SECTION 6

EXHAUST SYSTEM

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Exhaust System 6

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EXHAUST SYSTEM

Fan and radiator–cooled engines are equipped with an air–cooled exhaust manifold. A water–cooled exhaust manifold is provided for engines incorporating a heat exchanger or keel cooling system.

The outlet flange may be located at the end or at the mid–section of the exhaust manifold, depending upon the installation requirements. A flexible exhaust connection or a muffler may be attached to the outlet flange.

The exhaust manifold is attached to studs located between the exhaust ports and the outer side of the two end ports in the cylinder head. Special washers and nuts secure the manifold to the cylinder head.

EXHAUST MANIFOLD (AIR-COOLED)

Two types of exhaust manifolds are used. One type has an outlet to accommodate a square exhaust outlet flange (Fig. 1) and the other has a circular outlet which is connected to the exhaust pipe with a Marmon-type clamp (Fig. 2). Current manifolds, flanges (square) and flange gaskets have SAE standard dimensions.

On engines equipped with a mechanical automatic shutdown system, the exhaust manifold is provided with two 5/16"-18 tapped bolt holes and a 7/8" drilled hole to permit installation of the temperature shutdown valve adaptor and plug assembly.

Remove Exhaust Manifold

1. Allow the engine to cool. Then disconnect the exhaust pipe or muffler from the exhaust manifold flange.
2. If the engine is equipped with a mechanical automatic shutdown system, remove the two bolts and lock washers and withdraw the shutdown valve adaptor and plug assembly from the exhaust manifold.
3. Loosen, but do not remove, one of the center exhaust manifold nuts. Remove the other nuts and washers.
4. Support the manifold and remove the center nut and washer.
5. Remove the manifold and gasket from the cylinder head.

Inspection

Remove any loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold. Clean the manifold and check for cracks, especially in the holding lug areas.

Clean all traces of gasket material from the cylinder head.

Replace broken or damaged exhaust manifold studs. Apply sealant to the threads and drive new studs to 25–40 lb-ft (34–54 N·m) torque (1.40" to 1.50" height).

Install Exhaust Manifold

1. Place a new gasket over the studs and against the cylinder head.
2. Position the exhaust manifold over the studs and hold it against the cylinder head.
3. Install the washers and nuts on the studs. If beveled (dished) washers are used, position them so that the crown side faces the nut. On some engines, crabs are used in place of washers at the end positions (Fig. 2). Beginning with one of the center stud nuts and working alternately toward each end of the manifold, tighten the nuts to 30–35 lb-ft (41–47 N·m) torque.

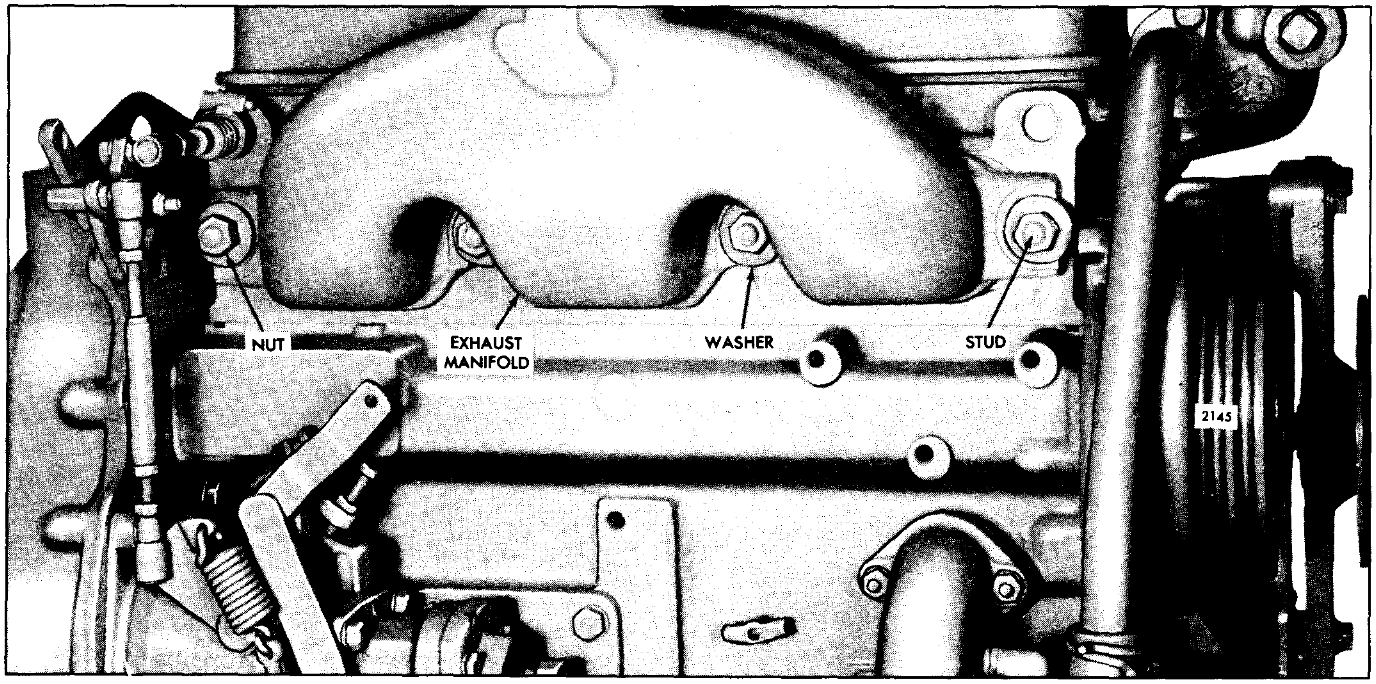


Fig. 1 – Typical Air-Cooled Exhaust Manifold (Square Flange) Mounting

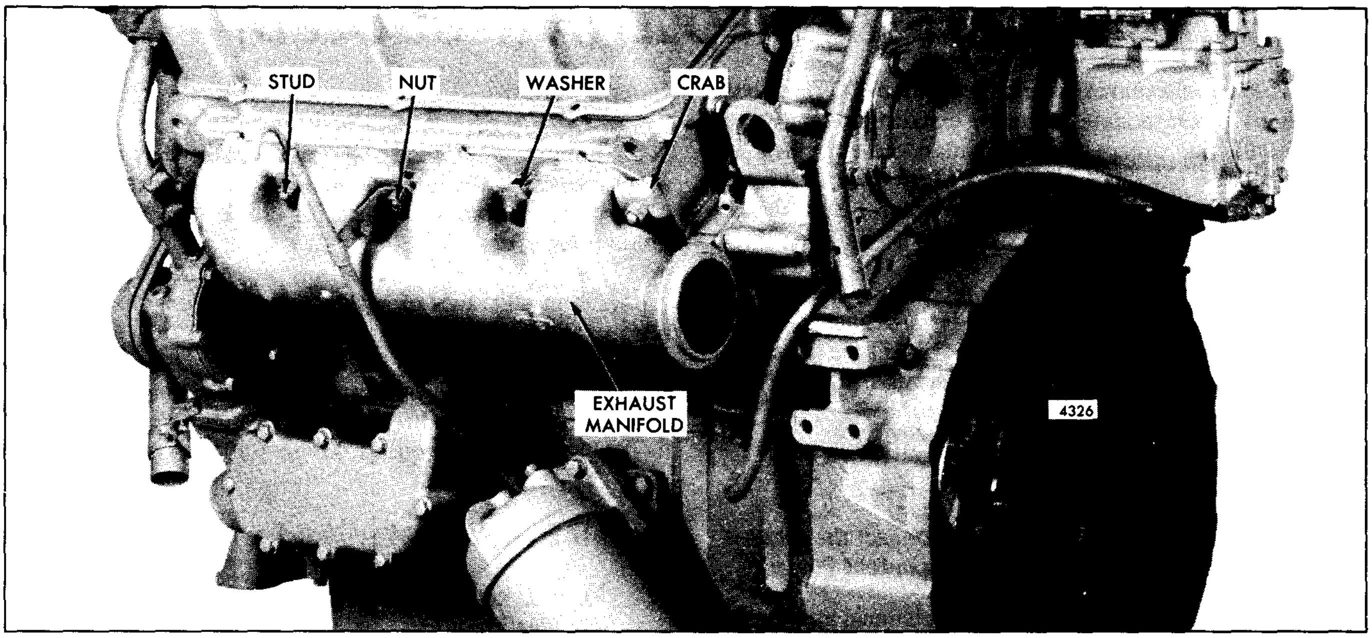


Fig. 2 – Exhaust Manifold with Marmon Flange

4. If the engine is equipped with a mechanical automatic shutdown assembly, install the shutdown valve adaptor and plug assembly in the exhaust manifold and secure it with two bolts and lock washers.

5. Connect the exhaust pipe or muffler to the exhaust manifold flange.

NOTICE: To avoid turbocharger damage, do not allow exhaust piping to impose excessive loads on the turbocharger.

6. Inspect the exhaust outlet piping for dents, holes and potential sources of water infiltration such as loose clamps or deteriorated seals. Repair or replace, if necessary.

EXHAUST MANIFOLD (WATER-COOLED)

A water jacket surrounds the exhaust chamber in the cast iron water–cooled exhaust manifold illustrated in Fig. 1. The engine coolant flows from the rear of the cylinder head through the water jacket around the exhaust manifold and through the thermostat housing and the water bypass tube to the water tank.

Remove Exhaust Manifold

1. Allow the engine to cool. Then remove the water tank filler cap and open the vent valve at the front end of the exhaust manifold.

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

2. Drain the cooling system.
3. Disconnect the exhaust pipe from the exhaust manifold flange.
4. Loosen the hose clamps and slide the hose back on the water inlet connector attached to the rear end of the cylinder head. On some engines, the connector is a formed hose which can be removed.
5. Disconnect the water tank vent tube, if used, at the exhaust manifold.
6. Loosen the hose clamps and slide the hoses back on the water bypass tube and the heat exchanger water inlet tube or the thermostat housing.
7. If a water filter is used, disconnect the filter hose to the exhaust manifold.
8. Loosen the hose clamps at each end of the raw water pump outlet intermediate tube and slide the hose back on the tube at the curved end, then slide the tube out of the hose at the heat exchanger end.
9. Support the manifold and remove the nuts and washers which secure it to the cylinder head.
10. Remove the manifold and manifold gasket.
11. If necessary, remove the exhaust manifold flange at the rear of the manifold and the water outlet flange at the front.

Inspection

Remove the loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold.

Clean all traces of gasket material from the cylinder head.

Examine the exhaust manifold studs for damage. If necessary, replace the studs. Apply sealant to the threads and drive new studs in to a height of 1.40" to 1.50" or to 25–40 lb–ft (34–54 N·m) torque.

Install Exhaust Manifold

1. If removed, install the exhaust flange and water outlet flange on the exhaust manifold.
2. Place a new gasket over the studs and against the cylinder head.

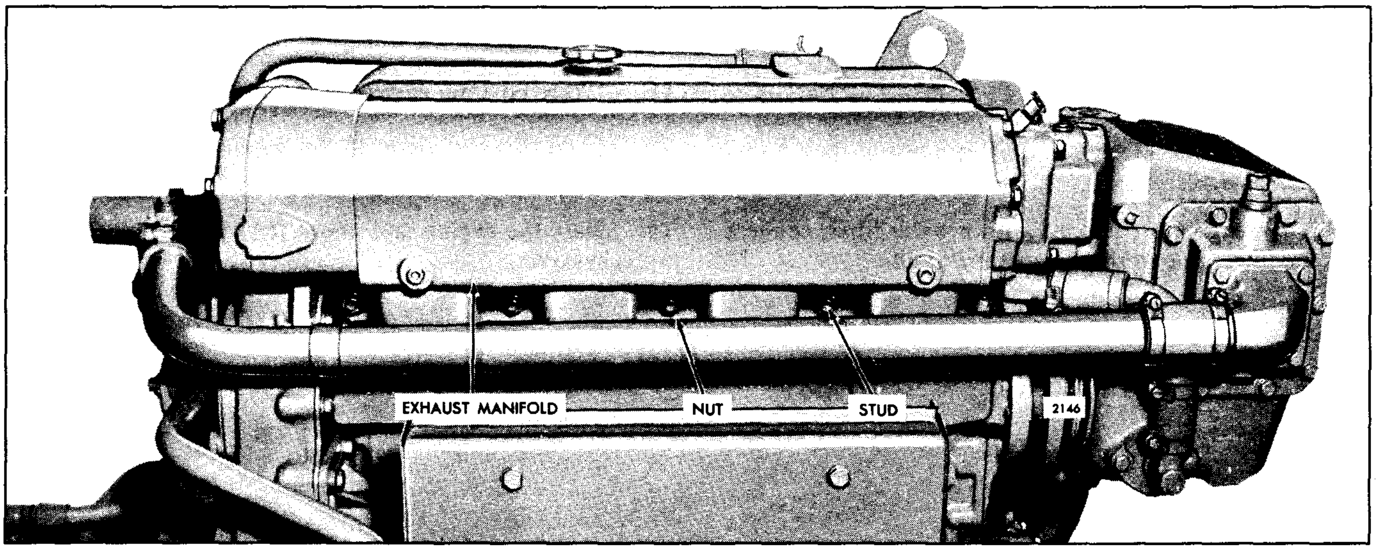
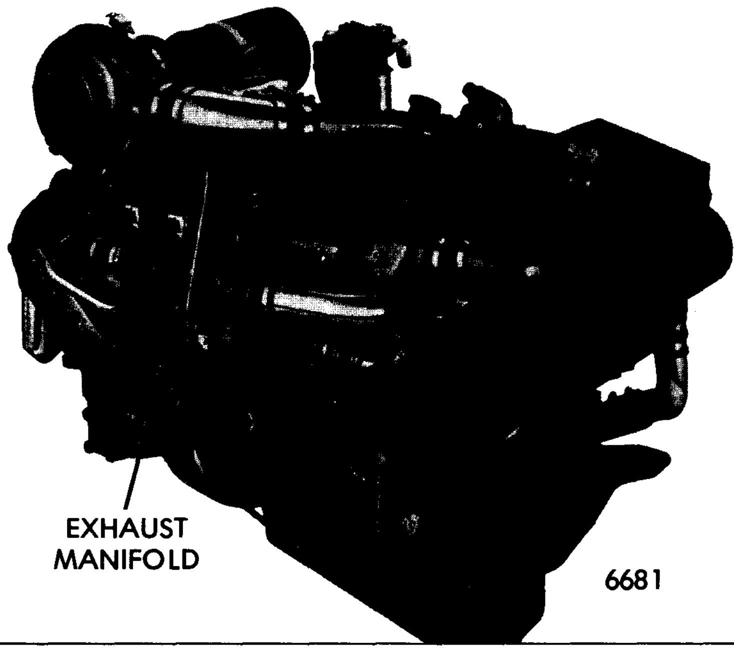


Fig. 1 – Typical Water–Cooled Exhaust Manifold Mounting (In–Line Engine)



• Fig. 2 – Typical Water-Cooled Exhaust Manifold Mounting (6V Engine)

3. Position the exhaust manifold over the studs and hold it against the cylinder head. Be sure the locating pads on the exhaust manifold rest on the cylinder block locating pads.
4. Install the washers and nuts on the studs. Beginning with one of the center stud nuts and working alternately toward each end of the manifold, tighten the nuts to 30–35 lb-ft (41–47 N·m) torque.
5. Slide the hoses in place on the water bypass tube and the heat exchanger water inlet tube or the thermostat housing and tighten the hose clamps.
6. Install the formed hose or slide the hose in place on the water inlet connector attached to the rear of the cylinder head. Tighten the hose clamps.
7. If used, connect the water tank vent tube to the exhaust manifold.
8. If the engine is equipped with a water filter, connect the filter hose to the exhaust manifold.
9. Install the raw water pump outlet intermediate tube, slide the hoses in place and tighten the hose clamps.
10. Connect the exhaust pipe to the exhaust manifold flange.

    NOTICE: To avoid turbocharger damage, do not allow exhaust piping to impose excessive loads on the turbocharger.

11. Inspect the exhaust outlet piping for dents, holes and potential sources of water infiltration such as loose clamps or deteriorated seals. Repair or replace, if necessary.
12. Close the drain valves and fill the cooling system.
13. Close the vent valve at the front end of the exhaust manifold and install the water tank filler cap.
14. Start the engine and check for leaks in the cooling system.

SECTION 7

ELECTRICAL EQUIPMENT, INSTRUMENTS AND PROTECTIVE SYSTEMS

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ELECTRICAL SYSTEM

A typical engine electrical system generally consists of the starting motor(s), a battery–charging alternator, storage batteries and the necessary wiring. Additional equipment such as an engine protective system may also be included.

Detailed information on maintenance and repair of the specific types of electrical equipment can be found in the service manuals and bulletins issued by the equipment manufacturer. Information regarding equipment manufactured by the Delco–Remy Division of General Motors Corporation may be obtained from their electrical equipment operation and service manuals. The manuals may be obtained from AC–Delco service outlets, or from the Technical Literature Section, Delco–Remy Division of General Motors Corporation, Anderson, Indiana.

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the manufacturer of the equipment. Replacement parts for electrical equipment should be ordered through the equipment manufacturer's outlets, since these parts are not normally stocked by Detroit Diesel Corporation. For electrical equipment manufactured by Delco–Remy Division, repair service and parts are available through AC–Delco branches and repair stations.

- **CAUTION: To avoid possible personal injury and/or engine damage from accidental engine startup, always disconnect the battery before servicing the electrical system.**

BATTERY-CHARGING ALTERNATOR

The battery–charging circuit consists of an alternator, battery (Section 7.2), and the wiring. The battery–charging alternator (Figs. 1 and 2) is introduced into the electrical system to provide a source of electrical current for maintaining the storage battery in a charged condition and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

- All In–line 53 engines and most 6V–53 engines use hinge–mounted (belt–driven) alternators. Certain 6V–53 models use flange–mounted (beltless) alternators.

• ALTERNATOR PRECAUTIONS

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

Avoid grounding or shorting the output wires or the field wires between the alternator and the regulator. Never run an alternator on an open circuit.

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

Accidentally reversing the battery connections must be avoided.

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

In marine applications which have two sets of batteries, switching from one set of batteries to the other while the engine is running will momentarily disconnect the batteries and result in damage to the alternator diodes.

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

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

Never attempt to polarize the alternator.

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

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

HINGE–MOUNTED ALTERNATOR (BELT–DRIVEN)

The hinge–mounted alternating current self–rectifying alternator, (Figs. 1 and 2) is belt–driven. The alternator drive pulley is keyed to a shaft which is coupled to the blower drive gear.

An adequate alternator drive ratio is necessary for an engine equipped with extra electrical accessories and one that has to operate for extended periods at idle speeds. Diodes, built into the slip ring end frame, rectify the three phase A.C. voltage to provide D.C. voltage at the battery terminal of the alternator, thereby eliminating the need for an external rectifier. The alternator is also available in various sizes and types, depending upon the specific application.

The SI series alternators have replaced the DN series alternator. With the new alternators, the need for a separately mounted voltage regulator is eliminated.

The 32 volt, 50 ampere 25SI alternator has been replaced by the 30SI alternator, rated at 60 amperes, for marine applications. When installing the 30SI alternator, a wire running from the alternator to the battery (insulated ground vs negative ground) must be installed.

The access hole permitting the external adjustment of the voltage regulator has been eliminated on current alternators. To adjust the voltage setting on the current alternators, remove the rectifier end plate. The voltage regulator adjustment is located on the voltage regulator circuit board. Refer to the pertinent Delco Service Bulletin for complete adjustment procedure.

The proper selection of an alternator which will meet the needs of the battery–charging circuit on the particular engine is mandatory. This, together with adherence to the recommended maintenance procedures will reduce alternator troubles to a minimum. Since most alternators adhere to the same basic design, the maintenance, removal and installation procedures for all are similar.

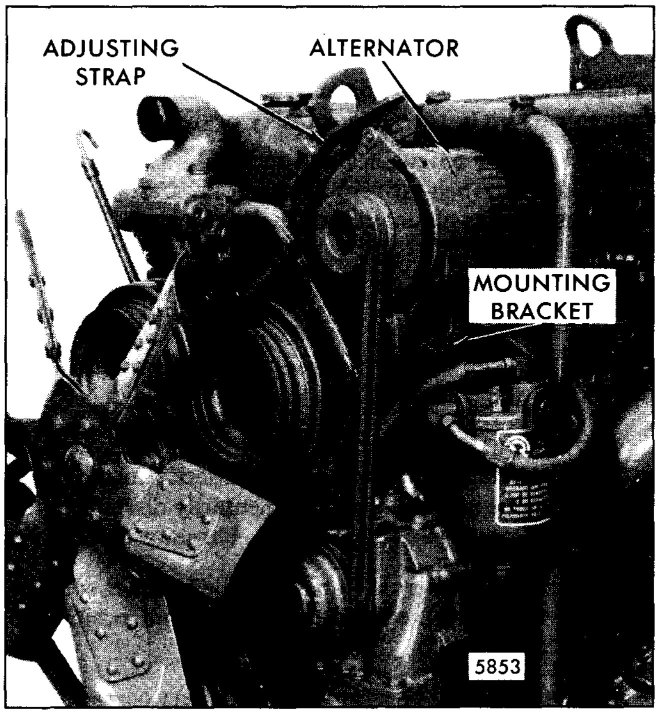


Fig. 1 – Typical Hinge–Mounted Alternator (In–line 53)

Alternator Maintenance

1. Maintain the proper drive belt tension. Replace worn or frayed belts. Belts should be replaced as a set when there is more than one belt on the alternator drive.

2. When installing or adjusting the drive belt, be sure the bolt at the pivot point is properly tightened, as well as the bolt in the adjusting slot.

3. Alternator bearings are permanently lubricated. There are no external oiler fittings.

Remove Alternator

1. Disconnect the cables at the battery supply.

   - **NOTICE:** To avoid alternator damage when removing battery connections, disconnect the negative (–) terminal first. When reinstalling connections, reconnect the negative terminal last.

   Disconnect all other leads from the alternator and tag each one to ensure correct reinstallation.

2. Loosen the mounting bolts and the adjusting strap bolt. Then remove the drive belts.

3. While supporting the alternator, remove the adjusting strap bolt and washers. Then remove the mounting bolts, washers and nuts. Remove the alternator carefully and protect it from costly physical damage.

4. Remove the pulley assembly if the alternator is to be replaced (Fig. 3).

Alternator Service

Repairs and overhaul work on alternators should be referred to an authorized repair station of the manufacturer of this equipment. Replacement parts for alternators should be ordered through the equipment manufacturer's outlets. For alternators manufactured by Delco–Remy Division, repair service and parts are available through AC Delco branches and repair stations.

Install Alternator

1. Install the drive pulley, if it was removed. Tighten the 5/8" – 18 pulley retaining nut to 70–80 lb–ft (95–108 N·m) torque (Fig. 3).

   NOTICE: If the pulley was not removed, check the retaining nut for proper torque.

2. Position the alternator on the mounting brackets and start the bolts, with washers in place, through the bolt holes in the end frames. If nuts are used, insert the bolts through the bolt holes in the mounting bracket and end frame. Make sure that the washers and nuts are in their proper locations.

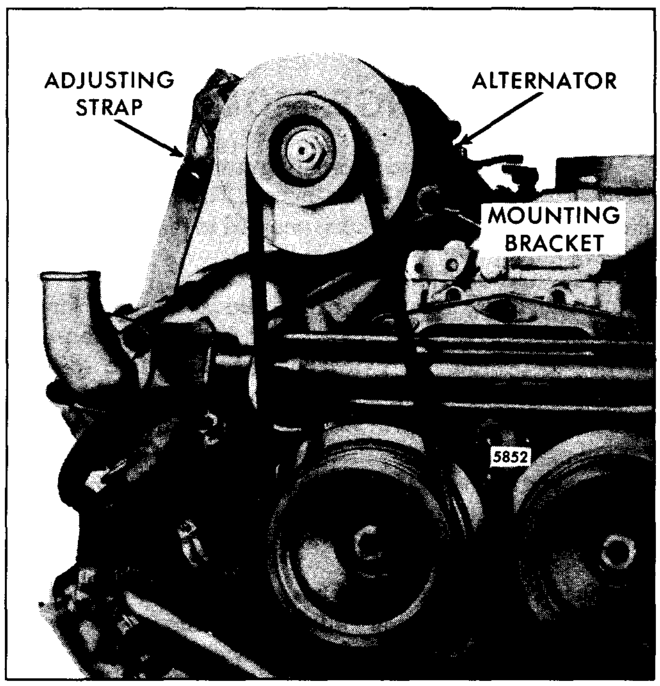


Fig. 2 – Typical Hinge–Mounted Alternator (V–53)

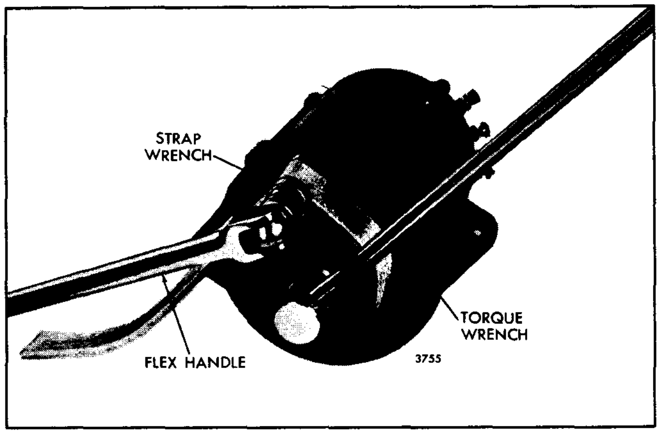


Fig. 3 – Tightening Alternator Pulley Retaining Nut

3. Align the threaded hole in the adjusting lug of the drive end frame with the slot in the adjusting strap. Start the bolt, with the washers, through the slot of the adjusting strap and into the threaded hole in the end frame.

4. Place the drive belts in the grooves of the pulleys.

5. Adjust the belt tension as outlined in Section 15.1. After the belt tightening is complete, tighten all mounting bolts.

6. Attach the wires and cables. Be sure that each one is correctly installed in accordance with its previous location on the alternator. Keep all connections clean and tight.

• FLANGE–MOUNTED ALTERNATOR (BELTLESS)

The flange–mounted alternator is coupling–driven through a drive hub attached to the blower drive gear. It is a self load limiting alternator with a fully adjustable solid state integral regulator. It is designed with slow speed characteristics which allow lower rotational speed of the alternator without sacrificing any amperage output at idle or top speed. The alternator shaft may be rotated in either direction without affecting the output or cooling of the unit. Six silicon diodes mounted in heat sinks convert alternating current from the delta wound stator into direct current.

The brushes and integral voltage regulator are located in a waterproof housing that may be removed for replacement or inspection.

Alternator Maintenance

1. Keep the mounting bolts securely tightened to prevent vibration damage, which will occur if the mounting bolts loosen.

2. Be sure the plug that seals the integral regulator adjusting hole is in place.

Remove Alternator

1. Disconnect the cables at the battery supply. Disconnect the leads from the alternator and tag each one to ensure correct reinstallation.

2. Loosen the three alternator mounting bolts.

3. While supporting the alternator, remove the mounting bolts, hardened washers and lock washers and lift the alternator and fan guard as a unit from the mounting adaptor. Protect the alternator and fan guard assembly from physical damage following removal from the engine.

NOTICE: The fan guard, which includes an oil seal, should not be separated from the alternator until the alternator half of the coupling is removed. Any attempt to separate the fan guard from the alternator could damage the oil seal.

4. Loosen the retaining nut and remove the coupling hub keyed to the alternator shaft.

5. If the alternator is to be replaced, separate the fan guard from the alternator.

6. Remove the alternator flange mounting adaptor from the flywheel housing, if necessary.

Alternator Service

To service the alternator, contact the alternator manufacturer.

Inspection

Inspect the drive coupling and hub for wear at the seal surface and the drive tangs. If worn excessively, replace them with new parts.

Oil leaks indicate a worn or damaged oil seal. Replace the oil seal in the fan guard, if necessary.

Inspect the alternator housing and flange adaptor at the mounting bolt holes for cracks and the pilot diameters for damage, cracks or distortion. Replace if necessary.

Install Alternator

1. If removed, attach the alternator mounting adaptor, using a new gasket, to the flywheel housing. The adaptor is secured to the engine by two short bolts into

the flywheel housing and four long bolts through the flywheel housing, end plate and blower drive support.

Make sure the alternator is properly fitted to the adaptor before it is bolted in place. Improper installation of the alternator can disturb adaptor alignment and cause gear train damage. See Section 1.7.7 for alignment procedure.

NOTICE: Special hardened, plain washers seat in the six counterbored bolt holes in the adaptor. Also, the current gasket has a positioning identification tab.

2. If the fan guard and hub were removed, locate the fan guard on the alternator by engaging the mating pilot diameters. Lubricate the seal diameter on the coupling hub and the seal lip. Install the coupling hub on the shaft. Be careful not to damage the lip of the oil seal. Install the retaining nut on the shaft and tighten it to 70–80 lb–ft (95–108 N·m) torque. If the fan guard and hub were not removed, check the retaining nut for proper torque. *Do not support the alternator on the fan guard.*

3. Place the slotted drive coupling on the drive hub. *Align the slotted drive coupling with the blower drive coupling when attaching the alternator assembly.*

4. Align the bolt holes in the fan guard with the mounting holes in the alternator housing. Support the alternator assembly against the mounting flange adaptor, using a new gasket, and install the three 3/8″–16 x 3 1/2″ bolts, lock washers and hardened washers through the alternator housing and fan guard mounting holes into the mounting adaptor. Tighten the bolts to 30–35 lb–ft (41–47 N·m) torque.

5. Attach the wires and cables. Be sure each one is correctly installed in accordance with its previous location on the alternator. Keep all connections clean and tight.

•STORAGE BATTERY

The battery is a device for storing electrical energy and converting chemical energy into electrical energy.

The three basic types of batteries currently being marketed are:

Filler Cap Batteries

These are lead–acid batteries with a high degree of antimony in the grid alloy. They require frequent servicing, especially the need for adding water, as well as cleaning salts from the terminal posts.

Semi–Maintenance Free Batteries

These are conventional filler cap batteries with reduced amounts of antimony in the grid alloy and, consequently, servicing is somewhat reduced. Water must still be periodically added. Terminal posts tend to accumulate salts.

