SECTION 8

POWER TAKE-OFF – TORQMATIC CONVERTER

For service and overhaul procedures for Allison products, contact the manufacturer:

Allison Transmission Division
General Motors Corporation
P.O. Box 894
Indianapolis, IN 46206

For service and overhaul procedures for Rockford products, contact the manufacturer:

Rockford Powertrain, Inc.
1200 Windsor Rd.
P. O. Box 2908
Rockford, IL 61132–2908

SECTION 9

TRANSMISSIONS

For service and overhaul procedures for Allison products, contact the manufacturer:

Allison Transmission Division
General Motors Corporation
P.O. Box 894
Indianapolis, IN 46206

For service and overhaul procedures for Twin Disc products, contact the manufacturer:

Twin Disc, Inc.
1328 Racine Street
Racine, Wisc. 53403

For service and overhaul procedures for Warner Gear products, contact the manufacturer:

Borg–Warner Automotive, Inc.
Transmission Systems
P.O. Box 2688
Muncie, IN 47302

SECTION 12

SPECIAL EQUIPMENT

CONTENTS

BILGE PUMP

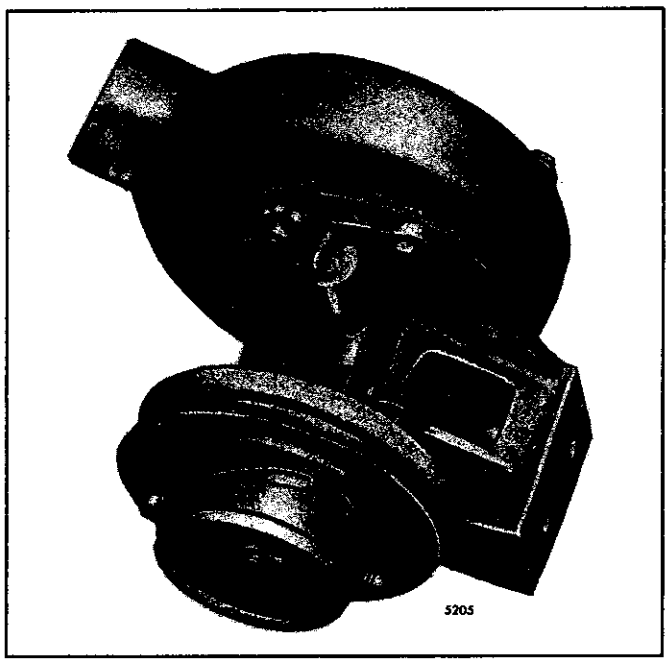

Fig. 1 – Bilge Pump

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 reassembled 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.

All piping on the intake side of the bilge pump must be air tight. Use pipe joint compound on the pipe threads at all connections.

VACUUM PUMP

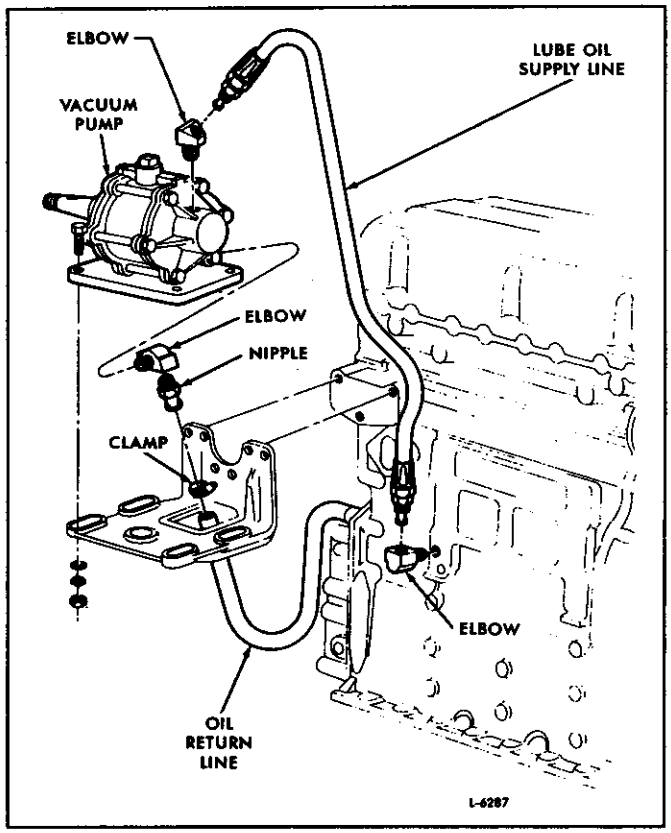

Fig. 1 – Vacuum Pump Installation

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 damage 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 Distributors only as assemblies. For component parts contact a Bendix Products Service outlet or Bendix Products Division, South Bend, Indiana.

AIR COMPRESSOR

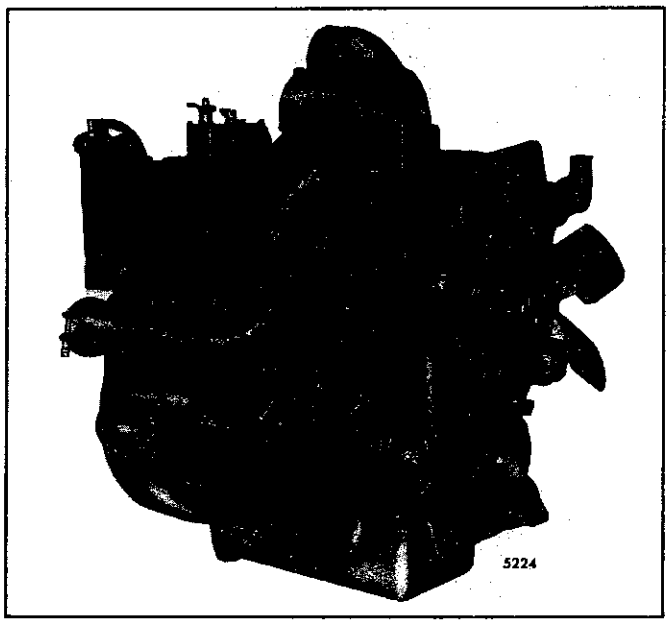

Fig. 1 – Air Compressor Mounting (Former Engines)

The air compressor (Figs. 1 and 2) may be mounted on a bracket atttached 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 conjuction with the unloading mechanism in the compressor cylinder block. The governor starts and stops the compression of air by loading or unloading the compressor when the air pressure in the system reaches the desired minimum or maximum pressure.

During the down stroke of each piston, a partial vacuum is created above the piston which unseats the inlet valve and then allows air drawn from the air box in the engine cylinder block or through an intake strainer to enter the cylinder above the piston. As the piston starts the upward stroke, the air pressure on top of the inlet valves, plus the inlet valve return spring force, closes the inlet valve. The air above the piston is further compressed until the pressure lifts the discharge valve and the compressed air is discharged through the discharge line into the reservoir.

As each piston starts its downstroke, the discharge valve above it returns to its seat, preventing the compressed air from returning to the cylinder and the same cycle is repeated.

When the air pressure in the reservoir reaches the maximum setting of the governor, compressed air from the reservoir passes through the governor into the cavity below the unloading pistons in the compressor cylinder block. The air pressure lifts the unloading pistons which in turn lifts the inlet valves off their seats.

With the inlet valves held off their seats, the air during each upstroke of the piston is merely passed back through the air inlet cavity and to the other cylinder where the piston is on the downstroke. When the air pressure in the reservoir drops to the minimum setting of the governor, the governor releases the air pressure beneath the unloading pistons. The unloading piston return spring then forces the piston down and the inlet valve springs return the inlet valves to their seats and compression is resumed.

Service Note

When installing a pulley or a drive hub on a flange mounted air compressor (Fig. 3), it is important the 3/4"–16 drive shaft slotted nut be tightened to 100 lb–ft (136 N·m) torque minimum before installing the 3/32" x 1–1/4" cotter pin.

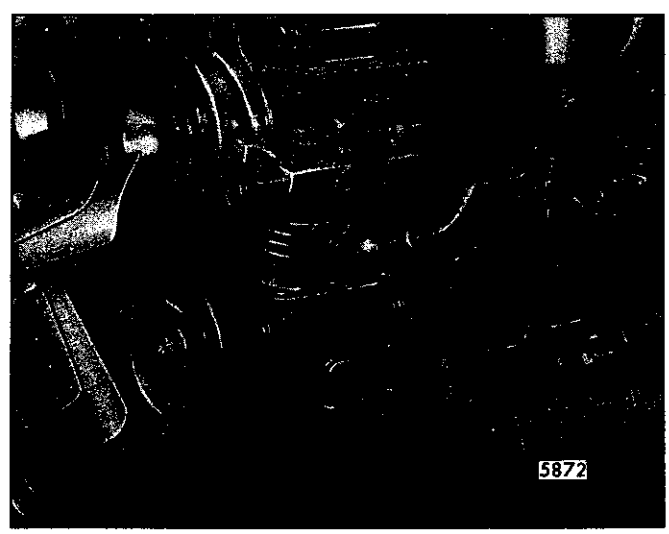

Fig. 2 – Air Compressor Mounting (Current Engines)

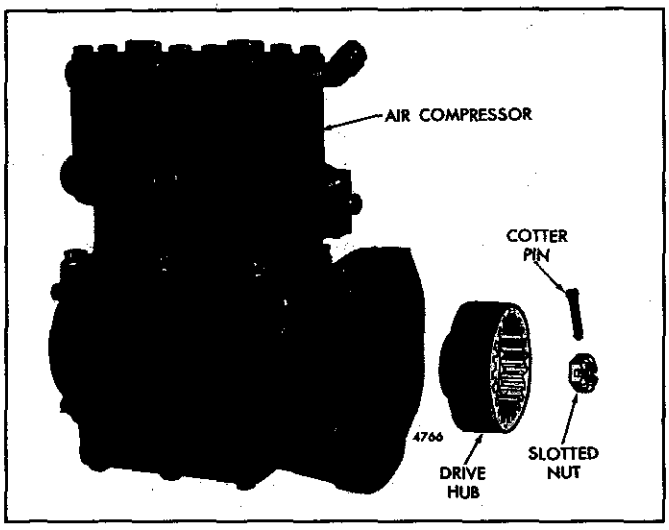

Fig. 3 – Typical Air Compressor with Drive Hub

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).

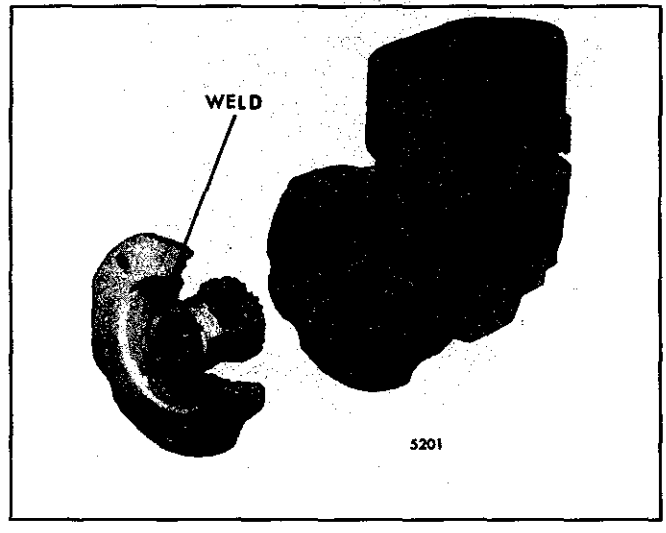

Fig. 4 – Fixture for Holding Drive While Installing or Removing Slotted Nut

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, cooling water 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 to ignite the fuel 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.

