lock washers and tighten the bolts to 30-35 lb-ft torque.

Install Clutch Assembly on Clutch Drive Shaft

1. Support the clutch housing and drive shaft assembly on wood blocks with the clutch drive shaft in a horizontal position and the inspection hole in the clutch housing facing up.

2. Lubricate the inside diameter of the clutch release sleeve with engine oil. Then start the clutch assembly over the tapered end of the clutch drive shaft with the keyway in the hub of the outer pressure plate in line with the keyway in the clutch drive shaft. Position the clutch release sleeve collar so that the grease fitting in the end of the release sleeve collar trunnion faces the opening in the side of the clutch housing; then guide the fingers of the release yoke over the trunnions on the release sleeve collar as shown in Fig. 17.

On the 11-1/2" diameter clutch, position the clutch release sleeve collar so the tapped hole in the collar faces the flexible grease tube hole in the side of the clutch housing.

CAUTION: The clutch release sleeve is a close fit on the drive shaft and must be started straight over the clutch drive shaft to prevent any bind between the release sleeve and the drive shaft.

3. Slide the clutch assembly back on the clutch drive shaft until it is tight against the taper on the drive shaft, then insert the key (35) in the keyway and tap it into place with a punch and a hammer.

4. Place the lock washer (38) on the drive shaft and against the outer pressure plate with the tang on the inner diameter of the lock washer in the keyway in the pressure plate.

5. Install the clutch drive shaft nut (39).

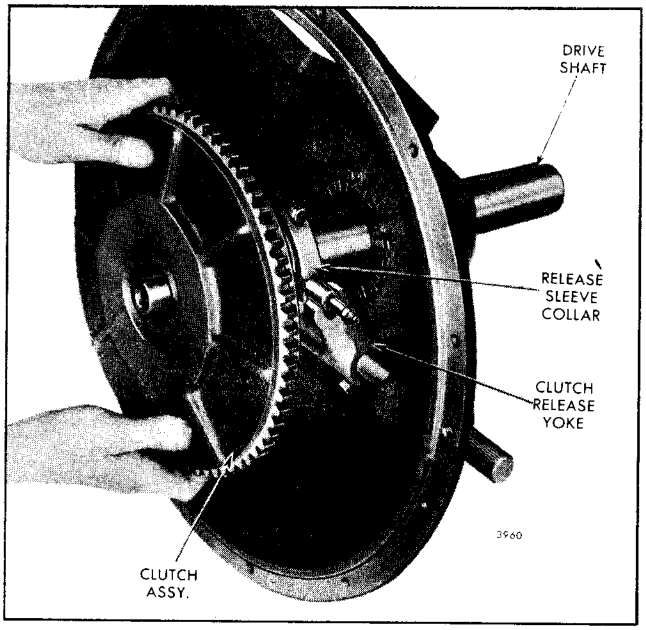

Fig. 17 - Installing Clutch Assembly

6. Install the key in the keyway of the clutch drive shaft. Attach a chain wrench to the drive shaft as shown in Fig. 8 to prevent the drive shaft from turning.

CAUTION: Be sure and place the teeth of the chain wrench on top of the key to prevent damage to the drive shaft while holding the drive shaft from turning. If the key or the shaft is damaged and cannot be cleaned up, they must be replaced.

7. Tighten the clutch drive shaft nut to the torque specified in the following table. Then bend the edge of the lock washer over against the flat side of the nut.

Clutch Size	Nut Size	Lb-Ft Torque
8"	1-1/8"-12	165-170
10"	1-5/16"-12	175-180
11-1/2"	1-3/4"-10	225-230

8. On the 11-1/2" diameter double-plate clutch power take-off unit thread the small end of the flexible grease tube in the hole in the side of the clutch release sleeve collar. Then insert the opposite end of the tube through the hole in the side of the clutch housing and install the tube retaining nut. Tighten the retaining nut while holding the tube nut inside the clutch housing from turning. Install the grease fitting in the tube, if it was removed.

9. Attach the inspection hole cover and gasket to the clutch housing.

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10. If removed, install the clutch release sleeve collar grease fitting cover on the side of the clutch housing (8" and 10" diameter clutch power take-offs).

11. For installation of the front mounted power take-off adaptor (1), refer to *Install Power Take-Off Adaptor* in Section 8.1.4.

Install Clutch Drive Shaft Pilot Bearing

If removed, install the clutch pilot bearing (45) in the clutch drive adaptor (46) or the flywheel (Fig. 1 or 2) as follows:

1. On the front mounted power take-off, lubricate the outside diameter of the pilot bearing with engine oil. Start the bearing, shielded side of bearing facing out, straight into the clutch drive adaptor, then drive the bearing into and against the shoulder in the adaptor with a bearing driver.

2. On the rear mounted power take-offs, with the flywheel attached to crankshaft with one bolt, install the pilot bearing as follows:

a. Lubricate the outside diameter of the pilot bearing with engine oil. Start the bearing, shielded side of bearing facing out, straight into the flywheel, then drive the bearing into and flush with the rear face of the flywheel with a bearing driver or tool J 3154-04 with suitable plates.

NOTE: The clutch drive shaft pilot bearing used on the 11-1/2" diameter clutch power take-off is a prelubricated bearing and is shielded on both sides. When installing this bearing, the numbered side of the bearing should face the rear (finished) face of the flywheel.

b. While holding the flywheel in place on the crankshaft by hand, remove the one flywheel attaching bolt. Then place the bearing retainer (scuff plate) against the flywheel and align the bolts holes in the retainer with the holes in the flywheel. Install the six flywheel attaching bolts and tighten them to the specified torque.

CAUTION: When removing or installing the flywheel attaching bolts, the flywheel must be held firmly against the crankshaft to prevent it from slipping off the end of the crankshaft. The flywheel is NOT doweled to the crankshaft.

ATTACH POWER TAKE-OFF TO ENGINE

With the power take-off assembled, attach it to the engine as follows:

1. If not previously installed, attach the clutch driving ring to the flywheel or the clutch drive adaptor with bolts and lock washers. Tighten the bolts to 30-35 lb-ft torque.

2. Support the power take-off assembly with a rope sling and chain hoist as shown in Fig. 7, then position the power take-off assembly at the rear of the flywheel housing, or the adaptor at the front end of the engine, with the clutch drive shaft in line with the pilot bearing in the flywheel or the clutch drive adaptor.

3. Push the power take-off forward and guide the forward end of the drive shaft straight into the clutch pilot bearing (45), Fig. 1 or 2, and engage the teeth on the outer diameter of the clutch facings (26) with the teeth in the inner diameter of the driving ring (3).

4. Guide the pilot on the clutch housing straight into the flywheel housing or the front end adaptor opening, then install the clutch housing to the flywheel housing with bolts and lock washers, or to the adaptor with bolts, lock washers and nuts. Tighten the bolts and nuts to 30-35 lb-ft torque.

5. Remove the chain hoist and the rope sling.

6. Install the clutch control hand lever (7) on the clutch release shaft (22) and secure it in place with a bolt and lock washer.

CAUTION: The thrust load on the clutch release sleeve collar should be kept at an absolute minimum. Therefore, the hand lever should be positioned on the shaft as near the 12 o'clock or 6 o'clock position as possible. The 9 and 3 o'clock positions are to be avoided.

7. Install all of the accessories on the engine that were removed.

8. Install the key and pulley on the clutch drive shaft.

9. Refer to *Lubrication* and lubricate the clutch release sleeve collar, clutch levers and linkage.

10. Before applying the load and with the clutch released, rotate the drive shaft by hand to be sure it rotates freely.

11. Refer to *Clutch Adjustment* and adjust the power take-off clutch as described for the clutch size being used.

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FRONT POWER TAKE-OFF ADAPTOR AND DRIVE MECHANISM

The front power take-off adaptor and drive mechanism (Fig. 1) consists of an adaptor which is bolted to the lower engine front cover, a clutch drive adaptor mounted on the front end of the crankshaft and a clutch driving ring.

The clutch drive adaptor is secured to the crankshaft with two cones, a washer and bolt. The clutch drive ring is bolted to the clutch drive adaptor. The forward end of the clutch drive shaft is supported by a pilot ball bearing in the clutch drive adaptor assembly.

Remove Power Take-Off Adaptor and Drive Mechanism

When removal of the front end power take-off adaptor or drive mechanism becomes necessary, they may be removed as follows:

1. Refer to *Remove Power Take-Off From Engine* in Section 8.1 for removal of the power take-off assembly.

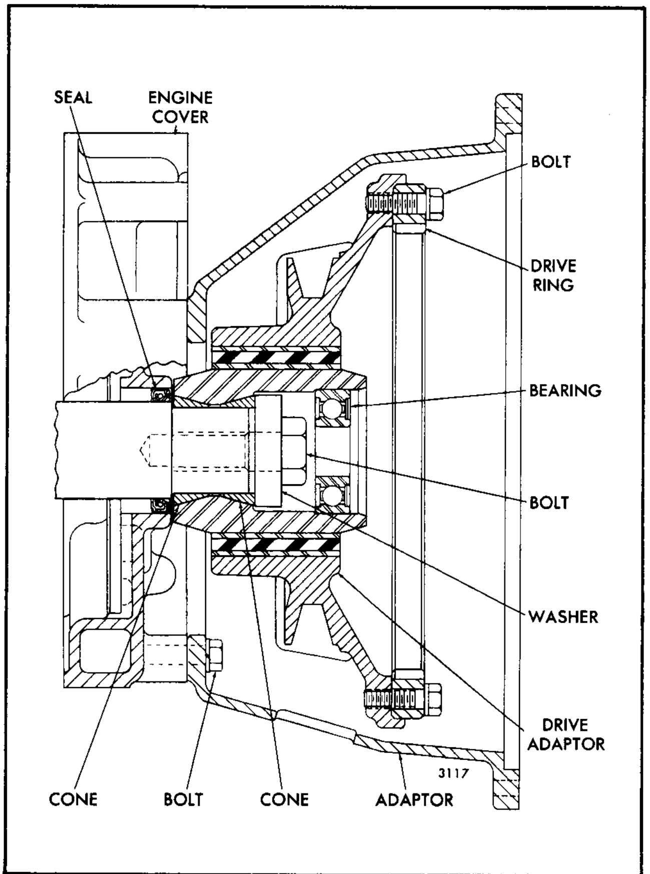

Fig. 1 - Front Power Take-Off Adaptor and Drive Mechanism

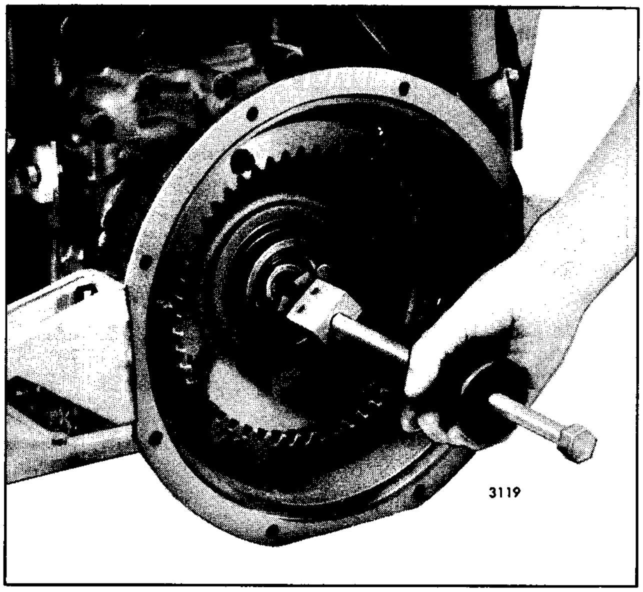

Fig. 2 - Removing Clutch Drive Shaft Pilot Bearing From Clutch Drive Adaptor

2. If used, loosen the bilge pump or the generator drive belt, then disconnect the belt by removing the connecting pins and remove the belt from the accessory drive pulley and bilge pump or generator pulley.

CAUTION: Use care not to lose the two-piece connecting pin after it has been removed.

3. Remove the clutch drive shaft pilot bearing from the clutch drive adaptor with slide hammer J 5901-1 and remover adaptor J 5901-2 as shown in Fig. 2.

4. Remove the clutch drive adaptor to crankshaft bolt and washer securing the drive adaptor to the crankshaft.

5. Use a wood block and hammer as shown in Fig. 3 to loosen the clutch drive adaptor from the crankshaft.

6. Insert the blade of a screw driver in the slot in the front cone to expand it, then withdraw it from the crankshaft.

7. Slide the clutch drive adaptor assembly from the crankshaft.

8. If necessary, slide the inner cone off the end of the crankshaft.

9. Remove the bolts and lock washers securing the front engine supports to the engine base.

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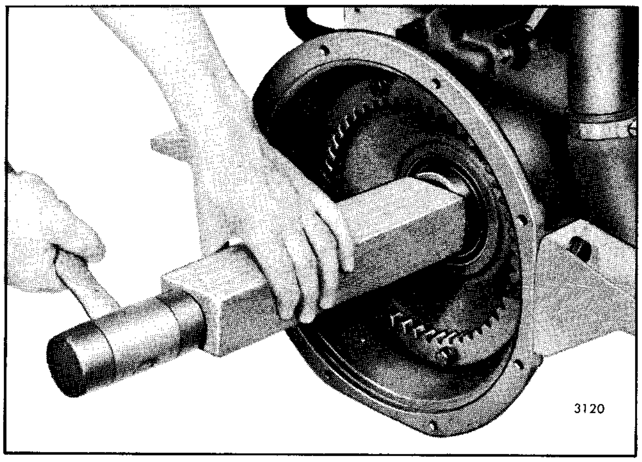

Fig. 3 - Loosening Clutch Drive Adaptor

10. Attach a suitable lifting sling and chain hoist to the front engine lifter bracket. Then lift the front end of the engine just enough to free the supports from the base.

11. Remove the six bolts and lock washers securing the power take-off adaptor to the engine front cover (Fig. 5).

12. Install a 3/8" -16 x 6" pilot stud in two of the attaching bolt holes, diametrically opposite each other to support the adaptor.

13. While supporting the front end of the power take-off adaptor, tap alternately against the back side of the engine supports with a plastic hammer to free the adaptor from the end plate and dowel pins in the engine front cover. Then slide the adaptor off of the pilot studs and crankshaft, being careful not to damage the oil seal.

Inspection

Wash all of the parts, except the shielded bearing, in clean fuel oil and dry them with compressed air. *Shielded bearings must not be washed*; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing.

Examine the clutch pilot ball bearing for corrosion or pitting. Lubricate the bearing with light engine oil; then, while holding the bearing inner race from turning, revolve the outer race slowly by hand. Replace the bearing if it is defective.

Inspect the clutch drive adaptor to make sure the rubber is firmly bonded to the metal at each end of the drive adaptor assembly. If the clutch drive adaptor has been exposed to fuel oil, lubricating oil or excessive heat, the rubber may have become loosened. In this event, the clutch drive adaptor assembly must be replaced.

Install Power Take-Off Adaptor and Drive Mechanism

Refer to Figs. 1 and 4 and proceed as follows:

1. Install a 3/8" -16 x 6" pilot stud in two of the attaching bolt holes, diametrically opposite each other, to support the adaptor.

2. Place the power take-off adaptor over the crankshaft and guide the pilot studs into the bolt holes of the adaptor. Then slide the adaptor back over the pilot studs and dowel pins and against the engine front cover.

3. Refer to Fig. 5 and install the six bolts and lock washers. Tighten the 3/8" -16 bolts to 30-35 lb-ft torque and the 7/16" -14 bolts to 46-50 lb-ft torque.

4. If removed, place the clutch drive adaptor hub rear cone over the end of the crankshaft with the tapered end of the cone facing the front end of the crankshaft, then slide the cone back against the shoulder on the crankshaft.

5. Place the clutch drive adaptor assembly over the end of the crankshaft and against the taper on the rear cone.

6. Place the front cone over the end of the crankshaft with the tapered end of the cone facing the adaptor hub. Insert the blade of a screw driver in the slot in the cone to expand it, then slide the cone straight forward until the taper on the cone contacts the taper on the adaptor hub. Remove the screw driver.

7. Place the washer on the clutch drive adaptor to crankshaft bolt and thread the bolt in the crankshaft. Tighten the 3/4" -16 bolt (In-Line and 6V engines) to 200-220 lb-ft torque; tighten the 1" -14 bolt (8V and 12V engines) to 290-310 lb-ft torque.

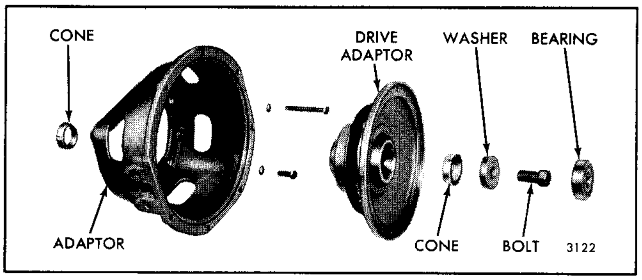

Fig. 4 - Front Power Take-Off Adaptor and Drive Details and Relative Location of Parts

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8. If removed, attach the clutch driving ring to the clutch drive adaptor with bolts and lock washers. Tighten the bolts to 30-35 lb-ft torque.

9. Install the clutch drive shaft pilot bearing in the clutch drive adaptor as follows:

a. Lubricate the outside diameter of the pilot bearing with engine oil.

b. Start the bearing, shielded side facing out, straight into the clutch drive adaptor, then drive the bearing straight into and against the shoulder in the adaptor with a bearing driver, or use a round bar as shown in Fig. 6.

NOTE: The round bar used to drive the bearing in should be slightly smaller than the outside diameter of the bearing and flat on the end.

10. Lower the front end of the engine so the front engine supports rest on the engine base, then install the bolts and lock washers securing the front engine supports to the engine base. Tighten the bolts securely.

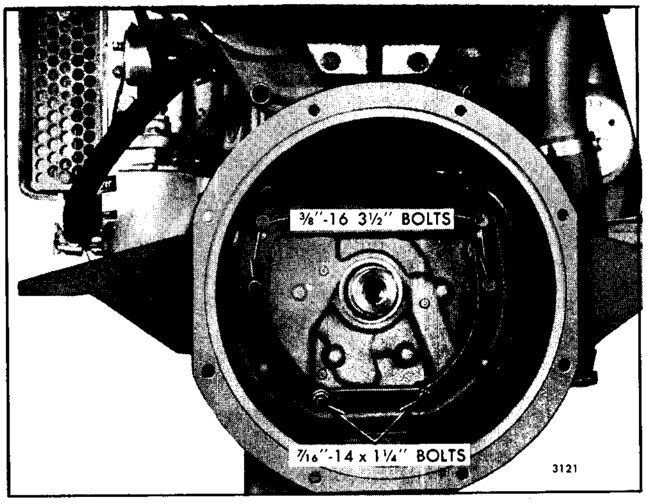

Fig. 5 - Location of Power Take-Off Adaptor to Engine Bolts

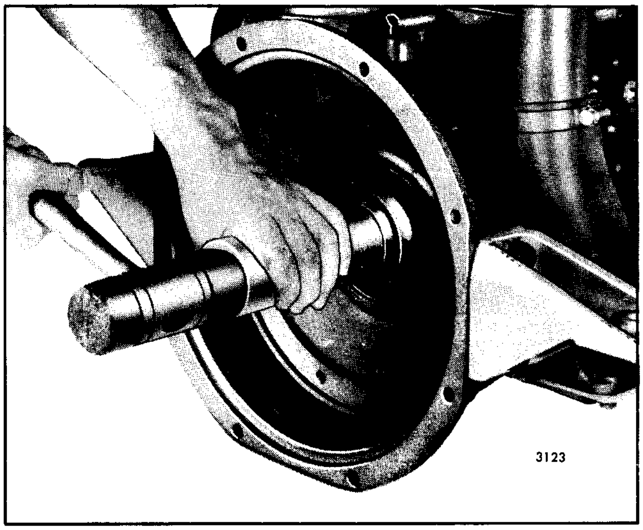

Fig. 6 - Installing Clutch Drive Shaft Pilot Bearing in Clutch Drive Adaptor

11. Remove the chain hoist and sling from the engine.

12. If used, insert one end of the drive belt through the opening in the side of the adaptor, over the accessory drive pulley, back out the adjacent hole in the side of the adaptor, over the bilge pump or generator pulley and connect the ends of the belt with the connecting pin. Then adjust the belt tension.

CAUTION: Use care not to lose the two piece connecting pin; also, be sure the pin is rotated to its locked position.

13. Refer to *Attach Power Take-Off To Engine* in Section 8.1 for the installation of the power take-off assembly.

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FLYWHEEL HOUSING DRIVE BEARING SUPPORT ASSEMBLY

The flywheel housing drive bearing support assembly is used on 4 and 6V-53 engines for connecting a remote mounted transmission (refer Section 8.0). This rear power takeoff adaptor housing assembly (support bearing) can be assemblied as follows:

1. Insert the spacer into the housing. Align the notch in the spacer with the grease fitting hole in the top of the housing.

2. Install a new bearing on each side of the spacer and secure them with the retainers.

3. Coat the sealing surface of the support housing with National Universal Sealant or equivalent and install the seals with the lip of the seal facing away from the engine. Clean any excess sealant from the support assembly.

4. If removed, install a grease fitting in the opening at the top of the housing.

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SHOP NOTES - TROUBLE SHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

CONNECTING A REMOTE MOUNTED TRANSMISSION TO AN ENGINE

When connecting a remote mounted transmission to an engine equipped with a rear power take-off adaptor housing assembly (support bearing) (Fig. 1), the inner oil seal in the power take-off housing must be in contact with the straight portion of the adaptor shaft.

Also the distance"A"(Fig. 1)between the rear face of the power take-off housing and the rear face of the adaptor shaft must be within the limits shown in Table 1.

Engine	Dimension A
4-53	1.540" min. - 1.800" max.
6V-53	2.140" min. - 2.400" max.

TABLE 1

NOTE: The above dimensions not to be used with drive shafts having a slip joint.

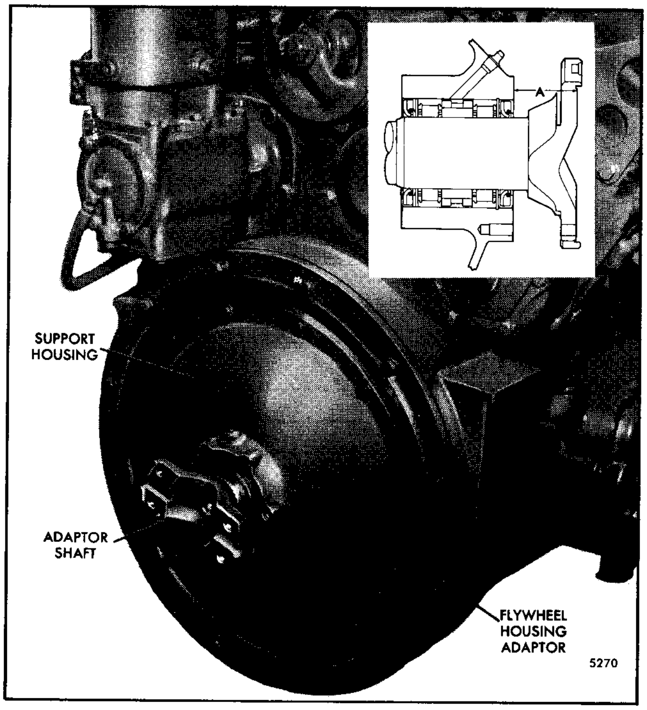

Fig. 1 - Typical Engine with Power Take-Off Adaptor Housing

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TROUBLE SHOOTING--POWER TAKE-OFF

FAULTY OPERATION

CLUTCH SLIPS

Check For

1. IMPROPER ADJUSTMENT
2. GREASE OR OIL ON FACINGS
3. FACINGS WORN
4. OVERLOADING

DRIVE SHAFT DAMAGE

Check For

11. MISALIGNMENT
12. BELT LOADING ABNORMALLY HIGH
13. DRIVE SHAFT BEARINGS WORN, DAMAGED OR NOT LUBRICATED

CLUTCH DOES NOT RELEASE

Check For

5. LINKAGE WORN OR BROKEN
6. CLUTCH RELEASE AND CLUTCH SEPARATOR SPRINGS WEAK OR BROKEN
7. MISALIGNMENT
8. PILOT BEARING DAMAGED

CLUTCH FACING TEETH WEAR

Check For

14. MISALIGNMENT AND SHOCK ENGAGEMENT

PILOT BEARING FAILURE

Check For

9. LACK OF LUBRICANT
10. MISALIGNMENT

OVERHEATING

Check For

15. TAPERED ROLLER BEARINGS
16. CLUTCH FACINGS

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FAULTY OPERATION

SUGGESTED REMEDY

1. Adjust the clutch as outlined under *Clutch Adjustment* in Section 8.1.

2. Disassemble the clutch and remove any excessive grease or oil from the clutch operating linkage. Remove all grease and oil from the pressure plates and facings. Replace clutch facings which are badly saturated.

3. Measure the thickness of the clutch facings. Replace clutch facings worn to the minimum thickness shown in the chart under *Replace Clutch Facings* in Section 8.1.

4. Check the installation and reduce the operating load on the unit as much as practical. Also, the shock loads and unnecessary belt loading should be reduced to a minimum. If necessary, install a power take-off assembly with a higher capacity clutch.

5. When the clutch operating linkage is badly worn or broken and the clutch is adjusted as in Step 1, the clutch may not disengage. Replace worn or broken linkage.

6. Broken or weak clutch release springs or clutch separator springs may cause the clutch to drag. Disassemble the clutch and replace the defective springs.

7. Misalignment is caused by overloading the clutch drive shaft or reduction gear driven shaft, shock loads, incorrect shimming of the outboard bearing or support bracket (if used), or the runout and out-of-round condition of the flywheel housing face and bore. Inspect the installation and determine whether the load on the clutch drive shaft or the reduction gear driven shaft is excessive (refer to Step 4).

The out-of-round (concentricity) and runout of a flywheel housing can be checked as outlined in Section 1.5.

8. Damage to the clutch drive shaft pilot bearing is usually the result of misalignment (Step 7), lack of lubricant (Step 9), or incorrect adjustment of the tapered roller bearings on direct drive units.

Adjust the clutch drive shaft tapered roller bearings after disassembling the power take-off and cleaning the bearings. Lubricate the bearings with engine oil. Then reinstall the clutch drive shaft and bearings and adjust the drive shaft end play as outlined under *Clutch Drive Shaft End Play Adjustment* in Section 8.1. Complete the assembly of the power take-off and lubricate the tapered roller bearings with an all purpose grease such as Shell Alvania No. 2, or equivalent (see Step 15).

9. The clutch drive shaft pilot bearing may fail from lack of lubricant. Remove the bearing from the flywheel or the coupling and flange assembly on front power take-offs and check the lubricant. Refer to *Lubrication* in Section 8.1.

To prolong the life of the clutch pilot bearing in an application where the power take-off is in continuous operation 8 hours or more a day, it is recommended that the engine be run at idle speed for at least 5 minutes each work shift with the power take-off disengaged. This will permit the grease to work its way into the pilot bearing.

10. Overloaded clutch drive shaft pilot bearing may fail. This condition may be corrected by referring to Step 7.

11. The clutch drive shaft or the reduction gear driven shaft may be damaged by misalignment (refer to Step 7).

12. High belt load may cause damage to the clutch drive shaft or reduction gear driven shaft (refer to Step 4).

13. Clutch drive shaft or reduction gear driven shaft bearings that are badly worn or damaged may damage the drive or driven shaft. Replace all worn bearings and properly adjust the direct drive clutch drive shaft end play.

14. Misalignment and shock engagement will place undue wear on the teeth of the clutch facings and result in rapid wear (refer to Step 7).

15. If the clutch drive shaft tapered roller bearings show evidence of overheating, replace the bearings. Overheating results from incorrect lubricating procedure or improper lubricant. Excessive side load or incorrect shaft end play can also be contributing factors. Lubricate the bearings with an all purpose grease such as Shell Alvania No. 2, or equivalent. Properly lubricated bearings will have a small ridge of grease on the drive shaft next to the clutch housing.

16. If inspection of the clutch facings reveals evidence of overheating, it is the result of clutch slippage. Refer to Step 1 to correct this condition.

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TROUBLE SHOOTING--TORQMATIC CONVERTER

Chart 1

LOW CONVERTER CHARGING PRESSURE

Probable Causes

1. LOW OIL SUPPLY
2. OIL LINE LEAKAGE
3. DEFECTIVE OIL PUMP
4. EXCESSIVE OIL FLOW TO TRANSMISSION
5. PLUGGED INLET LINE OR SCREEN
6. SUCTION SCREEN UNCOVERED
7. OIL FOAMING

SUGGESTED REMEDY

1. Add oil. Refer to the *Lubrication and Preventive Maintenance Chart* (Section 15.1).

2. Check for air leaks in the suction lines and oil leaks in the pressure lines.

3. Check for wear in the oil pump. Check for high stall speed (refer to the specific Torqmatic converter service manual).

4. Check the operation of the selector valve, check the valve, by-pass valve and transmission driven pump (Series 400 through 900 converters).

5. Check the inlet line and screen. Clean them if necessary (Series 400 through 900 converters).

6. Check the oil level or check for improper installation of the suction screen (Series 400 through 600 converters).

7. Check to be sure the oil return line is below the oil level in the sump.

Chart 2

MANUAL INPUT DISCONNECT CLUTCH SLIPPAGE

Probable Causes

1. CLUTCH FACING WEAR

SUGGESTED REMEDY

1. Adjust the clutch.

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Chart 3

HIGH OIL TEMPERATURE

Probable Causes

1. LOW OIL LEVEL (LOW FLOW RATE)
2. HIGH OIL LEVEL
3. LOW WATER LEVEL IN COOLING SYSTEM
4. LOW CONVERTER CHARGING PRESSURE
5. CLOGGED OR DIRTY HEAT EXCHANGER
6. OPERATING TOO LONG IN AN INEFFICIENT CONVERTER RANGE
7. ONE OR BOTH STATORS LOCKED
8. STATORS INTERCHANGED OR STATOR INSTALLED BACKWARD
9. STATOR(S) INSTALLED WITHOUT ROLLERS OR SPRINGS

SUGGESTED REMEDY

1. Add oil. Refer to the *Lubrication and Preventive Maintenance Chart* (Section 15.1).

2. Drain the oil to the proper level.

3. Add water. Check for leaks.

4. Refer to Chart 1.

5. Clean or replace the heat exchanger as necessary.

6. Readjust the work cycle to allow operation in an efficient converter range.

7. Check for the low maximum speed of the operating equipment.

The maximum converter "OUT" oil temperature is 250 °F (121 °C).

If it should become necessary to check for locked stator(s) by observing the temperature drop rate, increase the converter "OUT" temperature to 230 °F (110 °C) by stalling the converter output shaft at full throttle. Release the converter output shaft and immediately check the rate of temperature drop with no load on the converter and a maximum input speed. The temperature should start to drop after 15 seconds.

A slow temperature drop rate may indicate locked stator(s). A rapid temperature drop rate indicates normal stator operation.

8. Check for a lack of power at converter stall. (Refer to Chart 1).

Disassemble the converter and check the stators (refer to the specific Torqmatic converter service manual).

9. Disassemble the converter and install the missing parts (refer to Items 4 in Charts 4 and 5).

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Chart 4

HIGH ENGINE SPEED AT CONVERTER STALL

Probable Causes

1. LOW OIL SUPPLY
2. LOW CONVERTER CHARGING PRESSURE
3. HIGH OIL TEMPERATURE
4. STATOR(S) INSTALLED WITHOUT ROLLERS (SERIES 200-300 CONVERTERS)

SUGGESTED REMEDY

1. Add oil. Refer to the *Lubrication and Preventive Maintenance Chart* (Section 15.1).

2. Refer to Chart 1.

3. Refer to Chart 3.

4. Disassemble the converter and install the rollers (refer to the specific Torqmatic converter service manual).

Chart 5

LOW ENGINE SPEED AT CONVERTER STALL

Probable Causes

1. LOW ENGINE OUTPUT TORQUE
2. CONVERTER ELEMENT INTERFERENCE
3. STATORS INTERCHANGED OR STATOR INSTALLED BACKWARD
4. STATORS INSTALLED WITHOUT ROLLERS (SERIES 400-900 CONVERTERS)

SUGGESTED REMEDY

1. Tune the engine and check the output.

2. Check for noise at stall. Overhaul the converter if necessary.

3. Check for a lack of power at converter stall (refer to the specific Torqmatic converter service manual).

Disassemble the converter and check the stators.

4. Disassemble the converter and install the rollers.

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Chart 6

LOSS OF POWER

Probable Causes

1. STATORS INTERCHANGED (SERIES 300-900 CONVERTERS)
2. STATOR INSTALLED BACKWARD (SERIES 200 CONVERTERS)
3. STATOR(S) INSTALLED WITHOUT ROLLERS (HIGH STALL SPEED, SERIES 200; LOW STALL SPEED, SERIES 300-900)
4. LOW CONVERTER CHARGING PRESSURE
5. LOW ENGINE SPEED AT CONVERTER STALL

SUGGESTED REMEDY

1. Check for a lack of power at stall (refer to specific Torqmatic converter service manual).

Disassemble the converter and check the stators.

2. Check for a lack of power at stall.

Disassemble the converter and check the stator.

3. Disassemble the converter and install the rollers.

4. Refer to Chart 1.

5. Refer to Chart 5.

Chart 7

LOW LOCK-UP CLUTCH PRESSURE

Probable Causes

1. FAULTY LOCK-UP CLUTCH LINKAGE ADJUSTMENT
2. LOCK-UP CLUTCH SELECTOR VALVE NOT WORKING PROPERLY
3. FAILED OR WORN SEAL RINGS
4. STOPPAGE IN PASSAGE FROM OIL PUMP TO LOCK-UP PISTON

SUGGESTED REMEDY

1. Adjust the linkage.

2. Remove the charging oil pump cover and check the clutch selector valve.

3. Disassemble the converter. Replace the failed or worn seal rings.

4. Disassemble the converter and clean the passage. Inspect the converter for dirt.

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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 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 1 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

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EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)	TORQUE (Nm)
Flywheel bolts	1/2 -20	110-220	150-298
Crankshaft end bolt (in-line and 6V engines)	3/4 -16	200-220	271-298
Crankshaft end bolt (in-line engine with cone mounted pulleys not stamped with letter "A"	3/4 -16	290-310	393-421
Crankshaft end bolt (8V engine)	1 -14	290-310	393-421
Clutch-to-drive shaft nut (8" clutch)	1-1/8 -12	165-170	224-231
Clutch-to-drive shaft nut (10" clutch)	1-5/16-12	175-180	238-244
Clutch-to-drive shaft nut (11-1/2" clutch)	1-3/4 -10	225-230	305-312

SERVICE TOOLS

TOOL NAME	TOOL NO.
Oil seal remover and installer set	J 3154-04
Slide hammer and puller set	J 5901-01
Spring tester	J 22738-02

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SECTION 9

TRANSMISSIONS

CONTENTS

Warner Hydraulic Marine Gear (Models 71 and 72) **9.1.3**

Shop Notes - Troubleshooting - Specifications - Service Tools **9.0**

For service and overhaul procedures for the Twin Disc Marine Gear assembly, refer to:

Twin Disc, Inc.
1328 Racine Street
Racine, Wisc. 53403

For service and overhaul procedures for Model 73C Warner Marine Gear, refer to:

Warner Gear - Technical Service Dept.
Division of Borg-Warner Corp.
P.O. Box 2688
Muncie, Ind. 47302

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WARNER HYDRAULIC MARINE GEAR

Two models of the Warner Marine Gear are used with the Series 53 engine-- Model 71 shown in Fig. 1 and Model 72 shown in Fig. 2. Each model is available in direct drive, 1.5:1, 2.1:1, 2.5:1 and 3:1 reduction gear ratios. Since the two models of the marine gear are similar, the following general description as well as the procedures for removal, disassembly, assembly and replacement of parts apply to either model.

Although many parts are interchangeable between the two models, some of the parts are not interchangeable; therefore, make sure of the marine gear model before ordering replacement parts. The reduction gear ratio, model and serial numbers will be found on the name plate on the top left-hand side of the reverse gear housing.

The Warner Hydraulic Marine Gear assemblies, shown in Figs. 1 and 2, consist of a hydraulically operated multiple disc forward and reverse clutch, a 2.1:1 ratio reduction gear assembly, an oil pump and oil screen, an oil pressure regulator valve and an oil sump independent of the engine oil system. On current engines, the oil cooler is mounted at the heat exchanger. Former engines have the oil cooler engine mounted; thus, the marine gear is a self contained assembly.

Oil pressure for the operation of the marine gear is provided by a crescent type oil pump which is attached to the forward face of the gear housing adaptor and keyed to the drive gear (input) shaft. The oil pump is driven continuously while the engine is running. The oil is delivered under pressure from the pump to the selector (control) valve and to the pressure regulator valve inside of the selector valve.

The pressure regulator valve maintains constant pressure over a wide speed range, and the selector (control) valve directs the oil under pressure to either the forward or reverse clutch piston cavity, the lubricating circuit and the oil cooler. The operating oil pressure range for the marine gear at operating speed is 120 to 160 psi, and the maximum operating oil temperatures for the various marine gears are shown in the following chart.

MAXIMUM OIL TEMPERATURES

Gear Ratio	Forward	Reverse
1:1	200°F	250°F
1.5:1	215°F	250°F
2:1	225°F	250°F
2.5:1	215°F	250°F
3:1	215°F	250°F

All of the marine gear oil does not flow through the marine gear oil cooler. Only the oil that flows by the pressure regulator valve, when the oil pressure moves the valve off its seat, flows through the oil cooler and is cooled by the engine water flowing around the oil cooler core.

A breather assembly is mounted in the top of the marine gear housing directly above the selector (control) valve for venting the marine gear.

Figures 1, 4 and 5 illustrate the reduction gear assemblies used on the 1.5:1, 2.1:1 and 2.5:1 reverse and reduction gear assemblies.

The reduction gear assembly consists of a planetary gear set which reduces the revolutions put into the unit by a predetermined ratio and is always engaged. The direction of rotation of the drive shaft of the reduction gear assembly is the same as the engine rotation in forward drive. Lubrication of the reduction gear assembly is supplied by the marine gear oil pump.

Operation

FORWARD DRIVE

When the selector valve lever is moved to the forward position (lever should cover the letter "F" on the housing), the selector (control) valve directs the oil under pressure from the oil pump down through the oil passage in the gear housing and reduction gear input shaft, then through the drilled passages in the drive gear shaft and through the three drilled passages in the inner diameter of the forward clutch cylinder, and then to the cavity back of the forward clutch piston. The resulting movement of the forward clutch piston and the lever action of the clutch spring forces the multiple discs of the forward clutch together and, with the aid of the forward clutch hub, locks the input shaft to the ring gear. This in turn prevents rotation of the planetary pinions about their axis and thus locks the input shaft, ring gear and reduction gear input shaft together, causing them to rotate as a solid concentric coupling. In this way, input shaft speed and direction of rotation are transmitted directly to the reduction gear drive shaft.

NOTE: The position of the selector valve lever on the reverse gear when in forward should be shifted to the point where it covers the letter "F" on the gear housing and is located in its proper position by the poppet ball. *Do not* remove the selector valve lever poppet spring and/or ball, nor change the lever in any

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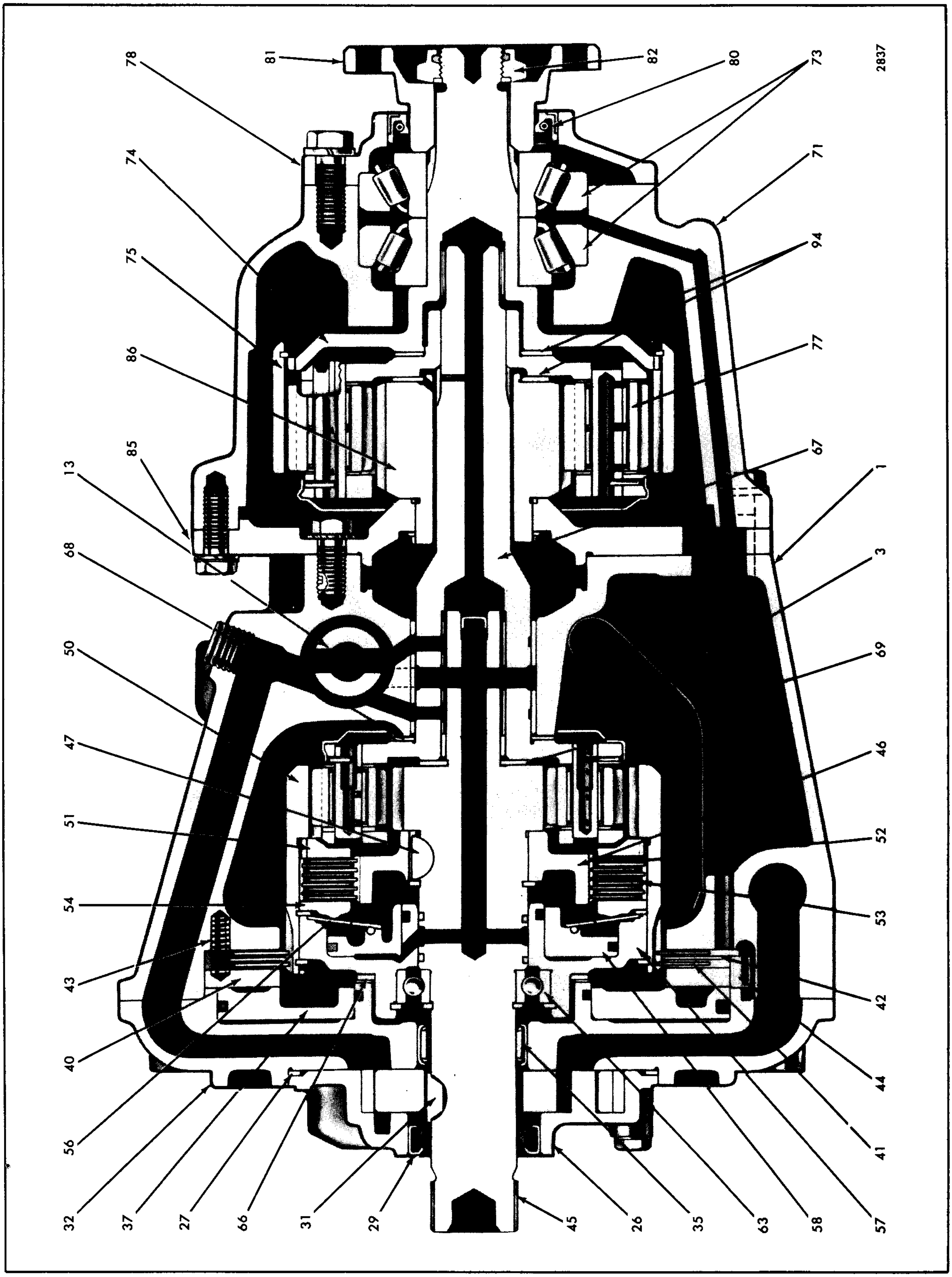

Fig. 1 - Warner Marine Gear Assembly (2.1:1 Ratio Model 71C Shown)

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Fig. 1 - Warner Marine Gear Assembly (2.1:1 Ratio Model 71C Shown)

1. Housing--Reverse Gear
3. Baffle--Gear Housing Oil
13. Valve--Selector Control
26. Pump Assy.--Reverse Gear Oil
27. Gasket--Oil Pump to Adaptor
29. Oil Seal--Oil Pump
31. Woodruff Key--Oil Pump Drive
32. Adaptor--Reverse Gear Housing
35. Bearing--Gear Housing Adaptor Roller
37. Piston--Reverse Clutch
40. Plate--Reverse Clutch Pressure
41. Plate--Reverse Clutch (Inner)
42. Plate--Reverse Clutch Stationary (Steel)
43. Spring--Pressure Plate Release
44. Pin--Reverse Clutch Stationary Plate Dowel
45. Shaft Assy.--Drive Gear Input
46. Hub--Forward Clutch
47. Woodruff Key--Forward Clutch Hub
50. Ring Gear--Forward Clutch Planetary
51. Plate--Forward Clutch Pressure (Rear)
52. Plate--Forward Clutch Inner (Copper Faced)
53. Plate--Forward Clutch (Steel)
54. Plate--Forward Clutch Pressure (Front)
56. Spring--Forward Clutch Release
57. Cylinder--Forward Clutch Piston
58. Piston--Forward Clutch
63. Bearing--Drive Gear Input Shaft Ball
66. Thrust Washer--Forward Clutch Cylinder
67. Shaft Assy.--Planetary Gear and Reduction Gear Input
68. Thrust Washer--Reduction Gear Input Shaft
69. Thrust Washer--Reduction Gear Planetary Gear
71. Housing--Reduction Gear
73. Bearing Assy.--Drive Shaft
74. Shaft Assy.--Reduction Gear Drive
75. Ring Gear--Reduction Gear Planetary
77. Gear Assy.--Reduction Gear Planetary
78. Retainer--Drive Shaft Bearing
80. Oil Seal--Bearing Retainer
81. Drive Flange
82. Nut--Drive Flange
85. Adaptor--Reduction Gear
86. Sun Gear--Reduction Gear
94. Thrust Washer--Planetary Gear

manner. Also *do not* reposition the linkage between the remote control and gear selector valve lever so that it does not have sufficient travel in both direction.

NEUTRAL

When the selector valve lever is moved to the neutral position, the selector (control) valve blocks off the flow of pressurized oil to the forward and reverse clutches and a portion of the oil flows into the gear housing for lubrication and a portion of the oil is by-passed through the oil cooler and back to the gear housing oil sump. The forward and reverse clutches are also vented, by a different portion of the selector valve, permitting the oil in the cavity behind the pistons to drain in the gear housing oil sump. The forward and reverse clutch release springs force the pistons back to their respective positions, thereby permitting complete disengagement of the forward and reverse clutches.

REVERSE DRIVE

When the selector valve lever is moved to the reverse position, the selector (control) valve directs oil under pressure from the oil pump through an oil passage in the top portion of the gear housing to the oil passage in the top of the gear housing adaptor, then to the cavity back of the reverse clutch piston. The resulting movement of the reverse clutch pressure plate locks the reverse clutch plates to the reverse gear housing. The stationary reverse clutch (steel) plate which is doweled to the gear housing and the two reverse clutch plates which are splined to the ring gear, prevent rotation of the ring gear. With the ring gear held stationary and the drive (sun) gear rotating at input speed, the pinions of the compound planetary gear assembly are rotated about their own axis and reverse the direction of rotation of the pinion carrier and reduction gear drive shaft.

CAUTION: Shift from forward to reverse drive through neutral at engine speeds below 1000 rpm to prevent damage to the engine, marine gear or reduction gear drive shaft.

It is recommended that vessels utilizing a marine gear have a suitable locking device or brake to prevent rotation of the propeller shaft when the vessel is not under direct propulsion. If the marine gear is not in operation and the forward motion of the vessel causes the propeller shaft to rotate, lubricating oil will not be circulated through the gear because the oil pump is not in operation. Overheating and damage to the marine gear may result unless rotation of the propeller shaft is prevented.

Lubrication

The reverse and reduction gear assembly is lubricated by pressure and splash. The main oil gallery is open to oil pump pressure whenever the engine is running and all of the moving parts are lubricated through drilled passages in the control valve, gear housing, drive gear (input) shaft, reduction gear input shaft, reduction gear drive shaft and reduction gear adaptor. Lubricating oil is transferred from the reduction gear housing to the reverse gear housing by gravity and jet flow through the drilled passage at the lower inside face of the reduction gear housing.

Check the oil level in the marine gear daily and add

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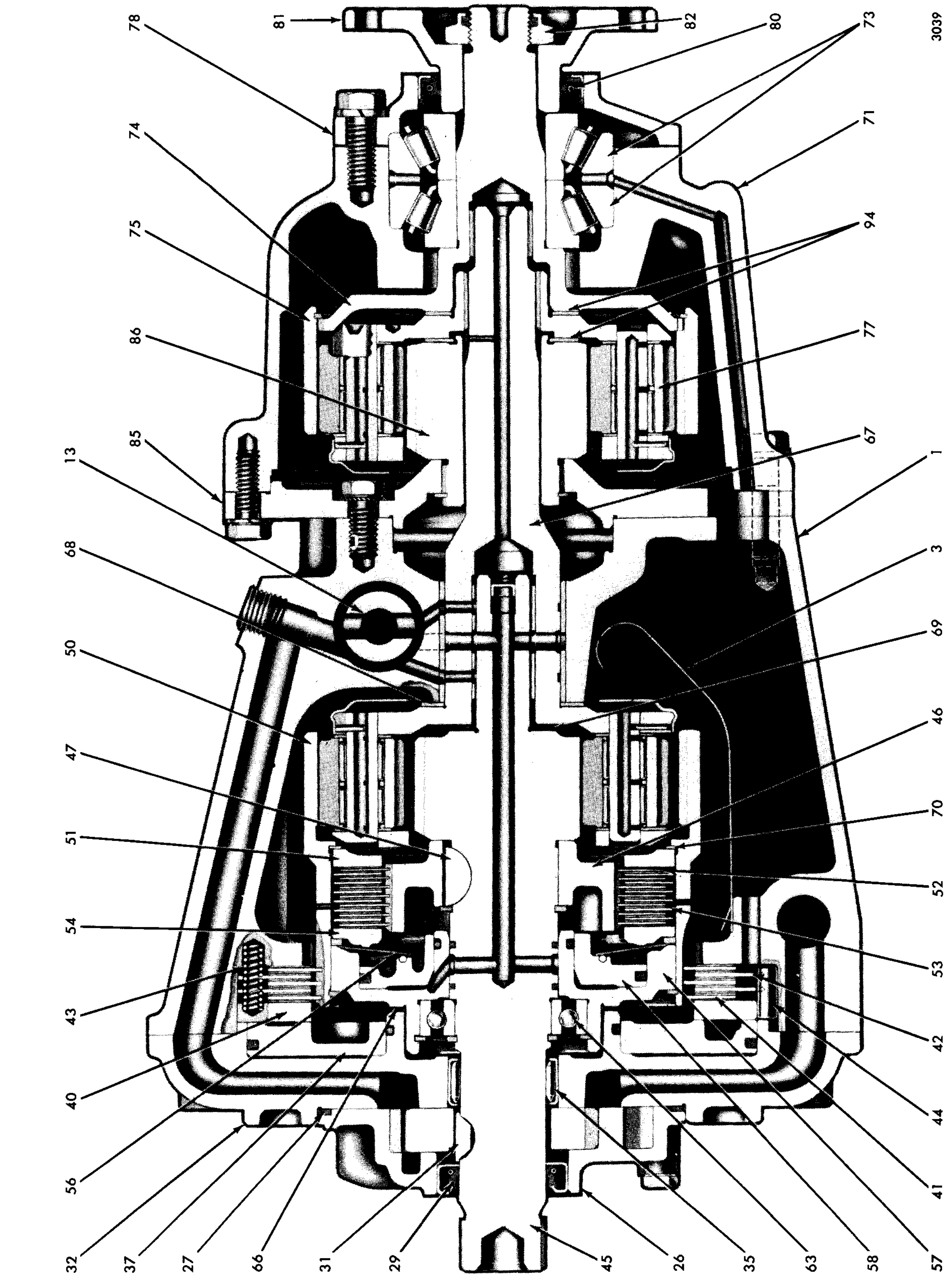

Fig. 2 - Warner Marine Gear Assembly (2.1:1 Ratio Model 72C Shown)

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Fig. 2 - Warner Marine Gear Assembly (2.1:1 Ratio Model 72C Shown)

1. Housing--Reverse Gear
3. Baffle--Gear Housing Oil
13. Valve--Selector Control
26. Pump Assy.--Reverse Gear Oil
27. Gasket--Oil Pump to Adaptor
29. Oil Seal--Oil Pump
31. Woodruff Key--Oil Pump Drive
32. Adaptor--Reverse Gear Housing
35. Bearing--Gear Housing Adaptor Roller
37. Piston--Reverse Clutch
40. Plate--Reverse Clutch Pressure
41. Plate--Reverse Clutch (Inner)
42. Plate--Reverse Clutch Stationary (Steel)
43. Spring--Pressure Plate Release
44. Pin--Reverse Clutch Stationary Plate Dowel
45. Shaft Assy.--Drive Gear Input
46. Hub--Forward Clutch
47. Woodruff Key--Forward Clutch Hub
50. Ring Gear--Forward Clutch Planetary
51. Plate--Forward Clutch Pressure (Rear)
52. Plate--Forward Clutch Inner (Copper Faced)
53. Plate--Forward Clutch (Steel)
54. Plate--Forward Clutch Pressure (Front)
56. Spring--Forward Clutch Release
57. Cylinder--Forward Clutch
58. Piston--Forward Clutch
63. Bearing--Drive Gear Input Shaft Ball
66. Thrust Washer--Forward Clutch Cylinder
67. Shaft Assy.--Planetary Gear and Reduction Gear Input
68. Thrust Washer--Reduction Gear Input Shaft
69. Thrust Washer--Reduction Gear Planetary Gear
70. Spacer--Forward Clutch Selective (Snap Ring)
71. Housing--Reduction Gear
73. Bearing Assy.--Drive Shaft
74. Shaft Assy.--Reduction Gear Drive
75. Ring Gear--Reduction Gear Planetary
77. Gear Assy.--Reduction Gear Planetary
78. Retainer--Drive Shaft Bearing
80. Oil Seal--Bearing Retainer
81. Drive Flange
82. Nut--Drive Flange
85. Adaptor--Reduction Gear
86. Sun Gear--Reduction Gear
94. Thrust Washer--Planetary Gear

oil as required to bring it up to the FULL mark on the dipstick.

NOTE: A new "Threaded Type" oil level dipstick assembly has replaced the former "Filler Cap Type" dipstick assembly used in the marine gears. To check the oil level in marine gears equipped with the current "Threaded Type" oil level dipstick, place the dipstick in the housing so the bottom of the threaded plug contacts the housing. Then remove the dipstick and check the oil level. The dipstick must be threaded into the housing after the oil level has been checked to prevent oil leakage during operation of the marine gear.

Change the marine gear oil every 200 hours of operation.

Drain the oil from the current marine gears, except the current 2.1:1 marine gears, by disconnecting the oil tube from the elbow at the lower right-hand side of the reverse gear housing, then remove the reducing bushing, oil return tube, nipple and elbow assembly from the housing. After draining the oil, remove the oil strainer assembly from the housing, rinse it thoroughly in clean fuel oil, dry it with compressed air, then reinstall the oil strainer assembly and the reducing bushing, oil return tube, nipple and elbow assembly in the housing and connect the oil tube to the elbow.

Drain the oil from the former marine gears and the current 2.1:1 marine gears by removing the oil strainer retaining plug at the lower right-hand side of the reverse gear housing. After draining the oil, remove the oil strainer assembly (oil deflector in current 2.1:1 marine gears) from the housing, rinse it thoroughly in clean fuel oil, dry it with compressed air, then reinstall the oil strainer assembly or oil deflector and the oil strainer retaining plug in the housing.

Refill the marine gear to the proper oil level on the dipstick (approximately 1-1/2 quarts in direct drive gears and 3 quarts in reverse and reduction gears) with the same heavy-duty lubricating oil that is used in the engine.

Start and run the engine and marine gear unit at idle speed for a few minutes to fill the lubrication system. Stop the engine, then immediately check the oil level in the marine gear. Bring the oil level up to the FULL mark on the dipstick. Do not overfill.

Remove Reverse Gear from Engine

If reconditioning of the reverse gear assembly becomes necessary, the reverse gear and reduction gear assembly must be removed from the engine.

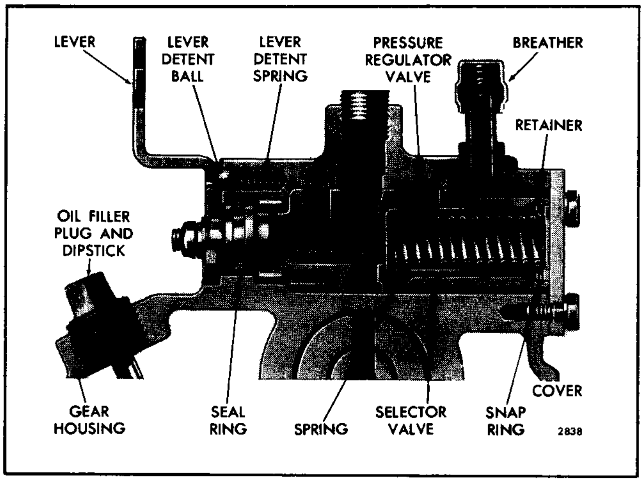

Fig. 3 - Marine Gear Control Valve Assembly

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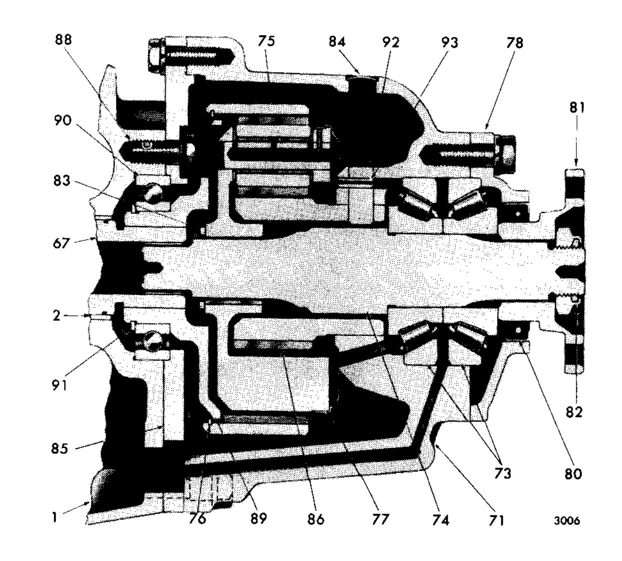


1. Housing--Reverse Gear
2. Bushing--Reverse Gear Housing
67. Shaft Assy.--Planetary Gear and Reduction Gear Input
71. Housing--Reduction Gear
73. Bearing Assy.--Drive Shaft
74. Shaft--Reduction Gear Drive
75. Ring Gear--Reduction Gear Planetary
76. Snap Ring--Planetary Ring Gear
77. Gear Assy.--Reduction Gear Planetary
78. Retainer--Drive Shaft Bearing
80. Oil Seal--Bearing Retainer
81. Drive Flange
82. Nut--Drive Flange
83. Snap Ring--Planetary Gear
84. Plug--Reduction Gear Housing Expansion
85. Adaptor--Reduction Gear
86. Sun Gear--Reduction Gear
88. Bolt--Adaptor Nylock
89. Gear--Reduction Gear Input
90. Bearing--Reduction Gear Input Gear
91. Snap Ring--Input Gear Bearing
92. Pin--Reduction Gear Sun Gear Dowel
93. Pin--Sun Gear Dowel Pin Roll

Fig. 4 - Reduction Gear Assembly (1.5:1 Ratio)

However, if reconditioning of only the reduction gear assembly is desired, the reduction gear assembly may be removed as a unit from the reverse gear assembly.

If space limitations do not allow the reverse and reduction gear to be lifted clear as an assembly, the reduction gear only may be removed first, then remove the reverse gear; however, if space permits, remove the reverse and reduction gear as an assembly.

The procedure for removal of the former marine gear is essentially the same for the current marine gear. Exceptions in the procedure for the current marine gears will be indicated. With the engine suitably supported, refer to Figs. 7 and 8 and remove the reverse and reduction gear assembly as follows:

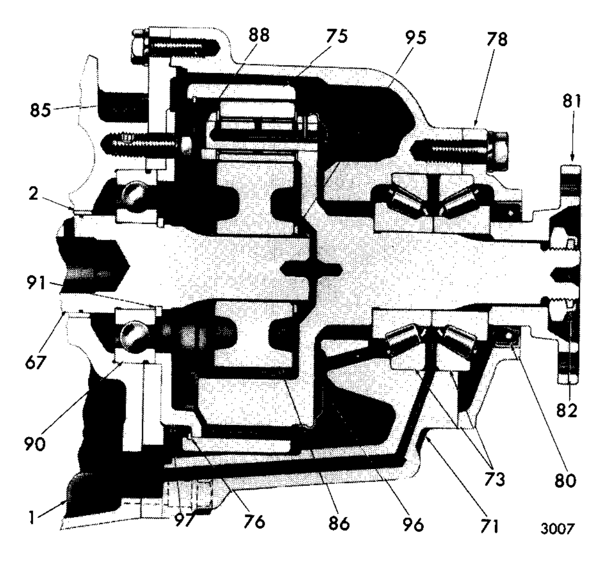
1. Disconnect the oil tube from the elbow at the lower right-hand side of the reverse gear housing, then remove the reducing bushing, oil return tube, nipple and elbow assembly from the housing. After draining the oil, reinstall the reducing bushing, oil return tube, nipple and elbow assembly in the housing.

On the former marine gears and the current 2.1:1 marine gear, remove the oil strainer retaining plug at the lower right-hand side of the reverse gear housing. After draining the oil, reinstall the plug in the housing.

2. Disconnect the reverse gear oil cooler supply tube at the top of the reverse gear housing.

3. On the former marine gears, disconnect the reverse gear oil cooler return tube at the lower right-hand side of the reduction gear housing or at the top of the reduction gear housing on current 2.1:1 marine gears.

4. Remove the two rear engine supports that are secured to the sides of the reverse gear housing.



1. Housing--Reverse Gear
2. Bushing--Reverse Gear Housing
67. Shaft Assy.--Planetary Gear and Reduction Gear Input
71. Housing--Reduction Gear
73. Bearing Assy.--Drive Shaft
75. Ring Gear--Reduction Gear Planetary
76. Snap Ring--Planetary Ring Gear
78. Retainer--Drive Shaft Bearing
80. Oil Seal--Bearing Retainer
81. Drive Flange
82. Nut--Drive Flange
85. Adaptor--Reduction Gear
86. Sun Gear--Reduction Gear
88. Bolt--Adaptor Nylock
90. Bearing--Reduction Gear Input Shaft
91. Snap Ring--Bearing
95. Snap Ring--Sun Gear
96. Shaft Assy.--Planetary Gear and Drive
97. Plate--Reduction Gear Ring Gear

Fig. 5 - Reduction Gear Assembly (2.5:1 Ratio)

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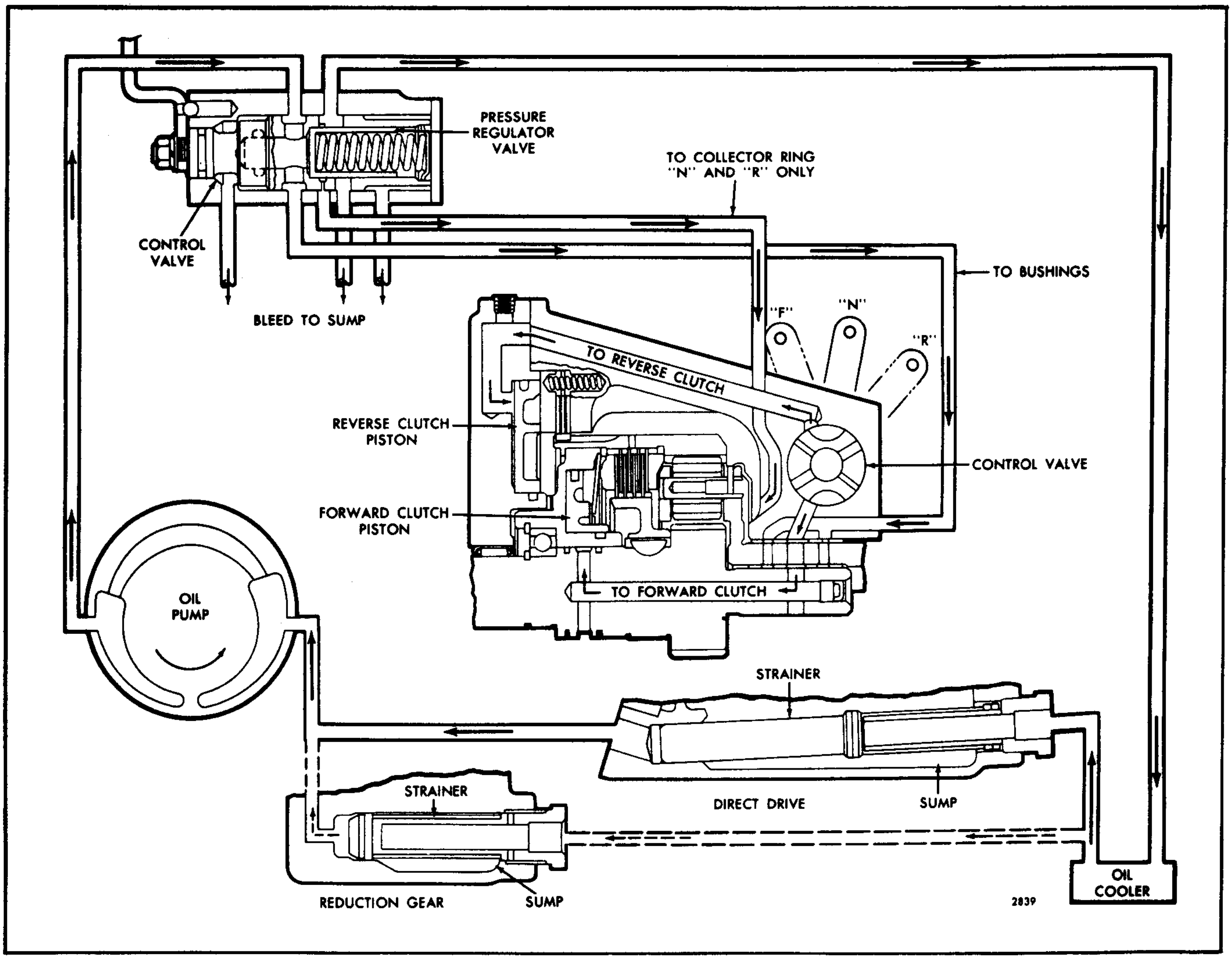

Fig. 6 - Marine Gear Oil Flow Diagram

5. Install a 7/16" -14 eyebolt in the top bolt hole at each side of the reverse gear housing (Fig. 9).

6. Support the reverse and reduction gear assembly with a rope sling and chain hoist as shown in Fig. 9.

7. Remove the six 7/16" -14 x 3-1/4" bolts and lock washers securing the reverse gear housing to the flywheel housing adaptor, then pull the reverse and reduction gear assembly away from the adaptor.

Disassemble Reverse and Reduction Gear

After removal from the engine, the reverse and reduction gear assembly may be divided into two sub-assemblies listed below to simplify the disassembly procedure.

Reverse Gear Assembly

Reduction Gear Assembly

Disassembly need be carried out only as far as is required to correct those difficulties which interfere with proper marine gear operation.

If, at any time, it becomes necessary to remove or recondition the reverse gear oil pump, reverse clutch assembly or forward clutch and ring gear assembly on any of the reverse gear assemblies, they may be removed from and reinstalled in the reverse gear housing without disturbing the drive flange on the direct drive unit or without removing the reduction gear assembly and adaptor from the reverse gear housing on reduction gear units.

On the 1.5:1 and 2.1:1 reverse and reduction gear units, the planetary gear and reduction gear input shaft assembly also may be removed from the reverse gear housing without removing the reduction gear assembly.

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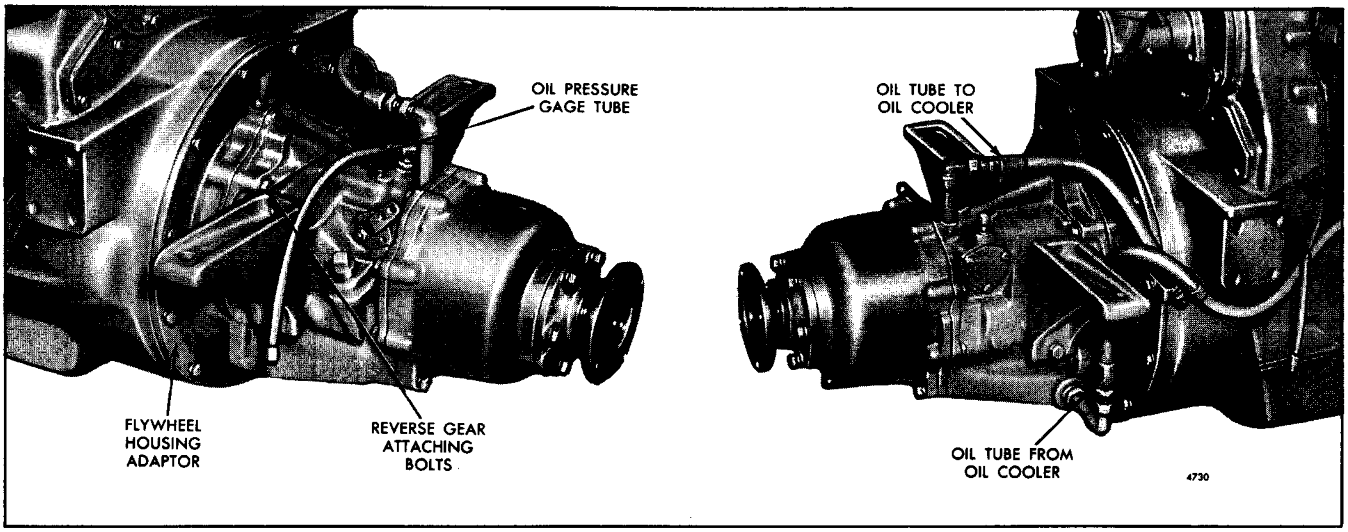

Fig. 7 - Reverse and Reduction Gear Mounting to Engine (Current)

On the direct drive reverse gear unit, the drive flange must be removed in order to remove the planetary gear and output shaft assembly from the reverse gear housing.

On the 2.5:1 and 3:1 reverse and reduction gear units, the reduction gear assembly, sun gear and reduction gear input shaft bearing snap ring must be removed in order to remove the planetary gear and reduction gear input shaft assembly from the reverse gear housing.

The disassembly procedure outlined below covers the right-hand and left-hand rotating direct drive, and 1.5:1, 2.1:1, 2.5:1 and 3:1 ratio reduction gears used on Model 71 and 72 marine gears.

To separate the reduction gear assembly from the reduction gear adaptor and reverse gear assembly, refer to Figs. 1, 4 and 5 for the various gear ratios and location of the parts and proceed as follows:

1. Support the reverse and reduction gear assembly on a bench with the top of the assembly facing up and the drive flange facing the outside of the bench.

2. Install two bolts, or bolts and nuts, in two of the bolt holes in the drive flange next to each other (Fig. 11).

3. Place a large spanner wrench over the outside of the two bolts with one end hooked over one bolt and the other end resting on the bench as shown in Fig. 11; then, while holding the reverse and reduction gear assembly from moving, attach a wrench to the drive flange nut and loosen it.

4. Remove the two 7/16" -14 bolts and lock washers and the six 3/8" -16 bolts and lock washers securing the reduction gear assembly to the reduction gear adaptor.

5. Place a 3/4" x 1" x 4" wood block under the reverse gear housing next to the flange of the reduction gear housing to support the reverse gear housing.

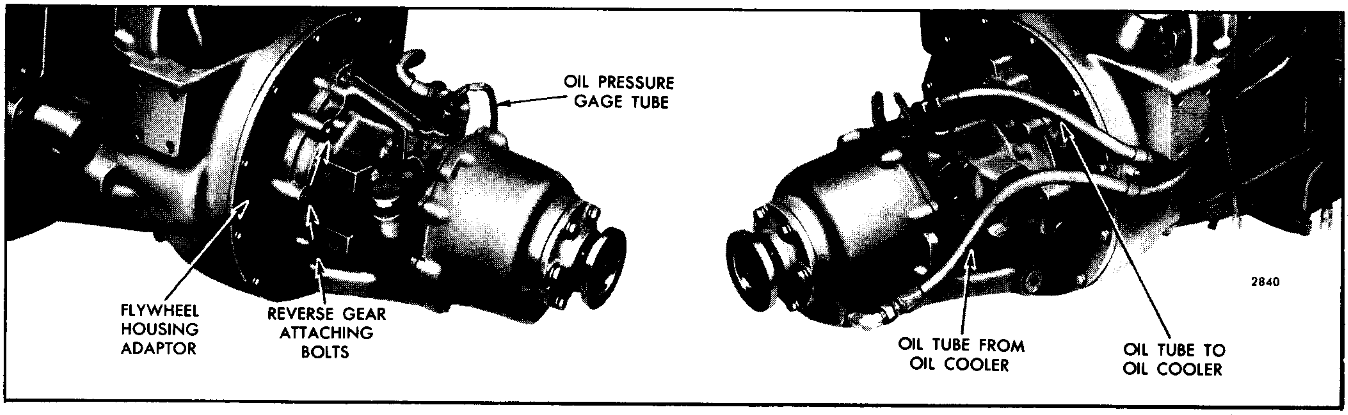

Fig. 8 - Reverse and Reduction Gear Mounting to Engine (Former)

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6. Tap the side of the drive flange with a plastic hammer to loosen the reduction gear assembly from the reduction gear adaptor, then lift the reduction gear assembly away from the reduction gear adaptor as shown in Fig. 12. Remove the gasket from the adaptor or the gear housing.

On a 2.1:1 ratio reduction gear, remove the reduction gear planetary gear assembly (77) and the two planetary gear thrust washers (94), Fig. 1, from the sun gear and the reduction gear input shaft as shown in Fig. 13.

7. Remove the reduction gear adaptor assembly from the reverse gear housing on the various reduction gears as outlined below.

On the 1.5:1 ratio reduction gear shown in Fig. 4, remove adaptor (85), reduction gear input gear (89), ring gear (75) and input gear bearing (90) as an assembly from the reverse gear housing as follows:

a. Remove and discard the six 7/16" -14 Nylock bolts and lock washers securing the adaptor to the reverse gear housing through the two access holes in the flange of the input gear as shown in Fig. 14.

b. Tap the forward face of the adaptor lightly with a plastic hammer to loosen the adaptor from the reverse housing and the input gear bearing.

c. Place two pinch bars diametrically opposite each other, between the adaptor and the rear face of the gear housing as shown in Fig. 15, and pry the input gear bearing out of the gear housing. Then slide the adaptor assembly straight off of the reduction gear input shaft. Remove the gasket from the adaptor or the gear housing.

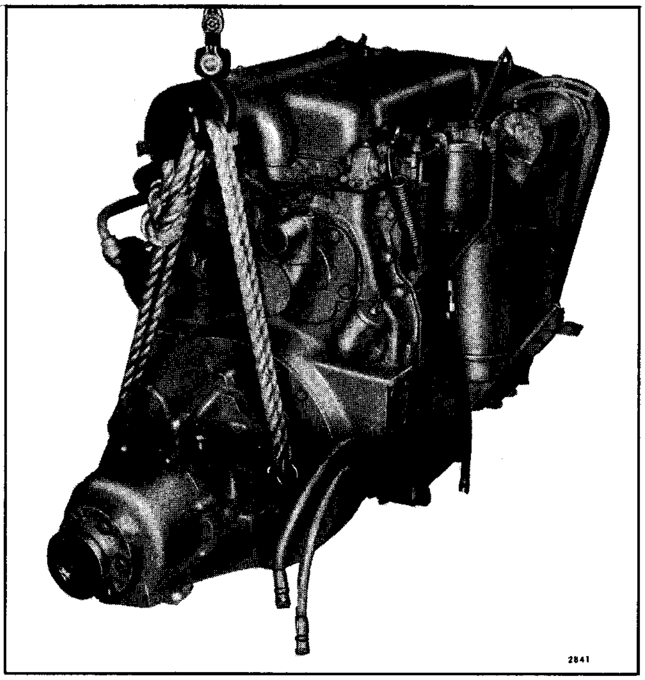

Fig. 9 - Removing Reverse and Reduction Gear Assembly from Engine

On the 2.1:1 ratio reduction gear shown in Fig. 1, remove adaptor (85) and sun gear (86) as an assembly from the reverse gear housing as follows:

a. Remove and discard the six 7/16" -14 Nylock bolts and lock washers securing the adaptor to the reverse gear housing.

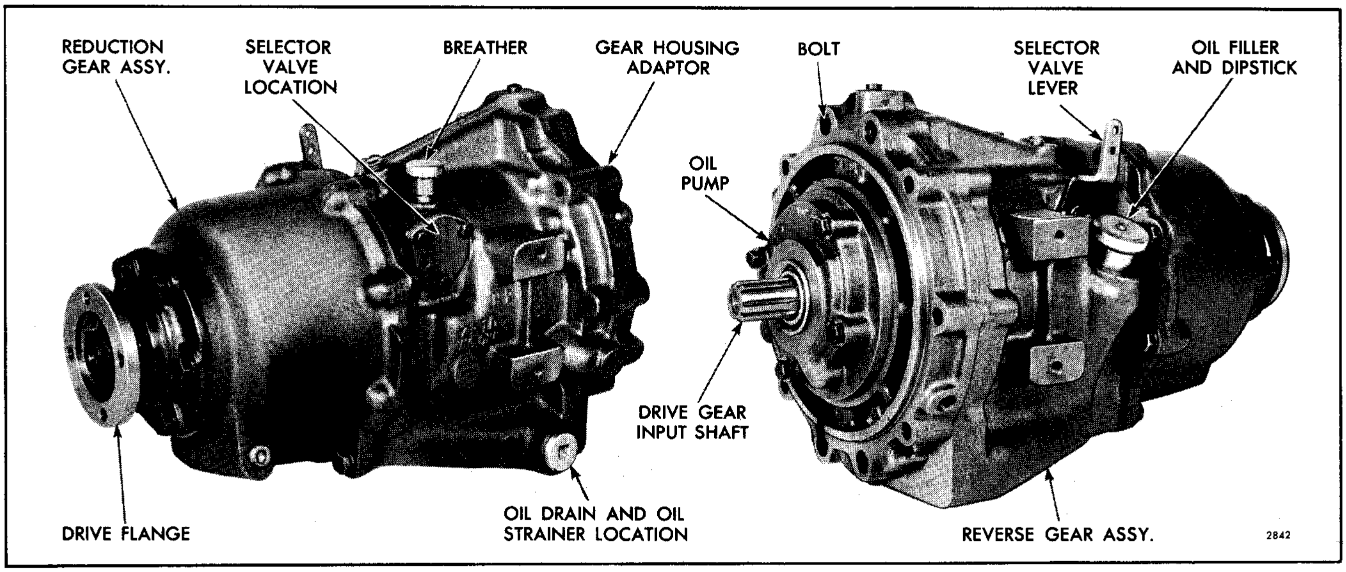

Fig. 10 - Three Quarter View of Former Reverse and Reduction Gear Assembly

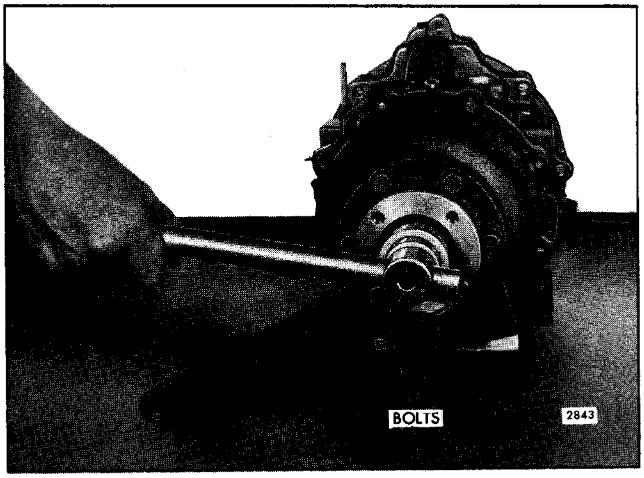

Fig. 11 - Loosening Drive Flange Retaining Nut

b. Tap the forward face of the adaptor lightly with a plastic hammer to loosen the adaptor from the reverse gear housing, then slide the adaptor and sun gear assembly straight off of the reduction gear input shaft as shown in Fig. 16. Remove the gasket from the adaptor or the gear housing.

On the 2.5:1 and 3:1 ratio reduction gears shown in Fig. 5, remove the reduction gear adaptor (85), planetary ring gear plate (97) and ring gear (75) as an assembly from the reverse gear housing as follows:

a. Remove the reduction gear sun gear snap ring from the reduction gear input shaft with a pair of snap ring pliers J 5586 as shown in Fig. 17. Then slide the sun gear off the end of the shaft.

NOTE: On a 3:1 ratio reduction gear, the reduction gear ring gear plate and adaptor may be removed without removing the sun gear from the reduction gear input shaft.

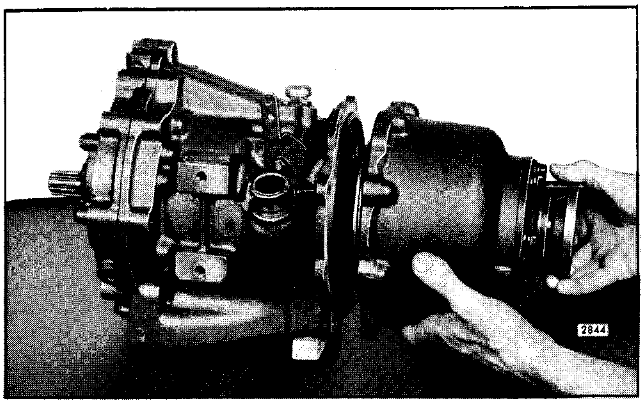

Fig. 12 - Removing or Installing Reduction Gear Assembly from/on Reverse Gear Assembly

b. Remove and discard the six 7/16"-14 Nylock bolts and lock washers securing the adaptor and the planetary ring gear plate to the reverse gear housing.

c. Tap the forward face of the adaptor lightly with a plastic hammer to loosen the adaptor from the reverse gear housing and the reduction gear input shaft bearing, then slide the adaptor assembly straight off of the reduction gear input shaft as shown in Fig. 18. Remove the gasket from the adaptor or the gear housing.

Disassemble Reverse Gear

With the direct drive reverse gear assembly removed from the engine, or the reduction gear assembly and reduction gear adaptor assembly removed from the reverse gear housing, the reverse gear may be disassembled as outlined below.

The disassembly procedure for the direct drive reverse gear and the reverse gears used in conjunction with the 1.5:1, 2.1:1, 2.5:1 and 3:1 ratio reduction gears are similar. Therefore, disassembly will be covered as a single procedure and any differences between the various assemblies will be noted therein.

The current 1.5:1 and 2.1:1 reverse and reduction gear units use a .061" to .063" thrust washer between the forward clutch piston cylinder and the gear housing adaptor to obtain the proper input shaft end play of .004" to .043". The former and current direct drive, 2.5:1 and 3:1 gears also use a .061" to .063" thrust washer.

In the former 1.5:1 and 2.1:1 reverse and reduction

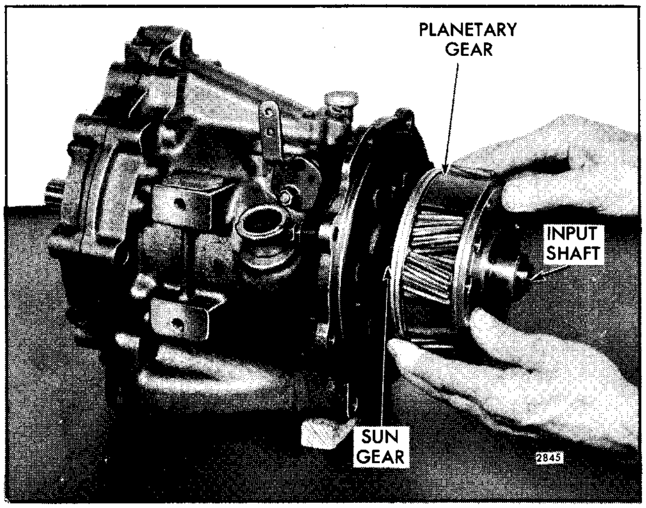

Fig. 13 - Removing or Installing Reduction Gear Planetary Gear Assembly from/on Sun Gear and Input Shaft (2.1:1 Ratio)

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gear units, one of two different thickness thrust washers was used between the forward clutch piston cylinder and the gear housing adaptor to obtain the proper input shaft end play of .004" to .043". They are .061" to .063" and .085" to .087" thick. However, when servicing the former 1.5:1 and 2.1:1 reverse and reduction gear units, use the .061" to .063" thrust washer only to obtain the proper input shaft end play of .004" to .043".

The end play of the input shaft should be taken and recorded at this time to determine if a new thrust washer should be used when reassembling the reverse gear unit.

Refer to Figs. 1, 2 and 43 for the location of the various parts and disassemble as follows:

1. Check the drive gear input shaft or reduction gear input shaft end play as follows:

a. Remove one of the selector valve cover bolts at the side of the gear housing, then install a 1/4"-20 x 1-1/2" bolt in the cover bolt hole, or install a 7/16"-14 x 2" bolt in one of the tapped holes in the side of the reverse gear housing. Tighten the bolt securely.

b. Attach a dial indicator to the 1/4"-20 or 7/16"-14 bolt with the indicator button contacting the end of the drive gear input shaft or the reduction gear input shaft as shown in Fig. 19.

NOTE: On the direct drive unit, the dial indicator must contact the forward end of the drive gear input shaft. On the reduction gear units, the dial indicator may contact the end of either the drive gear input shaft or the reduction gear input shaft.

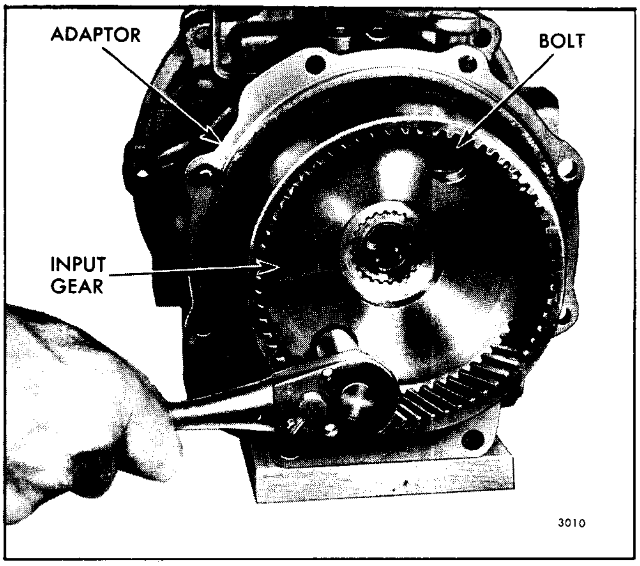

Fig. 14 - Removing Reduction Gear Adaptor to Reverse Gear Housing Bolts (1.5:1 Ratio)

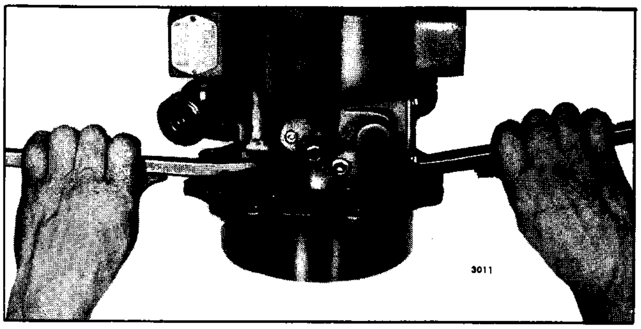

Fig. 15 - Removing Reduction Gear Input Gear and Bearing Assembly from Reverse Gear Housing (1.5:1)

c. Move all of the parts inside of the gear housing forward by pulling on the drive gear input shaft. Set the dial indicator at zero, move all of the parts back by pushing on the drive gear input shaft, then read the indicator and record the end play.

2. Remove the selector valve assembly from the reverse gear housing as follows:

a. Remove the nut, lock washer and flat washer securing the selector valve lever to the selector valve, then slide the lever off the end of the selector valve. Remove the selector valve lever detent steel ball and spring from the gear housing.

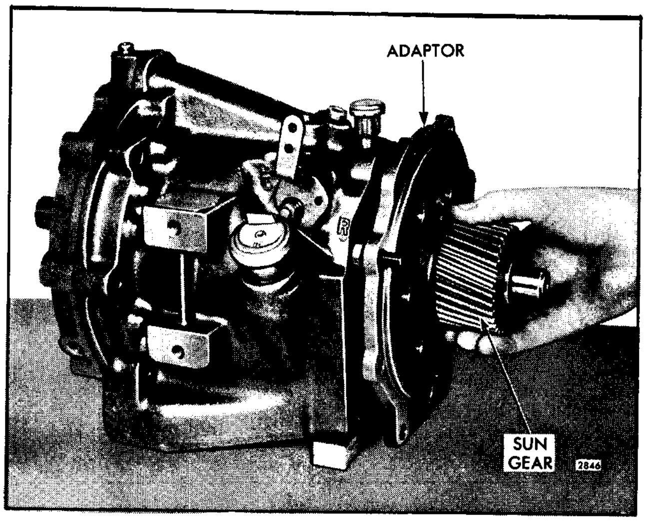

Fig. 16 - Removing or Installing Reduction Gear Adaptor and Sun Gear Assembly from/to Reverse Gear Housing (2.1:1 Ratio)

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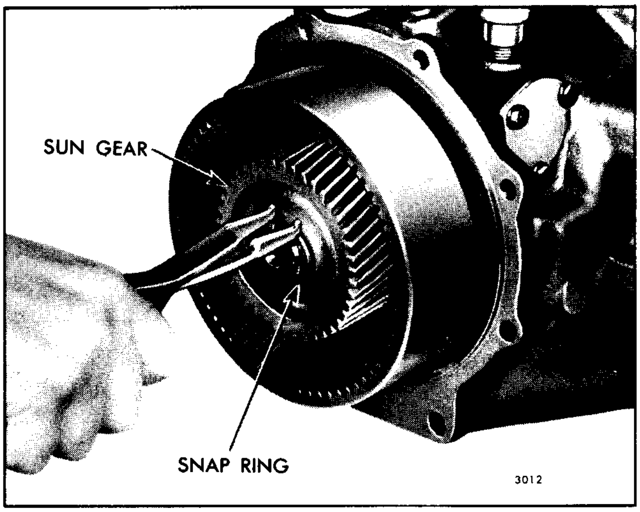

Fig. 17 - Removing or Installing Reduction Gear Sun Gear Snap Ring from/on Input Shaft (2.5:1 and 3:1 Ratio)

CAUTION: Do not lose the steel detent ball when removing the selector lever.

b. Remove the three 1/4" -20 bolts and lock washers securing the selector valve cover to the side of the reverse gear housing, then remove the cover and gasket.

c. Push on the threaded or lever end of the selector valve and force the selector valve out of the opposite side of the gear housing, then pull the selector valve straight out of the gear housing.

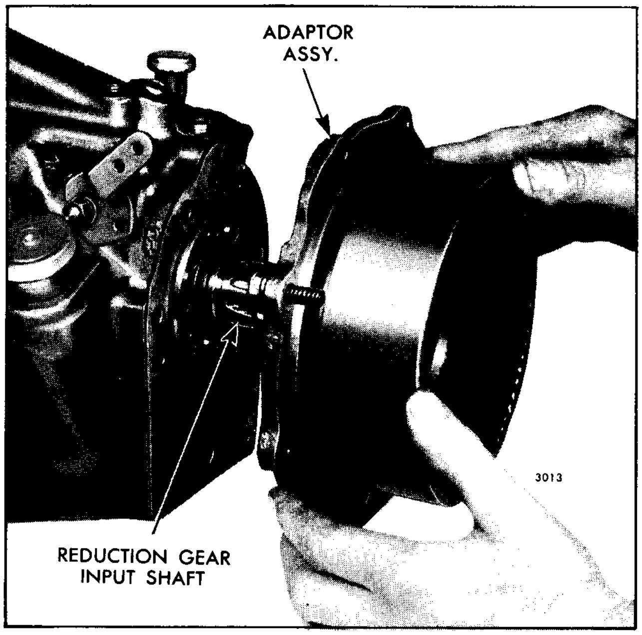

Fig. 18 - Removing or Installing Reduction Gear Adaptor, Planetary Ring Gear Plate and Ring Gear Assembly from/to Reverse Gear Housing (2.5:1 and 3:1 Ratios)

3. Remove the pressure regulator valve from the selector valve as follows:

a. Remove the selector valve seal ring from groove in the small or threaded end of the selector valve.

b. Place a 1-1/4" inside diameter sleeve approximately two inches long over the small or threaded end of the selector valve.

c. Support the selector valve and sleeve on the bed of an arbor press with the open end of the selector valve up.

d. Place a 3/4" diameter x 2" long round steel rod on top of the valve spring retainer and under the ram of an arbor press as shown in Fig. 20.

e. Compress the regulator valve spring just enough to permit removal of the snap ring. With the spring compressed, remove the snap ring from the groove inside of the selector valve with a small screw driver as shown in Fig. 20.

f. While supporting the selector valve assembly with one hand, very carefully release the load on the pressure regulator valve spring; then remove the selector valve and parts from the arbor press.

CAUTION: The valve spring retainer is a very close fit in the bore of the selector valve. Extreme care must be used when releasing the load on the valve spring so as not to allow the edge of the retainer to catch in the snap ring groove and damage the retainer.

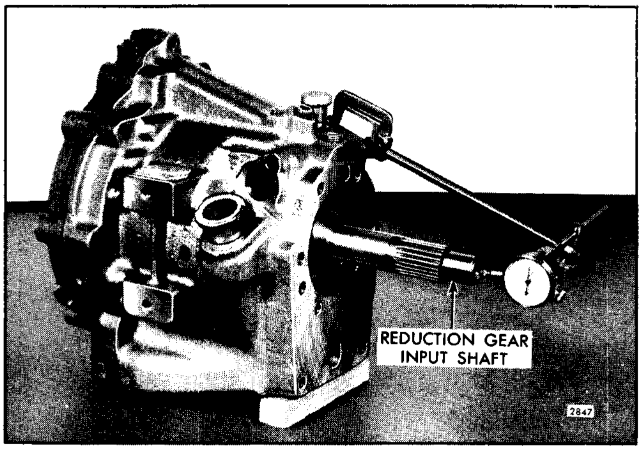

Fig. 19 - Checking Reduction Gear Input Shaft End Play

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g. Remove the pressure regulator valve spring and regulator valve from inside the selector valve.

4. Remove the reducing bushing, oil return tube, nipple and elbow assembly on the current marine gear, or the oil drain plug on the former marine gear, from the lower right-hand side of the reverse gear housing, then remove the oil strainer assembly from the housing.

5. Remove the reverse gear oil pump assembly from the reverse gear housing adaptor as follows:

a. Note and record the rotation marks on the forward face of the oil pump housing prior to removal. For a right-hand rotating input shaft, the TOP RH will be facing the top of the gear housing adaptor and for a left-hand rotating input shaft, the TOP LH will be facing the top of the gear housing adaptor (Fig. 86).

b. Remove the four 5/16" -18 bolts securing the oil pump assembly to the reverse gear housing adaptor.

c. Pull the oil pump assembly straight forward away from the gear housing adaptor and off the Woodruff key and input shaft.

d. Remove the oil pump gasket from the top of the oil pump housing or cover plate, or inside the counterbore of the gear housing adaptor.

e. Remove the oil pump inner rotor (gear) drive (Woodruff) key from the drive gear input shaft.

6. Dissassemble the reverse gear oil pump assembly as follows:

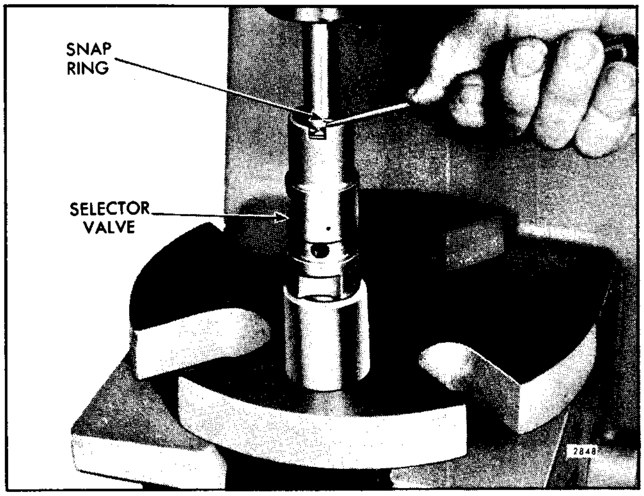

Fig. 20 - Removing Snap Ring from Selector Valve

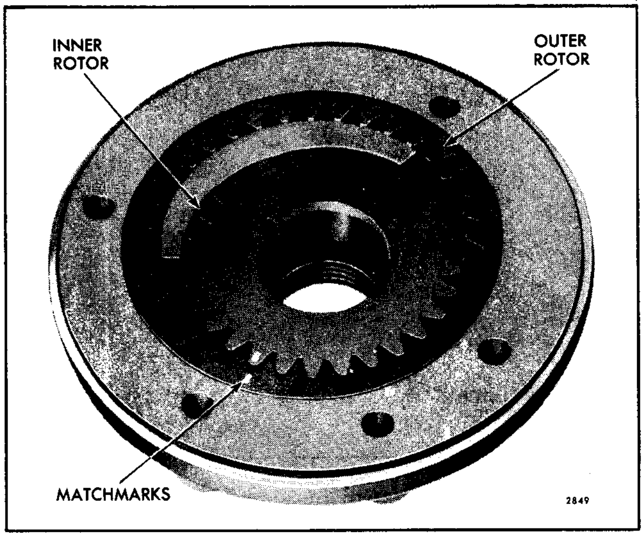

Fig. 21 - Location of Matchmarks on Inner and Outer Oil Pump Rotors (Gears)

a. On the former oil pump, remove the two flat head No. 10-24 screws securing the oil pump cover plate to the oil pump housing, then lift the oil pump cover plate straight out of the oil pump housing.

b. Matchmark the teeth of the inner and outer rotors (gears) where they mesh as shown in Fig. 21 so they may be reassembled in the same position.

c. Lift the inner and outer rotors (gears) straight up out of the oil pump housing.

d. To remove the oil seal in the oil pump housing.

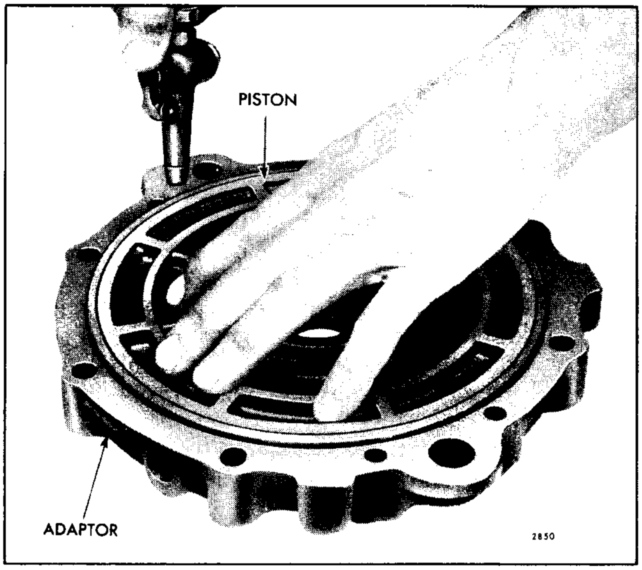

Fig. 22 - Removing Reverse Clutch Piston from Gear Housing Adaptor

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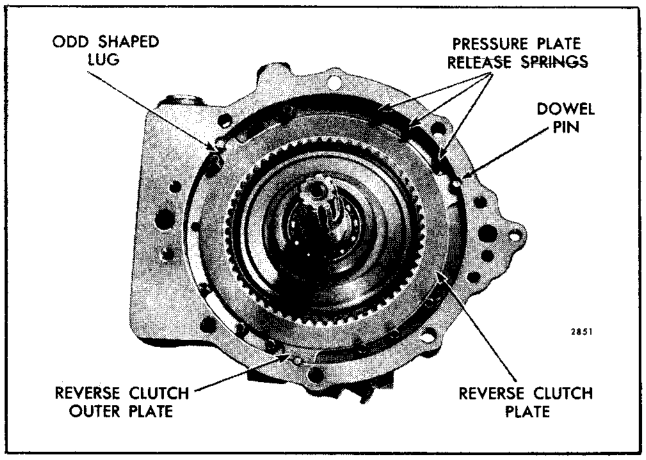

Fig. 23 - Location of Reverse Clutch Release Springs, Clutch Plates and Dowel Pins

support the oil pump housing on the bed of an arbor press with the oil seal over the opening in the bed of the press and the forward face of the housing down.

NOTE: Due to the various positions the oil seal has been installed in the reverse gear oil pump housing (Fig. 82), it is recommended that the position of the oil seal in the housing be noted and recorded before removal so that the new oil seal may be reinstalled in the same position.

e. Place a 1-7/8" x 3" round steel bar on top of the oil seal and under the ram of the press. Then press the oil seal out of the oil pump housing. Discard the oil seal.

7. On a direct drive reverse gear unit, stand the reverse gear assembly in a vertical position with the rear face of the drive flange resting on a bench.

On all other reverse gear assemblies, stand the reverse gear assembly in a vertical position with the rear face of the gear housing resting on wood blocks high enough to prevent the outer end of the reduction gear input shaft from resting on the bench.

8. Remove the four 3/8" -16 bolts securing the reverse gear housing adaptor to the gear housing, then lift the adaptor straight off of the drive gear input shaft. Remove the gasket from the adaptor or the gear housing.

On some early marine gear units, five 3/8" -16 bolts were used to secure the adaptor to the gear housing.

9. Remove the reverse clutch piston and roller (needle) bearing from the reverse gear housing adaptor as follows:

a. Place the gear housing adaptor on a bench with the reverse clutch piston side facing up.

b. Place the nozzle of an air hose in the small oil hole at the top of the adaptor, then apply light air pressure behind the reverse clutch piston and force the piston up out of the adaptor as shown in Fig. 22.

c. Remove the reverse clutch piston seal rings from the piston and the hub of the adaptor.

d. If the roller (needle) bearing is to be replaced, support the gear housing adaptor on the bed of an arbor press with the bearing over the opening in the bed of the press.

e. Place a 1-5/8" x 3" round steel bar on top of the roller bearing and under the ram of the press. Then press the bearing out of the gear housing adaptor. Catch the bearing by hand to prevent the bearing from falling on the floor.

10. Remove the thrust washer from the hub of the forward clutch piston cylinder.

11. Lift the reverse clutch pressure plate straight off of the clutch pressure plate release springs.

12. Refer to Fig. 23 for their location and remove the reverse clutch pressure plate release springs, reverse

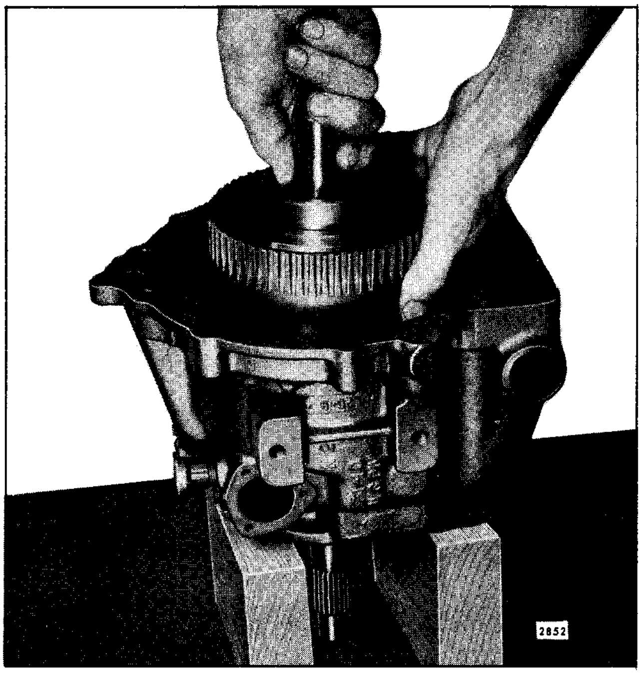

Fig. 24 - Removing Drive Gear Input Shaft, Forward Clutch and Ring Gear Assembly from Reverse Gear Housing

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clutch plates and dowel pins out of the reverse clutch cavity in the reverse gear housing.

13. Lift the drive gear input shaft, forward clutch and ring gear as an assembly straight out of the reverse gear housing as shown in Fig. 24.

14. Remove the reduction gear input shaft planetary gear thrust washer from the non-splined end of the drive gear input shaft, or from inside the reduction gear input shaft planetary gear.

15. Remove the drive gear input shaft and forward clutch hub assembly from the forward clutch and ring gear assembly as follows:

a. Place the drive gear input shaft, forward clutch and ring gear assembly on a wood block 3" thick and 6" square with a 1" hole in the center as shown in Fig. 25.

b. Remove the drive gear input shaft bearing snap ring from the groove in the shaft next to the bearing inner race with a pair of snap ring pliers J 5586 as shown in Fig. 25.

c. Place the drive gear input shaft, forward clutch and ring gear assembly on two steel supports on the bed of an arbor press with the non-splined end of the shaft over the opening in the bed of the press as shown in Fig. 26.

d. Press the drive gear input shaft and clutch hub assembly straight out of the bearing and forward clutch. Catch the drive gear input shaft assembly by hand to prevent the shaft assembly from falling and being damaged.