Maintenance–Free Batteries

These batteries use lead–calcium grid construction without antimony. They never need water, nor are provisions provided for adding water. As these batteries have no filler caps to leak acid fumes, terminal posts have less tendency to accumulate salts, and as a result require less frequent cable inspection and cleaning.

The chart below gives the minimum battery capacity recommended for acceptable engine cranking.

Function of Battery

The battery has three major functions:

1. It provides a source of current for starting the engine.
2. It acts as a stabilizer to the voltage in the electrical system.
3. It can, for a limited time, furnish current when the electrical demands exceed the output of the generator or alternator.

NOTICE: In the selection of a replacement battery, it is always good practice to select one of an "electrical size" at least equal to the battery originally engineered for the particular equipment by the manufacturer.

Install Battery

While the battery is built to satisfactorily withstand the conditions under which it will normally operate, excessive mechanical abuse leads to early failure.

Install the battery as follows:

1. Be sure the battery carrier is clean and that the battery rests level when installed.
2. Tighten the hold–down clamps evenly until snug. However, do not draw them down too tight or the battery case will become distorted or will crack.
3. Attach the cable clamps after making sure the cables and terminal clamps are clean and in good condition. To make the cable connections as corrosion resistant as possible, place a felt washer at the base of each terminal, beneath the cable clamp. Coat the entire connection with a heavy general purpose grease. Be sure the ground cable is clean and tight at the engine block or frame.
4. Check the polarity to be sure the battery is not reversed with respect to the generating system.
5. Connect the *grounded* terminal of the battery last to avoid short circuits which will damage the battery.

Servicing the Battery

A battery is a perishable item which requires periodic servicing. Only when the battery is properly cared for as described below can long and trouble–free service be expected.

1. On filler cap batteries or semi–maintenance free batteries, check the level of the electrolyte regularly. Add water if necessary, but do not overfill. Overfilling can cause poor performance or early failure.
2. Keep the terminal end of the battery clean. When necessary, wash with a baking soda solution and rinse with fresh water. Do not allow the soda solution to enter the cells.

ENGINE MODEL	SYSTEM VOLTAGE	MINIMUM BATTERY RATINGS SAE COLD CRANKING AMPS (CCA) @ 0°F (–17.8°C)
3–53 NA, T; 4–53 NA, T	12, 24, 32	625
6V–53 NA, T	12V	1250
	24V, 32V	625

• Fig. 1 – General Battery Recommendations

3. Inspect the cables, clamps and hold–down bracket regularly. Clean and reapply a coat of grease when needed. Replace corroded or damaged parts.

4. Use the standard battery test (below) as the regular service test to check the condition of the battery.

5. Check the electrical system if the battery becomes discharged repeatedly.

Many electrical troubles caused by battery failures can be prevented by systematic battery service.

Testing Batteries

CAUTION: Battery electrolyte is a solution of sulfuric acid. Avoid contact with clothing, skin, and eyes.

CAUTION: When batteries are being charged and tested, an explosive gas forms inside the battery. Some of this gas escapes through the holes in the vent plugs or vents in the battery cover and may form an explosive atmosphere around the battery itself if ventilation is poor. Sparks or flame can ignite this gas, causing an explosion which can shatter the battery. Flying pieces of the battery structure and splash of electrolyte can cause personal injury.

To avoid personal injury, observe these precautions before charging and/or testing a battery:

1. Wear face and eye protection.

2. Have a clean water supply available (to wash off any splashed electrolyte).

3. Provide proper ventilation.

4. Do not test near fire or flame.

Testing Maintenance–Free (Freedom) Batteries

Test each battery separately as follows:

1. Disconnect both terminals of each battery.

2. If battery has threaded stud terminals, use terminal adapters (AC–Delco #ST1201) when testing or charging.

3. Check each battery visually.

4. Examine the hydrometer "eye" (if no eye, proceed to Step 5).

   - Eye shows green – continue test.
   - Eye shows dark – recharge, then continue.
   - Eye shows yellow – replace battery.

5. Apply a 300 amp load for 15 seconds. Turn off load. Wait one minute.

6. If no hydrometer eye, measure terminal voltage (Fig. 2)

   - If 12.4 volts or more – continue.
   - If less than 12.4 volts – recharge, then repeat Steps 5 and 6.

7. Apply a test load of 1/2 CCA rating (in amps). After 15 seconds, with load still applied, measure the terminal voltage. Turn the load off.

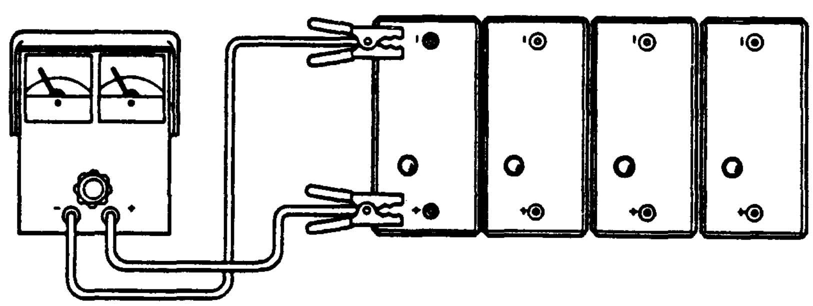


Fig. 2 – Battery Testing

8. Estimate the temperature of the battery. If measured voltage does not meet or exceed the values shown below, replace the battery.

TEMPERATURE	MIN. VOLTS
70°F (21.1°C)	9.6
50°F (10.0°C)	9.4
30°F (1.11°C)	9.1
15°F (-9.44°C)	8.8
0°F (-17.8°C)	8.5

9. Clean all cable ends and terminals of the battery with a wire brush.
10. Tighten the hold–down to specification.

Testing Filler Cap and Semi–Maintenance–Free Batteries

Test each battery separately as follows:

1. Disconnect both terminals of each battery.
2. If battery has threaded stud terminals, use terminal adapters (AC–Delco #ST1201) when testing or charging.
3. Check each battery visually.
4. Check electrolyte level.
   - If fluid is above the top of the plates in all cells, proceed to Step 5.
   - If not, add water, replace vent caps, and charge battery for 15 minutes at 15 to 25 amps to mix electrolyte. Proceed to Step 5.
5. Check specific gravity. If hydrometer readings for all cells are 1.230 or above and show less than 0.050 between high and low at electrolyte temperature of 80°F, proceed to Step 6.
   - If the readings show more than 0.050 difference – replace battery.
   - If the readings show less than 0.050 difference, but some cells read less than 1.230 – recharge battery.
   - If charging won't bring up the specific gravity – replace battery.
6. Remove vent caps and connect 300 amp load for 15 seconds.
   - If a blue haze or smoke is seen in any cell – replace battery.
   - If not, proceed to Step 7.
7. Measure electrolyte temperature and replace vent caps.
   - Connect voltmeter (Fig. 2) and a specific load of one–half the battery's rated CCA.
   - Read voltage after 15 seconds while load is still connected.
   - Disconnect load.
   - Compare voltage reading with the chart below.
   - If voltage is less than the chart, replace battery.
   - If voltage is equal or greater than the chart – the battery is good.

ELECTROLYTE TEMPERATURE	VOLTAGE
70°F (21.1°C)	9.6
60°F (15.6°C)	9.5
50°F (10.0°C)	9.4
40°F (4.44°C)	9.3
30°F (1.11°C)	9.1
20°F (-6.67°C)	8.9
10°F (-12.2°C)	8.7
0°F (-17.8°C)	8.5

8. Clean all cable ends and terminals of the battery with a wire brush.
9. Tighten the hold–down to specification.

STARTING MOTOR

The starting motor (Fig. 1) is mounted on the flywheel housing. When the starting circuit is closed, a small drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from overspeeding and damaging the starting motor.

See Section 7.0 for the mounting of a starter auxiliary magnetic switch.

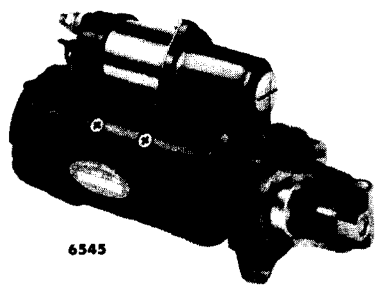


Fig. 1 – Typical Starting Motor

When repositioning of the solenoid is required on a service replacement starting motor, proceed as follows:

1. Remove the six socket head screws (1 short and 5 long) and six neoprene plugs, if a twelve hole starter mounting flange is used.
2. Turn the nose housing to the required position.

   NOTICE: The solenoid must never be located below the centerline of the starter or dust, oil, moisture and foreign material can collect and cause solenoid failures.

3. Install the six socket head screws, with the short screw in the shallow hole nearest the solenoid and six neoprene plugs, if a twelve hole starter mounting flange is used.
4. Tighten the screws to 13–17 lb–ft (18–23 N·m) torque.

Remove Starting Motor

Failure of the starting motor to crank the engine at normal cranking speed may be due to a defective battery, worn battery cables, poor connections in the cranking circuit, defective engine starting switch, low temperature, condition of the engine or a defective starting motor.

If the engine, battery and cranking circuit are in good condition, remove the starting motor as follows:

1. Remove the ground strap or cable from the battery or the cable from the starting motor solenoid. Tape the end of the cable to prevent discharging the battery from a direct short.
2. Disconnect the starting motor cables and solenoid wiring. *Tag each lead to ensure correct connections when the starting motor is reinstalled.*
3. Support the motor and remove the three bolts and lock washers which secure it to the flywheel housing. Then, pull the motor forward to remove it from the flywheel housing.

Check the starting motor in accordance with the Delco–Remy "Cranking Circuit" maintenance handbook.

Install Starting Motor

To install the starting motor, reverse the procedure outlined for removal. Tighten the 5/8"–11 starter attaching bolts to 137–147 lb–ft (186–200 N·m) torque when a cast iron flywheel housing is used or to 95–105 lb–ft (129–143 N·m) torque when an aluminum flywheel housing is used.

Keep all of the electrical connections clean and tight. When installing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10–32 connections to 16–30 **lb–in** (2–3 N·m) torque and the 1/2"–13 connections to 20–25 lb–ft (27–34 N·m) torque.

INSTRUMENTS AND TACHOMETER DRIVE

INSTRUMENTS

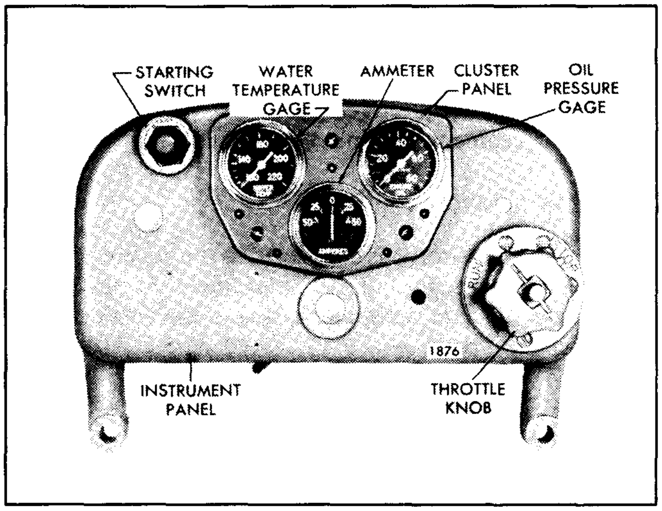


Fig. 1 – Typical Instrument Panel

The instruments generally required in the operation of a diesel engine consist of an oil pressure gage, water temperature gage, an ammeter and a mechanical tachometer. Also, closely related and usually installed in the general vicinity of these instruments are certain controls consisting of an engine starting switch, engine stop knob and an emergency stop knob (Fig. 1).

All Torqmatic converters are equipped with an oil pressure gage and, in some instances, with an oil temperature gage. These instruments are mounted on a separate panel.

Instruments, throttle control and engine starting and stopping controls are mounted in various locations depending upon the particular use of the engine.

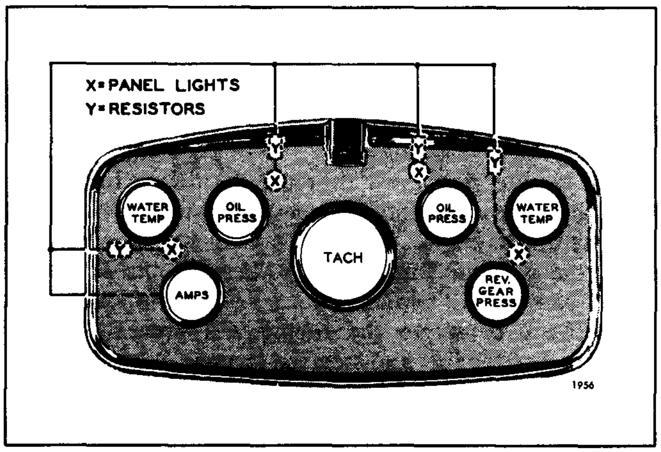


Fig. 2 – Installation of Resistors in Illuminated Instrument Panel

Marine propulsion engines are provided with an instrument panel which usually includes an engine oil pressure gage, reverse gear oil pressure gage, water temperature gage, ammeter and a tachometer. The instrument panels are generally mounted some distance from the engine. Illuminated instrument panels are provided for marine applications which require night operations.

All illuminated instrument panels are wired for a 12 volt lighting circuit. Therefore, when marine propulsion units incorporate either a 24 or 32 volt electrical system, a 12 volt tap–off from the battery may be made, or resistors (Table 1) may be installed in the circuit to protect the instrument panel bulbs. As indicated in Fig. 2, one resistor is used in the lead for each instrument panel bulb.

Resistor Specifications

Volts	Ohms	Watts
24	50	10
32	100	10

TABLE 1

Whenever performing service or preventive maintenance procedures on marine propulsion engine units which include a 24 or 32 volt electrical system, check the lighting circuit of the instrument panels to determine if either a 12 volt tap–off from the battery or resistors have been installed in the lighting circuit to protect the instrument panel bulbs.

Anti–Vibration Instrument Mountings

Anti–vibration mountings are used in many places to absorb engine vibration in the mounting of instruments, drop relays, tachometers, etc. When it may become necessary to service a part secured by rubber mounts, care should be exercised, during removal and installation of the part, so twist is not imposed into the rubber mount diaphram. At the time the part is removed from the engine for service, the mounts should be inspected for damage and replaced, if necessary.

The attaching screw, through the center of the mount, must be held from turning during final tightening of the nut. Support the screw and tighten the nut only. If this screw turns, it will pre–load the rubber diaphragm in torsion and considerably shorten the life of the mount.

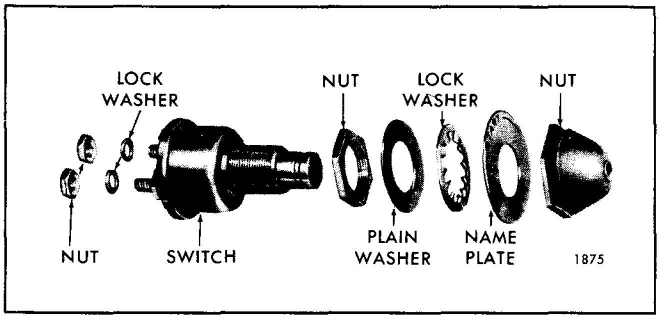


Fig. 3 – Typical Engine Starting Switch

Oil Pressure Gage

The oil pressure gage registers the pressure of the lubricating oil in the engine. As soon as the engine is started, the oil pressure gage should start to register. If the oil pressure gage does not register at least the minimum pressure listed in the *Operating Conditions* in Section 13.2, the engine should be stopped and the cause of the low oil pressure determined and corrected before the engine is started again.

Current oil pressure gages have male threads and require female fittings. When replacing a former gage with female threads, a new mounting clamp and connector must be used.

Water Temperature Gage

The engine coolant temperature is registered on the water temperature gage.

Incorrect coolant temperature readings will be registered if the gage assembly is incorrectly installed or the capillary tube is damaged.

To prevent damage to the gage assembly from vibration, the capillary tube must be securely fastened to the engine the full length with suitable clips at intervals of ten inches or less. Sharp bends in the tube must be avoided, particularly at the gage or bulb connection areas. Where the tube must be bent around any object, the bend must not be less than one inch radius.

Any extra length can be taken up by coiling, the diameter of which should not be less than two inches. The coils must be located so that they may be securely fastened to prevent vibration.

Ammeter

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

Tachometer

The tachometer, driven by the engine, registers the speed of the engine in revolutions per minute (rpm).

Throttle Control

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

Engine Starting Switch

To start the engine, a switch (Fig. 3) is used to energize the starting motor. Starting switches may vary in design and their contacts must be rated sufficiently to carry the starter solenoid current. Tighten the starting switch mounting nut to 36–48 ***lb–in*** (4–5.5 N·m) torque.

Engine Stop Knob

A stop knob is used to shut the engine down. When stopping an engine, the engine speed should be reduced to idle and the engine allowed to operate at idle for a few minutes to permit the coolant to reduce the temperature of the engine's moving parts. Then pull the stop knob and hold it until the engine stops. Pulling on the stop knob manually places the injector racks in the no–fuel position. Return the stop knob to its original position after the engine stops.

> **NOTICE:** When an emergency shut down is necessary on a current engine with the spring loaded fuel injector control tubes, the stop knob should be pulled immediately and held until the engine stops.

Emergency Stop Knob (Engine with Air Shutoff Valve)

In an emergency, or if the engine continues to operate after pulling the stop knob, the emergency stop knob may be used to stop the engine. When the emergency stop knob is pulled, the air shutoff valve, located between the air intake and the blower, will trip and shut off the air supply to the engine. Lack of air to the engine will prevent further combustion of the fuel and stop the engine.

The emergency stop knob must be pushed back in after the engine is stopped and the air shutoff valve must be reset manually. The cause of the malfunction should be determined before the engine is started again.

TACHOMETER DRIVE

A tachometer drive shaft is pressed into the end of the camshaft, balance shaft or governor drive shaft. On V-type engines, it is pressed into the end of either camshaft, the blower drive shaft or the accessory drive gear.

When required, a tachometer drive cable adaptor is used to change speed or to change direction of rotation, depending upon the location of the tachometer drive. A special key is used to connect the drive shaft to the tachometer drive cable adaptor.

The cable connection at the current tachometer head is a 5/8" threaded connection in place of the former 7/8" connection. To eliminate possible misalignment, the current tachometer angle drive has a short flexible cable and incorporates an integral oil seal. The output shaft key size has been increased from 5/32" to SAE 3/16". New flexible drive cables are also required with the current tachometers and angle drives.

Remove Tachometer Drive Shaft

If threads (5/16"-24 or 3/8"-24) are provided on the outer end of the tachometer drive shaft to accommodate a removing tool, thread remover J 5901-3 on the shaft. Then attach slide hammer J 23907-1 to the remover. A few sharp blows of the weight against the slide hammer rod will remove the tachometer drive shaft.

If threads are not provided on the outer end of the tachometer drive shaft, or if the end of the shaft is broken off, drill and tap the shaft. Then thread a stud into the shaft and remove the shaft with the remover and slide hammer.

> **NOTICE:** Use adequate protective measures to prevent metal particles from falling into the gear train and oil pan.

When installing a tachometer drive cover assembly or a drive adaptor, it is important they be aligned properly with the tachometer drive shaft (Section 7.0).

ENGINE PROTECTIVE SYSTEMS

MANUAL SHUTDOWN

A manually operated emergency engine shutdown device enables the engine operator to stop the engine in the event an abnormal condition should arise. If the engine continues to run after the engine throttle is placed in the no fuel position, or if combustible liquids or gases are accidentally introduced into the combustion chamber causing overspeeding of the engine, the shutdown device will prevent damage to the engine by cutting off the air supply and thus stopping the engine. The shutdown device consists of an air shutoff valve mounted in the air inlet housing and a suitable operating mechanism.

Operation

The manually operated shutdown device is operated by a knob located on the instrument panel and connected to the air shutoff valve shaft lever by a control wire. Pulling the knob all the way out will stop the engine. Push the knob all the way in and manually reset the air shutoff valve before starting the engine again.

Service

For disassembly and assembly of the shutdown device, refer to Section 3.3.

AUTOMATIC MECHANICAL SHUTDOWN

The automatic mechanical shutdown system is designed to stop the engine if an abnormal condition such as high engine coolant temperature, low engine oil pressure or engine overspeeding arises. The components of the shutdown system are schematically illustrated in Fig. 1.

A coolant temperature–sensing valve adaptor and plug assembly is mounted on the exhaust manifold with the plug extending into the manifold. Coolant from the engine is directed through the adaptor assembly, in which the bulb of the temperature–sensing valve assembly is located, to the suction side of the water pump.

Oil under pressure from the engine is directed through a restricted fitting to a "T" connection. One line from the "T" is connected to the temperature–sensing valve assembly and the other line leads to the oil pressure bellows. A line attached to the discharge side of the temperature valve directs any oil that passes through the valve to the engine crankcase. Oil under pressure entering the oil pressure bellows, works through the bellows against a spring, overcomes the spring tension and permits the latch to retain the air shutoff valve assembly in the open position. Should the oil pressure drop below a predetermined value, the spring in the oil pressure bellows will release the latch permitting the air shutoff valve to close, stopping the engine. The oil pressure bellows can be adjusted to release the latch at pressures ranging from approximately 5 to 25 psi (34.5 to 172 kPa).

The overspeed governor, used in some engine applications, consists of a small plunger and valve actuated by a set of spring–loaded weights. The plunger and valve are located in the oil line connecting the oil pressure bellows to the main oil gallery. An outlet in the valve is connected to the engine oil sump. Whenever engine speed exceeds the overspeed governor setting, the valve plunger (actuated by the governor weights) is lifted from its seat and permits oil in the line to flow to the engine sump. This results in a drop of oil pressure to the oil pressure bellows, thus actuating the shutdown mechanism and stopping the engine.

Operation

When starting the engine, it is necessary to first manually open the air shutoff valve and then press the engine starting switch, cranking the engine. As soon as the engine starts, the engine starting switch maybe released, but the air shutoff valve must be retained in the open position until the engine oil pressure exceeds the setting of the pressure sensitive device and permits the latch to retain the air shutoff valve in the open position.

During operation, if the oil pressure drops below the setting of the pressure sensitive bellows, the spring within the bellows will release the latch and permit the air shutoff valve to close, stopping the engine.

If the engine coolant overheats during operation, the high temperature will cause the temperature–sensing valve to open and permit the oil to flow to the engine crankcase. The opening of the temperature–sensing valve lowers the oil pressure on the discharge side of the restricted fitting. The spring in the pressure sensitive bellows will release the latch and permit the air shutoff valve to close, stopping the engine.

Should the engine lose its coolant during operation, the copper plug extending into the exhaust manifold will heat up and radiate heat to the temperature–sensing valve which will operate and shut the engine down.

Whenever the engine speed exceeds the overspeed governor setting, the oil in the line flows to the sump, resulting in a decrease in oil pressure. The oil pressure bellows will then release the latch and permit the air shutoff valve to close, stopping the engine.

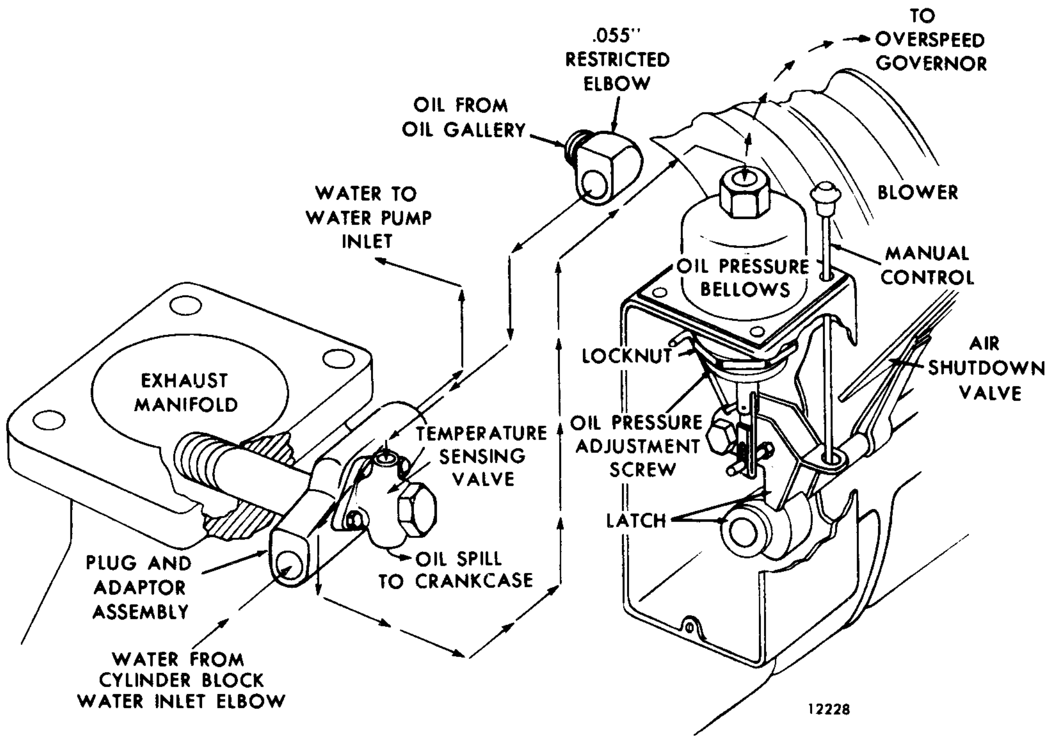


Fig. 1 – Mechanical Shutdown System Schematically Illustrated

After the engine has been stopped due to the action of a protective device, it cannot be restarted until the particular device which actuates the shutdown has returned to its normal position. The abnormal condition which stopped the engine must be corrected before attempting to start the engine again.

Adjustment

The only adjustments necessary in the automatic mechanical shutdown system are the low oil pressure setting of the bellows and the overspeed setting of the overspeed governor. Replace the temperature–sensing valve when operation is unsatisfactory.

To adjust the low oil pressure setting of the bellows, run the engine until normal operating temperature has been reached and the oil pressure has stabilized. Then reduce the engine speed slowly until the bellows disengages the latch on the air shutoff valve and stops the engine. Note the oil pressure at which the shut down occurred. units having a minimum idle speed of 500 rpm it is 10 psi (69 kPa). If adjustment is necessary, loosen the locknut on the bellows and turn the adjusting screw clockwise to increase the oil pressure setting or counterclockwise to decrease the setting. Hold the adjusting screw and tighten the locknut when the proper setting has been obtained.

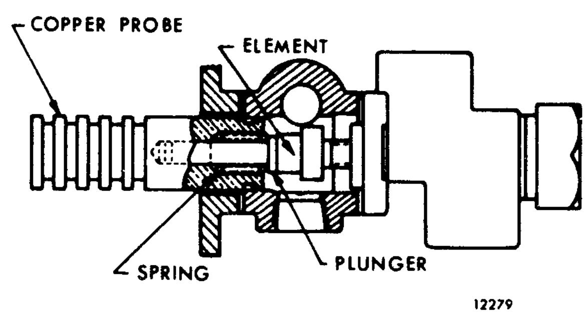


Fig. 2 – Temperature–Sensing Valve

Check the operation of the high coolant temperature–sensing valve by placing a cover over the radiator while the engine is operating at 1800 rpm under load. Observe the coolant temperature on a thermometer inserted at the radiator filler hole. An engine shut down should occur when the coolant is 200° to 210°F (93° to 99°C). If shut down does not occur, replace the coolant temperature–sensing valve assembly. If shut down occurs below 200°F (93°C), check the coolant flow through the plug and adaptor assembly. If circulation is satisfactory and shut down occurs below 200°F (93°C), replace the coolant temperature–sensing valve assembly. The coolant temperature–sensing valve cannot be adjusted.

NOTICE: If the temperature–sensing valve switch is removed, examine the temperature shutdown valve plunger in the copper probe (Fig. 2). If it is not free in the probe and adaptor, install a new plunger, spring and adaptor. Deposits from the engine coolant building up between the plunger, spring and plug can cause the plunger to stick in the probe.

The temperature–sensing valve can be bench tested by attaching an air hose (40 psi or 276 kPa air supply) to the oil inlet side and installing a tube from the outlet side to a can of water. Then, immerse the power element of the valve in a container of water that is heated and agitated.

- **CAUTION: To avoid personal injury when performing this test, wear adequate face and body protection (faceplate, gloves, boots, waterproof apron, etc.).**

Check the temperature of the water with a thermometer. Apply air to the valve. The valve should be open, as indicated by the flow of air, at a water temperature of 195°- 206°F (90°- 99°C).

Overspeed Shutdown Adjustment

1. Start the engine and bring it up to operating temperature.
2. Increase the engine speed to the specified overspeed shutdown speed. At this speed the bellows should disengage the air shutdown latch and stop the engine.
3. Adjust the overspeed governor setting, if necessary, by loosening the governor adjusting screw locknut (on the overspeed governor cap), then turning the adjusting screw clockwise to increase the speed at which the air shutdown mechanism is tripped. Turn counterclockwise to decrease the speed at which the latch will trip. Always tighten the locknut after each adjustment.
4. Stop the engine and replace the control shutdown housing cover.

AUTOMATIC ELECTRICAL SHUTDOWN

The automatic electrical shutdown system (Fig. 3) protects the engine against a loss of coolant, overheating of the coolant, loss of oil pressure or overspeeding. In the event one of the foregoing conditions arises, a switch will close the electrical circuit and energize the solenoid switch, causing the shutdown solenoid to release the air shutdown latch and stop the engine.

Operation

The electrical circuit is de–energized under normal operating conditions. When the engine is started, the oil pressure switch opens when the oil pressure reaches approximately 10 psi (69 kPa) and the fuel oil pressure switch closes at approximately 20 psi (138 kPa) fuel pressure. The water temperature switch remains open.

If the oil pressure drops below 10 psi (69 kPa), the oil pressure switch will close the circuit and energize the shutdown solenoid. This will activate the shutdown mechanism and stop the engine.

A loss of coolant or an increase in coolant temperature to approximately 200°–210°F (93°–99°C) will close the contacts in the water temperature switch, thus closing the electrical circuit and activating the shutdown mechanism.

The water temperature switch consists of a temperature–sensing valve and a micro–switch. The valve contacts a copper plug (heat probe) which extends into the exhaust manifold outlet. Engine water is directed over the power element of the valve and should the water temperature exceed approximately 203°F (94°C), the valve will close the contacts in the micro–switch and energize the shutdown circuit. If a loss of water occurs, the heat of the exhaust gases will be transmitted through the copper plug to the temperature–sensing valve and cause the shutdown circuit to be activated.

