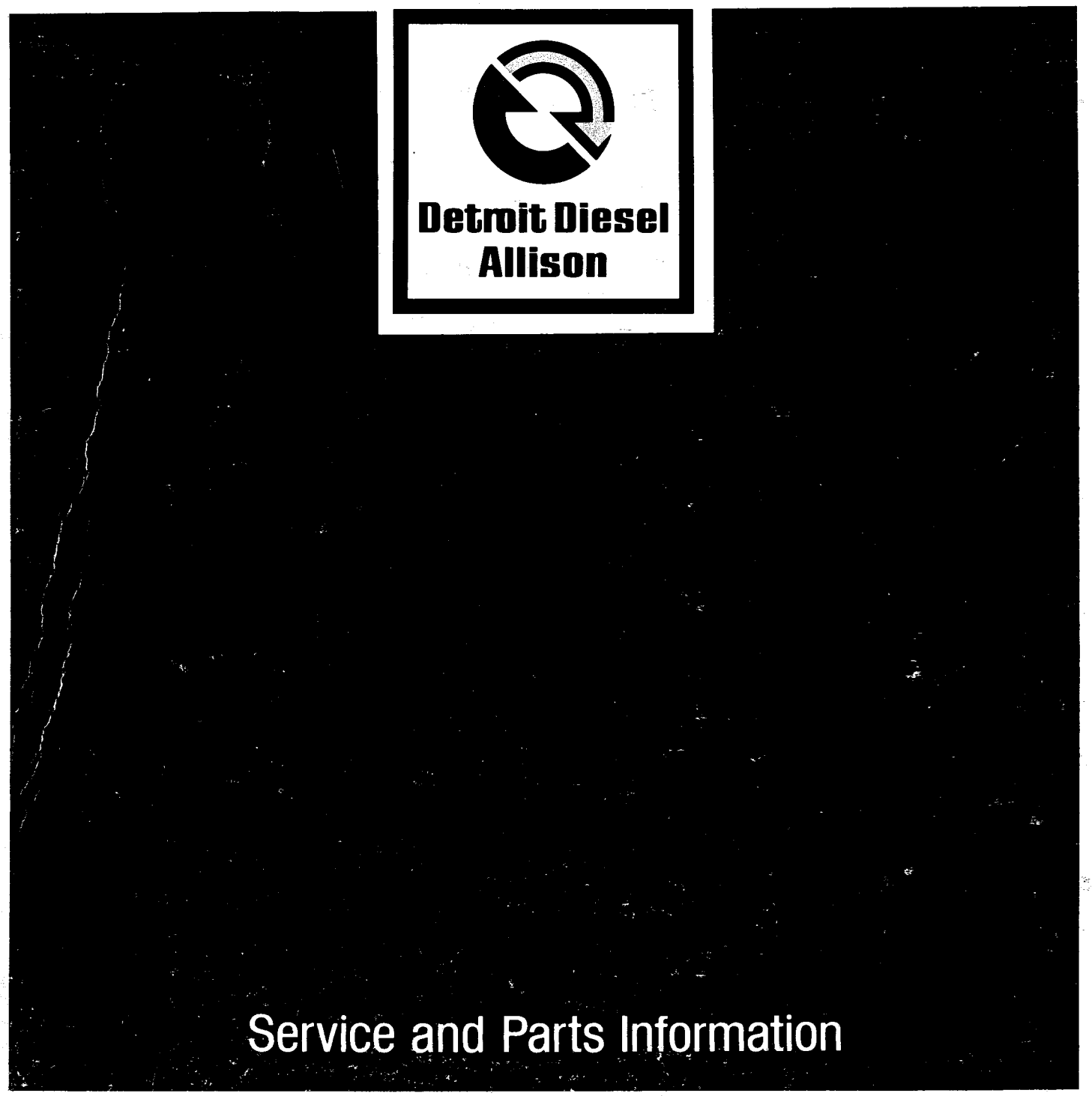
Detroit Diesel Engines

V-71 Operators Manual



Service and Parts Information

6SE323 (Rev. 9/74)

Operators Manual

V-71 Engines

Detroit Diesel Allison
Division of General Motors Corporation
Detroit, Michigan 48228

Printed in U.S.A.

TO THE OPERATOR

This manual contains instructions on the operation and preventive maintenance of your Detroit Diesel engine. Sufficient descriptive material, together with numerous illustrations, is included to enable the operator to understand the basic construction of the engine and the principles by which it functions. This manual does not cover engine repair or overhaul.

Whenever possible, it will pay to rely on an authorized *Detroit Diesel Allison Service Outlet* for all your service needs from maintenance to major parts replacement. There are over 1500 authorized service outlets in the U.S. and Canada. They stock factory original parts and have the specialized equipment and personnel with technical knowledge to provide skilled and efficient workmanship.

The operator should familiarize himself thoroughly with the contents of the manual before running an engine, making adjustments, or carrying out maintenance procedures.

The information, specifications and illustrations in this publication are based on the information in effect at the time of approval for printing. Generally, this publication is reprinted annually. It is recommended that users contact an authorized *Detroit Diesel Allison Service Outlet* for information on the latest revision. The right is reserved to make changes at any time without obligation.

WARRANTY

The applicable engine warranty is contained in the form entitled POLICY ON OWNER SERVICE, available from authorized Detroit Diesel Allison Service Outlets.

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DESCRIPTION

PRINCIPLES OF OPERATION

The diesel engine is an internal combustion power unit, in which the heat of fuel is converted into work in the cylinder of the engine.

In the diesel engine, air alone is compressed in the cylinder; then, after the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression.

The Two-Cycle Principle

In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes respectively, as shown in Fig. 1. In contrast, a four-cycle engine requires four piston strokes to complete an operating cycle; thus, during one half of its operation, the four-cycle engine functions merely as an air pump.

A blower is provided to force air into the cylinders for expelling the exhaust gases and to supply the cylinders with fresh air for combustion. The cylinder wall contains a row of ports which are above the piston when it is at the bottom of its stroke. These ports admit the air from the blower into the cylinder as soon as the rim of the piston uncovers the ports as shown in Fig. 1 (scavenging).

The unidirectional flow of air toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression as shown in Fig. 1 (compression).

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion chamber by the unit fuel injector as shown in Fig. 1 (power). The intense heat generated during the high compression of the air ignites the fine fuel spray immediately. The combustion continues until the injected fuel has been burned.

The resulting pressure forces the piston downward on its power stroke. The exhaust valves are again opened when the piston is about halfway down, allowing the burned gases to escape into the exhaust manifold as shown in Fig. 1 (exhaust). Shortly thereafter, the downward moving piston uncovers the inlet ports and the cylinder is again swept with clean scavenging air. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft, or, in other words, in two strokes; hence, it is a "two-stroke cycle".

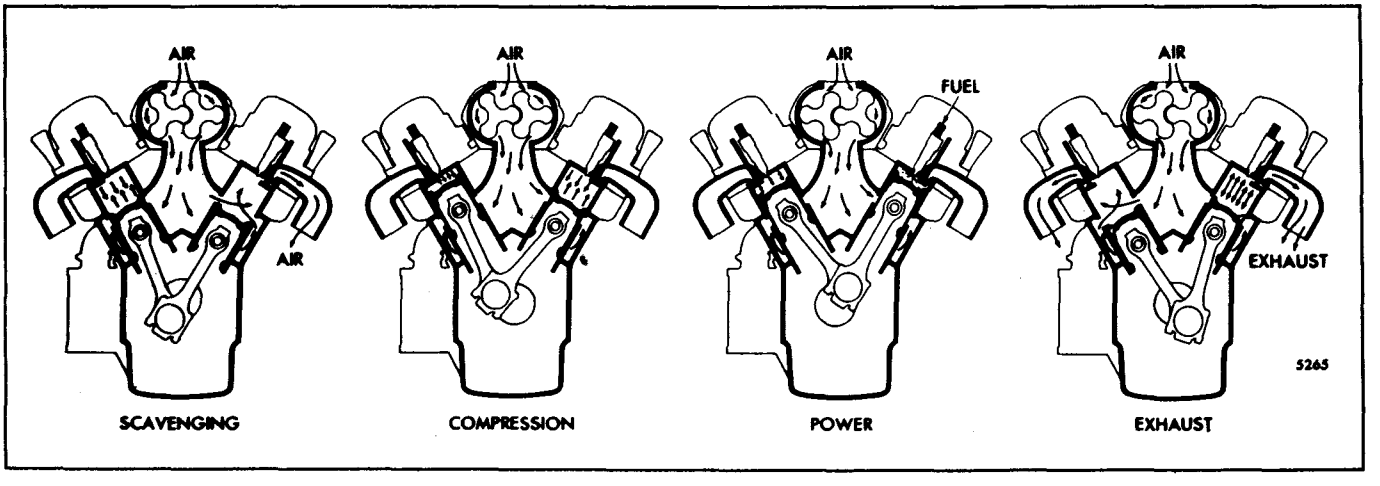


Fig. 1 - The Two-Stroke Cycle

GENERAL DESCRIPTION

The V-71 engines (6, 8, 12 and 16 cylinder models) covered by this manual have the same bore and stroke and use many of the same parts.

All cylinder blocks are symmetrical in design thus permitting oil cooler or starter installation on the same side or on opposite sides of the engine, depending upon the installation requirements. The engines are built with right-hand or left-hand crankshaft rotation. For example, the crankshaft in an RC engine, viewed from the flywheel end, will rotate counterclockwise, the oil cooler will be mounted on the right-hand side of the engine and the starter will be on the left-hand side of the engine (Fig. 2).

There are eight basic engine models. The letter L or R indicates left or right-hand engine rotation as viewed from the front of the engine. The letter A, B, C or D designates the location of the starter and oil cooler as viewed from the rear (flywheel) end. For the meaning of each digit in the model numbering system, refer to Fig. 2.

The engines are normally equipped with an oil cooler, lubricating oil filter(s), fuel oil strainer, fuel oil filter, air cleaner(s) or silencer(s), governor, heat exchanger and raw water pump or fan and radiator, and a starter.

Fuel is drawn from the supply tank and through a strainer by a gear-type fuel pump, then it is forced through the filter and the fuel inlet manifolds in the cylinder heads to the injectors. Excess fuel is returned to the supply tank via the return fuel manifolds and connecting lines. Since fuel is constantly circulating through the injectors, it serves to cool the injectors and carry off any air in the fuel system.

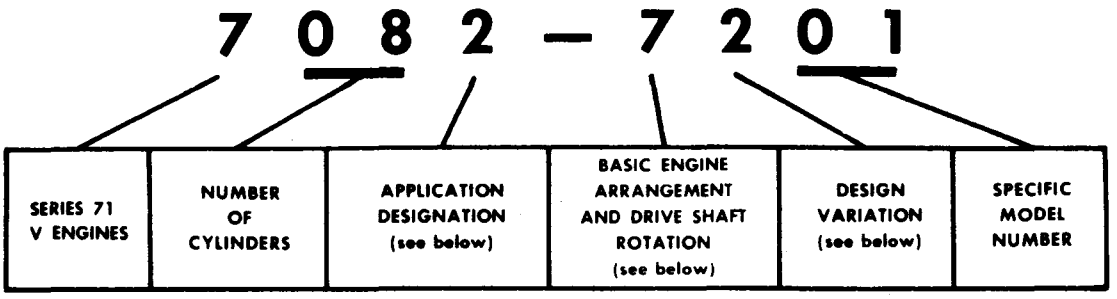
Air for scavenging and combustion is supplied by a blower(s) which pumps air into the engine cylinders via the air box and cylinder liner ports. All air entering the blower(s) first passes through an air cleaner or silencer.

Full pressure lubrication is supplied to all main, connecting rod and camshaft bearings, and to other moving parts of the engine. A gear-type pump draws oil from the oil pan through an intake screen and delivers it to the oil filter(s) and then to the oil cooler(s). From the oil cooler(s) the oil flows through passages that connect with the oil galleries in the cylinder block and cylinder heads for distribution to the bearings, rocker arm mechanism and other functional parts.

Coolant is circulated through the engine by a centrifugal type water pump. Heat is removed from the coolant, which circulates in a closed system, by either a radiator or heat exchanger. Control of the engine temperature is accomplished by thermostats that regulate the flow of the coolant within the cooling system.

Engine starting is provided by either a hydraulic or an electrical starting system.

Engine speed is controlled by a governor. Some engines have a mechanical limiting speed governor, some a mechanical variable speed governor, and other engines use a limiting speed or a variable speed hydraulic governor. The engine application determines which type of governor is used.



APPLICATION DESIGNATION:

7082-7200	MARINE
7083-7200	INDUSTRIAL F-F
7084-7200	POWER-BASE
7085-7200	GENERATOR
7087-7200	AUTOMOTIVE F-F
7088-7200	SPECIAL

DESIGN VARIATION:

7082-7000	V-71 "N" ENGINE
7082-7100	2 VALVE HEAD
7082-7200	4 VALVE HEAD
7082-7300	TURBOCHARGER
7082-7500	CUSTOMER SPEC. ENGINE

BASIC ENGINE ARRANGEMENTS:

Rotation: L (left) and R (right) designates rotation viewed from the front of the engine.

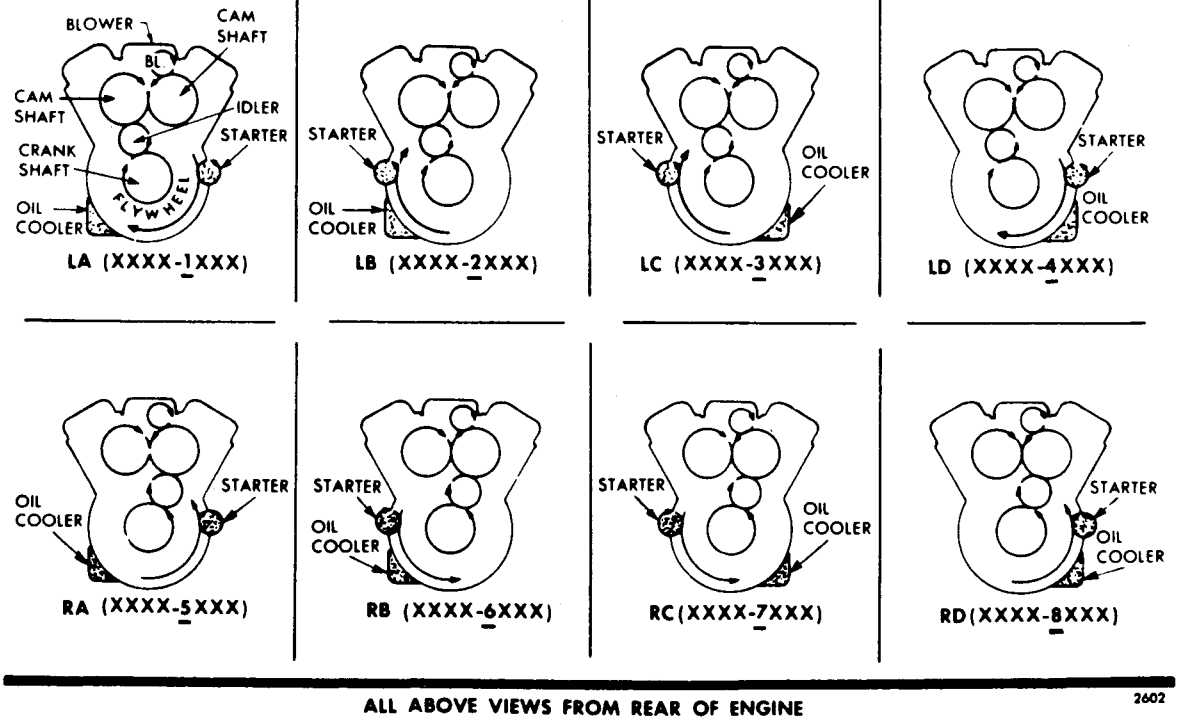
Type: A-B-C-D designates location of starter and oil cooler as viewed from the rear (flywheel) end.

Cylinder Bank: Left and right cylinder banks are determined from rear of engine.

DRIVE SHAFT ROTATION:

7242-0200	LEFT-HAND
7242-9200	RIGHT-HAND

Drive shaft rotation: shaft rotation on multiple units is determined from the rear of the unit.



ALL ABOVE VIEWS FROM REAR OF ENGINE

2602

Fig. 2 - Model Description, Rotation, and Accessory Arrangement

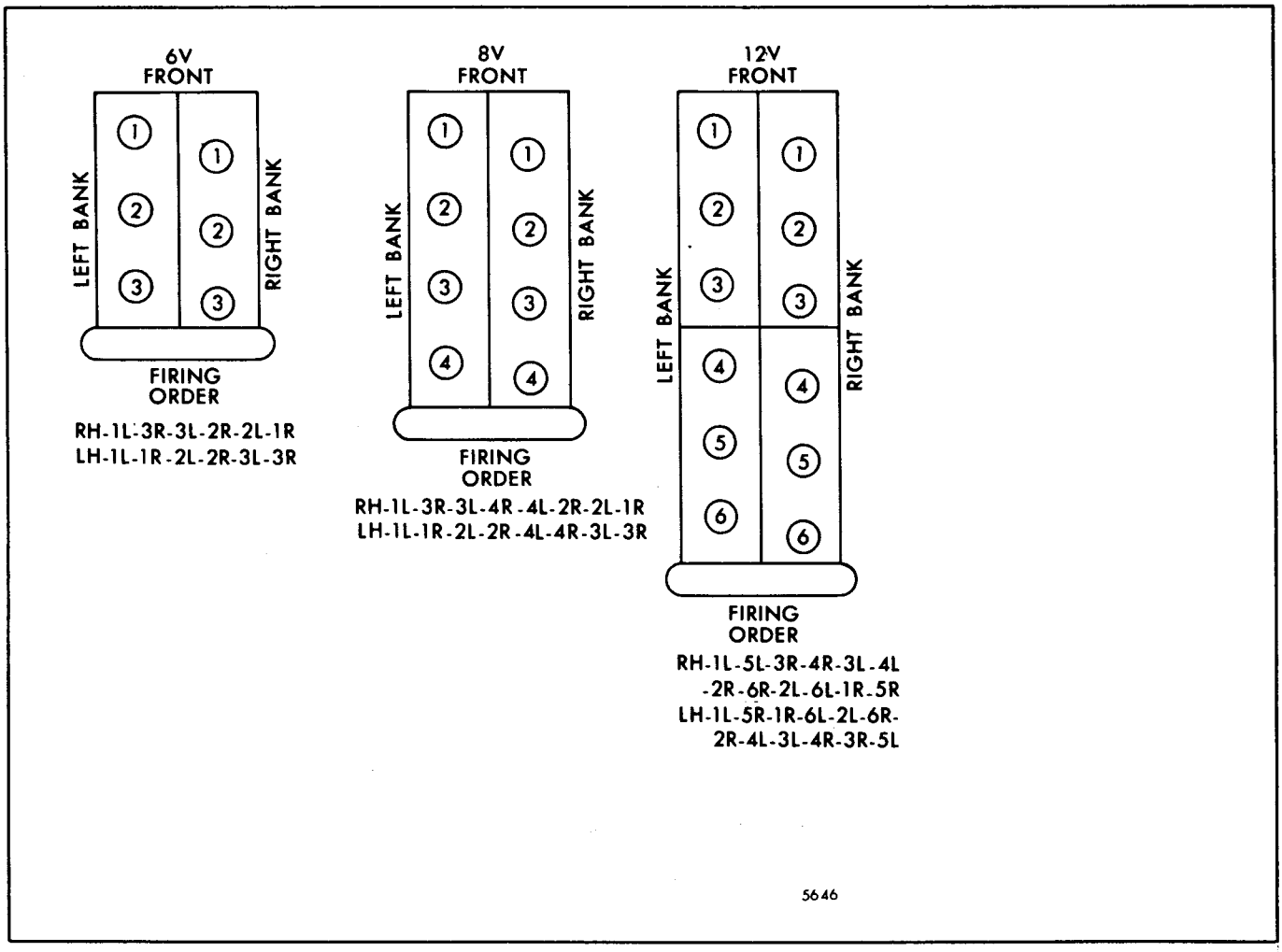


Fig. 3 - V-71 Cylinder Designation and Firing Order

GENERAL SPECIFICATIONS

	6V	8V	12V	16V
Type	2 Cycle	2 Cycle	2 Cycle	2 Cycle
Number of Cylinders	6	8	12	16
Bore	4 1/4 in.	4 1/4 in.	4 1/4 in.	4 1/4 in.
Stroke	5 in.	5 in.	5 in.	5 in.
Compression Ratio (Nominal)(Standard Engines)	17 to 1	17 to 1	17 to 1	17 to 1
Compression Ratio (Nominal)("N" Engines)	18.7 to 1	18.7 to 1	18.7 to 1	18.7 to 1
Total Displacement - Cubic Inches	426	568	852	1136
Number of Main Bearings	4	5	7	10

ENGINE MODEL AND SERIAL NUMBER DESIGNATION

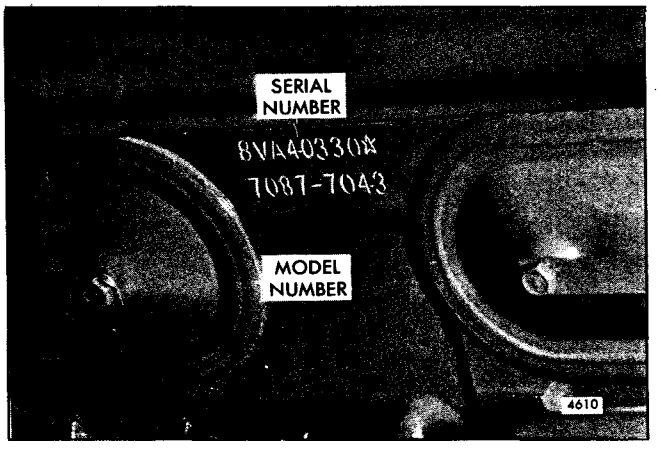


Fig. 4 - Typical Engine Serial Number and Model Number as Stamped on Cylinder Block

The engine serial number and model number are stamped on the right-side of the cylinder block (Fig. 4).