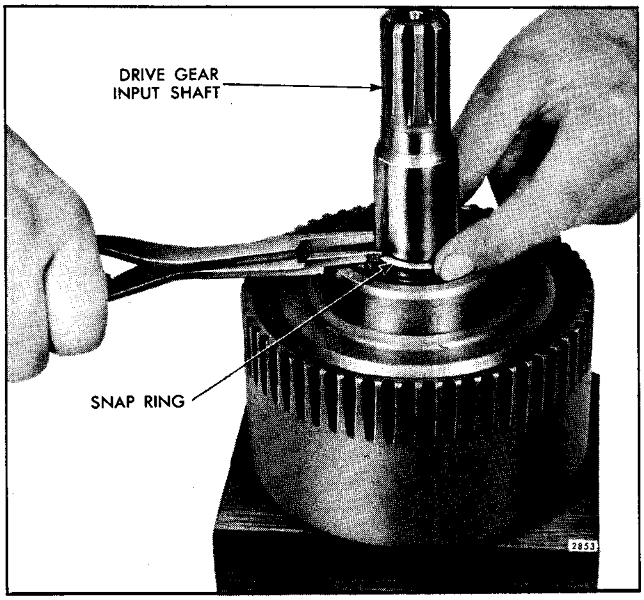

Fig. 25 - Removing or Installing Snap Ring from/on Drive Gear Input Shaft

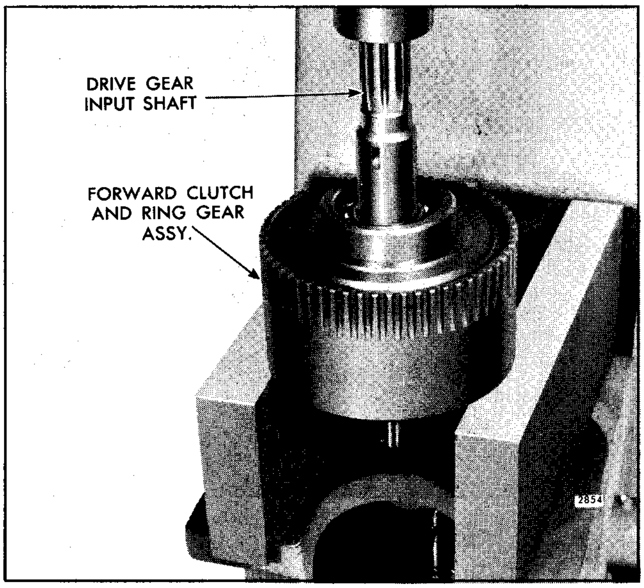

Fig. 26 - Removing Drive Gear Input Shaft from Bearing and Forward Clutch and Ring Gear Assembly

16. Remove the forward clutch piston assembly and the forward clutch plates from the ring gear as follows:

a. Remove the snap ring inside the ring gear that retains the forward clutch piston and cylinder assembly in the ring gear.

b. Lift the forward clutch piston and cylinder straight out of the ring gear.

If necessary, place the forward clutch and ring gear assembly on two steel supports on the bed of an arbor press as shown in Fig. 27. Space the supports far enough apart to permit the forward clutch piston cylinder to pass through between the supports.

Place a 2-1/2" outside diameter round steel bar on top of the forward clutch piston cylinder and under the ram of the press. Then press the forward clutch piston and cylinder assembly straight out of the ring gear as shown in Fig. 27. Catch the forward clutch piston and cylinder assembly by hand to prevent it from falling and being damaged.

c. Place the ring gear with the forward clutch plates on a bench with the forward clutch piston cylinder end of the ring gear facing up.

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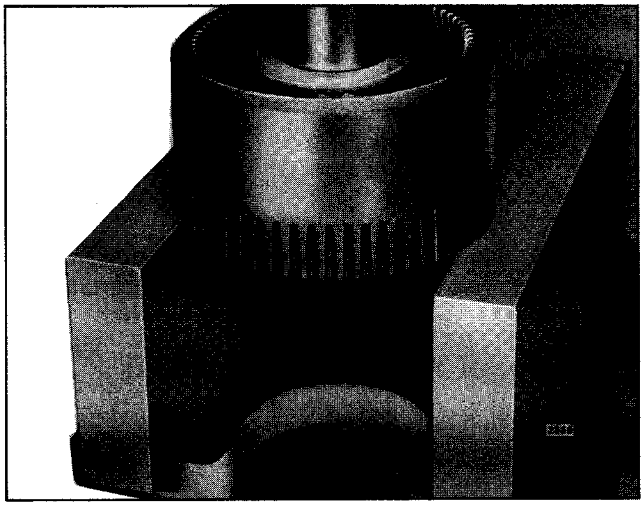

Fig. 27 - Removing Forward Clutch Piston and Cylinder Assembly from Ring Gear

d. Remove the snap ring (spacer) inside the ring gear next to the front clutch pressure plate from the ring gear.

e. Lift all of the forward clutch plates and pressure plates straight out of the ring gear.

f. On the Model 72 reverse gears, remove the rear clutch pressure plate spacer (snap ring) from the shoulder inside of the ring gear.

17. Remove the forward clutch piston and the drive gear input shaft bearing from the forward clutch piston cylinder as follows:

a. Place the forward clutch piston and cylinder assembly on a bench with the piston side of the assembly facing up.

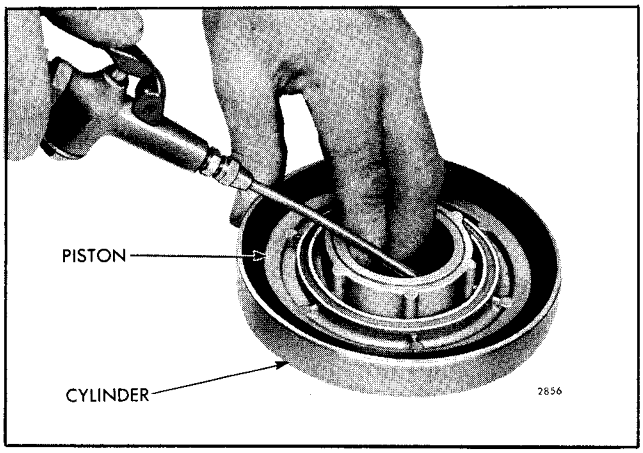

Fig. 28 - Removing Forward Clutch Piston from Forward Clutch Piston Cylinder

b. Remove the forward clutch spring support ring from the groove in the top of the forward clutch piston.

c. Place the nozzle of an air hose in one of the three oil holes in the inside diameter of the forward clutch piston cylinder. Then, while covering the two remaining oil holes as shown in Fig. 28, apply light air pressure behind the piston and force the piston up out of the cylinder.

d. Remove the forward clutch piston seal rings from the piston and the hub of the forward clutch piston cylinder.

e. Turn the forward clutch piston cylinder over and remove the snap ring from the groove inside the hub of the cylinder next to the bearing outer race.

f. Pull the drive gear input shaft bearing straight out of the forward clutch piston cylinder.

If necessary, use a hard wood block and hammer and tap the bearing straight out of the cylinder.

18. Remove the forward clutch hub from the drive gear input shaft as follows:

a. Place the non-splined end of the drive gear input shaft and forward clutch hub assembly in the 1" hole in the 3" x 6" wood block as shown in Fig. 29.

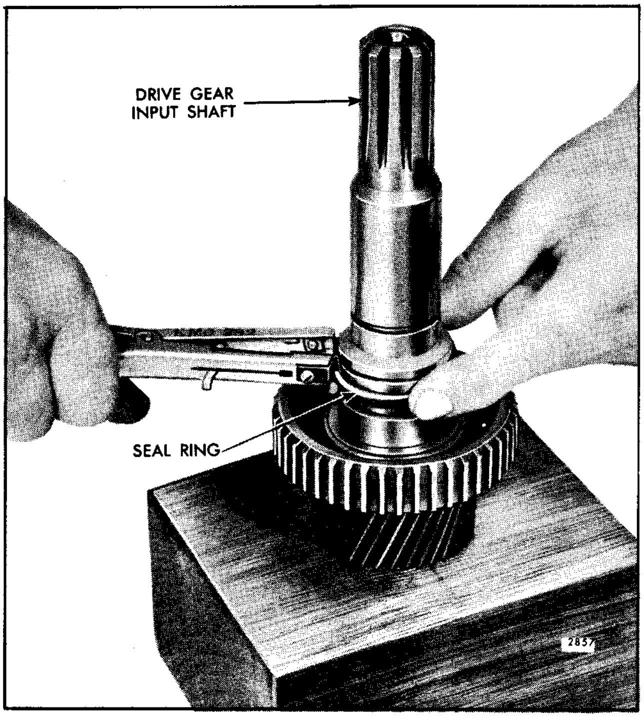

Fig. 29 - Removing Drive Gear Input Shaft Seal Rings from Shaft

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b. Unhook the ends of the drive gear input shaft seal rings. Then remove the seal rings from the grooves in the shaft with a pair of snap ring pliers as shown in Fig. 29.

CAUTION: To avoid breaking the seal rings, do not spread them any more than necessary to slip them over the shaft.

c. Remove the forward clutch hub snap ring from the grooves in the drive gear input shaft with a pair of snap ring pliers J 5586 as shown in Fig. 30.

d. Support the drive gear input shaft and forward clutch hub assembly on the bed of an arbor press with the rear face of the clutch hub resting on the bed of the press as shown in Fig. 31.

e. Then press the drive gear input shaft straight out of the forward clutch hub as shown in Fig. 31. Catch the drive gear input shaft by hand to prevent it from falling and being damaged when pressed from the hub.

f. If necessary, remove the forward clutch hub Woodruff key from the keyway in the drive gear input shaft.

19. On the direct drive units, remove the planetary gear and drive (output) shaft assembly from the reverse gear housing as follows:

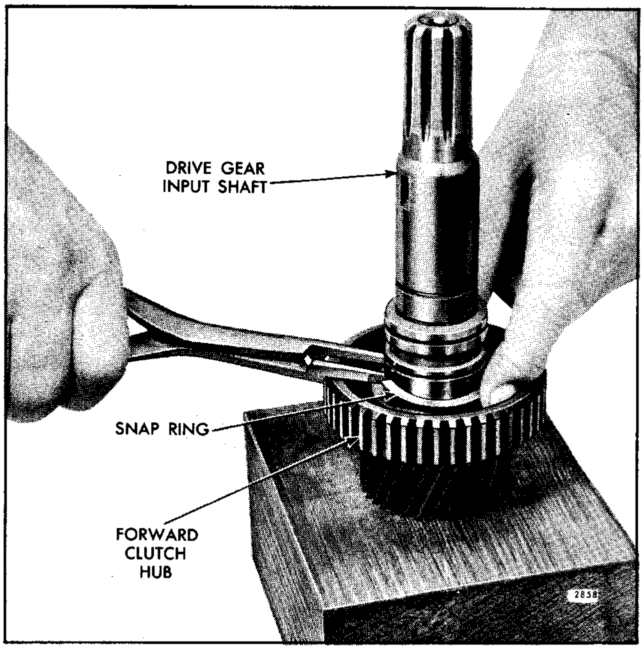

Fig. 30 - Removing or Replacing Forward Clutch Hub Snap Ring

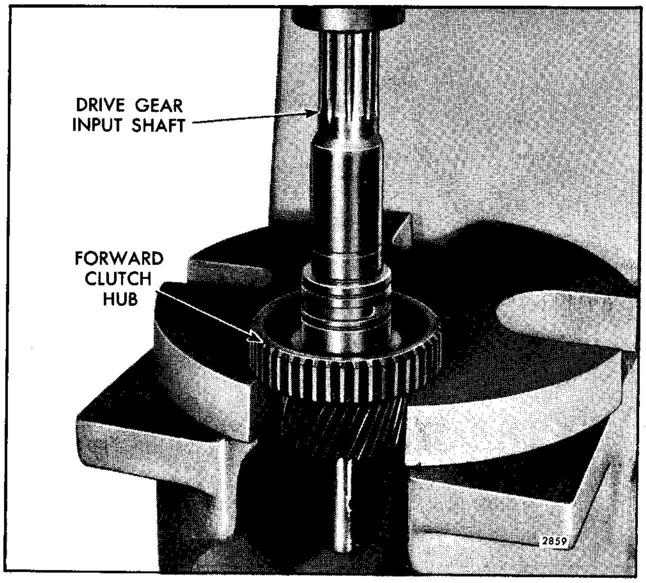

Fig. 31 - Removing Forward Clutch Hub from Drive Gear Input Shaft

a. If not previously performed, perform Steps 1, 2 and 3 under *Disassemble Reverse and Reduction Gear.*

b. Remove the drive flange nut, then pull the drive flange off the end of the drive (output) shaft.

If necessary, attach a bar type puller to the drive flange and pull the drive flange off the drive shaft.

c. Remove the six 7/16"-14 bolts and lock washers securing the drive shaft bearing retainer to the reverse gear housing.

d. Tap the sides of the bearing retainer lightly with a plastic hammer to loosen it, then lift the bearing retainer straight off the bearing. Remove the bearing retainer gasket.

e. Place a couple of clean folded shop towels on the bed of an arbor press to protect the forward face of the planetary gear and drive shaft assembly from being damaged when pressed from the drive shaft bearing.

f. Place the reverse gear housing over the top of the shop towels with the forward face of the gear housing resting on the bed of the press and the outer end of the drive shaft under the ram of press in the same manner as shown in Fig. 33.

g. Then press the planetary gear and drive shaft assembly out of the bearing.

h. Remove the reverse gear housing and the planetary gear and drive shaft assembly from the

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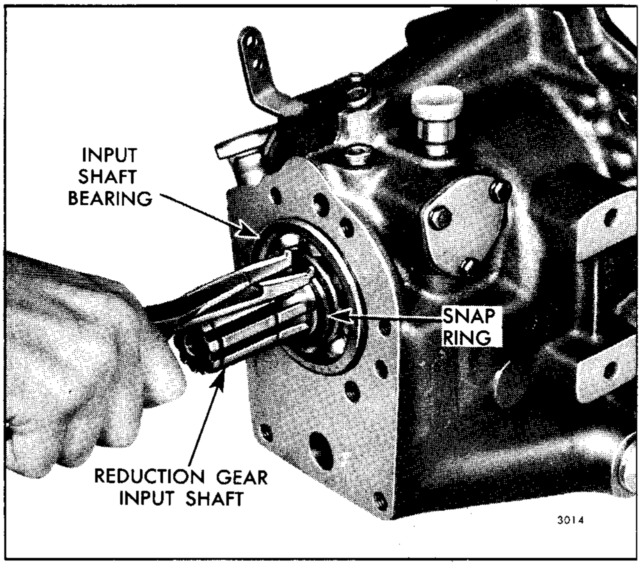

Fig. 32 - Removing or Installing Reduction Gear Input Shaft Bearing Snap Ring (2.5:1 and 3:1 Ratios)

arbor press. Do not drop the planetary gear and drive shaft assembly or injury to personnel or damage to the planetary gear and drive shaft assembly may result.

i. Lift the drive shaft bearing straight out of the reverse gear housing.

If necessary, use a hard wood block and hammer and tap the bearing out of the reverse gear housing.

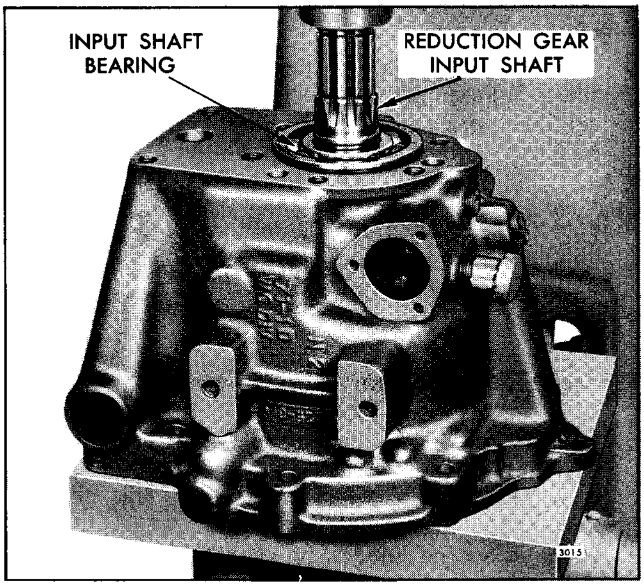

Fig. 33 - Removing Reduction Gear Planetary Gear and Input Shaft Assembly from Input Shaft Bearing (2.5:1 and 3:1 Ratios)

j. Refer to Step 9 under *Disassemble Reduction Gear* for removal of the oil seal from the drive (output) shaft bearing retainer.

20. On the 1.5:1 and 2.1:1 reverse and reduction gear units, lift the planetary gear and reduction gear input shaft assembly straight out of the reverse gear housing, then remove the thrust washer from the rear face of the planetary gear cage or from the boss inside of the reverse gear housing.

21. On the 2.5:1 and 3:1 reverse and reduction gear units, remove the planetary gear and reduction gear input shaft assembly from the reverse gear housing as follows:

a. Remove the snap ring from the groove in the reduction gear input shaft next to the bearing inner race with a pair of snap ring pliers J 5586 as shown in Fig. 32.

b. Place a couple of clean folded shop towels on the bed of an arbor press to protect the forward face of the planetary gear and reduction gear input shaft assembly from being damaged when pressed from the input shaft bearing.

c. Place the reverse gear housing over the top of the shop towels with the forward face of the gear

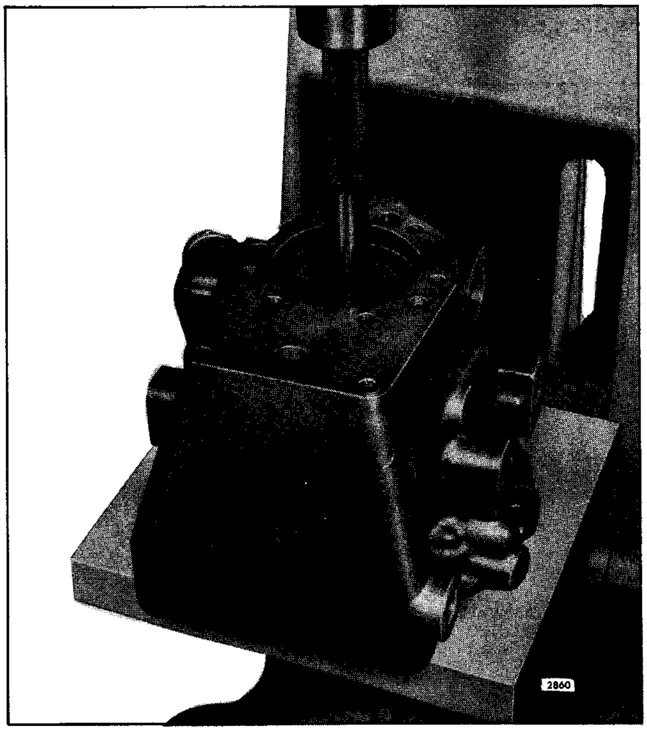

Fig. 34 - Removing Drive Shaft Bushings from Gear Housing

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housing resting on the bed of the press and the outer end of the input shaft under the ram of the press.

d. Then press the planetary gear and input shaft assembly out of the bearing as shown in Fig. 33.

e. Remove the reverse gear housing and the planetary gear and input shaft assembly from the arbor press. Do not drop the planetary gear and input shaft assembly or injury to personnel or damage to the planetary gear and input shaft assembly may result.

f. Lift the reduction gear input shaft bearing straight out of the reverse gear housing.

If necessary, use a hard wood block and hammer and tap the bearing out of the reverse gear housing.

22. Remove the oil baffle from the reverse gear housing as follows:

a. On a current direct drive gear unit, press down on the center of the oil baffle and pry the ends of the baffle off the cast bosses at each side of the gear housing with a screw driver; then, remove the oil baffle from the housing.

b. On a former direct drive and all reverse and reduction gear units, pull forward on the curved end of the oil baffle inside the reverse gear housing until the holes in the curved end of the oil baffle are off of the spherical bosses, then push the curved end of the baffle down under the spherical bosses. Lift the forward end of the oil baffle off of the spherical bosses and out of the gear housing.

23. Remove the drive (output) shaft or reduction gear input shaft outer bushings (if used) from the reverse gear housing.

If inspection of the bushings in the reverse gear housing, as outlined under *Inspection*, reveals the bushings need replacing, remove the bushings as follows:

a. Support the reverse gear housing on the bed of an arbor press with the rear face of the gear housing facing up.

b. Place the bushing remover and installer J 8466 with handle J 7079-2 down in the bushing with the handle under the ram of the press as shown in Fig. 34.

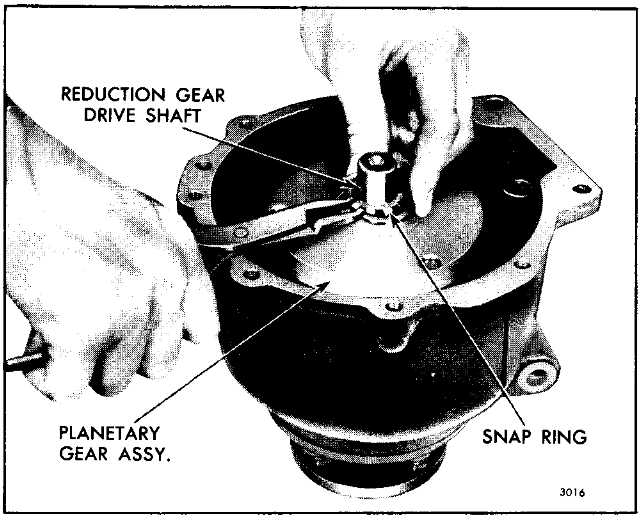

Fig. 35 - Removing or Installing Planetary Gear Snap Ring from/on Reduction Gear Drive Shaft (1.5:1 Ratio)

c. Then press the two bushings straight out of the gear housing. Catch the bushings and remover by hand so they will not drop on the floor when the top bushing is pressed out of the gear housing.

24. If the reverse gear housing is to be washed and cleaned, remove all of the pipe plugs, breather and lubricating oil fitting from the gear housing.

Disassemble Reduction Gear

The disassembly procedure for the various reduction gears will vary depending upon the ratio. The disassembly procedure for the 1.5:1 ratio reduction gear is covered separately. Due to the close similarity of the 2.1:1, 2.5:1 and 3:1 ratio reduction gears, the disassembly procedure for these gears will be covered as a single procedure and the difference noted therein.

With the reduction gear assembly removed from the reverse gear assembly, the reduction gear may be disassembled as outlined below.

Disassemble 1.5:1 Ratio Reduction Gear - Refer to Fig. 4 for the location of the parts and disassemble as follows:

1. Support the reduction gear assembly on a bench with the forward end of the drive shaft facing up.

2. Remove the planetary gear snap ring from the groove in the reduction gear drive shaft with a pair of snap ring pliers J 5586 as shown in Fig. 35.

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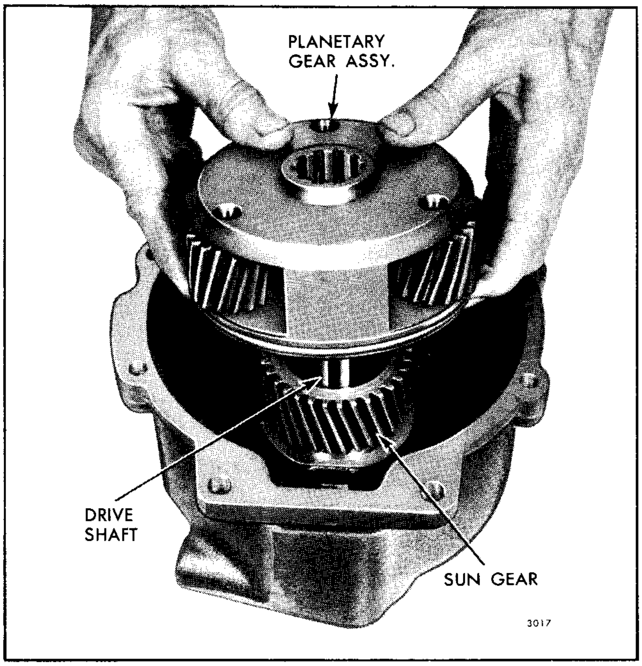

Fig. 36 - Removing or Installing Planetary Gear Assembly from/on Reduction Gear Drive Shaft (1.5:1 Ratio)

3. Lift the planetary gear assembly straight off of the reduction gear drive shaft and sun gear as shown in Fig. 36.

If difficulty is encountered in removing the planetary gear assembly from the drive shaft, it may be removed by tapping the shaft out of the planetary gear hub with a plastic hammer after performing Steps 4, 5 and 6 listed below.

4. Support the reduction gear housing on its side on a bench with the drive flange facing the outside of the bench.

5. Remove the drive flange nut, then pull the drive flange off the end of the reduction gear drive shaft.

If necessary, attach a bar type puller to the drive flange and pull the drive flange off the drive shaft.

6. Pull the reduction gear drive shaft (or planetary gear and drive shaft assembly) straight out of the roller bearing and gear housing from the forward end of the gear housing.

7. Remove the six 7/16" -14 bolts and lock washers securing the reduction gear drive shaft bearing retainer to the gear housing.

8. Tap the sides of the bearing retainer lightly with a plastic hammer to loosen it, then lift the bearing retainer straight off the bearing. Remove the bearing retainer gasket.

9. Remove the reduction gear drive shaft bearing retainer oil seal from the bearing retainer as follows:

a. Support the bearing retainer on the bed of an arbor press with the forward face down and the oil seal over the opening in the bed of the press.

b. Place a 2-1/2" round steel bar on top of the oil seal and under the ram of the press, then press the oil seal out of the bearing retainer. Discard the oil seal.

10. Remove the reduction gear drive shaft bearing from the reduction gear housing as follows:

a. Matchmark the outer roller bearing cone and bearing cup so it may be reinstalled in the same side of the bearing cup.

NOTE: The roller bearing cones and cup must be matchmarked so they can be reinstalled in the same position.

b. Lift the outer roller bearing cone out of the bearing cup and place it in a clean spot on the bench.

c. Support the rear face of the reduction gear housing on the bed of an arbor press with the roller bearing cup over the opening in the bed of the press as shown in Fig. 37.

d. Place the drive flange end of the reduction gear drive shaft straight down through the sun gear

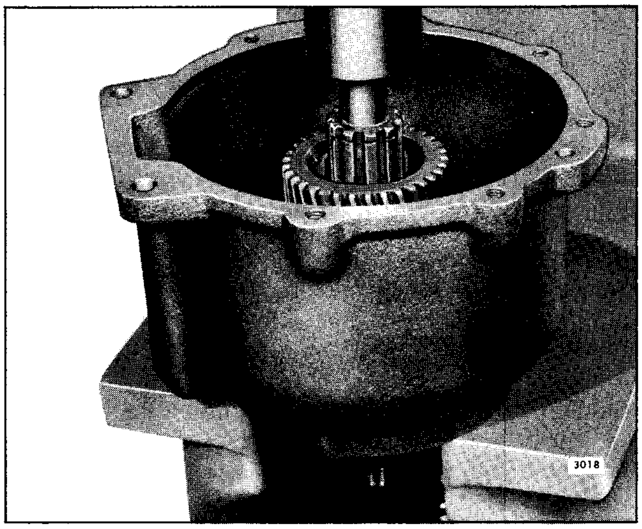

Fig. 37 - Removing Reduction Gear Drive Shaft Roller Bearing Cone and Cup from Gear Housing (1.5:1 Ratio)

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and roller bearing cone until the shoulder on the drive shaft rests on the bearing cone with the forward end of the drive shaft under the ram of the press.

e. Then press the roller bearing cup straight out of the reduction gear housing as shown in Fig. 37. Catch the roller bearing cup, cone and drive shaft by hand to prevent them from falling and being damaged.

f. Remove the drive shaft from the inner bearing cone and cup, then place the outer bearing cone inside of the bearing cup it was removed from and place the bearing assembly in a clean spot on the bench.

11. Remove the reduction gear sun gear from the reduction gear housing as follows:

a. Support the reduction gear housing on a bench with the rear face of gear housing facing up.

b. Place a 1/8" long shank punch in the drilled hole in the bearing bore of the gear housing as shown in Fig. 38 and drive the roll pin out of the sun gear dowel pin and gear housing.

c. Support the reduction gear housing, rear face up, on a bench, then push the sun gear dowel pin out of the sun gear and gear housing with an offset steel rod from the inside of the sun gear.

d. Lift the sun gear straight out of the gear housing.

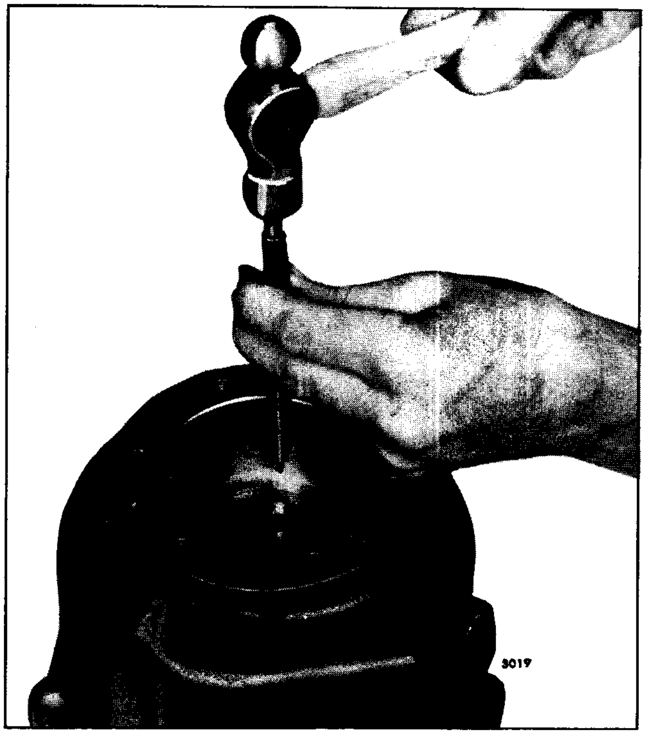

Fig. 38 - Removing Roll Pin from Sun Gear Dowel Pin (1.5:1 Ratio)

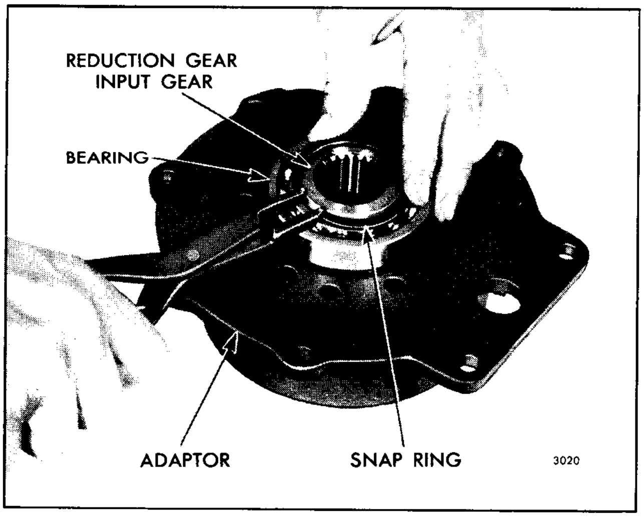

Fig. 39 - Removing or Installing Reduction Gear Input Gear Bearing Snap Ring (1.5:1 Ratio)

12. Remove the reduction gear input gear bearing, adaptor and ring gear from the input gear as follows:

a. Place the reduction gear adaptor, input gear and ring gear assembly on a bench with the bearing side facing up.

b. Remove the input gear bearing snap ring from the groove in the input gear hub with a pair of snap ring pliers J 5586 as shown in Fig. 39.

c. Support the reduction gear adaptor, input gear and ring gear assembly on two steel supports on the bed of an arbor press with the ring gear side down as shown in Fig. 40.

d. Place a 1-7/8" round steel bar on top of the input gear hub and under the ram of the press as shown in Fig. 40.

e. Then press the input gear and ring gear assembly out of the input gear bearing. Catch the input gear and ring gear assembly by hand to prevent it from falling and being damaged.

f. Remove the snap ring from the groove in the ring gear that retains the flange of the reduction gear input gear in the ring gear, then lift the input gear straight out of the ring gear.

Disassemble 2.1:1, 2.5:1 and 3:1 Ratio Reduction

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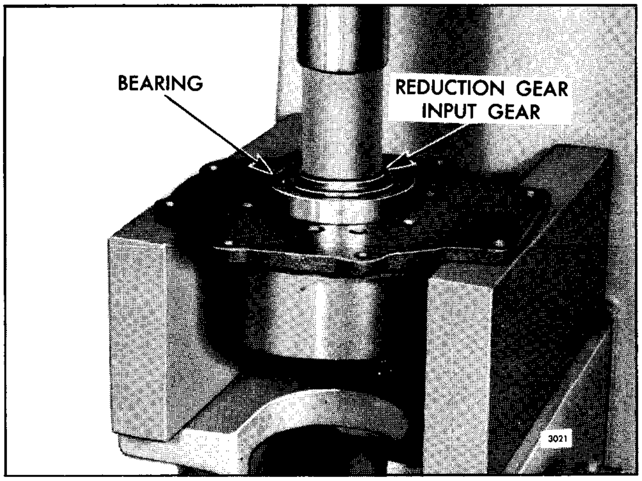

Fig. 40 - Removing Reduction Gear Input Gear from Input Gear Bearing (1.5:1 Ratio)

Gears - Refer to Figs. 1, 2 and 5 for the location of the parts and disassemble as follows:

1. Support the reduction gear assembly on a bench with the drive flange facing up.

2. Remove the drive flange nut, then lift the drive flange straight off the end of the reduction gear drive shaft.

If necessary, attach a bar type puller to the drive flange and pull the drive flange off the drive shaft.

3. On the 2.1:1 ratio reduction gear, lift the reduction gear housing straight off of the reduction gear planetary ring gear and drive shaft assembly.

On the 2.5:1 and 3:1 ratio reduction gears, lift the reduction gear housing straight off of the reduction gear planetary gear and drive shaft assembly.

4. Perform Steps 7, 8, 9, 10, a, b and c under *Disassemble 1.5:1 Ratio Reduction Gear* above, then proceed with Step "d" below.

d. Place a 2-1/4" round steel bar on top of the inner bearing cone, inside the reduction gear housing, and under the ram of the press as shown in Fig. 41.

e. Then press the roller bearing cup straight out of the reduction gear housing. Catch the roller bearing cup and cone by hand to prevent them from falling and being damaged.

f. Place the outer bearing cone inside of the bearing cup it was removed from and place the bearing assembly in a clean spot on a bench and cover.

5. On the 2.1:1 ratio reduction gear, remove the reduction gear sun gear from the reduction gear adaptor as follows:

a. Place the reduction gear adaptor and sun gear assembly on a bench with the forward face of the adaptor facing up.

b. Remove the snap ring from the groove in the sun gear with a pair of snap ring pliers as shown in Fig. 42, then lift the adaptor off of the sun gear.

6. On the 2.1:1 ratio reduction gear, remove the reduction gear drive shaft from the planetary ring gear as follows:

a. Place the reduction gear planetary ring gear and drive shaft assembly on a bench with the outer end of the shaft facing up.

b. Remove the snap ring from the groove in the inside diameter of the ring gear next to the drive shaft flange with a small screw driver. Then lift the drive shaft out of the planetary ring gear.

7. On the 2.5:1 and 3:1 ratio reduction gears, remove the reduction gear planetary ring gear plate from the adaptor and the planetary ring gear as follows:

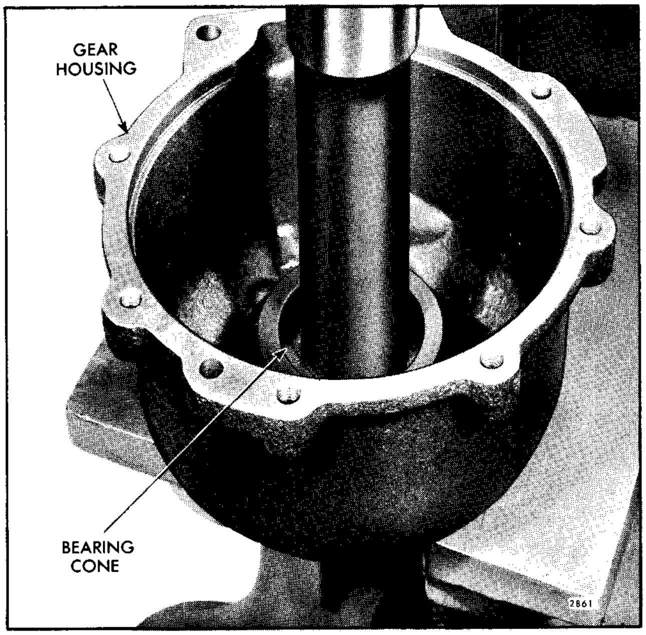

Fig. 41 - Removing Reduction Gear Drive Shaft Roller Bearing Cone and Cup from Gear Housing (2.1:1 Ratio)

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a. Support the adaptor, planetary ring gear plate and ring gear assembly on two 3" wood blocks with the ring gear side down and between the wood blocks.

b. Tap the planetary ring gear plate out of the reduction gear adaptor with a small brass rod and hammer.

c. Place the planetary ring gear plate and ring gear assembly on a bench with the ring gear plate side facing up.

d. Remove the snap ring from the groove in the inside diameter of the ring gear next to the outside diameter of the planetary ring gear plate with a small screw driver. Then lift the ring gear plate straight out of the ring gear.

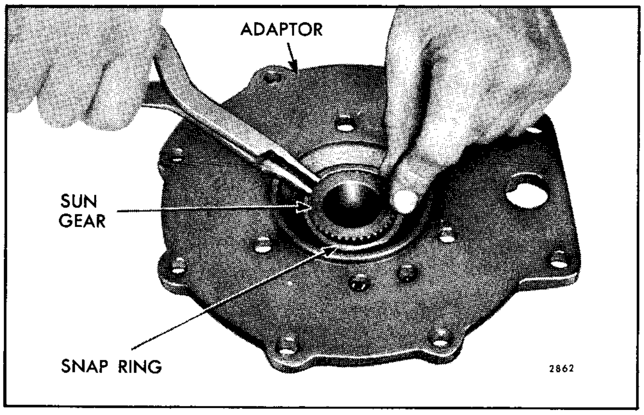

Fig. 42 - Removing or Installing Sun Gear Snap Ring (2.1:1 Ratio)

Inspection

Wash all of the marine and reduction gear parts thoroughly with clean fuel oil and dry them with compressed air.

Examine the ball and roller bearings for corrosion and pitting. Lubricate each bearing with light engine oil; then, while holding the inner race or cone from turning, revolve the outer race or cup slowly by hand and check for rough spots.

Examine the oil seals, and if the lips of the oil seals are rough or hard, replace the seals.

Examine the forward and reverse clutch piston seal rings for cuts or scratches.

Examine the oil pump rotors (gears), cover plate (if used) and housing for score marks and wear.

NOTE: The oil pump housing, rotors (gears) and cover are matched at the factory and are not serviced separately. If it becomes necessary to replace any of the oil pump parts, a new oil pump assembly must be used.

Examine the inside diameters of the forward and reverse clutch pistons which contact the seal ring for scratches.

Examine the inside diameters of the forward clutch cylinder and the gear housing adaptor, which contact the seal ring, for scratches.

Examine the forward and reverse clutch plates, pressure plates and the forward inside face of the marine gear housing which contact the reverse clutch plate for scoring, burning or warping; also, examine the teeth in the inner and outer diameters of the clutch plates for wear or peening.

Examine the teeth of the forward clutch hub and the internal and external teeth of the forward and reverse clutch ring gear for wear and peening.

Examine the thrust washers for wear and score marks.

If preliminary inspection of the planetary gears reveals nicks, burrs, pitting, over-heating, score marks or if excessive backlash (more than .015") between any two mating gears is found, the planetary gear assembly must be replaced.

NOTE: The parts of the reduction gear planetary gear are not serviced separately and must be replaced with a complete new assembly. Also, the reverse planetary gear and output shaft, which includes two inner bushings, is not serviced separately and must be replaced with a complete new assembly.

Examine the teeth of the drive gear and sun gear for wear, scoring or chipping. The gears may show considerable wear and still be usable.

Examine the splines on the shafts for wear and peening.

Examine the bushing in the reduction gear drive shaft for wear.

NOTE: The bushing in the reduction gear drive shaft is not serviced separately and requires replacement of the complete assembly.

On the reverse gear housing with bushings, examine the bushings inside the housing for wear. If worn excessively, they must be replaced. The bushings are

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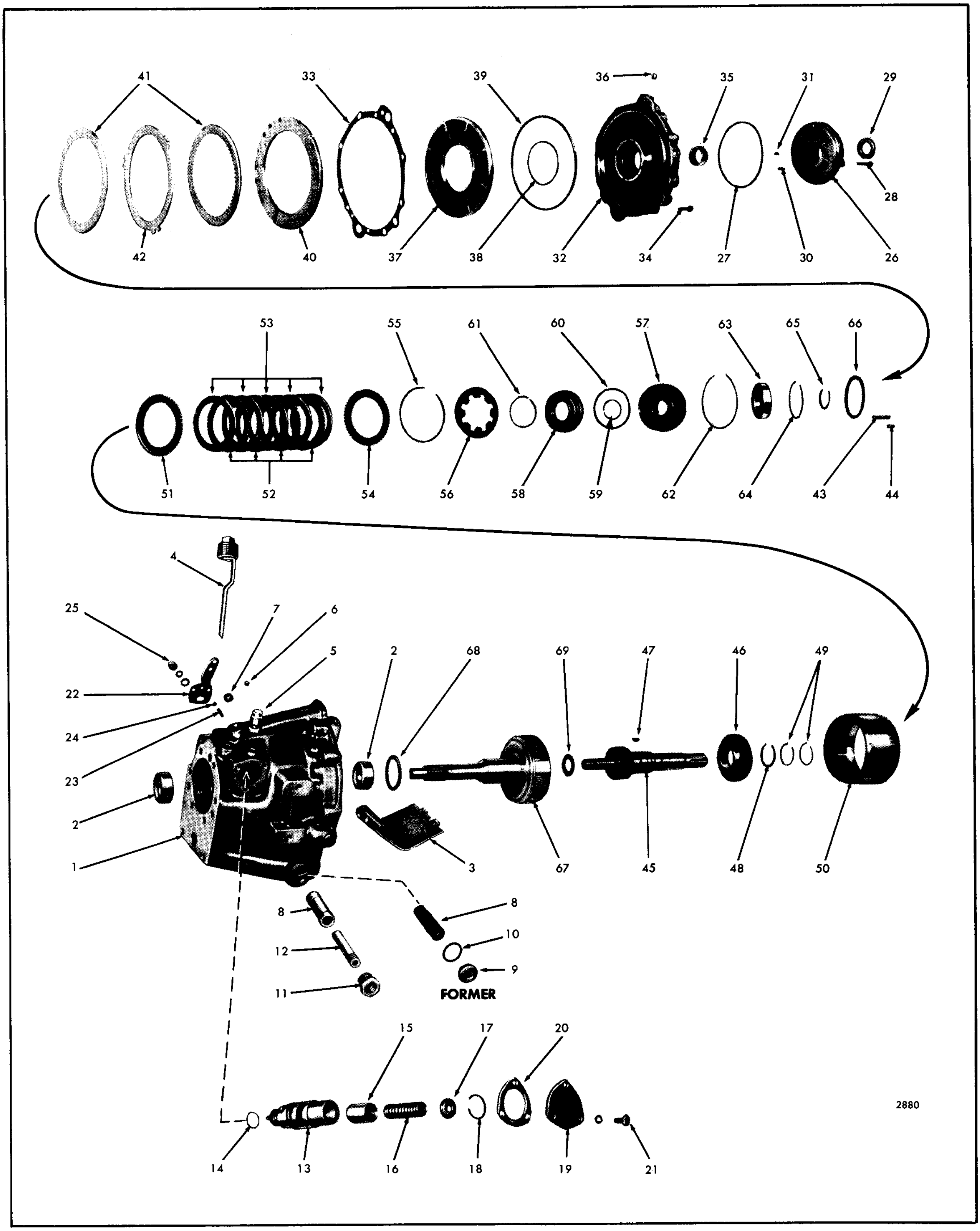

Fig. 43 - Reverse Gear Details and Relative Location of Parts (2.1:1 Ratio Model 71C Shown)

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Fig. 43 - Reverse Gear Details and Relative Location of Parts (2.1:1 Ratio Model 71C Shown)

1. Housing--Reverse Gear
2. Bushing--Reverse Gear Housing
3. Baffle--Gear Housing Oil
4. Oil Filler Plug and Dipstick Assy.
5. Breather Assy.--Gear Housing
6. Pipe Plug--1/8"
7. Pipe Plug--3/8"
8. Strainer Assy.--Reverse Gear Oil
9. Plug--Oil Drain
10. Gasket--Oil Drain Plug Annular
11. Bushing--Reducing
12. Tube--Oil Return
13. Valve--Selector Control
14. Seal Ring--Selector Control Valve
15. Valve--Pressure Regulator
16. Spring--Pressure Regulator Valve
17. Retainer--Regulator Valve Spring
18. Snap Ring--Valve Spring Retainer
19. Cover--Selector Control Valve
20. Gasket--Valve Cover
21. Bolt--Valve Cover
22. Lever--Selector Valve (Shifter)
23. Spring--Lever Detent
24. Ball--Lever Detent Spring
25. Nut--Lever Retaining
26. Pump Assy.--Reverse Gear Oil
27. Gasket--Oil Pump to Adaptor
28. Bolt--Oil Pump
29. Oil Seal--Oil Pump
30. Screw--Oil Pump Cover
31. Woodruff Key--Oil Pump Drive
32. Adaptor--Reverse Gear Housing
33. Gasket--Gear Housing Adaptor
34. Bolt--Gear Housing Adaptor
35. Bearing--Gear Housing Adaptor Roller
36. Pipe Plug--Adaptor
37. Piston--Reverse Clutch
38. Seal Ring--Reverse Clutch Piston (Inner)
39. Seal Ring--Reverse Clutch Piston (Outer)
40. Plate--Reverse Clutch Pressure
41. Plate--Reverse Clutch (Inner)
42. Plate--Reverse Clutch Stationary (Steel)
43. Spring--Pressure Plate Release
44. Pin--Reverse Clutch Stationary Plate Dowel
45. Shaft Assy.--Drive Gear Input
46. Hub--Forward Clutch
47. Woodruff Key--Forward Clutch Hub
48. Snap Ring--Clutch Hub
49. Seal Ring--Drive Gear Input Shaft
50. Ring Gear--Forward Clutch Planetary
51. Plate--Forward Clutch Pressure (Rear)
52. Plate--Forward Clutch Inner (Copper Faced)
53. Plate--Forward Clutch (Steel)
54. Plate--Forward Clutch Pressure (Front)
55. Snap Ring--Forward Clutch Pressure Plate
56. Spring--Forward Clutch Release
57. Cylinder--Forward Clutch
58. Piston--Forward Clutch
59. Seal Ring--Forward Clutch Piston (Inner)
60. Seal Ring--Forward Clutch Piston (Outer
61. Ring--Forward Clutch Release Spring Support
62. Snap Ring--Forward Clutch Cylinder
63. Bearing--Drive Gear Input Shaft Ball
64. Snap Ring--Bearing (Clutch Cylinder)
65. Snap Ring--Bearing (Input Shaft)
66. Thrust Washer--Forward Clutch Cylinder
67. Shaft Assy.--Planetary Gear and Reduction Gear Input
68. Thrust Washer--Reduction Gear Input Shaft
69. Thrust Washer--Reduction Gear Planetary Gear

prefinished and do not require reaming or boring after installation in the housing.

On the reverse gear housing without bushings, examine the planetary gear and reduction gear input shaft bore in the housing for score marks and wear.

Examine the inside diameter of the forward clutch piston cylinder for seal ring score marks.

Examine the drive gear input shaft seal rings for wear, scoring or cracks.

Examine the reverse clutch pressure plate release springs for defects and check the spring with spring tester J 9666. The spring has a free length of approximately 1.250". Replace the spring when a load of less than 13.5 lbs. will compress it to 1.00".

Examine the selector valve and the pressure regulator valve for scoring.

Examine the pressure regulator valve spring for defects and check the spring with spring tester J 9666. The spring has a free length of approximately 2.6562". Replace the spring when a load of less than 94 lbs. will compress it to 2.073".

Replace the selector valve seal ring at each teardown.

Examine the selector valve bore in the gear housing for burrs or score marks.

Blow out all oil passages in the various parts with compressed air.

Remove all of the old gaskets and clean the surfaces before installing new gaskets.

Replace all of the marine gear parts that cannot be cleaned up with crocus cloth, and the excessively worn or damaged parts.

ASSEMBLE REVERSE AND REDUCTION GEAR

With the parts cleaned and inspected and the necessary parts on hand, the reverse and reduction gear may be assembled as outlined below.

Assemble Reverse Gear

The assembly procedure for the direct drive reverse gear and the reverse gears used in conjunction with the 1.5:1, 2.1:1, 2.5:1 and 3:1 ratio reduction gears on Models 71 and 72 are similar. Therefore, assembly will be covered as a single procedure and any differences between the various assemblies will be noted therein.

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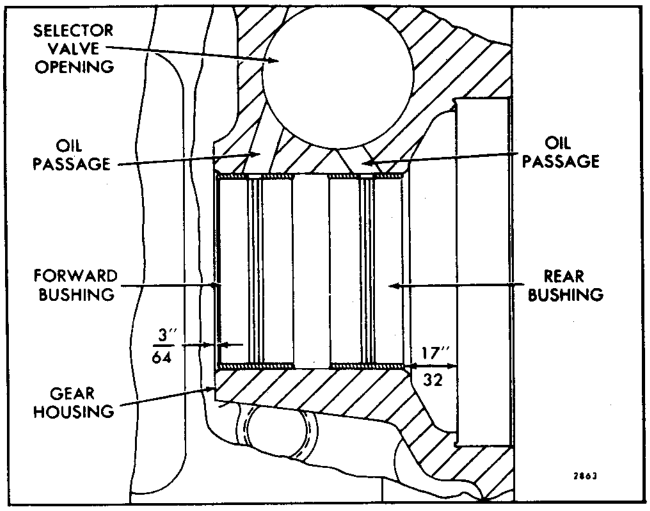

Fig. 44 - Location of Planetary Gear and Reduction Gear Input Shaft Bushings in Reverse Gear Housing

Three different types of reverse gear housings and two different types of planetary gear and reduction gear input shaft assemblies have been used in the marine gears. TYPE 1 incorporated two planetary gear and reduction gear input shaft prefinished bushings and a planetary gear and reduction gear input shaft assembly without oil grooves. In TYPE 2, the planetary gear and reduction gear input shaft bushings in the housings were eliminated and the bore in the housing reduced from 1.989" -1.990" to 1.8625" -1.8635", and a new planetary gear and reduction gear input shaft assembly with three oil grooves was used. In TYPE 3 (current type), the planetary gear and reduction gear input shaft bore in the housing was increased from 1.8625" -1.8635 to 1.989" -1.990" and new prefinished bushings were installed in the housing.

The finished inside diameter of the new bushings is 1.8625" -1.8635" and differ from the bushings used in the TYPE 1 reverse gear housing only by having a slightly larger outside diameter to assure a tighter fit in the housing.

The former planetary gear and reduction gear input shaft assembly, without oil grooves, and the current planetary gear and reduction gear input shaft assembly, with oil grooves, can be used in both TYPE 1 and TYPE 3 reverse gear housings with bushings. The current planetary gear and reduction gear input shaft assembly, with oil grooves, MUST be used in the TYPE 2 reverse gear housings without bushings.

Refer to Figs. 1, 2 and 42 for the location of the various parts and assemble them as follows:

1. If removed, install the new direct drive (output) shaft or the planetary gear and reduction gear input shaft outer bushings in the reverse gear housing as follows:

a. Lubricate the outside diameter of one bushing with engine oil, then start the bushing straight into the bushing bore of the reverse gear housing from the rear face with the oil hole in the bushing in alignment with the oil hole in the gear housing.

b. Support the reverse gear housing, forward face down, on the bed of an arbor press.

c. Place the bushing remover and installer J 8466 with handle J 7079-2 in the bushing with the end of the handle under the ram of the press as shown in Fig. 46. Then press the bushing straight into the gear housing to the dimension shown in Fig. 44.

CAUTION: Be sure the oil hole in the bushing is in alignment with the oil hole in the gear housing when the bushing is pressed into position.

d. Invert the gear housing on the bed of the arbor press, then install the second bushing in the gear housing as described in Steps a, b and c above.

2. If removed, install the oil baffle in the reverse gear housing as follows:

On a current direct drive unit, perform Step a.

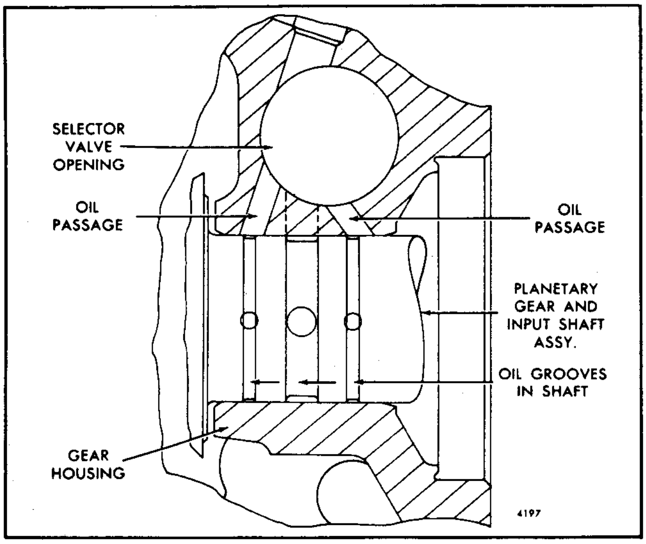

Fig. 45 - Location of Planetary Gear and Reduction Gear Input Shaft in Reverse Gear Housing Without Bushings

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a. Place the oil baffle inside the reverse gear housing with the notched edge facing the front and the curved side toward the bottom of the housing. Then press down on the center of the oil baffle and snap the rectangular slots at each end on the cast bosses at each side of the housing.

On a former direct drive unit and all reverse and reduction gear units, perform Steps b, c and d.

b. Place the oil baffle inside of the gear housing with the curved portion below the cast spherical bosses in the gear housing as shown in Figs. 1 and 47.

c. Position the forward end of the oil baffle so that the center of the baffle rests on top of the boss, at the front center of the gear housing, and the turned down corners of the baffle are located below the cast spherical bosses.

d. Snap the oil baffle into position by lifting up on the curved portion so that the two large holes are located on top of the spherical bosses at the rear inside face of the gear housing as shown in Figs. 1 and 47.

3. On the direct drive units, install the planetary gear and drive (output) shaft assembly in the reverse gear housing as follows:

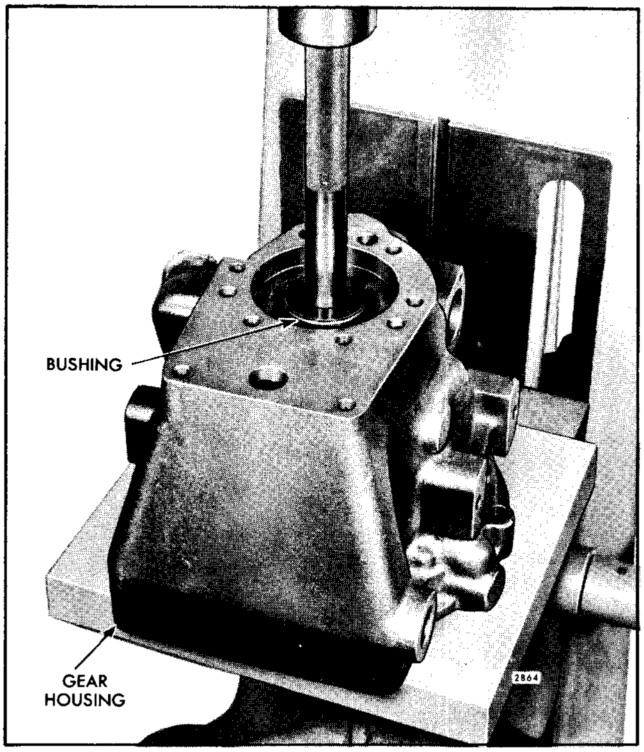

Fig. 46 - Installing Drive Shaft Bushings in Reverse Gear Housing

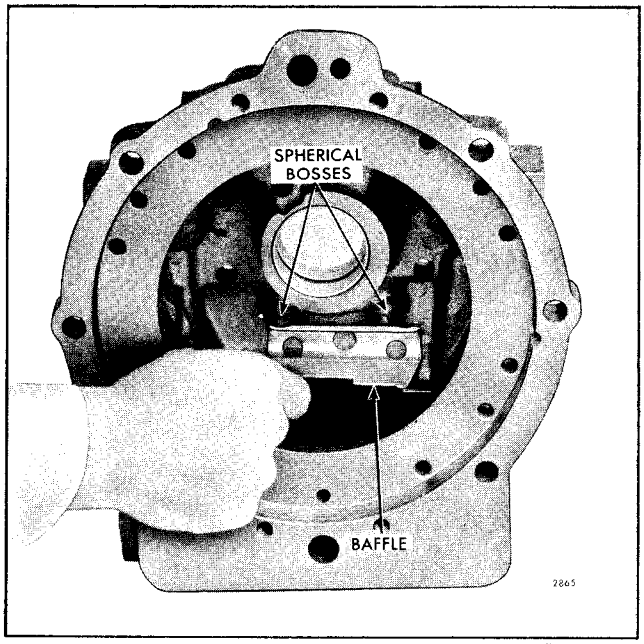

Fig. 47 - Installing Oil Baffle in Gear Housing

a. Support the reverse gear housing on two 3" wood blocks, with the forward face of the gear housing facing up and the opening in the rear face of the housing over the opening between the two wood blocks, thus allowing clearance for the end of the drive (output) shaft to project through the reverse gear housing when assembled.

b. Lubricate the pinion gears in the planetary gear and the outside diameter of the drive (output) shaft, where it makes contact with the bushings or the gear housing, with engine oil.

c. Position the planetary gear and drive (output) shaft assembly over the top of the gear housing (Fig. 51), then insert the end of the drive (output) shaft straight down through the bushings or housing until the rear face of the planetary gear rests on the gear housing.

d. Place a 3" x 6" x 6" wood block down inside the gear housing with the 6" face of the block resting on top of the planetary gear.

e. Place the reverse gear housing, planetary gear and drive shaft assembly and the wood block on the bed of an arbor press, with the forward face of the gear housing down and the assembly resting on the wood block (Fig. 49).

f. Lubricate the drive (output) shaft bearing with engine oil. Place the bearing over the end of the shaft with the groove in the outer race of the bearing up; then, start the bearing straight on the bearing surface of the shaft.

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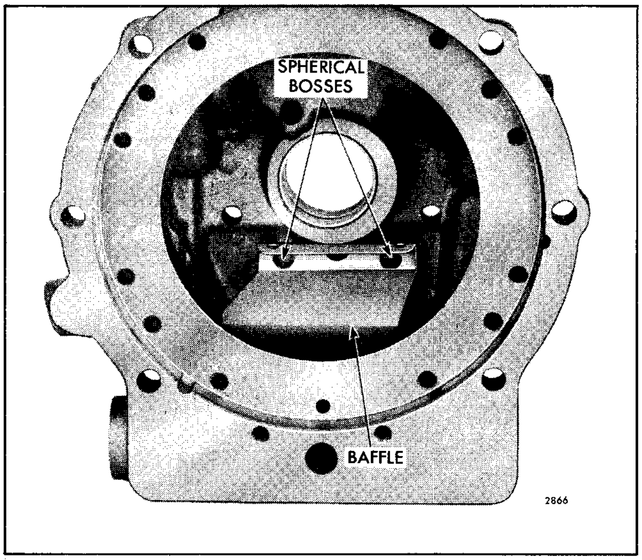

Fig. 48 - Oil Baffle in Position in Gear Housing

g. Place a sleeve over the end of the drive (output) shaft and rest it on the inner race of the bearing; then, place a flat steel plate on top of the sleeve and under the ram of the press as shown in Fig. 49. Then press the bearing straight down in the housing and on the shaft until it seats on the shoulder on the drive shaft.

h. Remove the reverse gear housing and drive (output) shaft assembly from the arbor press and place it on a bench, with the rear face of the gear housing facing up.

i. Refer to Step 4 under *Assemble Reduction Gear* for installing the oil seal in the drive (output) shaft bearing retainer.

j. Affix a new bearing retainer gasket to the rear face of the reverse gear housing with the bolt holes in the housing and gasket in alignment.

k. Place the bearing retainer over the end of the drive (output) shaft and start it straight over the bearing with the bolt holes in the retainer and housing in alignment. Then push it down tight against the gasket and housing.

l. Install the six 7/16" -14 x 1-1/4" bolts and lock washers. Tighten the bolts to 46-50 lb-ft torque.

m. Lubricate the splines of the drive shaft and the lip of the oil seal lightly with engine oil; then, start the drive flange on the end of the drive shaft and push it down tight against the bearing.

If necessary, tap the drive flange down on the drive shaft until it contacts the bearing with a hard wood block and hammer.

n. Lubricate the threads on the drive (output) shaft with engine oil. Then thread the retainer nut on the shaft and against the drive flange. Do not tighten the nut at this time.

4. On the 1.5:1 and 2.1:1 reverse and reduction gear units, install the planetary gear and reduction gear input shaft assembly in the reverse gear housing as follows:

a. Support the reverse gear housing on two 6" wood blocks, with the forward face of the gear housing facing up and the opening in the rear face of the housing over the opening between the two wood blocks, thus allowing clearance for the end of the reduction gear input shaft to project through the reverse gear housing when assembled.

b. Lubricate the reduction gear input shaft thrust washer with engine oil; then, place the thrust washer down in the reverse gear housing with the tang on the edge of the washer in the notch inside of the gear housing as shown in Fig. 50.

c. Lubricate the pinion gears in the planetary gear and the outside diameter of the input shaft, where it makes contact with the bushings or the gear housing, with engine oil.

NOTE: The 2.1:1 reverse and reduction gear unit cannot be reversed from right-hand rotation to left-hand rotation by relocating the

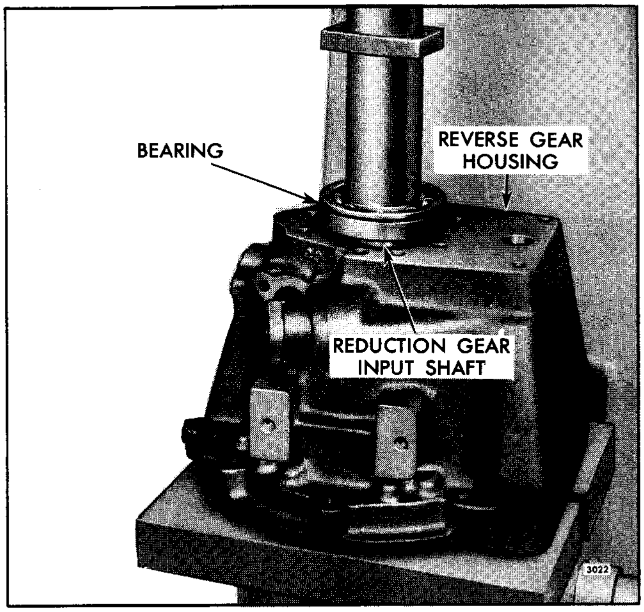

Fig. 49 - Installing Reduction Gear Input Shaft Bearing on Input Shaft and in Gear Housing (2.5:1 and 3:1 Ratios)

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reverse gear oil pump like the other reverse and reduction gear units. However, if it becomes necessary to change the rotation of the 2.1:1 reverse and reduction gear unit to the opposite hand rotation, it can be accomplished by removing the present reduction gear planetary gear assembly and installing the opposite hand rotating planetary gear assembly and relocating the oil pump assembly to the opposite hand rotation.

d. Position the planetary gear and input shaft assembly over the top of the gear housing as shown in Fig. 51; then, insert the end of the input shaft straight down through the thrust washer and bushings or housing until the rear face of the planetary gear rests on the thrust washer.

5. On the 2.5:1 and 3:1 reverse and reduction gear units, install the planetary gear and reduction gear input shaft assembly in the reverse gear housing as follows:

a. Support the reverse gear housing on two 6" wood blocks, with the forward face of the gear housing facing up and the opening in the rear face of the housing over the opening between the two wood blocks, thus allowing clearance for the end of the reduction gear input shaft to project through the reverse gear housing when assembled.

NOTE: The thrust washer shown in Fig. 50 is not used on the direct drive, 2.5:1 and 3:1 ratio reverse and reduction gear units.

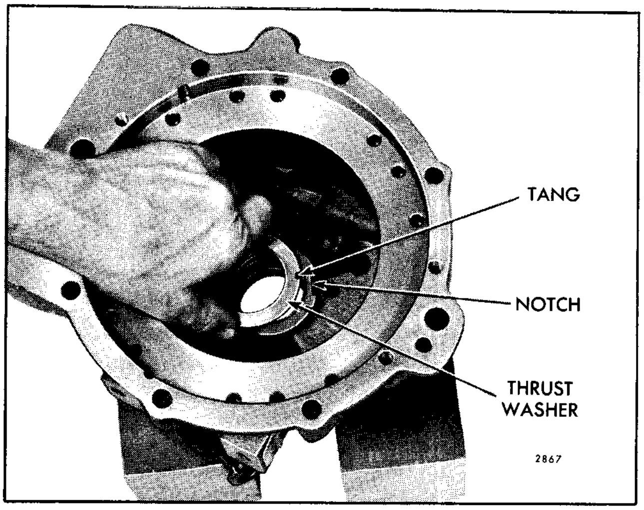

Fig. 50 - Installing Reduction Gear Input Shaft Thrust Washer in Gear Housing (1.5:1 and 2.1:1 Ratios)

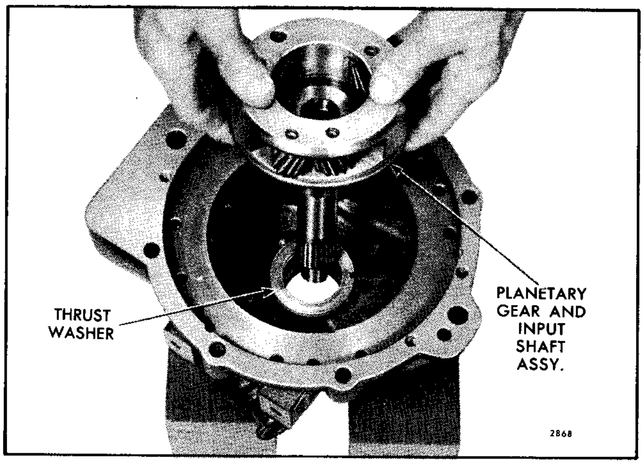

Fig. 51 - Installing Planetary Gear and Reduction Gear Input Shaft Assembly in Gear Housing (1.5:1 and 2.1:1 Ratios)

b. Lubricate the pinion gears of the planetary gear and the outside diameter of the input shaft, where it makes contact with the bushings or the gear housing, with engine oil.

c. Position the planetary gear and input shaft assembly over the top of the gear housing (Fig. 51); then, insert the end of the input shaft straight down through the bushings or housing until the rear face of the planetary gear rests on the gear housing.

d. Place a 3" x 6" x 6" wood block down inside the gear housing with the 6" face of the block resting on top of the planetary gear.

e. Place the reverse gear housing, planetary gear and input shaft assembly and the wood block on the bed of an arbor press, with the forward face of the gear housing down and the assembly resting on the wood block (Fig. 49).

f. Lubricate the reduction gear input shaft bearing with engine oil. Place the bearing over the end of the shaft with the groove in the outer race of the bearing up; then, start the bearing straight on the bearing surface of the shaft.

g. Place a sleeve over the end of the input shaft and rest it on the inner race of the bearing; then, place a flat steel plate on top of the sleeve and under the ram of the press as shown in Fig. 49. Press the bearing straight on the shaft and in the housing until it seats on the shoulder on the shaft and the snap ring groove in the shaft is fully exposed.

h. Install the snap ring in the groove in the shaft next to the bearing inner race with a pair of snap ring pliers J 5586.

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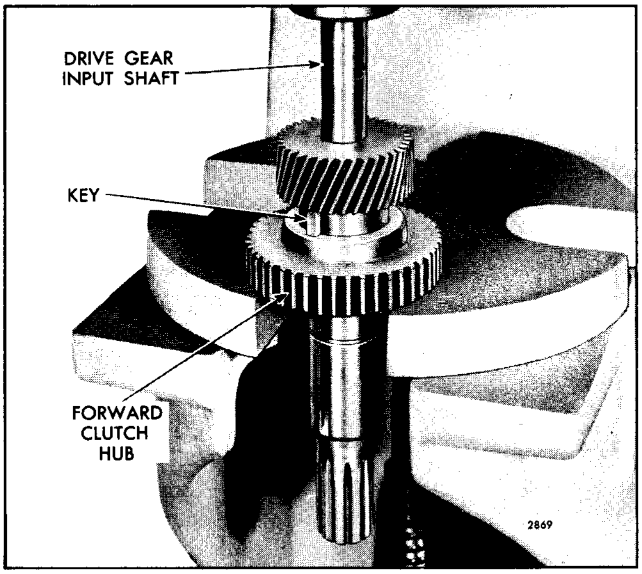

Fig. 52 - Installing Forward Clutch Hub on Drive Gear (Input) Shaft

i. Remove the reverse gear housing and input shaft assembly from the arbor press and place it on the two six inch wood blocks with the forward face of the gear housing facing up.

6. Install the forward clutch hub on the clutch drive gear shaft as follows:

A new drive gear input shaft assembly has replaced the former drive gear input shaft assembly. The current drive gear shaft differs from the former in that it is 1" shorter in length, has 26 splines at the pilot end, a relocated Woodruff keyway and a cup plug pressed in the small end of the shaft to seal off the horizontal oil passage. The former drive gear shaft was 1" longer in length, had 10 splines at the pilot end, and a steel ball and a roll pin in the small end of the shaft to seal off the horizontal oil passage.

a. Install the Woodruff key in the keyway provided in the shaft next to the drive gear.

b. Lubricate the outside diameter of the drive gear shaft, where it makes contact with the forward clutch hub, with engine oil.

c. Place the forward clutch hub over the end of the drive gear shaft, with the extended hub end of the clutch hub down, and lower it straight over the shaft with the keyway in the clutch hub in alignment with the Woodruff key in the shaft.

d. Place the forward clutch hub and drive gear shaft on the bed of an arbor press, with the short end of the drive gear shaft under the ram of press as shown in Fig. 52. Then press the drive gear shaft straight into the forward clutch hub and tight against the drive gear.

e. Install the snap ring in the groove in the shaft with a pair of snap ring pliers J 5586 as shown in Fig. 30. Be sure the snap ring is fully seated in its groove.

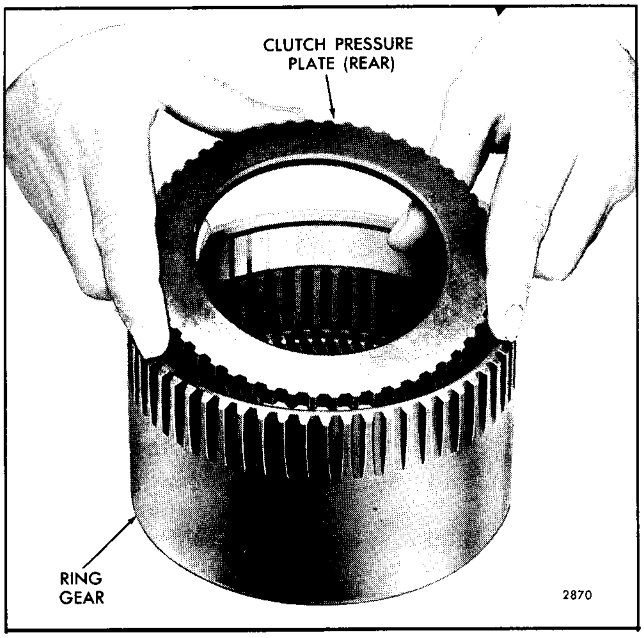

Fig. 53 - Installing Rear (Forward) Clutch Pressure Plate in Ring Gear

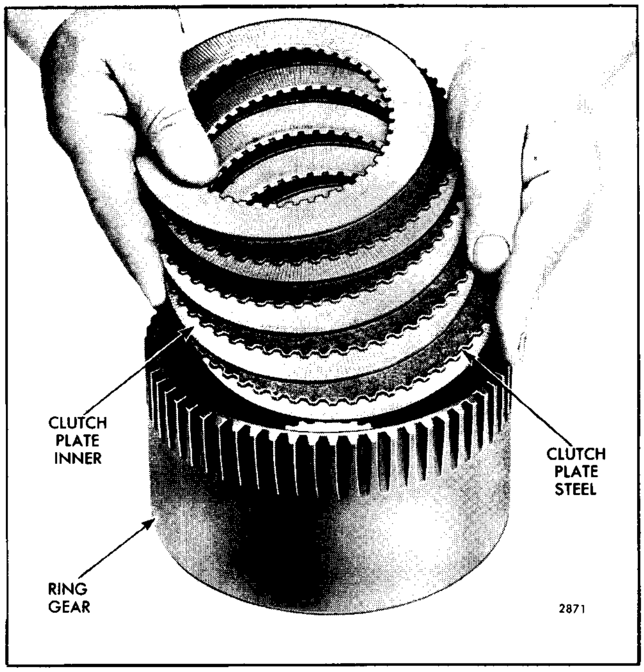

Fig. 54 - Position of Forward Clutch Plates for Assembly in Ring Gear

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NOTE: If a new service drive gear input shaft assembly is being installed, be sure the steel ball and roll pin or cup plug, whichever is used, is in place in the small (non-splined) end of the drive gear shaft before installing it in the reverse gear housing.

7. Install the forward clutch plates and the forward clutch piston and cylinder assembly in the planetary ring gear as follows:

a. Place the planetary ring gear on a bench, with the external teeth of the ring gear facing up.

b. Install the rear clutch pressure plate inside the planetary ring gear with the smooth flat face side facing up as shown in Fig. 53. Align the teeth on the pressure plate with the internal teeth in the ring gear; then, lower the pressure plate straight into the ring gear until it seats squarely on the shoulder inside the ring gear.

c. Lubricate the inner forward clutch plates (copper faced) and the outer forward clutch plates (steel) with engine oil.

d. Place an inner forward clutch plate (copper faced) down inside the ring gear and rest it on the rear clutch pressure plate. Then place the outer forward clutch plate (steel) down in the ring gear next to the inner clutch plate so the teeth on the clutch plate mesh with the internal teeth in the ring gear.

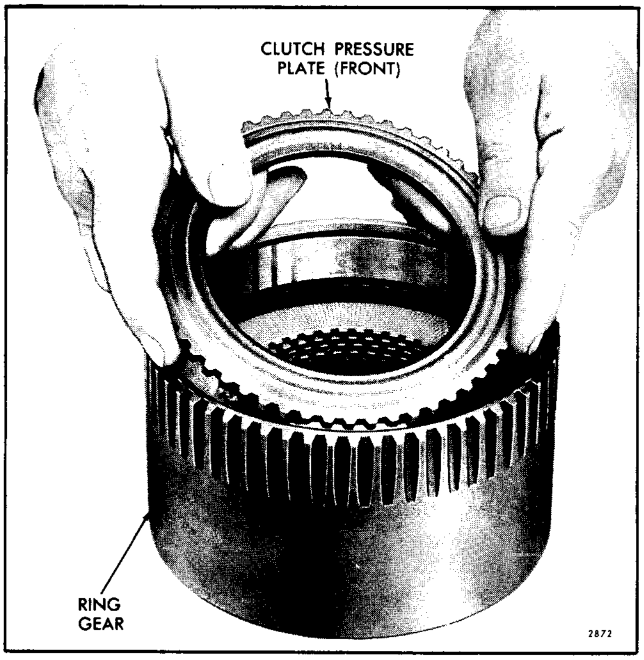

Fig. 55 - Installing Front (Forward) Clutch Pressure Plate in Ring Gear

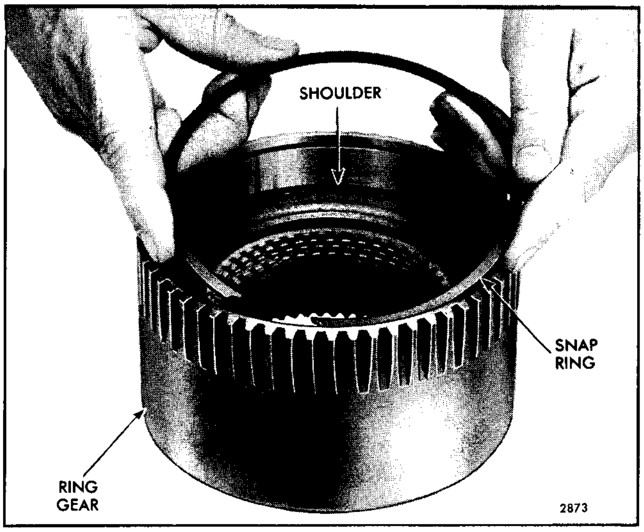

Fig. 56 - Installing Forward Clutch Pressure Plate Snap Ring in Ring Gear

Install the remaining inner and outer forward clutch plates as outlined above and in the same sequence as shown in Fig. 54.

e. Install the front clutch pressure plate inside the planetary ring gear with the smooth flat face side down as shown in Fig. 55.

Align the teeth on the pressure plate with the internal teeth in the ring gear; then, lower the pressure plate on top of the (copper faced) inner clutch plate.

f. Install the forward clutch pressure plate snap ring inside the ring gear and seat it squarely on the internal shoulder inside the ring gear as shown in Fig. 56.

NOTE: The forward clutch pressure plate snap ring shown in Fig. 56 is .090" to .093" thick and has a free diameter of 5-19/32" + 1/16" and is only used as a spacer and clutch release spring seat. The groove at the top of the shoulder in the ring gear is not designed to accommodate the snap ring.

g. Place the forward clutch release spring in the ring gear and rest it on the snap ring (spacer), with the concave side of the release spring facing down as shown in Fig. 57, and center it in the ring gear.

h. Lubricate the forward clutch piston outer seal ring with engine oil; then, install the seal ring in the groove in the outside diameter of the forward clutch piston as shown in Fig. 58.

i. Lubricate the forward clutch piston inner seal ring with engine oil; then, install the seal ring in the

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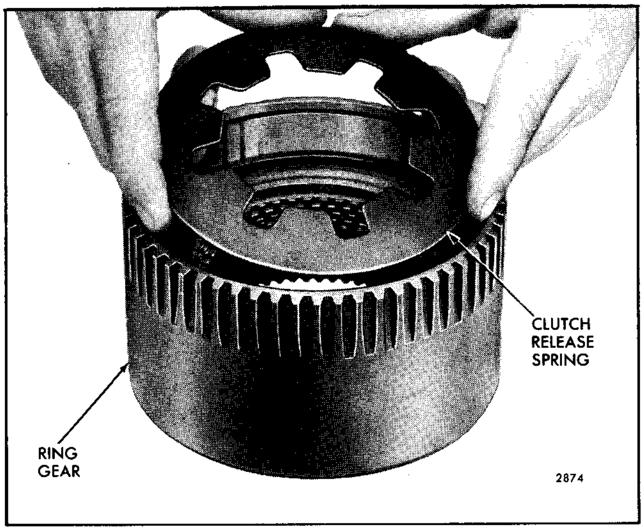

Fig. 57 - Installing Forward Clutch Release Spring in Ring Gear

groove in the hub of the forward clutch piston cylinder as shown in Fig. 59.

j. Lubricate the forward clutch piston inner and outer seal rings with engine oil; then, start the forward clutch piston with seal ring straight into the bore of the forward clutch piston cylinder, with the flat side of the piston facing down. Then push the piston straight down in the cylinder until it bottoms as shown in Fig. 60.

CAUTION: This is a hand assembly and should not be tapped in with a hammer or pressed in with an arbor press.

k. Install the forward clutch piston release spring support ring in the groove in the top of the piston (Figs. 1 and 43).

l. Lubricate the outside diameter of the forward clutch piston cylinder, where it makes contact with the ring gear, with engine oil; then, start the forward clutch piston and cylinder assembly straight into the bore of the ring gear, with the forward clutch piston side facing the piston release spring.

m. Place the planetary ring gear assembly on the bed of an arbor press, with the forward clutch piston cylinder end facing up and under the ram of the press. Place a short 3" outside diameter steel bar on top of the forward clutch piston cylinder; then, very carefully press the piston cylinder straight into the ring gear as shown in Fig. 61 until it contacts the snap ring and the groove in the top of the ring gear is fully exposed.

CAUTION: Be sure the forward clutch release spring is centrally located so the outer edge of the forward clutch piston cylinder will not ride on the edge of the spring. The clutch release spring must be centered so the outer edge of spring rides in the counterbore of the piston cylinder when the piston cylinder is down against the snap ring.

NOTE: If the snap ring groove in the top of the ring gear is not fully exposed when the piston cylinder is pressed down in the ring gear as far as it will go, it is evident that the piston cylinder is riding on the edge of the clutch release spring. This can be determined by removing the ring gear assembly from the arbor press and checking the fingers of the release spring through the rear of the ring gear to see if they are centrally located on the release spring support ring. If necessary, place a screw driver between the fingers of the spring and the edge of the piston and reposition the spring. Replace the ring gear assembly on the bed of the arbor press and press the forward

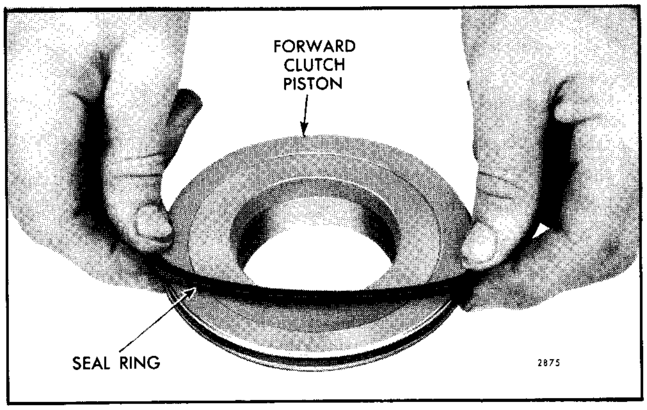

Fig. 58 - Installing Forward Clutch Piston Seal Ring on Piston

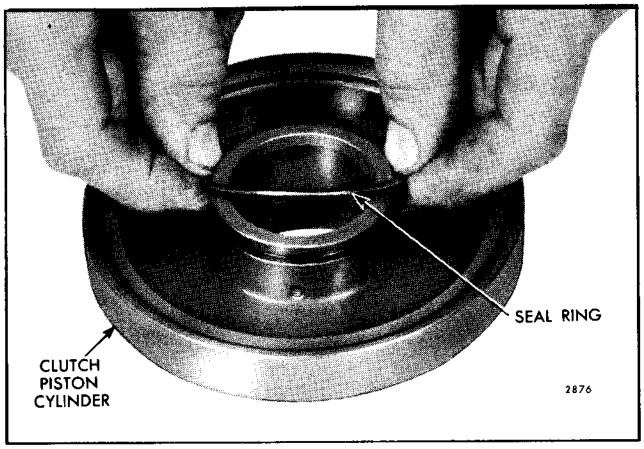

Fig. 59 - Installing Forward Clutch Piston Seal Ring in Clutch Piston Cylinder

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clutch piston cylinder down against the snap ring.

n. Place the ring gear and forward clutch assembly on a bench, with the forward clutch piston cylinder end facing up; then, install the snap ring in the groove inside the ring gear next to the piston cylinder as shown in Fig. 62.

If necessary, apply light pressure on the forward clutch piston cylinder with the arbor press while installing the snap ring.

NOTE: The forward clutch piston cylinder snap ring shown in Fig. 62 is .074" -.078" thick and has a free diameter of 5-7/8" + 1/16" and is only used at this location to retain the forward clutch piston cylinder in the ring gear.

7. On the Model 72 reverse gear units, perform the additional Steps a, b, c and d as outlined below:

a. Support the ring gear and forward clutch assembly on the bed of an arbor press, with the forward clutch piston cylinder end of the assembly facing down (Fig. 63) and the end of the ring gear resting on steel or wood supports.

CAUTION: Be sure the forward clutch piston cylinder does not contact or ride on the supports under the end of the ring gear.

b. Place a 1/4" x 4-1/2" diameter steel plate down inside the ring gear and rest it on the face of the rear clutch pressure plate.

c. Bring the ram of the press down on the center of the steel plate and apply just enough force to compress the pressure plates and clutch plates against the snap ring (spacer) between the front clutch pressure plate and the clutch piston cylinder. Then measure the clearance between the rear face of the rear pressure plate and the shoulder of the snap ring groove inside the ring gear at several places with feeler gages as shown in Fig. 63 and record.

d. Release the load off of the clutch plates and remove the steel plate from inside the ring gear. Then install one of the selective spacers (snap rings) in the snap ring groove between the rear face of the rear pressure plate and the shoulder of the snap ring groove as shown in Fig. 64.

One of three different thickness spacers (snap rings) are used between the rear pressure plate and the shoulder in the ring gear to retain the

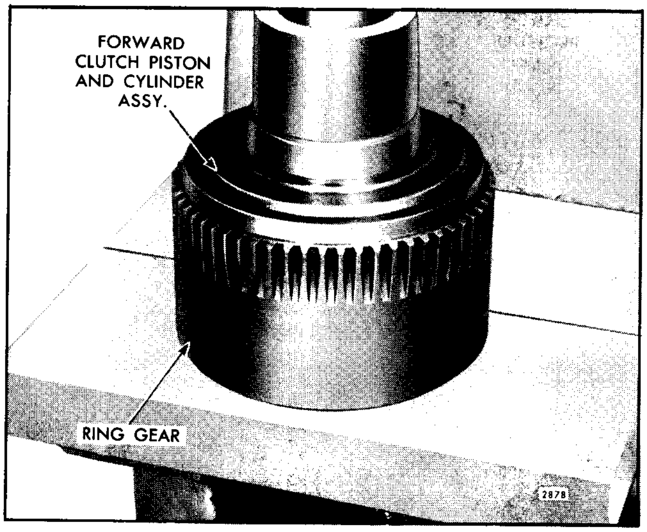

Fig. 61 - Installing Forward Clutch Piston and Cylinder Assembly in Ring Gear

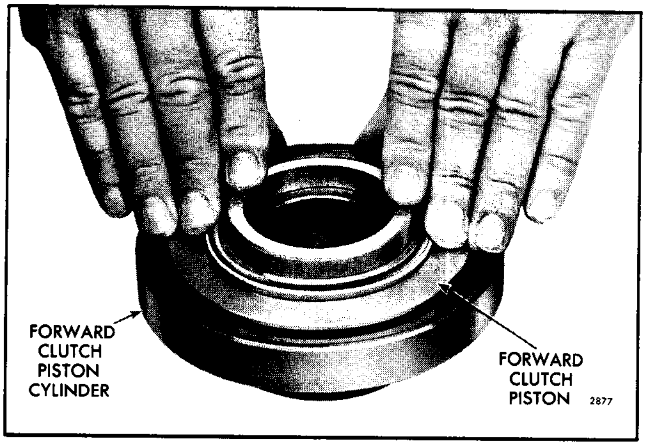

Fig. 60 - Installing Forward Clutch Piston in Clutch Piston Cylinder

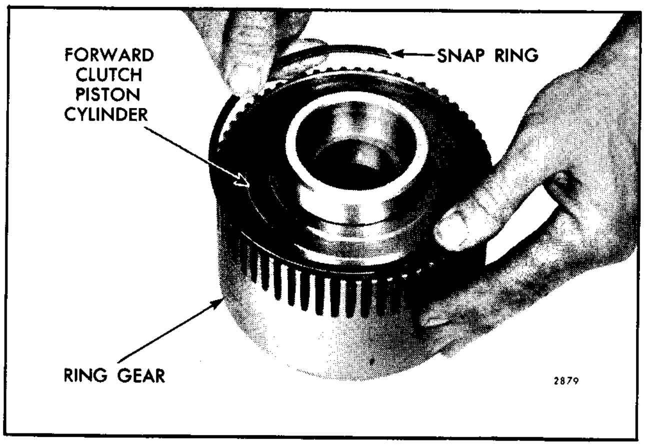

Fig. 62 - Installing Forward Clutch Piston Cylinder Snap Ring in Ring Gear

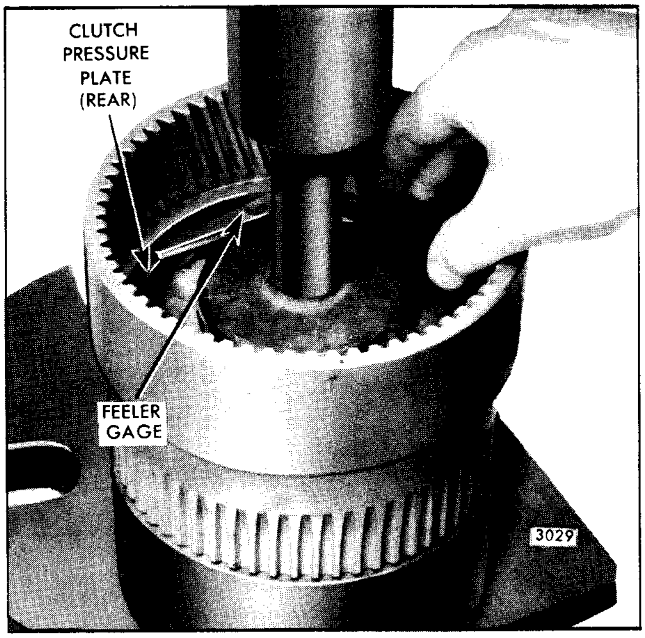

Fig. 63 - Measuring Gap for Forward Clutch Selective Spacer (Snap Ring)

proper clearance of .040" to .065" between the two parts. They are .050" to .054", .074" to .078" and .096" to .100" thick. All have a free diameter of 5-11/16 + 1/16" and are only used at this location on the Model 72 reverse gears.

The three different thickness spacers (snap rings) may be identified by a spot of paint on the outside diameter of each snap ring: green on .050" to .054", orange on .074" to .078" and white on .096" to .100".

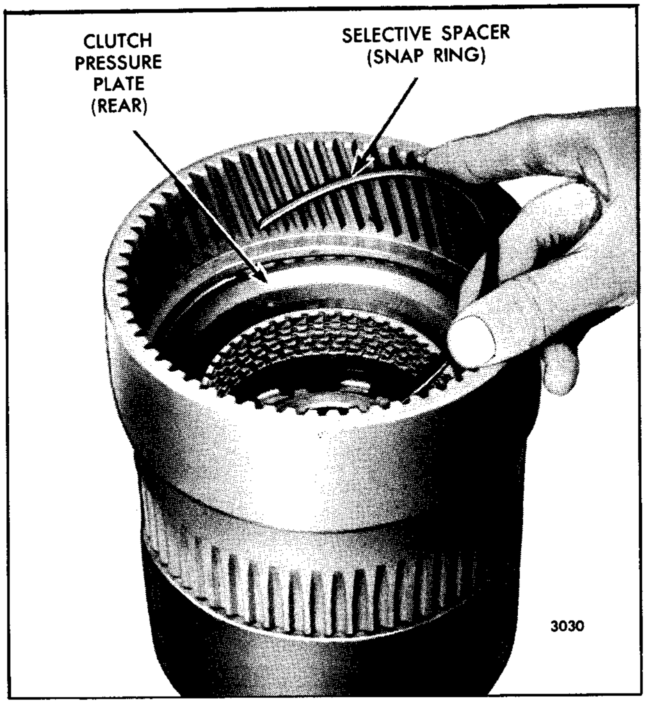

Fig. 64 - Installing Forward Clutch Selective Spacer (Snap Ring) in Ring Gear

8. Install the drive gear and forward clutch hub assembly in the ring gear and forward clutch assembly as follows:

a. Lubricate the drive gear input shaft seal rings with engine oil, then place the seal rings over the splined end of the drive gear input shaft and into the grooves in the shaft with a pair of snap ring pliers as shown in Fig. 29. Hook the ends of each seal ring together.

CAUTION: To avoid breaking the seal rings, do not spread them any more than necessary to slip them over the shaft.

b. Rotate the inner forward clutch plates in the ring gear so that all of the teeth on the plates are in alignment.

c. Place the ring gear assembly on its side on a bench. Lubricate the drive gear shaft and seal rings with engine oil; then, insert the splined end of the drive gear shaft in the rear of the ring gear as shown in Fig. 65. Push the drive gear shaft straight through the bore of the forward clutch piston cylinder until the seal ring enters the bore of the piston cylinder and the teeth of the clutch hub enter the teeth of the inner clutch plates; continue to work the clutch hub through all of the

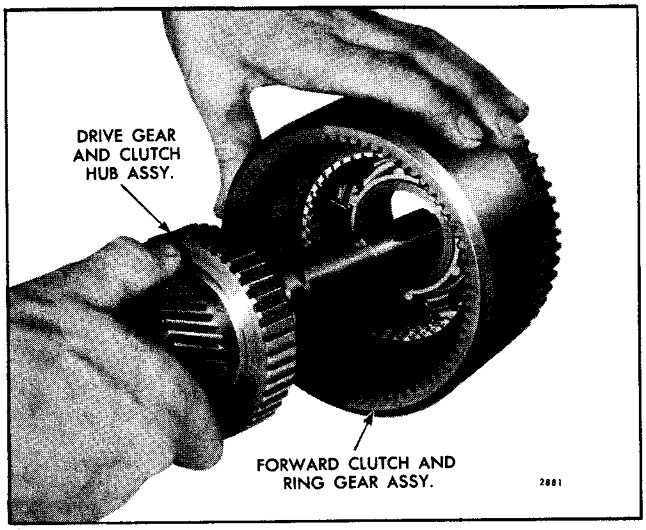

Fig. 65 - Installing Drive Gear and Forward Clutch Hub Assembly into Forward Clutch and Ring Gear Assembly

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inner clutch plates until the rear face of the drive gear is flush with the face of the ring gear as shown in Fig. 66.

CAUTION: Do not drive or force the drive gear and clutch hub assembly through the inner clutch plates. If forced, the teeth of the inner clutch plates will be damaged.

IMPORTANT: During assembly, the inner clutch plate at the rear of the forward clutch pack can move off center and hook over the rear face of the clutch hub. This will prevent alignment of the gear faces as mentioned in Step "c" above.

NOTE: When installing the drive gear and clutch hub assembly in the forward clutch piston cylinder and the inner clutch plates, do not push the drive gear and clutch hub in too far or the forward seal ring will slip out of the forward clutch piston cylinder and cannot be reinstalled in the piston cylinder by pulling the drive gear and clutch hub backwards. The seal ring must be removed from the groove in the shaft and the drive gear and clutch hub removed from the piston cylinder and the inner clutch plates and reinstalled again as outlined above.

d. Place the 3" x 6" x 6" wood block with the 1" hole drilled through its center over the drive gear shaft at the rear of the ring gear as shown in Fig. 67 to support the ring gear and drive gear assembly while installing the drive gear shaft bearing and snap rings.

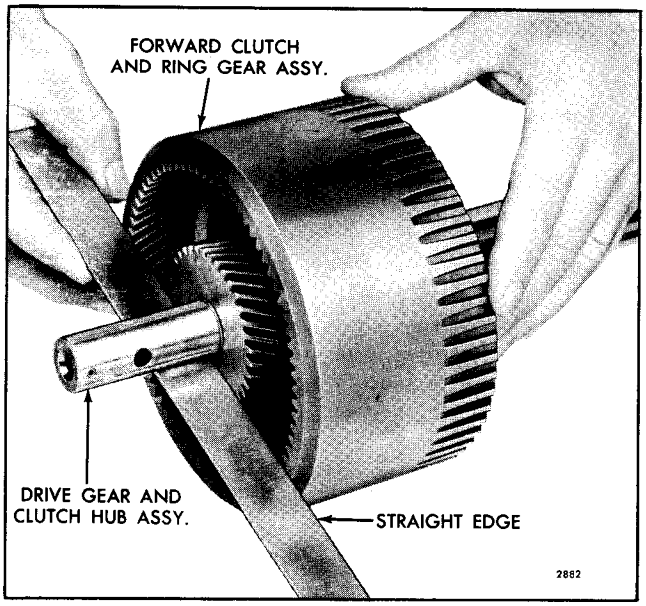

Fig. 66 - Aligning Rear Face of Drive Gear with Face of Ring Gear

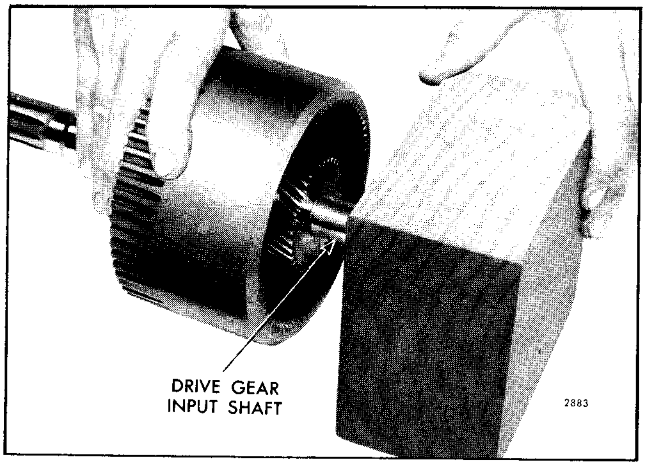

Fig. 67 - Placing Wood Block over End of Drive Gear Shaft

e. Place the drive gear, forward clutch and ring gear assembly with the wood block on the bed of an arbor press, with the splined end of the drive gear shaft facing up.

f. Lubricate the drive gear shaft ball bearing with engine oil; then, place the bearing, numbered end up, over the end of the drive gear shaft and start it straight into the bearing bore of the forward clutch piston cylinder.

g. Place a sleeve over the end of the drive gear shaft and rest it on the inner race of the bearing; then,

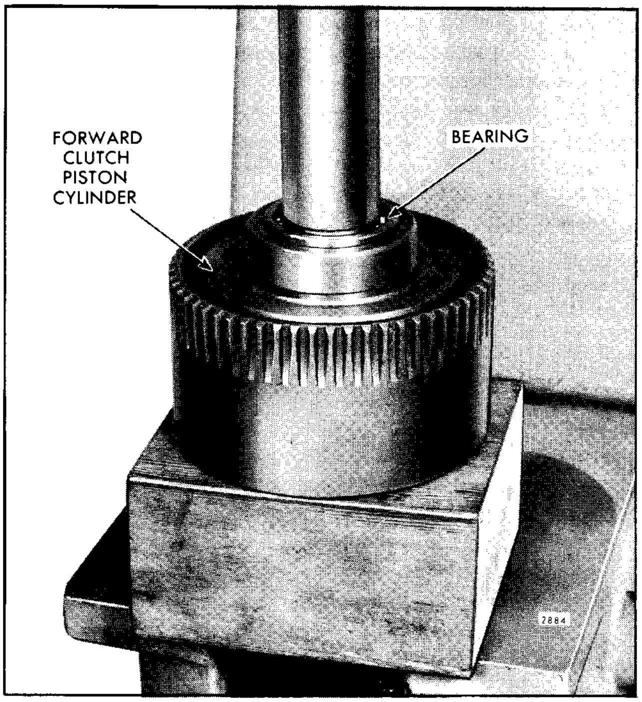

Fig. 68 - Installing Gear Shaft Bearing in Forward Clutch Piston Cylinder

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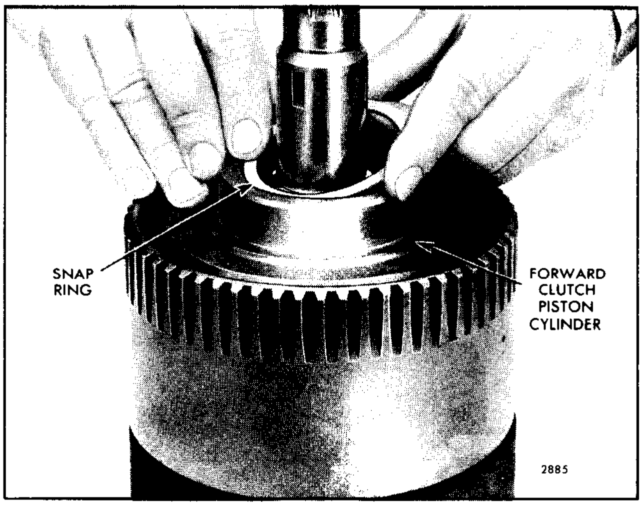

Fig. 69 - Installing Bearing Retaining Snap Ring in Forward Clutch Piston Cylinder

place a steel plate on top of the sleeve and under the ram of the press as shown in Fig. 68. Press the bearing straight into the bore of the forward clutch piston cylinder until it bottoms and the snap ring groove in the bearing bore of the piston cylinder is fully exposed.

h. Install the snap ring in the groove of the drive gear input shaft next to the bearing inner race with a pair of snap ring pliers J 5586 as shown in Fig. 25.

i. Install the snap ring in the groove of the forward clutch piston cylinder next to the bearing outer race as shown in Fig. 69.

9. Install the forward clutch and planetary ring gear assembly, reverse clutch plates and reverse clutch pressure plate in the reverse gear housing as follows:

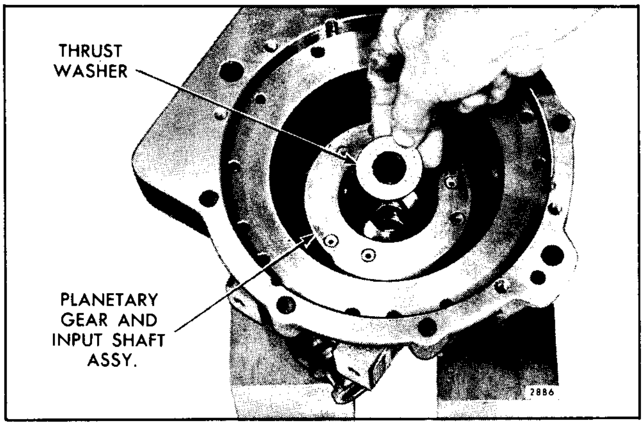

Fig. 70 - Installing Planetary Gear Thrust Washer

a. With the reverse gear housing still supported on the drive flange or the wood blocks and with the forward face of the gear housing facing up, install the planetary gear thrust washer down inside of the planetary gear as shown in Fig. 70 and center the thrust washer over the drive gear input shaft bore.

b. Lubricate the small end of the drive gear input shaft with engine oil; then, position the planetary ring gear assembly over the top of the gear housing with the splined end of the drive gear input shaft up as shown in Fig. 71.

c. Lower the planetary ring gear assembly into the reverse gear housing and enter the end of the drive gear input shaft straight through the thrust washer and into the bushings in the center of the direct drive (output) drive shaft or the reduction gear input shaft. Align the teeth of the drive gear with the teeth of the pinion gears, then lower the assembly until the drive gear rests on the thrust washer.

d. Install the twelve reverse clutch pressure plate release springs in the holes provided in the reverse clutch cavity as shown in Fig. 23. These holes should be free of foreign matter and the springs firmly seated.

e. Coat the three dowel pins with grease and install them in the grooves provided in the outside

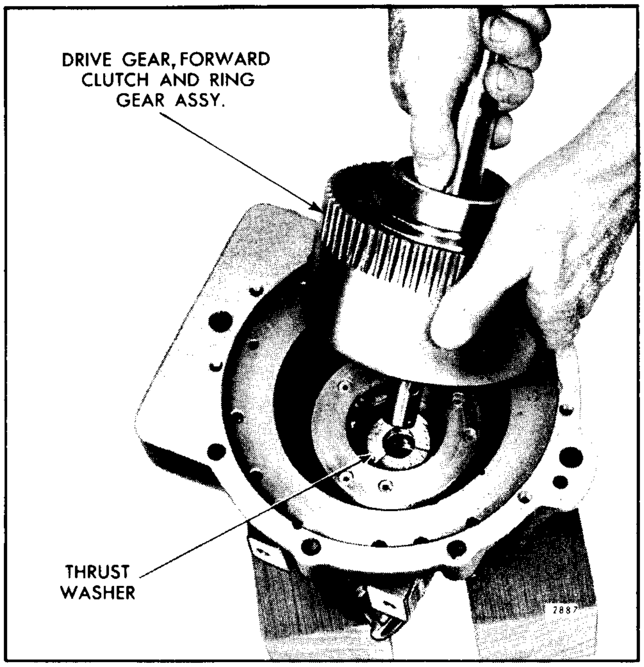

Fig. 71 - Installing Planetary Ring Gear, Forward Clutch and Drive Gear Assembly in Reverse Gear Housing

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diameter of the reverse clutch cavity as shown in Fig. 23. The dowel pins must be firmly seated in the grooves.

f. Place an inner reverse clutch plate down in the reverse clutch cavity of the gear housing with the teeth of the clutch plate in mesh with the splined teeth of the ring gear as shown in Fig. 72. Then place the stationary reverse clutch plate (steel) down over the dowel pins and on the inner clutch plate with the odd shaped lug over the left-hand lower dowel pin as shown in Fig. 73. Place the second reverse clutch plate down on the steel plate with the teeth of the clutch plate in mesh with the splined teeth of the ring gear.

The Model 72 reverse gear assemblies have been revised to incorporate two additional reverse clutch plates, one stationary plate and one with internal teeth, making a total of five reverse clutch plates (Fig. 2). Formerly, the reverse gear assemblies consisted of three reverse clutch plates: one stationary plate and two plates with internal teeth. When installing the reverse clutch plates in the current Model 72 reverse gear, place the two additional reverse clutch plates in the reverse gear housing in the same sequence as the other clutch plates are installed.

g. Place the reverse clutch pressure plate (with the twelve holes in the plate down) on top of the release springs and over the dowel pins with the cast slot in the outer rim of the pressure plate in alignment with the large oil hole in the top front face of the reverse gear housing as shown in Fig. 74.