If the engine speed exceeds the high speed setting of the overspeed governor, the governor switch will close and activate the shutdown mechanism.

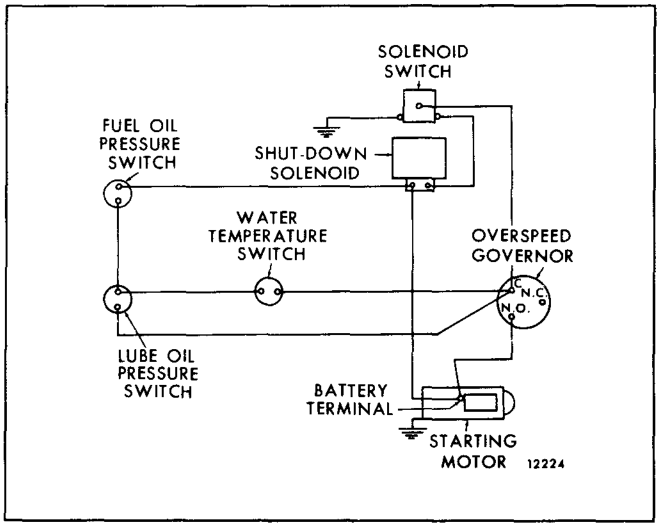
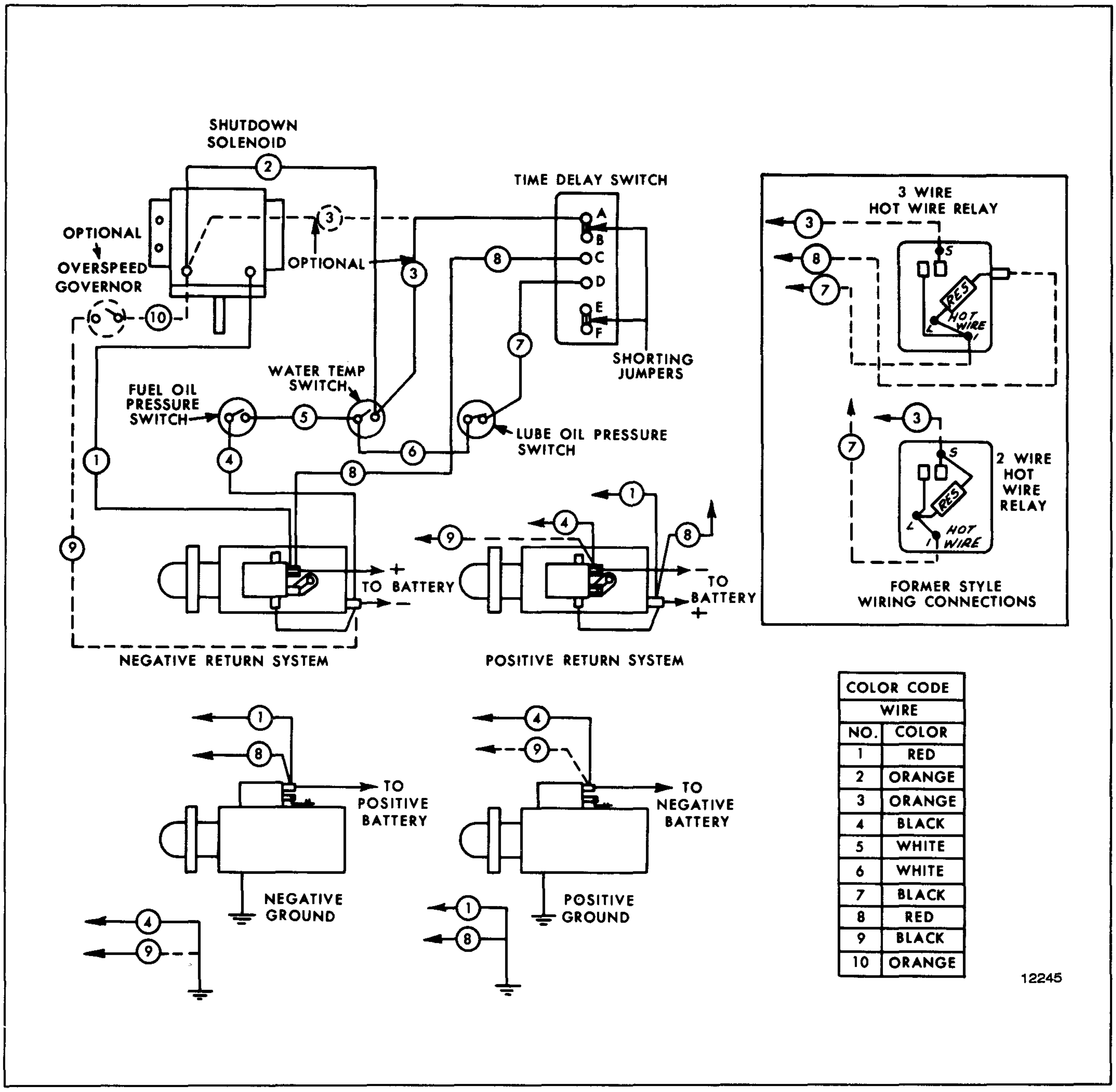


Fig. 3 - Automatic Electrical Shutdown System Diagram



COLOR CODE	
WIRE	
NO.	COLOR
1	RED
2	ORANGE
3	ORANGE
4	BLACK
5	WHITE
6	WHITE
7	BLACK
8	RED
9	BLACK
10	ORANGE

Fig. 4 – Automatic Electrical Shutdown System Incorporating Hot Wire Relay or Time Delay Switch

When the engine is shutdown, the decrease in speed will open the governor switch and the decrease in oil and fuel pressures will close the oil pressure switch and open the fuel pressure switch, thus de–energizing the circuit.

The cause of the abnormal conditions must then be determined and corrected before the engine is started again. Also, the air shutoff valve must be manually reset in the open position before the engine can be started.

Some engines are equipped with an electrically operated automatic shutdown system which incorporates a hot wire relay or solid state time delay switch (Fig. 4).

Since the fuel pressure builds up rapidly, the fuel oil pressure switch could close before the lubricating oil pressure switch opens, thereby effecting a shutdown of the engine. The hot wire relay or time delay switch, however, delays the closing of the fuel oil pressure switch for 3 to 10 seconds to enable the lubricating oil pressure to build–up and open the oil pressure switch contacts.

When the lubricating oil pressure falls below 10 ± 2 psi, the contacts in the oil pressure switch used in this system will close and current will flow to the hot wire relay or the time delay switch. The few seconds required to heat the hot wire relay provides sufficient delay to avoid an engine shutdown when low oil pressure is caused by a temporary condition such as an air bubble or a temporary overlap in the operation of the oil pressure switch and the fuel oil pressure switch when starting or stopping the engine.

The high water temperature switch is installed in the side of the thermostat housing. The switch contacts close when the water temperature reaches approximately 205°F (95°C).

Solid State Time Delay Switch

The current solid state time delay switch is designed as a direct replacement for the former hot wire relay (Fig. 4).

It is a solid–state time device which effectively withstands shock and vibrations. The switch is polarity–conscious. If a reverse polarity is applied the switch will not work.

The switch has two circuits: a time circuit and an electronic circuit which consists of a silicon control rectifier. The rectifier has sufficient capacity to handle standard loads such as the emergency shutdown solenoid. Abnormal load situations such as a collapsing magnetic field in a coil can damage the rectifier rendering it inoperative. To protect the rectifier a discharge diode is connected across the terminals B and C of the solid state time delay switch.

The time delay switch should be check periodically to be sure that it is operating properly (refer Section 7.0).

SHUTDOWN SYSTEM FOR DIRECT MOUNTED TURBOCHARGED ENGINES

With the use of a direct mounted turbocharger and the spring loaded fuel injector control racks, the air shutoff valve was eliminated from the air inlet housing. The spring loaded injector tube control rack enables the engine to come out of any advanced fuel position when an emergency situation arises.

When an engine is operating in an atmosphere subject to volatile fuel and is equipped with an air inlet housing without the air shutoff valve, a customer may request that the engine be equipped with an external or remote mounted emergency air shutdown assembly.

The remote mounted emergency air shutdown assembly that is equipped with the air shutoff valve can be installed upstream of the air inlet side of the turbocharger.

Care should be taken when installing the emergency air shutdown assembly between the turbocharger and the air cleaner. Because the engine shutdown system is activated, all of the piping between the shutdown system and the engine will be subjected to an abnormally high suction which may cause some of the piping components, i.e., rubber hoses and elbows to collapse. Therefore, it is recommended that all of these components be designed to withstand the maximum suction without a failure which would allow air to reach the engine air intake.

A 7 to 5 inch diameter reducing 90° rubber hose or a 7 to 5 inch diameter hump hose reducer can be used to adapt the shutdown to the turbocharger.

The rubber elbow can be obtained from the manufacturer; Griffin Rubber Mills in Portland, Oregon under their part number – 51759.

The customer is required to provide the mounting support brackets.

The emergency air shutdown assembly is manually operated. To be an automatic shutdown system, it will be necessary to install a solenoid.

ALARM SYSTEM

The alarm system is similar in many respects to the automatic shut–down system, but does not include the automatic shut–down feature incorporating the electrical solenoid or the flap valve in the air shut–down housing which is operated by the solenoid. A bell is substituted for the solenoid in the alarm system. The alarm may be substituted for the shut–down solenoid, or it may be added to the automatic shut–down system. In either case, the alarm notifies the operator of a dangerous condition in the engine.

The voltage used through the alarm bell, however, must not exceed 12 volts.

Note that the cranking motor performs no essential function in the circuit.

An oil pressure switch, introduced into the engine oil gallery, is closed when the engine is not running, but opens after starting and remains open while the engine is running. This switch will close only in case of lowered oil pressure, thus causing the alarm to operate, or it will close if the engine is stopped by the operator. A water temperature switch always remains open except in case of high water temperature when it closes and operates the alarm.

An automatic fuel oil switch closes after the engine is started and normal fuel oil pressure has been attained.

An optional overspeed switch is sometimes introduced into the system.

The water temperature switch and the oil pressure switch are similar to the same switches used in the automatic shut–down device.

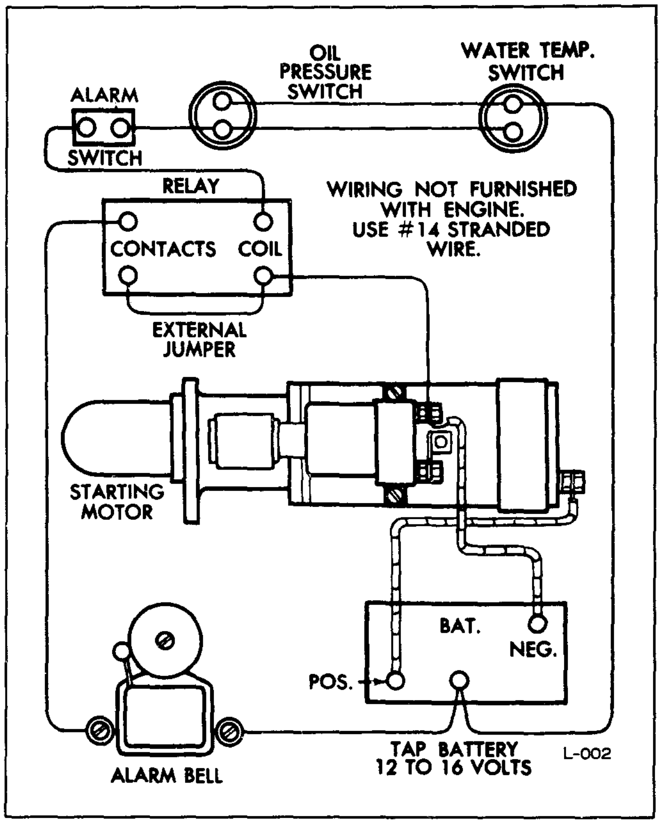


Fig. 1 – Alarm System Wiring Diagram

Service of the alarm system is usually limited to replacement of the alarm bell.

OVERSPEED GOVERNORS

ELECTRIC (TWO SWITCH)

The series GY-2 Synchro-Start overspeed governor (Fig. 1) contains two separate snap action switches with single-pole double-throw contacts which operate at two different speeds. The governor is adjusted by the manufacturer to trip at the speeds required as indicated on the name plate. Unless otherwise specified, the name plate indicates trip points on increasing speed. The contacts will return to normal when the speed is decreased approximately 100 rpm below the trip speed, except on the high speed switch of those models having a manual reset button. The letter "M" after any model number indicates the high speed switch must be reset manually.

Service

1. The snap action switches may be replaced as follows:

   a. Mark the position of the dust cover and remove both hold-down screws.

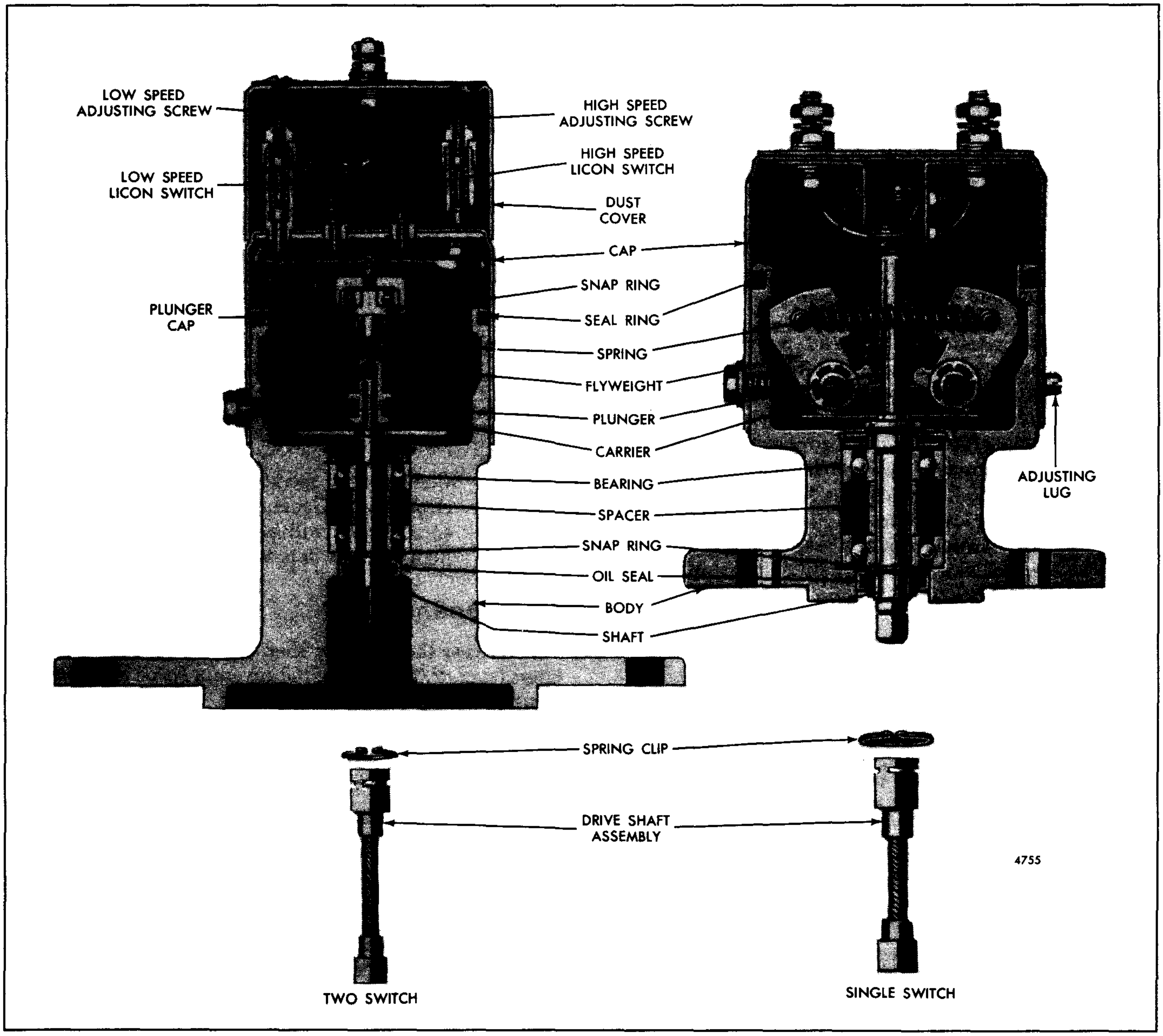


Fig. 1 – Electric Overspeed Governors

b. Observe the position of the switches. Usually they are positioned with 1/64" clearance between the switch button and the lifters. If the lifters are replaced, make certain that the long lifter is placed beneath the low speed switch and the short lifter is placed beneath the high speed switch.

c. Install the new switches by reversing the above procedure. When replacing the dust cover on a governor with a manual reset, make certain the switch wiring does not interfere with the reset mechanism.

d. Adjust the speed as outlined under *Speed Adjustment*.

2. Remove the governor cap as follows:

a. Observe the marking on the cap and the body and remove the three holding screws.

b. Remove the cap assembly, being careful not to damage the seal ring.

c. Replace any internal parts as required and reassemble and return the cap to the original position. A light coat of grease will facilitate assembly of the seal ring to the body.

The position of the cap is very critical on governors in which the difference in trip points between the two switches is more than 1000 rpm and the trip point of the high speed switch is above 2100 rpm. These governors use elongated loop flyweight springs. If, after assembly, the No. 1 switch trips at a far higher point than normal, lower the cap position slightly. If the No. 2 switch trips at a very low speed, raise the cap position slightly. If difficulty arises, refer to Step 5 below.

d. Adjust the speed as outlined under *Speed Adjustment*.

3. Replace the speed adjusting springs as follows:

a. Hold the speed adjusting stud with a 5/16" open end wrench and loosen the adjusting stud nut with a 3/8" open end wrench.

b. After the above nut is removed, the adjusting spring and related parts may be removed and replaced as necessary. Exercise care to prevent particles of dirt from accumulating on the parts.

4. Replace the flexible drive shaft as follows:

a. Insert a sharp pointed instrument in the loop of the spring clip and pull it from the shaft as far as possible and remove the shaft assembly.

b. Upon reassembly, first install the spring clip in the groove of the fitting on the end of the governor shaft.

c. Push the shaft assembly into the square end of the governor shaft and the spring clip will snap in place.

Check the position of the spring clip. If the clip has sprung out of position, use a small screw driver to push it into place.

5. Adjust the governor cap (with the dust cover in place):

a. Turn the low speed adjusting screw out for minimum speed adjustment. In this position, the top of the adjusting screw is approximately 1/8" from the top of the dust cover.

b. Turn the high speed adjusting screw in for almost maximum speed adjustment. In this position, the top of the adjusting screw is approximately 5/16" from the top of the dust cover.

c. With partial tension on the cap holding screws, turn the governor cap to the maximum extended position.

d. Operate the governor at 200 rpm above the trip point of the low speed switch.

e. Rotate the cap slowly in a clockwise direction until the low speed switch trips, mark the cap position and stop the engine. Then turn the cap another 1/16" and lock the holding screws securely.

f. Complete the operation as outlined under *Speed Adjustment*. Generally, the trip point of the low speed switch will have to be increased and the high speed switch decreased.

Maintenance

Grease the governor shaft ball bearings every 10,000 hours (every 5,000 hours if the governor speed is above 2500 rpm) as follows:

1. Remove the governor cap.
2. Remove the flexible drive shaft.
3. Remove the retaining ring from the groove in the housing. Then remove the weight and shaft assembly.
4. Inspect the oil seal and, if necessary, replace it as follows:

a. Place the governor body in an arbor press, with the mounting flange toward the bottom, and use a 9/16" diameter rod to press the oil seal out.

b. Press a new seal in place 3/64" from the bottom of the bearing cavity.

5. Fill the grease reservoir between the bearings *only 3/4 full* with Texaco "Unitemp" grease, or equivalent.

6. Reassemble the governor by reversing the procedure for disassembly and adjust the trip speeds as outlined below:

Speed Adjustment

Both switches may be individually adjusted. The dust cover screw marked "1" covers the low speed adjuster; the screw marked "2" covers the high speed adjuster. Proceed as follows:

1. Remove the appropriate dust cover screw. Then insert a 1/16" Allen wrench into the adjusting screw.

2. Turn the screw clockwise to increase the trip speed or counterclockwise to decrease the speed.

NOTICE: If the adjusting screws are turned in too far, the switch will no longer operate. Do not attempt to use the slots in the cap for normal speed adjustments. This position is set and marked by the manufacturer for operation in the speed range required.

ELECTRIC (SINGLE SWITCH)

Series GWA, GYA and GAA Synchro–Start overspeed governors (Fig. 1) are calibrated by the manufacturer to open or close the switch contacts at the particular speed required. The switch contacts will reset automatically when the speed is reduced approximately 100 rpm below the trip speed.

Service

Grease the governor shaft ball bearings every 10,000 hours (every 5000 hours if the governor speed is above 2500 rpm) as follows:

1. Remove the adjusting screw and the adjusting stud, then remove the governor cap.

2. Insert a sharp pointed instrument in the loop of the spring clip and pull the clip from the flexible shaft as far as possible. Then remove the shaft assembly.

3. Remove the retaining ring from the groove in the housing.

4. Remove the weight and shaft assembly.

5. Inspect the oil seal and, if necessary, replace the seal as follows:

   a. Place the governor body in an arbor press with the mounting flange facing down and use a 9/16" diameter rod to press the oil seal out of the body.

   b. Press the new oil seal in place, 3/64" from the bottom of the bearing cavity.

6. Fill the grease reservoir between the bearings *only 3/4 full* with Texaco "Unitemp" grease, or equivalent.

7. Reassemble the governor by reversing the procedure for disassembly and adjust the trip speed as outlined below.

Speed Adjustment

Loosen the cap adjusting lock screw and turn the cap until the desired trip speed is reached. Clockwise rotation of the cap lowers the trip speed and counterclockwise rotation increases the trip speed. The total range of adjustment of the particular governor is indicated on the governor name plate. The governor should not be adjusted to trip below 100 rpm above the normal running speed of the governor. Make sure the governor cap locking screw is tightened after the adjustment has been completed.

NOTICE: Under no circumstances should the governor switch be by–passed to prevent engine shut–down in the event of overspeed. Serious damage to the engine and the governor may result, since the governor is not designed to operate above its tripping speed.

HYDRAULIC

The hydraulic overspeed governor which contains a set of spring–loaded weights prevents excessive engine speeds.

Figure 2 illustrates the old and new hydraulic overspeed governors. The new governor differs from the old governor in the use of a new housing, cover and speed adjusting screw. The new housing is shorter and the new cover is longer than the old cover. The new adjusting screw differs from the former screw in the width of the seal ring groove which is wider on the new screw.

The overspeed governor is mounted in an adaptor which is mounted on the rear of the flywheel housing. A seal ring in the adpator end of the governor housing prevents oil seepage from the flywheel housing. The governor is driven by a flexible drive assembly from the blower drive shaft. Oil under pressure is supplied to the governor by a tube which is connected to the oil gallery in the cylinder block.

Operation

When the engine speed reaches the value for which the overspeed governor is set, the centrifugal force of the weights in the overspeed governor overcomes the spring tension and opens a pilot valve in the governor. The pilot valve dumps oil from the oil tube, lowering the pressure at the engine oil pressure switch, thus closing the switch and energizing the shut-down solenoid and closing the shut-down valve.

Lubrication

The overspeed governor is lubricated by oil from the engine crankcase.

Adjustment

The engine shut-down speed is determined by the position of the adjusting screw in the overspeed governor cover. To change the setting, loosen the lock nut and turn the adjusting screw in to increase the speed or out to decrease the speed. When the proper setting is obtained, tighten the adjusting screw lock nut.

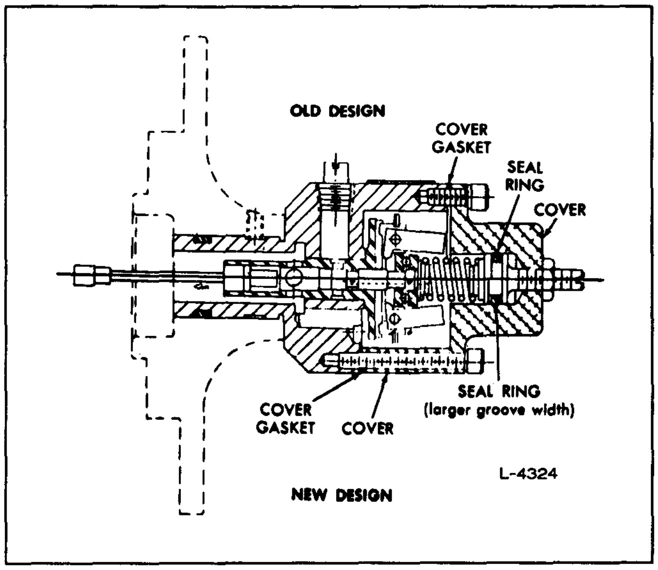


Fig. 2 - Hydraulic Overspeed Governor

SHOP NOTES - TROUBLESHOOTING SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

PROPER OPERATION OF THE SWITCHES OR ALARM SYSTEM FOR TESTING THE ELECTRICAL SHUTDOWN

The protective system is activated whenever low lubricating oil pressure, high coolant temperature, engine overspeed or any other abnormal condition develops that could damage the engine.

In a properly maintained installation, the shutdown system seldom has cause to function. Therefore, it is advisable to check the system periodically to be sure that it will function when needed.

Check each component of the shutdown system as outlined below. It is important to thoroughly warm–up the engine before any component of the shutdown system is checked.

Overspeed Governor

1. Remove the valve rocker cover. Discard the gasket.
2. Start the engine and move the speed control lever to the *full–speed* position.
3. While watching a tachometer, manually move the control tube slowly towards the *increased fuel* position until the air shutoff valve closes, stopping the engine. Do not exceed the engine no–load operating speed by more than 10%.
4. Note the speed at which the engine stops and adjust the overspeed governor, if necessary, as outlined in Section 7.4.3.
5. Using new gaskets reinstall the valve rocker cover.

Water Temperature Switch

The terminals of the water temperature switch are connected into the shutdown system and when the engine water temperature reaches 210°F (99°C), the switch closes and completes the circuit in the shutdown or alarm system.

1. Cover the radiator with a sheet of cardboard to prevent circulation of air.
2. Remove the radiator cap, if the engine is operating near sea level, and insert a steel jacketed thermometer.

The boiling point of water lowers approximately 2° for each 1000 foot rise in altitude. As an example, water boils at approximately 203°F (95°C) at 5000 feet and at 195°F (91°C) at 9000 feet altitude. It is necessary to retain the radiator pressure cap on engines which operate in excess of 1000 feet altitude to prevent the coolant from boiling while performing this test. The engine temperature gage, if it is found to be accurate, may be used when performing this test.

Do not exceed 210°F (99°C) when performing this test.

3. Start and run the engine at rated speed and with enough load to raise the water temperature gradually until the air shutoff valve closes. The water temperature switch will usually be set at 210°F (99°C).
4. Note the temperature at which the air shutoff valve closed.
5. Remove the radiator cover and start the engine without load immediately after the engine stops. This will permit the engine to cool down to normal operating temperature.

Fuel Oil Pressure Switch

The fuel oil pressure switch is set to make contact at an increasing fuel pressure of 20 psi (138 kPa). The phrase "20–MAKE" is stamped on the switch cover.

As the fuel pressure increases upon starting the engine, a diaphragm in the switch body expands and forces the plunger upwards (Fig. 1). Since the bottom of the adjusting screw bears against this plunger, the adjusting screw and the lower breaker point are also forced upwards. When the fuel pressure reaches 20 psi (138 kPa), the breaker points close and current flows to the terminals of the lubricating oil pressure switch and the water temperature switch.

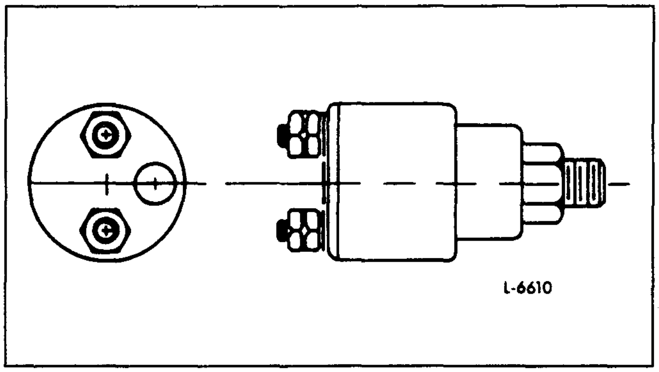


Fig. 1 – Fuel Oil Pressure Switch

When the engine is stopped, the fuel pressure decreases and the diaphragm in the switch body contracts. This action causes the plunger to lower and, when the fuel pressure decreases to 20 psi (138 kPa), permits the lower breaker point arm to lower and break the electrical circuit. The bracket to which the lower breaker point arm and the adjusting screw are attached is spring-loaded, which provides for positive breaking of the connection when the fuel pressure decreases sufficiently.

1. Insert a pressure gage on the discharge side of the fuel strainer.
2. Remove one of the leads from the lubricating oil pressure switch while this test is being performed, to prevent the engine from being shut down.
3. Start and run the engine at idle speed.
4. Slow the engine down by moving the speed control lever towards the *no-fuel* position until the fuel pressure is approximately 15 psi (103 kPa), with the engine barely turning over.
5. Place a jumper wire across the water temperature switch terminals.
6. Raise the engine speed slowly and watch the fuel oil pressure gage until the air shutoff valve closes.
7. Note the fuel pressure at which the air shutoff valve closed and, if necessary, replace the switch.
8. Remove the jumper wire from the water temperature switch and reconnect the lubricating oil pressure switch.

Lubricating Oil Pressure Switch

The construction of the lubricating oil pressure switch is very similar to that of the fuel oil pressure switch, except that the lubricating oil pressure switch is calibrated to break contact when the lubricating oil pressure increases to 10 psi (69 kPa). The phrase "10 BREAK" is stamped on the switch cover.

A 20 psi (138 kPa) break switch is used on some engines whose predominant operation is constant speed.