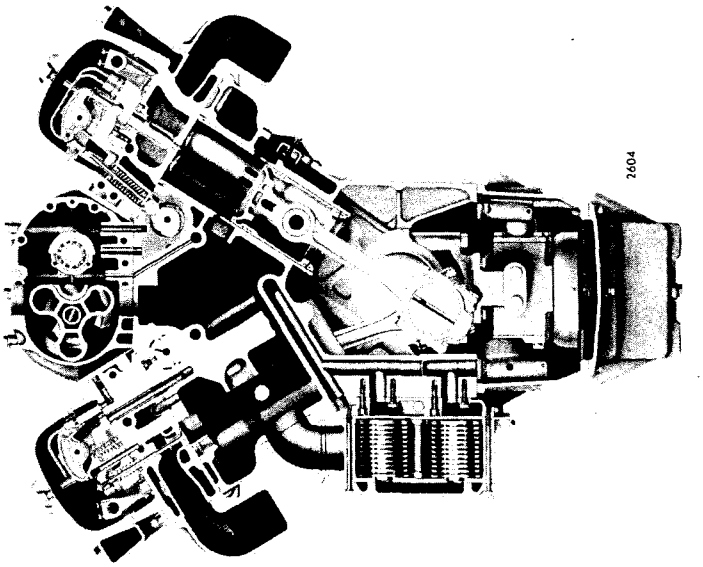
Engines with optional equipment have an option plate attached to one of the valve rocker covers. The engine serial number and model number are also stamped on this plate.

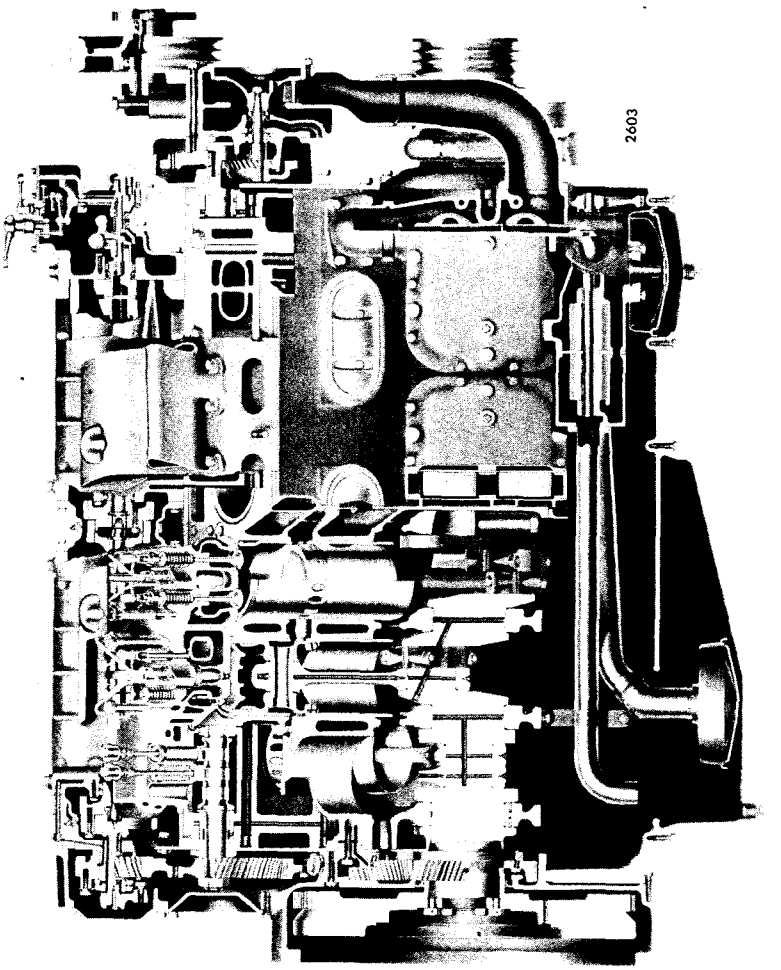
Power take-off assemblies, torque converters, hydraulic marine gears, etc. may also carry name plates pertaining to the particular assembly to which they are attached. The information on these name plates should be included when ordering parts for these assemblies.

BUILT-IN PARTS BOOK

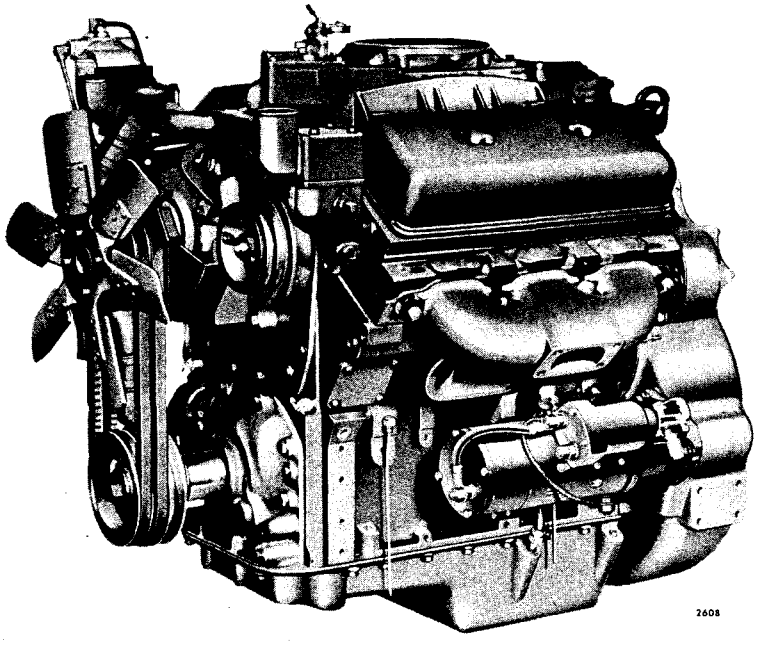
The *Built-In Parts Book* is an anodized aluminum plate (option plate) that fits into a retainer on one of the engine valve rocker covers and contains the necessary information required when ordering parts. It is recommended that the engine user read the section on the *Built-In Parts Book* in order to take full advantage of the information provided on the engine option plate.

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

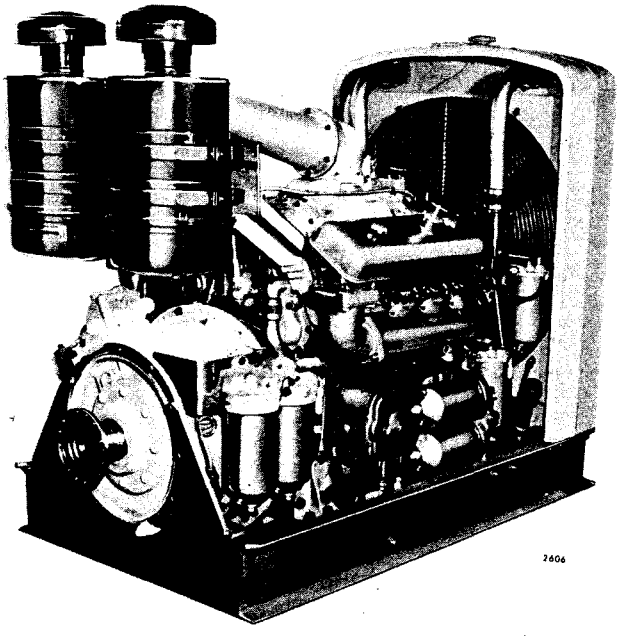




Cross Section Views of a Typical V-71 Engine



Typical Fan-to-Flywheel Unit (6V)



Typical Industrial Torque Converter Unit (8V)

ENGINE SYSTEMS

The V-71 Detroit Diesel engines incorporate four basic systems which direct the flow of fuel, air, lubricating oil, and engine coolant.

A brief description of each of these systems and their components, and the necessary maintenance and adjustment procedures, are given in this manual.

FUEL SYSTEM

The fuel system (Fig. 1) consists of the fuel injectors, fuel pipes, fuel pump, fuel strainer, fuel filter and the necessary connecting fuel lines.

A restricted fitting is located in the outlet passage in one of the cylinder heads on 6, 8 and 12V engines to maintain pressure in the fuel system. Two of the cylinder heads on 16V engines have a restricted fitting.

Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Upon leaving the pump under pressure, the fuel is forced through the fuel filter and into the fuel inlet manifold where it passes through fuel pipes into the inlet side of each fuel injector. The fuel is filtered through elements in the injectors and atomized through small spray tip orifices into the combustion chamber. Surplus fuel, returning from the injectors, passes through the fuel return manifold and connecting fuel lines back to the fuel tank.

The continuous flow of fuel through the injectors helps to cool the injectors and remove air from the fuel system.

A check valve may be installed between the fuel strainer and the source of supply as optional equipment to prevent fuel drain back when the engine is not running.

Fuel Injector

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder. The injector creates the high pressure necessary for fuel injection, meters the proper amount of fuel, atomizes the fuel, and times the injection into the combustion chamber.

Since the injector is one of the most important and carefully constructed parts of the engine, it is recommended that the engine operator replace the injector as an assembly if it is not operating properly. Authorized *Detroit Diesel Allison Service Outlets* are properly equipped to service injectors.

Remove Injector

An injector may be removed in the following manner:

1. Remove the valve rocker cover.

2. Disconnect the fuel pipes from both the injector and the fuel connectors.

3. Immediately after removing the fuel pipes, cover the injector inlet and outlet fittings with shipping caps to prevent dirt from entering.

4. Turn the crankshaft manually in the direction of engine rotation or crank the engine with the starting motor, if necessary, until the rocker arms for the particular cylinder are aligned in a horizontal plane.

CAUTION: 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 as the bolt may be loosened. Either remove the

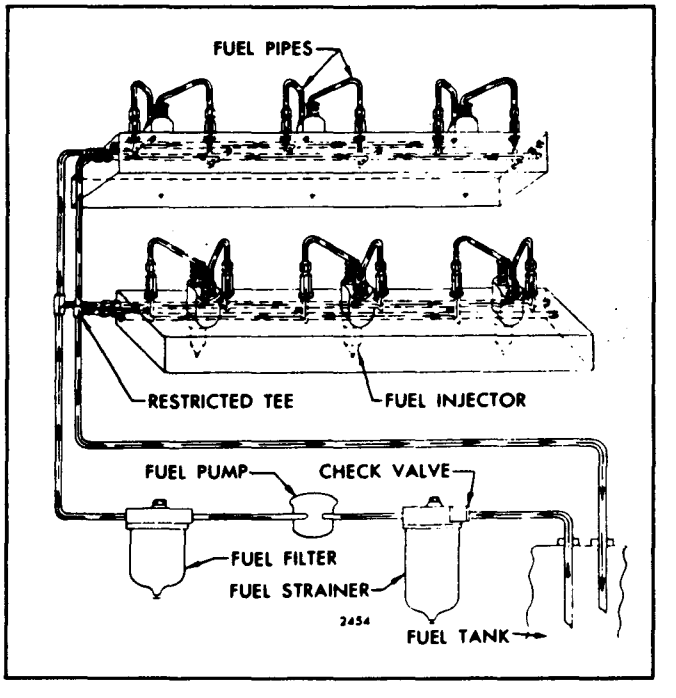


Fig. 1 - Schematic Diagram of Typical Fuel System

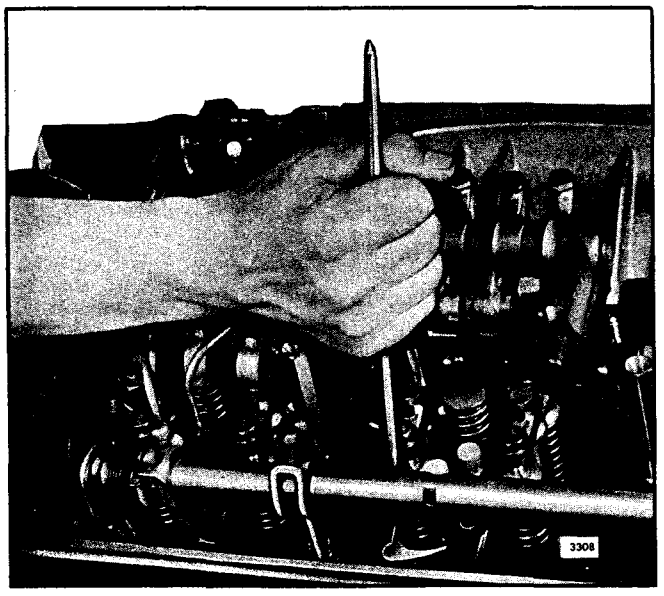


Fig. 2 - Removing Injector from Cylinder Head

starting motor or the pipe plug in the flywheel housing and use a pry bar against the teeth of the flywheel ring gear to turn the crankshaft.

5. Remove the two rocker shaft bracket bolts and swing the rocker arm assembly away from the injector and valves.

6. Remove the injector clamp bolt, washer and clamp.

7. Loosen the inner and outer adjusting screws on the injector rack control lever and slide the lever away from the injector.

8. Free the injector from its seat as shown in Fig. 2 and lift it from the cylinder head.

9. Cover the injector hole in the cylinder head to keep foreign particles out of the cylinder.

Install Injector

Before installing an injector, be sure the beveled seat of the injector tube is free from dirt particles and carbon deposits.

A new or reconditioned injector may be installed by reversing the sequence of operations given for removal.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter until it runs out the outlet filter.

Do not tighten the injector clamp bolt to more than 20-25 lb-ft torque, as this may cause the moving parts of the injector to bind. Tighten the rocker shaft bolts to 90-100 lb-ft torque.

Align the fuel pipes and connect them to the injector and the fuel connectors. Use socket J 8932-01 and a torque wrench to tighten the fuel pipe nuts to 12-15 lb-ft torque.

> **CAUTION:** Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

Time the injector, position the injector rack control lever and adjust the exhaust valve clearance (cold setting) as outlined in the engine tune-up procedure. If all of the injectors have been replaced, perform a complete tune-up on the engine.

Fuel Pump

A positive displacement gear type fuel pump is attached to the blower and driven off the front end of the blower.

A spring-loaded relief valve, incorporated in the pump body, normally remains in the closed position, operating only when the pressure on the outlet side (to the fuel filter) becomes excessive due to a plugged filter or fuel line.

The fuel pump incorporates two oil seals. Two tapped holes are provided in the underside of the pump body to permit draining off any leakage of oil.. If fuel leakage exceeds one drop per minute, the seals must be replaced. An authorized *Detroit Diesel Allison Service Outlet* is properly equipped to replace the seals.

The fuel pump used on the V-71 engines is a left-hand rotating pump. Regardless of engine rotation, the pump will always rotate in a left-hand direction.

Fuel Strainer and Fuel Filter

A replaceable element type fuel strainer and fuel filter (Figs. 1 and 3) are used in the fuel system to remove impurities from the fuel. The strainer removes the larger foreign particles and the filter removes the small foreign particles.

The fuel strainer and fuel filter are basically identical in construction, both consisting of a cover, shell and replaceable element. Since the fuel strainer is placed between the fuel supply tank and the fuel pump, it functions under suction; the fuel filter, which is

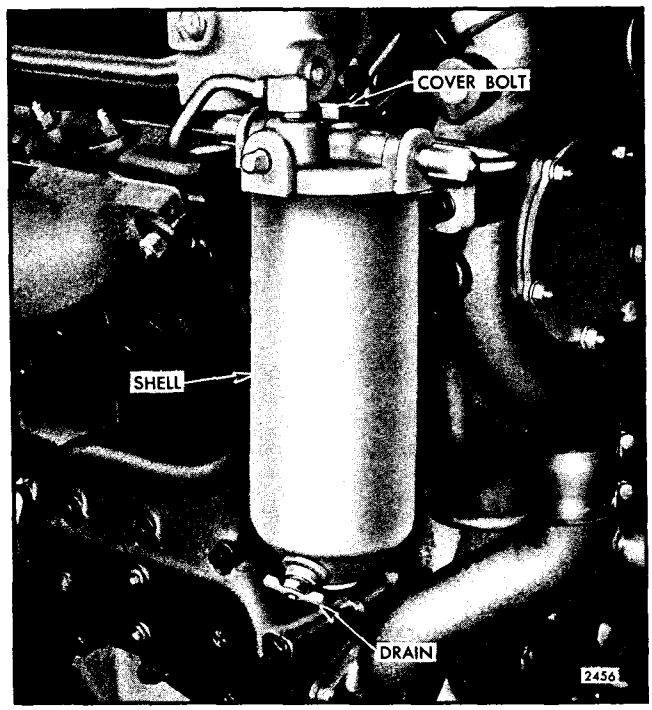


Fig. 3 - Typical Fuel Filter Mounting

installed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under pressure.

Replace the elements as follows:

1. With the engine shut down, place a suitable container under the fuel strainer or filter and open the drain cock. The fuel will drain more freely if the cover nut is loosened slightly.

2. Support the shell, unscrew the cover nut and remove the shell and element.

3. Remove and discard the element and gasket. Clean the shell with fuel oil and dry it with compressed air.

4. Place a new element, which has been thoroughly soaked in clean fuel oil, over the stud and push it down on the seat. Close the drain cock and fill the shell approximately two-thirds full with clean fuel oil.

5. Affix a new shell gasket, place the shell and element into position under the cover and start the cover nut on the shell stud.

6. Tighten the cover nut only enough to prevent fuel leakage.

7. Remove the plug in the strainer or filter cover and fill the shell with fuel. Fuel system primer J 5956 may be used to prime the fuel system.

8. Start and operate the engine and check the fuel system for leaks.

Spin-On Type Fuel Filter

A spin-on type fuel strainer and fuel filter is used on certain engines. The spin-on filter cartridge consists of a shell, element and gasket combined into a unitized replacement assembly. No separate springs or seats are required to support the filters.

The filter covers incorporate a threaded sleeve to accept the spin-on filter cartridges. The word "Primary" is cast on the fuel strainer cover and the word "Secondary" is cast on the fuel filter cover for identification.