Since the twelve pressure plate release springs are

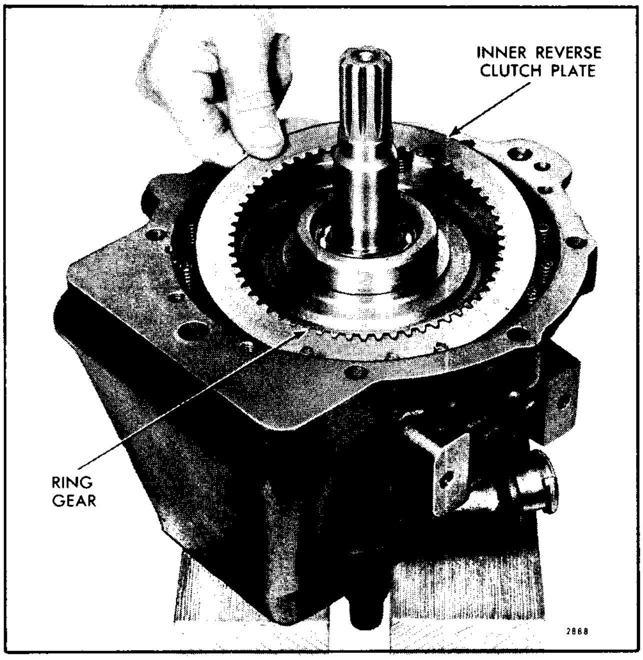

Fig. 72 - Installing Inner Reverse Clutch Plate in Gear Housing

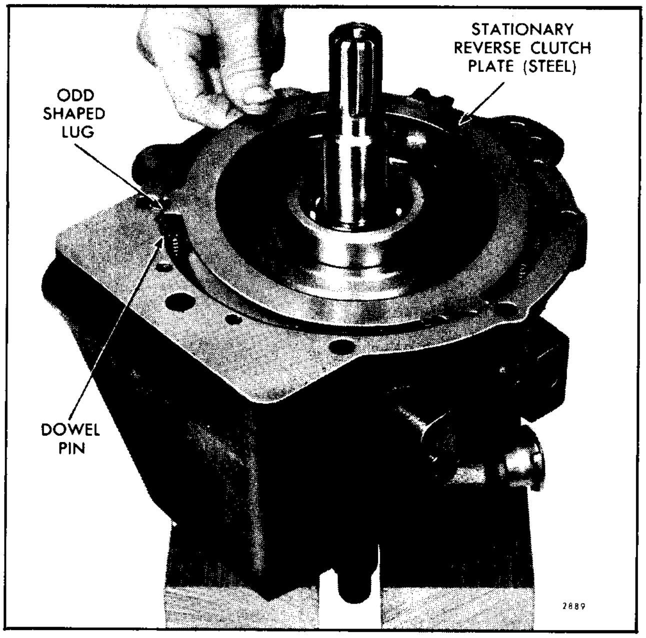

Fig. 73 - Installing Stationary Reverse Clutch Plate (Steel) in Gear Housing

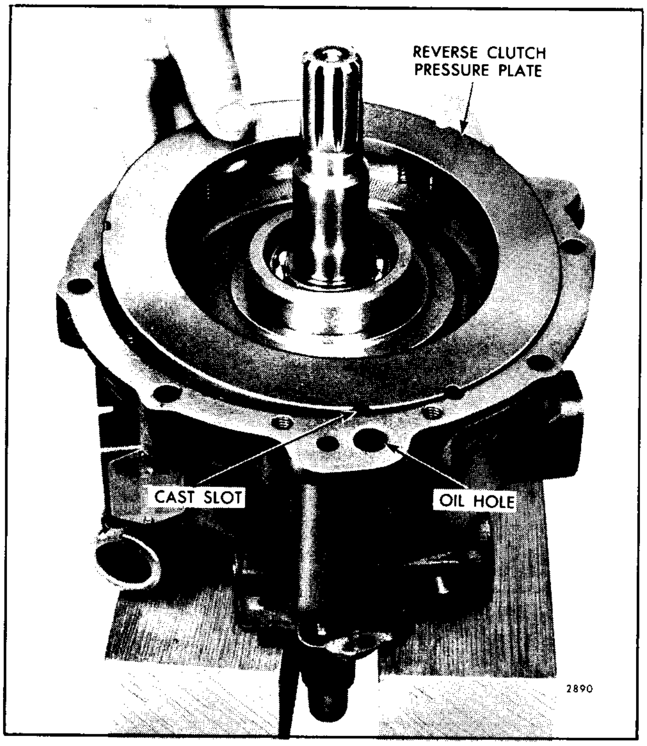

Fig. 74 - Installing Reverse Clutch Pressure Plate in Gear Housing

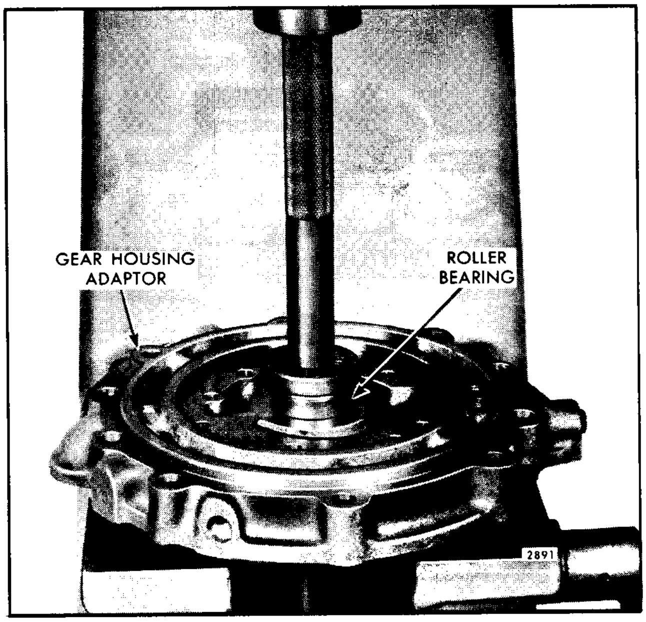

Fig. 75 - Installing Roller (Needle) Bearing in Gear Housing Adaptor

not evenly spaced, it is necessary that the cast slot in the pressure plate and the large oil hole in the gear housing be in alignment in order to properly locate the holes in the pressure plate with the springs in the gear housing.

NOTE: If the pressure plate does not go down into position, approximately flush with the front face of the housing, check the three dowel pins and the springs for misalignment.

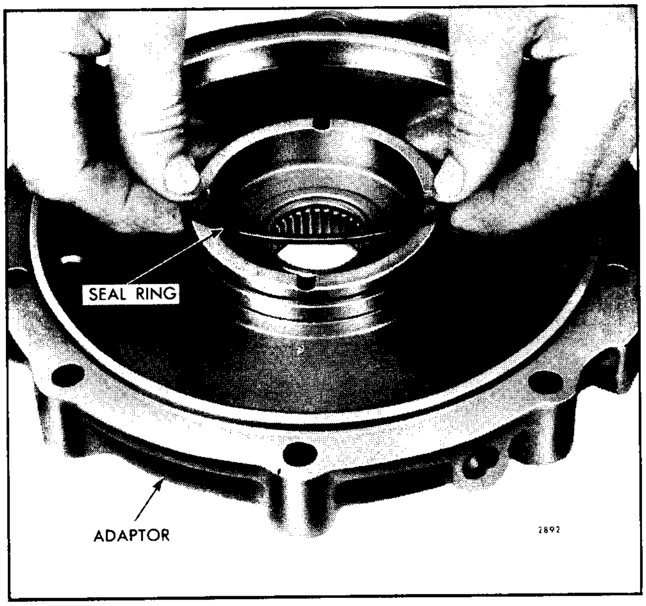

Fig. 76 - Installing Reverse Clutch Piston Seal Ring in Adaptor

10. Install the roller (needle) bearing and the reverse clutch piston in the reverse gear housing adaptor as follows:

a. Lubricate the outside diameter of the roller (needle) bearing with engine oil; then, start the bearing straight into the bearing bore of the adaptor from the forward face side of the adaptor.

b. Support the reverse gear housing adaptor with the bearing on the bed of an arbor press, with the rear face of the adaptor down as shown in Fig. 75.

c. Place the bearing installer J 8561 with handle J 7079-2 in and on top of the bearing, with the end of the handle under the ram of the press as shown in Fig. 75. Then press the bearing straight into the adaptor until the installer J 8561 contacts the face of the adaptor.

A step under the flange of the installer J 8561 properly positions the bearing in the adaptor.

d. Lubricate the reverse clutch piston inner seal ring with engine oil; then, install the seal ring in the groove in the hub of the gear housing adaptor as shown in Fig. 76.

e. Lubricate the reverse clutch piston outer seal ring with engine oil and install the seal ring in the groove in the outside diameter of the reverse clutch piston as shown in Fig. 77.

f. Lubricate the reverse clutch piston inner and outer seal rings with engine oil; then, start the reverse clutch piston with seal ring straight into the bore of the gear housing adaptor, with the flat smooth side of the piston down. Press down on the piston with one hand while pulling a clean screw driver around the exposed portion of the seal ring as

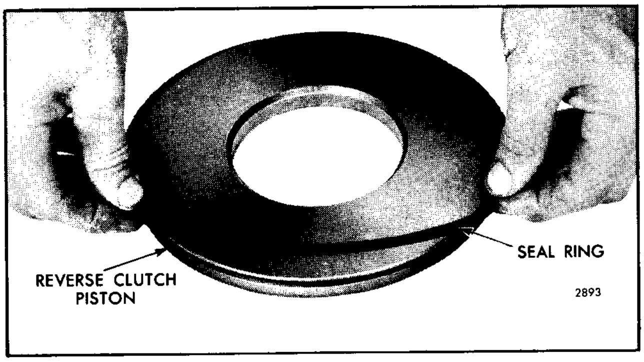

Fig. 77 - Installing Reverse Clutch Piston Seal Ring on Piston

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shown in Fig. 78, to aid the chamfered bore in the adaptor to compress the seal ring into the groove of the piston.

Push the assembly straight down in the bore of the adaptor until it bottoms. The exposed face of the reverse clutch piston should be flush with the adjacent surrounding surface of the adaptor when completely assembled.

CAUTION: This is a hand assembly and should not be tapped in with a hammer or pressed in with an arbor press.

11. Select the forward clutch piston cylinder thrust washer as outlined below.

The current 1.5:1 and 2.1:1 reverse and reduction gear units use a .061" to .063" thrust washer between the forward clutch piston cylinder and the gear housing adaptor to obtain the proper input shaft end play of .004" to .043". The former and current direct drive, 2.5:1 and 3:1 gears also use a .061" to .063" thrust washer.

In the former 1.5:1 and 2.1:1 reverse and reduction gear units, one of two different thickness thrust washers was used between the forward clutch piston cylinder and the gear housing adaptor to obtain the proper input shaft end play of .004" to .043". They are .061" to .063" and .085" to .087" thick. However, when servicing the former 1.5:1 and 2.1:1 reverse and reduction gear units, use the .061" to .063" thrust washer only to obtain the proper input shaft end play of .004" to .043".

Refer to the record of the input shaft end play when the reverse gear was disassembled to determine if a

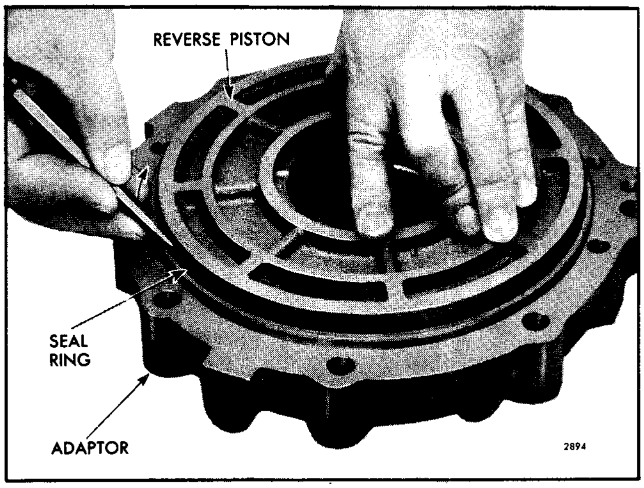

Fig. 78 - Installing Reverse Clutch Piston in Adaptor

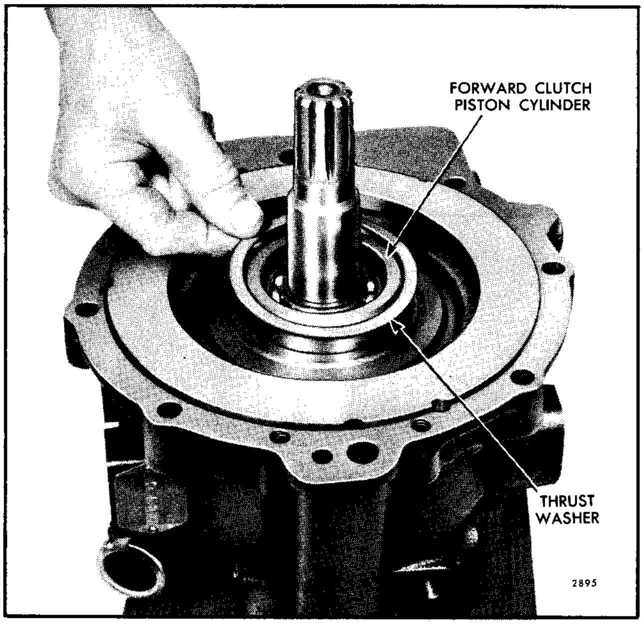

Fig. 79 - Installing Forward Clutch Piston Cylinder Thrust Washer

new forward clutch piston cylinder thrust washer is needed.

Refer to Step 12 below for the installation of the gear housing adaptor and the reverse clutch piston assembly and checking the input shaft end play.

12. Install the reverse gear housing adaptor and reverse clutch piston assembly on the reverse gear housing and check the input shaft end play as follows:

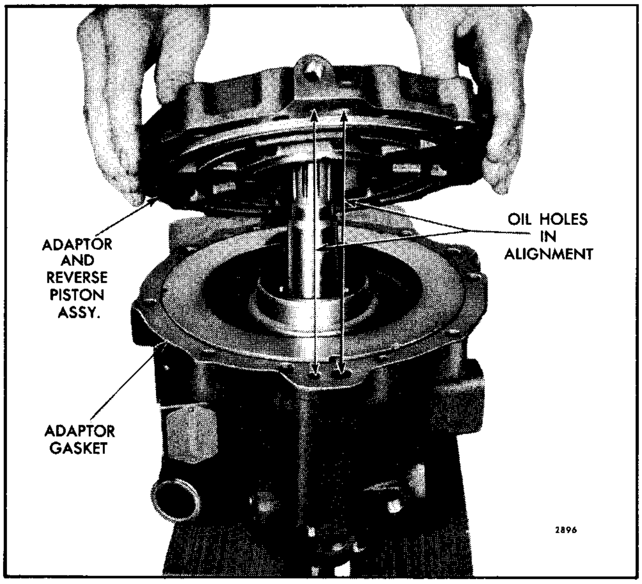

Fig. 80 - Installing Adaptor and Reverse Clutch Piston Assembly on Input Shaft and Gear Housing

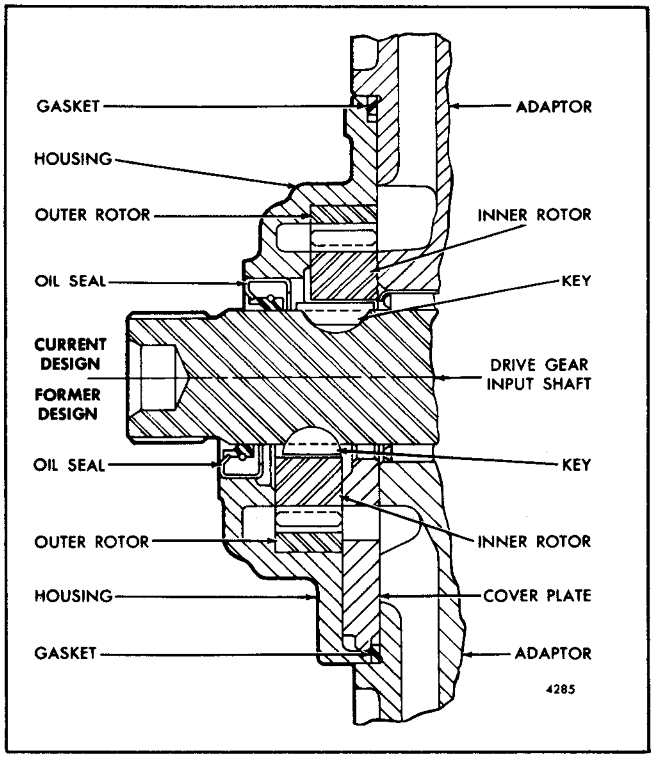

Fig. 81 - Current and Former Marine Gear Oil Pump Assemblies

a. Refer to Step 11 above for the dimensions of the thrust washers and install a new thrust washer over the hub of the forward clutch piston cylinder as shown in Fig. 79.

b. Affix a new gear housing adaptor gasket to the bolting flange of the gear housing with the bolt and oil holes in the gasket and the gear housing in alignment as shown in Fig. 80.

c. Lubricate the rollers (needles) of the bearing in the adaptor with engine oil; then, position the gear housing adaptor over the top of the drive gear input shaft, with the oil holes in the adaptor in alignment with the oil holes in the gear housing as shown in Fig. 80.

d. Enter the drive gear input shaft in the roller (needle) bearing, then lower the adaptor assembly over the shaft and rest it on top of the reverse clutch pressure plate.

e. Install the four bolts in the four counter-sunk bolt holes in the adaptor. Tighten the bolts evenly and draw the pilot on the rear face of the adaptor straight into the mating bore of the reverse gear housing. Tighten the bolts to 28-30 lb-ft torque.

On some marine gear units, five bolts were used to secure the adaptor to the gear housing.

NOTE: When drawing the adaptor down, check frequently for any bind by rotating the drive gear input shaft by hand.

f. Support the reverse gear housing on wood blocks or a bench, with the drive gear input shaft in a horizontal position.

g. Install a 1/4" -20 x 1-1/2" bolt in one of the selector valve cover bolt holes, or install a 7/16" - 14 x 2" bolt in one of the tapped holes in the side of the reverse gear housing. Tighten the bolt securely.

h. Attach a dial indicator to the bolt with the indicator button contacting the end of the drive gear input shaft or the reduction gear input shaft as shown in Fig. 19.

NOTE: On the direct drive units, the dial indicator must contact the forward end of the

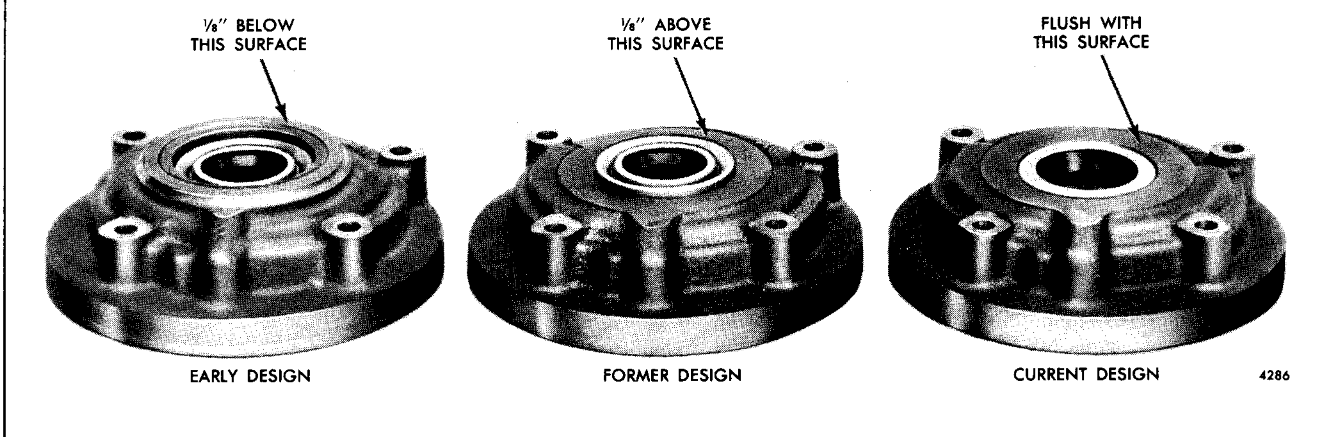

Fig. 82 - Position of Oil Seals Installed in Marine Gear Oil Pump Housings

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drive gear input shaft. On the reduction units, the dial indicator may contact the end of either the drive gear input shaft or the reduction gear input shaft.

i. Move all of the parts inside of the gear housing forward by pulling on the drive gear input shaft. Set the indicator at zero, then move all of the parts back by pushing on the drive gear input shaft and read the indicator.

If the end play is within the limits of .004" to .043", continue with the assembly.

13. Assemble the reverse gear oil pump.

A new reverse gear oil pump assembly shown in the upper half of Fig. 81 has replaced the former reverse gear oil pump assembly shown in the lower half of Fig. 81. The current oil pump assembly differs from the former in that the cover plate attached to the rear face of the former oil pump housing has been eliminated and the oil pump housing has been redesigned. The current reverse gear oil pump requires the current double-lip oil seal. The former reverse gear oil pump requires the former single-lip oil seal.

Removal of the oil pump cover plate allows the oil pump assembly to be moved 9/32" toward the rear of the reverse gear.

Moving the oil pump assembly back made it necessary to relocate the oil pump drive key and the keyway in the drive gear input shaft (Fig. 81). The revised drive gear input shaft can be used with either the former or the current oil pump assembly and adaptor. The former drive gear input shaft cannot be used with the current oil pump assembly and adaptor as the oil pump drive key would interfere with the oil pump oil seal.

Refer to the record taken at disassembly or Fig. 82 for the installed seal position in the reverse gear oil pump housing and proceed as follows:

a. Support the oil pump housing on the bed of an arbor press with the inside face of the housing facing down.

b. Apply a thin coat of sealing compound to the outside diameter of a new oil seal casing.

c. Start the oil seal straight into the oil pump housing with the lip of the oil seal facing down.

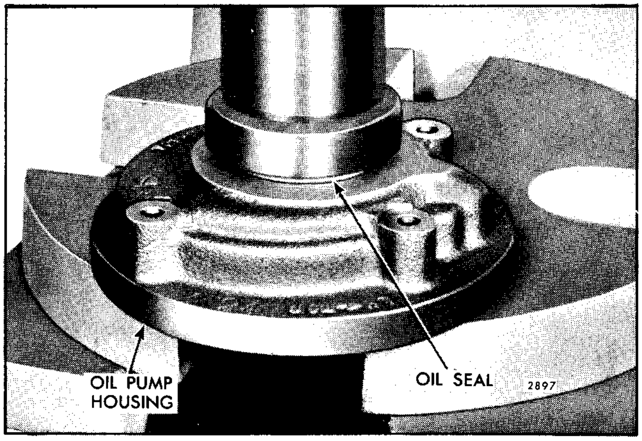

Fig. 83 - Installing Oil Seal in Oil Pump Housing

d. Place the oil seal installer on top of the oil seal and under the ram of the press as shown in Fig. 83; then, press the oil seal straight into the housing until the flange of the installer contacts the housing.

NOTE: If both lips of the current double-lip oil seal do not ride on the shaft, the seal will be ineffective.

Use oil seal installer J 8467 for the oil seal that extends 1/8" above the forward face of the oil pump housing and oil seal installer J 22389 for the oil seal that is flush with the forward face of the housing.

NOTE: On the early design oil pump housing, the oil seal was pressed in 1/8" below the outside face of the housing (Fig. 82).

e. Lubricate the inner and outer rotors (gears) with engine oil, then place the outer rotor (gear) inside of the oil pump housing with the matchmark between two of the rotor teeth facing up.

f. Place the inner rotor (gear) over the center of the oil pump housing, align the matchmark on the inner rotor with the marchmark on the outer rotor, then lower the inner rotor straight in the housing with the teeth of the two rotors (gears) in mesh (Fig. 21).

g. If used, place the oil pump cover plate on top of the rotors and inside the oil pump housing with the plain flat side of the cover facing down and the bolt holes in the cover and housing in

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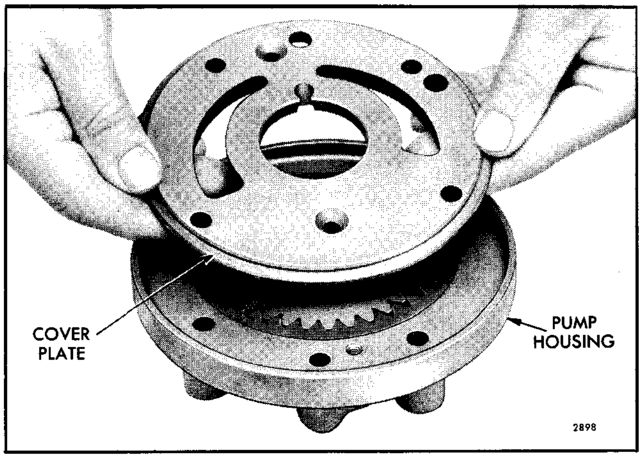

Fig. 84 - Installing Oil Pump Cover Plate on Oil Pump Housing

alignment as shown in Fig. 84. Install the two No. 10-24 x 3/4" flat head screws in the two countersunk holes in the cover plate and tighten them securely.

14. Install the reverse gear oil pump on the drive gear input shaft and the gear housing adaptor as follows:

a. Install the Woodruff key in the keyway of the drive gear input shaft next to the roller bearing in the gear housing adaptor, then turn the shaft until the key faces the top of the gear housing.

b. Place the oil pump to gear housing adaptor gasket in the oil pump cavity of the adaptor as shown in Fig. 85.

c. Support the reverse gear assembly on a bench, with the drive gear input shaft and the reduction gear input shaft in a horizontal position and the top side of the reverse gear housing facing up (Fig. 87).

d. Rotate the oil pump rotors (gears) so the keyway in the inner rotor (gear) is pointed toward the TOP L.H. or TOP R.H. mark (whichever rotation is being used) on the forward face of the oil pump housing.

NOTE: Two keyways are present in the inner rotor (gear); it makes no difference which one is used at assembly.

e. Lubricate the lip of the oil seal with engine oil; then, carefully insert the tapered end of the oil seal lip protector through the oil seal from the forward face of the oil pump housing.

Use oil seal lip protector J 8491 when installing the oil pump assembly on the former drive gear input shaft incorporating 10 splines and oil seal lip protector J 22390 when installing the oil pump assembly on the current drive gear input shaft incorporating 26 splines.

If an oil seal lip protector is not available, place a piece of .005" x 4" x 4" shim stock around the

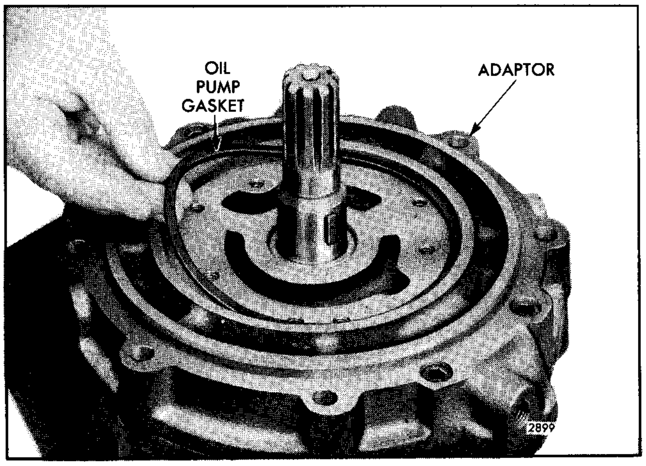

Fig. 85 - Installing Oil Pump Gasket in Adaptor

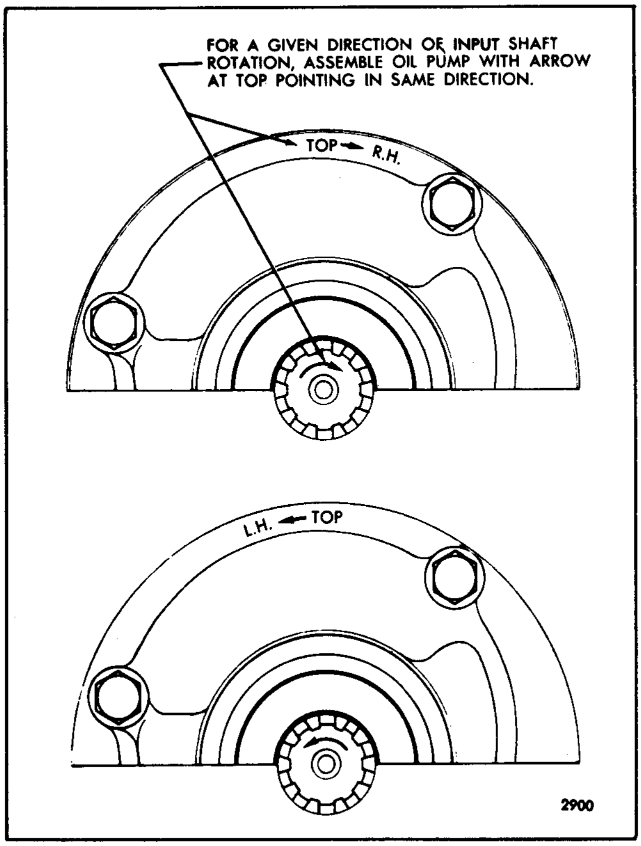

Fig. 86 - Location of Oil Pump Markings in Relationship to Input Shaft Rotation

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splines on the end of the drive gear input shaft; then, place a strip of cellulose tape over the seam of the shim stock to protect the lip of the oil seal from being cut or damaged.

f. Note the markings on the forward face of the oil pump housing which are TOP L.H. and TOP R.H. Then determine the direction the drive gear input shaft will turn when the unit is attached to the engine. With this in mind, position the oil pump assembly with the arrow mark on the forward face of the oil pump housing corresponding with the drive gear input shaft rotation as shown in Fig. 86, and the marks TOP L.H. or TOP R.H. on the oil pump housing (whichever rotation is desired) facing up towards the top side of the gear housing, as viewed from the forward face of the unit.

NOTE: The 2.1:1 reverse and reduction gear unit cannot be reversed from right-hand rotation to left-hand rotation by relocating the reverse gear oil pump like the other reverse and reduction gear units. However, if it becomes necessary to change the rotation of the 2.1:1 reverse and reduction gear unit to the opposite hand rotation, it can be accomplished by removing the present reduction gear planetary gear assembly and installing the opposite hand rotating planetary gear assembly and relocating the oil pump assembly to the opposite hand rotation.

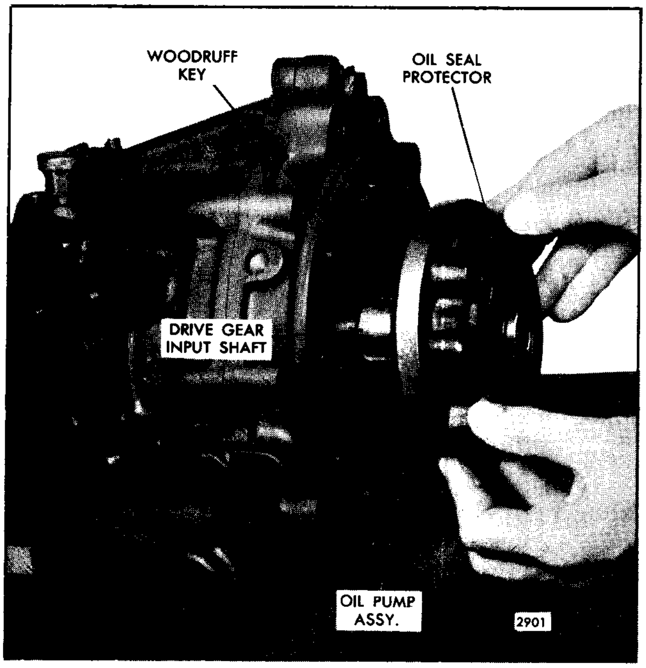

Fig. 87 - Installing Oil Pump Assembly on Input Shaft and Adaptor

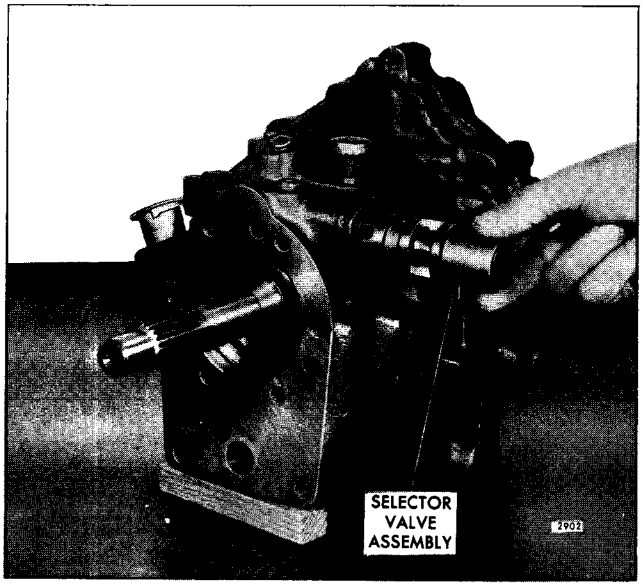

Fig. 88 - Installing Selector Valve Assembly in Gear Housing

g. Start the oil pump assembly with the oil seal lip protector in place, straight over the end of the shaft as shown in Fig. 87; then, push the oil seal lip protector against the shoulder on the shaft. Push the oil pump assembly in and enter the Woodruff key in the shaft straight in the keyway in the inner rotor (gear); continue to push the oil pump assembly in against the gasket in the counterbore of the adaptor.

h. Remove the oil seal lip protector from the oil seal and the drive gear shaft.

i. Rotate the oil pump assembly slightly to the right or left to align the bolt holes, then install the four 5/16" -18 bolts (less lock washers). Tighten the bolts to 13-17 lb-ft torque.

15. Assemble the reverse gear selector valve assembly as follows:

a. Lubricate the outside diameter of the pressure regulator valve with engine oil, then insert the valve into the opening in the end of the selector valve with the open end of the pressure regulator valve facing up.

b. Place the pressure regulator valve spring in the pressure regulator valve and push the valve down until it seats inside the selector valve.

c. Place the pressure regulator valve spring retainer on top of the valve spring with the concave side of the retainer on the spring.

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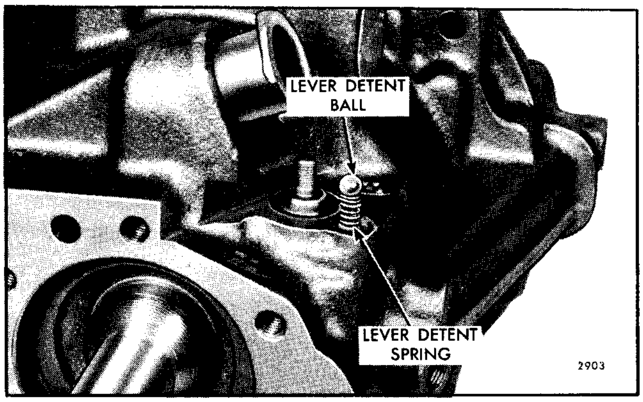


Fig. 89 - Location of Selector Valve Lever Detent Spring and Ball in Gear Housing

d. Place the selector valve, pressure regulator valve, valve spring and valve spring retainer assembly in a 1-1/4" inside diameter sleeve and rest it on the bed of an arbor press as shown in Fig. 20.

e. Place a 3/4" diameter x 2" long round steel rod on top of the valve spring retainer and under the ram of the press (Fig. 20).

f. Hold the steel rod to keep it from tipping; then, carefully press the valve spring and retainer straight down into the selector valve until the snap ring groove inside of the selector valve is exposed.

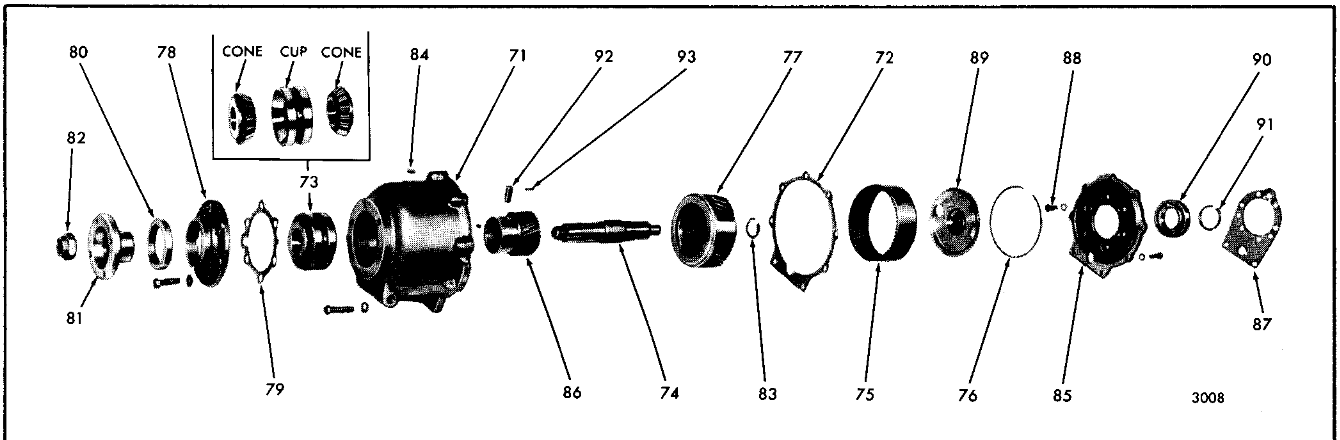
CAUTION: The valve spring retainer is a very close fit in the bore of the selector valve. Extreme care must be used when pressing the spring retainer down in the bore of the selector valve so as not to allow the edge of the retainer to catch on the top of the bore or the snap ring groove in the selector valve and damage the retainer.

g. While holding the valve spring and retainer down in the selector valve, install the snap ring in the groove inside of the selector valve.

h. Install a new selector valve seal ring in the groove at the small or threaded end of the selector valve.

16. Install the reverse gear selector valve assembly in the reverse gear housing as follows:

a. Lubricate the outside diameter of the selector valve and seal ring with engine oil, then insert the small or threaded end of the selector valve in the opening, on the right rear side of the gear housing as shown in Fig. 88, with the flat spot on the shoulder of the selector valve, at the threaded end, facing down toward the bottom of the gear housing. Push the selector valve straight into the gear housing until it contacts the shoulder in the housing.



71. Housing--Reduction Gear
72. Gasket--Gear Housing
73. Bearing Assy.--Drive Shaft
74. Shaft--Reduction Gear Drive
75. Ring Gear--Reduction Gear Planetary
76. Snap Ring--Planetary Ring Gear
77. Gear Assy.--Reduction Gear Planetary
78. Retainer--Drive Shaft Bearing
79. Gasket--Bearing Retainer
80. Oil Seal--Bearing Retainer
81. Drive Flange
82. Nut--Drive Flange
83. Snap Ring--Planetary Gear
84. Plug--Reduction Gear Housing Expansion
85. Adaptor--Reduction Gear
86. Sun Gear--Reduction Gear
87. Gasket--Adaptor
88. Bolt--Adaptor Nylock
89. Gear--Reduction Gear Input
90. Bearing--Reduction Gear Input Gear
91. Snap Ring--Input Gear Bearing
92. Pin--Reduction Gear Sun Gear Dowel
93. Pin--Sun Gear Dowel Pin Roll

Fig. 90 - Reduction Gear Details and Relative Location of Parts (1.5:1 Ratio)

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b. Affix a new gasket to the rear face of the selector valve cover.

c. Place the selector valve cover and gasket over the selector valve opening in the gear housing and install the three 1/4" -20 bolts and lock washers. Tighten the bolts to 7-9 lb-ft torque.

d. Turn the reverse gear housing assembly on its side so the selector valve will be in a vertical position with the threaded end of the selector valve facing up.

e. Place the selector valve lever detent spring in the drilled hole in the gear housing just above the threaded end of the selector valve (Fig. 89).

f. Place the 5/16" steel ball on top of the selector valve lever detent spring (Fig. 89).

g. Place the selector valve lever over the end of the selector valve with the flat portion in the large hole of the lever over the flat on the end of the selector valve and against the steel ball. Then install a flat washer, lock washer and nut. Tighten the nut to 12-16 lb-ft torque.

17. Insert the tapered end of the lubricating oil strainer assembly in the opening in the lower right-hand side of the gear housing (Fig. 43); then, install the reducing bushing, oil return tube, nipple and elbow assembly (current marine gears), or install the annular gasket and oil drain plug (former marine gears) and tighten securely.

18. If removed, install the breather assembly, pipe plugs and lubricating oil fitting in the reverse gear housing.

Assemble Reduction Gear

The assembly procedure for the various reduction gears will vary depending upon the ratio. The assembly procedure for the 1.5:1 ratio reduction gear is covered separately. Due to the close similarity of the 2.1:1, 2.5:1 and 3:1 ratio reduction gears, the assembly procedure for these gears will be covered as a single procedure and the differences noted therein.

With the reduction gear parts cleaned and inspected and the necessary parts on hand, the reduction gear may be assembled as outlined below.

Assemble 1.5:1 Ratio Reduction Gear - Refer to Figs. 4 and 90 for the location of various parts and assemble as follows:

1. Install the ring gear (75), adaptor (85) and bearing (90) on the reduction gear input gear (89) and attach the reduction gear adaptor assembly to the reverse gear housing as follows:

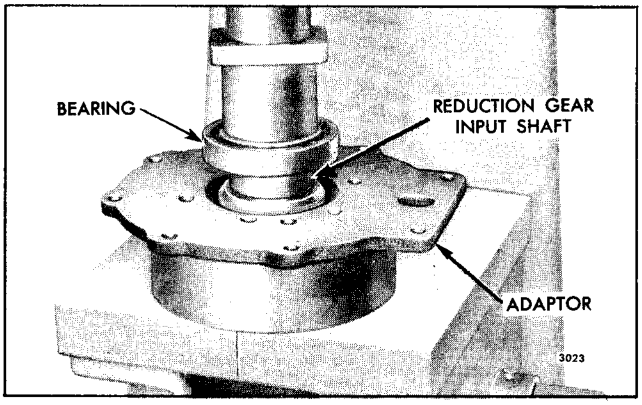

Fig. 91 - Installing Reduction Gear Input Gear Bearing on Input Gear (1.5:1 Ratio)

a. Place the reduction gear planetary ring gear on a bench with the end which incorporates a snap ring groove in the inside diameter facing up.

b. Position the reduction gear input gear over the top of the planetary ring gear. Align the splines in the flange of the input gear with the splines inside the ring gear; then, lower the input gear straight in the ring gear until it seats on the shoulder in the ring gear.

c. Install the snap ring in the groove in the ring gear.

d. Place the reduction gear adaptor over the hub of the input gear with the forward face (flat surface) facing up and rest it on the input gear.

e. Lubricate the inside diameter of the reduction gear input gear bearing with engine oil; then, start the bearing, numbered end up, straight on the hub of the input gear.

f. Place the bearing, adaptor, input gear and ring gear assembly, bearing side up, on the bed of an arbor press.

g. Place a sleeve on the inner race of the bearing and a steel plate on top of the sleeve as shown in Fig. 91. Then press the bearing straight on the hub of the input gear and against the shoulder on the gear.

h. Install the snap ring in the ring groove in the hub of the input gear with a pair of snap ring pliers J 5586 as shown in Fig. 39. Be sure the snap ring is fully seated in the groove.

i. Affix a new gasket to the forward face of the adaptor with the bolt and oil holes in alignment.

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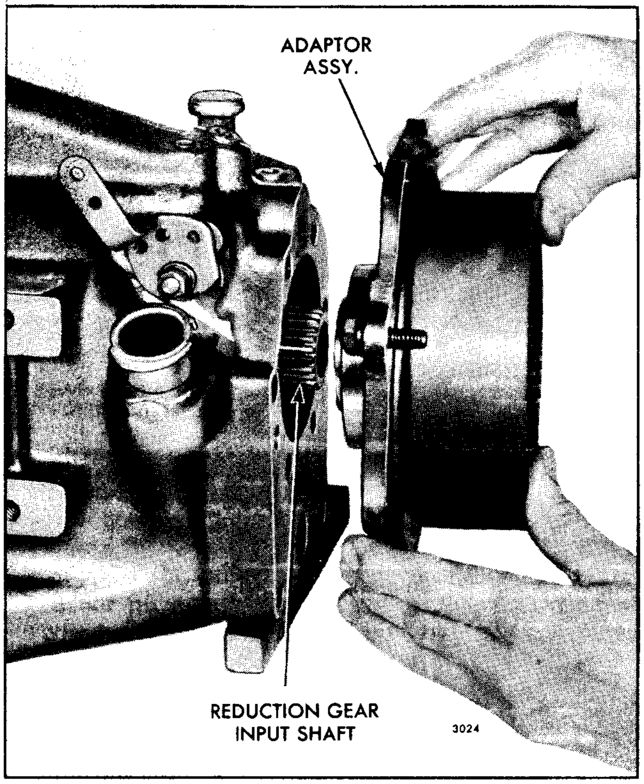

Fig. 92 - Installing Reduction Gear Adaptor, Input Gear, Ring Gear and Bearing Assembly to Reverse Gear Housing (1.5:1 Ratio)

j. On the reverse gear assembly incorporating the oil filler tube, install a 3/8" -16 reduction gear housing adaptor to gear housing bolt and lock washer in the bolt hole of the adaptor adjacent to the oil filler tube (Fig. 92).

k. Lubricate the outside diameter of the reduction gear input gear bearing with engine oil; then, start the hub of the input gear straight on the end of the reduction gear input shaft as shown in Fig. 92 with the splines of the gear and shaft in alignment. Push the assembly straight forward on the input shaft and enter the bearing straight into the bearing bore in the reverse gear housing, then continue to push the assembly forward until the bearing seats on the shoulder in the gear housing.

If necessary, tap the input gear bearing in the gear housing by tapping on the rear face of the input gear with a plastic hammer.

l. Raise the adaptor slightly and enter the counterbore of the adaptor straight over the rear face of the bearing. Align the bolt holes in the adaptor with the bolt holes in the gear housing, then push the adaptor against the reverse gear housing.

m. Install six new 7/16" -14 Nylock bolts and lock washers with external teeth in the six countersunk bolt holes in the adaptor through the two access holes in the flange of the input gear as shown in Fig. 14. Tighten the bolts to 46-50 lb-ft torque.

2. Install the reduction gear sun gear in the reduction gear housing as follows:

a. Place the reduction gear housing on a bench with the forward face of the gear housing facing up.

b. Insert the sun gear dowel pin in the dowel pin hole in the gear housing with the roll pin hole in the dowel pin towards the outside of the gear housing and in alignment with the roll pin hole in the gear housing as shown in Fig. 93.

c. Lubricate the outside diameter of the sun gear hub, where it makes contact with the reduction gear housing, with engine oil.

d. Start the hub of the sun gear straight into the bore of the reduction gear housing with the dowel pin hole in the side of the hub in alignment with the dowel pin as shown in Fig. 93. Lower the sun gear until the hole in the hub of the sun gear is in alignment with the dowel pin, then push the dowel pin in until the roll pin hole in the dowel pin is in alignment with the roll pin hole in the gear housing.

e. Start the roll pin in the roll pin hole in the gear housing; then, drive the roll pin down into the dowel pin, until it is flush with the face of the gear housing, with a punch and hammer.

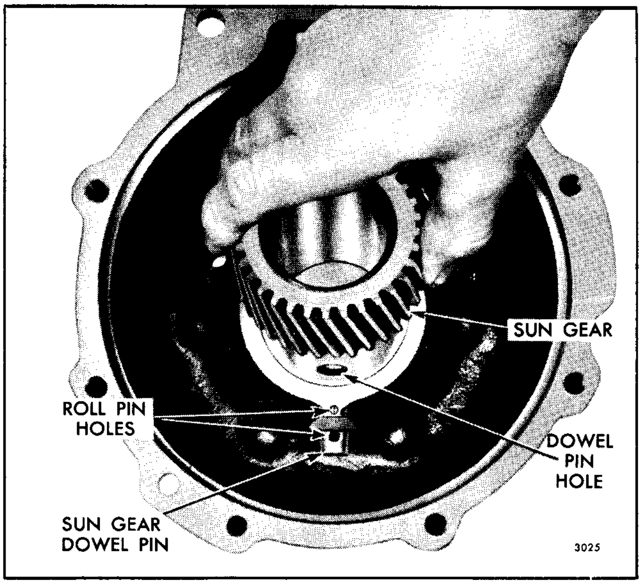

Fig. 93 - Installing Sun Gear in Reduction Gear Housing (1.5:1 Ratio)

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3. Install the reduction gear drive shaft bearing in the reduction gear housing as follows:

a. Note the matchmarks previously placed on the reduction gear drive shaft bearing cone and cup at disassembly.

CAUTION: When installing the same bearing that was removed from the reduction gear housing, it must be installed in its original position.

b. Lubricate the rollers of the inner bearing cone with engine oil, then place the inner bearing cone down in the bearing bore in the rear face of the reduction gear housing with the (tapered) small outside diameter of the cone facing up (Fig. 94).

c. Lubricate the outside diameter of the bearing cup with engine oil, then start it straight into the bearing bore of the reduction gear housing, with the matchmarked inner cone side of the cup facing down.

d. Support the forward face of the reduction gear housing on the bed of an arbor press. Place a steel plate on top of the bearing cup and under the ram of the press as shown in Fig. 95. Then press the bearing cup straight into the gear housing until it seats on the shoulder in the housing.

e. Lubricate the rollers of the outer bearing cone with engine oil, then place it down in the bearing cup with the (tapered) small outside diameter of the cone facing down.

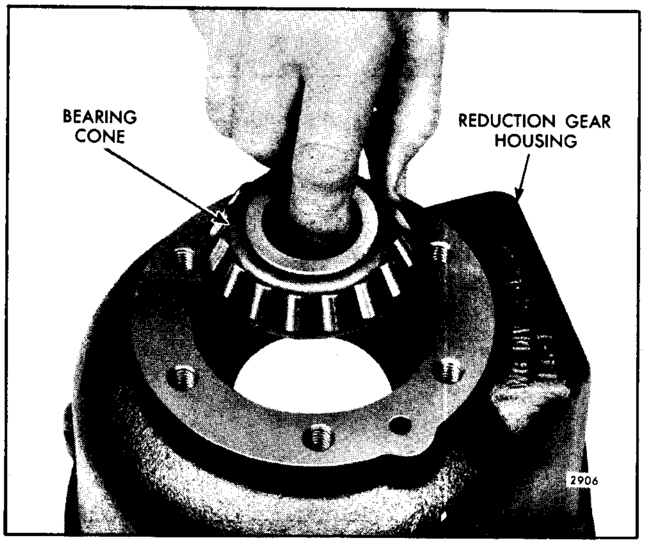

Fig. 94 - Installing Reduction Gear Drive Shaft Inner Bearing Cone in Gear Housing

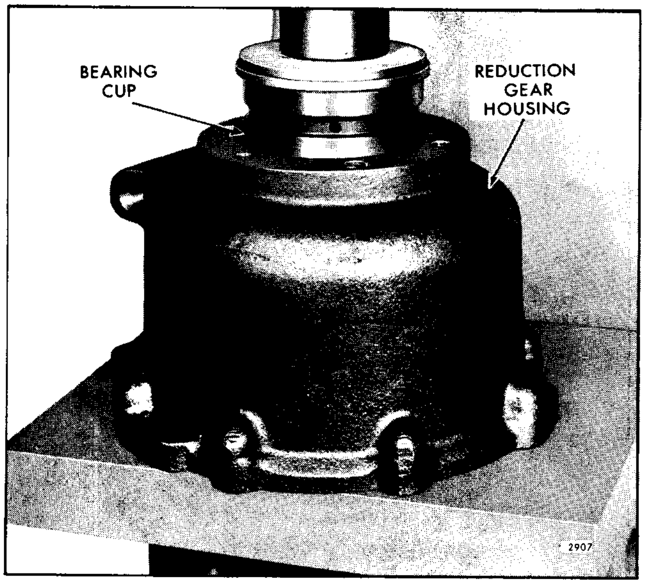

Fig. 95 - Installing Reduction Gear Drive Shaft Bearing Cup in Gear Housing

4. Install a new double-lip oil seal in the reduction gear drive shaft bearing retainer as follows:

NOTE: The current reduction gear includes a double-lip oil seal; the former reduction gear used a single-lip oil seal. Only the double-lip oil seal is serviced.

a. Apply a thin coat of sealing compound to the outside diameter of the bearing retainer oil seal casing.

b. Start the oil seal straight into the bore of the bearing retainer, from the rear face, with the lip of the oil seal facing down.

c. Support the bearing retainer and oil seal on the bed of an arbor press, with the rear face of the retainer and oil seal facing up.

d. Place a steel plate, or tool J 3154-04 with suitable plates, on top of the oil seal as shown in Fig. 96. Then press the oil seal straight into and flush with the outside face of the bearing retainer.

NOTE: If both lips of the double-lip oil seal do not ride on the drive flange, the seal will be ineffective.

5. Attach the reduction gear drive shaft bearing retainer and oil seal assembly to the reduction gear housing as follows:

a. Affix a new gasket to the rear face of the reduction gear housing, with the notch in the inner diameter

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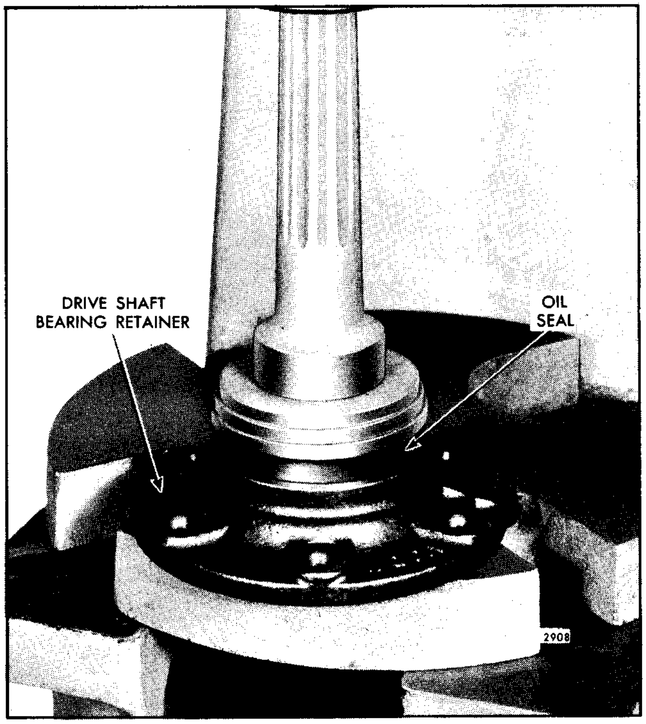

Fig. 96 - Installing Oil Seal in Drive Shaft Bearing Retainer

of the gasket over the oil hole and the bolt holes in the gasket and gear housing in alignment as shown in Fig. 97.

b. Place the bearing retainer straight over the bearing and gasket with the oil drain notch in the retainer directly over the oil hole in the gear housing, and the bolt holes in the retainer and gear housing in alignment as shown in Fig. 97.

c. Install the six 7/16" -14 bolts and lock washers. Tighten the bolts to 46-50 lb-ft torque.

6. Install the reduction gear drive shaft in the reduction gear housing as follows:

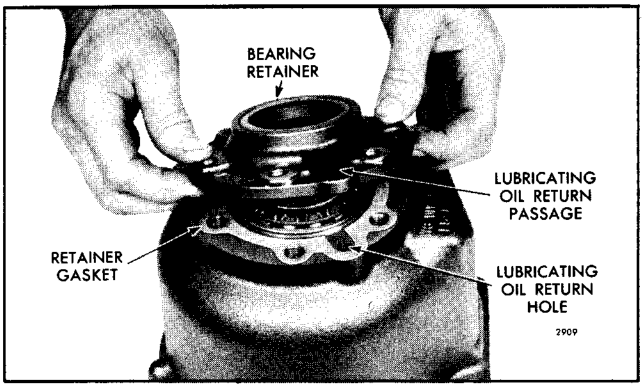

Fig. 97 - Installing Drive Shaft Bearing Retainer on Gear Housing

a. Lubricate the bearing contact surface of the reduction gear drive shaft with engine oil; then, insert the drive flange end (threaded end) of the drive shaft straight through the sun gear and the drive shaft bearing from the forward face of the gear housing as shown in Fig. 98.

b. Lubricate the splines of the drive shaft and the lip of the oil seal with engine oil. Start the drive flange straight over the splines of the drive shaft; then, while holding the drive shaft, push the drive flange tight against the bearing.

If necessary, tap the drive flange on the drive shaft and against the bearing with a plastic hammer.

c. Install the drive flange retaining nut on the drive shaft. Do not tighten it at this time.

7. Install the reduction gear planetary gear assembly on the drive shaft and sun gear as follows:

a. Support the reduction gear housing and drive shaft assembly on a bench with the forward face of gear housing facing up.

b. Lubricate the splines on the forward end of the drive shaft and the pinions of the planetary gear assembly with engine oil; then, start the planetary gear assembly over the forward end of the drive shaft and sun gear as shown in Fig. 36, with the splines in the hub of the planetary gear and the splines of the drive shaft in alignment. Lower the planetary gear assembly on the drive shaft and engage the pinions of the gear assembly with the teeth of the sun gear, then lower the assembly until the snap ring groove in the end of the drive shaft is fully exposed.

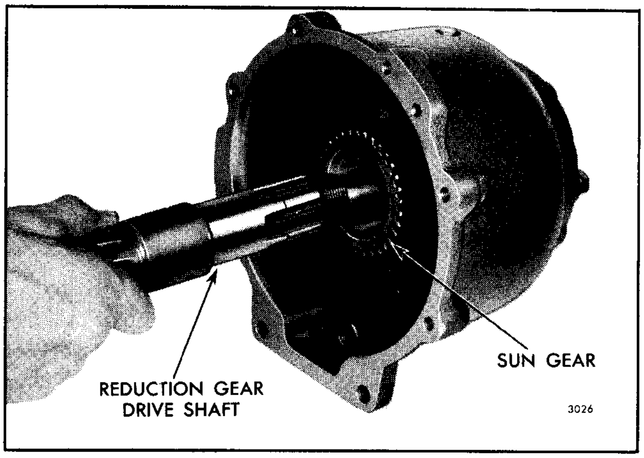

Fig. 98 - Installing Reduction Gear Drive Shaft in Sun Gear and Bearing (1.5:1 Ratio)

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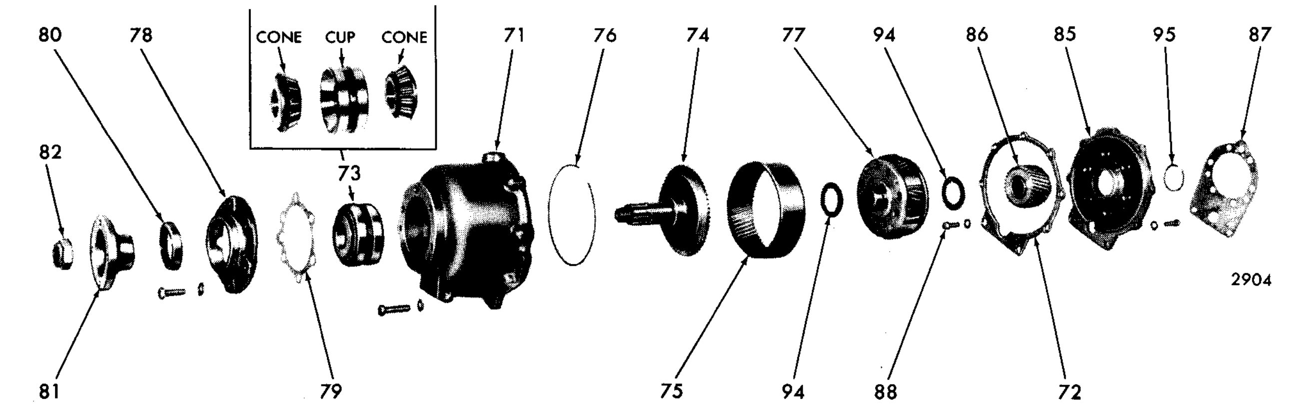


71. Housing--Reduction Gear
72. Gasket--Gear Housing
73. Bearing Assy.--Drive Shaft
74. Shaft Assy.--Reduction Gear Drive
75. Ring Gear--Reduction Gear Planetary
76. Snap Ring--Planetary Ring Gear
77. Gear Assy.--Reduction Gear Planetary
78. Retainer--Drive Shaft Bearing
79. Gasket--Bearing Retainer
80. Oil Seal--Bearing Retainer
81. Drive Flange
82. Nut--Drive Flange
85. Adaptor--Reduction Gear
86. Sun Gear--Reduction Gear
87. Gasket--Adaptor
88. Bolt--Adaptor (Nylock)
94. Thrust Washer--Planetary Gear
95. Snap Ring--Sun Gear

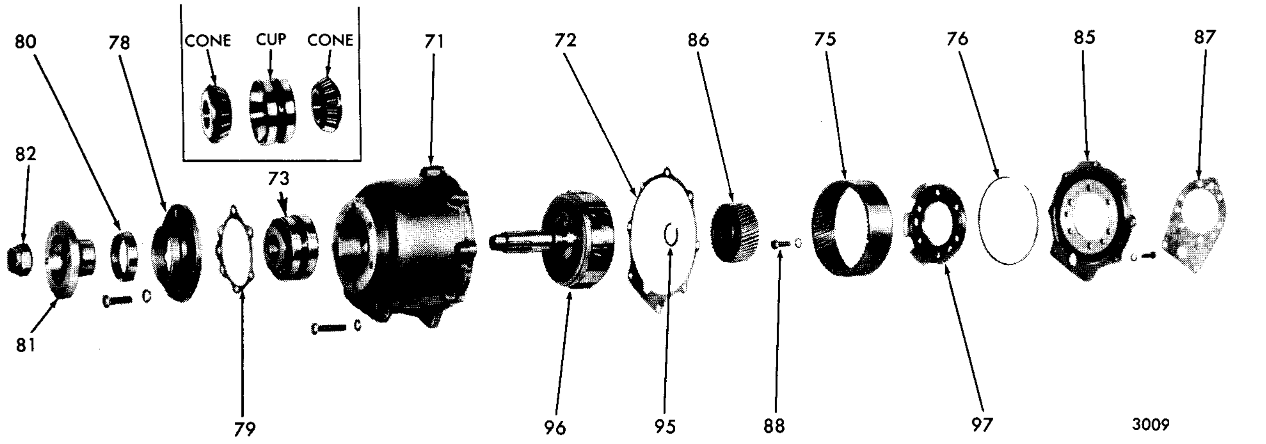
Fig. 99 - Reduction Gear Details and Relative Location of Parts (2.1:1 Ratio)

c. Install the snap ring in the ring groove in the drive shaft, next to the hub of the planetary gear assembly, with a pair of snap ring pliers J 5586 as shown in Fig. 35.

Assemble 2.1:1, 2.5:1 and 3:1 Ratio Reduction Gears - Refer to Figs. 1, 2, 5, 99 and 100 for the location of the various parts and assemble them as follows:

1. On the 2.1:1 ratio reduction gear, install the sun gear (86) in reduction gear adaptor (85) as follows:

a. Place the reduction gear adaptor on a bench with the rear face of the adaptor facing up.



71. Housing--Reduction Gear
72. Gasket--Gear Housing
73. Bearing Assy.--Drive Shaft
75. Ring Gear--Reduction Gear Planetary
76. Snap Ring--Planetary Ring Gear
78. Retainer--Drive Shaft Bearing
79. Gasket--Bearing Retainer
80. Oil Seal--Bearing Retainer
81. Drive Flange
82. Nut--Drive Flange
85. Adaptor--Reduction Gear
86. Sun Gear--Reduction Gear
87. Gasket--Adaptor
88. Bolt--Adaptor (Nylock)
95. Snap Ring--Sun Gear
96. Shaft Assy.--Planetary Gear and Drive
97. Plate--Reduction Gear Ring Gear

Fig. 100 - Reduction Gear Details and Relative Location of Parts (2.5:1 and 3:1 Ratios)

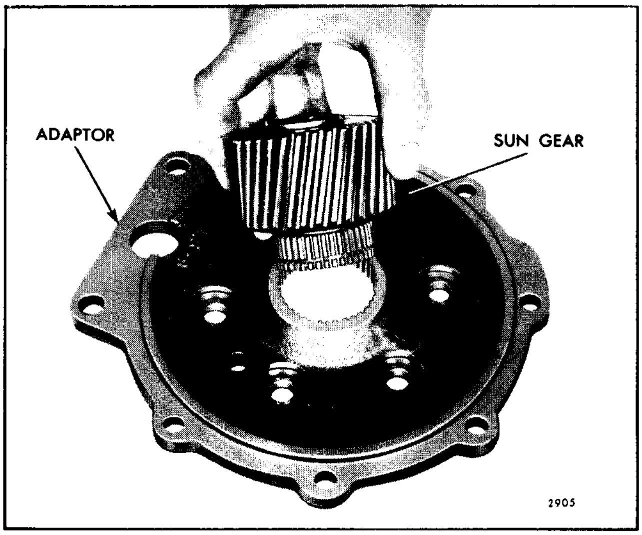


Fig. 101 - Installing Sun Gear in Reduction Gear Adaptor (2.1:1 Ratio)

b. Insert the splined end of the sun gear straight in the hub of the adaptor as shown in Fig. 101 until it seats against the shoulder of the adaptor.

c. Turn the adaptor and sun gear assembly over and rest the rear face of the sun gear on the bench.

d. Install the snap ring in the groove in the splined end of the sun gear with a pair of snap ring pliers J 5586 as shown in Fig. 42.

2. On the 2.5:1 and 3:1 ratio reduction gears, install the reduction gear planetary ring gear plate (97) in the planetary ring gear (75) and the planetary ring gear plate in the reduction gear adaptor (85) as follows:

a. Place the reduction gear planetary ring gear on a bench with the end incorporating the ring groove in its inside diameter facing up.

b. Position the planetary ring gear plate over the top of the planetary ring gear. Align the splines in the outside diameter of the ring gear plate with the splines inside of the ring gear, then lower the plate straight in the ring gear as shown in Fig. 102 until it seats on the shoulder in the ring gear.

c. Install the snap ring in the ring groove in the ring gear, just above the ring gear plate.

d. Lubricate the inside diameter of the reduction gear adaptor with engine oil, then place the adaptor on a bench with the forward face (flat surface) facing down.

e. Position the planetary ring gear plate and ring gear assembly over the top of the adaptor. Align the bolt and oil holes in the ring gear plate with the holes in the adaptor, then start the ring gear plate straight into the bore of the adaptor and push the ring gear plate down until it seats on the adaptor.

Due to the close fit, it may be necessary to tap the ring gear plate lightly at several places with a plastic hammer after it has been started in the adaptor.

3. Attach the reduction gear adaptor assembly to the reverse gear housing on the 2.1:1, 2.5:1 and 3:1 ratio reduction gears as follows:

a. Affix a new gasket to the forward face of the adaptor with the bolt and oil holes in the gasket and the adaptor in alignment.

CAUTION: On the 2:1 ratio reduction gear, the lubrication of the reduction gear planetary gear assembly originates from the oil hole in the upper portion of the reverse gear housing rear face. If the small oil hole in the adaptor is plugged by improper gasket installation, failure of the planetary gear assembly will result.

b. On the reverse gear assembly incorporating the oil filler tube, install a 3/8"-16 reduction gear housing adaptor to gear housing bolt and lock washer in the bolt hole of the adaptor adjacent to the oil filler tube (Fig. 16).

c. On the 2.1:1 ratio reduction gear, place the adaptor and sun gear assembly over the end of the reduction gear input shaft as shown in Fig. 16

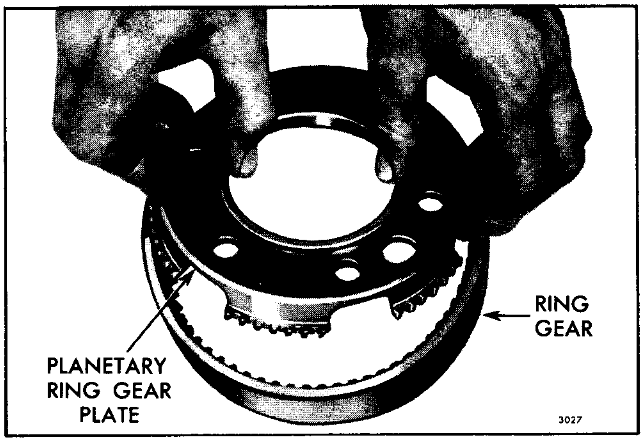


Fig. 102 - Installing Reduction Gear Planetary Ring Gear Plate in Ring Gear (2.5:1 and 3:1 Ratios)

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and enter the flange on the forward face of the adaptor straight into the counterbore of the gear housing. Then push the adaptor up against the gear housing.

On the 2.5:1 and 3:1 ratio reduction gears, place the reduction gear adaptor, planetary ring gear plate and ring gear assembly over the end of the reduction gear input shaft in the same manner as shown in Fig. 18. Start the adaptor straight over the reduction gear input shaft bearing and push it up against the gear housing.

d. Align the bolt holes and install six new 7/16" -14 Nylock bolts and lock washers with external teeth in the six countersunk bolt holes. Tighten the bolts to 46-50 lb-ft torque.

4. On the 2.5:1 and 3:1 ratio reduction gears, install the reduction gear sun gear on the reduction gear input shaft as follows:

a. Lubricate the splines of the reduction gear input shaft with engine oil. Then start the sun gear straight on the input shaft with the splines in the hub of the sun gear and the splines on the input shaft in alignment. Push the sun gear on the input shaft until the snap ring groove in the input shaft is fully exposed.

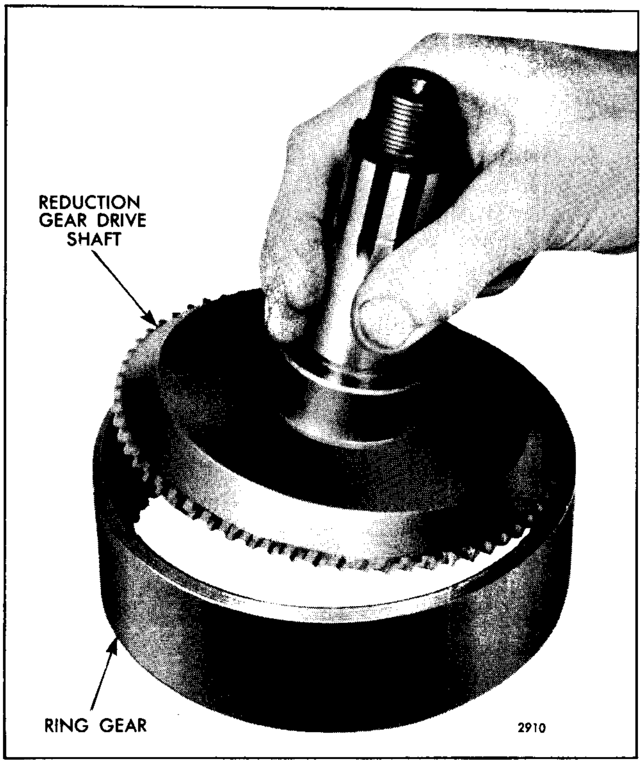

Fig. 103 - Installing Reduction Gear Drive Shaft in Ring Gear (2.1:1 Ratio)

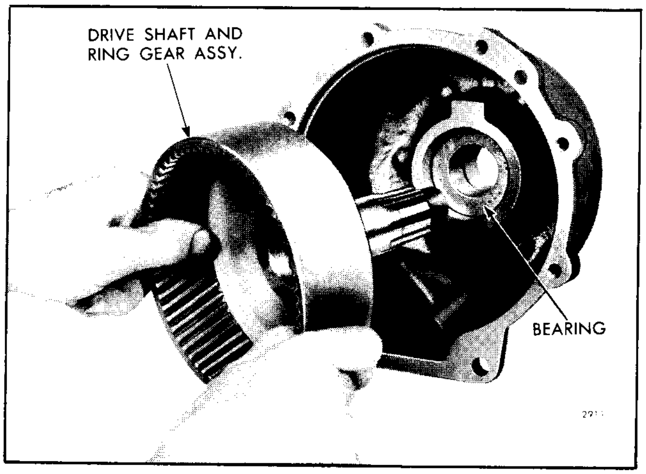

Fig. 104 - Installing Reduction Gear Drive Shaft and Ring Gear Assembly in Gear Housing (2.1:1 Ratio)

b. Install the snap ring in the ring groove in the reduction gear input shaft, next to the sun gear, with a pair of snap ring pliers J 5586 as shown in Fig. 17.

5. Perform Steps 3, 4 and 5 under *Assemble 1.5:1 Ratio Reduction Gear* above, then proceed with Step 6 below.

6. On the 2.1:1 ratio reduction gear, install the reduction gear drive shaft in the reduction gear planetary ring gear as follows:

a. Place the planetary ring gear on a bench with the end incorporating the ring groove in the inside diameter facing up.

b. Position the reduction gear drive shaft over the top of the planetary ring gear. Align the splines in the flange of the drive shaft with the splines inside of the ring gear, then lower the drive shaft straight in the ring gear as shown in Fig. 103 until it seats on the shoulder in the ring gear.

c. Install the snap ring in the ring groove just above the reduction gear drive shaft flange.

7. Install the reduction gear drive shaft and ring gear assembly or the reduction gear drive shaft and planetary gear assembly in the reduction gear housing as follows:

a. Place the reduction gear housing on its side on a bench. Lubricate the outside diameter of the reduction gear drive shaft and ring gear assembly

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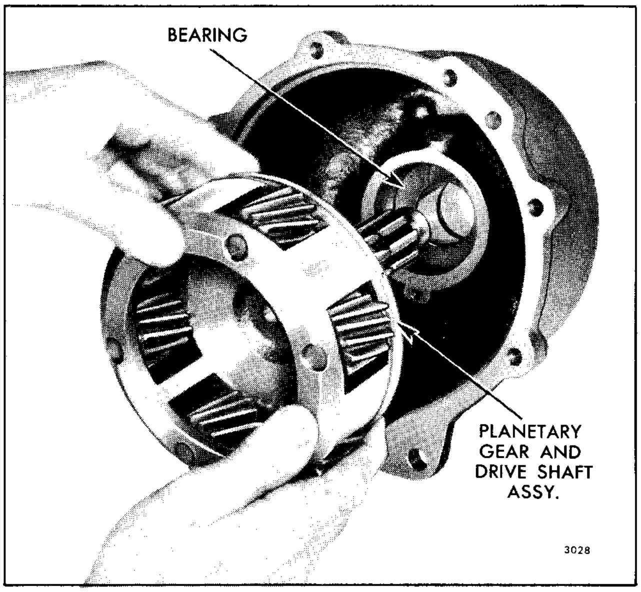

Fig. 105 - Installing Reduction Gear Drive Shaft and Planetary Gear Assembly in Gear Housing (2.5:1 and 3:1 Ratios)

or the drive shaft and planetary gear assembly with engine oil. Then insert the end of the drive shaft straight through the reduction gear drive shaft bearing from the forward face of the gear housing as shown in Figs. 104 or 105.

b. On the 2.1:1 ratio reduction gear, place a 4" square wood block inside the ring gear and against the forward face of the reduction gear drive shaft, then stand the reduction gear housing and drive shaft assembly up and rest it on the wood block.

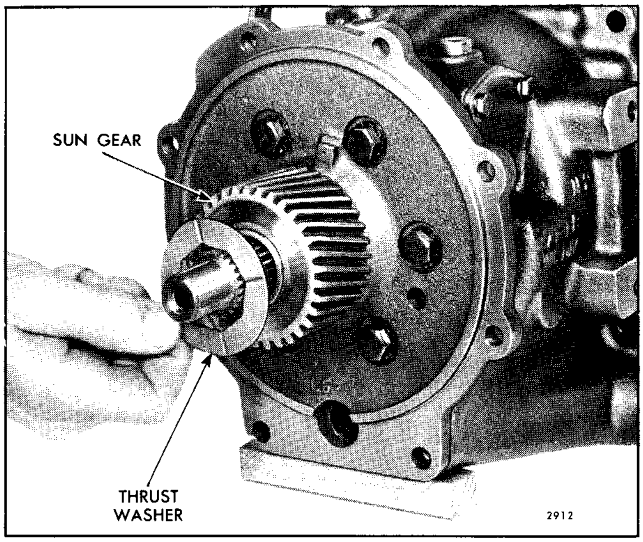

Fig. 106 - Installing Thrust Washer on Hub of Sun Gear (2.1:1 Ratio)

On the 2.5:1 and 3:1 ratio reduction gears, place a 1" x 6" x 6" wood block against the planetary gear assembly, then stand the reduction gear housing and drive shaft assembly up and rest it on the wood block.

c. Lubricate the splines of the drive shaft and the lip of the oil seal with engine oil; then, start the drive flange on the splined end of the drive shaft and push it down tight against the bearing.

If necessary, tap the drive flange on the drive shaft with a plastic hammer until it contacts the bearing.

d. Install the drive flange retaining nut on the drive shaft. Do not tighten it at this time.

8. On the 2.1:1 ratio reduction gear, install the reduction gear planetary gear assembly and thrust washers on the reduction gear input shaft and sun gear as follows:

NOTE: The planetary gear assembly for the left-hand rotation reduction gear assembly is identified by two drill spots on the rear face of the planetary cage.

a. Place the reverse gear assembly on a bench with the reduction gear input shaft in a horizontal position, with a small wood block directly under the rear bottom side of the gear housing (Fig. 106).

b. Lubricate both sides of the planetary gear thrust washer with engine oil. Then place the thrust washer over the end of the reduction gear input shaft and against the rear face of the sun gear as shown in Fig. 106.

c. Lubricate the pinions of the planetary gear assembly with engine oil. Then place the planetary gear assembly over the end of the input shaft with the internal splined hub end of the gear assembly out as shown in Fig. 13. Engage the pinion gears of the planetary gear assembly with the teeth of the sun gear and rotate the gear assembly slightly to align the splines in the hub of the cage with the splines on the reduction gear input shaft. Then push the gear assembly against the thrust washer.

d. Lubricate the second planetary gear thrust washer with engine oil. Then place it over the input shaft and hub of the planetary gear and against the rear face of the planetary gear assembly as shown in Fig. 107.

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9. Attach the reduction gear assembly to the reduction gear adaptor as follows:

a. Affix a new gasket to the bolting flange of the reduction gear adaptor with the notch in the inner diameter of the gasket over the oil return hole in the lower (square) portion of the adaptor and the bolt holes in the gasket and adaptor in alignment.

b. On the 1.5:1 ratio reduction gear, lubricate the reduction gear drive shaft bushing in the end of the reduction gear input shaft with engine oil.

On the 2.1:1 ratio reduction gear, lubricate the reduction gear input shaft bushing in the center of the reduction gear drive shaft with engine oil.

c. Position the reduction gear assembly in back of the reverse gear assembly with the oil hole in the lower portion of the reduction gear housing in alignment with the oil hole in the lower portion of the reduction gear adaptor (Fig. 12).

d. On the 1.5:1 ratio reduction gear, place the reduction gear assembly up against the planetary ring gear and engage the teeth of the pinion gears with the teeth of the ring gear by rotating the drive flange slightly. Then carefully push the reduction gear assembly forward and enter the forward end of the reduction gear drive shaft straight into the bushing in the end of the reduction gear input shaft.

On the 2.1:1 ratio reduction gear, place the reduction gear assembly up against the planetary gear assembly and engage the teeth of the ring gear with the teeth of the pinion gears by rotating the drive flange slightly. Then carefully push the reduction gear assembly straight forward and enter the end of the reduction gear input shaft straight into the bushing in the center of the reduction gear drive shaft.

On the 2.5:1 and 3:1 ratio reduction gears, place the reduction gear assembly up against the planetary ring gear and sun gear and engage the teeth of the pinion gears with the teeth of the ring gear and the sun gear by rotating the drive flange slightly.

e. Push the reduction gear assembly up against the adaptor with the bolt holes in the adaptor in alignment with the bolt holes in the gear housing. Then enter the pilot on the rear face of the adaptor into the bore of the gear housing.

f. Install the two 7/16" -14 bolts and lock washers in the two holes at the bottom side of the gear housing, and the six 3/8" -16 bolts and lock washers in the six remaining bolt holes in the forward face of the adaptor.

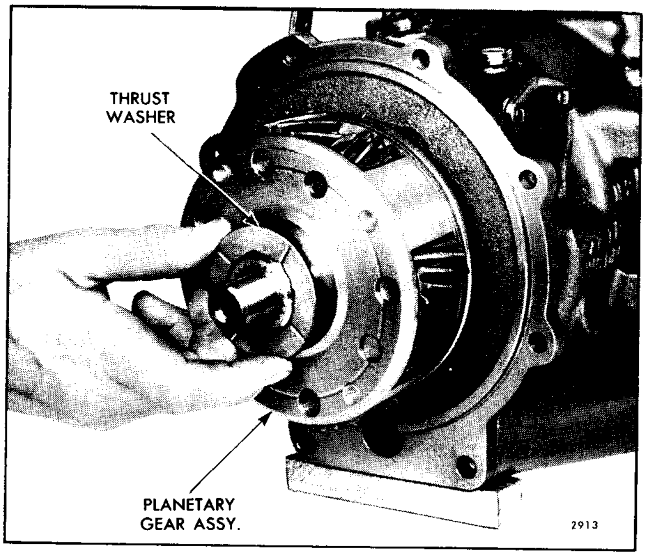

Fig. 107 - Installing Thrust Washer on Hub of Planetary Gear Assembly (2.1:1 Ratio)

g. Tighten the 3/8" -16 bolts to 30-35 lb-ft torque and the 7/16" -14 bolts to 46-50 lb-ft torque.

10. Attach a spanner wrench to the drive flange, as shown in Fig. 11, to prevent it from turning. Then, while holding the reverse and reduction gear from moving, attach a wrench to the drive flange nut (Fig. 11) and tighten it to 150-200 lb-ft torque.

11. On the former reverse and reduction gear units, install the lubricating oil fitting in the lower right-hand side of the reduction gear housing, if removed.

Attach Reverse Gear to Engine

With the reverse and reduction gear assembled, refer to Figs. 7 and 8 and proceed as follows:

1. If removed, attach the marine gear drive coupling to the engine flywheel.

2. Install a 7/16" -14 eyebolt in the top bolt hole at each side of the reverse gear housing (Fig. 9).

3. Support the reverse and reduction gear assembly with a rope sling and a chain hoist as shown in Fig. 9, then position the assembly at the rear of the flywheel housing adaptor, with the drive gear input shaft in line with the center of the drive coupling attached to the flywheel.

4. Lubricate the splines of the input shaft with engine oil. Push the gear assembly straight forward and enter

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the input shaft straight into the splines of the drive coupling. Then push the gear assembly up against the flywheel housing adaptor and enter the pilot on the gear housing adaptor straight in the bore of the flywheel housing adaptor.

5. Align the bolt holes in the gear housing with the holes in the flywheel housing adaptor, then install the six 7/16" -14 bolts and lock washers. Tighten the bolts to 46-50 lb-ft torque.

6. Remove the chain hoist, rope sling and eyebolts from the reverse gear housing.

7. Attach the two rear engine supports to the sides of the reverse gear housing.

8. Refer to Figs. 7 and 8 and connect the oil cooler return tube to the elbow at the lower right-hand side of the reverse gear housing on current marine gears (except current 2.1:1 marine gear), or the lower right-hand side of the reduction gear housing on former marine gears or at the top of the reduction gear housing on current 2.1:1 marine gears.

9. Connect the reverse gear to oil cooler tube to the elbow at the top of the reverse gear housing.

10. Refill the marine gear with lubricating oil as specified under *Lubrication*.

11. Start and run the engine and marine gear unit at idle speed for a few minutes to fill the lubrication system. Stop the engine, then immediately check the oil level in the marine gear. Bring the oil level up to the FULL mark on the dipstick. Do not overfill.

OIL COOLER

In order to provide additional cooling for the lubricating oil used in the marine gear, a separate oil cooler, similar to the engine lubricating oil cooler, is mounted at the heat exchanger. Thus, sufficient additional cooling is provided to insure that normal operating temperatures are maintained in the marine gear oil system under all conditions of speed and load in both forward and reverse.

On current 6 and 8V engines, the oil cooler core and cover is a one piece assembly mounted in the heat exchanger housing directly below the heat exchanger core. On former engines, the oil cooler core was mounted on the side of the engine.

Remove the oil cooler core for cleaning and inspection as follows:

The oil cooler core should be removed and cleaned periodically, or at the time of each engine or marine gear overhaul.

1. Drain the engine cooling system.

2. Disconnect the two marine gear oil tubes from the elbows in the oil cooler cover.

NOTE: Tag the oil tubes, inlet and outlet, for future reference.

3. Remove the bolts and lock washers securing the oil cooler cover to the heat exchanger. If necessary, tap the edge of the oil cooler cover with a plastic hammer to loosen it.

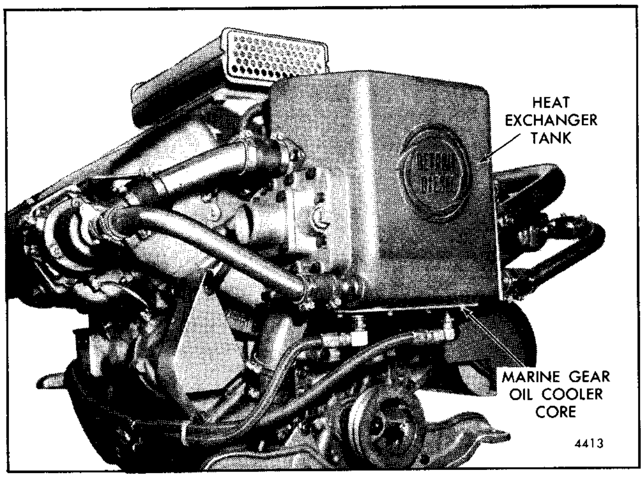

Fig. 108 - Typical Marine Gear Oil Cooler Core Mounting

4. Remove the gasket from the oil cooler cover or heat exchanger.

5. Clean and pressure check the oil cooler core as outlined in Section 4.4.

6. Use a new gasket and install the oil cooler core by reversing the procedure for removal.

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SHOP NOTES - TROUBLE SHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

WARNER MARINE GEARS - 73 SERIES

The 73 series Warner marine gears (Fig. 1) have replaced the 72 series marine gears on 6V-53 engines effective with engine serial number 6D-92538. The capacity of the new 73 series gears permits 6V-53 engine application for both pleasure and work boats. The former 72 series gears were limited to pleasure craft only.

The current 73 series gear assemblies differ from the 72 series gear assemblies as follows:

1. The new direct drive gear assemblies are 2.03 " longer and the new reduction gear assemblies are 1.64 "longer.

2. The span between the gear support pads is 9 1/2 ". The span on the former gears was 9 ".

3. The propeller drive flange diameter is 5 3/4 " and has six .520 " diameter holes on a 4 3/4 " bolt circle. The former flange is 5 " in diameter and has four .453 " diameter holes on a 4 1/4 " bolt circle.

4. The 73 series 2:1 reduction gear assemblies differ from the 72 series 2:1 assemblies in that shaft rotation is reversed within the gear assembly.

NOTE: When converting a 2:1 reduction gear assembly from a 72 series to the 73 series gear, the propeller rotation reverses. On singe engine installations, the propeller must be changed from LH to RH if the installation utilizes a RH engine. Conversely, the propeller must be changed from RH to LH if the installation is a LH engine. On dual engine installations, the propellers must be interchanged which will provide *inboard* turning propeller rotation. To maintain the same outboard propeller rotation as formerly achieved with the 72 series 2:1 reduction ratio, the propellers must be interchanged and the engine positions reversed, port to starboard and starboard to port. Therefore, when used with a 73 series 2:1 reduction ratio gear assembly, engine model 5062-3000 which is normally the starboard engine becomes the port engine and engine model 5062-7000 which is normally the port engine becomes the starboard engine.

When converting to the 73 series gear assembly, new gear mounting bolts and a new 5 3/4 " propeller half-coupling with its attaching parts are required. In addition, either the engine must be moved forward or the propeller shaft shortened to compensate for the increased length of the new gear assembly. Because of the increased span between the gear mounting pads, new holes are necessary in the mounting rails. The propeller change or engine relocation port to starboard and starboard to port is required only with the 2:1 ratio 73 series gear assemblies (2.5:1 ratio not available on 73 series). Gear lubricating oil lines to and from the cooler are also affected when converting from the 72 series to the 73 series assemblies.

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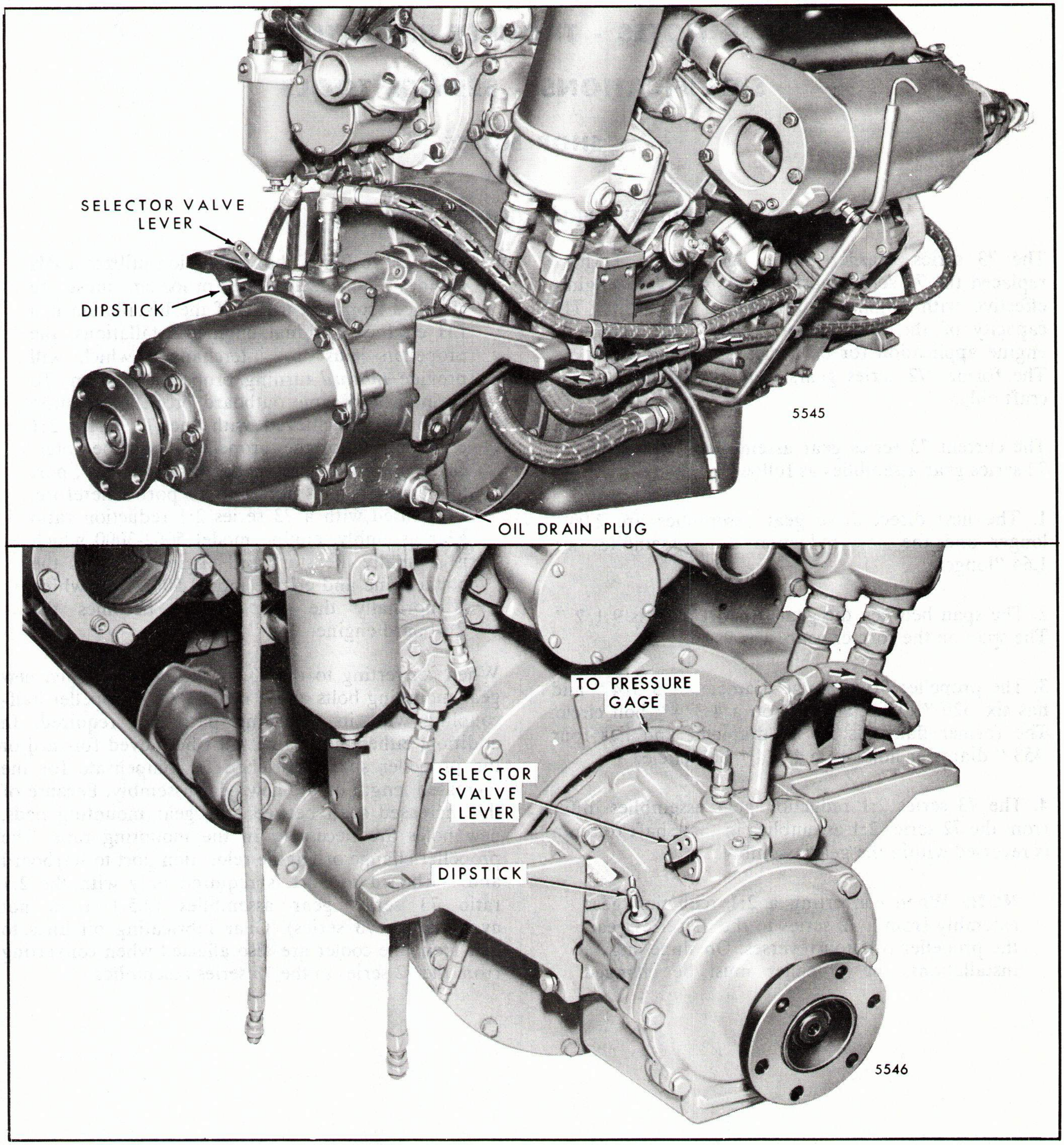

Fig. 1 Views of 73 Series Warner Marine Gear

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TROUBLESHOOTING

Chart 1

GEAR INOPERATIVE

DRIVE SHAFT DOES NOT ROTATE WITH SELECTOR VALVE IN FORWARD OR REVERSE

CHECK FOR

1. LOW OIL PRESSURE
2. HIGH OIL TEMPERATURE
3. FAILURE OF PLANETARY ASSEMBLY
4. FAILURE OF REDUCTION GEAR
5. FAILURE OF REDUCTION GEAR INPUT SHAFT OUTER BUSHINGS

SUGGESTED REMEDY

1. Check the following items:

a. Low oil supply. Check for correct dipstick. Add oil (refer to *Lubrication* in Section 9.1.3).

b. Faulty oil gage. Replace the gage. Oil gage slow to register due to air or obstruction in the oil gage line. Clean and bleed the oil gage line.

c. Plugged oil inlet screen. Clean the screen.

d. Oil pressure relief valve scored and sticking. Remove the relief valve. Clean the valve and valve bore in the selector valve housing with crocus cloth to free up the valve or replace.

e. Defective piston seal rings. Replace the seal rings.

f. Defective oil pump. Check for wear and sheared drive key. Replace, if necessary.

2. Check the following items:

a. Low oil supply. Check for correct dipstick. Add oil (refer to *Lubrication* in Section 9.1.3).

b. Low water level in cooling system. Add water and check for leaks.

c. Clogged or dirty oil cooler element. Remove and clean the oil cooler element (refer to Section 4.4).

3. Remove the reverse planetary assembly and check for defective or damaged parts. Replace the planetary assembly, if necessary.

4. Remove the reduction gear and planetary assembly and check for defective or damaged parts. Replace the defective or damaged parts.

5. Worn bushings and misalignment of the oil holes in the bushings with the oil holes in the gear housing. If worn excessively or bushings are out of alignment, replace the bushings.

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Chart 2

GEAR DRAGGING

CHECK FOR

1. DEFECTIVE FORWARD OR REVERSE CLUTCH PLATES
2. DEFECTIVE FORWARD OR REVERSE CLUTCH PISTON RELEASE SPRINGS
3. BINDING IN REVERSE PLANETARY ASSEMBLY
4. BINDING IN REDUCTION GEAR

SUGGESTED REMEDY

1. Forward and reverse clutch plates warped and sticking. Remove the clutch plates and replace.

2. Forward and reverse clutch piston release springs broken or weak. Replace the springs.

3. Check the following items:

   a. Bearings and gears worn excessively in the planetary assembly. Replace the planetary assembly.

   b. Input shaft bearing worn excessively causing misalignment of the input shaft. Replace the necessary parts.

4. Check the following items:

   a. Bearings and gears worn excessively in the planetary assembly. Replace the planetary assembly.

   b. Bushings in the reduction gear input shaft and drive shaft worn excessively causing misalignment of the input and drive shaft. Replace the necessary parts.

   c. Reduction gear drive shaft roller bearing worn excessively. Replace the bearing.

Chart 3

GEAR SLIPPING OR SLOW TO ENGAGE

WITH SELECTOR VALVE IN FORWARD OR REVERSE POSITION

CHECK FOR

1. LOW OIL PRESSURE
2. WORN FORWARD OR REVERSE CLUTCH PLATES

SUGGESTED REMEDY

1. Low oil pressure (refer to Chart 1, Item 1).

2. Remove the forward and reverse clutch plates and check for wear. If worn excessively, replace the clutch plates.

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Chart 4

INTERNAL AND EXTERNAL LEAKS

CHECK FOR

1. EXCESSIVE OIL IN FLYWHEEL HOUSING

2. WATER IN LUBRICATING OIL OR OIL IN COOLING WATER

3. OIL ON EXTERIOR OF MARINE GEAR UNIT

SUGGESTED REMEDY

1. Defective reverse gear oil pump oil seal, pump to adaptor gasket or loose oil pump bolts. Replace the oil seal and gasket. Tighten the oil pump bolts.

2. Check the following items:

   a. Hole in the oil cooler element permitting water to seep into the oil compartment, or oil seeping into the engine cooling system due to the oil pressure being greater than the water pressure. Replace the oil cooler element.

   b. Oil cooler gaskets damaged. Replace the oil cooler gaskets.

3. Check the following items:

   a. Reverse gear housing adaptor, reduction gear adaptor, reduction gear housing and bearing retainer gaskets damaged.

   b. Defective selector valve "O" seal ring. Replace the seal ring.

   c. Defective reduction gear drive shaft bearing retainer oil seal. Replace the oil seal.

   d. Loose reverse gear to oil cooler supply and return oil tube fittings. Tighten all of the fittings.

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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 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 1 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

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EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb-ft)	TORQUE (Nm)
Selector valve lever to selector valve nut	5/16-24	12-16	16-22
Reverse gear housing adaptor to gear housing bolts	3/8 -16	28-30	38-41
Drive flange nut (elastic stop)	1 -20	100-200	136-271
Drive flange nut (Marsden)	1 -20	150-200	204-271

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SERVICE TOOLS

TOOL NAME	TOOL NO.
Oil seal removing and replacing tool set	J 3154-04
Snap ring pliers	J 5586
Universal remover and installer tool handle	J 7079-2
Gear housing bushing remover and installer	J 8466
Oil pump oil seal installer	J 8467
Spring tester	J 22738-02

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SECTION 12

SPECIAL EQUIPMENT

CONTENTS

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Vacuum Pump 12.3

Air Compressor 12.4

Cold Weather Starting 12.6
Hydrostarter System 12.6.1

Trouble Shooting - Specifications - Service Tools 12.0

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BILGE PUMP

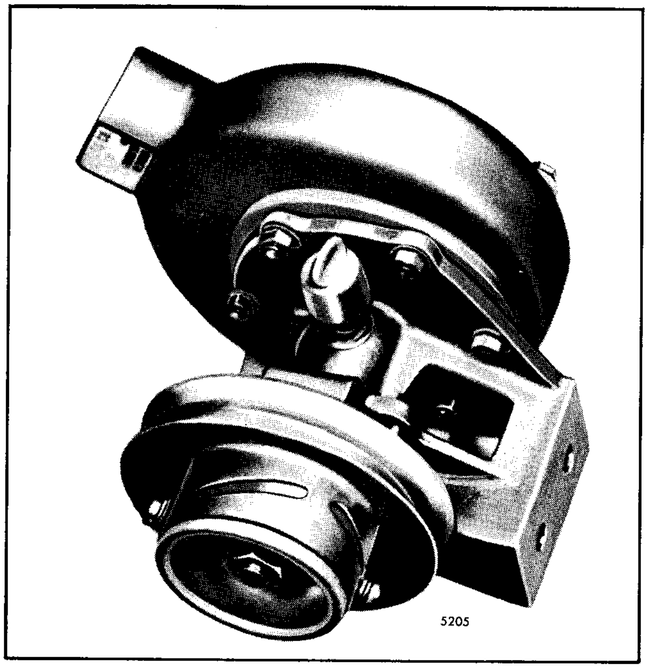

Fig. 1 - Bilge Pump

The bilge pump (Fig. 1) is mounted at the front of the engine and is driven by a V-belt from a pulley on the crankshaft.

The bilge pump runs continuously whenever the engine is operating and is kept in prime by a stream of overflow water from the engine, introduced on the intake side of the pump, through a priming pipe.

The drive shaft is supported on a bronze bushing at the impeller end and a ball bearing to take radial load at the pulley end.

Lubrication

A grease cup provides lubrication for the bronze bushing at the impeller end of the shaft. The cup should be given one-half turn daily, using water-proof grease of the same grade as used on the raw water pump. The ball bearing used at the pulley end of the shaft is grease packed and requires no attention.

A packing gland is provided to adjust the seal on the shaft. Do not tighten it more than necessary to stop leakage. When tightening, draw the nuts down evenly to avoid leaks and scoring of the pump shaft.

Service

Since the bilge pump runs continuously when the engine is operating, the drive belt should be checked at regular intervals. Tension on the belt should be sufficient to avoid slipping, but not great enough to impose an undue load on the pump bearings. Three-fourths inch slack midway between the two pulleys should provide satisfactory operation. Adjustment is accomplished by loosening the adjusting screws at the forward pulley hub and moving the hub in the slot to obtain suitable slack. In freezing weather, open the drain cock to empty the pump if the engine is to be standing idle for any length of time.

Remove and Install Pump

The bilge pump may be removed from the engine by removing the four bolts which attach the mounting bracket to the engine.

The pump is simple in construction and may be disassembled for inspection and re-assembled without special instructions. Since the pump priming pipe is permanently connected to the pump as installed on the engine, no special precautions are required for installation other than to make correct connections to the inlet and outlet sides.

CAUTION: All piping on the intake side of the bilge pump must be air tight. Use white lead or red lead on pipe threads at all connections.

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VACUUM PUMP

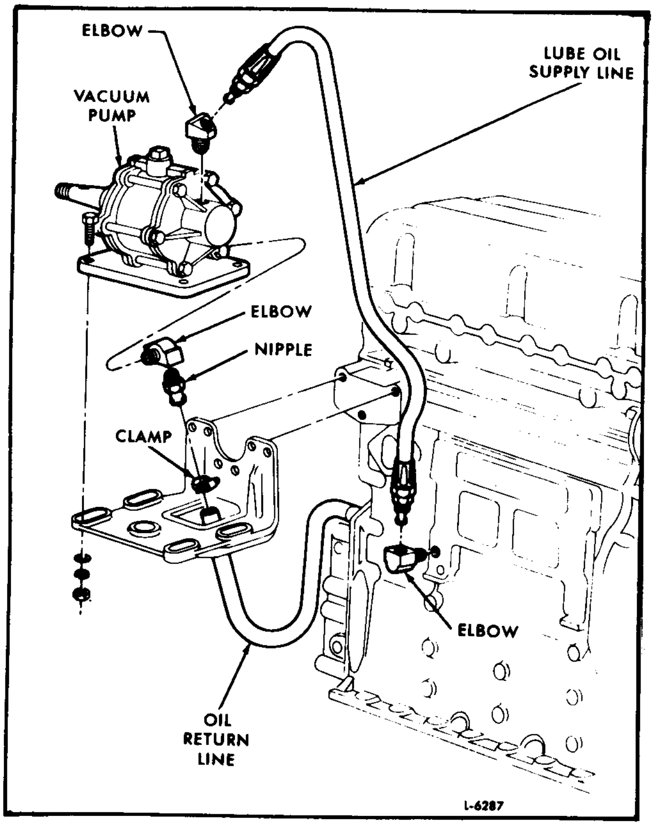

Fig. 1 - Vacuum Pump Installation

Installing a Vacuum Pump

When a former style vacuum pump is replaced with a current design pump, the location of the lube oil supply line on the new pump will differ from that on the replaced pump.

Former vacuum pumps had the oil supply line routed to a threaded hole on the underside of the support bracket. Pump components were lubricated by means of a drilled passage in the base of the pump body which lined up with the inlet hole in the support bracket.

Current pumps do not have the drilled passage for lubrication. Instead, pump components are lubricated by an oil supply line routed to a threaded hole in the top of the rear cover plate (Fig. 1).

To eliminate the possibility of internal vacuum pump damage caused by improper lube oil line hookup, follow this procedure when installing a new pump.:

1. Mount the new pump securely on the support bracket. Make sure the support bracket is properly bolted to the engine.

2. Locate the threaded hole in the pump rear cover plate (opposite the pulley end) and remove the plastic shipping plug.

3. Connect the oil supply line to the pump at the threaded hole. Apply 3M EC No. 971 Pipe Sealant (or equivalent) to the male threads of all fittings before installing them in the vacuum pump. Do not apply sealant to the inside diameter of any holes.

Connecting the oil supply line at the threaded hole on the underside of current pumps will result in no lubrication going to the pump. Operation of the pump without lubrication will cause severe damage to the bearing and shaft assembly.

CAUTION: Loss of vacuum caused by internal dmaage to the vacuum pump may create a potential safety hazard for driver and passengers by lessening vehicle braking force, thus increasing the possibility of accident.

Vacuum pumps are sold by Detroit Diesel Allison Distributors only as assemblies. For component parts contact a Bendix Products Service outlet or Bendix Products Division, South Bend, Indiana.

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AIR COMPRESSOR

The air compressor (Figs. 1 and 2) may be mounted on a bracket attached to the cylinder block of the engine and belt-driven from the crankshaft pulley, or it may be flange-mounted to the flywheel housing and gear driven by means of an accessory drive attached to the camshaft or balance shaft gear on In-line engines, or on either camshaft gear on V-engines.

A six bolt design air compressor mounting base, mounting bracket and gasket are used on current engines equipped with a belt-driven air compressor. Formerly, the air compressor was attached to the base and bracket with four bolts. When installing a new air compressor, it is recommended that the new mounting parts be used to eliminate the possibility of the bracket loosening and causing oil seepage at the gasket.

The air compressor runs continuously while the engine is running. While the compressor is running, actual compression of air is controlled by the compressor governor which acts in conjunction with the unloading mechanism in the compressor cylinder block. The governor starts and stops the compression of air by loading or unloading the compressor when the air pressure in the system reaches the desired minimum or maximum pressure.

During the down stroke of each piston, a partial vacuum is created above the piston which unseats the inlet valve and then allows air drawn from the air box in the engine cylinder block or through an intake strainer to enter the cylinder above the piston. As the piston starts the upward stroke, the air pressure on top of the inlet valves, plus the inlet valve return spring force, closes the inlet valve. The air above the piston is further compressed until the pressure lifts the discharge valve and the compressed air is discharged through the discharge line into the reservoir.