As the lubricating oil pressure increases upon starting, the diaphragm in the switch body expands and forces the plunger upwards (Fig. 2). Since the bottom of the adjusting screw bears against the plunger, and the adjusting screw is attached to the bracket which controls the upper breaker point arm, the arm is also forced upwards. When the lubricating oil pressure increases to 10 psi (69 kPa), the points separate. Current flows to the lubricating oil pressure switch only after the fuel oil pressure switch closes, at which time the points of the lubricating oil switch are open. Should the lubricating oil pressure decrease to 10 psi (69 kPa) during operation, the breaker point will close and either the alarm bell or shutdown solenoid will be energized.

1. Start and run the engine at idle speed.

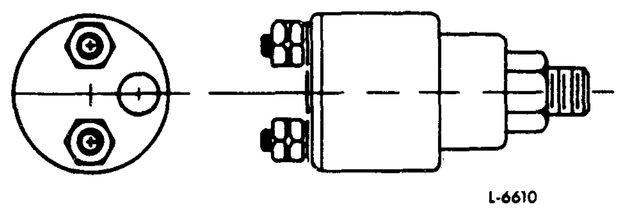


Fig. 2 – Lubricating Oil Pressure Switch

2. Place a jumper wire on the hot wire relay between the "1" and "S" terminals.
3. Place a jumper wire across the fuel oil pressure switch terminals.
4. Reduce the engine speed by moving the control lever towards the *no-fuel* position while watching the lubricating oil pressure gage.
5. Note the oil pressure at which the switch stops the engine and, if necessary, replace the switch.
6. Remove the jumper wire.

Hot Wire Relay

1. Start and operate the engine at idle speed.
2. Place the jumper wire across the terminals of the lubricating oil pressure switch while watching a second hand of a clock.
3. Not more than three (3) to ten (10) seconds should elapse between the time the jumper wire is placed across the terminals of the lubricating oil pressure switch and the air shutoff valve closes.

The above procedures completely test the normally open electrical shutdown system on an engine.

NOTICE: When the engine is operating at idle speed or above, the air shutoff valve will completely close off the air from the engine causing it to stop. However, when the engine is operating at the very low speeds that are necessary when performing the test on the fuel shutdown switch and the lubricating oil shutdown switch, the air damper solenoid will close the air shutoff valve, but the engine may continue to run very slowly. This may be due to insufficient force exerted by the low air flow on the back of the shutoff valve to completely close it.

Solid State Time Delay Switch 12, 24 or 32 Volts–Direct Current

A solid state time delay switch is used on current engines in place of the former hot wire relay.

A bench test procedure for the solid state time delay switch (Fig. 3) is as follows:

1. Remove the time delay switch from the engine.
2. Install the jumper straps on terminals "A" to "B" and "E" to "F", if they have been removed. Normally, the jumper straps are on the Time Delay Switches as supplied.
3. Install a positive battery lead to terminal "A".
4. Install a negative battery lead to one side of a 12 volt light which is a known good test lamp.
5. Install a lead from the opposite side of the light to terminal "D". A switch may be used in this lead, if desired.
6. After the negative lead is connected to "D" or the switch is closed, the lamp should light in eight (8) to ten (10) seconds. If not, the time delay switch must be replaced.

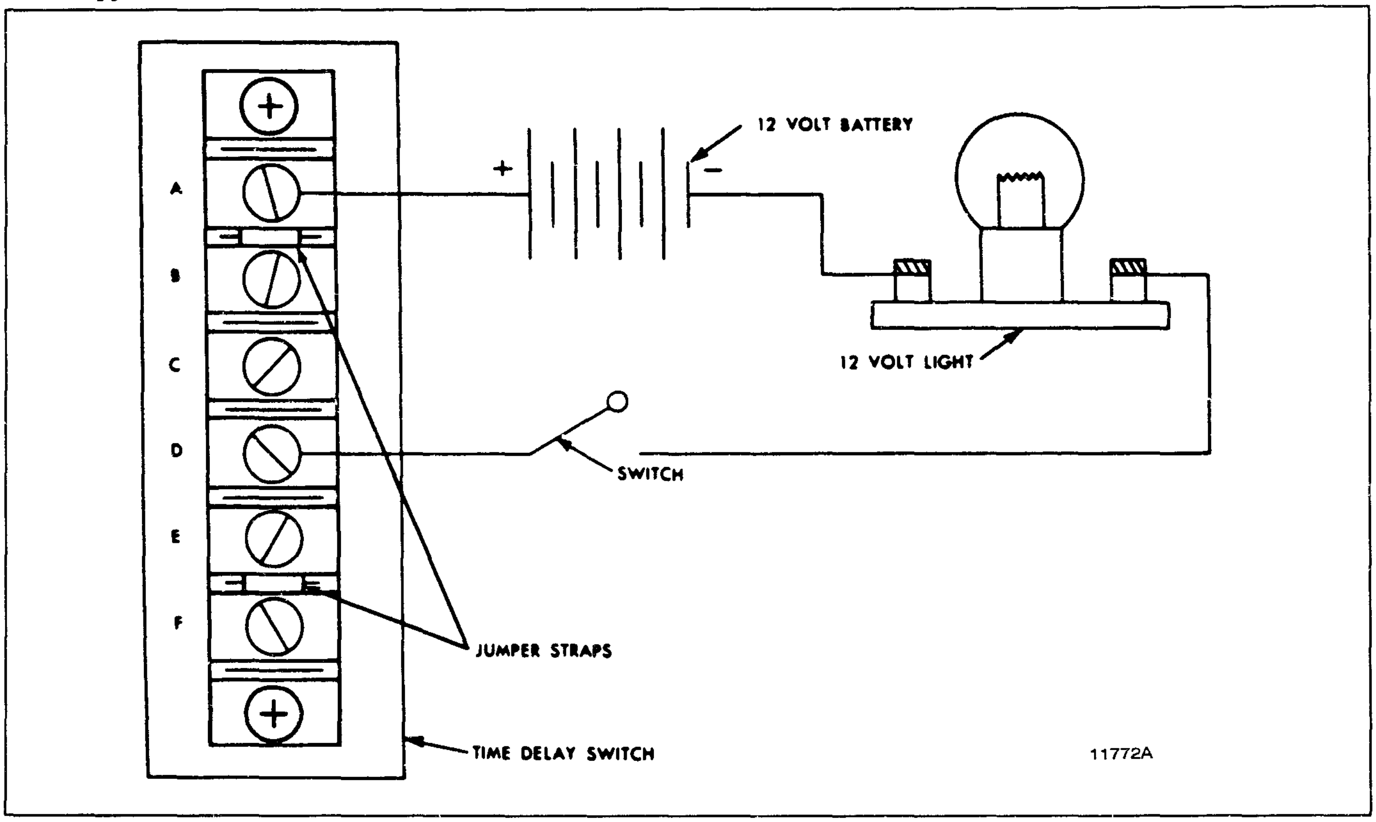


Fig. 3 – Time Delay Switch Testing Diagram

CHECK ENGINE STARTING SWITCH

If difficulty in starting motor engagement has been experienced in a vehicle which has been repowered by a diesel engine, check to see if the key–type starting switch on the instrument panel has been retained.

Key–type starting switches are usually not capable of carrying the current required for heavy–duty diesel engine starter solenoids. The excessive voltage drop in the solenoid circuit restricts the solenoid pull and results in failure of the starter to engage and crank. When tooth abutment occurs and the switch is turned off and on several times, breaking of the solenoid current causes burning or welding of the switch contacts.

Install a push button type starting switch which is capable of making, breaking and carrying the solenoid current without damage (refer to *Engine Starting Motor Switch* in Section 7.4). Otherwise, a heavy–duty magnetic switch should be used in the solenoid control circuit in addition to the key–type switch. The magnetic switch must be capable of making and breaking at least 90 amperes in a 12 volt system; the key switch would then carry no more than one ampere, which is sufficient to operate the magnetic switch.

ALIGNMENT TOOLS FOR TACHOMETER DRIVE COVERS AND ADAPTORS

Whenever a tachometer drive cover assembly or a tachometer drive adaptor is installed on a engine, it is important that the cover assembly or adaptor be aligned properly with the tachometer drive shaft.

Misalignment of a tachometer drive shaft can impose a side load on a tachometer drive cable adaptor resulting in possible gear seizure and damage to other related components.

Use one of three tools in set J 23068 to establish the proper alignment. Fig. 4 illustrates the use of the tools.

Because of the many different combinations of tachometer drive shafts, covers and adaptors, it is not practical to itemize specific usages for each tool. When confronted with an alignment job, test fit each tool to determine which provides the best fit and proceed to make the alignment with that tool.

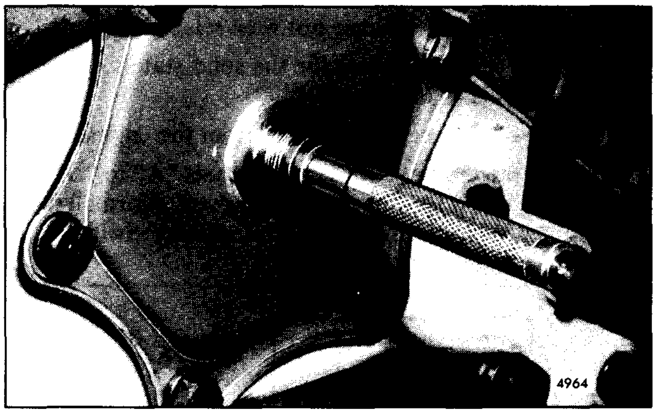


Fig. 4 – Checking Tachometer Drive Shaft Alignment

Correct alignment is established when there is no tachometer drive shaft bind on the inside diameter of the tool when one complete hand rotation of the engine is made.

MOUNTING THE STARTER AUXILIARY MAGNETIC SWITCH

On certain railcar and highway units equipped with Detroit Diesel engines and Delco–Remy starter auxiliary magnetic switches, no–start conditions may result from damage to the starter auxiliary magnetic switch caused by vibration. The vibration may result from improper mounting of the auxiliary magnetic switch.

The following guidelines should be followed when mounting a Delco–Remy starter auxiliary magnetic switch (Fig. 5):

1. Do not mount the switch on the engine.
2. Position the mounting pads of the switch vertically (one above the other).
3. Mount the switch on a rigid bracket, base rail or fire wall.

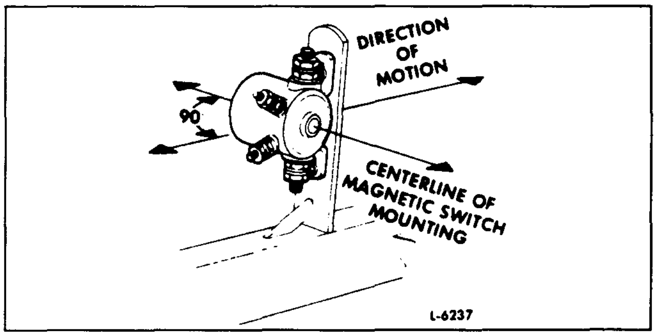


Fig. 5 – Starter Auxiliary Magnetic Switch Mounting

4. Mount the switch on a surface perpendicular (90°) to the forward motion of the vehicle so that contact disc movement is not in line with gravity or vehicle movement.

TROUBLESHOOTING

CHECKING ENGINE ELECTRICAL GENERATING SYSTEM

Whenever trouble is indicated in the electrical generating system, the following quick checks can be made to assist in localizing the cause.

A *fully charged battery and low charging rate* indicates normal alternator–regulator operation.

A *low battery and high charging rate* indicates normal alternator–regulator operation.

A *fully charged battery and high charging rate* condition usually indicates the voltage regulator is set too high or is not limiting the alternator output. A high charging rate to a fully charged battery will damage the battery and other electrical components.

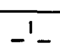
A *low battery and low or no charging rate* condition could be caused by: Loose connections or damaged wiring, defective battery or alternator and defective regulator or improper regulator setting.

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

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BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb–ft)	TORQUE (lb–in)	TORQUE (N·m)
Tachometer drive cover bolt	7/16–14	30–35		41–47
Starting motor connector	1/2–13	20–25		27–34
Tachometer drive cover bolt	1/2–13	30–35		41–47
Starting motor connector	No. 10–32	—	16–30	2–3.5
Tachometer drive shaft (blower)	1/2–20	55–65		75–88
Starting motor attaching bolts (alum. flywheel hsg.)	5/8–11	95–105		129–143
Starting motor switch mounting nut	5/8–32	—	36–48	4–5.5

SERVICE TOOLS

TOOL NAME	TOOL NO.
Puller set	J 5901–01
Tachometer drive shaft remover	J 5901–3
Tachometer drive alignment tool set	J 23068

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 12.2

Vacuum Pump 12.3

Air Compressor 12.4

Cold Weather Starting 12.6
Hydrostarter System 12.6.1

Troubleshooting – Specifications – Service Tools 12.0

BILGE PUMP

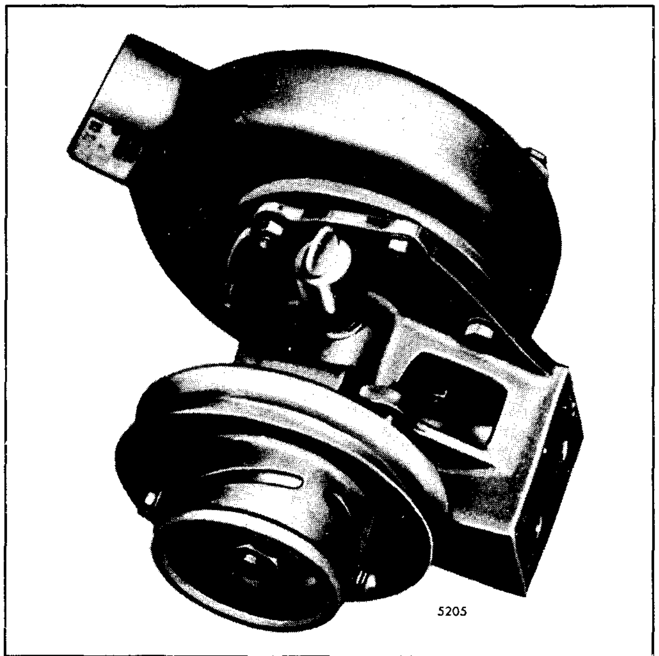

Fig. 1 – Bilge Pump

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 giand 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

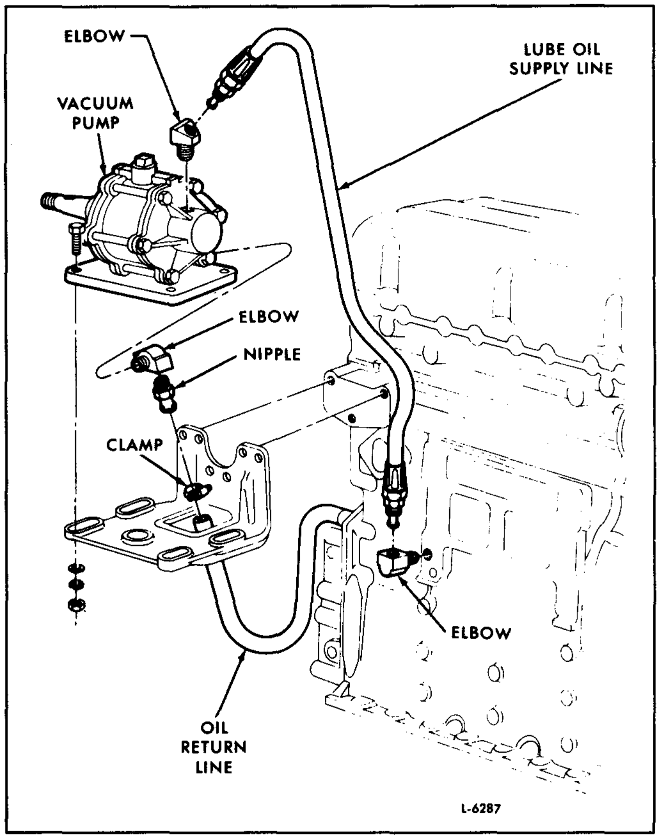

Fig. 1 – Vacuum Pump Installation

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

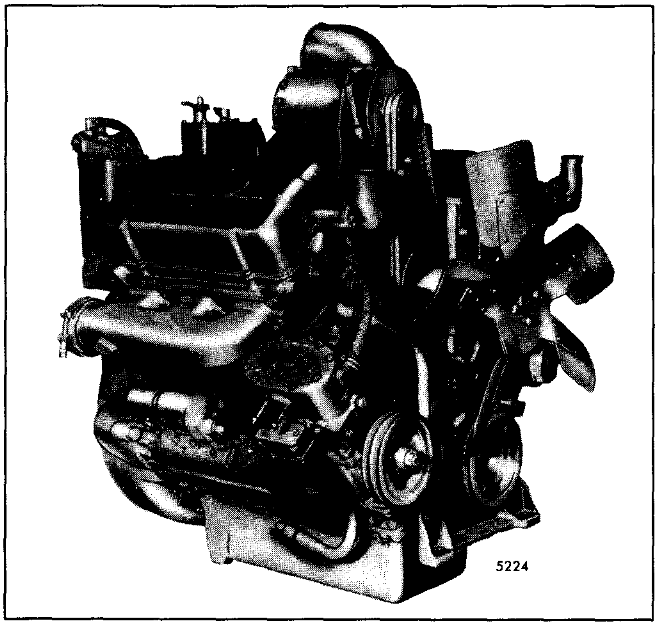

Fig. 1 – Air Compressor Mounting (Former Engines)

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.

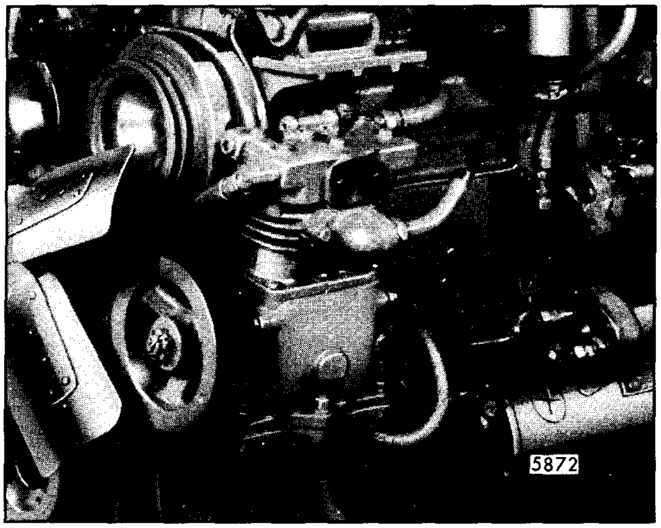

Fig. 2 – Air Compressor Mounting (Current Engines)

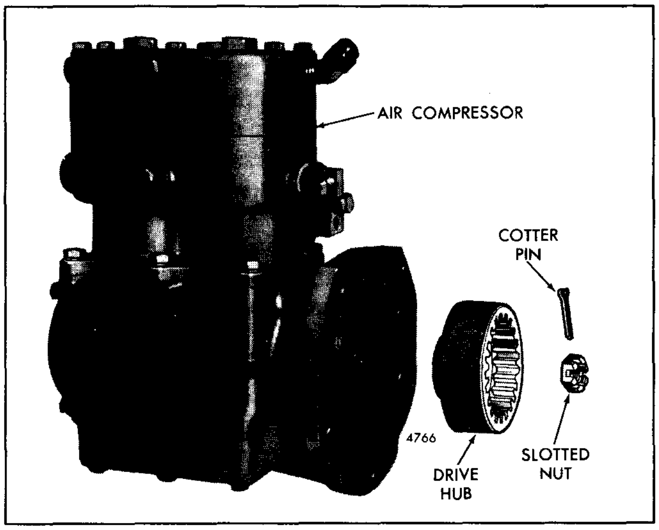

Fig. 3 – Typical Air Compressor with Drive Hub

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).

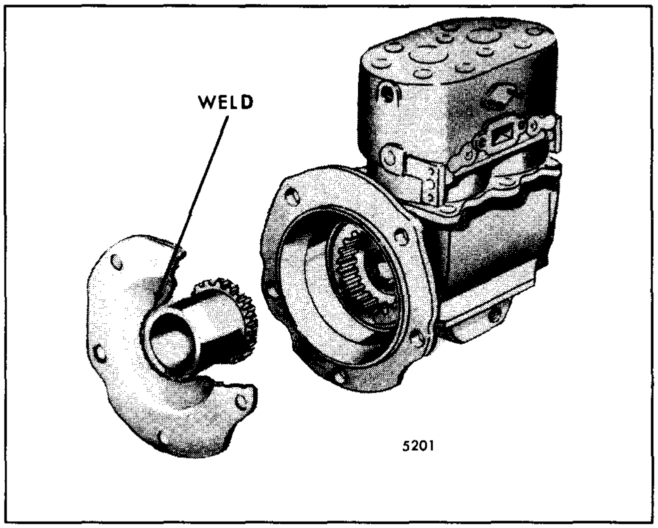

Fig. 4 – Fixture for Holding Drive While Installing or Removing Slotted Nut

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.

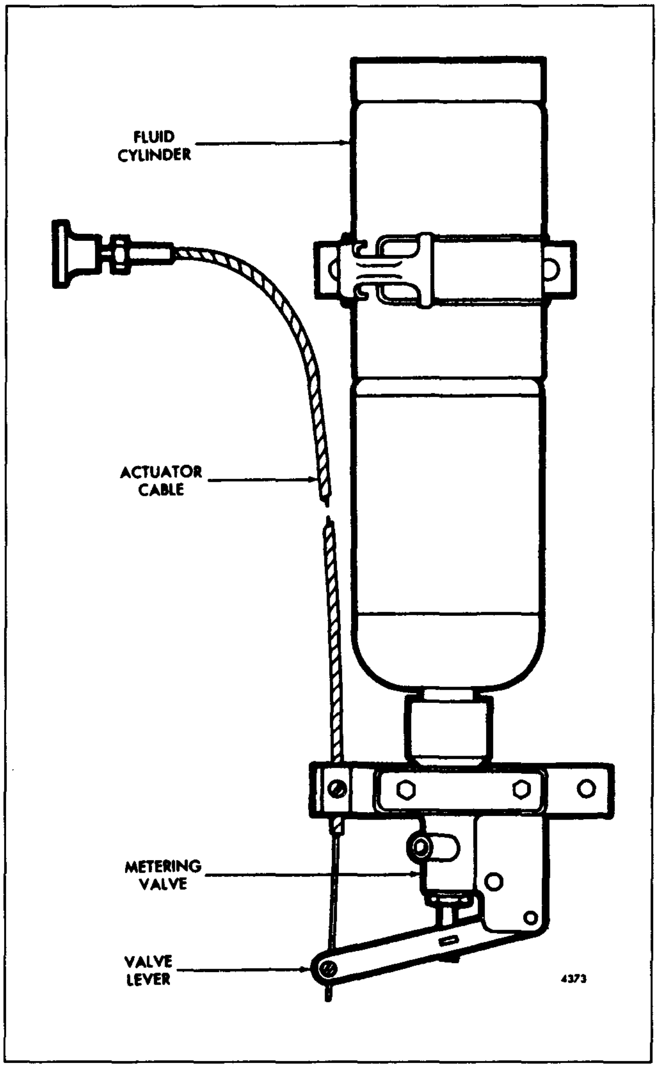

Fig. 1 – Quick Start Assembly

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

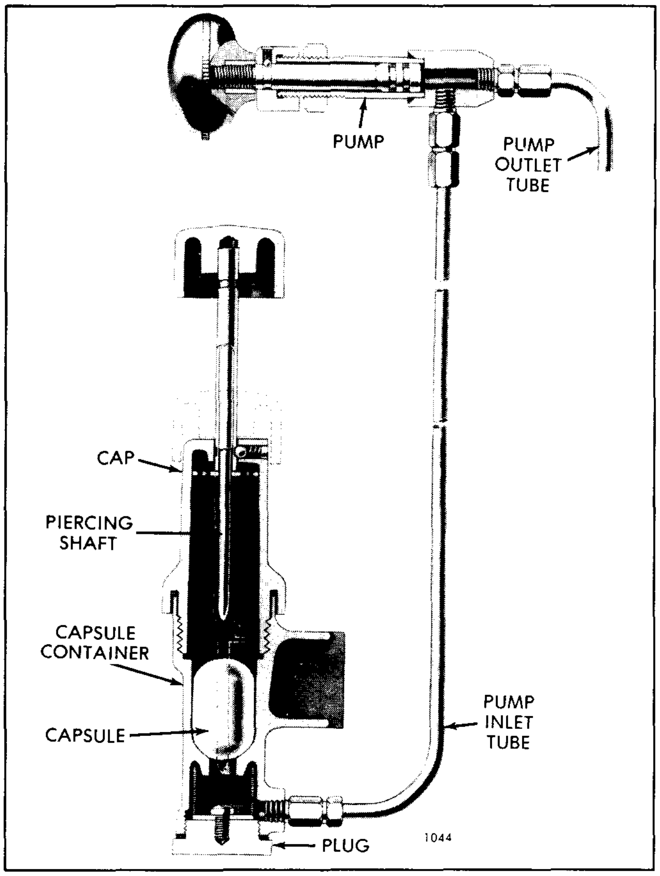

Fig. 2 – Fluid Starting Aid

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.

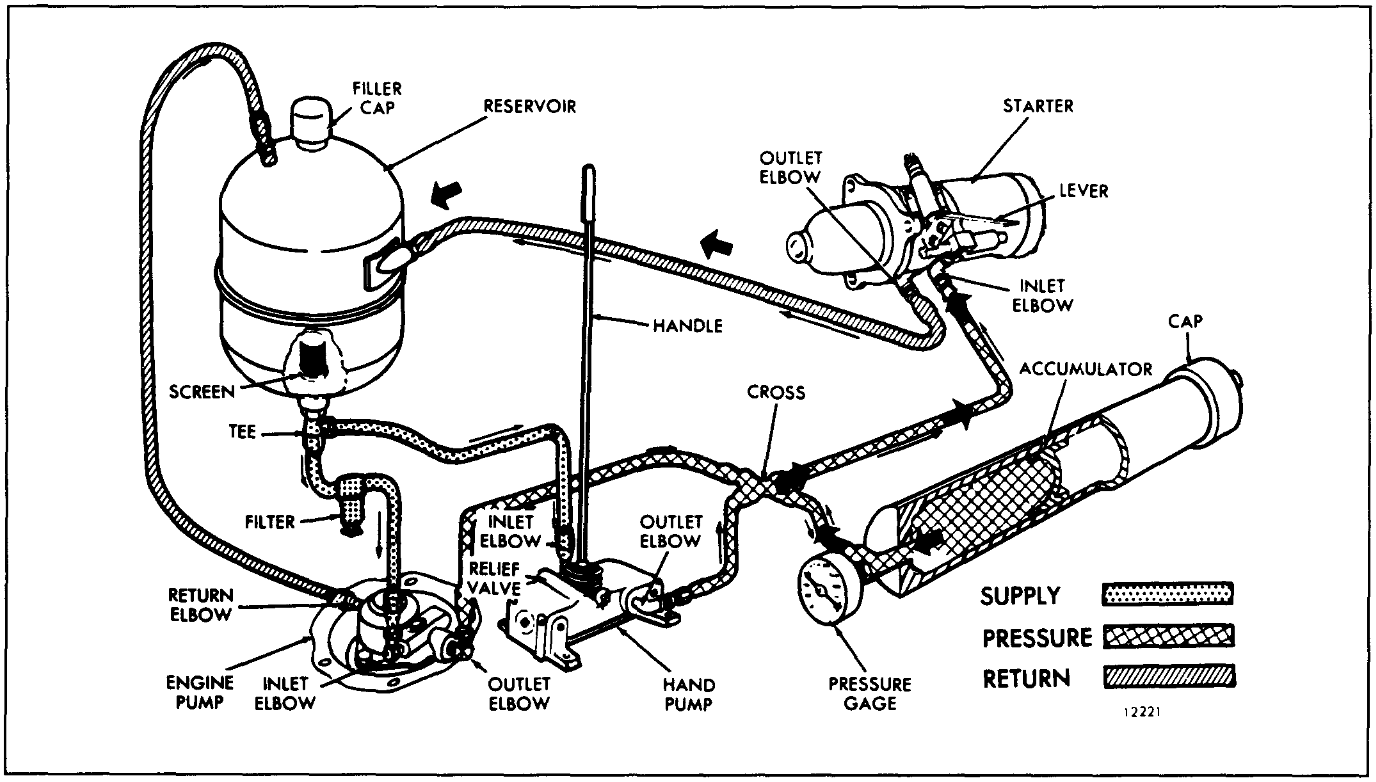

Fig. 1 – Schematic Diagram of Hydrostarter System Showing Oil Flows

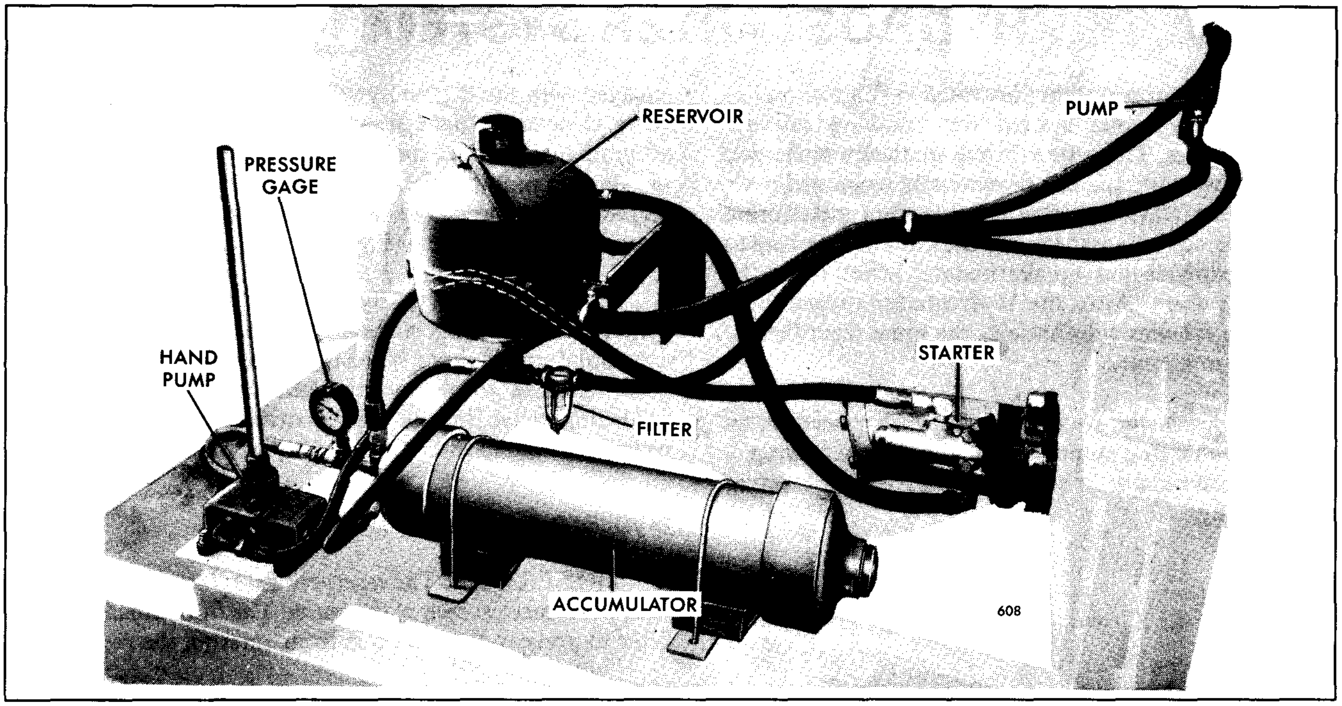

Fig. 2 – Typical Hydrostarter System Mounting

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.