Starting aids are not intended to correct other 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.

NOTICE: To avoid starter damage, 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.

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.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

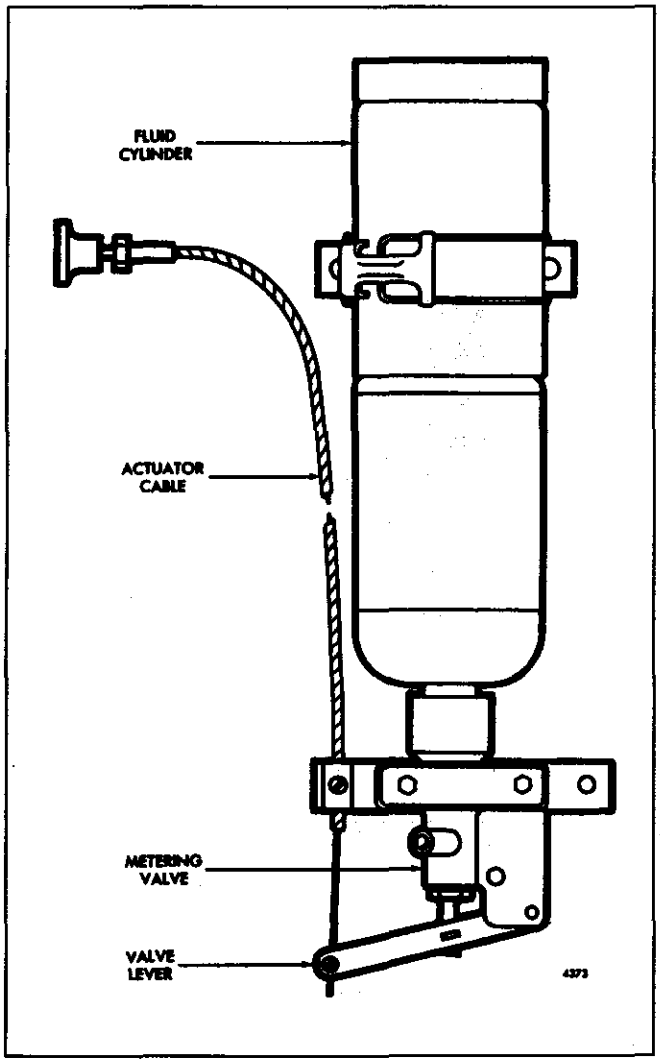

Fig. 1 – Quick Start Assembly

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 highly volatile fluid could result in a minor explosion, engine damage, and possible personal injury.

7. Check the fluid cylinder for hand tightness.

FLUID STARTING AID

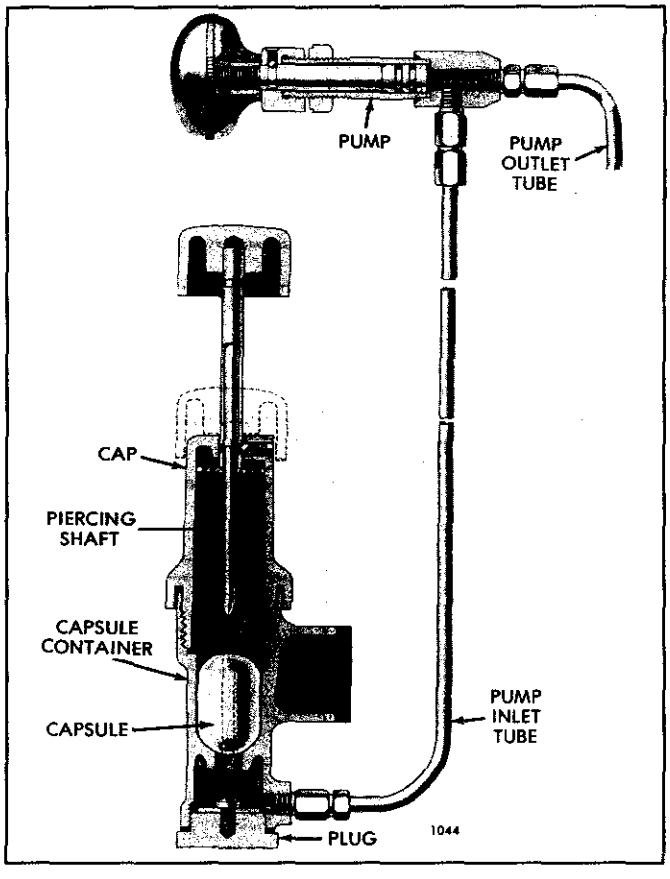

Fig. 2 – Fluid Starting Aid

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.

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 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 highly flammable, toxic, and possesses sleep-inducing properties.

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. When not in use, the piercing shaft should be all the way down.

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.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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.

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 accumulator pressure. Its operation is entirely automatic and will operate in either direction of rotation.

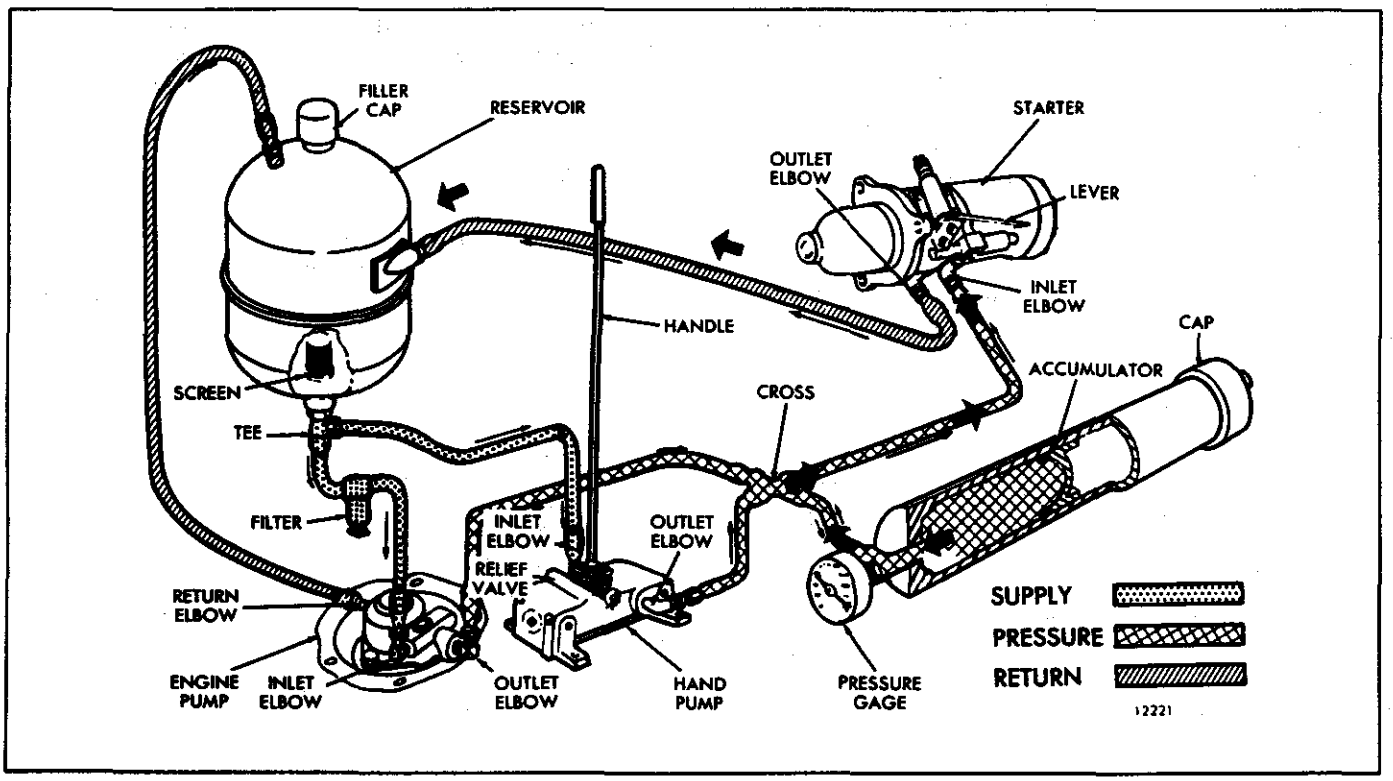

Fig. 1 – Schematic Diagram of Hydrostarter System Showing Oil Flows

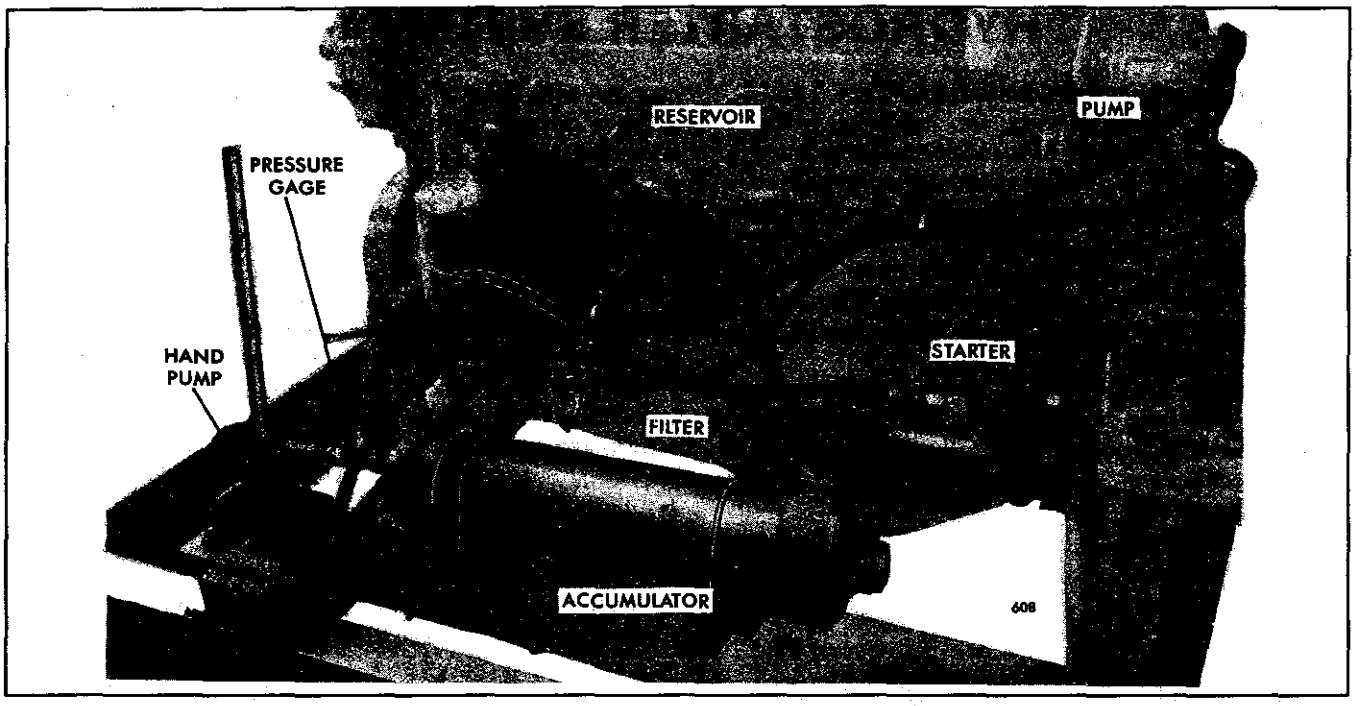

Fig. 2 – Typical Hydrostarter System Mounting

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.