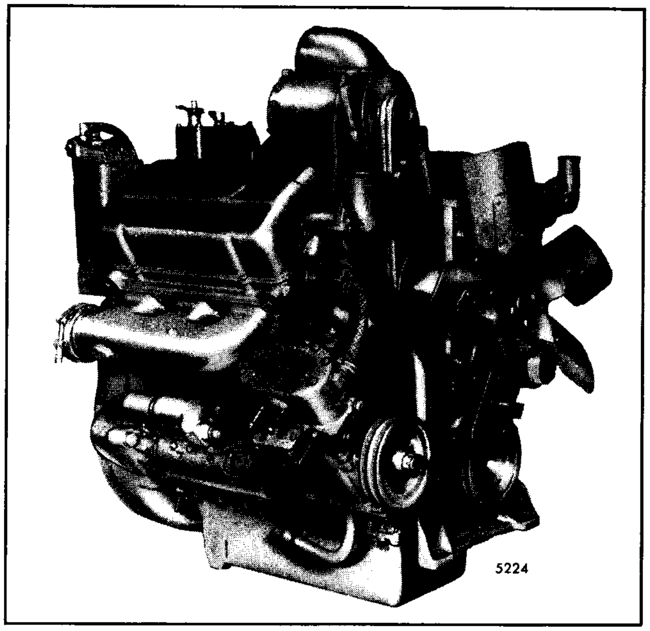

Fig. 1 - Air Compressor Mounting (Former Engines)

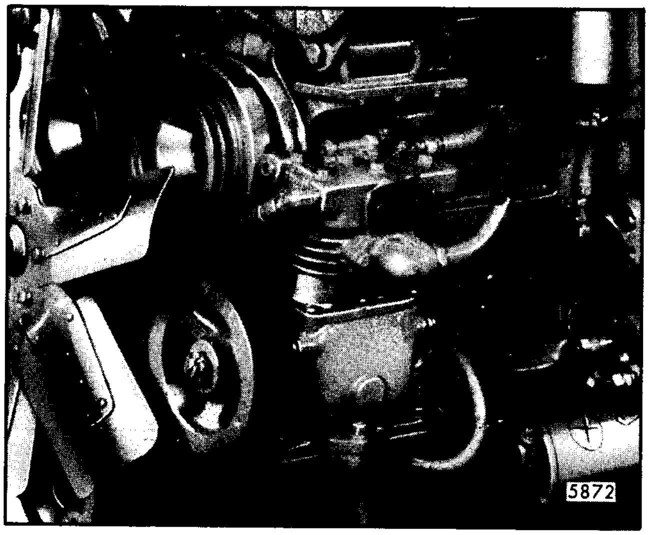

Fig. 2 - Air Compressor Mounting (Current Engines)

As each piston starts its downstroke, the discharge valve above it returns to its seat, preventing the

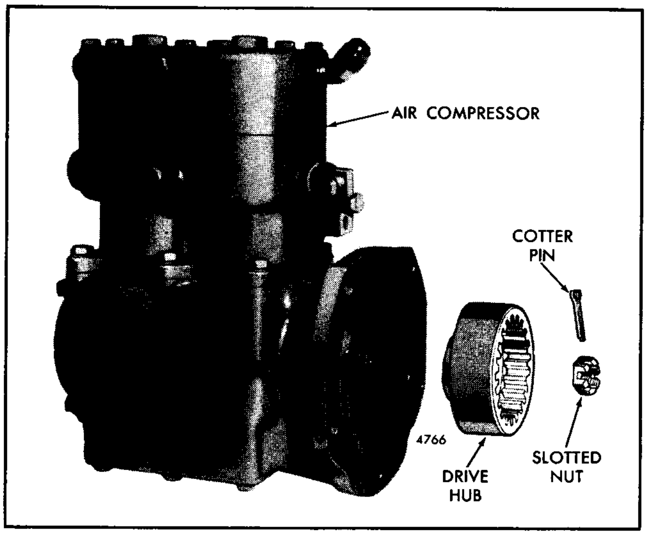

Fig. 3 - Typical Air Compressor With Drive Hub

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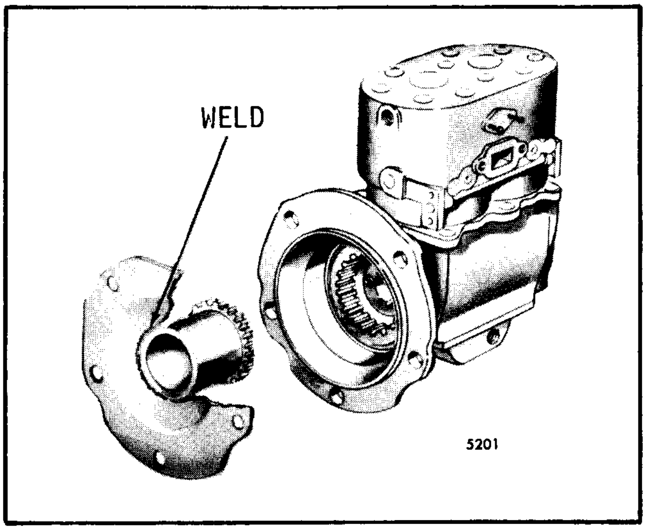

Fig. 4 - Fixture For Holding Drive While Installing or Removing Slotted Nut

compressed air from returning to the cylinder and the same cycle is repeated.

When the air pressure in the reservoir reaches the maximum setting of the governor, compressed air from the reservoir passes through the governor into the cavity below the unloading pistons in the compressor cylinder block. The air pressure lifts the unloading pistons which in turn lifts the inlet valves off their seats.

With the inlet valves held off their seats, the air during each upstroke of the piston is merely passed back through the air inlet cavity and to the other cylinder where the piston is on the downstroke. When the air pressure in the reservoir drops to the minimum setting of the governor, the governor releases the air pressure beneath the unloading pistons. The unloading piston return spring then forces the piston down and the inlet valve springs return the inlet valves to their seats and compression is resumed.

Service Note

When installing a pulley or a drive hub on a flange mounted air compressor (Fig. 3), it is important the 3/4"-10 drive shaft slotted nut be tightened to 100 lb-ft (136 Nm) torque minimum before installing the 3/32" x 1-1/4" cotter pin.

The air compressor drive shaft will turn during the torquing operation unless some provision is made to hold it. One way this can be done is to weld a modified drive coupling to a support or base which in turn can be anchored to the mounting flange of the compressor. An old flywheel housing cover that matches the flange of the compressor makes an ideal base for the modified coupling. With the exterior splines of the coupling in mesh with the internal splines of the drive hub and the entire assembly secured to the compressor housing, the hub and shaft are kept from rotating when the torque is applied. That part of the base within the inner diameter of the coupling must be removed to permit placement of the wrench socket on the nut. Two bolts will secure the base to the compressor during the torquing operation (Fig. 4).

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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 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, cold weather starting devices are available.

> **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.

PRESSURIZED CYLINDER STARTING AID

Operation

Start the engine during cold weather, using the "Quick Start" starting aid system (Fig. 1) as follows:

1. Press the engine starter button.

2. Pull out the "Quick Start" knob for one or two seconds, then release it.

3. Repeat the procedure if the engine does not start on the first attempt.

> **CAUTION:** Do not crank the engine more than 30 seconds at a time when using an electric starting motor. Always allow one minute intervals between cranking attempts to allow the starting motor to cool.

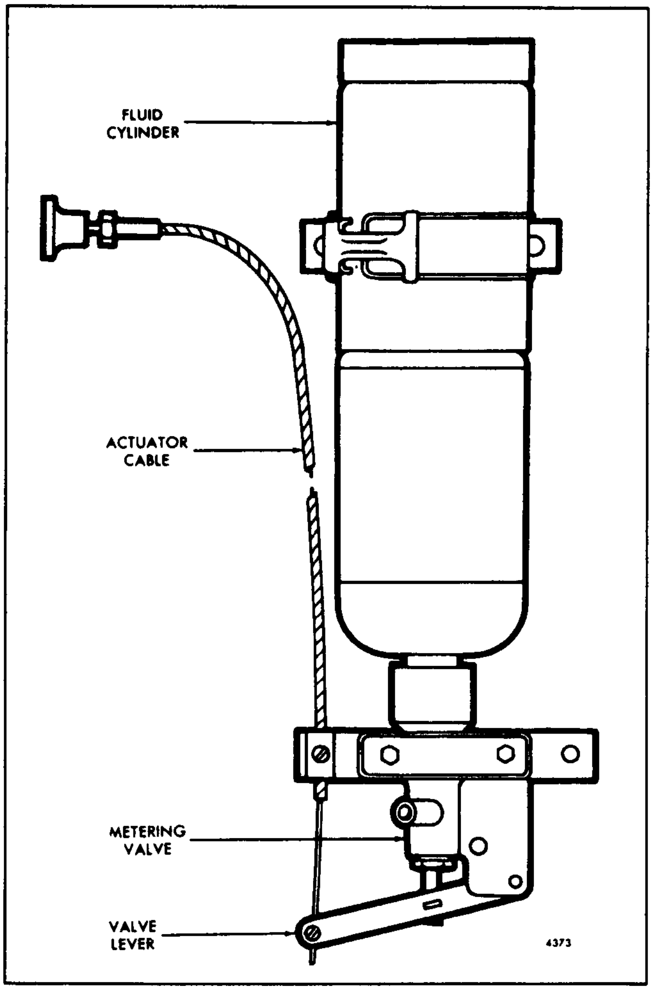

Fig. 1 - "Quick Start" Assembly

Service

Periodically perform the following service items to assure good performance:

1. Remove the fluid cylinder and lubricate the valve around the pusher pin under the gasket with a few drops of oil.

2. Lubricate the actuator cable.

3. Actuate the valve with the cable to distribute the oil on the cable and allow the oil to run down through the valve.

4. Remove any dirt from the orifice by removing the air inlet housing fitting, the orifice block and the screen. Then blow air through the orifice end only.

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5. Assemble and tighten the air inlet housing fitting to the actuator valve and tube.

6. Check for leakage of fluid (fogging) on the outside of the engine air inlet housing by actuating the starting aid while the engine is stopped. If fogging occurs, disassemble and retighten the air inlet housing fitting to the housing.

CAUTION: Do not actuate the starting aid more than once with the engine stopped. *Over-loading the engine air box with this high volatile fluid could result in a minor explosion.*

7. Check the fluid cylinder for hand tightness.

FLUID STARTING AID

The fluid starting aid is designed to inject a highly volatile fluid into the air intake system to assist ignition of the fuel at low ambient temperatures. It consists essentially of a pump and nozzle for injecting the fluid into the air intake and a suitable container for the fluid (Fig. 2). The fluid is contained in suitable capsules to facilitate handling.

This starting aid consists of a cylindrical capsule container fitted with a screw cap. Inside the container is a sliding plunger-like piercing shaft. From the capsule container, a tube leads from the container to a hand-operated pump and another tube leads from the pump to an atomizing nozzle threaded into a tapped hole in the air inlet housing.

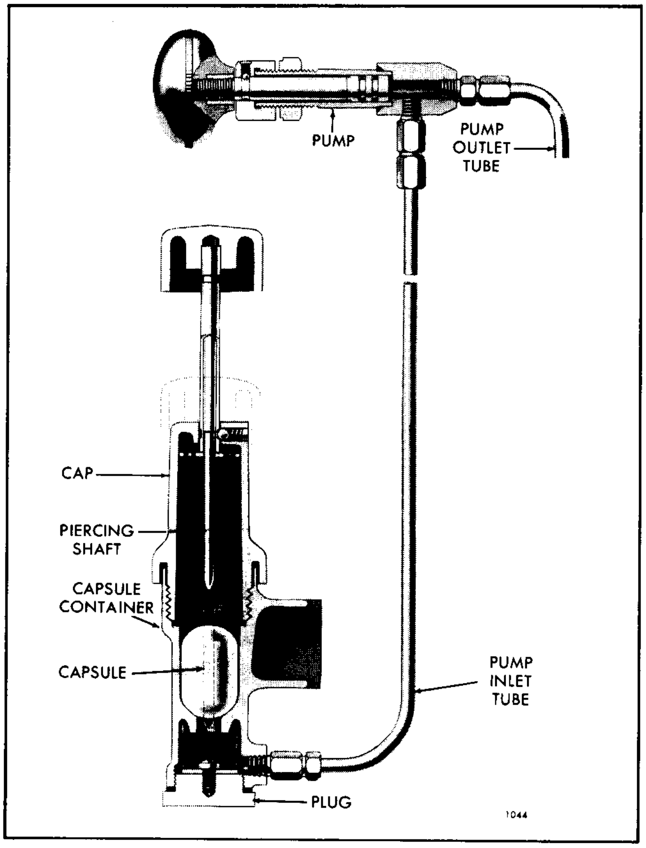

Fig. 2 - Fluid Starting Aid

Installation

The pump may be mounted on the instrument panel or in some other convenient location. The capsule container must be mounted in a vertical position away from such high heat areas as the exhaust manifold, muffler, etc. and should not be located under a hood or in a cab. The atomizing nozzle is screwed into a tapped hole in the air inlet housing. The tank-to-pump tube should be 3/16 " O.D. copper tubing and the pump-to-nozzle tube 1/8 " O.D.

Operation

1. Refer to Fig. 2 and remove the cap from the capsule container. Insert a fluid capsule in the container.

CAUTION: Mount the capsule in an upright position within the container. Use care when handling, since the starting fluid is both toxic and inflammable.

2. Pull the piercing shaft all the way out and thread the cap tight on the container.

3. Push the piercing shaft down until it bottoms. This will break the capsule and fill the container with starting fluid vapor.

4. Move the engine throttle to the full-fuel position.

5. Engage the starter and simultaneously pull the pump plunger all the way out. Then push the plunger in *slowly*, forcing the starting fluid through the atomizing nozzle and into the air intake. Continue to push the pump plunger in until the engine starts. If the plunger is not all the way in when the engine starts, push it in *very slowly* until it locks in the *in* position.

6. Unscrew the cap and remove the used capsule. *Do not leave the empty capsule in the container.*

7. Reinstall the cap tightly on the container body.

NOTE: When not in use, the piercing shaft should be all the way down.

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Starting Aid Pump

The principal parts of the starting aid pump are the body, plunger and the spring-loaded ball type inlet and outlet check valves (Fig. 2). The pump body is threaded externally at one end for mounting purposes. One end of the plunger is threaded into the operating knob. Two seal rings of oil resistant material are located in grooves at the other end of the plunger. The inlet check valve, which opens on the suction stroke of the plunger and seats under pressure, is located in the side opening of the pump body. The outlet check valve, which seats under suction and opens under pressure, is installed in the end opening of the pump body. The check valves are identified by the number "1/2" stamped on the inlet valve and the number "30" on the outlet valve. An arrow indicating the direction of flow is also stamped on each check valve.

Remove Pump

Remove the starting aid pump from the mounting panel as follows:

1. Disconnect the starting fluid inlet and outlet tubes from the pump.

2. Unscrew the plunger nut from the pump body and withdraw the plunger assembly.

3. Loosen the pump body jam nut behind the mounting panel.

4. Remove the pump body from the rear of the panel.

5. Remove the jam nut from the pump body.

Disassemble Pump

When the pump was removed from its mounting panel, the plunger assembly was removed from the pump body. If further disassembly is required, proceed as follows:

1. Unscrew the knob from the plunger assembly.

2. Slide the plunger nut from the plunger.

3. The plunger lock ball and spring may be removed by tapping the plunger nut to dislodge them. It is not necessary to remove the plug.

4. Remove the inlet and outlet check valves.

Inspection

Clean the parts with fuel oil and dry them with compressed air. Examine the seal rings for wear or cracks. Replace the seal rings if necessary. The check valves cannot be disassembled. However, they may be cleaned by forcing fuel oil through them with any suitable pump. Inoperative valves must be replaced.

If excessive resistance was encountered during operation of the pump, the nozzle in the air inlet housing may be plugged. Remove and clean the nozzle.

Assemble Pump

1. Install new seal rings on the plunger.

2. Install the lock spring in the plunger nut. Then place the steel ball on top of the spring.

3. Depress the lock ball and slide the plunger nut -- hex end first -- over the threaded end of the plunger.

4. Thread the knob on the plunger.

5. Install the outlet check valve (marked "30") in the end opening of the pump body. The arrow must point away from the pump body.

6. Install the inlet check valve (marked "1/2") in the side opening of the pump body. The arrow must point toward the pump body.

Install Pump

1. Thread the jam nut on the pump body.

2. Insert the thread end of the pump body through the mounting panel (from the rear of the panel).

3. Lubricate the seal rings and carefully slide the plunger assembly into the pump body. Thread the plunger nut on the end of the pump body and tighten it.

4. Install the starting fluid inlet and outlet tubes.

5. If removed, install the nozzle in the air inlet housing.

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HYDROSTARTER SYSTEM

The Hydrostarter system illustrated in Figs. 1 and 2 is a complete hydraulic system for cranking internal combustion engines. The system is automatically recharged after each engine start, and can be manually recharged in an emergency. The starting potential does not deteriorate during long periods of inactivity and continuous exposure to hot or cold climates has no detrimental effect upon the Hydrostarter system. Also, the Hydrostarter torque for a given pressure remains substantially the same regardless of the ambient temperature.

The Hydrostarter system consists of a reservoir, an engine-driven charging pump, a manually operated pump, a piston type accumulator, a starting motor and connecting hoses and fittings.

Operation

Hydraulic fluid flows by gravity or slight vacuum from the reservoir to either the engine-driven pump inlet or hand pump inlet. The hand pump is used to supply the initial charge or to recharge the system after servicing or overhaul. Fluid discharging from either pump outlet at high pressure flows into the accumulator and is stored at 3250 psi under the pressure of compressed nitrogen gas. When the starter is engaged with the engine flywheel ring gear and the control valve is opened, high pressure fluid is forced out of the accumulator, by the expanding nitrogen gas, and flows into the starting motor which rapidly accelerates the engine to a high cranking speed. The used fluid returns from the starter directly to the reservoir (Fig. 1).

The engine-driven Hydrostarter charging pump runs continuously during engine operation, recharging the accumulator with fluid. When the proper amount of fluid has been returned to the accumulator, a pressure-operated unloading valve in the engine-driven pump opens and returns the pump discharge directly to the reservoir.

System Components

RESERVOIR

The reservoir is a cylindrical steel tank with a fine mesh screen at the outlet. The filler cap contains a filter to prevent dust and dirt from entering the reservoir.

ENGINE-DRIVEN CHARGING PUMP

The engine-driven charging pump is a single piston, positive displacement type and should run at approximately engine speed. It contains ball check valves and an unloading valve operated by the

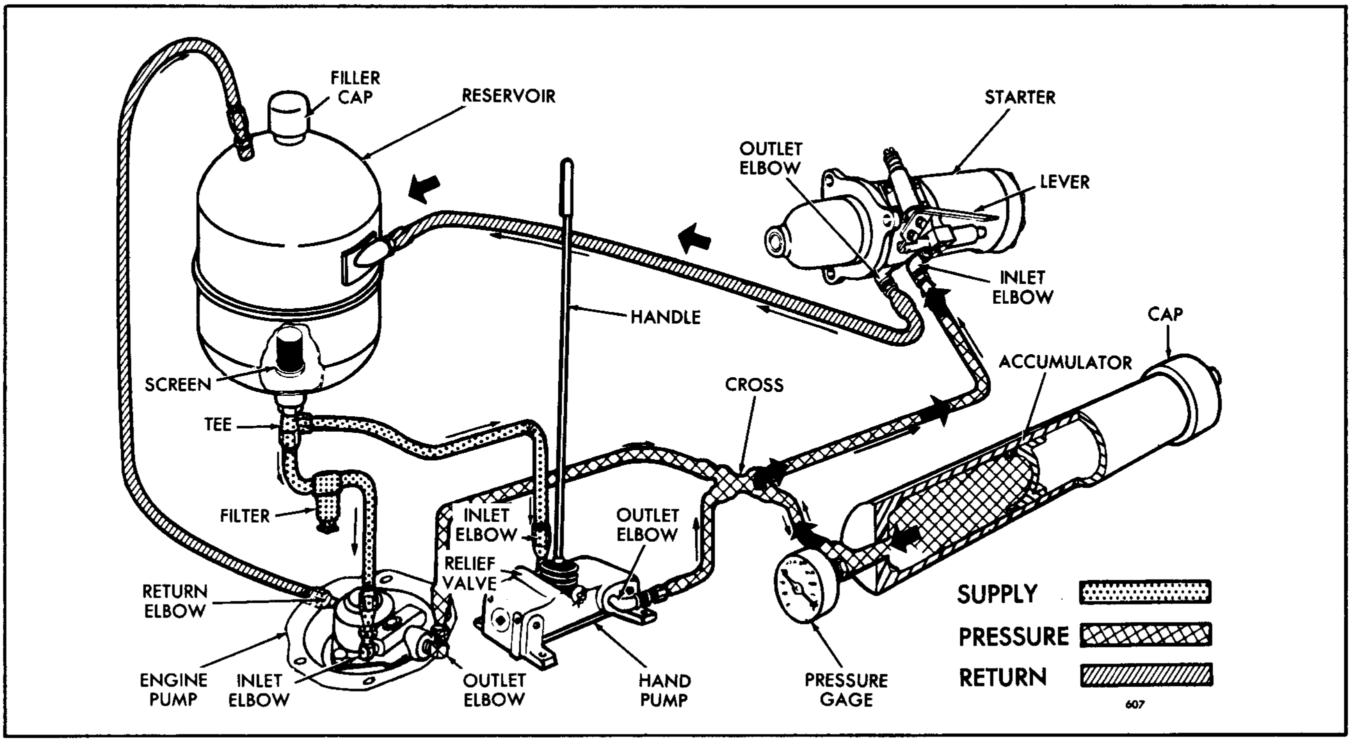

Fig. 1 - Schematic Diagram of Hydrostarter System Showing Oil Flows

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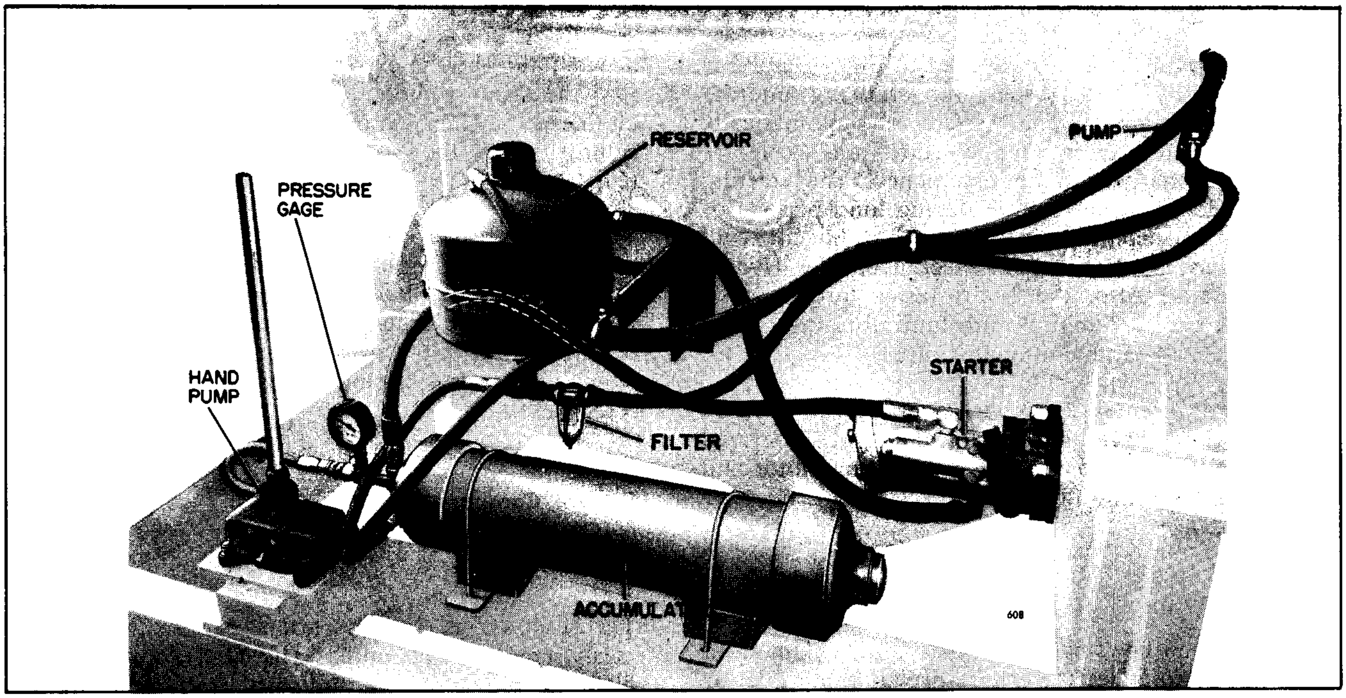

Fig. 2 - Typical Hydrostarter System Mounting

accumulator pressure. Its operation is entirely automatic and will operate in either direction of rotation.

HAND PUMP

The hand pump is a single piston, double-acting, positive displacement type. Flow through the pump is controlled by ball check valves. A manually operated relief valve is provided in this pump so that the accumulator pressure may be relieved when servicing of any components is required.

ACCUMULATOR

The piston-type accumulator is precharged with nitrogen through a small valve. A seal ring between the piston and the shell prevents the loss of gas into the hydraulic system. The accumulator is supplied with the proper precharge.

STARTER

The starter mounts on the flywheel housing and has a pinion gear with an overrunning clutch for engaging the flywheel ring gear. Movement of the starter control lever engages the pinion and opens the control valve in the proper sequence. The motor is a multi-piston, swash plate type. Provision is made so that if pinion tooth abutment occurs, the motor rotates slowly until the pinion snaps into full engagement. When the control lever is released, the pinion is disengaged and the valve is closed by spring action.

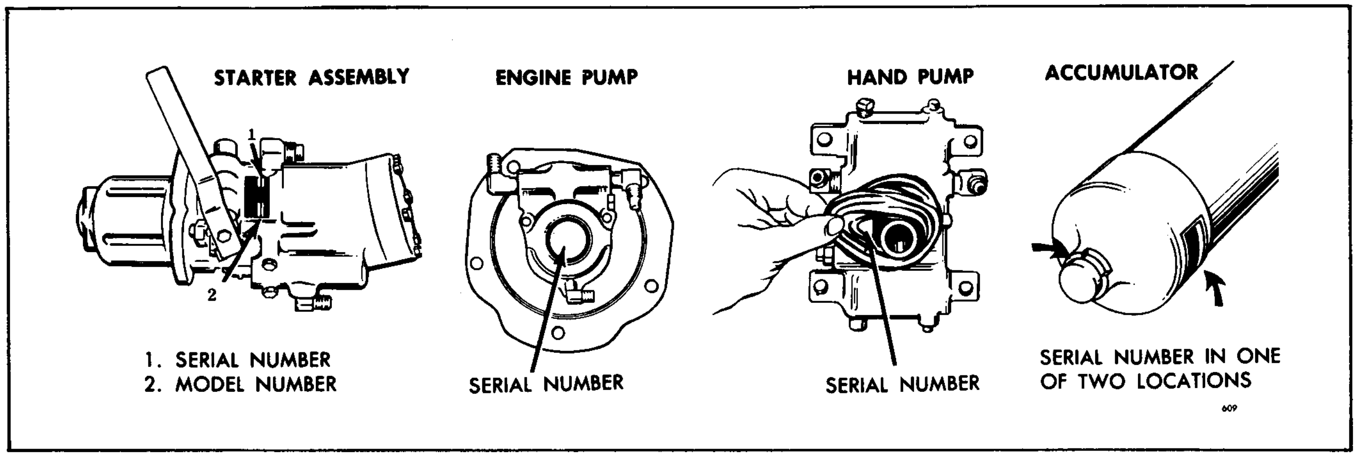

Fig. 3 - Hydrostarter Cómponent Serial Number Locations

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Ordering Parts

When ordering replacement parts, always specify the information located by the arrows on each component as shown in Fig. 3. Also include the engine model and serial number to ensure obtaining the correct parts.

FILLING, PURGING AND STARTING

Fill Hydrostarter System

Remove the filler cap from the reservoir and add a sufficient quantity of recommended hydraulic fluid (a mixture of 75% diesel fuel and 25% SAE 10 or 30 lubricating oil) to fill the system.

The required amount of hydraulic fluid will vary depending upon the size of the reservoir, length of the hydraulic hoses and the size and number of accumulators. The reservoir is available in 10, 12 and 23 quart capacities. In a 10 quart capacity reservoir, add approximately 8 quarts of hydraulic fluid; add approximately 10 or 21 quarts of hydraulic fluid to the 12 and 23 quart capacity reservoirs respectively.

> **NOTE:** When the accumulator is charged to 3000 psi and all hoses are filled, there should be enough hydraulic fluid remaining in the reservoir to completely cover the screen in the bottom of the reservoir.

Purge Hydraulic Remote Control System, Hand Pump and Starter of Air

On units equipped with a hydraulic remote control starting system (Fig. 25) consisting of a foot pedal, master cylinder and connecting hose and fittings, purge that portion of the Hydrostarter system as follows: Fill the master cylinder reservoir with diesel fuel oil. Loosen the hose swivel fitting at the back of the starter control valve body and actuate the master cylinder pedal to allow the air to escape from the hydraulic remote starting system. Replenish the fluid in the master cylinder reservoir as required during the purging operation. Then tighten the hose swivel fitting.

Remove the pressure hose (Fig. 1) on the side of the hand pump and pump a few strokes to prime the pump. Priming is complete when a full stream of oil is discharged at each end of the pumping stroke. Then reconnect the pressure hose.

Move the starter control lever (Fig. 4) to engage the starter pinion with the flywheel ring gear and to open the control valve. While holding the lever in this position, operate the hand pump until the starter has turned several revolutions. Then release the starter control lever.

Check Accumulator Precharge Pressure Prior to Initial Engine Start

The precharge pressure of the accumulator is the pressure of the nitrogen gas with which the accumulator is initially charged. This pressure should be checked before the system pressure is raised for the initial engine start. To check the precharge pressure, open the relief valve (Fig. 1) on the side of the hand pump, approximately 1/2 turn, allowing the pressure gage to return to zero. Close the relief valve and pump several strokes on the hand pump. The gage should show a rapid pressure rise from zero to the nitrogen precharge pressure, where it will remain without change for several additional strokes of the pump.

Initial Engine Start

Use the hand pump (Fig. 1) to raise the accumulator pressure until the gage reads as indicated in the following chart.

Ambient Temperature	Pressure Gage Reading
Above 40°F.	1500 psi
+40°F. to 0°F.	2500 psi
Below 0°F.	3300 psi

> **NOTE:** Use the priming pump (Fig. 24) to make sure the fuel filter, fuel lines and injectors are full of fuel before attempting to start the engine.

For ambient temperatures below 45°F., use a fluid starting aid.

> **NOTE:** Add starting fluid just prior to moving the Hydrostarter lever and during the cranking cycle as required. Do not wait to add the starting fluid after the engine is turning over because the accumulator charge may be used up before the engine starts. In this case, the accumulator charge must be replaced with the hand pump.

With the engine controls set for start (throttle at least half-open), push the control lever (Fig. 4) to

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simultaneously engage the starter pinion with the flywheel ring gear and to open the control valve. Close the valve quickly when the engine fires to conserve the oil pressure in the accumulator and to prevent excessive overrunning of the starter drive clutch assembly.

Three different basic types of flywheel ring gears are used -- no chamfer, Bendix chamfer and Dyer chamfer on the gear teeth. Some difficulty may be encountered in engaging the starter pinion with the Dyer chamfered ring gears. When this happens, it is necessary to disengage and re-engage until the starter pinion is cammed in the opposite direction enough to allow the teeth to mesh.

Purge Engine-Driven Pump of Air

With the engine running at 1500 rpm or above, loosen the hose connection at the discharge side of the engine-driven pump until a full stream of oil is discharged from the pump. Connect the hose to the pump and alternately loosen and tighten the swivel fitting on the discharge hose until the oil leaking out when the fitting is loose appears free of air bubbles. Tighten the fitting securely and observe the pressure gage. The pressure should rise rapidly to the accumulator precharge pressure (1250 psi at 70°F.) then increase slowly to 2900 to 3300 psi in 6 to 10 minutes, depending upon the size of the particular accumulator.

If the accumulator pressure does not rise, make certain the relief valve (Fig. 1) is closed after the pressure is released and repeat the above purging procedure.

Engine-Driven Pump By-Pass Check

The engine-driven pump should by-pass oil to the reservoir when the pressure reaches 2900 to 3300 psi. Check to determine that the pump is by-passing by removing the reservoir filler cap and disconnecting the pump by-pass hose at the reservoir and holding the hose over the open reservoir filler spout. An occasional spurt of oil may emit from the hose prior to by-passing. When the pump by-passes, a full and continuous stream of oil will flow from the hose. Reconnect the hose at the reservoir and install the filler cap.

HYDROSTARTER MOTOR

The Hydrostarter (starting) motor is mounted on the flywheel housing in the same manner as a conventional starting motor. This starting motor has an inherently high rate of acceleration; therefore, the engine is cranked faster than is possible with other starting systems. Right and left-hand starters are achieved by assembling the motor housing (Fig. 4) to the valve plate in one of two positions 180° apart and by changing the drive clutch assembly. The drive housing can be adjusted in 12 different positions to accommodate various flywheel housing configurations.

The control lever may be attached in any one of four positions where it is most accessible.

Positive starting motor engagement is assured because movement of the control lever mechanically pushes the starter pinion into engagement with the engine flywheel ring gear before the control valve is fully opened. When a tooth abutment is encountered, the valve permits a small flow of oil to turn the pinion slowly until it snaps into full engagement. Spring action disengages the pinion and closes the control valve when the lever is released. An overrunning clutch protects the starting motor at all times from being driven at high speeds by the engine before disengagement of the pinion.

Remove Hydrostarter Motor

1. Release the oil pressure in the hoses and the accumulator by opening the relief valve (Fig. 1) on the side of the hand pump.

CAUTION: The oil pressure in the system must be released prior to servicing the Hydrostarter motor or other parts to prevent possible injury to personnel or equipment.

2. Clean all of the exterior dirt from the Hydrostarter and the hydraulic hoses.

3. Disconnect the remote control hose or linkage, if used.

4. Disconnect the two hydraulic hoses from the starting motor. Cover the open ends of the hoses with masking tape to prevent the entry of dirt.

5. Remove the three bolts and lock washers and lift the starting motor away from the flywheel housing.

Disassemble Hydrostarter Motor

With the exterior of the Hydrostarter motor cleaned, scribe marks on the drive housing, clutch housing,

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valve plate and motor housing prior to disassembly to ensure their correct reassembly. Refer to Figs. 4 and 6 and proceed as follows:

1. Remove the two bolts and lock washers and lift the control valve assembly from the valve plate. Remove the body seal ring from the valve plate.

2. Withdraw the control valve from the valve body.

3. Remove the control valve plug only if the control valve body seals are to be replaced. If necessary, remove the valve seal rings from the valve body, being careful not to scratch or damage the valve body.

4. Remove the four bolts and lock washers and slide the drive housing off the shaft. Remove the plug and the oil wick from the drive housing.

5. Remove the four bolts and lock washers and separate the clutch housing and the clutch assembly from the valve plate by sliding them off the shaft. Rotate the control shaft and disengage the overrunning clutch from the fork.

6. Lift the clutch yoke from the drive clutch assembly. Remove the fork from the control shaft.

7. Remove the torsion spring from the control shaft and pull the shaft from the clutch housing. Remove the seal rings from the control shaft. Remove the control lever only if broken or if its position on the control shaft is to be changed.

8. On the Hydrostarter motors equipped with the former control valve assembly, shown in the inset in Fig. 4, remove the drive shaft oil seal washer from the starter shaft.

9. Withdraw the motor housing and needle bearing assembly together with the end cover and bearing as

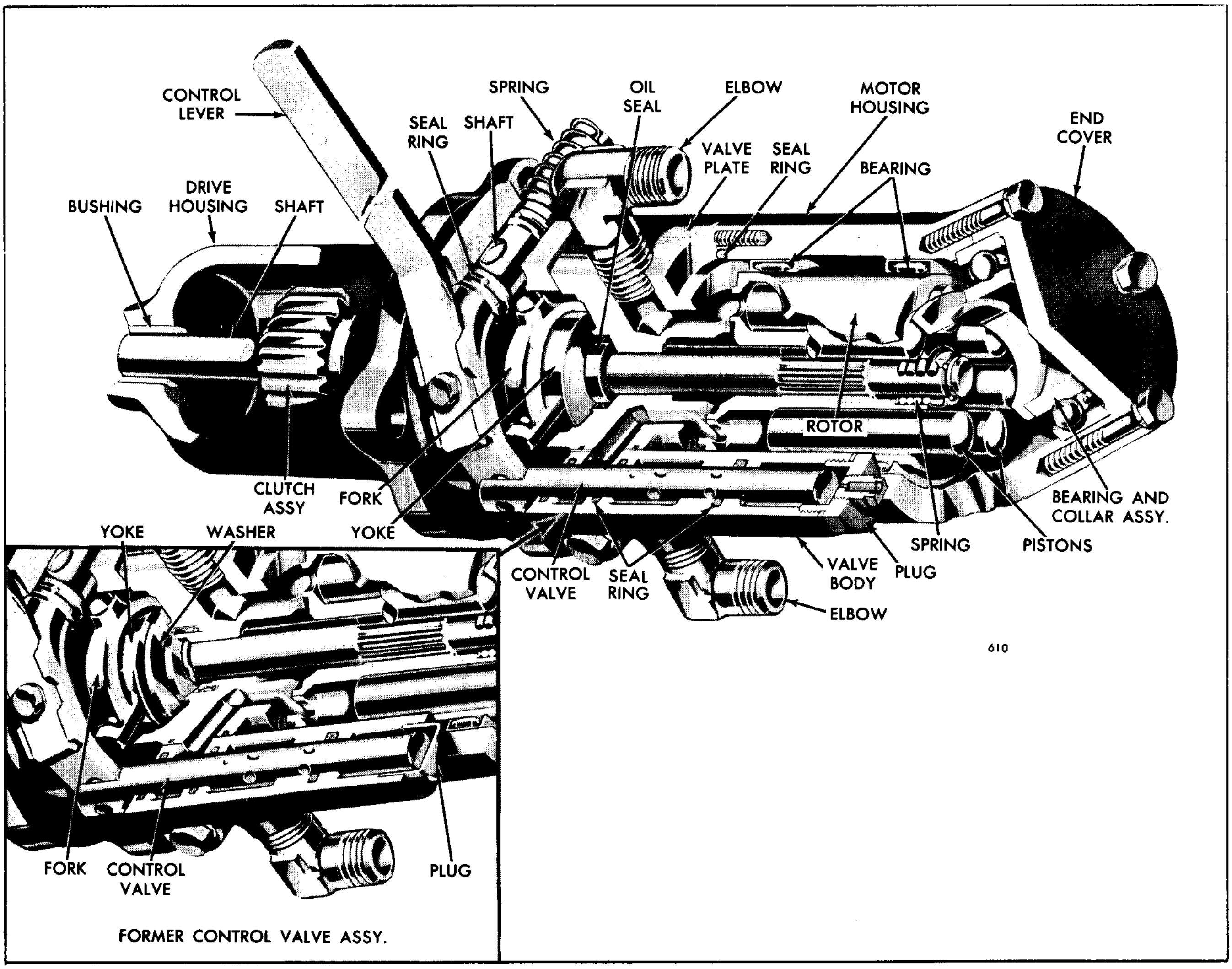

Fig. 4 - Cutaway View of Hydrostarter

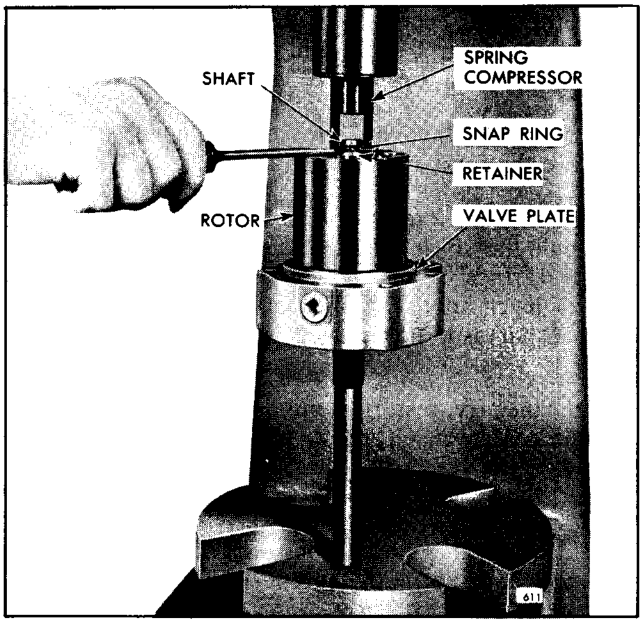

Fig. 5 - Removing Snap Ring from Starter Shaft

an assembly from the valve plate, being careful not to drop the pistons from the rotor.

10. Remove the pistons from the rotor.

11. Locate the shaft in an arbor press and, using spring compressor J 7187, press on the edge of the retainer to compress the spring as shown in Fig. 5. Then remove the snap ring.

12. Remove the retainer and compression spring from the starter shaft. Then slide the rotor and the valve plate assembly off of the starter shaft.

13. Remove the starter shaft compression spring shims from the spring bore in the rotor, if used.

14. Remove the starter shaft oil seal from the valve plate only if it is leaking.

15. Remove the seal ring from the motor housing.

16. Remove the bolts and lock washers and separate the end cover, bearing and gasket as an assembly from the motor housing.

17. Lift the bearing and collar assembly from the end cover.

Inspect Hydrostarter Motor Parts

Wash all of the parts in clean fuel oil and dry them with compressed air, with the exception of the drive clutch assembly.

Examine the teeth and internal splines of the drive clutch assembly for excessive wear and replace if necessary.

If the overrunning clutch slips, preventing positive pinion engagement, replace it unless the slippage is due to extremely cold weather which would cause the grease to set up and prevent the clutch from operating. Then wash it thoroughly in clean fuel oil to free the rollers in the clutch shell and lubricate with SAE 5W oil. Attach a tag to the starter, noting the lubricant used in the clutch assembly.

> **NOTE:** When replacing the drive clutch assembly, only the Delco Remy drive clutch assemblies are available for service and, if the unit did not incorporate a Delco Remy drive clutch before, it will be necessary to replace the drive housing also.

Check the rotor and pistons for scoring or other damage.

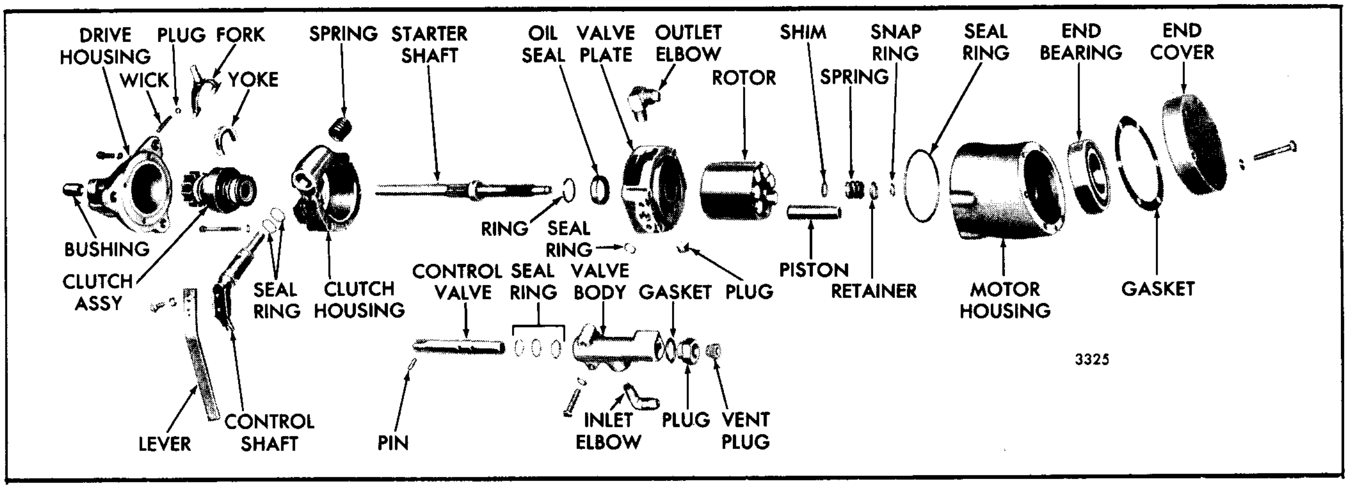

Fig. 6 - Hydrostarter Motor Details and Relative Location of Parts

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Replace the yoke if it is cracked or worn on the faces near slots.

Replace the clutch fork if the trunnions or machined shank of the fork is bent, or are worn out of alignment.

Replace the starter shaft oil seal if the lip is rough or hard.

The rotor bearings (Fig. 4) should not require replacement; however, if they are worn excessively, a new motor housing and bearing assembly must be installed.

Apply light engine oil to the end bearing. Then hold the inner race and revolve the outer race slowly by hand to check for rough spots.

Replace the control shaft torsion spring or compression spring if either is broken or damaged in any way.

A square section split ring was used with the compression spring retainer on early Hydrostarter motors. The current type retainer is used with a round section snap ring. The drive shaft was revised accordingly. When an early type shaft is replaced, a new spring retainer and snap ring are required.

The current Hydrostarter motor incorporates a new design control valve assembly that may be identified by the threaded plug in the end of the valve housing. A tapped hole in the plug is provided for attachment of a flexible hose when a remote control is used, otherwise, a 1/8" - 27 vent plug is installed. A cup plug was pressed in the former valve housing.

NOTE: The washer between the shaft seal and the clutch yoke (see inset in Fig. 4) is used ONLY in the early Hydrostarter motors with the former type control valve. If the Hydrostarter motor is overhauled and a new control valve assembly is installed, remove the washer. However, if the control valve assembly is replaced and the motor is not disassembled, the washer may be left in the motor.

Assemble Hydrostarter Motor

Refer to Figs. 4 and 6 and assemble the Hydrostarter motor as follows:

NOTE: Do not reassemble a R.H. starter for L.H. rotation. The drive clutch for a R.H. starter will not drive at all if assembled on a L.H. starter. Similarly, the drive clutch for a L.H. starter will not drive if assembled on a R.H. starter. In both of these cases, the clutch will run free and will transmit no torque. The clutch will be forced to run at excessive speeds with a full accumulator and no driving load.

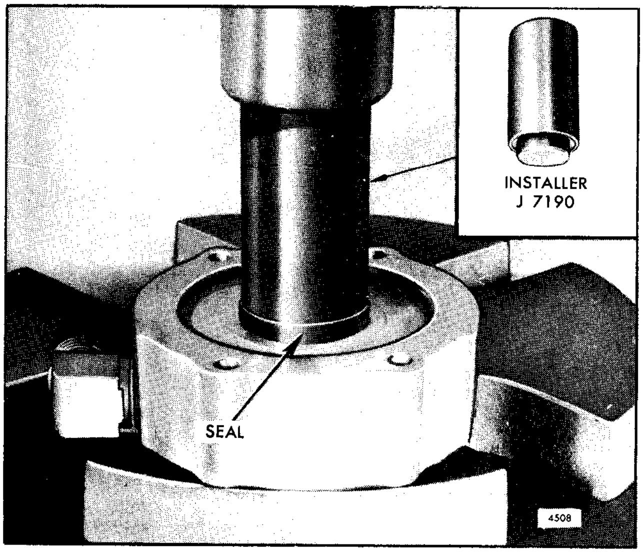

Fig. 7 - Installing Hydrostarter Shaft Seal in Valve Plate

1. Place the bearing and collar assembly in the end cover, thrust collar side up, and attach the end cover to the motor housing with bolts and lock washers. Use a new gasket between the cover and the housing.

2. If the shaft oil seal was removed, install a new seal in the valve plate with the lip of the seal facing in, using installer J 7190 (Fig. 7). The seal is properly positioned when the installer bottoms in the valve plate. Install the oil seal retaining ring in the ring groove in the valve plate.

On the former valve plate that does not incorporate the shaft oil seal retaining ring groove, stake the seal in place in at least six places.

3. Apply a thin coat of grease on the forward face of the starter shaft collar, then place the valve plate, seal side first, over the forward splined end of the starter shaft, followed by the rotor, shims (if used), compression spring and the spring retainer.

4. With the assembly in an arbor press and using spring compressor J 7187 as shown in Fig. 5, install the snap ring in the shaft ring groove.

On the current Hydrostarter motors, a .031" shim(s) is used on the starter shaft back of the compression spring as shown in Fig. 8, to limit the starter shaft travel and prevent the collar on the shaft from moving past the lip of the oil seal and damaging the seal when the shaft returns to its normal position. When reassembling a Hydrostarter motor, the starter shaft

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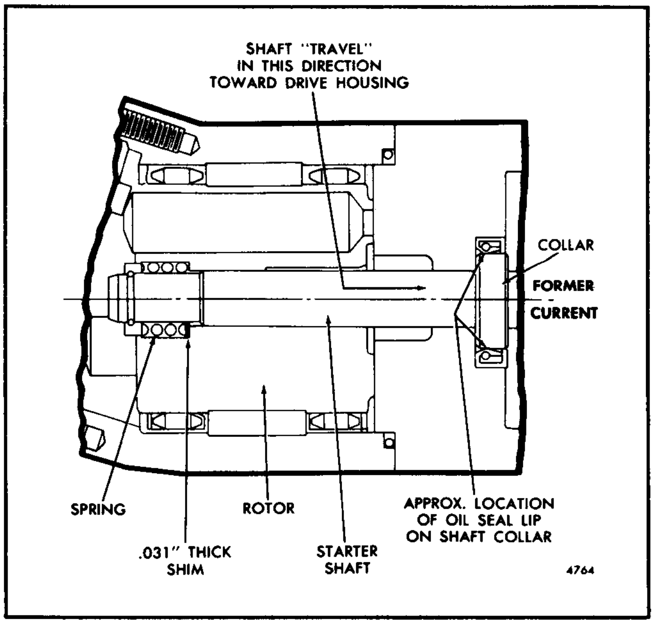

Fig. 8 - Location of Starter Shaft Compression Spring Shim(s)

should be checked as shown in Fig. 9. If the starter shaft travel is more than .100", a .031" shim(s) must be placed back of the compression spring to limit the shaft travel.

5. Insert the pistons, open end first, in the rotor.

6. Install the seal ring on the valve plate. Then assemble the motor housing to the valve plate, noting the scribe marks previously made on the housing and the valve plate.

7. Lubricate and install new seal rings on the control shaft and guide the shaft into the clutch housing gently so as not to damage the seal rings.

8. Install the torsion spring on the end of the control shaft. Apply grease to the fingers of the clutch fork and insert the shank of the fork into the control shaft.

9. Apply grease to the slots of the yoke and to the spool of the drive clutch assembly. Then set the yoke in the collar of the drive clutch assembly.

10. Grease the internal splines in the drive clutch assembly and the external splines on the starter shaft. Rotate the control shaft and insert the clutch fork trunnions into the slots of the yoke. Slide the oil seal washer, if used, onto the shaft. Then slide the assembly, yoke end first, over the starter shaft and engage the clutch and the shaft splines.

NOTE: The starter shaft oil seal washer, mentioned in Step 10, is only used on Hydrostarter motor assemblies using the former control valve assembly shown in the inset in Fig. 4.

11. Align the scribe marks and the bolt holes of the motor housing, valve plate and clutch housing and install the attaching bolts and lock washers.

12. Dip the oil wick in engine oil and insert the wick in the drive housing and secure it with the pipe plug.

13. Align the scribe marks on the drive housing and the clutch housing, then secure the drive housing with bolts and lock washers.

14. If removed, install new seal rings in the seal ring grooves inside the control valve body, then install the control valve body plug in the valve body and the vent plug in the body plug.

NOTE: On a former control valve body, shown in the inset in Fig. 4, press the cup plug against the shoulder in the control valve body.

15. Lubricate the control valve with engine oil, then start the control valve, slotted end out, straight in the control valve body and push it through the three seal rings in the body.

16. Place a new seal ring in the counterbore of the valve plate, engage the roll pin in the slot of the control shaft and attach the control valve assembly to the valve plate with bolts and lock washers.

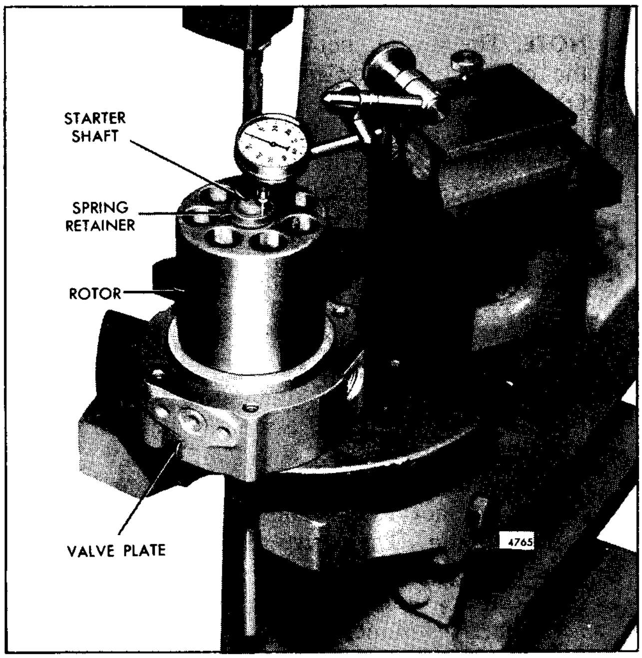

Fig. 9 - Checking Starter Shaft Travel

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17. If removed, attach the control lever to the control shaft with bolts and lock washers.

Install Hydrostarter Motor

1. Attach the Hydrostarter motor securely to the flywheel housing with three bolts and lock washers.

2. Connect the two hydraulic hoses to the starter.

3. Connect the remote control hose or linkage, if used.

NOTE: Make sure the hoses and fittings are clean before any connections are made.

ENGINE-DRIVEN HYDROSTARTER CHARGING PUMPS

Depending upon the engine application, either a direct engine-driven charging pump or a belt-driven pump is included in the Hydrostarter system to maintain the proper operating pressure.

The charging pump runs continuously to maintain a pressure of approximately 2900-3300 psi in the accumulator. However, the pump must not be driven at a constant speed exceeding 2500 rpm. An unloading valve, contained within the pump body, by-passes the pump discharge to the reservoir after the operating pressure is attained and, thereafter, permits the pump to operate at less load.

The pump, which will operate in either direction of rotation, will maintain the Hydrostarter system pressure, without appreciable loss, for long periods of time after the engine is shut down.

A sediment bowl is installed in the suction hose to provide the necessary finer degree of filtration required to protect the engine-driven pump mechanism. The sediment bowl encloses a stacked disc type element that may be cleaned and reused.

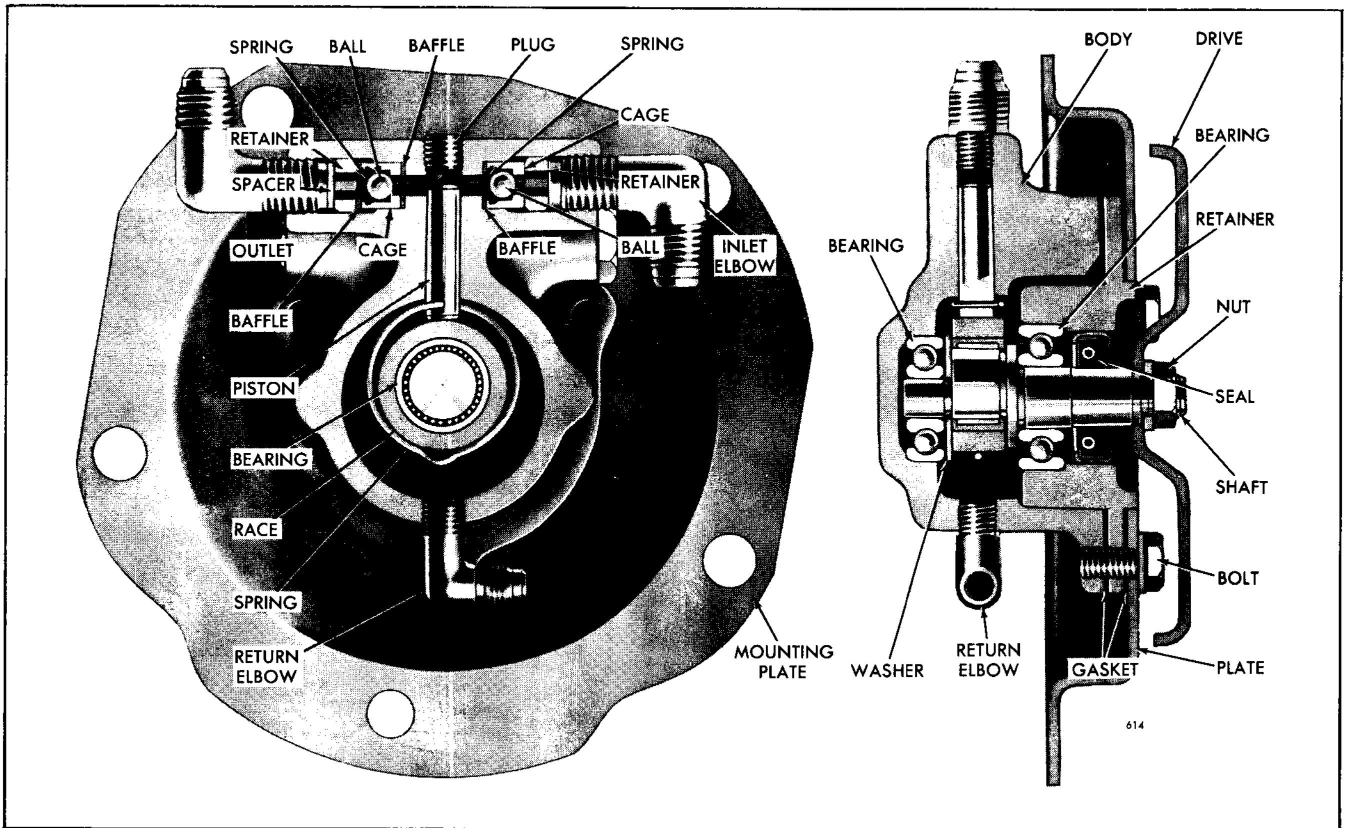

Fig. 10 - Direct Engine-Driven Hydrostarter Charging Pump

DIRECT ENGINE-DRIVEN CHARGING PUMP

The direct engine-driven charging pump is a single-piston positive displacement type. The ball check valves are automatically controlled by the accumulator pressure. The pump shaft is supported on ball

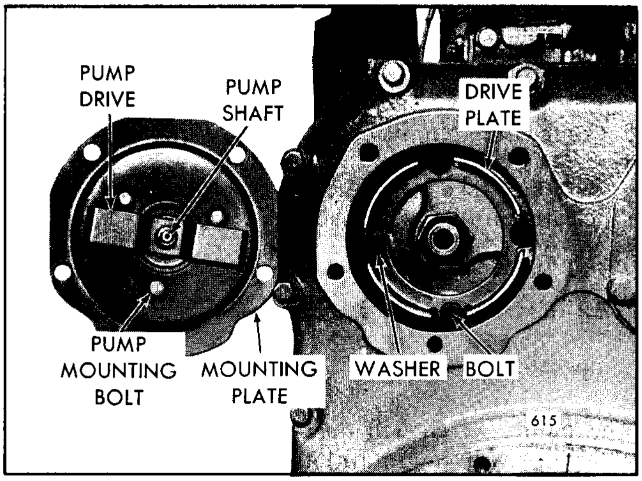

Fig. 11 - Pump Drive Plate Mounting

bearings and a seal, pressed into the pump bearing retainer, prevents leakage. The pump is attached to the flywheel housing and is driven by a drive plate bolted to the camshaft or balance shaft gear (Fig. 11).

Remove Pump

If required, remove the pump as follows:

1. Release the oil pressure in the system by opening the relief valve (Fig. 1) on the side of the hand pump about 1/2 turn.

CAUTION: The oil pressure in the system must be released prior to servicing the pump or other parts to prevent possible injury to personnel or equipment.

2. Clean all of the exterior dirt from the pump and the hydraulic hoses.

3. Disconnect the hydraulic hoses from the charging pump. Then cover the open ends of the hoses to prevent the entry of dirt.

4. Remove the five bolts and lock washers securing the charging pump and mounting plate assembly to the flywheel housing (Fig. 11). Then remove the pump and mounting plate assembly. Remove the mounting plate gasket.

Disassemble Pump

With the pump removed from the engine, refer to Figs. 10 and 12 and proceed as follows:

1. Remove the nut and lock washer and withdraw the pump drive from the shaft.

2. Scribe marks on the mounting plate and the pump body prior to disassembly to ensure their correct reassembly.

3. Remove the three bolts and lock washers and separate the mounting plate from the pump. Remove and discard the gasket. Withdraw the bearing retainer from the pump body. Remove and discard the second gasket.

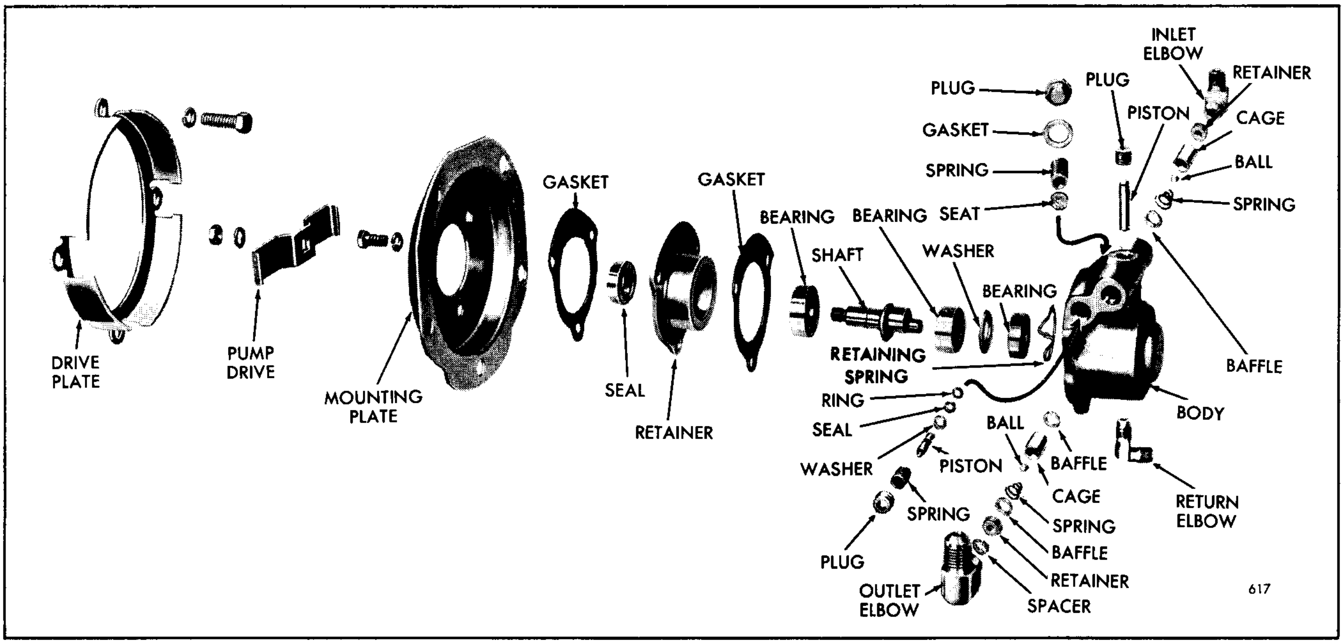

Fig. 12 - Direct Engine-Driven Charging Pump Details and Relative Location of Parts

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4. Remove the shaft, bearings and fiber washer as an assembly from the pump body.

5. If inspection reveals the bearings and fiber washer are worn excessively, remove them from the pump shaft for replacement by new parts.

6. Remove the pump piston and the retaining spring from the pump body.

7. Remove the pressure relief spring retaining plug, gasket, spring and spring seat.

8. Remove the compression spring retaining plug, compression spring, pressure relief piston, washer, seal ring and back-up ring.

9. Remove the pump outlet elbow, spacer, retainer and baffle.

The helical spring, ball and cage may then be removed as an assembly. Remove the baffle. DO NOT separate the helical spring and ball from the cage. If the check valve on either side of the pump is defective, replace the complete check valve assembly.

10. Remove the pump inlet elbow and the check valve retainer. Then remove the cage, ball and spring as an assembly. Remove the baffle. DO NOT separate the spring and ball from the cage.

11. The pump-to-reservoir return elbow and plug may be removed, if necessary, to clean the pump body.

12. Remove the oil seal from the bearing retainer if the seal is worn or damaged.

Assemble Pump

After cleaning, inspecting and replacing the necessary parts, refer to Figs. 10 and 12 and proceed as follows:

1. Insert the spring seat and pressure relief spring in the pump body and lock them in place with a gasket and plug.

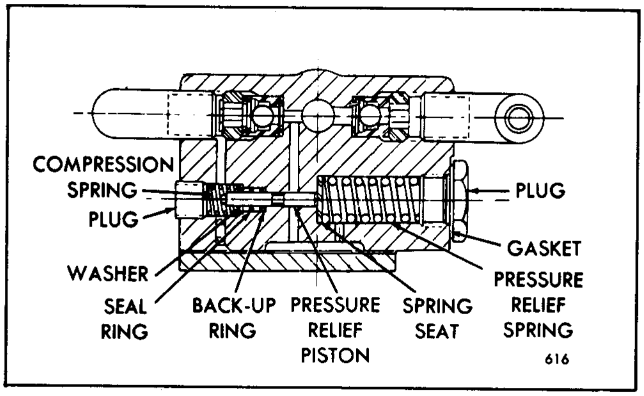

Fig. 13 - Engine-Driven Hydrostarter Charging Pump Pressure Relief Piston Assembly

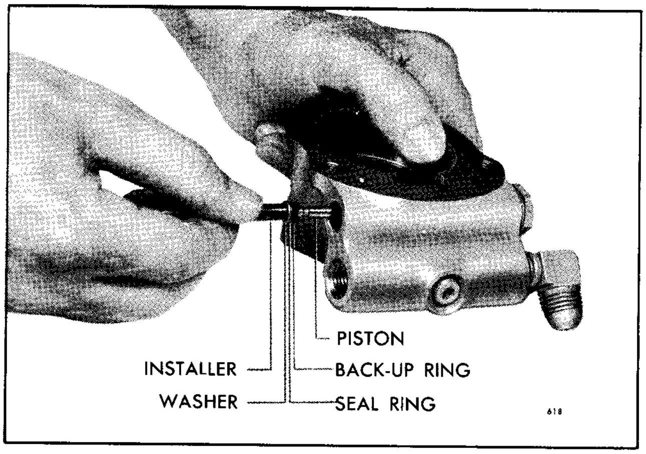

Fig. 14 - Installing Pressure Relief Piston, Back-Up Ring, Seal Ring and Washer in Pump Body with Installer J 7192

2. Slide a new back-up ring, new seal ring and washer onto the end of the pressure relief piston, opposite the flat end. DO NOT slide the seal across the groove in the piston.

3. Coat the back-up ring and seal ring liberally with hydraulic fluid. Then insert the relief piston assembly into the pump body, the flat end of the piston first, using installer J 7192. Apply manual force to the installer in order to gradually work the back-up ring and seal ring into the counterbore around the pressure relief piston. Care must be taken to avoid cutting the seal ring as it is worked into place. Refer to Figs. 13 and 14.

4. Remove the washer and inspect the work to make certain the seal ring is completely in the counterbored hole and that the pressure relief piston is down solidly against the spring seat.

5. Reassemble the washer over the pressure relief piston and insert the compression spring and secure it in place with the plug. Use sealant (Permatex No. 2, or equivalent) sparingly on the threads of the plug.

6. Insert the baffle, check valve assembly (with the spring end facing out) and the baffle into the pump body. Screw the check valve retainer into the body, against the baffle, and tighten it to 120-140 **in-lb** torque.

7. Place the spacer in the body on top of the check valve retainer and install the pump outlet elbow, using sealant (Permatex No. 2, or equivalent) on the threads. DO NOT apply sealant on the last thread nearest the open end of the elbow.

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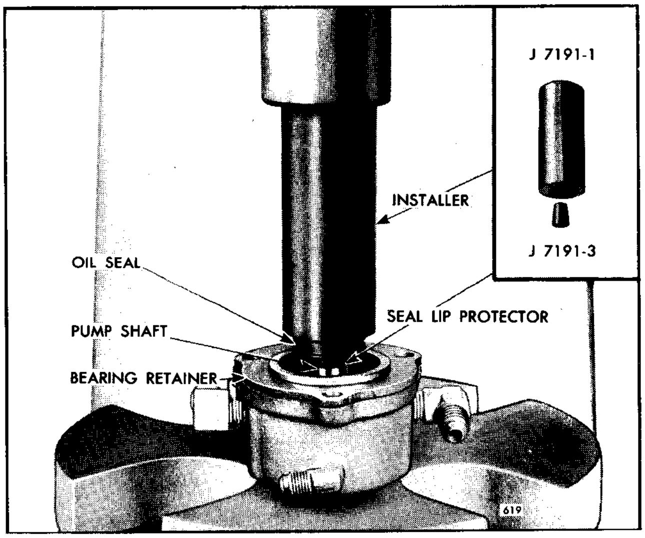

Fig. 15 - Installing Pump Shaft Oil Seal in Bearing Retainer

8. Insert the baffle and check valve assembly (with the spring end of the assembly in first) into the pump body. Screw the check valve retainer into the pump body against the check valve cage and tighten it to 120-140 **in-lb** torque. Install the pump inlet elbow, using sealant (Permatex No. 2, or equivalent) on all of the threads except the last one nearest the open end of the elbow.

9. If the pump-to-reservoir return elbow and plug were removed, apply sealant to all except the first thread on the elbow and plug and reinstall them.

10. Assemble the pump piston and retaining spring in the pump body.

11. Install the bearing and shaft assembly in the pump body. Work the retaining spring up on the bearing.

12. Affix a new gasket to the pump body and press the bearing retainer by hand into the pump body.

13. Install a new oil seal in the bearing retainer as follows:

a. Apply a thin coat of sealing compound to the outside diameter of the oil seal casing.

b. Place the seal lip protector J 7191-3 over the shaft, lubricate the lip of the seal and slide the seal, lip side first, over the seal lip protector and down to the bearing retainer.

c. Place the seal installer J 7191-1 over the seal lip protector J 7191-3, covering the threaded end of the shaft. Then press the seal in flush with the retainer surface. Refer to Figs. 10 and 15.

14. Place a second gasket on the bearing retainer. Align the three bolt holes of the mounting plate, bearing retainer, pump body and both gaskets and secure the parts together with bolts and lock washers. Make sure the scribe marks previously made on the mounting plate and the pump body are aligned to ensure proper position of the pump when it is installed on the engine.

15. Secure the pump drive on the shaft with a nut and lock washer.

Install Pump

Refer to Figs. 2 and 11 and install the pump as follows:

1. Affix a new gasket to the flywheel housing using a non-hardening gasket cement on the flywheel housing side only.

2. Align the tangs on the pump drive with the slots in the drive plate. Attach the pump and mounting plate securely to the engine with bolts and lock washers.

CAUTION: Do not force the pump into place. Use of force, or tightening the bolts when the mounting flange is not against the flywheel housing, will force the drive arm against the pump body and result in damage to the pump when the engine is started.

3. Connect the hydraulic hoses to the pump.

BELT-DRIVEN CHARGING PUMP

The belt-driven charging pump (Fig. 16) is similar in design and operation to the direct engine-driven pump, but has a longer shaft to accommodate a drive pulley.

Disassemble Pump

With the pump removed from the engine, refer to Figs. 16 and 17 and proceed as follows:

1. After removing the pulley retaining nut and lock washer, remove the pulley from the shaft, using a suitable puller.

2. Scribe marks on the bearing retainer and pump body prior to disassembly to ensure their correct reassembly.

3. Remove the three retaining bolts and lock washers. Separate the bearing retainer and pump shaft,

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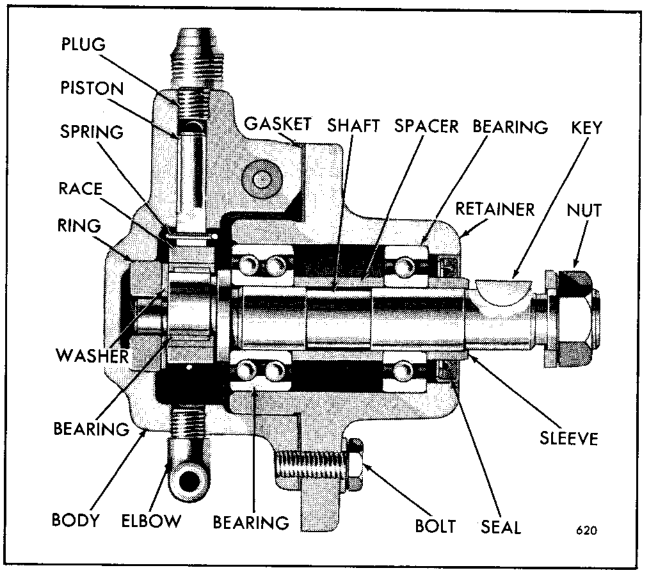

Fig. 16 - Belt-Driven Hydrostarter Charging Pump

including the shaft bearings, as an assembly from the pump body. Remove and discard the pump body gasket.

4. Press the pump shaft assembly from the bearing retainer using an arbor press or by tapping on the threaded end of the shaft with a plastic hammer.

5. If inspection reveals the pump shaft bearings and oil seal sleeve are worn excessively, remove them from the pump shaft for replacement by new parts.

6. Remove the needle bearing and outer race, fiber washer, retaining spring, piston and thrust ring from the pump body.

7. Remove the oil seal from the bearing retainer if the seal is worn or damaged.

8. Remove the pressure relief spring retaining plug, gasket, spring and spring seat.

9. Remove the compression spring retaining plug, compression spring, pressure relief piston, washer, seal ring and back-up ring.

10. Remove the pump outlet elbow, spacer, retainer and baffle. The helical spring, ball and cage may then be removed as an assembly. Remove the baffle. DO NOT separate the helical spring and ball from the cage. If the check valve on either side of the pump is defective, replace the complete check valve assembly.

11. Remove the pump inlet elbow and the check valve retainer. Then remove the cage, ball and spring as an assembly. Remove the baffle. DO NOT separate the spring and ball from the cage.

12. The pump-to-reservoir return elbow and plug may be removed, if necessary, to clean the pump body.

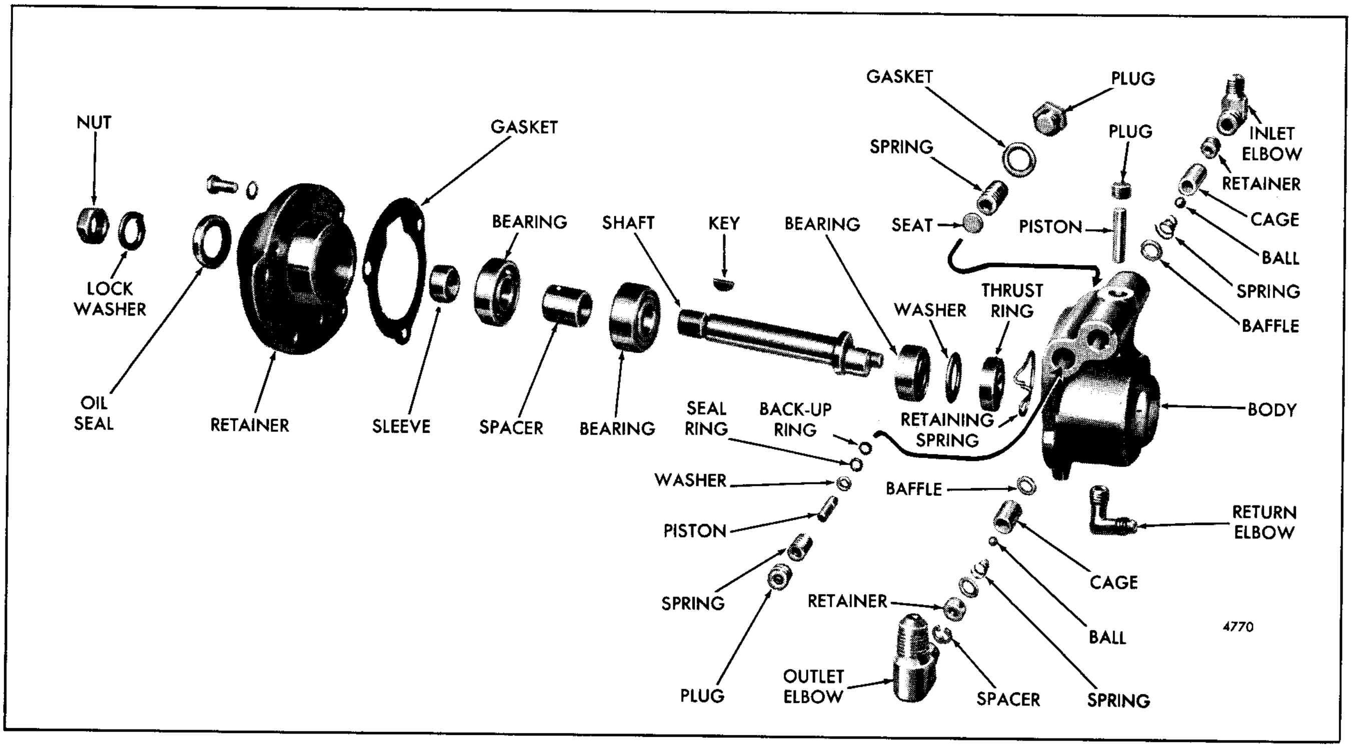

Fig. 17 - Belt-Driven Charging Pump Details and Relative Location of Parts

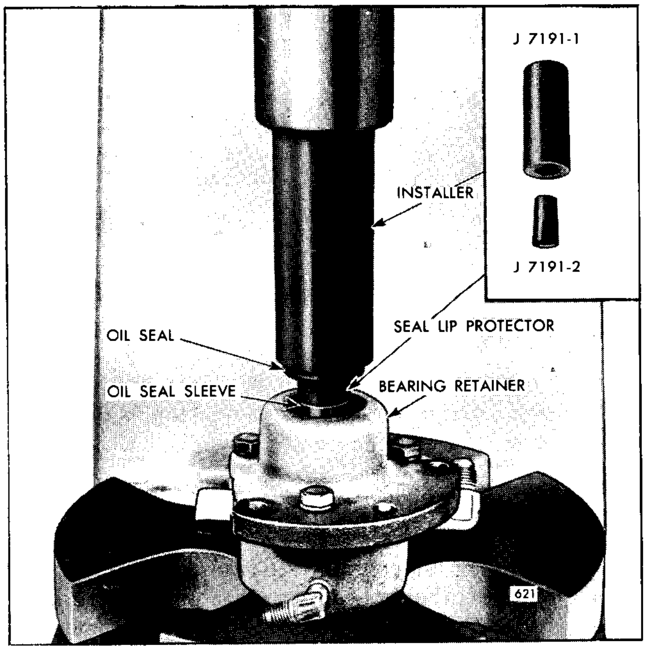

Fig. 18 - Installing Pump Shaft Oil Seal in Bearing Retainer

Assemble Pump

After cleaning, inspection and replacing the necessary parts, refer to Figs. 16 and 17 and proceed as follows:

1. Insert the spring seat and pressure relief spring in the pump body and lock them in place with a gasket and plug.

2. Slide a new back-up ring, new seal ring and washer onto the end of the pressure relief piston, opposite the flat end. DO NOT slide the seal across the groove in the piston.

3. Coat the back-up ring and seal ring liberally with hydraulic fluid. Then insert the relief piston assembly into the pump body, the flat end of the piston first, using installer J 7192. Apply manual force to the installer in order to gradually work the back-up ring and seal ring into the counterbore around the pressure relief piston. Care must be taken to avoid cutting the seal ring as it is worked into place. Refer to Figs. 13 and 14.

4. Remove the washer and inspect the work to make certain the seal ring is completely in the counterbored hole and that the pressure relief piston is down solidly against the spring seat.

5. Reassemble the washer over the pressure relief piston and insert the compression spring and secure it in place with the plug. Use sealant (Permatex No. 2, or equivalent) sparingly on the threads of the plug.

6. Insert the baffle, check valve assembly (with the spring end facing out) and baffle into the pump body. Screw the check valve retainer into the body, against the baffle, and tighten it to 120-140 **in-lb** torque.

7. Place the spacer in the pump body on top of the retainer and install the pump outlet elbow, using sealant (Permatex No. 2, or equivalent) on the threads. DO NOT apply sealant on the last thread nearest the open end of the elbow.

8. Insert the baffle and check valve assembly (with the spring end of the assembly in first) into the pump body. Screw the check valve retainer into the pump body against the check valve cage and tighten it to 120-140 **in-lb** torque. Install the pump inlet elbow, using sealant (Permatex No. 2 or equivalent) on all of the threads except the last one nearest the open end of the elbow.

9. If the pump-to-reservoir return elbow and the plug were removed, apply sealant to all except the first thread on the elbow and plug and reinstall them.

10. Install the thrust ring in the counterbore of the pump body. Lay the fiber washer on the thrust ring.

11. Assemble the pump piston and the retaining spring in the pump body.

12. Install the needle bearing with its outer race in the retaining spring.

> **NOTE:** The current belt-driven pumps incorporate a 5/8" diameter shaft. Former pumps used on 11/16" diameter shaft. When an old pump assembly or shaft is replaced by a current pump or shaft, a new pulley with a 5/8" bore must also be provided. The diameter of the pulley must be such that the pump will not exceed a constant speed of 2500 rpm.

13. Slide the end of the pump shaft assembly through the needle bearing, and the fiber washer into the thrust ring.

14. Affix a new gasket to the pump body. Assemble the bearing retainer to the pump body. Align the scribe marks previously made on the retainer and pump body and install the retaining bolts and lock washers.

15. Install a new oil seal in the bearing retainer as follows:

a. Apply a thin coat of sealing compound to the outside diameter of the oil seal casing.

b. Place the oil seal lip protector J 7191-2 over the shaft, lubricate the lip of the seal and slide the

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seal, lip side first, over the oil seal lip protector and down to the bearing retainer.

c. Place the oil seal installer J 7191-1 over the seal lip protector J 7191-2, covering the threaded end of the shaft. Then press the seal in flush with the outer face of the retainer. Refer to Figs. 16 and 18.

16. Install the pulley on the shaft.

17. Install the charging pump on the engine and connect the hydraulic hoses to the pump.

HAND PUMP

The hand pump (Fig. 19), is a single piston double-acting positive displacement type. It is mounted in such a manner that the pumping action is never in a vertical direction and the handle clears all obstructions throughout its complete stroke. The handle may be removed and stored when the pump is not in use.

The hand pump is used to provide the initial hydraulic pressure for a new Hydrostarter installation or to build-up the pressure in the Hydrostarter system if it has been released for any reason.

Flow through the pump is controlled by ball check valves. A manually operated relief valve is provided in the hand pump to release the pressure when servicing of any of the components in the Hydrostarter system is required.

Remove Hand Pump

Remove the hand pump as follows:

1. Release the pressure in the Hydrostarter system by opening the relief valve (Fig. 19) on the side of the pump approximately 1/2 turn.

CAUTION: The oil pressure in the system must be released prior to servicing the hand pump or any other components of the system to prevent possible injury to personnel or equipment.

2. Clean all of the exterior dirt from the hand pump and the hydraulic hoses.

3. Disconnect the hydraulic hoses at the pump.

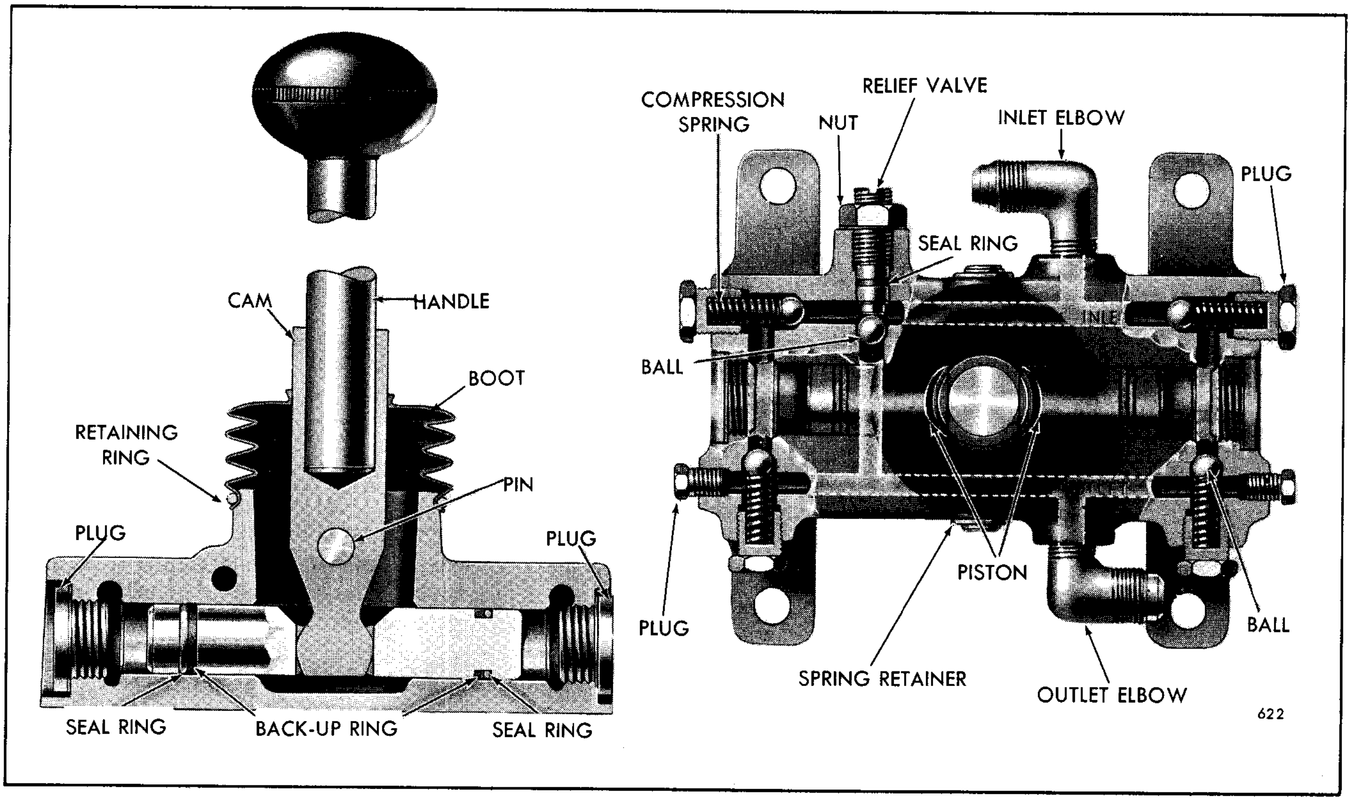

Fig. 19 - Cross Sections of Hydrostarter Hand Pump

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4. Remove the attaching bolts and lock washers and lift the pump from its mounting.

Disassemble Hand Pump

1. Withdraw the handle from the pump cam. Release the rubber boot from the pump body by removing the retaining ring.

2. Remove the two spring retainers and withdraw the pin.

3. Withdraw the cam and boot from the pump body.

4. Remove the four plugs, compression springs and check valve balls.

5. Remove the two plugs and metal gaskets and withdraw the piston, with the back-up rings and seal rings, from the pump body.

6. Remove the relief valve and ball. The pump inlet and outlet elbows and remaining plugs may be removed, if necessary, in order to clean or inspect the pump body.

7. Remove the seal rings and the seal back-up rings from the piston.

Assemble Hand Pump

After an initial cleaning, inspect the pump parts. Stone the check valve ball seats in the pump body, if necessary. Then thoroughly clean the pump parts and reseat the balls in the pump body, using a non-hardened steel rod. Assemble the pump as follows:

1. Thoroughly soak new back-up rings in warm oil prior to installation. Slide the back-up rings and new seal rings on the piston.

2. Insert the piston in the pump body, notched side up, and secure it in place with plugs and new metal gaskets.

3. Clean and install the four check valve balls and springs. Install the retaining plugs.

4. If the pump inlet and outlet elbows and plugs were removed, reinstall them in the pump body. Use Permatex No. 2, or equivalent, on all male threads except the thread nearest to the open end.

5. Assemble a new seal ring on the relief valve, then insert the ball in place and secure it with the relief valve and lock nut.

6. Install the cam and insert the pin through the pump body and cam. Install the spring retainers on the pin. Install the rubber boot and secure it with a retaining ring.

7. Slide the handle into the cam.

Install Hand Pump

1. Secure the pump to its mounting with the attaching bolts and lock washers.

2. Refer to Fig. 1 and connect the two hydraulic hoses to the pump.

NOTE: Make sure the hoses and fittings are clean before any connections are made.

ACCUMULATOR

Three different types of accumulators (Fig. 20) have been used with the Hydrostarter system. The accumulator consists of a heavy duty shell assembly and piston designed to hold the nitrogen pressure for an extended period of time.

The accumulator is preloaded with nitrogen through a small valve and sealed at the time of manufacture. A seal ring is assembled in the groove of the piston, between two teflon (formerly leather) back-up rings, to prevent the nitrogen from entering the hydraulic system. The nitrogen is stored in the air valve end of the accumulator and the fluid is discharged at the opposite end.

A rubber seal ring and a teflon (formerly leather) back-up ring are used at each cap to prevent the escape of fluid and nitrogen from the shell. Nitrogen is used because it is an inert gas that will not rust or corrode the piston or the accumulator. Also, it is inexpensive, non-toxic, non-explosive and readily available.

Oil enters the accumulator under pressure from either the engine-driven pump or the hand pump and forces the piston back, compressing the nitrogen gas and storing the energy to operate the system.

The accumulator is available in either 1-1/2 or 2-1/4 gallon capacity.

If a longer cranking period is desired, two or more accumulators may be connected in parallel, provided that a reservoir of sufficient capacity is used.

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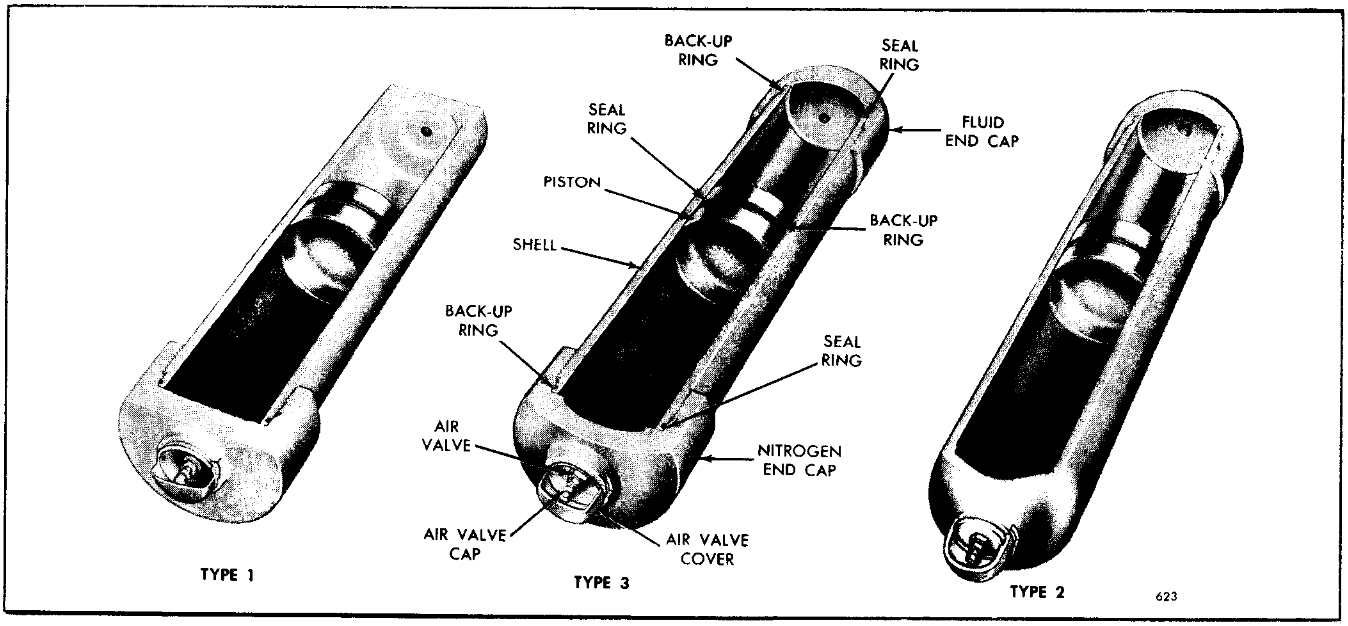

Fig. 20 - Cross Section of Typical Accumulators

Service replacement accumulators are supplied with a precharge of nitrogen (1250 ± 50 psi).

Remove Accumulator

1. Release the oil pressure in the hoses and the accumulator by opening the relief valve (Fig. 1) on the side of the hand pump.

CAUTION: The oil pressure in the Hydrostarter system must be released prior to servicing the accumulator or other components to prevent possible injury to personnel or equipment.

2. Clean all of the exterior dirt from the accumulator and the hydraulic hoses.

3. Disconnect the hydraulic hose at the accumulator.

4. Remove the pressure gage and the fittings from the fluid end cap of the accumulator.

5. Remove the attaching U bolts and lift the accumulator from its mounting.

Disassemble Accumulator

Normally, no maintenance of the accumulator is required other than painting to resist external corrosion. However, if there is a loss of the nitrogen precharge pressure due to a leaky air valve, indicated by bubbles in a soap solution applied around the valve, or due to leakage past the piston, indicated by bubbles and foaming in the reservoir, replace either the air valve or the piston seal rings as required. Seal rings between the end cap and the shell will rarely require replacement, unless the accumulator is disassembled.

1. If a defective air valve was the cause of leakage, remove the air valve cover (Fig. 20) from the accumulator cap and the air valve cap from the air valve. Loosen the 5/8" hex swivel nut on the air valve stem approximately 1-1/2 turns and then depress the valve core to release any remaining nitrogen pressure before removing the air valve. Remove the valve and replace it with a new part.

However, if damaged piston and cap seal rings are surmised, continue with the disassembly.

2. Remove the accumulator caps from the shell with a strap wrench, then push the piston out of the shell by hand.

On the former accumulator (TYPE 1 or 2), remove the cap from the shell with a strap wrench, then insert a rod through the tapped hole in the fluid end or air valve end of the shell and push the piston out of the shell. Do not damage the threads in the accumulator with the rod.

3. Remove and discard the seal ring and the back-up rings from the piston.

4. Remove and discard the seal rings and the back-up rings from the shell.

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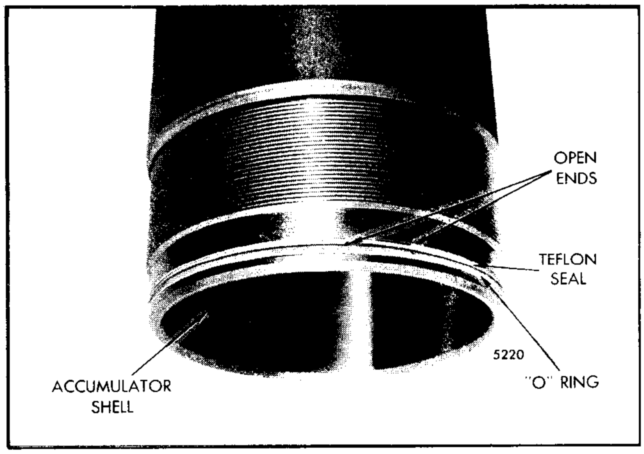

Fig. 21 - Proper Installation of Teflon Back-up Ring

Assemble Accumulator

After cleaning the shell, piston and cap thoroughly, assemble the accumulator as follows:

1. Install new teflon back-up rings (Fig. 20) and new seal rings ("O" rings) in the grooves of the shell, with the seal ring nearest the open end of the shell (Fig. 21).

NOTE: It is important that the teflon seal be installed in the ring groove of the shell so that the open ends do not catch on the threads of the steel cap when it is threaded into the end of the shell. Lubricate the seal ring and the sealing surface of the end cap with engine oil before installing the cap. Reverse positioning of the open ends of the back-up ring can cause contact between the ends and the cap itself. This can cause the back-up ring to buckle and result in an improper seal ring seal when the cap is threaded on the shell.

2. On the current TYPE 3 accumulator, install the fluid end cap on the shell, being careful not to damage the seal ring.

3. Assemble a new seal ring between the two new teflon back-up rings in the piston ring groove. To insure correct positioning of the seal ring ("O" ring) and the two teflon back-up rings, it is recommended that a suitable ring compressor with a diameter capacity of 3-1/2" to 7" and a 3-1/2" high compression band be used.

4. Install the ring compressor on the piston and rings and place the entire assembly on the open end of the shell (Fig. 22). Lubricate the inner surface of the ring compressor and the beginning inner region of the shell with engine oil to reduce friction between the piston and the shell.

5. Carefully drive the piston into the shell with a hammer and block of wood, tapping gently to slowly move the seal ring and back-up rings across the chamfered edge of the shell.

a. On TYPE 1 and 3 accumulators, slide the piston, crown side first, into the shell.

On a TYPE 2 accumulator, slide the piston, crown side facing out, into the shell.

b. On TYPE 1 and 3 accumulators, install the nitrogen end cap on the shell.

On a TYPE 2 accumulator, install the fluid end cap on the shell.

6. Install the fittings and pressure gage in the fluid end cap. Use sealant (Permatex No. 2, or equivalent) on all male threads except the thread nearest the open end.

Install Accumulator

1. Secure the accumulator to its mounting with the U bolts.

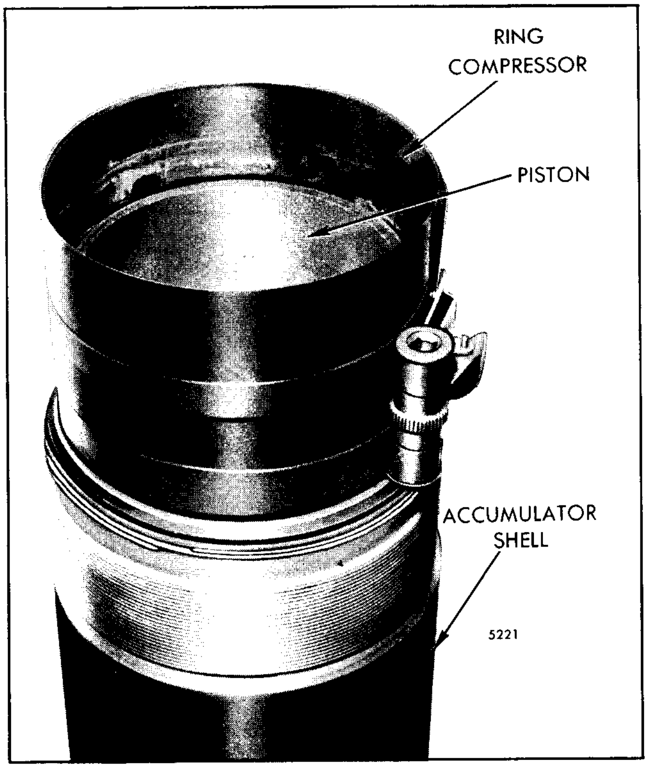

Fig. 22 - Installing Piston in Accumulator Shell

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2. Connect the hydraulic hoses to the accumulator.

NOTE: Make sure the hoses and fittings are clean before any connections are made.

Charge Accumulator

Use the following procedure in precharging an accumulator with commercial nitrogen.

1. Attach the gage end of charging kit J 6714-02 to the nitrogen tank (Fig. 23).

2. Remove the air valve cover (Fig. 20) from the accumulator cap and the cap from the air valve.

3. Install the air valve stem extension on the air valve.

4. Completely back-off the shaft pin in the air check valve connector on the charging kit hose and install the connector on the air valve stem extension. Draw the swivel nut up tight.

5. Loosen the 5/8" hex lock nut on the accumulator air valve stem by turning it counterclockwise. Do not turn the lock nut more than one and one-half turns.

6. Turn the shaft pin in the air check valve connector clockwise until the valve core in the air valve is depressed.

7. Charge the accumulator by opening the valve on the nitrogen tank and allow a small flow of nitrogen to enter the accumulator until the charging kit gage registers 1300 psi. Close the nitrogen tank valve.

To check the precharge pressure during charging, simply shut off the valve to the nitrogen tank, allow a small increment of time for the pressure to stabilize and the pressure indicated on the gage is the accumulator precharge pressure.

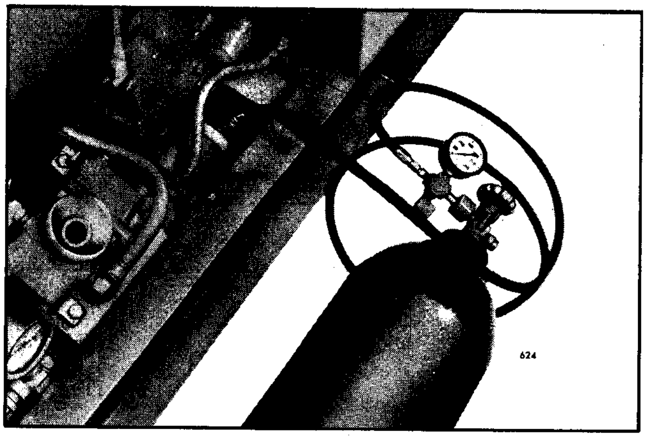

Fig. 23 - Charging Accumulator with Charging Kit J 6714-02

8. Back-off the shaft pin in the air check valve and tighten the 5/8" hex lock nut on the accumulator valve stem. This isolates the pressure in the charging kit hose.

9. Depress the bleed-off valve on the pressure gage to reduce the pressure in the hose to zero.

10. Repeat Steps 5 and 6 to check for a precharge pressure of 1250 psi.

11. Disconnect the accumulator charging kit from the accumulator and from the nitrogen tank.

12. Check for gas leakage by applying a soap solution to the accumulator valve stem.

13. Replace the cap on the air valve and install the air valve cover on the accumulator cap.

14. Make sure a caution decal is on the accumulator. The decal states: *This vessel pre-charged to 1250 psi with dry nitrogen.*

RESERVOIR

The reservoir consists of a cylindrical steel tank of sufficient capacity to hold the entire oil supply for the Hydrostarter system. A filler cap and breather assembly, with a dry-type filter, is located at the top of the reservoir. A fine mesh screen at the reservoir outlet filters all of the fluid flowing to the suction side of the pump.

Reservoirs are available in two basic shapes to fit various installations. There are three sizes of reservoirs: 10, 12, or 23 quart capacity. The size of the reservoir used depends upon the requirements of the particular Hydrostarter installation.

The supply hoses (Fig. 1) leading to the engine-driven pump and the hand pump are connected to the screen at the bottom of the reservoir. A return hose from the engine-driven pump connects to the top of the reservoir, while a drain hose from the Hydrostarter motor is connected to the fitting at the side of the reservoir.

The reservoir must be mounted (with the filler cap at the top) so that the outlet at the bottom of the tank is not more than 36" below nor 12" above the inlet of the engine-driven pump.

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The reservoir requires very little attention other than periodically draining and flushing the old fluid out and cleaning the screen. After cleaning, fill the reservoir with new clean fluid. Make certain that the oil level is sufficient to completely cover the screen at the bottom of the reservoir. This check is made after the accumulator is charged and the engine-driven pump is by-passing oil to the reservoir.

FUEL SYSTEM PRIMING PUMP

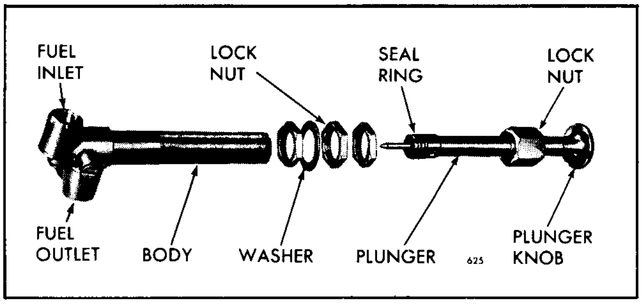

Fig. 24 - Fuel System Priming Pump and Relative Location of Parts

The small compact priming pump (Fig. 24) is used to permit the operator to prime the injectors. Before starting the engine, the operator must make sure ample fuel is present in the injectors, fuel lines, fuel filters and fuel manifolds.

The priming pump requires very little service other than an occasional cleaning of the ball check valves in the inlet and outlet passages of the pump or replacement of the seal rings. To clean the ball check valves, remove the plugs, springs and ball check valves. Clean the parts with fuel oil and reinstall them in the pump.

To replace the seal rings, loosen the lock nut and withdraw the plunger. Discard the oil seal rings. Install new seal rings and insert the plunger carefully in the pump body. Tighten the lock nut.

HYDRAULIC REMOTE CONTROL SYSTEM

The hydraulic remote control system consists of a master cylinder, a pedal, a lever arm, two springs and a flexible hose. It is an independent hydraulic system using diesel fuel oil as the hydraulic fluid to actuate the Hydrostarter control valve by means of the manually operated master cylinder.

The master cylinder (Figs. 25 and 26) is a single piston, positive displacement type of mechanism and is connected to the control valve on the Hydrostarter by a flexible hose. The fluid displaced by the piston is ported to the rear of the control valve.