No drain cocks are provided on the spin-on filters. Where water is a problem, it is recommended that a water separator be installed. Otherwise, residue may be drained by removing and inverting the filter. Refill the filter with clean fuel oil before reinstalling it.

A 1" diameter twelve-point nut on the bottom of the filter is provided to facilitate removal and installation.

Replace the filter as follows:

1. Unscrew the filter (or strainer) and discard it.

2. Fill a new filter replacement cartridge about two-thirds full with clean fuel oil. Coat the seal gasket lightly with clean fuel oil.

3. Install the new filter assembly and tighten it to two-thirds of a turn beyond gasket contact.

4. Start the engine and check for leaks.

Fuel Tank

Refill the fuel tank at the end of each day's operation to prevent condensation from contaminating the fuel.

CAUTION: A galvanized steel tank should never be used for fuel storage because the fuel oil reacts chemically with the zinc coating to form powdery flakes which quickly clog the fuel strainer and filter and damage the fuel pump and injectors.

AIR SYSTEM

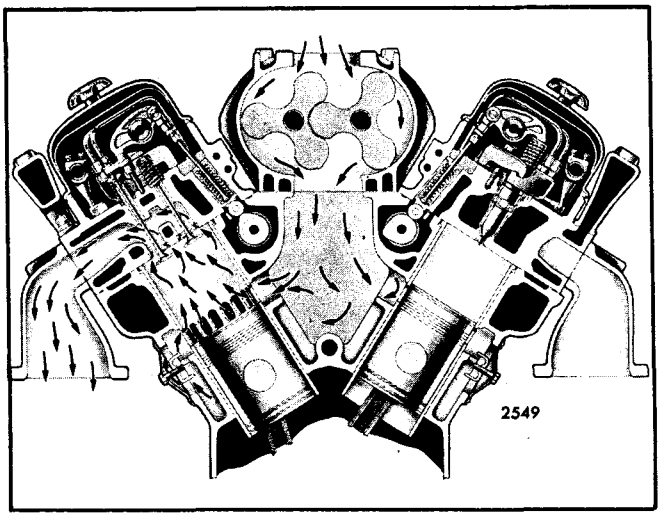


Fig. 4 - Air Intake System Through Blower and Engine

In the scavenging system used in two-cycle engines and illustrated in Fig. 4, a charge of air, forced into the cylinders by the blower(s), sweeps all of the exhaust gases out through the exhaust valve ports, leaving the cylinders filled with fresh air for combustion at the end of each upward stroke of the pistons. This air also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, each cylinder is filled with fresh, clean air which provides for efficient combustion.

The blower(s) supplies fresh air required for combustion and scavenging. The hollow three-lobe rotors are closely fitted into the blower housing(s) which is bolted to the cylinder block. The revolving motion of these rotors pulls fresh air through the air cleaner or silencer and provides a continuous and uniform displacement of air in each combustion chamber. The continuous discharge of fresh air from the blower creates a pressure in the air box (air box pressure).

OIL BATH TYPE AIR CLEANERS

Several types of air cleaners are available for use with the V-71 engines. The light duty oil bath air cleaner (Fig. 5) is used with some marine models and a light or heavy-duty oil bath air cleaner (Fig. 6) is available for industrial engines. Some engines are equipped with a heavy-duty dry type air cleaner or a two-stage dry type air cleaner (Fig. 7). The air cleaners are designed for fast, easy disassembly to facilitate efficient servicing. Maximum protection of the engine against dust and other forms of air contamination is possible if the air cleaner is serviced at regular intervals.

The oil bath air cleaner consists of the body and fixed filter assembly which filters the air and condenses the oil from the air stream so that only dry air enters the engine. The condensed oil is returned to the cup where the dirt settles out of the oil and the oil is recirculated. A removable element assembly incorporated in the heavy-duty oil bath air cleaners removes a major part of the dust from the air stream thereby decreasing the dust load to the fixed element. An inner cup, which can be removed from the outer oil cup, acts as a baffle in directing the oil laden air to the element and also controls the amount of oil in circulation and meters the oil to the element. The oil cup supports the inner cup, and is a reservoir for oil and a settling chamber for dirt.

Service the *light-duty* oil bath air cleaner (Fig. 5) as follows:

1. Loosen the wing bolt and remove the air cleaner assembly from the air inlet housing. The cleaner may then be separated into two sections; the upper section or body assembly contains the filter element and the lower section consists of the oil cup, removable inner cup or baffle, and the center tube.

2. Soak the body assembly and element in fuel oil to loosen the dirt; then flush the element with clean fuel oil and allow it to drain thoroughly.

3. Pour out the oil, separate the inner cup or baffle from the oil cup, remove the sludge and wipe the baffle and outer cup clean.

4. Push a lint-free cloth through the center tube to remove dirt or oil.

5. Clean and check all of the gaskets and sealing surfaces to ensure air tight seals.

6. Refill the oil cup to the oil level mark only, install the baffle and reassemble the air cleaner.

7. Check the air inlet housing before installing the air cleaner assembly on the engine. The inlet will be dirty if air cleaner servicing has been neglected or if dust laden air has been leaking past the air cleaner to the air inlet housing seals.

8. Make sure that the air cleaner is seated properly on

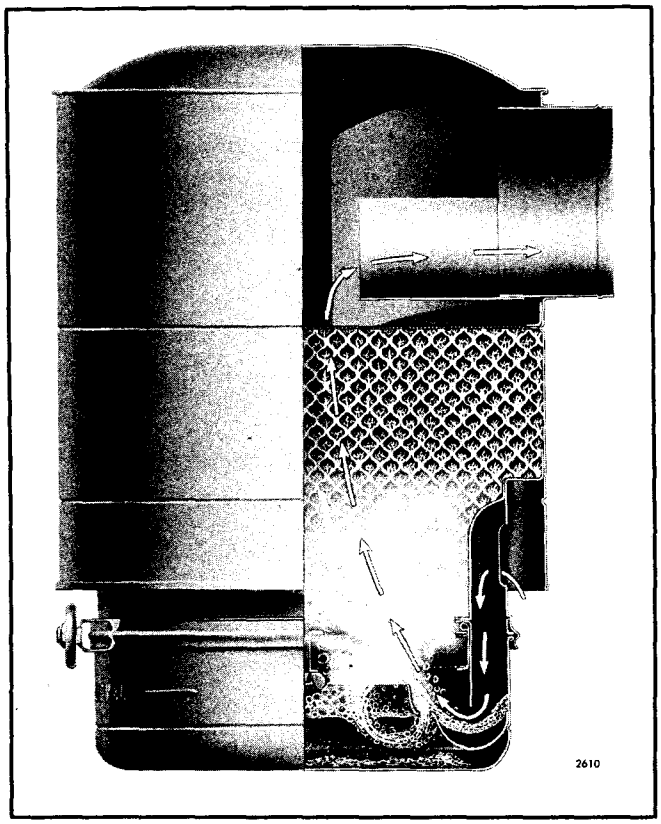


Fig. 5 - Typical Light-Duty Air Cleaner

the inlet housing and the seal is installed correctly. Tighten the wing bolt until the air cleaner is securely mounted.

Service the *heavy-duty* oil bath air cleaner (Fig. 6) as follows:

1. Loosen the wing nuts and detach the lower portion of the air cleaner assembly.

2. Lift out the removable element assembly and hold it up to a light. An even, bright pattern of light through the wire element indicates it is clean. Even a partially plugged element must be cleaned with a suitable solvent or fuel oil and blown out with compressed air to remove any dirt, lint or chaff.

3. Pour out the oil, separate the inner cup or baffle

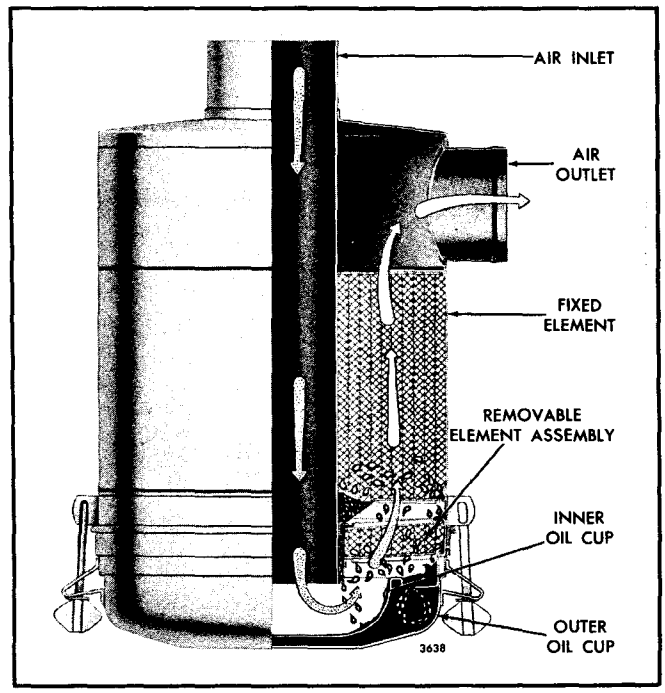


Fig. 6 - Heavy-Duty Oil Bath Air Cleaner

from the outer cup, remove the sludge and wipe the baffle and outer cup clean.

4. Clean and inspect the gaskets and sealing surfaces to ensure an air tight seal.

5. Reinstall the baffle in the oil cup and refill to the proper oil level with the same grade of oil as used in the engine.

6. Inspect the lower portion of the air cleaner body and center tube each time the oil cup is serviced. If there are any indications of plugging, the body assembly should be removed and cleaned by soaking and then flushing with clean fuel oil. Allow the unit to drain thoroughly.

7. Place the removable element in the body assembly. Install the body if it was removed from the engine for servicing.

8. Install the outer cup and baffle assembly. Be sure the cup is tightly secured to the assembly body.

HEAVY-DUTY DRY-TYPE AIR CLEANER

The *dry-type* air cleaner consists of a removable cover attached to the air cleaner body which contains a replaceable paper filter cartridge and a dust cup. Air entering the air cleaner is given a centrifugal pre-cleaning by a turbine-type vane assembly. Air rotates at high speed around the filter element throwing the dust to the outside where it flows down the wall of the body and is ejected into a dust cup. The dust cup is baffled to prevent the re-entry of the dust. The pre-cleaned air passes through the paper filter and enters the engine.

Some air cleaners are equipped with an indicator which will aid in determining the servicing requirements.

Service the *dry-type* air cleaner as follows:

1. Loosen the wing bolt and remove the air cleaner assembly from the air inlet housing.

2. Detach the cover and wing bolt and remove the element. Then empty and wipe the dust cup clean.

3. Clean the filter element as follows: If the element is dry and dusty, use compressed air. The air should be blown through the element opposite to the normal direction of air flow.

4. If the element is oily or has soot deposits, use a water hose (less than 40 psi) and wash with warm water and a non-sudsing detergent. Dry the element thoroughly.

5. Reassemble all of the air cleaner parts, place the assembly on the air inlet housing and secure it with the wing bolts.

TWO-STAGE DRY-TYPE AIR CLEANER

The dry-type air cleaner illustrated in Fig. 7 is designed to provide highly efficient air filtration under all operating conditions and is not affected by engine speed. The cleaner assembly consists of a centrifugal air cleaner in series with a replaceable impregnated paper filter element. The dust collected in the centrifugal cleaner is exhausted by connecting the dust bin to an exhaust gas aspirator. The centrifugal cleaner and replaceable filter element are held together in a steel housing. Positive sealing between the two elements and the housing is provided by rubber gaskets. The steel housing incorporates filter fasteners, mounting flanges and an outlet for the filtered air.

Operation

The deflector vanes (Fig. 8) impart a swirling motion to the air entering the air cleaner and centrifuge the dust particles against the walls of the tubes. The dust particles are then carried to the dust bin at the bottom of the cleaner by approximately 10% bleed-off air and are finally discharged into the atmosphere through an exhaust gas aspirator.

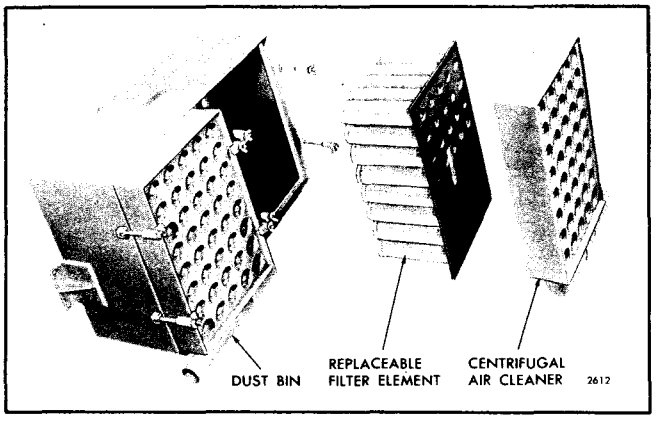


Fig. 7 - Dry Type Air Cleaner

The exhaust gas aspirator is connected into the exhaust system of the engine (Fig. 9). A flexible hose carries the dust particles from the cleaner dust bin to the aspirator where the waste energy of the exhaust gases draws the dust-laden bleed-off air out and discharges it into the atmosphere along with the engine exhaust gases. Approximately 90% of the total dust load is disposed of in this manner. The centrifugal air cleaner is fully effective at either high or low velocities.

The remainder of the air in the cleaner reverses direction and spirals back along the discharge tubes again centrifugally moving the air. The filtered air then reverses direction again and enters the replaceable filter element through the center portion of the discharge tubes. The air is filtered once more as it passes through the pleats of the impregnated paper element before leaving the outlet port of the cleaner housing.

An air cleaner restriction indicator (Fig. 9) may be attached near the outlet side of the cleaner. As the restriction in the cleaner increases, suction created will pull the indicator plunger upward. A brightly colored

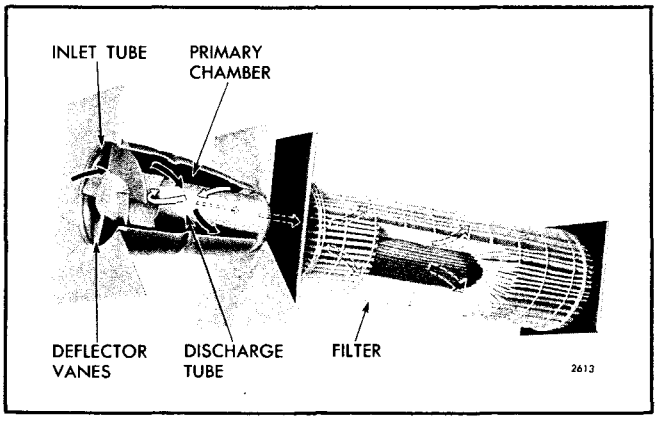


Fig. 8 - Flow of Air Through Filter Element Segment

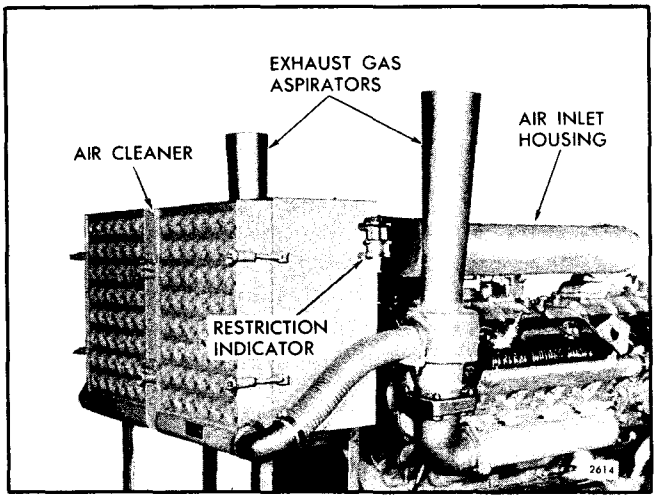


Fig. 9 - Typical Dry Type Air Cleaner Mounting

card, attached to the plunger and visible through a small window in the indicator, will indicate the relative amount of air restriction in the cleaner. When the card is fully visible, the air cleaner should be cleaned and the indicator reset by pushing the plunger all the way up and then releasing it.

Service

The first stage centrifugal air cleaner tends to be self-cleaning due to the action of the exhaust gas aspirator. However, it should be inspected and any accumulated foreign material removed during the periodic replacement of the impregnated paper filter element. Overloading of the paper element will not cause dirt particles to by-pass the filter and enter the engine, but will result in starving the engine for air.

The filter element may be replaced as follows:

1. Disconnect the flexible aspirator hose at the dust bin of the air cleaner.

2. Loosen the wing nuts on the filter fasteners and swing the retaining bolts away from the cleaner.

3. Lift the cleaner away from the housing and inspect it. Clean out any accumulated foreign material.

4. Withdraw the paper filter element and discard it.

5. Install a new filter element. New sealing gaskets are provided with the element to insure a positive air seal at all times.

6. Install the cleaner and secure it in place with the fasteners.

7. Connect the aspirator hose to the dust bin, making sure the connection is air tight.

AIR SILENCER

The air silencer (Fig. 10), used on some marine models, is bolted to the air intake side of the blower housing. The silencer has a perforated steel partition welded in place parallel with the outside faces, enclosing flame proof, felted cotton waste which serves as a silencer for air entering the blower.

While no servicing is required on the air silencer proper, it may be removed when necessary to replace the air intake screen. This screen is used to filter out any large foreign particles which might seriously damage the blower assembly.

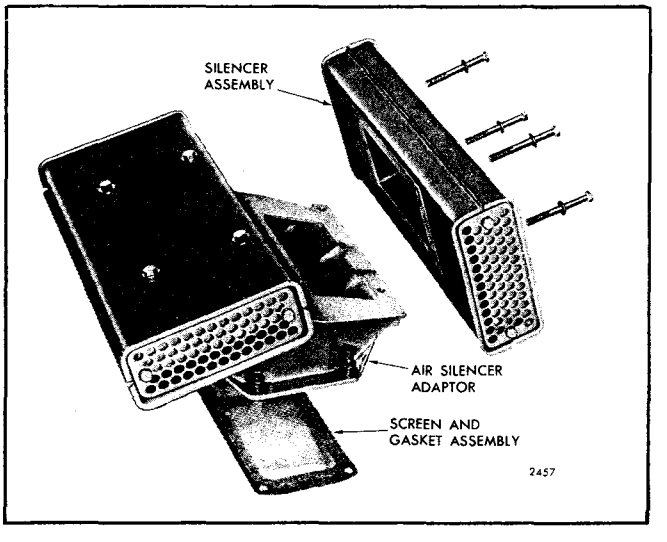


Fig. 10 - Silencer Assembly

AIR BOX DRAINS

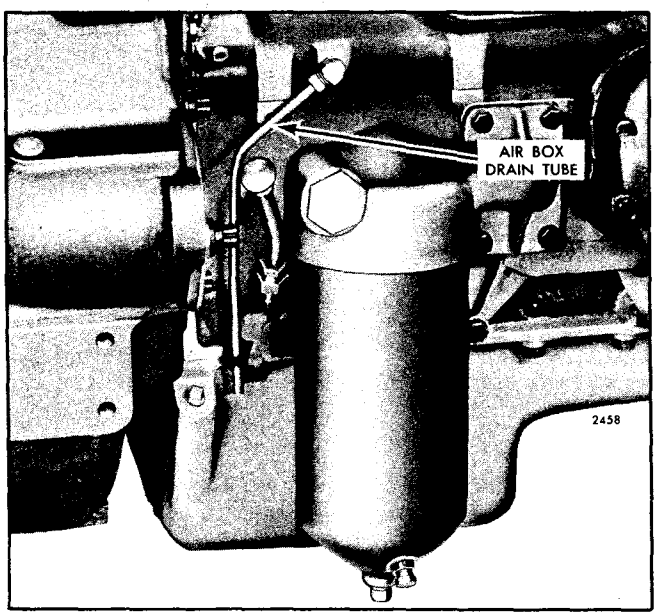


Fig. 11 - Air Box Drains

In normal operation, a slight amount of vapor from the air condenses and settles at the bottom of the air box. This condensation is drained through air box drain tubes (Fig. 11) which direct the expelled air and vapor down and away from the engine.