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.

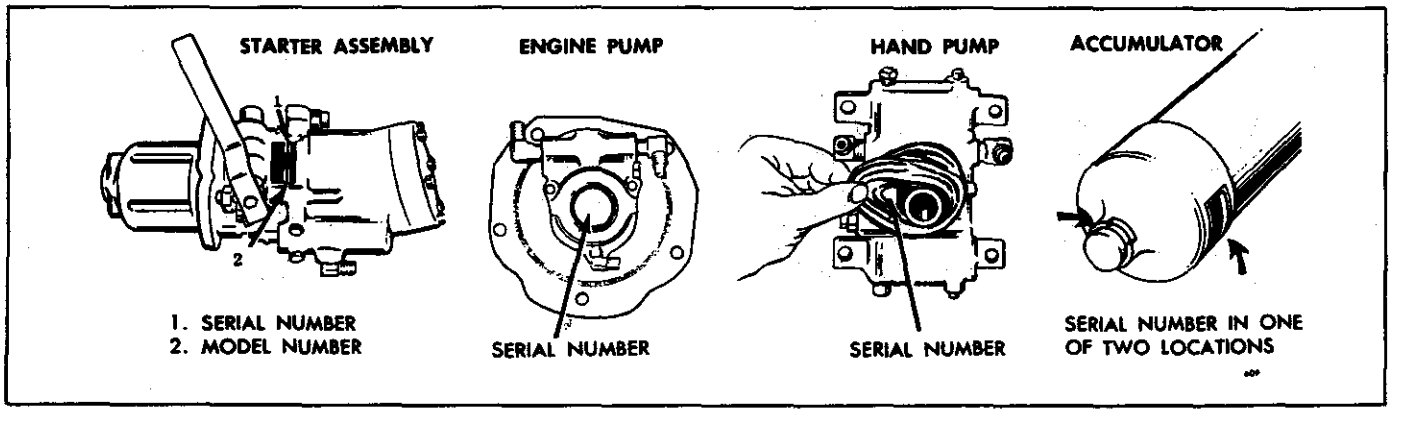

Fig. 3 – Hydrostarter Component Serial Number Locations

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, 16 and 23 quart capacities. In a 10 quart capacity reservoir, add approximately 8 quarts of hydraulic fluid; add approximately 10, 14 or 21 quarts of hydraulic fluid to the 12, 16 and 23 quart capacity reservoirs respectively.

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 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 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

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.

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 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 damage.

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, 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.

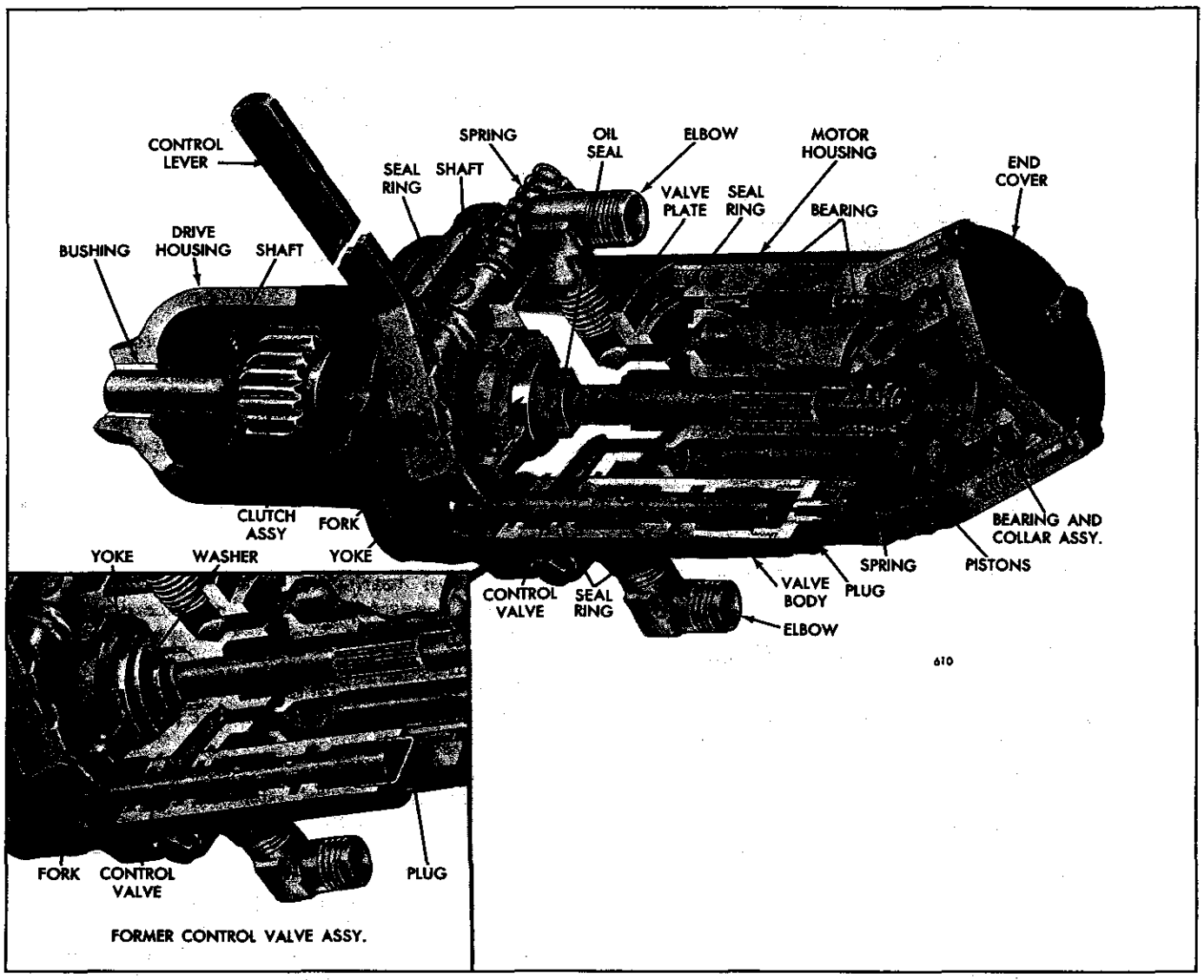

Fig. 4 – Cutaway View of Hydrostarter

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 a Series "20" Hydrostarter motor 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 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. On a Series "20" motor, remove the starter shaft compression spring shim(s), if used, from the spring bore in the rotor.

On a Series "35" motor, remove the starter shaft compression spring special washer from the spring bore in the rotor.

14. Remove the starter shaft oil seal from the valve plate only if it is leaking.

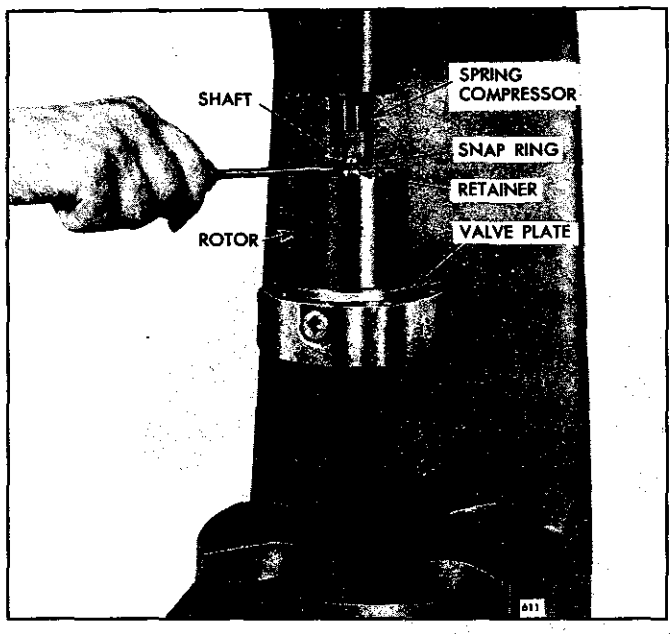

Fig. 5 – Removing Snap Ring from Starter Shaft

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. Remove the bearing and collar assembly ("20" series motor) or the bearing assembly ("35" Series motor) 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.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

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.

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.

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 Series "20" 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.

The washer between the shaft seal and the clutch yoke (see inset in Fig. 4) is used ONLY in the early Series "20" 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.

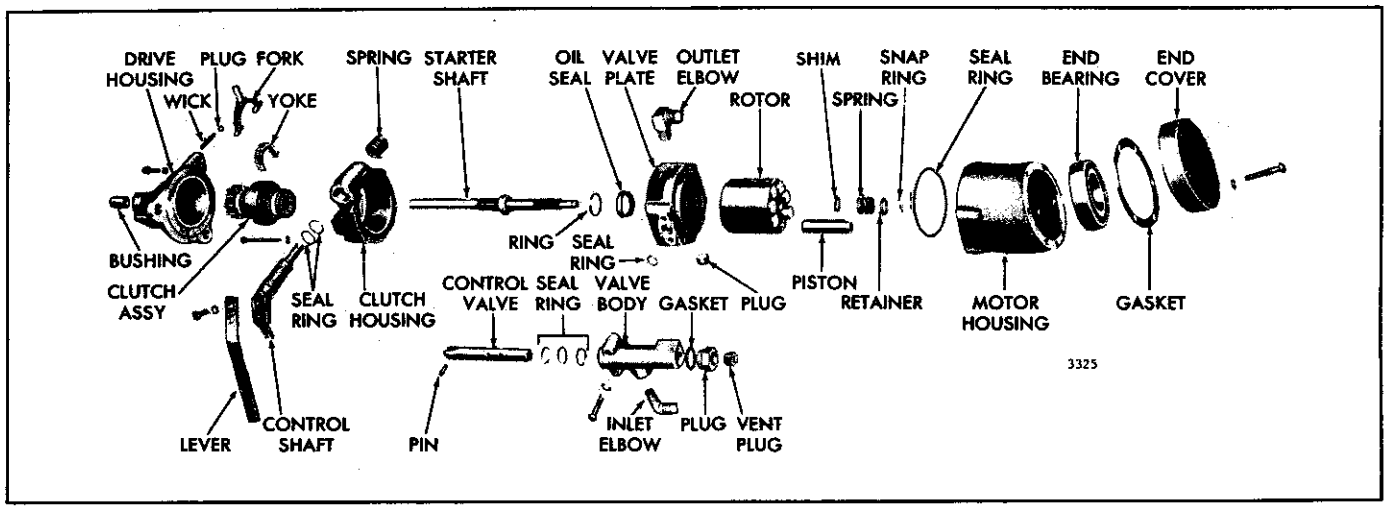

Fig. 6 – Hydrostarter Motor Details and Relative Location of Parts ("20" Series Motor Shown)

Assemble Hydrostarter Motor

Refer to (Figs. 4 and 6) and assemble the Hydrostarter motor as follows:

NOTICE: 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.