Hydraulic pressure opens the control valve and engages the starter pinion with the engine flywheel ring gear in the proper sequence.

The master cylinder may be located at any desired location. However, for distances greater than 15 feet, 1/4" O.D. steel or copper tubing must be used between the flexible hose and the master cylinder. The flexible hose is always connected to the Hydrostarter control valve housing.

Current Hydrostarter motors are equipped with a control valve that incorporates a threaded valve housing plug with a 1/8" - 27 tapped hole in the center for installation of the flexible hose. A 1/8" - 27 vent plug is installed when the remote control system is not used. A cup plug was used in the valve housing on former Hydrostarter motors.

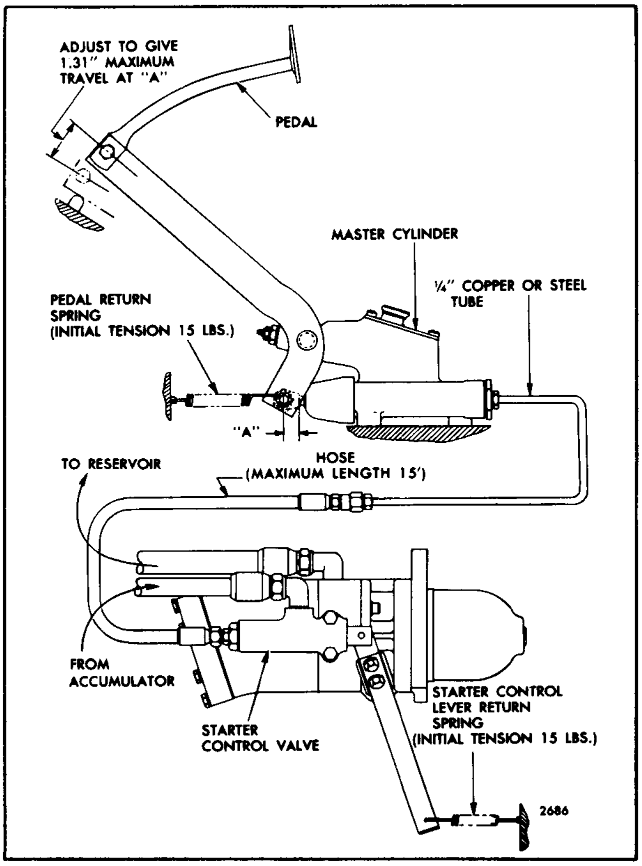

Fig. 25 - Hydraulic Remote Control System for Hydrostarter

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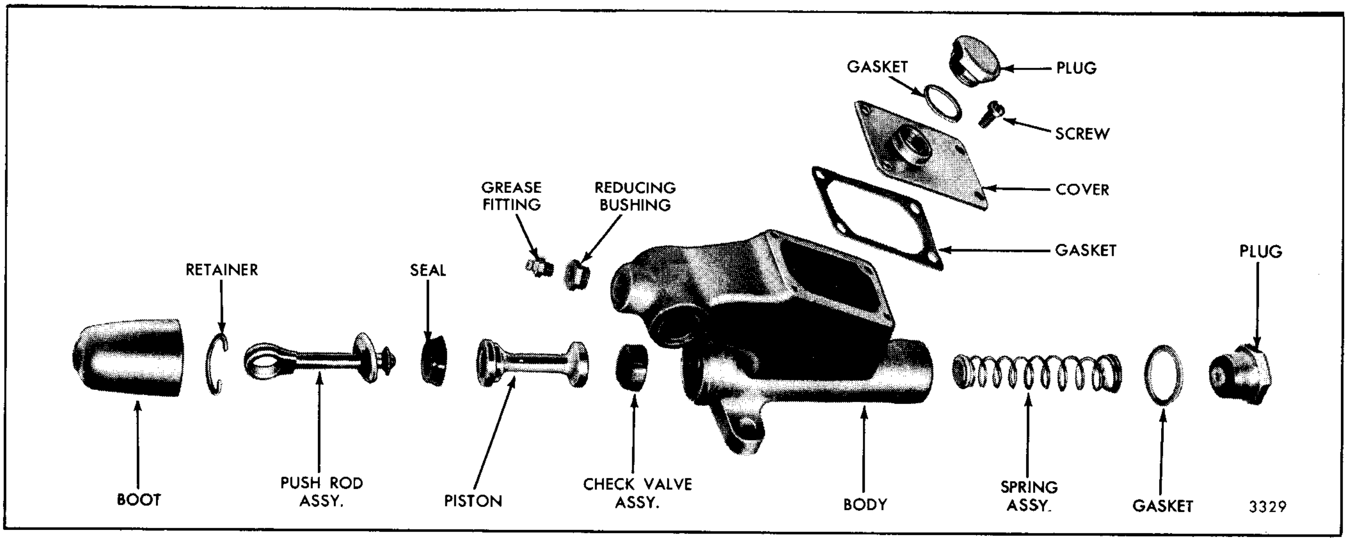

Fig. 26 - Hydraulic Starter Remote Control Master Cylinder Details and Relative Location of Parts

Springs are used to return the master cylinder piston and the Hydrostarter control lever to the off position. The springs have an initial tension of 15 lbs (Fig. 25).

The master cylinder lever arm must be adjusted to give the piston push rod a maximum travel of 1.31" (Fig. 25). The Hydrostarter control valve must be free to open to a minimum of 1-1/16".

The Hydrostarter remote control system may be purged of air as follows:

1. Fill the master cylinder with fuel oil.

2. Loosen the hose fitting at the Hydrostarter control valve.

3. Actuate the master cylinder pedal until all of the air is discharged from the system and a solid stream of fuel oil is being discharged with each stroke.

> **NOTE:** Replenish the fluid in the master cylinder as required during the purging operation.

4. Tighten the hose fitting and check for leaks.

LUBRICATION AND PREVENTIVE MAINTENANCE

Inspect the system periodically for leaks. Primarily, examine the high pressure hoses, connections, fittings and the control valve on the starter. Make certain that the oil level in the reservoir is sufficient to completely cover the screen at the bottom of the tank. Make this check after the accumulator is charged and the engine-driven pump is by-passing oil to the reservoir.

Every 2000 hours, or as conditions warrant, drain the reservoir and remove the screen. Flush out the reservoir and clean the screen and filler cap. Then reinstall the screen.

Remove the bowl and element from the filter in the engine-driven pump supply hose (Fig. 1). Wash the bowl and element in clean fuel oil and reassemble the filter.

Release the pressure and drain the remaining hydraulic fluid from the system by disconnecting the hoses from the Hydrostarter components. Then reconnect all of the hydraulic hoses.

> **CAUTION:** The oil pressure in the system must be released prior to servicing the Hydrostarter motor or other components to prevent possible injury to personnel or equipment.

> **NOTE:** Make sure all hoses and fittings are clean before any connections are made.

Fill the Hydrostarter system with new clean fluid as recommended.

Lubrication

Remove the Hydrostarter from the engine every 2000 hours for lubrication. Before removing the Hydrostarter, release the pressure in the system by means of the relief valve in the hand pump. Then remove the three bolts that retain the starting motor to the flywheel housing. Remove the starting motor without disconnecting the hydraulic hoses. This will prevent dirt and air from entering the hydraulic system.

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Apply a good quality, lightweight grease on the drive clutch pinion to make sure the clutch will slide freely while compressing the spring. Also apply grease to the fingers of the clutch fork and on the spool of the clutch yoke engaged by the fork. This lubrication period may be reduced or lengthened according to the severity of service.

Remove the pipe plug from the starting motor drive housing and saturate the shaft oil wick with engine oil. Then reinstall the plug.

After lubricating, install the starting motor on the flywheel housing and recharge the accumulator with the hand pump.

On units equipped with a hydraulic remote control system, lubricate the shaft in the master cylinder through the pressure grease fitting every 2000 hours.

Cold Weather Operation

Occasionally, when an engine is operated in regions of very low temperatures, the starter drive clutch assembly may slip when the starter is engaged. If the clutch slips, proceed as follows:

1. Release the oil pressure in the system by opening the relief valve in the hand pump.

   CAUTION: The oil pressure in the system must be released prior to servicing the Hydrostarter motor or other components to prevent possible injury to personnel or equipment.

2. Disconnect the hydraulic hoses from the starting motor.

3. Remove the three retaining bolts and lock washers and withdraw the starting motor from the flywheel housing.

4. Disassemble the starting motor.

5. Wash the Hydrostarter drive clutch assembly in clean fuel oil to remove the old lubricant.

6. When the clutch is free, apply SAE 5W lubricating oil.

7. Reassemble the starting motor and reinstall it on the engine. Then attach a tag to the starter noting the lubricant used in the clutch.

8. Recharge the accumulator with the hand pump.

Marine Application

In addition to the normal Hydrostarter lubrication and maintenance instructions, the following special precautions must be taken for marine installations or other cases where equipment is subject to salt spray and air, or other corrosive atmospheres:

1. Clean all exposed surfaces and apply a coat of zinc-chromate primer, followed by a coat of suitable paint.

2. Apply a liberal coating of Lubriplate, type 130-AA, or equivalent, to the following surfaces.

   a. The exposed end of the starter control valve and around the control shaft where it passes through the clutch housing (Fig. 4).

   b. The exposed ends of the hand pump cam pin (Fig. 19).

3. Operate all of the moving parts and check the protective paint and lubrication every week.

Trouble Shooting

The ability of the Hydrostarter system to provide positive starts under all conditions, with little service over a long period of time, depends primarily on proper maintenance.

Certain abnormal conditions that may interfere with the satisfactory performance of the Hydrostarter system, together with the methods of determining the cause of such conditions, are covered in the Trouble Shooting Charts in Section 12.0.

Service

Before any work is performed, the oil pressure in the Hydrostarter system must be released to prevent possible injury to personnel or equipment.

Remove all of the exterior dirt before any portion of the hydraulic system is opened. Dust, dirt or other foreign material must never be allowed to enter the system.

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TROUBLE SHOOTING - SPECIFICATIONS - SERVICE TOOLS

TROUBLE SHOOTING (Hydrostarter)

Chart 1

LOW OR NO ACCUMULATOR PRESSURE

ENGINE DRIVEN PUMP FAILS TO RAISE PRESSURE

Probable Causes

1. AIR IN SYSTEM
2. LOW FLUID LEVEL
3. SCREEN OR FILTER PLUGGED
4. CHECK VALVES NOT FUNCTIONING PROPERLY
5. DRIVE BELT SLIPPING (BELT-DRIVEN PUMP)
6. DRIVE ARM DEFECTIVE (DIRECT-DRIVEN PUMP)

SUGGESTED REMEDY

1. To purge the engine driven pump of air:

a. Operate the engine at maximum no-load engine speed.

b. Break the hose connection at the discharge side of the engine-driven pump until a full stream of oil is discharged from the pump.

c. Connect the hose to the pump and alternately loosen and tighten the swivel fitting on the discharge hose until oil leaking out, when the fitting is loose, appears free of air bubbles.

d. Tighten the fitting securely and observe the pressure gage. The pressure must rise rapidly to the accumulator precharge pressure (1250 psi (8 619 kPa) at 70 °F or 21 °C) then increase slowly to 2900-3300 psi (19 996 to 22 754 kPa) in six to ten minutes, depending upon the size of the particular accumulator. If the accumulator pressure does not rise, make certain that the hand pump relief valve is closed after the pressure is released and repeat the above purging procedure.

2. The fluid level in the reservoir must be sufficient to completely cover the screen at the bottom of the tank after the accumulator is charged and the engine-driven pump is by-passing a full stream of fluid to the reservoir.

3. Remove and clean the reservoir screen and flush out the reservoir tank. Also clean the filter located in the supply hose between the reservoir and the engine-driven pump.

4. Open the relief valve on the side of the hand pump, while the engine is running, to permit the engine-driven pump to wash the check valves free from particles.

If the accumulator can be charged with the hand pump but not with the engine-driven pump, then a check valve in the engine pump is defective. Replace the faulty check valve assembly.

5. Adjust or replace the drive belt if necessary.

6. Replace the pump drive arm.

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Chart 2

CRANKING SPEED TOO LOW

Probable Causes

1. HYDROSTARTER SYSTEM FLUID TOO HEAVY
2. ENGINE OIL TOO HEAVY
3. CONTROL VALVE NOT FULLY OPEN

SUGGESTED REMEDY

1. Check the mixture of fluid in the system. Use fluid consisting of 75% diesel fuel and 25% SAE 10 or 30 lubricating oil.

2. Replace the oil with the proper viscosity grade. Refer to the *Engine Lubricating Oil Specifications* in Section 13.3.

3. Check the travel of the control valve located on the side of the starter. Minimum travel is 1-1/16″. Remove any obstruction that prevents sufficient control valve or control lever handle travel.

Chart 3

LOSS OF FLUID FROM RESERVOIR

Probable Causes

1. EXTERNAL LEAKS
2. WORN STARTER SHAFT SEAL
3. DEFECTIVE GASKET UNDER STARTER COVER
4. WORN SHAFT SEAL (BELT-DRIVEN PUMP)
5. WORN SHAFT SEAL (DIRECT-DRIVEN PUMP)

SUGGESTED REMEDY

1. With pressure in the system, check all hoses and fittings for leaks. Tighten or replace the fittings and any defective parts.

2. Remove the starter after releasing the system pressure and observe the inside of the clutch housing. If evidence of system fluid is found, replace the shaft seal.

3. Operate the starter. During the cranking cycle, watch closely for fluid leaking around the cover or any of the retaining bolts.

4. While the pump is by-passing at full system pressure, examine the shaft for evidence of leaks. Replace the seal if necessary.

5. After the pump has been by-passing at full system pressure, remove the pump from the flywheel housing and examine the back of the mounting plate near the seal for evidence of leaks. Replace the shaft seal if necessary.

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Chart 4

LOSS OF FLUID PRESSURE WHEN ENGINE IS NOT RUNNING

Probable Causes

1. AMBIENT TEMPERATURE DECREASE
2. ENGINE DRIVEN PUMP CHECK VALVES NOT HOLDING
3. HAND PUMP VALVES NOT HOLDING
4. DAMAGED SEAL RING IN STARTER CONTROL VALVE SHOWN BY EXTERNAL LEAKAGE
5. DAMAGED MIDDLE SEAL RING IN STARTER CONTROL VALVE, NO VISIBLE EXTERNAL LEAKAGE
6. EXTERNAL LEAKAGE IN SYSTEM
7. STARTER CONTROL VALVE OUT OF TIME - BENT SHIFTING FORK
8. LOSS OF ACCUMULATOR PRE-CHARGE (NITROGEN)

SUGGESTED REMEDY

1. A drop in temperature will decrease the nitrogen pressure. Adjust the pressure as needed for cranking requirements by use of the hand pump.

2. Disconnect the return hose and inlet hose from the engine-driven pump. Leakage from the inlet fitting means that both check valves are defective. Leakage at the return fitting means that only the outlet check valve is defective. Replace the defective check valve assembly(s).

3. Disconnect the inlet hose from the hand pump. Leakage from the inlet fitting means that either the relief valve alone or both the inlet and outlet check valves are defective. Stone and clean the ball seats in the pump body and replace the balls and springs if necessary.

4. Remove the control valve from the starter and replace the seal ring.

5. Disconnect the return hose from the starter. Use the hand pump to raise the pressure if necessary. If fluid leaks from the return fitting when the control valve is closed, the middle seal ring is damaged. Remove the control valve and replace the seal ring.

6. Examine all hoses and fittings for leaks. Tighten or replace the fittings and any defective parts.

7. With the control valve closed, check the length of the piston protruding beyond the valve body. The correct length is 7/8 " ±1/32 ". If the length is incorrect, the shifting fork may be bent or the nylon yoke between the fork and the clutch collar may be damaged. Replace the faulty parts.

8. See Chart 7.

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Chart 5

HAND PUMP FAILS TO DISCHARGE FLUID

Probable Causes

1. MANUAL RELIEF VALVE OPEN
2. CHECK VALVES LEAKING
3. RESERVOIR SCREEN PLUGGED
4. FLUID LEVEL LOW
5. AIR IN SYSTEM
6. DIRT IN PUMP
7. PISTON SEAL RINGS DAMAGED

SUGGESTED REMEDY

1. Close the relief valve.

2. If caused by dirt, open the relief valve and operate the hand pump slowly for a few minutes to wash the particles out of the check valves. If this is unsuccessful, stone and clean the ball seats in the pump body and replace the balls and springs if necessary.

3. Remove and clean the reservoir screen, flush the reservoir tank and reassemble.

4. See Chart 1, Item 2.

5. To purge the hand pump of air:

   a. Relieve any system pressure, then disconnect the outlet hose from the hand pump.

   b. Close the manual relief valve and operate the pump until fluid is discharged when stroking in both directions.

   c. Reconnect the outlet hose.

6. See Item 2.

7. Replace the seal rings.

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Chart 6

STARTER TURNS BUT ENGINE DOES NOT

Probable Causes

1. PINION NOT ENGAGING FLYWHEEL RING GEAR
2. PINION CLUTCH SLIPPING (COLD WEATHER OR HEAVY LUBRICANT)
3. OVERRUNNING CLUTCH BURNED OUT
4. STARTER ASSEMBLED WRONG

SUGGESTED REMEDY

1. Check the shifting fork. If the fork is bent, replace it.

2. Wash out the heavy lubricating oil and replace it with SAE 5W or SAE 10 oil.

3. Replace the clutch. If a mechanical linkage is attached to the control lever, add sufficient spring force to assure that the clutch is withdrawn from engagement, and that the control valve is returned to the shut-off position. If no mechanical linkage is used, disengage the starter as soon as the engine starts. Prolonging the period during which the clutch overruns will reduce clutch life.

4. The starter may be assembled for L.H. rotation but with a R.H. overrunning clutch. Remove the starter and assemble it correctly.

Chart 7

LOSS OF ACCUMULATOR PRE-CHARGE (NITROGEN)

Probable Causes

1. DAMAGED SEAL RING ON PISTON
2. DEFECTIVE AIR VALVE
3. DAMAGED SEAL RING BETWEEN SHELL AND END CAP

SUGGESTED REMEDY

1. With some nitrogen precharge but no fluid pressure in the system, bubbles and foaming in the reservoir indicate that the nitrogen is leaking past the seal ring on the accumulator piston. Overhaul the accumulator.

2. Release the pressure in the system by opening the relief valve on the side of the hand pump. Then loosen the hex lock nut on the nitrogen valve approximately 3/4 turn to release the remaining precharge before attempting to remove the valve from the accumulator. Replace the air valve.

3. Apply light oil on the threaded end of the accumulator at the end of the cap. Bubbling of the oil indicates a leak past the end cap seal. Release the nitrogen precharge before removing the cap to replace the seals.

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Chart 8

HIGH PRESSURE IN SYSTEM 3500 psi (24 133 kPa) or above

Probable Causes

1. DEFECTIVE GAGE

2. ENGINE DRIVEN PUMP UNLOADING VALVE NOT OPERATING PROPERLY

SUGGESTED REMEDY

1. Replace the gage.

2. Overhaul the pump.

Chart 9

FLUID EMERGES FROM RESERVOIR FILLER CAP WHEN STARTER IS USED

Probable Causes

1. FILTER ELEMENT IN FILLER CAP LOADED WITH DIRT

2. NITROGEN IN FLUID RETURNED TO RESERVOIR

3. EXCESS FLUID IN RESERVOIR

SUGGESTED REMEDY

1. Rinse the filler cap thoroughly in fuel oil and dry it with compressed air.

2. Overhaul the accumulator. See Chart 7, Item 1.

3. Check the fluid level after the accumulator is charged and the engine-driven pump is by-passing a full stream of oil to the reservoir. The fluid level must be sufficient to completely cover the screen in the bottom of the tank.

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Chart 10

FLUID EMERGES AROUND RUBBER BOOT ON HAND PUMP

Probable Cause

1. DAMAGED PISTON SEAL RINGS

SUGGESTED REMEDY

1. Replace the seal rings and leather back-up rings on the pump piston.

Chart 11

FLUID EMERGES FROM ENDS OF STARTER CONTROL VALVE WHEN STARTER IS OPERATED

Probable Causes

1. DAMAGED FRONT CONTROL VALVE SEAL RING

2. BENT SHIFTING FORK CAUSING END OF CONTROL VALVE TO MOVE PAST THE REAR SEAL RING

SUGGESTED REMEDY

1. Operate the starter. If fluid emerges around the front end of the control valve, the seal ring is damaged.

2. See Chart 4, Item 7. Also operate the starter. If fluid emerges from the cap on the rear of the control valve, the fork is bent and the seal ring may be damaged.

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HYDROSTARTER SPECIFICATIONS

Hydrostarter Motor	
Type	Swash plate
Number of pistons	Seven
Displacement per revolution *20 Series*	2 cu. in. (32.8 cm^3)
Displacement per revolution *35 Series*	3.5 cu. in. (57.4 cm^3)
Maximum torque at 3000 psi *20 Series*	80 lb-ft (108 Nm)
Maximum torque at 3000 psi *35 Series*	140 lb-ft (190 Nm)
Drive	Overrunning clutch
Inlet port *20 and 35 Series*	No. 8 elbow (J1C 37 ° flare)
Return port *20 Series*	No. 10 elbow (SAE 45 °flare)
Return port *35 Series*	No. 12 elbow (SAE 45 ° flare)
Engine-Driven Pump	
Type	Positive displacement
Number of pistons	One
Displacement per revolution	0.0208 cu. in. (.400 cm^3)
Inlet port	No. 6 elbow (SAE 45 ° flare)
Outlet port	No. 6 elbow (J1C 37 ° flare)
By-pass port	No. 4 elbow (SAE 45 ° flare)
Maximum discharge pressure	3250 psi (22 409 kPa)
Maximum continuous speed	2500 rpm
Manual Pump	
Type	Positive displacement
Number of pistons	One
Displacement per stroke	0.773 cu. in. (12.67 cm^3)
Inlet port	No. 6 elbow (SAE 45 ° flare)
Outlet port	No. 6 elbow (J1C 37 ° flare)
Accumulator	
Type	Piston
Capacity	200 or 300 cu. in. (3278 or 4916 cm^3)
Precharge (nitrogen)	1250 psi (8 619 kPa)
Operating pressure	2900-3000 psi (19 996-20 685 kPa)
Port	3/8 NPTF
Reservoir	
Capacity	10, 12, 16 or 23 qt. (9.5, 11.4, 15.1 or 21.8 litres)
Outlet port	1/4 NPT
Pump return port	1/8 NPT
Starter return port	1/2 NPT
Drain (plug) port	1/8 NPT
Remote Control Master Cylinder	
Type	Positive displacement
Number of pistons	One
Displacement per stroke	1.2 cu. in. (19.7 cm^3)
Outlet port	7/16-24 inverted flare tap
Filter	
Type	Sediment bowl-stacked disc
Degree of filtration	50 microns
Inlet port	1/8 NPTF
Outlet port	1/8 NPTF

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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 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 1 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

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SERVICE TOOLS

TOOL NAME	TOOL NO.
Accumulator charging kit	J 6714-02
Piston, back-up ring, seal ring and washer installer	J 7192
Spring compressor	J 7187

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SECTION 13

OPERATING INSTRUCTIONS

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Engine Run-In Instructions 13.2.1

Fuels, Lubricants and Coolants 13.3

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ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

Before starting an engine for the first time, carefully read and follow the instructions in Sections 13 and 14 of this manual. Attempting to run the engine before studying these instructions may result in serious damage to the engine.

> **NOTE:** When preparing to start a new or overhauled engine or an engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart*, Section 15.1.

Cooling System

Install all of the drain cocks or plugs in the cooling system (drain cocks are removed for shipping).

Open the cooling system vents, if the engine is so equipped.

Remove the filler cap and fill the cooling system with a coolant specified under *Coolant Specifications* in Section 13.3. Keep the liquid level about two inches below the filler neck to allow for fluid expansion.

Close the vents, if used, after filling the cooling system.

On marine installations, prime the raw water cooling system and open any sea cocks in the raw water pump intake line. Prime the raw water pump by removing the pipe plug or electrode provided in the pump outlet elbow and pour water in the pump.

> **NOTE:** Failure to prime the raw water pump may result in damage to the pump impeller.

Lubrication System

The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one which has been in storage, may be insufficient for proper lubrication when the engine is started for the first time. Insufficient lubrication at start-up can cause serious damage to the engine components.

To ensure an immediate flow of oil to all bearing surfaces at initial engine start-up, DDA recommends that the engine lubrication system be charged with a commercially available pressure pre-lubricator. Use the following procedure:

1. Remove the pipe plug from the engine main oil gallery and attach the pre-lubricator hose.

2. Remove the valve rocker cover(s) and, using a positive displacement pump set at 25-35 psi (172-241 kPa), pump in the recommended grade of engine lubricating oil until it is observed flowing from the rocker arms.

3. If the engine is turbocharged, disconnect the oil supply lines at the turbo bearing (center) housings and fill the bearing housing cavities with approximately one pint of the recommended grade of clean engine oil. Turn the rotating assemblies by hand to coat all internal surfaces with oil and reinstall the turbo oil supply lines (refer to Section 3.5).

4. After 20 minutes, check the crankcase oil level. Add enough oil to bring the level to the "full" mark on the dipstick. *Do not overfill.*

5. Disconnect the pre-lubricator hose, plug the main oil gallery hole and replace all components previously removed.

6. Before initial engine start-up, DDA also recommends cranking the engine with the governor in the no-fuel position until oil pressure registers on the gage.

For engine lubricating oil recommendations, see *Lubrication Specifications* in Section 13.3 or contact a Detroit Diesel Allison distributor.

If a pressure prelubricator is not available, fill the crankcase to the proper level with *heavy-duty* lubricating oil as specified under *Lubrication Specifications* in Section 13.3. Then, prelubricate the upper engine parts by removing the valve rocker cover(s) and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms.

Turbocharger

1. Clean the area and disconnect the oil inlet line at the bearing housing.

2. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

3. Add additional engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

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

4. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig - 69 kPa at idle speed).

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

Air Cleaner

If the engine is equipped with oil bath air cleaners, fill the air cleaner oil cups to the proper level with clean engine oil. *Do not overfill.*

Transmission

Check the oil level and, if necessary, fill the transmission case, marine gear or torque converter supply tank to the proper level with the lubricant specified under *Lubrication and Preventive Maintenance* in Section 15.1.

Fuel System

Fill the fuel tank with the fuel specified under *Fuel Specifications* in Section 13.3.

If the unit is equipped with a fuel valve, it must be opened.

To ensure prompt starting, fill the fuel system between the pump and the fuel return manifold with fuel. If the engine has been out of service for a considerable length of time, prime the fuel system between the fuel pump and the fuel return manifold. The system may be primed by removing the plug in the top of the filter cover and slowly filling the filter with fuel.

In addition to the above, on an engine equipped with a hydrostarter, use a priming pump to make sure the fuel lines and the injectors are full of fuel before attempting to start the engine.

NOTE: The fuel system is filled with fuel before leaving the factory. If the fuel is still in the system when preparing to start the engine, priming should be unnecessary.

Lubrication Fittings

Fill all grease cups and lubricate at all fittings with an all purpose grease. Apply lubricating oil to the throttle linkage and other moving parts and fill the hinged cap oilers with a hand oiler.

Drive Belts

Adjust all drive belts as recommended under *Lubrication and Preventive Maintenance* in Section 15.1.

Storage Battery

Check the battery. The top should be clean and dry, the terminals tight and protected with a coat of petroleum jelly and the electrolyte must be at the proper level.

NOTE: When necessary, check the battery with a hydrometer: the reading should be 1.265 or higher. However, hydrometer readings should always be corrected for the temperature of the electrolyte.

Generator Set

Where applicable, fill the generator end bearing housing with the same lubricating oil as used in the engine.

A generator set should be connected and grounded in accordance with the applicable local electrical codes.

NOTE: The base of a generator set must be grounded.

Clutch

Disengage the clutch, if the unit is so equipped.

STARTING

Before starting the engine for the first time, perform the operations listed under *Preparation For Starting Engine First Time.*

Before a routine start, see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart* in Section 15.1.

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Ambient Temperature	Pressure Gage Reading	
	psi	kPa
Above 40° F (4.4° C)	1500	10 342
40 - 0° F (4.4 to -18° C)	2500	17 237
Below 0° F (-18° C)	3300	22 753

TABLE 1

If a manual or an automatic shutdown system is incorporated in the unit, the control must be set in the open position before starting the engine. The blower will be seriously damaged if operated with the air shutoff valve in the closed position.

Starting at air temperatures below 40° F (4° C) requires the use of a cold weather starting aid. See *Cold Weather Starting*, Section 12.6.

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

The instructions for the use of a cold weather fluid starting aid will vary dependent on the type being used. Reference should be made to these instructions before attempting a cold weather start.

Initial Engine Start (Electric)

Start an engine equipped with an electric starting motor as follows: Set the speed control lever at part throttle, then bring it back to the desired no-load speed. In addition, on mechanical governors, make sure the stop lever on the governor cover is in the *run* position; on hydraulic governors, make sure the stop knob is pushed all the way in. Then, press the starting motor switch firmly. If the engine fails to start within 30 seconds, release the starting switch and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

NOTE: To prevent serious damage to the starter, if the engine does not start, do not press the starting switch again while the starting motor is running.

Initial Engine Start (Hydrostarter)

Start an engine equipped with a hydrostarter as follows:

Use the priming pump to make sure the fuel filter, fuel lines and injectors are full of fuel before attempting to start the engine.

Raise the hydrostarter accumulator pressure with the hand pump until the gage reads as indicated in Table 1.

Set the engine controls for starting with the throttle at least half open.

NOTE: During cold weather, add starting fluid at the same time the hydrostarter motor lever is moved. Do not wait to add the fluid after the engine is turning over.

Push the hydrostarter control lever to simultaneously engage the starter pinion with the flywheel ring gear and to open the control valve. Close the valve as soon as the engine starts to conserve the accumulator pressure and to avoid excessive over-running of the starter drive clutch assembly.

RUNNING

Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, stop the engine and check the lubricating oil system. Refer to the *Troubleshooting Charts* in Section 15.2.

Warm-Up

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

If the unit is operating in a closed room, start the room ventilating fan or open the windows, as weather conditions permit, so ample air is available for the engine.

Inspection

While the engine is running at operating temperature, check for coolant, fuel or lubricating oil leaks. Tighten the line connections where necessary to stop leaks.

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Engine Temperature

See Section 13.2 for normal engine coolant temperatures.

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain (approximately twenty minutes) back into the crankcase and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the *heavy duty* lubricating oil specified under *Lubrication Specifications* in Section 13.3.

Cooling System

Remove the radiator or heat exchanger tank 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 an ethylene glycol base antifreeze.

Transmission

Check and, if necessary, add sufficient oil to bring it to the proper level.

Turbocharger

Make a visual inspection of the turbocharger for leaks and excessive vibration. Stop the engine immediately if there is an unusual noise in the turbocharger.

Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings and rapid accumulation of sludge in the engine.

> **NOTE:** When prolonged engine idling is necessary, maintain at least 800 rpm.

STOPPING

Normal Stopping

1. Release the load and decrease the engine speed. Put all shift levers in the *neutral* position.

2. Allow the engine to run at half speed or slower with no load for four or five minutes, then move the stop lever to the *stop* position to stop the engine.

Emergency Stopping

To stop an engine (normal or emergency) equipped with the spring-loaded (one screw) design injector control tube, pull the governor stop lever to the stop position. If an engine equipped with the non-spring loaded (two screw) design injector control tube does not stop after using the normal stopping procedure, pull the *Emergency Stop* knob all the way out. 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.

> **NOTE:** The emergency shutdown system should never be used except in an emergency. Use of the emergency shutdown can cause oil to be sucked past the oil seals and into the blower housing.

The air shutoff valve, located on the blower air inlet housing, must be reset by hand and the *Emergency Stop* knob pushed in before the engine is ready to start again.

Fuel System

If the unit is equipped with a fuel valve, close it. Fill the fuel tank; a full tank minimizes condensation.

Exhaust System

Drain the condensation from the exhaust line or silencer.

Cooling System

Drain the cooling system if it is not protected with antifreeze and freezing temperatures are expected. Leave the drains open. Open the raw water drains of a heat exchanger cooling system.

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Crankcase

Check the oil level in the crankcase. Add oil, if necessary, to bring it to the proper level on the dipstick.

Transmission

Check and, if necessary, add sufficient oil to bring it to the proper level.

Inspection

Make a visual check for leaks in the fuel, lubricating and cooling systems.

Clean Engine

Clean and check the engine thoroughly to make certain it will be ready for the next run.

Refer to *Lubrication and Preventive Maintenance Chart* in Section 15.1 and perform all of the daily maintenance operations. Also, perform the operations required for the number of hours or miles the engine has been in operation.

Make the necessary adjustments and minor repairs to correct difficulties which may have occurred during the previous run.

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ALTERNATING CURRENT POWER GENERATOR SET
OPERATING INSTRUCTIONS

These instructions cover the fundamental procedures for operating an alternating current power generator set (Fig. 1). The operator should read these instructions before attempting to operate the generator set.

Never operate a generator set for a short (15 minute) interval - the engine will not reach normal operating temperature in so short a period.

Avoid operating the set for extended periods at no-load.

Ideally, operate the set for one hour with at least 40% load (generator rating).

When a test must be made with a line load of less than 40% of the generator rating, add a supplementary load.

Connect the supplementary load to the load terminals of the control cabinet circuit breaker so that the generator can be "loaded" whenever the breaker is closed.

Make certain that the supplementary load is such that it can be controlled to permit a reduction in the load should a normal load increase occur while the set is operating. Locate the supplementary load outside the engine room, if desirable, to provide adequate cooling.

Loading the generator set to 40% of the generator rating and operating it for one-hour intervals will bring the engine and generator to normal operating temperatures and circulate the lubricants properly. Abnormal amounts of moisture, carbon and sludge are due primarily to low internal operating temperatures which are much less likely to occur when the set is tested properly.

PREPARATION FOR STARTING

Before attempting to start a new or an overhauled engine or an engine which has been in storage, perform all of the operations listed under *Preparation for Starting Engine First Time* in Section 13.1. Before a routine start, see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart* in Section 15.1.

In addition to the *Engine Operating Instructions,* the following instructions also apply when operating an alternating current power generator set.

1. Before the first start, check the generator main

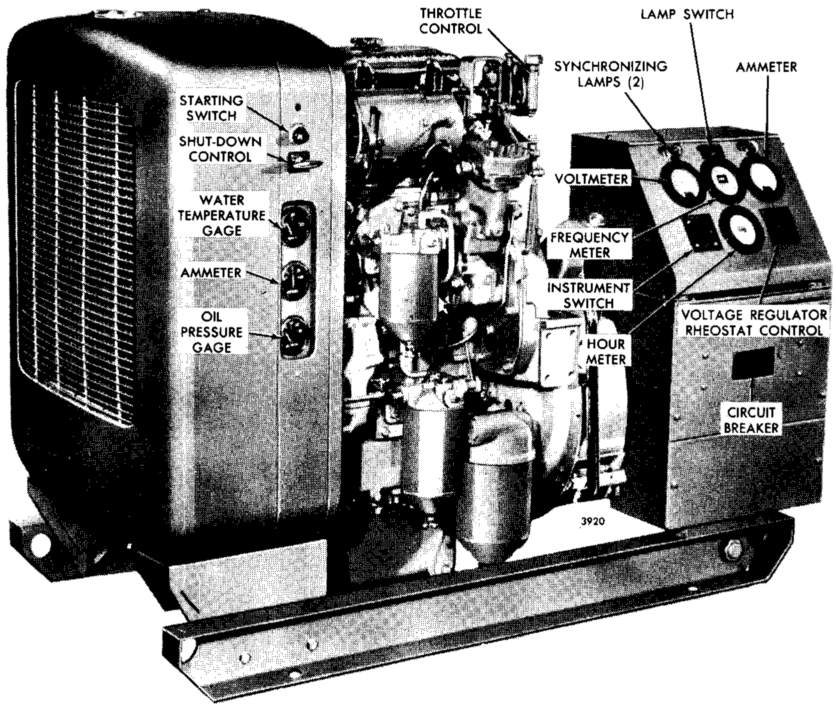

Fig. 1 - Location of Controls on Power Generator Set

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bearing oil reservoir. If necessary, add sufficient lubricating oil, of the same grade as used in the engine crankcase, to bring it to the proper level on the sight gage.

2. Check the interior of the generator for dust or moisture. Blow out dust with low pressure air (25 psi maximum). If there is moisture on the interior of the generator, it must be dried before the set is started. Refer to the appropriate Delco Products Maintenance bulletin.

3. The air shut-off valve located in the air inlet housing must be in the open or reset position.

4. Refer to Fig. 1 and place the circuit breaker in the **off** position.

5. If the generator set is equipped with synchronizing lamps, place the lamp switch in the **off** position.

6. Turn the voltage regulator rheostat knob counter-clockwise to its lower limit.

7. Make sure the power generator set has been cleared of all tools or other objects which might interfere with its operation.

STARTING

If the generator set is located in a closed space, start the ventilating fan or open the doors and windows, as weather permits, to supply ample air to the engine.

The engine may require the use of a cold weather starting aid if the ambient temperature is below 40°F. Refer to *Cold Weather Starting Aids* in Section 12.6.

Press the throttle button and turn the throttle control (Fig. 1) counterclockwise to a position midway between **run** and **stop**. Then press the starting switch firmly.

If the engine fails to start within 30 seconds, release the starting switch and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

> **CAUTION:** To prevent serious damage to the starter, if the engine does not start, do not press the starting switch again while the starting motor is rotating.

RUNNING

Observe the engine oil pressure gage immediately after starting the engine. If there is no oil pressure indicated within 10 to 15 seconds, stop the engine and check the engine lubricating system.

If the oil pressure is observed to be normal, increase the throttle setting to cause the engine to run at its synchronous speed.

PREPARING GENERATOR FOR LOAD

After the engine is warmed up (or the oil pressure has stabilized), prepare the generator set for load as follows:

1. Bring the engine up to the rated speed.

2. Turn the instrument switch to the desired position.

3. Turn the voltage regulator rheostat knob slowly in a clockwise direction to raise the voltage, while watching the voltmeter, until the desired voltage is attained.

4. If the generator set is equipped with a frequency meter, adjust the engine speed with the vernier throttle knob until the desired frequency is indicated on the meter.

5. Make sure all power lines are clear of personnel, then place the circuit breaker control in the **on** position.

> **NOTE:** Perform Step 5 only if the generator set is not being paralleled with an existing power source. If it is being paralleled with a power source already on the line, read and follow the instructions under *Paralleling* before turning the circuit breaker control to the **on** position.

PARALLELING

If the load conditions require an additional unit to be placed on the line, the following instructions will apply to power generator sets of equal capacity, with one generator set in operation on the line.

1. Prepare the generator set to be paralleled as outlined under *Preparation For Starting, Starting Running* and items 1 through 4 under *Preparing Generator for Load.*

2. Check the voltmeter (Fig. 1); the voltage must be the same as the line voltage. Adjust the voltage regulator rheostat control if the voltages are not the same.

3. Place the synchronizing lamp switch, of the generator set to be paralleled, in the **on** position.

4. Turn the vernier throttle knob until both units are operating at approximately the same frequency as

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indicated by the slow change in the brilliancy of the synchronizing lamps.

5. When the synchronizing lamps glow and then go out at a very slow rate, time the dark interval. Then, in the middle of this interval, turn the circuit breaker control to the **on** position. This places the incoming generator set on the line, with no load. The proper share of the existing load must now be placed on this generator.

6. The division of the kilowatt load between the alternating current generators operating in parallel depends on the power supplied by the engines to the generators as controlled by the engine governors and is practically independent of the generator excitation. Divide the kilowatt load between the generators by turning the vernier throttle knob counterclockwise on the incoming generator and clockwise on the generator that has been carrying the load (to keep the frequency of the generators constant) until both ammeters read the same, indicating that each generator is carrying its proper percentage of the total K.W. load.

7. The division of the reactive KVA load depends on the generator excitation as controlled by the voltage regulator. Divide the reactive load between the generators by turning the voltage regulator rheostat control on the incoming generator (generally clockwise to raise the voltage) until the ammeters read the same on both generator sets and the sum of the readings is minimum.

> **NOTE:** The generator sets are equipped with a resistor and current transformer connected in series with the voltage coil of the regulator (cross-current compensation) which equalizes most but not all of the reactive KVA load between the generators.

8. When the load is 80 per cent power factor lagging (motor and a few lights only), turn the vernier throttle knob on the incoming generator until the ammeter on that unit reads approximately 40 per cent of the total current load.

9. Rotate the voltage regulator rheostat control on the incoming generator clockwise to raise the voltage until the ammeters read the same on both units.

> **NOTE:** If a load was not added during paralleling, the total of the two ammeter readings should be the same as the reading before paralleling. Readjust the voltage regulator rheostat on the incoming generator, if necessary.

10. To reset the load voltage, turn the voltage regulator rheostat controls slowly on each unit. It is necessary to turn the controls the same amount and in the same direction to keep the reactive current equally divided.

Power generator sets with different capacities can also be paralleled by dividing the load proportionately to their capacity.

STOPPING

The procedure for stopping a power generator set or taking it out of parallel is as follows:

1. Turn off all of the load on the generator when stopping a single engine unit.

2. Shift the load from the generator when taking it out of parallel operation by turning the vernier throttle knob until the ammeter reads approximately zero.

3. Place the circuit breaker control in the **off** position.

4. Turn the voltage regulator rheostat control in a counterclockwise direction to the limit of its travel.

5. Press the throttle button and turn the throttle control to **stop** to shut-down the engine.

> **NOTE:** When performing a tune-up on a generator set that will be operated in parallel with another unit, adjust the speed droop as specified in *Engine Tune-Up*.

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OPERATING INSTRUCTIONS FOR SERIES 2-53 POWER GENERATOR UNITS IN RAILROAD REFRIGERATION CARS

Before Starting Each Trip

1. Check the engine oil level in the crankcase with the dipstick which is attached to a pipe cap with an integral bar grip and is located at the front of the engine below the radiator. The crankcase oil level should be at, or near, the *full* mark on the dipstick. The large capacity of the oil pan permits extended operation without frequently replenishing the oil supply. However, never let the oil level fall below the *add* mark on the dipstick. When adding oil between drain periods, add only sufficient oil to complete the trip or to get the unit to the next railroad service station. Use only the *heavy-duty* lubricating oils as specified under *Lubrication Specifications* in Section 13.3.

2. Check the engine hour meter, if the unit is so equipped, or log book to determine whether the engine lubricating oil should be changed. Change oil every 750 to 1,000 hours.

3. Check the coolant lever in the radiator. Fill with a solution of an ethylene glycol base antifreeze and water as specified by the railroad operating division. Coolant drains located at the bottom of the radiator, side of the engine cylinder block and bottom of the oil cooler must be closed.

4. Fill the fuel tanks with clean fuel oil. Select the proper grade of fuel in accordance with the *Fuel Specifications* in Section 13.3.

5. Check the condition of the storage battery as recommended by the battery manufacturer. Check electrical connections for tightness.

6. Check the power plug to make sure that it is in position and that the clamp ring is tight.

7. Drain the water and sediment from the fuel oil strainer and the fuel oil filter by opening the drain cock at the bottom of each. Drain off 1/4 pint, or more if necessary, to remove accumulated water and sediment. Close the drain cocks.

8. Check the sump tank located under the car between the main fuel tanks for water and sediment. Drain off 1/4 pint, or more, if necessary, to remove accumulated water and sediment. On some cars, the sump is formed as part of the main fuel tanks.

9. Service the engine air cleaner. Refer to Section 3.1 for oil bath air cleaners.

On units equipped with dry type air cleaners, proceed as follows:

a. Loosen the wing nuts on the filter fasteners and swing the retaining bolts away from the cleaner.

b. Lift the cleaner away from the housing and inspect it. Clean out any accumulated foreign material.

c. Withdraw the paper filter element and discard it.

d. Inspect the inside of the air cleaner housing to be sure it is free of foreign material.

e. Install the cleaner and secure it in place with the fasteners.

10. Check the oil level indicator, if the unit is so equipped, located on the end of the alternator. Add engine oil if the oil level is low.

Starting the Diesel Engine

For a normal start, pull the starting control rod located near the starter button. This opens the air inlet valve. While holding the starting control rod out, press the starter button. Do not release the starting control rod the instant the engine starts, but hold it out for approximately 30 seconds to allow the oil pressure to build up and set the **Fail-Safe** protective device. The starting control knob may then be released.

If the engine does not start after cranking for 30 seconds, allow the cranking motor to rest for a minute, and then repeat the cranking attempt. If the engine does not start after three or four cranking periods, investigate for the cause of trouble (refer to *Troubleshooting* in Section 15.2).

To assist in starting the engine during low ambient temperatures, a "Fluid Starting Aid" is used. This device consists of a pump and nozzle for injecting engine starting fluid into the air intake, and a tube container for holding the capsule containing the fluid. The pump (knob marked AIR HEATER) and the capsule container are mounted at the front of the engine.

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Running Check

After the engine has started, check the engine speed and voltage.

First check the engine speed with a hand tachometer. Engines operating at 1800 rpm full load should run 1850 rpm no load. Engines operating at 1200 rpm full load should run at 1240 rpm no load.

Then, check the voltage at the terminals with a voltmeter. The voltage should be 208-220 volts at full load and should not exceed 240 volts at no load.

On some units equipped with brushless power generators, the voltage may be adjusted by moving the regulator voltage adjusting screw. Turning the screw clockwise raises the voltage and turning the screw counterclockwise lowers the voltage.

1. The coolant temperature gage should read about 170° F (77° C) when the engine has warmed up and the thermostat has started to open. Temperatures will vary between 165° F and 185° F (74° C and 85° C), depending upon the load and the ambient air temperature.

2. Since the shutdown control prevents operating without adequate oil pressure, some units are not equipped with oil pressure gages. On these units, the oil pressure may be checked at the valve which is located above the shutdown bellows on the blower side of the engine. The oil pressure should be about 40 to 50 psi (276 kPa to 345 kPa) at 1800 rpm or 28 to 40 psi (193 kPa to 276 kPa) at 1200 rpm when the coolant temperature is normal. If the oil pressure is below 30 psi (207 kPa) at 1800 rpm or 28 psi (193 kPa) at 1200 rpm, check for the cause and make the necessary corrections.

3. No battery-charging ammeter is provided. However, the charging rate may be easily determined by connecting an ammeter in series with the wire leading to the BATT terminal of the generator voltage regulator. After completing the test, securely tighten the screw attaching the wire to the BATT terminal. For additional information on the electrical system, refer to Section 7 in this manual.

4. Leaks -- Check the unit carefully for fuel, lubricating oil and coolant leaks. Make any necessary repairs.

5. Clean radiator -- Check the condition of the radiator core to make sure it is clean and free of dirt.

Stopping the Diesel Engine

Pull the knob, marked "PULL TO STOP", which is located at the front of the engine. Hold the knob in the out position until the engine comes to a complete stop. Return the knob to its original position.

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ENGINE OPERATING CONDITIONS

The engine operating charts 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.

2-53, 3-53 and 4-53 ENGINES

(2-Valve Cylinder Head)

	1200 rpm #	1800 rpm	2000 rpm	2200 rpm
Lubrication System				
Lubricating oil pressure (psi):				
Normal (2-53 and 4-53)	30-50	40-60	40-60	40-60
Normal (3-53)		45-65	45-65	45-65
Minimum for safe operation	18	30	30	30
†Lubricating oil temperature (deg. F) - Normal:				
(2-53)	190-230	190-220	190-225	
(3-53 and 4-53)		200-235	200-235	200-235
Air System				
Air box pressure (inches mercury) - min. full load:				
At zero exhaust back pressure (2-53)	2.0	4.1	5.2	
At zero exhaust back pressure (3-53, 4-53)		3.8	4.9	6.2
At max. full load exh. back press. (2-53)	3.0	5.7	7.2	
At max. full load exh. back press. (3-53, 4-53)		5.5	6.9	8.6
Air inlet restriction (inches water) - full load max.:				
Dirty air cleaner - oil bath or dry type (2-53)	6.8	13.4	16.0	
Dirty air cleaner - oil bath or dry type (3-53, 4-53)	6.8	13.4		18.8
Clean air cleaner:				
2-53 oil bath type	4.5	9.5	10.8	
3-53, 4-53 oil bath type	4.5	9.5	10.8	12.0
2-53 dry type with pre-cleaner	4.5	6.8	10.8	
3-53, 4-53 dry type with pre-cleaner	4.5	6.8	10.8	12.0
2-53 dry type less pre-cleaner	3.0	5.5	6.5	
3-53, 4-53 dry type less pre-cleaner	3.0	5.5	6.5	7.4
Crankcase pressure (inches water) - max.	0.5	0.5	0.5	0.5
Exhaust back pressure (inches mercury) - max.:				
Full load	1.3	2.1	2.5	3.0
§Full load (fork lift truck)	4.2	9.7	12.1	
No load	0.6	1.3	1.7	2.1
§No load (fork lift truck)	2.5	6.0	7.5	
Fuel System				
Fuel pressure at inlet manifold (psi):				
Normal with .070" restriction	45-60	45-70	45-70	45-70
Minimum	35	35	35	35
Fuel spill (gpm) - minimum at no load:				
.070" restriction	0.6	0.6	0.6	0.6
Pump suction at inlet (inches mercury) - max.:				
Clean system	6.0	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0	12.0

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	1200 rpm #	1800 rpm	2000 rpm	2200 rpm
Cooling System				
Coolant temperature (deg. F) - Normal	160-185	160-185	160-185	160-185
Raw water pump:				
Inlet restriction (inches mercury) - max.		@ 8.0	@ 8.0	8.0
Outlet pressure (psi) - max.		@10.0	@10.0	10.0
Keel cooler pressure drop (psi)				
Maximum through system		@ 6.0	@ 6.0	6.0
Compression				
Compression pressure (psi at sea level):				
Average - new engine - at 600 rpm	525			
Minimum - at 600 rpm	475			

3-53, 4-53, 6V-53, 8V-53 and 53N ENGINES

(4-Valve Cylinder Head)

	2200 rpm	2500 rpm	2800 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal (4-53, 6V-53 and 8V-53)	40-60	40-60	40-60
Normal (3-53)	45-65	45-65	45-65
Minimum for safe operation	30	32	32
†Lubricating oil temperature (deg. F) - Normal	200-235	200-235	205-240
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure	3.7	4.8	6.1
At maximum exhaust back pressure	5.4	8.0	9.3
Air inlet restriction (inches water) - full load max.:			
Dirty air cleaner - oil bath or dry type	18.8	23.0	25.0
Clean air cleaner - oil or dry w/pre-cleaner	12.0	14.0	16.0
Clean air cleaner - dry type without pre-cleaner	7.4	8.7	10.0
Crankcase pressure (inches water) - max.	0.8	0.9	1.0
√Crankcase pressure (inches water) - max.	1.1	1.2	1.3
Exhaust back pressure (inches mercury) - max.:			
Full load	3.0	@ 4.0	+ 4.0
§Full load (fork lift truck)	6.5	8.4	10.5
×Full load (6V-53 Veh.)	3.0	4.0	6.0
No load	2.1	@ 2.7	++ 2.7
§No load (fork lift truck)	4.2	5.5	7.0
×No load (6V-53 Veh.)	2.1	2.7	3.2
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .070″ restriction	45-70	45-70	45-70
Minimum	35	35	35
Fuel spill (gpm) - minimum at no load:			
.070″ restriction	0.6	0.6	0.6
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0

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	2200 rpm	2500 rpm	2800 rpm
Cooling System			
Coolant temperature (deg. F) - Normal	160-185	160-185	160-185
Vehicle engines built 1976 and later	170-195	170-195	170-195
Raw water pump:			
Inlet restriction (inches mercury) - max.	@ 5.0	@ 5.0	5.0
Outlet pressure (psi) - max.	@10.0	@10.0	10.0
Keel cooler pressure drop (psi)			
Maximum through system	@ 6.0	@ 6.0	6.0
Compression			
Compression pressure (psi at sea level):			
Average - new engine - at 600 rpm ... 480			
Average - new "N" engine - at 600 rpm ... 590			
Minimum - at 600 rpm ... 430			
Minimum-"N" engine - at 600 rpm ... 540			

†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.
+Marine engines only 5.5 inches mercury at 2800 rpm.
++Marine engines only 3.8 inches mercury at 2800 rpm.
√ For 53 N engines with front cover breathing systems only.
@Maximum when this is the full-load engine speed.
×For 6V53 N (Veh.) engines with certification label build date of June, 1978 or later.
§Fork lift trucks only when performance required is less than rated for injector used as power loss may be as high as 9-12%—@ maximum rpm.
#2-53 reefer car engines only.

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3-53 TURBOCHARGED ENGINES

INDUSTRIAL

	2200 rpm	2500 rpm	2600 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	40-60	40-60	40-60
Minimum for safe operation	36	36	36
†Lubricating oil temperature (deg. F) - Normal	200-235	200-235	200-235
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
5A55 injector - 118 BHP		36.0	
5A55 injector - 117 BHP		34.0	
5A60 injector		37.0	41.0
5N45 injector	20.0		
N50 injector		31.0	
N65 injector		39.0	
Air inlet restriction (inches water) - full load max.:			
Dirty air cleaner	20.0	20.0	20.0
Clean air cleaner	12.0	12.0	12.0
Exhaust back pressure (inches mercury) - max.:			
Full load	2.5	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .070″ restriction	45-70	45-70	45-70
Minimum	35	35	35
Fuel spill (gpm) - minimum at no load:			
.070″ restriction	0.6	0.6	0.6
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 (deg. F) - Normal	170-187	170-187	170-187
Compression			
Compression pressure (psi at sea level):			
Average - new engine - at 600 rpm ... 510			
Minimum - at 600 rpm ... 460			

†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.

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4-53 TURBOCHARGED ENGINES

	Marine 2500 rpm	Industrial 2500 rpm	Vehicle 2500 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	40-60	40-60	40-60
Minimum for safe operation	32	36	36
†Lubricating oil temperature (deg. F) - Normal	205-240	200-235	200-235
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
5A55 injector		36.0	36.0
5A60 injector (Federal)		39.0	39.0
5A60 injector (California)			41.0
N65 injector		39.0	
N70 injector (clean ports)	31.5-38.5		
At maximum exhaust back pressure:			
5A55 injector		31.5	
5A60 injector (Federal)		34.5	
5A60 injector (California)			37.0
N65 injector		34.5	
N70 injector	29.6-36.6		
Air inlet restriction (inches water) - full load max.:			
Air silencer	20.0		
Air cleaner (dirty)		20.0	20.0
Air cleaner (clean)		12.0	12.0
Crankcase pressure (inches water) - max.	1.0	3.0	3.0
Exhaust back pressure (inches mercury) - max.:			
Full load	2.5	3.0	2.5
No load			1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .070″ restriction	45-70	45-70	45-70
Minimum	35	35	35
Fuel spill (gpm) - minimum at no load:			
.070″ restriction	0.6	0.6	0.6
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.-	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) - Normal	160-185	170-187	180-197
Compression			
Compression pressure (psi at sea level):			
Average - new engine - at 600 rpm	480	510	510
Minimum - at 600 rpm	430	460	460

†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.

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6V-53 TURBOCHARGED ENGINES

	Marine 2800 rpm	Industrial 2500 rpm	Vehicle 2600 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	40-60	40-60	40-60
Minimum for safe operation	32	36	36
†Lubricating oil temperature (deg. F) - Normal	205-235	200-235	200-235
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
5A50 injector (Federal)		34.0	36.5
5A50 injector (California)			38.0
5A55 injector		39.5	
5N65 injector	38.0		
N-70 injector	39.3		
At maximum exhaust back pressure:			
5A50 injector (Federal)		29.5	32.8
5A50 injector (California)			34.3
5A55 injector		35.0	
5N65 injector	33.5		
N-70 injector	47.3		
Air inlet restriction (inches water) - full load max.:			
Air silencer	20.0		
Air cleaner (dirty)		20.0	20.0
Air cleaner (clean)		12.0	12.0
Crankcase pressure (inches water) - max.	1.0	3.0	3.0
N-70 injector	2.8		
Exhaust back pressure (inches mercury) - max.:			
Full load	3.0	2.5	2.5
N-70 injector — Twin Turbo	2.5		
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .070″ restriction	45-70	45-70	45-70
Minimum	35	35	35
Fuel spill (gpm) - minimum at no load:			
.070″ restriction	0.6	0.6	0.6
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 (deg. F) - Normal	160-185	170-187	180-197
N-70 injector	170-185	—	—
Compression			
Compression pressure (psi at sea level):			
Average - new engine - at 600 rpm	480	510	510
Minimum - at 600 rpm	430	460	460

†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.

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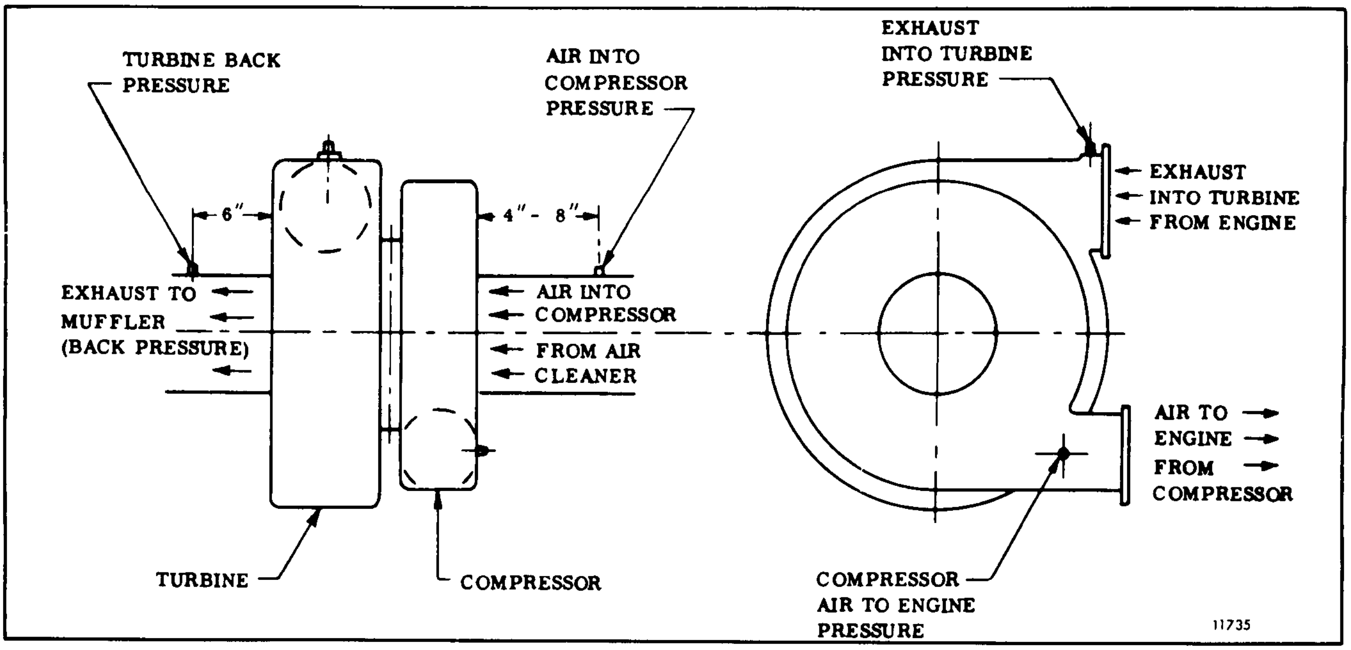

Fig. 1 - Points to Measure Intake and Exhaust Restriction

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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 10 °F or 6 °C higher than the water inlet temperature. Though a 10 °F or 6 °C rise across an engine is recommended, it has been found that a 15 °F or 8 °C temperature rise maximum can be permitted.

Thermostats are used in the engine to control the coolant flow. Therefore, be sure they are in place and fully operative or the engine will overheat during the Run-In. However, if the dynamometer has a water standpipe with a temperature control regulator, such as a Taylor valve or equivalent, the engine should be tested without thermostats.

NOTE: Because of the wet cylinder liners in the Series 53 engine, it is desirable that the engine Run-In be made on a closed (heat exhanger type) cooling system where the coolant can be treated with a rust inhibitor (refer to Section 13.3). Use of a good rust inhibitor in the coolant system during engine Run-In will prevent the rusting of the outside diameter of

Time Minutes	Speed RPM	Injector Size	ENGINE BRAKE HORSEPOWER									
			4-Valve Cylinder Head							2-Valve Cyl. Head		
			3-53 NA	3-53 **T	4-53 NA	4-53 **T	6V-53 NA	6V-53 **T	8V-53 NA	2-53 NA	3-53 NA	4-53 NA
10	600	All	0	0	0	0	0	0	0	0	0	0
◆30	2800	All		0		0		0				
10	1500	All	15	15	20	20	30	30	40	10	15	20
10	Rated Speed	5A50						112				
		5A55		58		78		117				
		5A60		63		84						
		N-65		65		87						
		5N65*						138				
10	Rated Speed	5A50						225				
		5A55		117		156		234				
		5A60		126		168						
		N-65		131		175						
		5N65*						275				
120	2000	All								40		
30	2200	All	64		87		130		175			
120	2200	All									62	93
30	2800	All	85		115		171		228			
Power Check	Rated Speed	All	Final BHP to be within ±5% of rated									

◆ Turbocharged engines *must* be operated within this RPM range for a full 30 minutes.
*5N65 rating for 6V-53T Marine engine only.
After run-in, *do not* run continuous full load during first 10 hours or 500 miles.
"O" BHP indicates running at no-load for specified time and speed.
**Prior to starting the engine, remove the turbocharger oil supply line at the turbocharger and add CLEAN engine oil to the turbocharger oil inlet to ensure pre-lubrication of the unit. Reconnect the oil line and idle the engine for at least one minute after starting and before increasing the engine speed to 1200 rpm.

BASIC ENGINE RUN-IN SCHEDULE

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the cylinder liners after the engine has been removed from the dynamometer test stand.

The *Basic Engine Run-In Schedule* is shown in the following Table. The horsepower shown is at SAE conditions: dry air density .0705 lb/cu. ft. (1.129 Kg/cu. m, air temperature of 85°F (29.4°C) and 500 ft. 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 alternator typify accessories not considered on the basic engine.

In situations where other than basic engine equipment is used during the test, proper record of this fact should be made on the *Engine Test Report*. The effects of this additional equipment on engine performance should then be considered when evaluating test results.

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 or Nm) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula:

$$BHP = (T \times RPM)/5250$$

Where:

BHP = brake horsepower
T = torque in lb-ft or Nm
RPM = revolutions per minute

Some dynamometers indicate direct brake horsepower readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded immediately on an *Engine Test Report* (see sample on page 3).

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.

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.

i. Adaptor for connecting a pressure gage or mercury manometer to the turbocharger.

In some cases, gages reading in pounds per square inch or kilopascals 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

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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.

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finely divided if accuracy is desired. This is especially true of a gage reading in psi or kPa, 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"
Inches of water = kPa x 4.02"
Inches of mercury = kPa x 0.30"

NOTE: Before starting the Run-In or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions on *Preparation for Starting Engine First Time* in Section 13.1.

Run-In Procedure

The procedure outlined below will follow the order of the sample *Engine Test Report.*

A. PRE-STARTING

1. Fill the lubrication system as outlined under *Lubrication System -- Preparation for Starting Engine First Time* in Section 13.1.

2. Prime the fuel system as outlined under *Fuel System -- Preparation for Starting Engine First Time* in Section 13.1.

3. A preliminary valve clearance adjustment must be made before the engine is started. See *Valve Clearance Adjustment* in Section 14.1.

4. A preliminary injector timing check must be made before starting the engine. See *Fuel Injector Timing* Section 14.2.

5. Preliminary governor adjustments must be made as outlined in Section 14.

6. Preliminary injector rack adjustment must be made (Section 14).

NOTE: Prior to starting a turbocharged engine, remove the oil supply line at the turbocharger and add clean engine oil to the oil inlet to ensure pre-lubrication of the turbocharger. Reconnect the oil line and idle the engine for at least one minute after starting and before increasing the speed.

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, air cleaner and inlet piping to insure 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 (7 Nm) on the torque gage (or 10-15 HP on a horsepower gage). This is necessary, on some units, to lubricate the absorption unit seals and to protect them from damage.

Set the engine throttle at idle speed, check the lubricating oil pressure and check all connections to be sure there are no leaks.

Refer to the *Engine Test Report* sample which establishes the sequence of events for the test and Run-In, and to the *Basic Engine Run-In Schedule* which indicates the speed (rpm), length of time and the brake horsepower required for each phase of the test. Also refer to the *Operating Conditions* in Section 13.2 which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

Engine governors in most cases must be reset at the maximum full-load speed designated for the Run-In. If a governor is encountered which 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.*

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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 Section 14.

E. FINAL RUN-IN

After all of the tests have been made and the *Engine Test Report* is completed through Section "D", the engine is ready for final test. This portion of the test and Run-In procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut down for one hour or longer, it will be necessary to have a warm-up period of 10 minutes at the same speed and load used for warm-up in the Basic Run-In. If piston rings, cylinder liners or bearings have been replaced as a result of findings in the Basic Run-In, the entire Basic Run-In must be repeated as though the Run-In and test procedure were started anew.

All readings observed during the Final Run-In should fall within the range specified in the *Operating Conditions* in Section 13.2 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 or kPa after being taken at engine speeds indicated in the *Operating Conditions*, Section 13.2.

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 0-103 kPa) or manometer (15-0-15) to an air box drain or to a hand hole plate prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure should be recorded in inches of mercury.

Check the *crankcase pressure* while the engine is operating at maximum Run-In speed. Attach a manometer, calibrated to read in inches of water, to the oil level dipstick opening. Normally, crankcase pressure should decrease during the Run-In indicating that new rings are beginning to "seat-in"

Check the *air inlet restriction* with a water manometer connected to a fitting in the air inlet ducting located 2" above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to a fitting installed in the 1/4" pipe tapped hole in the engine air inlet housing. If a hole is not provided, a stock housing should be drilled, tapped and kept on hand for future use.

The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. On turbocharged engines, take the reading on the inlet side of the turbocharger. The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal *air intake vacuum* at various speeds (at no-load) and compare the results with the *Engine Operating Conditions* in section 13.2. Record these readings on the *Engine Test Report*.

Check the *exhaust back pressure* (except turbocharged

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engines) at the exhaust manifold companion flange or within one inch of this location. This check should be made with a mercury manometer through a tube 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. On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the turbine outlet. The tapped hole must be in a comparatively straight area for an accurate measurement. The manometer check should produce a reading in inches that is below the *Maximum Exhaust Back Pressure* for the engine (refer to Section 13.2).

Turbocharger compressor outlet pressure and turbine inlet pressures are taken at full-load and no-load speeds.

Refer to the *Engine Run-In Schedule* and determine the maximum rated brake horsepower and the full-load speed to be used during the Final Run-In. Apply the load thus determined to the dynamometer. If a hydraulic governor is used, the droop may be adjusted at this time by following the prescribed procedure. The engine should be run at this speed and load for 1/2 hour. While making the Final Run-In, the engine should develop, within 5%, the maximum rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrections made.

When the above conditions have been met, adjust the maximum no-load speed to conform with that specified for the particular engine. This speed may be either higher or lower than the maximum speed used during the Basic Run-In. This will ordinarily require a governor adjustment.

All information required in Section "E", Final Run-In, of the *Engine Test Report* should be determined and filled in. After the prescribed time for the Final Run-In has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine. The Final Run-In is complete.

F. INSPECTION AFTER FINAL RUN-IN

After the Final Run-In and before the *Engine Test Report* is completed, a final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rustproofing the fuel system as outlined in Section 15.3 and adding a rust inhibitor into the cooling system (refer to Section 13.3). The lubricating oil filters should also be changed.

NOTE: A rust inhibitor in the coolant system of a Series 53 engine is particularly important because of the wet cylinder liners. Omission of a rust inhibitor will cause rusting of the outside diameter of the cylinder liners and interference with liner heat transfer.

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FUEL SPECIFICATIONS

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 acceptable 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 NORTH AMERICA	VV-F-800, DF-2 OTHER	ASTM D-975 2-D
Flash Point, min.	38°C 100°F	38°C 100°F	52°C 125°F	56°C 133°F	52°C 125°F
Carbon Residue (10% residuum), mass % max.	0.15	0.15	0.35	0.20	0.35
Water & Sediment, % by vol, max.	—	0.05	—	—	0.05
Ash, % by wt., max.	0.01	0.01	0.01	0.02	0.01
Distillation Temperature, 90% by vol. recovery, min.	—	—	—	—	282°C 540°F
max.	288°C 550°F	288°C 550°F	338°C 640°F	357°C 675°F	338°C 640°F
End Point max.	330°C 626°F	—	370°C 698°F	370°C 698°F	—
Viscosity Kinematic, cSt, min. @ 40°C	1.3	1.3	1.9	1.8@20°C	1.9
Saybolt, SUS, min. @ 100°F	—	—	—	—	32.6
Kinematic, cSt, max. @ 40°C	2.9	2.4	4.1	9.5@20°C	4.1
Saybolt, SUS, max. @ 100°F	—	34.4	—	—	40.1
Sulfur, mass % max.	0.50	0.50	0.50	0.70	0.50
Cetane No., min.	45	40.0	45	45	40.0

FUEL CLEANLINESS

Fuel oil should be clean and free of 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 detrimental 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 possibly be reduced. Consult the FUEL OIL SELECTION CHART.

FUEL OIL SELECTION CHART

Application	General Fuel Classification	Final Boiling Point (Max.)	Cetane Number (Min.)	Sulfur Content (Max.)	Cloud Point
City Buses	No. 1-D	550°F 288°C	45	0.30	SEE NOTES
	Winter No. 2-D*	675°F 357°C	45	0.50	
	Summer No. 2-D*	357°C	40	0.50	
All Other Applications	Winter No. 2-D	675°F 357°C	45	0.50	SEE NOTES
	Summer No. 2-D	675°F 357°C	40	0.50	

*No. 2-D diesel fuel 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 (6°C) below the lowest expected fuel temperature 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.

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 (50 or above). Slowly ignited fuels have low cetane numbers (40 or below). The lower the ambient temperature, the greater the need for a high cetane fuel that will ignite rapidly.

Difficult starting may be experienced if the cetane number of the fuel is too low. Furthermore, engine knock and puffs of white smoke may be experienced during engine warmup 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.

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DISTILLATION END POINT

Fuel can be burned in an engine only after 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.

DETROIT DIESEL FUEL OIL SPECIFICATIONS

Detroit Diesel Allison designs, develops and manufactures commercial diesel engines to operate on diesel fuels classified by the ASTM as Designation D-975 (grades 1-D and 2-D). These grades are very similar to grades DF-1 and 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 fluid that is marketed as either diesel fuel (ASTM D-975) or domestic heating fuel (ASTM D-396) sometimes 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 Range, Cetane Number, Sulfur Content, and Cloud Point* are four of the most important properties of 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 fuel) should be 10°F (6°C) below the lowest expected fuel temperature in order to prevent clogging of the fuel filters 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 that meets Detroit Diesel Allison specifications lies with the fuel supplier as well 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 DETROIT DIESEL ENGINES

Numerous fuels meeting the properties shown in the FUEL OIL SELECTION CHART may be used in Detroit Diesel engines. The table (next page) 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 (jet) fuels, and burner fuels.

PROPOSED ASTM 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 grade of fuel was proposed, but not accepted by, the ASTM.

The grade 3-D which was proposed is undesireable 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 carbon residue), and allows the blending of heavier, more viscous boiling point fractions that are difficult to burn. The latter tend to increase combustion chamber deposits. This type of fuel usually manifests poor cold

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FUELS BURNED IN DETROIT DIESEL ENGINES

ASTM Desig-nation	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-6	Referee Grade JP-5 Type Jet Fuel. Limited Quantities Supplied To Military Only.

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.

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 DIESOHOL AND GASOHOL AND/OR ADDING ALCOHOL AND/OR GASOLINE TO DIESEL FUEL

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 adequate protection.

Commercially marketed DIESOHOL or GASOHOL or GASOLINE should never be added to diesel fuel. An explosive and fire hazard exists if these blends are mixed and/or burned.

COMPARISON OF ASTM D-975 GRADE 2-D AND PROPOSED GRADE 3-D PROPERTIES

Property	Grade Recommended 2-D	Grade 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)

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. It is accordingly contrary to the policy of General Motors to recommend the regular and continued use of supplementary additives in fuels and lubricants."

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, tune-up 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.

LUBRICATION SPECIFICATIONS

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). Oil quality can also be affected by handling cleanliness, contamination, dirt, water, etc.

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 a decision made as to its effect 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.

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LUBE OIL SPECIFICATIONS

API PERFORMANCE DESIGNATIONS, LUBE SUPPLIER, AND BRAND NAMES

Lubricants are blended to meet specific industry accepted tests developed by the American Society for Testing and Materials (ASTM). The service for which these products are intended is defined by the American Petroleum Institute (API). The lube supplier markets these products under a specific brand or trade name. The container identification indicates whether the contents meet or exceed specific API letter code designations (example: SF, CD).

RECOMMENDATION

Lubricating oils that meet the following performance levels, viscosity grades, sulfated ash limits and zinc requirements are recommended for Detroit Diesel engines. It is also recommended that the oil supplier provide to the user evidence of satisfactory performance of his products in Detroit Diesel engines.

LUBE OIL PERFORMANCE LEVELS

Lubricants are formulated to meet all the performance criteria defined in either commercial (API) and/or military specifications. Table L-1 shows the current commercial industry and military oil performance levels. The API letter designations are defined in SAE recommended practice J-183 published in the SAE Handbook.

Specific oil performance level recommendations for Detroit Diesel engines are indicated in Table L-1.

TABLE L-1
LUBE OIL PERFORMANCE LEVELS

API PERFORMANCE DESIGNATION		COMPARABLE MILITARY SPECIFICATION	RECOMMENDED FOR USE IN DDA ENGINES		COMMENTS & CURRENT API OR MILITARY QUALIFICATION STATUS
DIESEL ENGINES	GASOLINE ENGINES		2-CYCLE	4-CYCLE	
CB	—	MIL-L-2104A (Supplement 1)	YES	NO	Obsolete, still limited availability.
CC	—	MIL-L-2104B	YES	NO	Obsolete, still readily available.
CD	—	MIL-L-45199B (Series 3)	YES	NO	Still limited availability.
CC	SE	MIL-L-46152	YES	YES	Obsolete Diesel performance, intended for passenger cars burning gasoline.
CC	SF	NONE	YES	YES	Primarily for passenger cars burning gasoline.
CD	SC	MIL-L-2104C	YES	YES	Current spec. for heavy duty diesel powered military vehicles, acceptable for commercial diesel powered vehicles.
CD	SE		YES	YES	Diesel performance requirements are current. Gasoline fueled passenger cars performance requirements are obsolete.
CD	SF		YES	YES	Meet current diesel & gasoline performance requirements.
—	SF		NO	YES	Service station lubes.

VISCOSITY GRADES

Single grade SAE-40 and 30 lubricants are preferred and recommended for use in all Detroit Diesel 2-cycle engines. Table L-2 shows a viscosity grade selection chart as related to ambient temperatures. Note that 15W-40 multigrade oils are recommended as a third choice for Series 53, 71 and 92 engines only when ambient temperatures are below 32°F (0°C). Multigrade oils, including 15W-40, should never be used in Series 149 engines.

TABLE L-2
VISCOSITY — SAE GRADE SELECTION CHART

Ambient Temperature		ENGINE SERIES								
		149		92, 71, 53			8.2L			
		2-CYCLE		2-CYCLE			4-CYCLE			
Deg. Fahr.	Deg. Celsius	First	Second	First	Second	Third	First	Second	Third	Fourth
		**								
above 50	above 10	SAE 40	SAE 30	SAE 40	SAE 30	None	15W-40	10W-40	20W-40	30
50 to 32	10 to 0	SAE (40)	SAE 30 *	SAE (40)	SAE 30 *	None	* 15W-40	* 10W-40	* 20W-40	None
32 to 0	0 to −18	SAE (40)	SAE (30)	SAE (40)	SAE (30)	* 15W-40	(15W-40)	* 10W-40	(20W-40)	None
0 to −25	−18 to −32	SAE (40)	SAE (30)	SAE (40)	SAE (30)	(15W-40)	(15W-40)	(10W-40)	(20W-40)	None

( ) Numbers in parentheses indicate that starting aids are required.

* Usually unaided starts can be accomplished.

** SAE 50 grade lube oil is recommended if the top tank coolant temperature is 195°F or above. (CAUTION: Do not use SAE-50 grade lube oil when or where cold ambient temperatures prevail.)

OTHER MULTIGRADE OILS

15W-40 oils are the only acceptable multigrade lubricants that should be considered in Series 53, 71 and 92 engines if prolonged cold ambient temperatures below 32°F (0°C) are expected. Detroit Diesel Allison does not recommend the use of any multigrade oils other than 15W-40 in these 2-cycle engines. Never use any kind of multigrade oils in Series 149 engines.

OIL CHANGES

CONDITION A: THE SULFUR CONTENT OF THE DIESEL FUEL IS LESS THAN 0.50% BY WEIGHT

Table L-3 shows the initial oil drain intervals recommended for all Detroit Diesel engines. Oil drain intervals may be increased or decreased depending upon the condition of the lubricant. Used lube oil analysis guidelines, indicating contamination limits, are shown elsewhere in Table L-4. DDA recommends that if the total base number (TBN by ASTM D-664) is reduced to 1.0 or if the TBN (ASTM-2896) is reduced to 2.0, the oil should be drained immediately.

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CONDITION B: THE SULFUR CONTENT OF THE DIESEL FUEL IS GREATER THAN 0.50% BY WEIGHT

The detrimental effects of burning high sulfur fuel are known in industry. The use of high sulfur diesel fuel may be unavoidable in some locations.

The use of high TBN/ash oils (TBN greater than 10, ash up to 2.500% by weight) is recommended to counteract corrosion.

The trend manifested by extremely high TBN oils (TBN greater than 20/ash between 2.000 to 2.500% by weight) is to drop several TBN numbers and then level off. The condition of the used oil under these circumstances is that it has retained some alkaline reserve (neutralization power) but will become overloaded with suspended solids that tend to become insoluble, resulting in the formation of excessive engine deposits. Therefore, when using high TBN/ash oils, a rule of thumb for oil change intervals is to drain the oil when the TBN drops to one-half of the new oil TBN. *Since lubricant composition varies from brand to brand the time and rate of TBN reduction will vary.* These differences manifested by the various high TBN/ash oils will influence the drain interval.

TABLE L-3

RECOMMENDED LUBE OIL DRAIN AND FULL-FLOW FILTER CHANGE INTERVALS WHEN BURNING LOW SULFUR DIESEL FUELS (0.5% BY WT. OR LESS)*

SERVICE APPLICATION	ENGINE SERIES	ENGINE DESIGN	LUBE OIL DRAIN INTERVAL**	FILTER CHANGE INTERVAL
Hwy. Truck & Inter-City Buses	71 & 92 8.2L	2-Cycle 4-Cycle	20,000 Miles 6,000 Miles	20,000 Miles 6,000 Miles
City Transit Coaches & Pick-Up & Delivery Truck Service (Stop-and-Go) Short Distance	53, 71, 92 8.2L	2-Cycle 4-Cycle	12,000 Miles 6,000 Miles	12,000 Miles 6,000 Miles
Industrial & Marine	53, 71, 92 8.2L	2-Cycle 4-Cycle	150 Hours 150 Hours	150 Hours 150 Hours
Large Industrial & Marine	149 (NA) 149 (T)	2-Cycle 2-Cycle	500 Hrs. or One Yr. 300 Hrs. or One Yr.	500 Hrs. or One Yr. 300 Hrs. or One Yr.
Stationary (Stand-By) Engines	53, 71, 92 149 8.2L	2-Cycle 2-Cycle 4-Cycle	150 Hrs. or One Yr. 150 Hrs. or One Yr. 150 Hrs. or One Yr.	150 Hrs. or One Yr. 150 Hrs. or One Yr. 150 Hrs. or One Yr.
Generator Sets (Prime Power)	53, 71, 92	2-Cycle	500 Hrs. or One Mo.	500 Hrs. or One Mo.

* See sections indicating Detroit Diesel's recommendations when burning high sulfur content (0.5% by Wt. or more) diesel fuels.

** May be increased or decreased, depending on the results obtained from used lube oil analysis.

FULL-FLOW FILTER CHANGE PERIOD

Table L-3 shows the DDA recommended full-flow filter change period for the various service applications. The filter element should be changed at the same time the crankcase oil is drained. Filter life is affected by heat and vibration in addition to contaminant filtration. Filter change should not exceed 25,000 miles/500 hours maximum.

TABLE L-4

USED LUBE OIL ANALYSIS GUIDELINES

These values indicate the need for an immediate oil change, but do not necessarily indicate internal engine problems requiring engine teardown. Characteristics relating to lube oil dilution should trigger corrective action to identify and fix the source(s) of leaks, if these values are realized.

	ASTM Designation	ENGINE SERIES — WARNING LIMITS				
		2-CYCLE Series 149	2-CYCLE Series 92	2-CYCLE Series 71	2-CYCLE Series 53	4-CYCLE Series 8.2L
Pentane Insolubles, Wt. %	D-893	1.00	1.00	1.00	1.00	1.00
Carbon (Soot) Content Wt. % Max.	TGA †	0.80	0.80	0.80	0.80	2.00
Viscosity at 100°F, SUS	D-445 & D-2161					
% Max. Increase		40.0	40.0	40.0	40.0	40.0
% Max. Decrease		15.0	15.0	15.0	15.0	15.0
Total Base Number (TBN), Min.	D-664	1.00	1.00	1.00	1.00	1.00
Total Base Number (TBN), Min.	D-2896	2.00	2.00	2.00	2.00	2.00
Water Content (Dilution), Vol. %, Max.	D-85	0.30	0.30	0.30	0.30	0.30
Flash Point, °F, Max. Reduction	D-92	40.0	40.0	40.0	40.0	40.0
Fuel Dilution, Vol. %, Max.	—	1.00	2.50	2.50	2.50	2.50
Glycol Dilution, PPM., Max.	D-2982	1000.00	1000.00	1000.00	1000.00	1000.00
Iron Content, PPM., Max.	‡	35	150	150	150	250
Sodium Content, PPM Max. Allowed Over Lube Oil Baseline	‡	50	50	50	50	50
Boron Content, PPM., Max. Allowed Over Lube Oil Baseline	‡	20	20	20	20	20

† TGA = Thermogravimetric analysis used and recommended by Detroit Diesel. No ASTM procedure designation.

‡ Elemental analyses are conducted using either emission spectographic or atomic absorption instruments. Neither method has ASTM designation.

FREQUENCY OF LUBE OIL SAMPLES FOR ANALYSIS

The interval at which used lube oil samples may be obtained for analysis can be scheduled for the same period as when other preventative maintenance is conducted. For example, in highway truck applications, a sample may be obtained every 10,000 miles when engines are brought in for fuel and coolant filter replacement. (Reference instructions in Detroit Diesel Engine Service Manuals).

USED LUBE OIL ANALYSIS PROGRAM

A used lube oil analysis program is recommended for monitoring the condition of the crankcase oil in all engines.

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Primarily, used lube oil analyses indicate the condition of the oil but not necessarily the condition of the engine. Never tear down an engine based solely on the analysis results obtained from a single used oil sample. However, the condition of the engine should be investigated using conventional mechanical and/or electronic diagnostic instruments. Frequently, visual inspections are all that is required to detect problem areas related to engine wear. It is also prudent to obtain another oil sample from the suspected distressed unit for analysis.

Abnormal concentrations of some contaminants such as diesel fuel, coolant, road salt, or airborne dirt cannot be tolerated for prolonged periods. Their presence will be reflected in accelerated engine wear, which can result in less than optimum engine life. The oil should be changed immediately if any contamination is present in concentrations exceeding the warning limits shown in Table L-4.

Experience in specific engine applications operating specific model engines is a prerequisite for proper interpretation of laboratory used lube oil sample analysis results. It is imperative to remember, in scrutinizing laboratory used lube oil sample results, that it is the change in value or deviation from baseline data obtained from the new oil (same brand or mixture of brands) that is significant. This is especially important to remember in investigations such as wear metal analysis, total base number and viscosity determinations.

SULFATED ASH LIMIT (ASTM D-874)

There is a performance trade-off when using either high or low ash oils. High ash oils (greater than 1.000% by weight) sometimes provide excessive exhaust valve and ring groove deposits but have shown superior anti-wear performance on compression rings and cylinder liners. Low ash oils, historically, have shown minimal engine deposit formation tendencies but premature wear has been experienced in some applications. As indicated in the oil changes section, low ash oils do not provide sufficient neutralization capability when high sulfur diesel fuels are used.

Therefore, DDA recommends that low ash (less than 1.000% by weight) oils continue to be used where satisfactory performance has been experienced. High ash oils (2.500% by weight max.) may be used under the following circumstances:

A. At locations where high sulfur diesel fuels (greater than 0.50% by weight) are continuously used.

B. At locations, regardless of the fuel sulfur content, where the oil supplier has submitted documented, conclusive evidence to the user that the lubricant provided satisfactory field test performance in Detroit Diesel engines.

ZINC CONTENT

The zinc content (zinc diorganodithiophosphate) of all low ash (less than 1.000% by weight) lube oils recommended for use in Detroit Diesel 2-cycle and 4-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 in Detroit Diesel engines.

Some specific high ash oils (2.500% by weight maximum) do not contain zinc additives. These oils may be used under the following circumstances:

1. Where diesel fuels with greater than 0.50% by weight sulfur content are continuously used.

2. The oil supplier has submitted documented, conclusive evidence to the user that the lubricant has provided satisfactory field test performance in Detroit Diesel engines.

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-5. 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 bushing wear (Note: Trunk pistons used in Series 53 engines)
- Overall valve train and bearing wear levels.

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TABLE L-5

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.

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.

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, CD/SE or MIL-L-2104B, etc.) shown elsewhere in this specification are met. Viscosity grades SAE-40 or SAE-30 are recommended.

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.

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 Only)
SA	None
SB	None
SC	Auto Passenger Car 1964 MS Oils - Obsolete System
SD	Auto Passenger Car 1968 MS Oils - Obsolete System
SE	Auto Passenger Car 1972 MS Oils - Obsolete System
SF	Auto Passenger Car 1980 Production

‡ 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.

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

See statement at the end of "FUEL OILS" section.

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COOLANT SPECIFICATIONS

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.

COOLANT REQUIREMENTS

Coolant solutions used in Detroit Diesel engines 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 during cold weather operation and boil-over protection in hot weather.

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 solutions are recommended for year-round 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 be 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 of these. Chlorides, sulfates, magnesium and calcium are among the materials which make up dissolved solids. Water, within the limits specified in Table 1 is satisfactory an 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.

	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

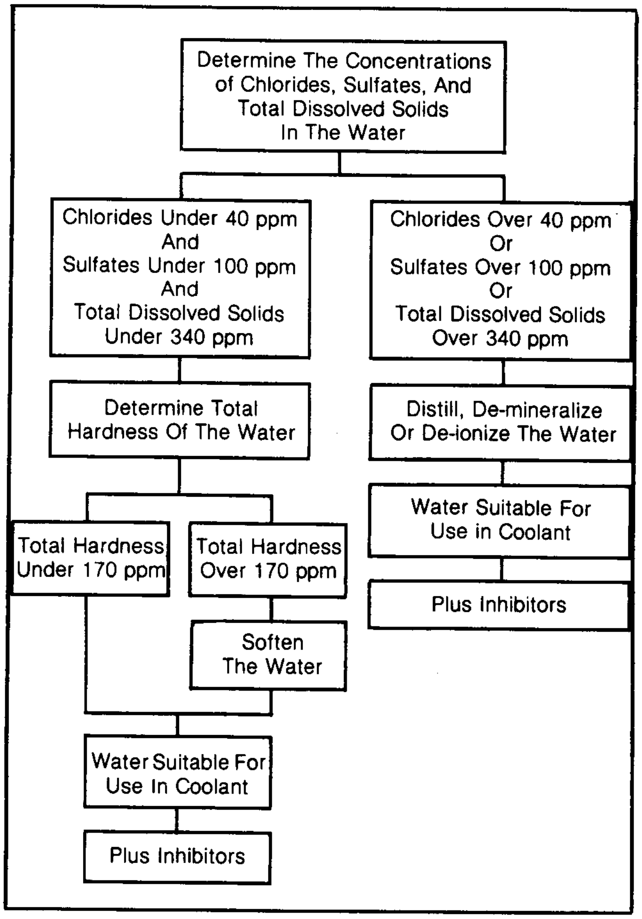

TABLE 2

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 adding inhibitors, as required after testing the coolant.

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 1" of cast iron is equivalent to 4-1/4" of cast iron in heat transferability (Fig. 1).

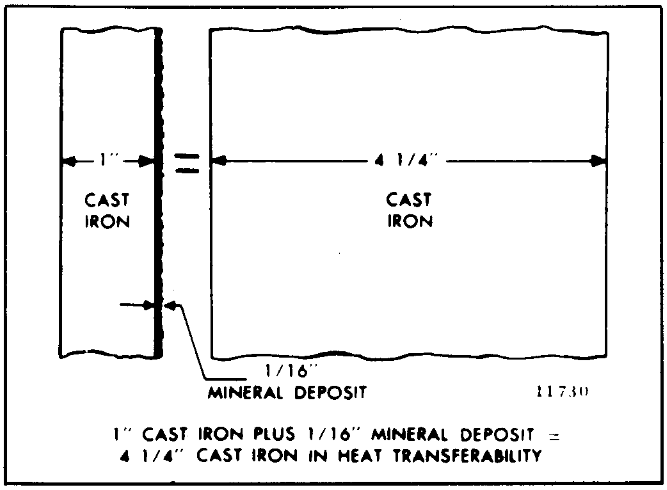

Fig. 1 - Heat Transfer Capacity

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, reducing the heat transfer rate resulting in engine overheating (Fig. 1). 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 (borates, 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.* 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 integral parts 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

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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.

Inhibitor Additives

Commercially packaged inhibitor systems are available which can be added directly to the engine coolant. Both chromate and non-chromate systems are available and care should be taken regarding inhibitor compatibility with other coolant constituents.

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 as required, to maintain original strength levels. Always follow the supplier's recommendations on inhibitor usage and handling.

TEST STRIPS

Test kits and test strips are commercially available to check engine coolant for corrosion inhibitor strength level. Coolant should be tested to determine the need for corrosion inhibitor supplements and the amount required. Do not use one manufacturer's test to measure the inhibitor strength level of another manufacturer's product. 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 anitfreeze is not recomended 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

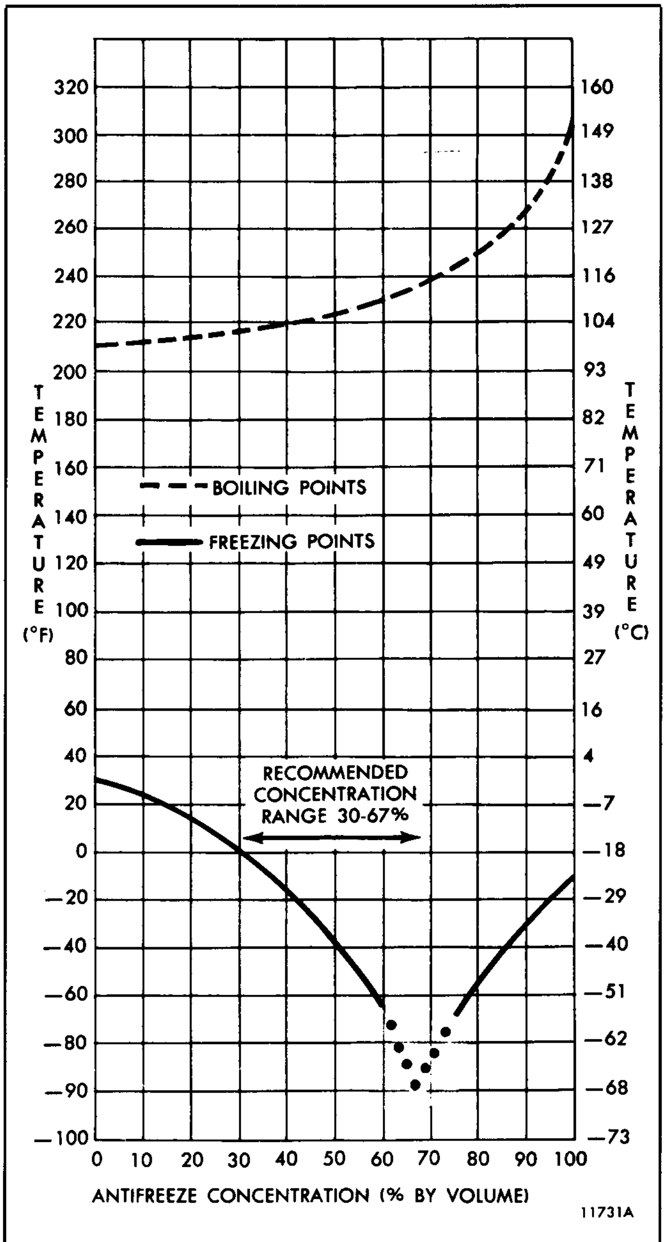

Fig. 2 - Coolant Freezing and Boiling Temperatures vs. Antifreeze Concentration (Sea Level)

contaminants, etc. If deposits are present, the cooling system must be chemically cleaned with a commerical grade heavy-duty descaler.

The inhibitors in antifreeze solutions should be replenished with a non-chromate corrosion inhibitor supplement when indicated by testing the coolant. Engine coolant should be checked at approximately 500 hour or 20,000 mile intervals.

Antifreeze solutions should be used year-round to provide freeze protection in the winter, boil-over protection in the summer, and a stable environment for seals and hoses in the cooling system of the engine.

Sealer Additives

The use of antifreeze containing sealer additives or the addition of sealer additive to any type coolant

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in Detroit Diesel engines is not recommended 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 leak-free, 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.

1. 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 non-chromate inhibitor system.
7. Do not use a chromate inhibitor with antifreeze.
8. Do not use methoxy propanol base antifreeze.
9. Do not mix ethylene glycol base antifreeze with methoxy propanol base antifreeze in the cooling system.
10. Do not use sealer additives or antifreeze containing sealer additives.
11. Do not use methyl alcohol base antifreeze.
12. Use extreme care when removing the radiator pressure control cap.
13. Do not add inhibitor supplements to *new* antifreeze solutions.
14. Use an antifreeze solution year-round for freeze and boil-over protection. Seasonal changing of coolant from an antifreeze solution to an inhibitor/water solution is *not recommended.*

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SECTION 14

ENGINE TUNE-UP

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Fuel Modulator 14.14
Starting Aid Screw (see Section 14.3.1 and 14.3.2)

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 for on-highway vehicle engines; injector timing, exhaust valve clearance, engine idle and no-load speeds, throttle delay or fuel modulator settings must be checked and adjusted, if necessary, at 50,000 mile intervals (refer to Section 15.1).

The type of governor used depends upon the engine application. Since each governor has different characteristics, the tune-up procedure varies accordingly. The following types of governors are used:

1. Limiting speed mechanical.

2. Variable speed mechanical.

3. Constant speed mechanical.

4. Hydraulic.

The mechanical governors are identified by a name plate attached to the governor housing. The letters

D.W.-L.S. stamped on the name plate denote a double-weight limiting speed governor. A single-weight variable speed governor name plate is stamped S.W.-V.S.

Normally, when performing a tune-up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if a cylinder head, governor or injectors have been replaced or overhauled, then certain tune-up adjustments are required. Accurate tune-up adjustments are very important if maximum performance and economy are to be obtained.

NOTE: If a supplementary governing device, such as a load limit device, is used, it must be disconnected prior to the tune-up. After the governor and injector rack adjustments are completed, the supplementary governing device must be reconnected and adjusted.

To tune-up an engine completely, perform all of the adjustments in the applicable tune-up sequence given below.

CAUTION: To prevent the possibility of personal injury, use turbocharger inlet shield J 26554-A anytime the turbocharger inlet is exposed.

Use new valve rocker cover gaskets after the tune-up is completed.

Tune-Up Sequence for Mechanical Governor

Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover, the serviceman must determine that the injector racks move to the no-fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever.

CAUTION: An overspeeding engine can result in engine damage which could cause personal injury.

1. Adjust the exhaust valve clearance, cold.
2. Time the fuel injectors.
3. Adjust the governor gap.
4. Position the injector rack control levers.
5. Adjust the maximum no-load speed.
6. Adjust the idle speed.
7. Adjust the buffer screw.
8. Adjust the throttle booster spring (variable speed governor only).
9. Adjust the supplementary governing device, if used.

Tune-up Sequence for Hydraulic Governor

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the fuel rod.
4. Position the injector rack control levers.
5. Adjust the load limit screw.
6. Compensation adjustment (PSG governors only).
7. Adjust the speed droop.
8. Adjust the maximum no-load speed.

EMISSION REGULATIONS FOR ON-HIGHWAY VEHICLE ENGINES

On-highway vehicle and coach engines built by Detroit Diesel Allison are certified to be in compliance with Federal and California Emission Regulations established for each model year beginning with 1970.

Engine certification is dependent on five physical characteristics:

1. Fuel injector type.
2. Maximum full-load engine speed.
3. Camshaft timing.
4. Fuel injector timing.
5. Throttle delay (orifice size).

The following Charts summarize all of the pertinent data concerning the specific engine configurations required for each model year.

When serviced, all on-highway vehicle and coach engines should comply with the specifications for the specific model year in which the engine was built.

Trucks in a fleet containing engines of various model years can be tuned to the latest model year, provided the engines have been updated to meet the specifications for that particular year.

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1970-1973 CERTIFIED AUTOMOTIVE CONFIGURATIONS

Year	1970	1971	1972	1973
Engines	3-53N 4-53N 6V-53N 8V-53N	3-53N 4-53N 6V-53N 8V-53N	3-53N 4-53N 6V-53N 8V-53N	3-53N 4-53N 6V-53N 8V-53N
Injectors	N40 N45 N50**	N40 N45 N50**	N40 N45 N50	C40 C45 C50
▼ Maximum Full-load Engine Speed	2800	2800	2800	2800
Camshaft Timing	Adv.	Adv.	Adv.	Adv.
■ Injector Timing	1.460"	1.460"	1.460"	1.460"
Timing Gage	J 1853	J 1853	J 1853	J 1853
Throttle Delay	No	No	*Yes	*Yes
Yield Link	—	—	—	—

*Throttle delay must have .016" diameter orifice.
**Exempt for fire fighting apparatus.
▼No-load engine speed will vary with injector size and governor type.
■The adjusted height of the fuel injector follower in relation to the injector body.

1974-1976 CERTIFIED AUTOMOTIVE CONFIGURATIONS

Year	1974	1975	1976
Engines	4-53N 6V-53N	4-53N 6V-53N	4-53N 6V-53N
Injectors	C40 C45 C50	C40 C45 C50	C40 C45 C50
▼ Maximum Full-load Engine Speed	2800	2800	2800
Camshaft Timing	Adv.	Adv.	Adv.
■ Injector Timing	1.470"	1.470"	1.470"
Timing Gage	J 24236	J 24236	J 24236
Throttle Delay	Yes ●	Yes ●	Yes ●
Yield Link	Yes	Yes	Yes

▼No-Load engine speed will vary with injector size and governor type.
■The adjusted height of the fuel injector follower in relation to the injector body.
●.250" diameter fill hole, .016" diameter discharge orifice.

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1977 CERTIFIED AUTOMOTIVE CONFIGURATIONS

Engine	4-53N	6V-53N
(a) Injectors	C40 C45 C50	C40 C45 C50
(a) Maximum Rated Speed	2800	2800
(a) Minimum Rated Speed	2800 (C40) 2400 (C45) 2500 (C50)	2600 (C40) 2500 (C45) 2100 (C50)
Gear Train Timing	Adv.	Adv.
Injector Timing	1.470"	1.470"
Timing Gage	J 24236	J 24236
Throttle Yield Link Setting	(e) Yes .454"	(e) Yes .454"
Liner Port Height Compression Ratio Blower Drive Ratio	.840" 21:1 2.487:1	.840" 21:1 2.487:1
Governor Type	Limiting Speed	
Thermostat	170-180° F (77-82° C) Nominal Opening Temperature	

(a) Not to exceed injector size and maximum operating speed that has been established. No-load speed will vary with injector size and governor type.

(e) Large fill hole (.250" dia.), .016" discharge orifice. Use a minimum idle speed at 500 rpm on all engines.

1978 CERTIFIED AUTOMOTIVE CONFIGURATIONS

	FEDERAL			CALIFORNIA
ENGINE FAMILIES	4L-53N	4-53T	6V-53N	4-53TC
INJECTORS (a)	C40 C45 C50	5A55 5A60	C40 C45 C50	5A55 5A60
MAXIMUM FULL LOAD SPEED (b)	2800	2500	2800	2500
MINIMUM FULL LOAD SPEED	2400	2500	2400	2500
CAMSHAFT LOBE POSITION	ADV.	STD.	ADV.	STD.
INJECTOR TIMING	1.470	1.496	1.470	5A55-1.496 5A60-1.508
THROTTLE DELAY YIELD LINK	(e) REQ.	FUEL MODULATOR	(e) REQ.	FUEL MODULATOR
TURBOCHARGER A/R		T04B98 .96 3LM-353 2.7 Sq. In.		T04B98 .96 3LM-353 2.7 Sq. In.

(a) See Engine Application Rating (Sales Tech Data Book 1, Vol. 3) for specific application usage of injector size and full-load speed combination. No-load speed will vary with injector size and governor type.

(b) Use a minimum idle speed of 400 rpm on all coach engines with throttle delay and a minimum idle speed of 500 rpm on all other engines.

(e) Large fill hole (.250" dia.), .016" discharge orifice.

FUEL INJECTOR TIMING GAGE CHART

INJECTOR	TOOL NO.	SETTING	CAM LOBE POSITION
5A55	J 9595	1.496	Standard
5A60	J 9595	1.496	Standard
5A60 (Calif. Cert. only)	J 8909	1.508	Standard

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1979 CERTIFIED AUTOMOTIVE CONFIGURATIONS

	FEDERAL		CALIFORNIA	
FAMILIES	**4L-53T**	**6V-63T**	**4L-53TC**	**6V-53TC**
INJECTORS	5A55 5A60	5A50	5A55 5A60	5A50
MAXIMUM FULL LOAD SPEED	2500	2600	2500	2600
MINIMUM FULL LOAD SPEED	2500	2500	2500	2500
MINIMUM IDLE SPEED	500	500	500	500
GEAR TRAIN TIMING	STD.	STD.	STD.	STD.
INJECTOR TIMING	1.496	1.490	5A55-1.496 5A60-1.508	1.500
FUEL MODULATOR SETTING #	.365#	.404#	5A55-.365 5A60-.404#	.404#
LINER PORT HEIGHT	.84	.84	.84	.84
LINER PART NUMBER	5132803	5132803	5132803	5132803
TURBOCHARGER A/R	TO4B98 .96 A/R ##	TV6123 1.20 A/R	TO4B98 .96 A/R ##	TV6123 1.20 A/R
TURBOCHARGER PART NUMBER	5103905##	5104082	5103905##	5104082
BLOWER DRIVE RATIO	2.49:1	2.49:1	2.49:1	2.49:1
BLOWER PART NUMBER	5103563-LH 5103466-RH	5104298	5103563-L 5103466-R	5104298
COMPRESSION RATIO	18.7:1	18.7:1	18.7:1	18.7:1
EXHAUST VALVE MATERIAL	NIMONIC 90	NIMONIC 90	NIMONIC 90	NIMONIC 90
EXHAUST VALVE PART NUMBER	5109925	5109925	5109925	5109925
CERTIFICATION LABEL NUMBER	14B7-264	14B7-266	14B7-265	14B7-267

53T Uses fuel modulator.
Optional 3LM-353, 2.7 Sq. in., 5104803.

THROTTLE DELAY AND STARTING AID GAGES
J 28779 For .365"
J 28479 For .395"
J 9509-2 For .404"
J 23190 For .454"
J 25559 For .570"
J 26646 For .290"

PIN GAGE
J 25558 For .069" & .072"

TIMING GAGES
J 1853 For 1.460"
J 24236 For 1.470"
J 1242 For 1.484"
J 29066 For 1.490"
J 9595 For 1.496"
J 25454 For 1.500"
J 8909 For 1.508"

1980-1981 CERTIFIED AUTOMOTIVE CONFIGURATIONS

FEDERAL

ENGINE FAMILIES	4L-53T	6V-53T
INJECTORS (a)	5A55 5A60	5A50
MAXIMUM FULL LOAD SPEED (a)	2500	2600
MINIMUM FULL LOAD SPEED	2500	2500 (b) 2200 (c)
MINIMUM IDLE SPEED	500	600
GEAR TRAIN TIMING	STD.	STD.
INJECTOR TIMING	1.496	1.490
THROTTLE DELAY SETTING	.365 (e)	.404 (e)
TURBOCHARGER A/R	T04B98 .96 A/R 3LM-353 2.7 Sq. In.	TV6123 21.20 A/R

(a) Refer to Engine Application Rating (Sales Tech Data Book 1, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.
(b) 1980
(c) 1981
(e) 53T uses fuel modulator.

