SECTION 8

POWER TAKE-OFF

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POWER TAKE-OFF - HYDRAULIC (REAR MOUNTED)

The hydraulic power take-off (PTA-0101-H) is a self-contained unit with an integral lubricating oil pump, independent oil supply and 10.5” eight-plate half pack hydraulic clutch (Fig. 1). The oil pump is gear driven from the input hub and supplies oil under pressure through a control valve to the clutch. The input hub in coupled to the engine through flexible discs bolted directly to the flywheel.

Oil flow is from the sump through the full flow filter screen to the oil pump, then to the valve assembly. The valve assembly is preset and regulates pressure and channels oil to the supply pressure line, the lubricating oil line, or back to the sump as the position of the regulator valve dictates. Shaft bearings are oiled internally, therefore this unit requires no external lubrication other than periodic oil changes based on hours of operation.

NOTICE: This unit is not recommended for use in side load applications.

Operation

Run the engine a short time, allowing the oil pressure to stabilize, before engaging the clutch. Without sufficient oil flow, low oil pressure could cause extended clutch slippage to the disc pack. Extended clutch slippage should be avoided as it may generate extreme heat build-up which can cause plate warpage.

After the oil pressure is stabilized, clutch engagement is accomplished by moving the lever at the back of the valve body, which is mounted directly on top of the power take-off.

Full clutch actuation is possible in .6 of a second, but this may be extended by pulling the lever slowly to the over-center position.

The clutch may be engaged at any engine speed provided the driven load does not exceed the maximum torque rating of the power take-off. When the engine is stopped, the clutch will automatically release and the operating valve will return to the release position due to low oil pressure. *

The operating lever of the valve has three positions:

1. The clutch is engaged by pulling the lever back away from the valve body. The lever is held in this position by the supply oil pressure.

2. The release position is obtained when the operating handle is parallel with the back of the valve body. The supply pressure is shut off and only lubricating oil is permitted to flow, which cools the clutch and oils bearings that are still operating.

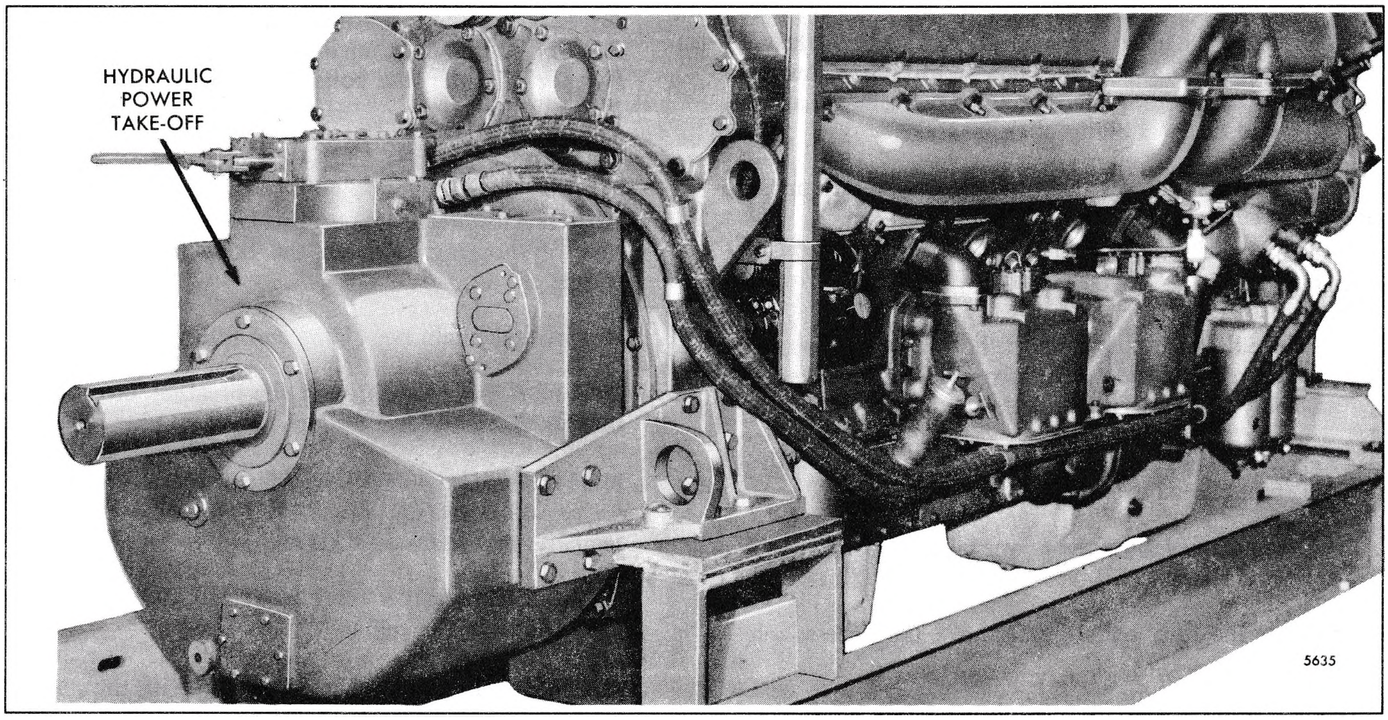

Fig. 1 - Hydraulic Power Take-Off Mounting

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3. The third position is with the operating lever pushed forward toward the back of the valve body. This is used primarily to dump the lubricating oil pressure, reduce drag between clutch plates and to facilitate shifting when the power take-off is coupled to a gear box. As the operating lever is spring-loaded, it must be held in this position. When released, the lever automatically returns to the release position.

Oil System

Main or supply oil pressure is from 150 to 200 psi (1034—1378 kPa) and can be checked by removing the 1/8" pipe plug in the ditch plate under the valve assembly. Oil pressure is from 8 to 30 psi (55-207 kPa) and can be checked by removing the 3/8" pipe plug in the ditch plate.

Engine speed and oil temperature will cause variations in both lubricating oil and main pressures; but if the pressures are maintained within the given range, performance of the unit will not be affected.

The oil should be changed after each 1000 hours of operation. The oil capacity is 47 quarts (44.5 litres) (does not include heat exchanger). Along with each oil change, thoroughly clean the filter screen in the sump and the breather filter 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.

To remove the filter screen cover plate, remove the six bolts at the bottom of the power take-off directly below the output shaft. Discard the plate gasket and replace with a new gasket to avoid the possiblility of an oil leak.

Inspect a new power take-off the first few hours of operation to ensure that the unit is not leaking oil.

Remove Power Take-Off

1. Remove the pipe plug from the bottom of the housing and drain the lubricating oil from the power take-off assembly. Reinstall and tighten the pipe plug.
2. Remove the breather filter and install an eyebolt with a 3/4" pipe thread to lift the power take-off.
3. Support the weight of the power take-off with a chain hoist and sling.
4. Loosen the four bolts and remove the access hole cover.
5. Disconnect the six bolts holding the clutch drive discs to the flywheel.
6. Remove the four bolts holding each support bracket to the power take-off.
7. Remove the sixteen bolts and lock washers securing the power take-off to the engine flywheel housing.
8. Install two of the above bolts into the tapped holes provided in the bolting flange of the clutch housing and move the power take-off straight back away from the flywheel housing.

Disassemble And Assemble Power Take-Off

For service and overhaul procedures for the hydraulic power take-off (PTA-0101-H), refer to Borg Warner Corp., Rockford Clutch Division, Rockford, Illinois.

Install Power Take-Off

1. Support the power take-off assembly with a chain hoist and sling. Then position the power take-off square against the engine flywheel housing.
2. Enter the pilot of the clutch housing straight into the flywheel housing. Secure the power take-off in place with the sixteen 1/2"-13 x 1 1/2" bolts and lock washers (includes two bolts installed in tapped holes in the clutch housing for positioning power take-off). Tighten the bolts to 71-75 lb-ft (96—102 N*m) torque.
3. With the access cover removed, rotate the clutch driven discs and assemble (if removed) the six 5/8"-ll x 1 1/2" clutch drive attaching bolts into the flywheel. Tighten the bolts to 81-97 lb-ft (110-132 N*m) torque.
4. Secure the access hole cover with four bolts.
5. Align and install the support bracket bolts in the power take-off housing. Tighten the bolts to the proper torque.
6. Remove the chain hoist sling and lifting eye.
7. Add lubricating oil through the breather filter hole tube until the oil level reaches the check plug hcde.

   NOTICE: Use SAE 30W oil for temperatures above 32°F (0°C) or SAE 10W oil for temperatures below 32°F (0°C).

8. Reinstall the breather filter and check the hole plug before starting the engine.

   NOTICE: Before applying load and with the clutch released, rotate the shaft by hand to check for free turning.

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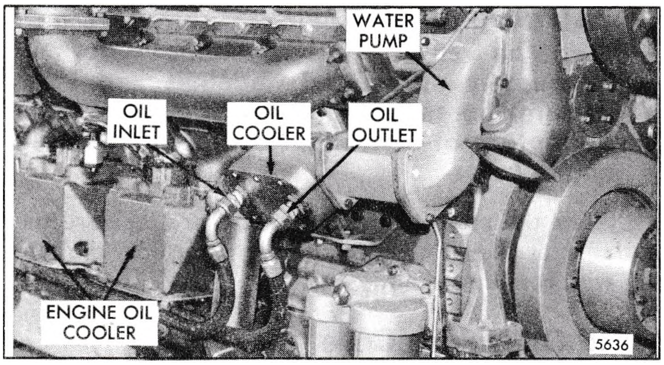

Fig. 2 - Power Take-Off Oil Cooler Mounting

Power Take-Off Oil Cooler

To provide cooling for the oil used in the hydraulic power take-off, a separate oil cooler (Fig. 2), similar to the engine lubricating oil cooler, is mounted on the side of the engine adjacent to the engine water pump. Thus sufficient cooling is provided to ensure that normal operating temperatures are maintained in the system under all conditions of speed and load.

The oil cooler core is contained in a single housing which is attached to the front of the cylinder block and is located between the fresh water pump discharge line and the engine oil cooler.

Oil is drawn from the oil sump through the oil strainer by the oil pump. The oil is then forced through the oil filter to the oil cooler.

The oil cooler core should be removed and cleaned periodically, or at the time of each engine or power take-off overhaul, to prevent overheating of the power take-off oil.

Remove Oil Cooler Core

The oil cooler core (Fig. 3) may be removed from the housing for cleaning and inspection as follows:

1. Drain the engine cooling system.
2. Matchmark the end of the cooler core and cooler housing with a punch or file so they can be installed in their same relative positions.
3. Disconnect the two power take-off oil tubes from the elbows in the oil cooler core.

   NOTICE: Tag the inlet and outlet oil tubes for future reference.

4. Remove the bolts and lock washers securing the core to the oil cooler housing.

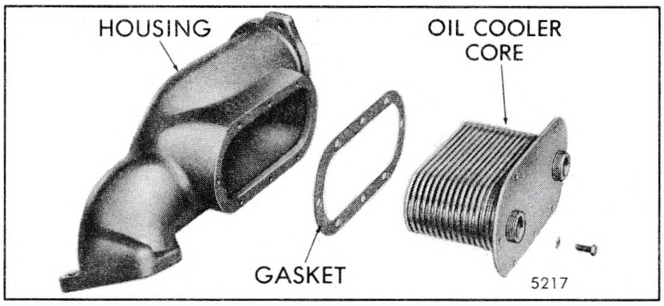

Fig. 3 - Power Take-Off Oil Cooler

5. Tap the edge of the core with a plastic hammer to loosen it.
6. Remove the oil cooler core from the oil cooler housing.
7. Remove the gasket from the oil cooler core or housing.

Clean Oil Cooler Core

1. *Clean the oil side of the core:* Circulate a solution of 1, 1, 1 trichloroethane through the core passages with a force pump to remove the carbon and sludge. Clean the core before the sludge hardens. If the oil passages are badly clogged, circulate an oakite or alkaline solution through the core and flush thoroughly with clean hot water.

   CAUTION: To avoid persona! injury, wear adequate protective clothing (face shield, rubber gloves, apron). This operation should be done in the open or in a well ventilated room when trichloroethane or other chemicals are used for cleaning.

2. *Clean the water side of the core:* After cleaning the oil side of the core, immerse it in the following solution: Add one-half pound of oxalic acid to each two and one-half gallons of solution composed of one-third muratic acid and two-thirds water. The cleaning action is evidenced by bubbling and foaming. Watch the process carefully and, when bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution and thoroughly flush it with clean hot water. After cleaning, dip the core in light engine oil.

   NOTICE: Cleaning an oil cooler core is not recommended where the history of usage shows power take-off failure which has released metal particles from worn or broken parts into the lubricating oil. In this instance, replacement of the oil cooler core is strongly recommended.

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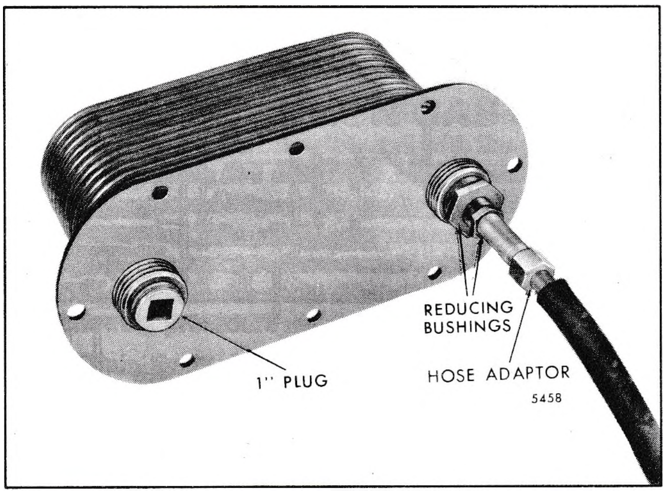

Fig. 4 - Oil Cooler Core Prepared for Pressure Test

Pressure Check

After the oil cooler has been cleaned, it may be checked for leaks as follows:

1. Install a 1" pipe plug in one of the core openings. In the other opening, install the necessary reducing bushings and a suitable air hose adaptor as shown in Fig. 4.

2. Attach an air hose and apply approximately 75-150 psi (517-1034 kPa) air pressure and submerge the core and plate assembly in a tank of water heated to 180°F (82°C). Any leaks will be indicated by air bubbles in the water. If leaks are indicated, replace the core.

CAUTION: When making this pressure test, be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose or the oil cooler core.

3. After the pressure check is completed, remove the adaptor and air hose from the core, then dry the core with compressed air.

Install Oil Cooler Core

1. Affix a new gasket to the oil cooler housing.

2. Align the matchmarks previously placed on the core and housing and install the oil cooler core in the oil cooler housing.

3. Install the bolts and lock washers. Tighten the bolts to 13-17 lb-ft (18-23 N*m) torque.

4. Connect the two oil tubes to the elbows in the oil cooler.

NOTICE: Be sure the inlet and outlet tubes are reinstalled in their original positions, otherwise the oil flow will be reversed and could result in loosening foreign particles that may not have been removed and circulating them through the power take-off.

5. Fill the engine cooling system.

6. Start the engine and check for oil and water leaks

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SECTION 9

TRANSMISSIONS

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‘For service and overhaul procedures for the Twin Disc Marine Gear assembly, refer to the manufacturer:

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

t Current engines not equipped with marine gear oil cooler.

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MARINE GEAR OIL COOLER

To provide cooling for the oil used in the marine gear, a separate oil cooler, similar to the engine lubricating oil cooler, is mounted on the side of the engine adjacent to the engine water pump. Thus, sufficient cooling is provided to insure that normal operating temperatures are maintained in the marine gear oil system under all conditions of speed and load in both forward and reverse.

The oil cooler core is contained in a single housing which is attached to the front of the cylinder block and is located between the fresh water pump discharge line and the engine oil cooler (Fig. 1).

Oil is drawn from the marine gear oil sump through the oil strainer by the marine gear oil pump. The oil is then forced through the oil filter to the oil cooler and through the oil cooler to the selector control valve.

The oil cooler core should be removed and cleaned periodically, or at the time of each engine or marine gear overhaul, to prevent overheating of the marine gear oil.

Effective with approximate engine serial numbers 12E-5615 and 16E-5195, engines equipped with or for a Twin Disc marine gear will no longer be supplied with an engine mounted marine gear oil cooler.

NOTICE: Twin Disc now recommends oil temperatures lower than 185° F (85°C) for many applications. Since Detroit Diesel oil coolers use 180°F (82°C) engine coolant, it is not possible for our marine gear oil cooler to achieve the conditions recommended by Twin Disc using a practical oil cooler size.

Remove Oil Cooler Core

The oil cooler core may be removed from the housing for cleaning and inspection as follows:

1. Drain the engine cooling system.

2. Matchmark the end of the cooler core and cooler housing with a punch or file so they can be installed in their same relative positions.

3. Disconnect the two marine gear oil tubes from the elbows in the oil cooler core.

   NOTICE: Tag the inlet and outlet oil tubes for future reference.

4. Remove the bolts and lock washers securing the core to the oil cooler housing.

5. Tap the edge of the core with a plastic hammer to loosen it.

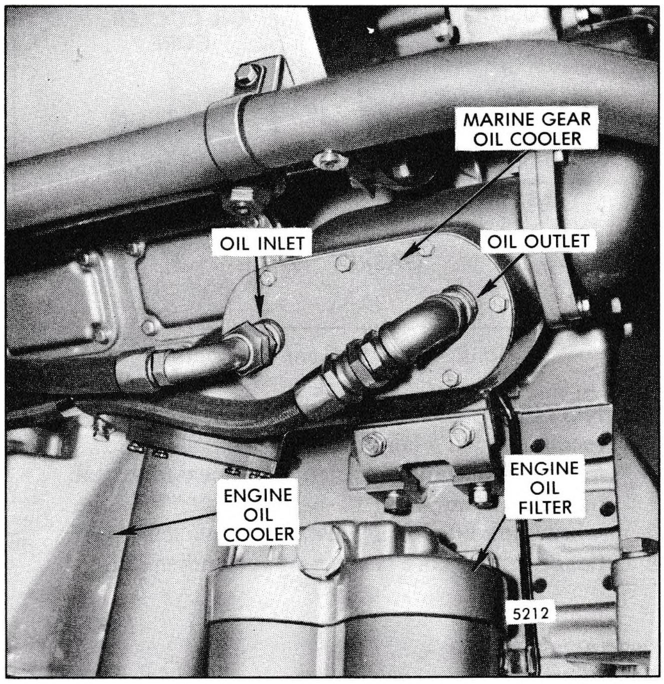

Fig. 1 - Marine Gear Oil Cooler Mounting

6. Remove the oil cooler core from the oil cooler housing.

7. Remove the gasket from the oil cooler core or housing.

Clean Oil Cooler Core

1. Clean the oil side of the core: Circulate a solution of 1,1,1-trichloroethane through the core passages with a force pump to remove the carbon and sludge. Clean the core before the sludge hardens. If the oil passages are badly clogged, circulate an oakite or alkaline solution through the core and flush thoroughly with clean hot water.

   CAUTION: To avoid personal injury, wear adequate protective clothing (face shield, gloves, apron, rubber boots) and work in the open or in a well ventilated area.

2. Clean the water side of the cover: After cleaning the oil side of the core, immerse it in the following solution: Add one-half pound of oxalic acid to each two and one-half gallons of solution composed of one-third muriatic acid and two-thirds water. The cleaning action is evidenced by bubbling and foaming. Watch the process carefully and when bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution and thoroughly flush it with clean hot water. After cleaning, dip the core in light engine oil.

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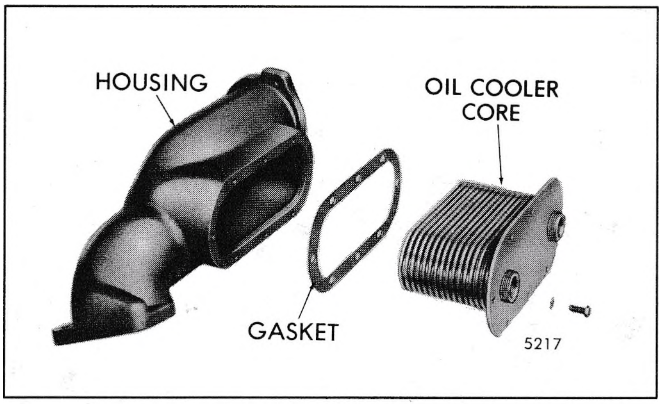

Fig. 2 – Marine Gear Oil Cooler

NOTICE: Cleaning an oil cooler core is not recommended where the history of usage shows marine gear failure which has released metal particles from worn or broken parts into the lubricating oil. In this instance, .replacement of the oil cooler core is strongly recommended.

Pressure Check

After the oil cooler core has been cleaned, it may be checked for leaks as follows:

1. Install a 1" pipe plug in one of the core openings. In the other opening, install the necessary reducing bushings and a suitable air hose adaptor as shown in Fig. 3.

CAUTION: When making a pressure test, be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose or the oil cooler core.

2. Attach an air hose and apply approximately 75-150 psi (517-1 034 kPa) air pressure and submerge the core and plate assembly in a tank of water heated to 180°F (82°C). Any leaks will be indicated by air bubbles in the water. If leaks are indicated, replace the core.

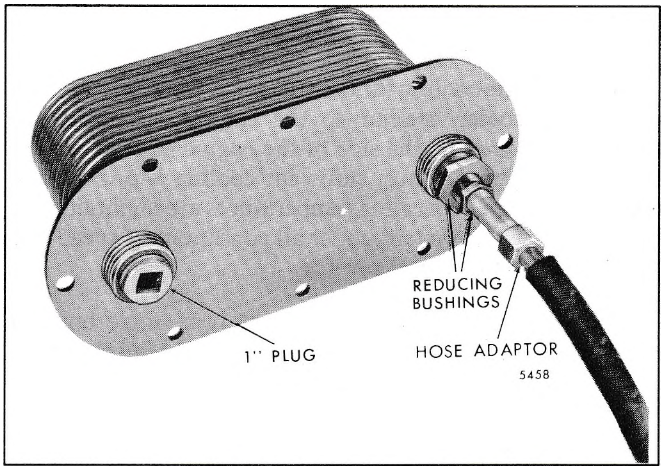

Fig. 3 - Oil Cooler Element Prepared for Pressure Test

3. After the pressure check is completed, remove the adaptor and air hose from the core, then dry the core with compressed air.

Install Oil Cooler Core

With the oil cooler core cleaned and inspected, it may be installed as follows:

1. Affix a new gasket to the oil cooler housing.
2. Align the matchmarks previously placed on the core and housing and install the oil cooler core in the oil cooler housing.
3. Install the bolts and lock washers. Tighten the bolts to 13-17 lb-ft (18-23 N*m) torque.
4. Connect the two oil tubes to the elbows in the oil cooler.

NOTICE: Be sure the inlet and outlet tubes are reinstalled in their original positions, otherwise the oil flow will be reversed and could result in loosening foreign particles that may not have been removed and circulating them through the marine gear. ..

5. Fill the engine cooling system.
6. Start the engine and check for oil and water leajcs.

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SECTION 12

SPECIAL EQUIPMENT

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AIR COMPRESSOR

• The air compressor (Fig. 1) may be mounted on a bracket attached to the cylinder block of the engine and belt-driven from the crankshaft pulley, or it may be flange-mounted to the flywheel housing and gear-driven by means of an accessory drive attached to a camshaft. Series 149 engines currently use 12 CFM (inline configuration) or 24 CFM (vee configuration) air compressors.

The air compressor runs continuously while the engine is running. While the compressor is running, actual compression of air is controlled by the compressor governor which acts in conjunction with the unloading mechanism in the compressor cylinder block. The governor starts and stops the compression of air by loading or unloading the compressor when the air pressure in the system reaches the desired minimum or maximum pressure.

During the downstroke 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.

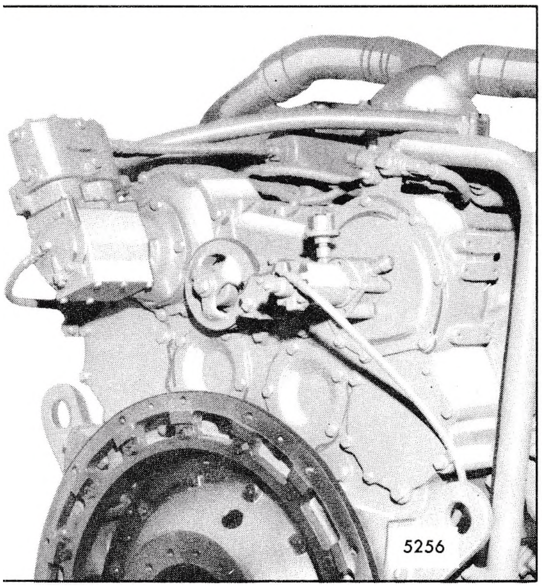


Fig. 1 - Air Compressor Mounting

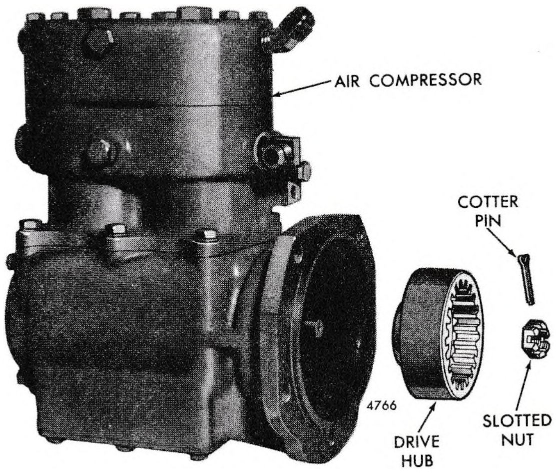
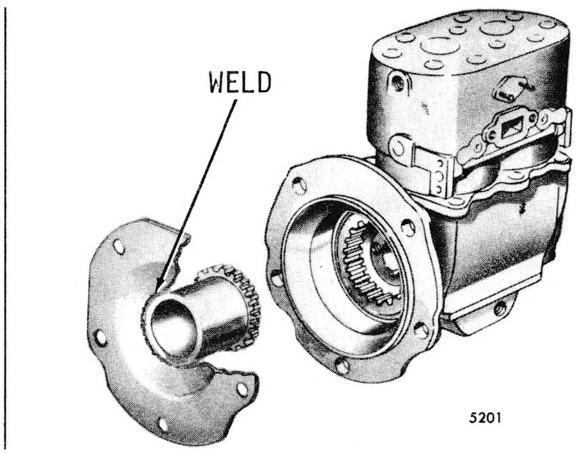


Fig. 2 - Typical Air Compressor With Drive Hub



Fig, 3 - Fixture For Holding Drive While Installing or Removing Slotted Nut

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Service Note

When installing a pulley or a drive hub on a flange mounted air compressor (Fig. 2), 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.

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. 3).

• Air Compressor Service

For air compressor disassembly, assembly, or overhaul procedures, consult with an authorized service center for the manufacturer’s product.

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COLD WEATHER STARTING

When starting an internal combustion engine in cold weather, a large part of the energy of combustion is absorbed by the pistons, cylinder walls, coolant and in overcoming friction.

Under extremely low outside temperatures, the cold oil in the bearings and between the pistons and cylinder walls creates very high friction and the effort required to crank the engine is much greater than when the engine is warm.

In a diesel engine, the normal means of igniting the fuel sprayed into the combustion chamber is by the heat of the air compressed in the cylinder. This temperature is high enough under ordinary operating conditions, but at extremely low outside temperatures may not be sufficiently high enough to ignite the fuel injected.

To assist in starting an engine under low temperature conditions, cold weather starting devices are available.

NOTICE: Starting aids are not intended to correct deficiencies such as low battery, heavy oil, etc. They are for use when other conditions are normal but the air temperature is too low for the heat of compression to ignite the fuel-air mixture.

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

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:. Do not crank the engine more than 30 seconds at a time when using an electric starting motor. Always allow one minute intervals between cranking attempts to allow the starting motor to cool.

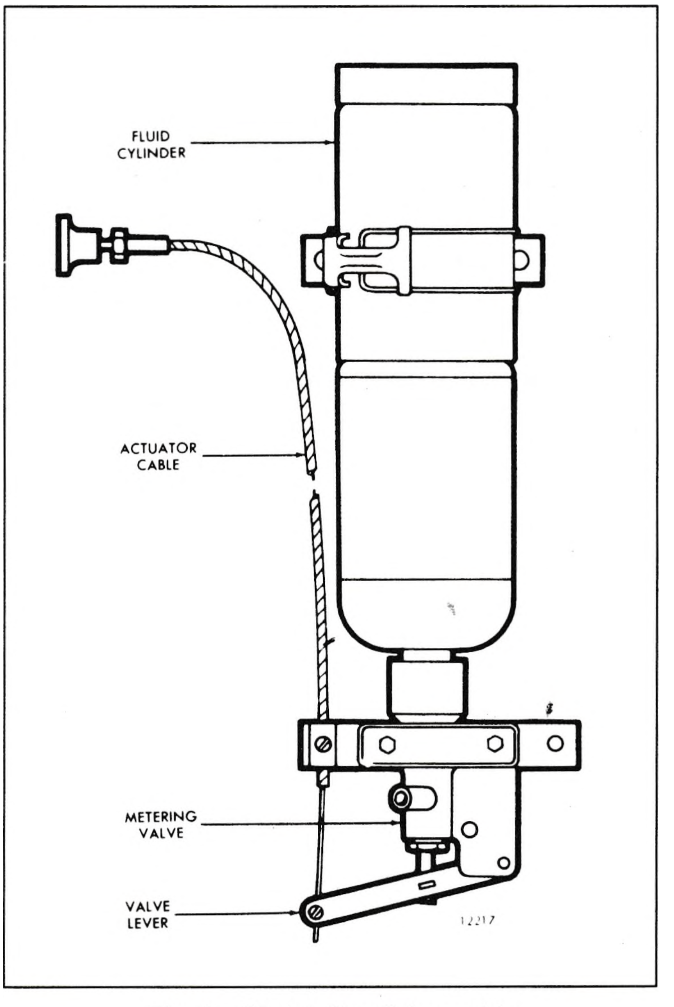

Fig. 1 – “Quick Start” Assembly

Service

Periodically perform the following service items to assure good performance:

1. Remove the fluid cylinder and lubricate the valve around the pusher pin under the gasket with a few drops of oil.
2. Lubricate the actuator cable.
3. Actuate the valve with the cable to distribute the oil on the cable and allow the oil to run down through the valve.
4. Remove any dirt from the orifice by removing the air inlet housing fitting, the orifice block and the screen. Then blow air through the orifice end only.

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5. Assemble and tighten the air inlet housing fitting to the actuator valve and tube.

6. Check for leakage of fluid (fogging) on the outside of the engine air inlet housing by actuating the starting aid while the engine is stopped. If fogging occurs, disassemble and retighten the air inlet housing fitting to the housing.

NOTICE: 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 and serious engine damage.*

7. Check the fluid cylinder for hand tightness.

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SERVICE TOOLS

TOOL NAME	TOOL NO.
Air Compressor Hub Remover	J 36309
Air Compressor Hub Installer	J 36311

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ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

Before starting an engine for the first time, carefully read and follow the instructions in Sections 13 and 14 of this manual. Attempting to run the engine before studying these instructions may result in serious damage to the engine.

NOTICE: When preparing to start a new or overhauled engine or an engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart,* Section 15.1.

Cooling System

Install all of the drain cocks in the cooling system (drain cocks are removed for shipping).

• Open the cooling system vents, *if* the engine is so equipped. The majority of Series 149 engines use a rapid warm-up cooling system which is self-venting.

• Remove the radiator or heat exchanger pressure control cap and fill the cooling system with clean, soft properly inhibited water or an ethylene glycol base antifreeze, if the engine will be exposed to freezing temperatures (refer to Section 13.3). Fill to the filler neck.

Close the vents, *if used,* after filling the cooling system.

On marine installations, prime the raw water cooling system and open any sea cocks in the raw water pump intake line. Prime the raw water pump by removing the pipe plug or electrode provided in the pump outlet elbow and pour water in the pump.

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.

To ensure an immediate flow of oil to all bearing surfaces at initial engine start-up, DDC recommends that the engine lubrication system be 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 prelubricator hose.

• 2. Remove the valve rocker cover and gasket 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. Refer to section 13.3 for *Lubricating Oil Recommendations.*

• 3. If the engine is turbocharged, disconnect the oil supply lines at the turbocharger bearing (center) housings and fill the bearing housing cavities with approximately one (1) pint of the recommended grade of clean engine oil. Remove air inlet duct and turn the rotating assemblies by hand to coat all internal surfaces with oil and reinstall the turbocharger oil supply lines (refer to Section 3.5). Refer to Section 13.3 for lubricating oil recommendations.

4. After twenty (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 prelubricator hose, plug the main oil gallery hole and replace all components and gaskets 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.

• If a pressure prelubricator is not available, fill the crankcase to the proper level with *heavy duty* lubricating oil as specified 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. Using new gasket, reinstall the valve rocker covers.

Turbocharger

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

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

1. Clean the area and disconnect the oil inlet line at the bearing housing.

• 2. Fill the bearing housing cavity with clean engine oil. Remove air inlet duct and turn the rotating assembly by hand to coat all of the internal surfaces with oil.

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

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

Fill the transmission case, marine gear or torque converter supply tank to the proper level with the lubricant recommended by the gear manufacturer.

• Fuel System

Fill the tank with the fuel specified under *Fuel Recommendations* (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 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 if 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 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.

NOTICE: 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.

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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. A blower will be seriously damaged if operated with the air shutoff valve in the *closed* position.

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

Starting

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.

- If the unit is located 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.

- The engine may require the use of a cold weather starting aid if the ambient temperature is below 40°F (4°C).

• CAUTION: Starting fluid used in capsules is highly flammable, toxic, and possesses sleep-inducing properties.

• Initial Engine Start (Electric)

Start an engine equipped with an electric starting motor 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. Press the starter switch firmly.

   NOTICE: To prevent serious starting motor damage, do not press the starter switch again after the engine has started.

3. If the engine fails to start within 30 seconds, release the starter 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.

• 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 Start (Hydrostarter)

Start an engine equipped with a hydrostarter 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 say in.

2. Use the priming pump to make sure the fuel filter, fuel lines and injectors are full of fuel before attempting to start the engine.

3. Raise the hydrostarter accumulator pressure with the hand pump until the gage reads as indicated in Table 1.

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

   NOTICE: 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.

5. Push the hydrostarter control lever to simultaneously engage the starter pinion with the flywheel ring gear and to open the control valve. i

6. 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.

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

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RUNNING

Oil Pressure

• Observe the oil pressure gage immediately after starting the engine. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (5 psi - 34.5 kPa at idle speed). If there is no oil pressure indicated within 10 to 15 seconds, stop the engine and check the lubricating system. The pressure should not fall below 50 psi (345 kPa) at 1800 rpm, and normal operating pressure should be higher.

Warm-Up

Run the engine at part throttle and no load for approximately five (5) minutes, allowing it to warm up before applying a load.

Operating Oil Pressure at 180° F (82° C)*				
Marine Gear	Position	t Test rpm	Test Pressure psi	Test Pressure kPa
MG-527	Neutral	600	45-85	310-586
	Neutral	1800	65-100	448-689
	Engaged	600	180-215	1241-1481
	Engaged	1800	188-220	1296-1516
	Cruising	min.	165	1137 i
MG-540 SAE #0	Neutral	600	50-75	345-517
	Neutral	1800	78-95	538-655
	Engaged	600	226-251	1557-1730
	Engaged	1800	239-265	1647-1826
	Cruising	Min.	220	1516

* Sump or heot exchanger inlet 210° F (99° C) maximum.
Normal operating range desired 140-180° F (60-82° C) minimum.

t Sump or heat exchanger inlet 225° F (107° C) maximum intermittent permissable in pleasure craft.

TABLE 2 - Twin Disc Marine Gear Operating Conditions

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 water, fuel or lubricating oil leaks. Tighten the line connections where necessary to stop leaks.

Temperature

Normal engine coolant temperature is 160°-185°F (71°-85°C).

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain (approximately twenty (20) minutes) back into the crankcase and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick

Use only the *heavy duty* lubricating oil as specified under *Lubrication Recommendations* in Section 13.3

• **NOTICE:** If the oil level is constantly above normal and excess lube oil has not been added to the crankcase, consult with a DDC distributor for the cause. Fuel or coolant dilution of lube oil can result in serious engine damage.

Cooling System

Check coolant level after the engine has operated approximately two minutes to determine if the fill system has trapped air or a false fill condition. Remove the radiator or heat exchanger tank cap *slowly* after the engine has reached normal operating temperature and check the engine coolant level. The coolant level should be near the top of the opening. If necessary, add clean soft water with a corrosion inhibitor or an ethylene glycol base antifreeze.

Transmission

Check the marine gear oil pressure (refer to Table 1). Check and, if necessary, replenish the oil supply in the transmission.

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 turbochargers 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.

NOTICE: When prolonged engine idling is necessary, maintain at least 800 to 1000 rpm. Do not operate between 1100-1300 rpm for prolonged periods.

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STOPPING

Normal Stopping

1. Release the load and decrease the engine speed.
2. Allow the engine to run at half speed or slower with no load for four (4) or five (5) minutes, then move the stop lever to the *stop* position to shut down the engine.

Emergency Stopping

If the engine is equipped with the two-screw design injector control tube (Section 2.9) and 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 valves, located on the blower air inlet housings, 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

• Check the oil level in the crankcase (about 20 minutes after stopping). Add oil, if necessary, to bring it to the proper level on the dipstick.

Transmission

Check and, if necessary, replenish the oil supply in the transmission.

Clean Engine

Clean and check the engine thoroughly to make certain it will be ready for the next run.

Refer to *Lubrication and Preventive Maintenance* 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 became apparent to the operator during the last run.

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ENGINE OPERATING CONDITIONS

The engine operating charts are included as an aid for engine operation and trouble shooting. Any variations from the conditions as listed may indicate an abnormal situation in need of correction. Make sure that the readings represent true values, and that instruments are accurate, before attempting to make corrections to the engine.

12V AND 16V-149 ENGINES (NON-TURBOCHARGED)

120 and 130 Injectors	1500 rpm	1800 rpm	1900 rpm
Lubrication System			
Lubricating oil pressure (psi) - normal..	35-65	40-70	45-75
f Lubricating oil temperature (deg. **F)** - max..............................	225	225	225
Air System			
Air Box Pressure (Inches Mercury) - Min. Full Load:			
At zero exhaust back pressure	3.5	4.6	5.0
At max. exhaust back pressure	5.4	7.3	8.0
# Air inlet restriction (inches water) - max. full load:			
Dirty air cleaner - oil bath and dry (heavy duty)	20.0	25.0	25.0
Clean air cleaner - oil bath and dry (heavy duty	12.0	14.2	14.2
Crankcase pressure (inches water) - max....................................	0.5	0.7	0.8
Exhaust back pressure (inches mercury) - max.:			
Full load	2.5	3.6	4.0
No load	1.5	2.3	2.6
Fuel System			
Fuel pressure at inlet manifold (psi) - normal:			
With 0.136" restriction	50-80	60-80	60-80
Fuel spill (gpm) - min. at no load:			
With 0.136" restriction	2.0	2.0	2.0
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
Compression			*
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm 500			
Minimum at 600 rpm 450			t

+ 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.

Measured in duct 2" from hose or flange connection at engine.

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12V-149T ENGINE INDUSTRIAL AND MARINE

140 and 150 Injectors	1500 rpm	1800 rpm	1900 rpn
Lubrication System			
Lubricating oil pressure (psi) - normal................................	35-65	40-70	45-75
fLubricating oil temperature (deg. F) - max........................	225	230	230
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
140 Injector...	17.3	22.0	26.0
150 Injector...	19.2	24.0	27.0
At max. exhaust back pressure:			
140 Injector........................	15.4	20.5	24.3
150 Injector...	17.3	22.5	25.3
+ Air inlet restriction (inches water):			
Max. full load:			
Dirty air cleaner - dry type (heavy duty)	13.0	17.5	20.0
Clean air cleaner - dry type (heavy duty...................	7.5	10.5	12.0
Max. no load:			
Dirty air cleaner - dry type (heavy duty)	7.5	10.4	12.0
Clean air cleaner - dry type (heavy duty)..................	4.5	6.3	7.0
§ Crankcase pressure (inches water) - max.:			
140 Injector	1.7	1.9	2.0
150 Injector	1.7	2.1	2.2
Exhaust back pressure (inches mercury) - max.:			
Full load..	1.5	2.2	2.5
No load	1.1	1.6	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with 0.136" restriction	50-80	60-80	60-80
Fuel spill (gpm) - min. no load:			
With 0.136" restrictions	2.0	2.0	2.0
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
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm.................................. 500			
Minimum at 600 rpm 450			

f 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.

+ Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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12V-149T ENGINE (WITH TV7101 TURBOCHARGERS)
(1.39 A/R* * Turbine Housing)
INDUSTRIAL AND MARINE

140 and 150 Injectors	1500 rpm	1800 rpm	1900 rpir
Lubrication System			
Lubricating oil pressure (psi) - normal.....................................	35-65	40-70	45-75
■(Lubricating oil temperature (deg. F) - max...........................	225	230	230
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
140 Injector...	16.4	25.0	29.0
150 Injector...	18.0	27.5	30.0
At max. exhaust back pressure:			
140 Injector...	15.3	23.3	27.1
150 Injector...	16.9	25.9	28.1
+ Air inlet restriction (inches water):			
Max. full load:			
Dirty air cleaner - dry type (heavy duty)	13.0	17.5	20.0
Clean air cleaner - dry type (heavy duty).........................	7.5	10.5	12.0
§ Crankcase pressure (inches water) - max.:			
140 Injector	1.7	1.9	2.0
150 Injector	1.7	2.1	2.2
Exhaust back pressure (inches mercury) - max.:			
Full load..	1.5	2.2	2.5
No load..	1.1	1.6	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with 0.136" restriction	40-70	60-80	60-80
Fuel spill (gpm) - min. no load:			
With 0.136" restriction... .	2.0	2.0	2.0
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

Compression
Compression pressure (psi at sea level):
Average - new engine - at 600 rpm...500
Minimum at 600 rpm 450

+ 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.

* Turbine Housing Designation.

-f Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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12V AND 16V-149T ENGINES (WITH T18A40 TURBOCHARGERS) GENERATOR SET

165 and 180 Injectors	1500 rpm 12V	1500 rpm 16V	1800 rpm 12V	1800 rpm 16V
Lubrication System				
Lubricating oil pressure (psi) - normal	35-65	35-65	40-70	40-70
(•Lubricating oil temperature (deg. F) - max	230	230	230	230
Air System				
Air box pressure (inches mercury) - min. full load:				
At zero exhaust back pressure:				
165 Injector	19.0	23.0	28.0	30.0
180 Injector	21.5	25.0	30.0	34.0
At max. exhaust back pressure:				
165 Injector	17.9	21.9	26.4	28.4
180 Injector	20.4	23.9	28.4	32.4
+ Air inlet restriction (inches water):				
Max. full load:				
Dirty air cleaner - dry type (heavy duty	13.0	13.0	20.0	20.0
Clean air cleaner - dry type (heavy duty)	7.5	7.5	12.0	12.0
Max. no load:				
Dirty air cleaner - dry type (heavy duty)	7.5	7.5	12.0	12.0
Clean air cleaner - dry type (heavy duty)	5.0	5.0	7.0	7.0
§ Crankcase pressure (inches water) - max	1.5	1.5	2.2	2.2
Exhaust back pressure (inches mercury) - max.:				
Full load	1.5	1.5	2.2	2.2
No load	1.1	1.1	1.6	1.6
Fuel System				
Fuel pressure at inlet manifold (psi):				
Normal with 0.136" restriction	50-80	50-80	60-80	60-80
Fuel spill (gpm) - minimum at no load:				
With 0.136" restriction	2.0	2.0	2.0	2.0
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
			V	
Cooling System				
Coolant temperature (deg. F) - normal	160-185	160-185	160-185	160-185

Compression

Compression pressure (psi at sea level):

Average - new engine at 600 rpm 500

Minimum at 600 rpm 450

fThe 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.

+ Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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12V-149T ENGINE (WITH TV7101 TURBOCHARGERS)
(1.39 A/R* Turbine Housing)
GENERATOR SET

170 Injectors	1500 rpm	1800 rpm
Lubrication System		
Lubricating oil pressure (psi) - normal	35-65	40-70
■(Lubricating oil temperature (deg. F) - max	225	230
Air System		
Air box pressure (inches mercury) - min. full load:		
At zero exhaust back pressure	22.3	32.0
At max. exhaust back pressure	21.2	30.4
+ Air inlet restriction (inches water):		
Max. full load:		
Dirty air cleaner - dry type (heavy duty)	13.0	20.0
Clean air cleaner - dry type (heavy duty)	7.5	12.0
§ Crankcase pressure (inches water) - max.:	1.8	**2.2**
Exhaust back pressure (inches mercury) - max.:		
Full load	1.5	**2.2**
No load	1.1	1.6
Fuel System		
Fuel pressure at inlet manifold (psi):		
Normal with 0.136" restriction	40-70	60-80
Fuel spill (gpm) - min. no load:		
With 0.136" restriction	2.0	2.0
Pump section at inlet (inches mercury) - max.:		
Clean system	6.0	6.0
Dirty system	12.0	12.0
Cooling System		
Coolant temperature (deg. F) - normal	160-185	160-185
Compression		
Compression pressure (psi at sea level):		
Average - new engine - at 600 rpm	500	*
Minimum - at 600 rpm	450	

t 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.

* Turbine Housing Designation.

+ Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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12V-149TI ENGINE (WITH TV7101 TURBOCHARGERS) (1.39 A/R* Turbine Housing) TURBO-INTERCOOLED

165 and 170 Injectors		1500 rpm	1800 rpm	1900 rpm
Lubrication System				
Lubricating oil pressure (psi) - normal.......................		35-65	40-70	45-75
tLubricating oil temperature (deg. F) - max................		225	230	230
Air System				
Air box pressure (inches mercury) - min. full load:				
At zero exhaust back pressure:				
165 Injector...		23.5	34.5	38.0
170 Injector...		25.0	36.0	39.0
At max. exhaust back pressure:				
165 Injector...		22.4	32.9	36.1
170 Injector...		23.9	34.4	37.1
+ Air inlet restriction (inches water):				
Max. full load:				
Dirty air cleaner - dry type (heavy duty) ...		13.0	17.5	20.0
Clean air cleaner - dry type (heavy duty) ...		7.5	10.5	12.0
§ Crankcase pressure (inches water) - max.:				
165 Injector		2.1	2.3	2.4
170 Injector		2.1	2.4	2.5
Exhaust back pressure (inches mercury) - max.:				
Full load..		1.5	2.2	2.5
No load..		1.1	1.6	1.8
Turbocharger				
Compressor outlet pressure (inches mercury):				
Full load max. exhaust back pressure:				
165 Injector...		23.0-27.0	29.4-33.4	30.0-34.C
170 Injector...		25.0-29.0	30.4-34.4	32.0-36.C
Fuel System				
Fuel pressure at inlet manifold (psi):				
Normal with 0.136" restriction...............................		40-70	60-80	60-80
Fuel spill (gpm) - min. at no load:				
With 0.136" restriction...		2.0	2.0	2.0
Pump suction at inlet (inches mercury) - max.:				
Clean system		6.0	6.0	6.0
Dirty System		12.0	12.0	sl2.0
Cooling System				
Coolant temperature (deg. F) - normal........................		160-185	160-185	160-185
Compression				
Compression pressure (psi at sea level):				
Average - new engine at 600 rpm..........................	420			
Minimum - at 600 rpm	370			

fThe 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.

‘Turbine Housing Designation.

+ Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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12V-149TI ENGINE (WITH TV7101 TURBOCHARGERS)
(1.39 A/R* * Turbine Housing) - TURBO-INTERCOOLED

195 Injectors	1500 rpm	1800 rpm	1900 rpm
Lubrication System			
Lubricating oil pressure (psi) - normal	35-65	40-70	45-75
•(Lubricating oil temperature (deg. F) - max	225	230	230
Air System			
Air box pressure (inches mercury - min. full load):			
At zero exhaust back pressure	28.7	43.4	44.6
At max. exhaust back pressure	27.5	41.1	42.7
+ Air inlet restriction (inches water):			
Max. full load:			
Dirty air cleaner - dry type (heavy duty)	10.9	17.5	20.0
Clean air cleaner - dry type (heavy duty)	6.5	10.5	12.0
Max. no load:			
Dirty air cleaner - dry type (heavy duty)	6.4	10.2	12.0
Clean air cleaner - dry type (heavy duty)	4.0	6.4	7.3
§ Crankcase pressure (inches water) - max	2.3	2.7	2.8
Exhaust back pressure (inches mercury) - max.:			
Full load	1.5	2.3	2.5
No load	1.1	1.6	1.8
Turbocharger			
Compressor outlet Pressure (inches mercury):			
Full load max. exhaust back pressure	28.0-34.0	34.0-40.0	35.0-41.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with 0.136" restriction	40-70	60-80	60-80
Fuel spill (gpm) - min. at no load:			
With 0.136" restriction	2.0	2.0	2.0
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

Compression

Compression pressure (psi at sea level):

Average - new engine - at 600 rpm 420

Minimum - at 600 rpm 370

t 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.

* Turbine Flousing Designation.

\+ Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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12V-149TI ENGINE (WITH T18A40 TURBOCHARGERS) TURBO-INTERCOOLED GENERATOR SET

165 and 180 Injectors	1500 rpm	1800 rpm	1900 rpm
Lubrication System			
Lubricating oil pressure (psi) - normal	35-65	40-70	45-75
•(Lubricating oil temperature (deg. F) - max	230	230	230
Air System			
Air box pressure (inches mercury - min. full load):			
At zero exhaust back pressure:			
165 Injector	24.5	33.0	36.5
180 Injector	27.0	39.0	42.0
At max. exhaust back pressure:			
165 Injector	22.9	31.4	34.6
180 Injector	25.9	37.4	40.1
+ Air inlet restriction (inches water):			
Max. full load:			
Dirty air cleaner - dry type (heavy duty)	13.0	20.0	20.0
Clean air cleaner - dry type (heavy duty)	7.5	12.0	12.0
Max. no load:			
Dirty air cleaner - dry type (heavy duty)	7.5	12.0	12.0
Clean air cleaner - dry type (heavy duty)	5.0	7.0	7.0
§ Crankcase pressure (inches water) - max.:			
165 injector	1.5	2.4	2.5
180 injector	1.5	2.4	2.5
Exhaust back pressure (inches mercury) - max.:			
Full load	1.5	2.2	2.5
No load	1.1	1.6	1.8
Turbocharger			
Compressor outlet pressure (inches mercury):			
Full load max. exhaust back pressure:			
165 Injector	21.0-25.0	26.0-30.0	28.0-32.0
180 Injector	23.0-27.0	30.0-34.0	32.0-36.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with 0.136" restriction	50-80	60-80	60-80
Fuel spill (gpm) - min. at no load:			
With 0.136" restriction	2.0	2.0	2.0
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

Compression

Compression pressure (psi at sea level):

Average - new engine at 600 rpm 420

Minimum at 600 rpm 370

fThe 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.

+ Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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12V-149TI ENGINE (WITH TV7511 TURBOCHARGERS) (1.08 A/R* Turbine Housing) TURBO INTERCOOLED

240 Injectors	1500 rpm	1800 rpm	1900 rpir
Lubrication System			
Lubricating oil pressure (psi) - normal......................................	55-65	65-75	65-80
■(Lubricating oil temperature (deg. F) - max...........................	225	230	230
Air System			
Air box pressure (inches mercury - min. full load):			
At zero exhaust back pressure:			
240 Injector..	41.0	49.0	51.0
At max. exhaust back pressure:			
240 Injector...	39.9	47.9	49.9
+ Air inlet restriction (inches water):			
Max. full load:			
Dirty air cleaner - dry type (heavy duty..........................	10.9	17.5	20.0
Clean air cleaner - dry type (heavy duty)........................	6.5	10.5	12.0
§ Crankcase pressure (inches water) - max.:			
240 Injector	1.8	2.2	2.5
Exhaust back pressure (inches mercury) - max.:			
Full load (new)	1.0	1.3	1.5
No load..	0.6	0.9	1.0
Full load (dirty)..	1.2	1.8	2.0
Turbocharger			
Compressor outlet pressure (inches mercury):			
Full load max. exhaust back pressure:			
240 Injector...	35.9	43.9	45.9
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with 0.136" restriction...	40-70	60-80	60-80
Fuel spill (gpm) - min. at no load:			
With 0.136" restriction..	2.0	2.0	2.0
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

Compression

Compression pressure (psi at sea level):

Average - new engine - at 600 rpm 500

Minimum at 600 rpm .... 450 *

fThe 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.

* Turbine Housing Designation.

\+ Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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16V-149T ENGINE
INDUSTRIAL AND MARINE

140 and 150 Injectors	1500 rpm	1800 rpm	1900 rpm
Lubrication System			
Lubricating oil pressure (psi) - normal	35-65	40-70	45-75
•(Lubricating oil temperature (deg. F) - max.	225	230	230
Air System			
Air box pressure (inches mercury - min. full load):			
At zero exhaust back pressure:			
140 Injector	18.4	25.0	28.0
150 Injector	20.0	27.0	30.5
At max. exhaust back pressure:			
140 Injector	16.5	23.3	26.3
150 Injector	18.1	25.3	28.8
+ Air inlet restriction (inches water):			
Max. full load:			
Dirty air cleaner - dry type (heavy duty)	13.0	17.5	20.0
Clean air cleaner - dry type (heavy duty)	7.5	10.5	12.0
Max. no load:			
Dirty air cleaner - dry type (heavv duty)	7.5	10.4	12.0
Clean air cleaner - dry type (heavy duty)	4.5	6.3	7.0
§ Crankcase pressure (inches water) - max.:			
140 Injector	1.7	1.9	2.0
150 Injector	1.7	2.1	2.2
Exhaust back pressure (inches mercury) - max.:			
Full load	1.5	2.2	2.5
No load	1.1	1.6	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with 0.136" restriction	50-80	60-80	60-80
Fuel spill (gpm) - min. no load:			
With 0.136" restriction	2.0	2.0	2.0
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 (dee. F) - normal	160-185	160-185	160-185 $
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	500		
Minimum at 600 rpm	450		

tThe 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.

-f Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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12V-149TI ENGINE (WITH TV7511 TURBOCHARGERS) (1.08 A/R* Turbine Housing) TURBO INTERCOOLED

240 Injectors	1500 rpm	1800 rpm	1900 rpm
Lubrication System			
Lubricating oil pressure (psi) - normal................................	55-65	65-75	65-80
•(Lubricating oil temperature (deg. F) - max.......................	225	230	230
Air System			
Air box pressure (inches mercury - min. full load):			
At zero exhaust back pressure:			
240 Injector...	41.0	49.0	51.0
At max. exhaust back pressure:			
240 Injector...	39.9	47.9	49.9
+ Air inlet restriction (inches water):			
Max. full load:			
Dirty air cleaner - dry type (heavy duty.....................	10.9	17.5	20.0
Clean air cleaner - dry type (heavy duty)...................	6.5	10.5	12.0
§ Crankcase pressure (inches water) - max.:			
240 Injector	1.8	2.2	2.5
Exhaust back pressure (inches mercury) - max.:			
Full load (new)	1.0	1.3	1.5
No load...	0.6	0.9	1.0
Full load (dirty)..	1.2	1.8	2.0
Turbocharger			
Compressor outlet pressure (inches mercury):			
Full load max. exhaust back pressure:			
240 Injector...	35.9	43.9	45.9
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with 0.136" restriction......................................	40-70	60-80	60-80
Fuel spill (gpm) - min. at no load:			
With 0.136" restriction..	2.0	2.0	2.0
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 *i*
Compression			
Compression pressure (psi at sea level):			
Average - new engine - at 600 rpm	500		
Minimum at 600 rpm	450		

f 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.

* Turbine Housing Designation.

+ Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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16V-149TI ENGINE (WITH TV8115 TURBOCHARGERS) (1.60 A/R* Turbine Housing) - TURBO-INTERCOOLED

195 Injectors	1500 rpm	1800 rpm	1900 rpm
Lubrication System			
Lubricating oil pressure (psi) - normal	35-65	40-70	45-75
■(Lubricating oil temperature (deg. F) - max	225	230	230
Air System			
Air box pressure (inches mercury - min. full load):			
At zero exhaust back pressure	28.4	40.8	45.1
At max. exhaust back pressure	27.3	39.1	43.2
+ Air inlet restriction (inches water):			
Max. full load:			
Dirty air cleaner - dry type (heavy duty)	10.9	17.5	20.0
Clean air cleaner - dry type (heavy duty)	6.5	10.5	12.0
Max. no load:			
Dirty air cleaner - dry type (heavy duty)	6.4	10.2	12.0
Clean air cleaner - dry type (heavy duty)	4.0	6.4	7.3
§ Crankcase pressure (inches water) - max	2.3	2.7	2.8
Exhaust back pressure (inches mercury) - max.:			
Full load	2.8	3.5	4.0
No load	1.1	1.6	1.8
Turbocharger			
Compressor outlet pressure (inches mercury):			
Full load max. exhaust back pressure	25.0-31.0	32.0-38.0	34.0-40.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with 0.136" restriction	40-70	60-80	60-80
Fuel spill (gpm) - min. at no load:			
With 0.136" restriction	2.0	2.0	2.0
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
Compression			$
Compression pressure (psi at sea level):			
Average - new engine - at 600 rpm	420		
Minimum - at 600 rpm	370		

tThe 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.

* Turbine Housing Designation.

\+ Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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16V-149TI ENGINE (WITH T18A40 TURBOCHARGERS) TURBO-INTERCOOLED GENERATOR SET

165 and 180 Injectors	1500 rpm	1800 rpm	1900 rpm
Lubrication System			
Lubricating oil pressure (psi) - normal	35-65	40-70	45-75
†Lubricating oil temperature (deg. F) - max.	230	230	230
Air System			
Air box pressure (inches mercury - min. full load):			
At zero exhaust back pressure:			
165 Injector	24.0	31.5	35.5
180 Injector	27.0	35.0	40.0
At max. exhaust back pressure:			
165 Injector	22.9	29.9	33.6
180 Injector	25.9	33.4	38.1
+ Air inlet restriction (inches water):			
Max. full load:			
Dirty air cleaner - dry type (heavy duty)	13.0	20.0	20.0
Clean air cleaner - dry type (heavy duty)	7.5	12.0	12.0
Max. no load:			
Dirty air cleaner - dry type (heavy duty)	7.5	12.0	12.0
Clean air cleaner - dry type (heavy duty)	5.0	7.0	7.0
§ Crankcase pressure (inches water) - max.:			
165 Injector	1.5	2.4	2.5
180 Injector	1.5	2.4	2.5
Exhaust back pressure (inches mercury) - max.:			
Full load	1.5	2.2	2.5
No load	1.1	1.6	1.8
Turbocharger			
Compressor outlet pressure (inches mercury):			
Full load max. exhaust back pressure:			
165 Injector	21.0-25.0	26.0-30.0	28.0-32.0
180 Injector	24.0-28.0	30.0-34.0	32.0-36.0
Fuel System			
Fuel Pressure at inlet manifold (psi):			
Normal with 0.136" restriction	50-80	60-80	60-80
Fuel spill (gpm) - min. at no load:			
With 0.136" restriction	2.0	2.0	2.0
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
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	420		
Minimum - at 600 rpm	370		

† 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.
+ Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.
§ Leakage from the breather must not exceed 12 drops of oil per minute.

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16V-149TI ENGINE (WITH TV8402 TURBOCHARGERS) (1.23 A/R* TURBINE HOUSING) TURBO-INTERCOOLED

240 Injectors	1500 rpm	1800 rpm	1900 rpir
Lubrication System			
Lubricating oil pressure (psi) - normal................................	55-65	65-75	65-80
fLubricating oil temperature (deg. F) - max........................	225	230	230
Air System			
Air box pressure (inches mercury - min. full load):			
At zero exhaust back pressure:			
240 Injector..	42.0	50.0	52.0
At max. exhaust back pressure:			
240 Injector..	40.9	48.9	50.9
+ Air inlet restriction (inches water):			
Max. full load:			
Dirty air cleaner - dry type (heavy duty)	10.9	17.5	20.0
Clean air cleaner - dry type (heavy duty)..................	6.5	10.5	12.0
§ Crankcase pressure (inches water) - max.:			
240 Injector	1.8	2.2	2.5
Exhaust back pressure (inches mercury) - max.:			
Full load (new)	1.0	1.3	1.5
No load..	0.6	0.9	1.0
Full load (dirty)	1.2	1.8	2.0
Turbocharger			
Compressor outlet pressure (inches mercury):			
Full load max. exhaust back pressure (min.):			
240 Injector..	36.9	44.9	46.9
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with 0.136" restriction.......................................	40-70	60-80	60-80
Fuel spill (gpm) - min. at no load:			
With 0.136" restriction...	2.0	2.0	2.0
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
Compression			
Compression pressure (psi at sea level):			
Average - new engine - at 600 rpm 420			
Minimum at 600 rpm 370			

t 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.

* Turbine Housing Designation.

\+ Includes air cleaner and duct measured 6" to 8" before the turbocharger compressor inlet.

§ Leakage from the breather must not exceed 12 drops of oil per minute.

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• COOLING SYSTEM REQUIREMENTS SERIES 149 DIRECT RADIATOR-COOLED ENGINES

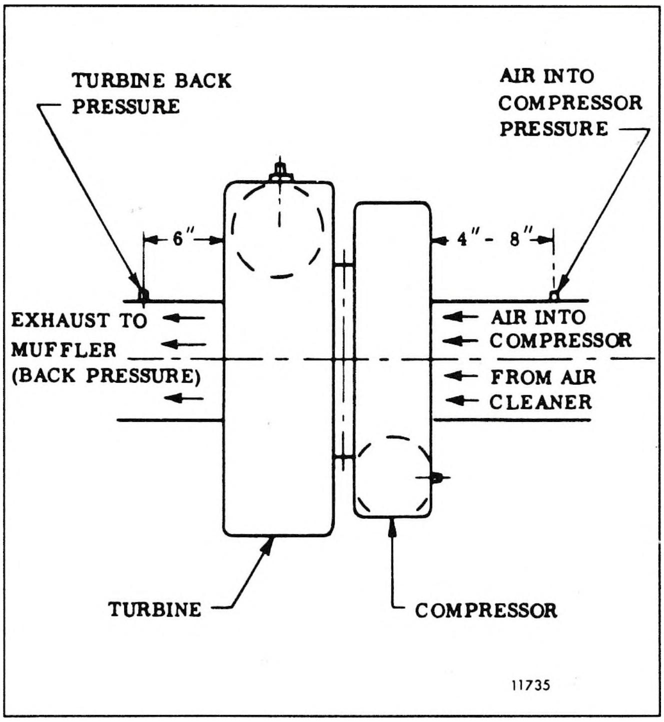

Fig. 1 - Points at which to Measure Air Inlet Restrictions and Exhaust Restriction (8V-149 Only)

'On 1 2V and 1 6V engines take reading 6" from outlet flange.

This section is intended to emphasize the basic cooling system requirements' of Series 149 engines. Although these requirements apply to all direct radiator-cooled engine applications, including off-highway haul truck, industrial, marine, generator sets and military, recommendations are *primarily intended for mine haul trucks and loaders. For more detailed information, refer to Engineering Bulletin No. 28, "Cooling of Off-Highway Industrial Engines" (Form 18SA202), available from DDC Distributors.*

The engine coolant and cooling system components control internal engine temperature by dissipating heat generated from combustion and friction. Anything that interferes with this heat transfer can result in serious engine damage and reduce engine life.

PRESSURIZED COOLING SYSTEM

The cooling system must be pressurized to operate properly. Pressure in the cooling system prevents cavitation, suction leaks and localized boiling.

System pressure is produced by the expansion of the coolant as it is heated. Checking the coolant level while coolant temperature is hot will result in a loss of this pressure. This pressure may not be completely restored until the system is allowed to cool and then heated again. To avoid this situation an auxiliary air supply is required to maintain system pressure (see Fig. 2). The pressure from this air supply should be regulated to 7-10 psi (48.3-68.9 kPa).

MAXIMUM ENGINE COOLANT TEMPERATURE

The heat dissipating capacity of the Series 149 engine cooling system and related components must be sufficient to prevent the engine coolant-out temperature from rising above 200°F (93.3°C). This temperature must not be exceeded under any engine operating condition, regardless of altitude, type of coolant used, or cooling system condition. When the cooling system is sized properly, the engine will operate under thermostat control so that the coolant-out temperature is between 170°F and 187°F (76.7°C - 86°C) the majority of the time. Maximum engine life will be obtained when the engine is operating under thermostat control. Coolant temperatures above 187°F (86°C) are out of thermostatic control and will rise on a 1 to 1 basis with an increase in the ambient air temperature.

COOLING INDEX

The cooling index is a measurement that represents differences between the stabilized coolant-out temperature and the true ambient air temperature while the engine is operating under full load conditions at rated speed with the thermostats fully open. This temperature difference is referred to as "ATW" (air-to-water) and indicates the performance of the cooling system. The cooling index is corrected to sea level so that it can be compared to cooling index requirements for specific operating sites. Smaller ATW values have greater cooling capability than larger ATW values.

A new measured cooling index must be determined if changes are made to the applications that influence engine cooling. These changes include increasing the horsepower, altering fan pitch, fan size, shrouding or baffles around the radiator, any site condition or operating location changes.

COOLING INDEX REQUIREMENT

The *cooling index requirment* is a calculated number representing the maximum allowable cooling index (ATW) that will provide adequate engine cooling. This number is based on the requirement that the engine coolant-out temperature must not exceed 200°F (93.3°C) during the most severe ambient conditions for a specific operating site. The number is calculated by applying correction factors for altitude, maximum operating temperature, and type of coolant from the maximum engine coolant-out temperature. A brief description of these parameters follows (see Fig. 3 for sample calculation):

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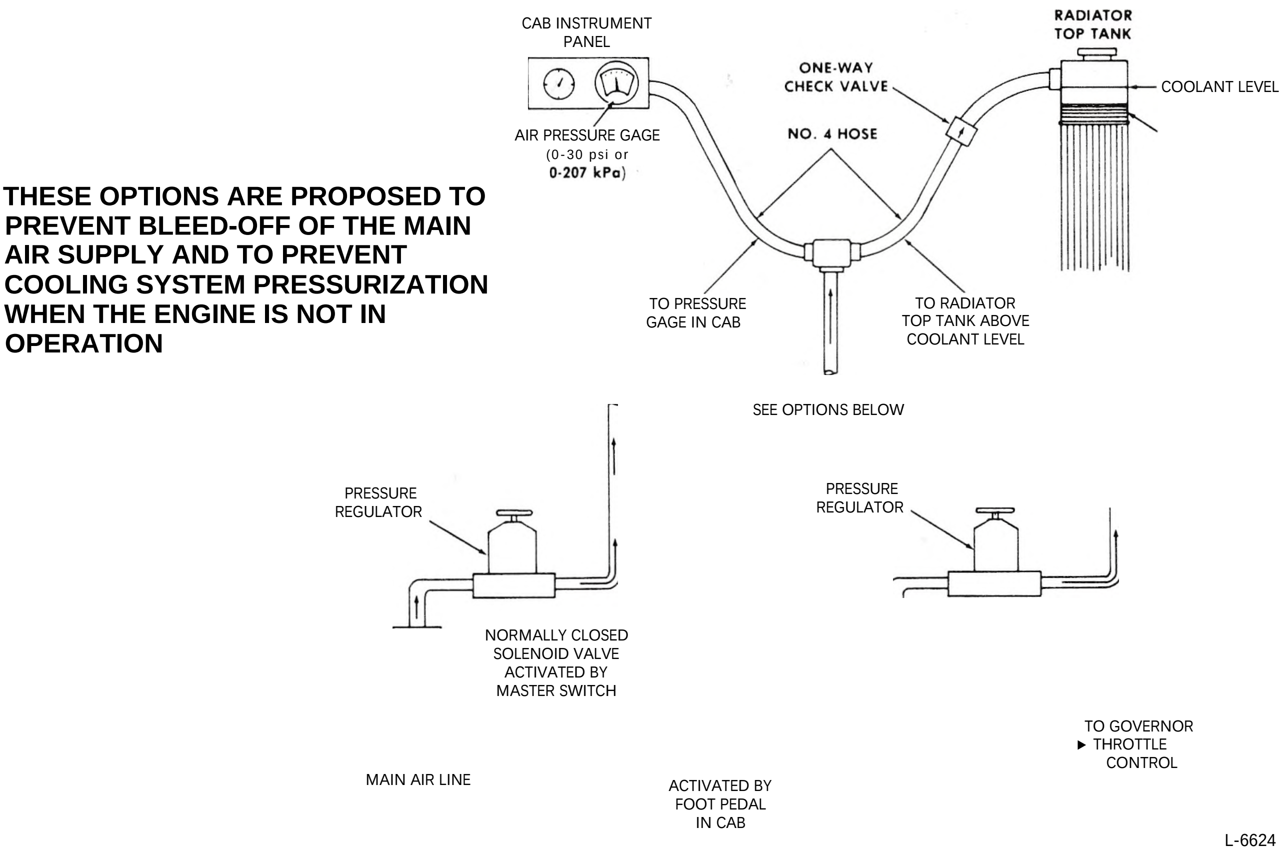

Fig. 2 - Pressurized Top Tank Installation

ALTITUDE

Increasing altitude reduces air density and the ability of the cooling system to dissipate engine heat to the air. Higher altitudes will increase the cooling index by 2°F (1.1°C) per 1000 feet (305m). Altitude corrections to sea level are applied to the cooling index and the cooling index requirement for comparative purposes.

MAXIMUM OPERATING SITE TEMPERATURE

When calculating the cooling index requirements, the maximum ambient temperature for the operating location must be determined. To establish this tempertaure, the nearest official weather recording station must be consulted to determine the highest ambient temperature ever recorded at that station. Once this is established, the difference between that station and the operating site must be determined. For example, a characteristic of deep pit mines is that the pit temperature can be as much as 30°F (16.7°C) higher than the ambient temperature recorded in the nearest official temperature recording station. Combining the maximum weather station recorded temperature with the difference of the operating site and weather station temperatures, will establish the maximum ambient temperature design criteria for the cooling system. Furthermore, additional variations in ambient temperature can occur on the same haul road due to tail winds causing recirculation of air around the radiator, pit wall radiated heat, etc. *Actual tests should be conducted to establish the highest ambient temperature encountered during a haul cycle, including the effect of winds and radiated heat.*

ENGINE COOLANT

The use of ethylene glycol antifreeze reduces the ability of the cooling system to dissipate heat. For example, a 50/50 mixture of water and ethylene glycol (the maximum concentration of antifreeze recommended by DDC) will increase the measured cooling index by 6°F (3.3°C). Water is generally used for the coolant when the cooling test is performed. Therefore, *the cooling index requirement must be reduced by 6°F (3.3°C) if antifreeze is to be used in the application.*

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Site Conditions:	
Operating site altitude	8000 Feet
Maximum recorded temperature at nearest official temperature recording station	10f F (38.36°C)
Site temperature difference compared to nearest temperature recording station	+ 4° F (2.22°C)
Special site conditions	2° F (1.11° C)
Type of coolant (Ethylene Glycol/Water)	50/50 Mix
Calculations:	
Maximum allowed coolant-out temperature	200°F (93°C)
Altitude compensation (2° F/1000 Ft) 8000 Ft/1000 +2° F	-16° F (-8.89° C)
Maximum recorded temperature	-101° F (—56.16° C)
Temperature difference, operating site to official weather station	—4°F (-2.22°C)
Recirculation effects	—2°F (-1.11° C)
Coolant compensation	—6° F (-3.3T C)
Cooling index requirement (ATW) Corrected to sea level	71° F (21.7° C)
Conclusions:	
The measured cooling index (ATW) for this application must be 71° F (21.7° C) or less to qualify at this operating site.	

Fig. 3 - Sample Calculation for Determining Required Cooling Index

SHORT DURATION FULL LOAD OPERATION

In cases where full-fuel operation is less than 8 minutes and the duty cycle *will not* increase, test data has shown that the cooling index requirement can be increased. *Written concurrences by DDC's Engineering Department is necessary to exceed the cooling index requirement.*

The individual cooling system requirements for each Series 149 engine are shown on sheet 2 of the specific engine performance curve. Curves are contained in Sales Tech Data Book 18SA323, *Construction, Industrial Engines Performance Curves.* This information is available from Detroit Diesel Corporation Distributors. A broad general summary of Series 149 Engine Cooling System Requirements is shown below.

Maximum Coolant-Out Temperature .... 200°F (93.3°C)

Minimum Coolant Pump Inlet Pressure .... Not Less than Zero
(Fill Line Operating)

Maximum Coolant Pump Inlet Pressure.............................. ....-3.0 in. Hg (10.0 kPa)
(Fill Line Blocked)

Minimum Coolant Flow.. .... 95% Rated (See Sheet 2 of the engine performance curves)

Minimum Fill Line Size.. .... 1 3/8 in. (34.9mm) I.D.

Deaeration Line Size (Quantity of 2)
Minimum... .... 3/8 in. (9.5mm) I.D.
Maximum ....7/16 in. (1 1.1mm) I.D.

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Series 149 Engine Cooling System Requirements (Cont'd)

Minimum Drawdown Capacity	See Chart in Engineering Bulletin No. 28, "Cooling of Off-Highway Industrial Engines" Form 18SA202.
Minimum Expansion Volume	6% of Total System Capacity
Top Tank Stand Pipe Size (Quantity of 2)	
Minimum	7/1 6 in. (1 1.1 mm) I.D.
Maximum	1/2 in. (12.7mm) I.D.
Minimum Deaeration Capability	1cfm (2.8 liters/min.) Per Cyl. (corrected)
Minimum System Pressure (Supplied by External Source)	7-10 psi (48.3-68.9 kPa)
Minimum Cap Pressure	14 psi (96.6 kPa)
Minimum Fill Rate (closed thermostats)	5 gpm (18.9 liters/min.)

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ENGINE RUN-IN INSTRUCTIONS

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

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

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear. Normal coolant temperature (160-185°F or 71-85°C) should be maintained throughout the Run-In.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 10°F (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 the thermostats.

Because of the wet cylinder liners in the Series 149 engine, it is desirable that the engine Run-In be made 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 rusting of the outside diameter of the cylinder liners after the engine has been removed from the dynamometer test stand.

The *Basic Engine Run-In Schedule* is shown in Table 1. The *Final Engine Run-In Schedule* is shown in Table 2. The horsepower shown in the tables 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 x RPM)/5250

Where:

BHP = brake horsepower

T = torque in lb-ft

RPM = revolutions per minute

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

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During the actual operation, all data taken should be recorded immediately on an *Engine Test Report* (see sample on page 4).

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.

The new steel hand hole cover used in production has no provision for checking the air box pressure. When checking air box pressure a service only hand hole cover with a tapped hole for attaching a gage is now available.

d. Water temperature gage installed in the thermostat housing.

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

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

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

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

i. Adaptors 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"

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.

• 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:

Drill and tap a l/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. 1). 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 the flow of the heavier oil may cause filter gasket leakage or bearing surface damage from inadequate oil film.

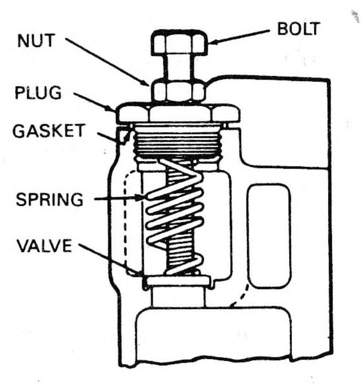

Fig. 1 - Bypass Valve with Modified Valve Plug Installed

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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 *Lubricating System — Preparation for Starting Engine First Time* in Section 13.1.

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

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

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

Prior to starting a turbocharged engine, remove the oil supply line at each turbocharger and add clean 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 serviceman who performed the overhaul. Minor difficulties should be detected and corrected so that a major problem will not develop.

After performing the preliminary steps, be sure all water valves, fuel valves, etc. are open. Also inspect the exhaust system, air cleaner and 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 H.P. on a horsepower gage). This is necessary, on some units, to lubricate the absorption unit seals and to protect them from damage.

See Engine Test Report, "Basic Engine Run-in" and "Final Run-in" (Sections B and E).

Point	Speed (RPM)	Load (% of rated hp)	Time (Minutes)
1	1200	20*	10
2	1500	25	15
3	1800	40	30
4	1900	75	30
Final	Rated rpm#	100	30

* But not more than 300 hp.
44 But not less than 1 800 rpm.

Table 1 - Basic Engine Run-in Schedule

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.

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Injector Size	Engine Horsepower at 1800 RPM						
	8VTI	12V	12VT	12VTI	16V	16VT	16VTI
120							
130		770			1025		
140							
145			980			1315	
150							
160	780						
165			1155			1545	
170				1175			1580
180							
190/7110#	860			1290			1740
195							
230							
240							
270	1010			1515			2020
290/6810				1700			2275
300				1750			2350

#190 and 7 1 10 injectors should never be mixed in an engine.
* Within 5% of brake horsepower rating shown above at governor speed.

Size	Engine Horsepower at 1900 RPM						
	8VTI	12V	12VT	12VTI	16V	16VT	16VTI
120		727			970		
130		805	910		1070	1195	
140	635		940	980		1275	1325
145	740		1050	1100		1400	1480
150				1130			1515
160	800			1200			1600
170	825			1240			1650
180	850			1275			1700
190/7110#	900			1350			1800
195	950			1425			1900
230				1500			i 2000
240	1000						

190 and 7110 injectors should never be mixed in an engine.
* Within 5% of brake horsepower rating shown above at governor speed.

Table 2 - Rated Engine Horsepower at RPM/Injector Size

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ENGINE TEST REPORT

Date___ ____________ Unit Number________

Repair Order Number _____________ Model N umber _

PRE-STARTING

PRIME LUBE ' OIL SYSTEM	PRIME FUEL ' SYSTEM	ADJUST VALVES AND BRIDGES	TIME 4- IN J.	, ADJ. ' GOV.	ADJUST INJ. 6' RACKS

B BASIC ENGINE RUN-IN							C BASIC RUN-IN INSPECTION	
TIME AT SPEED	TIME START	TIME STOP	RPM	BHP	WATER TEMP.	LUBE OIL PRESS.	1. Check oil at rocker 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.	

INSPECTION AFTER BASIC RUN-IN

I. Tighten Rocker Shaft Bolts

2. Adjust Valves (Hot)

3. Time Injectors

4. Adjust Governor Gap

5. Adjust Injector Racks

6.

FINAL RUN-IN

TIME START	TIME STOP	TOP RPM NO LOAD	TOP RPM FULL LOAD	BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE FA	CRANKCASE PRESSURE FA

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

INSPECTION AFTER FINAL RUN

I. Inspect Air Box, Pistons, Liners, Rings

2, Inspect Blower

3. Check Generator Charging Rote

4. Wash Oil Pan, Check Gasket

5. Clean Oil Pump Screen, Remove Cloth

6. Replace Lube Filter Elements

7. Tighten Flywheel Bolts

8. Rust Proof Cooling System

9.

UL.

REMARKS'

Final Run OK'd Dynamometer Date

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

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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. 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 shutdown 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, pistons, cylinder liners or bearings have been replaced as a result of findings in the Basic Run-In, the entire Basic Run-In must be repeated as though the Run-In and test procedure were started anew.

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

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

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

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

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

Check the *air box pressure* while the engine is operating at maximum speed and load. This check may be made by attaching a suitable gage (0-15 psi or 0-103 kPa) or manometer (15-0-15) to an air box drain or to a hand hole plate prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure should be recorded in inches of mercury.

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

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

The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. 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.

On turbocharged engines, measure the air inlet restriction, at each turbocharger, with a water manometer connected in the large diameter of the air duct just before it is reduced to enter the turbocharger compressor. There should not be more than 2" of water difference in the compressor inlet readings for the turbochargers being supplied from a common air cleaner(s).

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).

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ENGINE TEST REPORT

Date_____ ____________ Unit Number________
Repair Order Number Model Number,

PRE-STARTING

PRIME LUBE ' OIL SYSTEM	PRIME FUEL ' SYSTEM	ADJUST VALVES AND BRIDGES	TIME 4> INJ.	- ADJ. GOV.	ADJUST INJ. RACKS

B

BASIC ENGINE RUN-IN

TIME i AT j SPEED ¹	TIME START	STOP	RPM	BHP	WATER TEMP.	LUBE OIL PRESS.

BASIC RUN-IN INSPECTION

1. Check oil at rocker 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

INSPECTION AFTER BASIC RUN-IN

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

FINAL RUN-IN

TIME START	STOP	TOP RPM NO LOAD	FULL LOAD	BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE FA	CRANKCASE PRESSURE FA

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

INSPECTION AFTER FINAL RUN

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

REMARKS:

Final Run OK'd Dynamometer Date

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

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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. 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 shutdown 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, pistons, cylinder liners or bearings have been replaced as a result of findings in the Basic Run-In, the entire Basic Run-In must be repeated as though the Run-In and test procedure were started anew.

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

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

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

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

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

Check the *air box pressure* while the engine is operating at maximum speed and load. This check may be made by attaching a suitable gage (0-15 psi or 0-103 kPa) or manometer (15-0-15) to an air box drain or to a hand hole plate prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure should be recorded in inches of mercury.

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

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

The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. 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.

On turbocharged engines, measure the air inlet restriction, at each turbocharger, with a water manometer connected in the large diameter of the air duct just before it is reduced to enter the turbocharger compressor. There should not be more than 2" of water difference in the compressor inlet readings for the turbochargers being supplied from a common air cleaner(s).

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).

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Turbocharger compressor outlet 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 prescibed 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 to the cooling system (refer to Section 13.3). The lubricating oil filters should also be changed.

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

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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. MU-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.

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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.

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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

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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	60,7 1 8.92	20,000 Miles (32,000 kM)
City Transit Coaches	53, 71 8. 92	6,000 Miles (9,600 kM)
Pick-up & Delivery, Stop & Go, Short Trip	53, 71, 92 8.2L	12,000 Miles (19,000 kM) 6,000 Miles (9,600 kM)
Industrial, Agricultural and Marine	149NA 1 49T	500 Hrs. or 1 Yr. 300 Hrs. or 1 Yr.
	53, 60, 71, 92 8. 8.2L	150 Hrs.
Stationary Units Full Time	53, 71,92 81 149	500 Hrs. or 1 Mo.
Standby	53, 71,92, 149 8. 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 8.2L	8.000 Mi. (12,500 kM) 4.000 Mi. (6,400 kM)	12,000 Mi. (20,000 kM) 6,000 Mi. (9,600 kM)
Industrial, Agricultural and Marine	149NA 149T	300 Hrs. 200 Hrs.	500 Hrs. 300 Hrs. (or 1 Yr. Maximum)
	53, 60, 71, 92 & 8.2L	100 Hrs.	1 50 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 8. 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 8.2L	4.000 Mi. (6,500 kM) 2.000 Mi. (3,000 kM)	8.000 Mi. (12,500 kM) 4.000 Mi. (6,400 kM)
Industrial, Agricultural and Marine	149NA 149T	150 Hrs. 100 Hrs.	300 Hrs. 200 Hrs. (or 6 Mos. Maximum)
	53, 60, 71, 92 8. 8.2L	50 Hrs.	100 Hrs.
Stationary Units Full Time	53, 71,92 & 149	150 Hrs.	300 Hrs.
Standby	53, 71,92, 149 8. 8.2L	50 Hrs. (or 6 Mos.	100 Hrs. Maximum)

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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 1 131	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.

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FUELOIL

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 fC)	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) IBP, Typical # 10% Typical # 50% Typical # 90% + End Point #	D 86	 350 (177) 385 (196) 425 (218) 500 (260) Max. 550 (288) Max.	 375 (191) 430 (221) 510(256) 625 (329) 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.

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FUELOIL

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
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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. -f-	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.

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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.

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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.

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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.

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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 T54 1 T632 T9 15 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 HH7400AT2UPRBP Element HC7400SUP-4H
Secondary (Alternate)	5	–	AC Spark Plug	TP916L TP928L TP959L

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LUBRICATING OIL FILTER RECOMMENDATION
Series 53, 71, 92, 149

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Full Flow	12	75	AC Spark Plug Div. GM	PF91 1 L P/N 25013192

LUBRICATING OIL FILTER RECOMMENDATION
Series 60

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Full Flow	45	80	AC Spark Plug Div. GM	PF9 1 1 P/N 25010495
By-Pass	10	90	AC Spark Plug Div. GM	P-940 P/N 2501 1 188

LUBRICATING OIL FILTER RECOMMENDATION
Series 8.2L

Filter Type	Micron Rating	Beta Ratio	Manufacturer	Filter No.
Full Flow	25	88	AC Spark Plug Div. GM	PF35 P/N 6438384

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COOLANT SPECIFICATIONS

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

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

TABLE 1

COOLANT REQUIREMENTS

Coolant solutions used in Detroit Diesel engines must meet the following basic requirements:

1. Provide for adequate heat transfer.
2. Provide a corrosion-resistant environment within the cooling system.
3. Prevent formation of scale or sludge deposits in the cooling system.
4. Be compatible with the cooling system hose and seal materials.
5. Provide adequate freeze protection during cold weather operation and boil-over protection in hot weather.

The first four requirements are satisfied by combining a suitable water with reliable inhibitors. When freeze protection is required, a solution of suitable water and an antifreeze containing adequate inhibitors will provide a satisfactory coolant. Ethylene glycol-based antifreeze solutions are recommended for year-round use in Detroit Diesel engines.

WATER

Whether of drinking quality or not, any water will produce a corrosive environment in the cooling system, and the mineral content may permit scale deposits to form on internal cooling system surfaces. Therefore, water selected as a coolant must be properly treated with inhibitors to control corrosion and scale deposition.

To determine if a particular water is suitable for use as a coolant when properly inhibited, the following characteristics must be considered: the concentration of chlorides and sulfates, total hardness and dissolved solids.