1. On a Series "20" motor, place the bearing and collar assembly in the end cover, thrust collar side up. On a Series "35" motor, place the bearing assembly, numbered end up, in the end cover. Then 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 on a "20" series motor or installer J 9555 on a "35" series motor (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 ("20" series motor) 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) on a "20" series motor, a special washer ("35" series motor), 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 Series "20" 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 Series "20" Hydrostarter motor, the starter shaft 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.

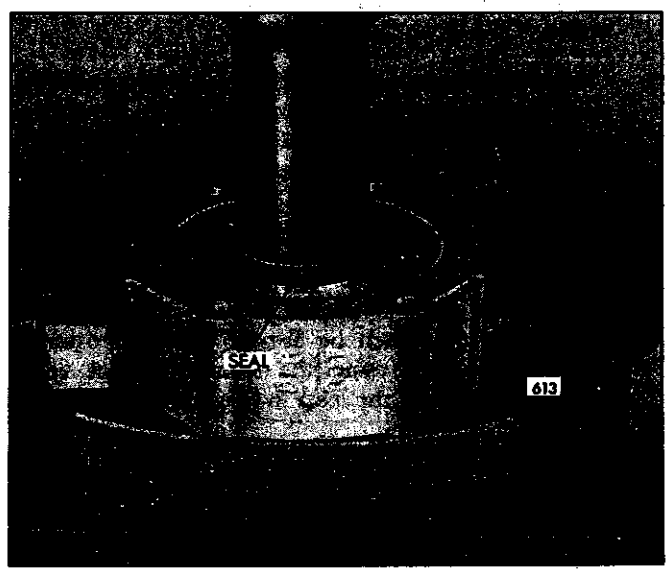

Fig. 7 – Installing Hydrostarter Shaft Seal in Valve Plate

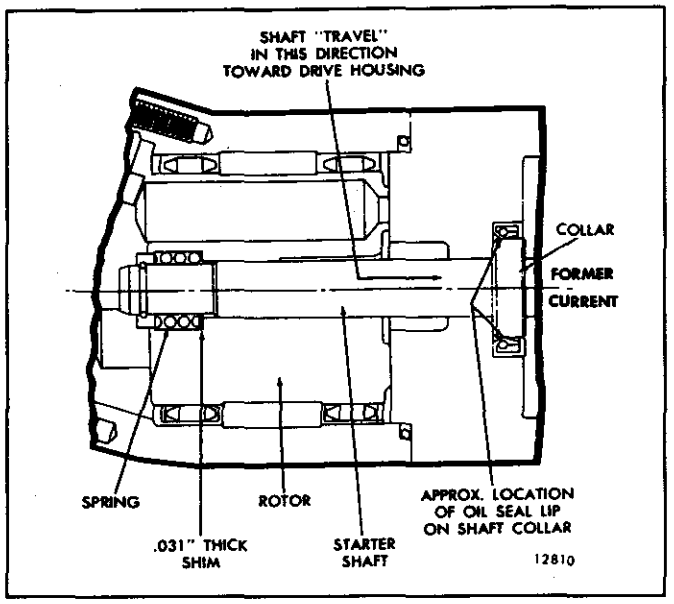

Fig. 8 – Location of Starter Shaft Compression Spring Shim (Series "20" Motor)

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.

    The starter shaft oil seal washer, mentioned in Step 10, is only used on Series "20" 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.

    On a former (Series "20" motor) 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.

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. Make sure the hoses and fittings are clean before any connections are made.

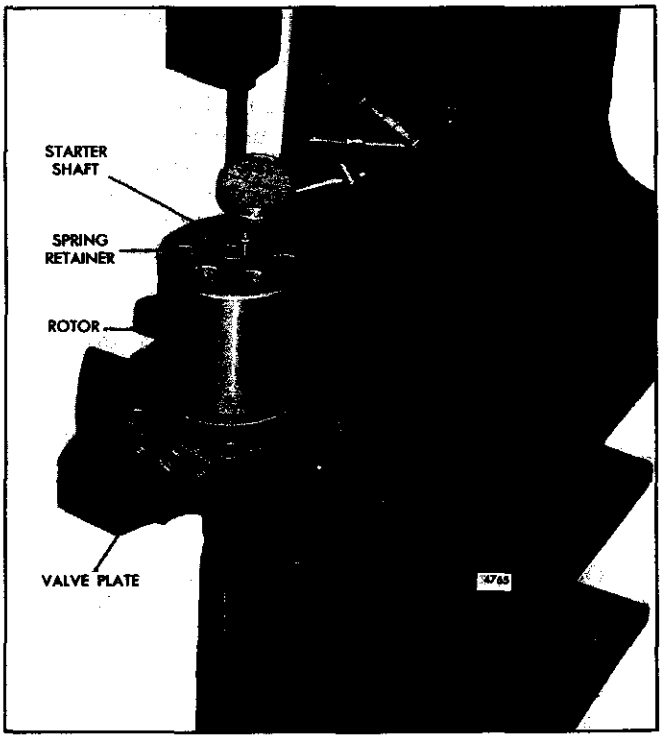

Fig. 9 – Checking Starter Shaft Travel (Series "20" Motor)

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.

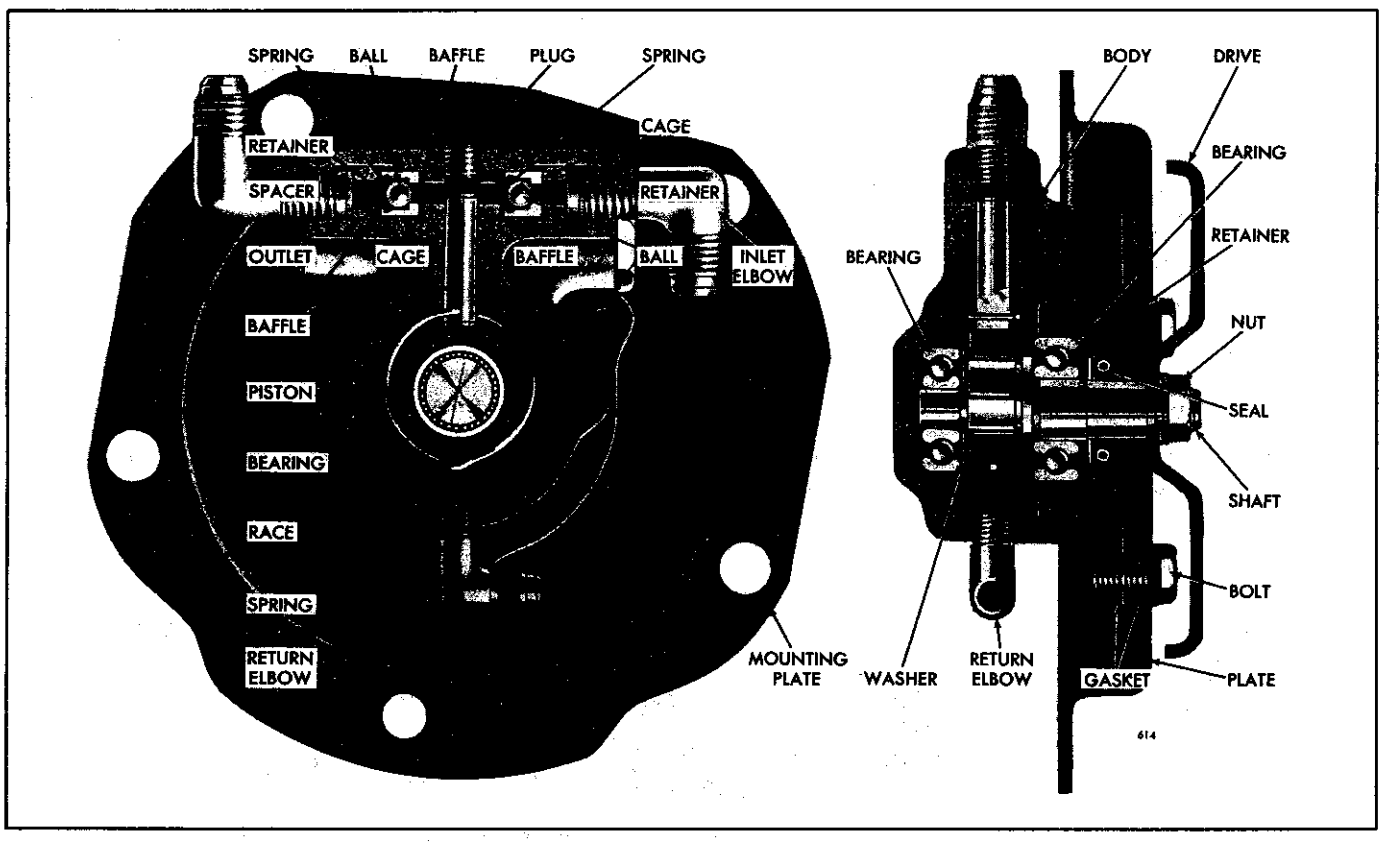

Fig. 10 – Direct Engine–Driven Hydrostarter Charging Pump

DIRECT ENGINE–DRIVEN CHARGING PUMP

The direct engine–driven charging pump (Fig. 10) is a single –piston positive displacement type. The ball check valves and the unloading valve are automatically controlled by the accumulator pressure. The pump shaft is supported on ball 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 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.

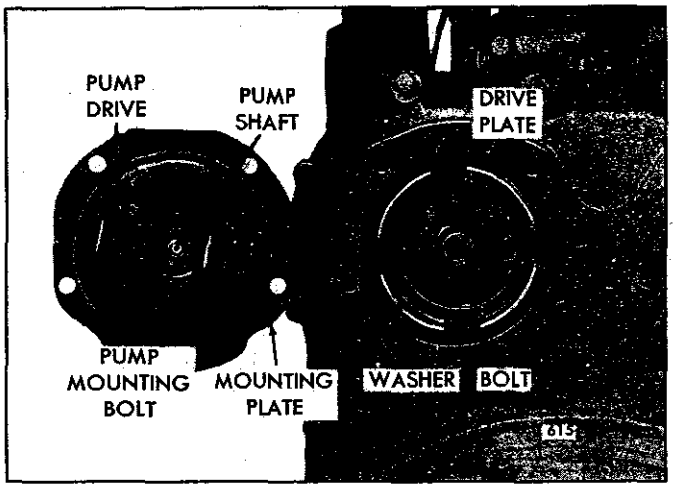

Fig. 11 – Pump Drive Plate Mounting

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 damage.

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.
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.