1980 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
4-53T	5A55 5A60	155 @ 2500 170 @ 2500	379 @ 1800 402 @ 1800
6V-53T	5A50	225 @ 2600	550 @ 1800

1981 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
4-53T	5A55 5A60	155 @ 2500 170 @ 2500	379 @ 1800 402 @ 1800
6V-53T	5A50	215 @ 2200 223 @ 2500 225 @ 2600	550 @ 1800

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS

85°F (29.4°C) — AIR INLET TEMPERATURE
29.00 IN. HG. (98.19 kPa) — BAROMETER (DRY)

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1982 CERTIFIED AUTOMOTIVE CONFIGURATIONS

FEDERAL

ENGINE FAMILIES	4L-53T	6V-53T
INJECTORS (a)	5A55 5A60	5A50
MAX. FULL LOAD SPEED	2500	2600
MIN. FULL LOAD SPEED	2500	2200
MIN. IDLE SPEED	500	600
GEAR TR. TIMING	STD.	STD.
INJECTOR TIMING	1.496	1.490
THROTTLE DELAY SETTING	.365 (a)	.404 (a)
LINER PORT HGHT.	.84	.84
LINER PART NO.	5132803	5132803
TURBOCHARGER A/R	T04B98 (b) .96 A/R (c)	TV6123 1.20 A/R
TURBOCHARGER P/N	5103905	5104082
BLOWER DR. RATIO	2.49:1	2.49:1
BLOWER PART NO.	5107528L 5107527R	5107523
COMP. RATIO	18.7:1	18.7:1
EXHAUST VALVE P/N	5109925	5109925
CERT. LABEL NO.	14B7-327	14B7-328

(a) 53T uses fuel modulator.
(b) For "RD" configuration optional turbocharger 5106635 & 5106636 are available.
(c) Optional 3LM-353, 2.7 sq. in. 5104803

1982 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
4-53T	5A55 5A60	155 @ 2500 170 @ 2500	379 @ 1800 402 @ 1800
6V-53T	5A50	225 @ 2600	550 @ 1800

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS

85°F (29.4°C) — AIR INLET TEMPERATURE
29.00 IN. HG. (98.19 kPa) — BAROMETER (DRY)

Effective January 1, 1982, California allowed the use of Federal certified engines in *Public Transit Busses* and in *Authorized Emergency Vehicles* as defined in section 165 of the California Vehicle Code.

1983 CERTIFIED AUTOMOTIVE CONFIGURATIONS

FEDERAL

ENGINE FAMILIES	4L-53T	6V-53T
INJECTORS (a)	5A55 5A60	5A50
MAXIMUM FULL LOAD SPEED (a)	2500	2600
MINIMUM FULL LOAD SPEED	2500	2200
MINIMUM IDLE SPEED	500	600
GEAR TRAIN TIMING	STD.	STD.
INJECTOR TIMING	1.496	1.490
MODULATOR SETTING	.365	.404
TURBOCHARGER A/R	T04B98 .96 A/R 3LM-353 2.7 Sq. In.	TV6123 1.20 A/R
TURBOCHARGER PART NO.	5103905 5104803	5104082
BLOWER DRIVE RATIO	2.49:1	2.49:1
BLOWER PART NO.	5107528L 5107527R	5107523
COMPRESSION RATIO	18.7:1	18.7:1
EXHAUST VALVE PART NO.	5109925	5109925
LINER PART NO.	5132803	5132803
LINER PORT HEIGHT	.84	.84
CERT. LABEL NO.	14B7-347	14B7-348

(a) Refer to Engine Application Rating (Sales Tech Data Book 1, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

1983 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
4-53T	5A55 5A60	155 @ 2500 170 @ 2500	379 @ 1800 402 @ 1800
6V-53T	5A50	225 @ 2600	550 @ 1800

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS

85°F (29.4°C) — AIR INLET TEMPERATURE
29.00 IN. HG. (98.19 kPa) — BAROMETER (DRY)

Effective January 1, 1982, California allowed the use of Federal certified engines in *Public Transit Busses* and in *Authorized Emergency Vehicles* as defined in section 165 of the California Vehicle Code.

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1984 CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	4L-53T	6V-53T
Injectors (a)	5A55 5A60	5A50
Maximum Full Load Speed (a)	2500	2600
Minimum Full Load Speed	2500	2200
Minimum Idle Speed	500	600
Gear Train Timing	Std.	Std.
Injector Timing	1.496	1.490
Throttle Delay Setting	DNA	DNA
Modulator Setting	.365	.404
Turbocharger A/R	T04B98 .96 A/R 3LM-353 2.7 Sq. In.	TV6123 1.20 A/R
CERT. LABEL NO.	14B7-373	14B7-374

DNA Does not apply.

(a) Refer to Engine Application Rating (Sales Tech Data Book 18SA315) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

1984 CERTIFIED AUTOMOTIVE ENGINES			
ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
4-53T	5A55 5A60	155 @ 2500 170 @ 2500	379 @ 1800 402 @ 1800
6V-53T	5A50	225 @ 2600	550 @ 1800
ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE J 1349 CONDITIONS			

Effective January 1, 1982, California allowed the use of Federal certified engines in *Public Transit Busses* and in *Authorized Emergency Vehicles* as defined in section 165 of the California Vehicle Code.

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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 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.

ENGINES WITH TWO VALVE CYLINDER HEADS

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)

TXT 1. Remove the loose dirt from the valve rocker cover(s) and remove the cover(s).

2. Place the governor speed control lever in the *idle speed* position. If a stop lever is provided, secure it in the *stop* position.

3. Rotate the crankshaft, manually or with the starting motor, until the injector follower is 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 be loosened.

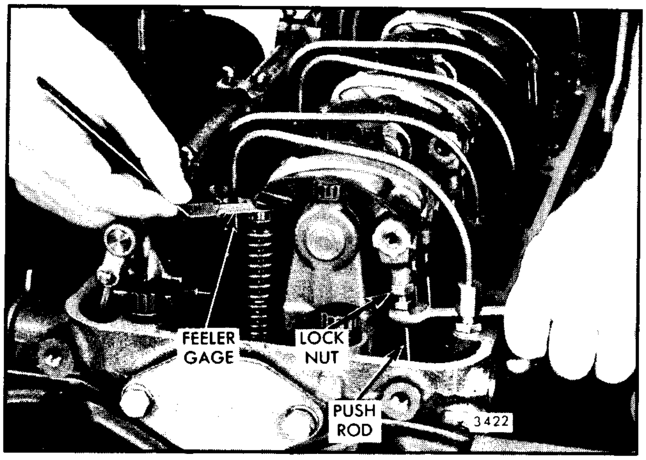

Fig. 1 - Adjusting Valve Clearance (Two Valve Head)

4. Loosen the exhaust valve rocker arm push rod locknut.

5. Place an .011" feeler gage (J 9708-01) between the exhaust valve stem and the rocker arm (Fig. 1). 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 .010" feeler gage (J 9708-01 will pass freely between the valve stem and the rocker arm, but the .012" feeler gage will not pass through. Readjust the push rod, if necessary.

8. Adjust and check the remaining exhaust valves in the same manner as above.

Valve Clearance Adjustment (Hot Engine)

NOTE: It is *not* necessary to make a final hot engine exhaust valve clearance adjustment after a cold engine adjustment has been performed. However, if a hot engine adjustment is desired, use the following procedure.

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.

NOTE: Since these adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

1. With the engine at normal operating temperature (refer to Section 13.2), set the exhaust valve clearance with feeler gage J 9708-01. At this time, if the valve clearance is correct, the .008" gage will pass freely between the end of the valve stem and the rocker arm

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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 (Section 14.2).

Check Exhaust Valve Clearance Adjustment

1. With the engine at 100° F (38° C) or less, check the valve clearance.

2. If a .011" feeler gage (±.004") will pass between the valve stem and the rocker arm bridge, the valve clearance is satisfactory. If necessary, adjust the push rod.

ENGINES WITH FOUR VALVE CYLINDER HEADS

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)

1. Remove the loose dirt from the valve rocker cover(s) and remove the cover(s).

2. Place the governor speed control lever in the *idle* speed position. If a stop lever is provided, secure it in the *stop* position.

3. Rotate the crankshaft, manually or with the starting motor, until the injector follower is 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 be loosened.

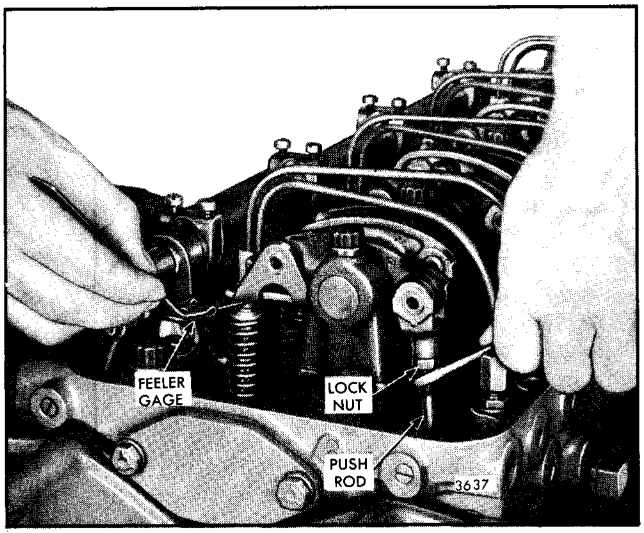

Fig. 2 - Adjusting Valve Clearance (Four Valve Head)

4. Loosen the exhaust valve rocker arm push rod locknut.

5. Place a .026" feeler gage (J 9708-01) between the end of one exhaust valve stem and the rocker arm bridge (Fig. 2). 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 .025" feeler gage will pass freely between the end of one valve stem and the rocker arm bridge, but the .027" feeler gage will not pass through. Readjust the push rod, if necessary.

8. Adjust and check the remaining exhaust valves in the same manner as above.

Valve Clearance Adjustment (Hot Engine)

> **NOTE:** It is *not* necessary to make a final hot engine exhaust valve clearance adjustment after a cold engine adjustment has been performed. However, if a hot engine adjustment is desired, use the following procedure.

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.

> **NOTE:** Since these adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

1. With the engine at normal operating temperature (refer to Section 13.2), set and exhaust valve clearance with feeler gage J 9708-01. At this time, if the valve clearance is correct, the .023" gage will pass freely between the end of one valve stem and the rocker arm

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bridge, but the .025" feeler gage will not pass through. Readjust the push rod, if necessary.

2. After the exhaust valve clearance has been adjusted, check the fuel injector timing (Section 14.2).

Check Exhaust Valve Clearance Adjustment

1. With the engine at 100° F (38° C) or less, check the valve clearance.

2. If a .026" feeler gage (±.006") will pass between the valve stem and the rocker arm bridge, the valve clearance is satisfactory. If necessary, adjust the push rod.

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FUEL INJECTOR TIMING

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 (Section 14.1), time the fuel injectors as follows:

TRUNK PISTONS

INJECTOR	TIMING DIMENSION	TIMING GAGE	CAMSHAFT TIMING	ENGINE
35	1.484"	J 1242	Standard	53 (2 valve)
35	1.508"	J 8909	Standard	(Reefer Car)
40	1.484"	J 1242	Standard	53, V53
45	1.484"	J 1242	Standard	53, V53
S40	1.460"	J 1853	Standard	53, V53
S45	1.460"	J 1853	Standard	53, V53
S50	1.460"	J 1853	Standard	53, (2 valve)
L40	1.460"	J 1853	Standard	(Lift Truck)
N35	1.460"	J 1853	—	—
N35	1.484"	J 1242	Standard	—
N35	1.508"	J 8909	Standard	Reefer Car
N40	1.460"	J 1853	Standard	53N, V53N
N40	1.460"	J 1853	Standard	—
N45	1.460"	J 1853	Standard	53N, V53N
N45	1.460"	J 1853	Standard	—
N45	1.484"	J 1242	Standard	—
N50	1.460"	J 1853	Standard	53N, V53N
N50	1.460"	J 1853	Standard	—
N60	1.460"	J 1853	—	—
N60	1.460"	J 1853	Standard	SGS*
N65	1.508"	J 8909	Standard	4-53T
N65	1.508"	J 8909	Standard	Industrial & SGS*
N65	1.460"	J 1853	Standard	SGS*
N65	1.508"	J 8909	Standard	Generator
N70	1.460"	J 1853	Standard	Marine
N70	1.460"	J 1853	—	—
N70	1.460"	J 1853	Standard	SGS*
M40	1.460"	J 1853	Standard	SGS*
M55	1.460"	J 1853	Standard	SGS*
M60	1.460"	J 1853	Standard	SGS*
5N65	1.460"	J 1853	Standard	6V-53T
5N65	1.460"	J 1853	Standard	Marine
5N45	1.460"	J 1853	Standard	—
5A50	1.490"	J 29066	Standard	Industrial
5A50	1.484"	J 1242	Standard	6V-53T†
5A55	1.496"	J 9595	Standard	Industrial
5A55	1.484"	J 1242	Standard	3-53T†
5A55	1.484"	J 1242	Standard	6V-53T†
5A60	1.496"	J 9595	Standard	Industrial & SGS*
5A60	1.484"	J 1242	Standard	SGS*
5A60	1.484"	J 1242	Standard	3-53T†

For automotive applications, refer to Section 14.
*Special Gov't. Sale.
†With bypass blower.

TABLE 1 (Injector Timing)

1. Place the governor speed control lever in the *idle* speed position. If a stop lever is provided, secure it in the *stop* position.

2. Rotate the crankshaft, manually or with the starting motor, until the exhaust valves are fully depressed on the particular cylinder to be timed.

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 could 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 Tables 1 or 2 for the correct timing gage (for vehicle engines, refer to Section 14).

CROSS-HEAD PISTONS

INJECTOR	TIMING DIMENSION	TIMING GAGE	CAMSHAFT TIMING	ENGINE
5C50	1.480	J 29065	Standard	4-53T 6V-53T
5E50	1.480	J 29065	Standard	3-53T
5C55	1.480	J 29065	Standard	4-53T 6V-53T
5E55	1.480	J 29065	Standard	3-53T
5C60	1.480	J 29065	Standard	4-53T 6V-53T
5E60	1.480	J 29065	Standard	3-53T

TABLE 2 (Injector Timing)

4. Loosen the injector rocker arm push rod locknut.

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.

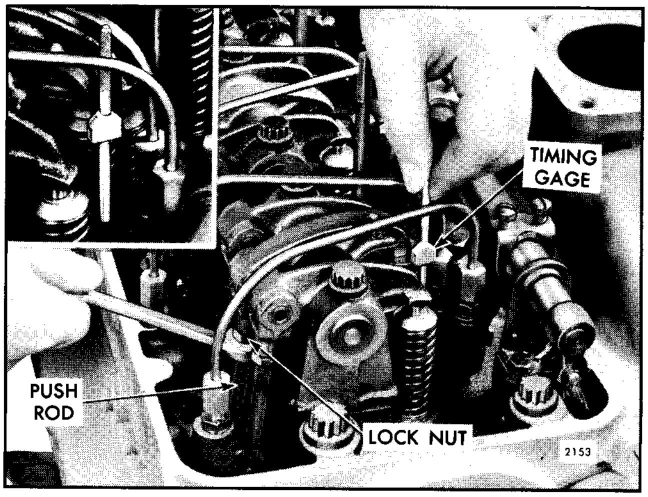

Fig. 1 - Timing Fuel Injector

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6. Hold the push rod and tighten the locknut. Check the adjustment and, if necessary, readjust the push rod.

7. Time the remaining injectors in the same manner as outlined above.

8. If no further engine tune-up is required, install the valve rocker cover(s), using a new gasket.

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LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

IN-LINE ENGINE

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

NOTE: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. On turbocharged engines, the fuel (air box) modulator lever and roller assembly must be positioned free from cam contact. After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

A 3/4"-16 tapped hole has been added to the SAE No. 2 flywheel housings used on certain 4-53 turbocharged engines. The tapped hole located at the 7:30 o'clock position on the bottom rail accomodates the probe for the digital tachometer J 26791. A 3/4"-16 plug is used to seal this tachometer pick-up hole.

Adjust Governor Gap

With the engine stopped and at operating temperature, adjust the governor gap as follows:

1. Remove the high-speed spring retainer cover.

2. Back out the buffer screw until it extends approximately 5/8" from the locknut.

3. Clean and remove the valve rocker cover.

4. Start the engine and adjust the idle speed screw to obtain an idle speed of 500-600 rpm (Fig. 8).

NOTE: The recommended idle speed is 500-600 rpm, but may vary with special engine applications.

5. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker cover. Discard the gasket.

6. Start and run the engine between 1100 and 1300 rpm by manual operation of the differential lever.

NOTE: Do not overspeed the engine.

7. Check the gap between the low-speed spring cap and the high-speed spring plunger with a feeler gage (Fig. 1). The gap should be .002"-.004". If the gap setting is incorrect, reset the gap adjusting screw.

8. On governors without the starting aid screw, hold the gap adjusting screw and tighten the locknut.

9. Recheck the gap with the engine operating between 1100 and 1300 rpm and readjust, if necessary.

10. Install the governor cover. The governor cover should be placed on the housing with the pin of the speed control lever projecting into the slot in the differential lever.

11. Install the screws and lock washers finger tight. Pull the cover away from the engine and tighten the screws. This step will properly locate the cover on the governor housing.

Position Injector Rack Control Levers

The position of the injector racks 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:

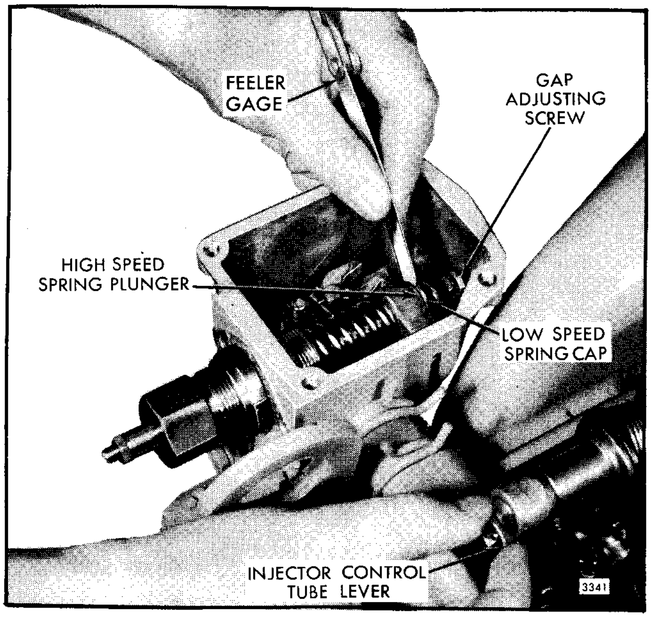

Fig. 1 - Adjusting Governor Gap

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1. Speed control lever at the maximum speed position.

2. Governor low-speed gap closed.

3. High-speed spring plunger on the seat in the governor control housing.

4. Injector racks in the full-fuel position.

Adjust the rear injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the speed control lever.

2. Turn the idle speed adjusting screw until 1/2" of the threads (12-14 threads) project from the locknut, when the nut is against the high-speed plunger. This adjustment lowers the tension of the low-speed spring so it can be easily compressed. This permits closing the low-speed gap without bending the fuel rods or causing the *yield mechanism springs to yield or stretch.*

> **NOTE:** A false fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above.

3. Back out the buffer screw approximately 5/8", if it has not already been done.

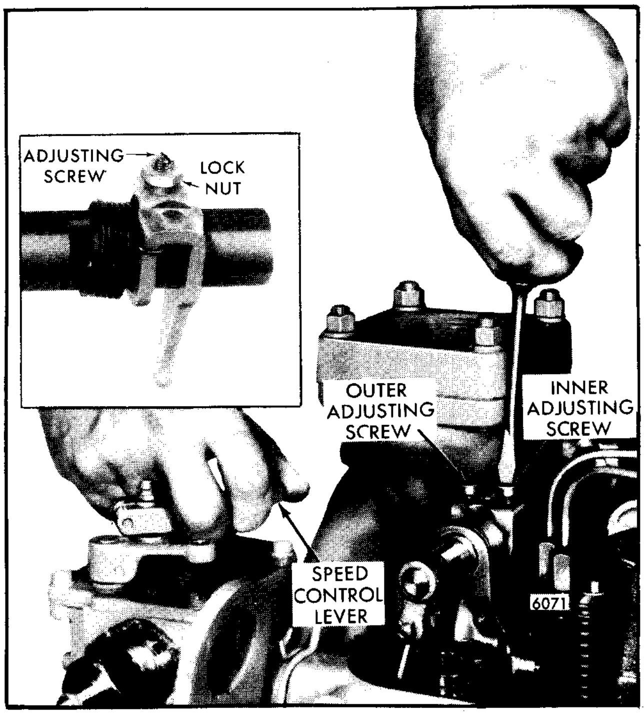

Fig. 2 - Positioning the Rear Injector Rack Control Lever

4. Loosen all of the inner and outer injector rack control lever adjusting screws or the adjusting screws and locknuts (Fig. 2). Be sure all of the levers are free on the injector control tube.

5. Move the speed control lever to the full fuel position and hold it in that position with light finger pressure.

Two Screw Assembly

Turn the inner adjusting screw on the rear injector rack control lever down until a slight movement of the control lever is observed or a step-up in effort to turn the screwdriver is noted. This will place the rear 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.

One Screw and Locknut Assembly

Tighten the adjusting screw of the rear injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Tighten the screw approximately 1/8 of a turn more and lock securely with he adjusting screw locknut. This will place the rear injector rack in the full-full position.

> **NOTE:** Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adusting screws is 24-36 **lb-in** (3-4 Nm).

The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full load.

6. To be sure of the proper rack adjustment, hold the speed control lever in the full-fuel position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack when the speed control lever is in the maximum speed position (Fig. 3). Hold the speed control lever in the maximum speed position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward and when the pressure of the screwdriver is released, the control rack should "spring" back upward (Fig. 4).

If the rack does not return to its original position, it is too loose. To correct this condition with the *Two Screw Assembly,* back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly. To correct this condition with the *One Screw and Locknut Assembly* loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

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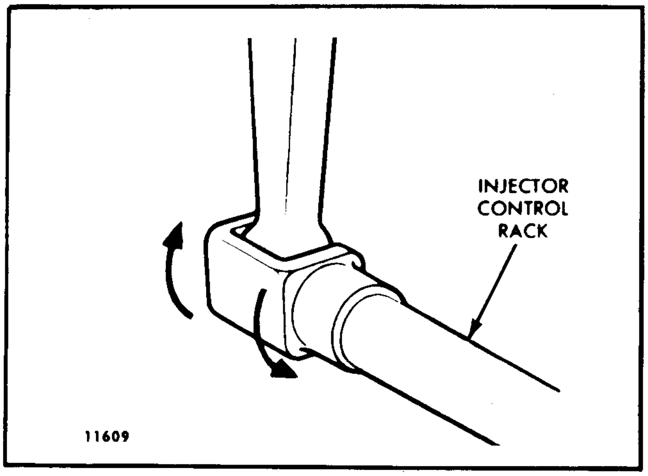

Fig. 3 - Checking Rotating Movement of Injector Control Rack

The setting is too tight if, when moving the speed control lever from the no speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step-up in effort required to move the speed control lever to the end of its travel. To correct this condition with the *Two Screw Assembly,* back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly. To correct this condition with the *One Screw and Locknut Assembly,* loosen the locknut and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

NOTE: 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.

7. To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rod and the injector control tube lever. Hold the injector control racks in the full-fuel position by means of the lever on the end of the control tube and proceed as follows:

Two Screw Assembly

a. Turn down the inner adjusting screw on the injector rack control lever of the adjacent injector until the injector rack has moved into the full-fuel position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

b. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while adjusting the adjacent injector. If the rack of the rear injector has become loose, back off the inner adjusting screw slightly on the adjacent injector rack control lever. Tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.

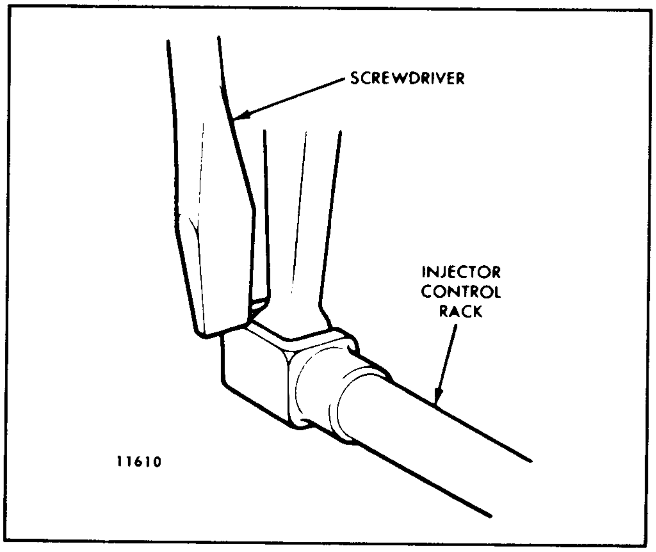

Fig. 4 - Checking Injector Rack "Spring"

c. Position the remaining injector rack control levers as outlined in Steps 6 and 7.

NOTE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **lb-in** (3-4 Nm).

One Screw and Locknut Assembly

a. Tighten the adjusting screw of the No. 2L injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Securely lock the adjusting screw locknut.

NOTE: Overtightening of the injector rack control tube 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).

b. Verify the rear injector rack adjustment, as outlined in Step 7. If it does not "spring" back upward, turn the adjacent injector rack adjusting

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screw counterclockwise slightly until the rear injector rack returns to its full-fuel position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both the rear and the adjacent injectors. Turn clockwise or counterclockwise the adjacent injector rack adjusting screw until both the rear and the adjacent injector racks are in the full-fuel position when the locknut is securely tightened.

c. Adjust the remaining injectors using the proceedures outlined in Step "b", always verifying proper injector rack adjustment.

8. Connect the fuel rod to the injector control tube lever.

9. Turn the idle speed adjusting screw in until it projects 3/16" from the locknut to permit starting the engine. Tighten the locknut.

10. On *turbocharged engines* adjust the internal starting aid screw, as follows:

NOTE: The starting aid screw has a locknut and the gap adjusting screw has a self locking patch.

a. Install a cutaway governor cover assembly, on the governor housing (Fig. 5).

b. With the engine *stopped*, place the governor stop lever in the *run* position and the speed control lever in the *idle* position.

c. Hold the gap adjusting screw to keep it from turning and adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the counter bore in the injector body (Fig. 5). Move the gage back and forth along the injector rack until a clearance of 1/64" is noted. The setting is measured at any convenient cylinder. Tighten the locknut on the starting aid screw sufficiently to prevent oil leakage as well as to hold the adjusting screw setting.

d. Check the injector rack clevis-to-body clearance after performing the following:

1. Position the stop lever in the *run* position.

2. Move the speed control lever from the *idle* position to the maximum speed position.

3. Return the speed control lever to the *idle* position.

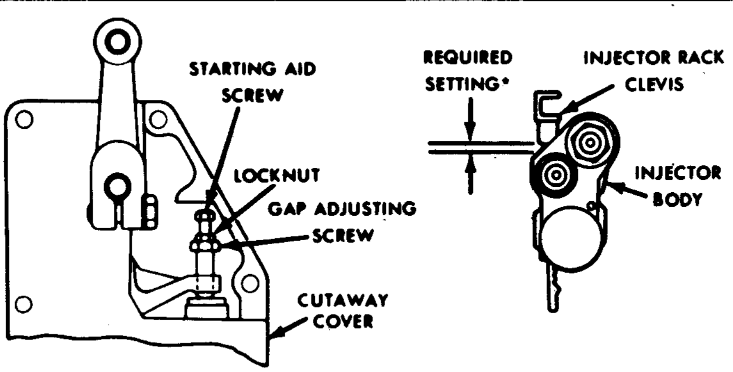
NOTE: Movement of the governor speed control lever is to take up clearances in the governor linkage. The clevis-to-body clearance can be increased by backing out the starting aid screw or reduced by turning it farther into the gap adjustment screw.

e. Start the engine and recheck the running gap (.0015") and, if necessary, reset it and reposition the injector racks. Then stop the engine.

f. Remove the cutaway governor cover assembly.

g. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the throttle control shaft assembly in the slot of the differential lever and the dowel pins in the housing in the dowel pin holes of the cover. Tighten the screws.

CAUTION: Before starting an engine after an engine speed control adjustment, or after removal of the engine governor cover and lever assembly, the serviceman must determine that the injector racks 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



INJECTOR	GAGE SETTING*	TOOL NUMBER
5A55	.345"	J 24889
5A60	.345"	J 24889
N55	.345"	J 24889
N60	.345"	J 24889
N65	.385"	J 24882
N70	.385"	J 24882
M60	.345"	J 24889
M70	.385"	J 24882

L-5870

Fig. 5 - Starting Aid Screw Adjustment

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with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

11. Use a new gasket and replace the valve rocker cover.

Adjust Maximum No-Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine option plate, set the maximum no-load speed as follows:

TYPE A GOVERNOR SPRINGS (Fig. 7):

1. Loosen the locknut (Fig. 6) and back off the high-speed spring retainer approximately five turns.

2. With the engine at operating temperature and no load on the engine, place the speed control lever in the full-fuel position. Turn the high-speed spring retainer IN until the engine is operating at the recommended no-load speed.

The best method of determining the engine speed is with an accurate tachometer.

3. Hold the high-speed spring retainer and tighten the locknut.

TYPE B GOVERNOR SPRINGS (Fig. 7):

1. Start the engine and after it reaches normal operating temperature, remove the load from the engine.

2. Place the speed control lever in the maximum speed position and note the engine speed.

3. Stop the engine and, if necessary, adjust the no-load speed as follows:

a. Remove the high-speed spring retainer, high-speed spring and plunger.

NOTE: To prevent the low-speed spring and cap from dropping into the governor, be careful not to jar the assembly while it is being removed.

b. Remove the high-speed spring from the high-speed plunger and add or remove shims as required to establish the desired engine no-load speed.

NOTE: For each .010" shim added, the engine speed will be increased approximately 10 rpm.

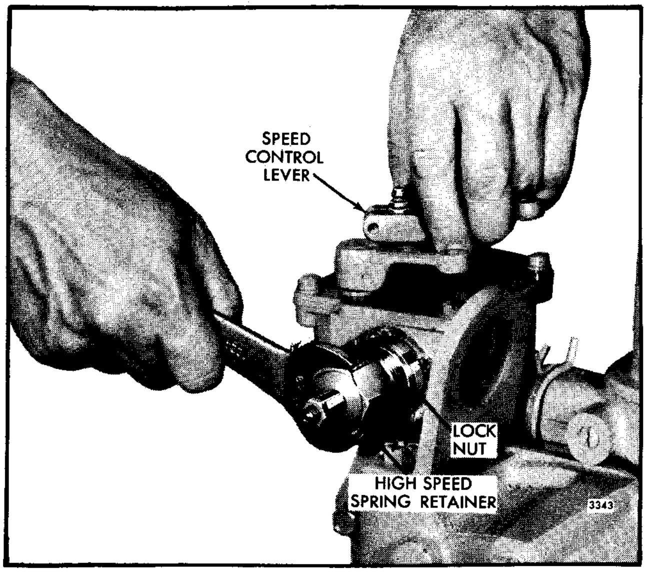

Fig. 6 - Adjusting Maximum No-Load Speed

c. Install the high-speed spring on the high-speed spring plunger and assemble the spring assembly in the governor housing. Install the spring retainer in the governor housing and tighten it securely.

d. Start the engine and recheck the engine no-load

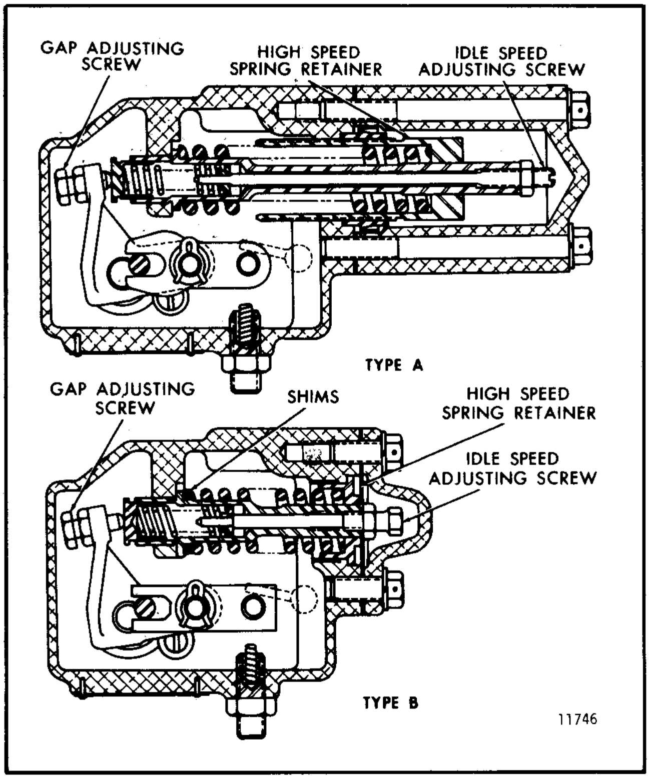

Fig. 7 - Governor Spring Assemblies

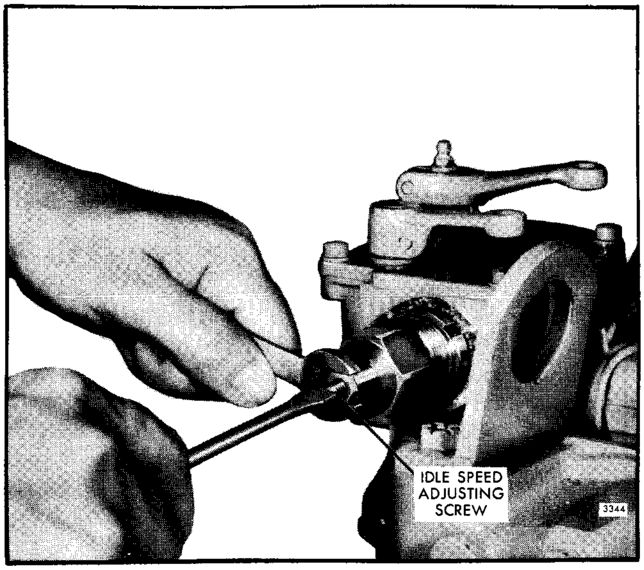

Fig. 8 - Adjusting Engine Idle Speed

speed. Repeat the steps above as necessary to establish the no-load speed.

Adjust Idle Speed

With the maximum no-load speed properly adjusted, adjust the idle speed as follows:

1. With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw until the engine is operating at approximately 15 rpm below the recommended idle speed (Fig. 8).

The recommended idle speed is 500-600 rpm, but may vary with the particular engine application.

2. Hold the idle speed adjusting screw and tighten the locknut.

3. Install the high-speed spring cover and tighten the two bolts.

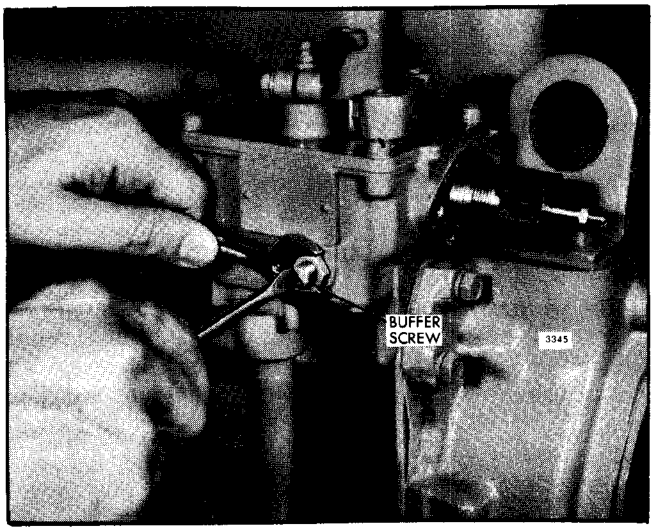

Fig. 9 - Adjusting the Buffer Screw

Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, loosen the locknut and turn the buffer screw in so that it contacts the differential lever as lightly as possible and still eliminates engine roll (Fig. 9).

NOTE: Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Recheck the maximum no-load speed. If it has increased more than 25 rpm from the maximum speed attained in Step 1, back off the buffer screw until the increase is less than 25 rpm.

3. Hold the buffer screw and tighten the locknut.

If the engine is equipped with a supplementary governing device, refer to Section 14.14 and adjust it at this time.

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LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT (V-TYPE ENGINE)

6V-53 ENGINE

The limiting speed mechanical governor is mounted at the rear of the engine, between the flywheel housing and the blower (Fig. 1). The governor is driven by the right blower rotor drive gear. The left blower rotor drive gear is driven by a shaft, that passes through the governor housing, from the engine gear train. There are two types of limiting speed governor assemblies. The difference in the two governors is in the spring mechanism (Fig. 8). One has a long spring mechanism, the other has a short spring mechanism.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

NOTE: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. On turbocharged engines, the fuel (air box) modulator lever and roller assembly must be positioned free from cam contact. After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

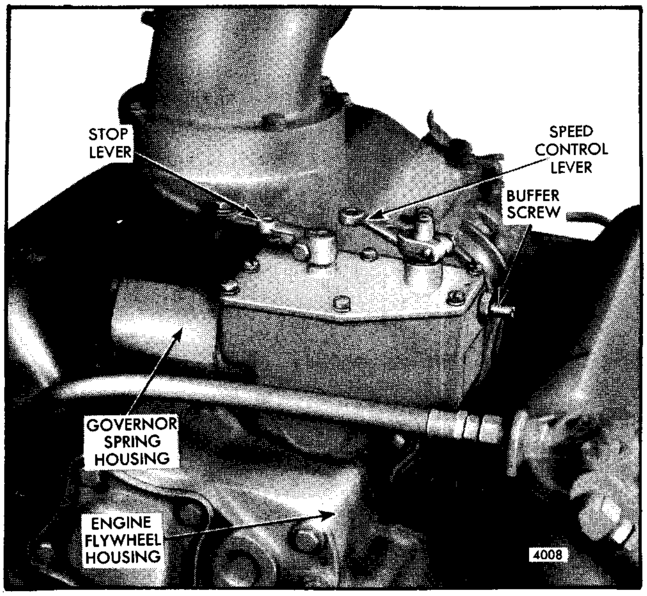

Fig. 1 - Limiting Speed Governor Mounting

Adjust Governor Gap

With the engine stopped and at operating temperature, adjust the governor gap as follows:

1. Remove the high-speed spring retainer cover.

2. Back out the buffer screw (Fig. 10) or de-energize the fast idle cylinder until it extends approximately 5/8" from the locknut.

NOTE: Do not back the buffer screw out beyond the limits given, or the control link lever may disengage the differential lever.

3. Start the engine and loosen the idle speed adjusting screw locknut. Then adjust the idle screw to obtain the desired idle speed (Fig. 9). Hold the screw and tighten the locknut to hold the adjustment.

NOTE: Governors used in turbocharged engine include a starting aid screw and locknut threaded into the governor gap adjusting screw.

4. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker covers. Discard the gaskets.

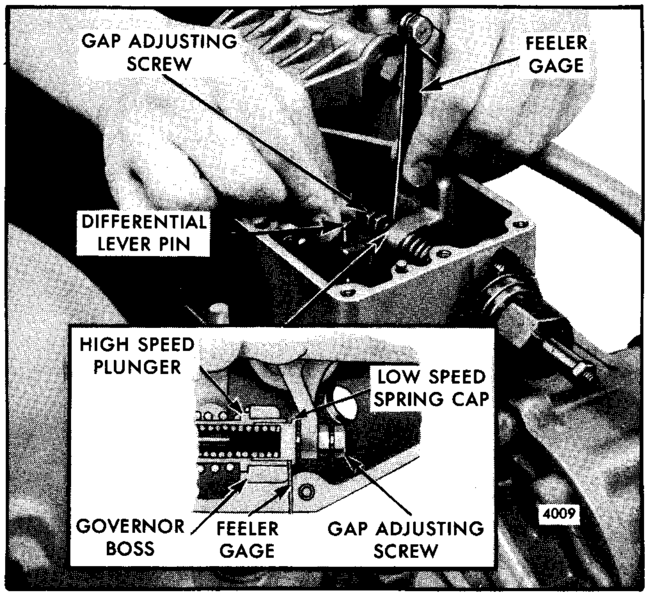

Fig. 2 - Adjusting Governor Gap

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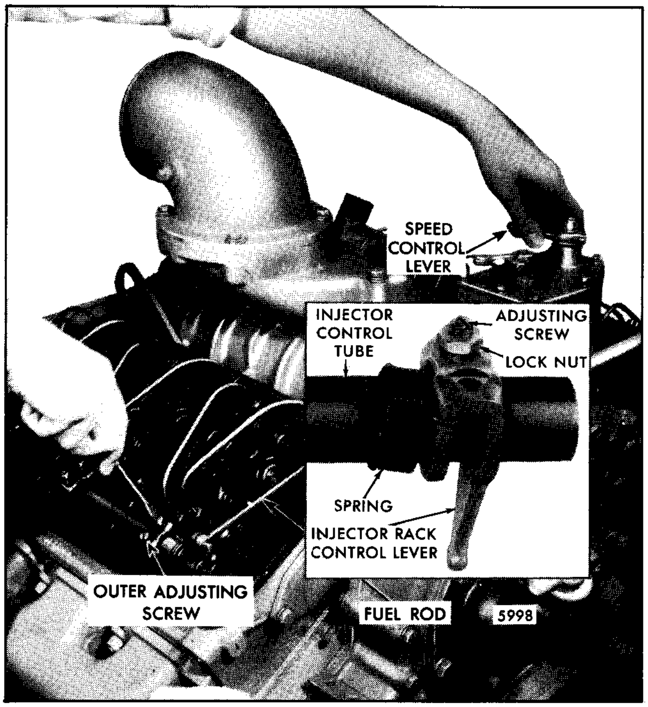

Fig. 3 - Positioning No. 3L Injector Rack Control Lever

5. Start and run the engine between 1100 and 1300 rpm by manual operation of the differential lever.

NOTE: Do not overspeed the engine.

6. Check the gap between the low-speed spring cap and the high-speed spring plunger with a feeler gage (Fig. 2). The gap should be .002"-.004". If the gap setting is incorrect, reset the gap adjusting screw.

7. On governors without the starting aid screw, hold the gap adjusting screw and tighten the locknut.

8. Recheck the gap with the engine operating between 1100 and 1300 rpm and readjust, if necessary.

9. Stop the engine and, using a new gasket reinstall the governor cover.

NOTE: Do not install the governor cover and lever assembly at this time on turbocharged engines as they include an internal starting aid screw and locknut.

Position Injector Rack Control Levers

The position of the injector racks 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.

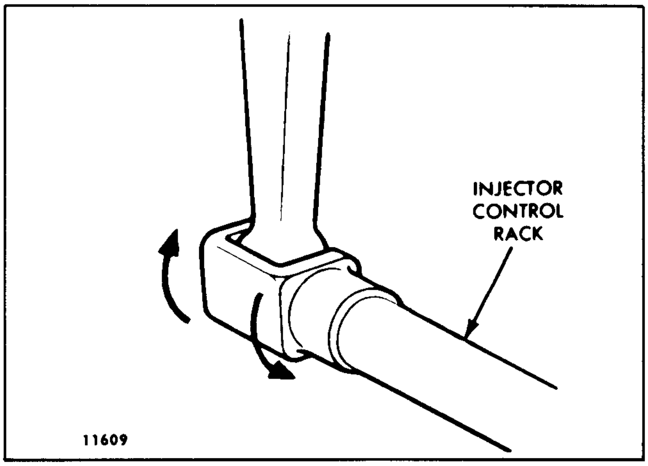

Fig. 4 - Checking Rotating Movement of Injector Control Rack

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the *maximum speed* position.

2. Governor low-speed gap closed.

3. High-speed spring plunger on the seat in the governor control housing.

4. Injector fuel control racks in the full-fuel position.

The letters "R" or "L" indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the

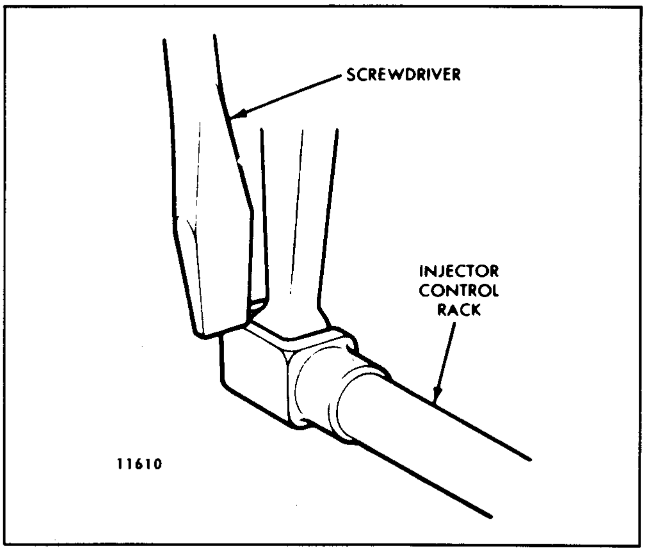

Fig. 5 - Checking Injector Control Rack "Spring"

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No. 3L injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect the linkage attached to the speed control lever.

2. Turn the idle speed adjusting screw until 1/2" of the threads (12-14 threads) project from the locknut when the nut is against the high-speed plunger. This adjustment lowers the tension of the low-speed spring so it can be easily compressed. This permits closing the low-speed gap without bending the fuel rods or causing the *yield mechanism springs to yield or stretch.*

> **NOTE:** A false fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above.

3. Back out the buffer screw approximately 5/8" if it has not already been done.

4. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.

5. Loosen all of the inner and outer injector rack control lever adjusting screws or the adjusting screws and locknuts on both injector control tubes (Fig. 3). Be sure all of the injector rack control levers are free on the injector control tubes.

6. Move the speed control lever to the *maximum speed* position and hold it in that position with light finger pressure.

Two Screw Assembly

Turn the inner adjusting screw on the No. 3L injector rack control lever down until a slight movement of the control tube lever is observed or a step-up in effort to turn the screwdriver is noted (Fig. 3). This will place the No. 3L injector 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.

One Screw and Locknut Assembly

Tighten the adjusting screw of the No. 3L injector rack control lever until the injector rack clevis is observed to roll up up or an increase in effort to turn the screwdriver is noted. Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut. This will place the No. 3L injector rack in the full-fuel position.

> **NOTE:** Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **lb-in** (3-4 Nm).

The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full load.

7. To be sure of the proper rack adjustment, hold the speed control lever in the *maximum speed* position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack when the speed control lever is in the *maximum speed* position (Fig. 4). Hold the speed control lever in the *maximum speed* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward and when the pressure of the screwdriver is released, the control rack should "spring" back upward (Fig. 5).

If the rack does not return to its original position, it is too loose. To correct this condition with the *Two Screw Assembly,* back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly. To correct this condition with the *One Screw and Locknut Assembly,* loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

The setting is too tight if, when moving the speed control lever from the *no-speed* position to the *maximum speed* position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step-up in effort required to move the speed control lever to the end of its travel. To correct this condition with the *Two Screw Assembly,* back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly. To correct this condition with the *One Screw and Locknut Assembly,* loosen the locknut and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

8. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.

9. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 3R injector rack control lever as previously outlined in Step 6 for the No. 3L injector rack control lever.

10. Insert the clevis pin in the fuel rod and the left cylinder bank injector control tube lever. Repeat the check on the No. 3L and 3R injector rack control levers as outlined in Step 7. Check for and eliminate any deflection which may occur at the bend in the fuel rod where it enters the cylinder head.

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11. To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rods and the injector control tube levers. Hold the injector control racks in the full-fuel position by means of the lever on the end of the control tube and proceed as follows:

Two Screw Assembly

a. Turn down the inner adjusting screw of the injector rack control lever until the screw bottoms (injector control rack in the full-fuel position).

b. Turn down the outer adjusting screw of the injector rack control lever until it bottoms on the injector control tube.

c. While still holding the control tube lever in the full fuel position, adjust the inner and outer adjusting screws to obtain the same condition as outlined in Step 7. Tighten the screws.

NOTE: Overtightening of the injector rack control tube 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).

One Screw and Locknut Assembly

a. Tighten the adjusting screw of the No. 2L injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted. Securely lock the adjusting screw locknut.

NOTE: Overtightening of the injector rack control tube 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).

b. Verify the injector rack adjustment of No. 3L as outlined in Step 7. If No. 3L does not "spring" back upward, turn the No. 2L adjusting screw counterclockwise slightly until the No. 3L injector rack returns to its full-fuel position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 3L and No. 2L injectors. Turn clockwise or counterclockwise the No. 2L injector rack adjusting screw until both No. 3L and No. 2L injector racks are in the full-fuel position when the locknut is securely tightened.

c. Adjust the remaining injectors using the proceedures outlined in Step "b" always verifying proper injector rack adjustment.

NOTE: Once the No. 3L and No. 3R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

12. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the full-fuel position, check each control rack as in Step 7. All of the control racks must have the same "spring" condition with the control tube lever in the full-fuel position.

13. Insert the clevis pin in the fuel rod and the injector control tube levers.

14. Turn the idle speed adjusting screw in until it projects 3/16" from the locknut to permit starting of the engine.

15. On *turbocharged engines* adjust the internal starting aid screw, as follows:

NOTE: The starting aid screw has a locknut and the gap adjusting screw has a self locking patch.

a. Install a cutaway governor cover assembly, on the governor housing (Fig. 6).

b. With the engine stopped, place the governor stop lever in the *run* position and the speed control lever in the *idle* position.

c. Hold the gap adjusting screw to keep it from turning and adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the counter bore in the injector body (Fig. 6). Move the gage back and forth along the injector rack until a clearance of 1/64" (.016) is noted. The setting is measured at the No. 3R injector rack clevis. Tighten the locknut on the starting aid screw sufficiently to prevent oil leakage as well as to hold the adjusting screw setting.

d. Check the injector rack clevis-to-body clearance after performing the following.

1. Position the stop lever in the *run* position.
2. Move the speed control lever from the *idle* position to the *maximum speed* position.
3. Return the speed control lever to the *idle* position.

NOTE: Movement of the governor speed control lever is to take up clearances in the governor linkage. The clevis-to-body clearance can be increased by backing out the starting aid screw

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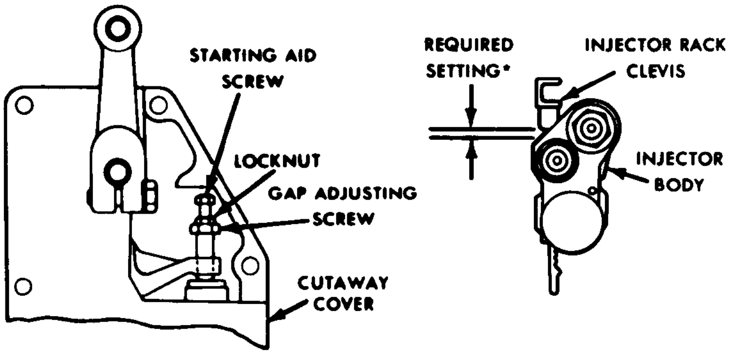

INJECTOR	GAGE SETTING*	TOOL NUMBER
5A55	.345"	J 24889
5A60	.345"	J 24889
N55	.345"	J 24889
N60	.345"	J 24889
N65	.385"	J 24882
N70	.385"	J 24882
M60	.345"	J 24889
M70	.385"	J 24882

L-5870

Fig. 6 - Starting Aid Screw Adjustment

or reduced by turning it farther into the gap adjustment screw.

e. Start the engine and recheck the running gap (.0015") and, if necessary, reset it and reposition the injector racks. Then stop the engine.

f. Remove the cutaway governor cover assembly.

g. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the throttle control shaft assembly in the slot of the differential lever and thae dowel pins in the housing in the dowel pin holes of the cover. Tighten the screws.

CAUTION: Before starting an engine after an engine speed control adjustment, or after removal of the engine governor cover and lever assembly, the serviceman must determine that the injector racks 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. An overspeeding engine can result in engine damage which could cause personal injury.

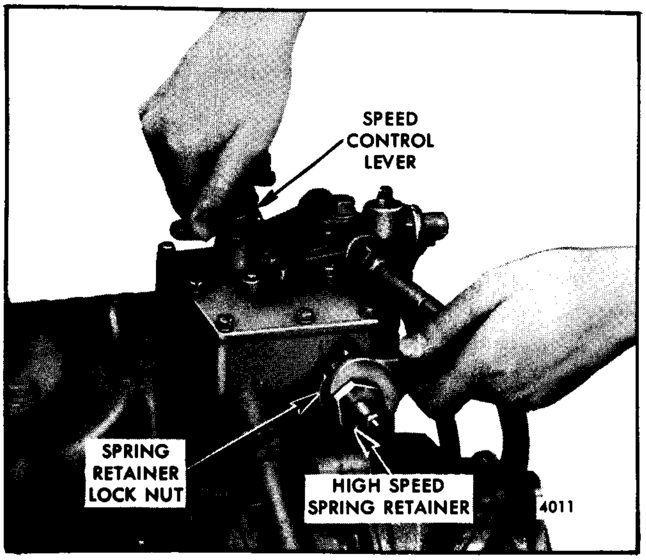

Fig. 7 - Adjusting Maximum No-Load Engine Speed

16. Use new gaskets and reinstall the valve rocker covers.

Adjust Maximum No-Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine name plate, set the maximum no-load speed as follows:

TYPE A GOVERNOR SPRINGS (Fig. 8):

1. Loosen the locknut with a spanner wrench and back off the high-speed spring retainer several turns. Then start the engine and increase the speed slowly. If the speed exceeds the required no-load speed before the speed control lever reaches the end of its travel, back off the spring retainer a few additional turns.

2. With the engine at operating temperature and no load on the engine, place the speed control lever in the *maximum speed* position. Turn the high-speed spring retainer in (Fig. 7) until the engine is operating at the recommended no-load speed. Use an accurate hand tachometer to determine the engine speed. The maximum no-load speed varies with the full-load operating speed.

3. Hold the spring retainer and tighten the locknut.

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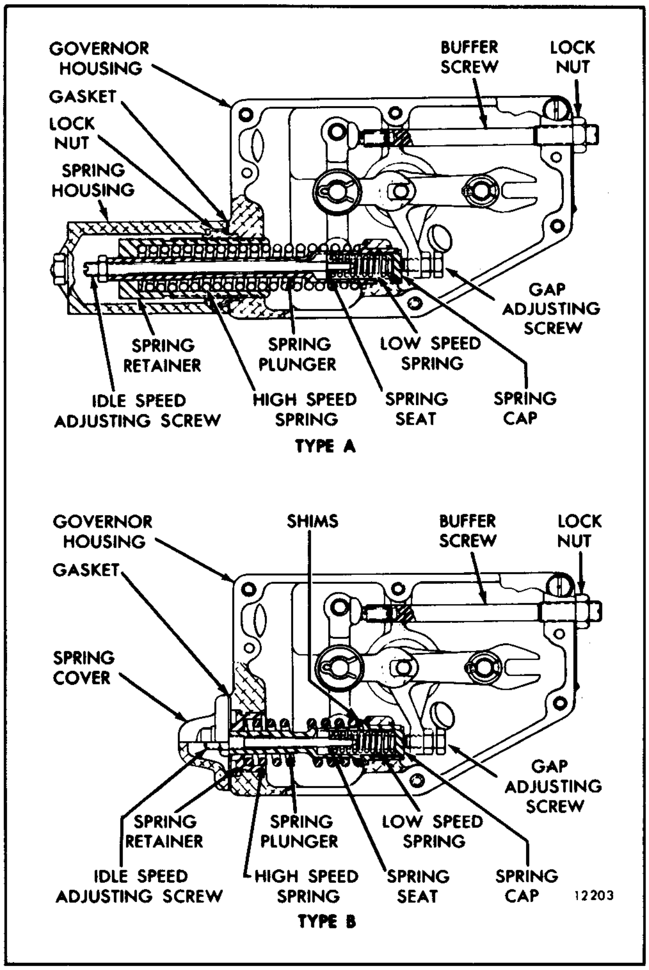

Fig. 8 - Governor Spring Assemblies

TYPE B GOVERNOR SPRINGS (Fig. 8):

1. Start the engine and, after it reaches normal operating temperature, remove the load from the engine.

2. Place the speed control lever in the *maximum speed* position and note the engine speed.

3. Stop the engine and, if necessary, adjust the no-load speed as follows:

a. Remove the high-speed spring retainer with tool J 5895 and withdraw the high-speed spring and plunger assembly.

NOTE: To prevent the low-speed spring and cap from dropping into the governor, be careful not to jar the assembly while it is being removed.

b. Remove the high-speed spring from the high-speed spring plunger and add or remove shims as required to establish the desired engine no-load speed.

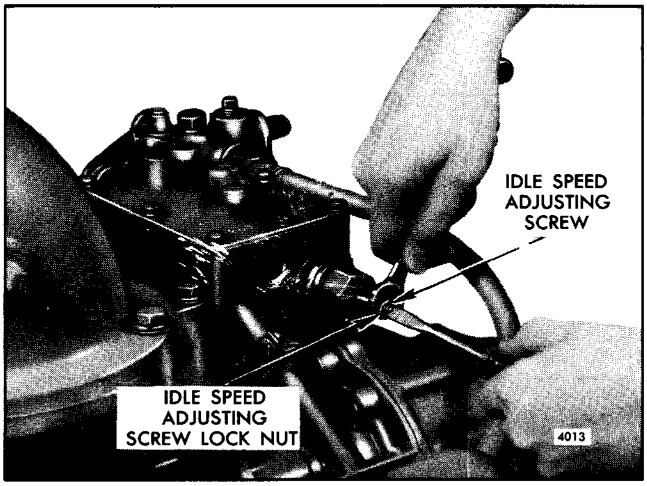

Fig. 9 - Adjusting Engine Idle Speed

NOTE: For each .010" in shims added, the engine speed will be increased approximately 10 rpm.

c. Install the high-speed spring on the plunger and install the spring assembly in the governor housing. Tighten the spring retainer securely. The maximum no-load speed varies with the full-load operating speed desired (Table 1).

Full Load RPM	Maximum Governor Droop RPM
2401-2600	150
2601-2800	140

TABLE 1 - Engine Speed Droop

EXAMPLE: If the full-load speed is to be 2800 rpm, then the no-load speed setting should be 2940 rpm to ensure the governor will move the injector racks into the *full-fuel* position at the desired full-load speed.

d. Start the engine and recheck the no-load speed. Repeat the procedure, as necessary, to establish the no-load speed required.

Adjust Idle Speed

With the maximum no-load speed properly adjusted, adjust the idle speed as follows:

1. With the engine running at normal operating

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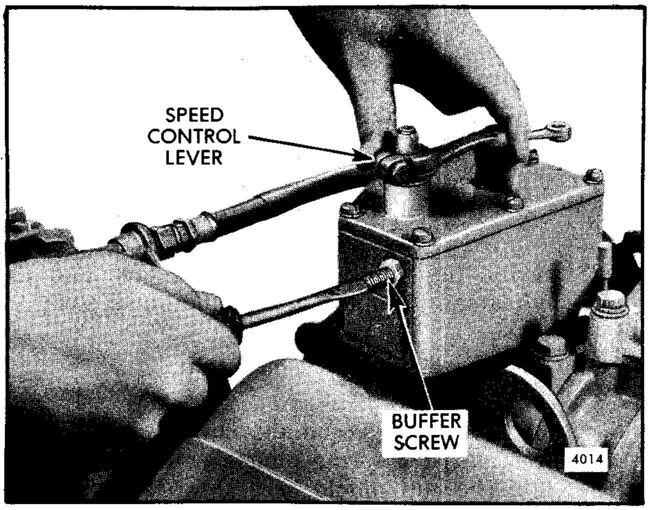

Fig. 10 - Adjusting Buffer Screw

temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw (Fig. 9) 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.

If the engine has a tendency to stall during deceleration, install a new buffer screw. The current buffer screw uses a heavier spring and restricts the travel of the differential lever to the *off (no-fuel)* position.

2. Hold the idle screw and tighten the locknut.

3. Install the high-speed spring retainer cover and tighten the two bolts.

Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, turn the buffer screw in so it contacts the differential lever as lightly as possible and still eliminates engine roll (Fig. 10).

> **NOTE:** Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Recheck the maximum no-load speed. If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.

3. Hold the buffer screw and tighten the locknut.

8V-53 ENGINE

The limiting speed mechanical governor assembly is mounted on the front end of the blower (Fig. 11). The governor weight carrier shaft is attached to and driven by the left-hand helix rotor.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

> **NOTE:** Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

Adjust Governor Gap

With the engine stopped and at normal operating temperature, set the governor gap as follows:

> **CAUTION:** If the governor gap adjustment is to be made with the engine in the vehicle, it is suggested that the fan assembly be removed due to the closeness of the fan blades to the engine governor.

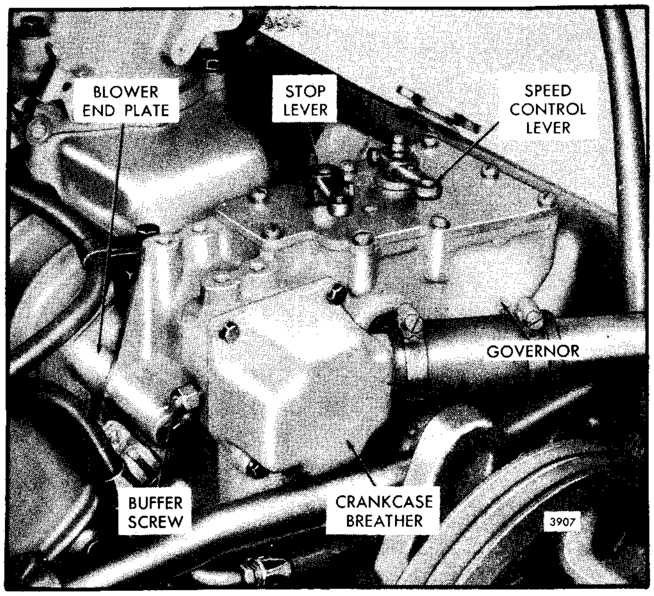

Fig. 11 - Limiting Speed Governor Mounting

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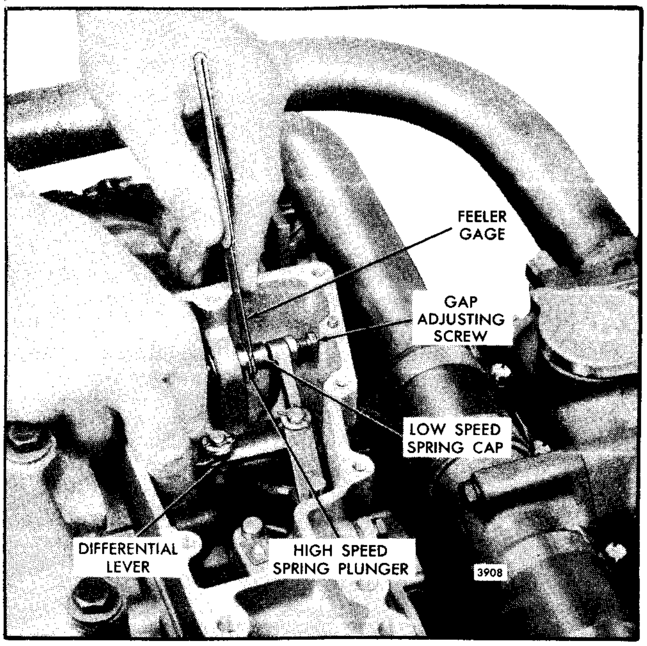

Fig. 12 - Checking Governor Gap

1. Remove the high-speed spring retainer cover.

2. Back out the buffer screw until it extends approximately 5/8" from the locknut (Fig. 17).

NOTE: Do not back the buffer screw out beyond the limits given, or the control link lever may disengage the differential lever.

3. Start the engine and loosen the idle speed adjusting screw or locknut, if used. Then adjust the idle screw to obtain the desired idle speed (Fig. 16). Hold the screw and tighten the locknut to hold the adjustment.

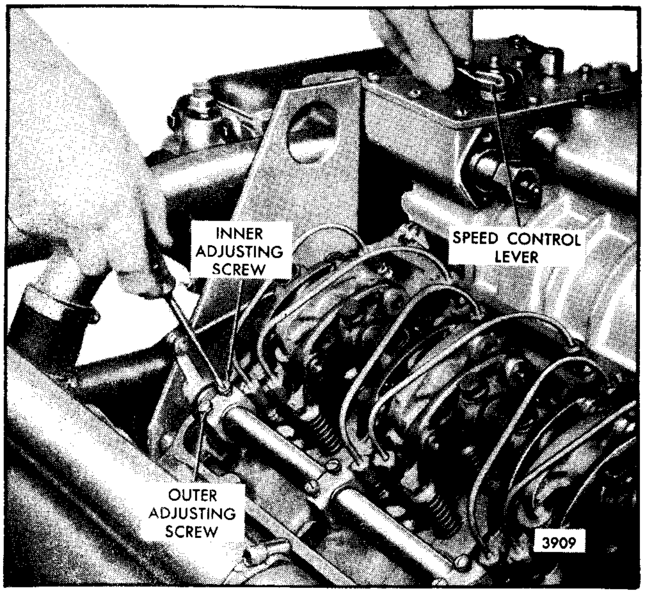

Fig. 13 - Positioning No. 1L Injector Rack Control Lever

4. Run the engine until the proper operating temperature is reached, then stop the engine and remove the governor cover, lever assembly and the engine valve rocker covers. Discard the gaskets.

5. Start and run the engine, between 1100 and 1300 rpm, by manual operation of the differential lever.

NOTE: Do not overspeed the engine.

6. Check the gap between the low-speed spring cap and the high-speed spring plunger with a feeler gage (Fig. 12). The gap should be .002"-.004". If the gap setting is incorrect, reset the gap adjusting screw.

7. On governors without the starting aid screw, hold the gap adjusting screw and tighten the locknut.

NOTE: Governors which include a starting aid screw threaded into the end of the gap adjusting screw do not require a locknut as both screws incorporate a nylon patch in lieu of a locknut.

8. Recheck the gap with the engine operating between 1100 and 1300 rpm and readjust if necessary.

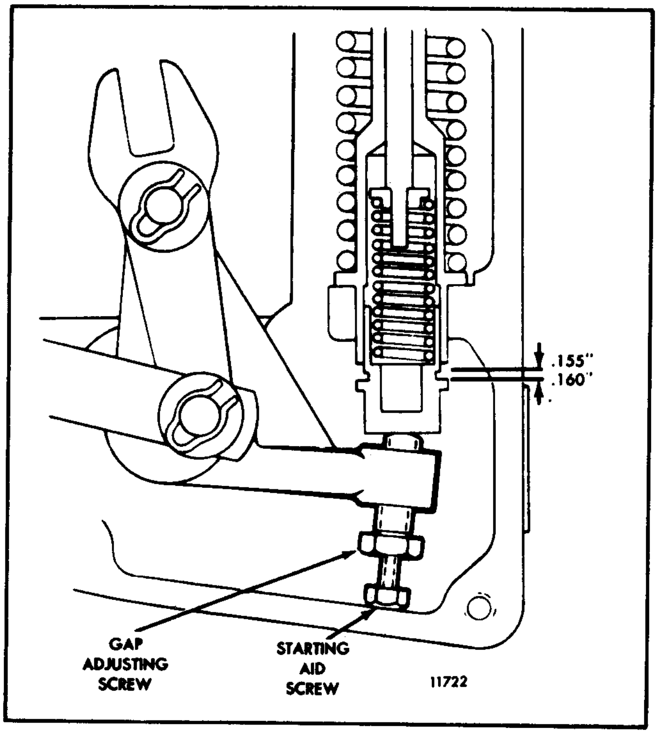

Fig. 14 - Adjust Starting Aid Screw

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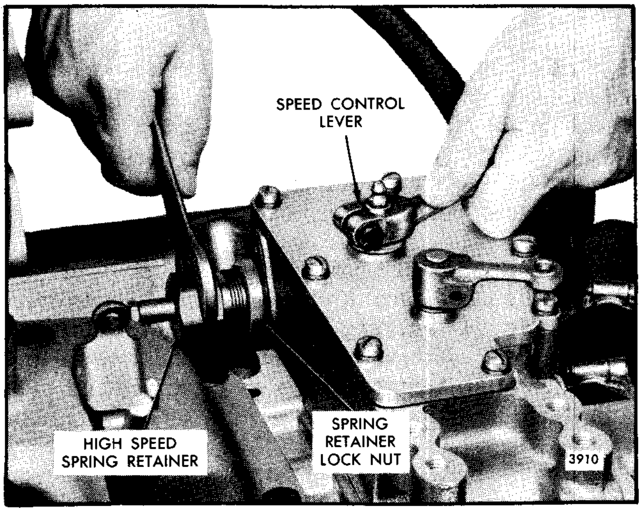

Fig. 15 - Adjusting Maximum No-Load Engine Speed

9. Stop the engine and, using a new gasket, install the governor cover.

10. If a starting aid screw is used, adjust it after the injector rack control levers are positioned.

Position Injector Rack Control Levers

The position of the injector racks 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:

1. Speed control lever at the *full-fuel* position.

2. Governor low-speed gap closed.

3. High-speed spring plunger on the seat in the governor control housing.

4. Injector fuel control racks in the *full-fuel* position.

The letters "R" or "L" indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 1L injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect the linkage attached to the speed control lever.

2. Turn the idle speed adjusting screw until about 1/2" of the threads (12-14 threads) projects from the locknut when the nut is against the high-speed plunger. This adjustment lowers the tension of the low-speed spring so it can be compressed, while closing the low-speed gap, without bending the fuel rods.

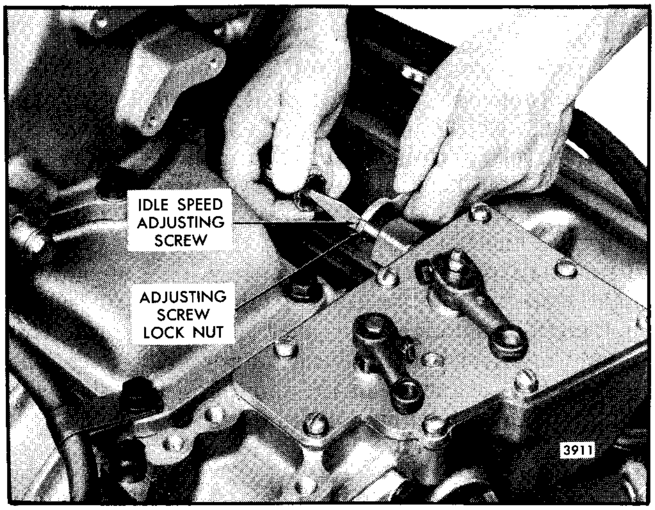

Fig. 16 - Adjusting Engine Idle Speed

NOTE: A false fuel rack setting may result if the idle speed adjusting screw is not backed out as noted above.

3. If not already done, back out the buffer screw as outlined in Step 2 under *Adjust Governor Gap.*

4. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.

5. Loosen all of the inner and outer injector rack control lever adjusting screws on both injector control

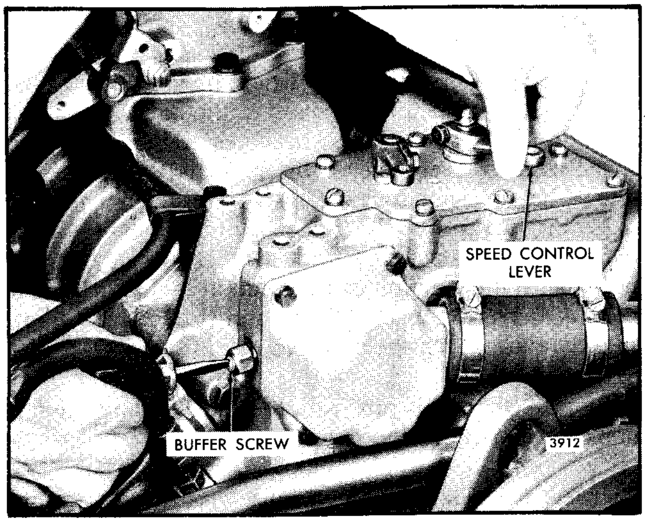

Fig. 17 - Adjusting Buffer Screw

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tubes. Be sure all of the injector rack control levers are free on the injector control tubes.

6. Move the speed control lever to the full-fuel position and hold it in that position with light finger pressure. Turn the inner adjusting screw of the No. 1L injector rack control lever down (Fig. 13) until a slight movement of the control tube lever is observed or a step-up in effort to turn the screwdriver is noted. This will place the No. 1L injector 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. This should result in placing the governor linkage and the control tube assembly in the same positions they will attain while the engine is running at full load as previously described.

> **NOTE:** Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **lb-in** (3-4 Nm).

7. To be sure of the proper rack adjustment, hold the speed control lever in the *full-fuel* position and press down on the injector rack with a screwdriver or finger tip and note the "rotating" movement of the injector control rack when the speed control lever is in the *full-fuel* position (Fig. 4). Hold the speed control lever in the *full-fuel* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward (Fig. 5), and when the pressure of the screwdriver is released, the control rack should "spring" back upward.

The setting is sufficiently tight if the rack returns to its original position. If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer adjusting screw slightly and tighten the inner adjusting screw.

The setting is too tight if, when moving the speed control lever from the *idle speed* to the *maximum speed* position, the injector rack becomes tight before the speed control lever reaches the end of its travel (stop under the governor cover). This will result in a step-up in effort to move the speed control lever to its *maximum speed* position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend). If the rack is too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw.

8. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.

9. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 1R injector rack control lever as previously outlined in Step 6 for the No. 1L injector rack control lever.

10. Insert the clevis pin in the fuel rod and the left cylinder bank injector control tube lever. Repeat the check on the No. 1L and No. 1R injector rack control levers as outlined in Step 7. Check for and eliminate any deflection which occurs at the bend in the fuel rod where it enters the cylinder head.

11. Manually hold the No. 1L injector rack in the *full-fuel* position and turn down the inner adjusting screw of the No. 2L injector rack control lever until the injector rack of the No. 2L injector has moved into the Then alternately tighten both the inner and outer adjusting screws.

12. Recheck the No. 1L injector rack to be sure it has remained snug on the ball end of the rack control lever while positioning the No. 2L injector rack. If the rack of the No. 1L injector has become loose, back off the inner adjusting screw slightly on the No. 2L injector rack control lever. Tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.

13. Position the No. 3L and 4L injector rack control levers as outlined in Steps 11 and 12.

14. Position the No. 2R, 3R and 4R injector racks as outlined above for the left cylinder bank.

15. Turn the idle speed adjusting screw in until it projects 3/16" from the locknut to permit starting of the engine.

16. Use new gaskets and reinstall the valve rocker covers.

Adjust Starting Aid Screw

The internal starting aid screw is threaded into the governor gap adjusting screw (Fig. 13). This screw is adjusted to position the injector racks at less than full-fuel when the governor speed control lever is in the *idle* position. The reduced fuel makes starting easier and reduces the amount of smoke on start-up.

> **NOTE:** The effectiveness of the starting aid screw will be eliminated if the speed control lever is advanced to wide open throttle during starting.

After the normal governor *running* gap of .0015" has been set and the injector racks positioned, adjust the starting aid screw as follows:

1. With the engine stopped, place the governor stop

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lever in the *run* position and move the speed control lever to the *idle* position.

2. Hold the gap adjusting screw, to keep it from turning, and adjust the starting aid screw to obtain .330" to .360" clearance between the shoulder on the No. 1L injector rack clevis and the injector body, with the head of the starting aid screw against the governor wall.

> **NOTE:** With the engine stopped, this adjustment will provide a gap of .155" to .160" between the high-speed spring plunger and the low-speed spring cap (Fig. 14).

3. Move the stop lever to the *stop* position, with the speed control lever still in the *idle* position, and return it to the *run* position.

4. Recheck the injector rack clevis-to-body clearance. Movement of the governor stop lever is to take-up clearances in the governor linkage. The clevis to body clearance can be increased by backing out the starting aid screw or reduced by turning it farther into the gap adjusting screw.

5. Start the engine and recheck the *running* gap (.0015") and, if necessary, reset it. Then stop the engine.

Adjust Maximum No Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine name plate, set the maximum no-load speed as outlined below.

1. Loosen the locknut with a spanner wrench and back off the high-speed spring retainer several turns. Then start the engine and increase the speed slowly. If the speed exceeds the required no-load speed before the speed control lever reaches the end of its travel, back off the spring retainer a few additional turns.

2. With the engine at operating temperature and no load on the engine, place the speed control lever in the *maximum speed* position. Turn the high-speed spring retainer in (Fig. 14) until the engine is operating at the recommended no-load speed. Use an accurate hand tachometer to determine the engine speed. The recommended speed droop is 150 rpm for governors with a full-load speed range of 2500-2800 rpm.

3. Hold the spring retainer and tighten the locknut.

Adjust Idle Speed

With the maximum no-load speed properly adjusted, adjust the idle speed as follows:

1. With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw (Fig. 16) until the engine is operating at approximately 15 rpm below the recommended idle speed.

> **NOTE:** The recommended idle speed is 500 to 600 rpm, but may vary with special engine applications.

2. Hold the idle screw and tighten the locknut.

3. Install the high-speed spring retainer cover and tighten the two bolts.

Adjust Buffer Screw

With the idle speed properly adjusted, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, turn the buffer screw in (Fig. 17) so it contacts the differential lever as lightly as possible and still eliminates engine roll.

> **NOTE:** Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Recheck the maximum no-load speed. If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.

3. Hold the buffer screw and tighten the locknut to retain the adjustment.

After the governor adjustments are completed, adjust any supplementary governing device that may be used as outlined in Section 14.14.

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LIMITING SPEED MECHANICAL GOVERNOR ADJUSTMENT

(Variable Low-Speed)

IN-LINE AND 6V-53 ENGINES

The variable low-speed limiting speed mechanical governor used on In-line and 6V-53 highway vehicle engines is of the double-weight type. It is used where the same engine powers both the vehicle and the auxiliary equipment for unloading bulk products (such as cement, grain or liquids) and a 500 to 1200 rpm idle speed range is desired during auxiliary operation. A service kit is available to convert the short spring pack 6V-53 double weight limiting speed governor assembly to a cable operated variable low-speed limiting speed governor for 500 - 1600 rpm idle speed range auxiliary operations.

During highway operation, the governor functions as a limiting speed governor, controlling the engine idling speed and limiting the maximum operating speed. At the unloading area, the throttle is left in the idle speed position and the speed adjusting handle, on the cable operated governor (Fig. 1), is turned to the speed required within the above range to operate the auxiliary equipment. For the air operated governor (Fig. 2), the engine speed is changed to the speed required by increasing or decreasing the air supply pressure to the governor. The governor then functions as a variable speed governor, maintaining a constant speed when the load is constantly changing, during the unloading operation. Before resuming highway operations, the speed adjusting handle on the cable operated governor must be turned back to the stop, then turned ahead about one-quarter of a turn. The air operated governor's air supply pressure must be vented before resuming highway operations.

Governor identification is provided by a name plate attached to the governor housing. The letters V.L.S.-L.S. stamped on the name plate denote a variable low-speed limiting speed mechanical governor.

After adjusting the exhaust valves and timing the injectors, adjust the governor and position the injector rack control levers.

Adjust Governor Gap

With the engine at operating temperature, adjust the governor gap as follows:

1. Stop the engine, remove the two bolts and withdraw the spring housing. Discard the gasket.

2. Back out the buffer screw until it extends approximately 5/8" from the lock nut.

3. For *Cable Operated Governors* make a preliminary idle speed (normal highway idle speed) adjustment as follows (FIg. 1):

a. Back out the variable low-speed adjusting shaft until the shoulder on the shaft contacts the shaft retainer.

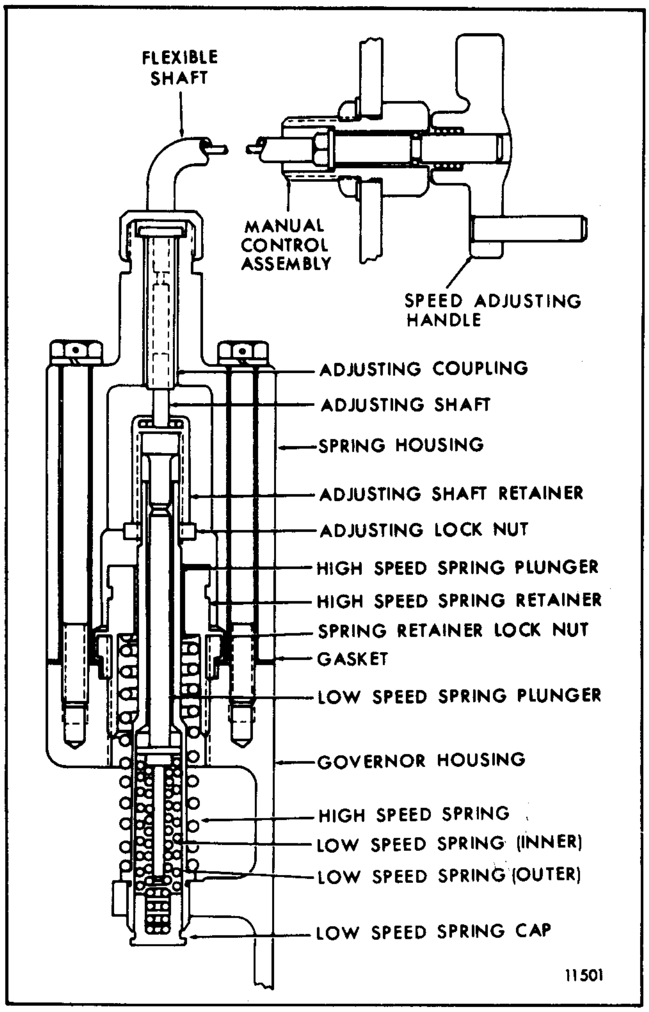

Fig. 1 - Cable Operated Governor Spring Housing and Components

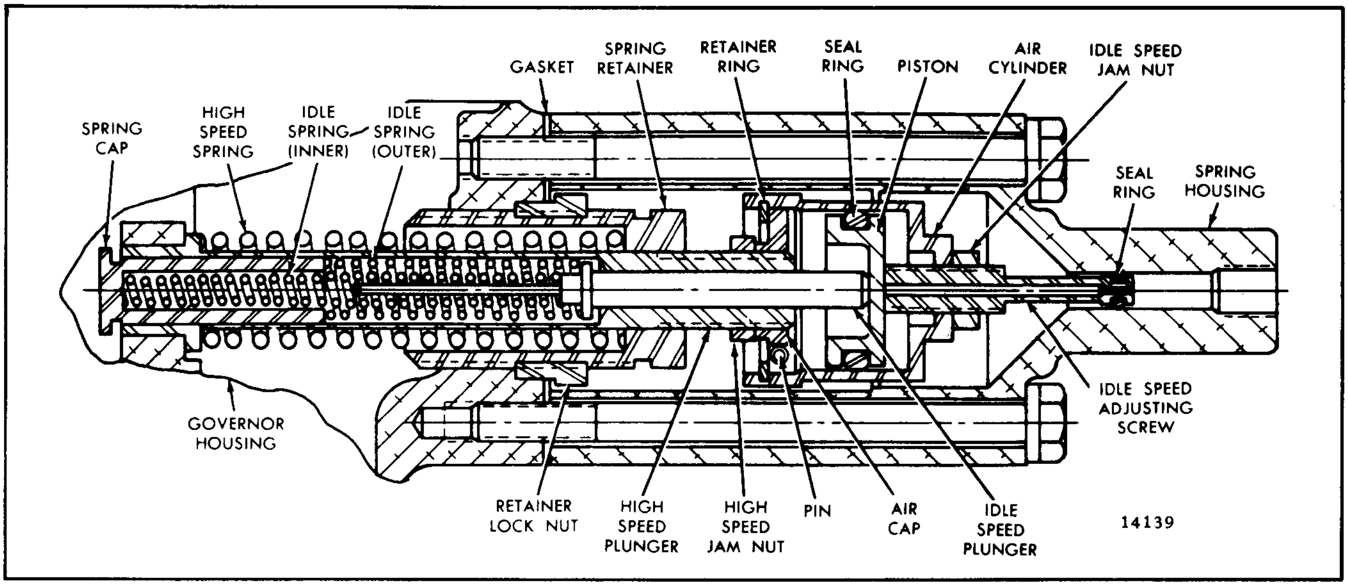

Fig. 2 - Air Operated Governor Spring Housing and Components

b. Start the engine. Then hold the lock nut and loosen the low-speed adjusting shaft retainer.

c. Adjust the retainer and shaft assembly to obtain the desired idle speed (500 rpm minimum). Then hold the retainer and tighten the lock nut to retain the adjustment.

NOTE: It may be necessary to use the buffer screw to eliminate engine roll. Back out the buffer screw, after the idle speed is established, to the previous setting (5/8").

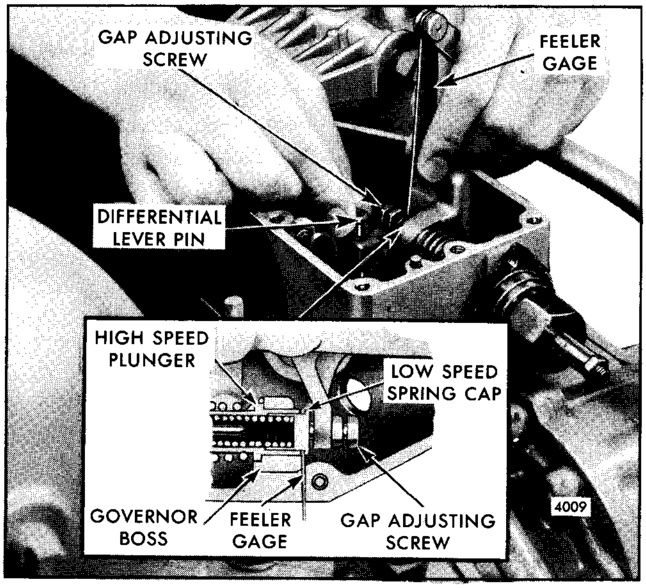

Fig. 3 - Adjusting Governor Gap

d. Install the spring housing, using a new gasket. Tighten the attaching bolts.

4. For *Air Operated Governors* make a preliminary idle speed (normal highway idle speed) adjustment as follows (Fig. 2).

Adjust the maximum idle speed.

a. Loosen the idle speed and high idle speed jam (lock) nuts.

b. Turn the idle speed adjusting screw clockwise into the air cylinder, until the piston contacts the air cap.

NOTE: The air cylinder should be 2 or 3 threads from its position of maximum engagement with the high speed spring plunger, to prevent the piston from contacting the high speed plunger before it contacts the air cap.

IMPORTANT: Do not force the idle speed adjusting screw.

c. Start the engine. With the speed control lever in the idle position, turn the air cylinder clockwise to raise the idle speed and counterclockwise to lower the idle speed.

d. Lock the air cylinder to the high speed plunger with the jam nut in the position which provides the desired maximum idle speed.

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Adjust the minimum idle speed adjustment.

NOTE: Make this adjustment after the maximum idle speed adjustment is completed.

a. Run the engine with the speed control lever in the idle speed position.

b. Turn the idle speed adjusting screw counterclockwise to lower the idle speed and clockwise to raise the idle speed.

c. Lock the idle speed adjusting screw with the jam nut, in the position which provides the desired minimum idle speed.

d. Stop the engine and lubricate the bore of the spring housing with engine lubricating oil.

e. Install the spring housing, using a new gasket. Tighten the attaching bolts.

5. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker covers. Discard the gaskets.

6. Start and run the engine between 1100 and 1300 rpm by manual operation of the differential lever.

NOTE: Do not overspeed the engine.

7. Check the gap between the low-speed spring cap and the high-speed spring plunger with a feeler gage (Fig. 1). The gap should be .002"-.004". If the gap setting is incorrect, reset the gap adjusting screw.

8. On governors without the starting aid screw, hold the gap adjusting screw and tighten the lock nut.

9. Recheck the gap with the engine operating between 1100 rpm and 1300 rpm and readjust if necessary.

10. Reinstall the governor cover and lever assembly.

Position Injector Rack Control Levers

Position the injector rack control levers as outlined in Section 14.3.1 or 14.3.2.

Adjust Maximum No-Load Engine Speed

Adjust the maximum no-load engine speed as outlined for the limiting speed mechanical governor in Section 14.3.1 or 14.3.2.

Adjust Idle Speed

Adjust the normal highway idle speed as follows:

With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, hold the lock nut and loosen the variable low-speed adjusting shaft retainer. Adjust the retainer and shaft assembly to obtain a minimum of 500 rpm.

NOTE: It may be necessary to use the buffer screw to eliminate engine roll. Back out the buffer screw, after the idle speed is established, to the previous setting (5/8").

Adjust Buffer Screw

Adjust the buffer screw as outlined in Section 14.3.1 or 14.3.2.

After the governor tune-up is completed, install the variable low-speed adjuster coupling and spring housing. Center the coupling before securing the spring housing to the governor. Install the flexible shaft and manual control assembly.

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LIMITING SPEED MECHANICAL GOVERNOR ADJUSTMENT

(Fast Idle Cylinder)

The limiting speed governor equipped with a fast idle air cylinder is used on vehicle engines where the engine powers both the vehicle and auxiliary equipment.

The fast idle system consists of a fast idle air cylinder installed in place of the buffer screw and a throttle locking air cylinder mounted on a bracket fastened to the governor cover (Fig. 1). An engine shutdown air cylinder, if used, is also mounted on the governor cover.

The fast idle air cylinder and the throttle locking air cylinder are actuated at the same time by air from a common air line. The engine shutdown air cylinder is connected to a separate air line.

The air supply for the fast idle air cylinder is usually controlled by an air valve actuated by an electric solenoid. The fast idle system should be installed so that it will function only when the parking brake system is in operation to make it tamper-proof.

The vehicle accelerator-to-governor throttle linkage is connected to a yield link so the operator cannot overcome the force of the air cylinder holding the speed control lever in the idle position while the engine is operating at the single fixed high idle speed.

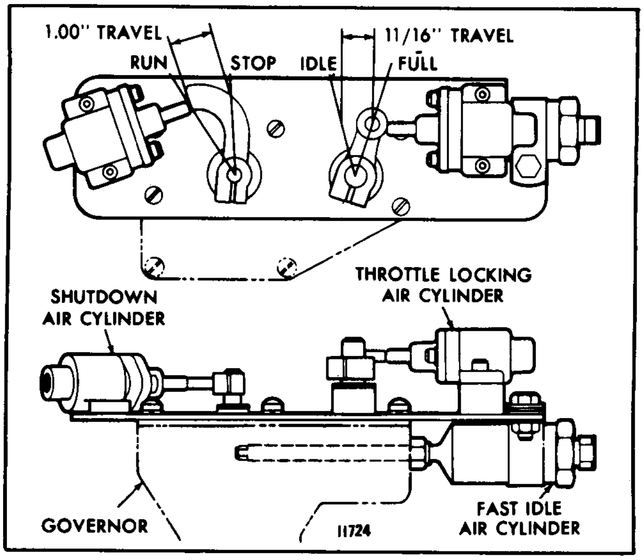

Fig. 1 - Governor with Fast Idle Cylinder

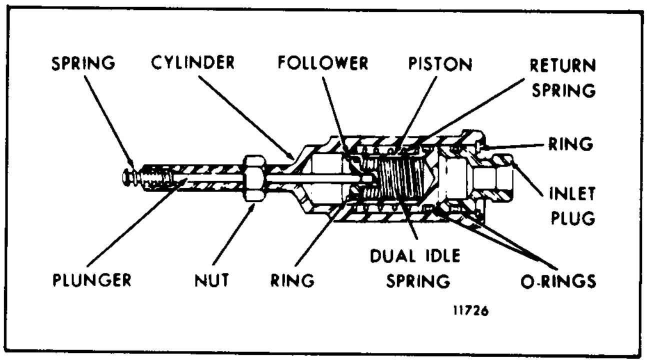

Fig. 2 - Fast Idle Air Cylinder

Operation

During highway operation, the governor functions as a limiting speed governor.

For operation of auxiliary equipment, the vehicle is stopped and the parking brake set. Then, with the engine running, the low speed switch is placed in the ON position. When the fast idle air cylinder is actuated, the force of the dual idle spring (Fig. 2) is added to the force of the governor low-speed spring, thus increasing the engine idle speed.

The governor now functions as a constant speed governor at the high idle speed setting, maintaining a near constant engine speed regardless of the load within the capacity of the engine. The fast idle system provides a single fixed high idle speed that is not

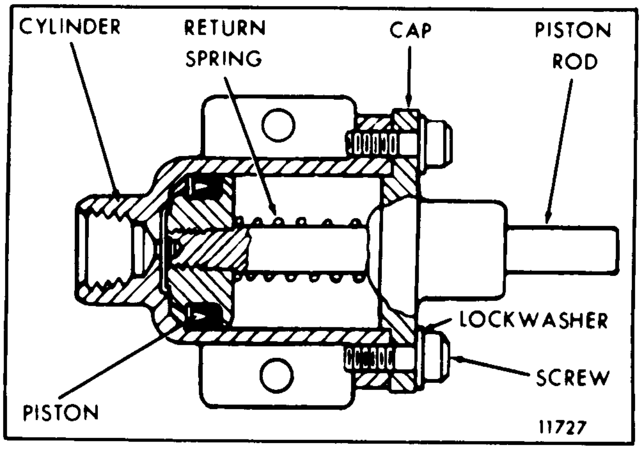

Fig. 3 - Throttle Locking Air Cylinder

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adjustable, except by disassembling the fast idle air cylinder and changing the dual idle spring. As with all mechanical governors, when load is applied, the engine speed will be determined by the governor droop.

Adjust Governor

Adjust the governor as outlined in Section 14.3.2. However, before adjusting the governor gap, back out the de-energized fast idle air cylinder until it will not interfere with the governor adjustments. After the normal idle speed setting is made, adjust the de-energized fast idle air cylinder as follows:

1. Turn in the fast idle cylinder assembly until an increase of idle speed is noted. The increase in idle speed should not exceed 15 rpm. Tighten the fast idle jam nut.

2. Lock the governor throttle in the idle position and apply full shop air pressure to the fast idle air cylinder. The engine idle speed must increase 250-800 rpm, depending upon the dual idle spring used.

The throttle locking air cylinder is adjusted on its mounting bracket so it will lock the throttle in the idle position when it is activated, but will not limit the throttle movement when not activated.

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VARIABLE SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT (PIERCE)

IN-LINE INDUSTRIAL ENGINES

After adjusting the exhaust valves and timing the fuel injectors, position the injector rack control levers and adjust the governor.

Position Injector Rack Control Levers

The injector rack settings govern the quantity of fuel injected into each cylinder. All of the injectors must be set to inject the same quantity of fuel into each cylinder to ensure equal distribution of the load. Position the injector rack control levers as follows:

1. Disconnect the linkage between the governor rocker shaft lever and the bell crank mounted on the flywheel housing.

2. Loosen all of the inner and outer rack control lever adjusting screws (Fig. 1). Be sure all of the levers are free on the injector control tube.

3. Lift upward on the bell crank, as shown in Fig. 1, to move the injector racks into the full-fuel position and turn the inner adjusting screw down until a 1/16" clearance exists between the fuel rod and the cylinder head or the cylinder head bolt, whichever it contacts.

Turn the outer adjusting screw down until it bottoms on the control tube, then alternately tighten the inner and outer screws to retain the adjustment.

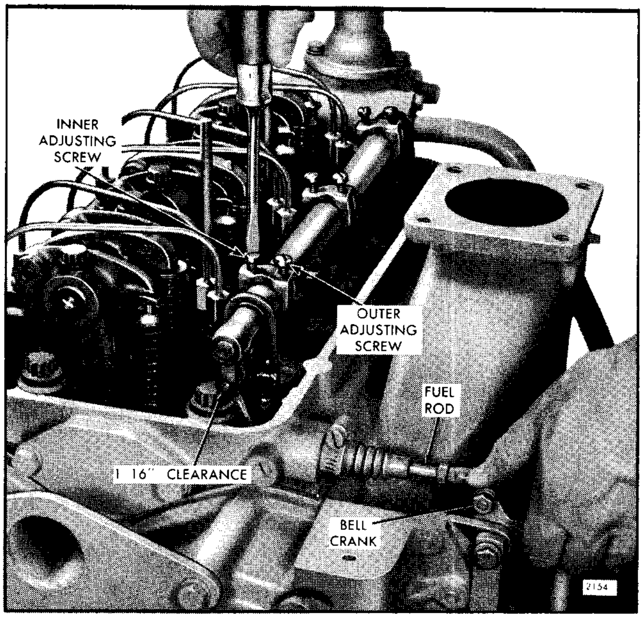

Fig. 1 - Positioning Injector Rack Control Lever

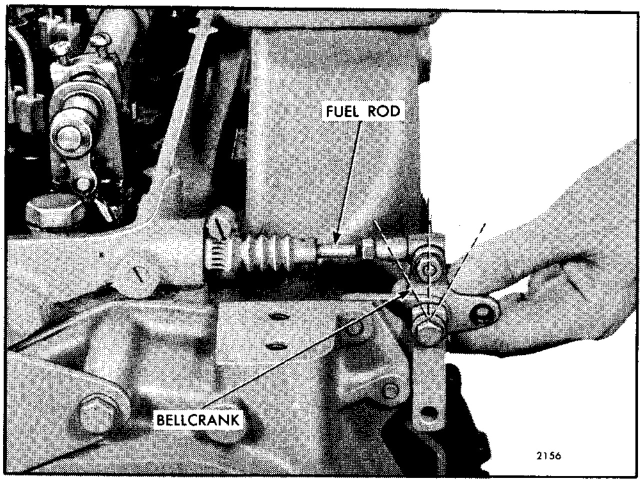

Fig. 2 - Adjusting the Fuel Rod

4. Manually hold the rear injector control rack in the full-fuel position and turn the inner adjusting screw of the adacent injector rack control lever down until it has moved into the full-fuel position and the 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 screws.

> **NOTE:** Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **in-lb**.

5. Recheck the rear injector rack to be sure it has remained snug on the pin of the rack control lever while positioning the adjacent injector rack. If the rack of the rear injector has become loose, back off the inner adjusting screw slightly on the adjacent injector rack control lever and tighten the outer adjusting screw to retain the adjustment. When the settings are correct, the racks of both injectors will be snug on the ball end of each rack control lever.

6. Position the remaining rack control levers as outlined in Steps 4 and 5.

Adjust Governor Linkage

1. Check the travel of the bell crank as shown in Fig. 2. The vertical arm of the bell crank should move

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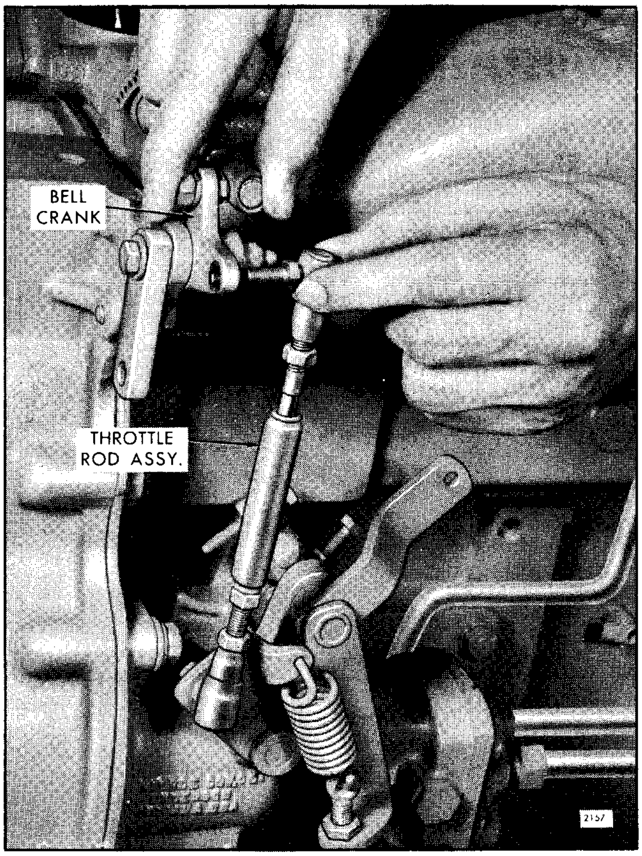

Fig. 3 - Adjusting the Throttle Rod Assembly

an equal distance on either side of center when moving the fuel injector racks from the full-fuel to the no-fuel positions. Position the bell crank by loosening the fuel rod lock nut and remove the ball joint from the bell crank. Turn the ball joint to adjust the length of the fuel rod to give the bell crank the correct travel. Reinstall the ball joint on the bell crank and tighten the lock nuts to retain the adjustment.

2. Advance the governor rocker shaft lever to the maximum fuel position and retain it in this position by advancing the governor speed control lever to its maximum speed position (Fig. 5) or by turning the idle speed adjusting screw down until the rocker shaft lever is held at the end of its travel.

NOTE: Back out the maximum speed adjusting screw only as far as necessary to permit the idle speed adjusting screw to move the rocker shaft lever to the end of its travel.

3. Hold the injector control racks in the full-fuel position, then adjust the length of the throttle rod assembly, by turning the ball and socket on the throttle rod, until it can be connected to the bell crank as shown in Fig. 3, without compressing the spring within the rod more than 1/32".

4. Check the injector racks to be sure the governor holds the racks in the full-fuel position.

5. Back out the idle speed adjusting screw (Fig. 6).

6. Place the speed control lever in the minimum speed position and move the injector racks to the no-fuel position. Then check for interference between the rocker shaft lever and the throttle rod assembly; no interference should occur.

NOTE: If the spring in the throttle rod assembly is compressed more than 1/32", interference may occur with the rocker shaft lever.

7. Adjust the speed adjusting spring eye bolt until one-half of the threads extend through the speed control lever. Secure the adjustment by tightening the lock nuts on the eyebolt.

8. Back out the buffer screw until it is within 1/16" to 1/8" of the governor speed control shaft.

Adjust Maximum No-Load Speed

1. Start the engine and move the speed control lever to the full-speed position.

NOTE: Do not overspeed the engine.

2. Loosen the lock nut and adjust the maximum speed adjusting screw (Fig. 4) until the desired no-load speed is obtained.

3. Tighten the maximum speed adjusting screw lock nut to retain the adjustment.

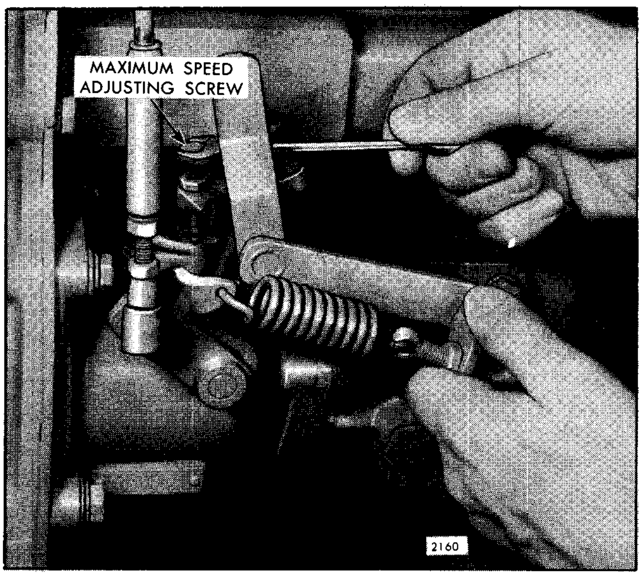

Fig. 4 - Adjusting Maximum Speed

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Adjust Engine Speed Droop

With the engine operating at maximum speed, depress the linkage to the injector control tube to cause a speed decrease of several hundred rpm. Release the linkage and check for hunting when the governor returns the engine to the maximum speed setting. If the engine stabilizes in less than three surges, the droop may be excessive. If the engine does not stabilize in five surges, the droop may be insufficient. The speed droop may be set as follows:

1. If the speed droop is excessive, increase the tension of the speed adjusting spring (Fig. 5). If the speed droop is insufficient, decrease the tension of the speed adjusting spring.

NOTE: Make sure the eye of the eye bolt is in a vertical position to avoid twisting the spring.

2. Reset the maximum engine no-load speed if necessary.

3. Check the speed droop. The engine speed should be stable when the governor speed droop is 7 1/2% to 10% of the full-load speed. Thus, if the engine is operating at 2000 rpm full load, the speed droop should be 150 to 200 rpm. Therefore, the engine no-load speed would be set between 2150 to 2200 rpm.

Adjust Engine Idle Speed

1. Start the engine and adjust the idle speed adjusting screw, as shown in Fig. 6, to obtain the desired idle speed.

Fig. 6 - Adjusting Engine Idle Speed

NOTE: The idle speed must be set in excess of 575 rpm or engine operation at idle will be erratic.

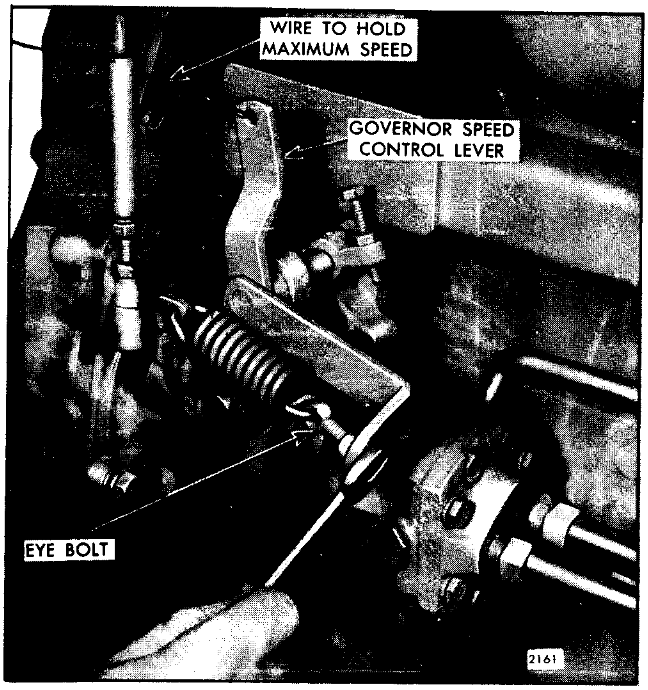

Fig. 5 - Adjusting Engine Droop

Adjust Buffer Screw

1. Loosen the buffer screw lock nut and, with the engine operating at idle speed, turn the buffer screw in (Fig. 7) until engine roll is eliminated.