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

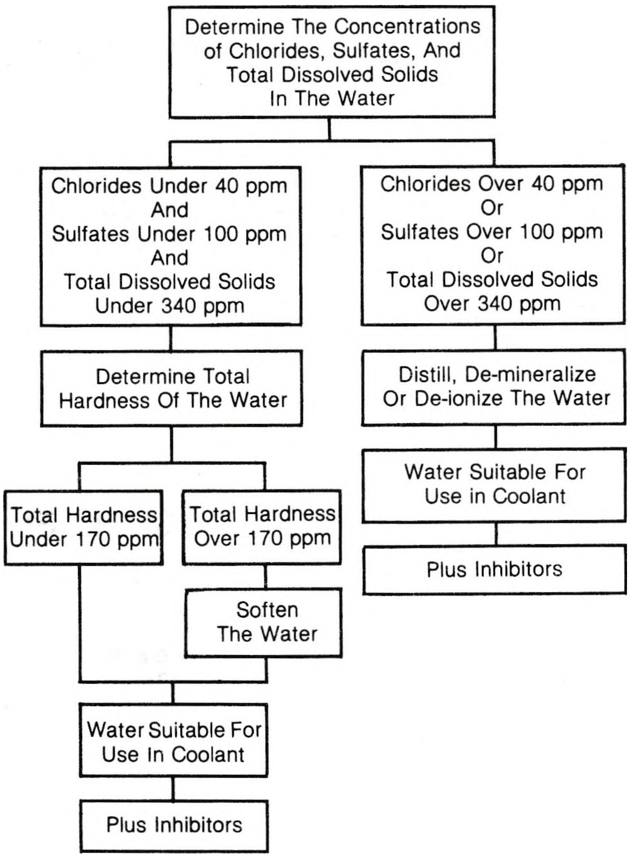

TABLE 2

CORROSION INHIBITORS VITAL

A corrosion inhibitor is a water-soluble chemical compound which protects the metallic surfaces of the cooling system against corrosive attack. Some of the more commonly used corrosion inhibitors are chromates, borates, nitrates, nitrites and soluble oil. (Soluble oil is not recommended as a corrosion inhibitor). Depletion of all types of inhibitors occurs through normal operation.

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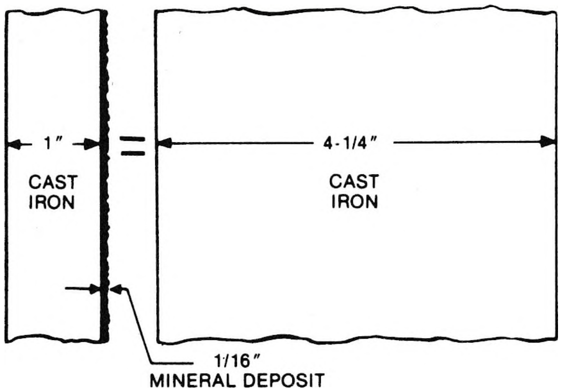
Therefore, strength levels must be maintained by adding inhibitors as required after testing the coolant.

The importance of a properly inhibited coolant cannot be overstressed. A coolant which has insufficient inhibitors, the wrong inhibitors, or no inhibitors at all invites the formation of rust and scale deposits within the cooling system. Rust, scale, and mineral deposits can wear out water pump seals and coat the walls of the cylinder block water jackets and the outside walls of the cylinder liners. As these deposits build up, they insulate the metal and reduce the rate of heat transfer. For example, a 1/16" deposit of rust or scale on 1" of cast iron is equivalent to 4—1/4" of cast iron in heat transferability (Fig. 1).

HEAT TRANSFER CAPACITY



1" CAST IRON PLUS 1/16" MINERAL DEPOSIT =
4-1/4" CAST IRON IN HEAT TRANSFERABILITY

Fig. 1 - Heat Transfer Capacity

An engine affected in this manner overheats gradually over a period of weeks or months. Liner scuffing, scoring, piston seizure and cylinder head cracking are the inevitable results. An improperly inhibited coolant can also become corrosive enough to “eat away” coolant passages and seal ring grooves and cause coolant leaks to develop. If sufficient coolant accumulates on top of a piston, a hydrostatic lock can occur while the engine is being started. This, in turn, can result in a bent connecting rod.

An improperly inhibited coolant can also contribute to *cavitation erosion.* Cavitation erosion is caused by the collapse of bubbles (vapor pockets) formed at the coolant side of an engine component. The collapse results from a pressure differential in the liquid caused by the vibration of the engine part. As bubbles collapse, they form pin points of very high pressure. Over a period of time, the rapid succession of millions of tiny bursting bubbles can wear away (erode) internal engine surfaces.

Components such as fresh water pump impellers and cylinder liners are especially susceptible to cavitation erosion. In extreme cases their surfaces can become so deeply pitted that they appear to be spongy, and holes can develop completely through them.

Chromates

Sodium chromate and potassium dichromate are two of the best and most commonly used water system corrosion inhibitors. Care should be exercised in handling these materials due to their toxic nature.

Chromate inhibitors should *not* be used in antifreeze solutions. Chromium hydroxide, commonly called “green slime”, can result from the use of chromate inhibitors with antifreeze. This material deposits on the cooling system passages, reducing the heat transfer rate (Fig. 1) and resulting in engine overheating. Engines which have operated with a chromate-inhibited water must be chemically cleaned before the addition of antifreeze. A commercial heavy-duty descaler should be used in accordance with the manufacturer’s recommendation for this purpose.

Soluble Oil

Soluble oil has been used as a corrosion inhibitor for many years. It has, however, required very close attention relative to the concentration level due to adverse effects on heat transfer if the concentration exceeds 1 % by volume. For example: 1.25% of soluble oil in the cooling system increases fire deck temperatures 6% and a 2.50% concentration raises fire deck temperatures up to 15%. *Soluble oil is not recommended as a corrosion inhibitor.*

Non-Chromates

Non-chromate inhibitors (borates, nitrates, nitrites, etc.) provide corrosion protection in the cooling system with the basic advantage that they can be used with either water or a water-and-antifreeze solution.

INHIBITOR SYSTEMS

An inhibitor system is a combination of chemical compounds which provide corrosiom protection, pH control and water-softening ability. Corrosion protection is discussed under the heading *Corrosion Inhibitors Vital.* pH control is used to maintain an acid-free solution. The water-softening ability deters formation of mineral deposits. Inhibitor systems are available in various forms such as coolant filter elements, liquid and dry bulk inhibitor additives and as integral parts of antifreeze.

Coolant Filter Elements

Replaceable elements are available with various chemical inhibitor systems. Compatibility of the element with other ingredients of the coolant solution cannot always be taken for granted.

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Problems have developed from the use of the magnesium lower support plate used by some manufacturers in their coolant filters. The magnesium plate will be attacked by solutions which will not be detrimental to other metals in the cooling system. The dissolved magnesium will be deposited in the hottest zones of the engine where heat transfer is most critical. The use of an aluminum or zinc support plate in preference to magnesium is recommended to eliminate the potential of this type of deposit.

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

Inhibitor Additives

Commercially packaged inhibitor systems are available which can be added directly to the engine coolant. Both chromate and non-chromate systems are available and care should be taken regarding inhibitor compatibility with other coolant constituents.

Non-chromate inhibitor systems are recommended for use in Detroit Diesel engines. These systems can be used with either water or water-and-antifreeze solutions and provide corrosion protection, pH control and water softening. 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, they require no additional hardware or plumbing.

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

NOTICE: Over-inhibiting antifreeze solutions can cause silicate dropout. Always follow the supplier's recommendations on inhibitor usage and handling.

TEST METHODS

Test kits and test strips are commercially available to check engine coolant for corrosion inhibitor strength level. Coolant should be tested to determine the need for corrosion inhibitor supplements and the amount required. Do not use one manufacturer's test to measure the inhibitor strength level of another manufacturer's product. Always follow the manufacturer's recommended test procedures.

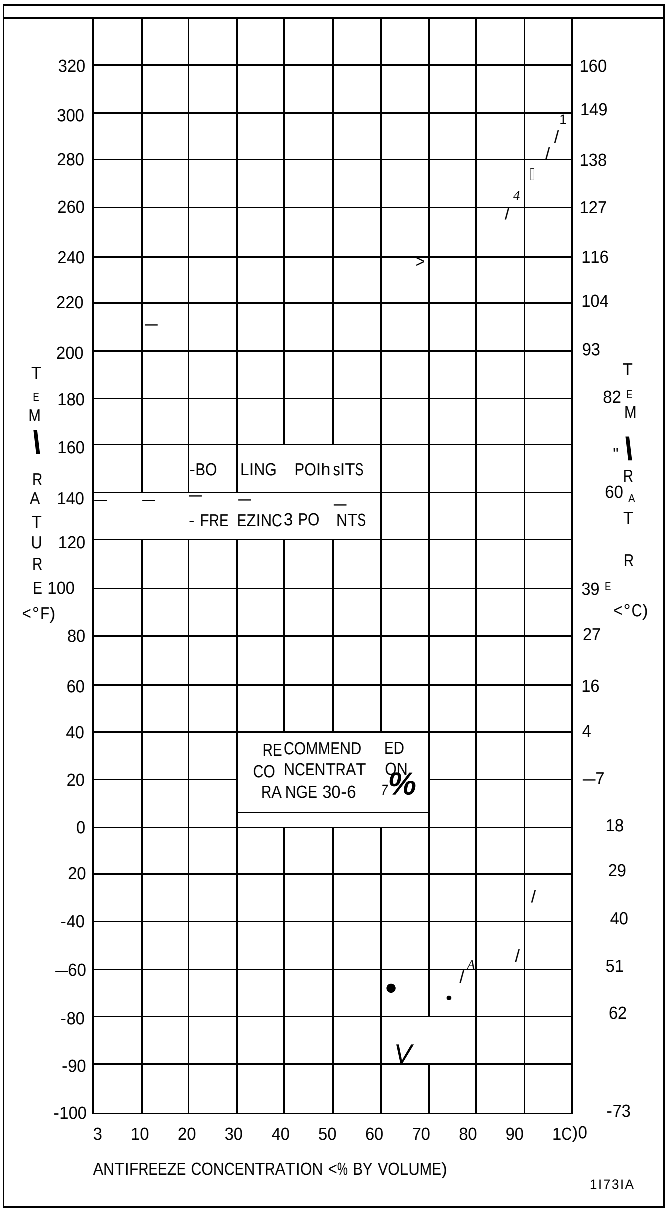

Fig. 2 - Coolant Freezing and Boiling Temperatures vs. Antifreeze Concentration (Sea Level)

ANTIFREEZE

When freeze protection is required, use an Antifreeze that meets the GM 603 8M formulation, which limits silicate to 0.15% maximum or an equivalent formulation meeting the 0.15% maximum silicate and GM 1899M performance requirements.

Solutions of less than 30% do not provide adequate corrosion protection. Concentrations over 67% adversely affect freeze protection, heat transfer rates and silicate stability. A 50% antifreeze solution is normally used as factory-fill.

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Ethylene glycol base antifreeze is recommended for use in all Detroit Diesel engines. Methyl alcohol base antifreeze is not recommended because of its effect on the non-metallic components of the cooling system and because of its low boiling point. Methoxy propanol base antifreeze is not recommended for use in Detroit Diesel engines due to the presence of fluoroelastomer seals in the cooling system.

Antifreeze solutions should be used year-round to provide freeze protection in the winter, boil-over protection in the summer and a stable environment for seals and hoses in the cooling system of the engine.

The inhibitors in antifreeze solutions should be replenished with a non-chromate corrosion inhibitor supplement when indicated by testing the coolant. Engine coolant should be checked at approximately 500 hour or 20,000 mile intervals.

• A cooling system properly maintained and protected with supplemental corrosion inhibitors can be operated up to two years, 200,000 miles, or 6000 hours, whichever comes first. At this interval the antifreeze should be drained and the cooling system cleaned thoroughly. The cooling system should then be replenished with an ethylene glycol-base antifreeze/water solution in the required concentration (see graph).

NOTICE: Failure to maintain inhibitors at proper levels can result in damage to the cooling system and its related components. Conversely, *overinhibiting antifreeze solutions can cause silicate dropout.* Always follow the supplier's recommendations on inhibitor usage and handling.

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 on the color of the coolant solution 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 a gritty abrasive deposit that can cause 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 minimized by using GM 603 8M formulation antifreeze at the required freeze protection level, corrosion inhibitor supplements as needed to maintain protection and water that meets Detroit Diesel requirements.

GENERAL RECOMMENDATIONS

All Detroit Diesel engines incorporate pressurized cooling systems which permit operation at temperatures higher than non-pressurized systems. It is essential that these systems be kept clean and leak-free, that filler caps and pressure relief mechanisms be correctly installed at all times and that coolant levels be maintained.

Always maintain engine coolant at the proper level. A low coolant level allows the water pump to mix air with the coolant. Air bubbles in the coolant can "insulate" the cylinder walls, preventing normal heat transfer. An abnormally low coolant level can cause the water pump to become "air-bound," a condition in which it works feverishly but pumps nothing. Without proper heat transfer, silicone elastomer head-to-block water hole seals can deteriorate and cylinder components can expand so that pistons rapidly cut through the lubricant on the liner walls. Scuffing and piston seizure may follow.

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

An engine may contain the correct amount of properly inhibited coolant, but still fail to adequately cool the engine. In cases where this occurs, other causes of low coolant flow, either engine or cooling system related, should be investigated.

1. Always use a properly inhibited coolant.
2. Do not use soluble oil.
3. Maintain the prescribed inhibitor strength level by adding inhibitors as needed after testing the coolant.
4. Always follow the manufacturer's recommendations on inhibitor usage and handling.
5. If freeze protection is required, use a solution of water and antifreeze that meets the GM 6038M formulation or an equivalent antifreeze with a 0.15% maximum silicate content that meets GM 1899M performance specifications.
6. Reinhibit antifreeze with a non-chromate inhibitor system.
7. Do not use a chromate inhibitor with antifreeze.
8. Do not use methoxy propanol base antifreeze.

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9. Do not mix ethylene glycol base antifreeze with methoxy propanol base antifreeze in the cooling system.

10. Antifreeze makeup solutions should be mixed at the same concentration as the original coolant.

11. Do not use sealer additives or antifreeze containing sealer additives.

12. Do not use methyl alcohol base antifreeze.

13. Use extreme care when removing the radiator pressure-control cap.

14. Do not add inhibitor supplements to *new* antifreeze solutions, except for the *initial fill* to provide optimum cavitation protection.

15. 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.*

• 16. A cooling system properly maintained and protected with supplemental corrosion inhibitors can be operated up to two years, 200,000 miles, or 6000 hours, whichever comes first. At this interval the antifreeze should be drained and the cooling system cleaned thoroughly.

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SECTION 14

ENGINE TUNE-UP

CONTENTS

ENGINE TUNE-UP PROCEDURES

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanism, governor, etc. should only be required periodically to compensate for normal wear on parts.

The type of governor used depends upon the engine application. Since each governor has different characteristics, the tune-up procedure varies accordingly. The following types of governors are used:

1. Limiting speed mechanical.

2. Variable speed mechanical.

3. Hydraulic.

The mechanical governors are identified by a name plate attached to the governor housing. The letters D.W.-L.S. stamped on the name plate denote a double-weight limiting speed governor. A single-weight variable speed governor name plate is stamped S.W.-V.S.

Normally, when performing a tune-up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if a cylinder head, the governor or injectors have been replaced or overhauled, then certain preliminary adjustments are required before the engine is started.

The preliminary adjustments consist of the first four items in the tune-up sequence. The procedures are the same except that the valve clearance is greater for a cold engine.

If a supplementary governing device, such as the throttle delay mechanism, is used, it must b! disconnected prior to the tune-up. After the governor and injector rack adjustments are completed, the supplementary governing device must be reconnected and adjusted.

To tune-up an engine completely, perform all of the adjustments in the applicable tune-up sequence given below after the engine has reached normal operating temperature. Since the adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

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EXHAUST VALVE CLEARANCE ADJUSTMENT

The correct exhaust valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine.

Insufficient valve clearance can result in loss of compression, misfiring cylinders and, eventually, burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, increased valve face wear and valve lock damage.

Whenever a cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, the valve clearance must first be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm-up period. This will ensure a valve setting that is close enough to the specified clearance to prevent damage to the valves when the engine is started.

The exhaust valve bridges must be adjusted and the adjustment screws locked securely at the time the cylinder head is installed on the engine. The necessary adjustment procedure is outlined in Section 1.2.2.

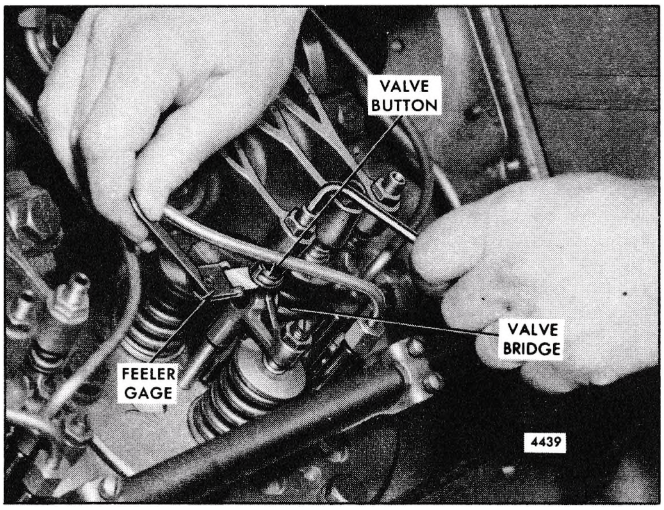

Fig. 1 - Adjusting Valve Clearance

The exhaust valve bridge balance should be checked when a general valve adjustment is performed. After the bridges are balanced, adjust the valve clearance. Do not disturb the exhaust valve bridge adjusting screw.

All of the exhaust valves may be adjusted in firing order sequence during one full revolution of the crankshaft. Refer to the *General Specifications* at the front of the manual for the engine firing order.

Valve Clearance Adjustment (Cold Engine)

1. Remove the loose dirt from the valve rocker covers and remove the covers. Discard the gaskets. Cover all drain cavities in the cylinder block to prevent foreign niaterial from entering*-
2. Place the governor speed control lever in the *idle* position. If a stop lever is provided, secure it in the *stop* position.
3. Rotate the crankshaft, by using either barring tool J 22582 or the starting motor, until the injector follower is fully depressed on the particular cylinder to be adjusted. If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may loosen.

CAUTION: To reduce the risk of persona! injury when barring over or "bumping" the starter while performing an engine tune-up, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.

4. Loosen the exhaust valve adjusting screw locknut on the rocker arm.
5. Place a .016" feeler gage (J 9708-01) between the end of the valve button and the pallet of the valve bridge (Fig. 1). Adjust the valve adjusting screw to obtain a smooth pull on the feeler gage.
6. Remove the feeler gage and tighten the locknut to 30-35 lb-ft (41—-47 N-m) torque.
7. Recheck the clearance and adjust, if necessary.
8. Adjust and check the remaining exhaust valves in the same manner as above.

Valve Clearance Adjustment (Hot Engine)

Maintaining normal engine operating temperature is particularly important when making the fin^l exhaust valve clearance adjustment. If the engine is allowed to cool before setting any of the valves, the clearance when running at full load may become insufficient.

1. With the engine at normal operating temperature (see Section 13.2), recheck the exhaust valve clearance with feeler gage J 9708-01. At this time, if the valve clearance is correct, a .012" feeler gage will pass freely between the valve button and the valve bridge.
2. After the exhaust valve clearance has been adjusted, check the fuel injector timing (Section 14.2).

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FUEL INJECTOR TIMING

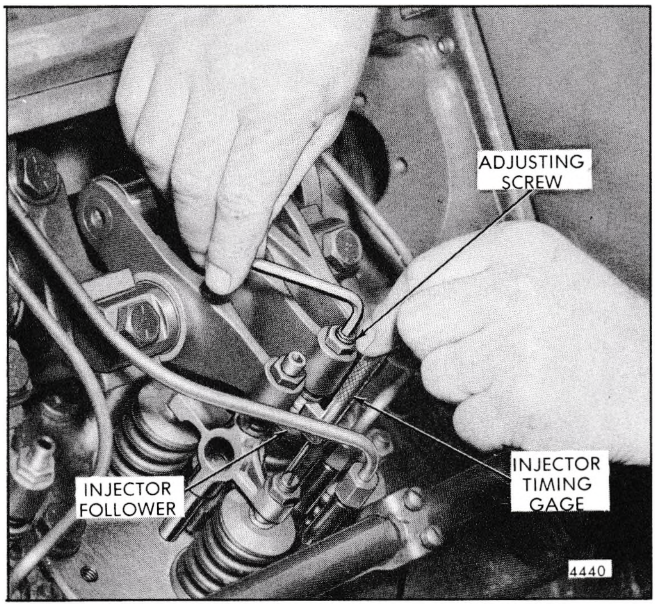

Fig. 1 - Timing Fuel Injector

All of the injectors can be timed in firing order sequence during one full revolution of the crankshaft. Refer to the *General Specifications* at the front of the manual for the firing order.

Time Fuel Injector

After the exhaust valve clearance has been adjusted (Section 14.1), time the fuel injectors as follows:

1. Place the governor speed control lever in the *idle speed* position. If a stop lever is provided, secure it in the *stop* position.

2. Rotate the crankshaft, with the starting motor or with engine barring tool J 22582 (refer to Section 1.2.2), until the exhaust valves are fully depressed on the particular cylinder to be timed.

• CAUTION: To reduce the risk of personal injury when barring over or bumping the starter while performing an engine tune-up, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.

Injector	Timing Gage Dimension	Timing Gage Tool No.	Camshaft Timing
120	2.1750"	J 22412	Std.
130	2.1750"	J 22412	Std.
140	2.1750"	J 22412	Std.
*140	2.2050"	J 24283	Std.
145	2.2050"	J 24283	Std.
150	2.1750"	J 22412	Std.
*150	2.2050"	J 24283	Std.
155	2.2050"	J 24283	Std.
*160	2.2050"	J 24283	Std.
165	2.1750"	J22412	Std.
*165	2.2050"	J 24283	Std.
170	2.1750"	J 22412	Std.
*170	2.2050"	J 24283	Std.
*180	2.2050"	J 24283	Std.
185	2.2050"	J 24283	Std.
*190	2.2050"	J 24283	Std.
*195	2.1850"	J 29116	Std.
230	2.1750"	J 22412	Std.
240	2.1850"	J 29116	Std.
270	2.1850"	J 29116	Std.
290	2.1750"	J 22412	Std.
315	2.1750"	J 22412	Std.
6810	2.1750"	J 22412	Std.
*7110	2.2050"	J 24283	Std.

*Used on turbocharged-intercooled engines.
Notice: Do not mix 190 and 7110 injectors in the same engine. L-6627

• TABLE 1 - INJECTOR TIMING

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

3. Place the small end of the injector timing gage (refer to Table 1 for the correct timing gage) in the hole provided in the top of the injector body with the flat of the gage toward the injector follower (Fig. 1).

Loosen the injector rocker arm adjusting screw locknut.

Turn the adjusting screw to adjust the injector rocker arm until the extended part of the gage will just pass over the top of the injector follower.

Hold the adjusting screw and tighten the locknut to 30-35 lb-ft (41-47 N-m) torquq. Check the adjustment and, if necessary, readjust the rocker arm.

Time the remaining injectors in the same manner as outlined above.

8. If no further engine tune-up is required, install the valve rocker covers, using new gaskets.

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LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers (Fig. 1).

Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14.14.

Adjust Governor Gap

With the engine stopped and at operating temperature, adjust the governor gap, as follows:

1. Back out the buffer screw until it extends approximately 5/8" from the locknut (Fig. 1).
2. Remove the high-speed spring retainer cover.
3. Start the engine.
4. Loosen the locknut and adjust the former idle speed adjusting screw or the current idle speed adjusting set screw to obtain the desired engine idle speed (Fig. 9).

The recommended engine idle speed is 550-750 rpm (current engines) or 450-550 rpm (former engines), but may vary with special engine applications.

5. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker covers. Discard the gaskets.

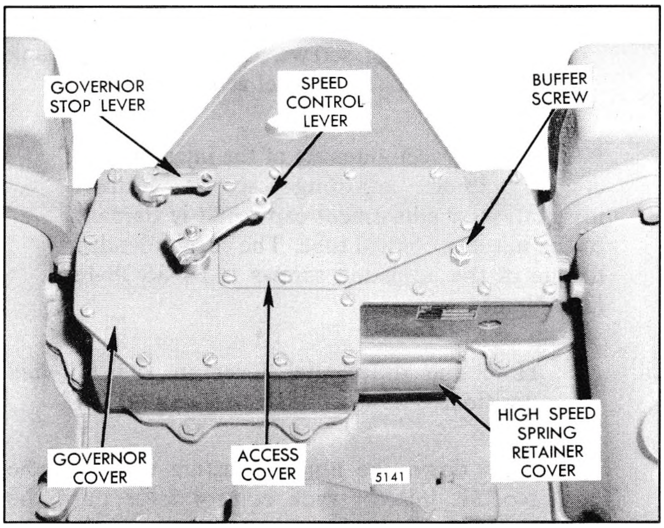

Fig. 1 - Limiting Speed Governor Mounting

6. Start and run the engine between 1,100 and 1,300 rpm by manual operation of the differential lever. Do not overspeed the engine.
7. Check the gap between the low-speed spring cap and the high-speed spring plunger with a feeler gage (Fig. 2). The gap should be .002"-.004". If the gap setting is incorrect, reset the gap adjusting screw.
8. On governors without the starting aid screw, hold the gap adjusting screw and tighten the locknut.
9. Recheck the gap with the engine operating between 1,100 and 1,300 rpm and readjust, if necessary.

Current governors include a starting aid screw threaded into the governor gap adjusting screw. A locknut is not required as both screws incorporate a nylon patch in lieu of locknuts.

10. Stop the engine.
11. If a starting aid screw is used, adjust it after the injector rack control levers are positioned.

Position Injector Rack Control Levers

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Properly positioned injector rack control levers (with the engine at full load) will result in the following:

1. Speed control lever at the *full-fuel* position.

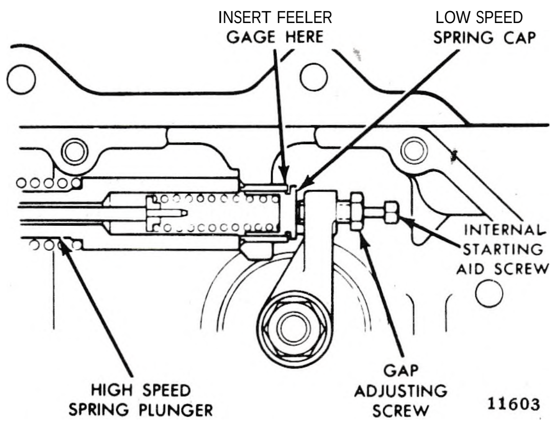

Fig. 2 - Governor Gap Adjustment

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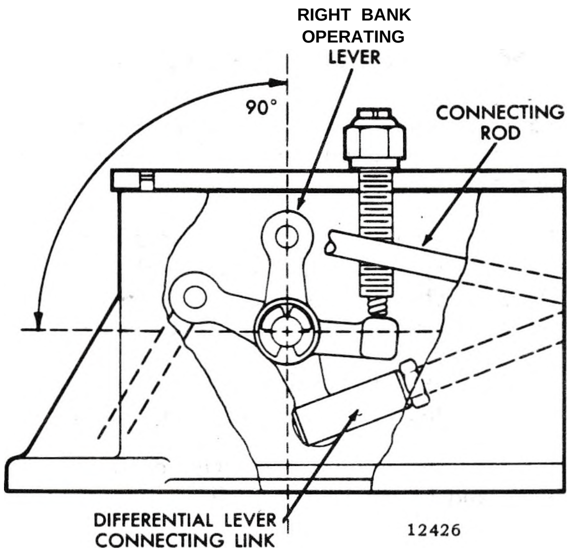

Fig. 3 - Operating Lever in Position (Current Governor)

2. Governor low-speed gap closed.

3. Fligh-speed spring plunger on the seat in the governor control housing.

4. Injector fuel control racks in the *full-fuel* position.

The letters “R” and “L” indicate the injector location in the right or left cylinder bank as viewed from the rear of the engine. The cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 1L and No. 1R injector rack control levers first to establish a guide for adjusting the remaining injector rack control levers.

The injectors incorporate an “injector rack stop”. The stop limits the travel of the injector rack and has been preset at the factory. *Under no circumstances should the injector stop setting be altered.*

1. Adjust the current idle speed adjusting set screw or the former idle speed adjusting screw until 1/2" of the threads (12-14 threads) project from the locknut when the nut is against the high-speed spring plunger. A false full-fuel rack setting may result if the idle speed adjusting screw is not backed out, as noted above.

2. Clean and remove the valve rocker covers. Discard the gaskets.

3. Loosen all of the inner and outer injector rack control lever adjusting screws or adjusting screws and locknuts. Be sure all of the injector rack control levers are free on the injector control tubes.

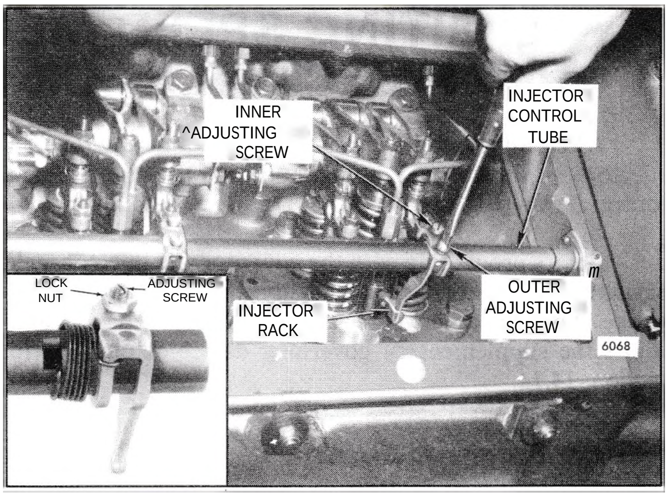

Fig. 4 - Positioning No. 1 Injector Rack Control Lever

4. **On current governors,** position the right bank operating lever (Fig. 3) with the arm that carries the connecting rod in the vertical position. Then, set the No. 1R and No. 1L injector rack control levers, as follows:

Two Screw Assembly (Former)

a. With the fuel rod on the left bank injector control tube disconnected and the fuel rod on the right bank injector control tube connected, turn down the outer adjusting screw (Fig. 4) of the No. 1R injector control lever until the ball-end of the lever is just snug against the injector rack (with the rack in the *no-fuel* position).

b. Turn down the inner adjusting screw until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws. Connect the left bank injector control tube fuel rod.

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NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24—36 **lb-in** (3-4 N-m).

c. Hold the differential lever in the *full-fuel* position.

d. Turn down the inner adjusting screw in the No. 1L injector rack control lever until the ball-end of the lever is just snug against the injector rack.

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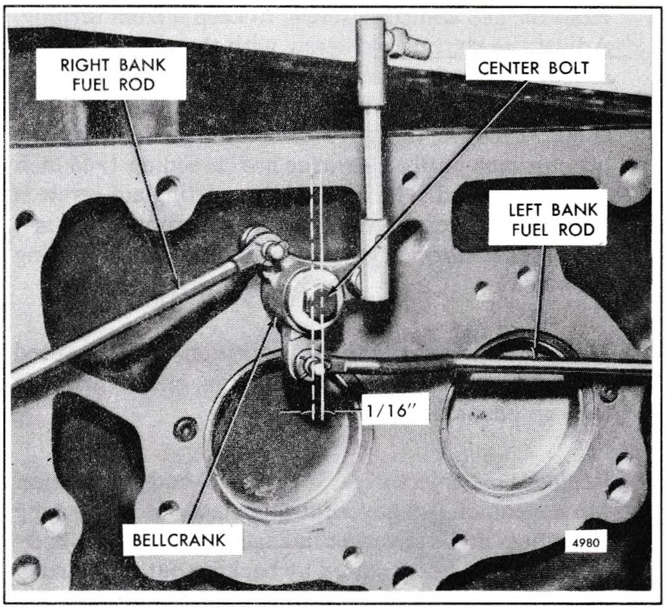

Fig. 5 - Bellcrank in Position (Former Governor)

e. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws.

One Screw and Locknut Assembly (Current)

a. With the fuel rod on the left bank injector control tube disconnected and the fuel rod on the right bank injector control tube connected, tighten the adjusting screw (Fig. 4) of the No. 1R injector control lever until the ball-end of the lever is just snug against the injector rack (with the rack in the *no-fuel* position).

b. Securely lock the adjusting screw locknut. Connect the left bank injector control tube fuel rod.

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24—36 **lb-in** (3-4 N-m).

c. Hold the differential lever in the *full-fuel* position.

d. Tighten the adjusting screw in the No. 1L injector rack control lever until the ball-end of the lever is just snug against the injector rack.

e. Securely lock the adjusting screw locknut.

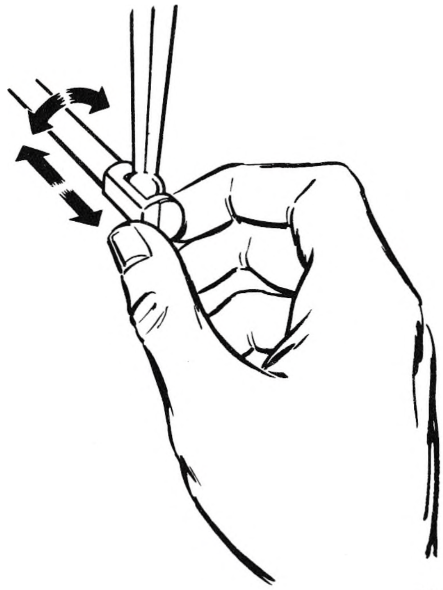

Fig. 6 - Checking Movement of Injector Control Rack

5. **On former governors,** position the elongated pin in the bellcrank — the pin which carries the left bank fuel rod — so that it lines up with the center bolt of the bellcrank from vertical to approximately 1/16" off center toward the right cylinder bank (Fig. 5).

a. With the fuel rod on the right bank injector control tube disconnected and the fuel rod on the left bank injector control tube connected, turn down the outer adjusting screw (Fig. 4) of the No. 1L injector control lever until the ball-end of the lever is just snug against the injector rack (with the rack in the *no-fuel* position).

b. Turn down the inner adjusting screw until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws. Install the right bank fuel rod.

c. Hold the terminal lever in the *full-fuel* position. Refer to Section 2.7.1. *

d. Turn down the inner adjusting screw in the No. 1R injector control tube lever until the ball—and of the lever is just snug against the injector rack.

e. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws to 24—36 **lb-in** (3-4 N • m) torque.

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6. Balance the No. IRandNo. 1L injector control rack levers by grasping each rack (No. IRandNo. 1L — one at a time) with the thumb and index finger and, using a push-pull rotating motion (Fig. 6) , note the amount of movement of each injector control rack. If the movement is the same between the No. 1R and No. 1L injector control racks, the two levers are in adjustment. On former governors, if the movement is not the same between the two racks, loosen either the inner or outer adjusting screw of the No. 1R control rack lever and adjust the lever until the two racks are balanced. On current governors, loosen either the inner or outer adjusting screw (Two Screw Assembly) or turn the adjusting screw (One Screw and Locknut Assembly) of the No. 1L control rack lever and adjust the lever until the two racks are balanced.

Never alter the setting of the No. 1L injector rack control lever (former governors) or the No. 1R injector rack control lever (current governors) after they have been initially set.

7. Set the remaining control rack levers in the same manner as described in Steps “4d” or “5d”, using the No. 1R and No. 1L injector rack control levers as a guide for each respective bank. Use a spring of suitable length to fasten each control tube in the *full-fuel* position.

Once the No. 1 injector rack control lever on each bank has been set (either former or current governors), do not alter their settings. All further adjustments are made on the remaining injector control racks.

Adjust Starting Aid Screw

The starting aid screw (Figs. 2 and 7) is threaded into the governor gap adjusting screw. This screw is adjusted to position the injector racks at less than full fuel when the governor speed control lever is in the *idle* position.

The reduced fuel makes starting easier and reduces the amount of smoke on start-up.

The effectiveness of the starting aid screw will be eliminated if the speed control lever is advanced to wide open throttle during starting.

After the normal governor *running* gap of .0015" has been set and the injector racks positioned, adjust the starting aid screw, as follows:

1. Provide a cutaway cover to adjust the starting aid screw (Fig. 7).

2. With the engine *stopped*, place the governor stop lever in the *run* position and move the speed control lever to the *idle* position.

3. Hold the gap adjusting screw, to keep it from turning. Adjust the starting aid screw with the proper gage to obtain the required clearance between the shoulder on the No. 1L injector rack clevis and the injector body (Fig. 7). Move the gage back and forth along the injector rack until a clearance not exceeding 1/64 inch (.016") is noted. The head of the starting aid screw is against the governor wall (current governor) or against the bracket (former governor equipped with starting aid screw).

4. Move the stop lever to the *stop* position, with the speed control lever still in the *idle* position, and return it to the *run* position.

5. Recheck the injector rack clevis-to-body clearance. Movement of the governor stop lever is to take-up clearances in the governor linkage. The clevis-to-body clearance can be increased by backing out the starting aid screw or reduced by turning it farther into the gap adjusting screw.

CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no-fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever.
An overspeeding engine can result in engine damage which could cause personal injury.

6. Start the engine and recheck the *running* gap (.0015") and, if necessary, reset it. Then, stop the engine.

Adjust Differential Lever Connecting Link

If necessary, pre-adjust the differential * lever connecting link by positioning the ball joints on the link to have 6 13/16" between the inside ends of the ball joints, thus obtaining an approximate link setting.

1. Remove cutaway governor cover.

2. Use a new gasket and install the governor cover (access cover removed).

3. Back off the idle speed adjusting screw.

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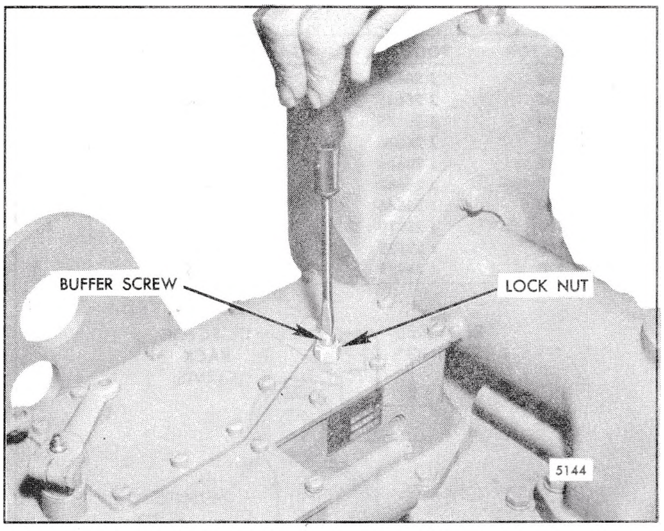

Fig. 10 – Adjusting Buffer Screw

Adjust Maximum No-Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine option label, the maximum no-load speed may be set, as follows:

Be sure the buffer screw projects 5/8" from the locknut to prevent interference while adjusting the maximum no-load speed.

1. Loosen the spring retainer locknut (Fig. 8) and back off the high-speed spring retainer, if necessary, so that a minimum of 3/8" of the threads on the retainer extend beyond the locknut.
2. With the engine running at operating temperature and no load, place the speed control lever in the *maximum* speed position. Turn the high-speed spring retainer until the engine is operating at the recommended no-load speed.
3. Hold the high-speed spring retainer and tighten the locknut.

Adjust Idle Speed

Adjust the engine idle speed, as follows:

1. With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the former idle speed adjusting screw (Fig. 9) or the current idle speed adjusting set screw until the engine is operating at approximately 15 rpm below the recommended idle speed. The recommended idle speed is 550-750 rpm (current engines) or 450-550 rpm (former engines), but may vary with special engine applications.

The increased idle speed of current engines results from the use of lighter low-speed governor weights in the current governor.

It may be necessary to use the buffer screw to eliminate engine roll. Back out the buffer screw, after the engine idle speed is established, to the previous setting (5/8").

2. Hold the current set screw or the former idle speed adjusting screw and tighten the locknut.
3. Install the high-speed spring retainer cover.

Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw, as follows:

1. With the engine running at normal operating temperature, *turn the buffer screw (Fig. 10) IN* so that it contacts the right bank operating lever as lightly as possible and still eliminates engine roll. Do not increase the engine idle speed more than 15 rpm with the buffer screw.
2. Recheck the maximum no-load speed. If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.
3. Hold the buffer screw and tighten the locknut.

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VARIABLE SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device, as outlined in Section 14.14.

Adjust Governor Gap

With the engine stopped and at normal operating temperature, set the governor gap, as follows:

1. Disconnect any linkage attached to the governor stop lever.
2. Back out the buffer screw until it extends approximately 5/8" from the locknut.
3. Clean and remove the governor cover (Fig. 1), including the stop lever bracket (current engines). Discard the gasket.
4. Place the speed control lever in the *maximum speed* position.
5. Insert a .006" feeler gage between the spring plunger and the plunger guide (Fig. 2). If required, loosen the locknut and turn the adjusting screw until a slight drag is noted on the feeler gage.
6. Hold the adjusting screw and tighten the locknut. Check the gap again and, if necessary, readjust.

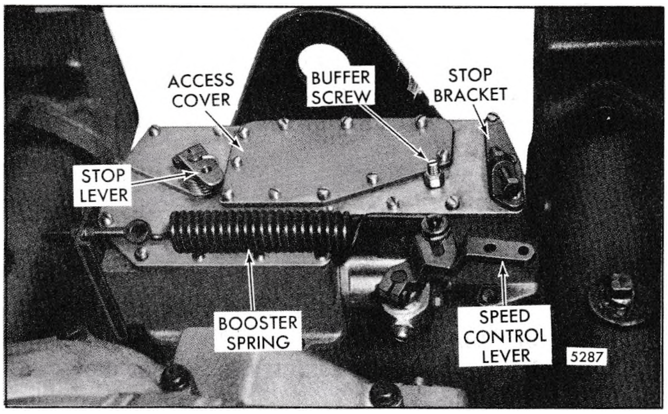

Fig. 1 - Variable Speed Governor Mounting

Position Injector Rack Control Levers

The position of the injector control rack levers must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Properly positioned injector rack control levers, with the engine at full load, will result in the following:

1. Speed control lever at the *full-fuel* position.
2. Stop lever in the *run* position.
3. Variable speed spring plunger within .005" to .007" of its seat in the governor control housing.
4. Injector fuel control racks in the *full-fuel* position.

The letters "R" and "L" indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. The cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 1L and No. 1R injector rack control levers first to establish a guide for adjusting the remaining control levers.

The injectors incorporate an "injector rack stop". The stop limits the travel of the injector rack and has been preset at the factory. *Under no circumstances should the injector stop setting be altered.* Refer to Section 2.1,1.

1. Clean and remove the valve rocker covers and discard the gaskets.

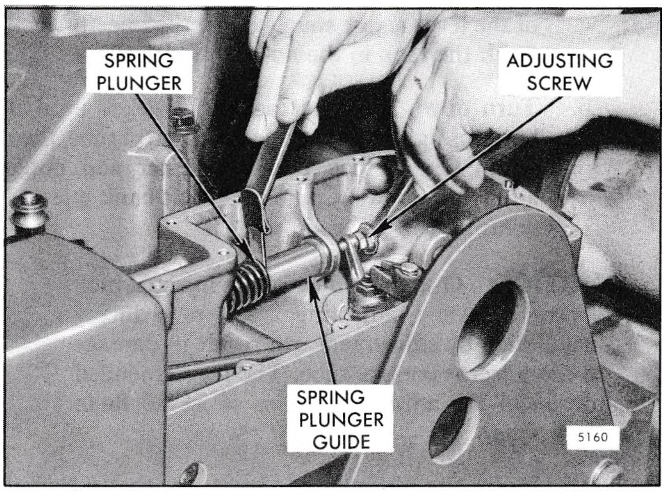

Fig. 2 – Adjusting Governor Gap

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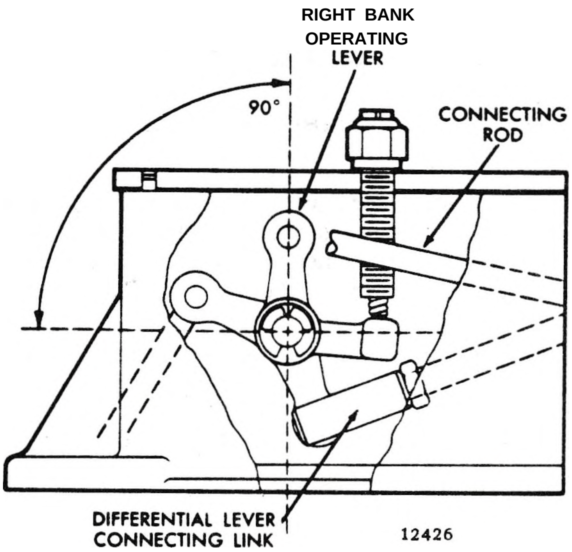

Fig. 3 - Operating Lever in Position (Current)

2. Loosen all of the inner and outer injector rack control lever adjusting screws or adjusting screws and locknuts. Be sure all of the injector rack control levers are free on the injector control tubes.