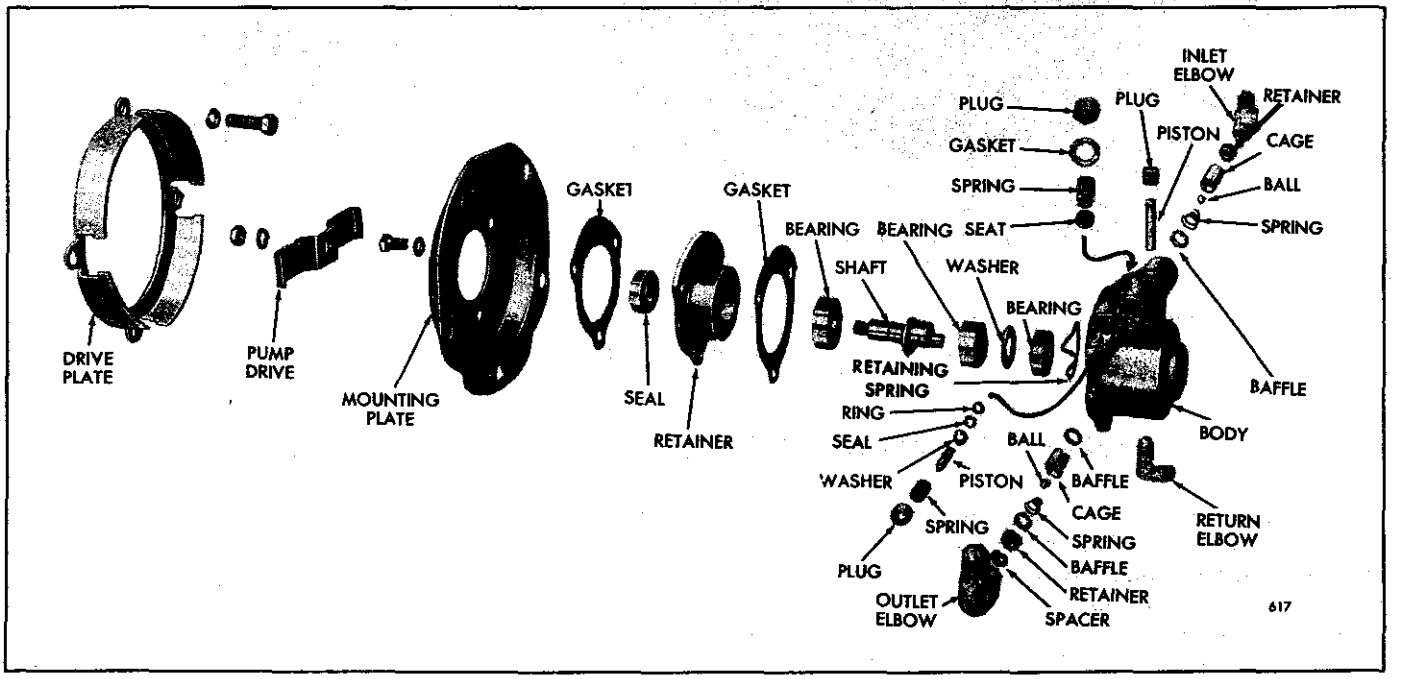

Fig. 12 – Direct Engine–Driven Charging Pump Details and Relative Location of Parts

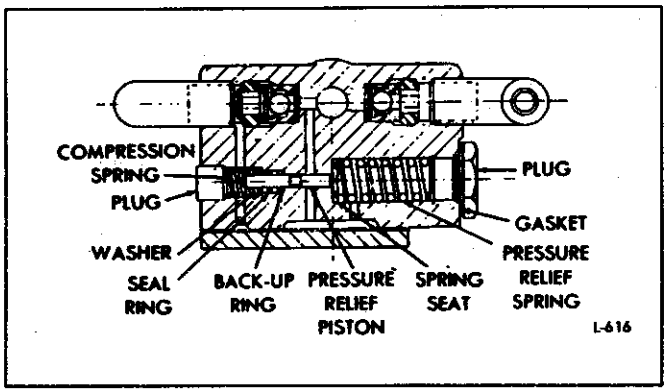

Fig. 13 – Engine–Driven Hydrostarter Charging Pump Pressure Relief Piston Assembly

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.

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 ***lb–in*** 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.

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 ***lb–in*** 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.

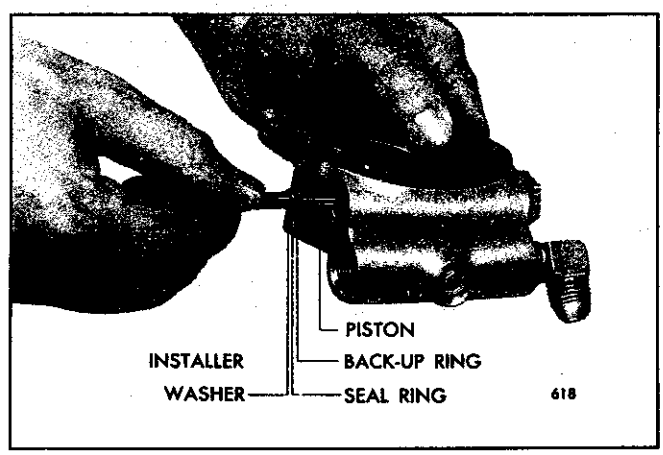

Fig. 14 – Installing Pressure Relief Piston, Back–Up Ring, Seal Ring and Washer in Pump Body with Installer J 7192

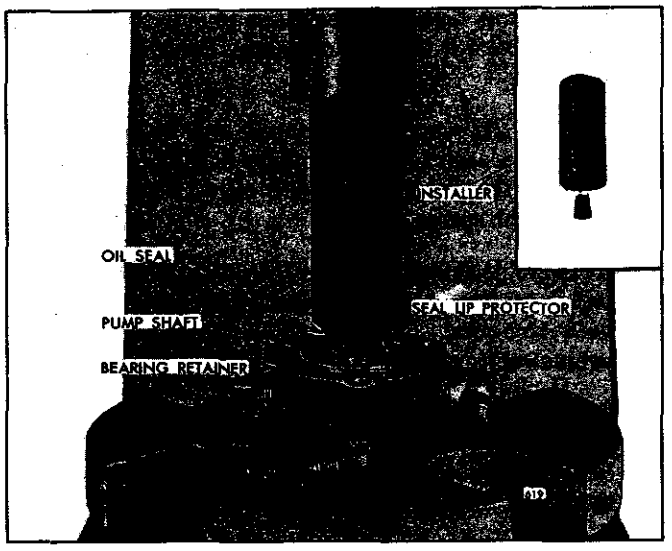

Fig. 15 – Installing Pump Shaft Oil Seal in Bearing Retainer

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.

   NOTICE: 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, 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.

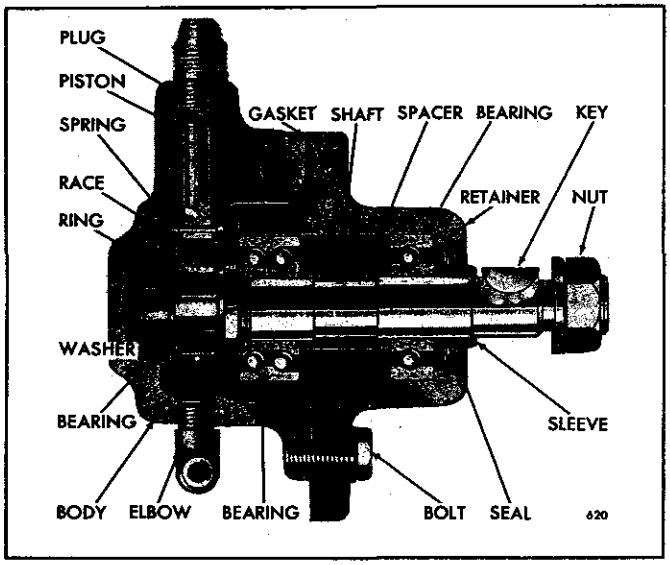

Fig. 16 – Belt-Driven Hydrostarter Charging Pump

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.

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).

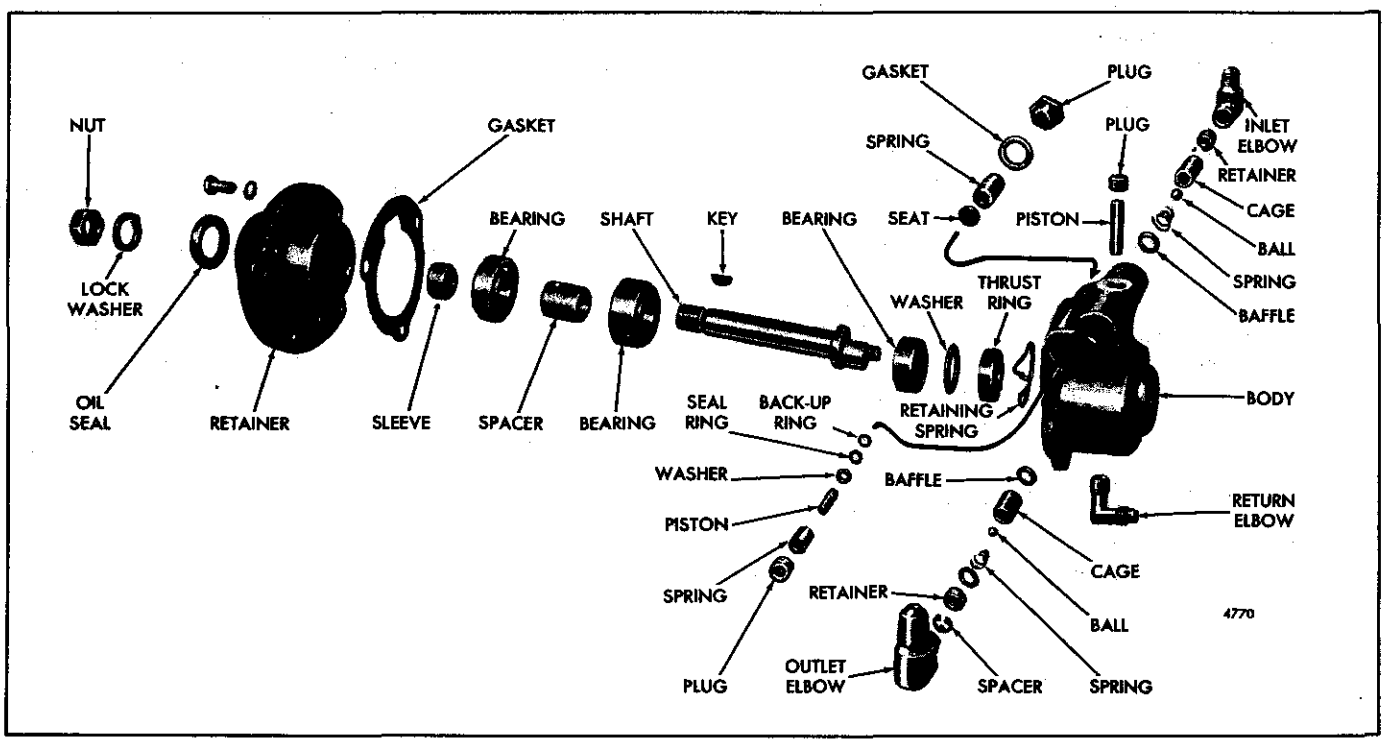

Fig. 17 – Belt-Driven Charging Pump Details and Relative Location of Parts

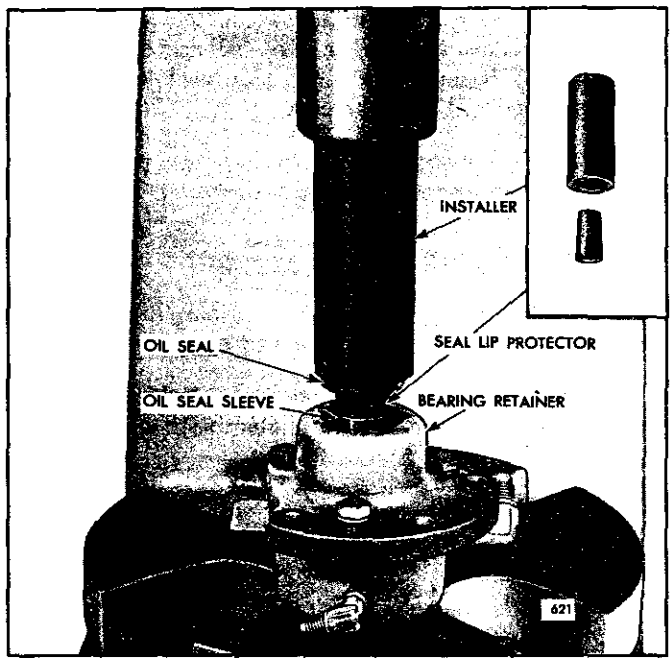

Fig. 18 – Installing Pump Shaft Oil Seal in Bearing Retainer

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 ***lb–in*** 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 ***lb–in*** 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.