Air box drains must be open at all times; otherwise, water and oil may accumulate in the air box and be drawn into the cylinders with the incoming fresh air. Therefore, periodic checks should be made to ensure they are open. Remove the air box covers and examine the air box floor for oil or an accumulation of water. If oil or water is found, wipe the air box dry with clean rags and remove and clean the air box drain tubes.

CRANKCASE VENTILATION

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train, and valve compartment by a continuous pressurized ventilation system.

Breathing is through two openings in the rear main bearing bulkhead of the crankcase, which connects to a chamber. Two crimped-steel mesh breather pads, which cover the openings (Fig. 12), filter out the oil as the vapors pass into the chamber.

A breather pipe is pressed into or flange mounted on top of the cylinder block to provide an exit for the crankcase vapors.

Some engines have an additional breather assembly mounted on the flywheel housing or on one of the valve rocker covers (Fig. 13).

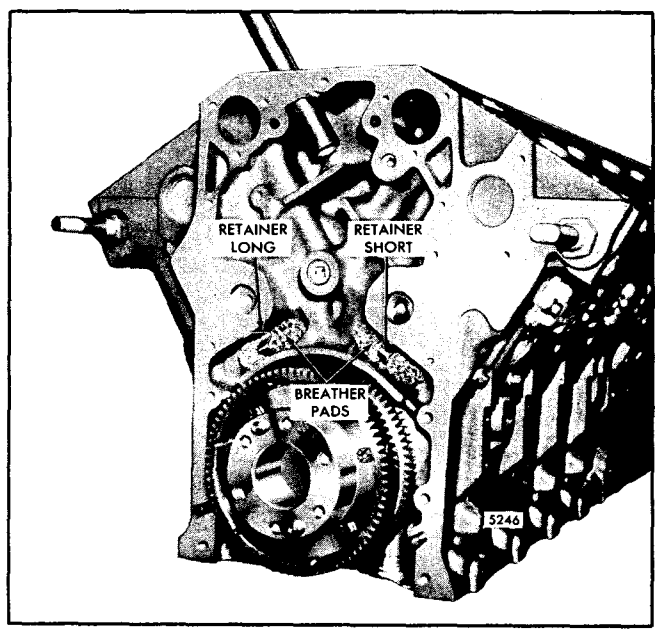


Fig. 12 - Breather Pads and Retainers Installed in Cylinder Block

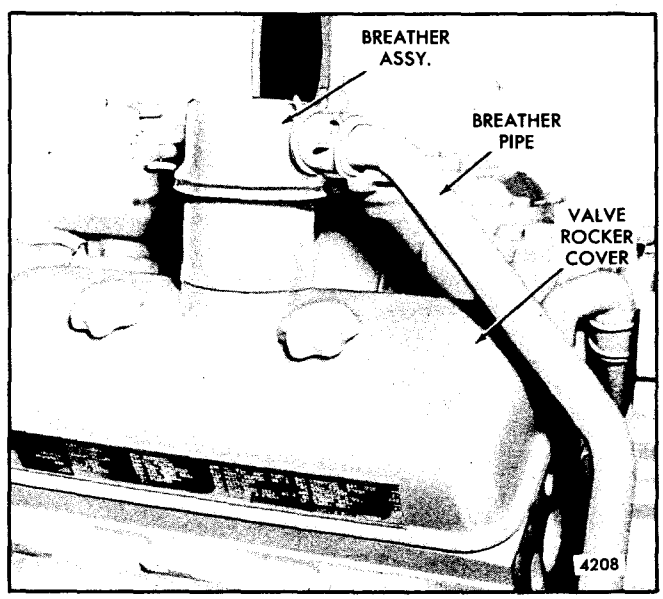


Fig. 13 - Typical Mounting of Breather Assemly on Valve Rocker Cover

LUBRICATING SYSTEM

The lubricating oil systems schematically illustrated in Figs. 14 and 15 consist of an oil pump, oil cooler, a full-flow oil filter, by-pass valves at the oil cooler and filter and pressure regulator valves at the pump and in the cylinder block main oil gallery. Positive lubrication is ensured at all times by this system. A by-pass oil filter may also be incorporated into the lubricating system at the owner's option.

Oil for lubricating the connecting rod bearings and piston pins and for cooling the piston head is provided through the drilled hole in the crankshaft from the adjacent forward main bearings. The gear train is lubricated by the overflow of oil from the camshaft pocket through a connecting passage into the flywheel housing. A certain amount of oil spills into the flywheel housing from the camshaft and idler gear bearings. The blower drive gear is lubricated from the rear of the blower.

The oil pump on the 6 and 8V engines is driven by a pump drive hub on the front end of the crankshaft and consists of a large and small spur gear meshing in a cavity inside the crankshaft cover.

The gear-type oil pump used on the 12 and 16V engines is mounted on the main bearing caps. The pump on the 12V engine is driven from the front end of the crankshaft and on the 16V engine the pump, which is mounted on the number 9 and 10 main bearing caps, is driven from the rear end of the crankshaft.

The pressure regulator valve, located at the end of a vertical oil gallery in the front of the cylinder block, maintains a stabilized oil pressure. The 16V engine

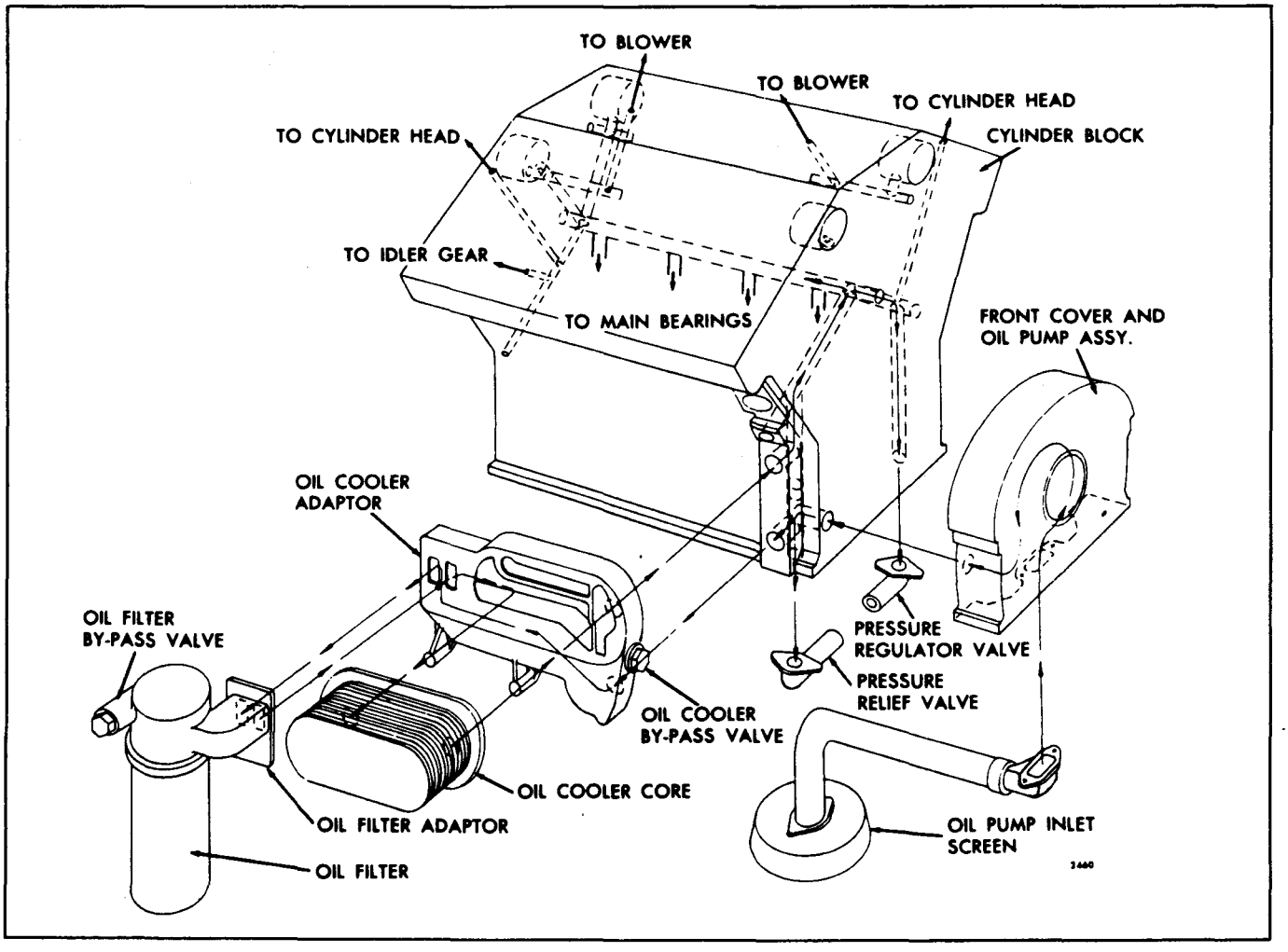


Fig. 14 - Schematic Diagram of Typical 6V and 8V Lubricating Systems

has two pressure regulator valves located at the ends of the vertical oil galleries. When the oil pressure at the regulator valve(s) exceeds 50 psi, the valve(s) open and discharge the excess oil to the sump.

Oil Filters

Engines are equipped with a full-flow type lubricating oil filter. If additional filtering is required, a by-pass type oil filter may also be installed. The full-flow filter assembly can be remotely mounted or mounted on the engine as shown in Fig. 16. A by-pass valve, which opens at 15 psi, is located in the filter base to ensure engine lubrication in the event the filter should become plugged.

All of the oil supplied to the engine passes through the full-flow filter that removes the larger foreign particles without restricting the normal flow of oil.

The by-pass filter assembly, when used, continually

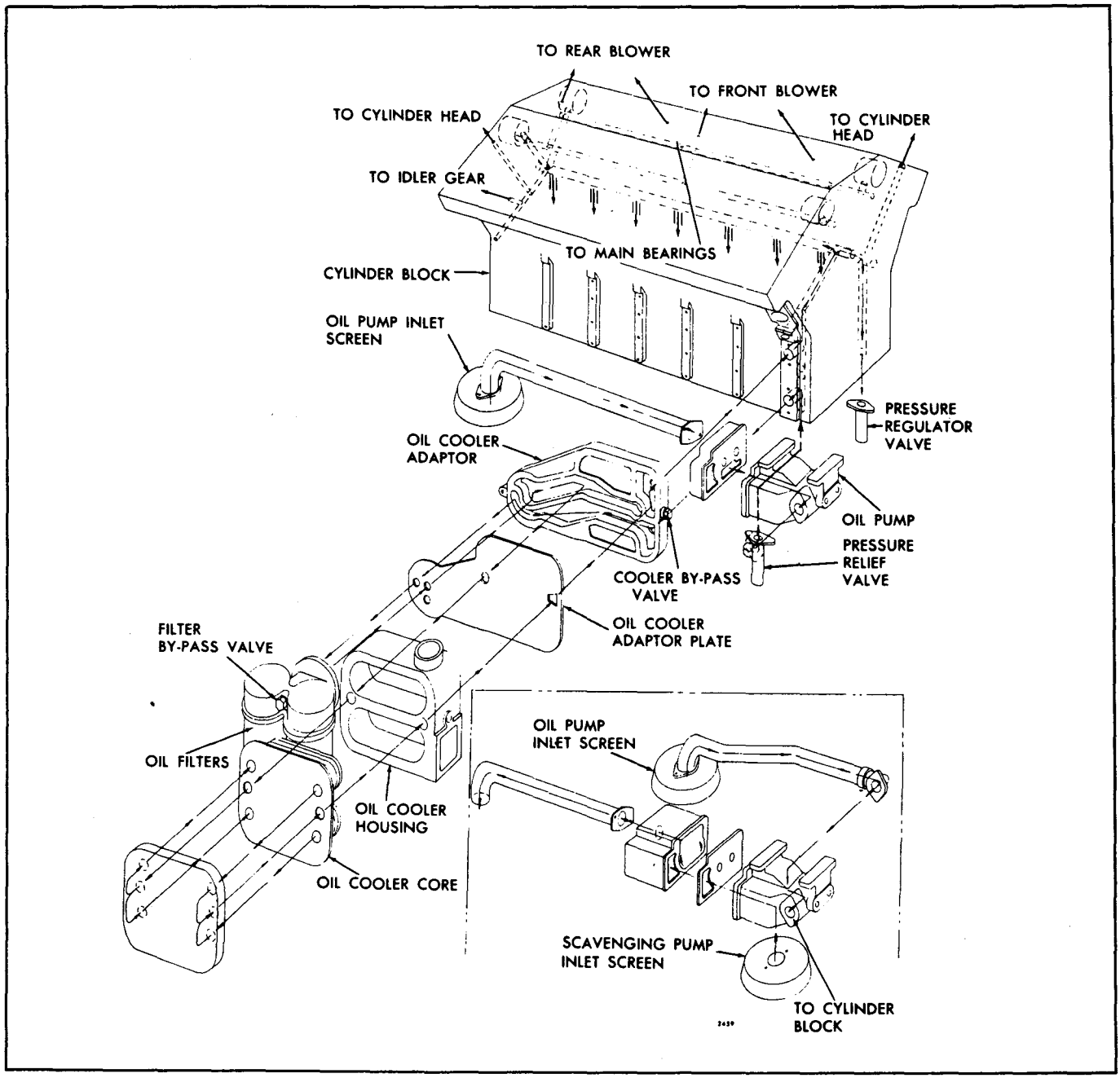


Fig. 15 - Schematic Diagram of Typical 12V Lubricating Systems

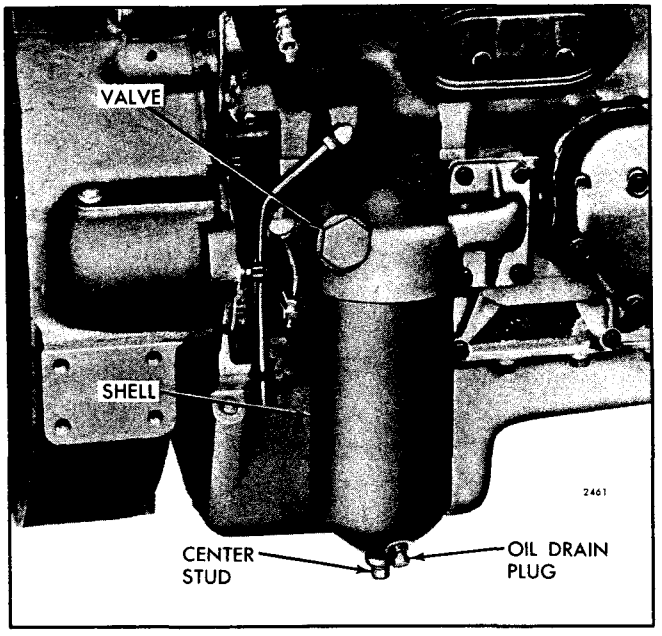


Fig. 16 - Typical Full-Flow Filter Mounting

filters a portion of the lubricating oil that is being bled off the oil gallery when the engine is running. Eventually all of the oil passes through the filter, filtering out minute foreign particles that may be present.

Some engines may be equipped with a by-pass filter assembly consisting of two filter elements, each enclosed in a shell which is mounted on a single base. An oil passage in the filter base connects the two annular spaces surrounding both filter elements.

The full flow and by-pass filter elements should be replaced, each time the engine oil is changed, as follows:

1. Remove the drain plug and drain the oil (Fig. 16).

2. The filter shell, element and stud may be detached as an assembly, after removing the center stud from the base. Discard the gasket.

3. Clean the filter base.

4. Discard the used element, wipe out the filter shell and install a new element on the center stud.

5. Place a new gasket in the filter base, position the shell and element assembly on the gasket and tighten the center stud carefully to prevent damaging the gasket or center stud.

6. Install the drain plug and, after the engine is started, check for oil leaks.

COOLING SYSTEM

To effectively dissipate the heat generated by the engine, one of three different types of cooling systems is used on a V-71 engine; radiator and fan, heat exchanger and raw water pump, or keel cooling. Each system is provided with a centrifugal type water pump that circulates the engine coolant. Each system incorporates thermostats to maintain a normal engine operating temperature of 160°F-185°F. A typical cooling system is illustrated in Fig. 17.

Radiator and Fan Cooling

Coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler housing and into the cylinder block. From the cylinder block the coolant passes up through the cylinder heads and, when the engine is at normal operating temperature, through the thermostat housings and into the upper portion of the radiator. Then the coolant passes down a series of tubes where the coolant temperature is lowered by the air stream created by the revolving fan.

Upon starting a cold engine or when the coolant is below operating temperature, the coolant is restricted at the thermostat housing and a by-pass provides water circulation within the engine during the warm-up period.

Heat Exchanger Cooling

In the heat exchanger cooling system, the coolant is drawn by the fresh water pump from the heat exchanger and is forced through the engine oil cooler, cylinder block, cylinder heads, exhaust manifolds and to the thermostat housings. A by-pass tube from the thermostat housings to the inlet side of the water pump permits circulation of the coolant through the engine while the thermostats are closed. When the thermostats open, the coolant can flow through the heat exchanger and then, after being cooled, to the engine fresh water pump for re-circulation.

While passing through the core of the heat exchanger, the coolant temperature is lowered by raw water which is drawn by the raw water pump from an outside supply. The raw water enters the heat exchanger at one side and is discharged at the opposite side.

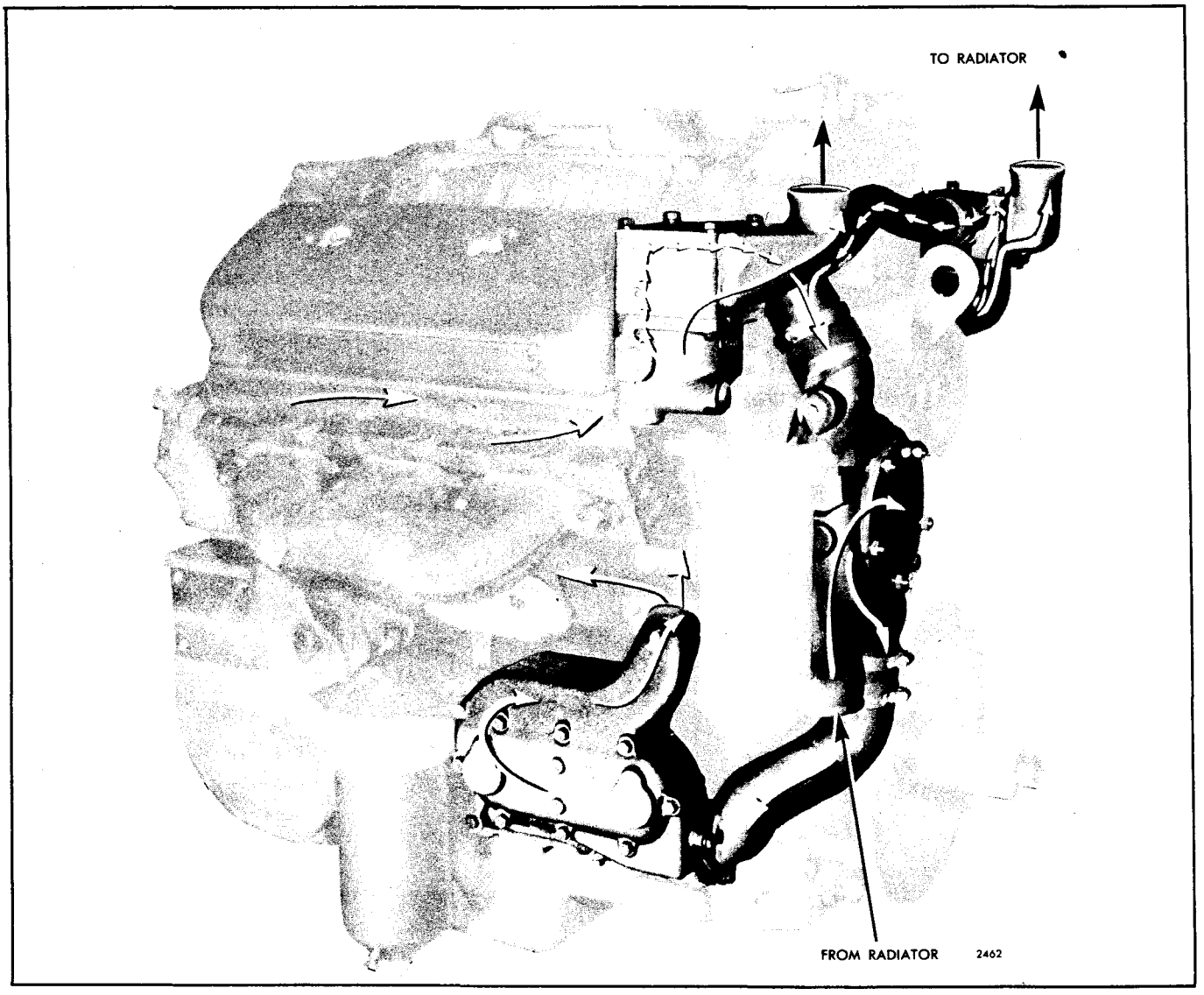


Fig. 17 - Cooling System

To protect the heat exchanger element from electrolytic action, a zinc electrode is located in both the heat exchanger inlet elbow and the raw water pump inlet elbow and extends into the raw water passage.