3. **On current governors,** with the governor cover removed, position the right bank operating lever (Fig. 3) with the arm that carries the connecting rod in the vertical position. Then set the No. 1R injector control lever in the *no-fuel* position, as follows:

Two Screw Assembly

a. With the fuel rod on the left bank injector control tube disconnected and the fuel rod on the right bank injector control tube connected, turn down the outer adjusting screw (Fig. 4) of the No. 1R injector control lever until the ball-end of the lever is just snug against the injector rack (with the rack in the *no-fuel* position).

b. Turn down the inner adjusting screw until it bottoms lightly on the injector control tube, then alternately tighten both the inner and outer adjusting screws. Connect the left bank injector control tube fuel rod.

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **lb-in** (3-4 N-m).

c. Hold the differential lever in the *full-fuel* position.

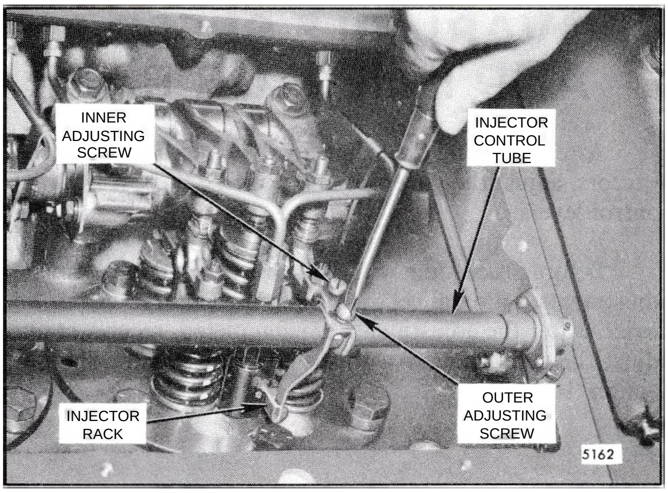

Fig. 4 - Positioning No. 1 Injector Rack Control Lever

d. Turn down the inner adjusting screw in the No. 1L injector control lever until the ball-end of the lever is just snug against the injector rack.

e. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws.

One Screw and Locknut Assembly

a. With the fuel rod on the left bank injector control tube disconnected and the fuel rod on the right bank injector control tube connected, tighten the adjusting screw (Fig. 4) of the No. 1R injector control lever until the ball-end of the lever is just snug against the injector rack (with the rack in the *no-fuel* position).

b. Securely lock the adjusting screw locknut. Connect the left bank injector control tube fuel rod.

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 **lb-in** (3-4 N-m).

c. Hold the differential lever in the *full-fuel* position.

d. Tighten the adjusting screw in the No. 1L injector control lever until the ball-end of the lever is just snug against the injector rack.

e. Securely lock the adjusting screw locknut.

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4. On former governors, position the elongated pin in the bellcrank (the pin which carries the left bank fuel rod) so that it lines up with the center bolt of the bellcrank from vertical to approximately 1/16" off center toward the right cylinder bank (Fig. 5). Then, set the No. 1L injector in the *no-fuel* position, as follows (Fig. 4):

   a. With the fuel rod on the right bank injector control tube disconnected and the fuel rod on the left bank injector control tube connected, turn down the outer adjusting screw on the No. 1L injector control lever until the ball-end of the lever is just snug against the injector rack.

   b. Turn down the inner adjusting screw until it bottoms lightly on the injector control tube, then alternately tighten both the inner and outer adjusting screws. Connect the right bank fuel rod.

   c. Hold the terminal lever (Fig. 3, Section 2.7.2) in the *full-fuel* position.

   d. Turn down the inner adjusting screw in the No. 1R injector control lever until the ball-end of the lever is just snug against the injector rack.

   e. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws to 24-36 lb-in (3-4 N • m) torque.

5. Balance the No. IRandNo. 1L injector rack control levers by grasping each rack (No. 1R and 1L — one at a time) with the thumb and index finger and, using a push-pull rotating motion (Fig. 6), note the amount of movement of each injector control rack. If the movement is the same between the No. 1R and No. 1L injector control racks, the two control levers are in adjustment. On former governors, if the movement is not the same between the two racks, loosen either the inner or outer adjusting screw of the No. 1R rack control lever and adjust the lever until the two racks are balanced. On current governors, loosen either the inner or outer adjusting screw (Two Screw Assembly) or turn the adjusting screw (One Screw and Locknut Assembly) of the No. 1L control rack lever and adjust the lever until the two racks are balanced. Never alter the setting of the No. 1L injector rack control lever (former governors) or the No. 1R injector rack control lever (current governors) after they have been initally set.

6. Set the remaining rack control levers in the same manner as described in Steps “3d” or “4d”, using the No. IRandNo. 1L injector rack control levers as a guide for each respective bank. Use a spring of suitable length and fasten each control tube in the *full-fuel* position.

Once the No. 1 injector rack control lever on each bank has been set (either former or current governors), do not alter their settings. All further adjustments are made on the remaining control racks.

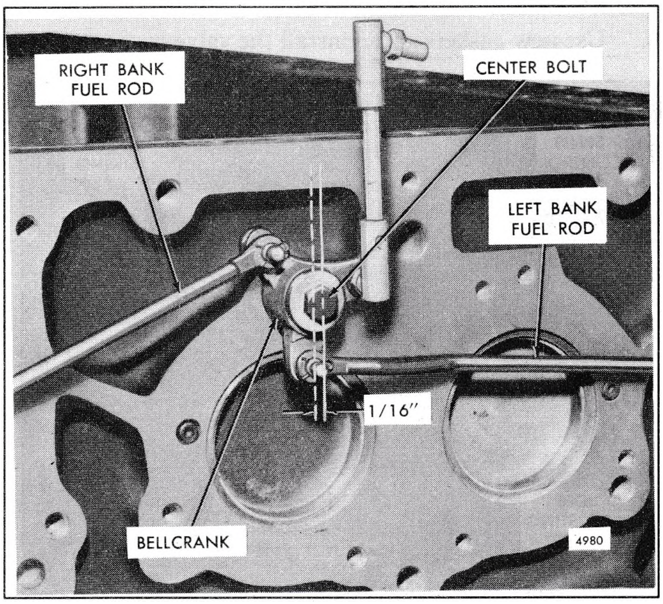

Fig. 5 - Bellcrank in Position (Former)

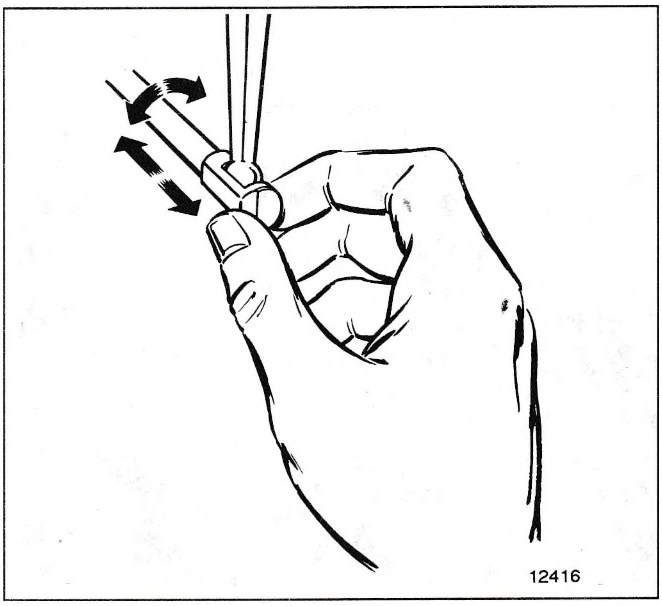

Fig. 6 - Checking Movement of Injector Control Rack

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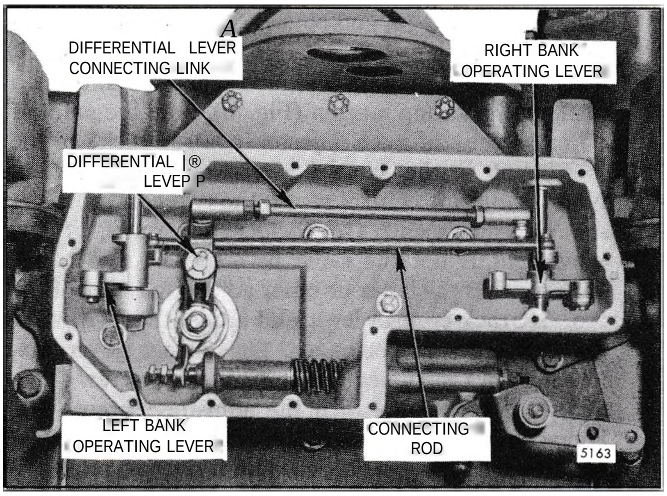

Fig. 7 - Variable Speed Governor with Cover Removed (Solid Connecting Link)

Adjust Differential Lever Connecting Link

If necessary, pre-adjust the differential lever connecting links by positioning the ball joints on the link to have 6 13/16" between the inner ends of the ball joints, thus obtaining an approximate link setting.

1. Use a new gasket and install the governor cover (access cover removed) and speed control stop bracket. Be sure the stop bolt is turned in far enough so that it will not interfere with the *full-speed* position of the speed control lever. The stop lever spring must be disconnected.

2. On governors with a connecting yield (spring) link (Fig. 8), hold the stop lever in its *run* position and move the speed control lever to full speed. Then, adjust the link until it just starts to compress. Lock the link in this position. On governors with a solid connecting link, hold the stop lever in the *run* position and adjust the differential lever connecting link (Fig. 7) until there is no step-up in effort when moving to the *run* position. Lock the link in this position.

   A short yield link will cause a low power condition because the injector rack cannot reach the *full-speed* position. A long yeild link will result in not being able to reach the *no-speed* position with the stop lever.

3. Check the differential lever connecting link, to see that all governor and injector control linkage is tight, by moving the stop lever to the *run* position and noticing a very slight return of the stop lever when released.

4. Check for any bind in the governor-to-control tube linkage by moving the linkage through its full range of travel with one hand on the stop lever and the other hand on one of the control tube levers.

5. With the speed control lever at the *maximum speed* position and the stop lever in the *run* position, be sure that all of the injector rack control levers are in the *full-fuel* position.

CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no-fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

6. Use new gaskets and reinstall the valve rocker covers.

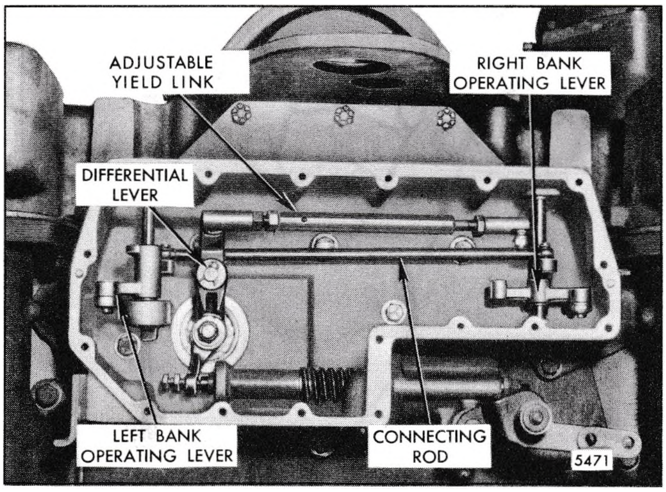

Fig. 8 - Variable Speed Governor with Cover Removed (Adjustable Yield Link)

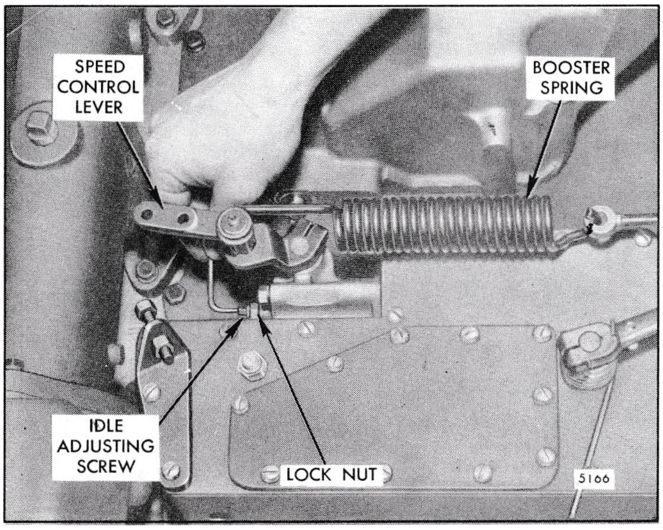

Fig. 9 - Adjusting Idle Speed

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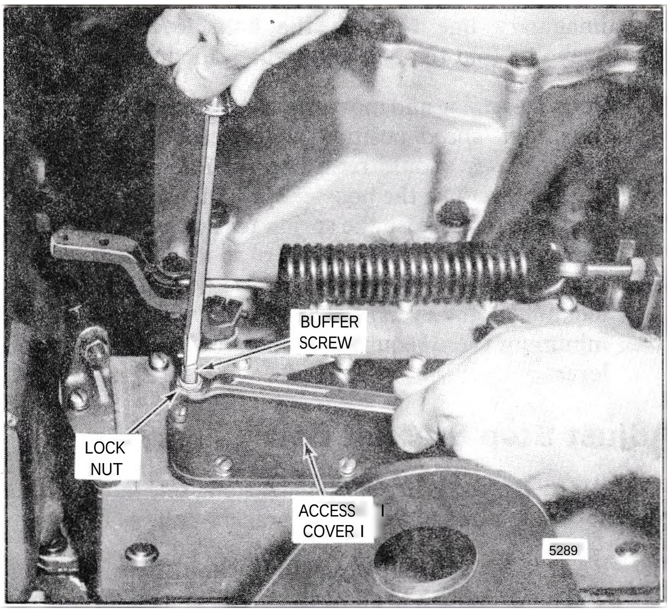


Fig. 10 - Adjusting Buffer Screw

Adjust Maximum No-Load Speed

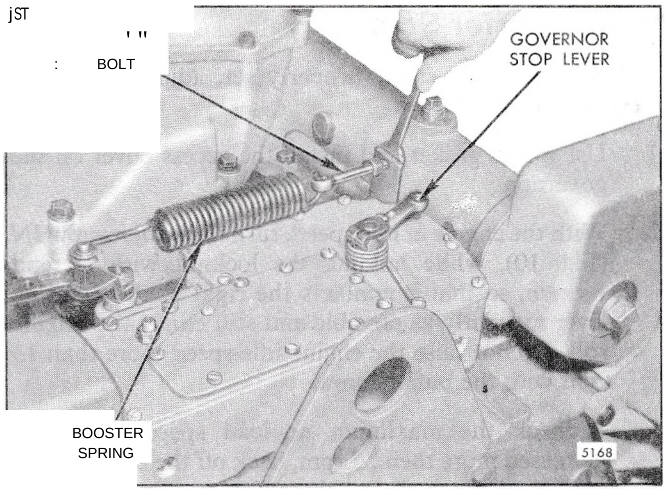
Disconnect any linkage (throttle actuator) attached to the speed control lever.

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine option plate, the maximum no-load speed may be set, as follows:

Be sure the buffer screw projects 5/8" from the locknut to prevent interference while adjusting the maximum no-load speed.

Use an accurate tachometer and determine the maximum no-load speed of the engine. Then, make the following adjustments, if required:

1. Disconnect the booster spring.
2. Remove the two bolts and withdraw the variable speed spring housing from the governor housing.
3. Set the recommended maximum no-load speed by adding or removing shims, as required.
4. Install the variable speed spring housing and recheck the maximum no-load speed.



S-ig. 1 1 - Adjusting Booster Spring

Adjust idle **Speed**

With the maximum no-load speed properly adjusted, adjust the idle speed, as follows:

1. Place the stop lever in the *run* position and the speed control lever in the *idle* position.
2. With the engine running at normal operating temperature, loosen the locknut and turn the idle speed adjusting screw (Fig. 9) until the engine is operating at approximately 15 rpm below the recommended idle speed. The recommended idle speed is 550 rpm, but may vary with special engine applications.
3. Hold the idle speed adjusting screw and tighten the locknut.

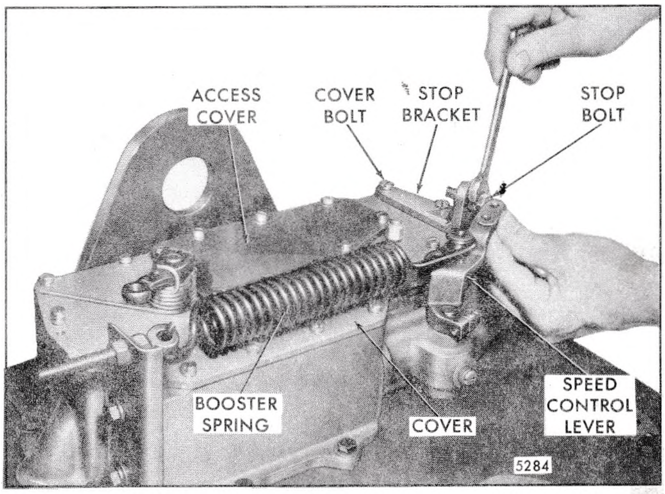


Fig. 1 2 - Adjusting Stop Bracket Bolt

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Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw, as follows:

1. Use a new gasket and install the access cover on the governor.
2. With the engine at idle speed, *turn the buffer screw IN* (Fig. 10), while holding the locknut with an end wrench, so that it contacts the right bank operating lever as lightly as possible and still eliminates engine roll. Do not raise the engine idle speed more than 15 rpm with the buffer screw.
3. Recheck the maximum no-load speed. If it has increased more then 25 rpm, back off the buffer screw until the increase is less then 25 rpm.
4. Hold the buffer screw and tighten the locknut.

Adjust Booster Spring

With the engine idle speed set, adjust the booster spring, as follows:

1. Move the speed control lever to the *idle* speed position.
2. Refer to Fig. 11 and loosen the booster spring retaining nut on the speed control lever. Loosen the locknuts on the bolt at the opposite end of the spring.
3. Move the spring retaining bolt in the slot of the speed control lever until the center of the bolt is on or slightly over center (toward the *idle speed* position) of an imaginary line through the bolt, lever shaft and eyebolt. Hold the bolt and tighten the locknut.
4. Start the engine and move the speed control lever to the *maximum speed* position and release it. The speed control lever should return to the *idle* position. If it does not, reduce the booster spring tension; if it does, continue to increase the spring tension until the point is reached that it will not return to idle. Then, reduce the tension until it does return to idle and tighten the locknut on the eyebolt. This setting will result in the minimum force required to operate the speed control lever.

Adjust Stop Bracket Bolt

With the booster spring tension set, adjust the governor speed control lever stop bracket bolt, as follows:

1. Refer to Fig. 12 and loosen the locknut. Turn the stop bolt in far enough to allow the speed control lever to be held in its *full-speed* position.
2. Operate the engine at the maximum no-load speed.
3. Hold the speed control lever in the *full-speed* position. Set the stop bolt so that the head of the stop bolt moves the speed control lever towards idle until the no-load speed is reduced 5 to 10 rpm.
4. Tighten the locknut to hold the setting.

If the governor is equipped with a starting aid system, adjust the components as outlined in Section 14.14.

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HYDRAULIC GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

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Fig. 1 - Throttle Delay Yield Link Assembly

Adjust the governor and the injector rack control levers after adjusting the exhaust valve clearance and timing the injectors.

Effective with engines built April 1, 1980 a throttle delay yield link assembly (Fig. 1) replaces the vertical link assembly, for those applications where a throttle delay mechanism is used in conjunction with the hydraulic governor (refer to Section 14.14).

Adjust Governor Linkage And Position Injector Rack Control Levers

1. Clean and remove the valve rocker cover from each cylinder bank.

2. Loosen all of the inner and outer injector rack control lever adjusting screws or loosen all of the adjusting screws and locknuts. Be sure all of the control levers are free on the injector control tubes.

3. Disconnect the yield link assembly or vertical link assembly from the governor operating lever (Fig. 2).

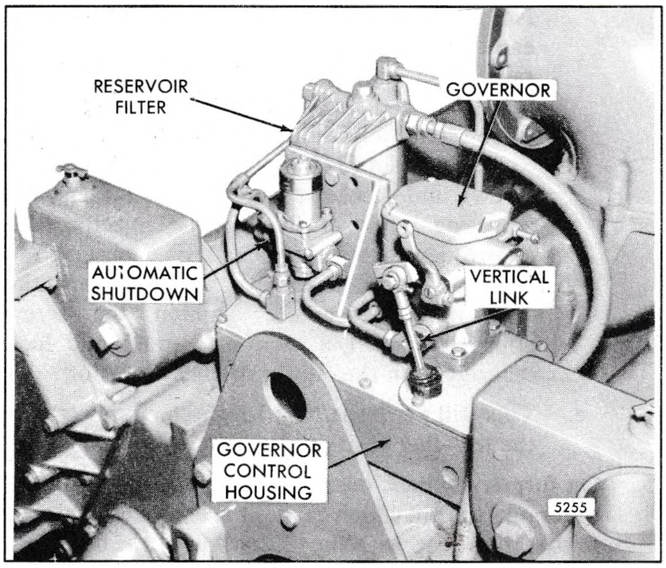

Fig. 2 - Hydraulic Governor Mounting and Linkage (Current with Vertical Link)

Do not remove the lever. On current engines, remove the small cover from the governor control housing and disconnect the yield link or vertical link from the left-bank operating lever (Fig. 3). On former engines, remove the small cover on top of the engine front cover and disconnect the vertical link from the bellcrank lever (Fig. 4).

The letters R and L indicate the injector location in the right or left cylinder bank, as viewed from the rear of the engine. The cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 1L and No. 1R injector rack control levers first to establish a guide for adjusting the remaining levers.

The injectors incorporate an injector rack stop. The stop limits the travel of the injector rack and has been preset at the factory. *Under no circumstances should the injector stop setting be altered.*

4. **On current engines,** position the linkage setting gage J 23475-01 as shown in Fig. 5. This will place the left-bank operating lever in the correct *no-fuel* position.

The former gage J 23475 can only be used with current engines that have 120, 130, 140 or 150mm fuel injectors. Gage J 23475-01 can be used on engines equipped with any size fuel injector.

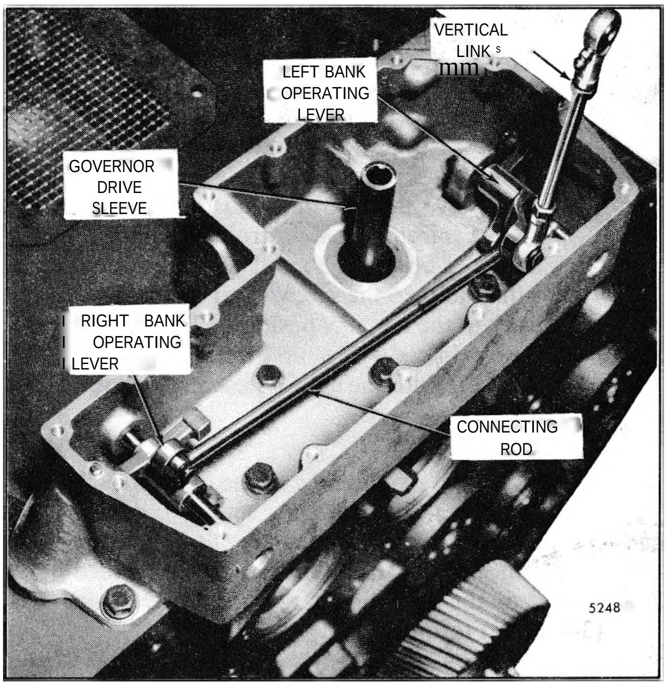

Fig. 3 - Governor Control Housing and Linkage (Current with Vertical Link)

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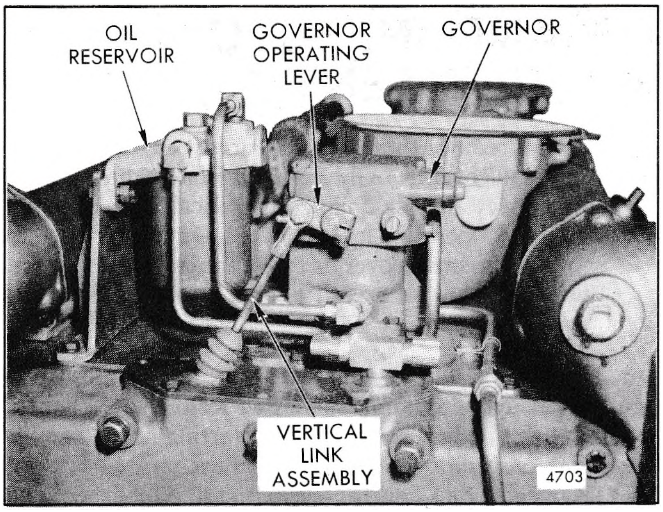

Fig. 4 - Hydraulic Governor Mounting and Linkage (Former with Vertical Link))

At the *no-fuel* position, the distance from the top of the main cover on the governor control housing to the center line of the bolt hole on the arm of the left-bank operating lever (which carries the yield link or vertical link) is 1.80".

Maintain the above dimension and set the No. 1L and No. 1R injector rack control levers, as follows:

a. With the fuel rod on the right-bank injector control tube removed and the fuel rod on the left-bank injector control tube installed, turn down the outer adjusting screw (two screw assembly) of the No. 1L injector rack control lever until the ball end of the lever is just snug against the injector rack (with the rack in the *no-fuel* position). Turn down the inner adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both adjusting screws. On the one screw and locknut assembly, tighten the adjusting screw of the No. 1 injector rack control lever until the rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted (with the rack in the *no- fuel* position). Tighten the screw approximately 1/8 of a turn more and lock securely_with the adjusting screw locknut. Refer to Fig. 6,

NOTICE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24—36 **lb-in** (3—4 N-m) torque.

Remove the gage and install the right-banl{ injector control tube fuel rod.

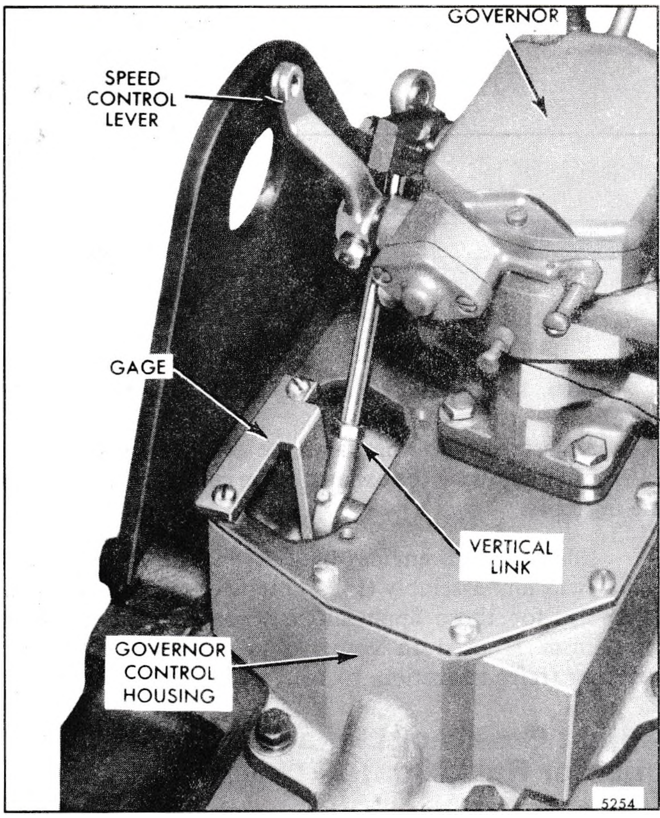

Fig. 5 Positioning of Current Governor Operating Link with Vertical Link (Gage J 23475-01)

c. Move the No. 1 left bank injector control lever to the full-fuel position by depressing the arm of the left-bank operating lever (which carries the yield link or vertical link).

Hold this position and turn dow-n the inner adjusting screw (two screw assembly) in the No. 1R injector rack control lever until the ball end of the lever is just snug against the injector rack. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both adjusting screws to 24-36 **lb-in** (3—4 N-m) torque/On the one' screw and locknut assembly, ‘ tighten the adjusting screw of the No. 1R injector rack control lever until the rack clevis is observed to roll up or an increase in effort to {urn the screwdriver is noted. Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut.

e. This will place the No. 1 right-bank injector in the *full-fuel* position. '

5. **On former engines,** position the elongated pin in the bellcrank (the pin which carries the left-bank fuel rod) so that it lines up with the center bolt of the bellcrank ^ from vertical to approximately 1/16" off center toward the right cylinder bank (Fig. 7).

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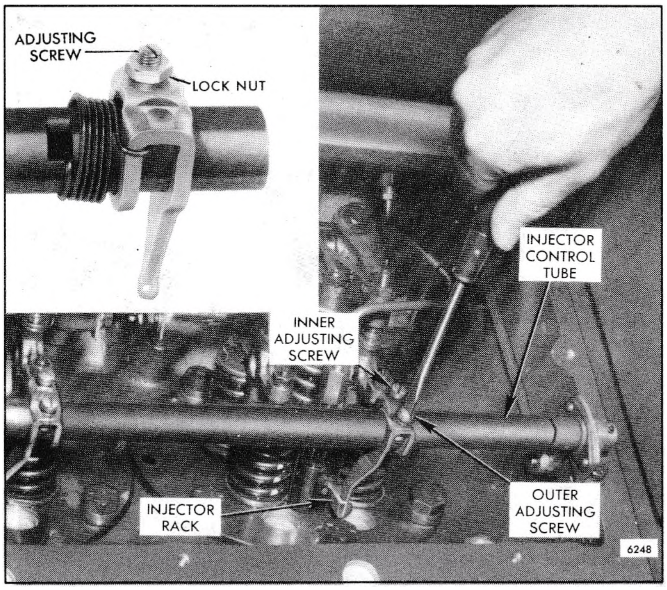


Fig. 6 - Positioning the No. 1 Injector Rack Control Lever

a. With the fuel rod on the right-bank injector control tube removed and the fuel rod on the left-bank injector control tube installed, turn down the outer adjusting screw of the No. 1L injector rack control lever until the ball end of the lever is just snug against the injector rack (with the rack in the no-fuel position). Refer to Fig- 5.

b. Turn down the inner adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both adjusting screws. The recommended torque of the adjusting screws is 24-36 lb-in (3-4 N-m) torque.

c. Install the right-bank fuel rod.

d. Hold the bellcrank lever in the full-fuel position and turn down the inner adjusting screw in the No. 1R injector rack control lever until the ball end of the lever is just snug against the injector rack.

e. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then alternately tighten both adjusting screws to 24-36 lb-in (3^4 N-m) torque.

6. Check the adjustment of the No. 1L and No. 1R injector control racks in the full-fuel position by moving the left-bank operating lever (current) or the bellcrank (fofmer) and determine if the adjustment between the two injector control racks is equal.

a. Grasp each injector control rack (one at a time) with the thumb and index finger and, using a push-pull rotating motion, note the amount of movement of each lever within the rack opening

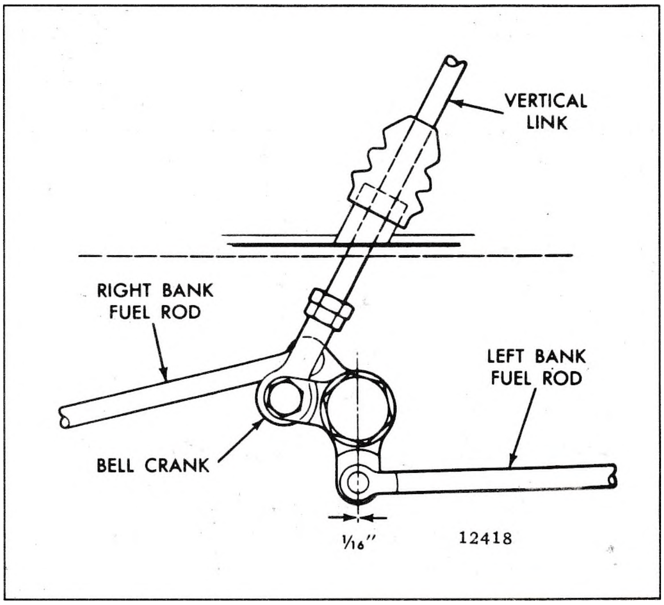
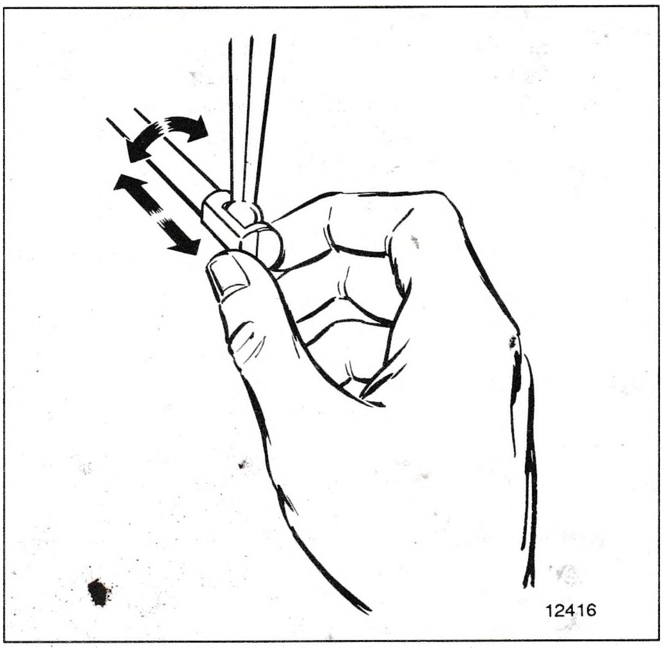


Fig. 7 - Positioning of the Bellcrank (Former Engines)

(Fig. 8). If the movement is the same for both, the two rack control levers are in adjustment. If the movement is not the same, loosen either the inner or outer adjusting screw (two screw assembly) of the No. 1R rack control lever and adjust the lever until both, the No. 1L and No. 1R levers are balanced, On the one screw and locknut assembly, loosen the locknut on the ; No. 1R rack control lever and turn the r adjusting screw clockwise or counterclockwise until both the No. 1L and No. 1R levers are balanced. Tighten the locknut securely.



8 – Checking Injector Rack Movement

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Governor	Distance Between Center Lines of End Bearing Bolt Holes
SG (current)	7.00" (Approx.)
PSG	7.44" (Approx.)
SG (former)	8.88" (Approx.)

TABLE 1

Never alter the setting of the No. 1L injector rack control lever after it has once been set.

7. Set the remaining injector rack control levers, using he No. 1R and No. 1L control levers as a guide for each respective cylinder bank. Use a spring of suitable length to hold each injector control tube in the full-fuel position.

8. Remove the governor cover.

9. Adjust the load limit screw to obtain a distance of 2" from the outside face of the boss on the governor subcap to the end of the screw.

10. Position the governor operating lever on the shaft toward the left cylinder bank (on *current* engines) or toward the right cylinder bank (on *former* engines/so that the center of the bolt hole is approximately 5/16" above a horizontal line through the shaft (with the lever in the no-fuel position).

11. Refer to Table 1 and adjust the length of the yield link or vertical link so that the bolt holes of the levers and the rod end bearings are lined up with the governor lever and the injector racks are in the no-fuel position. Always install the throttle delay yield link of a Series 149 hydraulic governor with the yieldable end inside the governor control housing (Fig. 1). Positioned in this manner the yieldable end is protected from abrasives which can accelerate shaft wear.

12. Replace the two bolts in the levers and tighten the bolts.

Adjust Load Limit

With the injector rack control levers properly adjusted, set the load limit as follows:

1. With the governor cover removed and the load limit screw locknut loosened, move the governor operating lever toward the full-fuel position until the injector racks just reach the full-fuel position. Do not overstress the linkage.

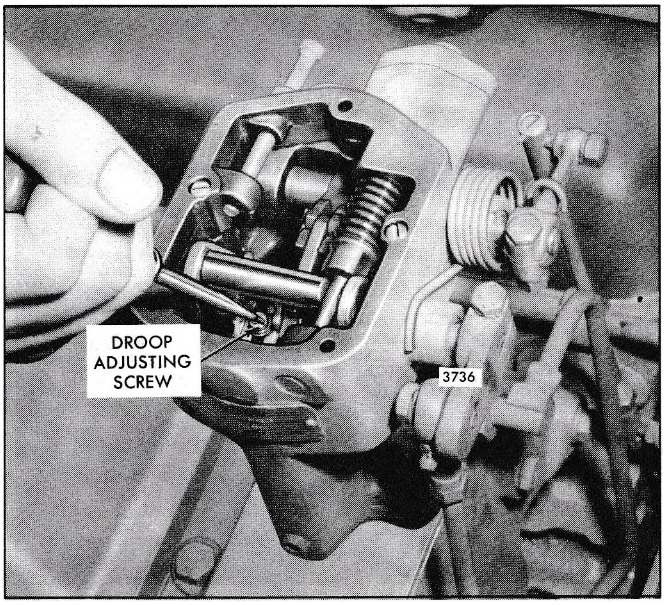

Fig. 9 - Adjusting Speed Droop

2. Turn the load limit adjusting screw inward until the injector racks just loosen on the ball ends of the control levers.

3. Release the governor operating lever and hold the load limit screw while tightening the locknut. Install the governor cover.

Adjust Governor Speed Droop

INTERNAL DROOP ADJUSTMENT

The purpose of adjusting the speed droop is to establish a definite engine speed at no load with a given speed at rated full load. The governor speed droop is set at the factory and further adjustment should be unnecessary.

However, if the governor has been overhauled, the speed droop must be readjusted.

If a full-rated load can be established on the engine, and the fuel rods, injector rack control levers and the load limit have been adjusted, set the speed droop as follows: *

1. Start the engine and run it at approximately one-half the rated no-load speed until the lubricating oil temperature stabilizes. When the engine lubricating oil is cold, the governor regulation may be erratic. Regulation will become increasingly stable as the temperature of the oil increases.

2. Stop the engine and remove the governor cover.

3. Loosen the locknut and back off the maximum speed adjusting screw approximately 5/8".

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4. Loosen the droop adjusting screw. Move the droop adjusting bracket so that the screw is midway between the ends of the slot in the bracket. Tighten the screw (Fig. 9).

5. With the throttle in the *run* position, adjust the engine speed until the engine is operating at 3% to 5% above the recommended full-load speed. Use an accurate tachometer to determine the engine speed.

6. Apply the full-rated load on the engine and readjust the engine speed to the correct full-load speed.

7. Remove the load and note the engine speed after the speed stabilizes under no load. If the speed droop is correct, the engine speed will be approximately 3% to *5%* higher than the full-load speed.

8. If the speed droop is too high, stop the engine, loosen the droop adjusting screw and move the adjusting bracket *in* toward the center of the governor. Tighten the adjusting screw. If the speed droop is too low, move the bracket *out*, away from the center of the governor.

The speed droop in governors which control engines driving generators in parallel must be identical, otherwise the electrical load will not be equally divided.

Adjust the speed droop bracket in each governor to obtain the desired variation between engine no-load and full-load speeds. The recommended speed droop for generator sets operating in parallel is 50 rpm (2-1/2 cycles) for units operating at 1000 or 1200 rpm and 75 rpm (2-1/2 cycles) for units operating at 1500 or 1800 rpm (Table 2).

However, this droop recommendation may be varied to suit the individual application.

EXTERNAL DROOP CONTROL

Some PSG type governors are equipped with an external adjustable droop control. This permits the speed droop to be adjusted without removing the governor cover. With this feature, a unit can be paralleled with another unit that is operating at constant frequency (zero droop). The incoming unit must have its droop bracket set in the maximum position while it is being paralleled and while operating in parallel. When it is desired to stop the unit operating at constant frequency, shift the load to the incoming unit and move the governor droop bracket to zero droop.

Fu 11 Load	No-Load
50 cycles 1000 rpm	52.5 cycles 1050 rpm
60 cycles 1200 rpm	62.5 cycles 1250 rpm
50 cycles 1500 rpm	52.5 cycles 1575 rpm
60 cycles 1800 rpm	62.5 cycles 1875 rpm

TABLE 2

Then, adjust the outgoing unit to maximum droop, remove it from the line and stop the engine. The incoming unit will now be carrying the load and operating at constant frequency (zero droop).

Adjust the governor speed droop as follows:

1. Start the engine and run it at approximately one-half of the rated full-load speed until the lubricating oil temperature stabilizes.

2. Remove the load from the engine.

3. Back off the compensation needle valve to release any air that may be trapped in the system. Turn the needle valve in slowly to reduce governor “hunting”. The correct needle valve setting will be between 1/8 and 1/2 turn open.

4. Back out the maximum droop setting screw.

5. Loosen the droop adjusting knob and move the slide all the way toward the minimum adjusting screw. Then tighten the knob.

6. Loosen the locknut on the maximum speed adjusting screw and turn the screw out until 5/8" of the threads are exposed.

7. With the engine operating at the recommended full-load speed, apply the full-rated load and recheck the engine speed If required, readjust the engine to full-load speed.

8. Remove the load and note the engine speech If the zero droop setting is correct, the engine speed will remain constant. If the engine speed is higher, loosen the droop adjusting knob and set the slider to a reduced droop position.

9. When the desired minimum droop setting is reached, turn the minimum droop setting screw inward until it contacts the droop linkage within the governor. This will be felt by a step-up of resistance while turning the adjusting screw. Lock the adjusting screw in this position.

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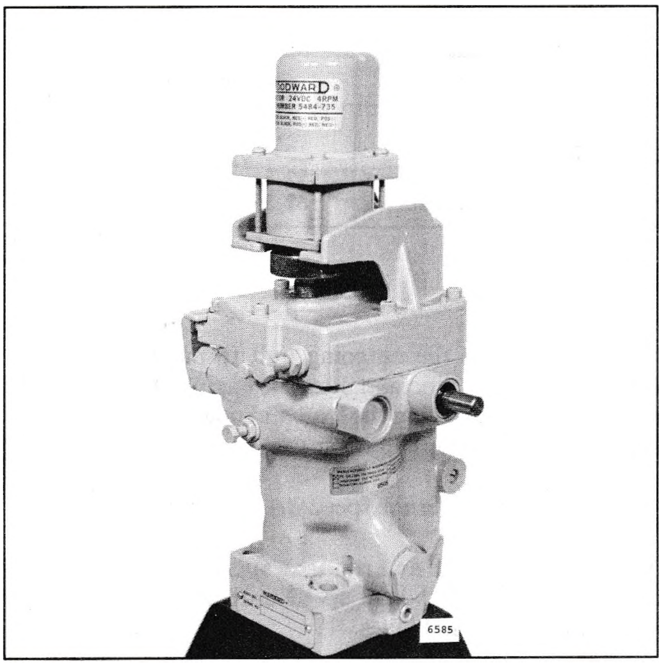

Fig. 10 - Typical Synchronizing Motor Mounting

10. Loosen the droop adjusting knob and slide the droop bracket in a direction to increase the droop. Perform Steps 7 and 8 to check the droop until the desired maximum speed droop is attained.