    The current belt–driven pumps incorporate a 5/8" diameter shaft. Former pumps used an 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 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 damage.

2. Clean all of the exterior dirt from the hand pump and the hydraulic hoses.
3. Disconnect the hydraulic hoses at the pump.
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.

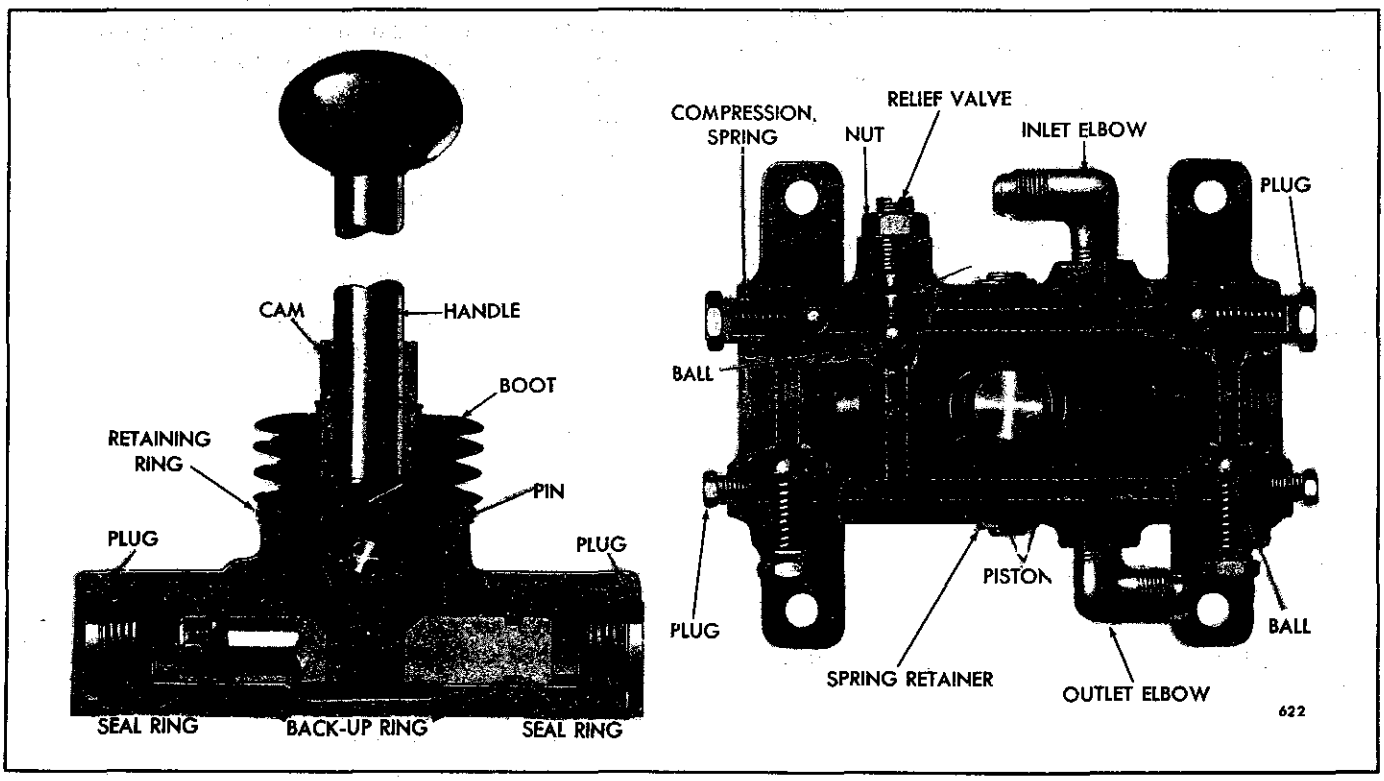

Fig. 19 – Cross Sections of Hydrostarter Hand Pump

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. *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 expensive, 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.

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 damage.

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.

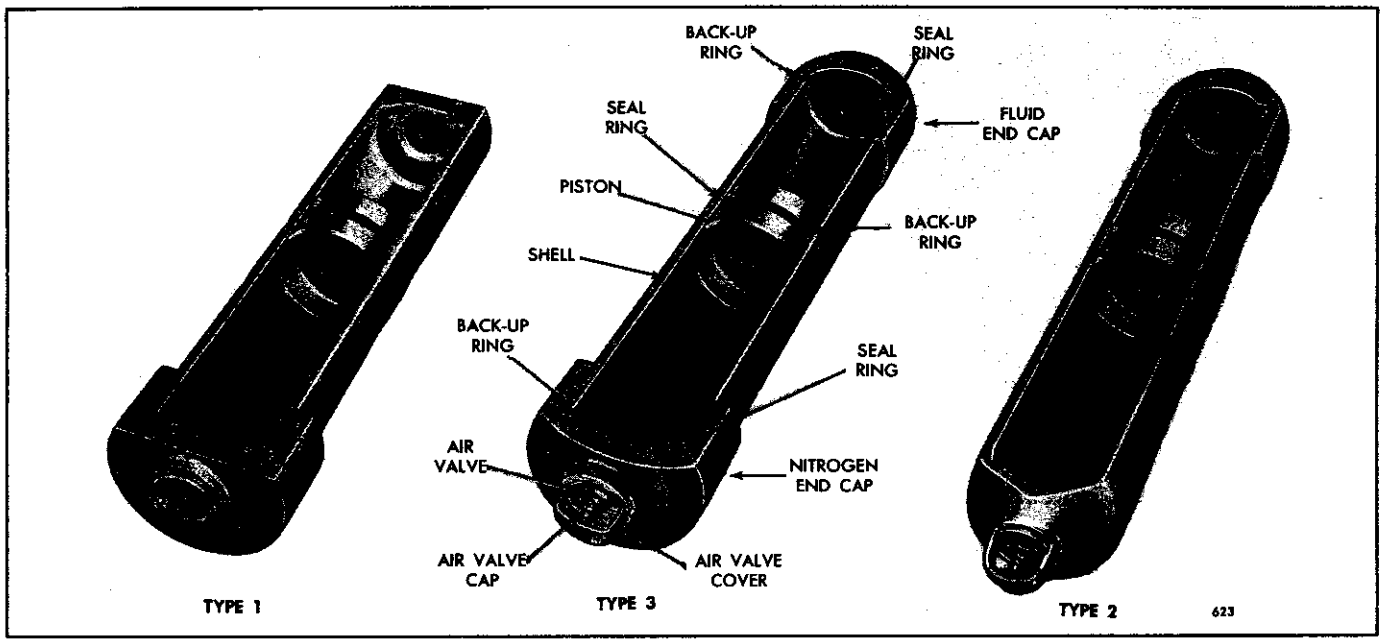

Fig. 20 – Cross Section of Typical Accumulators

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.

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).

NOTICE: Make sure the teflon seal be installed is 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.

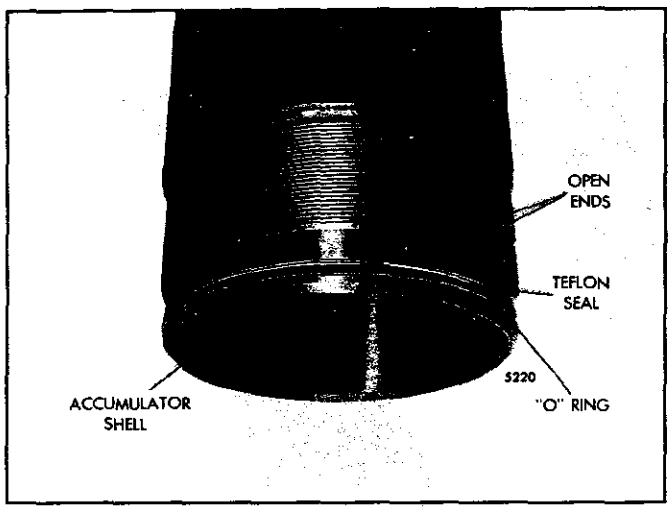

Fig. 21 – Proper Installation of Teflon Back–up Ring

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.

2. Connect the hydraulic hoses to the accumulator. *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.

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.