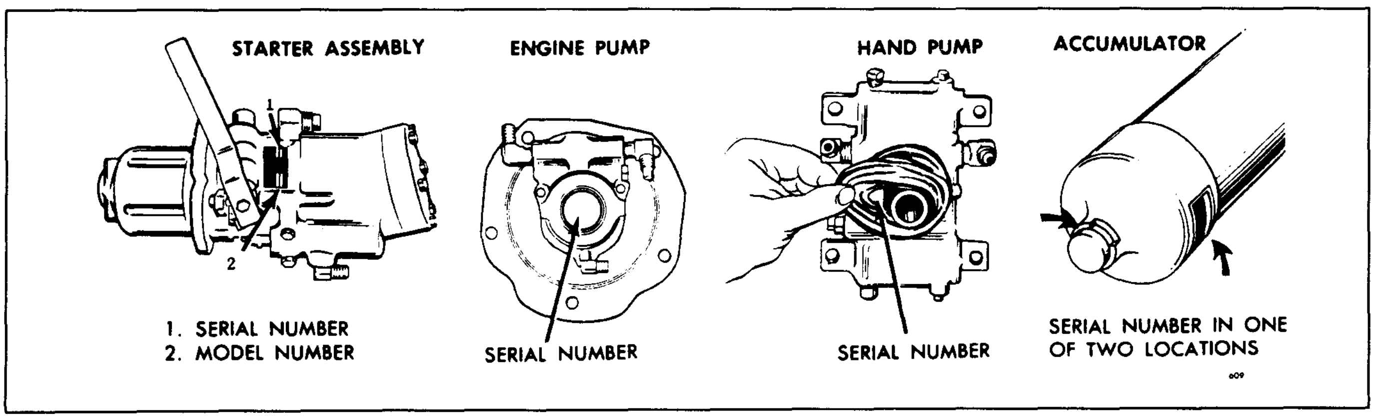

Fig. 3 – Hydrostarter Component Serial Number Locations

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.

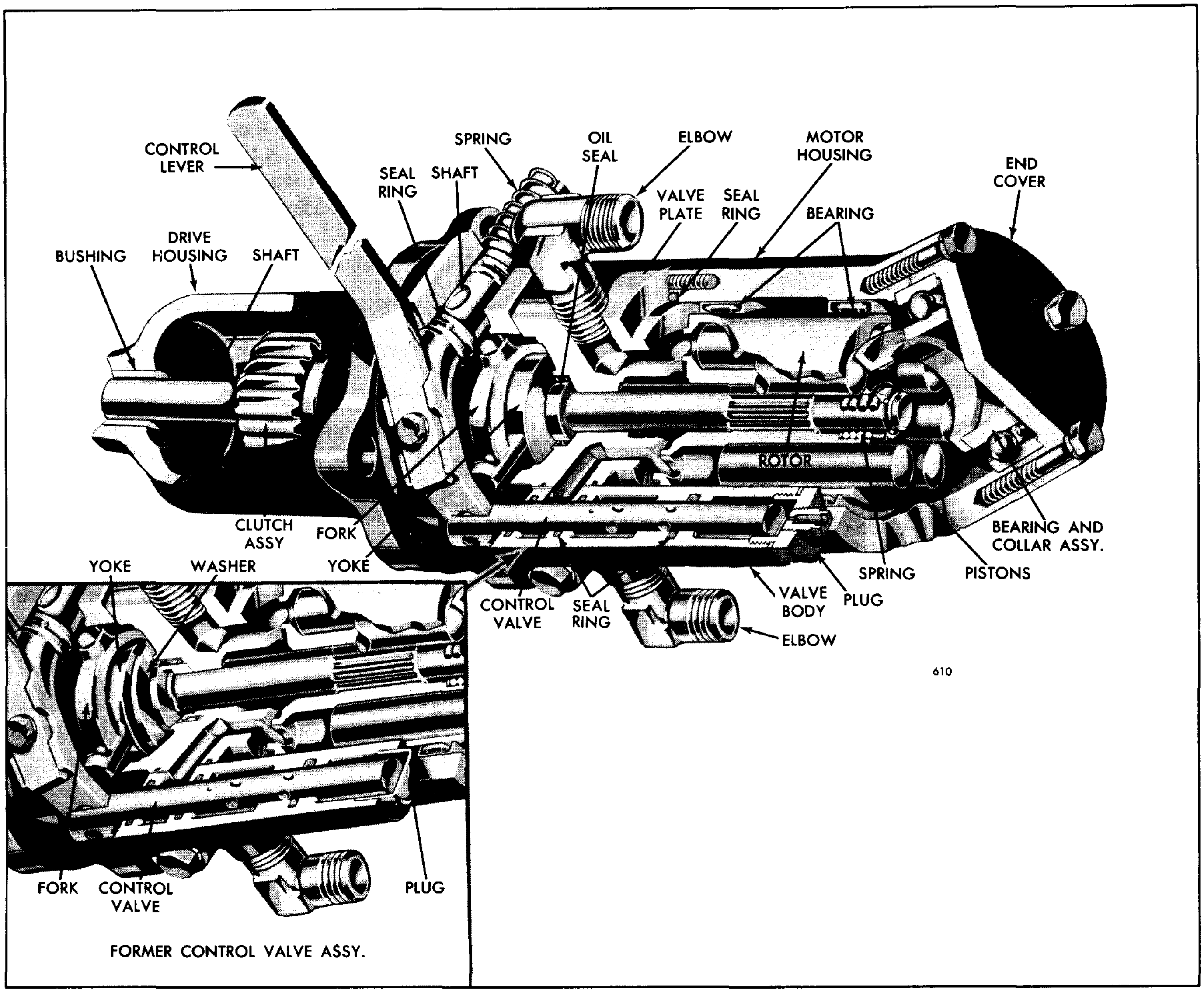

Fig. 4 – Cutaway View of Hydrostarter

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.

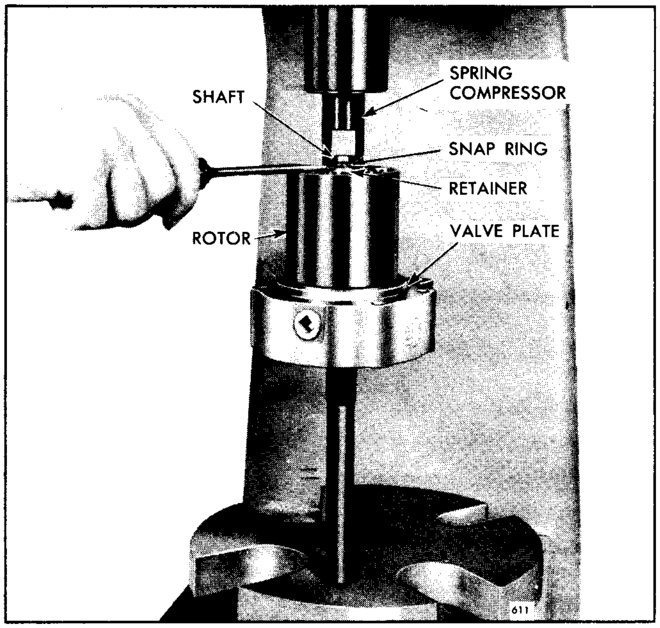

Fig. 5 – Removing Snap Ring from Starter Shaft

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.

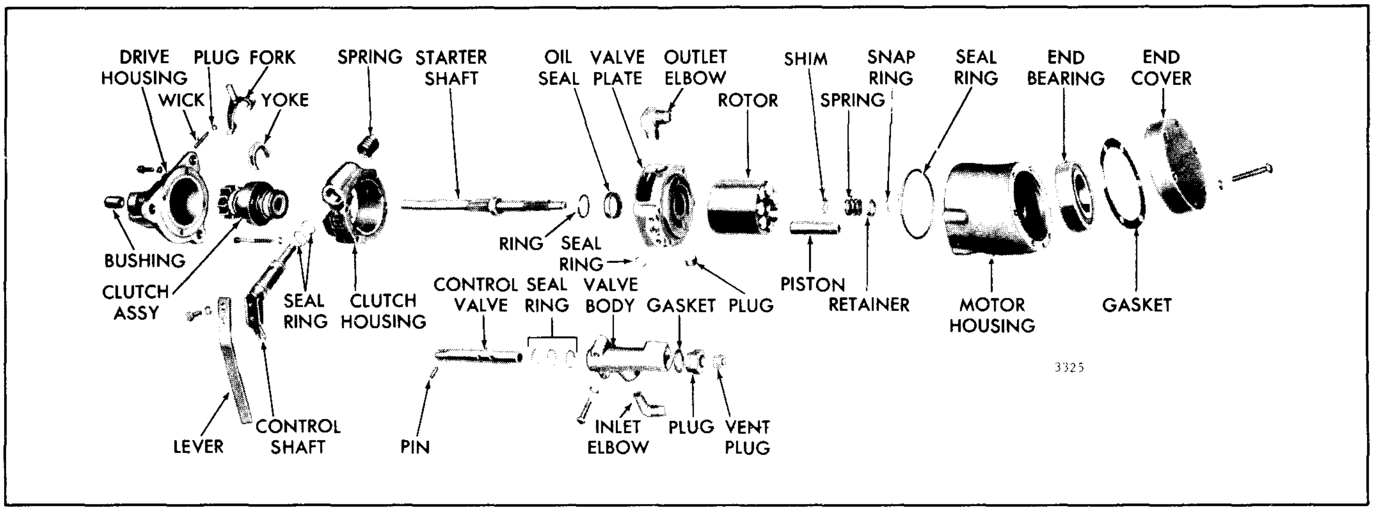

Fig. 6 – Hydrostarter Motor Details and Relative Location of Parts ("20" Series Motor Shown)

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.

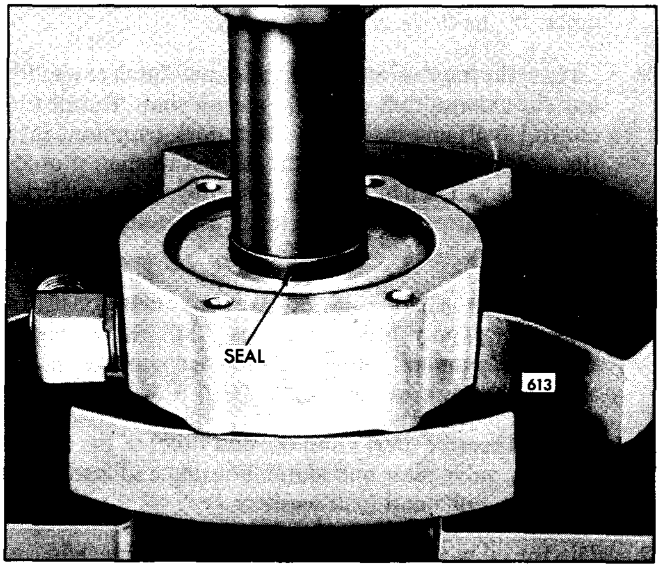

Fig. 7 – Installing Hydrostarter Shaft Seal in Valve Plate

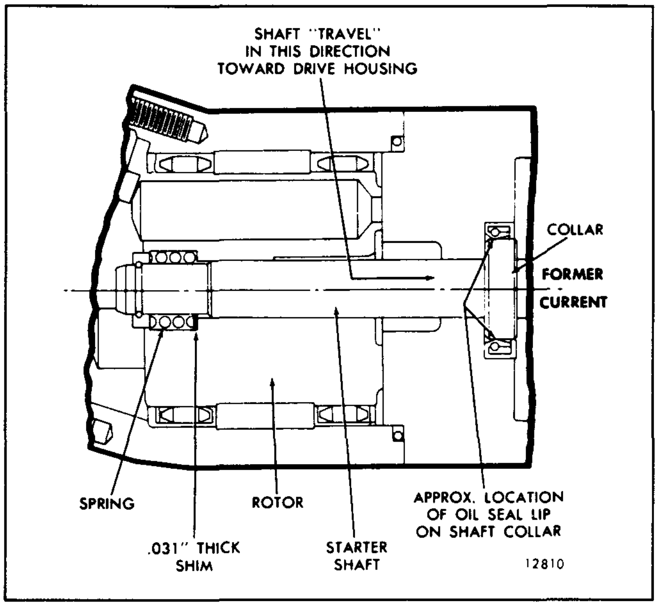

Fig. 8 – Location of Starter Shaft Compression Spring Shim (Series "20" Motor)

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.

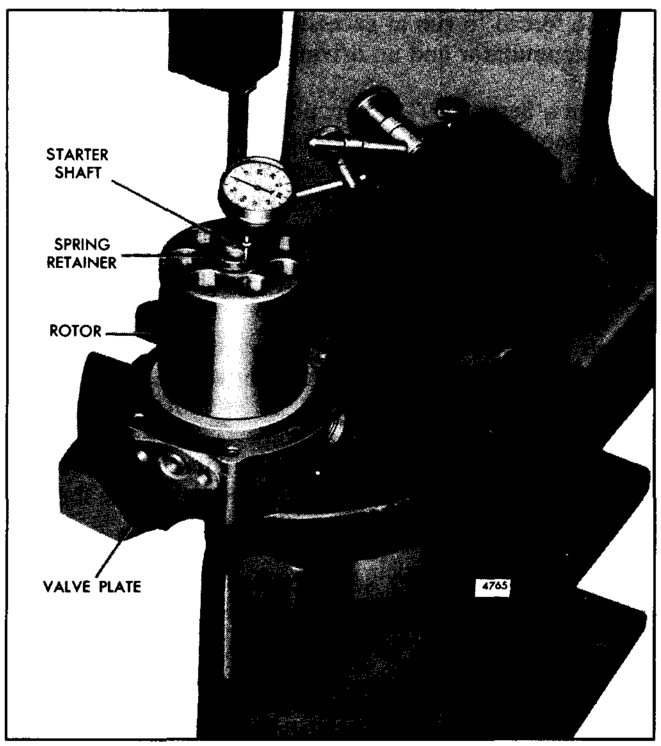

Fig. 9 – Checking Starter Shaft Travel (Series "20" Motor)

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.

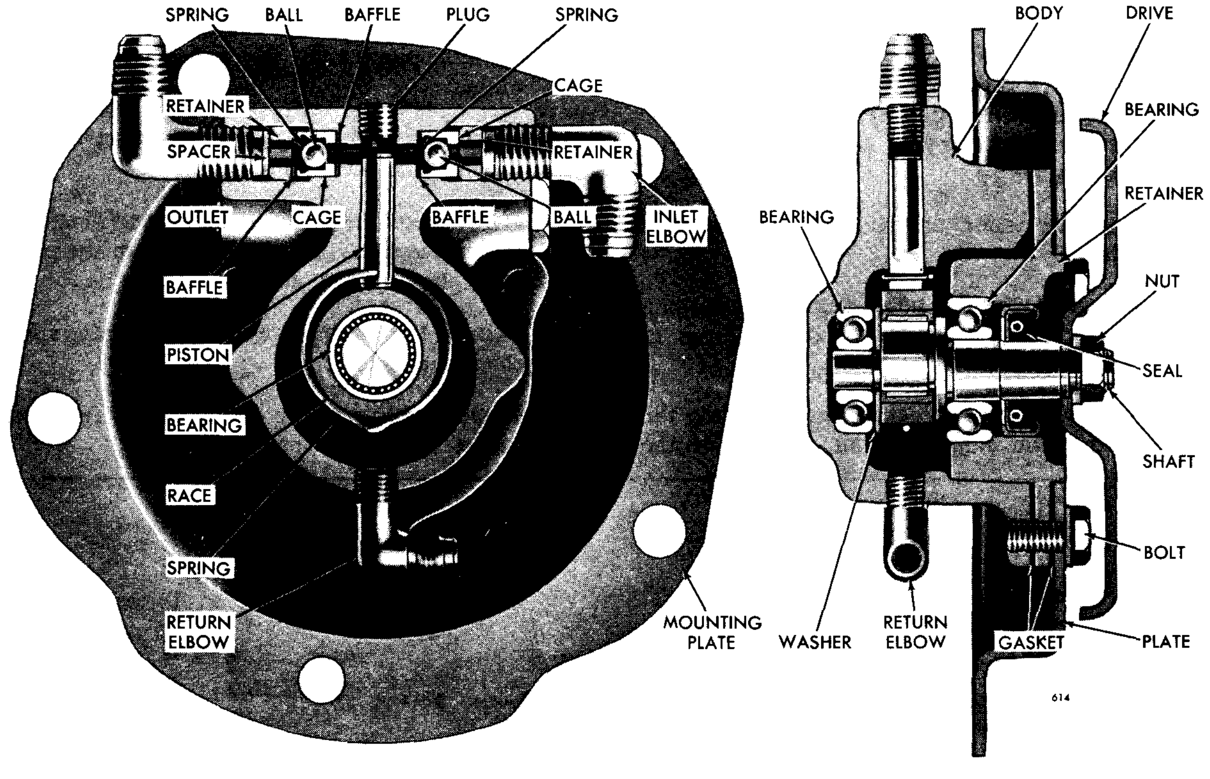

Fig. 10 – Direct Engine–Driven Hydrostarter Charging Pump

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.

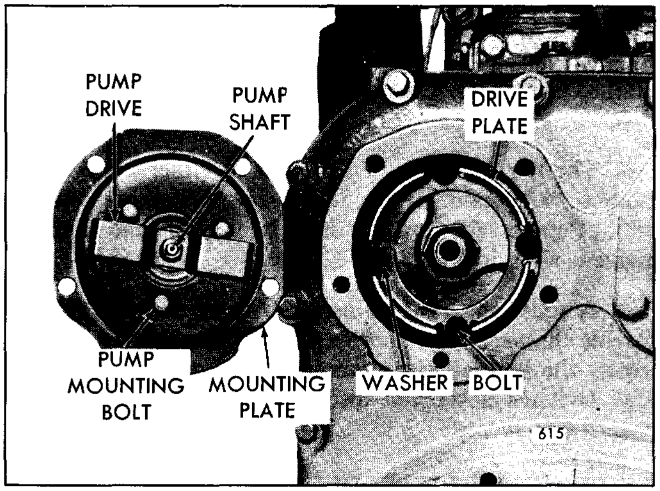

Fig. 11 – Pump Drive Plate Mounting

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.

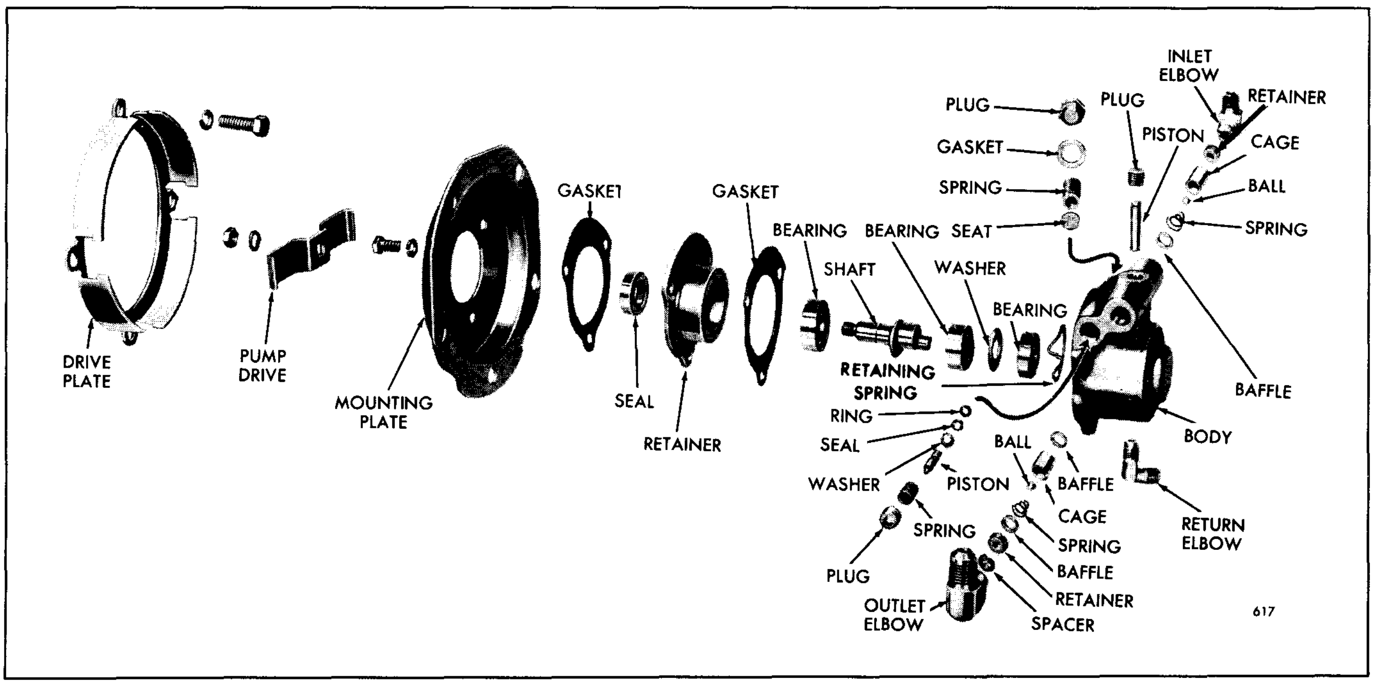

Fig. 12 – Direct Engine–Driven Charging Pump Details and Relative Location of Parts

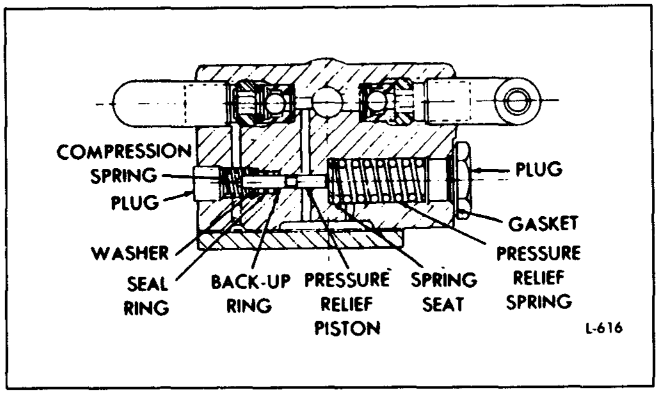

Fig. 13 – Engine–Driven Hydrostarter Charging Pump Pressure Relief Piston Assembly

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.

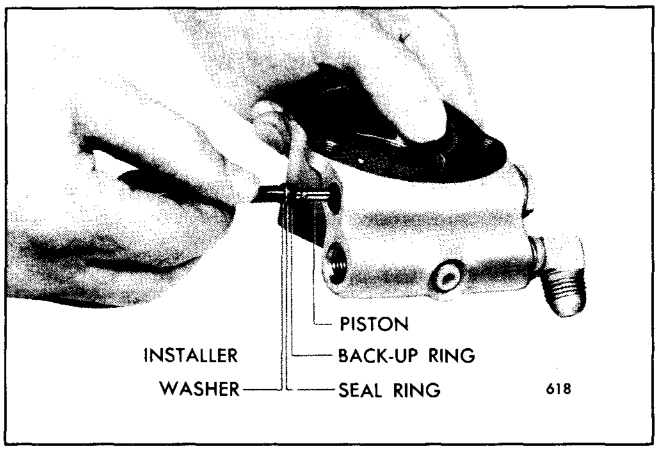

Fig. 14 – Installing Pressure Relief Piston, Back–Up Ring, Seal Ring and Washer in Pump Body with Installer J 7192

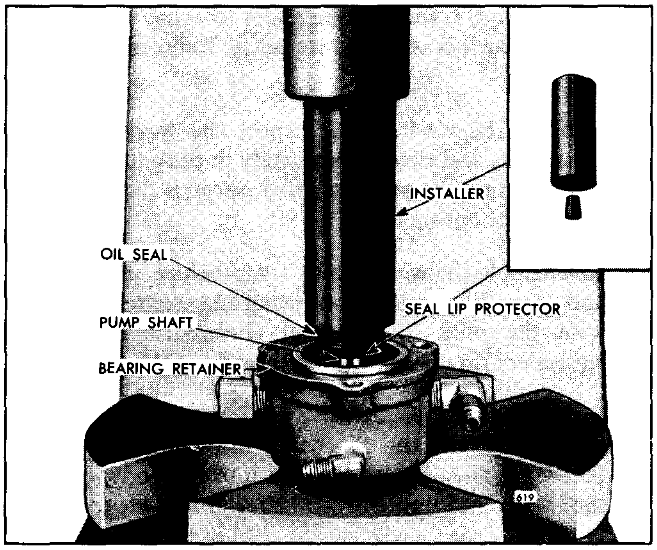

Fig. 15 – Installing Pump Shaft Oil Seal in Bearing Retainer

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.

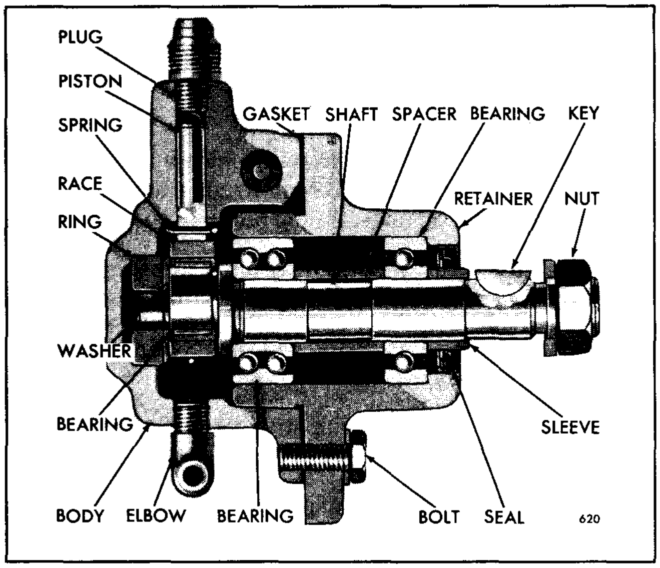

Fig. 16 – Belt–Driven Hydrostarter Charging Pump

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).

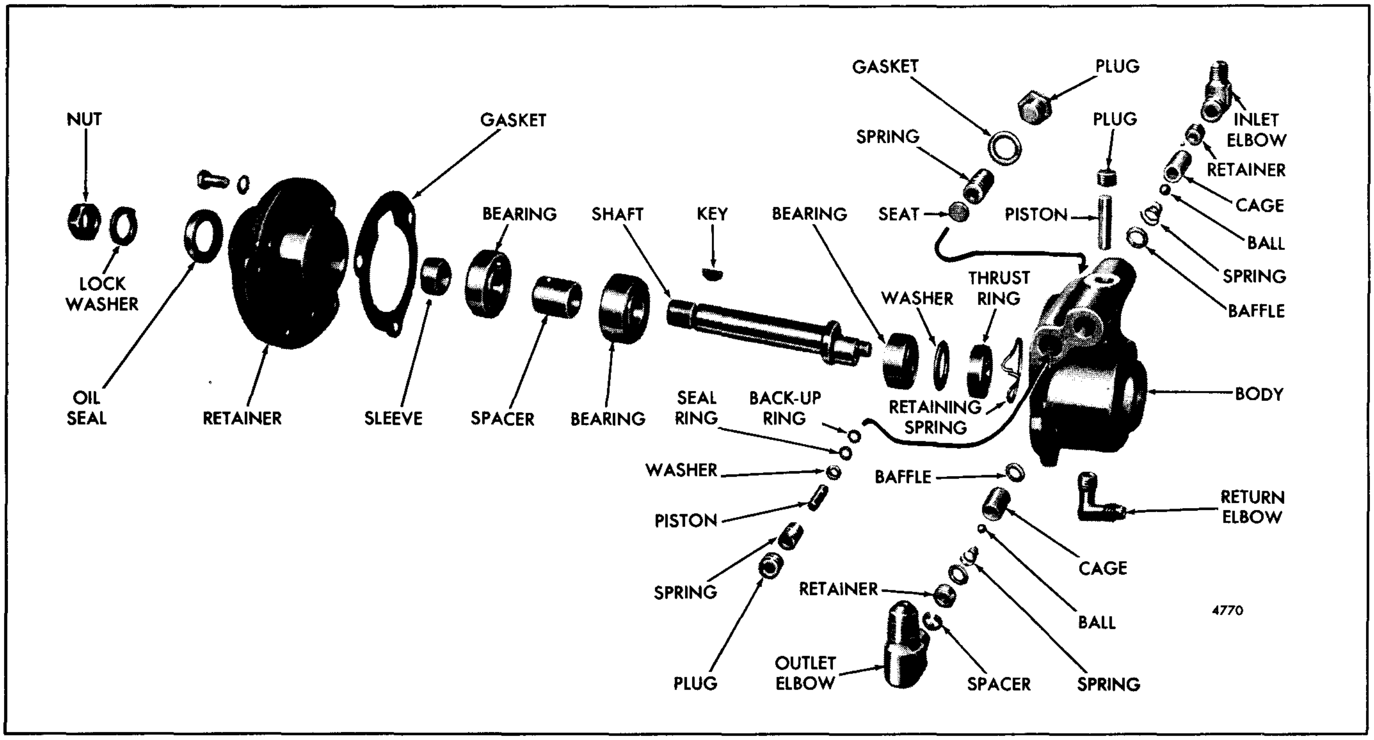

Fig. 17 – Belt–Driven Charging Pump Details and Relative Location of Parts

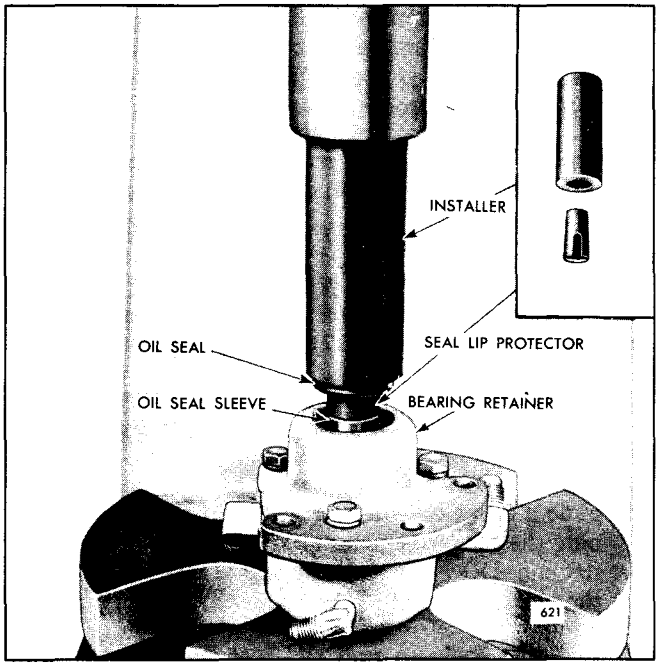

Fig. 18 – Installing Pump Shaft Oil Seal in Bearing Retainer

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.