11. When the desired maximum droop setting is reached, loosen the locknut and turn the maximum droop setting screw inward until it contacts the droop slider arm. Lock the adjusting screw in this position.

12. Recheck the minimum and maximum droop setting as outlined in Steps 7 and 8 and adjust the adjustment screws, if necessary, until the correct settings are obtained.

Adjust Maximum No-Load Speed

With the speed droop properly adjusted, set the maximum no-load speed as follows:

1. With the engine operating.at no load, adjust the speed until the engine is operating at approximately 8% higher than the rated full-load speed.

2. Turn the maximum speed adjusting screw in until the screw contacts the throttle linkage internally, limiting the maximum speed of the engine at 8% above the rated full-load speed (Fig. 10).

3. Hold the screw and tighten the locknut.

Governors With Synchronizing Motor

Some hydraulic governors are equipped with a reversible electric synchronizing motor mounted on the governor cover (Fig. 10).

The adjustments are the same as on a governor without a motor. However, the governor cover and motor assembly must be removed when setting the engine speed droop (except on the PSG type governor equipped with an external droop adjustment). The cover and motor must be reinstalled to check the speed droop.

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HYDRAULIC **GOVERNOR**
(Pneumatically **Operated Isochronous Type)**

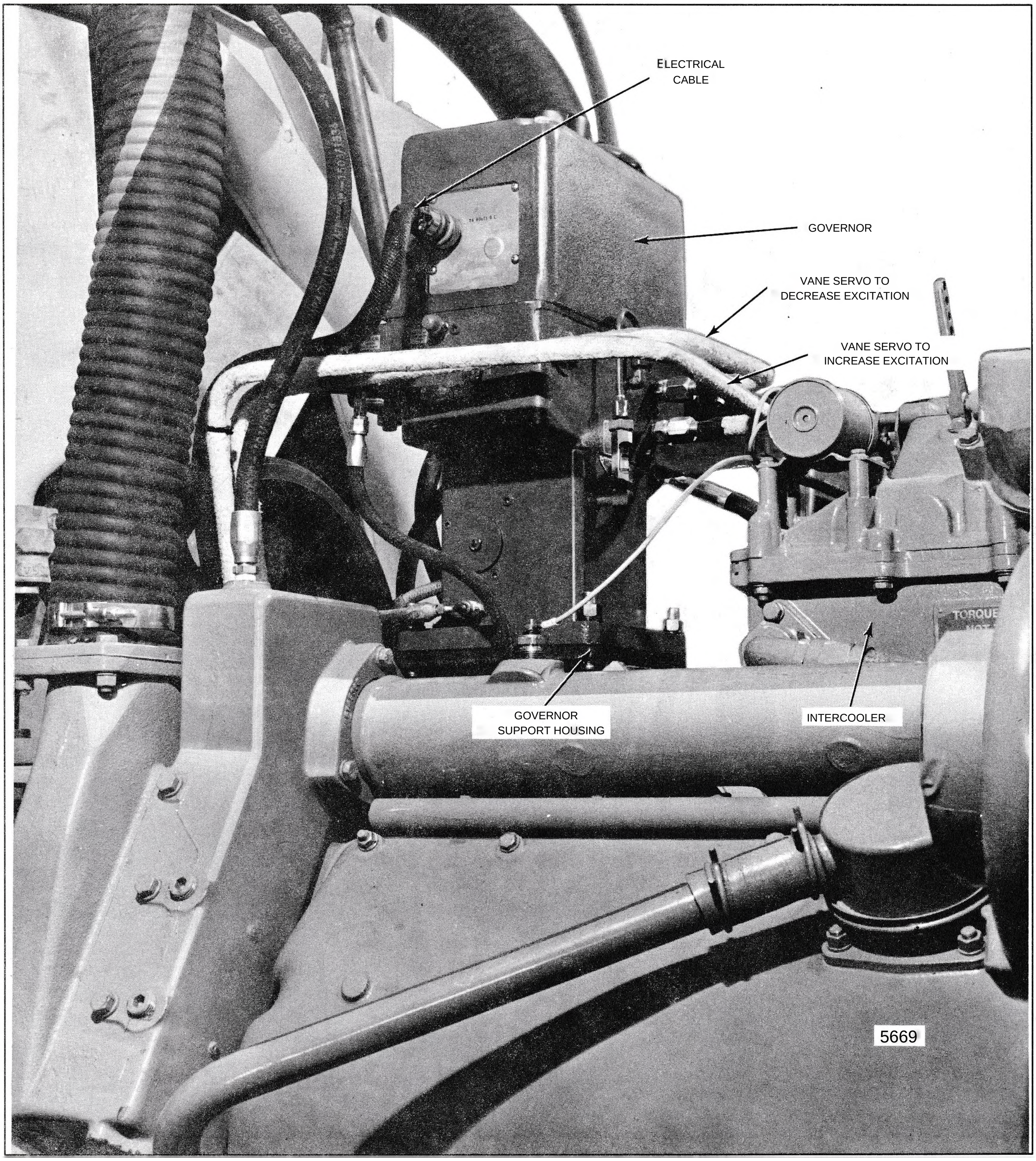

Fig. 1 - Hydraulic Governor Mounting

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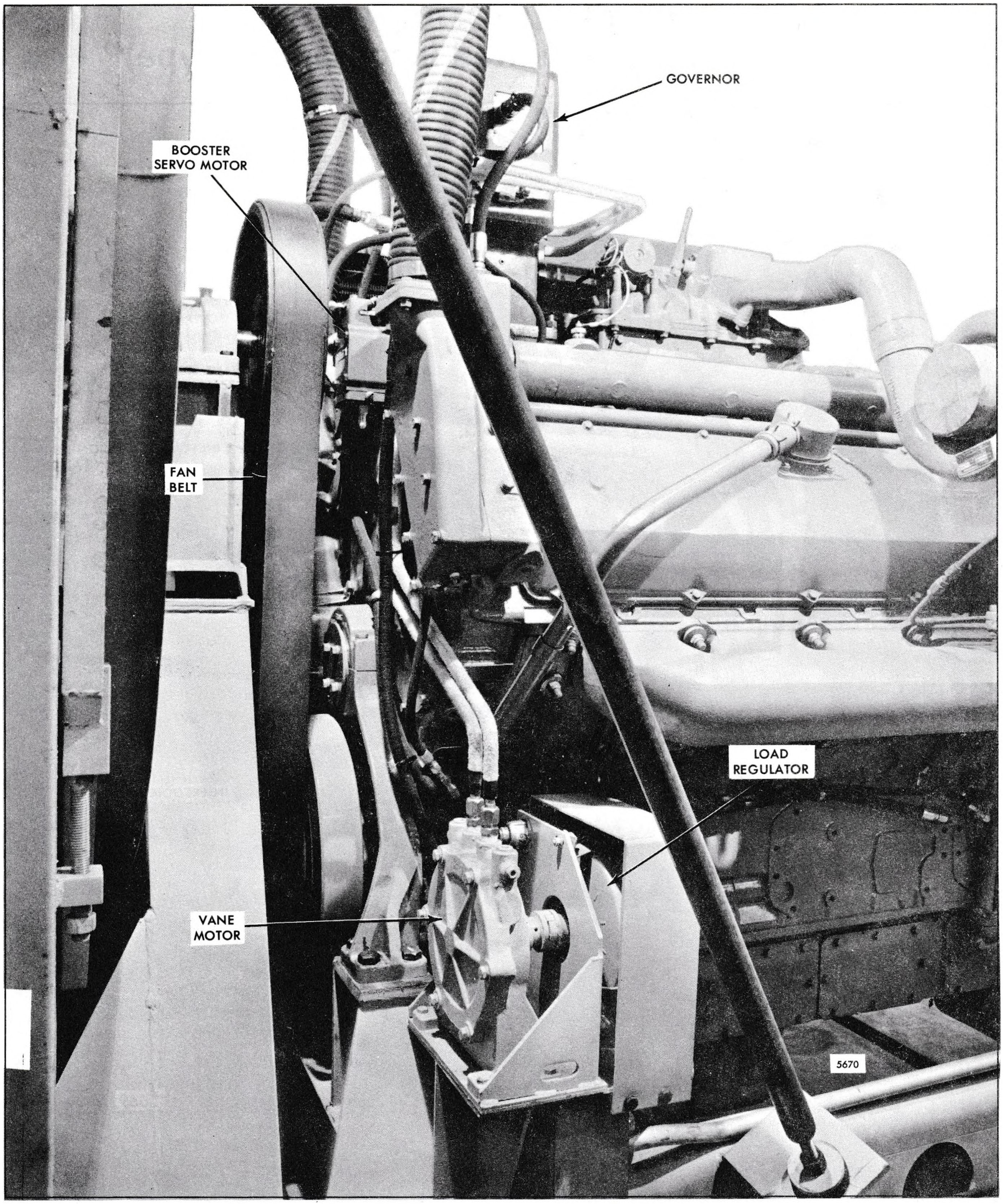

Fig. 2 - Location of Governor, Booster Servomotor, Vane Motor and Load Regulator

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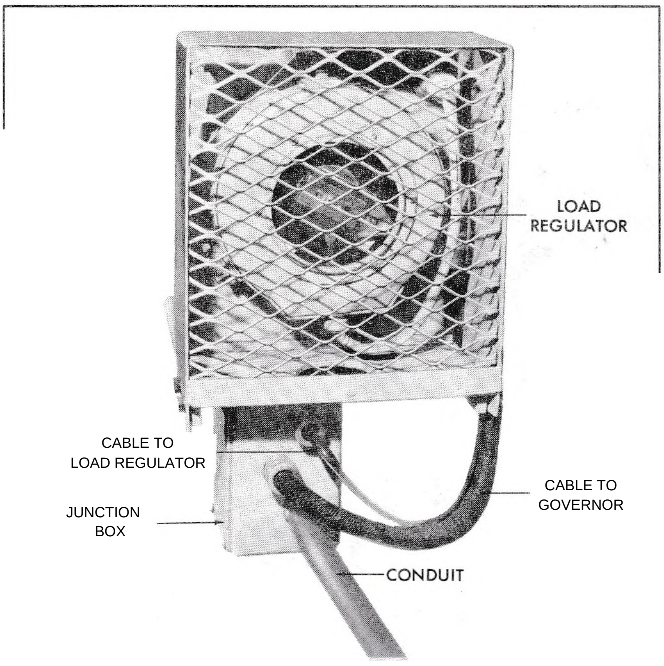

Fig. 3 - Load Regulator

The governor is located at the front of the engine and is mounted on a governor support housing (Fig. 1) which encloses the governor operating linkage. The governor is driven by one of the blower rotors through a bevel gear and shaft arrangement and actuates the injector control tubes through a linkage. For location of the governor, booster, vane motor and load regulator, refer to Fig. 2.

The governor is a pneumatically operated isochronous hydraulic type. The isochronous feature of the governor is its ability for any given speed setting to maintain a constant engine speed, regardless of changing load conditions on the engine. Speed change of the engine is accomplished by varying the air pressure to the governor, by means of the foot throttle in the operator's cab, from zero psi for an idle speed of 800 rpm to 60 psi (414 kPa) for a full governed engine speed of 1900 rpm.

Operation

With most governor applications, the primary purpose of the governor is to control fuel flow to the engine in sufficient amounts to maintain a certain set speed under varying load conditions. In this application, while the primary objective is still to maintain a desired engine speed, a secondary function is to maintain a constant horsepower output of the engine for each specific speed setting (throttle position).

Thus, for each setting of the throttle, not only is there a constant engine speed desired, but also a fixed pre-determined setting of fuel to the engine. To accurately

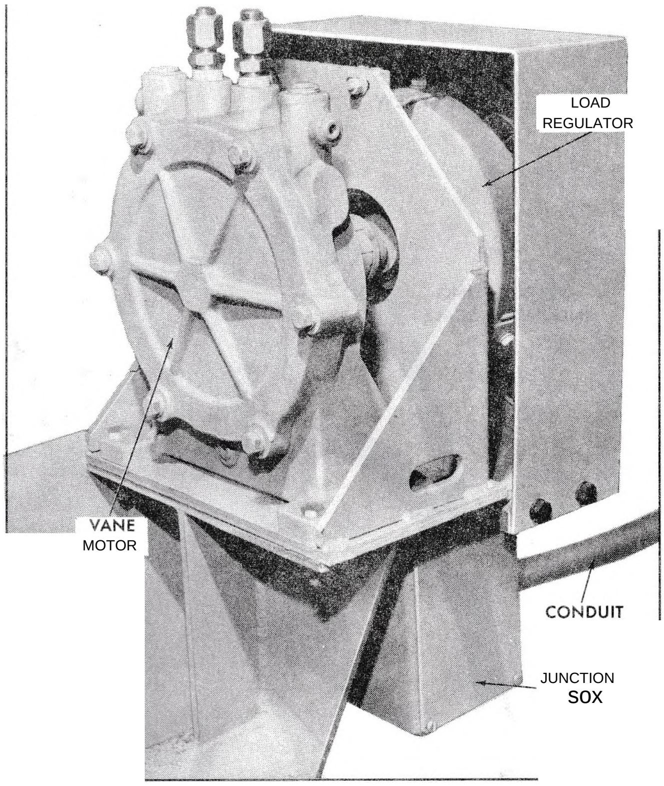

Fig. 4 - Hydrauiicaliy Operated Vane Motor

establish these conditions, it is necessary to control the load on the engine at a constant value for each throttle position.

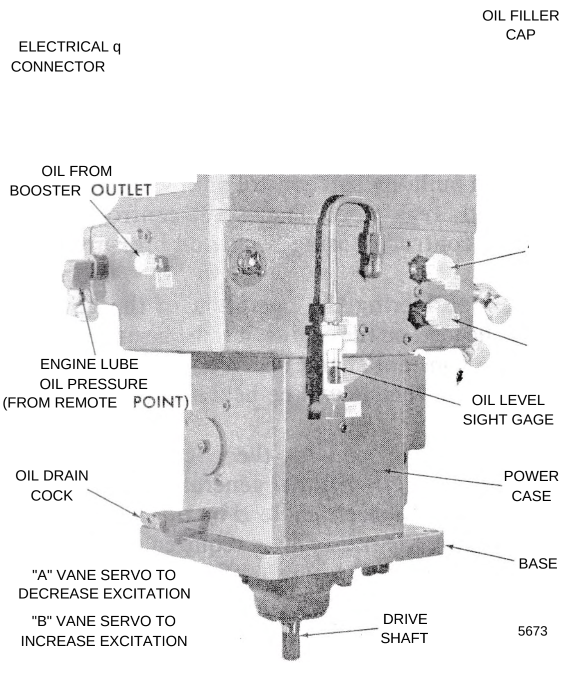

Fig. 5 - Pneumatic-Hydraulic Governor

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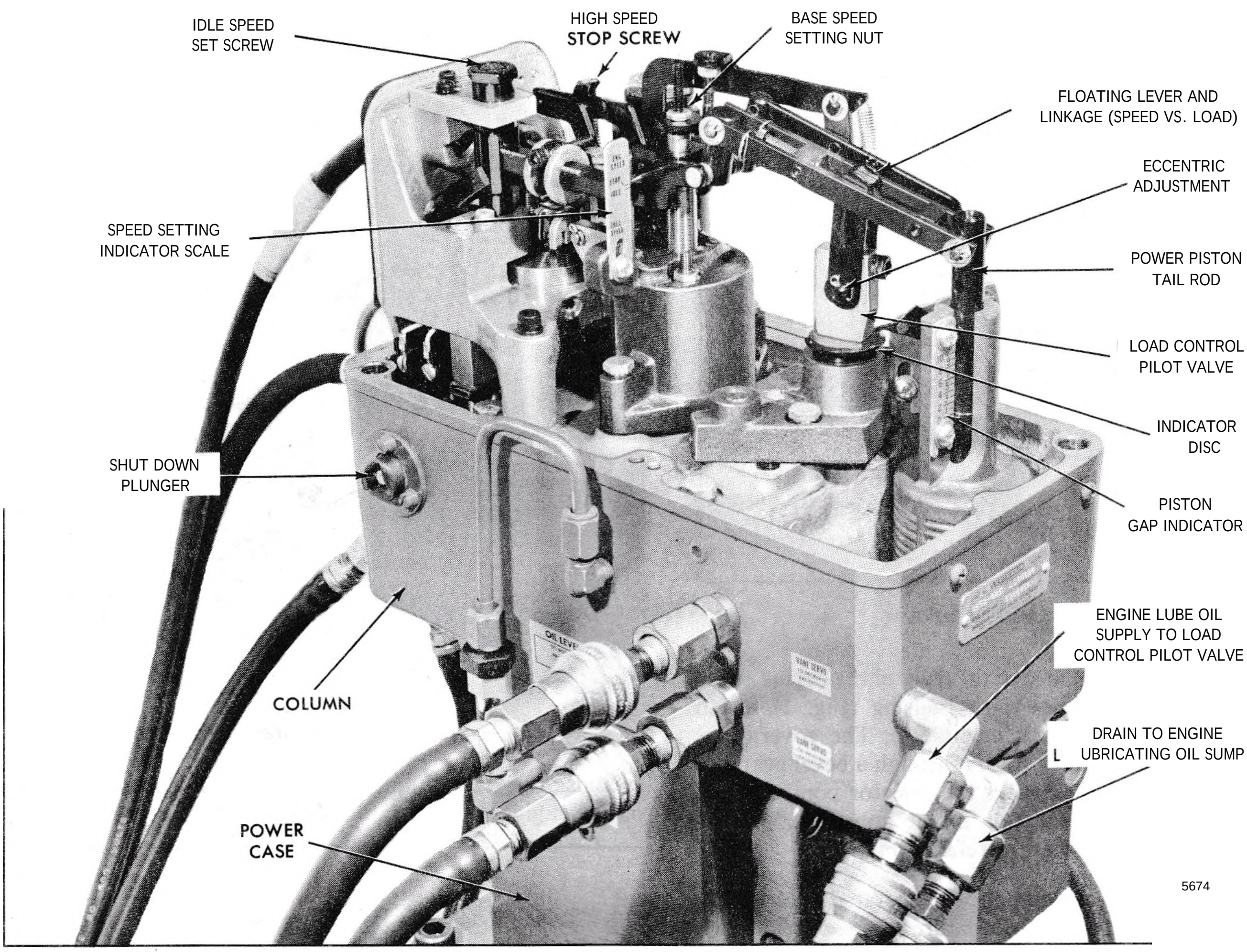

Fig. 6 - Governor Interior

This is achieved by means of a load control system consisting of a built-in load control pilot valve and a remote mounted load regulator. The load control system is hydraulically controlled using engine oil pressure (Fig. 3).

While considering the operation of the governor in controlling the load on the engine, it must be understood that maintaining a constant engine speed does not mean that the road speed of the vehicle will be held constant.

Control of the load on the engine is obtained by adjusting the strength of the generator field excitation current whenever the electrical load on the generator varies, and so controlling the horsepower required of the engine by the generator at a constant value for each specific speed setting. The excitation current of the generator is adjusted through the use of a variable resistance in the field excitation circuit, mounted in the load regulator assembly (Fig. 3), and actuated by means of the hydraulically operated vane motor (Fig. 4) which is controlled by the governor load control pilot valve.

The load control linkage in the governor is so arranged that for each speed setting there is only one fuel setting (or horsepower output) at which the load control pilot valve will be centered. A change in speed setting of the governor, or a change in horsepower requirements (load on the generator), will uncenter the load control pilot valve and permit» flow of oil to the vane motor. This in turn will move the vane motor clockwise or counterclockwise, depending upon the flow of oil, and adjust excitation.

The governor has a built-in provision for sensing low engine oil pressure, which is used to operate an alarm system.

A connection is made from a remote point of the engine lubricating system to a low oil pressure switch in the governor (Fig. 5).

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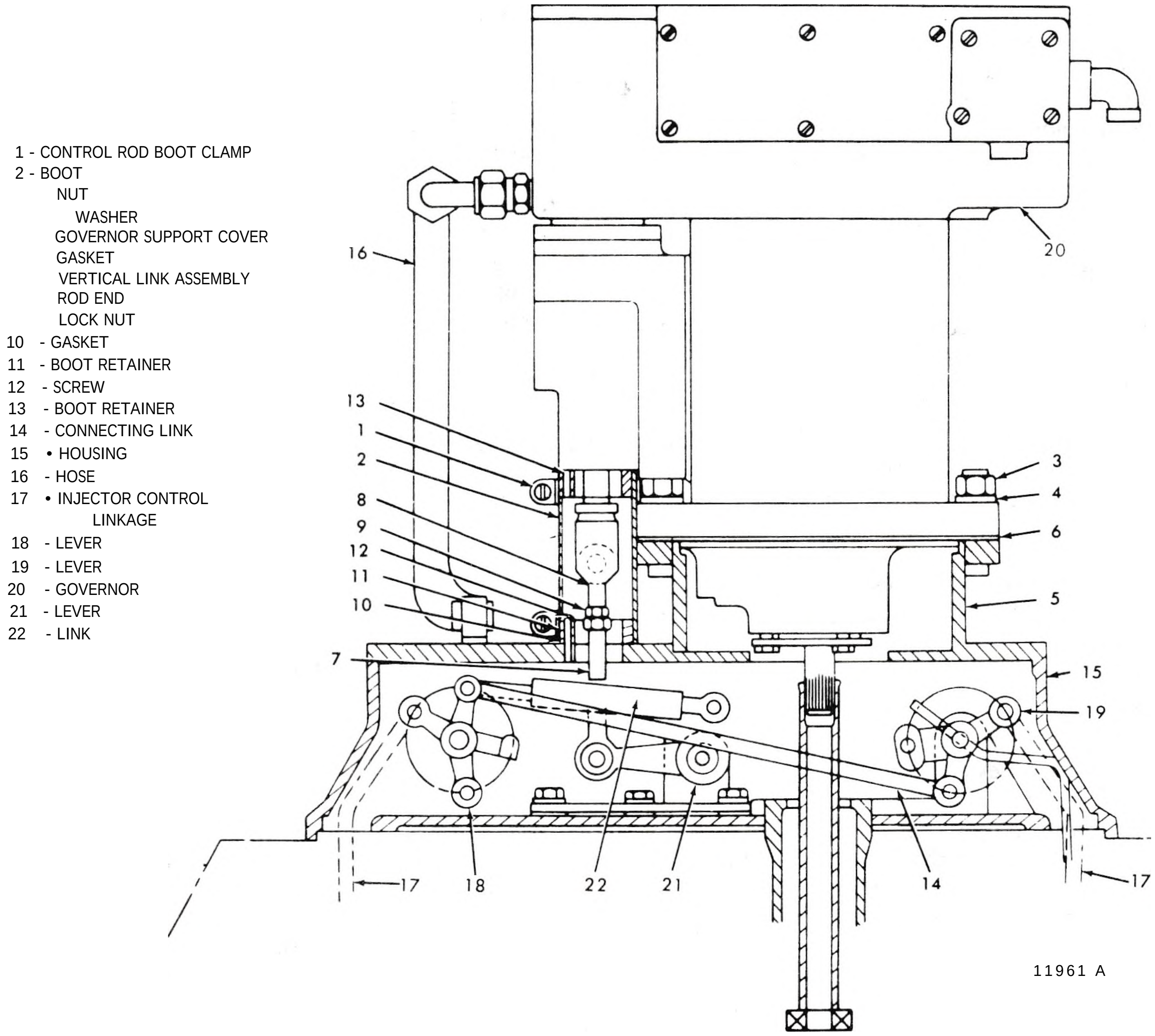

Fig. 7 - Governor Operating Linkage

There is a built-in delay period of 35-45 seconds to allow engine oil pressure to build-up upon initial start up of the engine. If, after this delay period or at any time when the engine is idling at 800 rpm, an oil pressure of 10+ 2 psi (69+ 14 kPa) is not achieved, the low oil pressure switch will close and operate an alarm bell and a warning light in the operator's cab. The same sequence of events will occur if the engine oil pressure at full governed engine speed of 1900 rpm drops below or does not obtain 4 0 + 2 psi (276 ± 14 kPa).

In both cases, upon restoration of oil pressure, the alarm circuit will reset automatically. The position of the low oil pressure switch can be checked externally by observing the governor. Low oil pressure is indicated when the low oil pressure switch plunger (Fig. 5) protrudes from the governor approximately 1/2" more than the normal operating position.

Normal shut down of the engine is effected by depressing the engine stop switch in the operator's cab. This electrically energizes a shutdown solenoid in the governor which moves the power piston to the no-fuel position and shuts the engine down.

If it is necessary to remove the governor from the engine in order to carry out repair work, proceed as explained in the following paragraph.

If the governor is removed from the engine due to a malfunction in the governor, it is strongly recommended that the governor be returned to the factory for overhaul or to the nearest governor repair shop which is equipped with a test stand and trained personnel. *Under no circumstances should untrained personnel be allowed to tamper with the governor.*

For a view of the interior of the governor, refer to Fig. 6.

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General Oil Specifications

Use SAE 20 or 30 oil for ordinary temperature conditions. If governor operating conditions are extremely hot, use SAE 40 or 50; if extremely cold, use SAE 10. The oil must not contain additives, which are used to free up rings, remove carbon, etc., unless a non-foaming additive is also present.

The oil should not foam or sludge when agitated, or form gummy deposits when heated.

Use clean, new oil or filtered oil. All containers must be clean and should be rinsed with light grade fuel oil or kerosene before using.

Keep the governor oil level *between* the lines in the oil gage *while the engine is running.* The oil may be added to the governor through the oil filler cup in the top cover. Add oil slowly to avoid over-filling.

Oil level above or below the lines on the gage, when running, will cause aeration of the oil and result in a hunting condition.

Remove Governor

Numbers in parentheses refer to Fig. 7.

NOTICE: Before attempting to remove the governor, it is essential that the governor and the top of the engine in the vicinity of the governor be thoroughly clean and free from loose scale and debris which could find its way into the engine.

1. Disconnect the electrical cable to the governor by unscrewing the connector counterclockwise.
2. Drain the governor by means of the oil drain cock located on the power case of the governor.
3. Disconnect all air and oil lines at the governor and identify each line to its appropriate connector to facilitate installation. Cap all hoses and plug all connectors to prevent dirt from getting into the system.
4. Loosen the governor control rod boot clamp (1) at the bottom end of the boot (2) and ease the boot upwards until the control rod clevis pin is exposed.
5. Remove the split pin and the clevis pin from the control rod.
6. Remove the four 1/2"—13 UNC nuts (3) and lock washers (4) securing the governor (20) to the governor support cover (5).
7. Screw a 3/8"—16 UNC bolt into the top of the governor in the tapped hole provided and, using a suitable lifting tackle, carefully lift the governor clear of the support cover, taking care not to damage the stud threads.
8. Remove the governor from the unit and stand it vertically on a wooden base with holes provided to accept the governor gear box and power piston.
9. Remove and discard the gasket (6) and cover the governor and control rod openings in the governor support to prevent dirt and foreign matter from entering the engine.
10. Remove the gasket (10) and boot retainer (11).

Install Governor

Numbers in parentheses refer to Fig. 7.

Before installing a new or factory reconditioned governor, perform a complete engine tune-up.

1. Measure the center-to-center distance of the vertical link assembly (7) and set the center-to-center distance of the rod ends (8) to measure approximately 4.1875" by threading the rod ends on an equal amount. Leave the upper lock nut (9) loose at this stage.
2. Install the gasket (10) and boot retainer (11) and secure them to the governor power piston housing, using three 5"^10 x 3/4" long screws (12).
3. Apply the protective boot (2) and secure it to the boot retainer on the governor by means of the gear clamp **CD-**
4. Attach the gasket (6) to the governor support housing cover (5).
5. Lower the governor carefully over the mounting studs ensuring that the splined governor shaft is located in the splined governor drive sleeve and the vertical link rod (8) is located in the clevis of the power piston rod end.

   NOTICE: If the governor does not rest flat on the support housing (35), the cause should*be investigated. Do not seat the governor by means of the nuts, since if the governor is “hung up” on the drive shaft splines, the pre-load imposed by pulling the governor down will pre-load the drive shaft gear and bearing which could lead to a drive shaft failure, resulting in serious damage to the engine.

6. Install the lock washers (3) and nuts (4) on the mounting studs and torque the nuts to 58 lb-ft (79 N-m).

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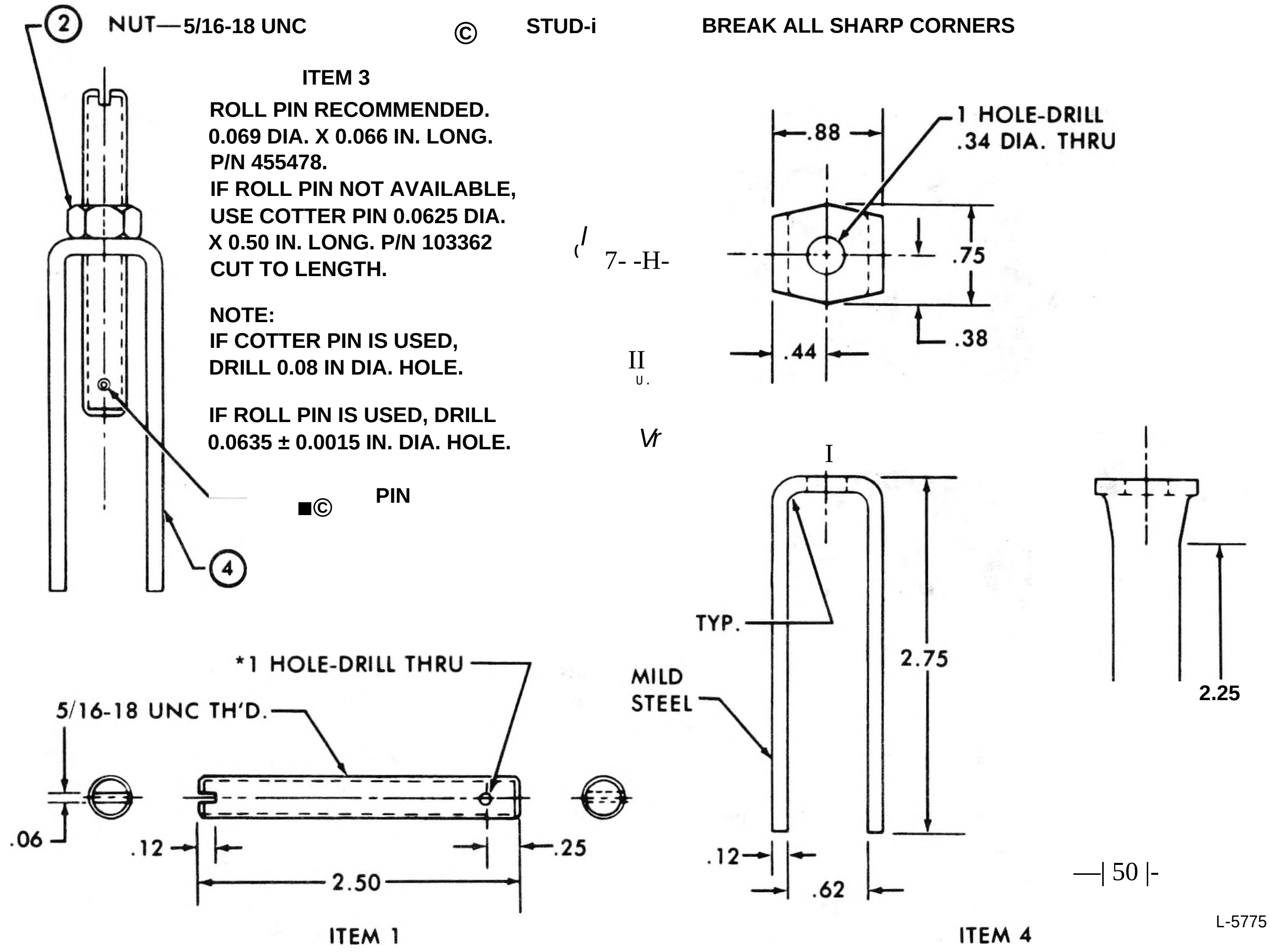

Fig. 8 - Governor Piston Rod Jack Fabrication

7. Check that the hole in the spherical bushing of the vertical link rod end (8) lines up with the hole in the power piston rod end.

NOTICE: The power piston rod end is in the *no-fuel* position when the governor is disconnected or shut down. The vertical link (7) must be adjusted to this *no-fuel* position to within .010". When checking the line-up of the spherical bushing with the power piston rod end, exert moderate pressure in the downward direction on the vertical link rod end (8) to ensure that the injector racks are in the *no-fuel* position. Should it be found necessary to adjust the center-to-center distance of the vertical link assembly once the governor is in position, proceed as in Steps 8 through 9.

8. Remove the governor cover and, using a power piston jack, raise the governor power piston until the scribed line on the power piston tail rod lines up with the full load fuel scribe mark on the scale next to the tail rod.

NOTICE: The power piston jack can be fabricated as shown in Figure 8.

9. Hold the injector racks in the *full-fuel* position, ease boot (2) upward and check that the hole in the spherical bushing of the vertical link rod end (8) lines up with the hole in the power piston rod clevis within ± .010". Should it be necessary to adjust the center-to-center distance of the vertical link assembly once the governor is in position, proceed as in Steps 13 and 14.

10. Allow the fuel racks to return to the *no-fuel* position, thus lowering the rod end.

11. Rotate the rod end clockwise, or counterclockwise, whichever way is required to increase or decrease the center-to-center distance of the vertical link (7).

Return the fuel racks to the *full-fuel* position and check the line-up between the rod end hole and the power piston clevis hole. Repeat the procedure until the holes are in line.

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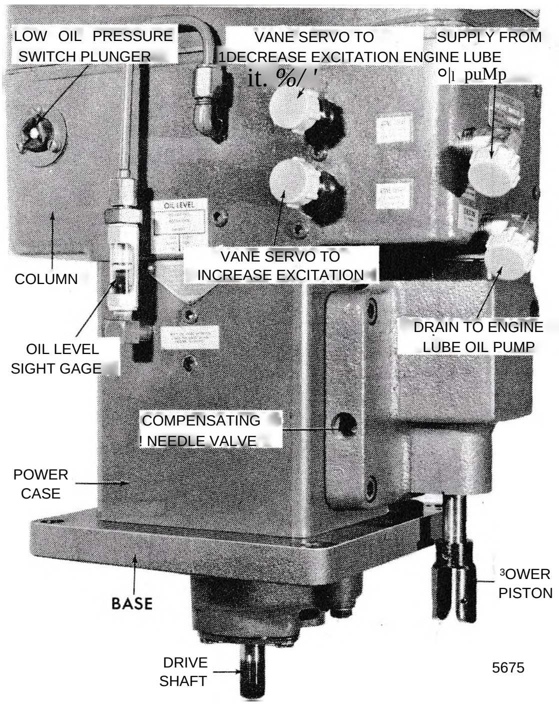

Fig. 9 - Governor

NOTICE: It is important that the center-to-center distance of the vertical link assembly was originally set at 4.1875" as outlined in Step 1. If this was not done, it is possible when adjusting the vertical link as explained in Step 14, to either run out of adjustment one way or unscrew the rod end completely the other.

If this situation occurs, or if it is felt that there is insufficient thread length securing the rod end to the vertical link, remove the governor and completely re-adjust the vertical link.

12. Once the line-up of the power piston rod end and the vertical link rod end (8) clevis pin hole has been achieved, install the clevis pin and retain it in position with a split pin. With the power piston in the *"full-fuel"* position, tighten the lock nut (9) to secure the vertical link rod end (8). Remove the tail rod jack and install the governor cover.

13. Slide the protective boot (2) over the boot retainer (13) on the governor support housing cover (5) and install the clamp (1).

14. Connect all air and oil lines to the governor ensuring that each line is connected to the appropriate connector.

15. Plug in the electrical cable and secure it by screwing the connector cap clockwise.

16. Fill the governor with oil to the prescribed level, as shown on the oil level gage, by removing the cap on on the governor cover and filling through the top cover. Add oil slowly to avoid over filling.

Installation Adjustments

On all new or factory rebuilt governors, the speed settings and other operating adjustments are made at the factory when the governor is tested before shipment, leaving only the compensating needle valve (Fig. 9) to be adjusted to suit the engine on which the governor is to be used.

Compensation Adjustment

When the engine is started for the first time, or after the governor has been drained and cleaned or if the governor has been removed and replaced for any reason, the governor must be filled with oil to the prescribed level and the governor oil system purged of trapped air.

To do this, loosen the air vent plug, shown in Fig. 10, far enough to establish a leak. Start the engine and allow it to run at *idle speed.*

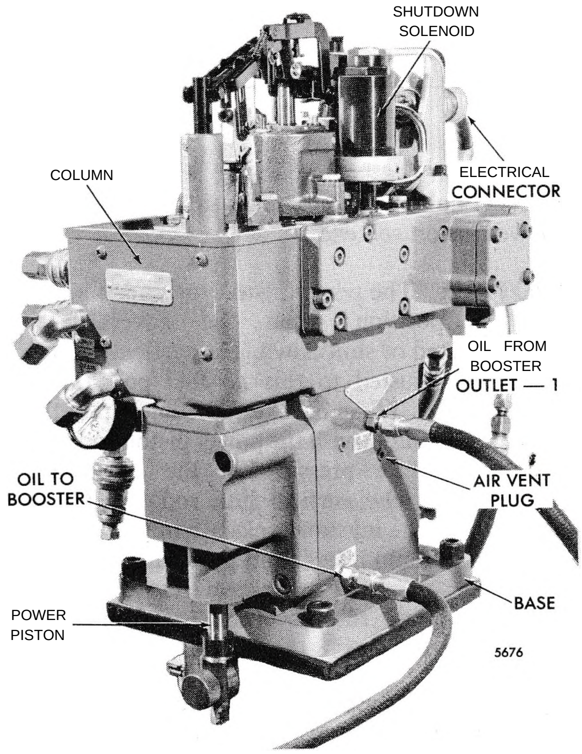

Fig. 10 - PG Governor

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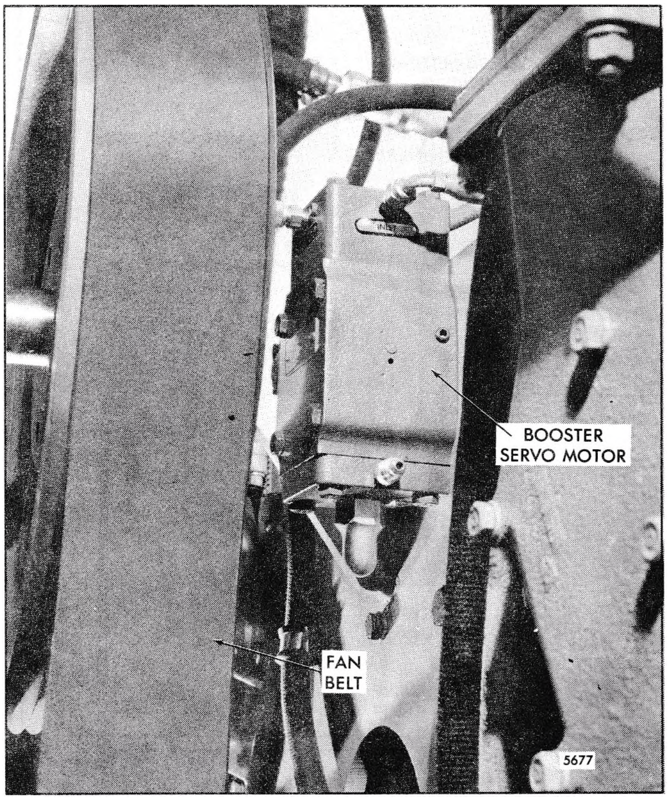

Fig. 1 1 - Location of Booster Servomotor

Open the compensating needle valve (Fig. 9) several turns. This should cause the engine to hunt, and the alternating movements of the governor parts will force all trapped air out of the governor oil passages and out of the governor at the vent plug.

Allow the engine to hunt at idle speed long enough to bleed all trapped air from the governor oil system. This will be evidenced by leakage of only oil at the vent screw. Tighten the vent screw and, if necessary, add oil to the governor to restore the correct level. Close the compensating needle valve slowly until the hunting condition is minimized, or eliminated, and allow the engine to run at idle speed until the engine and the governor reach normal operating temperature.

When operating temperature has been reached, open the compensating needle valve again several turns, enough to cause the engine to hunt, then close the needle valve slowly until the hunting is entirely eliminated. This will usually occur when the needle valve is open between one-quarter turn and three full turns. The correct setting will depend upon the characteristics of the engine. .

Test stability by disturbing the engine speed. If the engine returns to steady speed, the adjustment is satisfactory. But if the engine starts hunting, close the needle valve slightly and test again.

Keep the needle valve as far open as possible to prevent sluggishness and still obtain stability. Once it is correctly adjusted for the engine, it should not be necessary to change the setting of the needle valve except for a large permanent temperature change affecting the viscosity of the governor oil.

The needle valve setting will vary from 1/16 to 2 turns open. The needle valve must never be closed tight, as the governor can not operate satisfactorily when this condition exists.

Booster Servomotor

To facilitate a quick start and conserve starting air, a booster servomotor is used in conjunction with the governor. The booster servomotor is located on the front engine lifter bracket below the governor (Fig. 11) and is connected to the governor by flexible lines.

The booster servomotor's function is to supply oil under pressure to the governor at the instant starting air is supplied to the engine; this results in the governor moving the power piston into a fuel on position. The engine will then fire at once instead of after the time lag normally required for the rotary gear pump within the governor to build-up oil pressure to move the piston.

To ensure that the booster servomotor receives air at the instant starting air is supplied to the engine, the booster servomotor air supply is taken from the same solenoid-operated air start valve that operates the two main air starting valves mounted on the two starting air reservoirs.

See Fig. 12 for schematic operation of the booster servomotor.

The sequence of operation of the booster servomotor is as follows:

1. Compressed air is admitted to the air cylinder of the booster at the same time that the engine is started.
2. Air pressure moves the piston up, creating pressure in the oil cylinder and seating the inlet check valve.

   Refer to the direction arrows in Fig. 13.
3. Pressure oil passes through outlet checldvalve No. 1 to the governor pressure oil system.
4. Oil pressure moves the governor power piston in the direction to increase fuel.
5. For governors having speed setting servomotors, pressure oil also passes through outlet check valve No. 2 and forces the speed setting piston down. The piston loads the speeder spring which pushes the pilot valve plunger down so that the control land is below its centered position. Oil from the governor gear pump can then flow towards the governor power piston.