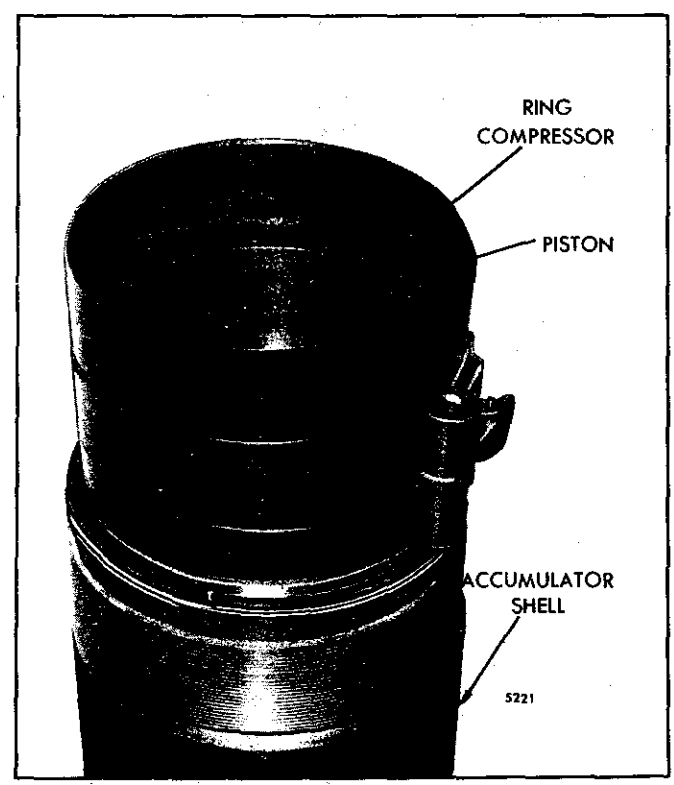

Fig. 22 – Installing Piston in Accumulator Shell

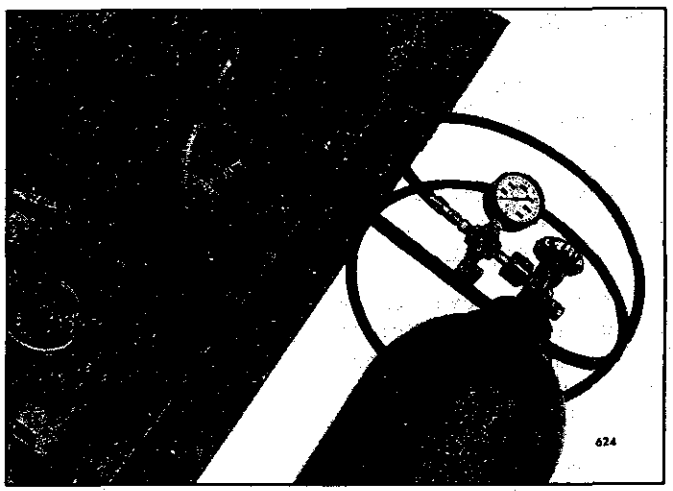

Fig. 23 – Charging Accumulator with Charging Kit J 6714–02

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. Be sure Caution Decal ("CAUTION: This Vessel Pre–Charged to 1250 psi with Dry Nitrogen") is on accumulator.

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 four sizes of reservoirs: 10, 12, 16 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.

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

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.

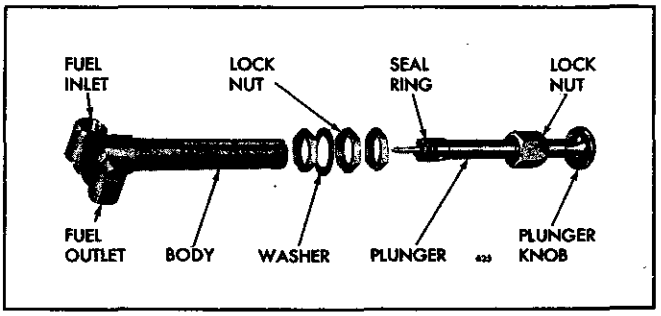

Fig. 24 – Fuel System Priming Pump and Relative Location of Parts

HYDRAULIC REMOTE CONTROL SYSTEM

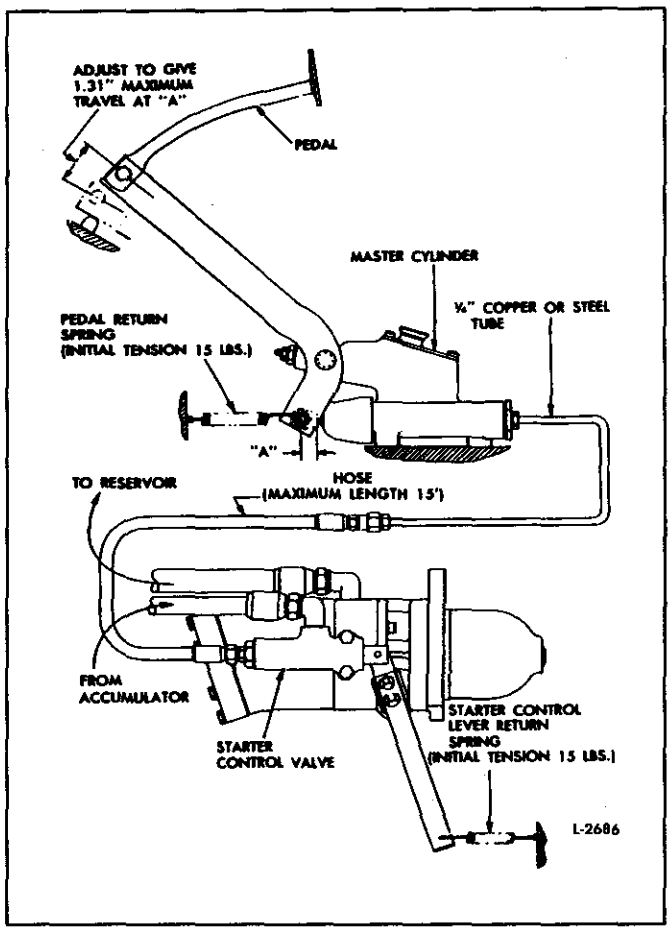

Fig. 25 – Hydraulic Remote Control System for Hydrostarter

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.

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. Replenish the fluid in the master cylinder as required during the purging operation.
4. Tighten the hose fitting and check for leaks.

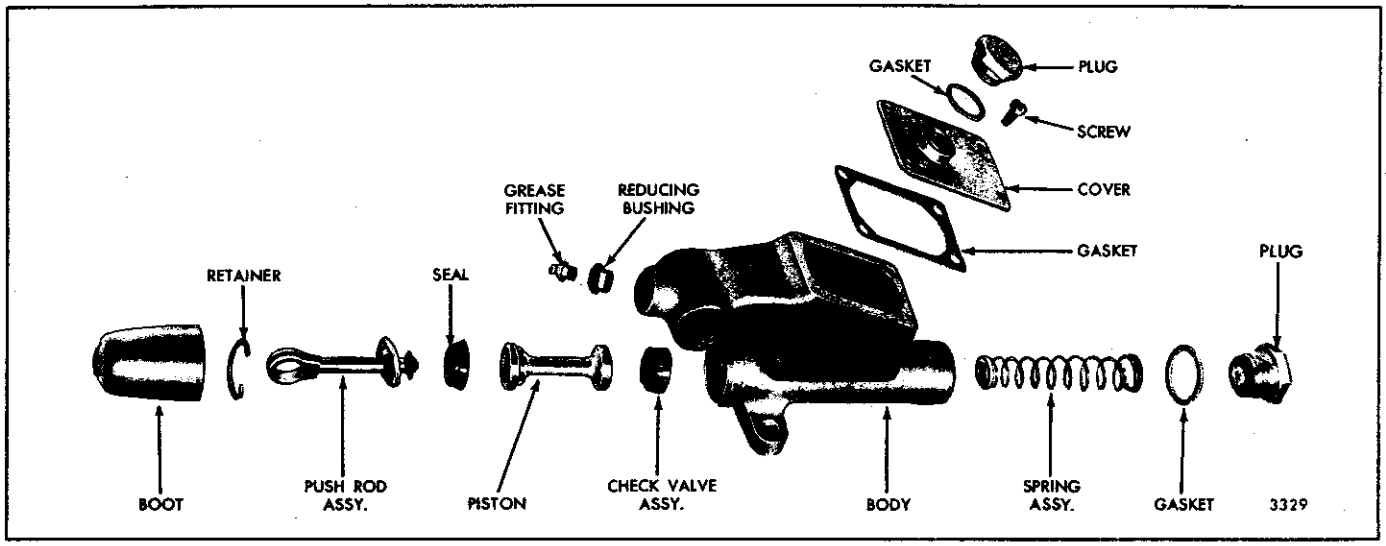

Fig. 26 – Hydraulic Starter Remote Control Master Cylinder Details and Relative Location of Parts

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 damage.

NOTICE: 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.

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 damage.

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.

Troubleshooting

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 Troubleshooting 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.

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 LIBRICANT)
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 locknut 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.

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. 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.
3. Check the fluid level after the accumulator is charged and the engine–driven pump is bypassing 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.

Chart 10

FLUID EMERGES AROUND RUBBER BOOT ON HAND PUMP

Probable Causes

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 RINGS

SUGGESTED REMEDY

1. Operate the starter. If fluid emerges around the front end of the control valve, the seal ring is damaged.
2. 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.

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.

HYDROSTARTER SPECIFICATIONS

Hydrostarter Motor

Type	Swash plate
Number of pistons	Seven
Displacement per revolution *20 Series*	2 cu. in. (32.8 cu. cm³)
Displacement per revolution *35 Series*	3.5 cu. in. (57.4 cu. cm³)
Maximum torque at 3000 psi *20 Series*	80 lb–ft (108 N·m)
Maximum torque at 3000 psi *35 Series*	140 lb–ft (190 N·m)
Drive	Overrunning clutch
Inlet port *20 and 35 Series*	No. 8 elbow (JIC 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 cu. cm³)
Inlet port	No. 6 elbow (SAE 45° flare)
Outlet port	No. 6 elbow (J1C 37° flare)
Bypass 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 cu. cm³)
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 cu. cm³)
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 liters)
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 cu. cm³)
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

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	260M BOLTS TORQUE N·m	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	280M OR BETTER TORQUE N·m
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	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

SERVICE TOOLS

TOOL NAME	TOOL NO.
Air Compressor Hub Remover	J 36309
Air Compressor Hub Installer	J 36311
Accumulator charging Kit	J 6714–D

SECTION 13

OPERATING INSTRUCTIONS

CONTENTS

ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

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.

NOTICE: 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.

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 and pouring water into the pump.

NOTICE: 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, DDC recommends that the engine lubrication system by charged with a commercially available pressure prelubricator. 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 turbocharger bearing (center) housing 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 turbocharger oil supply lines.
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, DDC 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 *Lubricating Oil* in Section 13.3 or contact a Detroit Diesel distributor.

If a pressure prelubricator is not available, fill the crankcase to the proper level with *heavy–duty* lubricating oil as specified under *Lubricating Oil* in Section 13.3. Then, prelubricate the upper engine parts by removing the valve rocker covers and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms.

Turbocharger

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

1. Clean the area and disconnect the oil inlet line at the bearing housing.
2. Fill the bearing housing cavity with clean engine oil.
3. Reinstall the oil line. Clean off any spilled oil.

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 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 supply shutoff valve, it must be opened. Special note should be taken of the direction of flow through any check valves used in the system to be sure of their proper installation.

To ensure prompt starting and even running, the fuel system must be purged of air and full of fuel from the supply tank to the restricted fitting at the fuel return line. To accomplish this, a manual priming pump, such as J 5956 or an electrical type priming pump can be adapted easily to the fittings provided on the primary or secondary filters. To be sure the injectors are lubricated and in order to have less resistance to priming flow caused by the static fuel pump, priming through the secondary filter is preferred. The system should be primed until no air is present in the fuel flow from the return line. Pressure should not exceed 15 psi (103 kPa) for ease of handling and safety reasons.

Pressurization of the fuel tank, although not recommended, can be used with controlled air pressure and a modified filler cap (do not exceed 15 psi or 103 kPa). If this system is used, be sure the return line from the head is disconnected to bleed the system, or no flow will occur. Reverse flow through the return line should be avoided to prevent reverse flushing of filters and flushing residue from the fuel tank into the injectors. Special provisions may have to be made on dual tanks to prevent loss of pressure from the vent on the tank opposite the tank being pressurized.