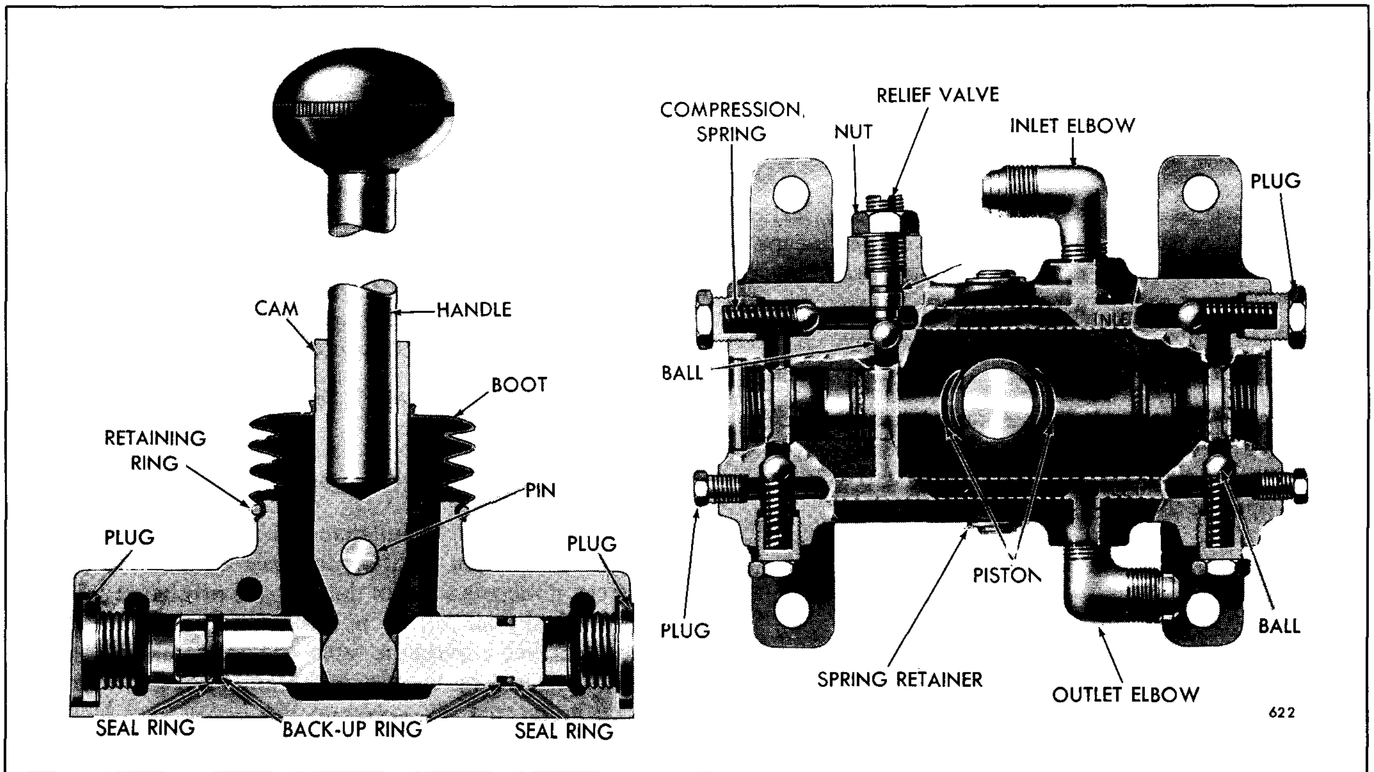

Fig. 19 – Cross Sections of Hydrostarter Hand Pump

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.

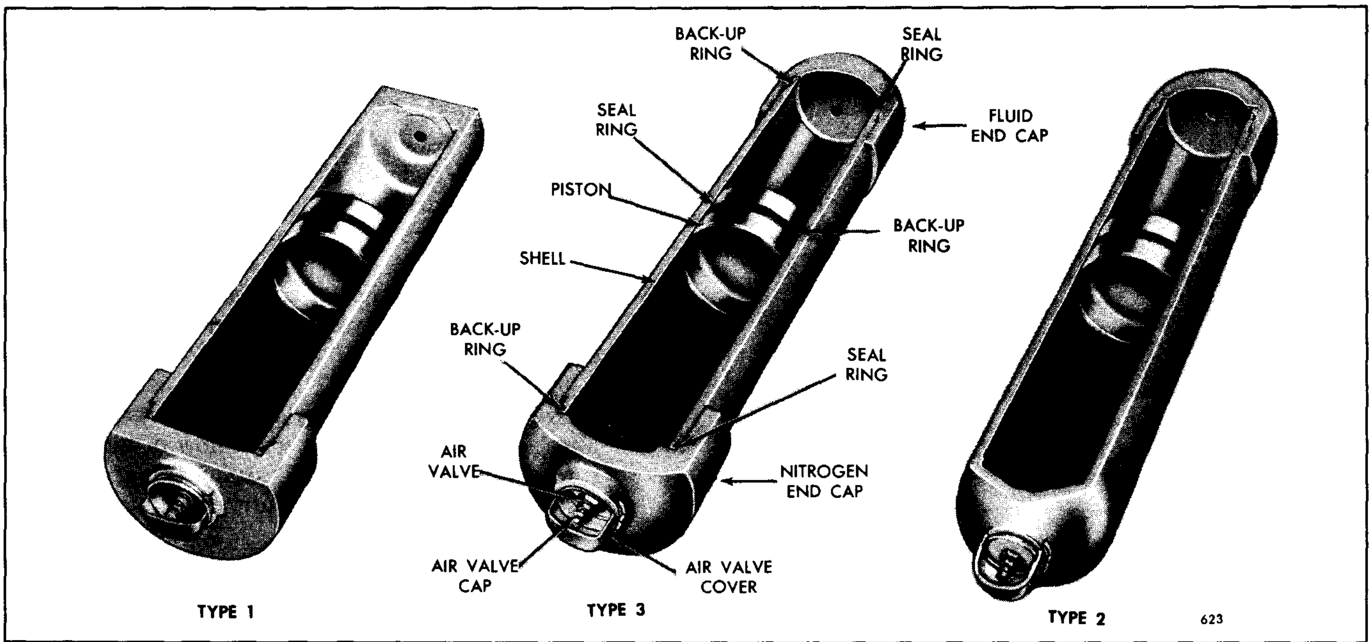

Fig. 20 – Cross Section of Typical Accumulators

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.

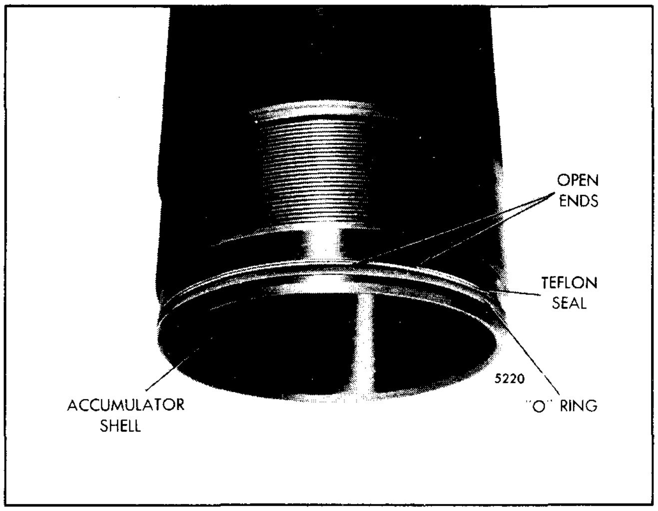

Fig. 21 – Proper Installation of Teflon Back-up Ring

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.

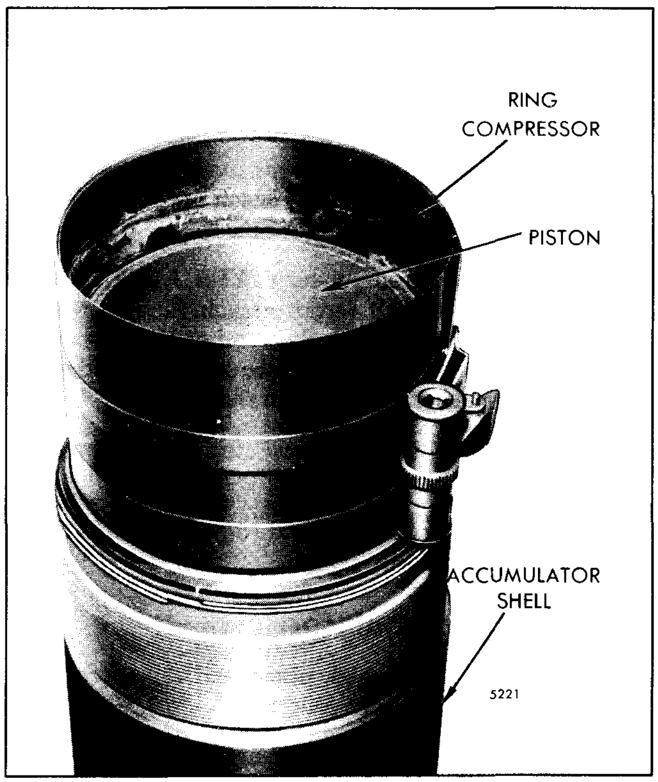

Fig. 22 – Installing Piston in Accumulator Shell

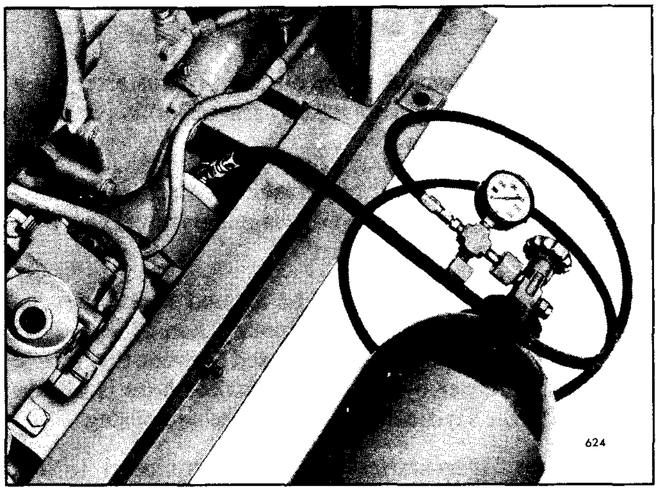

Fig. 23 – Charging Accumulator with Charging Kit J 6714-02

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.

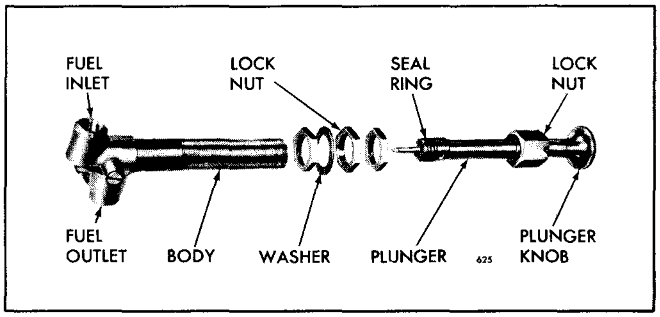

Fig. 24 – Fuel System Priming Pump and Relative Location of Parts

HYDRAULIC REMOTE CONTROL SYSTEM

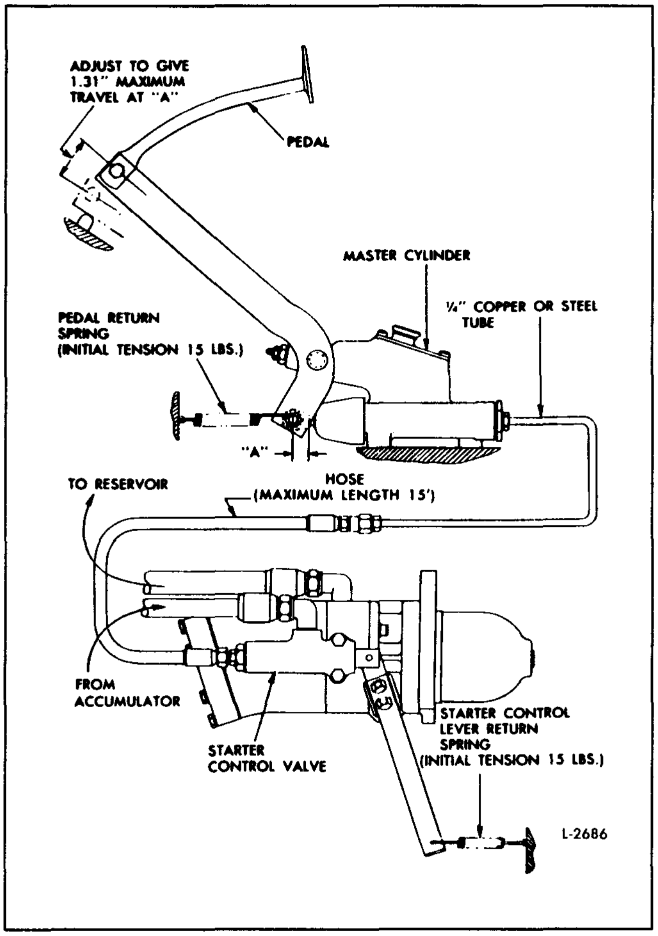

Fig. 25 – Hydraulic Remote Control System for Hydrostarter

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.

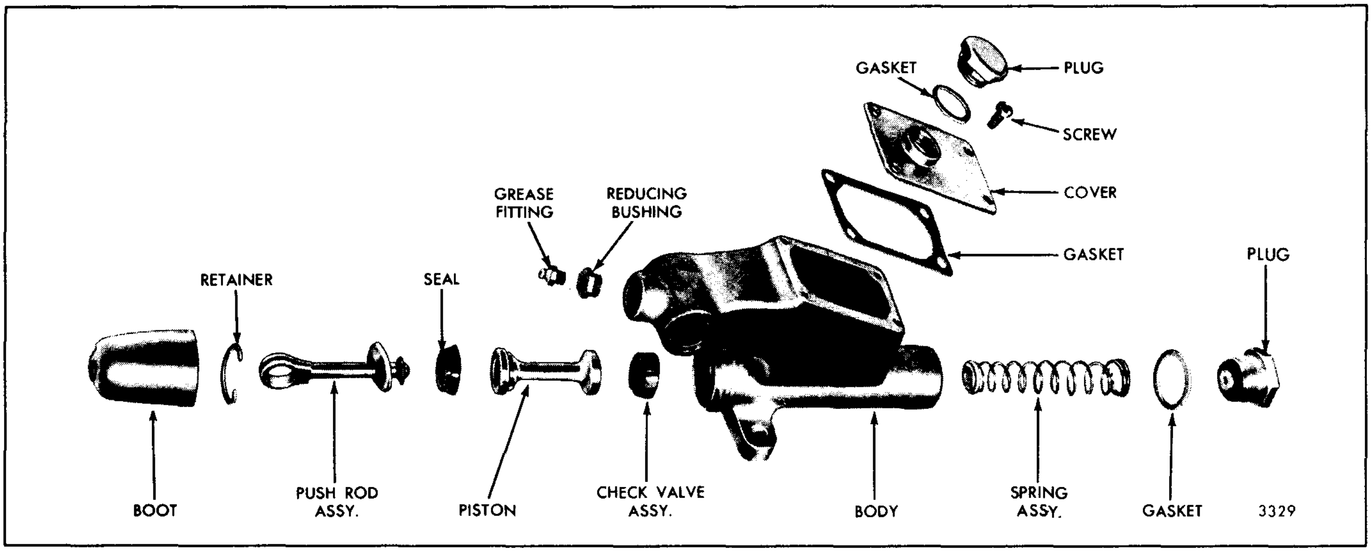

Fig. 26 – Hydraulic Starter Remote Control Master Cylinder Details and Relative Location of Parts

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.

TROUBLESHOOTING - SPECIFICATIONS - SERVICE TOOLS

TROUBLESHOOTING (Hydrostarter)

Chart 1

LOW OR NO ACCUMULATOR PRESSURE

ENGINE DRIVEN PUMP FAILS TO RAISE PRESSURE

Probable Causes

1. AIR IN SYSTEM
2. LOW FLUID LEVEL
3. SCREEN OR FILTER PLUGGED
4. CHECK VALVES NOT FUNCTIONING PROPERLY
5. DRIVE BELT SLIPPING (BELT–DRIVEN PUMP)
6. DRIVE ARM DEFECTIVE (DIRECT–DRIVEN PUMP)

SUGGESTED REMEDY

1. To purge the engine driven pump of air:
   a. Operate the engine at maximum no–load engine speed.
   b. Break the hose connection at the discharge side of the engine–driven pump until a full stream of oil is discharged from the pump.
   c. Connect the hose to the pump and alternately loosen and tighten the swivel fitting on the discharge hose until oil leaking out, when the fitting is loose, appears free of air bubbles.
   d. Tighten the fitting securely and observe the pressure gage. The pressure must rise rapidly to the accumulator precharge pressure (1,250 psi (8 619 kPa) at 70°F or 21°C), then increase slowly to 2,900 to 3,300 psi (19 996 to 22 754 kPa) in six to ten minutes, depending upon the size of the particular accumulator. If the accumulator pressure does not rise, make certain that the hand pump relief valve is closed after the pressure is released and repeat the above purging procedure.
2. The fluid level in the reservoir must be sufficient to completely cover the screen at the bottom of the tank after the accumulator is charged and the engine–driven pump is bypassing a full stream of fluid to the reservoir.
3. Remove and clean the reservoir screen and flush out the reservoir tank. Also, clean the filter located in the supply hose between the reservoir and the engine–driven pump.
4. Open the relief valve on the side of the hand pump, while the engine is running, to permit the engine–driven pump to wash the check valves free from particles.

   If the accumulator can be charged with the hand pump but not with the engine–driven pump, then a check valve in the engine pump is defective. Replace the faulty check valve assembly.
5. Adjust or replace the drive belt, if necessary.
6. Replace the pump drive arm.

Chart 2

CRANKING SPEED TOO LOW

Probable Causes

1. HYDROSTARTER SYSTEM FLUID TOO HEAVY
2. ENGINE OIL TOO HEAVY
3. CONTROL VALVE NOT FULLY OPEN

SUGGESTED REMEDY

1. Check the mixture of fluid in the system. Use fluid consisting of 75% diesel fuel and 25% SAE 10 or 30 lubricating oil.
2. Replace the oil with the proper viscosity grade. Refer to the *Lubrication Specifications* in Section 13.3.
3. Check the travel of the control valve located on the side of the starter. Minimum travel is 1–1/16″. Remove any obstruction that prevents sufficient control valve or control lever handle travel.

Chart 3

LOSS OF FLUID FROM RESERVOIR

Probable Causes

1. EXTERNAL LEAKS
2. WORN STARTER SHAFT SEAL
3. DEFECTIVE GASKET UNDER STARTER COVER
4. WORN SHAFT SEAL (BELT–DRIVEN PUMP)
5. WORN SHAFT SEAL (DIRECT–DRIVEN PUMP)

SUGGESTED REMEDY

1. With pressure in the system, check all hoses and fittings for leaks. Tighten or replace the fittings and any defective parts.
2. Remove the starter after releasing the system pressure and observe the inside of the clutch housing. If evidence of system fluid is found, replace the shaft seal.
3. Operate the starter. During the cranking cycle, watch closely for fluid leaking around the cover or any of the retaining bolts.
4. While the pump is bypassing at full system pressure, examine the shaft for evidence of leaks. Replace the seal, if necessary.
5. After the pump has been bypassing at full system pressure, remove the pump from the flywheel housing and examine the back of the mounting plate near the seal for evidence of leaks. Replace the shaft seal, if necessary.

Chart 4

LOSS OF FLUID PRESSURE WHEN ENGINE IS NOT RUNNING

Probable Causes

1. AMBIENT TEMPERATURE DECREASE
2. ENGINE DRIVEN PUMP CHECK VALVES NOT HOLDING
3. HAND PUMP VALVES NOT HOLDING
4. DAMAGED SEAL RING IN STARTER CONTROL VALVE SHOWN BY EXTERNAL LEAKAGE
5. DAMAGED MIDDLE SEAL RING IN STARTER CONTROL VALVE, NO VISIBLE EXTERNAL LEAKAGE
6. EXTERNAL LEAKAGE IN SYSTEM
7. STARTER CONTROL VALVE OUT OF TIME - BENT SHIFTING FORK
8. LOSS OF ACCUMULATOR PRE–CHARGE (NITROGEN)

SUGGESTED REMEDY

1. A drop in temperature will decrease the nitrogen pressure. Adjust the pressure as needed for cranking requirements by use of the hand pump.

2. Disconnect the return hose and inlet hose from the engine–driven pump. Leakage from the inlet fitting means that both check valves are defective. Leakage at the return fitting means that only the outlet check valve is defective. Replace the defective check valve assembly(s).

3. Disconnect the inlet hose from the hand pump. Leakage from the inlet fitting means that either the relief valve alone or both the inlet and outlet check valves are defective. Stone and clean the ball seats in the pump body and replace the balls and springs, if necessary.

4. Remove the control valve from the starter and replace the seal ring.

5. Disconnect the return hose from the starter. Use the hand pump to raise the pressure, if necessary. If fluid leaks from the return fitting when the control valve is closed, the middle seal ring is damaged. Remove the control valve and replace the seal ring.

6. Examine all hoses and fittings for leaks. Tighten or replace the fittings and any defective parts.

7. With the control valve closed, check the length of the piston protruding beyond the valve body. The correct length is 7/8" ± 1/32". If the length is incorrect, the shifting fork may be bent or the nylong yoke between the fork and the clutch collar may be damaged. Replace the faulty parts.

8. See Chart 7.

Chart 5

HAND PUMP FAILS TO DISCHARGE FLUID

Probable Causes

1. MANUAL RELIEF VALVE OPEN
2. CHECK VALVES LEAKING
3. RESERVOIR SCREEN PLUGGED
4. FLUID LEVEL LOW
5. AIR IN SYSTEM
6. DIRT IN PUMP
7. PISTON SEAL RINGS DAMAGED

SUGGESTED REMEDY

1. Close the relief valve.
2. If caused by dirt, open the relief valve and operate the hand pump slowly for a few minutes to wash the particles out of the check valves. If this is unsuccessful, stone and clean the ball seats in the pump body and replace the balls and springs, if necessary.
3. Remove and clean the reservoir screen, flush the reservoir tank and reassemble.
4. The fluid level in the reservoir must be sufficient to completely cover the screen at the bottom of the tank after the accumulator is charged and the engine–driven pump is bypassing a full stream of fluid to the reservoir.
5. To purge the hand pump of air:
   a. Relieve any system pressure, then disconnect the outlet hose from the hand pump.
   b. Close the manual relief valve and operate the pump until fluid is discharged when stroking in both directions.
   c. Reconnect the outlet hose.
6. See Item 2.
7. Replace the seal rings.

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. cm^3)
Displacement per revolution *35 Series*	3.5 cu. in. (57.4 cu. cm^3)
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. cm^3)
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. cm^3)
Inlet port	No. 6 elbow (SAE 45° flare)
Outlet port	No. 6 elbow (J1C 37° flare)

Accumulator

Type	Piston
Capacity	200 or 300 cu. in. (3278 or 4916 cu. cm^3)
Precharge (nitrogen)	1250 psi (8 619 kPa)
Operating pressure	2900–3000 psi (19 996–20 685 kPa)
Port	3/8 NPTF

Reservoir

Capacity	10, 12, 16 or 23 qt. (9.5, 11.4, 15.1 or 21.8 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. cm^3)
Outlet port	7/16–24 inverted flare tap

Filter

Type	Sediment bowl–stacked disc
Degree of filtration	50 microns
Inlet port	1/8 NPTF
Outlet port	1/8 NPTF

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb–ft)	N·m	THREAD SIZE	280M OR BETTER TORQUE (lb–ft)	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

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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 13.1

Engine Operating Conditions 13.2
Engine Run-In Instructions 13.2.1

Fuels, Lubricants and Coolants 13.3

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.

6V-53 "SILVER" TURBOCHARGED-INTERCOOLED ENGINES MARINE

	2800 rpm
Lubrication System	
Lubricating oil pressure (psi):	
Normal	40–60
Minimum for safe operation	32
†Lubricating oil temperature (deg. F) – Normal	200–250
Air System	
Air box pressure (inches mercury) – min. full load:	
At zero exhaust back pressure:	
7005 injector	62.2
Air inlet restriction (inches water) – full load max.:	
Air silencer	20.0
Crankcase pressure (inches water) – max.	4.0
Exhaust back pressure (inches mercury) – max.:	
Full load	2.5
Fuel System	
Fuel pressure at inlet manifold (psi)	
Normal with .070″ restriction	45–70
Minimum	35
Fuel spill (gpm) – min. at no load:	
.070″ restriction	1.05
Pump suction at inlet (inches mercury) – max.:	
Clean system	6.0
Dirty system	12.0
Cooling System	
Coolant temperature (deg. F) – Normal	167–187

† 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.

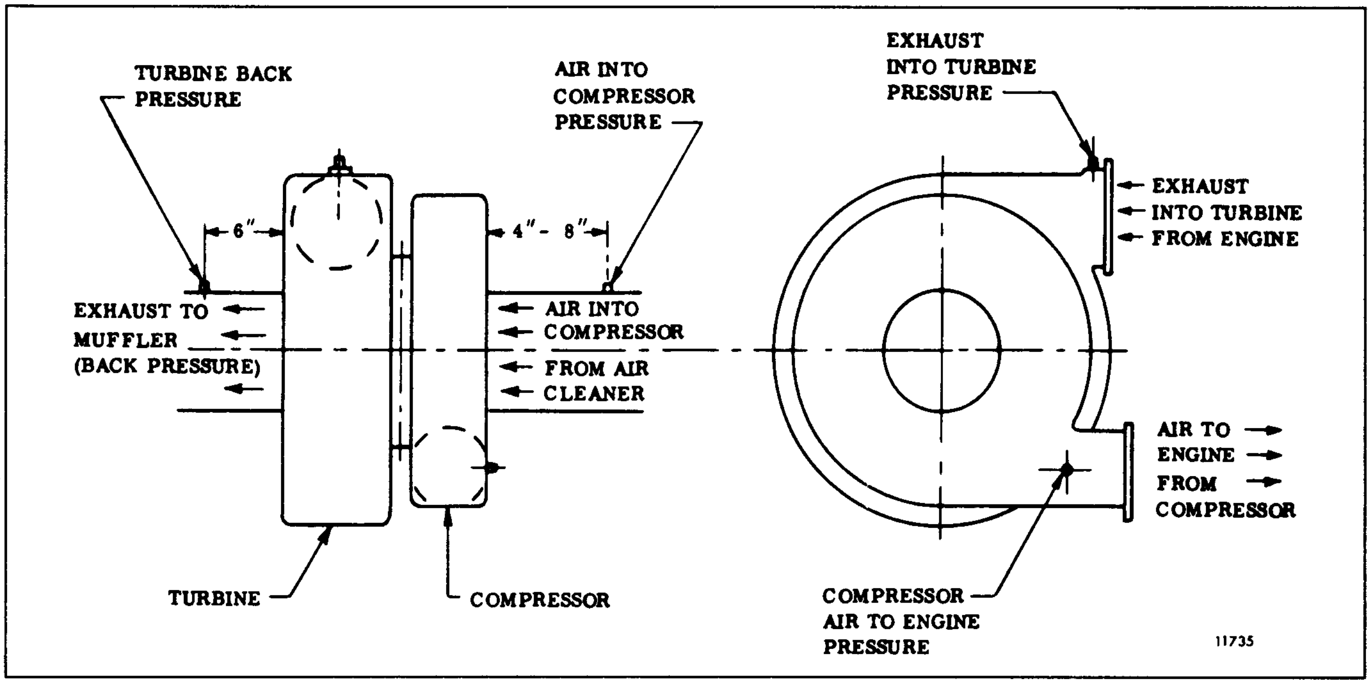


Fig. 1 – Points to Measure Intake and Exhaust Restriction

ENGINE RUN–IN INSTRUCTIONS

Following a complete overhaul or any major repair job involving the installation of piston rings, pistons, cylinder liners or bearings, the engine should be "Run–In" on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine. It permits the technician to physically and visually inspect and check the engine while it is operating. It is an excellent method of detecting improper tune–up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear. Normal coolant temperature (see Section 13.2) should be maintained throughout the Run–In.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 10°F (6°C) higher than the water inlet temperature. Though a 10°F (6°C) rise across an engine is recommended, it has been found that a 15°F (8°C) temperature rise maximum can be permitted.