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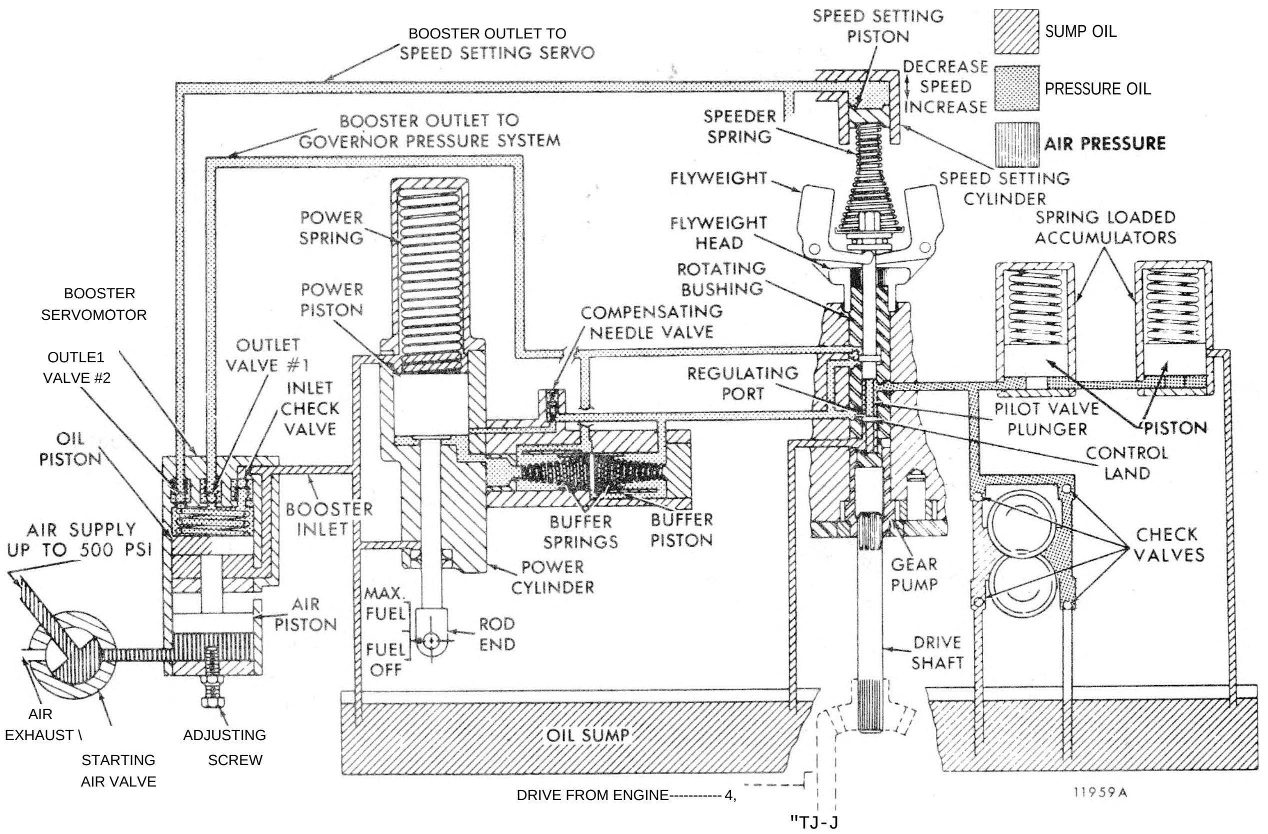

Fig. 1 2 - Schematic Diagram of Booster Servomotor

6. **As soon as the engine fires, the air cylinder of the booster is vented to the atmosphere.**

7. **After several revolutions, the governor** pump **builds up pressure, seating the outlet check valve.**

8. **Spring force returns the piston to its original position. Refer to the direction arrows in Fig. 14.**

9. **Oil flows from the sump into the oil cylinder of the booster.**

10. **The booster is then ready for another start.**

Troubleshooting

If the engine is slow to start or does not start at all due to lack of fuel, the booster servomotor should be checked for correct operation as follows:

1. **Ensure that the booster is receiving sufficient air pressure from the solenoid-operated air start valve by installing a *tee* fitting in the air line at the booster and connecting to a pressure gage. The pressure gage should indicate air start system pressure of between 100-200 psi (689-1378 kPa).**

2. **Check that all air has been purged from the oil lines between the booster and the governor (refer to *Adjustments)* and that there are no restrictions or blockages in the oil lines.**

3. **Adjust the limit screw on the booster as explained under *Adjustments.***

If all of the above checks have been mad^ and the booster still does not function, it should be removed and dismantled as covered under the appropriate headings.

Remove Booster Servomotor

1. **Drain the governor oil.**

2. **Identify and disconnect all oil and air lines at the booster servomotor and cap all lines and connectors securely to prevent the entry of dirt into the system.**

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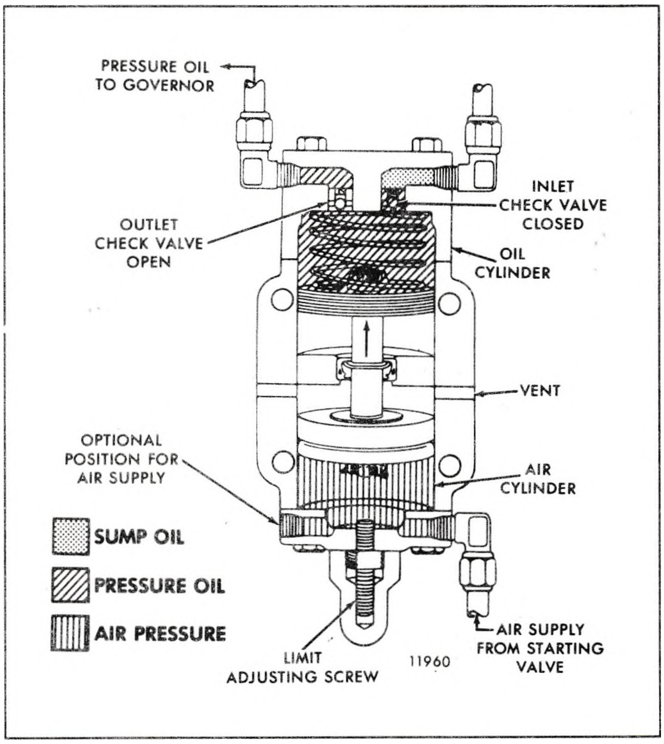

Fig. 13 - Oil Pressure Outlet Check Valve in Open Position

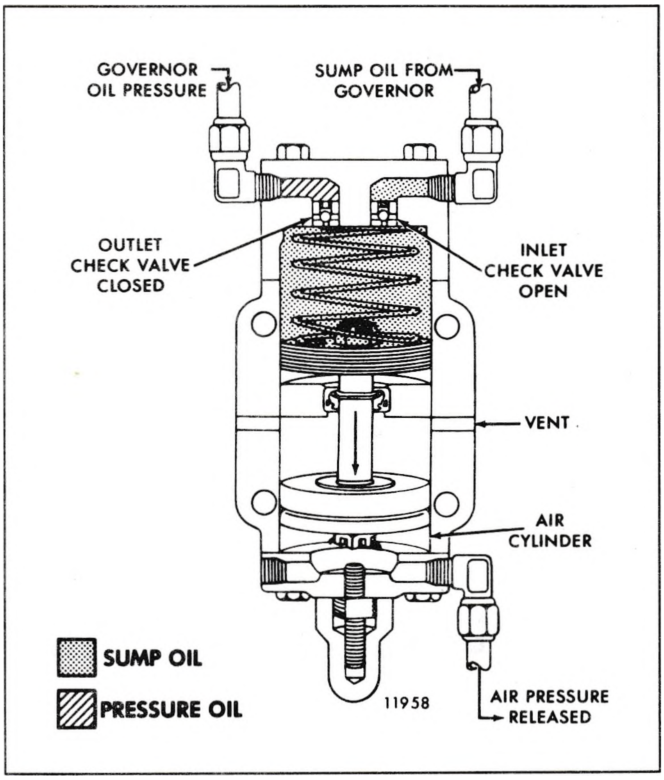

Fig. 1 4 - Oil Pressure Outlet Check Valve in Closed Position

NOTICE: It is possible to avoid draining the governor of oil by removing the oil lines one at a time and quickly capping the hose and its connector. If adopting this method, it is essential that the governor oil level be checked before putting the unit back into service in case any of the caps have been leaking oil.

3. Remove the four bolts, lock washers and nuts securing the booster servomotor to the front engine lifter bracket and remove the booster servomotor from the unit.

Disassembly

Numbers in parentheses refer to Fig. 15.

1. Thoroughly clean the exterior of the booster servomotor, using a suitable grease solvent, and dry with compressed air.

2. Remove the four cap screws (25) and lock washers (3) securing the cylinder head (7) at the oil end of the booster to the power cylinder (6). Remove the cylinder head (7), gasket (17) and spring (16).

3. Remove the four cap screws (24) and lock washers (3) securing the cylinder head (10) at the air end of the booster and remove the cylinder head (10) and gasket (17).

4. Remove the split pin (1) and castle nut (5) securing the washer (15), washer seal (12), piston (8) and washer (32) to the piston rod (18) and remove.

5. The piston rod (18) and oil piston (20) assembly can now be removed for further disassembly.

6. Press out the piston rod oil seal (14) from the air end of the power cylinder (6).

7. Thoroughly clean all components in a suitable solvent and dry. Clean the washer seal (12) and oil seal (14) in a non-petroleum based cleaner.

8. Inspect all components for signs of damage and wear and inspect the outlet and inlet check valve assemblies (21) for correct operation and seating. Replace all damaged or worn parts and gaskets.

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Assembly

1. Lightly coat the inside of the power cylinder with governor oil and assemble in the reverse order of disassembly.

Install On Engine

1. Mount the booster servomotor on the front engine lifter bracket, with the oil cylinder head uppermost. Secure it with four 5/16"—18 UNC bolts, nuts and lock washers and torque the nuts to 13 lb-ft (18 N-m).

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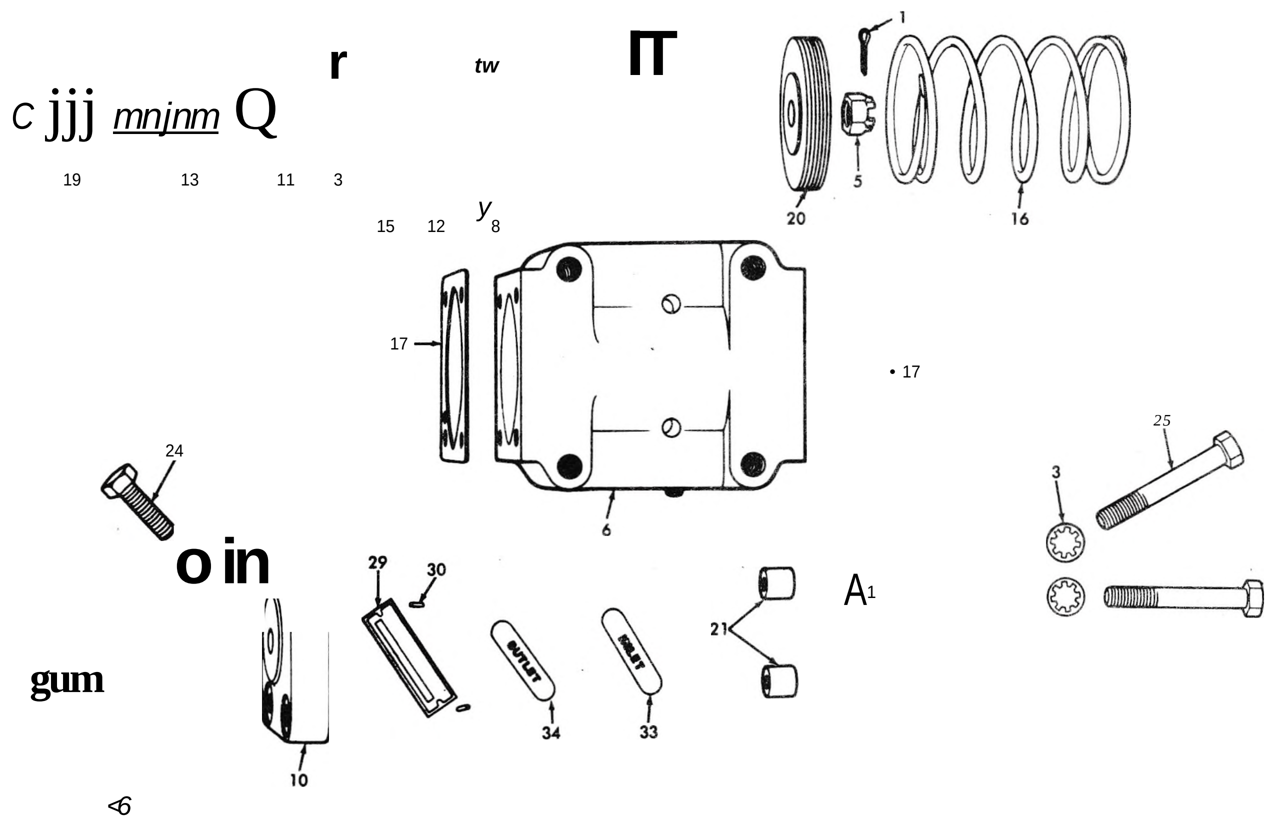
2. Reconnect the oil and air lines to the booster servomotor ensuring that each line is connected to the appropriate fitting.
3. Fill and check the oil level in the governor.
4. Purge the booster servomotor of air as explained under *Booster Servomotor Adjustments.*

NOTICE: If the governor hunts when the engine is started, purge the governor of air as covered under *Compensation Adjustment.*

Booster Servomotor Adjustments

Under normal circumstances, no adjustment is required to the booster servomotor. However, if the booster servomotor has been removed and overhauled, the oil lines from the booster servomotor to the governor will need to be purged of air. To do this, simply remove the air start lines at the air start motors and then operate the air start valve three or four times by actuating the engine start toggle switch in the cab.

After all of the air has been removed from the oil lines, the initial opening of the fuel racks can be adjusted to the desired stroke by adjusting the limit screw located on the end of the booster servomotor under the end nut. Turn counterclockwise to increase starting fuel and vice versa. This screw limits the intake stroke of the booster piston and thus the volume of oil supplied to the governor in one stroke of the booster piston.



1.	Split Pin	11.	Lock Nut	17.	Gasket	25.	Cap Screw
3.	Lock Washer	12.	Seal Washer	18.	Piston Rod	29.	Name Plate
5.	Castle Nut	13.	Adjusting Screw	19.	End Nut	30.	Pin
6.	Power Cylinder	14.	Oil Seal	20.	Piston	32.	Washer
7.	Cylinder Head	15.	Washer	21.	Check Valve	33.	Decal (Inlet)
8.	Piston	16.	Spring	24.	Cap Screw	34.	Decal (Outlet)
10.	Cylinder Head						

Fig. 1 5 - Booster Servomotor Details and Relative Location of Parts

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MECHANICAL OUTPUT SHAFT GOVERNOR AND LINKAGE ADJUSTMENT

A Pierce mechanical governor is used to maintain a near constant output shaft speed on engines equipped with a torque converter. The governor (Fig. 1) is mounted on the engine governor and is driven by a flexible shaft from the converter output shaft and is connected, through linkage, to the engine governor.

The output shaft governor is lubricated by engine oil contained within the governor housing. The governor sump is filled through the hinged cap oiler until the oil begins to drip out of the oil level hole. After filling, a plug is installed in the oil level hole to prevent leakage. The oil level should be checked every 8 service hours and changed every 500 hours.

The output shaft governor is connected to the engine governor by a control rod and levers as illustrated in Fig. 1. The control rod end ball joints are sealed assemblies and do not require lubrication. However, the throttle control shaft bearings should be lubricated periodically with all purpose grease through the grease fitting. Other moving parts of the control linkage should be lubricated with engine oil.

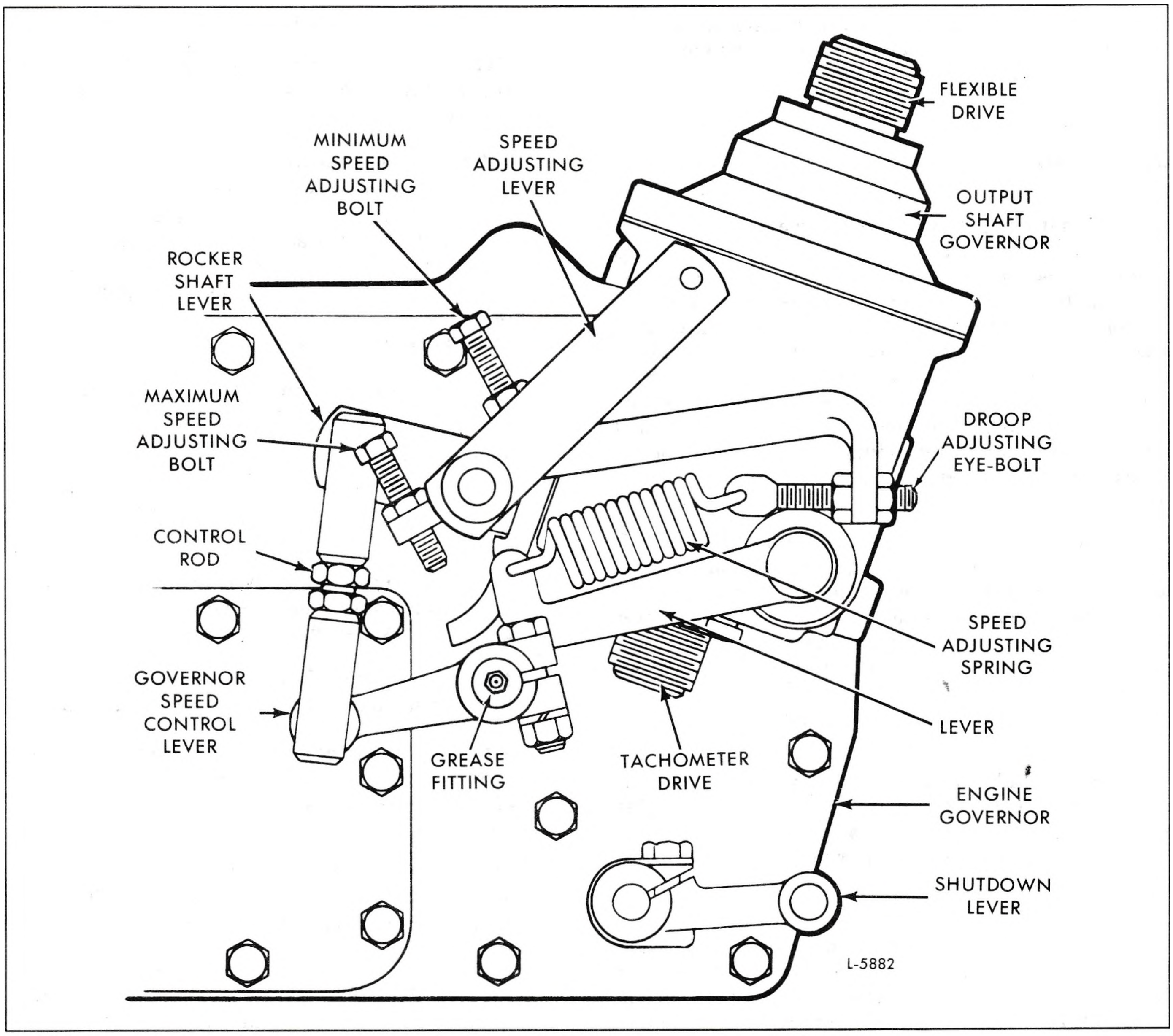

Fig. 1 – Mechanical Cable–Driven Output Shaft Governor and Linkage

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The centrifugal force of the revolving output shaft governor flyweights is converted into linear motion which is transmitted through a riser, thrust bearing, operating fork and rocker shaft to an external speed adjusting spring. The speed of the torque converter output shaft is governed by the tension of the speed adjusting spring. This spring tension is established by the operator when he moves the output shaft governor speed adjusting lever to the desired speed setting.

Movement of the output shaft governor speed adjusting lever is limited by the maximum and minimum speed adjusting bolts.

The engine shutdown lever is connected through a shaft to another lever, under the governor cover, which bears against an arm of the left bank control link operating lever. To stop the engine, the shutdown lever is used to move the control link lever to the no-fuel position.

Operation

When the output shaft governor speed adjusting lever is advanced, the tension on the speed adjusting spring is increased. The force resulting from the increased spring tension is transmitted through the rocker shaft lever and control linkage to the engine governor speed control lever which advances the injector racks. Engine speed increases, as a result of the increased fuel, until the output shaft governor weight force is sufficient to balance the increased spring tension. The weights then move against the spring and reduce the injector rack fuel setting to an amount sufficient to maintain the higher engine speed setting.

Should the operator move the speed adjusting shaft lever to a decreased speed position, the tension on the speed adjusting spring will decrease and the governor weights will overcome the spring tension and move the rocker shaft lever to a decreased fuel position. The engine speed will be reduced until the force of the output shaft governor weights equals the tension of the speed adjusting spring. The engine will then operate at the desired reduced engine speed.

When a load is applied to the unit, the output shaft slows down and the force exerted by the governor flyweights is reduced, allowing the spring to move the rocker shaft lever to an increased fuel position to provide sufficient power to equal the new load.

When the load on the unit is removed, the output shaft speed will increase and the force exerted by the governor flyweights will increase, overcoming the spring tension and moving the rocker shaft lever to a decreased fuel position to reduce the power to match the reduced load.

Tune-Up

Adjust the exhaust valve clearance, time the injectors and adjust the engine and output shaft governors as follows:

1. Adjust the exhaust valve clearance and time the fuel injectors (Sections 14.1 and 14.2).

2. Disconnect the output shaft governor control rod. Then adjust the engine governor as outlined under *Limiting Speed Mechanical Governor and Injector Rack Control Adjustment* (Section 14.3).

   NOTICE: Set the no-load engine speed to that specified on the engine option plate. The no-load speed varies with the converter used and the maximum output shaft speed setting.

3. Reconnect the control rod linkage to the governor speed control lever only and check the total travel of the speed control lever.

   NOTICE: The speed control lever on the engine governor moves approximately 32 1/2 degrees from the idle speed to the full-fuel position. It should be adjusted so that when it is in the center of its travel, it is perpendicular to the engine center line. This will provide optimum linearity between the output shaft operating lever and engine speed control lever.

4. Move the engine governor speed control lever to the maximum speed position.

5. Move the output shaft governor rocker shaft lever to the maximum fuel position and retain it by moving the output shaft speed adjusting lever to the full-speed position.

6. Adjust the output shaft governor control rod length until it will just slide into the hole of the output shaft governor rocker shaft lever. Tighten the adjustment.

7. Move the output shaft governor speed adjusting lever to the minimum speed position and start the engine.

8. Advance the output shaft governor speed adjusting lever to the desired maximum output shaft spfeed and adjust the maximum speed adjusting bolt to retain the lever.

9. Move the output shaft governor speed adjusting shaft lever to the desired minimum speed position and adjust the minimum speed adjusting bolt to retain the lever.

10. Recheck the output shaft maximum and minimum speeds and readjust the position of the speed adjusting bolts, if necessary.

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11. To check the unit for stability as affected by governor speed droop, move the speed adjusting shaft lever, with the engine operating at no load, to the maximum speed position. Then move the output shaft governor rod to cause a speed decrease of several hundred rpm. Release the rod and check for hunting when the governor returns the engine to the maximum speed setting. If the engine stabilizes in less than three surges, the droop may be set too high; if the engine does not stabilize in five surges, the droop may be set too low. Set the speed droop as follows:

    a. If the engine hunts less than three surges, back . off the inner speed adjusting spring eye bolt nut one full turn and tighten the outer nut one turn to retain the adjustment. If the engine hunts more than five surges, back off the outer speed adjusting spring eye bolt nut one full turn and tighten the inner nut one turn to retain the adjustment.

NOTICE: The eye of the bolt must be in a horizontal plane to avoid twisting the spring.

    b. Reset the maximum engine no-load speed, if necessary, as outlined in Steps 8 and 9.

    c. Recheck the speed droop. The engine speed should be stable when the governor droop is 7-1/2% to 10% of the full-load speed. For example, at an output shaft speed setting of 1800 rpm full load, the output shaft speed droop should be 150 to 200 rpm. Therefore, the no-load output shaft speed should be set at 1950 to 2000 rpm.

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SUPPLEMENTARY GOVERNING DEVICE ADJUSTMENT

THROTTLE DELAY MECHANISM

A throttle delay mechanism has been added to certain Series 149 turbocharged engines equipped with a mechanical governor or a hydraulic governor with a throttle delay yield link. This device reduces smoke emission by momentarily retarding full-fuel injection when the engine is accelerated.

The throttle delay mechanism is installed on the number one cylinder of the right-bank cylinder head (Fig. 1). It consists of a cylinder, piston, oil supply tube, ball check valve, orifice plug, lever and connecting link.

The throttle delay mechanism may be installed on former turbocharged engines. However, on engines prior to serial number 12E-139 with the original cylinder block and governor, it may be necessary to rework the throttle delay cylinder by grinding or filing the cylinder to eliminate possible interference with operation of the governor fuel rod (Fig. 2). On engines equipped with a hydraulic governor it will also be necessary to replace the vertical link with a throttle delay yield link (Section 14.7.2). Also, a different spring-loaded connecting link, oil supply tube and connector must be used on these engines. The oil supply tube used on current engines connects to an oil supply hole machined horizontally into the right-hand side of the cylinder block; on the early cylinder blocks, the oil hole was drilled vertically into the cylinder block.

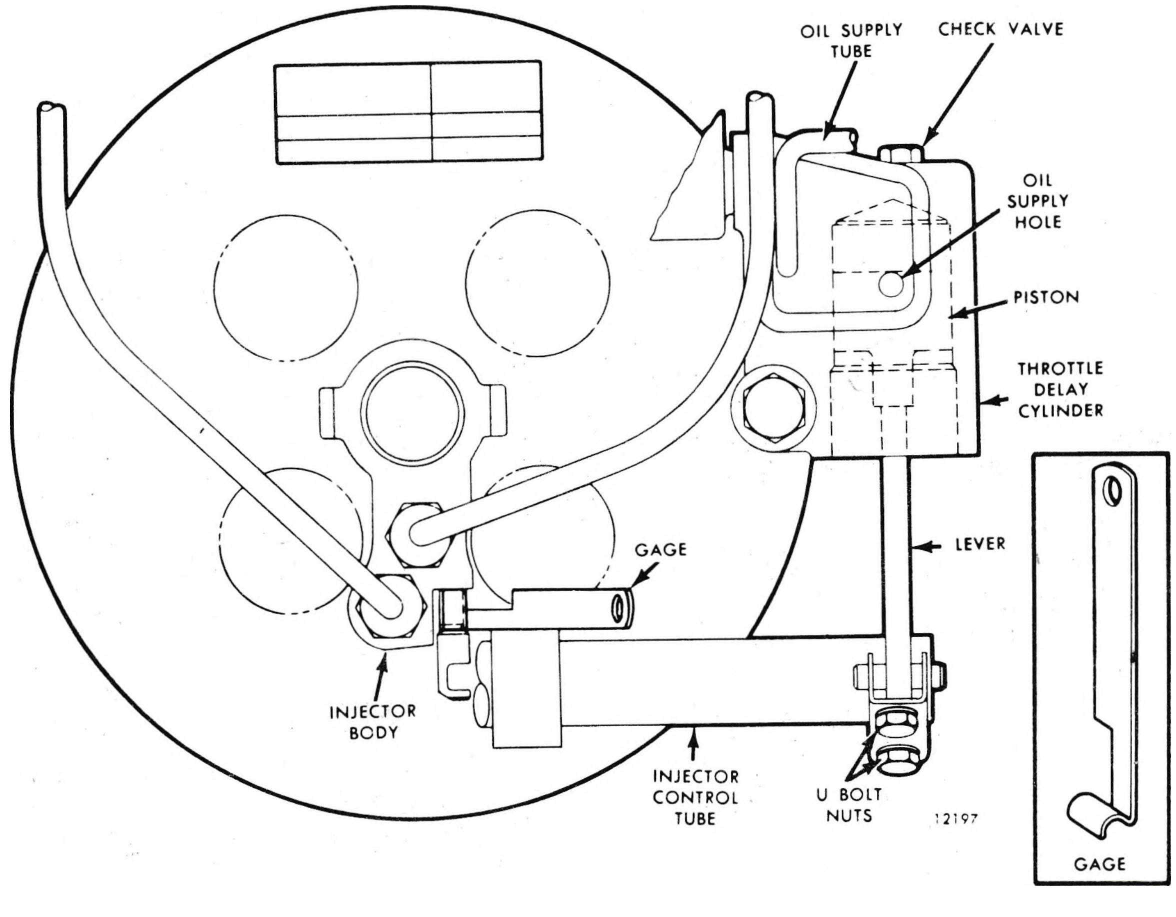

Fig. 1 - Throttle Delay Adjustment

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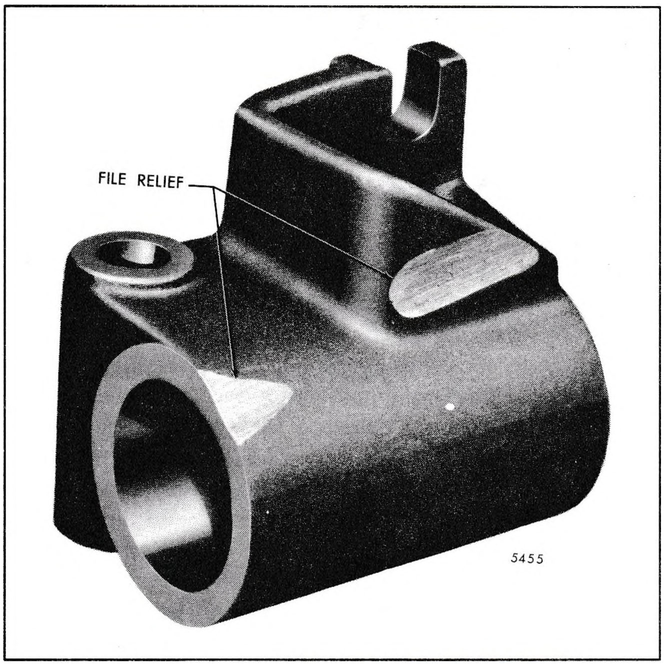

Fig. 2 - Reworked Throttle Delay Cylinder

Operation

Oil is supplied to a reservoir above the throttle delay cylinder through an oil supply tube from the cylinder block As the injector racks move toward the no-fuel position, free movement of the throttle delay piston is assured by air drawn into the cylinder through the ball check valve. Further movement of the piston uncovers an opening which permits oil from the reservoir to enter the cylinder and displace the air. When the engine is accelerated, movement of the injector racks toward the full-fuel position is momentarily retarded while the piston expels the oil from the cylinder through an orifice. To permit full throttle travel, regardless of the retarded position of the injector racks, the current limiting speed and variable speed mechanical governors have been revised by replacing the solid differential lever connecting link by a spring-loaded connecting link.

Adjustment

Whenever the injector rack control levers are adjusted, disconnect the throttle delay mechanism by loosening the

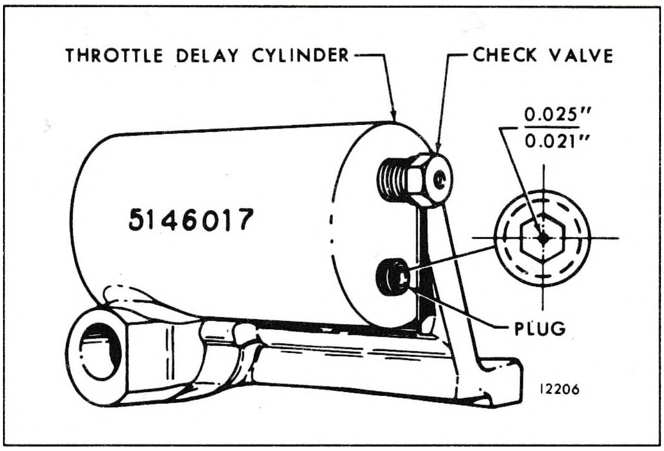

Fig. 3 - Throttle Delay Cylinder Plug Location

U-bolt which clamps the lever to the injector control tube. After the injector rack control levers have been positioned, the throttle delay mechanism must be readjusted. With the engine stopped, proceed as follows:

1. RefertoFig. landusegageJ 23190(.454" setting)or gage J 28779 (.365" setting) for 195 injector. Insert the gage between the injector body and the shoulder on the injector rack. Then exert a light pressure on the injector control tube in the direction of full fuel.

2. Align the throttle delay piston so that the leading edge of the piston just covers the oil fill hole.

3. Tighten the U-bolt on the injector control tube and remove the gage.

4. Move the injector rack from the no-fuel to the full-fuel position to make sure it does not bind.

Inspection

The diameter of the orifice in the throttle delay cylinder plug has been enlarged to improve engine response in electric drive off-highway trucks (Fig. 3).

If unsatisfactory engine response is experienced, install a current plug (.021 "-.025" orifice) or rework the former plug (.014"—.018" orifice) by enlarging the orifice with a No. 74 drill (.0225" diameter). Only the current plug is available for service.

STARTING AID SYSTEM

A starting aid system has been provided for turbocharged (including intercooled) engines equipped with variable speed mechanical governors (Fig. 4).

The starting aid limits the fuel during engine starting. This is accomplished by an air cylinder mounted on the governor. The air cylinder is connected to the starting air supply line (Fig. 4) or is activated by a throttle control (air solenoid) valve which is operated by the electric starting switch (Fig. 5). The air cylinder is controlled so that it is pressurized when the engine is being started. Pressurizing the air cylinder results in the air cylinder piston rod contacting and moving the governor stop lever from the run position. Thus the movement of the stop lever from the run position moves the injector racks from their full-fuel position.

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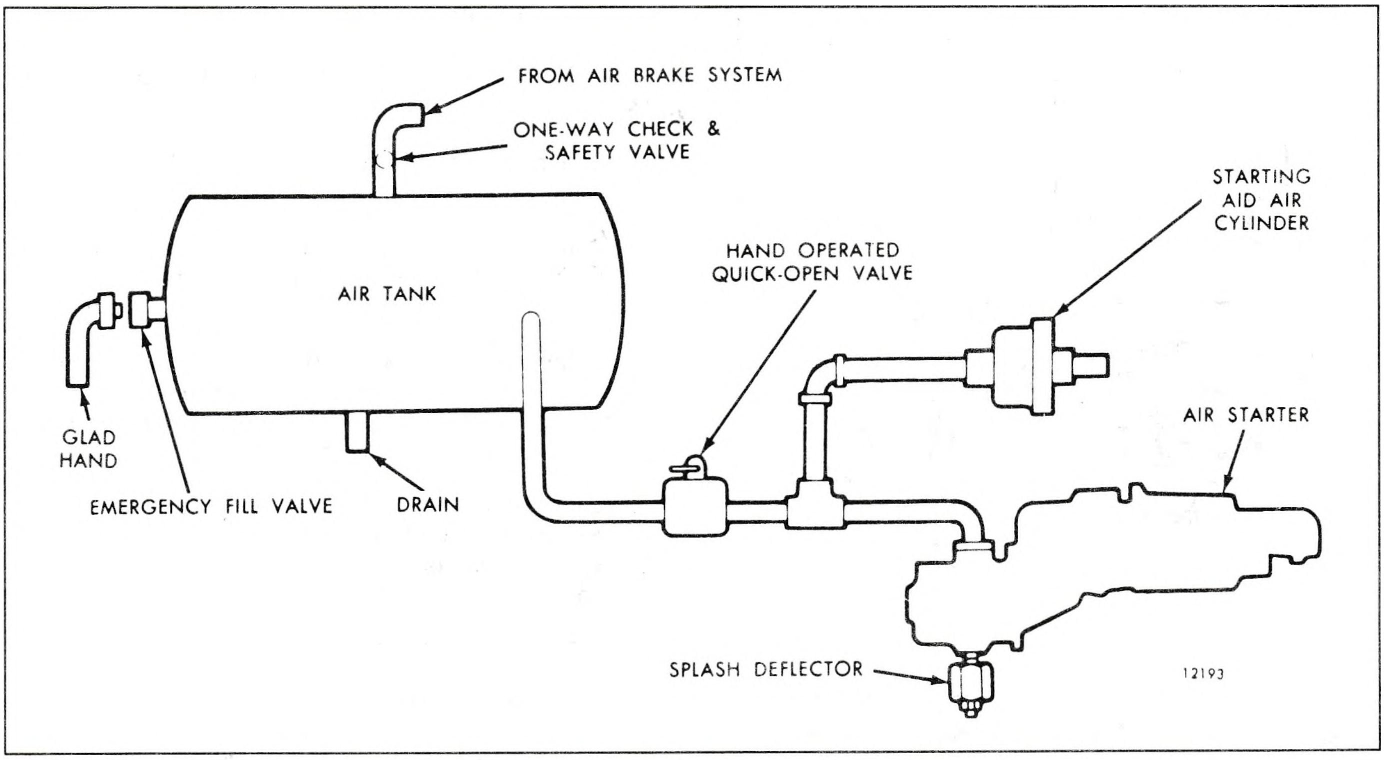

Fig. 4 – Typical Starting Aid System

The air cylinder is vented after starting, allowing the air cylinder piston rod to retract and the governor stop lever to return to the run position, thus permitting full fuel operation. The main components of the starting aid system are an air cylinder, an air cylinder mounting bracket and special stop lever plus customer furnished items such as the air supply hose and connections, air solenoid valve, etc. An electric shutdown solenoid or a wire cable can be used with the system.

Adjustment

Adjust the starting aid system by positioning the governor stop lever and the air cylinder to obtain the proper air cylinder to stop lever clearance as outlined below.

Position Solenoid Operated Stop Lever

Refer to Fig. 6 and position the solenoid operated governor stop lever as follows:

1. Remove the bolt connecting the solenoid plunger rod end eye to the stop lever.

2. Align and clamp the stop lever to the shutdown shaft so that, at its mid-travel position, it is perpendicular to the solenoid plunger. This will ensure that the linkage will travel as straight as possible. The solenoid plunger has available 1/2" of travel which is more than adequate to move the injector control racks from the full fuel to the no-fuel position and to accomplish shutdown prior to attaining full plunger travel.

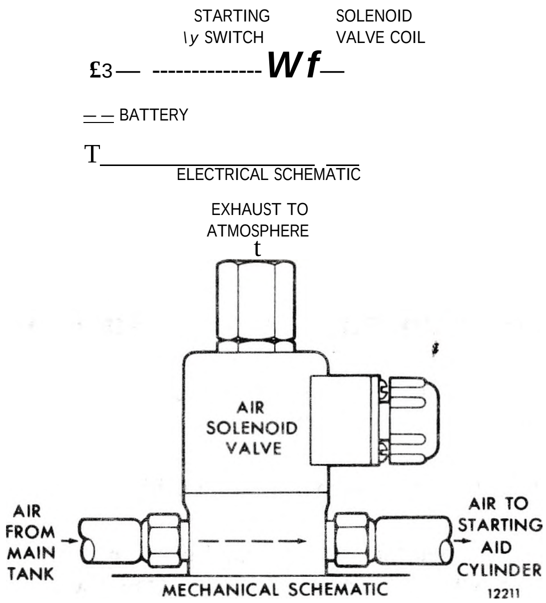

Fig. 5 - Starting Aid Schematic

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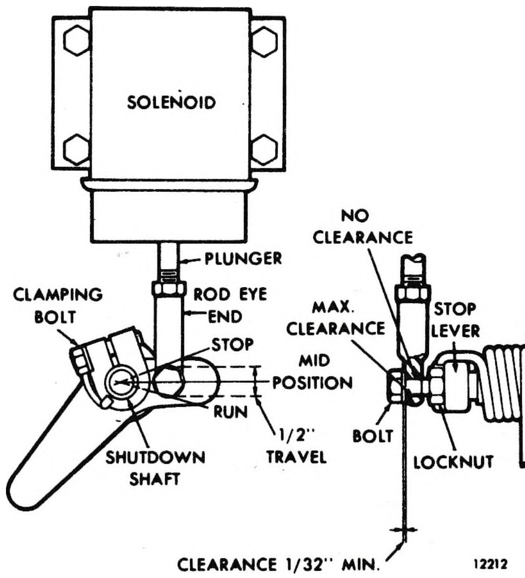

Fig. 6 - Positioning Solenoid Operated Stop Lever

3. With the stop lever in the *run* position, adjust the solenoid plunger rod end eye to position its slot to the bolt for minimum engagement when the connecting bolt is installed. The oversize hole in the rod will permit the solenoid to start closing the air gap, with a resultant buildup of pull in force prior to initiating stop lever movement.

4. Adjust the connecting bolt to a height which will allow approximately 1/32" clearance above and below the rod end eye and lock the bolt in place on the stop lever.

5. Move the lever to the *stop* position and check the solenoid plunger for possible bind. If necessary, loosen the mounting bolts and realign the solenoid to provide free plunger movement.

Position Manually Operated Stop Lever

Refer to Fig. 7 and position the manually operated governor stop lever as follows:

1. Place the stop lever in the *run* position.

2. Then loosen the stop lever and position it so that the centerline of the lever is 2 13/16" from the centerline of the cover screw as indicated in Fig. 7.

3. Tighten the stop lever clamping bolt.

Position Air Cylinder

Refer to Figs. 7 and 8 and position the starting aid air cylinder as follows:

1. Attach the air cylinder to its mounting bracket with two screws.

2. Install the mounting bracket, spacers and air cylinder on the governor cover with three screws.

•3. With the governor stop lever properly positioned as outlined above, observe the slots in the mounting bracket and position the air cylinder to provide the air cylinder piston-to-governor stop lever clearance indicated in Figs. 7 and 8.

4. After the air cylinder has been positioned and secured in place, connect the air supply line to the air cylinder. An air supply of not less than 40 psi (276 kPa) nor more than 200 psi (1378 kPa) is required.

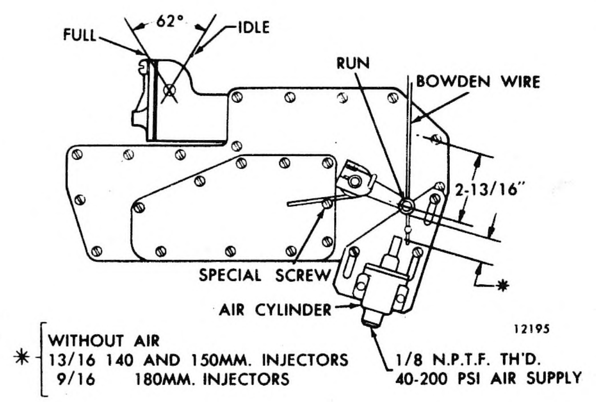

Fig. 7 - Positioning Manually Operated Stop Lever

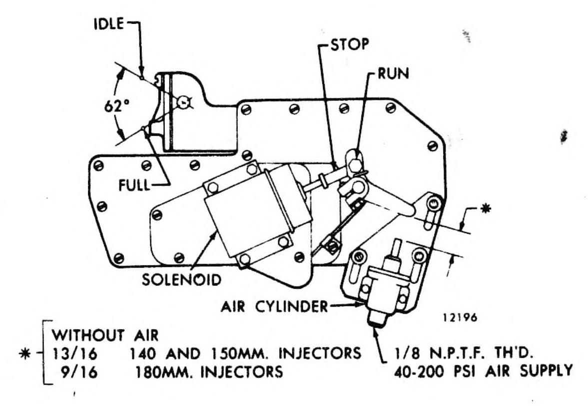

Fig. 8 – Positioning Air Cylinder

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ADJUSTMENT OF MECHANICAL GOVERNOR SHUTDOWN SOLENOID

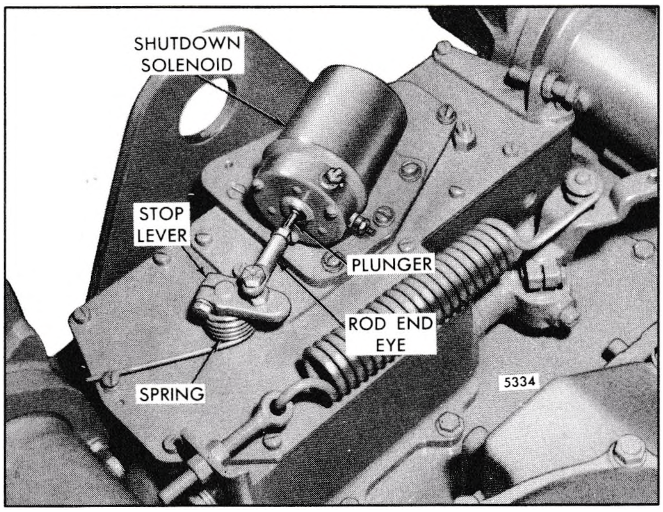

Fig. 9 - Typical Shutdown Solenoid Mounting

When a governor shutdown solenoid is used on an engine equipped with a mechanical governor, the Governor stop lever must be properly adjusted to match the shutdown solenoid plunger travel (Fig. 9).