Priming is not always necessary if the filter elements are filled with fuel when installed and the manifolds in the head are not drained of fuel. Prolonged use of the starter motor and engine fuel pump to prime the system can result in damage to the starter, fuel pump, injectors and erratic running of the engine, due to the amount of air in the lines and filters from the supply tank to the cylinder head.

Engines equipped with starting devices dependent on compressed air or gas reservoirs should always be primed prior to initial start–up, otherwise reserve pressure can be exhausted. Injectors can be damaged from lack of lubrication and cooling.

> **NOTICE:** Under no circumstances should a starting aid such as ether be used to run the engine until the fuel system is primed. Injector damage will occur is this method is used. The heat generated by the external fuel source will cause the tips to be damaged when the fuel cools them. The plunger and bushing can be scored from running without lubrication.

Lubrication Fittings

Fill all grease cups and lubricate at all fittings (except for fan hub pulley fitting—refer to Section 15.1) 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. Check the "Eye" of maintenance–free batteries for charge. Check standard lead–acid and semi–maintenance free batteries, when necessary, 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. 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,* Section 15.1.

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. On engines with dual air shutdown housings, both air shutoff valves must be in the *open* position before starting the engine.

NOTICE: 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. The instructions for the use of a cold weather fluid starting aid will vary depending on the type being used. Reference should be made to these instructions before attempting a cold weather start.

CAUTION: Starting fluid used in capsules is highly inflammable, toxic and possesses sleep–inducing properties.

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.

NOTICE: 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 (Air Starter)

Because of the limited volume of most storage tanks and the relatively short duration of the cranking cycle, it is important to make sure the engine is **ready to start** before activating the air starter. Start an engine equipped with an air starter as follows:

1. Set the speed control lever at part throttle, then bring it back to the desired no–load speed. In addition, make sure the stop lever on the cover of mechanical governors is in the **run** position. On hydraulic governors, make sure the stop knob is pushed all the way in.
2. Check the pressure in the air storage tank. If necessary, add air to bring the pressure up to at least the recommended minimum for starting.
3. Press the starter button firmly and hold until the engine starts.

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.

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

Set the engine controls for starting with the throttle at least half open.

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).

• "SILVER 53" ENGINE COLD START RECOMMENDATIONS/ADJUSTMENTS

If cold weather starting difficulties are experienced with Series 53 Silver engines, the following recommendations should be adhered to for optimum unaided cold start performance:

1. Fuel should be No. 2–D with a minimum cetane number of 45 (refer to "Fuel Oil Selection" in section 13.3).

2. A 12–volt system should use one (1) 625 CCA (cold cranking amp) battery for in–line engines, two (2) 625 CCA batteries for V–engines. Circuit resistance should not exceed .0012 ohms.

3. A 24–volt system should use two (2) 625 CCA batteries and circuit resistance should not exceed .002 ohms.

4. All in–line Silver 53 engines are equipped with Delco 40 MT or 37 MT starters. Older engines may have 30 MT starters, which may not provide adequate cranking speed for colder climates. The 6V–53 Silver engines must use 40 MT starters.

5. Parasitic loads at starting should be minimized. A minimum cranking speed of 130 rpm at 30°F (-1.11° C) must be maintained for successful cold start characteristics. A cold diesel engine does not produce as much torque at lower rpm as an engine at normal operating temperatures. For this reason, applications where the parasitic load is in excess of 50 lb–ft (68 N·m) torque at cranking speed may result in unsatisfactory cold start characteristics.

STARTING. For temperatures below 30°F (-1.11° C), use this starting procedure:

Holding the governor out of fuel, crank the engine for 15 seconds. Ease the governor into fuel while continuing to crank for an additional 15 seconds. If ether is used, inject while the engine is being cranked in fuel. Allow the starter to cool for 15 seconds and continue with 30–second cranking periods, separated by 15–second cool down periods, until the engine starts.

> **NOTICE:** *Overfueling or "flooding" the engine during cold start will reduce compression tempereatures, wash lube oil from cylinder walls, reduce compression pressure, and decrease the likelihod of a successful start.*

If these recommendations do not solve the starting difficulty, it may be necessary, in some cases, to retune the engine to the specifications shown in the chart. These settings apply to engines using 5C and 5E fuel injectors only.

Injector Timing/Modulator Setting		
	Standard	Cold Start*
3–53T	1.480/ .290	1.500/ .200
4–53T	1.480/ .290	1.500/ . 200
6V–53T	1.480/ .290	1.500/ .290

* The rack setting tool used for a .200 modulator setting is J35586. The 1.500 injector timing tool is J 25454.

> **NOTICE:** *The above timing changes are not to be made on early (non–Silver) Series 53 engines EPA–certified for highway service.*

These changes can be made on a permanent basis or at change of seasons, whichever is preferred. It should be noted that changing to 1.500 injector timing could result in a slight increase in fuel consumption, compared to standard timing at SAE standard conditions. The .200 modulator setting may slightly increase visible smoke levels as well.

Temperatures below 30°F (-1.11° C) may require some of the following special considerations:

1. Cold weather fuel and/or oil selection (Refer to Section 13.3 for recommendations).
2. Water jacket (coolant) heater.
3. Lubricating oil heater (oil pan).
4. Hot air space heaters applied to engine compartment.
5. Cold weather hydraulic fluids if accesory pumps cannot be disengaged.
6. Insulated or heated battery boxes for maximum battery efficiency.

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.

Engine Temperature

See Section 13.2 for normal engine coolant temperature.

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached. Allow the oil to drain back into the crankcase for approximately twenty minutes and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick. *Do not overfill.*

Use only the *heavy duty* lubricating oil specified under *Lubricating Oil* in Section 13.3.

Clutch

Do not engage the clutch (with a sintered iron clutch plate) at engine speeds over 850 rpm. A clutch with an asbestos or vegetable fiber material clutch plate must not be engaged at speeds over 1,000 rpm.

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.

CAUTION: Use extreme care when removing the coolant pressure control cap. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

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 the marine gear oil pressure. The operating oil pressure range at operating speed varies with the gear used. Refer to the gear manufacturer's recommendations. Check the oil and, if necessary, add oil to bring it to the proper level.

Turbocharger

• 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.

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. 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 governer 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.

NOTICE: 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.

Crankcase

Allow the oil to drain back into the crankcase for approximately twenty minutes and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the *heavy-duty* lubricating oil specified under *Lubricating Oil* in Section 13.3.

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 the *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.

ENGINE OPERATING CONDITIONS

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) – min. 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

	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
Keep 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)	40–65	40–65	40–65
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) – full load min.:			
At zero exhaust back pressure	3.7	4.8	6.1
At max. 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 withour 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

	2200 rpm	2500 rpm	2800 rpm
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) – min. 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	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Raw wate pump:			
Inlet restriction (inches mercury) – max.	& 5.0	& 5.0	5.0
Outlet pressure (psi) – max..	&10.0	&10.0	10.0
Keep 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% at maximum rpm.

#2–53 reefer car engines only.

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) – min. 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.

•3–53 "SILVER" TURBOCHARGED ENGINES INDUSTRIAL

	2200 rpm	2500 rpm
Lubrication System		
Lubricating oil pressure (psi):		
Normal	40–60	40–60
Minimum for safe operation	30	32
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235
Air System		
Air box pressure (inches mercury) – min. full load:		
At zero exhaust back pressure:		
5E50 injector	27.5	33
5E55 injector	32.5	38
5E60 injector	37.5	44
injector		
injector		
injector		
Air inlet restriction (inches water) – full load max.:		
Dirty air cleaner	20	20
Clean air cleaner	12	12
Crankcase pressure (inches water) – max.	2.8	3.0
Exhaust back pressure (inches mercury) – max.:		
Full load	2.5	3.0
Fuel System		
Fuel pressure at inlet manifold (psi)		
Normal with .070" restriction	45–70	45–70
Minimum	35	35
Fuel spill (gpm) – min. at no load:		
.070" restriction	0.6	0.6
Pump suction at inlet (inches mercury) – max.:		
Clean system	6.0	6.0
Dirty system	12.0	12.0
Cooling System		
Coolant temperature (deg. F) – Normal	170–187	170–187
Compression		
Compression pressure (psi at sea level):		
Average – new engine – at 600 rpm	470	470
Minimum – at 600 rpm	420	420

†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.

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	6.0	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.

•4–53 "SILVER" TURBOCHARGED ENGINES INDUSTRIAL

	2200 rpm	2500 rpm
Lubrication System		
Lubricating oil pressure (psi):		
Normal	34–54	37–57
Minimum for safe operation	30	32
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235
Air System		
Air box pressure (inches mercury) – min. full load:		
At zero exhaust back pressure:		
5C50 injector	28.7	36.0
5C55 injector	35.4	41.4
5C60 injector	40.0	45.5
At maximum exhaust back pressure:		
5C50 injector		
5C55 injector		
5C60 injector		
Air inlet restriction (inches water) – full load max.:		
Air cleaner (dirty)	20	20
Air cleaner (clean)	12	12
Crankcase pressure (inches water) – max.	2.8	3.0
Exhaust back pressure (inches mercury) – max.:		
Full load	2.5	3.0
Fuel System		
Fuel pressure at inlet manifold (psi)		
Normal with .070" restriction	45–70	45–70
Minimum	35	35
Fuel spill (gpm) – min. at no load:		
.070" restriction	0.6	0.6
Pump suction at inlet (inches mercury) – max.:		
Clean system	6.0	6.0
Dirty system	12.0	12.0
Cooling System		
Coolant temperature (deg. F) – Normal	170–187	170–187
Compression		
Compression pressure (psi at sea level):		
Average – new engine – at 600 rpm	470	470
Minimum – at 600 rpm	420	420

†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.

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	—	—

	Marine 2800 rpm	Industrial 2500 rpm	Vehicle 2600 rpm
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.

•6–53 "SILVER" TURBOCHARGED ENGINES INDUSTRIAL

	2200 rpm	2500 rpm
Lubrication System		
Lubricating oil pressure (psi):		
Normal	40–60	40–60
Minimum for safe operation	30	32
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235
Air System		
Air box pressure (inches mercury) – min. full load:		
At zero exhaust back pressure:		
5C50 injector	29.1	36.1
5C55 injector	31.5	38.2
5C60 injector	40.5	47.1
At maximum exhaust back pressure:		
5C50 injector		
5C55 injector		
5C60 injector		
Air inlet restriction (inches water) – full load max.:		
Air cleaner (dirty)	20	20
Air cleaner (clean)	12	12
Crankcase pressure (inches water) – max.	3.0	3.0
Exhaust back pressure (inches mercury) – max.:		
Full load	2.5	2.5
Fuel System		
Fuel pressure at inlet manifold (psi)		
Normal with .070" restriction	45–70	45–70
Minimum	35	35
Fuel spill (gpm) – min. at no load:		
.070" restriction	0.6	0.6
Pump suction at inlet (inches mercury) – max.:		
Clean system	6.0	6.0
Dirty system	12.0	12.0
Cooling System		
Coolant temperature (deg. F) – Normal	170–187	170–187
Compression		
Compression pressure (psi at sea level):		
Average – new engine – at 600 rpm	470	470
Minimum – at 600 rpm	420	420

†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.