Thermostats are used in the engine to control the coolant flow. Therefore, be sure they are in place and fully operative or the engine will overheat during the Run–In. However, if the dynamometer has a water standpipe with a temperature control regulator, such as a Taylor valve or equivalent, the engine should be tested without thermostats.

NOTICE: Because of the wet cylinder liners in the Series 53 engine, the engine should be run–in on a closed (heat exchanger type) cooling system where the coolant can be treated with a rust inhibitor (refer to Section 13.3). Use of a good rust inhibitor in the coolant system during engine Run–In will prevent the rusting of the outside diameter of cylinder liners.

The Run–In Schedule is shown on page 2. The horsepower shown is at SAE conditions: dry air density .0705 lb/cu. ft. (1.129 Kg/cu m.), air temperature of 85°F (29°C) and 500 ft. elevation.

DYNAMOMETER TEST AND RUN–IN PROCEDURES

The Basic Engine

The great number of engine applications make any attempt to establish comparisons for each individual model impractical. For this reason, each model has a basic engine rating for comparison purposes.

A basic engine includes only those items actually required to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the *Basic Engine Run–In Schedule.* The following items are included on the basic engine: blower, fuel pump, water pump and governor. The fan and battery–charging alternator typify accessories not considered on the basic engine.

In situations where other than basic engine equipment is used during the test, proper record of this fact should be made on the *Engine Test Report.* The effects of this additional equipment on engine performance should then be considered when evaluating test results.

Dynamometer

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (lb–ft or N·m) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula:

$$BHP = (T \times RPM)/5250$$

Where:

BHP = brake horsepower

T = torque in lb–ft

RPM = revolutions per minute

Some dynamometers indicate direct brake horsepower readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded immediately on an *Engine Test Report* (see sample on page 3).

BASIC ENGINE RUN-IN SCHEDULE

Time Minutes	Speed RPM	Injector Size	ENGINE BRAKE HORSEPOWER									
			4-Valve Cylinder Head							2-Valve Cyl. Head		
			3-53		4-53		6V-53		8V-53	2-53	3-53	4-53
			NA	**T	NA	**T	NA	**T	NA	NA	NA	NA
10	600	All	0	0	0	0	0	0	0	0	0	0
◆30	2800	All		0		0		0				
10	1500	All	15	15	20	20	30	30	40	10	15	20
10	Rated Speed	5A50						112				
		5A55		58		78		117				
		5A60		63		84						
		N-65		65		87						
		5N65*						138				
10	Rated Speed	5A50						225				
		5A55		117		156		234				
		5A60		126		168						
		N-65		131		175						
		5N65*						275				
120	2000	All								40		
30	2200	All	64		87		130		175			
120	2200	All									62	93
30	2800	All	85		115		171		228			
Power Check	Rated Speed	All	Final BHP to be within ±5% of rated									

◆ Turbocharged engines *must* be operated within this RPM range for a full 30 minutes.
*5N65 rating for 6V-53T Marine engine only.
After run-in, *do not* run continuous full load during first 10 hours or 500 miles.
"O" BHP indicates running at no-load for specified time and speed.
**Prior to starting the engine, remove the turbocharger oil supply line at the turbocharger and add CLEAN engine oil to the turbocharger oil inlet to ensure pre-lubrication of the unit. Reconnect the oil line and idle the engine for at least one minute after starting and before increasing the engine speed.

Instrumentation

Certain instrumentation is necessary so that data required to complete the *Engine Test Report* may be obtained. The following list contains both the minimum amount of instruments and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

a. Oil pressure gage installed in one of the engine main oil galleries.

b. Oil temperature gage installed in the oil pan, or thermometer installed in the dipstick hole in the oil pan.

c. Adaptor for connecting a pressure gage or mercury manometer to the engine air box.

d. Water temperature gage installed in the thermostat housing or water outlet manifold.

e. Adaptor for connecting a pressure gage or water manometer to the crankcase.

f. Adaptor for connecting a pressure gage or mercury manometer to the exhaust manifold at the flange.

g. Adaptor for connecting a vacuum gage or water manometer to the blower inlet.

h. Adaptor for connecting a fuel pressure gage to the fuel manifold inlet passage.

i. Adaptor for connecting a pressure gage or mercury manometer to the turbocharger.

In some cases, gages reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gage be of low range and finely divided if accuracy is desired. This is especially true of a gage reading in psi, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

Inches of water = psi x 27.7"
Inches of mercury = psi x 2.04"
Inches of water = kPa x 4.02"
Inches of mercury = kPa x 0.30"

NOTICE: Before starting the Run-In or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions on *Preparation for Starting Engine First Time* in Section 13.1.

ENGINE TEST REPORT

Date ______ Unit Number ______

Repair Order Number ______ Model Number ______

A PRE-STARTING

1. PRIME LUBE OIL SYSTEM	2. PRIME FUEL SYSTEM	3. ADJUST VALVES	4. TIME INJ.	5. ADJ. GOV.	6. ADJUST INJ. RACKS

B BASIC ENGINE RUN-IN

TIME AT SPEED	TIME		RPM	BHP	WATER TEMP.	LUBE OIL PRESS.
	START	STOP				

C BASIC RUN-IN INSPECTION

1. Check oil at rocker arm mechanism	
2. Inspect for lube oil leaks	
3. Inspect for fuel oil leaks	
4. Inspect for water leaks	
5. Check and tighten all external bolts	
6.	

D INSPECTION AFTER BASIC RUN-IN

1. Tighten Rocker Shaft Bolts		4. Adjust Governor Gap	
2. Adjust Valves (Hot)		5. Adjust Injector Racks	
3. Time Injectors		6.	

E FINAL RUN-IN

TIME		TOP RPM		BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE F/L	CRANKCASE PRESSURE F/L
START	STOP	NO LOAD	FULL LOAD				

BLOWER INTAKE RES. - F/L	FUEL OIL PRESSURE RET. MAN. F/L	WATER TEMP. FULL LOAD	LUBE OIL TEMP. F/L	LUBE OIL PRESSURE		IDLE SPEED
				FULL LOAD	IDLE	

F INSPECTION AFTER FINAL RUN

1. Inspect Air Box, Pistons, Liners, Rings	6. Tighten Oil Pump Bolts
2. Inspect Blower	7. Inspect Oil Pump Drive
3. Check Generator Charging Plate	8. Replace Lube Filter Elements
4. Wash Oil Pan, Check Gasket	9. Tighten Flywheel Bolts
5. Clean Oil Pump Screen	10. Rust Proof Cooling System

REMARKS:

Final Run OK'd ______ Dynamometer Operator ______ Date ______

NOTE: Operator must initial each check and sign this report.

• Block Oil Filter Bypass Before Initial Start–Up and Dynamometer Test of Rebuilt Engines

Cold engine start–up causes the lubricating oil filter bypass valve to open until oil temperature increases. When an engine is rebuilt and then dynamometer tested, this bypass condition may result in the circulation of abrasive (harmful) debris introduced into the engine during rebuild.

To prevent unnecessary circulation of debris through the lube oil system, DDC recommends plugging the filter bypass before start–up and during basic engine run–in. This allows all the lube oil to flow through the filter(s), trapping contaminants. To plug the bypass, proceed as follows:

If the valve is secured by a retainer and screw, remove the spring and install a spacer of the appropriate length under the retainer (Fig. 1). The spacer must be long enough to contact the valve and keep it from moving during the dynamometer test. When the test is completed, remove the spacer and reinstall the spring. Then change the filter(s).

If the valve is secured by a plug, drill and tap a 1/4" – 20 hole in a filter bypass valve plug. Install a bolt long enough to contact the valve and keep it from opening and a nut to lock the bolt in position (Fig. 2). When the dynamometer test is completed, replace the modified plug with a standard plug and change the filter(s).

NOTICE: To avoid damaging the phenolic bypass valve, the bolt should be finger–tightened only and then secured in place with the lock nut. On filter adaptors with more than one bypass valve, install modified valve plugs in all valve openings before starting or dynamometer testing the engine.

DDC recommends bringing lube oil temperature up to at least 60°F (15.6°C) before starting the engine prior to testing. If the lube oil is too cold when the engine is started, the resistance to flow of the heavier oil may cause filter gasket leakage or bearing surface damage from inadequate oil film.

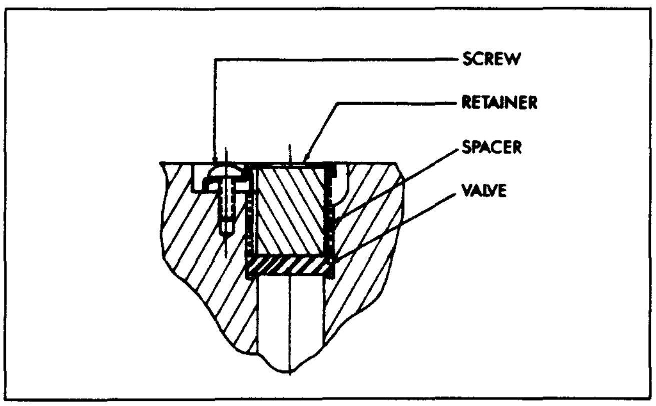


Fig. 1 – Bypass Valve with Spacer Installed

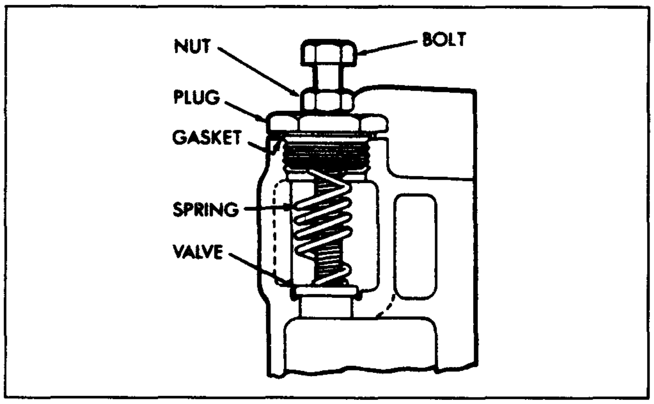


Fig. 2 – Bypass Valve with Modified Valve Plug Installed

Run–In Procedure

The procedure outlined below will follow the order of the sample *Engine Test Report.*

A. PRE–STARTING

1. Fill the lubrication system as outlined under *Lubrication System — Preparation for Starting Engine First Time* in Section 13.1.

2. Prime the fuel system as outlined under *Fuel System* — Preparation for Starting Engine First Time in Section 13.1.

3. preliminary valve clearance adjustment must be made before the engine is started. See *Valve Clearance Adjustment* in Section 14.1.

4. A preliminary injector timing check must be made before starting the engine. See *Fuel Injector Timing* in Section 14.2.

5. Preliminary governor adjustments must be made as outlined in Section 14.

6. Preliminary injector rack adjustment must be made (Section 14).

NOTICE: Prior to starting a turbocharged engine, remove the oil supply line at each turbocharger and add clean engine oil to the oil inlet to ensure pre–lubrication of the turbochargers. Reconnect the oil lines and idle the engine for at least one minute after starting and before increasing the speed.

B. BASIC ENGINE RUN–IN

The operator should be observant at all times, so that any malfunction which may develop will be detected. Since the engine has just been reconditioned, this Run–In will be a test of the workmanship of the technician who performed the overhaul. Minor difficulties should be detected and corrected so that a major problem will not develop.

After performing the preliminary steps, be sure all water valves, fuel valves, etc. are open. Also, inspect the exhaust system, air cleaner and air inlet piping to insure that it is properly connected to the engine. Always start the engine with minimum dynamometer resistance.

After the engine starts, if using a water brake type dynamometer, allow sufficient water, by means of the control loading valves, into the dynamometer absorption unit to show a reading of approximately 5 lb–ft (7 N·m) on the torque gage (or 10–15 HP on a horsepower gage). This is necessary, on some units, to lubricate the absorption unit seals and to protect them from damage.

Set the engine throttle at idle speed, check the lubricating oil pressure and check all connections to be sure there are no leaks.

Refer to the *Engine Test Report* sample which establishes the sequence of events for the Test and Run–In, and to the *Basic Engine Run–In Schedule* which indicates the speed (rpm), length of time and the brake horsepower required for each phase of the test. Also, refer to the *Operating Conditions* in Section 13.2 which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

Engine governors in most cases must be reset at the maximum full–load speed designated for the Run–In. If a governor is encountered which cannot be adjusted to this speed, a stock governor should be installed for the Run–In.

After checking the engine performance at idle speed and being certain the engine and dynamometer are operating properly, increase the engine speed to half speed and apply the load indicated on the *Basic Engine Run–In Schedule.*

The engine should be run at this speed and load for 10 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length of time, speed, brake horsepower, coolant temperature and lubricating oil pressure on the *Engine Test Report.*

Run the engine at each speed and rating for the length of time indicated in the *Basic Engine Run–In Schedule.* This is the Basic Run–In. During this time, engine performance will improve as new parts begin to "seat in". Record all of the required data.

C. BASIC RUN–IN INSPECTION

While the engine is undergoing the Basic Run–In, check each item indicated in Section "C" of the *Engine Test Report.* Check for fuel oil or water leaks in the rocker arm compartment.

During the final portion of the Basic Run–In, the engine should be inspected for fuel oil, lubricating oil and water leaks.

Upon completion of the Basic Run–In and Inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.

D. INSPECTION AFTER BASIC RUN–IN

The primary purpose of this inspection is to provide a fine engine tune–up. First, tighten the cylinder head and rocker arm shaft bolts to the proper torque. Next, complete the applicable tune–up procedure. Refer to Section 14.

E. FINAL RUN–IN

After all of the tests have been made and the *Engine Test Report* is completed through Section "D", the engine is ready for final test. This portion of the Test and Run–In procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut down for one hour or longer, it will be necessary to have a warm–up period of 10 minutes at the same speed and load used for warm–up in the Basic Run–In. If piston rings, cylinder liners or bearings have been replaced as a result of findings in the Basic Run–In, the entire Basic Run–In must be repeated as though the Run–In and Test procedure were started anew.

All readings observed during the Final Run–In should fall within the range specified in the *Operating Conditions* in Section 13.2 and should be taken at full load unless otherwise specified. Following is a brief discussion of each condition to be observed.

The engine *water temperature* should be taken during the last portion of the Basic Run–In at full load. It should be recorded and should be within the specified range.

The *lubricating oil temperature* reading must be taken while the engine is operating at full load and after it has been operating long enough for the temperature to stabilize. This temperature should be recorded and should be within the specified range.

The *lubricating oil pressure* should be recorded in psi after being taken at engine speeds indicated in the *Operating Conditions*, Section 13.2.

The *fuel oil pressure* at the fuel manifold inlet passage should be recorded and should fall within the specified range. Fuel pressure should be recorded at maximum engine speed during the Final Run–In.

Check the *air box pressure* while the engine is operating at maximum speed and load. This check may be made by attaching a suitable gage (0–15 psi) or manometer (15–0–15) to an air box drain or to a hand hole plate prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure should be recorded in inches of mercury.

Check the *crankcase pressure* while the engine is operating at maximum Run–In speed. Attach a manometer, calibrated to read in inches of water, to the oil level dipstick opening. Normally, crankcase pressure should decrease during the Run–In indicating that new rings are beginning to "seat–in".

Check the *air inlet restriction* with a water manometer connected to a fitting in the air inlet ducting located 2″ above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to a fitting installed in the 1/4″ pipe tapped hole in the engine air inlet housing on naturally aspirated engines. If a hole is not provided, a stock housing should be drilled, tapped and kept on hand for future use.

The restriction at this point should be checked at a specific full–load engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. On turbocharged engines, take the reading on the inlet side of one of the turbochargers (see Chart at the end of Section 13.2). The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal *air intake vacuum* at various speeds (at no–load) and compare the results with the *Engine Operating Conditions* in Section 13.2. Record these readings on the *Engine Test Report.*

Check the *exhaust back pressure* (except turbocharged engines) at the exhaust manifold companion flange or within one inch of this location. This check should be made with a mercury manometer through a tube adaptor installed at the tapped hole. If the exhaust manifold does not provide a 1/8″ pipe tapped hole, such a hole can be incorporated by reworking the exhaust manifold. Install a fitting for a pressure gage or manometer in this hole. Care should be exercised so that the fitting does not protrude into the stack. On turbocharged engines, check the exhaust back pressure in the exhaust piping 6″ to 12″ from the turbine outlet. The tapped hole must be in a comparatively straight area for an accurate measurement. The manometer check should produce a reading in inches that is below the *Maximum Exhaust Back Pressure* for the engine (refer to Section 13.2).

Turbocharger compressor outlet pressure and turbine inlet pressures are taken at full–load and no–load speeds.

Refer to the *Final Engine Run–In Schedule* and determine the maximum rated brake horsepower and the full–load speed to be used during the Final Run–In. Apply the load thus determined to the dynamometer. If a hydraulic governor is used, the droop may be adjusted at this time by following the prescribed procedure. The engine should be run at this speed and load for 1/2 hour. While making the Final Run–In, the engine should develop, within 5%, the maximum rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrections made.

When the above conditions have been met, adjust the maximum no–load speed to conform with that specified for the particular engine. This speed may be either higher or lower than the maximum speed used during the Basic Run–In. This will ordinarily require a governor adjustment.

All information required in Section "E", Final Run–In, of the *Engine Test Report* should be determined and filled in. After the prescribed time for the Final Run–In has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine. The Final Run–In is complete.

F. INSPECTION AFTER FINAL RUN–IN

After the Final Run–In and before the *Engine Test Report* is completed, a final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rustproofing the fuel system as outlined in Section 15.3 and adding a rust inhibitor into the cooling system (refer to Section 13.3). The lubricating oil filters should also be changed.

NOTICE: A rust inhibitor in the coolant system of a Series 53 engine is particularly important because of the wet cylinder liners. Omission of a rust inhibitor will cause rusting of the outside diameter of the cylinder liners and interference with liner heat transfer.

LUBRICATING OIL, FUEL OIL AND FILTER RECOMMENDATIONS

Selection of the proper quality of fuel and lubricating oil is important to achieve the long and trouble–free service for which Detroit Diesel engines are designed. Conversely, operation with improper fuels and lubricants can cause problems. The manufacturer's warranty applicable to Detroit Diesel engines provides, in part, that warranty shall not apply to any engine which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow manufacturer's fuel or lubricating recommendations may not be covered by the warranty.

A requirement of Detroit Diesel Corporation's extended warranty program (Power Protection Plan) is that the customer use the lubricants, fuels and filters recommended in this publication.

It is Detroit Diesel's policy to build engines which will operate satisfactorily with fuels and lubricants available in the commercial market. However, not all fuels and lubricants are adequate. Product selection should be made based on these recommendations and in consultation with a reliable supplier who understands the equipment and its application.

LUBRICATING OIL

Engine service life depends upon selecting the proper lubricating oil and maintaining proper oil drain and filter change intervals.

LUBRICANT SELECTION

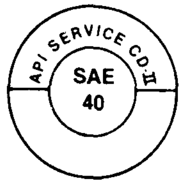
There are hundreds of commercial oils marketed today, but labeling terminology differs among suppliers and can be confusing. Some marketers may claim that their lubricant is suitable for all makes of diesel engines and may list engine makes and types, including Detroit Diesel, on their containers. Such claims by themselves are insufficient as a method of lubricant selection for Detroit Diesel engines.

The proper lubricating oil for all Detroit Diesel engines is selected based on SAE Viscosity Grade and API (American Petroleum Institute) Service Designation. Both of these properties are displayed on oil containers in the API symbol. In addition, military specifications may be used for selecting engine lubricants. Mil–L–2104D represents the most current military specification for diesel lubricants and the only one recommended for Detroit Diesel engines. For two–cycle Detroit Diesel engines, the proper lubricant must also possess a sulfated ash content below 1.0% mass. Refer to the following specific recommendations.

TWO–CYCLE ENGINES
Detroit Diesel Series 53, 71, 92, 149

LUBRICANT RECOMMENDATION

API Symbol:



SAE Viscosity Grade: 40
API Classification: CD–II
Military Spec.: Mil–L–2104D
Sulfated Ash: less than 1.0%

This is the only engine oil recommended for Detroit Diesel two–cycle engines. Lubricants meeting these criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules.

A more detailed description of each of these selection criteria may be found in a further section of this publication. Certain engine operating conditions may require exceptions to this recommendation. They are as follows:

1. For continuous high temperature operation (over 100°F ambient or 200°F Coolant Out) the use of an SAE grade 50 lubricant in all series two–cycle DDC engines is recommended.

2. At ambient temperatures below freezing where starting aids are not available or at very cold temperatures (0 to –25°F), the use of multiviscosity grade 15W–40 or monograde SAE 30 lubricants will improve startability. **Exception: Do not use these lubricants in two–cycle marine engines or DDC series 149 engines under any circumstances.**

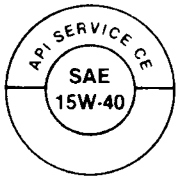
3. The API category CD–II is relatively new and may not be fully in use at the time of this publication. API category CD may be used provided the recommended military specification is satisfied. Oils with API designation CE are not recommended in DDC two–cycle engines unless accompanied by CD–II.

4. When the use of high sulfur fuel is unavoidable, lubricants with a Total Base Number exceeding 10 are recommended. Such a lubricant may have a Sulfated Ash content above 1.0% mass. High sulfur fuels require modification to oil drain intervals. For further information refer to that section of this publication.

FOUR-CYCLE ENGINES
Detroit Diesel Series 60 and 8.2L

LUBRICANT RECOMMENDATION

API Symbol:



SAE Viscosity Grade: 15W–40
API Classification: CE
Military Spec.: Mil–L–2104D

This is the only engine oil recommended for Detroit Diesel Series 60 and 8.2L engines. Lubricants meeting these criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules.

When the use of high sulfur fuel is unavoidable, lubricants with a TBN exceeding 10 are recommended. High sulfur fuels require modification to oil drain intervals. For further information refer to that section of this publication.

LUBRICATING OIL SELECTION CRITERIA

SAE VISCOSITY GRADE

Viscosity is a measure of an oil's ability to flow at various temperatures. The SAE Viscosity Grade system is defined in SAE Standard J300 which designates a viscosity range with a grade number. Lubricants with two grade numbers separated by a "W" are classified as multigrade, while those with a single number are monograde. The higher the number the higher the viscosity.

API SERVICE CLASSIFICATION

The American Petroleum Institute has established a means of classifying lubricant performance suitable for different types of engines and types of service. The higher performance or quality API classifications for diesel engines include CD, CE (for four–cycle diesel engines) and CD–II (for two–cycle diesel engines). Detroit Diesel does not recommend the use of the older and lower performance classifications such as CC, CB and CA.

Multiple API Service Classifications such as "API SERVICE CD, CE" or "API SERVICE CE/CD–II" are frequently listed. Additional classifications not listed here may also be included. It is important that the DDC recommended classification be among those listed.

API SYMBOL

Lubricant marketers have adopted a uniform method of displaying the SAE viscosity grade and API service classification information on product containers and in product literature. The three segment "donut" contains the SAE grade number in the center, and the API service in the top segment. The lower segment is used to designate energy conserving status for gasoline engine use and has no significance for diesel engine use.

MILITARY SPECIFICATION

U.S. Military specifications are another means of classifying the performance of lubricants. As with the API system, lubricants must meet performance criteria before approval is given. The essential difference, however, is that lubricants meeting military specifications, particularly those possessing Qualified Products Listing (QPL) Numbers, have been reviewed by a committee consisting of engine manufacturers, including Detroit Diesel.

Military Specification Mil–L–2104D represents the current specification for heavy–duty diesel engines and the only one recommended by Detroit Diesel Corporation.

SULFATED ASH AND TOTAL BASE NUMBER

This is a lubricant property obtained by a laboratory test (ASTM D874) to determine potential for the formation of metallic ash. The ash residue is related to the oil's additive composition and is significant in predicting lubricants which may cause valve distress under certain operating conditions. Sulfated ash is related to Total Base Number (TBN), also a laboratory test (ASTM D2896) which measures an oil's ability to neutralize acids. As TBN increases, sulfated ash also increases to where lubricants with TBNs above 10 will likely have sulfated ash contents above 1.0% mass.

Total Base Number is important to deposit control in four–cycle diesel engines and to neutralize the effects of high sulfur fuel in all diesel engines. In general, Detroit Diesel recommends lubricants with sulfated ash contents below 1.0% mass and TBNs between 7 and 10 for all Series engines operating on low sulfur fuel.

UNIVERSAL OILS

Universal oils are designed for use in both gasoline and diesel engines and provide an operational convenience in mixed fuel engine fleets. These products are identified with combination API category designations such as SF/CD or SG/CE. Although such products can be used in Detroit Diesel engines (provided they satisfy all DDC requirements), their use is not as desirable as lubricants formulated specifically for diesel engines, and bearing only the API CD–II or CE designations.

SYNTHETIC OILS

Synthetic oils may be used in Detroit Diesel engines provided they meet the viscosity, performance classification and chemical recommendations listed for non–synthetic lubricants. Product information about synthetic oils should be reviewed carefully since these lubricants are often claimed to be of monograde viscosity. Their use does not permit extension of recommended oil drain intervals.

MARINE LUBRICANTS, RAILROAD DIESEL LUBRICANTS

The petroleum industry markets specialty lubricants for use in diesel engines designed specifically for marine propulsion or railroad locomotive use. These lubricants take into consideration the unique environments and operational characteristics of this type of duty, and consequently, they are formulated quite differently from the types of lubricants recommended by Detroit Diesel. Although in some cases they may be suitable in Detroit Diesel engines, they should not be used without specific consultation with your Detroit Diesel distributor or regional office and the lubricant supplier.

USE OF SUPPLEMENTAL ADDITIVES

Lubricants meeting the Detroit Diesel recommendations outlined in this publication already contain a balanced additive treatment. The use of supplemental additives, such as break–in oils, top oils, graphitizers, and friction–reducing compounds, is generally unnecessary and can even be harmful. Never use a lubricant supplement to "fix" a mechanical problem, and be cautious of products purporting to prevent one. The best approach is to follow DDC's lubricant recommendations.

EVIDENCE OF SATISFACTORY LUBRICANT PERFORMANCE

These recommendations are intended to provide a guideline for lubricating oil selection based on favorable service history in typical applications of Detroit Diesel engines. Specific situations may warrant consideration of a lubricant that does not fit these guidelines. Such a lubricant may perform satisfactorily in certain circumstances, and be inappropriate for others.

For such products, evidence of satisfactory performance should be obtained from the oil supplier on the specific lube oil blend being considered and compared with the performance of a DDC recommended lubricant as reference. Comparative performance evidence would include stationary engine tests and field testing in a similar application and severity.

The type of field test used by the oil supplier depends on the series engine in which the candidate oil will be used and the service application. The candidate test oil engines should all operate for the mileage/hours indicated in the table below. Any serious mechanical problems should be recorded. At the conclusion of the test, the engines should be disassembled and quantitatively compared with reference oil engines for:

- Ring conditions (broken, stuck and wear)
- Cylinder liner and piston skirt scuffing
- Exhaust valve face and seat deposits and distress
- Piston pin and slipper bushing wear
- Piston ring land deposits
- Overall valve train and bearing wear

Several stationary engine tests have been designed by and utilized by Detroit Diesel for evaluation of lubricants. These tests include:

100 Hour Series 92 Accelerated Engine Test
– evaluates liners, rings and slipper bushings

Series 71 Valve Guttering Test
– evaluates effects of high ash on valve distress

100 Hour Series 60 Truck Cycle Test
– evaluates deposit and ring sticking

240 Hour 6V53T Endurance Test (FTM 355)
– evaluates liner and ring wear (used for CD–II)

LUBRICATING OIL FIELD TESTING GUIDELINES

ENGINE SERIES	SERVICE APPLICATION	TEST DURATION	NO. ENGINES ON CANDIDATE TEST OIL	NO. ENGINES ON REFERENCE BASELINE OIL
53	Pickup & Delivery	50,000 Miles	5	5
60, 71, 92	Highway Truck, GVW 78,000 lbs	200,000 Miles	5	5
149	Off–Road 120 Ton Rear Dump	10,000 Hours	3	3

Although stationary engine testing provides important lubricant performance evaluation, it should be considered secondary to a properly conducted field test evaluation.

Upon completion of the field and stationary testing of products which meet or exceed the performance of lubricants recommended in this publication, Detroit Diesel will issue a written approval for their use in the application field tested. Such approval will be limited to the specific formulation (identical basestock and additive treatment) in which the testing was conducted.

OIL CHANGE INTERVALS

During use, engine lubricating oil undergoes deterioration from combustion by-products and contamination. For this reason, regular oil drain intervals are necessary. These intervals however, may vary in length depending upon engine operation, fuel quality, and lubricant quality. The oil drain interval may be established on recommendations of a Detroit Diesel Oil Analysis Program until the most practical oil change interval has been determined. Under no circumstances, however, should the drain intervals in the chart be exceeded. Refer to the "Used Lubricating Oil Analysis" section of this publication for more information. All engine oil filters should be changed when the lube oil is changed.

MAXIMUM RECOMMENDED OIL DRAIN INTERVALS (Normal Operation)

SERVICE APPLICATION	ENGINE SERIES	OIL DRAIN INTERVAL
Highway Truck	60, 71 & 92	20,000 Miles (32,000 kM)
City Transit Coaches	53, 71 & 92	6,000 Miles (9,600 kM)
Pick-up & Delivery, Stop & Go, Short Trip	53, 71, 92	12,000 Miles (19,000 kM)
	8.2L	6,000 Miles (9,600 kM)
Industrial, Agricultural and Marine	149NA	500 Hrs. or 1 Yr.
	149T	300 Hrs. or 1 Yr.
	53, 60, 71, 92 & 8.2L	150 Hrs.
Stationary Units Full Time	53, 71, 92 & 149	500 Hrs. or 1 Mo.
Standby	53, 71, 92, 149 & 8.2L	150 Hrs. or 1 Yr.

OIL CHANGE INTERVALS WHEN USING HIGH SULFUR FUEL

When the continuous use of high sulfur fuel (greater than 0.5%) is unavoidable, lubricant selection and oil drain interval must be modified. A lubricant with a Total Base Number (TBN per ASTM D 2896) above 10 is recommended. It is likely that such a lubricant will also exhibit a sulfated ash above 1.0%. The proper oil drain interval must be determined by oil analysis when operating on high sulfur fuel. A reduction in TBN (D 2896) to one third of the initial value provides a general drain interval guideline.