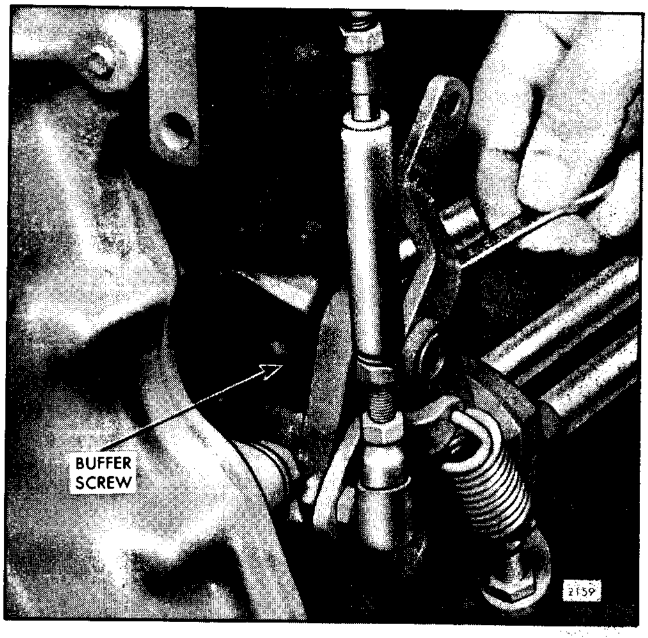

Fig. 7 - Adjusting Buffer Screw

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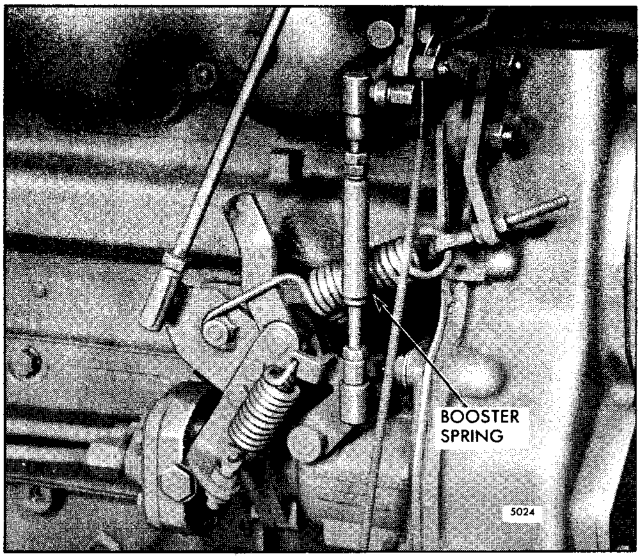

Fig. 8 - Governor Booster Spring

NOTE: Do not raise the engine speed more than 20 rpm with the buffer screw.

2. Tighten the lock nut to retain the adjustment.

Adjust Governor Booster Spring

The governor booster spring is used on some engines to reduce the force necessary to move the governor speed control lever from the idle speed position to the maximum speed position. Adjust the booster spring as follows:

1. Reduce the tension on the booster spring (Fig. 8) to the minimum by backing off the outer nut.

2. Adjust the eye bolt so an imaginary center line drawn through the booster spring will align with an imaginary outer line drawn through the speed adjusting shaft. Secure the lock nuts on the eye bolt to retain the adjustment.

3. Move the governor speed control lever from the idle speed position to the maximum speed position, noting the force required.

4. To reduce the force required to move the governor speed control lever, back off on the inner eye bolt nut and tighten the outer nut, increasing the booster spring tension.

NOTE: Before tightening the eye bolt nuts, reposition the booster spring as in Step 2.

The setting is correct when the governor speed control lever can be moved from the idle speed to the maximum speed position, while the engine is operating, with a fairly constant force and, when released, will return to the idle speed position.

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VARIABLE SPEED MECHANICAL GOVERNOR (OPEN LINKAGE) AND INJECTOR RACK CONTROL ADJUSTMENT

IN-LINE ENGINES

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor (Fig. 1) and the injector rack control levers.

NOTE: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. On turbocharged engines, the fuel (air box) modulator lever and roller assembly must be positioned free from cam contact. After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

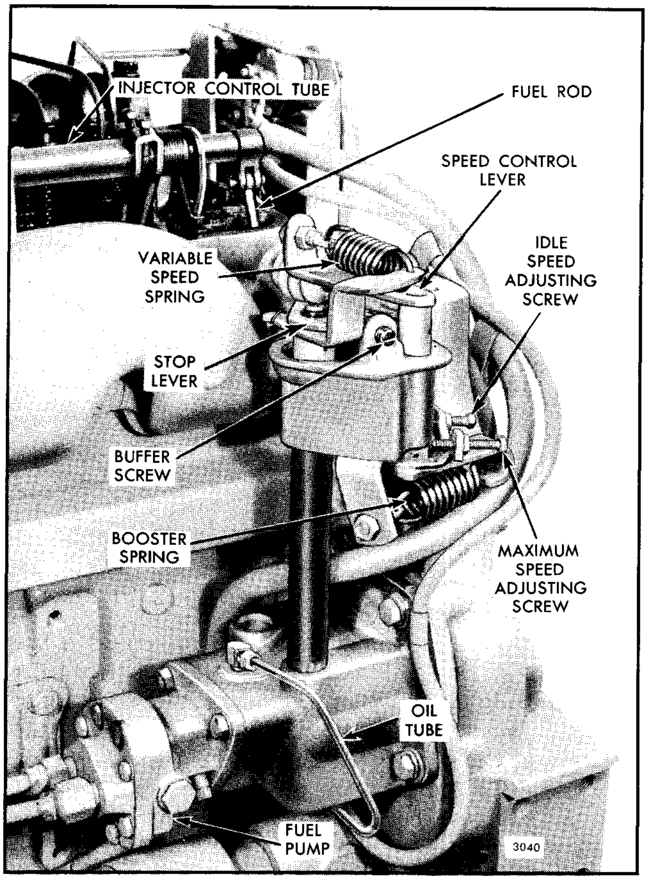

Fig. 1 - Variable Speed Open Linkage Governor Mounted on Engine

Preliminary Governor Adjustments

1. Clean the governor linkage and lubricate the ball joints and bearing surfaces with clean engine oil.

2. Back out the buffer screw until it projects 9/16" from the boss on the control housing.

3. Back out the booster spring eyebolt until it is flush with the outer locknut.

Adjust Variable Speed Spring Tension

1. Adjust the variable speed spring eyebolt until 1/8" of the threads project from the outer locknut (Fig. 2).

2. Tighten both locknuts to retain the adjustment.

NOTE: This setting of the eyebolt will produce approximately 7% droop in engine speed from no load to full load.

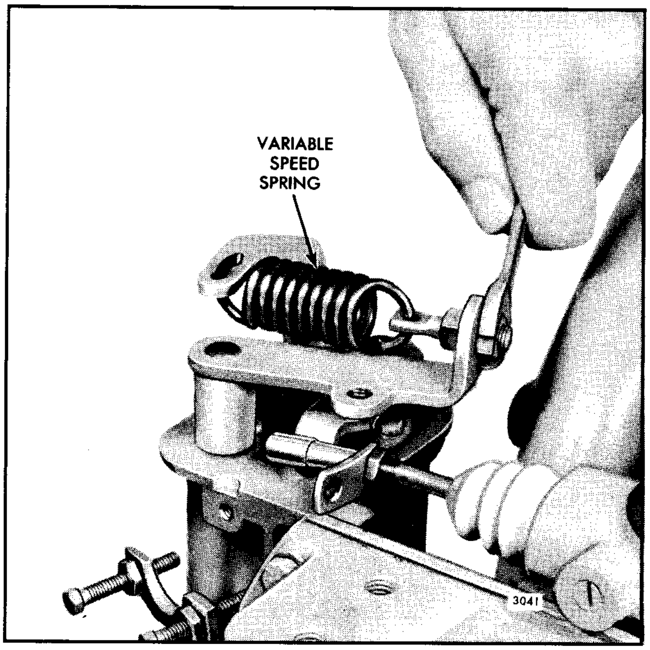

Fig. 2 - Adjusting Governor Spring Eyebolt

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Position Injector Rack Control Levers

The position of the injector control racks 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. Adjust the rear injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Clean and remove the valve rocker cover. Discard the gasket.

2. Disconnect the fuel rod at the stop lever.

3. Loosen all of the injector rack control lever adjusting screws. Be sure all of the injector rack control levers are free on the injector control tube.

4. Move the speed control lever to the maximum speed position.

5. Move the rear injector control rack into the full-fuel position and note the clearance between the fuel rod and the cylinder head bolt. The clearance should be 1/32" or more. If necessary, readjust the injector rack adjusting screws until a clearance of at least 1/32" to 1/16" exists. Tighten the adjustment screws or screw and locknut (Fig. 3).

6. Loosen the nut which locks the ball joint on the fuel rod. Hold the fuel rod in the full-fuel position and adjust the ball joint until it is aligned and will slide on the ball stud on the stop lever (Fig. 4). Position the shutdown cable clip and tighten the fuel rod locknut to retain the adjustment.

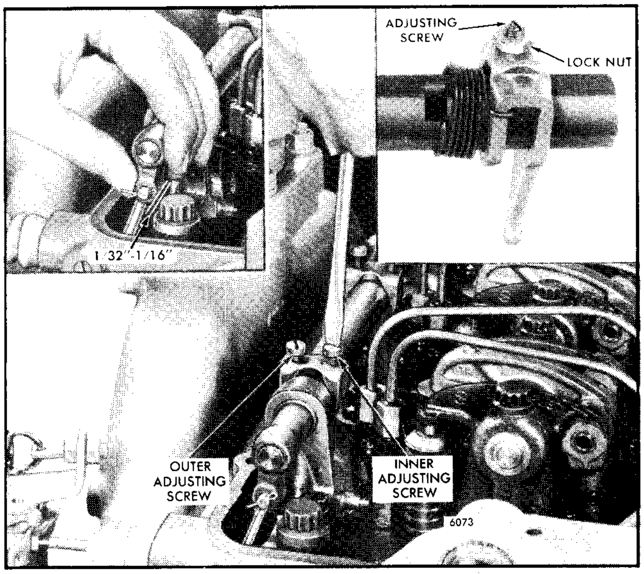

Fig. 3 - Adjusting Injector Rack Control Lever Adjusting Screws

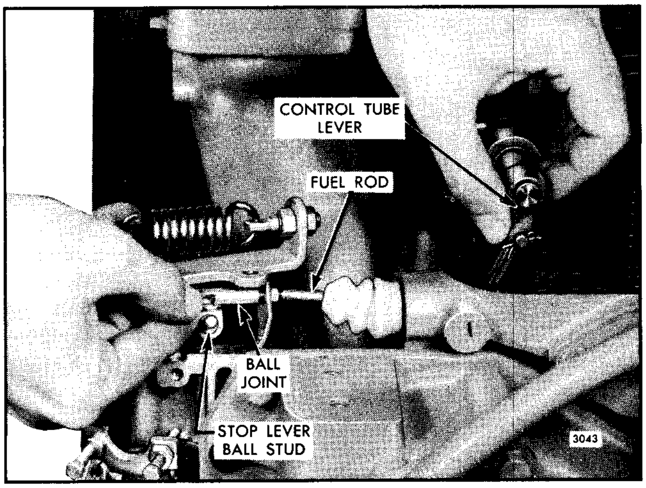

Fig. 4 - Adjusting Fuel Rod Length

7. Check the adjustment by pushing the fuel rod toward the engine and make sure the injector control rack is in the full-fuel position. If necessary, readjust the fuel rod. On units having the governor on the opposite side of the control rack, be sure the control rack lever will not contact the rocker cover.

8. Manually hold the rear injector rack in the full-fuel position, with the lever on the injector control tube. Turn the adjusting screw of the adjacent injector rack control lever until the injector rack moves into the full-fuel position. On the *Two Screw Assembly*, 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. On the *One Screw and Locknut Assembly*, turn the adjusting screw until a slight roll-up on the injector rack clevis is observed or an increase in effort to turn the screwdriver is noted, then securely lock the adjusting screw locknut.

> **NOTE:** Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **lb-in** (3-4 Nm).

9. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the rack control lever while adjusting the adjacent injector rack. If the rack of the rear injector has become loose, back off the adjusting screw slightly on the adjacent injector rack control lever. When the settings are correct, the racks of all injectors must be snug on the ball end of their respective control levers.

10. Position the remaining injector rack control levers as outlined in Steps 8 and 9.

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Adjust Maximum No-Load Speed

1. With the engine running, move the speed control lever to the maximum speed position. Use an accurate tachometer to determine the no-load speed of the engine.

NOTE: Do not overspeed the engine.

2. Loosen the locknut and adjust the maximum speed adjusting screw (Fig. 6) until the required no-load speed is obtained.

3. Hold the adjusting screw and tighten the locknut.

Adjust Engine Idle Speed

1. Make sure the stop lever is in the run position and place the speed control lever in the idle position.

2. With the engine running at normal operating temperature, loosen the locknut and turn the idle speed adjusting screw (Fig. 6) until the engine idles at the recommended speed. The recommended idle speed is 500 rpm. However, the idle speed may vary with special engine applications.

3. Hold the idle speed adjusting screw and tighten the locknut.

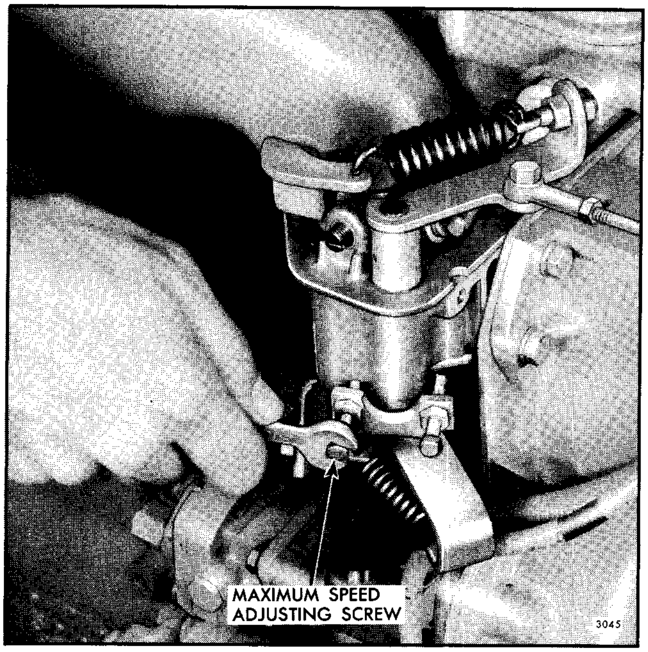

Fig. 5 - Adjusting Maximum No-Load Engine Speed

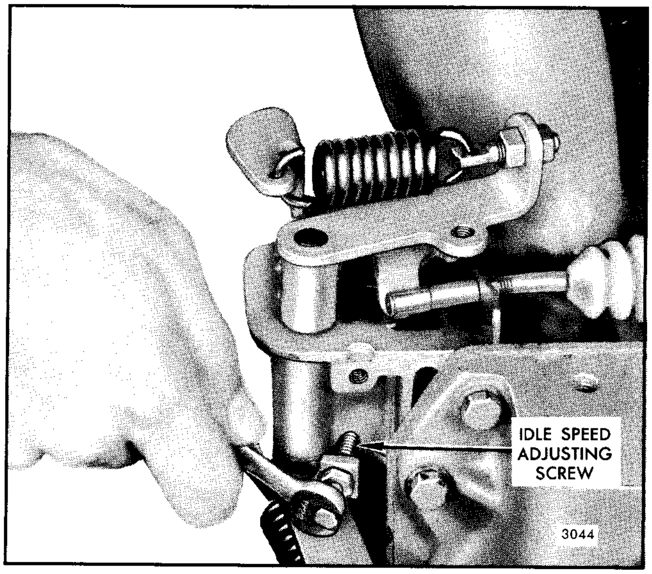

Fig. 6 - Adjusting Idle Speed

Adjust Buffer Screw

1. With the engine running at idle speed, turn the buffer screw in (Fig. 7) so that it contacts the stop lever as lightly as possible and still eliminates engine roll.

NOTE: Do not raise the engine idle speed more than 20 rpm with the buffer screw. Check the maximum no-load speed to make sure it has not increased over 25 rpm by the buffer screw setting.

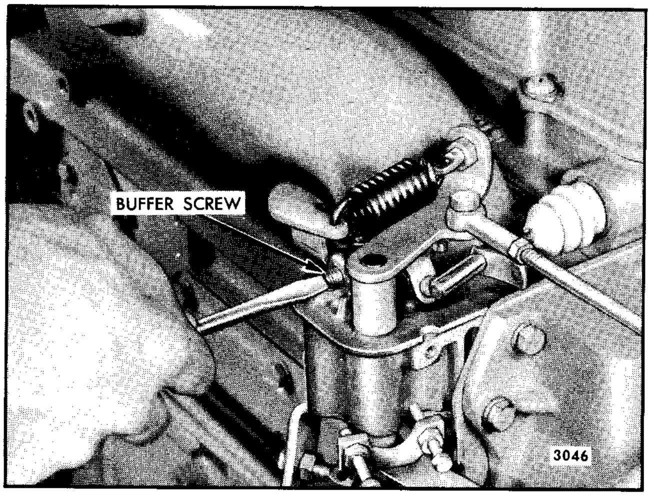

Fig. 7 - Adjusting Buffer Screw

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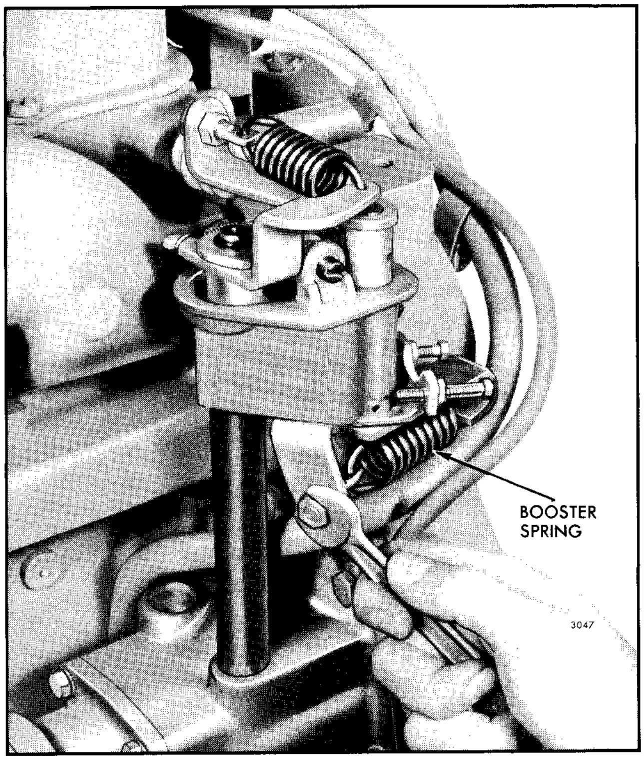

Fig. 8 - Adjusting Booster Spring

Adjust Governor Booster Spring

The governor booster spring is used on some engines to reduce the force necessary to move the speed control lever from the idle speed position to the maximum speed position. Adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.

2. Reduce the tension on the booster spring, if not previously performed, to the minimum by backing off the outer locknut (Fig. 8) until the end of the booster spring eyebolt is flush with the end of the nut.

3. Adjust the eyebolt in the slot in the bracket so that an imaginary line through the booster spring will align with an imaginary center line through the speed control shaft. Secure the locknuts on the eyebolt to retain the adjustment.

4. Move the speed control lever to the maximum speed position and note the force required. To reduce the force, back off the inner locknut and tighten the outer locknut to increase the tension on the booster spring.

> **NOTE:** Before tightening the locknuts, reposition the booster spring as in Step 3.

The setting is correct when the speed control lever can be moved from the idle speed position to the maximum speed position with a constant force, while the engine is running, and when released it will return to the idle speed position.

Adjust Engine Speed Droop

The adjustment of the spring tension as outlined under *Adjust Variable Speed Spring Tension* will result in approximately 7% droop from the maximum no-load speed to the full-load speed. This is the optimum droop setting for most applications. However, the droop may be changed as necessary, for a particular engine application.

1. Lower the speed droop by increasing the spring tension.

2. Raise the speed droop by decreasing the spring tension.

> **NOTE:** A change in the variable speed spring tension will change the engine idle speed and maximum no-load speed, which must also be readjusted.

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VARIABLE SPEED MECHANICAL GOVERNOR (ENCLOSED LINKAGE) AND INJECTOR RACK CONTROL ADJUSTMENT

IN-LINE ENGINES

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

NOTE: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. On turbocharged engines, the fuel (air box) modulator lever and roller assembly must be positioned free from cam contact. After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

Back out the external starting aid screw.

Adjust Governor Gap

With the engine stopped and at operating temperature, adjust the governor gap as follows:

1. Disconnect any linkage attached to the governor levers.

2. Back out the buffer screw until it extends approximately 5/8" from the locknut.

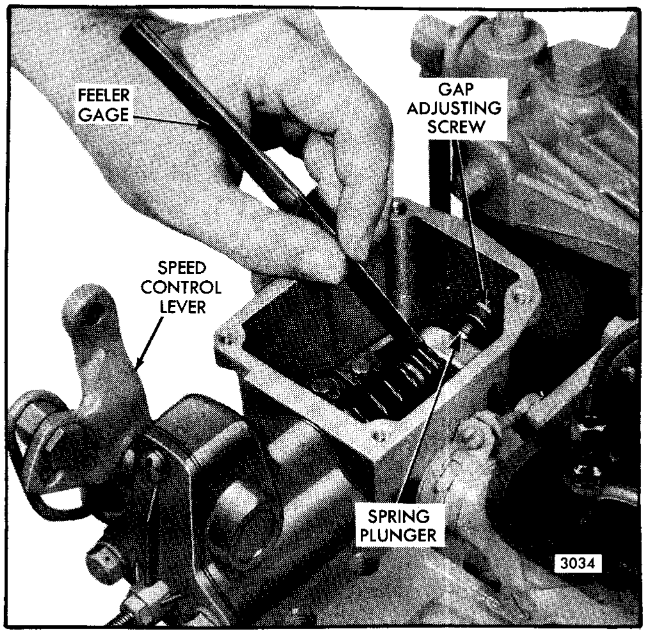

Fig. 1 - Checking Governor Gap

3. Clean and remove the governor cover and valve rocker cover. Discard the gaskets.

4. Place the speed control lever in the maximum speed position (Fig. 1).

5. Insert a .006" feeler gage between the spring plunger and the plunger guide (Fig. 1). If required, loosen the locknut and turn the gap adjusting screw in or out until a slight drag is noted on the feeler gage.

6. Hold the adjusting screw and tighten the locknut. Check the gap and readjust, if necessary.

7. Use a new gasket and install the governor cover as follows:

a. Place the cover on the governor housing, with the pin in the throttle shaft assembly entering the slot in the differential lever.

b. Install the four cover screws and lock washers finger tight.

c. Pull the cover assembly in a direction away from the engine, to take up the slack, and tighten the cover screws.

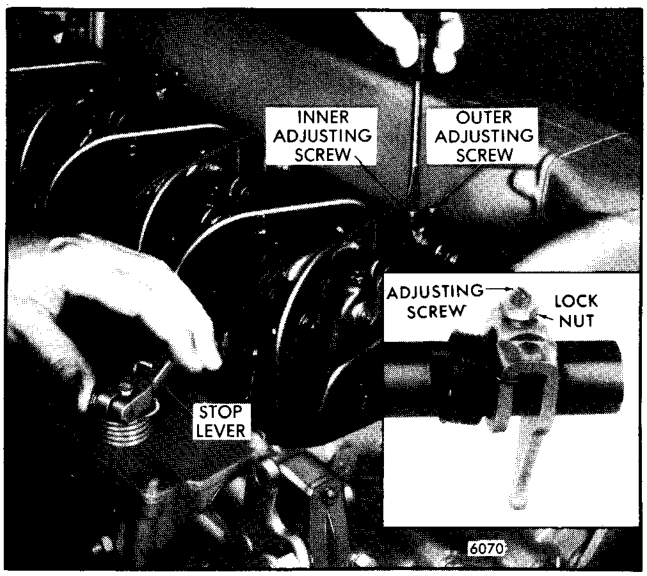

Fig. 2 - Positioning the Rear Injector Rack Control Lever

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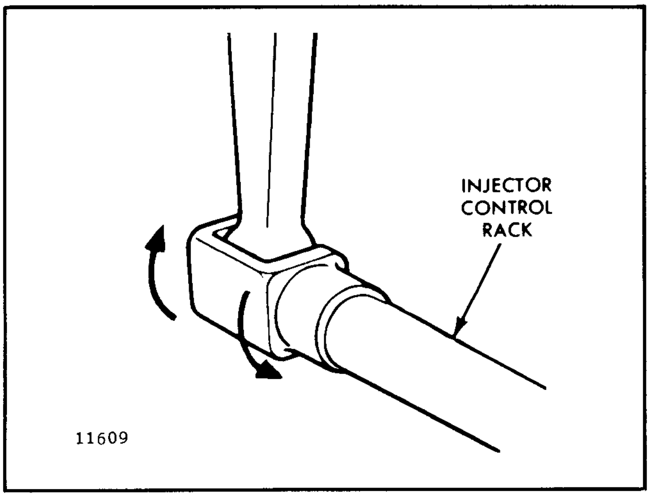

Fig. 3 - Checking Rotating Movement of Injector Control Rack

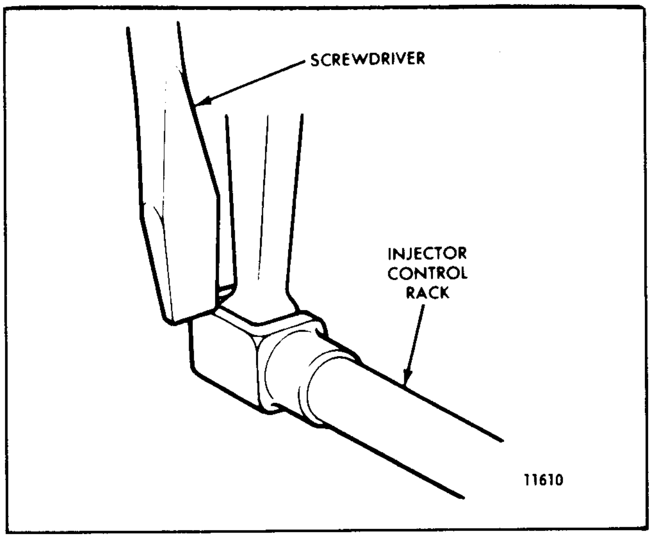

Fig. 4 - Checking Injector Control Rack "Spring"

NOTE: This step is required since no dowels are used to locate the cover on the housing.

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 control rack levers with the engine at full load will result in the following:

1. Speed control lever at the *maximum speed* position.

2. Stop lever in the *run* position.

3. Injector fuel control racks in the full-fuel position.

Adjust the rear injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Loosen all of the inner and outer injector rack control lever adjusting screws or the adjusting screws and locknuts (Fig. 2). Be sure all of the levers are free on the injector control tube.

2. Move the speed control lever to the *maximum speed* position.

3. Move the stop lever to the *run* position and hold it in that position with light finger pressure.

Two Screw Assembly

Turn the inner adjusting screw of the rear injector rack control lever down until a slight movement of the control tube is observed or a step-up in effort to turn the screwdriver is noted. This will place the rear injector rack in the full-fuel position. 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.

One Screw and Locknut Assembly

Tighten the adjusting screw of the rear injector rack control lever until the injector rack clevis os observed to roll up or an increase in effort to turn the screwdriver is noted. Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut. This will place the rear injector rack in the *full-fuel* position.

This should result in placing the governor linkage and control tube in the respective positions that they will attain while the engine is running at full load.

NOTE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **lb-in** (3-4 Nm).

4. To be sure of proper rack adjustment, hold the stop lever in the *run* position and press down on the injector rack with a screwdriver or finger tip and note "rotating" movement of the injector control rack (Fig. 3). Hold the stop lever in the *run* position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward (Fig. 4) and, when the pressure of the screwdriver is released, the control rack should "spring" back upward.

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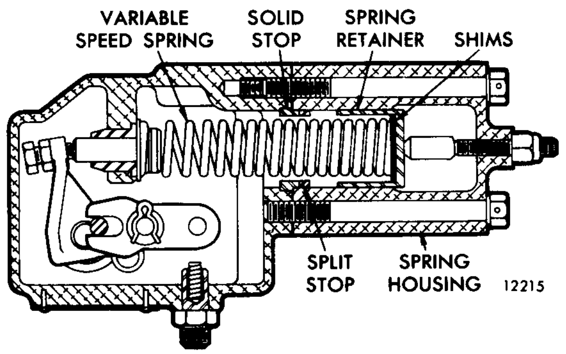

Fig. 5 - Location of Shims and Stops

If the rack does not return to its original position, it is too loose. To correct this condition with the *Two Screw Assembly,* back off the outer adjusting screw slightly and tighten the inner adjusting screw. To correct this condition with the *One Screw and Locknut Assembly,* loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

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. This will result in a step-up in effort required to move the stop lever to the *run* position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend). If the rack is found to be too tight with the *Two Screw Assembly,* back off the inner adjusting screw slightly and tighten the outer adjusting screw. To correct this condition with the *One Screw and Locknut Assembly,* loosen the locknut and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

5. Manually hold the rear injector control rack in the full-fuel position with the lever on the injector control tube and proceed as follows:

Two Screw Assembly

a. Turn down the inner adjusting screw on the injector rack control lever of the adjacent injector until the injector rack has moved into the full-fuel position and the inner adjusting screw is bottomed on the injector control tube.

b. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube.

c. Then alternately tighten both the inner and outer adjusting screws.

One Screw and Locknut Assembly

a. Tighten the adjusting screw of the adjacent injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted.

b. Securely lock the adjusting screw locknut.

NOTE: Overtightening of the injector rack control tube 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).

6. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the rack control lever while adjusting the adjacent injector rack. If the rack of the rear injector has become loose with the *Two Screw Assembly,* back off the inner adjusting screw slightly on the adjacent injector rack control lever and tighten the outer adjusting screw. With the *One Screw and Locknut Assembly,* turn the adjusting screw counterclockwise slightly until the rear injector rack returns to its full-fuel position and secure the adjusting screw locknut. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective control levers.

7. Position the remaining injector rack control levers as outlined in Steps 4, 5 and 6.

8. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the full-fuel position, check each control rack as in Step 4. All of the control racks must have the same "spring" condition with the control tube lever in the full-fuel position.

9. Insert the clevis pin in the fuel rod and the injector control tube levers.

10. Use a new gasket and reinstall the valve rocker cover.

Adjust Maximum No-Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the option plate, the maximum no-load speed may be set as follows:

1. Refer to Fig. 8 and disconnect the booster spring and the stop lever retracting spring.

2. Remove the two attaching bolts and withdraw the

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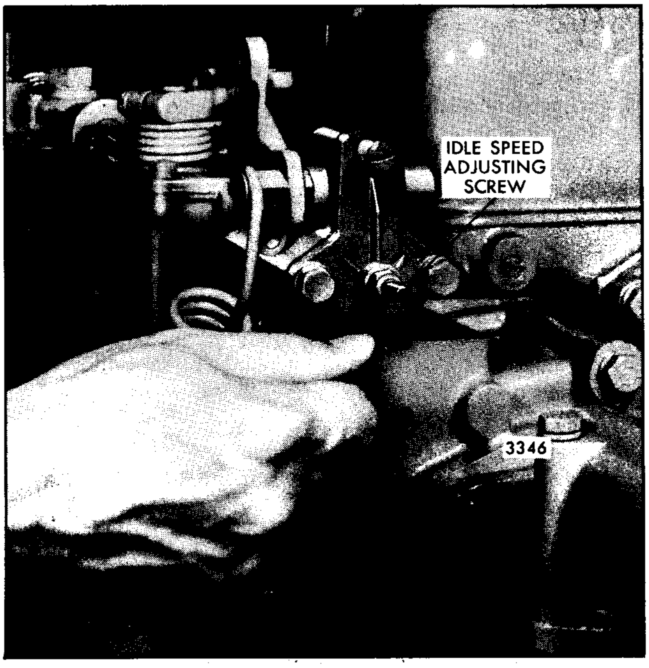

Fig. 6 - Adjusting Idle Speed

variable speed spring housing and the variable speed spring retainer located inside of the housing.

3. Refer to Table 1 and determine the stops or shims required for the desired full-load speed (Fig. 5). Do not use more than four thick and one thin shim. A *split stop can only be used with a solid stop.*

Full Load Speed RPM	STOPS		SHIMS
	Solid Ring	Split Ring	
2575-2800	0	0	As Required
2101-2575	1	0	As Required
1701-2100	1	1	As Required
1200-1700	1	2	As Required

TABLE 1

4. Install the variable speed spring retainer and housing and tighten the two bolts.

5. Connect the booster spring and stop lever spring. Start the engine and recheck the maximum no-load speed.

6. If required, add shims to obtain the necessary operating speed. For each .001" in shims added, the operating speed will increase approximately 2 rpm. If the maximum no-load speed is raised or lowered more

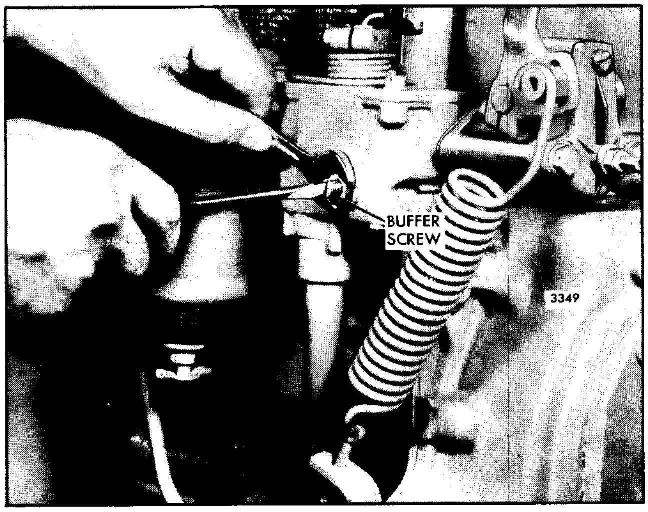

Fig. 7 - Adjusting Buffer Screw

than 50 rpm by the installation or removal of shims, recheck the governor gap. If readjustment of the governor gap is required, the position of the injector racks must be rechecked.

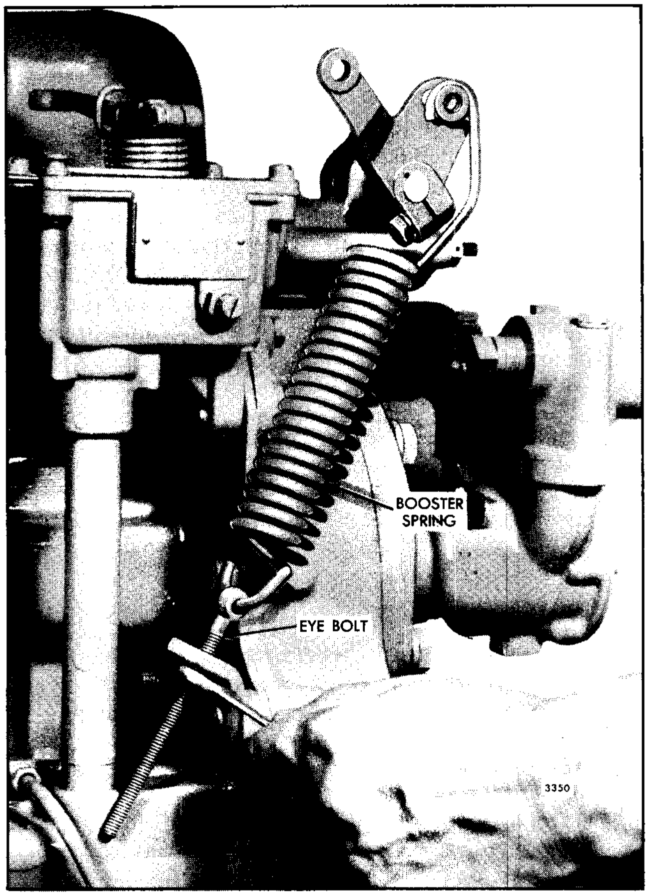

Fig. 8 - Adjusting Booster Spring

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NOTE: Governor stops are used to limit the compression of the governor spring which determines the maximum speed of the engine.

Adjust Idle Speed

With the maximum no-load speed properly set, adjust the idle speed as follows:

1. Place the stop lever in the *run* position and the speed control lever in the *idle* position.

2. With the engine running at normal operating temperature, back out the buffer screw to avoid contact with the differential lever.

3. Loosen the locknut and turn the idle speed adjusting screw until the engine is operating at approximately 15 rpm below the recommended idle speed (Fig. 6). The recommended idle speed is 550 rpm, but may vary with special engine applications.

4. Hold the idle speed adjusting screw and tighten the locknut.

Adjust Buffer Screw

1. With the engine running at normal operating temperature, turn the buffer screw in (Fig. 7) so that it contacts the differential lever as lightly as possible and still eliminates engine roll.

NOTE: Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Hold the buffer screw and tighten the locknut.

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. 8 and loosen the booster spring retaining nut on the speed control lever. Loosen the locknuts on the eyebolt 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 eyebolt. Hold the bolt and tighten the locknut.

4. Start the engine and move the speed control lever to the *maximum speed* position and release it. The lever should return to the *idle speed* position. If it does not, reduce the booster spring tension. If it does, continue to increase the spring tension until the point is reached where it will not return to idle. Then reduce the spring tension until the lever does return to idle and tighten the locknuts on the eyebolt. This setting will result in the minimum force required to operate the speed control lever.

5. Connect the linkage to the governor levers.

If the engine is equipped with a supplementary governing device, refer to Section 14.14 and adjust it at this time.

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VARIABLE SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT (PIERCE)

IN-LINE TRACTOR ENGINE

After timing the fuel injectors and adjusting the exhaust valves, position the injector rack control levers and adjust the governor.

Position Injector Rack Control Levers

The injector rack settings govern the quantity of fuel injected into each cylinder. All of the injectors must be set to inject the same quantity of fuel into each cylinder to ensure equal distribution of the load. Position the injector rack control levers as follows:

1. Disconnect the linkage between the governor rocker shaft lever and the bell crank mounted on the end plate.

2. Loosen all of the inner and outer rack control lever adjusting screws (Fig. 1). Be sure all of the levers are free on the injector control tube.

3. Lift upward on the bell crank to move the injector racks into the full-fuel position and turn the inner adjusting screw down until a 1/16" clearance exists between the fuel rod and the cylinder head or the cylinder head bolt, whichever it contacts.

Turn the outer adjusting screw down until it bottoms on the control tube, then alternately tighten the inner and outer screws to retain the adjustment.

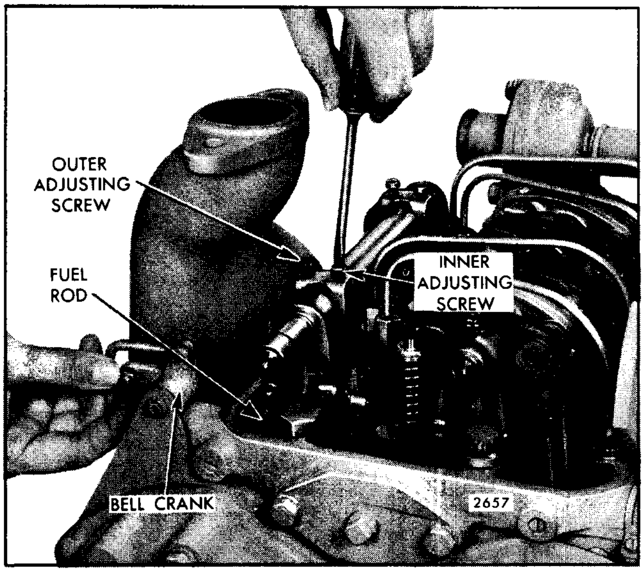

Fig. 1 - Positioning Injector Rack Control Levers

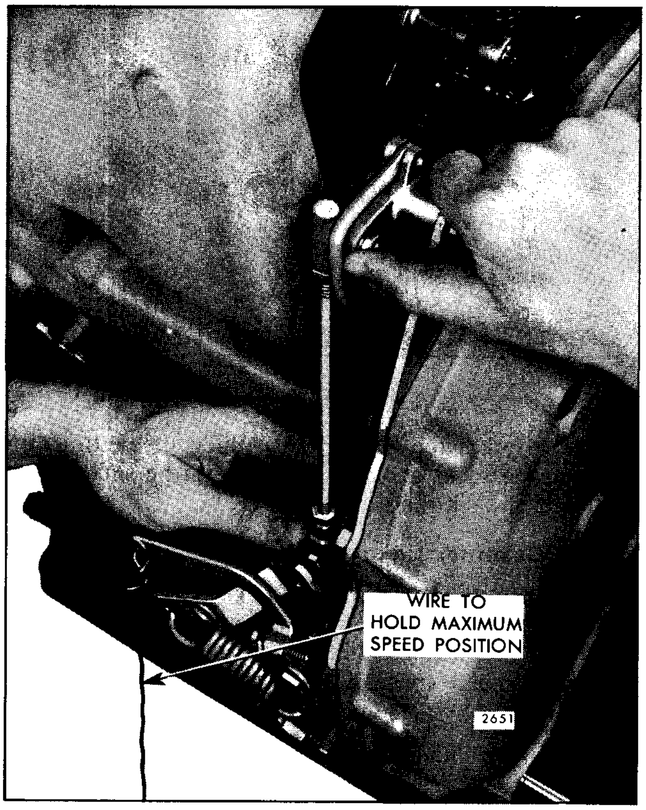

Fig. 2 - Adjusting the throttle rod

4. Manually hold the rear injector control rack in the full-fuel position and turn the inner adjusting screw of the adjacent injector rack control lever down until it has moved into the full-fuel position and the 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 screws.

> **NOTE:** Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **in-lb.**

5. Recheck the rear injector rack to be sure it has remained snug on the pin of the rack control lever while positioning the adjacent injector rack. If the rack of the rear injector has become loose, back off the inner adjusting screw slightly on the adjacent injector rack control lever and tighten the outer adjusting

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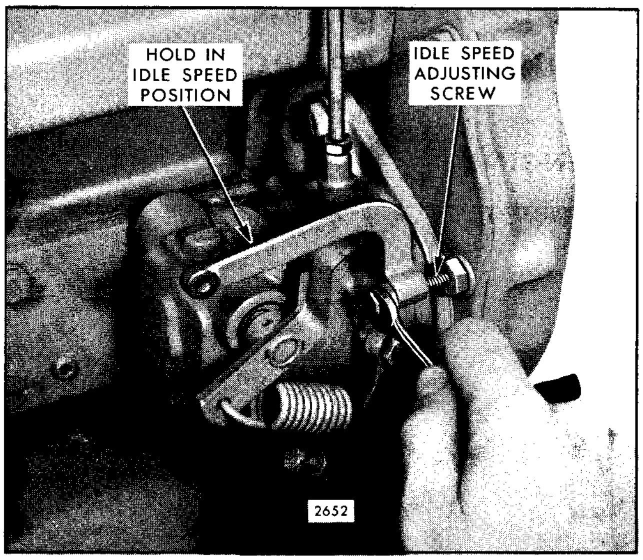

Fig. 3 - Adjusting Idle Speed

screw to retain the adjustment. When the settings are correct, the racks at both injectors will be snug on the ball end of each rack control lever.

Adjust Governor Linkage

1. Advance the governor rocker shaft lever to the maximum fuel position. Hold the lever in this position, after backing out the buffer screw, by advancing the governor speed control lever to its maximum speed position.

2. Hold the injector control racks in the full-fuel position; then adjust the length of the throttle rod, by turning the ball and socket on the rod, until it can be connected to the rocker shaft lever (Fig. 2).

3. Check the injector racks to be sure the governor holds the racks in the full-fuel position.

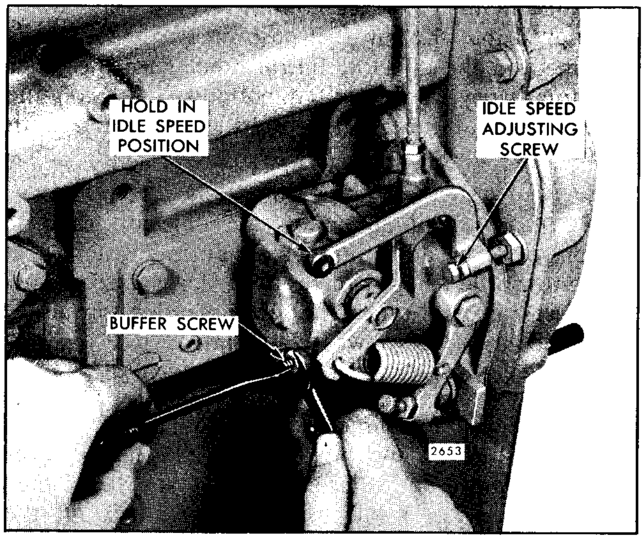

Fig. 4 - Adjusting Buffer Screw

Adjust Engine Idle Speed

1. Back out the buffer screw.

2. Start the engine and adjust the idle speed adjusting screw (Fig. 3) to obtain the desired idle speed.

> **NOTE:** The idle speed must be set in excess of 575 rpm or engine operation at idle will be erratic.

Adjust Buffer Screw

1. Loosen the buffer screw lock nut and, with the engine operating at idle speed, turn the buffer screw (Fig. 4) in until engine roll is eliminated.

> **NOTE:** Do not raise the engine speed more than 20 rpm with the buffer screw.

2. Tighten the lock nut to retain the adjustment.

Adjust Maximum No-Load Speed

1. Move the speed control lever, with the engine running, to the full-speed position.

> **NOTE:** Do not overspeed engine.

2. Adjust the maximum speed adjusting screw (Fig. 5) until the desired no-load speed is obtained.

3. Tighten the maximum speed adjusting screw lock nut to retain the adjustment.

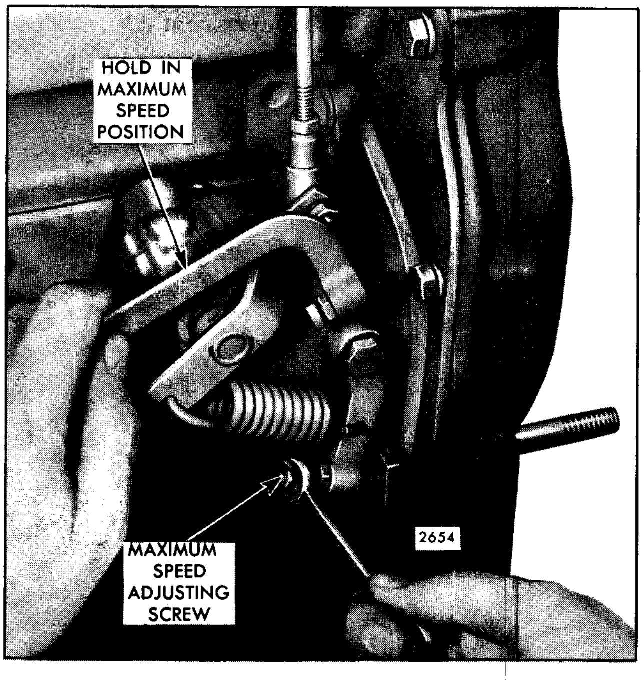

Fig. 5 - Adjusting Maximum No-Load Speed

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VARIABLE SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

6V ENGINE

The variable speed mechanical governor assembly is mounted at the rear of the 6V engine, between the flywheel housing and the blower (Fig. 1). The governor is driven by the right-hand blower rotor drive gear.

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 in the maximum speed position.

4. Insert a .006" feeler gage between the spring plunger and the plunger guide as shown in Fig. 2. 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 readjust if necessary.

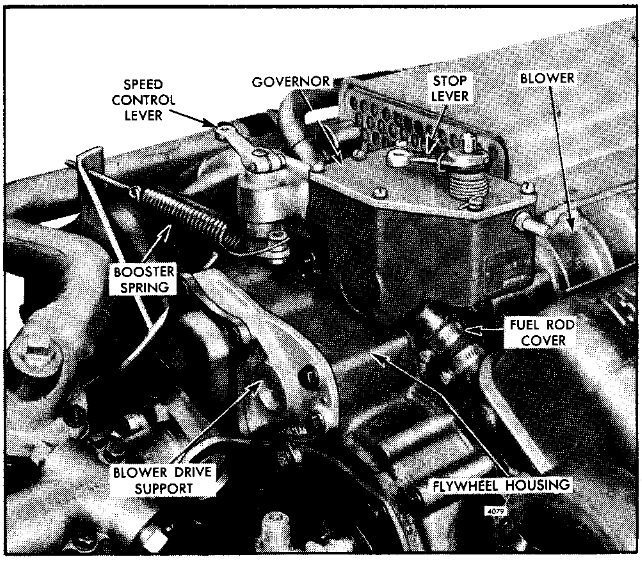

Fig. 1 - Variable Speed Governor Mounting

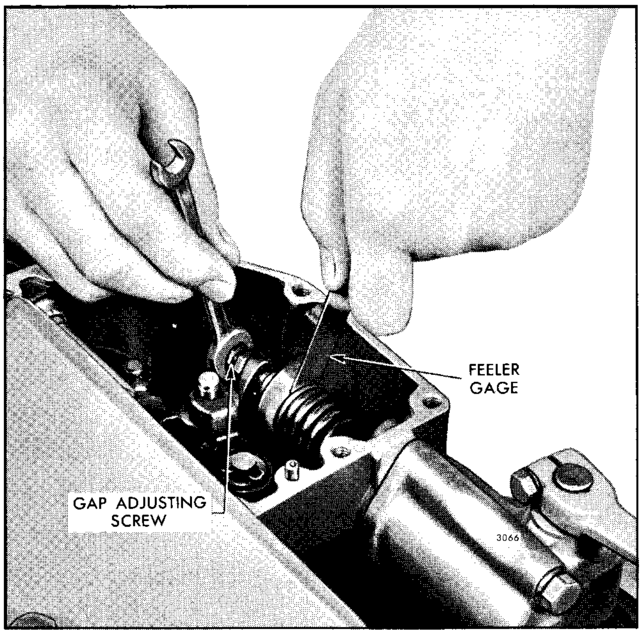

Fig. 2 - Adjusting Governor Gap

6. Install the governor cover.

Position Injector Rack Control Levers

The position of the injector control racks 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.

The letters R or L indicate the injector location in the right or left cylinder bank as viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 3L injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Loosen the lock nut and back out the buffer screw approximately 3/4" .

2. Remove the valve rocker covers.

3. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.

4. Loosen all of the inner and outer injector rack control lever adjusting screws on both injector control tubes. Be sure all of the injector rack control levers are free on the injector control tubes.

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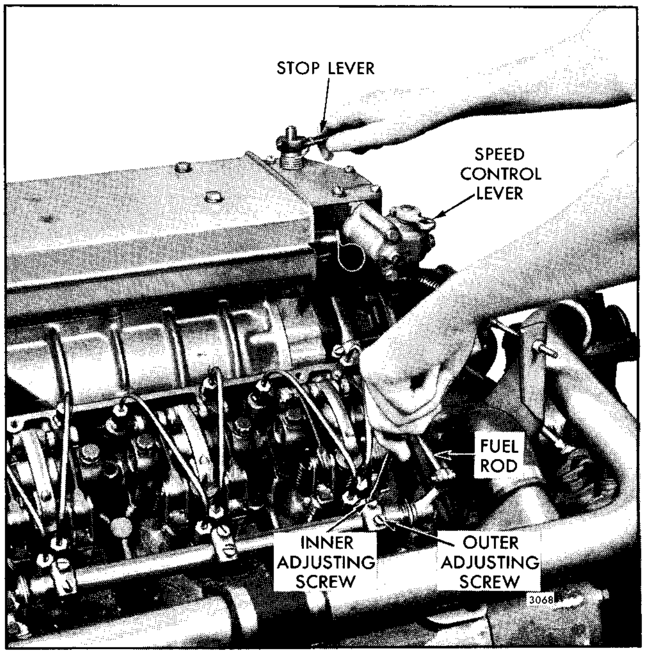

Fig. 3 - Positioning No. 3L Injector Rack Control Lever

5. Move the speed control lever to the maximum speed position.

6. Move the stop lever to the RUN position and hold it in that position with light finger pressure. Turn the inner adjusting screw of the No. 3L injector rack control lever down (Fig. 3) until a slight movement of the control tube is observed, or a step-up in effort to turn the screw driver is noted. This will place the No. 3L injector rack in the full-fuel position. 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.

> **NOTE:** Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is **24-36 in-lb**.

The above steps should result in placing the governor linkage and control tube in the respective positions that they will attain while the engine is running at full load.

7. To be sure the control lever is properly adjusted, hold the stop lever in the RUN position and press down on the injector rack with a screw driver or finger tip causing the rack to rotate. The setting is sufficiently tight if the rack returns to its original position. If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer adjusting screw slightly and tighten the inner adjusting screw. The setting is too tight if, when moving the stop lever from the STOP to the RUN posiiton, the injector rack becomes tight before the governor stop lever reaches the end of its travel. This will result in a step-up in effort required to move the stop lever to the RUN position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend). If the rack is found to be too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw.

8. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.

9. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 3R injector rack control lever as previously outlined in Step 6 for the No. 3L control lever.

10. Insert the clevis pin in the fuel rod and the left bank injector control tube lever. Repeat the check on the 3L and 3R injector rack control levers as outlined in Step 7. Check for and eliminate any deflection which may occur at the bend in the fuel rod where it enters the cylinder head.

11. Manually hold the No. 3L injector rack in the full-fuel position, with the lever on the injector control tube, and turn the inner adjusting screw of the No. 2L injector rack control lever down until the injector rack of No. 2L injector has moved into the full-fuel position. 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.

12. Recheck the No. 3L injector rack to be sure that it has remained snug on the ball end of the rack control lever while positioning the No. 2L injector rack. If the rack of the No. 3L injector has become loose, back off the inner adjusting screw slightly on No. 2L injector rack control lever and tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective control levers.

13. Positon the 1L injector rack control lever as outlined in Steps 11 and 12.

14. Position the No. 2R and 1R injector rack control levers as outlined above for the left cylinder bank in Steps 11 through 13.

15. Install the valve rocker covers.

Adjust Maximum No-Load Speed

The maximum no-load speed varies with the full-load operating speed desired.

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Use an accurate hand tachometer to determine the maximum no-load speed of the engine, then make the following adjustments, if required.

1. Refer to Fig. 7 and disconnect the booster spring and the stop lever retracting spring.

2. Remove the two attaching bolts and withdraw the variable speed spring housing and the variable speed spring retainer located inside of the housing.

3. Refer to the following table and determine the stops or shims required for the desired full-load speed. A split stop can only be used with a solid stop (Fig. 4).

Full-Load Speed	Stops		Shims*
	Solid	Split	
1200-2100	1	1	As Required
2100-2500	1	0	As Required
2500-2800	0	0	As Required

*Maximum amount of shims .325"

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. For each .001" in shims added, the operating speed will increase approximately 2 rpm.

> **IMPORTANT:** If the maximum no-load speed is raised or lowered more than 50 rpm by the installation or removal of shims, recheck the governor gap. If readjustment of the governor gap is required, the position of the injector racks must be rechecked.
>
> **NOTE:** Governor stops are used to limit the compression of the governor spring, which determines the maximum speed of the engine.

Adjust Idle Speed

After the maximum no-load speed has been set, adjust the idle speed as follows:

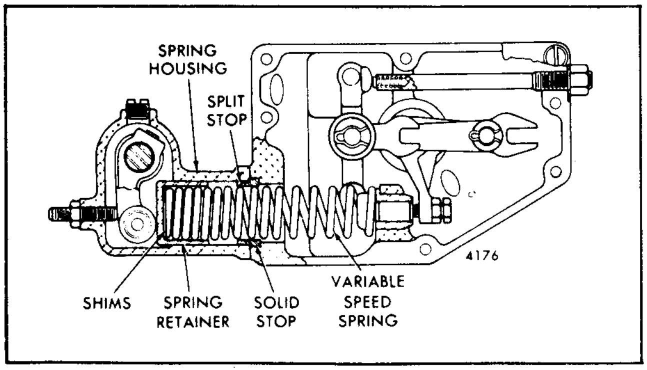

Fig. 4 - Location of Shims and Stops

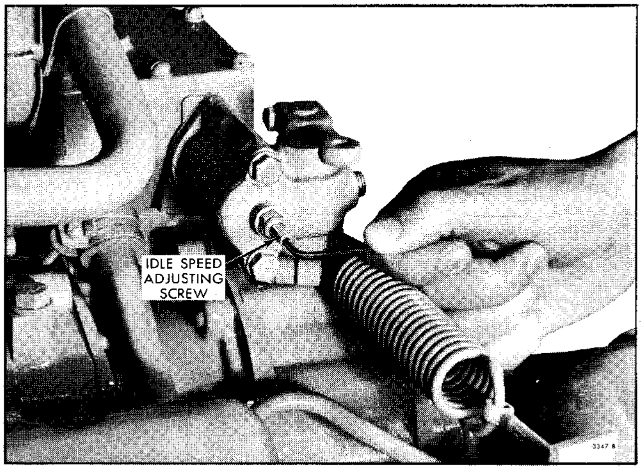

Fig. 5 - Adjusting Idle Speed

1. Place the stop lever in the RUN position and the speed control lever in the IDLE position.

2. With the engine operating, loosen the lock nut and turn the idle speed adjusting screw (Fig. 5) in or out until the engine idles at the recommended idle speed. The recommended idle speed is 550 rpm, but may vary with special engine applications.

3. Hold the idle speed adjusting screw and tighten the lock nut.

Adjust Buffer Screw

With the engine idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at idle speed, turn the buffer screw in (Fig. 6) so that it contacts the

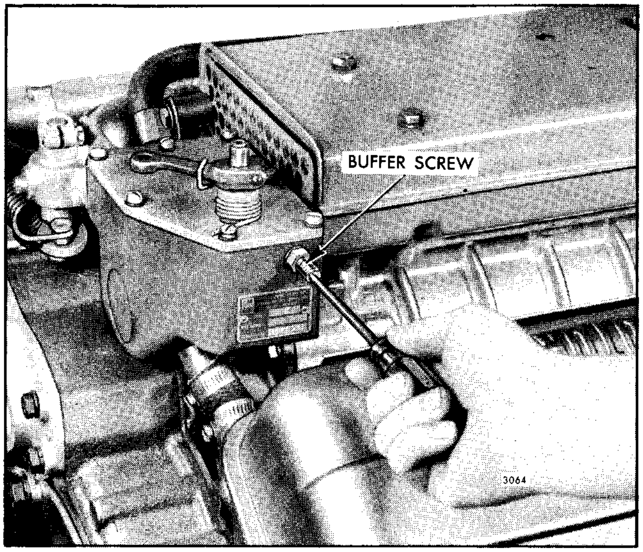

Fig. 6 - Adjusting Buffer Screw

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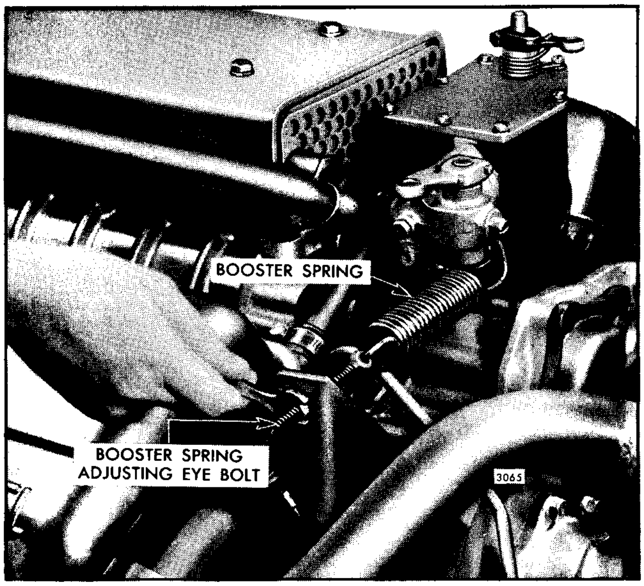

Fig. 7 - Adjusting Booster Spring

differential lever as lightly as possible and still eliminates engine roll.

NOTE: Do not raise the engine idle speed more than 15 rpm with the buffer screw.

2. Hold the buffer screw and tighten the lock nut.

Adjust Booster Spring

With the idle speed set, adjust the booster spring as follows:

1. Refer to Fig. 7 and loosen the booster spring retaining nut on the speed control lever. Loosen the lock nuts on the eye bolt at the other end of the spring.

2. Move the spring retaining bolt in the slot of the speed control lever until the center of the bolt is on an imaginary line through the center of the bolt, lever shaft and eye bolt. Hold the bolt and tighten the lock nut.

3. Start the engine and move the speed control lever to the maximum speed position and release it. The speed control lever should return to the idle position. If it does not, reduce the tension on the booster spring. If the lever does return to the idle position, continue to increase the spring tension until the point is reached that it will not return to idle. Then reduce the tension until it does return to idle and tighten the lock nut on the eye bolt. This setting will result in the minimum force required to operate the speed control lever.

4. Connect the linkage to the governor levers.

8V ENGINE

The variable speed mechanical governor assembly (Fig. 8) is mounted at the front end of the 8V engine. 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 in the maximum speed position.

4. Insert a .006" feeler gage between the spring plunger and the plunger guide as shown in Fig. 9. 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 readjust, if necessary.

6. Install the governor cover.

Position Injector Rack Control Levers

The position of the injector control racks 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.

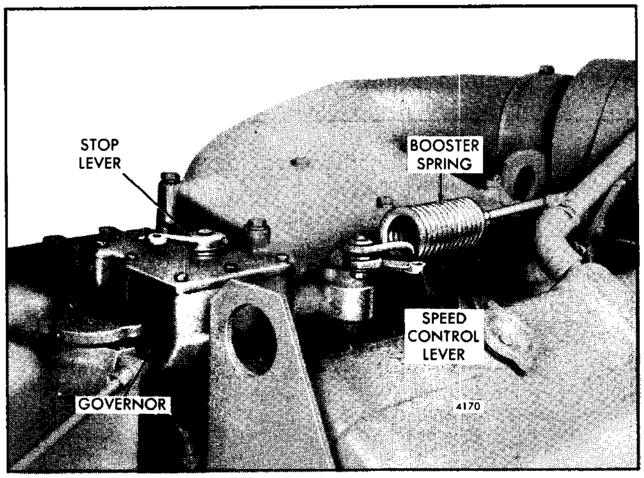

Fig. 8 - Variable Speed Governor Mounting

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The letters R or L indicate the injector location in the right or left cylinder bank as viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 1L injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Loosen the lock nut and back out the buffer screw approximately 3/4" .

2. Remove the valve rocker covers.

3. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.

4. Loosen all of the inner and outer injector rack control lever adjusting screws on both injector control tubes. Be sure all of the injector rack control levers are free on the injector control tubes.

5. Move the speed control lever to the maximum speed position.

6. Move the stop lever to the RUN position and hold it in that position with light finger pressure. Turn the inner adjusting screw of the No. 1L injector rack control lever down (Fig. 10) until a slight movement of the control tube is observed, or a step-up in effort to turn the screw driver is noted. This will place the No. 1L injector rack in the full-fuel position. 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.

> **NOTE:** Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **in-lb.**

The above steps should result in placing the governor linkage and control tube in the respective positions that they will attain while the engine is running at full load.

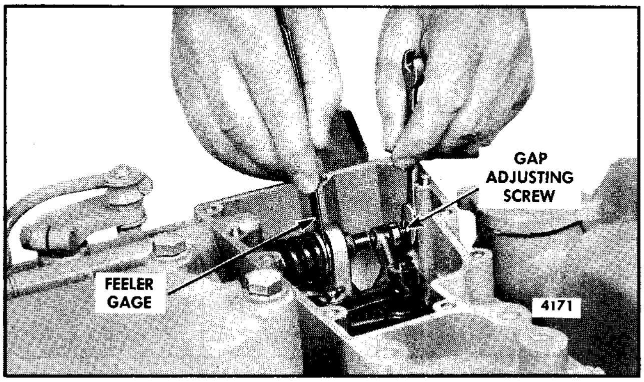

Fig. 9 - Adjusting Governor Gap

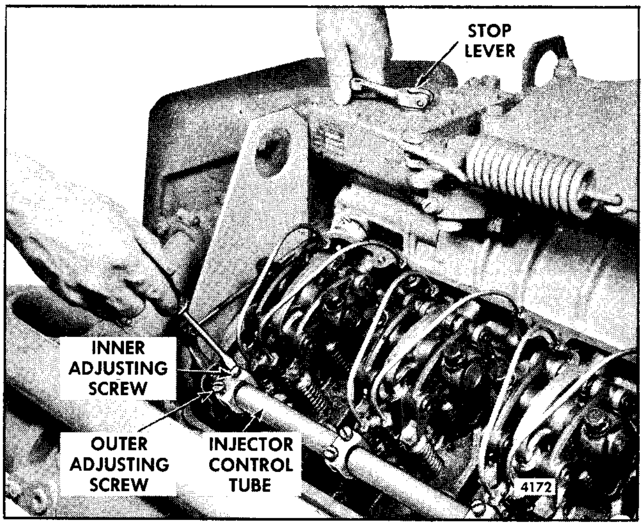

Fig. 10 - Positioning No. 1L Injector Rack Control Lever

7. To be sure the control lever is properly adjusted, hold the stop lever in the RUN position and press down on the injector rack with a screw driver or finger tip causing the rack to rotate. The setting is sufficiently tight if the rack returns to its original position. If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer adjusting screw slightly and tighten the inner adjusting screw. The setting is too tight if, when moving the stop lever from the STOP to the RUN position, the injector rack becomes tight before the stop lever reaches the end of its travel. This will result in a step-up in effort required to move the stop lever to the RUN position and a deflection in the fuel rod (fuel rod deflection can be seen at the bend). If the rack is found to be too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw.

8. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.

9. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 1R injector rack control lever as previously outlined in Step 6 for the No. 1L control lever.

10. Insert the clevis pin in the fuel rod and the left bank injector control tube lever. Repeat the check on the 1L and 1R injector rack control levers as outlined in Step 7. Check for and eliminate any deflection which may occur at the bend in the fuel rod where it enters the cylinder head.

11. Manually hold the No. 1L injector rack in the full-fuel position, with the lever on the injector control tube, and turn the inner adjusting screw of the No. 2L injector rack control lever down until the No. 2L injector rack moves into the full-fuel position. Turn

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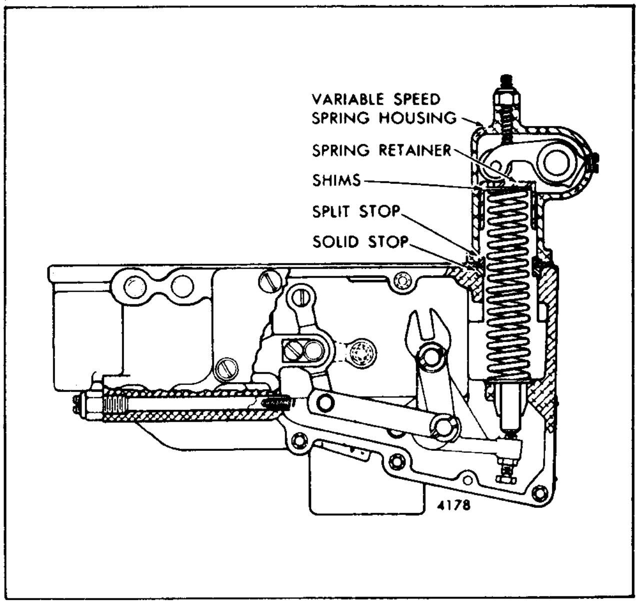

Fig. 11 - Location of Shims and Stops

the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

12. Recheck the No. 1L injector rack to be sure that it has remained snug on the ball end of the rack control lever while positioning the No. 2L injector rack. If the rack of the No. 1L injector has become loose, back off the inner adjusting screw slightly on the No. 2L injector rack control lever and tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective control levers.

13. Position the No. 3L and No. 4L injector rack control levers as outlined in Steps 11 and 12.

14. Position the No. 2R, 3R and 4R injector rack control levers as outlined for the left cylinder bank in Steps 11 through 13.

15. Install the valve rocker covers.

Adjust Maximum No-Load Speed

The maximum no-load speed must not exceed 150 rpm above the full-load speed.

Use an accurate hand tachometer to determine the maximum no-load speed of the engine, then make the following adjustments, if required.

1. Refer to Fig. 14 and disconnect the booster spring and the stop lever retracting spring.

2. Remove the two attaching bolts and withdraw the variable speed spring housing and the spring retainer located inside of the housing.

3. Refer to the following table and determine the stops or shims required for the desired full-load speed. A split stop can only be used with a solid stop (Fig. 11).

Full-Load Speed	Stops		Shims*
	Solid	Split	
1200-2100	1	1	As Required
2100-2500	1	0	As Required
2500-2800	0	0	As Required

*Maximum amount of shims .325"

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. For each .001" in shims added, the speed will increase approximately 2 rpm.

> **IMPORTANT:** If the maximum no-load speed is raised or lowered more than 50 rpm by the installation or removal of shims, recheck the governor gap. If readjustment of the governor gap is required, the position of the injector racks must be rechecked.

> **NOTE:** Governor stops are used to limit the compression of the governor spring, which determines the maximum speed of the engine.

Adjust Idle Speed

After the maximum no-load speed has been set, adjust the idle speed as follows:

1. Place the stop lever in the RUN position and the speed control lever in the IDLE position.

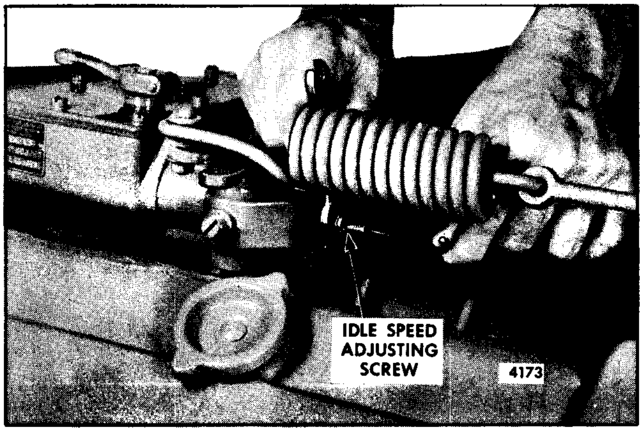

Fig. 12 - Adjusting Idle Speed

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2. With the engine operating, loosen the lock nut and turn the idle speed adjusting screw (Fig. 12) in or out until the engine idles at 600 rpm.

3. Hold the idle speed adjusting screw and tighten the lock nut.

Adjust Buffer Screw

With the engine idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at idle speed, turn the buffer screw in (Fig. 13) so that it contacts the differential lever as lightly as possible and still eliminates engine roll.

> **NOTE:** Do not raise the engine idle speed more than 15 rpm with the buffer screw.

2. Hold the buffer screw and tighten the lock nut.

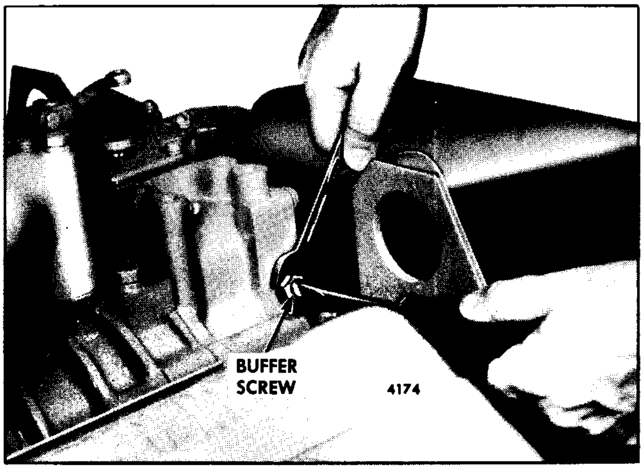

Fig. 13 - Adjusting Buffer Screw

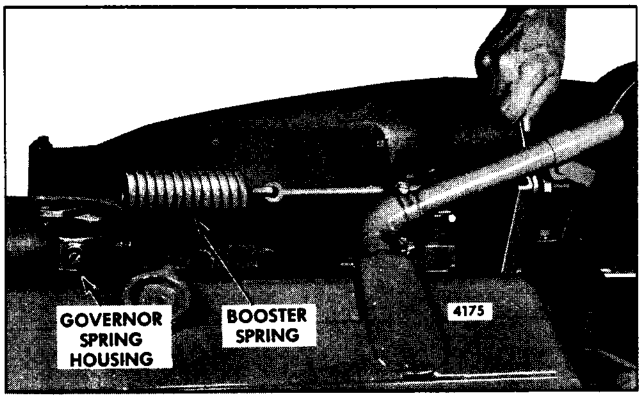

Fig. 14 - Adjusting Booster Spring

Adjust Booster Spring

With the engine idle speed set, adjust the booster spring as follows:

1. Refer to Fig. 14 and loosen the booster spring retaining nut on the speed control lever. Loosen the lock nuts on the eye bolt at the other end of the spring.

2. Move the spring retaining bolt in the slot of the speed control lever until the center of the bolt is on an imaginary line through the center of the bolt, lever shaft and eye bolt. Hold the bolt and tighten the lock nut.

3. Start the engine and move the speed control lever to the maximum speed position and release it. The speed control lever should return to the idle position. If it does not, reduce the tension on the booster spring. If the lever does return to the idle position, continue to increase the spring tension until the lever does not return to idle. Then reduce the tension until it does return to idle and tighten the lock nut on the eye bolt. This setting will result in the minimum force required to operate the speed control lever.

4. Connect the linkage to the governor levers.

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CONSTANT SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and injector rack control levers.

Adjust Governor Gap

1. Stop the engine and disconnect any linkage attached to the speed control lever.

2. Remove the governor cover and lever assembly.

3. Remove the fuel rod from the differential lever and the injector control tube lever.

4. Insert a .006" feeler gage between the spring plunger and the plunger guide as shown in Fig. 1. If required, loosen the lock nut and turn the gap 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 readjust if necessary.

6. Install the governor cover as follows:

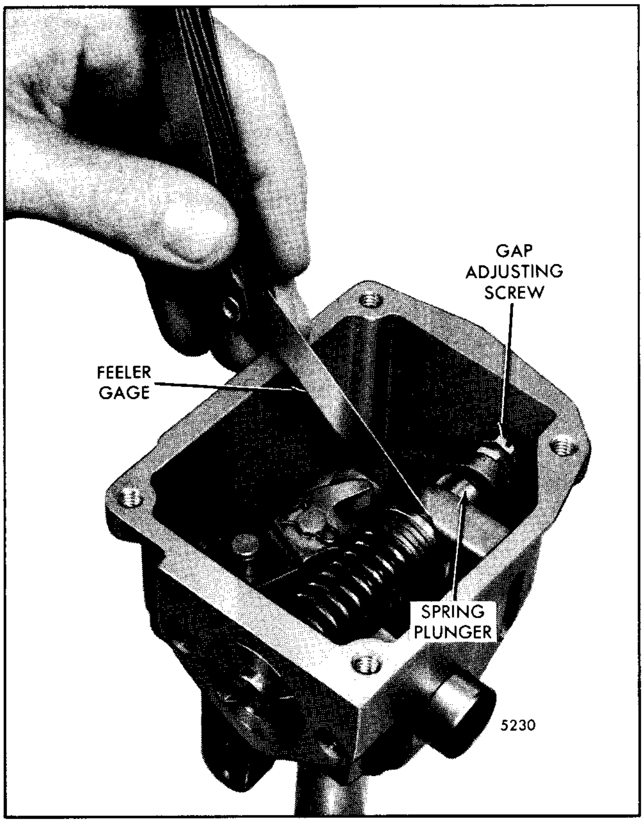

Fig. 1 - Adjusting Governor Gap

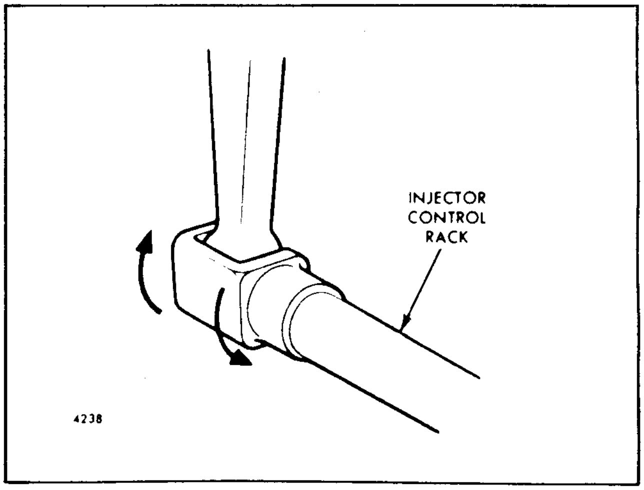

Fig. 2 - Checking Rotating Movement of Injector Control Rack

a. Place the cover on the governor housing, with the pin in the throttle shaft assembly entering the slot in the differential lever.

b. Install the four cover screws and lock washers finger tight.

c. Pull the cover assembly in a direction away from the engine, to take up the slack, and tighten the cover screws.

NOTE: This step is required since no dowels are used to locate the cover on the housing.

Position Injector Rack Control Levers

The position of the injector control racks 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.

Adjust the No. 1 injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the control lever.

2. Remove the valve rocker cover.

3. Loosen all of the inner and outer injector rack control lever adjusting screws. Be sure all of the control levers are free on the injector control tube.

4. Move the control lever to the maximum speed position. Turn the inner adjusting screw down until a step-up in effort is noted. This will place the No. 1

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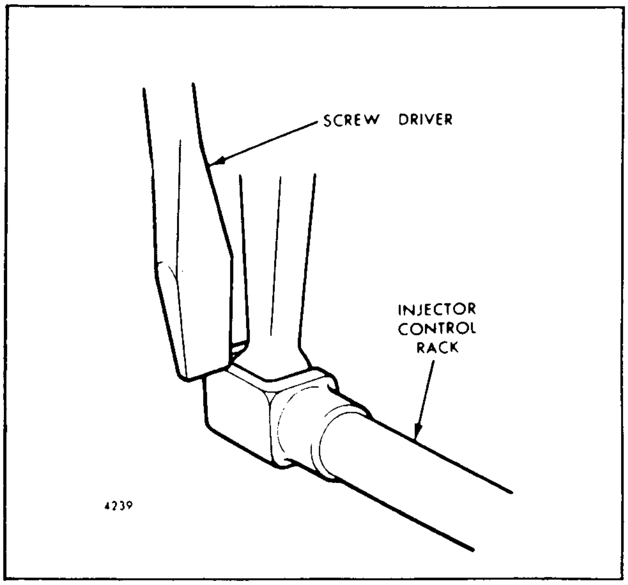

Fig. 3 - Checking Injector Control Rack "Spring"

injector rack in the full-fuel position. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

NOTE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **in-lb.**

5. 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 the "rotating" movement of the injector control rack (Fig. 2). 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. 3) and when the pressure of the screw driver is released, the control rack should "spring" back upward.

6. If no movement is observed, back off the inner adjusting screw approximately 1/8 of a turn and tighten the outer adjusting screw. If the movement exceeds that specified, back off the outer adjusting screw approximately 1/8 of a turn and tighten the inner adjusting screw. When the setting is correct, the injector rack will be snug on the pin of the rack control lever and still maintain the movement specified in Step 5.

NOTE: Performing Steps 4, 5 and 6 will result in placing the governor linkage and control tube assembly in the same positions that they will attain while the engine is running at full load. These positions are:

a. The governor speed control lever is at the maximum speed position.

b. The governor gap is closed.

c. The governor spring plunger is on its seat in the governor control housing.

d. The injector fuel control racks are in the maximum speed position.

7. Remove the clevis pin between the fuel rod and the injector control tube lever.

8. Manually hold the No. 1 injector in the maximum fuel position and turn down the inner adjusting screw of the No. 2 injector until the injector rack has moved into the maximum speed 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.

9. Recheck the No. 1 injector fuel rack to be sure that it has remained snug on the pin of the rack control lever while adjusting the No. 2 injector. If the rack of the No. 1 injector has become loose, back off slightly on the inner adjusting screw on the No. 2 injector rack control lever and tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the pins of their respective rack control levers.

10. Position the remaining control rack levers as outlined in Steps 8 and 9.

11. Insert the clevis pin between the fuel rod and the injector control tube lever.

12. Install the valve rocker cover.

Adjust Maximum No-Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine name plate, the maximum no-load speed may be set as follows:

1. Start and warm up the engine.

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2. Run the engine at no-load and observe the engine speed. Be sure the speed control lever is in the run position.

CAUTION: There must be no load on the engine during the maximum no-load speed adjustment.

3. Observe the engine speed and set it, if necessary, to the recommended speed with shims placed between the operating speed spring and the spring plunger.

Since the engine performance and efficiency will be governed, to a large extent, by the accuracy with which the tune-up adjustments are made, the serviceman should always perform these operations carefully.

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HYDRAULIC GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

IN-LINE ENGINE

The hydraulic governor is mounted on the 2-53, 3-53 and 4-53 engines (Fig. 1). The terminal lever return spring and the fuel rod are attached to an external terminal shaft lever. The maximum fuel position of the governor load limit is determined by the internal governor terminal lever striking against a boss that projects from the governor cover.

Adjust the hydraulic governor after adjusting the exhaust valve clearance and timing the fuel injectors.

NOTE: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. On turbocharged engines, the fuel (air box) modulator lever and roller assembly must be positioned free from cam contact. After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

Adjust Fuel Rod and Injector Rack Control Levers

1. Adjust the inner and outer adjusting screws (Fig. 2) on the rear injector rack control lever until both the screws are equal in height and tight on the control tube.

NOTE: Some engines use spring-loaded control tube assemblies which have a yield spring at each injector rack control lever and only one screw and locknut to keep each injector rack properly positioned. Adjust the single screw and locknut on each injector rack control lever to a central or middle position.

Check the clearance between the fuel rod and the cylinder head bolt or the cylinder head casting (below the bolt) for at least 1/16″ clearance when the injector rack is in the full-fuel position and the rack adjusting screws are tight. If the fuel rod contacts the bolt or the cylinder head casting, readjust the screws to obtain the 1/16″ clearance.

NOTE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **lb-in** (3-4 Nm).

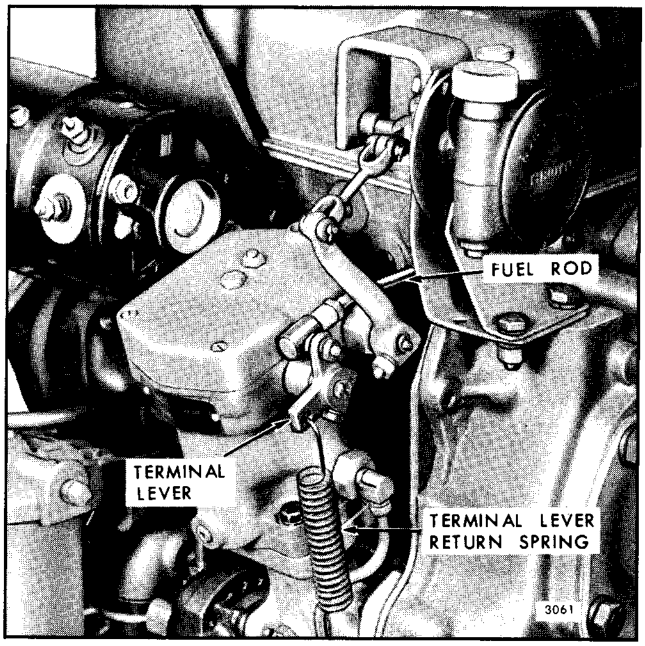

Fig. 1 - Hydraulic Governor Mounting

2. Remove the governor terminal lever return spring.

3. Remove the fuel rod end bearing or ball joint from the terminal shaft lever and the terminal lever from the terminal shaft.

4. Place the terminal lever on the terminal shaft so that the hole for attaching the fuel rod end bearing or ball joint is in line vertically above the terminal lever shaft at one half the arc of travel. Do not tighten the clamping bolt.

5. Hold both the injector rack control tube and the terminal lever in the *full-fuel* position and adjust the length of the fuel rod until the end bearing or ball joint will slide freely into the hole of the terminal lever (Fig. 3). Tighten the locknut, to retain the ball joint or end bearing, and the terminal lever clamping bolt securely.

NOTE: It will be necessary to slide the terminal lever partially off of the shaft to attach the fuel rod end bearing or ball joint to the terminal lever.

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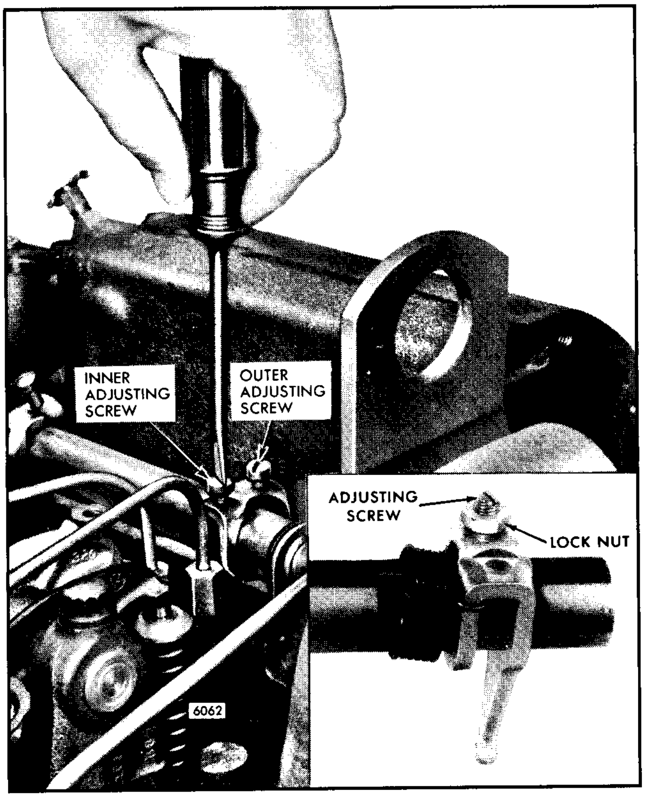

Fig. 2 - Adjusting Height of Rack Control Lever Adjusting Screws

On former governors that do not have the load limit screw in the cover, hold the terminal lever in the *full-fuel* position and loosen the inner adjusting screw 1/8 of a turn and tighten the outer adjusting screw 1/8 of a turn to retain the adjustment. This is done to prevent the governor from bottoming the injector racks.

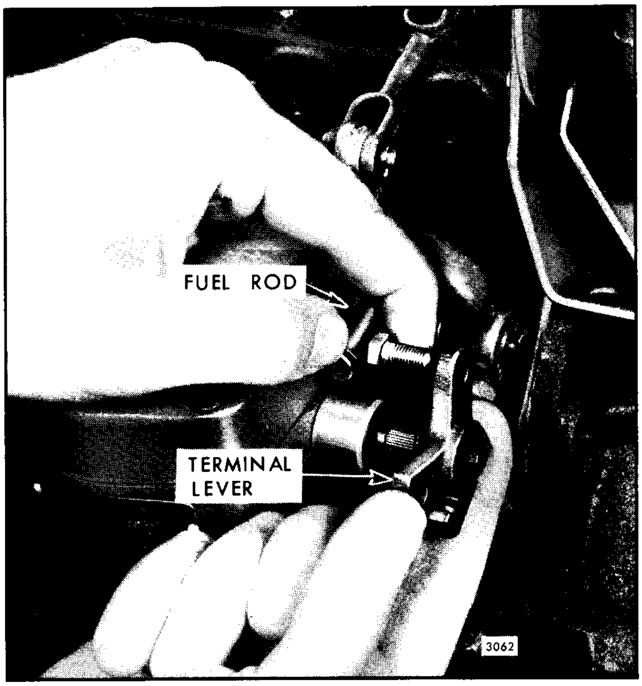

Fig. 3 - Adjusting Length of Fuel Rod

6. Remove the clevis pin between the fuel rod and the injector control tube lever.

> **NOTE:** Cover the cylinder head oil drain-back hole, located under the control lever, when removing the fuel rod clevis pin to prevent loss of the pin and possible damage to the engine.

7. Manually hold the rear injector in the *full-fuel* position with the lever on the injector control tube. Turn the adjusting screw of the rear injector rack control lever until the injector rack moves into the *full-fuel* position.

On a *Two Screw Assembly*, 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.

On a *One Screw and Locknut Assembly*, turn the adjusting screw until a slight roll-up on the injector rack clevis is observed or an increase in effort to turn the screwdriver is noted, then securely lock the adjusting screw locknut.

8. Recheck the rear injector fuel rack to be sure that it has remained snug on the ball end of the rack control lever while adjusting the adjacent injector. If the rack of the rear injector has become loose, back off slightly on the adjusting screw on the adjacent injector rack control lever. When the settings are correct, the racks of all injectors must be snug on the ball end of their respective rack control levers.

9. Position the remaining rack control levers as outlined in Steps 7 and 8.

10. Insert the clevis pin between the fuel rod and the injector control tube lever.

11. On current governors, that have the load limit screw in the governor cover (refer to Section 2.8.1), hold the terminal lever in the *full-fuel* position and adjust the load limit screw until it just contacts the terminal lever. Then, advance the load limit screw enough to cause the injector racks to just become loose on the control tube levers.

> **NOTE:** This will allow the terminal lever to reach full travel before the injector racks bottom.

12. Install the terminal lever return spring.

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Adjust Speed Droop

The purpose of adjusting the speed droop is to establish a definite engine speed at no load with a given speed at rated full load.

The governor droop is set at the factory and further adjustment should be unnecessary. However, if the governor has had major repairs, the speed droop should be readjusted.

The best method of determining the engine speed is by the use of an accurate hand tachometer.

If a full-rated load on the unit can be established and the fuel rod, injector rack control levers and load limit have been adjusted, the speed droop may be adjusted as follows:

1. Start the engine and run it at approximately one-half the rated no-load speed until the lubricating oil temperature stabilizes.

> **NOTE:** When the engine lubricating oil is cold, the governor regulation may be erratic. The regulation should become increasingly stable as the temperature of the lubricating oil increases.

2. Stop the engine and remove the governor cover. Discard the gasket.

3. Loosen the locknut and back off the maximum speed adjusting screw approximately 5/8″ (Fig. 5).

4. Refer to Fig. 4 and loosen the droop adjusting bolt. Move the droop bracket so that the bolt is midway between the ends of the slot in the bracket. Tighten the bolt.

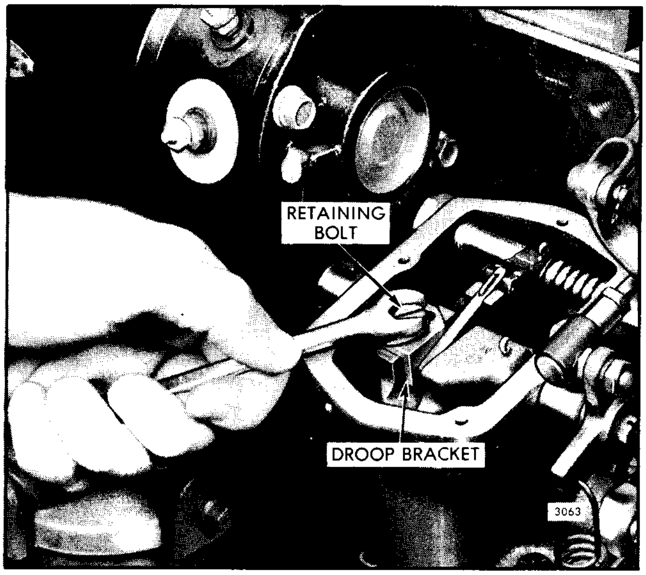

Fig. 4 - Adjusting Droop Bracket

5. With the throttle in the *run* position, adjust the engine speed until the engine is operating at 3% to 5% above the recommended full-load speed.

6. Apply the full-rated load on the engine and readjust the engine speed to the correct full-load speed.

7. Remove the rated load and note the engine speed after the speed stabilizes under no load. If the speed droop is correct, the engine speed will be approximately 3% to 5% higher than the full-load speed.

If the speed droop is too high, stop the engine and again loosen the droop bracket retaining bolt and move the droop adjusting bracket *in* toward the engine. Tighten the bolt. To increase the speed droop, move the droop adjusting bracket *out*, away from the engine.

The speed droop in governors which control engines driving generators in parallel must be identical, otherwise the electrical load will not be equally divided.

Adjust the speed droop bracket in each engine governor to obtain the desired variation between the engine no-load and full-load speeds (Table 1).

Full Load	No-Load
50 cycles 1000 rpm	52.5 cycles 1050 rpm
60 cycles 1200 rpm	62.5 cycles 1250 rpm
50 cycles 1500 rpm	52.5 cycles 1575 rpm
60 cycles 1800 rpm	62.5 cycles 1875 rpm

TABLE 1

The recommended speed droop of generator sets operating in parallel is 50 rpm (2-1/2 cycles) for units operating at 1000 and 1200 rpm and 75 rpm (2-1/2 cycles) for units operating at 1500 rpm and 1800 rpm full load. This speed droop recommendation may be varied to suit the individual application.

Adjust Maximum No-Load Speed

With the speed droop properly adjusted, set the maximum no-load speed as follows:

1. Loosen the maximum speed adjusting screw locknut and back out the maximum speed adjusting screw 3 turns.

2. With the engine operating at no load, adjust the engine speed until the engine is operating at approximately 8% higher than the rated full-load speed.

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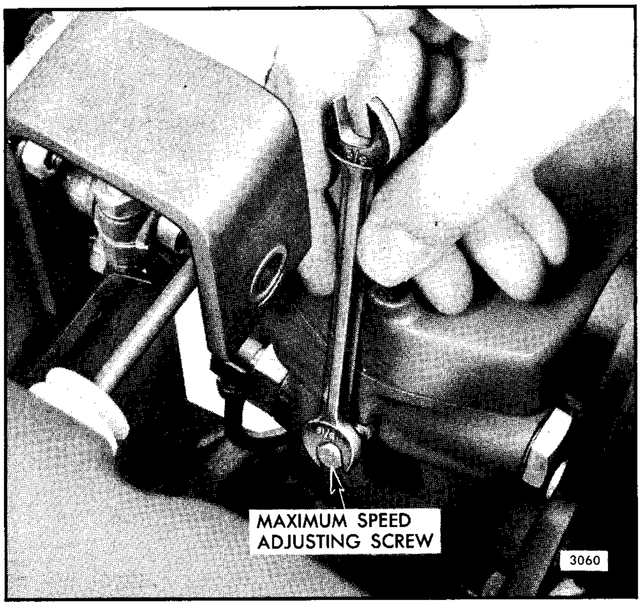

Fig. 5 - Adjusting Maximum Engine Speed

3. Turn the maximum speed adjusting screw in lightly until contact is felt with the linkage in the governor (Fig. 5).

4. Hold the maximum speed adjusting screw and tighten the locknut.

5. Use a new gasket and install the governor cover.

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HYDRAULIC GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

6V ENGINE

The hydraulic governor is mounted between the blower and the rear end plate as shown in Fig. 1. The vertical control link assembly is attached to the governor operating lever and the bell crank lever on the governor drive housing (Fig. 2).

Perform the following adjustment on a 6V engine that incorporates a hydraulic governor.

1. Remove the rocker covers.

2. Adjust the exhaust valve clearance and time the fuel injectors as stated in Sections 14.1 and 14.2.

3. Disconnect the vertical control link assembly from the governor operating lever.

4. Loosen all of the injector rack control lever adjusting screws.

5. While holding the bell crank lever (on the governor drive housing) in a horizontal position (full-fuel), set the No. 3 injector rack control levers on each bank to full-fuel.

6. Position the remaining rack control levers to the No. 3 control levers.

7. Remove the governor cover.

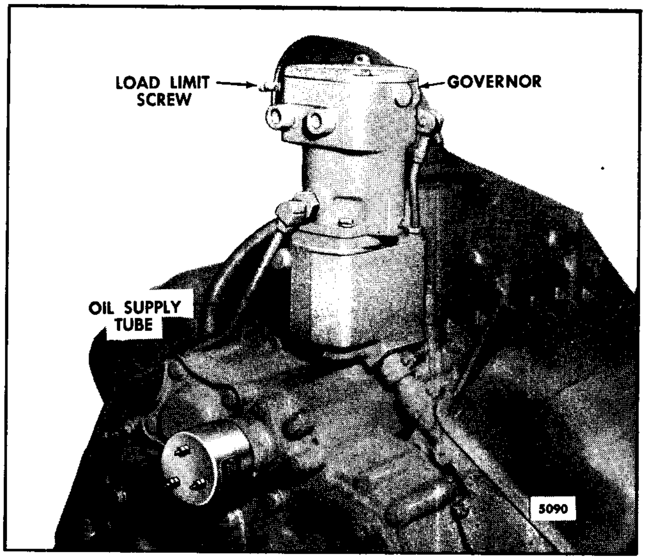

Fig. 1 - Hydraulic Governor Mounting

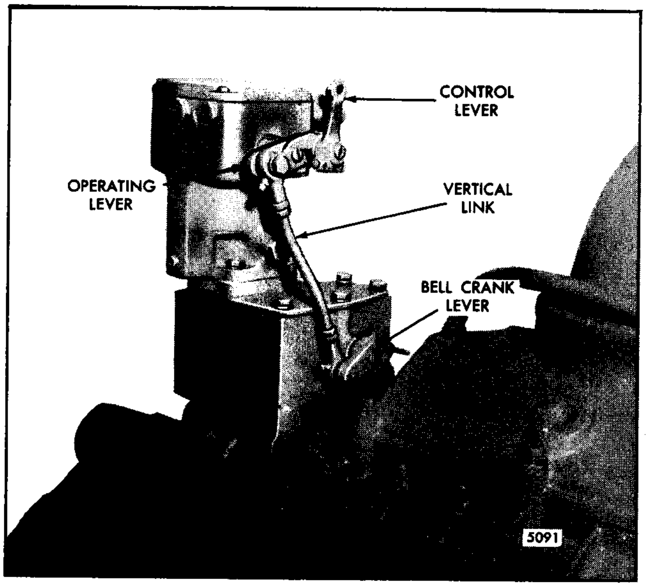

Fig. 2 - Hydraulic Governor Controls

8. To determine the full-fuel position of the terminal lever, adjust the load limit screw to obtain a distance of 2" from the outside face of the boss on the governor sub-cap to the end of the screw.

9. Adjust the operating lever (on the governor) so that it is horizontal, or slightly below (as close as the serrations on the shaft will permit), when the shaft is rotated to the full-fuel position or clockwise when viewed from the front of the engine.

10. Loosen the lock nut and adjust the length of the vertical link assembly, attached to the bell crank lever, to match the full-fuel position of the governor operating lever and the injector rack control levers. This length should be approximately 6-5/16". Tighten the lock nut.

11. With the governor operating lever held in the full-fuel position, turn the load limit screw (Fig. 1) inward until the injector racks just loosen on the ball end of the control levers to prevent the injector racks from bottoming.

12. Release the governor operating lever and hold the adjusting screw while tightening the lock nut.

13. Install the governor cover.

14. Install the rocker covers.

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SUPPLEMENTARY GOVERNING DEVICE ADJUSTMENT

ENGINE LOAD LIMIT DEVICE

Engines with mechanical governors may be equipped with a load limit device (Fig. 1) to reduce the maximum horsepower.

This device consists of a load limit screw threaded into a plate mounted between two adjacent rocker arm shaft brackets and a load limit lever clamped to the injector control tube.

The load limit device is located between the No. 2 and No. 3 cylinders of a three or four cylinder engine or between the No. 1 and No. 2 cylinders of *each* cylinder head on a V-type engine. However, when valve rocker covers with a breather are used, the load limit device is installed between the No. 1 and No. 2 cylinders on **In-line** engines and between the No. 2 and No. 3 cylinders on V-type engines to avoid interference with the rocker cover baffles.

When properly adjusted for the maximum horsepower desired, this device limits the travel of the injector control racks and thereby the fuel ouput of the injectors.

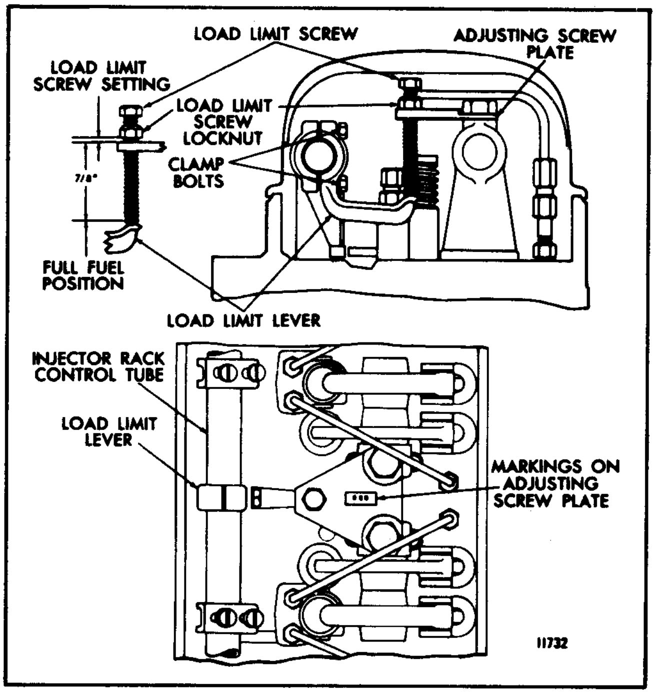

Fig. 1 - Engine Load Limit Device

Adjustment

After the engine tune-up is completed, make sure the load limit device is properly installed as shown in Fig. 1. Make sure the counterbores in the adjusting screw plate are up. The rocker arm shaft bracket bolts which fasten the adjusting screw plate to the brackets are tightened to 50-55 lb-ft (68-75 Nm) torque. Then adjust the load limit device, on each cylinder head, as follows:

1. Loosen the load limit screw lock nut and remove the screw.

2. Loosen the load limit lever clamp bolts so the lever is free to turn on the injector rack control tube.

3. With the screw out of the plate, adjust the load limit screw lock nut so the bottom of the lock nut is 7/8" from the bottom of the load limit screw for the initial setting (Fig. 1).

4. Loosen the load limit lever clamp bolts so that the lever is free to turn on the injector rack control tube.

5. Thread the load limit screw into the adjusting screw plate until the lock nut *bottoms* against the top of the plate.

6. Hold the injector rack control tube in the full-fuel position and place the load limit lever against the bottom of the load limit screw. Then tighten the load limit lever clamp bolts.

7. Check to ensure that the injector racks will just go into the full-fuel position -- readjust the load limit lever if necessary.

8. Hold the load limit screw to keep it from turning, then *set* the lock nut until the distance between the bottom of the lock nut and the top of the adjusting screw plate corresponds to the dimension (or number of turns) stamped on the plate. Each full turn of the screw equals .042", or .007" for each flat on the hexagon head.

> **NOTE:** If the plate is not stamped, adjust the load limit screw while operating the engine on a dynamometer test stand and note the number of turns required to obtain the desired horsepower. Then stamp the plate accordingly.

9. Thread the load limit screw into the plate until the lock nut *bottoms* against the top of the plate. Be sure the nut turns with the screw.

10. Hold the load limit screw to keep it from turning, then tighten the lock nut to secure the setting.

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THROTTLE DELAY MECHANISM

The throttle delay mechanism is used to retard full-fuel injection when the engine is accelerated. This reduces exhaust smoke and also helps to improve fuel economy.

The throttle delay mechanism (Fig. 2) is installed between the No. 1 and No. 2 cylinders on three cylinder engines, between the No. 2 and No. 3 cylinders on four cylinder engines, or between the No. 1 and No. 2 cylinders on the right-bank cylinder head of V-type engines. It consists of a special rocker arm shaft bracket (which incorporates the throttle delay cylinder), a piston, throttle delay lever, connecting link, orifice plug, ball check valve and U-bolt.

Effective with turbocharged engines built January, 1980 10-32x1 1/8" screws and 10-32 lock nuts are used in the lever assembly rather than 8-32 screws and lock nuts. Also, 10-32x3/4" screws and 10-32 lock nuts are used at each leg of the lever assembly, rather than 8-32 screws and nuts. The screw holes in the lever were enlarged to accommodate the 10-32 screws (Fig. 3).

NOTE: DO NOT use a 10-32 lock nut on an 8-32 screw. An 8-32 nut must be used with an 8-32 screw and a 10-32 nut used with a 10-32 screw.

Effective February, 1975, a new throttle delay lever is used on the 4 and 6V-53 engines (Fig. 3). The lever assembly consists of a throttle delay lever (not serviced separately), an 8-32 x 1-1/8" screw and a stop nut.