The length of time a heat exchanger will function satisfactorily before cleaning will be governed by the kind of coolant used in the engine and the kind of raw water used. Soft water plus rust inhibitor or high boiling point type antifreeze should be used as the engine coolant.

When foreign deposits accumulate in the heat exchanger, to the extent that cooling efficiency is impaired, such deposits can, in most instances, be removed by circulating a flushing compound through the fresh water circulating system without removing the heat exchanger. If this treatment does not restore the engine's normal cooling characteristics, contact an authorized *Detroit Diesel Allison Service Outlet.*

Keel Cooling

In the keel cooling system, the coolant is drawn by the fresh water pump from the keel cooler and is forced through the engine oil cooler, cylinder block, cylinder heads, exhaust manifolds and to the thermostat housings. A by-pass tube from the thermostat housings to the inlet side of the water pump permits circulation of coolant through the engine while the thermostats are closed. When the thermostats open, the coolant can

flow through the keel cooling coils and then to the suction side of the fresh water pump for re-circulation.

The heat of the engine coolant is transferred through the coils of the keel cooler to the surrounding water.

ENGINE COOLING SYSTEM MAINTENANCE

Engine Coolant

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinder, from the component parts such as exhaust valves, cylinder liners, and pistons which are surrounded by water jackets. In addition, the heat absorbed by the oil is also removed by the engine coolant in the oil-to-water cooler.

For the recommended coolant, refer to the section on *Engine Coolant.*

Cooling System Capacity

The capacity of the basic engine cooling system (cylinder block, head, water manifold, thermostat housing and oil cooler housing) is shown in Table 1.

To obtain the complete amount of coolant in the cooling system of a unit, the additional capacity of the radiator, hoses, etc. must be added to the capacity of the basic engine. The capacity of radiators and related equipment should be obtained from the equipment supplier.

Fill Cooling System

Before starting the engine, close all of the drain cocks and fill the cooling system with water. If the unit has a raw water pump, it should also be primed, since operation without water may cause impeller failure. The use of clean, soft water will eliminate the need for de-scaling solutions to clean the cooling system. A hard, mineral-laden water should be made soft by using water softener chemicals before it is poured into the cooling system. These water softeners modify the minerals in the water and greatly reduce or eliminate the formation of scale.

COOLING SYSTEM CAPACITY CHART (BASIC ENGINE)		
Engine	Capacity	(Gallons)
	Former Block	*WBP Block
6V	5 1/2	7
8V	7 3/4	10
12V	10 1/2	13 3/4
16V	15 1/2	19 3/4

*Water Below Port Cylinder Block

TABLE 1

Start the engine and, after the normal operating temperature has been reached, allowing the coolant to expand to its maximum, check the coolant level. The coolant level should be within 2" of the top of the filler neck.

Should a daily loss of coolant be observed, and there are no apparent leaks, there is a possibility of gases leaking past the cylinder head water seal rings into the cooling system. The presence of air or gases in the cooling system may be detected by connecting a rubber tube from the overflow pipe to a water container. Bubbles in the water in the container during engine operation will indicate this leakage. Another method for observing air in the cooling system is by inserting a transparent tube in the water outlet line.

Drain Cooling System

The engine coolant is drained by opening the cylinder block and radiator (heat exchanger) drain cocks and removing the cooling system filler cap. The removal of the cooling system filler cap permits air to enter the cooling passages and the coolant to drain completely from the system.

Drain cocks are located on each side of the cylinder block at both the front and rear of the engine. The drain cocks at the rear of the engine are below the exhaust manifold. The front surface of the cylinder block has drain cocks on each side above the engine front cover.

In addition to the drains on the block, the oil cooler housing has a drain cock at the extreme bottom. Radiators and other components that do not have a drain cock are drained through the oil cooler housing drain cock.

To ensure that all of the coolant is drained completely from a unit, all cooling system drains should be opened. Should any entrapped water in the cylinder block or radiator freeze, it will expand and may cause damage. When freezing weather is expected, drain all units not adequately protected by antifreeze. Leave all drain cocks open until refilling the cooling system.

Marine engine exhaust manifolds are cooled by the same coolant used in the engine. Whenever the engine

cooling system is drained, open the exhaust manifold drain cocks.

Raw water pumps are drained by loosening the cover attaching screws and tapping the cover gently to loosen it. After the water has drained, tighten the screws.

Flushing Cooling System

The cooling system should be flushed each spring and fall. The flushing operation cleans the system of antifreeze solution in the spring and removes the summer rust inhibitor in the fall, preparing the cooling system for a new solution. The flushing operation should be performed as follows:

1. Drain the previous season's solution from the engine.

2. Refill the cooling system with soft clean water. If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.

3. Start the engine and operate it for 15 minutes to circulate the water thoroughly.

4. Drain the cooling system completely.

5. Refill the system with the solution required for the coming season.

Cooling System Cleaners

If the engine overheats, and the fan belt tension and water level have been found to be satisfactory, clean and flush the entire cooling system. Remove scale formation by using a reputable and safe de-scaling solvent. Immediately after using the de-scaling solvent, neutralize the system with the neutralizer. It is important that the directions printed on the container of the de-scaler be thoroughly read and followed.

After the solvent and neutralizer have been used, completely drain the engine and radiator and reverse-flush before filling the system.

Reverse-Flushing

After the engine and radiator have been thoroughly cleaned, they should be reverse-flushed. The water pump should be removed and the radiator and engine reverse-flushed separately to prevent dirt and scale deposits clogging the radiator tubes or being forced through the pump. Reverse-flushing is accomplished by hot water, under air pressure, being forced through the cooling system in a direction opposite to the normal flow of coolant, loosening and forcing scale deposits out.

The radiator is reverse-flushed as follows:

1. Remove the radiator inlet and outlet hoses and replace the radiator cap.

2. Attach a hose at the top of the radiator to lead water away from the engine.

3. Attach a hose to the bottom of the radiator and insert a flushing gun in the hose.

4. Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.

5. Turn on the water and, when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between air blasts.

> **CAUTION:** Apply air gradually. Do not exert more than 30 psi air pressure. Too great a pressure may rupture a radiator tube.

6. Continue flushing until only clean water is expelled from the radiator.

The cylinder block and cylinder head water passages are reverse-flushed as follows:

1. Remove the thermostat and the water pump.

2. Attach a hose to the water inlet of the cylinder block to drain the water away from the engine.

3. Attach a hose to the water outlet at the top of the cylinder block and insert the flushing gun in the hose.

4. Turn on the water and, when the water jackets are filled, turn on the air in short blasts, allowing the engine to fill with water between air blasts.

5. Continue flushing until the water from the engine runs clean.

If scale deposits in the radiator cannot be removed by chemical cleaners or reverse-flushing as outlined above, it may be necessary to remove the upper tank and rod out the individual radiator tubes with flat steel rods. Circulate water through the radiator core from the bottom to the top during this operation.

Miscellaneous Cooling System Checks

In addition to the above cleaning procedures, the other components of the cooling system should be checked periodically to keep the engine operating at peak efficiency. The cooling system hoses, thermostats and

radiator pressure cap should be checked and replaced if found to be defective.

When water connection seals and hoses are installed, be sure the connecting parts are properly aligned and the seal or hose is in its proper position before tightening the clamps. All external leaks should be corrected as soon as detected.

The fan belt must be checked and adjusted, if necessary, to provide the proper tension and the fan shroud must be tight against the radiator core to prevent re-circulation of air which may lower the cooling efficiency.

Fresh Water Pump

The centrifugal type water pump is mounted on the engine front cover and is driven by a front camshaft gear. This pump circulates the engine coolant through the cylinder block, cylinder head, heat exchanger or radiator and the oil cooler.

The pump consists of a bronze impeller secured to a stainless steel shaft with a lock nut. A gear is pressed on the opposite end of the shaft and the shaft turns on two ball bearings. An oil seal is used ahead of the front bearing and a spring-loaded face type water seal is used in back of the impeller. The pump ball bearings are lubricated with oil splashed by the water pump gear.

Contact an authorized *Detroit Diesel Allison Service Outlet* if more information is needed.

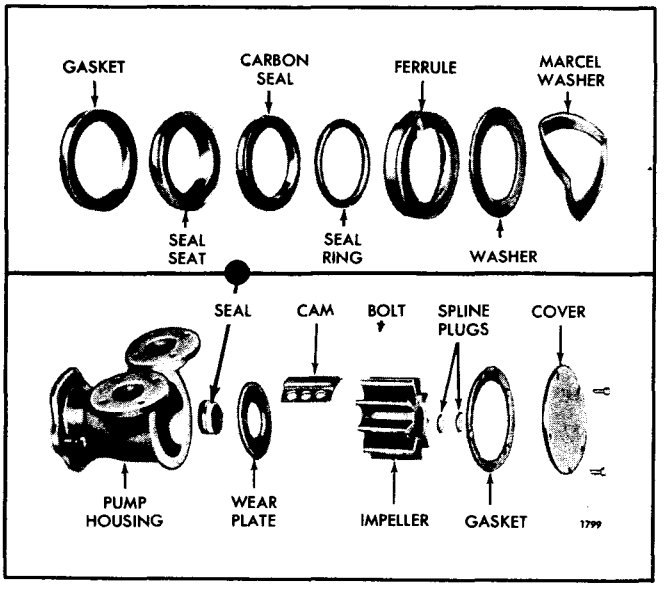


Fig. 18 - Raw Water Pump Details and Relative Location of Parts

Raw Water Pump

A positive displacement raw water pump driven by a coupling from a camshaft circulates raw water through the heat exchanger to lower the temperature of the engine coolant.

The impeller (Fig. 18) is self-lubricated by the water pumped and should be primed before starting the engine.

Rubber spline plugs have been inserted between the end of the drive shaft and cover to reduce the possibility of foreign material working into the splines and causing wear.

Note that the end cover is marked to show the outlet port for RH rotation and the outlet port for LH rotation. Follow these markings when installing the raw water pump to assure proper direction of flow. Also, when installing the inlet elbow or outlet elbow, be sure to use two flat washers on the bolt being installed in the blind hole in the pump housing.

A rotary type seal assembly prevents any leakage along the shaft.

A raw water pump seal failure is readily noticeable by the leakage of water from the openings in the pump housing. These openings, which are located between the pump mounting flange and the inlet and outlet ports, must remain open at all times.

It is possible to replace seal parts and the impeller without removing the pump from the engine.

Use care to prevent scratching the lapped surface of the seal seat or that portion of the shaft which the seal contacts.

The raw water pump seal parts and impeller may be removed and replaced as follows:

1. Remove the cover screws and lift the cover and gasket from the housing (Fig. 18). Note the position of the impeller blades to facilitate reassembly.

2. Grasp a blade at each side of the impeller with pliers and pull the impeller from the shaft. The spline plugs will come out with the impeller.

3. Remove the spline plugs by pushing a screw driver through the impeller from the opposite end.

> **CAUTION:** If the impeller is reusable, care should be exercised to prevent damage to the splined surfaces.

4. Inspect the bond between the neoprene and the metal of the impeller. Check the impeller blades. If

they have a permanent set, a new impeller should be used. If the impeller area which rides on the wear plate is damaged, the impeller should be replaced.

5. Insert two wires (each with a hook at one end) between the housing and seal, with the hooks over the edge of the carbon seal. Then pull the seal assembly from the shaft.

6. The seal seat and gasket may be removed in the same manner.

7. Remove the cam bolt and cam.

8. Remove the wear plate and check it for wear and burrs. If the plate is worn or burred, it may be reversed.

9. Install the wear plate. There is a dowel in the pump body, and the wear plate is notched to ensure correct installation.

10. Hold the cam in position and install the cam bolt.

11. If the seal seat and gasket are removed, place the gasket and seal seat over the shaft and press them into position in the seal cavity.

12. Place the seal ring securely in the ferrule and, with the carbon seal and washer correctly positioned against the ferrule, slide the ferrule over the shaft and against the seal seat. Be sure the seal ring is correctly contained within the ferrule so that it grips the shaft.

13. Install the flat washer and then the marcel washer.

14. Compress the impeller blades to clear the offset cam and press the impeller on the splined shaft. The impeller blades must be correctly positioned to follow the direction of rotation.

15. Turn the engine over a few revolutions to position the impeller blades properly. Install the spline plugs.

16. Use a new gasket and install the cover on the housing.

The Jabsco raw water pump is equipped with a synthetic rubber impeller. Since synthetic rubber loses its elasticity at low temperatures, impellers made of natural rubber should be installed when it is necessary to pump raw water that has a temperature below 40 ° F.

The synthetic rubber impeller must be used when the pump operates with water over 40 ° F.

ENGINE EQUIPMENT

INSTRUMENT PANEL, INSTRUMENTS AND CONTROLS

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

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

Oil Pressure Gage

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

Water Temperature Gage

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

Ammeter

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

Tachometer

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

Engine Starting Switch

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

Stop Knob

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

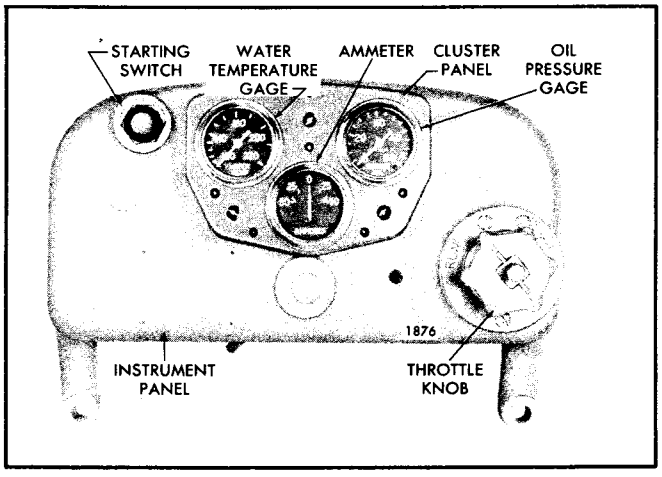


Fig. 1 - Typical Instrument Panel

Emergency Stop Knob

In an emergency, or if after pulling the engine stop knob the engine continues to operate, the emergency stop knob may be pulled to stop the engine. The emergency stop knob, when pulled, will trip the air shut-off valve located between the air inlet housing and the blower and shut off the air supply to the engine. Lack of air will prevent further combustion of the fuel and stop the engine.

The emergency stop knob must be pushed back in after the engine stops so the air shut-off valve can be opened for restarting after the malfunction has been corrected.

Throttle Control

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

ENGINE PROTECTIVE SYSTEMS

MANUAL SHUT-DOWN SYSTEM

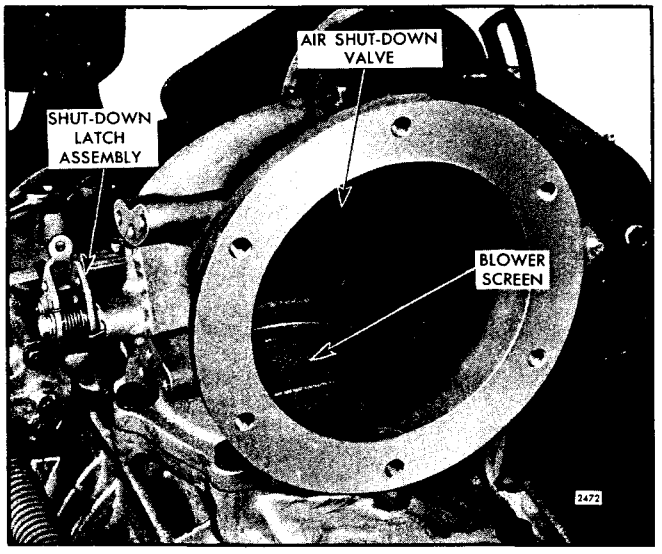


Fig. 2 - Manually Operated Emergency Engine Shut-Down Valve Mounting

A manually-operated emergency engine shut-down device, mounted in the air shut-down housing, enables the engine operator to stop the engine in the event an abnormal condition should arise. If the engine continues to run after the engine throttle is placed in the no-fuel position, or if combustible liquids or gases are accidentally introduced into the combustion chamber causing overspeeding of the engine, the shut-down device will prevent damage to the engine by cutting off the air supply and thus stopping the engine. The device consists of a shut-down valve mounted in the air shut-down housing and a suitable operating mechanism (Fig. 2).

The air shut-down valve is retained in the open position by a latch. A wire or cable assembly is used to trip the latch. Pulling the emergency shut-down knob all the way out will stop the engine. After the engine stops, the operator must push the emergency shut-down knob all the way in and manually reset the air shut-down valve before the engine is started again.

AUTOMATIC MECHANICAL SHUT-DOWN SYSTEM

The automatic mechanical shut-down system (Fig. 3) is designed to stop the engine if there is a loss of oil pressure, loss of engine coolant, overheating of the engine coolant, or overspeeding of the engine. Engine oil pressure is utilized to activate the components of the system.

A coolant temperature-sensing valve and an adaptor and copper plug assembly are mounted on the exhaust manifold outlet. The power element of the temperature-sensing valve is placed against one end of the copper plug, and the other end of the plug extends into the exhaust manifold. Engine coolant is directed through the adaptor and passes over the power element of the valve. Engine oil, under pressure, is directed through a restricted fitting to the temperature-sensing valve and to an oil pressure actuated bellows located on the air inlet housing.

The pressure of the oil entering the bellows overcomes the tension of the bellows spring and permits the latch to retain the air shut-down valve in the open position. If the oil pressure drops below a predetermined value, the spring in the bellows will release the latch and permit the air shut-off valve to close and thus stop the engine.

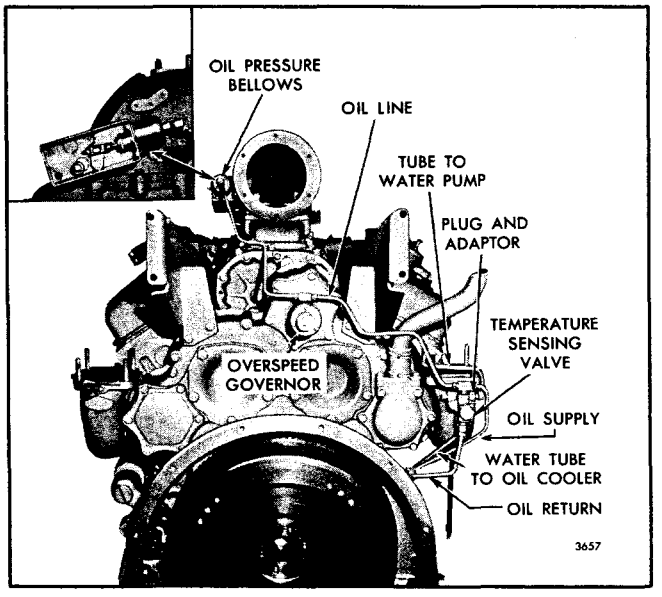


Fig. 3 - Automatic Mechanical Shut-Down System Mounting

The overspeed governor (Fig. 4), used on certain applications, consists of a valve actuated by a set of spring-loaded weights. Engine oil is supplied to the valve through a connection in the oil line between the bellows and the temperature-sensing valve. An outlet in the governor valve is connected to the engine oil sump. Whenever the engine speed exceeds the overspeed governor setting, the valve (actuated by the governor weights) is moved from its seat and permits the oil to flow to the engine sump. This decreases the oil pressure to the bellows, thus actuating the shut-down mechanism and stopping the engine.