MAXIMUM RECOMMENDED OIL DRAIN INTERVALS

FUEL SULFUR 0.5% TO 1.0%
Use a lubricant with TBN (ASTM D 2896) 10 to 30

SERVICE APPLICATION	ENGINE SERIES	OIL DRAIN INTERVAL 10-19 TBN	20-30 TBN
Highway Truck	60, 71 & 92	15,000 Mi. (24,000 kM)	20,000 Mi. (32,000 kM)
City Transit Coaches	53, 71 & 92	4,000 Mi. (6,400 kM)	6,000 Mi. (9,600 kM)
Pick-up & Delivery Stop & Go, Short Trip	53, 71 & 92	8,000 Mi. (12,500 kM)	12,000 Mi. (20,000 kM)
	8.2L	4,000 Mi. (6,400 kM)	6,000 Mi. (9,600 kM)
Industrial, Agricultural and Marine	149NA	300 Hrs.	500 Hrs.
	149T	200 Hrs.	300 Hrs.
		(or 1 Yr. Maximum)	
	53, 60, 71, 92 & 8.2L	100 Hrs.	150 Hrs.
Stationary Units Full Time	53, 71, 92 & 149	300 Hrs.	500 Hrs.
		(or 1 Mo. Maximum)	
Standby	53, 71, 92, 149 & 8.2L	100 Hrs.	150 Hrs.
		(or 1 Yr. Maximum)	

MAXIMUM RECOMMENDED OIL DRAIN INTERVALS

FUEL SULFUR ABOVE 1.0%
Use a lubricant with TBN (ASTM D 2896) 10 to 30

SERVICE APPLICATION	ENGINE SERIES	OIL DRAIN INTERVAL 10-19 TBN	20-30 TBN
Highway Truck	60, 71 & 92	7,500 Mi. (12,000 kM)	15,000 Mi. (24,000 kM)
City Transit Coaches	53, 71 & 92	2,000 Mi. (3,000 kM)	4,000 Mi. (6,400 kM)
Pick-up & Delivery Stop & Go, Short Trip	53, 71 & 92	4,000 Mi. (6,500 kM)	8,000 Mi. (12,500 kM)
	8.2L	2,000 Mi. (3,000 kM)	4,000 Mi. (6,400 kM)
Industrial, Agricultural and Marine	149NA	150 Hrs.	300 Hrs.
	149T	100 Hrs.	200 Hrs.
		(or 6 Mos. Maximum)	
	53, 60, 71, 92 & 8.2L	50 Hrs.	100 Hrs.
Stationary Units Full Time	53, 71, 92 & 149	150 Hrs.	300 Hrs.
Standby	53, 71, 92, 149 & 8.2L	50 Hrs.	100 Hrs.
		(or 6 Mos. Maximum)	

USED LUBRICATING OIL ANALYSIS

A used lubricating oil analysis program such as the Detroit Diesel Oil Analysis Program is recommended for the monitoring of crankcase oil in all engines. Since an oil analysis indicates the condition of the engine, not the lubricating oil, it should not be used to extend oil drain intervals. The oil should be changed immediately if any contamination is present in concentrations exceeding the warning limits shown in the table. It should not however, be concluded that the engine is worn out based on *a single* measurement that exceeds the warning level. Imminent engine wearout can only be determined through a *continuous* oil analysis program wherein the change in data or deviation from baseline data can be used to interpret condition of engine parts.

Characteristics relating to lubricating oil dilution should trigger corrective action to identify and fix the source(s).

Confirmation of the need for engine overhaul should be based on operational data (increasing oil consumption and crankcase pressure, for example) and physical inspection of parts.

USED LUBRICATING OIL ANALYSIS WARNING LIMITS

These values indicate the need for an immediate oil change, but do not necessarily indicate internal engine problems requiring engine teardown.

WARNING LIMITS

	ASTM Designation	Two Cycle		Four Cycle
		53, 71, 92	149	60, 8.2
Pentane Insolubles Mass % Max.	D 893	1.0	1.0	1.0
Carbon (Soot) Content, TGA Mass % Max.	E 1131	0.8		1.5
Viscosity at 40°c St % Max. Increase % Max. Decrease	D 445 & D 2161	40.0 15.0	40.0 15.0	40.0 15.0
Total Base Number (TBN) Min. Min.	D 664 D 2986	1.0 2.0	1.0 2.0	1.0 2.0
Water Content (dilution) Vol. % Max.	D 95	0.30	0.30	0.30
Flash Point °C Reduction Max.	D 92	40.0	40.0	40.0
Fuel Dilution Vol. % Max.	*	2.5	1.0	2.5
Glycol Dilution PPM Max.	D 2982	1000	1000	1000
Iron Content PPM Fe Max.	**	150	35	60=150 8.2=250
Copper Content PPM Cu Max.	**	25	25	60=90 8.2=30
Sodium Content PPM Na Over Baseline Max.	**	50	50	50
Boron Content PPM B Over Baseline Max.	**	20	20	20

* No ASTM Designation
** Elemental Analysis are conducted using either emission or atomic absorption spectroscopy.
Neither method has an ASTM designation.

FUEL OIL

QUALITY AND SELECTION

The quality of fuel used is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. DDC engines are designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties of ASTM Designation D 975 (grades 1–D and 2–D) have provided satisfactory performance. The ASTM D 975 specification however does not in itself adequately define the fuel characteristics necessary for assurance of fuel quality. The properties listed in the Fuel Oil Selection Chart have provided optimum engine performance.

FUEL OIL SELECTION CHART

General Fuel Classification	ASTM Test	No. 1 ASTM 1–D	No. 2* ASTM 2–D
Gravity, °API #	D 287	40–44	33–37
Flash Point Min. °F (°C)	D 93	100 (38)	125 (52)
Viscosity, Kinematic cST @ 100°F (40°C)	D 445	1.3–2.4	1.9–4.1
Cloud Point °F #	D 2500	See Note 1	See Note 1
Sulfur Content wt%, Max.	D 129	0.5	0.5
Carbon Residue on 10%, wt%, Max.	D 524	0.15	0.35
Accelerated Stability Total Insolubles mg/100 ml, Max. #	D 2274	1.5	1.5
Ash, wt%, Max.	D 482	0.01	0.01
Cetane Number, Min. +	D 613	45	45
Distillation Temperature, °F (°C)	D 86		
IBP, Typical #		350 (177)	375 (191)
10% Typical #		385 (196)	430 (221)
50% Typical #		425 (218)	510 (256)
90% +		500 (260) Max.	625 (329) Max.
End Point #		550 (288) Max.	675 (357) Max.
Water & Sediment %, Max.	D 1796	0.05	0.05

Not specified in ASTM D 975
+ Differs from ASTM D 975
* No. 1 diesel fuel is recommended for use in city coach engine models. No. 2 diesel fuel may be used in city coach engine models which have been certified to pass Federal and California emission standards.

Note 1: The cloud point should be 10°F (6°C) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals.

Note 2: When prolonged idling periods or cold weather conditions below 32°F (0°C) are encountered, the use of 1–D fuel is recommended. Number 1–D fuels should also be considered when operating continuously at altitudes above 5000 ft.

FUEL OIL SELECTION CRITERIA

DISTILLATION

The boiling range is a very important property in consideration of diesel fuel quality. The determination of boiling range is made using ASTM Test Method D 86. Many specifications contain a partial listing of the distillation results, ie., Distillation Temperature At 90% Recovered. Many diesel fuels are blended products which may contain constituents with boiling ranges much different than the majority of the fuel composition. The full boiling range as shown in the Fuel Oil Selection Chart should be used for proper selection.

FINAL BOILING POINT

Fuel can be burned in an engine only after it has been vaporized. The temperature at which fuel is completely vaporized is described as the End point Temperature in ASTM D 86 Distillation Test Method. This temperature must be low enough to permit complete vaporization at combustion chamber temperatures. The combustion chamber temperature depends on ambient temperature, engine speed and load. Poor vaporization is more apt to occur during severe cold weather, prolonged idling, and/or light load operation. Therefore engines operating under these conditions should utilize fuels with lower distillation end point temperatures.

COMPLETELY DISTILLED FLUID

Fuel selected should be completely distilled material. That is, the fuel should exhibit no less than 98% recovery when subjected to the ASTM D 86 Distillation Test Method.

CETANE NUMBER

Cetane Number is mistakenly used to indicate fuel quality. However, Cetane Number is most useful in predicting engine startup. A high Cetane Number should not be considered alone when evaluating fuel quality. Other properties such as end point distillation temperature and carbon residue should also be considered. Calculated Cetane Index is sometimes reported instead of Cetane Number. Cetane Index is an empirical property determined through the use of a mathematical equation whereas Cetane Number is determined through an engine test.

FUEL STABILITY

Diesel Fuel oxidizes in the presence of air and water, particularly if the fuel contains cracked products which are relatively unstable. The oxidation of fuel can result in the formation of undesirable gums and sediment. Such undesirable products can cause filter plugging, combustion chamber deposit formation and gumming or lacquering of injection system components with resultant sticking or wear.

ASTM Test Method D 2274 measures diesel fuel oxidative stability. Although the results of the test may vary with actual field storage, it does measure characteristics which will effect fuel storage stability for periods up to 12 months.

FUEL SULFUR CONTENT

The sulfur content of the fuel should be as low as possible to avoid premature wear and excessive deposit formation. Fuel containing no more than 0.5% sulfur are recommended. If the use of fuels with sulfur contents above 0.5% are unavoidable, lube oil drain intervals and lubricant selection need to be changed. Detroit Diesel recommends that the Total Base Number (TBN D 2896) of the lubricant be monitored and the oil drain interval be reduced.

FUEL OPERATING TEMPERATURE AND VISCOSITY

Since Diesel Fuel provides cooling of the injection system, the temperature of the fuel may vary considerably due to the ambient temperature, engine operating temperature, and the amount of fuel remaining in the tank. As fuel temperature increases, the fuel viscosity and therfore the lubrication capabilities of the fuel diminish. Maintaining proper fuel temperatures in combination with selection of fuels with the viscosity ranges shown in the Fuel Oil Selection Chart will assure proper injection system functioning.

DIESEL FUEL STORAGE

Fuel oil should be clean and free of contamination. Storage tanks and stored fuel should be inspected regularly for dirt, water, and sludge; and cleaned if contaminated. Diesel fuel tanks can be made of aluminum, monel stainless steel, black iron, welded steel or reinforced (non–reactive) plastic.

> **NOTICE:** Galvanized steel or sheet metal tanks and galvanized pipes or fittings should never be used in any diesel fuel storage, delivery or fuel system. The fuel oil will react chemically with the zinc coating, forming a compound which can clog the filters and can cause engine damage.

FUEL ADDITIVES

Detroit Diesel engines operate satisfactorily on a wide range of diesel fuels without the addition of supplemental additives. Such additives increase operating costs without providing benefit.

Fuel additives specifically NOT recommended include:

- Used Lubricating Oil
- Gasoline

Detroit Diesel does NOT recommend the use of drained lubricating oil or gasoline in diesel fuel. Furthermore Detroit Diesel Corporation will not be responsible for any detrimental effects which it determines resulted form this practice.

Some fuel additives provide temporary benefits but do not replace good fuel handling practices. Such additives are helpful when water contamination is suspected:

- Isopropyl Alcohol—1 pint per 125 gallons of fuel for winter freeze up protection.
- Biocide—For treatment of microbe growth or black "slime". Follow manufacturers' instructions for treatment.

Other fuel additives are of questionable benefit. These include a variety of independently marketed products which claim to be:

- Cetane Improvers
- Combustion Improvers
- Cold Weather Flow Improvers

These products should be accompanied with performance data supporting their merit. It is not the policy of Detroit Diesel Corporation to approve or endorse such products.

FILTER RECOMMENDATIONS

Filters make up an integral part of fuel and lubricating oil systems. Proper filter selection and maintenence are important to satisfactory engine operation and service life. Filters should be utilized for maintaining a clean system, not for cleaning up a contaminated system.

FUEL FILTER RECOMMENDATION
Regular Service

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Primary	30	—	AC Spark Plug Div. GM	T552 T553 T541 T632 T915 T936 T958
Secondary	12	—	AC Spark Plug Div. GM	TP509 TP540X TP624 TP916 TP928 TP959

FUEL FILTER RECOMMENDATION
Severe Duty Service

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Primary	—	—	Racor	B32002
Secondary	3	200	Pall Corp.	Head HH7400A12UPRBP Element HC7400SUP-4H
Secondary (Alternate)	5	—	AC Spark Plug	TP916L TP928L TP959L

LUBRICATING OIL FILTER RECOMMENDATION
Series 53

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Full Flow	12	75	AC Spark Plug Div. GM	PF911L P/N 25013192

COOLANT SPECIFICATIONS

COOLANT REQUIREMENTS

The coolant provides a medium for heat transfer and controls the internal temperature of the engine during operation. In an engine having proper coolant flow, the heat of combustion is conveyed through the cylinder walls and the cylinder head into the coolant. Without adequate coolant, normal heat transfer cannot take place within the engine, and engine temperature rapidly rises. In general, water containing various materials in solution is used for this purpose.

The water/ethylene glycol/inhibitor coolant mixture used in Detroit Diesel engines must meet the following basic requirements:

- Provide for adequate heat transfer.
- Provide a corrosion–resistant environment within the cooling system.
- Prevent formation of scale or sludge deposits in the cooling system.
- Be compatible with cooling system hose and seal materials.
- Provide adequate freeze and boil–over protection.

WATER

Water, whether of drinking quality or not, can produce a corrosive environment in the cooling system, and the mineral content may permit scale deposits to form on internal cooling system surfaces. Therefore, inhibitors *must* be added to control corrosion and scale deposits.

Chlorides, sulfates, magnesium, and calcium are among the materials which make up dissolved solids and may cause scale deposits, sludge deposits, corrosion, or a combination of these. Chlorides and/or sulfates tend to accelerate corrosion, while hardness (percentage of magnesium and calcium salts broadly classified as carbonates) causes deposits of scale. Water within the limits specified in Table A–1 is satisfactory as an engine coolant when properly inhibited. The procedure for evaluating water intended for use in a coolant solution is shown in Table A–2. Use of distilled water is ideal.

	PARTS PER MILLION	GRAINS PER GALLON
Chlorides (Maximum)	40	2.5
Sulfates (Maximum)	100	5.8
Total Dissolved Solids (Maximum)	340	20
Total Hardness (Maximum)	170	10

TABLE A–1

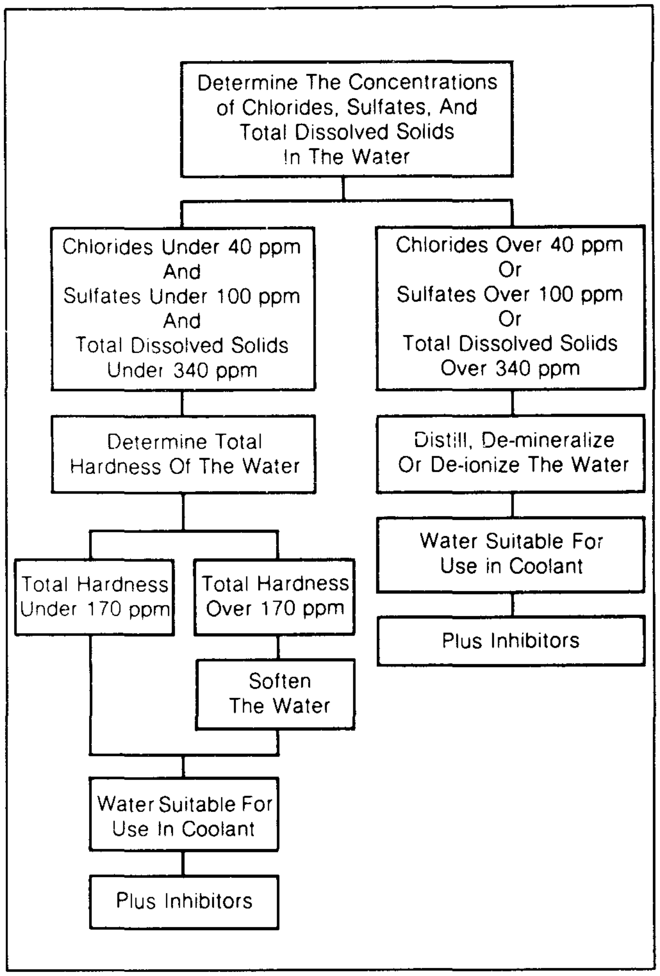


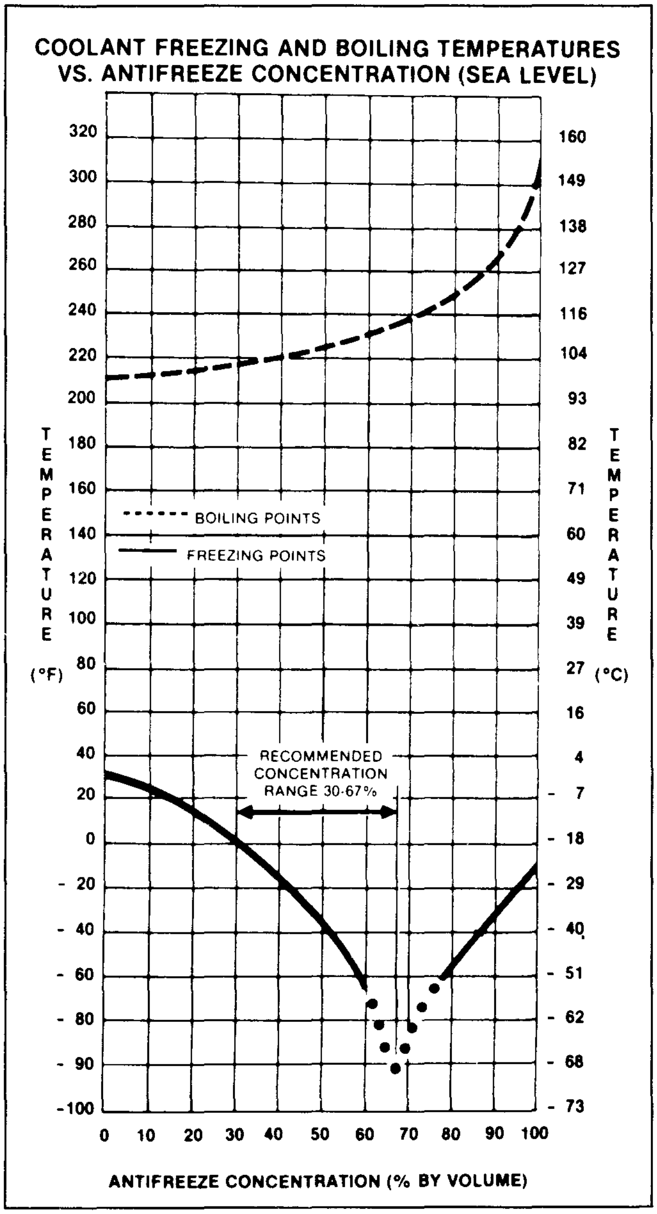
TABLE A–2

ANTIFREEZE

Use an ethylene glycol antifreeze that meets the GM 6038–M formulation, which limits silicate to 0.15% maximum, or an equivalent formulation meeting the 0.15% maximum silicate and GM 1899–M perfomance requirements. Ethylene glycol–base antifreeze meeting ASTM D 3306 requirements is also acceptable for use in Detroit Diesel engines.

A 50% antifreeze solution is normally used as a factory fill. Concentrations over 67% are not recommended because of poor heat transfer capability, adverse freeze protection and possible silicate drop–out. Concentrations below 30% offer little freeze, boil–over or corrosion protection.

Although most antifreezes contain inhibitor packages, all DDC and Perkins engines (except Perkins 500 Series) require supplemental inhibitors be added to the cooling system after an intial fill and maintained at proper protection level.



Antifreeze solution should be used year–round to provide freeze and boil–over protection as well as a stable environment for seals and hoses.

Only non–chromate inhibitors should be used with antifreeze solutions.

Coolant concentrate must be checked periodically at each oil change (600 hours or 20,000 miles maximum). Adjust concentration, if not at the proper protection level.

Pre–mix antifreeze/water makeup solution at the proper concentration before adding to the cooling system. This should prevent over– or under–coolant concentration problems.

Methyl alcohol–based antifreeze is not recommended for use in DDC engines because of its effect on the non–metallic components of the cooling system and its low boiling point. Methoxy propanol–based antifreeze is also not recommended for DDC engines because it is not compatible with fluoroelastomer seals found in the cooling system.

A cooling system properly maintained and protected with supplemental inhibitors can be operated up to two years, 200,000 miles, or 6000 hours, whichever comes first. At this interval the antifreeze must be drained, discarded in an appropriate manner, and the cooling system thoroughly cleaned. Inspect all components that make up the cooling system and make necessary repairs at this time. Refill the cooling system with a recommended ethylene glycol–base antifreeze and water solution in the required concentration (see graph). Add required inhibitors. After filling, run engine until thermostat(s) open and top off to recommended *full* level. Reinstall fill/pressure cap.

INHIBITOR

The importance of a properly inhibited coolant cannot be overemphasized. A coolant which has insufficient inhibitors, the wrong inhibitors, or no inhibitors at all invites the formation of rust, scale, sludge and mineral deposits within the cooling system. These deposits can cause water pump seal wear and coat the walls of the cylinder block, liners, and coolant passages. Heat transfer rate is reduced as the deposits build up. An engine affected in this manner can cause an overheating condition, resulting in liner scuffing, scoring, piston seizure and cylinder head cracking. This may occur quickly or over a long period of time, depending on the location and amount of deposits.

An improperly inhibited coolant can become corrosive enough to "eat away" coolant passages and seal ring grooves and cause coolant leaks to develop. If the coolant leak is internal and accumulates on top of a piston, a hydrostatic look can occur. This can result in a bent connecting rod.

Insufficiently inhibited coolant can also contribute to *cavitation erosion*. Cavitation erosion is caused by the collapse of bubbles (vapor pockets) against the surfaces of various engine coolant passages. The collapsing bubble forms a pin point of very high pressure. Over a period of time these collapsing bubbles can wear (erode) away internal engine surfaces. Components such as fresh water pump impellers, cylinder liners, and blocks are especially susceptible to cavitation erosion. In extreme cases their surfaces can become so deeply pitted that they appear to be spongy, and holes can develop completely through them.

INHIBITOR SYSTEMS

An inhibitor system is a combination of chemical componds which provide corrosion protection, pH control, water–softening ability and cavitation suppresion. These systems are available in various forms, such as coolant filter elements, liquid and dry inhibitor additive packages, and as integral parts of antifreeze.

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A corrosion inhibitor is a water–soluble chemical compound which protects the metallic surfaces of the cooling system against corrosive attack. Some of the more commonly used corrosive inhibitors are borates, nitrites, nitrates, chromates and soluble oil.

Chromates and soluble oils are not recommended as corrosion inhibitors for DDC engines.

- pH control chemicals are used to maintain an acid–free solution.
- Water–softening chemicals deter formation of mineral deposits.
- Cavitation suppression chemicals minimize the fomation of vapor pockets, preventing erosion of cooling system surfaces.

It is imperative that a supplemental inhibitor be added to the coolant on all DDC and Perkins engines after an initial fill and maintained at proper protection level.

NON–CHROMATES

Non–chromate inhibitor (borates, nitites, nitrates, etc.) systems are recommended for use with DDC engines. These systems can be used with either water or water–and–antifreeze solutions and provide corrosion protection, pH control, and water softening. Most non–chromate inhibitor systems offer the additional advantage of a simple on–site test to determine protection level. Since they are added directly to the coolant, no additional hardware or plumbing is required.

All inhibitors become depleted through normal operation, and additional inhibitor must be added to the coolant as required to maintain original strength levels.

NOTICE: Overinhibiting antifreeze solutions can cause silicate dropout. Always follow the manufacturer's recommendations on usage and handling.

SOLUBLE OIL

Soluble oils are not recommended for use in DDC engine cooling systems. A small amount of oil concentration has an adverse affect on heat transfer capabilities. For example, a 1.25% concentration of soluble oil in the cooling sytem increases fire deck temperature 6%, while a 2.50% concentration raises fire deck temperature 15%.

CHROMATES

Chromate inhibitors are not recommended for use in DDC engine cooling systems. Chromium hydroxide, commonly called "green slime", can result from the use of chromate inhibitors with antifreeze. This material deposits on the cooling system passages, reducing the heat transfer rate and causing engine overheating. Cooling systems (engine included) operated with chromate–inhibited coolant must be chemically cleaned and flushed with plain water prior to refilling with a recommended coolant mixture. A commercial heavy–duty descaler should be used in accordance with the manufacture's recommendation for this purpose.

COOLANT FILTER ELEMENT

Replaceable elements are available with various chemical inhibitor systems. There are two types of filters containing supplemental coolant additives (SCA's). One is a pre–charge which must be used at the time of initial cooling system fill. The second is a maintenance filter which is used at each service interval. Compatibility of the element with other ingredients of the coolant solution cannot always be taken for granted.

Problems have developed with coolant filters using magnesium lower support plates. The coolant solution attacks the plate, allowing dissolved magnesium to be deposited in the hottest zones of the engine where heat transfer is most critical. The use of an aluminum or zinc support plate is recommended to prevent these deposits.

High chloride coolants have a detrimental effect on the water–softening capabilities of systems using ion–exchange resins. Accumulations of calcium and magnesium ions removed from the coolant and held captive by the zeolite resin can be released into the coolant by the regenerative process caused by high chloride–content solutions.

Change coolant filters at regular intervals per manufacturer's recommendation.

INHIBITOR TESTING PROCEDURES

Test kits and test strips are commercially available to check engine coolant for inhibitor strength. Coolants should be tested at each oil change (600 hours or 20,000 miles maximum) to ensure that the inhibitor levels are maintained within the following ranges for two commonly available inhibitor systems:

SUPPLEMENTAL COOLANT ADDITIVE VALUES WITH GM 6038–M/ASTM D–3306 ANTIFREEZE

	Nitrate/ Borate System		Phosphate/ Molybdate System	
	Min. PPM	Max. PPM	Min. PPM	Max. PPM
Boron (B)	1000	1500	600	900
Nitite (NO_2)	800	2400	300	600
Nitrates (NO_3)	1000	2000	800	1800
Silica (S_i)	100	500	100	500
Phosphorous (P)	300	500	800	1200
Molybdenum (Mo)	—	—	200	400
pH	8.5	10.5	8.5	10.5

Do not use one manufacturer's test to measure the inhibitor strength of another manufacturer's product. Always follow the manufacturer's recommended test procedures.

SILICATE DROPOUT

Excessive amounts of chemicals in the engine coolant can cause *silicate dropout,* which creates a gel–type deposit that reduces heat transfer and coolant flow.

The gel takes the color of the coolant in the wet state, but appears as a white powdery deposit when dry. Although silica gel is non–abrasive, it can pick up solid particles in the coolant and become gritty, causing excessive wear of water pump seals and other cooling system components. The wet gel can be removed by non–acid (alkali) type heavy–duty cleaners, while the dried silicate requires engine disassembly and caustic solution or mechanical cleaning of individual components.

The total amount of chemicals in the coolant can be controlled to desirable levels by using GM 6038–M formulation antifreeze at the needed freeze protection concentration, adding inhibitors according to manufacturer's recommendations and water that meets DDC requirements.

NOTICE: Failure to use and maintain antifreeze/water and inhibitor coolant mixture at sufficient concentration levels can result in damage to the cooling system and its related components. Conversely, overconcentration of antifreeze and/or inhibitor can result in poor heat transfer, leading to engine overheat, silicate dropout, or both. Always maintain concentrations at recommended levels.

GENERAL COOLING SYSTEM RECOMMENDATIONS

Always maintain cooling system at the proper coolant level – Check daily. A low coolant level may cause aeration of the coolant. Air bubbles in the coolant can "insulate" the cylinder walls, preventing adequate heat transfer. Abnormally low coolant level can cause the water pump to become "air–bound", resulting in no coolant flow. Aerated coolant or an "air–bound" water pump can be catastrophic to engine life.

Overfilling a cooling system can result in unnecessary loss of cooolant and, in some rare cases, engine overcooling, especially during cold weather operation.

The cooling system must be pressurized to prevent localized boiling of the coolant. The system must be kept clean and leak–free. The fill cap or pressure relief valve must always be installed and checked periodically for proper operation.

Summary of Coolant Recommendations

1. Always use recommended antifreeze, inhibitor and water at proper concentration levels.
2. Use only ethylene glycol antifreeze meeting the GM 6038–M or ASTM D 3306 formulation or an equivalent antifreeze with a 0.15% maximum silicate content meeting GM 1899–M performance specifications.
3. Use an antifreeze solution year–round for freeze and boil–over protection. Seasonal changing of coolant from an antifreeze solution to an inhibitor/water solution is not recommended.
4. Pre–mix antifreeze makeup solutions at the proper concentration before adding to the cooling system.
5. Maintain the prescribed inhibitor strength levels as required. Test at each oil change interval and add inhibitor as needed. Do not use one manufacturer's test kits to measure the inhibitor strength of another manufacturer's product.
6. Follow the manufacturer's recommendations on inhibitor usage and handling. Do not mix different base inhibitor packages.
7. Use only non–chromate inhibitors.
8. Supplemental cavitation suppression inhibitors *must* be added to Series 53, 60, 92 and 149 engines after initial fill and *must* be maintained.
9. Change coolant filters at regular intervals per manufacturer's recommendation.
10. DO NOT USE THE FOLLOWING:
    - Soluble oil
    - Chromate inhibitor
    - Methoxy propanol–base antifreeze
    - Methyl alcohol–base antifreeze
    - Sealer additives or antifreezes containing sealer additives
11. Use only water meeting specifications found in Tables A–1 & A–2 (page 9). Use of distilled water is ideal.
12. Always maintain proper coolant level.
13. A cooling system properly maintained and protected with antifreeze and supplemental inhibitors can be operated up to two years, 200,000 miles, or 6000 hours, whichever comes first. At this interval the coolant must be drained, discarded in a safe manner, and the

cooling system cleaned thoroughly. Refill cooling system with a recommended water/antifreeze /inhibitor mixture at appropriate concentration level.

CAUTION: Never remove fill cap while coolant is hot. Remove cap *slowly* and only when coolant is at ambient conditions. A sudden release of pressure from a heated cooling system can result in possible personal injury from the expulsion of hot coolant.