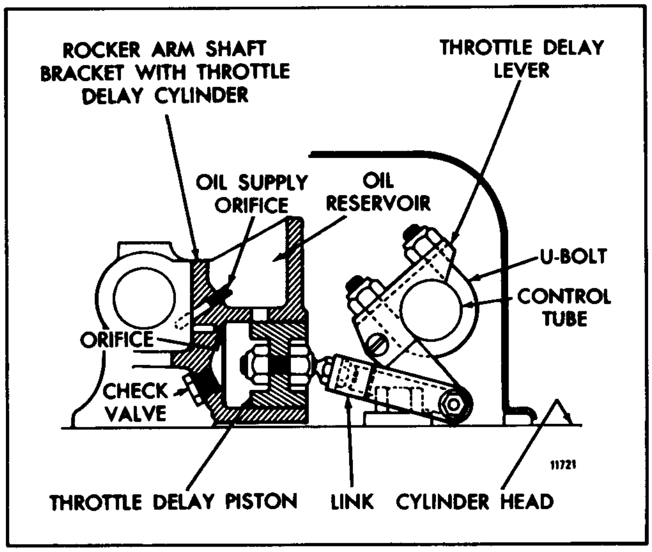

Fig. 2 - Throttle Delay Mechanism

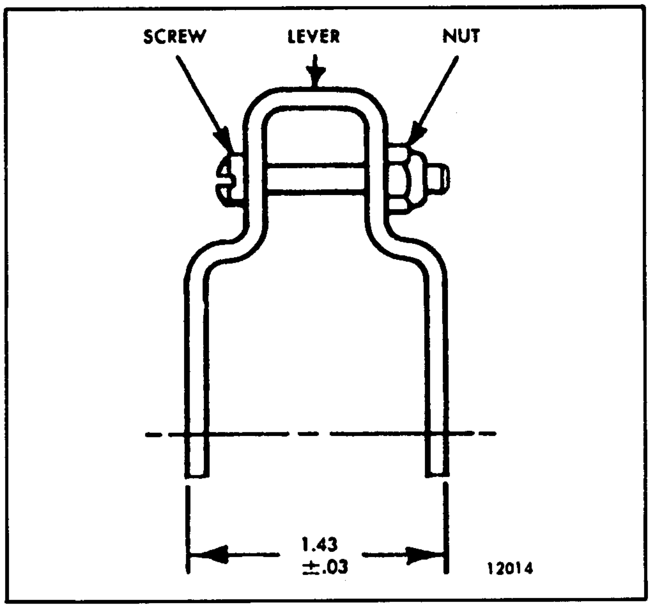

Fig. 3 - Current Throttle Delay Lever Assembly

NOTE: Install the throttle delay lever assembly on the injector control tube with the legs inward as shown in Fig. 2. A backward installation (legs outward) can result in a binding condition between the lever and the valve cover and possible loss of injector fuel control. Adjust the lever to obtain a leg width of 1.43" ±.03" (Fig. 3) to prevent binding.

Prior to May, 1973, the throttle delay lever assembly was the same as the current lever assembly, except that the lever was serviced separately and no adjustment dimension was specified.

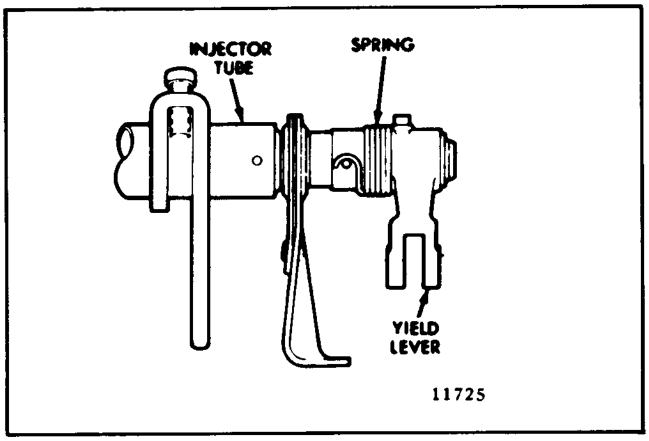

Fig. 4 - Throttle Delay Yield Lever (In-line Engine)

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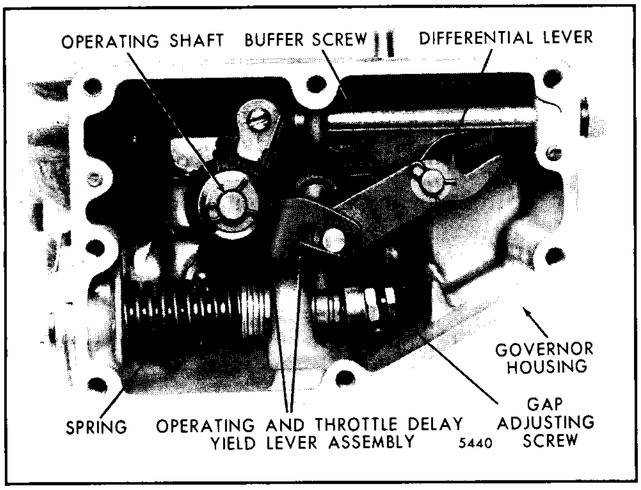

Fig. 5 - Throttle Delay Yield Lever (6V-53 Engine)

Effective May, 1973 and until February, 1975, the throttle delay lever was used with an 8-32 x 1.20" long spacer and an 8-32 x 2 1/2" screw instead of the two shorter 8-32 x 3/4" screws at each leg of the lever. Also, the 1 1/8" long adjusting screw was eliminated. The single 2 1/2" long screw and spacer was discontinued because it was found that the spacer could hit the cylinder head bolt preventing the fuel injectors from reaching full rack position.

Former engines can be updated by replacing the 1.20" long spacer and 2 1/2" screw with the shorter 3/4" screws and nuts at each leg of the throttle delay lever. Add the 1 1/8" long screw and nut to the lever.

Adjust the current throttle delay lever assembly (Fig. 3) by loosening or tightening the screw and nut in the lever to obtain a width of 1.43" ±.03" between the lever legs.

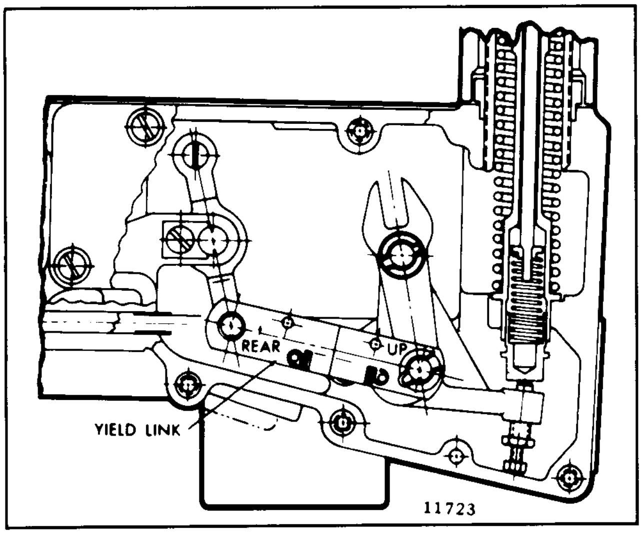

Fig. 6 - Throttle Delay Yield Link (8V-53 Engine)

NOTE: This dimension is required to prevent the lever from binding with the link.

A yield lever and spring assembly replaces the standard lever and pin assembly on the rear end of the injector control tube on In-line engines (Fig. 4). A yield lever replaces the standard operating lever in the governor of the 6V-53 engine (Fig. 5) and a yield link replaces the standard operating lever link in the 8V-53 governor (Fig. 6).

Operation

Oil is supplied to a reservoir above the throttle delay cylinder through an orifice plug in the drilled oil passage in the rocker arm shaft bracket (Fig. 2). As the injector racks are moved toward the no-fuel position, free movement of the throttle delay piston is assured by air drawn into the cylinder through the ball check valve. Further movement of the piston uncovers an opening which permits oil from the reservoir to enter the cylinder and displace the air. When the engine is accelerated, movement of the injector racks toward the full-fuel position is momentarily retarded while the piston expels the oil from the cylinder through an orifice. To permit full accelerator travel, regardless of

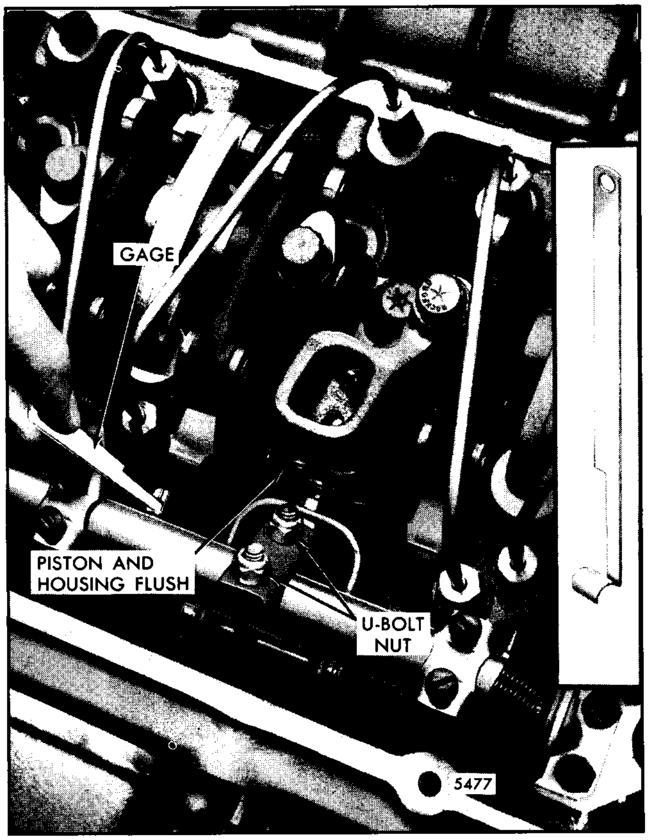

Fig. 7 - Adjusting Throttle Delay Cylinder

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the retarded injector rack position, a spring-loaded yield lever or link assembly replaces the standard operating lever connecting link to the governor.

Inspection

To inspect the check valve, fill the throttle delay cylinder with diesel fuel oil and watch for check valve leakage while moving the engine throttle from the idle position to the full-fuel position. If more than a drop of leakage occurs, replace the check valve.

Adjustment

Whenever the injector rack control levers are adjusted, disconnect the throttle delay mechanism by loosening the U-bolt which clamps the lever to the injector control tube. After the injector rack control levers have been positioned, the throttle delay mechanism must be readjusted. With the engine stopped, proceed as follows:

1. Refer to Fig. 7 and insert gage J 23190 (.454" setting) between the injector body and the shoulder on the injector rack. Then exert a light pressure on the injector control tube in the direction of full fuel.

2. Align the throttle delay piston so it is flush with the edge of the throttle delay cylinder.

3. Tighten the U-bolt on the injector control tube and remove the gage.

4. Move the injector rack from the no-fuel to the full-fuel position to make sure it does not bind.

Refer to *Engine Tune-Up* in Section 15.1 for maintenance.

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ADJUSTMENT OF MECHANICAL GOVERNOR SHUTDOWN SOLENOID

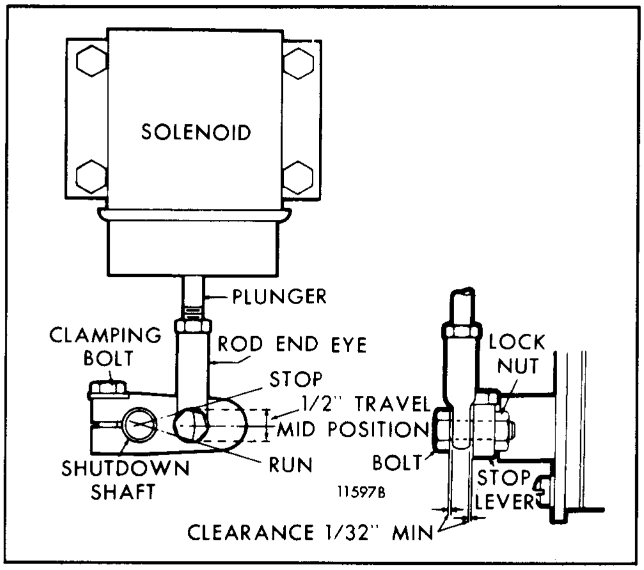

Fig. 8 - Typical Variable Speed Governor Lever Position

When a governor shutdown solenoid is used on an engine equipped with a mechanical governor, the governor stop lever must be properly adjusted to match the shutdown solenoid plunger travel.

The solenoid plunger can be properly aligned to the governor stop lever as follows:

1. Remove the bolt connecting the rod end eye (variable speed governor) or the right angle clip (limiting speed governor) to the stop lever (Figs. 8 and 9). Align and clamp the lever to the shutdown shaft in such a way that, at its mid-travel position, it is perpendicular to the solenoid plunger. This assures that the linkage will travel as straight as possible. The solenoid plunger has available 1/2″ travel which is more than adequate to move the injector control racks from the full-fuel to the complete no-fuel position and shutdown will occur prior to attaining complete travel.

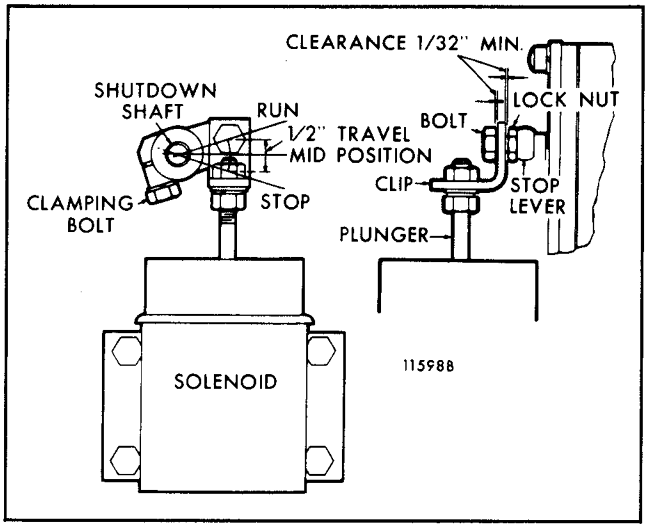

Fig. 9 - Typical Limiting Speed Governor Lever Position

2. With the stop lever in the *run* position, adjust the rod end eye or right angle clip for minimum engagement on the solenoid plunger when the connecting bolt in installed. The oversize hole in the eye or clip will thereby permit the solenoid to start closing the air gap, with a resultant build-up of pull-in force prior to initiating stop lever movement.

3. The bolt through the rod end eye or the right angle clip should be locked to the stop lever and adjusted to a height that will permit the eye or clip to float vertically. The clearance above and below the eye or clip and the bolt head should be approximately 1/32″ minimum.

NOTE: The locknut can be either on top of or below the stop lever.

4. Move the lever to the *stop* position and observe the plunger for any possible bind. If necessary, loosen the mounting bolts and realign the solenoid to provide free plunger motion.

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FUEL MODULATOR

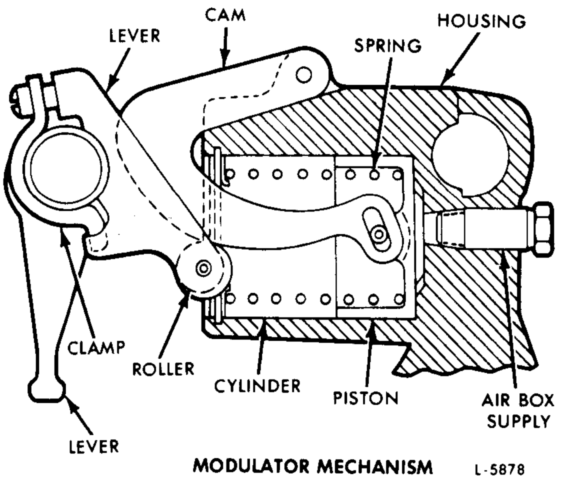

Fig. 10 - Typical Fuel Modulator Assembly

The fuel modulator, used on turbocharged engines, maintains the proper fuel to air ratio in the lower speed ranges where the mechanical governor would normally act to provide maximum injector output. It operates in such a manner that, although the engine throttle may be moved into the full-speed position, the injector racks cannot advance to the full-fuel position until the turbine speed is sufficient to provide proper combustion.

The fuel modulator will reduce exhaust smoke and also will help to improve fuel economy. The modulator mechanism is installed between the No. 1 and No. 2 cylinders.

A fuel modulator consists of a cast housing containing a cylinder, piston, cam and calibrated spring mounted on the cylinder head (Table 1). A lever and roller which controls the injector rack is connected to the injector control tube. Tubes run from the air box to the housing to supply pressure to actuate the piston.

FUEL MODULATING SPRING IDENTIFICATION

COLOR CODE	LOAD	RATE
Pink Stripe	5.61 ± 1.5 Lbs. @ 1.125 Length	6.00 Lbs. Per Inch.
Green Stripe	26.9 ± 1.34 Lbs. @ .65 Length	18.25 Lbs. Per Inch.
None	28.25 ± 1.4 Lbs. @ .65 Length	16.25 Lbs. Per Inch.

TABLE 1

The modulator tells the fuel system how much fuel the engine can efficiently use based on air box pressure. Increased air box pressure forces the piston and cam out of the cylinder bore allowing the rack to move toward full fuel. The spring is calibrated to the individual engine model air box pressure characteristics.

Whenever the fuel injector rack control levers are adjusted, the fuel (air box) modulator lever and roller assembly must first be positioned free of cam contact. This is done by loosening the clamp screw.

Inspection

At major repair or overhaul, inspect the roller and piston outer diameter and the cylinder bore inner diameter for wear. Also, inspect the operating surface, the lever roller, the roller pins at the cam pivot and the cam attachment to the piston.

The piston outer diamter must not be less than 1.6555″ and the cylinder bore inner diameter must not be more than 1.6605″

Adjust Fuel Modulator

After completing the injector rack control lever and governor adjustment, adjust the fuel modulator, as follows:

1. With the engine stopped, insert the proper gage between the injector body and the shoulder on the injector rack of the No. 2 injector which is adjacent to the modulator (Table 2).

TOOL NO.	DIM.	USAGE
J26646	.290	3, 4-53T Off-Highway, Industrial (except 4-53T with N65 injectors)
J28779	.365	4-53T Truck with 5A55 injectors and 4-53T Off-Highway Industrial with N65 injectors
J28779	.365	4-53T Truck with 5A60 injectors (except California)
J9509 C	.404	4-53T Truck with 5A60 injectors (California only)
J9509 C	.404	4-53T Truck with N65 injectors
J9509 C	.404	6V-53T Truck, Off-Highway, Industrial
J28779	.365	6V-53T Marine

TABLE 2

2. Position the governor speed control lever in the maximum speed position and the governor run stop lever in the *run* position.

3. Rotate the air box modulator lever assembly and clamp on the injector control tube until the lever roller contacts the modulator cam with sufficient force to take up the pin clearance (Fig. 10).

4. Check to make sure only the roller contacts the cam and not the lever stamping. Tighten the lever and clamp screw. After tightening, check to make sure that the gage is still in contact with the injector body and the shoulder on the injector rack of the No. 2 injector.

5. Remove the gage from between the injector body and the shoulder on the injector rack.

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SECTION 15

PREVENTIVE MAINTENANCE

TROUBLE SHOOTING - STORAGE

CONTENTS

Lubrication and Preventive Maintenance 15.1

Trouble Shooting 15.2

Storage 15.3

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LUBRICATION AND PREVENTIVE MAINTENANCE

The *Lubrication and Preventive Maintenance Schedule* is intended as a guide for establishing a preventive maintenance schedule. The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from a Detroit Diesel engine. The intervals indicated on the chart are time or miles (in thousands) of actual operation.

MAINTENANCE SCHEDULE EXPLANATION

The time or mileage increments shown apply only to the maintenance function described. These functions should be coordinated with other regularly scheduled maintenance such as chassis lubrication.

The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out the instructions given under *Preparation for Starting Engine First Time* under *Operating Instructions* in Section 13.1.

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EMISSION CONTROL MAINTENANCE SERVICE CHART
(VEHICLE ENGINES)

DAILY	
1. — Lubricating Oil	Ⓘ
2. — Fuel Tank	Ⓘ
3. — Fuel Lines and Flexible Hoses	Ⓘ
4. — Cooling System	Ⓘ
5. — Turbocharger	Ⓘ
3000 MILE INTERVALS	
6. — Battery	Ⓘ
7. — Tachometer Drive	Ⓘ
4000-6000 MILE INTERVALS	
8. — Air Cleaner (oil bath)	Ⓘ
9. — Drive Belts	Ⓘ
10. — Air Compressor	Ⓘ
11. — Throttle Control	Ⓘ
15,000 MILE INTERVALS	
(2.) — Fuel Tank	Ⓘ
(8.) — Air Cleaner (oil bath)	Ⓘ
25,000 MILE INTERVALS	
12. — Lubricating Oil Filter	Ⓡ

6 MONTHS OR 10,000 MILE INTERVALS	MONTHS / MILES (1000)	6 / 10	12 / 20	18 / 30	24 / 40	30 / 50	36 / 60	42 / 70	48 / 80	54 / 90	60 / 100
13. — Fuel Filter		Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ
14. — Coolant Filter and Water Pump		Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ
15. — Starting Motor		Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ
(2.) — Fuel Tank			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
(4.) — Cooling System (hoses)			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
(10.) — Air Compressor			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
16. — Air System			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
17. — Exhaust System			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
18. — Air Box Drain Tube				Ⓘ			Ⓘ			Ⓘ	
19. — Emergency Shutdown			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
20. — Engine (steam clean)			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
21. — Radiator			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
22. — Shutter Operation			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
23. — Oil Pressure			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
24. — Governor						Ⓘ					Ⓘ
25. — Fuel Injector & Valve Clearance						Ⓘ					Ⓘ
26. — Throttle Delay						Ⓘ					Ⓘ
27. — Generator or Alternator*											
28. — Engine & Transmission Mounts							Ⓘ				
29. — Crankcase Pressure							Ⓘ				
30. — Air Box Check Valves											Ⓘ
(1.) — Lubricating Oil*											
31. — Fan Hub*											

ANNUALLY	
(3.) — Fuel Lines and Flexible Hoses	Ⓘ
(4.) — Cooling System	Ⓘ
(8.) — Air Cleaners	Ⓘ
32. — Thermostats & Seals	Ⓘ
33. — Blower Screen	Ⓘ
34. — Crankcase Breather	Ⓘ
35. — Fan (thermo-modulated)	Ⓘ
AS REQUIRED	
36. — Engine Tune-Up	

Ⓘ= INSPECT, CORRECT OR REPLACE (IF NECESSARY)

Ⓡ= REPLACE

*** = SEE ITEM**

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INDUSTRIAL OFF HIGHWAY AND MARINE	TIME INTERVALS										
HRS. / MILES	DLY.	8 / 240	50 / 1,500	100 / 3,000	150 / 4,500	200 / 6,000	300 / 9,000	500 / 15,000	700 / 20,000	1,000 / 30,000	2,000 / 60,000
1. — Lubricating Oil	X				X						
2. — Fuel Tank	X							X	X		
3. — Fuel Lines and Flexible Hoses	X							X		X	
4. — Cooling System	X								X	X	
5. — Turbocharger	X										
6. — Battery				X							
7. — Tachometer Drive				X							
8. — Air Cleaners		X						X			
9. — Drive Belts		X				X					
10. — Air Compressor						X			X		
11. — Throttle and Clutch Controls						X					
12. — Lubricating Oil Filter							X			X	
13. — Fuel Strainer and Filter							X				
14. — Coolant Filter and Water Pump*								X			
15. — Starting Motor*											
16. — Air Systems									X		
17. — Exhaust System									X		
18. — Air Box Drain Tube										X	
19. — Emergency Shutdown									X		
21. — Radiator									X		
22. — Shutter Operation									X		
23. — Oil Pressure									X		
24. — Overspeed Governor								X			
26. — Throttle Delay*											
27. — Battery-Charging Alternator						X					
28. — Engine and Transmission Mounts											X
29. — Crankcase Pressure											X
30. — Air Box Check Valves*											
31. — Fan Hub*									X		
32. — Thermostats and Seals*									X		
33. — Blower Screen										X	
34. — Crankcase Breather										X	
36. — Engine Tune-Up*											
37. — Heat Exchanger Electrodes								X		X	
38. — Raw Water Pump	X										
39. — Power Generator				X			X				
40. — Power Take-Off		X	X					X			
41. — Marine Gear	X					X					
42. — Torqmatic Converter	X		X					X			
41. — Marine Gear	X					X				X	
42. — Torqmatic Converter	X		X					X		X	
46. — Hydrostarter System*											

*See Item

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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 Section 13.3).

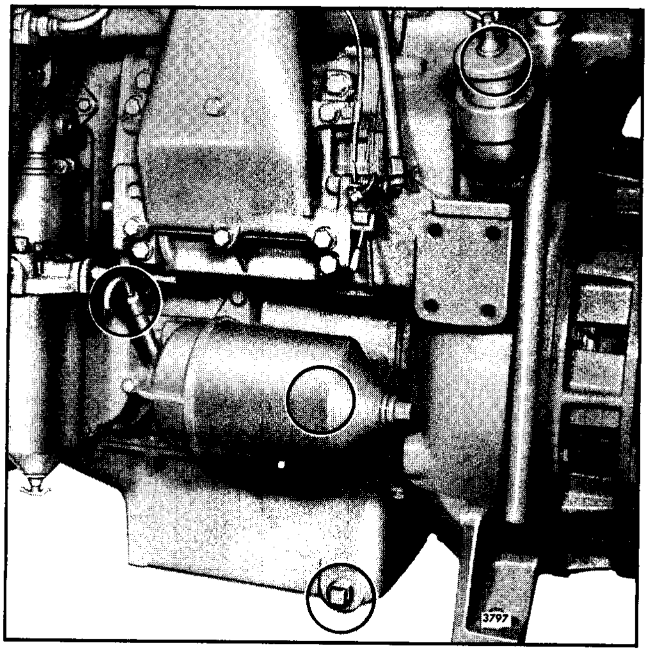
NOTE: Oil may be blown out through the crankcase breather if the crankcase is overfilled.

Make a visual check for oil leaks around the filters and the external oil lines.

Change the lubricating oil at the intervals shown in the Chart.

ENGINE OIL CHANGE INTERVALS (MAX.)			
Service Application	Diesel Fuel Sulfur Content % by Wt. Max.		
	0 to 0.50	0.51 to 0.75	0.76 to 1.00
Hyw. Truck & Inter-City Buses	20,000 Miles	20,000 Miles	10,000 Miles
City Transit Coaches & Pickup Delivery Truck Service	12,500 Miles	2,500 Miles	1,250 Miles
Industrial & Marine	150 Hours	30 Hours	15 Hours*

*These oil change intervals are based upon worst case with chrome-faced rings. Oil change periods with plasma-faced rings can be established by oil analysis.



Items 1 and 12

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 *Lubrication Specifications* in Section 13.3.

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 Tanks

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* in Section 13.3.

Open the drain at the bottom of the fuel tank every 500 hours or 15,000 miles to drain off any water and/or sediment.

Every 12 months or 20,000 miles (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 fuel systems 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 isopropy 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).

The microbes live in the fuel-water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, non-turbulent nature of the fuel tank.

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Microbe growth can be eliminated through the use of commerically available biocides. There are two basic types on the market.

The water soluble type treats *only the tank* where it is introduced. Microbe growth can start again if fuel is transferred from a treated to an untreated tank.

Diesel fuel soluble type, such as "Biobor" manufactured by U. S. Borax or equivalent, treats *the fuel* itself and therefore the entire fuel system.

Units going into storage should be treated as follows: Add the biocide according to the manufacturer's instructions. This operation is most effective when performed as the tank is being filled. Add dry gas in the correct proportions.

If the fuel tanks were previously filled, add the chemicals and stir with a clean rod.

Item 3 - Fuel Lines and Flexible Hoses

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.

The performance of engine and auxiliary equipment is greatly dependent on the ability of flexible hoses to transfer lubricating oil, air, coolant and fuel oil. Diligent maintenance of hoses is an important step in ensuring efficient, economical and safe operation of the engine and related equipment.

Check hoses daily as part of the pre-start up inspection. Examine hoses for leaks and check all fittings, clamps and ties carefully. Make sure that hoses are not resting or touching shafts, couplings, heated surfaces including exhaust manifolds, any sharp edges or other obviously hazardous areas. Since all machinery vibrates and moves to a certain extent, clamps and ties can fatigue with age. To ensure continued proper support, inspect fasteners frequently and tighten or replace them, as necessary.

Leaks

Investigate leaks immediately to determine if fittings have looseded or cracked or if hoses have ruptured or worn through. Take corrective action immediately. Leaks are not only potentially detrimental to machine operation, but they also result in added expense caused by the need to replace lost fluids.

CAUTION: Personal injury and/or property damage may result from fire due to the leakage of flamable fluids such as fuel or lube oil.

Service Life

A hose has a finite service life. The service life of a hose is determined by the temperature and pressure of the air or fluid within it, its time in service, its mounting, the ambient temperatures, amount of flexing and vibration it is subject to. With this in mind, all hoses should be thoroughly inspected at least every 500 operating hours (1,000 hours for the fire-resistant fuel and lube hoses and heat-insulating turbo/exhaust system blanket) and/or annually. Look for cover damage or indications of damaged twisted, worn, crimped, brittle, cracked or leaking lines. Hoses having the outer cover worn through or damaged metal reinforcement should be considered unfit for further service.

All hoses in or out of machinery should be replaced during major overhaul and/or after a maximum of five years service.

NOTE: The new hose assemblies do not require automatic replacement after five years of service or at major overhaul.

Item 4 - Cooling System

Before starting the engine, always check the coolant level. Make sure the coolant 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 (vehicle engines) or every 1,000 hours (30,000 miles - non-vehicle engines) 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 an ethylene glycol base antifreeze (refer to *Engine Coolant* in Section 13.3). 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.

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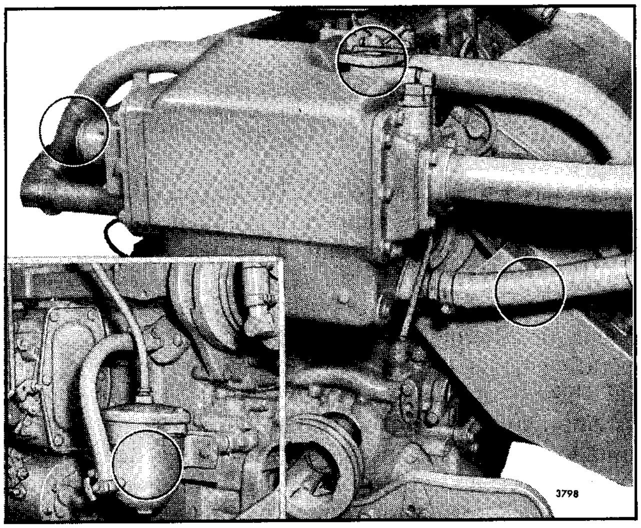


Items 4 and 14

Inspect all of the cooling system hoses at least once every 12 months or 20,000 miles (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 - Turbocharger

Inspect the mountings, intake and exhaust ducting and connections for leaks. Check the oil inlet and outlet lines for leaks or restrictions to oil flow. Check for unusual noise or vibration and, if excessive, remove the turbocharger and correct the cause.

Item 6 - Battery

Check the specific gravity of the electrolyte in each cell of the battery every 100 hours or 3,000 miles. 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 7 - Tachometer Drive

Lubricate the tachometer drive every 100 hours or 3,000 miles with an all purpose grease at the grease fitting. At temperatures above +30° F (−1° C), use a No. 2 grade grease. Use a No. 1 grade grease below this temperature.

Item 8 - Air Cleaner

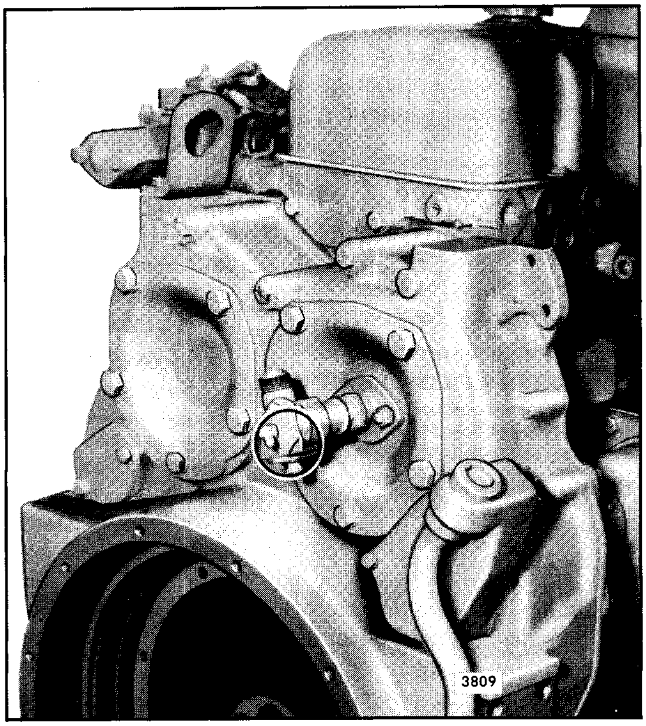
Under no engine operating conditions should the air inlet restriction exceed 25 inches of water (6.2 kPa) for non-turbocharged engines or 20 inches of water (5.0 kPa) for turbocharged engines. A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine.

Oil Bath

Remove the dirty oil and sludge from the oil bath type air cleaner cups and center tubes every 8 hours (every 6,000 miles for highway vehicle engines), or less if operating conditions warrant. Wash the cups and elements in clean fuel oil and refill the cups to the level mark with the same grade and viscosity *heavy-duty* oil as used in the engine. The frequency of servicing may be varied to suit local dust conditions. If heavy rain or snow has been encountered, check the air cleaner for an accumulation of water.

Remove and steam clean the air cleaner element and baffle annually.

It is recommended that the body and fixed element in the heavy-duty oil bath type air cleaner be serviced every 500 hours or 15,000 miles or as conditions warrant.



Item 7

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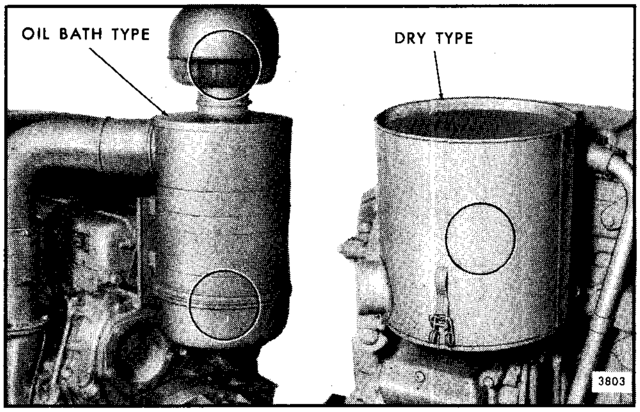
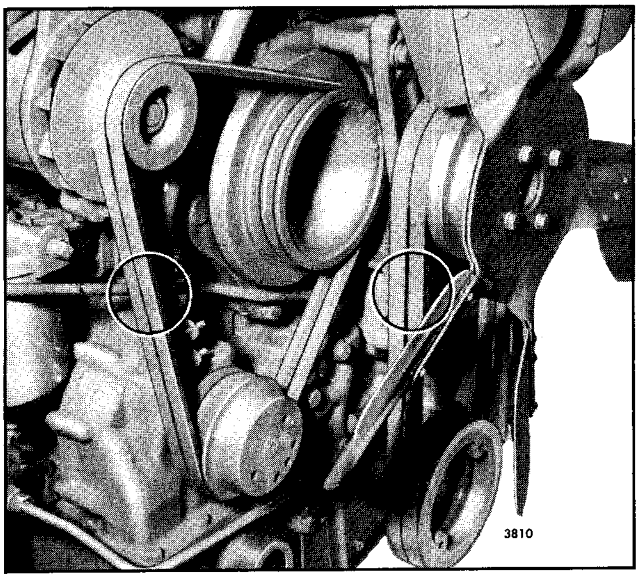


Item 8

Dry Type

Dry type air cleaner elements (Donaldson, Farr, etc.) used in on-highway applications should be discarded and replaced with new elements after one year of service, after 100,000 miles (Donaldson's recommended mileage interval) or when the maximum allowable air intake restriction has been reached (see Section 13.2), whichever comes first. No attempt should be made to clean or reuse on-highway elements after these intervals.

Dry type elements used in off-highway applications 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 Section 13.2), 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. Secondary (safety) elements should **not** be cleaned or reused. Inspection and replacement of the cover gaskets must also be done per the manufacturer's recommendations.



Item 9

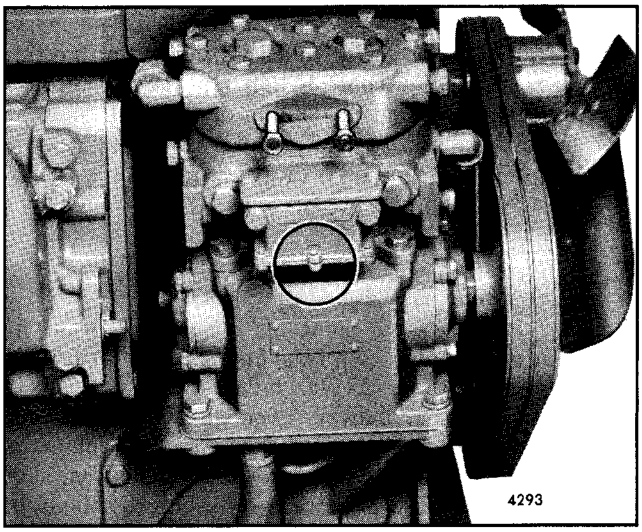
Item 9 - Drive Belts

New drive belts stretch during the first few hours of operation. Run the engine 15 *seconds* to seat the belts, then readjust the tension. Check the belts and tighten the fan drive, pump drive, battery-charging generator or alternator and other accessory drive belts after 1/2 hour or 15 miles and again after 8 hours or 240 miles of operation. Thereafter check the tension of the drive belts every 200 hours or 6,000 miles and adjust, if necessary. Belts should be neither too tight nor too loose. Belts which are too tight impose excess loads on cranksahft, fan and/or alternator bearings, shortening both belt and bearing life. Excessively overtightened belts can result in crankshaft breakage. 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". If belt tension gage J 23600-B or equivalent, is available, adjust the belt tension as outlined in the chart.

NOTE: When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory



Item 10

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Model	Fan Drive		Alternator/Generator Drive		
	2 or 3 belts	Single belt	Two 3/8" or 1/2" belts	One 1/2" belt	One Wide belt
3, 4-53	40-50	—	40-50	50-70	40-50
6, 8V-53	60-80	80-100	40-50	50-70	40-50
All	For 3-point or triangular drive use a tension of 90-120.				

BELT TENSION CHART (lbs/belt)

adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

Item 10 - Air Compressor

Remove and clean all air compressor air intake parts every 200 hours or 6,000 miles. To clean either the hair or polyurethane type element, saturate and squeeze it in fuel oil, or any other cleaning agent that would not be detrimental to the element, until dirt free. Then, dip it in lubricating oil and squeeze it dry before placing the element back in the air strainer.

For replacement of the air strainer element, contact the nearest Bendix Westinghouse dealer; replace with the polyurethane element, if available.

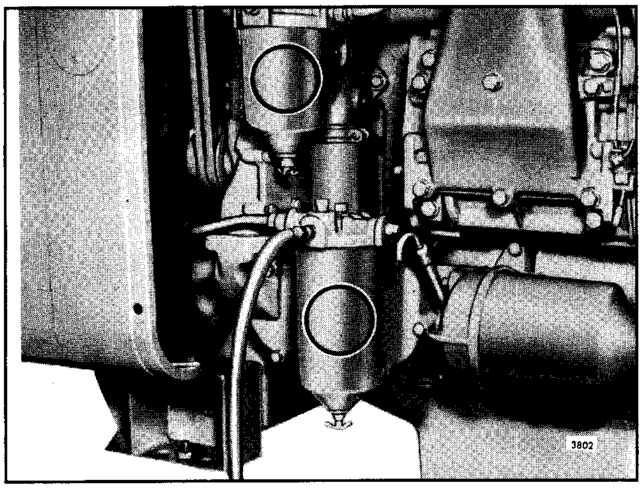
Every 12 months or 20,000 miles (700 hours) tighten the air compressor mounting bolts. If the air compressor is belt driven, check the belts for proper tension.

Item 11 - Throttle Control

Every 200 hours or 6,000 miles lubricate the limiting speed governor speed control shaft (In-line 53) through a grease fitting located in the end of the shaft. Use an all purpose grease (No. 2 grade) at temperatures +30° F (−1° C) and above. At temperatures below this use a No. 1 grade grease.

Item 12 - Lubricating Oil Filter

Install new oil filter elements and gaskets at 20,000 miles-highway truck, 25,000 miles - city coaches of 24,000 pick-up and delivery (vehicle engines) or 300 hours (non-vehicle engines) or each time the engine oil is changed, whichever comes 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.



Item 13

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.

When the engine is equipped with a turbocharger, pre-lubricate it as outlined under *Install Turbocharger* in Section 3.5 or 3.5.1.1.

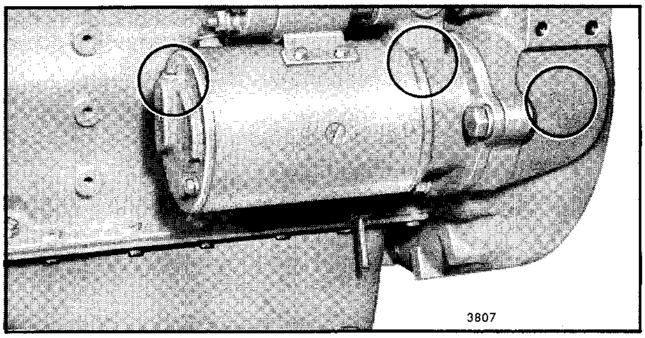
If the engine is equipped with a governor oil filter, change the element every 1,000 hours or 30,000 miles.

Check for oil leaks after starting the engine.

Item 13 - Fuel Filter

Install new elements every 6 months or 10,000 miles (vehicle engines) and 300 hours or 9,000 miles (non-vehicle engines) 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



Item 15

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exceed 6 inches of mercury (20.3 kPa). At normal operating speeds, the fuel pressure is 45 to 70 psi (310 to 483 kPa). Change the fuel filter elements whenever the inlet restriction (suction) 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 14 - Coolant Filter & Water Pump

If the cooling system is protected by a coolant filter and conditioner, the filter element should be changed every 6 months or 10,000 miles (vehicle engines) and 500 hours or 15,000 miles (non-vehicle engines). Select the proper coolant filter element in accordance with the instructions given under *Coolant Specifications* in Section 13.3. Use a new filter cover gasket when installing the filter element. After replacing the filter and cover gasket, start the engine and check for leaks.

Inspect the water pump drain hole every 6 months for plugging. If plugged, clean out the drain hole with a tool made from a front crankshaft seal or equivalent.

Replace the water pump seal after it has been in service for 200,000 miles or 6,000 hours.

Item 15 - Starting Motor

VEHICLE ENGINES

Starting motors which are provided with lubrication fittings (grease cups, hinge cap oilers or oil tubes sealed with pipe plugs) should be lubricated every 6 months or 10,000 miles. Add 8 to 10 drops of oil, of the same grade as used in the engine, to hinge cap oilers; if sealed tubes are provided, remove the pipe plugs, add oil and reseal the tubes. Grease cups should be turned down one turn. Refill the grease cups, if necessary. However, some starting motors do not require lubrication except during overhaul.

NON-VEHICLE ENGINES

The electrical starting motor is lubricated at the time of original assembly. Oil can be added to the oil wicks, which project through each bushing and contact the armature shaft, by removing the pipe plugs on the outside of the motor. The wicks should be lubricated whenever the starting motor is taken off the engine or disassembled.

The Sprag overrunning clutch drive mechanism should be lubricated with a few drops of light engine oil whenever the starting motor is overhauled.

Item 16 - 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 17 - 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, if one is used.

Item 18 - Air Box Drain Tubes

With the engine running, check for flow of air from the air box drain tubes every 18 months or 30,000 miles (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.

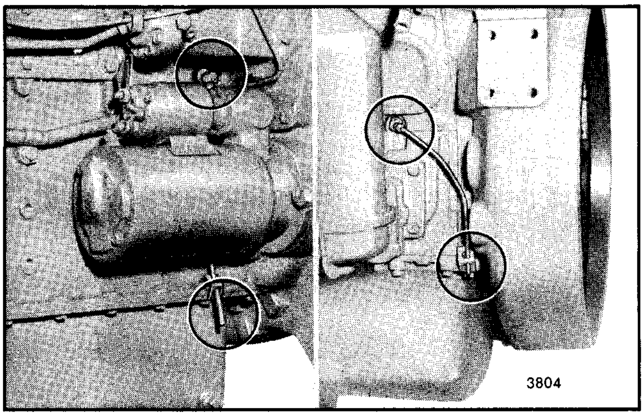
If the engine is equipped with an air box drain tank, drain the sediment periodically.

Item 19 - Emergency Shutdown

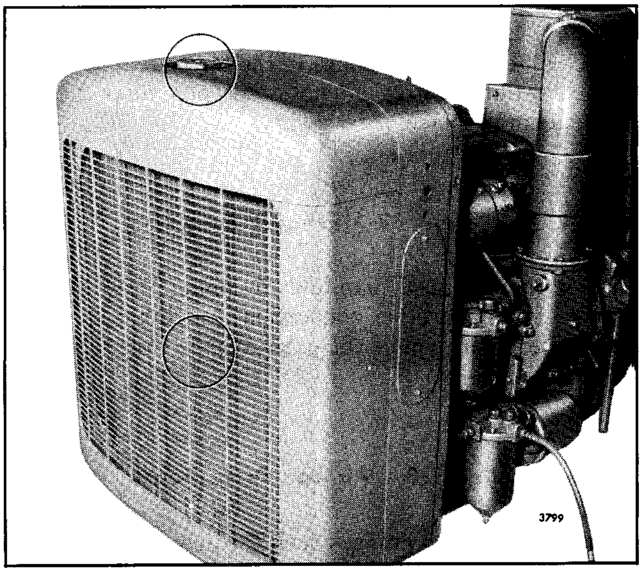
With the engine running at idle speed, check the operation of the emergency shutdown every 12 months or 20,000 miles. Reset the air shurdown valve in the open position after the check has been made.

Item 20 - Engine (Steam Clean)

Steam clean the engine and engine compartment.



Item 18



Item 21

NOTE: Do not apply steam or solvent directly on the battery-charging generator/alternator, starting motor or electrical components as damage to electrical equipment may result.

Item 21 - Radiator

Inspect the exterior of the radiator core every 12 months or 20,000 miles (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 22 - Shutter Operation

Check the operation of the shutters and clean the linkage and controls.

Item 23 - 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 or 20,000 miles.

Item 24 - 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.

Overspeed Governor

Lubricate the overspeed governor, if it is equipped with a hinge-type cap oiler or oil cup, with 5 or 6 drops of engine oil every 500 hours or 15,000 miles. Avoid excessive lubrication and do not lubricate the governor while the engine is running.

Item 25 - Fuel Injectors and Valve Clearance

Check the injector timing and exhaust valve clearance as outlined in Section 14.2 and 14.1 every 50,000 miles. The proper height adjustment between the injector follower and injector body is of primary importance to emission control.

Item 26 - Throttle Delay

Inspect and adjust, if necessary, every 30 months or 50,000 miles.

The throttle delay system limits the amount of fuel injected during acceleration by limiting the rate of injector rack movement with a hydraulic cylinder. The initial location of this cylinder must be set with the proper gage to achieve the appropriate time delay (Section 14.14).

Inspect the check valve by filling the throttle delay cylinder with diesel fuel and watching for valve leakage while moving the throttle from the idle to the full-fuel position. If more than a drop of fuel oil leaks, replace the check valve.

Item 27 - Generator or Alternator

Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.

VEHICLE ENGINES

If the battery-charging generator or alternator is equipped with hinge cap oilers, add a few drops of medium grade engine oil to each oiler during the unit or vehicle lubrication period. Alternators having a built-in supply of grease or sealed bearings require no additional lubrication except during engine or unit overhaul.

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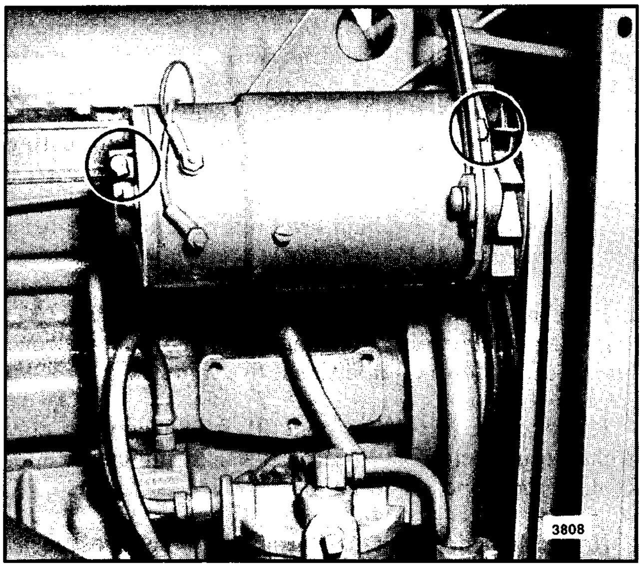


Item 27

NON-VEHICLE ENGINES

Lubricate the battery-charging genrator (alternator) bearings or bushings with 5 or 6 drops of engine oil at the hinge cap oiler every 200 hours or 6,000 miles.

On early generators equipped with grease cups, turn the cups down one full turn every 100 hours or 3,000 miles of operation. Keep the grease cups filled with *Delco-Remy Cam and Ball Bearing Lubricant*, or equivialent. Avoid excessive lubrication since this may cause lubricant to be forced onto the commutator.

Some generators or alternators have a built-in supply of grease, while others use sealed bearings. In these latter two cases, additional lubrication is not necessary.

On generators, inspect the commutator and brushes every 500 hours or 15,000 miles. Clean the commutator every 2,000 hours or 60,000 miles, if necessary, with No. 00 sandpaper or a brush seating stone. After cleaning reseat the brushes and blow out the dust.

On alternators, 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 28 - Engine and Transmission Mounts

Check the engine and transmission mounting bolts and the condition of the mounting pads every 36 months or 60,000 miles (2,000 hours). Tighten and repair as necessary.

Item 29 - Crankcase Pressure

Check and record the crankcase pressure every 36 months or 60,000 miles (2,000 hours) (refer to Section 15.2).

Item 30 - Air Box Check Valves

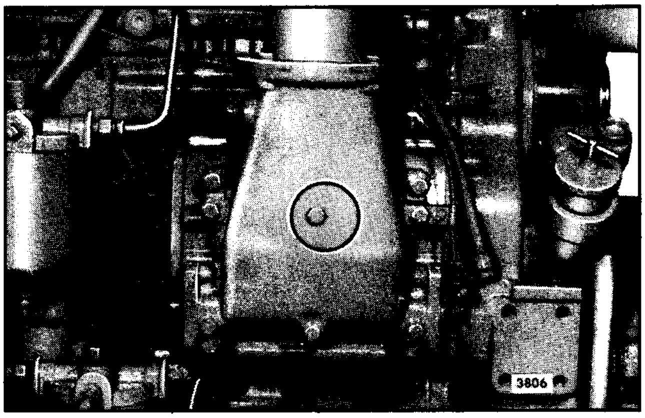
Every 100,000 miles or approximately 3,000 hours remove the check valves, clean them in solvent and blow out the lines with compressed air. Inspect for leaks after servicing.

Item 31 - Fan Hub

If the fan bearing hub assembly is provided with a grease fitting, 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 12 months or 20,000 milles (700 hours).

Every 2,500 hours or 75,000 miles (vehicle engines) and 4000 hours (non-vehicle engines) clean, inspect and repack the fan bearing hub assembly with the above recommended grease (refer to Section 5.4).

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 33

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Item 32 - Thermostats and Seals

Check the thermostats (see Section 5.2.1) and seals at 5,000 hours (non-highway engines), 200,000 miles (highway engines) or once a year (preferably at the time the cooling system is prepared for winter operation). The thermostats should *always* be replaced at overhaul. Replace the seals, if necessary.

Item 33 - Blower Screen

Inspect the blower screen and gasket assembly annually (vehicle engines) or every 1,000 hours or 30,000 miles (non-vehicle engines) and, if necessary, clean the screen in fuel oil and dry it with compressed air. Install the screen and gakset assembly with the screen side of the assembly toward the blower. Inspect for evidence of blower seal leakage.

Item 34 - Crankcase Breather

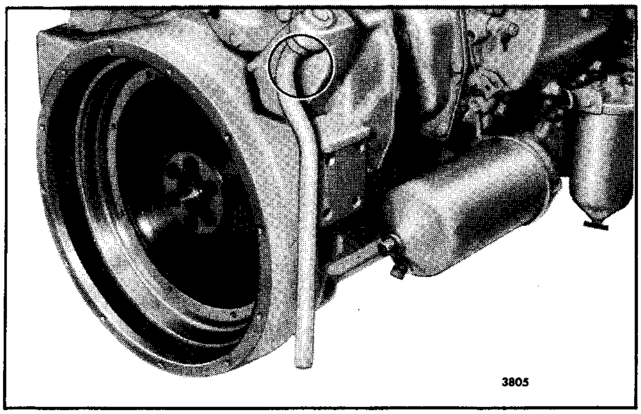
Remove the externally mounted crankcase breather assembly annually (vehicle engines) or every 1,000 hours or 30,000 miles (non-vehicle engines) and wash the steel mesh pad in clean fuel oil. This cleaning period may be reduced or lengthened according to severity of service.

Clean the breather cap, mounted on the valve rocker cover, in clean fuel oil every time the engine oil is changed.

Item 35 - Fan (Thermo-Modulated)

DRIVE FLUID LEVEL:

Check the fan drive fluid level to avoid improper operation and damage to the drive components.



Item 34

Current modulated fan drive housings have an inspection plug for checking the fluid level. Formerly partial disassembly of the drive was necessary to make the fluid level check. Former units can be updated by installing a current drive housing which includes the fluid inspection plug and a grease fitting for lubricating the bearing.

1. Check the fan drive fluid level after the unit has been idle for at least 1/2 hour.

2. Turn the fan drive so that the inspection plug is 3/4" below the horizontal center line, then allow the silicone fluid to drain down an additional five minutes.

3. Remove the inspection plug. If fluid begins to flow from the inspection hole, the drive has sufficient fluid. Replace the inspection plug.

4. If the fluid does not flow from the hole, proceed as follows:

a. Rotate the fan drive downward and observe when the fluid begins to flow from the hole. If it is necessary to lower the drain hole more than 2" below the horizontal center line, the fan drive should be removed from the engine, disassembled and inspected for possible damage to the components.

b. Turn the fan drive back so the inspection hole is 3/4" below the horizontal center line and add fluid until the overflow point is reached. Replace the inspection plug.

NOTE: Use only the manufacturer's Special 20 Cenistroke fluid.

DRIVE BEARING LUBRICATION:

The fan drive bearing should be lubricated as outlined in the chart with a Medium Consistency Silicone Grease (Dow Corning No. 44, or equivalent).

The bearing on current fan assemblies is lubricated through a grease fitting in the drive housing hub. Lubrication of the bearing in former assemblies requires the removal of the fan assembly and partial disassembly. The former assemblies can be updated to include a grease fitting by installing the current housing.

Item 36 - Engine Tune-Up

There is no scheduled interval for performing a complete engine tune-up. As long as the engine performance is satisfacotry, a complete tune-up should not be required. Minor adjustments such as injector timing, exhaust valve clearance, governor and throttle

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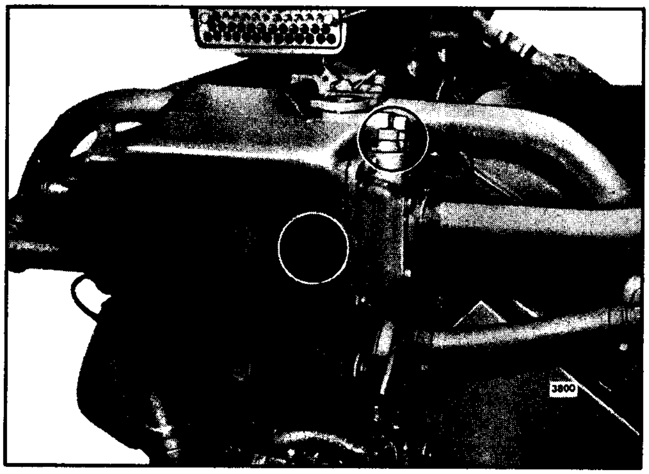


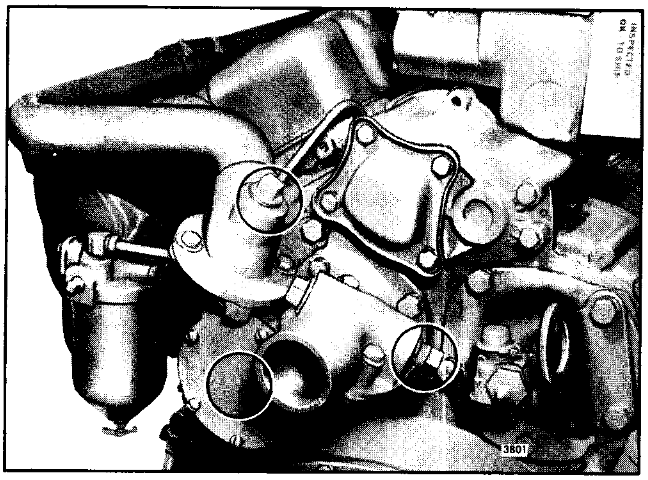
Item 37

delay (Items 24, 25 and 26) should be made every 50,000 miles to compensate for normal wear on parts.

Item 37 - Heat Exchanger Electrodes

Every 500 hours, drain the water from the heat exchanger raw water inlet and outlet tubes. Then remove the zinc electrodes from the inlet side of the raw water pump and the heat exchanger. Clean the elctrodes with a wire brush or, if worn excessively, replace with new electrodes. To determine the condition of a used electrode, strike it sharply against a hard surface; a weakened electrode will break.

Drain the cooling system, disconnect the raw water pipes at the outlet side of the heat exchanger and remove the retaining cover every 1,000 hours (30,000 miles) and inspect the heat exchanger core. If a



Item 38

considerable amount of scale or deposits are present, clean the core as outlined in Section 5.5.

Item 38 - Raw Water Pump

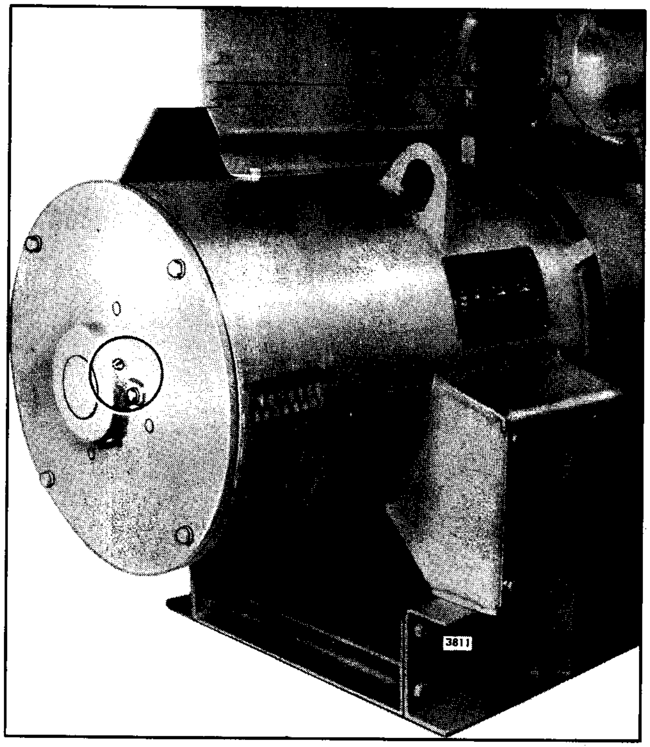
Check the prime on the raw water pump; the engine should not be operated with a dry pump. Prime the pump, if necessary, by removing the pipe plug provided in the pump inlet elbow and adding water. Reinstall the plug.

Item 39 - Power Generator

The power generator requires lubrication at only one point -- the ball bearing in the end frame.

If the bearing is oil lubricated, check the oil level in the sight gage every 300 hours (9,000 miles); change the oil every six months. Use the same grade and viscosity *heavy-duty* oil as specified for the engine. Maintain the oil level to the line in the sight gage. *Do not overfill.* After adding oil, recheck the oil level after running the generator for several minutes.

If the bearing is grease lubricated, a new generator has sufficient grease for three years of normal service. Thereafter, it should be lubricated at one year intervals. To lubricate the bearing, remove the filler and relief plugs on the side and the mottom of the



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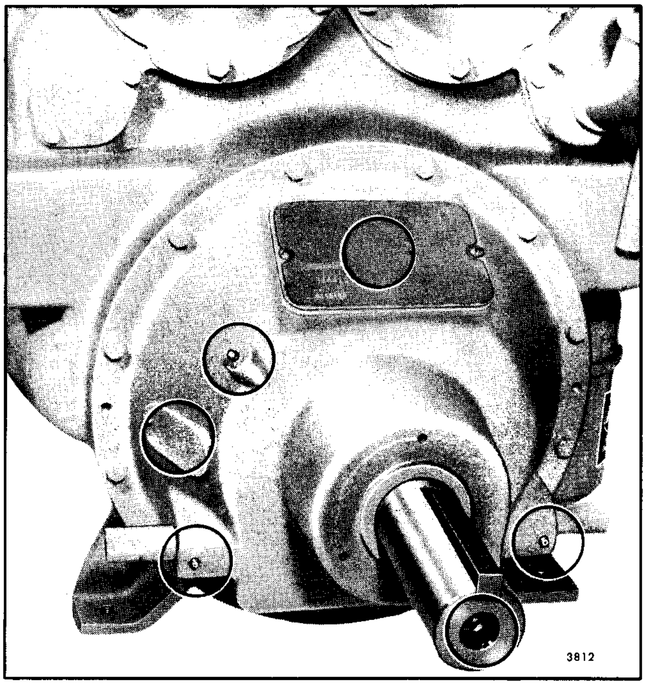
bearing reservoir. Add grease until new grease appears at the relief plug opening. Run the generator a few minutes to vent the excess grease; then reinstall the plugs.

The following greases, or their equivalents, are recommended:

Keystone 44H	Keystone Lubrication Co.
BRB Lifetime	Socony Vacuum Oil Co.
NY and NJ F926 or F927	NY and NJ Lubricant Co.

After 100 hours (3,000 miles) on new brushes, or brushes is generators that have not been in use over a long period, remove the end frame covers and inspect the brushes, commutator and collector rings. If there is no appreciable wear on the brushes, the inspection interval may be extended until the mose praticable period has been established (not to exceed six months). To prevent damage to the commutator or the collector rings, do not permit the brushes to become shorter than 3/4 inch.

Keep the generator clean inside and out. Before removing the end frame covers, wipe off the loose dirt. The loose dirt and dust may be blown out with low pressure air (25 psi or 172 kPa maximum). Remove all greasy dirt with a cloth.



Item 40

Item 40 - Power Take-Off

Lubricate all of the power take-off bearings with a all purpose grease such as Shell Alvania No. 2, or equivalent. Lubricate spraingly to avoid getting grease on the clutch facings.

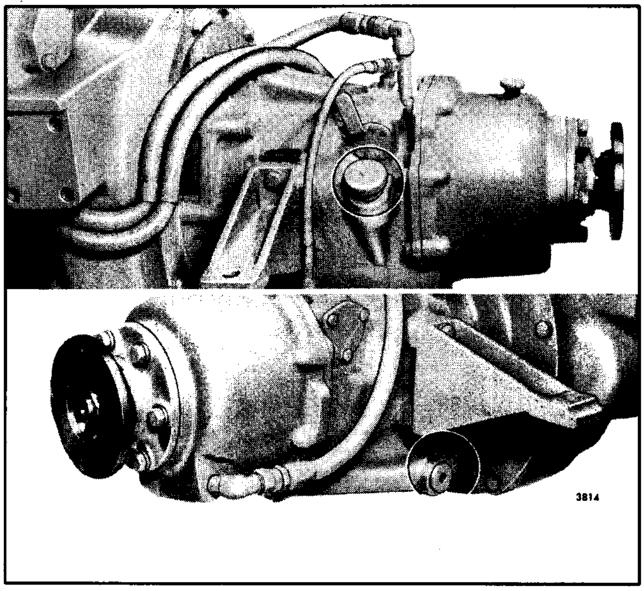
Open the cover on the side of the clutch housing (8" and 10" diameter clutch) and lubricate the clutch release sleeve collar through the grease fitting every 8 hours (240 miles). On the 11-1/2" diameter clutch, lubricate the collar through the fitting on the side of the clutch housing every 8 hours (240 miles).

Lubricate the clutch drive shaft pilot bearing through the fitting in the outer end of the drive shaft (8" and 10" diameter clutch power take-offs) every 50 hours (1500 miles) of operation. One or two strokes with a grease gun should be sufficient. The clutch drive shaft pilot bearing used with the 11-1/2" diameter clutch power take-off is prelubricated and does not require lubrication.

Lubricate the clutch drive shaft roller bearings through the grease fitting in the clutch housing every 50 hours (1,500 miles under normal operating comditions (not continuous) and more often under severe operating conditions or continuous operation.

Lubricate the clutch release shaft through the fittings at the rear of the housing every 500 hours (15,000 miles) of operation.

Lubricate the clutch levers and links spraingly with engine oil every 500 hours (15,000 miles) of operation. Remove the inspection hole cover on the clutch



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housing and lubricate the clutch release levers and pins witroiler.h a hand oiler. To avoid getting oil on the clutch facing, do not over lubricate the clutch release levers and pins.

Check the clutch facing for wear every 500 hours (15,000 miles). Adjust the clutch if necessary.

Item 41 - Marine Gear

WARNER MARINE GEAR:

Check the oil level daily. Start and run the engine at idle speed for a few minutes to fill the lubrication system. Stop the engine. Then, immediately after stopping the engine, check the oil level in the marine gear. Bring the oil level up to the proper level on the dipstick. Use the same grade and viscosity *heavy-duty* oil as used in the engine. *Do not overfill.*

Change the oil every 200 hours (6000 miles). After draining the oil from the unit, clean the removable oil screen thoroughly before refilling the marine gear with oil.

TWIN DISC MARINE GEAR:

Check the oil level daily. Check the oil level with the engine running at low idle speed and the gear in neutral. Keep the oil up to the proper level on the dipstick. Use the same grade and viscosity *heavy-duty* oil as used in the engine.

Change the oil every 200 hours (6,000 miles). Remove and clean the oil inlet strainer screen after draining the oil. The strainer is located in the sump at the lower end of the pump suction line. Reinstall the strainer and refill the marine gear with oil up to the full mark on the dipstick (approximately 5 quarts). Start the engine and, with the gear in neutral, run the engine at idle speed for three to five minutes. Then stop the engine and check the marine gear oil level. If necessary, add oil to bring it up to the full mark on the dipstick.

Item 42 - Torqmatic Converter

Check the oil level in the Torqmatic converter and supply tank daily. The oil level must be checked while the converter is operating, the engine idling and the oil is up to operating temperature (approximately 200°F). If the converter is equipped with an input disconnect clutch, the clutch must be engaged.

Check the oil level after running the unit a few minutes. The oil level should be maintained at the proper level on the dipstick. If required, add hydraulic transmission fluid type "C-2" (see chart). *Do not overfill* the converter as too much oil will cause foaming and high oil temperature.

Prevailing Ambient Temperature	Recommended Oil Specification
Above −10°F (−23°C)	Hydraulic Transmission Fluid, Type C-2.
Below −10°F (−23°C)	Hydraulic Transmission Fluid, Type C-2. Auxiliary preheat required to raise temperature in the sump to a temperature above −10°F. (−23°C)

OIL RECOMMENDATIONS

The oil should be changed every 500 hours (15,000 miles) of operation. Also, the oil should be changed whenever it shows traces of dirt or effects of high operating temperature as evidenced by discoloration or strong odor. If the oil shows metal contamination, refer to the separate manual covering the specific converter as this usually requires disassembly. Under severe operating conditions, the oil should be changed more often.

The converter oil breather, located on the oil level indicator (dipstick), should be cleaned each time the converter oil is changed. This can be accomplished by allowing the breather to soak in a solvent, then drying it with compressed air.

The full-flow oil filter element should be removed, the shell cleaned and a new element and gasket installed each time the converter oil is changed.

Lubricate the input clutch release bearing and ball bearing every 50 hours (1,500 miles) with an all purpose grease through the grease fittings provided on the clutch housing. This time interval may vary depending upon the operating conditions. Over-lubrication will cause grease to be thrown on the clutch facing, causing the clutch to slip.

The strainer (in the Torqmatic transmission) and the hydraulic system filters should be replaced or cleaned with every oil change.

Item 46 - Hydrostarter System

On engines equipped with a hydrostarter, refer to *Lubrication and Preventive Maintenance* in Section 12.6.1.

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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:

Minimum Compression Pressure at 600 rpm				Altitude Above Sea Level	
Std. Engine		"N" Engine			
psi	kPa	psi	kPa	Feet	Meters
430	2 963	540	3 721	500	152
400	2 756	500	3 445	2,500	762
370	2 549	465	3 204	5,000	1 524
340	2 343	430	2 963	7,500	2 286
315	2 170	395	2 722	10,000	3 048

TABLE 1

Locating a Misfiring Cylinder

1. Start the engine and run it at part load until it reaches normal operating temperature.

2. Stop the engine and remove the valve rocker cover(s).

3. Check the valve clearance (refer to Section 14.1).

4. Start the engine. Then hold an injector follower down with a screw driver to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short-circuiting a spark plug in a gasoline engine.

5. If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.

6. If the cylinder is misfiring, check the following:

a. Check the injector timing (refer to Section 14.2).

b. Check the compression pressure.

c. Install a new injector.

d. If the cylinder still misfires, remove the cam follower (refer to Section 1.2.1) and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushing.

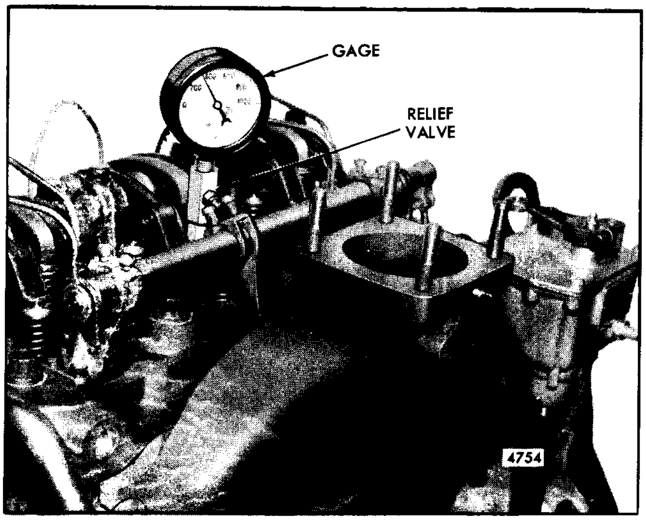

Fig. 1 - Checking Compression Pressure

Checking Compression Pressure

Compression pressure is affected by altitude as shown in Table 1.

Check the compression pressure as follows:

Cylinder	Gage Reading	
	psi	kPa
1	525	3 617
2	520	3 583
3	485	3 342
4	515	3 548

TABLE 2

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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 adaptor J 7915-02 and pressure gage and hose assembly J 6692 (Fig. 1).

4. Use a spare fuel pipe to fabricate a jumper connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.

5. Start the engine and run it at a 600 rpm. Observe and record the compression pressure indicated on the gage. *Do not crank the engine with the starting motor to obtain the compression pressure.*

6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder at a given altitude above sea level should not be less than the minimum shown in Table 1. In additon, 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 an "N" 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. 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.

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 shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.

3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.

4. Start the engine. Check the filter and strainer for leaks.

> **NOTE:** In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

Fuel Flow Test

The proper flow of fuel is required for satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter as outlined in Section 2.0 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

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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* in Section 13.2.

> **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 (except on turbocharged engines) by removing the 1/8 " pipe plug which is provided for that purpose. If no opening is provided, drill an 11/32 " hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8 " pipe plug.

On turbocharged engines, check the exhaust back pressure in the exhaust piping 6 " to 12 " from the turbine outlet (Fig. 1, Section 13.2). The tapped hole must be in a comparatively straight pipe area for an accurate measurement.

Check the readings obtained at various speeds (at no-load) with the *Engine Operating Conditions* in Section 13.2.

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* in Section 13.2.

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 (non-turbocharged engines) or the compressor inlet (turbocharged engines). When practicability prevents the insertion of a fitting at this point (non-turbocharged engines), the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air inlet vacuum at various speeds (at no-load) and compare the results with the *Engine Operating Conditions* in Section 13.2.

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PROPER USE OF MANOMETER

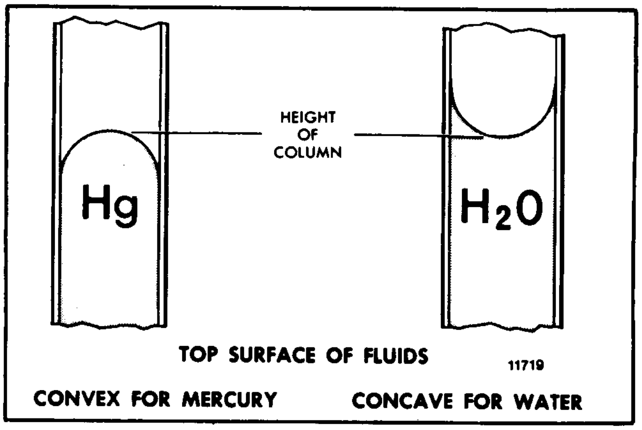

Fig. 2 - Comparison of Column Height for Mercury and Water Manometers

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. 2) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 3 to convert the manometer reading into other units of measurement.

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

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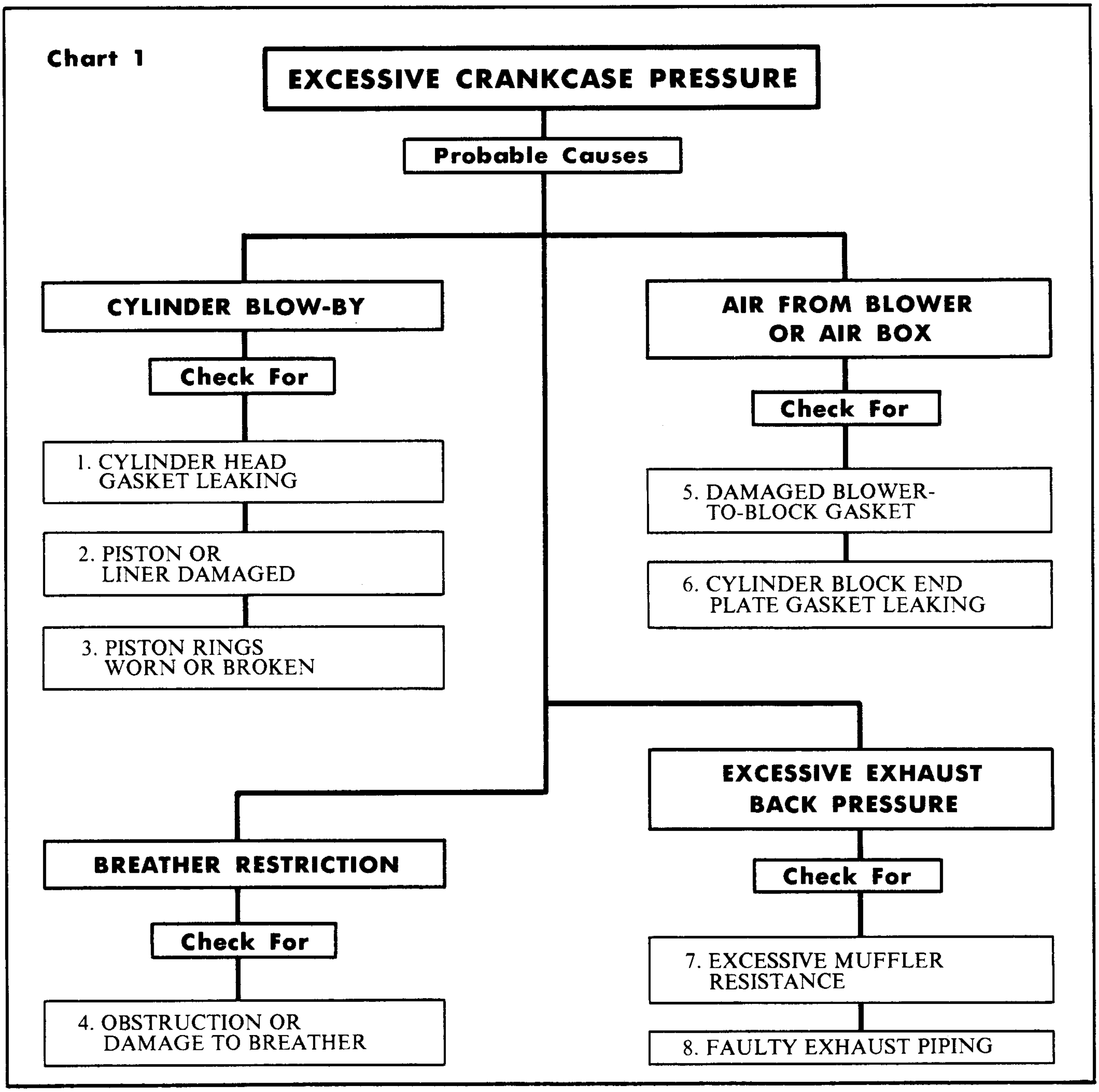

SUGGESTED REMEDY

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.

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Chart 2

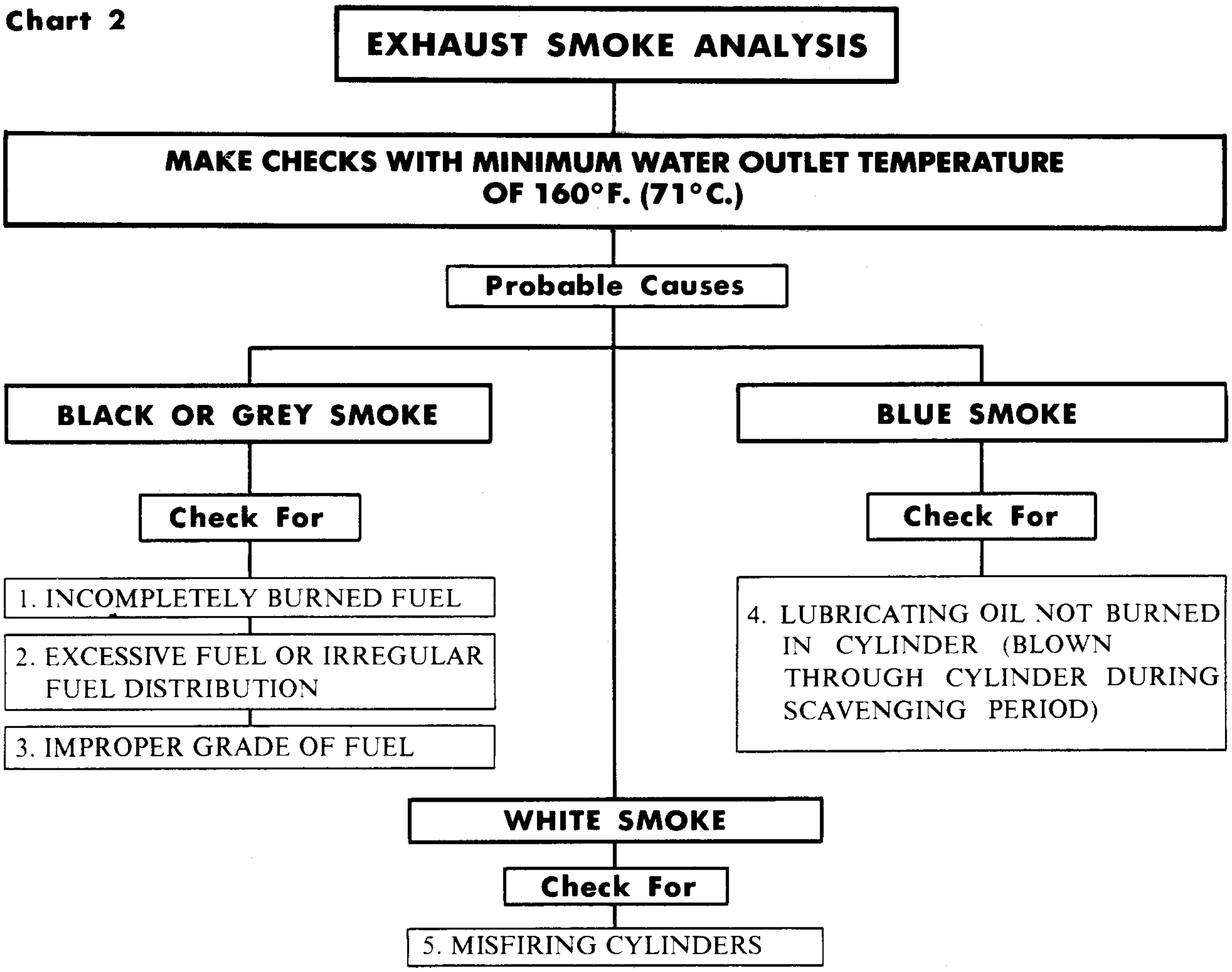

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Chart 2

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.

2. If the engine is equipped with a throttle delay, check for the proper setting, leaky check valve and restricted filling of the piston cavity with oil from the reservoir.

If the engine is equipped with a fuel modulator, check the cam to determine if it is stuck in the full fuel position. Verify tightness of the roller lever clamp on the control tube. Determine correctness (refer to Section 14.14) of the installed fuel modulator piston spring and check if the spring has taken a permanent "set", or if the spring rate is too low.

The above affects only excessive acceleration smoke, but does not affect smoke at constant speed.

Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune-up.

Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune-up.

Avoid lugging the engine as this will cause incomplete combustion.

3. Check for use of an improper grade of fuel. Refer to *Fuel Specifications* in Section 13.3.

4. Check for internal lubricating oil leaks and refer to the *High Lubricating Oil Consumption* chart.

5. Check for faulty injectors and replace as necessary.

Check for low compression and consult the *Hard Starting* chart.

The use of low cetane fuel will cause this condition. Refer to *Fuel Specifications* in Section 13.3.

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Chart 3

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

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Chart 3

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* in Section 13.3 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 Section 3.4 or 3.4.1).

14. Operate the starting aid according to the instructions under *Cold Weather Starting Aids*.

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Chart 4

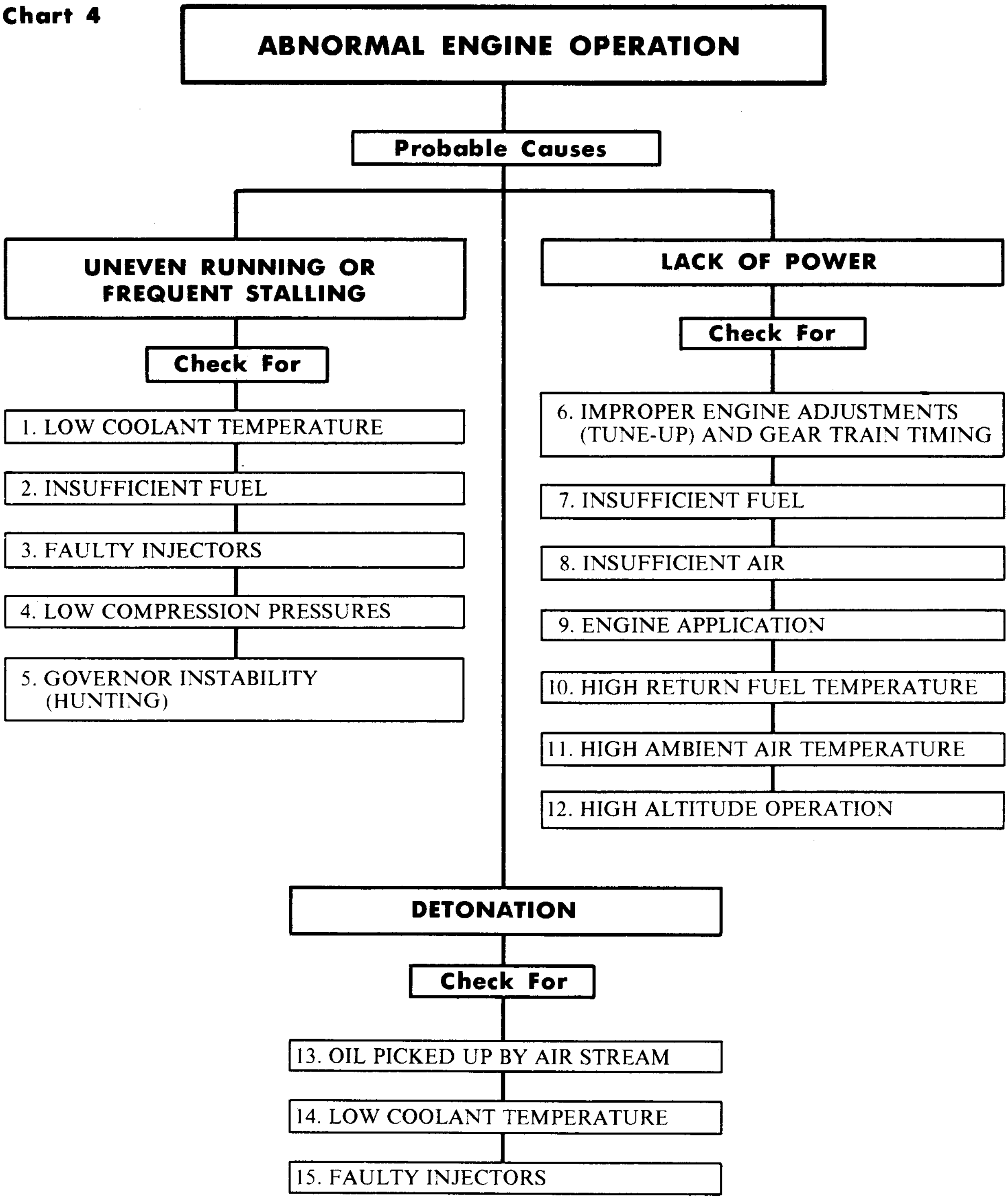

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Chart 4

ABNORMAL ENGINE OPERATION

SUGGESTED REMEDY

1. Check the engine coolant temperature gage and, if the temperature does not reach 160°to 185°F (71°to 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.

6. If the engine is equipped with a throttle delay, check for the proper setting, binding or burrs on the piston or bracket, and a plugged discharge orifice.

If equipped with a fuel modulator, determine if there is any interference with the roller assembly or roller contact with the cam at wide open throttle (WOT) position. Check for burrs and binding on the piston and bracket bore. Determine correctness (refer to Section 14.14) of the installed fuel modulator spring and check if the spring has taken a permanent "set", or if the spring rate is too high.

Perform an engine tune-up if performance is not satisfactory.

Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

7. Perform a *Fuel Flow Test* and, if less than the specified fuel is returning to the fuel tank, consult the *No Fuel or Insufficient Fuel* chart.

8. Check for damaged or dirty air cleaners and clean, repair or replace damaged parts.

Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

Check for blower air intake obstruction or high exhaust back pressure. Clean, repair or replace faulty parts.

Check the compression pressures (consult the *Hard Starting* chart).

9. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.

10. Refer to Item 13 on Chart 4.

11. Check the ambient air temperature. A power decrease of .15 to .50 horsepower per cylinder, depending upon injector size, for each 10°F (6°C) temperature rise above 90°F (32°C) will occur. Relocate the engine air intake to provide a cooler source of air.

12. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.

13. Fill oil bath air cleaners to the proper level with the same grade and viscosity lubricating oil that is used in the engine.

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.

14. Refer to Item 1 of this chart.

15. Check injector timing and the position of each injector rack. Perform an engine tune-up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

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Chart 5

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

FLOW OBSTRUCTION

Check For

5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURE LESS THAN 10 °F. (6°C.) ABOVE POUR POINT OF FUEL

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

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Chart 5

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 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.

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Chart 6

HIGH LUBRICATING OIL CONSUMPTION

Probable Causes

EXTERNAL LEAKS

Check For

1. OIL LINES OR CONNECTIONS LEAKING
2. GASKET OR OIL SEAL LEAKS
3. AUTOMATIC OIL FILLER
4. OIL PULLOVER - AIR COMPRESSOR
5. OVER-FILLED CRANKCASE
6. PLUGGED BREATHERS
7. HIGH CRANKCASE PRESSURE
8. BLUE EXHAUST SMOKE
9. EXCESSIVE OIL IN AIR BOX

INTERNAL LEAKS

Check For

10. BLOWER OIL SEALS LEAKING
11. TURBO OIL SEALS LEAKING
12. OIL COOLER CORE LEAKING
13. WORN EXHAUST VALVE GUIDES

OIL CONTROL AT CYLINDER

Check For

14. LOW COMPRESSION
15. PISTON PIN RETAINER LOOSE
16. OIL CONTROL RINGS WORN, BROKEN, IMPROPERLY INSTALLED OR SCORED.
17. EXCESSIVE OIL IN AIR BOX
18. DIRT IN AIR INTAKE SYSTEM
19. SCORED LINERS OR PISTONS
20. EXCESSIVE INSTALLATION ANGLE
21. EXCESSIVE OIL IN CRANKCASE

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Chart 6

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. Consult the original equipment manufacturer for proper repair of the automatic oil filler system.

4. Check the air compressor for oil pullover and/or remove and replace the compressor.

5. Check dipstick and tube for proper oil pan levels to correct overfilled crankcase.

6. Check crankcase pressure. Clean breathers and recheck crankcase pressure.

7. Overhaul blower, turbocharger or rekit engine (refer to Items 10, 11, 15 and 16). Also, refer to the *Excessive Crankcase Pressure* chart.

8. 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.

9. Refer to the *Abnormal Engine Operation* chart.

10. 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.

11. Check for indications of oil on compressor or turbine sides of the turbocharger. Refer to Section 3.5 of the Service Manual for the proper procedure to determine turbocharger oil seal leakage.

12. 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.

13. Replace worn exhaust valve guides.

14. Take compression test - refer to Item 16.

15. 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.

16. 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.

17. Refer to Items 10, 11, 15 and 16.

18. Refer to Item 16.

19. Check the crankshaft thrust washers for wear. Replace wore and defective parts.

20. Decrease the installation angle.

21. Fill the crankcase to the proper level only.

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Chart 7

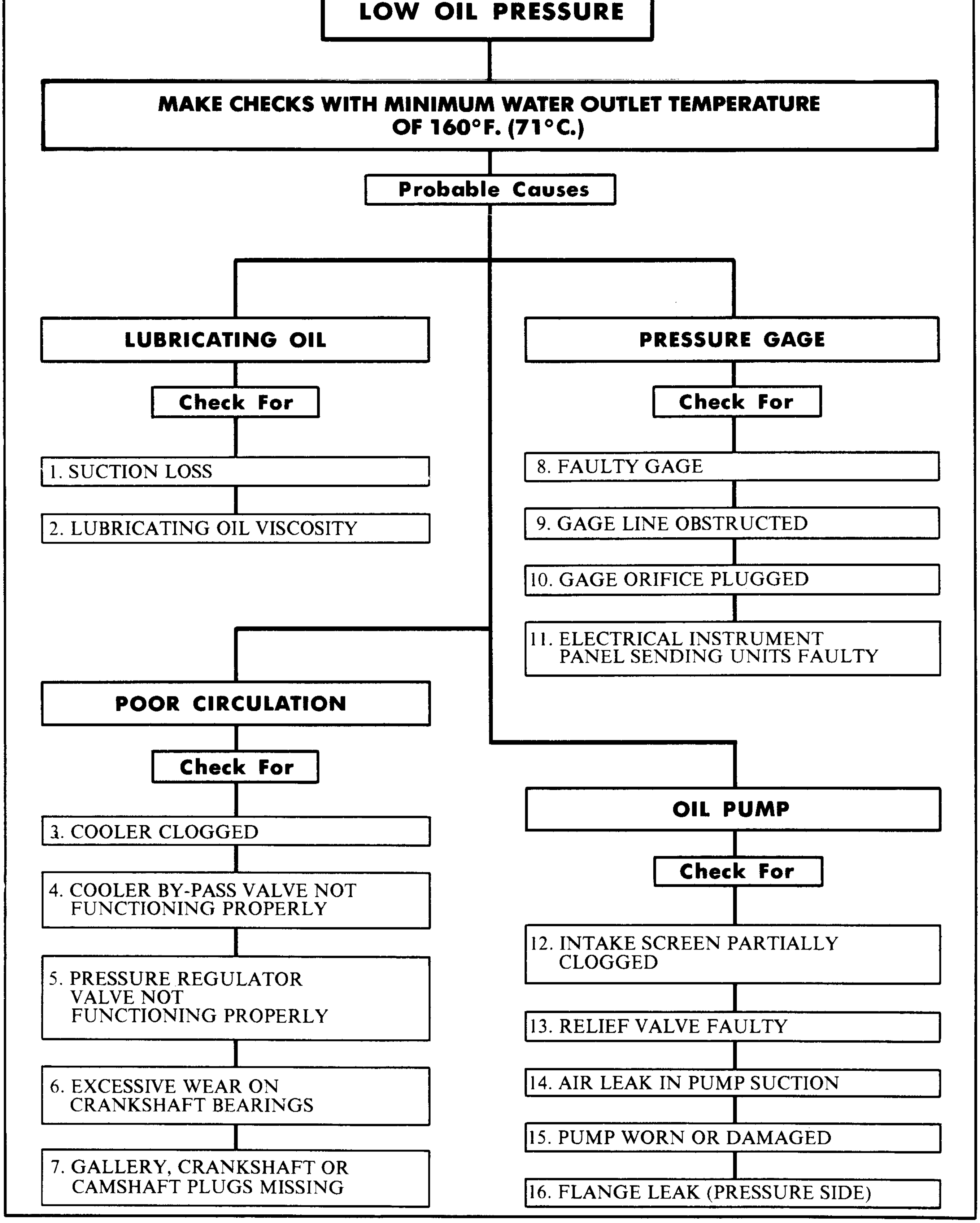

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Chart 7

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* in Section 13.3 for the recommended grade and viscosity of oil.

Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution. Refer to Fuel Leak Detection in Section 2.0

3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.

4. Remove the by-pass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

5. Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

6. Change the bearings. Consult the *Lubricating Oil Specifications* in Section 13.3 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* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.

13. Remove and inspect the valve, valve bore and spring. Replace faulty parts.

14. Disassemble the piping and install new gaskets.

15. Remove the pump. Clean and replace defective parts.

16. Remove the flange and replace the gasket.

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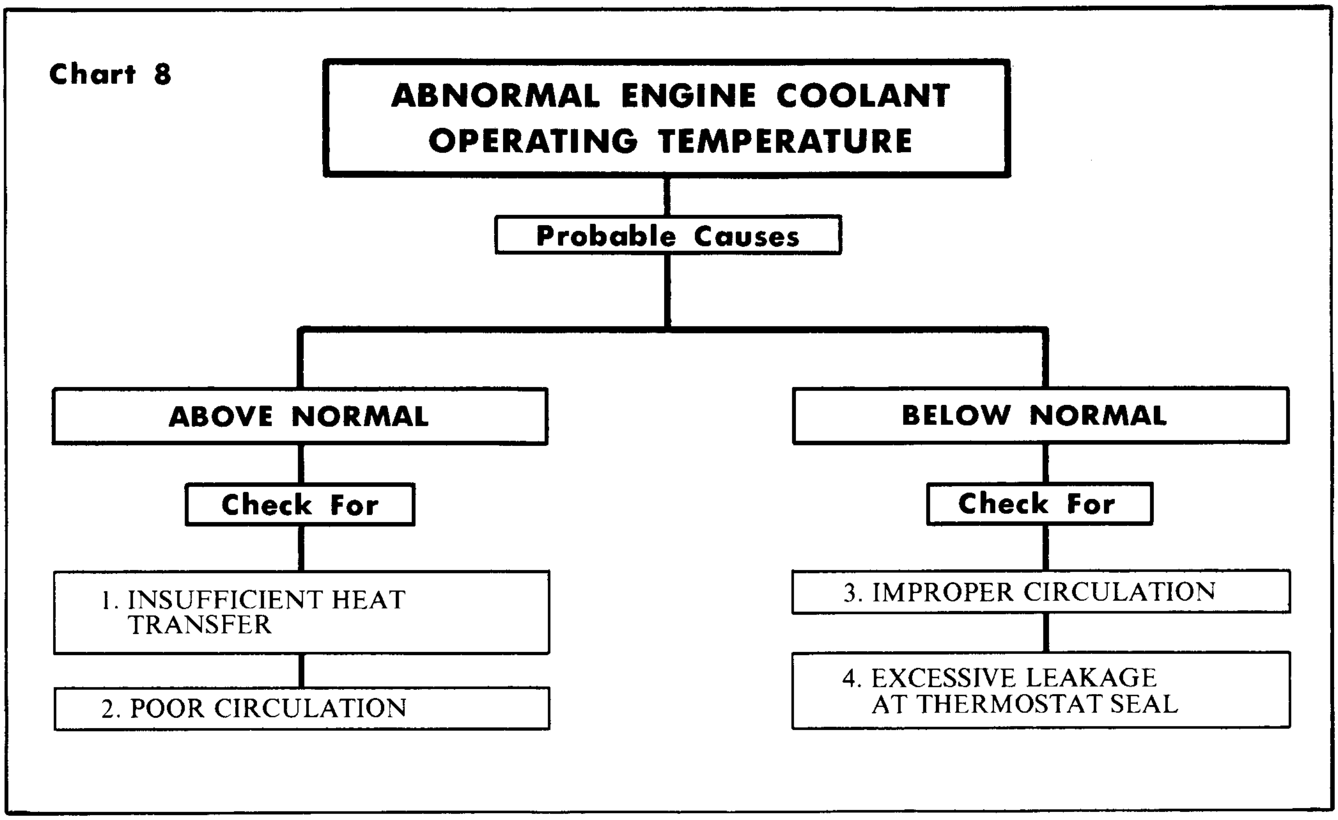

SUGGESTED REMEDY

1. Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits.

Clean the exterior of the radiator core to open plugged passages and permit normal air flow.

Adjust fan belts to the proper tension to prevent slippage.

Check for an improper size radiator or inadequate shrouding.

Repair or replace inoperative temperature-controlled fan or inoperative shutters.

2. Check the coolant level and fill to the filler neck if the coolant level is low.

Inspect for collapsed or disintegrated hoses. Replace faulty hoses.

Thermostat may be inoperative. Remove, inspect and test the thermostat; replace if found faulty.

Check the water pump for a loose or damaged impeller.

Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core.

Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets replaced if combustion gases are entering the cooling system.

Check for an air leak on the suction side of the water pump. Replace defective parts.

3. The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

Check for an improperly installed heater.

4. Excessive leakage of coolant past the thermostat seal(s) is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal(s).

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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 in Section 3.1.

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, lubricating oil, transmission, and priming the raw water pump if used.

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* in Section 13.3).

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 Section 13.2).

5. Stop the engine.

6. Drain the engine crankcase, then reinstall and tighten the drain plug. Install new lubricating oil filter elements and gaskets.

7. Fill the crankcase to the proper level with a 30 weight preservative lubricating oil MIL-L-21260C, Grade 2.

8. Drain the fuel tank. Refill with enough clean No. 1 diesel fuel or pure kerosene to permit the engine to operate for about ten minutes. If it isn't convenient to drain the fuel tank (i.e., marine) use a separate portable supply of the recommended fuel.

> **NOTE:** If engines in vehicles or marine units are stored where condensation of water in the fuel

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tank may be a problem, add pure, waterless isopropyl alcohol (isopropanol) to the fuel at a ratio of one pint to 125 gallons of fuel, or .010% by volume. Where biological contamination of fuel may be a problem, add a biocide such as Biobor JF, or equivalent, to the fuel. When using a biocide, follow the manufacturer's concentration recommendations, and observe all cautions and warnings.

9. Drain and disassemble the fuel filter and strainer. Discard the used elements and gaskets. Fill the cavity between the element and shell with No. 1 diesel fuel or pure kerosene, and reinstall on the engine. If spin-on fuel filters and strainers are used, discard the used cartridges, fill the new ones with No. 1 diesel fuel or pure kerosene, and reinstall on the engine.

10. Operate the engine for five minutes to circulate the clean fuel oil throughout the engine.

11. Refer to Section 3.1 and service the air cleaner.

12. MARINE GEAR

a. Drain the oil completely and refill with clean oil of the recommended grade and viscosity. Remove and clean or replace the strainer and filter element.

b. Start and run the engine at 600 rpm for ten minutes to coat all of the internal parts of the marine gear with clean oil. Engage the clutches alternately to circulate clean oil through all of the moving parts.

NOTE: The performance of this step is not necessary on torque converter units.

13. TORQMATIC CONVERTER

a. Start and operate the engine until the temperature of the converter oil reaches 150 °F (66 °C).

b. Stop the engine, remove the converter drain plug and drain the converter.

c. Remove the filter element.

d. Start the engine and stall the converter for **twenty seconds** at 1000 rpm to scavenge the oil from the converter. *Due to lack of lubrication, do not exceed the 20 second limit.*

e. Install the drain plug and a new filter element.

f. Fill the converter to the proper operating level with a commercial preservative oil which meets Government specifications MIL-L-21260 C, Grade 2. Oil of this type is available from the major oil companies.

g. Start the engine and operate the converter for at least ten minutes at a minimum of 1000 rpm. Engage the clutch, then stall the converter to raise the oil temperature to 225 °F (107 °C).

NOTE: Do not allow the oil temperature to exceed 225 °F (107 °C). If the unit does not have a temperature gage, *do not stall the converter for more than thirty seconds.*

h. Stop the engine and allow the converter to cool to a temperature suitable to the touch.

i. Seal the breather and all of the exposed openings with moisture-proof tape.

j. Coat all exposed, unpainted surfaces with preservative grease. Position all of the controls for minimum exposure and coat them with grease. The external shafts, flanges and seals should also be coated with grease.

14. POWER TAKE-OFF

a. Use an all purpose grease such as Shell Alvania No. 2, or equivalent, and lubricate the clutch throwout bearing, clutch pilot bearing, drive shaft main bearing, clutch release shaft and the outboard bearings (if so equipped).

b. Remove the inspection hole cover on the clutch housing and lubricate the clutch release lever and link pins with a hand oiler. Avoid getting oil on the clutch facing.

c. If the unit is equipped with a reduction gear, drain the gear box and flush with light engine oil. If the unit is equipped with a filter, clean the shell and replace the filter element. Refill the gear box to the proper level with the grade of oil indicated on the name plate.

15. TURBOCHARGER

Since turbocharger bearings are pressure lubricated through the external oil line leading from the engine cylinder block while the engine is operating, no further attention is required. However, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture resistant tape.

16. HYDROSTARTER SYSTEM

Refer to Section 12.6.1 for the lubrication and preventive maintenance procedure.

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17. 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.

18. Drain the engine cooling system.

19. Drain the preservative oil from the engine crankcase. Reinstall and tighten the drain plug.

20. Remove and clean the battery and battery cables with a baking soda-water solution and rinse 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.

21. Insert heavy paper strips between the pulleys and belts to prevent sticking.

22. Seal all engine openings, including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.

23. 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.

24. 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* in Section 13.1 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* (Section 13.3).

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 an ethylene glycol base antifreeze solution (refer to Section 13.3).

8. Install and connect the battery.

9. Service the air cleaner as outlined in Section 3.1.

10. POWER GENERATOR

Prepare the generator for starting as outlined under *Operating Instructions* in Section 13.1.1.

11. MARINE GEAR

Check the marine gear; refill it to the proper level, as necessary, with the correct grade of lubricating oil.

12. TORQMATIC CONVERTER

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a. Remove the tape from the breather and all of the openings.

b. Remove all of the preservative grease with a suitable solvent.

c. Start the engine and operate the unit until the temperature reaches 150 °F (66 °C). Drain the preservative oil and remove the filter. Start the engine and stall the converter for twenty seconds at 1000 rpm to scavenge the oil from the converter.

NOTE: A Torqmatic converter containing preservative oil should only be operated enough to bring the oil temperature up to 150 °F (66 °C).

d. Install the drain plug and a new filter element.

e. Refill the converter with the oil that is recommended under *Lubrication and Preventive Maintenance* (Section 15.1).

13. POWER TAKE-OFF

Remove the inspection hole cover and inspect the clutch release lever and link pins and the bearing ends of the clutch release shaft. Apply engine oil sparingly, if necessary, to these areas.

14. HYDROSTARTER

a. Open the relief valve on the side of the hand pump and release the pressure in the system.

b. Refer to the filling and purging procedures outlined in *Hydraulic Starting System* (Section 12.6.1). Then drain, refill and purge the hydrostarter system.

15. TURBOCHARGER

Remove the covers from the turbocharger air inlet and turbine outlet connections. Refer to the lubricating procedure outlined in *Preparation for Starting Engine First Time* in Section 13.1.

16. After all of the preparations have been completed, start the engine. The small amount of rust preventive compound which remains in the fuel system will cause a smoky exhaust for a few minutes.

NOTE: Before subjecting the engine to a load or high speed, it is advisable to check the engine tune-up.

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Detroit Diesel Engines

Series 53 Service Manual

Detroit Diesel Allison