A restricted fitting, which will permit a drop in oil pressure great enough to actuate the shut-down mechanism, is required in the oil line between the cylinder block oil gallery and the shut-down sensing devices.

Operation

To start an engine equipped with a mechanical shut-down system, first manually open the air shut-off valve and then press the engine starting switch. As soon as the engine starts, the starting switch may be released, but the air shut-off valve must be held in the open position until the engine oil pressure increases sufficiently to permit the bellows to retain the latch in the open position.

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

If the engine coolant overheats, the temperature-sensing valve will open and permit the oil in the protective system to flow to the engine crankcase.

The resulting decrease in oil pressure will actuate the shut-down mechanism and stop the engine. Also if the engine loses its coolant, the copper plug will be heated up by the hot exhaust gases passing over it and cause the temperature-sensing valve to open and actuate the shut-down mechanism.

Whenever the engine speed exceeds the overspeed governor setting, the oil in the line flows to the sump, resulting in a decrease in oil pressure. The oil pressure bellows then releases the latch and permits the air shut-off valve to close.

When an engine is stopped by the action of the shut-down system, the engine cannot be started again until the particular device which actuated the shut-down mechanism has returned to its normal position. The abnormal condition which caused the engine to stop must be corrected before attempting to start it again.

Adjustment

The only adjustments necessary in the mechanical shut-down system are the low oil pressure setting of the bellows and the overspeed setting of the overspeed governor or overspeed valve assembly. Replace the temperature-sensing valve when operation is unsatisfactory.

To adjust the low oil pressure setting of the bellows, start and run the engine until the normal operating temperature (160° -185° F.) has been reached and the oil pressure has stabilized. Then reduce the engine speed slowly until the bellows disengages the latch on the air shut-off valve and stops the engine. Note the oil pressure at which the shut-down occurred. The oil pressure at disengagement should be 5-10 psi at 450-600 rpm; 10-15 psi at 601-1400 rpm; or 15-20 psi at 1401 and above rpm. If adjustment is necessary, loosen the lock nut on the bellows and turn the adjusting screw clockwise to increase the oil pressure setting or counterclockwise to decrease the setting. Hold the adjusting screw and tighten the lock nut when the proper setting has been obtained.

> **NOTE:** Set the bellows disengagement pressure as near as possible to the high end of the pressure range for the low engine speed specified for the engine. For an engine equipped with a dual speed governor, set the bellows disengagement at the lower setting of the engine governor.

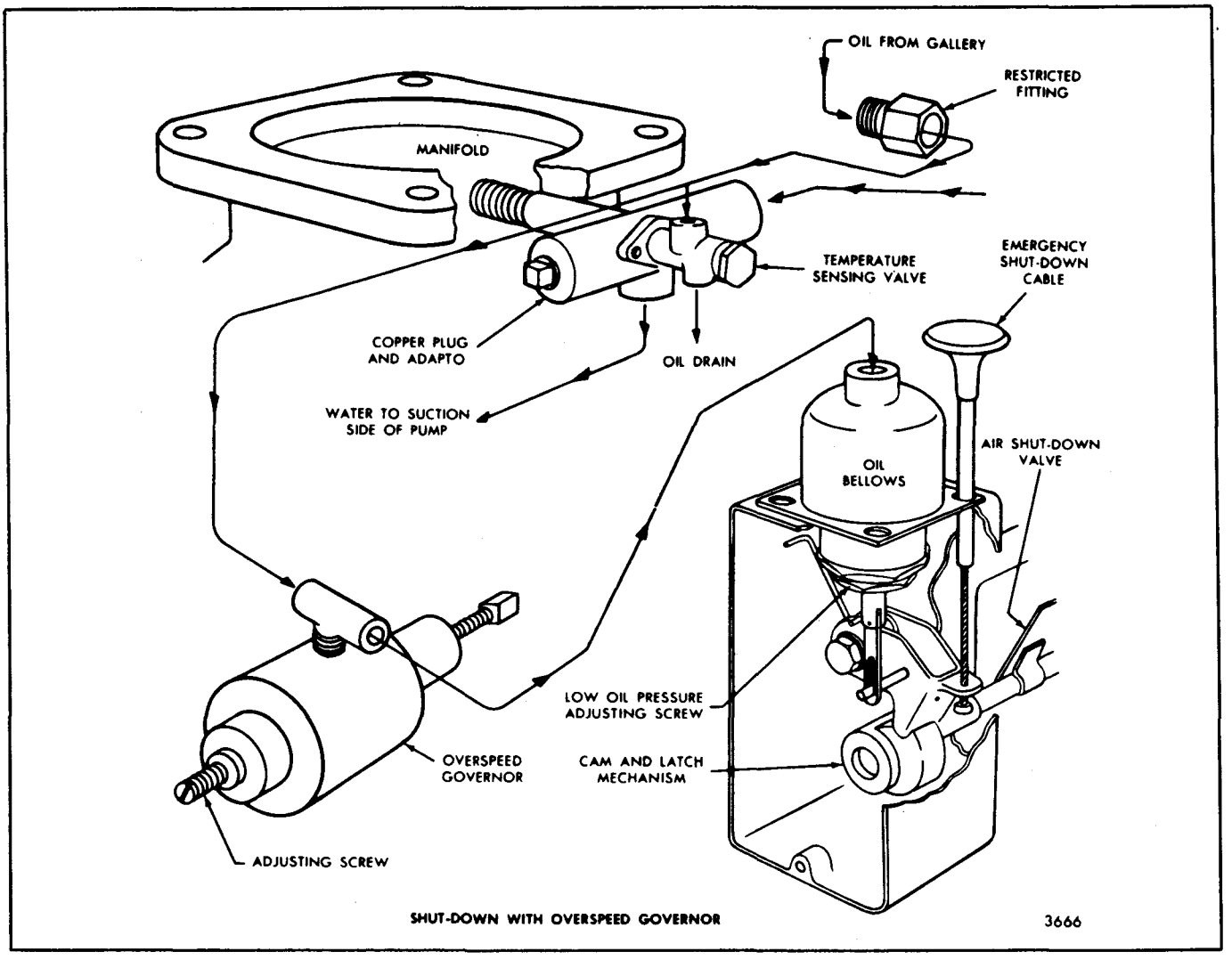


Fig. 4 - Schematic Drawing of Automatic Mechanical Shut-Down System with Overspeed Governor

Check the operation of the engine coolant temperature-sensing valve by placing a cover over the radiator while the engine is operating at part load and note the coolant outlet temperature at which the bellows disengages the air shut-down latch. The air shut-off valve should close and stop the engine within a temperature range of 200°-210°. If the engine is not shut-down in this range, replace the temperature-sensing valve. If the engine is shut-down below 200° F., check the coolant flow through the plug and adaptor assembly and, if circulation is satisfactory, replace the temperature-sensing valve.

NOTE: If a premature engine shut-down occurs, check the copper plug. A spring and plunger assembly are used with the current type plug to provide an unobstructed flow of coolant over the temperature-sensing valve element.

The temperature-sensing valve can be bench tested by attaching an air hose (40 psi air supply) to the oil inlet side and installing a tube from the outlet side to a can of water. Then immerse the power element of the valve in a container of water that is heated and agitated. Check the temperature of the water with a thermometer. Apply air to the valve. The valve should be open, as indicated by the flow of air, at a water temperature of 195°-206° F.

To adjust the overspeed governor, start and run the engine until normal operating temperature is reached. Then increase the engine speed to the desired overspeed shut-down speed. At this speed, the bellows should disengage the air shut-down latch and stop the engine. If necessary, adjust the overspeed governor setting by loosening the lock nut on the adjusting screw at the rear of the governor and turn the screw clockwise to increase the shut-down speed or

counterclockwise to decrease the shut-down speed. Then tighten the lock nut, while holding the adjusting screw, when the proper setting is obtained.

AUTOMATIC ELECTRICAL SHUT-DOWN SYSTEM

The automatic electrical shut-down system shown in Fig. 5 protects the engine against a loss of coolant, overheating of the coolant, loss of oil pressure, or overspeeding. In the event one of the foregoing conditions arises, a switch will close the electrical circuit and energize the solenoid switch, causing the shut-down solenoid to release the air shut-down latch and stop the engine.

Operation

The elèctrical circuit is de-energized under normal operating conditions. When the engine is started, one oil pressure switch opens when the oil pressure reaches approximately 5 psi and the fuel oil pressure switch closes at approximately 20 psi fuel pressure. As the engine speed increases, the second oil pressure switch opens at approximately 27 psi and at 1000-1100 rpm, the No. 1 switch in the overspeed governor will close. The water temperature switch remains open.

If the oil pressure drops below 27 psi, the oil pressure switch will close the circuit and energize the shut-down solenoid. This will activate the shut-down mechanism and stop the engine.

A loss of coolant or an increase in coolant temperature to approximately 203° F. will close the contacts in the water temperature switch, thus closing the electrical circuit and activating the shut-down mechanism.

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

If the engine speed exceeds the high speed setting of the overspeed governor, the No. 2 governor switch will close and activate the shut-down mechanism.

When the engine is shut-down, the decrease in speed will open the governor switches and the decrease in oil and fuel pressures will close the oil pressure switches and open the fuel pressure switch, thus de-energizing the circuit.

The cause of the abnormal conditions must then be determined and corrected before the engine is started

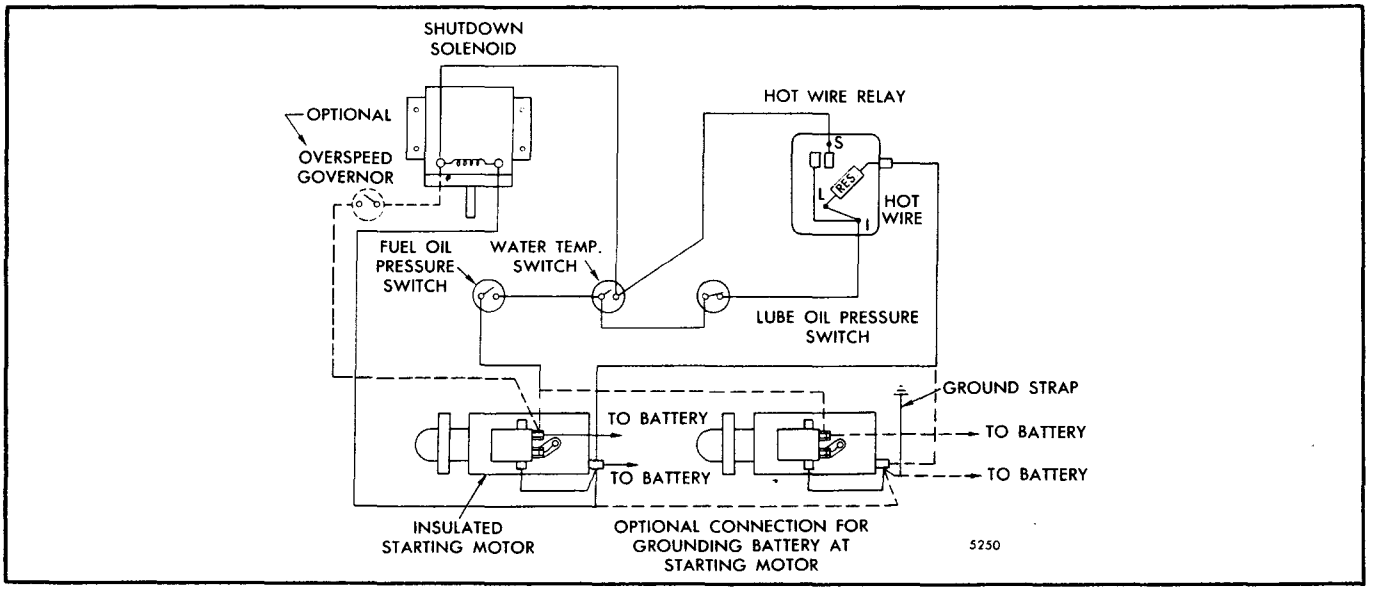


Fig. 5 - Automatic Electrical Shut-Down System Diagram

again. Also, the air shut-off valve must be manually reset in the open position before the engine can be started.

Some engines are equipped with an electrically operated automatic shut-down system which incorporates a hot wire relay and one oil pressure switch (Fig. 5).

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

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

Depending upon the particular shut-down system used, the high water temperature switch may be installed in one of the openings in the water manifold, or the temperature-sensing valve and micro-switch unit may be installed in the exhaust manifold outlet.

In some electrical shut-down applications, the temperature-sensing valve and the copper plug used in the mechanical shut-down system is utilized. The lubricating oil pressure switch is installed in the oil line to the valve. When an increase in water temperature causes the valve to open and permits the oil to flow back to the crankcase, the resulting decrease in oil pressure will close the oil pressure switch and energize the electrical shut-down circuit. Low engine oil pressure will also cause the contacts in the oil pressure switch to close and energize the shut-down circuit.

ALARM SYSTEM

The alarm system shown in Fig. 6 is similar to the automatic electrical shut-down system, but uses a warning bell in place of the air shut-off valve solenoid. The bell warns the engine operator if the engine coolant overheats or the oil pressure drops below the safe operating limit.

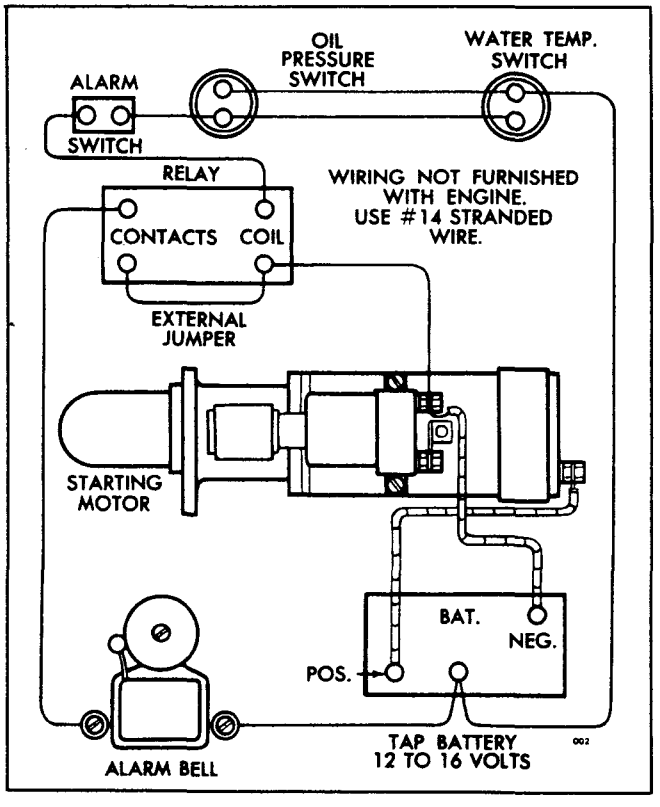


Fig. 6 - Alarm System Wiring Diagram

When the engine is started and the oil pressure is sufficient to open the oil pressure switch contacts (opening pressure is stamped on the switch cover), the alarm switch must be turned on manually to put the system in operation. The water temperature switch is normally open. Should the engine coolant exceed 200° to 205° F., the water temperature switch will close the electrical circuit and sound the alarm bell. Likewise, if the oil pressure drops below the setting of the oil pressure switch, the switch will close and cause the bell to ring. The bell will continue to ring until the engine operator turns the alarm switch off. The alarm switch must also be turned off before a routine stop since the decreasing oil pressure will close the oil pressure switch and cause the bell to ring.

If the alarm bell rings during engine operation, stop the engine immediately and determine the cause of the abnormal condition. Make the necessary corrections before starting the engine again.

An alarm bell may be connected to the electrical shut-down system as shown in Fig. 7. In this system, if an abnormal condition occurs, the engine will be stopped automatically and the alarm bell will ring to notify the operator. The bell will continue to ring until the operator pushes the reset button on the drop relay.

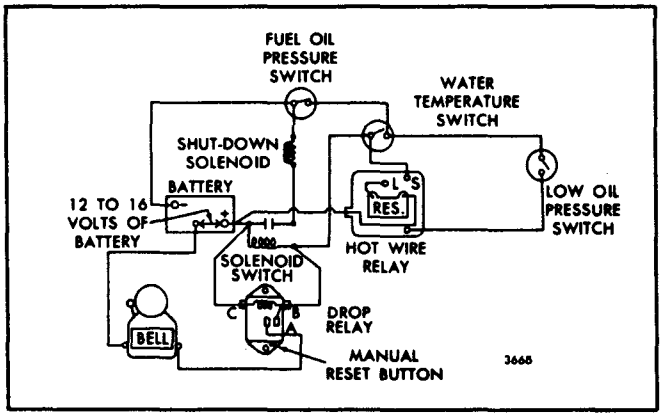


Fig. 7 - Alarm Bell Connected to Electrical Shut-Down System

The alarm system illustrated in Fig. 8 utilizes the temperature-sensing valve and the low oil pressure and overspeed valve used in the mechanical shut-down system.

When the engine is started, the oil pressure switch will open when the oil pressure reaches 10 psi and the fuel oil pressure switch will close when the fuel pressure reaches 20 psi. If overheating or loss of engine coolant occurs, the temperature-sensing valve will open and permit the oil to flow to the crankcase. The resulting drop in oil pressure will permit the contacts in the oil pressure switch to close and complete the electrical circuit to the alarm bell. A loss of engine oil pressure or overspeeding of the engine will cause the oil pressure and overspeed valve to open and activate the alarm system. Once the alarm system is activated, the bell will continue to ring until the engine operator stops the engine.

During a routine engine shut-down, the decreasing fuel pressure causes the fuel pressure switch to open the electrical circuit before the decreasing oil pressure can activate the alarm system.

On 16V-71 engines, coolant protection is also obtained through an exhaust probe and adaptor assembly and a temperature switch. In this system, the engine coolant is circulated around the switch power element to prevent the switch from being activated by the heat transfer from the exhaust probe. Therefore, an alarm will occur if coolant flow through the adaptor is interrupted for any reason. The switch will also operate when the engine coolant discharge temperature exceeds 200-205° F.

The oil pressure switch, mounted in the low oil pressure and overspeed valve (Fig. 8), will be activated to sound the alarm when the engine oil pressure drops below the safe operating pressure. The switch will also detect an engine overspeed. Engine oil is supplied to the valve. Should the engine oil pressure drop below a safe operating value, above 1200 rpm, the valve will operate, dropping the oil pressure at the switch which completes the circuit and sounds the alarm. Below 1200 rpm the oil pressure switch will close whenever the oil pressure is less than the switch setting.

Engine overspeed is detected by the operation of the valve which results in the oil switch closing. The travel of the piston in the valve, which is adjustable, controls the overspeed setting.

The relay is used to prevent damage to the pressure and temperature switches should the current to operate the alarm device be too high.

Should the alarm be activated for any reason, the engine should be stopped immediately and the cause found and corrected before the engine is started again.