The solenoid plunger can be properly aligned to the governor stop lever as follows:

1. Remove the bolt connecting the rod end eye (variable speed governor) or the right angle clip (limiting speed governor) to the stop lever (Figs. 10 and 11). Align and clamp the lever to the shutdown shaft in such a way that, at its mid travel position, it is perpendicular to the solenoid plunger. This assures that the linkage will travel as straight as possible. The solenoid plunger has available 1/2" travel which is more than adequate to move the injector control racks from the full-fuel to the complete no-fuel position and shutdown will occur prior to attaining complete travel.

2. With the stop lever in the *run* position, adjust the rod end eye or right angle clip for minimum engagement on the solenoid plunger when the connecting bolt is installed. The oversize hole in the eye or clip will thereby permit the solenoid to start closing the air gap, with a resultant buildup of pull in force prior to initiating stop lever movement.

3. The bolt through the rod end eye or the right angle clip should be locked to the stop lever and adjusted to a height that will permit the eye or clip to float vertically. The clearance above and below the eye or clip and the bolt head should be approximately 1/32" minimum. The lock nut can be either on top of or below the stop lever.

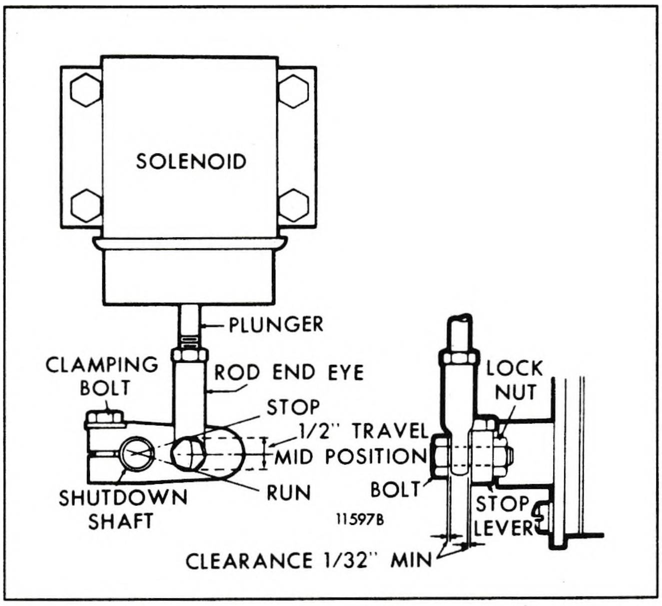

Fig. 10 – Typical Variable Speed Governor Lever Position

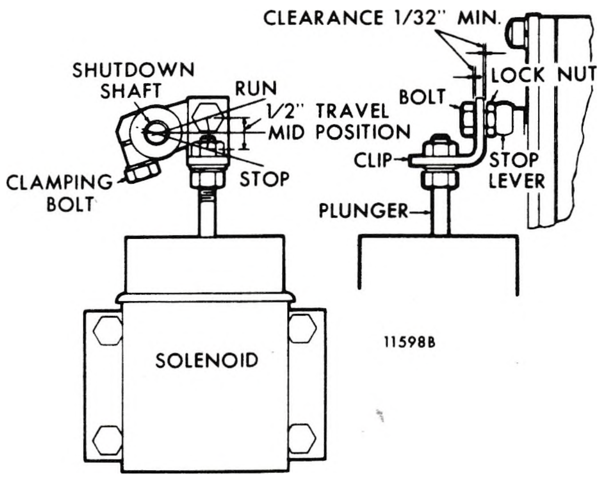

Fig. 11 - Typical Limiting Speed Governor Lever Position

4. Move the lever to the *stop* position and observe the plunger for any possible bind. If necessary, loosen the mounting bolts and realign the solenoid to provide free plunger motion.

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SECTION 15

PREVENTIVE MAINTENANCE - TROUBLESHOOTING - STORAGE

CONTENTS

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LUBRICATION AND PREVENTIVE MAINTENANCE

The *Lubrication and Preventive Maintenance Schedule* is intended as a guide for establishing a preventive maintenance schedule. The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from a Detroit Diesel engine. The intervals indicated on the charts are time or miles (in thousands) of actual operation.

MAINTENANCE SCHEDULE EXPLANATION

The time or mileage increments shown apply only to the maintenance function described. These functions should be coordinated with other regularly scheduled maintenance.

The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out the instructions given under *Preparation for Starting Engine First Time* under *Operating Instructions* in Section 13.1.

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INDUSTRIAL HRS.	DLY.	EACH SHIFT 8	300	600	1,000	5,000
1.-— Lubricating Oil		X	X			
2. — Fuel Tank		X		X		
3. — Fuel Lines and Flexible Hoses	X			X		
4. — Cooling System*		X		X		X
5. — Turbocharger	X					
6. — Battery			X			
7. — Tachometer Drive			X			
8. — Air Cleaners		X		X		
9. — Drive Belts		X	X			
10. — Air Compressor	X		X			X
11. — Throttle and Clutch Controls	X		X			
12. — Lubricating Oil Filter	X		X			
13. — Fuel Strainer and Filter			X			
14. — Coolant Filter				X		
15. — Starting Motor*						
16. — Air System	X		X			
17. — Exhaust System	X		X			
18. — Air Box Drain Tube					X	
19. — Emergency Shutdown	X		X			
21. — Radiator					X	
22. — Shutter Operation	X					
23. — Oil Pressure			X			
24. — Overspeed Governor				X		
26. — Throttle Delay*					X	X
27. — Battery-Charging Alternator*						
28. — Engine and Transmission Mounts					X	
29. — Crankcase Pressure					X	
31. — Fan Hub*						
32. — Thermostats and Seals						X
33, — Blower Screen					X	
34. — Crankcase Breather					X	
36. — Engine Tune-Up*						X
37. — Heat Exchanger*				X	x ,	
38. — Raw Water Pump*						
39. — Power Generator*						
40. — Power Take-Off*						1
41. — Marine Gear	X				X	
49. — Blower Bypass Valve* (Former)				X		
49. — Blower Bypass Valve* (Current)						X
50. — Crankcase Pressure Monitor				X		

*See Item

NOTICE; Certain preventive maintenance checks should be made on a daily basis or at the beginning of each (8 hour) shift. Intervals of 300 and 600 hours indicate preventive maintenance that should be performed every oil change or every other oil change. Intervals of 1000 and 5000 hours indicate long term preventive maintenance.

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Item 1 - Lubricating Oil

• Check the oil level at the beginning of each shift (every eight working hours) or before starting the engine. If the engine has just been stopped, wait approximately twenty (20) minutes to allow the oil to drain back to the oil pan. Add the proper grade oil as required to maintain the correct level on the dipstick (refer to Section 13.3).

NOTICE: Oil may be blown out through the crankcase breather if the crankcase is overfilled.

Make a visual check for oil leaks around the filters and the external oil lines.

• Change the lubricating oil at the intervals shown in the Chart. See Section 13.3 for drain intervals when using high sulfur fuel (above 0.50 mass percent).

ENGINE OIL CHANGE INTERVALS			
Service Application	Non-Turbo or Turbo	Max. Engine Oil Change Interval (Hours)	
		Diesel Fuel Sulfur Content % by Wt. Max.	
		0 to .50	
Industrial & Marine	Non-Turbo or Turbo	300 Hours or 1 Year	

When using high TBN/ash oils, a rule of thumb for oil change intervals is to drain the oil when the TBN drops to one-half of the new oil TBN. *Since lubricant composition varies from brand to brand, the time and rate of TBN reduction will vary.* These differences manifested by the various high TBN/ash oils will influence the drain interval.

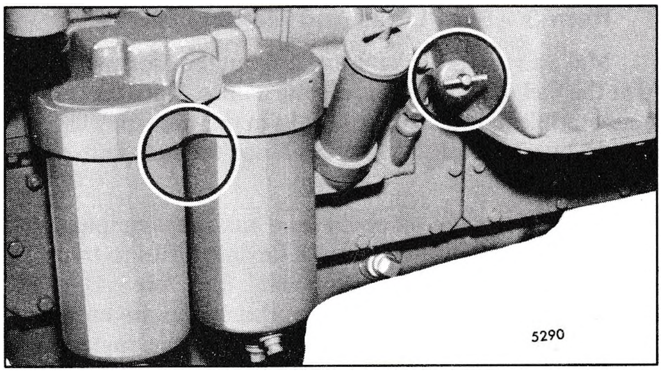
The drain interval may be established on the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the used oil sample analysis) until the most practical oil change period has been determined.

If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and will drain readily. Select the proper grade of oil in accordance with the instructions given in the *Lubricating Oil Recommentations* in Section 13.3.

Item 2 - Fuel Tanks

Check fuel level at the beginning of each shift. Keep the fuel tank filled to reduce condensation to a minimum. Select the proper grade of fuel in accordance with the *Fuel Recommendations* in Section 13.3.

• Open the drain at the bottom of the fuel tank every 600 hours or every other oil change to drain off any water and/or sediment. Tighten all fuel tank mountings and brackets at this *time. At the same time, check the seal in the fuel tank* cap, the breather hole in the cap and the condition of the crossover fuel line. Repair or replace the parts, as necessary.



Items 1 and 1 2

Diesel Fuel Contamination

The most common form of diesel fuel contamination is water. Water is harmful to the fuel system in itself, but it also promotes the growth of microbiological organisms (microbes). These microbes clog fuel filters with a “slime” and restrict fuel flow.

Water can be introduced into the fuel supply through poor maintenance (loose or open fuel tank caps), contaminated fuel supply or condensation.

Condensation is particularly prevalent on units which stand idle for extended periods of time, such as marine units. Ambient temperature changes cause condensation in partially filled fuel tanks.

Water accumulation can be controlled by mixing isopropyl alcohol (dry gas) into the fuel oil at a ratio of one pint (.5 liter) per 125 gallons (473 liters) fuel (or 0.10 by volume).

Marine units in storage are particularly susceptible to microbe growth. The microbes live in the fuel-water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, non-turbulent nature of the fuel tank.

Microbe growth can be eliminated through the use of commerically available biocides. There are two basic types on the market.

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1. The water soluble type treats *only the tank* where it is introduced. Microbe growth can start again if fuel is transferred from a treated to an untreated tank.
2. Diesel fuel soluble type, such as “Biobor” manufactured by U.S. Borax or equilvalent, treats *the fuel* itself and therefore the entire fuel system.

Marine units, or any other application, going into storage should be treated as follows: Add the biocide according to the manufacturer’s instructions. This operation is most effective when performed as the tank is being filled. Add dry gas in the correct proportions.

If the fuel tanks were previously filled, add the chemicals and stir with a clean rod.

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Item 3 - Fuel Lines and Flexible Hoses

Make a visual check for fuel leaks at the crossover lines and at the fuel tank suction and return lines. Since fuel tanks are susceptible to road hazards, leaks in this area may best be detected by checking for accumulation of fuel under the tanks.

The performance of engine and auxiliary equipment is greatly dependent on the ability of flexible hoses to transfer lubricating oil, air, coolant and fuel oil. Diligent maintenance of hoses is an important step in ensuring efficient, economical and safe operation of the engine and related equipment.

Check hoses daily as part of the pre-start up inspection. Examine hoses for leaks and check all fittings, clamps and ties carefully. Make sure that hoses are not resting or touching shafts, couplings, heated surfaces including exhaust manifolds, any sharp edges or other obviously hazardous areas. Since all machinery vibrates and moves to a certain extent, clamps and ties can fatigue with age. To ensure continued proper support, inspect fasteners frequently and tighten or replace them, as necessary.

Leaks

Investigate leaks immediately to determine if fittings have looseded or cracked or if hoses have ruptured or worn through. Take corrective action immediately. Leaks are not only potentially detrimental to machine operation, but they also result in added expense caused by the need to replace lost fluids.

CAUTION: Personal injury and/or property damage may result from fire due to the leakage of flamable fluids such as fuel or lube oil.

Service Life

• A hose has a finite service life. The service life of a hose is determined by the temperature and pressure of the air or fluid within it, its time in service, its mounting, the ambient temperatures, amount of flexing and vibration it is subject to. With this in mind, all hoses should be thoroughly inspected at least every 600 operating hours, every other oil change, or annually, whichever comes first. Look for cover damage or indications of damaged twisted, worn, crimped, brittle, cracked or leaking lines. Hoses having the outer cover worn through or damaged metal reinforcement should be considered unfit for further service.

All hoses in or out of machinery should be replaced during major overhaul and/or after a maximum of five years service.

Item 4 - Cooling System

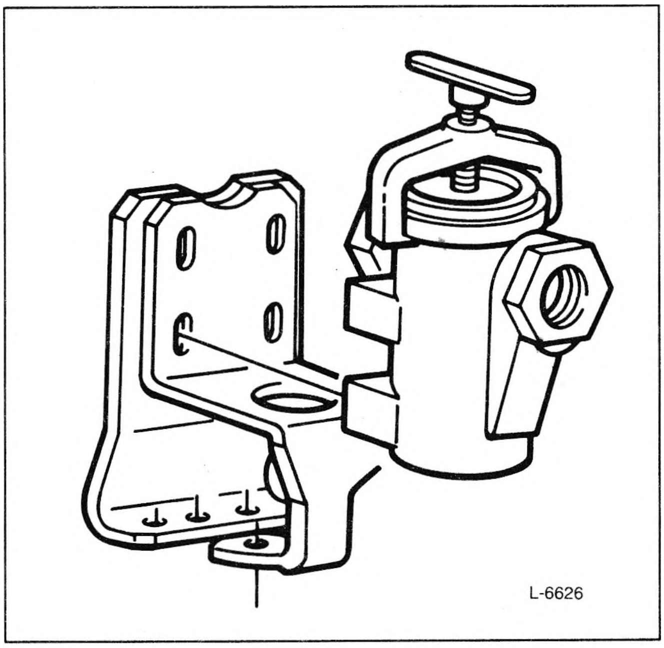
• CAUTION: Do not remove the pressure control cap from the radiator or heat exchanger or attempt to drain the coolant until the engine has cooled. Once the engine has cooled, use extreme care when removing the cap. The sudden release of pressure from a heated cooling system can result in a loss of coolant and possible personal injury (scalding) from the hot liquid.

Check the coolant level at the beginning of each shift and maintain it near the top of the heat exchanger tank or make sure it covers the radiator tubes. Add coolant, as necessary. *Do not overfill.*

Make a visual check for cooling system leaks. Check for an accumulation of coolant beneath the vehicle during periods when the engine is running and when the engine is stopped.

Clean the cooling system annually or every 5,000 hours using a good radiator cleaning compound in accordance with the instructions on the container. After the cleaning operation, rinse the cooling system thoroughly with fresh water. Then, fill the system with soft water, adding a good grade of rust inhibitor or an ethylene glycol base antifreeze solution (refer to *Coolant Specifications* in Section 13.3). With the use of a proper antifreeze or rust inhibitor, this interval may be lengthened until, normally, this cleaning is done only in the spring or fall. The length of this interval will, however, depend upon an inspection for rust or other deposits on the internal walls of the cooling system. When a thorough cleaning of the cooling system is required, it should be reverse flushed.

• The coolant circulated through the intercoolers on a turbocharged-intercooled engine is protected by a water strainer. Current engines use a bracket-mounted water strainer assembly located on top of the engine. This basket-type strainer filters the coolant going into the



● Item 4

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intercooler(s). Former engines used a 20 mesh cone-shaped screen located at the water connection in the water pump-to-engine oil cooler tube (“S-tube”).

The strainer should be removed and inspected for damage or clogging when the cooling system is cleaned. If badly clogged or damaged, replace the strainer. *Do not operate an intercooled engine without the strainer in place.*

• Inspect all of the cooling system hoses at least once every 600 hours or every other oil change, whichever comes first. Make sure the clamps are tight and properly seated on the hoses, and check or signs of deterioration.

• Check inhibitor and antifreeze concentration every 600 hours or every other oil change to insure proper cooling system protection. Replace the hoses, if necessary.

Item 5 - Turbocharger

Inspect the mountings, intake and exhaust ducting and connections for leaks daily. Check the oil inlet and outlet lines for leaks and restriction to air flow. Check for unusual noise or vibration and, if excessive, remove the turbocharger and correct the cause.

• CAUTION: To eliminate the possibility of personal injury when air inlet piping is removed, do not operate an engine unless the turbo inlet shield (J 26554-A) is installed.

• Item 6 - Battery

Check the “eye” of maintenance-free batteries for charge. If lead-acid or low maintenance batteries are used, check the specific gravity of the electrolyte in each cell every 300 hours. In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. The electrolyte level should be maintained in accordance with the battery manufacturer’s recommendations.

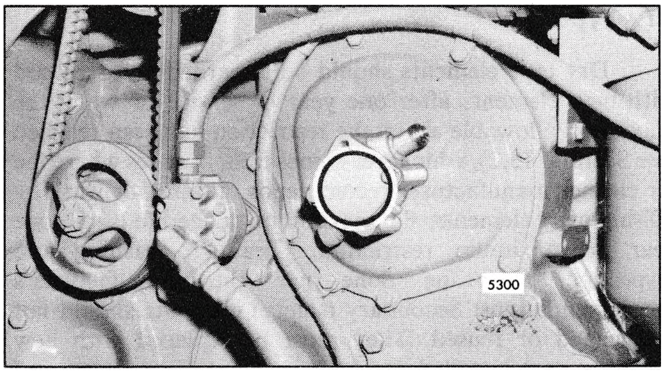
Item 7 - Tachometer Drive

• Lubricate the tachometer drive every 300 hours with an all purpose grease at the grease fitting. At temperatures above 30°F (-1°C), use a No. 2 grade grease. Use a No. 1 grade grease below this temperature.

Item 8 - Air Cleaner

Under no engine operating conditions should the air inlet restriction exceed 25 inches of water (6.2 kPa) for non-turbocharged engines or 20 inches of water (5.0 kPa) for turbocharged engines. A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine. ·

• Inspect air cleaner housing fasteners, clamps, and ducting for damage and tighteness at the beginning of each shift.



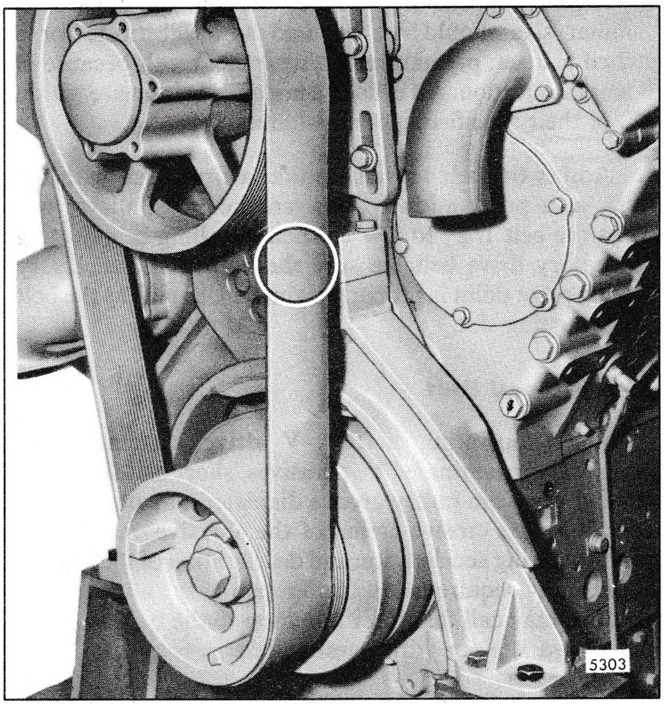
Item 7

Oil Bath

Remove the dirty oil and sludge from the oil bath type air cleaner cups and center tubes every 8 hours or less if operating conditions warrant. Wash the cups and elements in clean fuel oil and refill the cups to the level mark with the same grade and viscosity *heavy-duty* oil as used in the engine. The frequency of servicing may be varied to suit local dust conditions. If heavy rain or snow has been encountered, check the air cleaner for an accumulation of water.

Remove and steam clean the air cleaner element and baffle annually.

• It is recommended that the body and fixed element in the heavy-duty oil bath type air cleaner be serviced every 600 hours or as conditions warrant.



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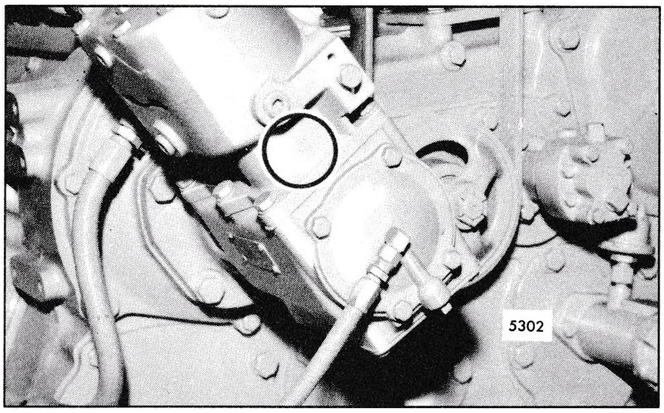

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Item 10 - Air Compressor

• Inspect daily for loose fittings, damaged hoses, and coolant leaks.

• Remove and wash all of the polyurethane sponge strainer parts every 300 hours. The strainer element should be cleaned or replaced. If the element is cleaned, it should be washed in commercial solvent or a detergent and water solution. The element should be saturated in clean engine oil, then squeezed dry before replacing it in the strainer. Be sure to replace the air strainer gasket if the entire air strainer is removed from the compressor intake.

• For replacement of the air strainer element, contact the nearest Bendix or Midland air compressor dealer; replace with the polyurethane element, if available.

• Every 5000 hours tighten the air compressor mounting bolts. If the air compressor is belt driven, check the belts for proper tension.

Item 11 - Throttle and Clutch Controls

• Inspect daily for loose linkage and tighten as required.

• Every 300 hours lubricate the throttle control mechanism. Use an all purpose grease (No. 2 grade) at temperatures 30° F (-1° C) and above. At temperatures below this use a No. 1 grade grease.

Lubricate all other control mechanisms, as required, with engine oil.

Item 12 - Lubricating Oil Filter

• Install new oil filter elements (and gaskets on cartridge type filter assemblies) each time the engine oil is changed.

• Make a visual check of all lubricating oil lines for wear and chafing on a daily basis. If any indication of wear is evident, replace the oil lines and correct the cause.

When the engine is equipped with a turbocharger, pre-lubricate it as outlined under *Install Turbocharger* in Section 3.5.

Check for oil leaks after starting the engine.

Item 13 - Fuel Strainer and Filter

• Install new elements every 300 hours or when plugging is indicated.

• A method of determining when elements are plugged to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet manifold and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction must not exceed 6 inches of mercury (20.3 kPa). With 16V non-turbocharged engine at normal operating speeds and with .170" restriction fittings (current engines) or .136" restriction fittings (former engines), the fuel pressure is 35-75 psi (241-517 kPa). With turbocharged engines, at normal operating speeds and with either .170" (current) or .136" (former) restriction fittings, the fuel pressure is 35-75 psi (241-517 kPa). Change the fuel filter elements whenever the inlet restriction at the fuel pump reaches 12 inches of mercury (41 kPa) at normal operating speeds and whenever the fuel pressure at the inlet manifold falls to the minimum fuel pressure shown above.

• **NOTICE:** *To improve starting, have replacement filters filled with fuel and ready to install immediately after used filters are removed. This will prevent possible fuel siphoning, causing fuel system aeration. If the engine fails to start after replacement of the fuel filter element(s), the fuel system will require priming with tool J 5956, or equivalent.*

Item 14 - Coolant Filter

• If the cooling system is protected by a coolant filter and conditioner, the filter element should be changed every 600 hours. Select the proper coolant filter element in accordance with the instructions given under *Coolant recommendations* in Section 13.3. Use a new filter cover gasket when installing the filter element. After replacing the filter and cover gasket, start the engine and check for leaks.

Item 15 - Starting Motor

• The electrical starting motor is permanently lubricated at the time of manufacture. No further lubrication is required. Follow starter manufacturer’s recommendations if disassembly or overhaul is required.

Item 16 - Air System

• Visually check all of the connections in the air system to be sure they are tight on a daily basis. Check all hoses for punctures or other damage and replace, if necessary. Retighten connections every 300 hours.

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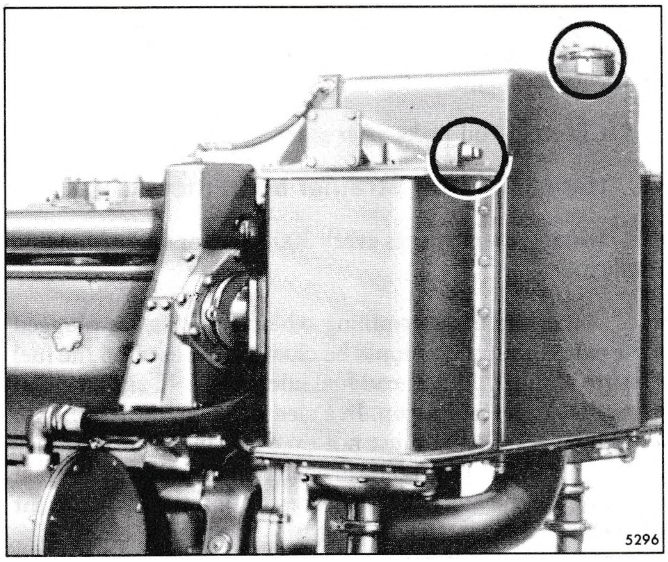

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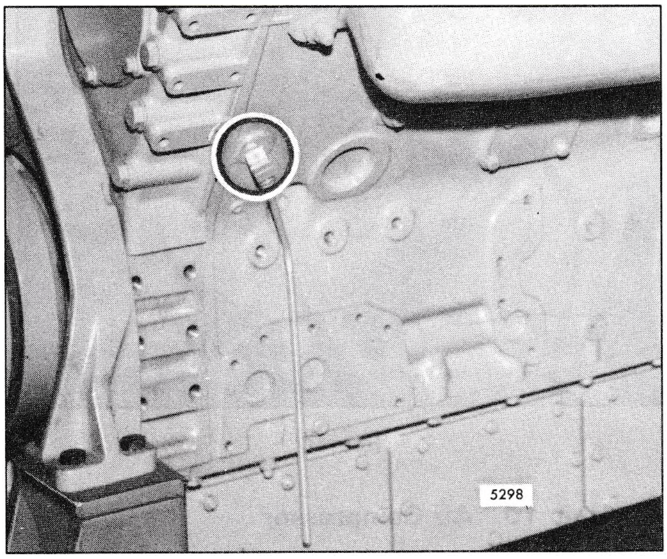

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Item 17 - Exhaust System

• Visually check the exhaust manifold retaining nuts, exhaust flange clamp and other connections for tightness on a daily basis. Check for proper operation of the exhaust pipe rain cap, if one is used. Retighten connections every 300 hours.

Item 18 - Air Box Drain Tube

With the engine running, check for flow of air from the air box drain tubes every 1,000 hours. If the tubes are clogged, remove, clean and reinstall the tubes. The air box drain tubes should be cleaned periodically even though a clogged condition is not apparent.

If the engine is equipped with an air box drain tank, drain the sediment periodically.

Item 19 - Emergency Shutdown

• Visually inspect emergency shutdown linkage for proper setting, wear, damage, etc. on a daily basis. With the engine running at idle speed, check the operation of the emergency shutdown every 300 hours. Reset the air shutdown valve in the open position after the check has been made.

Item 21 - Radiator

• Inspect the exterior of the radiator core every 1000 hours and, if necessary, clean it with a quality grease solvent such as mineral spirits and dry it with compressed air.

• CAUTION: To avoid personal injury, wear adquate eye protection and do not exceed to psi (276 kPa) air pressure.

Do not use fuel oil, kerosene or gasoline. Clean the radiator more frequently if the engine is being operated in extremely dusty or dirty areas.

Item 22 - Shutter Operation

Check the operation of the shutters and clean the linkage and controls daily.

Item 23 - Oil Pressure

• Under normal operation, oil pressure is noted each time the engine is started. In the event the engine is equipped with warning lights rather than pressure indicators, the pressure should be checked and recorded every 300 hours.

Item 24 - Overspeed Governor

• Lubricate the overspeed governor, if it is equipped with a hinge-type cap oiler or oil cup, with 5 or 6 drops of engine oil every 600 hours. Avoid excessive lubrication and do not lubricate the governor while the engine is running.

Item 26 - Throttle Delay

• Inspect and adjust throttle delay every 5000 hours. Inspect spring-loaded yield link every 1000 hours for proper operation. Replace yield link after 5000 hours, or earlier if required.

The throttle delay system limits the amount of fuel injected during acceleration by limiting the rate of injector rack movement with a hydraulic cylinder. The initial location of this cylinder must be set with the proper gage to achieve the appropriate time delay (Section 14.14).

Inspect the check valve by filling the throttle delay cylinder with diesel fuel and watching for valve leakage while moving the throttle from the idle to the *full-fuel* position.

Stem 27 - Battery-Charging Alternator

Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.

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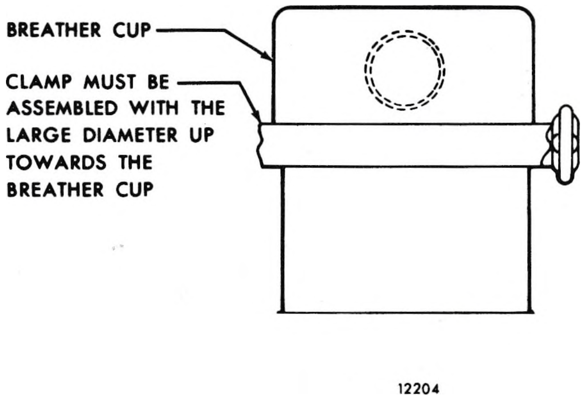

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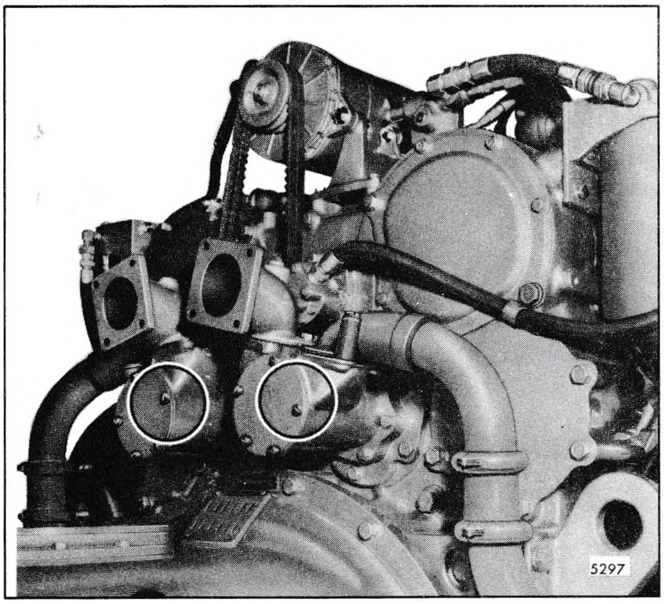

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or, if worn excessively, replace with new electrodes. To determine the condition of a used electrode, strike it sharply against a hard surface; a weakened electrode will break.

Drain the cooling system, disconnect the raw water pipes at the outlet side of the heat exchanger and remove the retaining cover every 1,000 hours and inspect the heat exchanger core. If a considerable amount of scale or deposits are present, clean the core as outlined in Section 5.5.

Item 38 - Raw Water Pump

• Always prime the raw water pump before starting the engine. Since water acts as a lubricant for the impeller, failure to prime the pump (or at least wet the impeller vanes to induce a self-priming suction) can result in severe impeller damage when the engine is started. Insufficient raw water flow into the heat exchanger caused by a damaged impeller can lead to overheating and subsequent engine damage. To prime the pump: a) remove the pipe plug from the water inlet elbow; b) pour in at least a pint of water; c) replace the plug.

Item 39 - Power Generator

• Follow the power generator manufacturer's lubrication and preventive maintenance recommendations at his suggested intervals.

Item 40 - Power Takeoff

Follow the power take-off manufacturer's lubrication and preventive maintenance recommendations at his suggested intervals.

Item 41 - Marine Gear

Check the oil level daily in the Twin Disc Marine Gear. Check the oil level with the engine running for three to five minutes at low idle speed and the gear in neutral. Keep the oil up to the proper level on the dipstick. Use the same grade and viscosity *heavy-duty* oil as used in the engine.

Change the oil and oil filter element every 1,000 hours. After draining the oil, thoroughly clean the removable oil screen and breather. Reinstall the breather and refill the marine gear with oil up to the full mark on the dipstick. Start the engine and, with the gear in neutral, run the engine at idle speed for three to five minutes and check the marine gear oil level. If necessary, add oil to bring it up to the full mark on the dipstick.

Item 49 - Bypass Blower Valve

Former System

• On engines with a former flapper-style bypass valve-equipped air induction system, make the following checks after every 600 hours of engine operation.

1. Visually inspect the entire bypass operating system, including air cylinders, lever and roll pin, operating shaft and ball joint connector for binding, misalignment or abnormal wear. Replace, if necessary.
2. With the engine stopped, disconnect the ball joint connector from the operating shaft lever. Rotate the lever through its arc of rotation to ensure that the shaft operates freely and that there is no excessive play. If excessive play is detected this could indicate a loose valve. Remove the housing and inspect the \jalve, the valve hold-down block and the shaft. Replace, if necessary.
3. Check the air cylinder for proper operation, using the following procedure:
   a. With the engine stopped and the air cylinder-to-valve linkage disconnected, detach the boost pressure line from the air inlet housing and install a tee fitting on the end of the hose. Attach a low pressure gage and an air supply line to the open ends of the tee fitting.

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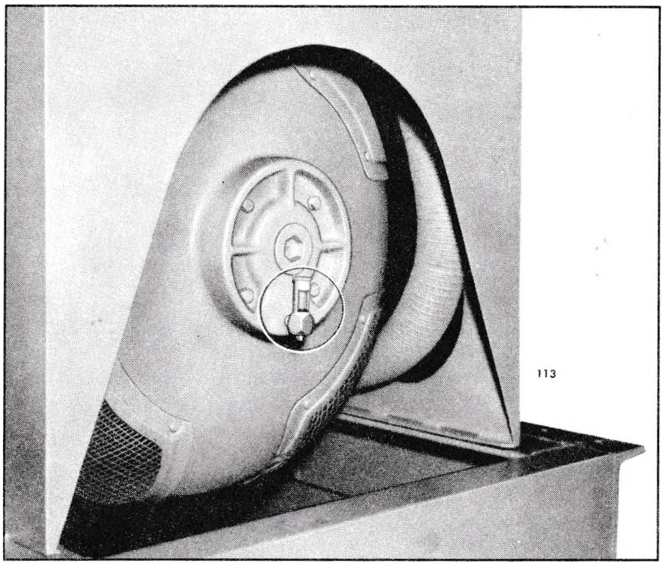
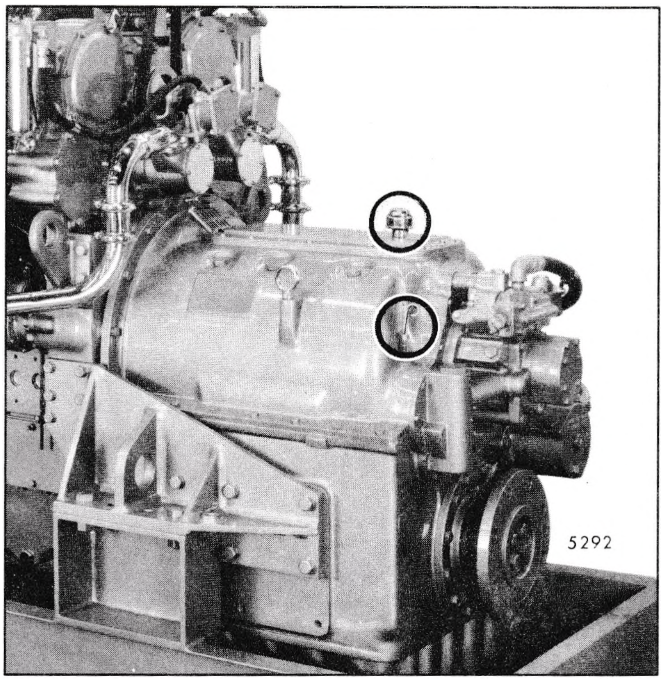


Item 39

b. Using regulated shop air, slowly charge the cylinder and watch the rod on the end of the piston. The rod should start to move at 7 psi (48 kPa) and be fully extended at 10 psi (69 kPa). As pressure drops, the rod should be fully seated in the cylinder at 3 psi (21 kPa). If the air cylinder fails this test, check the breather filter element on the end and replace, if plugged. A plugged breather filter element will not allow the cylinder to exhaust and intake air during engine operation. In areas where severe plugging is experienced, a remote mounted, dry type air filter may be installed. If the air cylinder still does not function properly, replace the cylinder.

c. If the air cylinder operates properly during the test but the valve continues to malfunction when linkage is reconnected, check the linkage for binding and misalignment. If this fails to correct the malfunction, the valve should be replaced.



Item 41

d. Remove the tee fitting and pressure gage. Reconnect the turbocharger boost line to the air cylinder.

• Current System

On engines with current piston-style bypass valve-equipped air induction systems, verify the settings on the control valve every 5000 hours. Refer to section 3.4.2 for procedure.

Item 50 - Crankcase Pressure Monitor

Check the crankcase pressure monitor for proper operation every 600 hours. Repair or replace as required. Refer to section 7.4 for procedure.

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TROUBLESHOOTING

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

Satisfactory engine operation depends primarily on:

1. An adequate supply of air compressed to a sufficiently high compression pressure.
2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given below:

Checking Compression Pressure

To prevent excessive oil splash and/or loss of oil when performing a compression pressure check, a spare rocker cover should be modified as shown in Fig. 1. This rocker cover can then be used at any one of the cover locations.

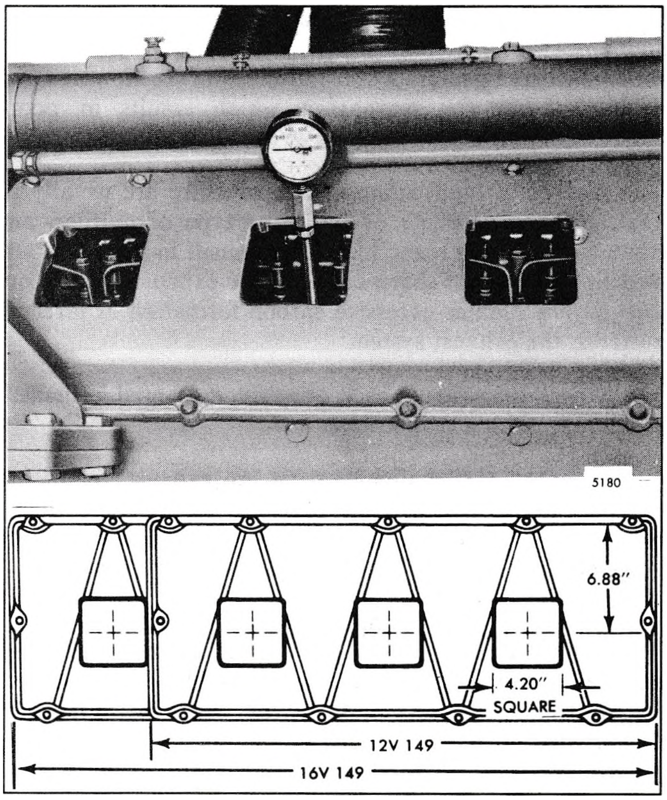

Fig. 1 - Instructions for Modifying the Rocker Cover for Compression Test

NOTICE: Be sure to reinstall each standard cover after performing the compression check with the modified cover.

Check the compression pressure as follows:

1. Start the engine and run it at approximately one-half rated load until normal operating temperature is reached.
2. Stop the engine and remove the fuel pipes from the injector and fuel connectors of the No. 1 cylinder.

   • **NOTICE:** To avoid dilution of lube oil, use a clean rag to catch and absorb fuel spill from the fuel mainfold.

3. Remove the injector from the No. 1 cylinder and remove the injector rocker arm. Then install spacer J 22503-7 in place of the injector rocker arm and install pressure gage J 22503, using the injector hold-down clamp to retain the pressure gage.
4. Use a spare fuel pipe to fabricate a jumper connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.

• To fabricate the jumper line connection, cut off the injector end of a spare fuel pipe and remove the injector nut. Slip a fuel manifold nut onto the pipe and flare the end of the tube. Bend the line to fit.

5. Start the engine and run it at 600 rpm. Observe and record the compression pressure indicated on the gage. *Do not crank the engine with the starting motor to obtain the compression pressure.*
6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder should not be less than shown in Table 1. In addition, the variation in compression pressures between cylinders must not exceed 25 psi (172 kPa) at 600 rpm.

Minimum Compression Pressure at 600 rpm				Altitude ^ above Sea Level		t Air Density
149 and 149T		149TI				
psi	kPa	psi	kPa	Feet	Meters	
450	3101	370	2550	0-500	0-152.4	.0715
415	2859	340	2343	2,500	762.0	.0663
385	2653	315	2170	5,000	1524.0	.0613
355	2446	290	1999	7,500	2285.0	.0567
330	2274	270	1861	10,000	3048.0	.0525

t Air density at 500 ft. altitude based on 85° F (29.4° C) and 29.38 in Hg (99.49 kPa) wet barometer.

TABLE 1

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Low compression pressure may result from any one of several causes:

A. Piston rings may be stuck or broken. To determine the condition of the rings, remove the air box cover and inspect them by pressing on the rings with a blunt tool. A broken or stuck ring will not have a “spring-like” action.

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

Engine Out Of Fuel

The problem in restarting an engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

When an engine has run out of fuel, there is a definite procedure to follow for restarting it.

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of 25 gallons (95 litres) of fuel.

2. Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.

3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.

4. Start the engine. Check the filter and strainer for leaks.

NOTICE: In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

Fuel Flow Test

The proper flow of fuel is required for satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter as outlined in Section 2.0 under *Troubleshooting.*

Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liners into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine lubricating oil through the crankcase ventilator or the dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow-by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, defective blower or cylinder head gaskets, or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

Check the crankcase pressure with a manometer connected to the oil level dipstick opening in the cylinder block. Check the readings obtained at various engine speeds with the *Engine Operating Conditions* in Section 13.2.

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

Exhaust Back Pressure

A slight pressure in the exhaust system is normal. How'ever, excessive exhaust back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss of efficiency of the blower. This means less air for scavenging which results in poor combustion and higher temperatures.

Causes of high exhaust back pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

Check the exhaust back pressure, measured in inches of mercury, with a manometer.

Connect the manometer to an exhaust manifold (except on turbocharged engines). If no opening is provided, drill an 11/32" hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8" pipe plug.