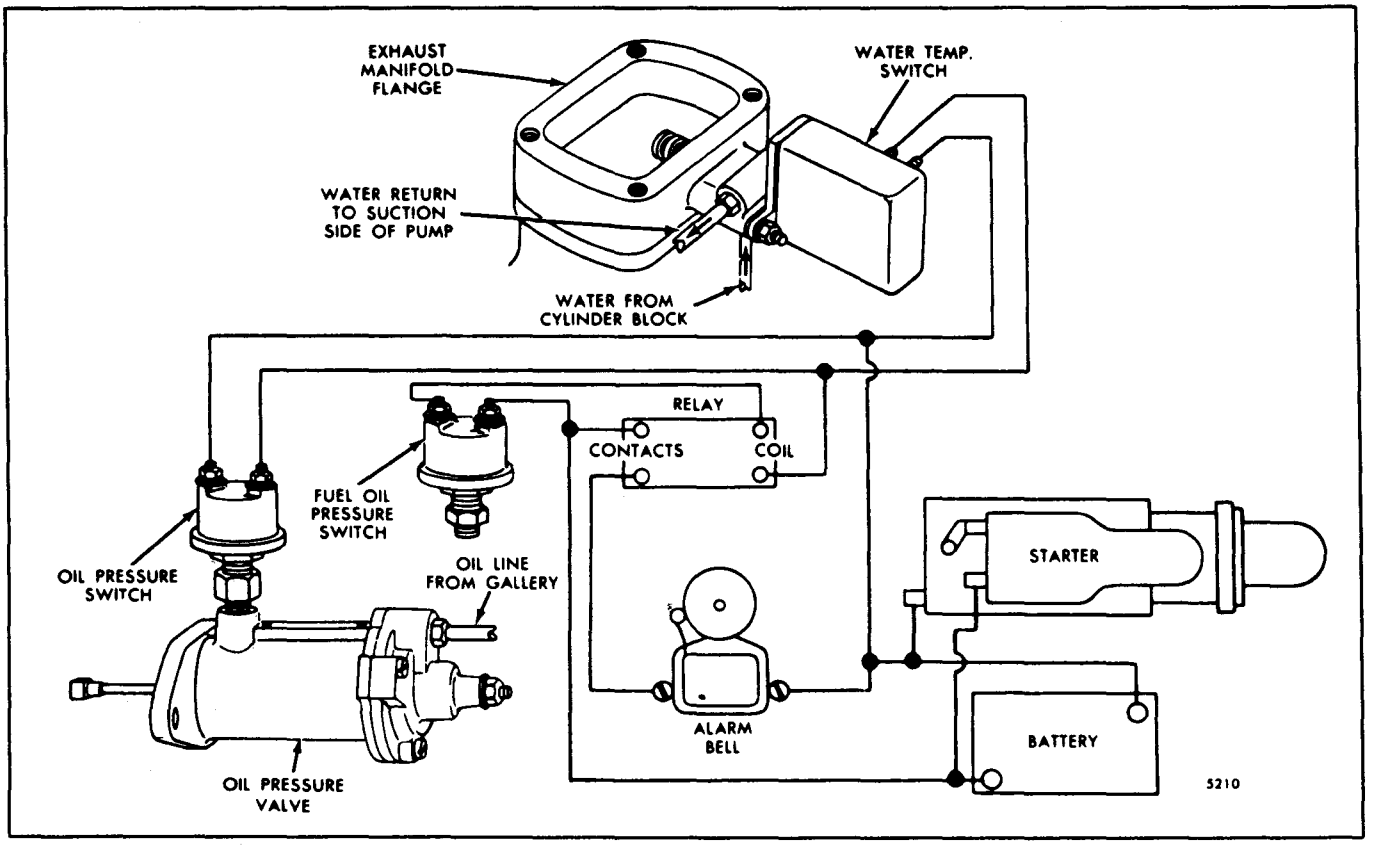


Fig. 8 - Alarm System with Mechanical Sensing Units

STARTING SYSTEMS

ELECTRICAL STARTING SYSTEM

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

Starting Motor

The electric starting motor has an overrunning clutch drive or a Bendix drive assembly. Bendix drive starters are generally used on applications where automatic starting is required, such as standby generator sets. The overrunning clutch drive starters have the solenoid mounted on the starter and have a totally enclosed shifting mechanism.

Starter Switch

To start the engine, a switch is used to energize the starting motor. Release the switch immediately after the engine starts.

Battery-Charging Alternator

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

Alternator Precautions

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

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

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

Accidentally reversing the battery connections must be avoided.

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

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

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

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

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

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

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

Regulator

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

Storage Battery

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

The battery has three major functions:

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

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

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

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

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

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

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

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

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

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

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

Consult an authorized *Detroit Diesel Allison Service Outlet* for information regarding the electrical system.

HYDRAULIC STARTING SYSTEM (HYDROSTARTER)

The Hydrostarter System schematically illustrated in Fig. 9 is a complete hydraulic system for starting internal combustion engines. The system is automatically recharged after each start, and can be manually recharged. The starting potential remains during long periods of inactivity, and continuous exposure to hot or cold climates has no detrimental effect upon the Hydrostarter System. Also, the Hydrostarter torque for a given pressure remains substantially the same regardless of the ambient temperature.

The Hydrostarter System consists of a reservoir, an engine-driven charging pump, a hand pump, a piston type accumulator, a starting motor and connecting hoses and fittings.

Operation

Hydraulic fluid flows by gravity, or a slight vacuum, from the reservoir to either the engine-driven pump or the hand pump inlet. Fluid discharging from either pump outlet at high pressure flows into the accumulator and is stored at 3250 psi under the pressure of compressed nitrogen gas.

When the starter is engaged with the engine flywheel ring gear and the control valve is opened, fluid under pressure is forced out of the accumulator, by the expanding nitrogen gas, and flows into the starting motor which rapidly accelerates the engine to a high cranking speed. The used fluid returns directly to the reservoir from the starter.

The engine-driven charging pump runs continuously during engine operation and automatically recharges the accumulator. When the required pressure is attained in the accumulator, a valve within the pump body opens and the fluid discharged by the pump is by-passed to the reservoir. The system can be shut down and the pressure in the accumulator will be maintained.

The precharge pressure of the accumulator is the pressure of the nitrogen gas with which the accumulator is initially charged. This pressure must be checked before the system pressure is raised for the initial engine start. To check the precharge pressure, open the relief valve, on the side of the hand pump, approximately 1/2 turn, allowing the pressure gage to return to zero. Close the relief valve and pump several strokes on the hand pump. The gage should show a rapid pressure rise from zero to the nitrogen precharge pressure, where it will remain without change for several additional strokes of the pump.

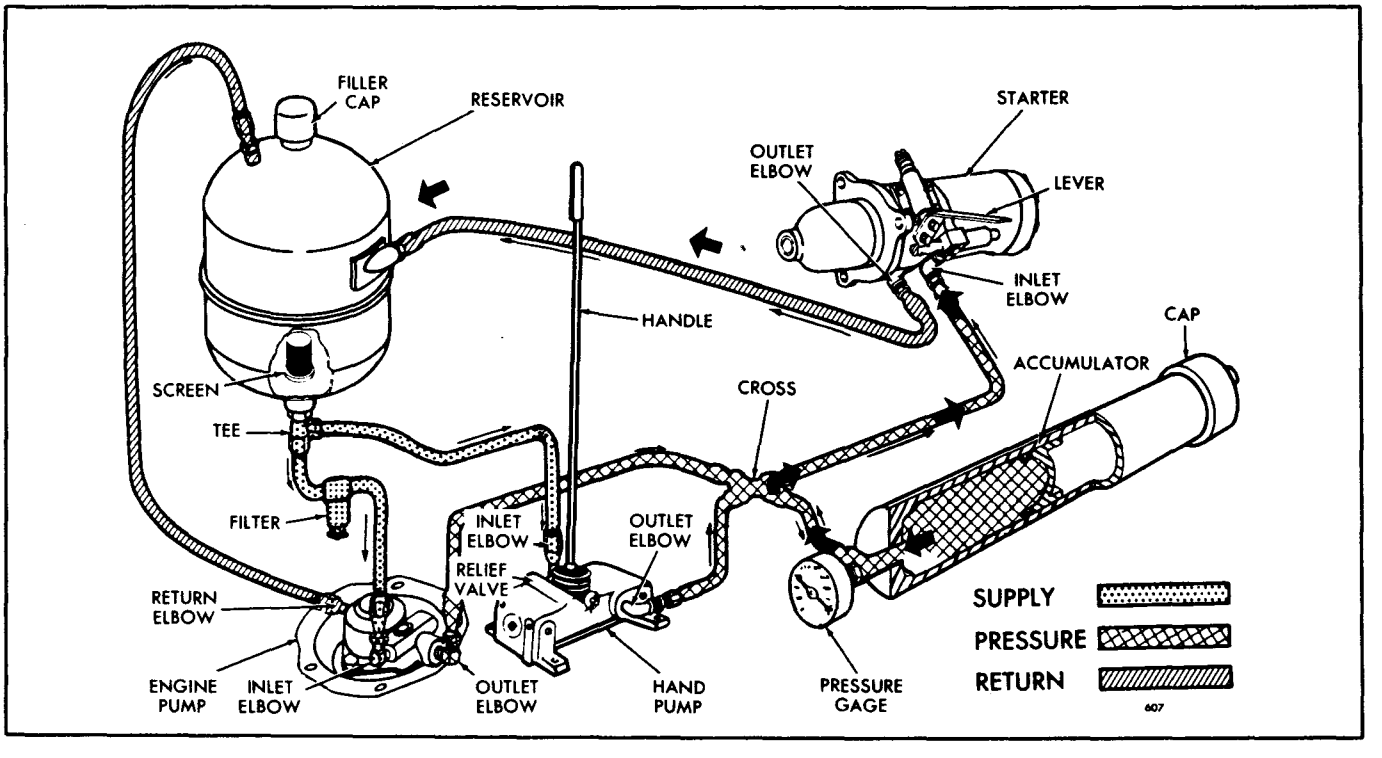


Fig. 9 - Schematic Diagram of Hydrostarter System Showing Oil Flow

Initial Engine Start

Use the hand pump to raise the accumulator pressure. An accumulator pressure of 1500 psi when the ambient temperature is above 40° F. will provide adequate cranking to start the engine. Between 40° F. and 0° F., 2500 psi should be sufficient. Below 0° F., the accumulator should be charged to the maximum recommended pressure. Although the Hydrostarter cranks the engine faster than other starting systems, starting aids should be used in cold weather.

> **NOTE:** Use the priming pump to make sure the filters, lines, manifolds and injectors are full of fuel before attempting to start the engine.

For ambient temperatures below 40° F., use a fluid starting aid. Add the starting fluid just prior to moving the Hydrostarter lever and during the cranking cycle as required. Do not wait to add the starting fluid after the engine is turning over, otherwise the accumulator charge may be used up before the engine can start. In this case, the accumulator charge must be replaced with the hand pump.

With the engine controls set for start (throttle at least half-open), push the Hydrostarter control lever to simultaneously engage the starter pinion with the flywheel ring gear and to open the control valve. Close the valve quickly when the engine starts, to conserve the accumulator pressure and to prevent excessive over- running of the starter drive clutch assembly.

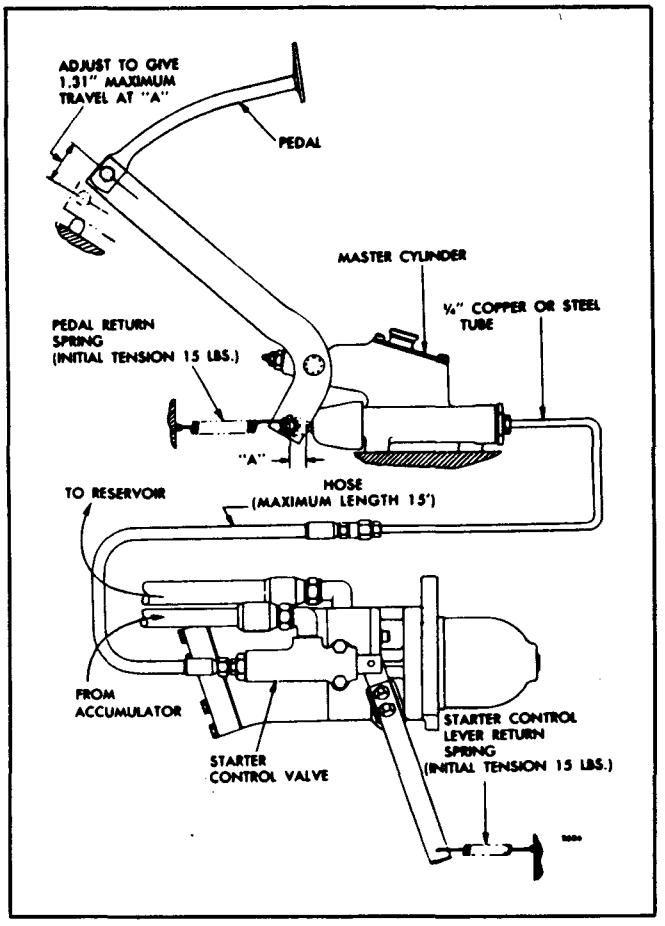


Fig. 10 - Hydrostarter Remote Control System

Remote Control System

The Hydrostarter remote control system (Fig. 10) consists of a master cylinder, a pedal, a lever arm, two springs, and a flexible hose. It is an independent hydraulic system using diesel fuel oil as a hydraulic fluid to actuate the Hydrostarter control valve by means of the pedal operated master cylinder.

The master cylinder is connected to the control valve on the Hydrostarter by a flexible hose. Pressing on the pedal forces the fluid through the hose to the control valve which engages the starter pinion with the engine flywheel ring gear. Release the pedal as soon as the engine starts.

The Hydrostarter motor is equipped with a control valve that incorporates a threaded valve housing plug with a 1/8"-27 tapped hole in the center for installation of the flexible hose. A 1/8"-27 pipe plug is installed when the remote control system is not used.

Springs are used to return the master cylinder pedal and the Hydrostarter control lever to the off position.

Filling

Remove the filler cap from the reservoir and add a sufficient quantity of hydraulic fluid (a mixture of 75% diesel fuel and 25% SAE 10 or 30 lubricating oil) to fill the system.

The required amount of hydraulic fluid will vary depending upon the size of the reservoir, length of hydraulic hoses and the size and number of accumulators. The reservoirs are available in 10, 12, 16 and 23 quart capacities. In a 10 quart capacity reservoir, add approximately 8 quarts of hydraulic fluid, 10 quarts in a 12 quart reservoir, 14 quarts in a 16 quart reservoir or 21 quarts in a 23 quart reservoir.

> **NOTE:** When the accumulator is charged to 3000 psi and all hoses are filled, there should be enough hydraulic fluid remaining in the reservoir to completely cover the screen in the bottom of the reservoir.

Purging

A by-pass valve is located on the inlet side of the hand pump. Loosen the lock nut and rotate this valve approximately one turn counterclockwise with a screw driver. Operate the hand pump for 12 to 15 complete strokes. Do not pump too rapidly. Close the by-pass valve tightly and tighten the lock nut.

1. Move the starter control lever to engage the pinion with the flywheel and open the control valve. While holding the lever in this position, operate the hand pump until the starter has turned several revolutions. Close the control valve. Loosen the swivel hose fitting at the discharge side of the engine-driven pump about two turns. Operate the hand pump to force air out until the oil begins to appear at the loose fitting. Tighten the swivel hose fitting and pressurize the system with the hand pump sufficiently to start the engine.

2. Perform the initial starting instructions under *Preparation for Starting Engine First Time.* Then, with the engine running at least 1500 rpm, purge the engine-driven pump of air. Break the hose connection at the discharge side of the engine-driven pump until a full stream of oil is discharged from the pump. Connect the hose to the pump and alternately loosen and tighten the swivel fitting on the discharge hose until the oil leaking out, when the fitting is loose, appears to be free of air bubbles. Tighten the fitting securely and observe the pressure gage. The pressure should rise rapidly to the accumulator precharge pressure (1250 psi at 70° F.), then increase slowly, reaching 2900 to 3300 psi.

3. After the pressure has stabilized near 3000 psi, examine all of the high pressure hoses, connections and fittings for leaks.

4. The engine-driven pump must by-pass oil to the reservoir when the accumulator pressure reaches 2900-3300 psi. To determine whether the pump by-pass valve is operating properly, remove the reservoir filler cap, disconnect the pump by-pass hose at the reservoir, and hold the hose over the open reservoir filler spout. An occasional spurt of oil may be emitted from the hose prior to by-passing. When the by-pass valve opens, a full and continuous stream of oil will flow from the hose. Reconnect the hose to the reservoir and install the filler cap.

5. Fill the reservoir to the proper level.

The Hydrostarter remote control system may be purged of air as follows:

1. Fill the master cylinder with fuel oil.

2. Loosen the hose fitting at the Hydrostarter control valve.

3. Actuate the master cylinder pedal until all of the air is discharged from the system and a solid stream of fuel oil is being discharged with each stroke.

> **NOTE:** Replenish the fluid in the master cylinder as required during the purging operation.

4. Tighten the hose fitting and check for leaks.

LUBRICATION AND PREVENTIVE MAINTENANCE

Inspect the system periodically for leaks. Primarily, examine the high pressure hoses, connections, fittings and the control valve on the starter. Make certain that the oil level in the reservoir is sufficient to completely cover the screen at the bottom of the tank. Make this check after the accumulator is charged and the engine-driven pump is by-passing oil to the reservoir.

Every 2000 hours, or as conditions warrant, drain the reservoir and remove the screen. Flush out the reservoir and clean the screen and filler cap. Then, reinstall the screen.

Remove the bowl and element from the filter in the engine-driven pump supply hose. Wash the bowl and element in clean fuel oil and reassemble the filter.

Release the pressure and drain the remaining hydraulic fluid from the system by disconnecting the hoses from the Hydrostarter components. Then reconnect all of the hydraulic hoses.

> **CAUTION:** The oil pressure in the system must be released prior to servicing the Hydrostarter motor or other components to prevent possible injury to personnel or equipment.

> **NOTE:** Make sure all hoses and fittings are clean before any connections are made.

Fill the Hydrostarter system with new clean fluid.

Lubrication

Remove the Hydrostarter from the engine every 2000 hours for lubrication. Before removing the Hydrostarter , release the pressure in the system by means of the relief valve in the hand pump. Then remove the three bolts that retain the starting motor to the flywheel housing. Remove the starting motor without disconnecting the hydraulic oil hoses. This will prevent dirt and air from entering the hydraulic system.

Apply a good quality, lightweight grease on the drive clutch pinion to make sure the clutch will slide freely while compressing the spring. Also apply grease to the fingers of the clutch fork and on the spool of the clutch yoke engaged by the fork. This lubrication period may be reduced or lengthened according to the severity of service.

Remove the pipe plug from the starting motor drive housing and saturate the shaft oil wick with engine oil. Then reinstall the plug.

After lubricating, install the starting motor on the flywheel housing and recharge the accumulator with the hand pump.

On engines equipped with a hydraulic remote control system, lubricate the shaft in the master cylinder through the pressure grease fitting every 2000 hours.

Cold Weather Operation

Occasionally, when an engine is operated in regions of very low temperatures, the starter drive clutch assembly may slip when the starter is engaged. If the clutch slips, proceed as follows:

1. Release the oil pressure in the system by opening the relief valve in the hand pump.

> **CAUTION:** The oil pressure in the system must be released prior to servicing the Hydrostarter motor or other components to prevent possible injury to personnel or equipment.

2. Disconnect the hydraulic hoses from the starting motor.

3. Remove the three retaining bolts and lock washers and withdraw the starting motor from the flywheel housing.

4. Disassemble the starting motor.

5. Wash the Hydrostarter drive clutch assembly in clean fuel oil to remove the old lubricant.

6. When the clutch is free, apply SAE 5W lubricating oil.

7. Reassemble the starting motor and reinstall it on the engine. Then attach a tag to the starter noting the lubricant used in the clutch.

8. Recharge the accumulator with the hand pump.

Marine Application

In addition to the normal Hydrostarter lubrication and maintenance instructions, the following special precautions must be taken for marine installations or other cases where equipment is subject to salt spray and air, or other corrosive atmospheres:

1. Clean all exposed surfaces and apply a coat of zinc-chromate primer, followed by a coat of suitable paint.

2. Apply a liberal coating of Lubriplate, type 130AA, or equivalent, to the following surfaces.

   a. The exposed end of the starter control valve and around the control shaft where it passes through the clutch housing.

   b. The exposed ends of the hand pump cam pin.