On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the turbine outlet (Fig. 1 of Section 13.2). The tapped hole must be in a comparatively straight pipe area for an accurate measurement.

Check the readings obtained at various speeds (at no-load) with the *Engine Operating Conditions* in Section 13.2.

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Air Box Pressure

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, an air leak from the air box or a clogged blower air inlet screen. Lack of power or black or grey exhaust smoke are indications of low air box pressure.

High air box pressure can be caused by partially plugged cylinder liner ports.

Check the air box pressure with a manometer connected to an air box drain tube.

Check the readings obtained at various speeds with the *Engine Operating Conditions* in Section 13.2.

Air Inlet Restriction

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower inlet restriction.

Check the air inlet restriction with a water manometer connected to a fitting in the air inlet ducting located 2" above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

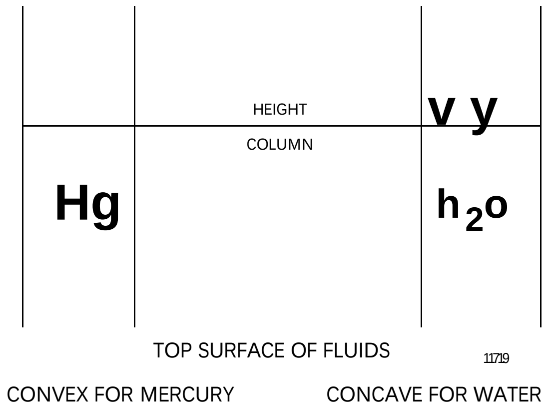

Fig. 2 - Comparison of Column Height for Mercury and Water Manometers

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.

On turbocharged engines, measure the air inlet restriction, at each turbocharger, with a water manometer connected in the large diameter of the air duct just before it is reduced to enter the turbocharger compressor (Fig. 1 in Section 13.2). There should not be more than 2" of water difference in the compressor inlet readings for turbochargers being supplied from a common air cleaner(s).

Check the normal air inlet vacuum at various speeds (at no-load) and compare the results with the *Engine Operating Conditions* in Section 13.2.

PROPER USE OF MANOMETER

The U-tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inch s one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 2) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 2 to convert the manometer reading into other units of measurement.

PRESSURE CONVERSION CHART			
	' water	-	.0735" mercury
	water	—	.0361 psi
	mercury	—	13.6000" water
	mercury	=	.4910 psi
i	psi	=	27.7000" water
i	psi	=	2.0360" mercury
i	psi	=	6.895 kPa
i	kPa		.145 psi

TABLE 2

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Chart 1

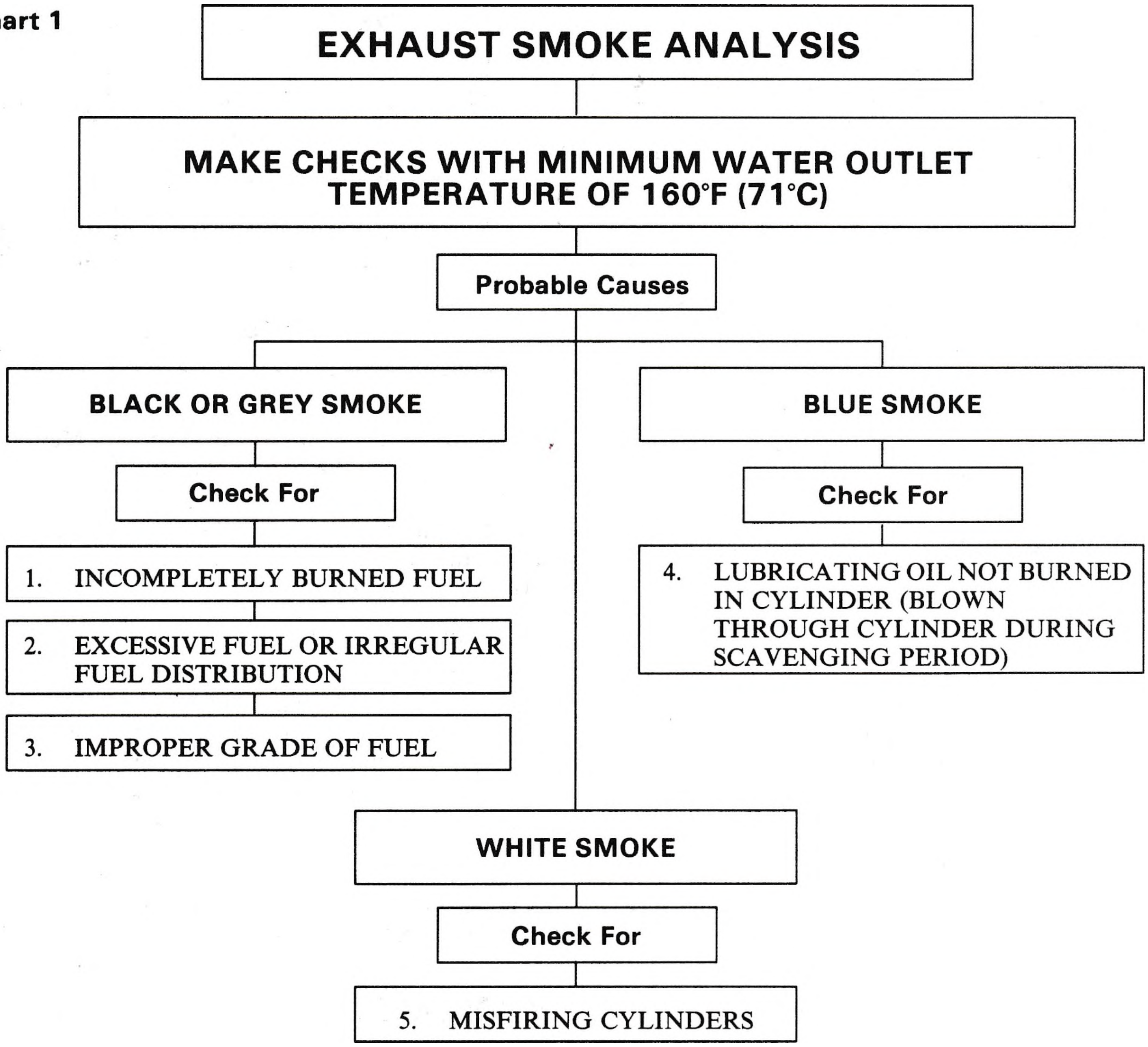

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Chart 1

EXHAUST SMOKE ANALYSIS

— SUGGESTED REMEDY —

1. High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner or blower air inlet screen. Clean these items. Check the emergency stop to make sure that it is completely open and readjust it if necessary.

2. Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune-up.

Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune-up.

Avoid lugging the engine as this will cause incomplete combustion.

3. Check for use of an improper grade of fuel. Refer to ***Fuel Oil Recommendations*** in Section 13.3.

4. Check for internal lubricating oil leaks and refer to the ***High Lubricating Oil Consumption*** chart.

5. Check for faulty injectors and replace as necessary.

The use of low cetane fuel will cause this condition. Refer to ***Fuel Oil Recommendations*** in Section 13.3.

Check for low compression and consult the ***Hard Starting*** chart.

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Chart 2

HARD STARTING

Probable Causes

ENGINE WILL NOT ROTATE

Check For

1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE

LOW CRANKING SPEED

Check For

4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER

NO FUEL

Check For

7. AIR LEAKS, FLOW OBSTRUCTION, FAULTY FUEL PUMP, FAULTY INSTALLATION
8. INJECTOR RACKS NOT IN FULL–FUEL POSITION WHEN STARTING AID SCREW IS NOT USED

LOW COMPRESSION

Check For

9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING

INOPERATIVE STARTING AID AT LOW AMBIENT TEMP

Check For

14. IMPROPER OPERATION OF FLUID STARTING AID

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Chart 2

HARD STARTING

SUGGESTED REMEDY

1. Refer to Items 2, 3 and 5 and perform the operations listed.

2. Replace the starting motor switch.

3. Hand crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.

4. Refer to *Lubricating Oil Recommendations* in Section 13.3 for the recommended grade of oil.

5. Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge.

   Replace terminals that are damaged or corroded.

At low ambient temperatures, use of a starting aid will keep the battery fully charged by reducing the cranking time.

6. Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.

7. To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the *No Fuel or Insufficient Fuel* chart.

8. Check for bind in the governor-to-injector linkage. Readjust the governor and injector controls if necessary.

9. Remove the cylinder head and recondition the exhaust valves.

10. Remove the air box covers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.

11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head gasket is damaged or the cylinder head is cracked. Remove the cylinder head and replace the gaskets or cylinder head.

12. Adjust the exhaust valve clearance.

13. Remove the blower drive shaft. Inspect the blower drive shaft and coupling. Replace damaged parts. Bar the engine over. If the engine does not rotate, remove the air inlet adaptor and visually inspect the blower rotors and end plates. If damaged, remove and overhaul the blower.

14. Operate the starting aid according to the instructions under *Cold Weather Starting Aids.*

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Chart 3

ABNORMAL ENGINE OPERATION

Probable Causes

UNEVEN RUNNING OR FREQUENT STALLING

Check For

1. LOW COOLANT TEMPERATURE
2. INSUFFICIENT FUEL
3. FAULTY INJECTORS
4. LOW COMPRESSION PRESSURES
5. GOVERNOR INSTABILITY (HUNTING)

LACK OF POWER

Check For

6. IMPROPER ENGINE ADJUSTMENTS (TUNE-UP) AND GEAR TRAIN TIMING
7. INSUFFICIENT FUEL
8. INSUFFICIENT AIR
9. ENGINE APPLICATION
10. HIGH RETURN FUEL TEMPERATURE
11. HIGH AMBIENT AIR TEMPERATURE
12. HIGH ALTITUDE OPERATION

DETONATION

Check For

13. OIL PICKED UP BY AIR STREAM
14. LOW COOLANT TEMPERATURE
15. FAULTY INJECTORS

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Chart 3

ABNORMAL ENGINE OPERATION

------- SUGGESTED REMEDY --------

1. Check the engine coolant temperature gage and, if the temperature does not reach 160-185°F (71-85°C) while the engine is operating, consult the *Abnormal Engine Coolant Temperature* chart.

2. Check engine fuel spill back and if the return is less than specified, consult the *No Fuel or Insufficient Fuel* chart.

3. Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune-up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.

4. Check the compression pressures within the cylinders and consult the *Hard Starting* chart if compression pressures are low.

5. Erratic engine operation may be caused by governor-to-injector operating linkage bind or by faulty engine tune-up. Perform the appropriate engine tune-up procedure as outlined for the particular governor used.

6. Perform an engine tune-up if performance is not satisfactory.

Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

7. Perform a *Fuel Flow Test* and, if less than the specified fuel is returning to the fuel tank, consult the *No Fuel or Insufficient Fuel* chart.

8. Check for damaged or dirty air cleaners and clean, repair or replace damaged parts.

Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

Check for blower air intake obstruction or high-exhaust back pressure. Clean, repair or replace faulty parts.

Check the compression pressures (consult the *Hard Starting* chart).

9. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.

10. Refer to Item 13 on Chart 4.

11. Check the ambient air temperature. A power decrease of .15 to .50 horsepower per cylinder, depending upon injector size, for each 10°F (5.6°C) temperature rise above 90°F (32.2°C) will occur. Relocate the engine air intake to provide a cooler source of air.

12. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.

13. Fill oil bath air cleaners to the proper level with the same grade and viscosity lubricating oil that is used in the engine.

Clean the air box and drain tubes to prevent accumulations that may be picked up by the air stream and enter the engine's cylinders.

Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

Check for a defective blower-to-block gasket. Replace the gasket, if necessary.

14. Refer to Item 1 of this chart.

15. Check injector timing and the position of each injector rack. Perform an engine tune-up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

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Chart 4

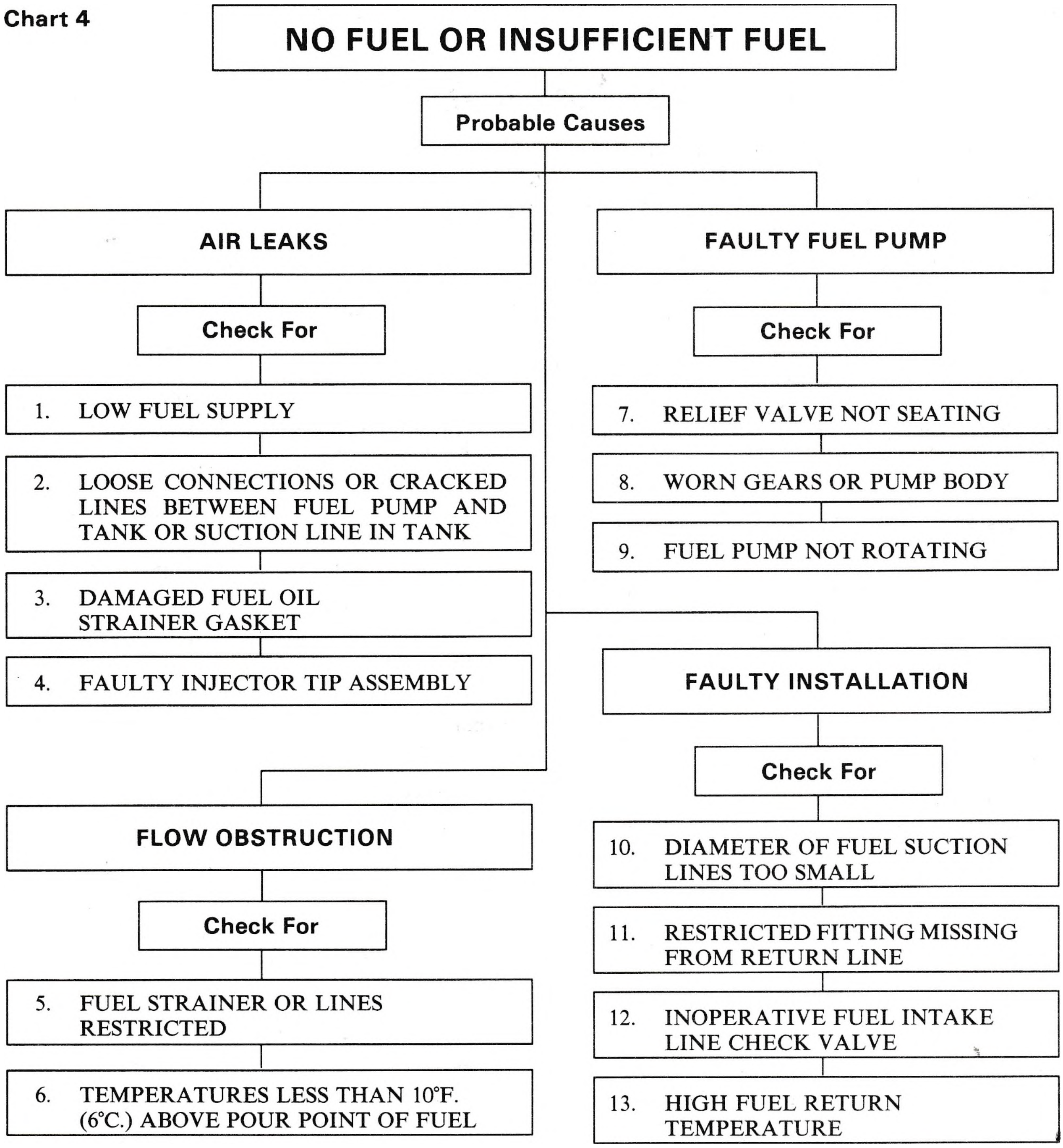

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Chart 3

ABNORMAL ENGINE OPERATION

------- SUGGESTED REMEDY --------

1. Check the engine coolant temperature gage and, if the temperature does not reach 160-185°F (71-85°C) while the engine is operating, consult the *Abnormal Engine Coolant Temperature* chart.

2. Check engine fuel spill back and if the return is less than specified, consult the *No Fuel or Insufficient Fuel* chart.

3. Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune-up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.

4. Check the compression pressures within the cylinders and consult the *Hard Starting* chart if compression pressures are low.

5. Erratic engine operation may be caused by governor-to-injector operating linkage bind or by faulty engine tune-up. Perform the appropriate engine tune-up procedure as outlined for the particular governor used.

6. Perform an engine tune-up if performance is not satisfactory.

Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

7. Perform a *Fuel Flow Test* and, if less than the specified fuel is returning to the fuel tank, consult the *No Fuel or Insufficient Fuel* chart.

8. Check for damaged or dirty air cleaners and clean, repair or replace damaged parts.

Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

Check for blower air intake obstruction or high exhaust back pressure. Clean, repair or replace faulty parts.

Check the compression pressures (consult the *Hard Starting* chart).

9. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.

10. Refer to Item 13 on Chart 4.

11. Check the ambient air temperature. A power decrease of .15 to .50 horsepower per cylinder, depending upon injector size, for each 10°F (5.6°C) temperature rise above 90°F (32.2°C) will occur. Relocate the engine air intake to provide a cooler source of air.

12. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.

13. Fill oil bath air cleaners to the proper level with the same grade and viscosity lubricating oil that is used in the engine.

Clean the air box and drain tubes to prevent accumulations that may be picked up by the air stream and enter the engine's cylinders.

Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

Check for a defective blower-to-block gasket. Replace the gasket, if necessary.

14. Refer to Item 1 of this chart.

15. Check injector timing and the position of each injector rack. Perform an engine tune-up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a* broken spray tip. Replace faulty injectors.

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Chart 4

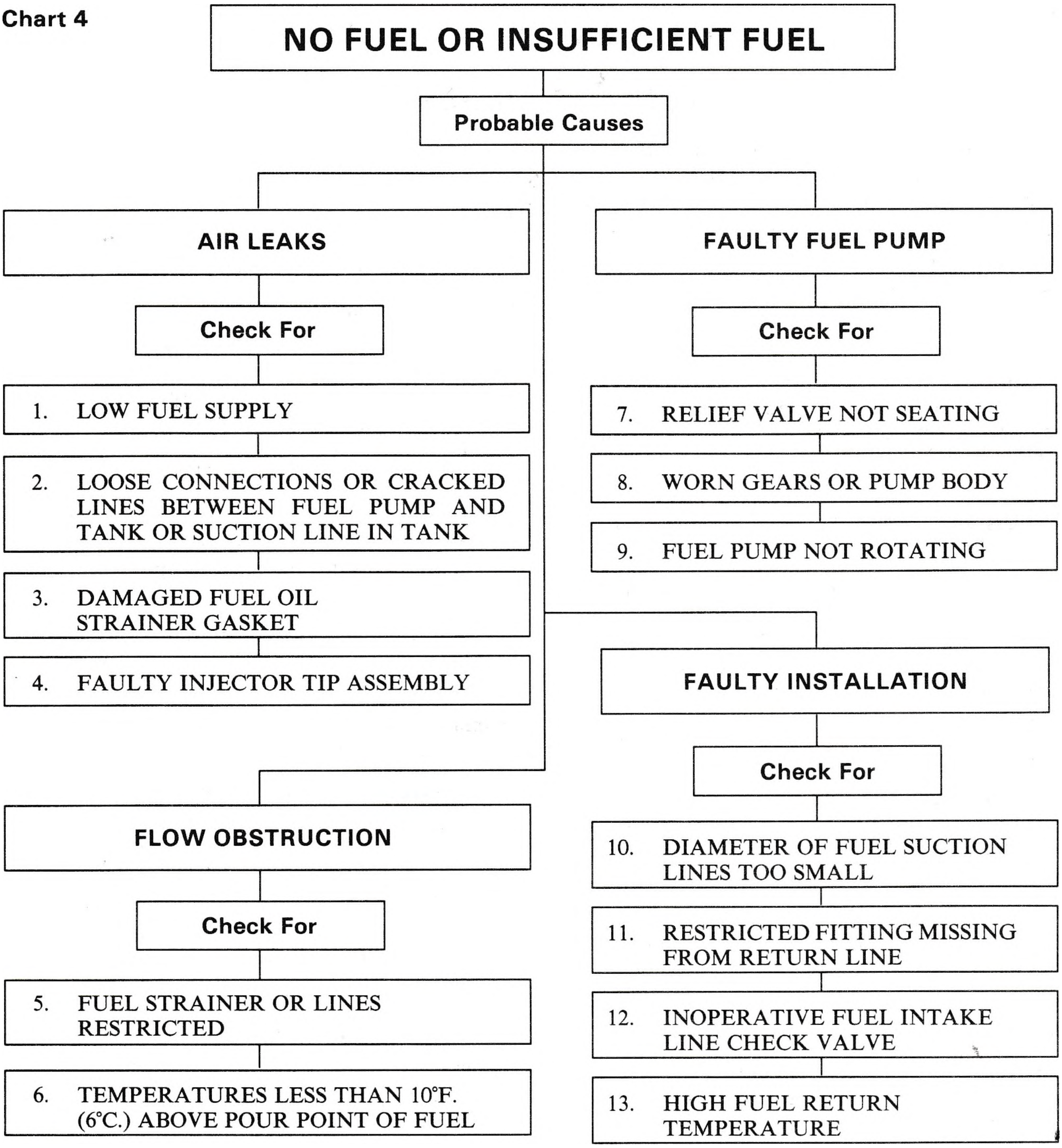

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Chart 4

NO FUEL OR INSUFFICENT FUEL

------ SUGGESTED REMEDY ------- *

1. The fuel tank should be filled above the level of the fuel suction tube.
2. Perform a ***Fuel Flow Test*** and, if air is present, tighten loose connections and replace cracked lines.
3. Perform a ***Fuel Flow Test*** and, if air is present, replace the fuel strainer gasket when changing the strainer element.
4. Perform a ***Fuel Flow Test*** and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.
5. Perform a ***Fuel Flow Test*** and replace the fuel strainer and filter elements and the fuel lines, if necessary,
6. Consult the ***Fuel Oil Recommendations*** for the recommended grade of fuel.
7. Perform a ***Fuel Flow Test*** and, if inadequate, clean and inspect the valve seat assembly.
8. Replace the gear and shaft assembly or the pump body.
9. Check the condition of the fuel pump drive and blower drive and replace defective parts.
10. Replace with larger tank-to-engine fuel lines.
11. Install a restricted fitting in the return line.
12. Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve if necessary. If the valve is inoperative, replace it with a new valve assembly.
13. Check the engine fuel spill-back temperature. The return fuel temperature must be less than 150°F (66°C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.

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Chart 5

HIGH LUBRICATING OIL CONSUMPTION

Probable Causes

EXTERNAL LEAKS

Check For

1. OIL LINES OR CONNECTIONS LEAKING
2. GASKET OR OIL SEAL LEAKS
3. HIGH CRANKCASE PRESSURE
4. EXCESSIVE OIL IN AIR BOX

INTERNAL LEAKS

Check For

5. BLOWER OIL SEALS LEAKING
6. OIL COOLER CORE LEAKING
7. EXCESSIVE OIL BUILDUP IN CYLINDER HEAD

OIL CONTROL AT CYLINDER

Check For

8. OIL CONTROL RINGS WORN, BROKEN, OR IMPROPERLY INSTALLED
9. PISTON PIN RETAINER LOOSE
10. SCORED LINERS. PISTONS OR OIL RINGS
11. PISTON AND ROD ALIGNMENT
12. EXCESSIVE INSTALLATION ANGLE
13. EXCESSIVE OIL IN CRANKCASE

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Chart 5

HIGH LUBRICATING OIL CONSUMPTION

------------ SUGGESTED REMEDY -------------

1. Tighten connections or replace defective parts.
2. Replace defective gaskets or oil seals.
3. Refer to the *Excessive Crankcase Pressure* chart.
4. Refer to the *Abnormal Engine Operation* chart.
5. Remove the air inlet housing and inspect the blower end plates while the engine is operating. If oil is seen on the end plate radiating away from the oil seal, overhaul the blower.
6. Inspect the engine coolant for lubricating oil contamination; if contaminated, replace the oil cooler core. Then use a good grade of cooling system cleaner to remove the oil from the cooling system.
7. Check for plugged or improper breather.
8. Replace the oil control rings.
9. Replace the piston pin retainer and defective parts.
10. Remove and replace the defective parts.
11. Check the crankshaft thrust washers for wear. Replace worn and defective parts.
12. Decrease the installation angle.
13. Fill the crankcase to the proper level only.

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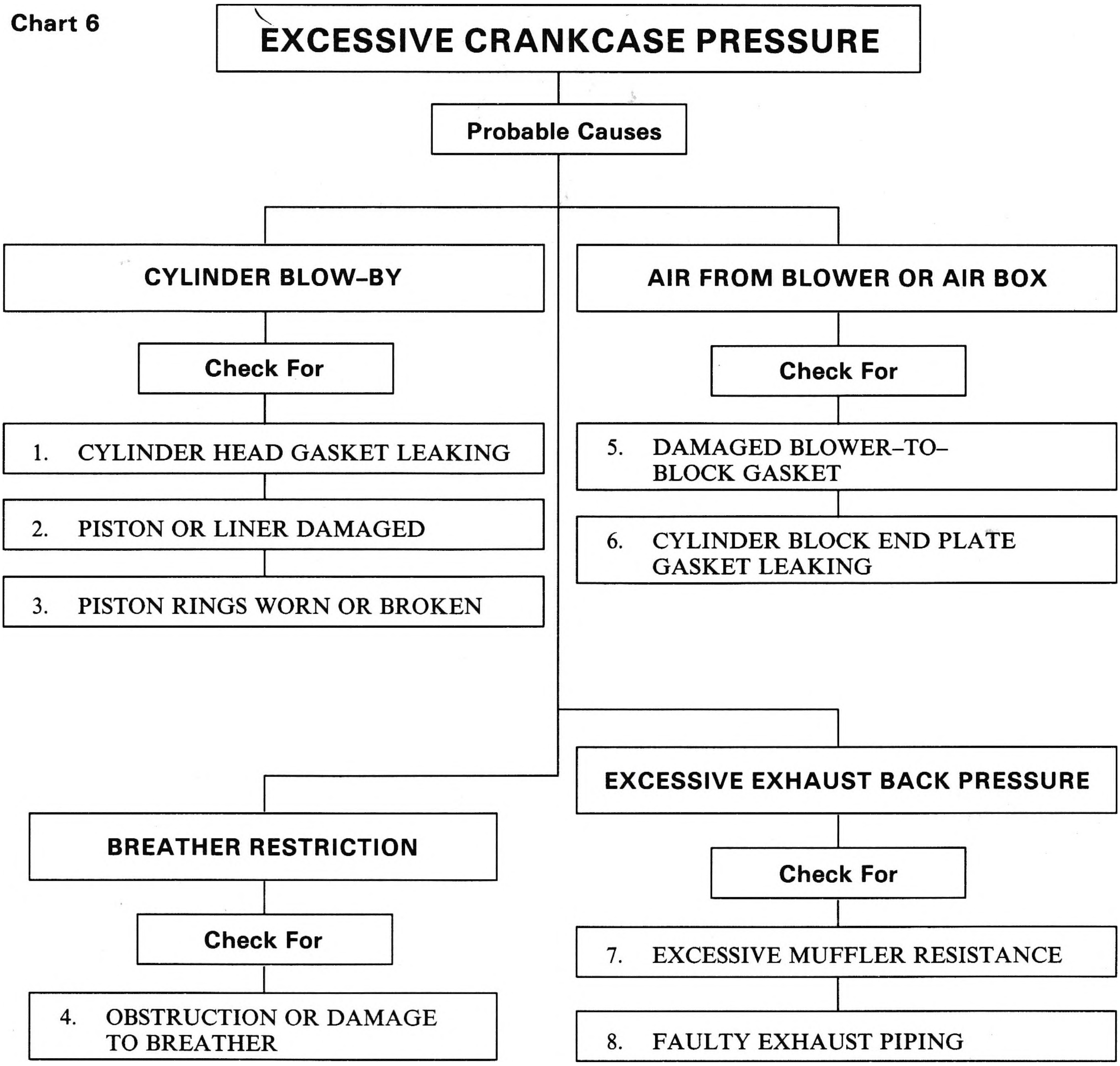
Chart 6



SUGGESTED REMEDY

1. Check the compression pressure and, if only one cylinder has low compression, remove the cylinder head and replace the head gaskets.
2. Inspect the piston and liner and replace damaged parts.
3. Install new piston rings.
4. Clean and repair or replace the breather assembly.
5. Replace the blower-to-block gasket.
6. Replace the end plate gasket.
7. Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.
8. Check the exhaust back pressure and install larger piping if it is determined that the piping is too small, too long or has too many bends.

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Chart 7

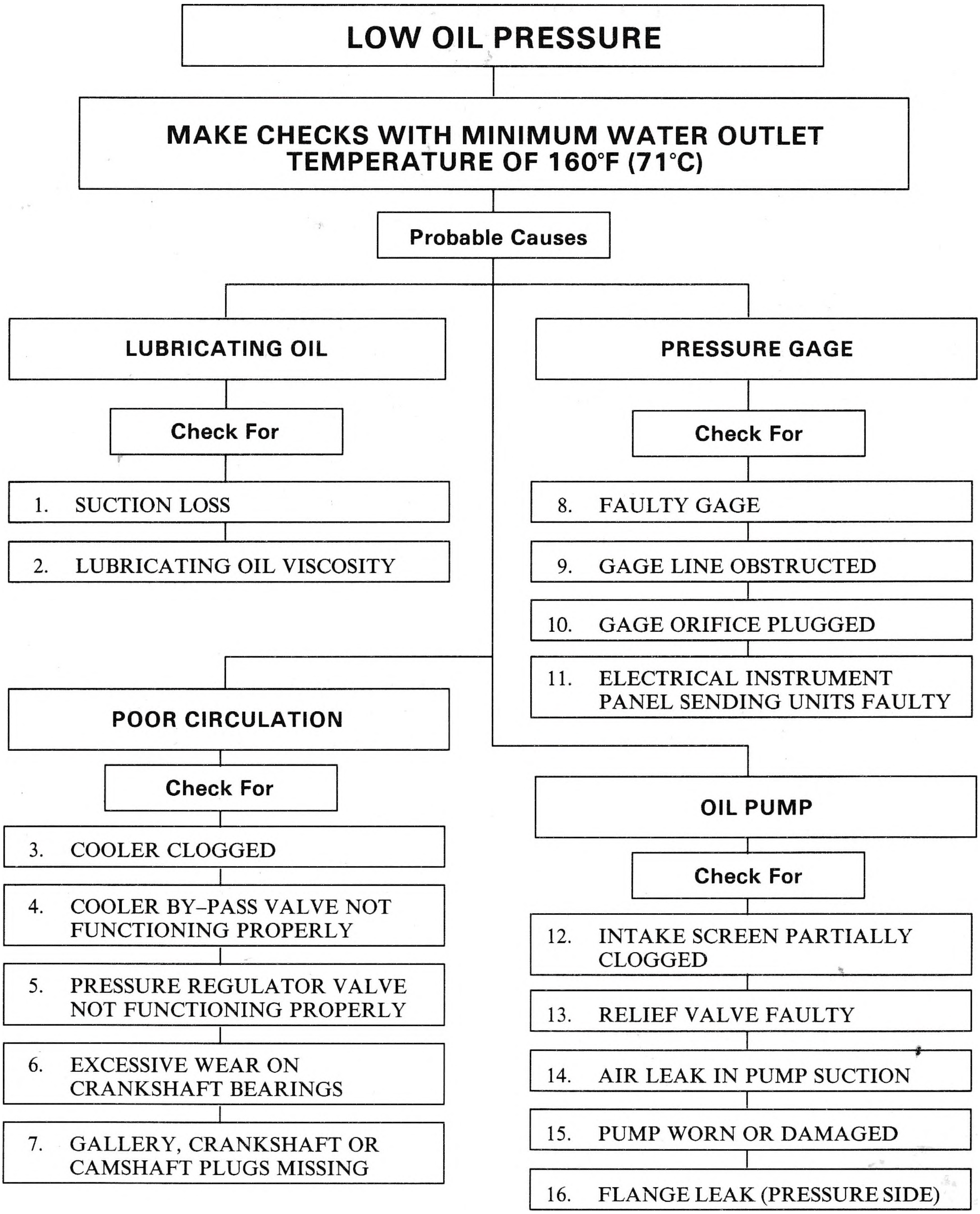

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Chart 7

LOW OIL PRESSURE

SUGGESTED REMEDY

1. Check the oil and bring it to the proper level on the dipstick or correct the installation angle.

2. Consult the *Lubricating Oil Recommendations* in Section 13.3 for the recommended grade and viscosity of oil.

Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution (refer to *Pressurize Fuel System - Check for Leaks* in Section 2.0).

3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.

4. Remove the bypass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

5. Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

6. Change the bearings. Consult the *Lubricating Oil Recommendations* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.

7. Replace missing plugs.

8. Check the oil pressure with a reliable gage and replace the gage if found faulty.

9. Remove and clean the gage line; replace it, if necessary.

10. Remove and clean the gage orifice.

11. Repair or replace defective electrical equipment.

12. Remove and clean the oil pan and oil intake screen. Consult the *Lubricating Oil Recommendations* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.

13. Remove and inspect the valve, valve bore and spring. Replace faulty parts.

14. Disassemble the piping and install new gaskets.

15. Remove the pump. Clean and replace defective parts.

16. Remove the flange and replace the gasket.

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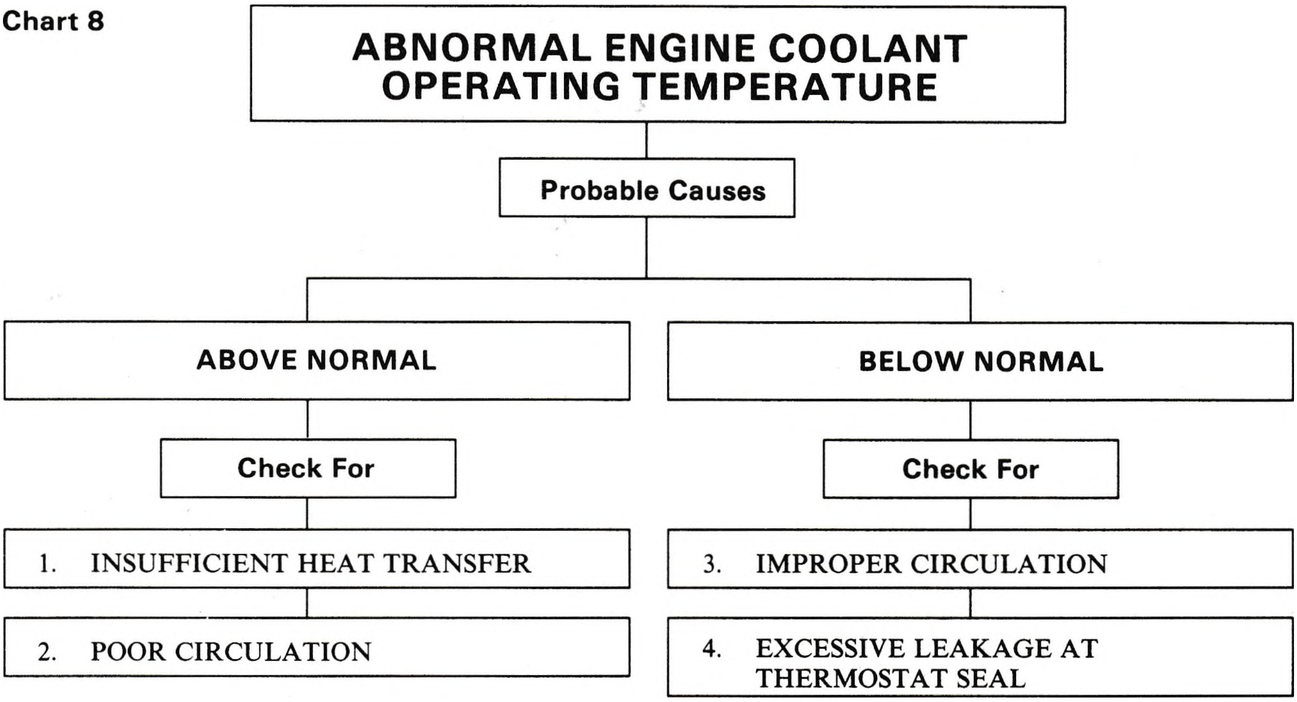
Chart 8



SUGGESTED REMEDY

1. Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits.

Clean the exterior of the radiator core to open plugged passages and permit normal air flow.

Adjust fan belts to the proper tension to prevent slippage.

Check for an improper size radiator or inadequate shrouding.

Repair or replace inoperative temperature-controlled fan or inoperative shutters.

2. Check the coolant level and fill to the filler neck if the coolant level is low.

Inspect for collapsed or disintegrated hoses. Replace faulty hoses.

Thermostat may be inoperative. Remove, inspect and test the thermostat; replace if found faulty.

Check the water pump for a loose or damaged impeller.

Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core.

Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets replaced if combustion gases are entering the cooling system.

Check for an air leak on the suction side of the water pump. Replace defective parts.

3. The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

Check for an improperly installed heater.

4. Excessive leakage of coolant past the thermostat seal(s) is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal(s).

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STORAGE

PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below.

It will be necessary to remove all rust or corrosion completely from any exposed part before applying a rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building which is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

TEMPORARY STORAGE (30 DAYS OR LESS)

To protect an engine for a temporary period of time, proceed as follows:

1. Drain the engine crankcase.
2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.
3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two minutes at 1,200 rpm and no load. Do not drain the fuel system or the crankcase after this run.
4. Check the air cleaner and service it, if necessary, as outlined in Section 3.1.
5. If freezing weather is expected during the storage period, add an ethylene glycol base antifreeze solution in accordance with the manufacturer's recommendations. Drain the raw water system and leave the drain cocks open.
6. Clean the entire exterior of the engine (except the electrical system) with fuel oil and dry it with compressed air.

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

7. Seal all of the engine openings. The material used for this purpose must be waterproof, vaporproof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

An engine prepared in this manner can be returned to service in a short time by removing the seals at the engine openings, checking the engine coolant, fuel oil, lubricating oil, transmission and priming the raw water pump, if used.

EXTENDED STORAGE (MORE THAN 30 DAYS)

To prepare an engine for extended storage, (more than 30 days), follow this procedure:

• 1. Drain the cooling system and flush with clean, soft water. Refill with clean, soft water and add a rust inhibitor to the cooling system (refer to *Corrosion Inhibitor* under *Coolant Specifications* in section 13.3).
2. Remove, check and recondition the injectors, if necessary, to make sure they will be ready to operate when the engine is restored to service.
3. Reinstall the injectors, time them and adjust the exhaust valve clearance.
4. Circulate the coolant by operating the engine until normal operating temperature is reachad (160°-185°F or 71°-85°C).
5. Stop the engine.
6. Drain the engine crankcase, then reinstall and tighten the drain plug. Install new lubricating oil filter elements and gaskets.
7. Fill the crankcase to the proper level with a 30-weight preservative lubricating oil MIL-L-21260C, Grade 2.

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8. Drain the fuel tank. Refill with enough clean No. 1 diesel fuel or pure kerosene to permit the engine to operate for about ten (10) minutes. If it isn't convenient to drain the fuel tank (i.e., marine) use a separate portable supply of the recommended fuel.

   NOTICE: If engines in vehicles or marine units are stored where condensation of water in the fuel tank may be a problem, add pure, waterless isopropyl alcohol (isopropanol) to the fuel at a ratio of one pint to 125 gallons of fuel, or .010% by volume. Where biological contamination of fuel may be a problem, add a biocide such as Biobor JF, or equivalent to the fuel. When using a biocide, follow the manufacturer's concentration recommendations, and observe all cautions and warnings.

9. Drain and disassemble the fuel filter and strainer. Discard the used elements and gaskets. Fill the cavity between the element and shell with No. 1 diesel fuel or pure kerosene, and reinstall on the engine. If spin-on fuel filters and strainers are used, discard the used cartridges, fill the new ones with No. 1 diesel fuel or pure kerosene, and reinstall on the engine.

10. Operate the engine for five (5) minutes to circulate the clean fuel oil throughout the fuel system.

11. Refer to Section 3.1 and service the air cleaner.

12. MARINE GEAR

    a. Drain the oil completely and refill with clean oil of the recommended grade and viscosity. Remove and clean or replace the strainer and filter element.

    b. Start and run the engine at 600 rpm for ten (10) minutes to coat all of the internal parts of the marine gear with clean oil. Engage the clutches alternately to circulate clean oil through all of the moving parts.

13. Since turbocharger bearings are pressure lubricated through the external oil line leading from the engine cylinder block while the engine is operatiing, no further attention is required. However, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture resistant tape.

14. Apply a *non-friction* rust preventive compound to all exposed parts. If convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.

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

15. Drain the engine cooling system.

16. Drain the preservative oil from the engine crankcase. Reinstall and tighten the drain plug.

17. Remove and clean the battery and battery cables with a baking soda-water solution and rinse them with fresh water. Do not allow the soda solution to enter the battery. Add distilled water to the electrolyte, if necessary, and fully charge the battery. Store the battery in a cool (never below 32°F or O^{0}C) dry place. Keep the battery fully charged and check the level and the specific gravity of the electrolyte regularly.

18. Insert heavy paper strips between the pulleys and belts to prevent sticking.

19. Seal all engine openings, including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.

20. Clean and dry the exterior painted surfaces of the engine and spray with a suitable liquid automobile body wax, a synthetic resin varnish or a rust preventive compound.

21. Protect the engine with a good weather-resistant tarpaulin and store it under cover, preferably in a dry building which can be heated during the winter months.

Detroit Diesel Corporation does not recommend the outdoor storage of engines. Nevertheless, DDC recognizes that in some cases outdoor storage may be unavoidable. If units must be kept out-off-doors, follow the preparation and storage instructions already given. Protect units with quality, weather-resistant tarpaulins (or other suitable covers) arranged to provide air circulation.

NOTICE: Do not use plastic sheeting for outdoor storage. Plastic is fine for indoor storage. When used outdoors, however, enough* moisture can condense on the inside of the plastic to rust ferrous metal surfaces and pit aluminum surfaces. If a unit is stored outside for any extended period of time, severe corrosion damage can result.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment, as required.

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PROCEDURE FOR RESTORING AN ENGINE TO SERVICE WHICH HAS BEEN IN EXTENDED STORAGE

1. Remove the covers and tape from all of the openings of the engine, fuel tank and electrical equipment. *Do not overlook the exhaust outlet.*
2. Wash the exterior of the engine with fuel oil to remove the rust preventive.
3. Remove the rust preventive from' the flywheel.
4. Remove the paper strips from between the pulleys and the belts.
5. Remove the drain plug and drain the preservative oil from the crankcase. Reinstall the drain plug. Then, refer to *Lubrication System* in Section 13.1 and fill the crankcase to the proper level, using a pressure prelubricator, with the recommended grade of lubricating oil.
6. Fill the fuel tank with the fuel specified under *Fuel oil* in Section 13.3.
7. Close all of the drain cocks and fill the engine cooling system with clean soft water and a rust inhibitor. If the engine is to be exposed to freezing temperatures, fill the cooling system with an ethylene glycol base antifreeze solution (refer to *Coolant Specifications* in Section 13.3).
8. Install and connect the battery.
9. Service the air cleaner as outlined in Section 3.1.
10. Check the marine gear; refill it to the proper level, as necessary, with the correct grade of lubricating oil.
11. Remove the covers from the turbocharger air inlet and turbine outlet connections. Refer to the lubricating procedure outlined in *Preparation for Starting Engine First Time* in Section 13.1.
12. After all of the preparations have been completed, start the engine. The small amount of rust preventive compound which remains in the fuel system will cause a smoky exhaust for a few minutes.

Before subjecting the engine to a load or high speed, it is advisable to check the engine tune-up.

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