3. Operate all of the moving parts and check the protective paint and lubrication every week.

Consult an authorized *Detroit Diesel Allison Service Outlet* for any information relating to the Hydrostarter system.

COLD WEATHER STARTING AIDS

In a diesel engine, the fuel injected into the combustion chamber is ignited by the heat of the air compressed into the cylinder. However, when starting an engine in extremely cold weather, a large part of the energy of combustion is absorbed by the pistons and cylinder walls and in overcoming the high friction created by the cold lubricating oil.

When the ambient temperature is low, it may be necessary to use an air heater or a starting fluid to assist ignition of the fuel.

> **NOTE:** Starting aids are NOT intended to correct for a low battery, heavy oil, or other conditions which cause hard starting. They are to be used only when other conditions are normal, but the air temperature is too cold for the heat of compression to ignite the fuel-air mixture.

FLUID STARTING AID

The fluid starting aid (Fig. 11) is designed to inject a highly volatile fluid into the air intake system at low ambient temperatures to assist in igniting the fuel oil

injected. This fluid is contained in suitable capsules to facilitate handling.

The starting aid consists of a cylindrical capsule container with a screw cap, inside of which a sliding piercing shaft operates. A tube leads from the capsule container to the hand operated pump and another tube leads to the atomizing nozzle threaded into a tapped hole in the air inlet housing.

The capsule container should be mounted in a vertical position and away from any heat.

Start the engine, using the fluid starting aid, as follows:

1. Remove the threaded cap and insert a fluid capsule in an upright position within the container.

CAUTION: The starting fluid is toxic and inflammable. Use caution when handling.

2. Pull the piercing shaft all the way out and install and tighten the cap on the container.

3. Push the piercing shaft all the way down. This will rupture the capsule and fill the container with the starting fluid.

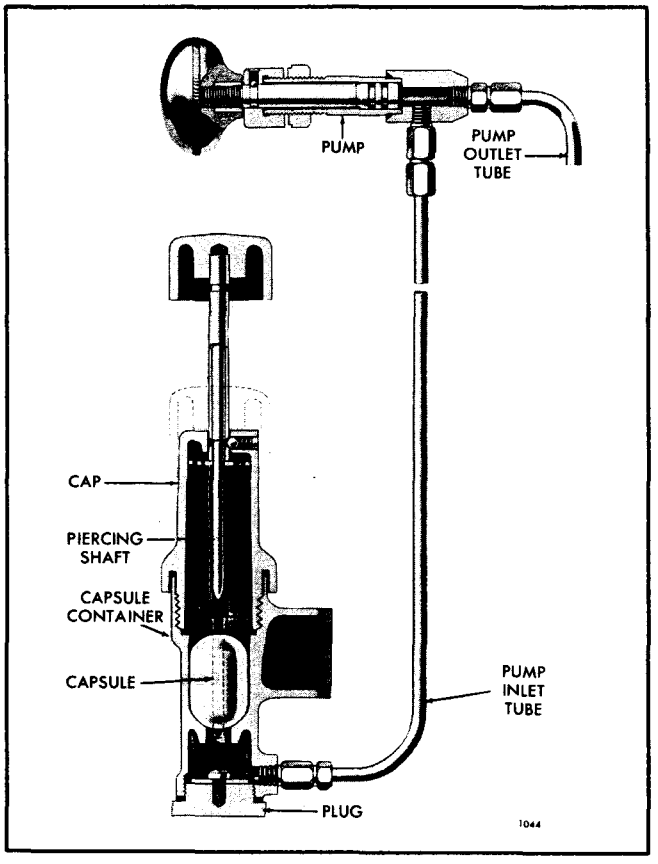


Fig. 11 - Typical Fluid Starting Aid

4. Move the engine throttle to the maximum speed position.

5. Engage the starter and at the same time pull the pump plunger all the way out. Push the plunger in slowly, forcing the starting fluid through the atomizing nozzle into the air intake. Continue to push the pump in until the engine starts. If the plunger is not all the way in when the engine starts, push it in slowly until it locks in the **IN** position.

6. Unscrew the cap and remove the capsule. *Do not leave the empty capsule in the container.*

7. Replace the cap on the capsule container and make sure the piercing shaft is all the way down.

Service

The cold weather fluid starting aid will require very little service. Replace the piston seal packing if the pump leaks. If there is an excessive resistance to pumping, the nozzle may be plugged. Remove the nozzle and clean it.

PRESSURIZED CYLINDER STARTING AID

Start the engine during cold weather, using the "Quick Start" starting aid system (Fig. 12) as follows:

1. Press the engine starter button.

2. Pull out the "Quick Start" knob for two seconds, then release it.

3. Repeat the procedure if the engine does not start on the first attempt.

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

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.

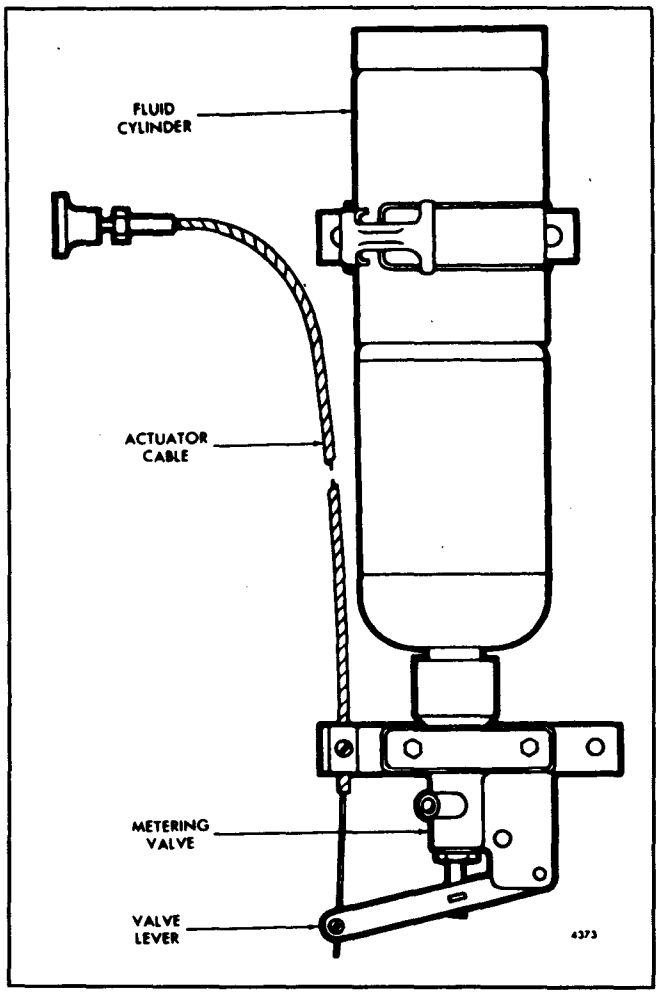


Fig. 12 - Quick Start Assembly

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.

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

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

> **CAUTION:** Do not actuate the starting aid more than once with the engine stopped. *Over-loading the engine air box with this high volatile fluid could result in a minor explosion.*

7. Check the fluid cylinder for hand tightness.

GOVERNORS

Engine Governors

Horsepower requirements of an engine may vary continually due to the fluctuating loads; therefore, a means must be provided to control the amount of fuel required to hold the engine speed reasonably constant during such load fluctuations. To accomplish this control, one of three types of governors is used on the engine, depending upon the application. Installations requiring maximum and minimum speed control, together with manually controlled intermediate speeds, ordinarily use a limiting speed mechanical governor. Applications requiring a near constant engine speed, under varying load conditions that may be changed by the operator, are equipped with a variable speed mechanical governor. The hydraulic governor is used where a uniform engine speed is required, under varying load conditions, with a minimum speed droop.

Lubrication

Mechanical governors are lubricated by oil that is sprayed from an orifice in the front blower end plate. This orifice directs a stream of oil into the revolving governor weights. The weights throw the oil to all moving parts within the governor.

Surplus oil returns to the engine crankcase through connecting passages in the blower and cylinder block.

When an engine equipped with a hydraulic governor is running, oil is supplied under pressure from the engine to the governor and a portion of the oil flows past the power piston and pilot valve plunger to lubricate the moving parts in the governor housing.

Oil which collects on the floor of the governor housing

drains into the drive housing, thus providing lubrication for the drive and driven shafts and their bearings. If the engine should fail to supply oil to the governor, the power piston will drop allowing the fuel rod to return to the no-fuel position; thus the hydraulic governor also acts as an automatic shut-down device.

Service

Fluctuations of the engine speed usually indicates governor malfunction. However, these fluctuations can also be caused by an excessive load on the engine, misfiring, or binding linkage. Contact an authorized *Detroit Diesel Allison Service Outlet* for information regarding governors.

Output Shaft Governors

On certain applications equipped with a Torqmatic converter, it is sometimes desirable to maintain a constant output shaft speed regardless of the engine speed or load fluctuations. To acquire the necessary results, a governor driven by the output shaft is installed in conjunction with an engine governor. This governor is called an output shaft governor and may be mechanical or hydraulic.

The output shaft governor controls the engine governor (usually a limiting speed type) in the engine speed range between idle and maximum speed. The engine speed is prevented from going below idle or exceeding the maximum speed setting by the engine governor.

Service

Refer to the *Engine Tune-Up Procedures* for any adjustments to the output shaft governors or contact an authorized *Detroit Diesel Allison Service Outlet* for information regarding output shaft governors.

TRANSMISSIONS

This manual includes information on the lubrication and preventive maintenance of the transmissions. It also includes adjustment procedures covering some of the more common power transmissions.

Problems relating to the repair and overhaul of these transmissions should be referred to an authorized *Detroit Diesel Allison Service Outlet.*

POWER TAKE-OFF ASSEMBLIES

The front and rear power take-off units are basically similar in design, varying in clutch size to meet the requirements of a particular engine application.

The power take-off unit is attached to either an adaptor (front power take-off) or the engine flywheel housing (rear power take-off). Each power take-off unit has a single or double plate clutch. The drive shaft is driven by the clutch assembly and is supported by a pilot bearing in the flywheel or the adaptor and by two tapered roller bearings mounted in the clutch housing.

Clutch Adjustment

These instructions refer to field adjustment for clutch facing wear. Frequency of adjustment depends upon the amount and nature of the load.

To ensure a long clutch facing life and the best performance, the clutch should be adjusted before slippage occurs.

When the clutch is properly adjusted, a heavy pressure is required at the outer end of the hand lever to move the throwout linkage to the "over center" or locked position.

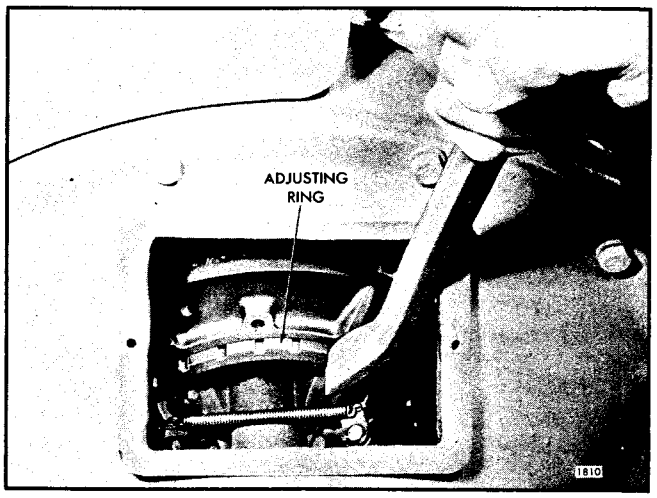


Fig. 13 - Power Take-Off Showing Typical 8 and 11-1/2 Inch Diameter Clutch Adjustment Ring

Adjust the 8", 11-1/2" and 14" diameter clutches as follows:

1. Disengage the clutch with the hand lever.

2. Remove the inspection hole cover to expose the clutch adjusting ring.

3. Rotate the clutch, if necessary, to bring the clutch adjusting ring lock within reach.

4. On the 8" and 11-1/2" diameter clutches, remove the clutch adjusting ring spring lock screw and lock from the inner clutch pressure plate and adjusting ring. Then, while holding the clutch drive shaft to prevent the clutch from turning, turn the clutch adjusting ring counterclockwise as shown in Fig. 13 and tighten the clutch until the desired pressure on the outer end of the hand lever, or at the clutch release shaft (Fig. 16), is obtained as shown in Table 1.

5. On the 14" diameter single and double plate clutches, raise the end of the adjusting ring lock up out of the splined groove in the hub of the outer clutch pressure plate. Then, while holding the clutch drive shaft to prevent the clutch from turning, turn the clutch adjusting ring clockwise as shown in Fig. 14

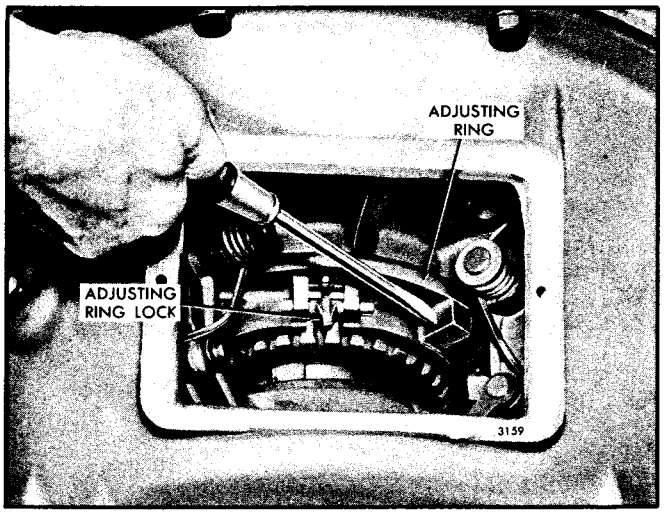


Fig. 14 - Power Take-Off Assembly Showing 14 Inch Diameter Clutch Adjustment Ring

and tighten the clutch until the desired pressure on the outer end of the hand lever, or at the clutch release shaft (Fig. 16), is obtained as shown in Table 1.

6. Install the clutch adjusting ring spring lock on the 8" and 11-1/2" diameter clutches. The ends of the lock must engage the notches in the adjusting ring. On the 14" diameter clutch, reinstall the end of the adjusting ring lock in one of the splined grooves in the hub of the outer pressure plate. Then install the inspection hole cover.

Adjust the 18" diameter clutch as follows:

1. Rotate the clutch, if necessary, to bring the adjustment lock and the pinion within reach through the inspection hole.

2. Loosen the lock bolt and pull the lock out of mesh with the adjusting ring; then, tighten the lock bolt to hold the lock out of the adjusting ring. While holding the clutch drive shaft to prevent the clutch from turning, turn the adjustment pinion clockwise to tighten the clutch as shown in Fig. 15.

3. Loosen the lock bolt and move the lock so it will mesh with the teeth of the adjusting ring, then tighten the lock bolt.

When properly adjusted, the approximate pressure required at the outer end of the hand lever to engage the various diameter clutches is shown in the table. These specifications apply only with the hand lever which is furnished with the power take-off.

A suitable spring scale may be used to check the pounds pressure required to engage the clutch. However, a more accurate method of checking the clutch adjustment is with a torque wrench as shown in Fig. 16.

To fabricate an adaptor, saw the serrated end off of a clutch hand lever and weld a 1-1/8" nut (across the hex) on it as shown in Fig. 16. Then saw a slot through the nut.

When checking the clutch adjustment with a torque wrench, engage the clutch slowly and note the amount of torque immediately before the clutch engages (goes over center). The specified torque is shown in Table 1.

The facings of the clutch discs wear only along the area where they contact the pressure plates during engagement. The area on each side of the disc beyond the pressure plates does not wear proportionately, thus resulting in a ridge. This ridge on three segment clutches can complicate the job of making an adjustment inasmuch as the top segment tends to drop down when the engine is stopped. This drop lets the ridge locate between the pressure plates. The drive ring cannot be properly adjusted to the recommended

Clutch	Hand Lever Length	Pressure (lbs.)	Torque Wrench (lb-ft)
8"	20"	40	56-63
11-1/2"	20"	65	94-100
14"	25"	75	132-149
18"	40-3/8"	90	278-298

TABLE 1

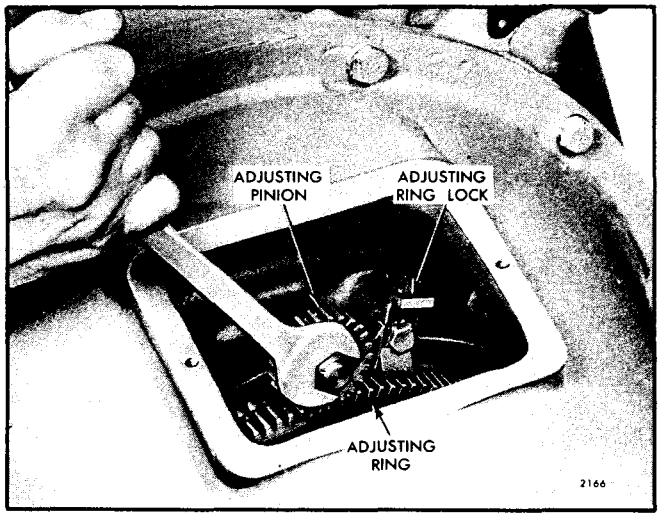


Fig. 15 - Power Take-Off Assembly Showing Method of Adjusting 18 Inch Diameter Clutch

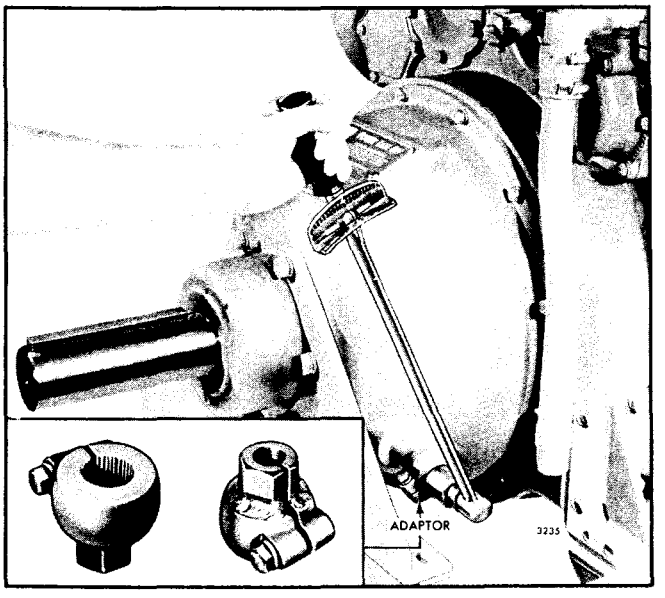


Fig. 16 - Checking Power Take-Off Clutch Adjustment with Torque Wrench and Adaptor

engaging pressure with the disc so positioned. The condition can result in excessive slippage and a need for early clutch facing replacement.

Make a final clutch adjustment check with the engine running, to make sure the adjustment was not made against the ridge. The procedure is outlined below:

1. Start the engine and operate it at idling speed (approximately 500 rpm) with the clutch disengaged. The speed will be sufficient to move the segments out to operating position.

2. Check the pounds pressure required to engage the clutch. The engagement pressure should be the same as that following the adjustment. If the clutch engages at a lower pressure, the adjustment was probably made against the unworn portion of the facing.

3. Stop the engine and readjust the clutch, making sure all disc segments are properly positioned. Install the inspection hole cover.

TORQMATIC MARINE GEAR

The Torqmatic marine gear is used on 6V and 8V single engine marine units and tandem twin marine units. The marine gear consists of a reverse gear section and a reduction gear section. Each marine gear is available in several gear ratios.

The oil for operating the hydraulic clutches and for lubricating the reverse gear is contained in the reverse gear sump and is circulated throughout the system by a hydraulic oil pump mounted on the flywheel housing and driven from the blower drive shaft through a flexible coupling.

The oil pressure ranges for the marine gear at forward operating speed are 130 to 155 psi and 110 to 150 psi in reverse. The average operating oil temperature is 200° F. in forward and a maximum of 250° F. in reverse.

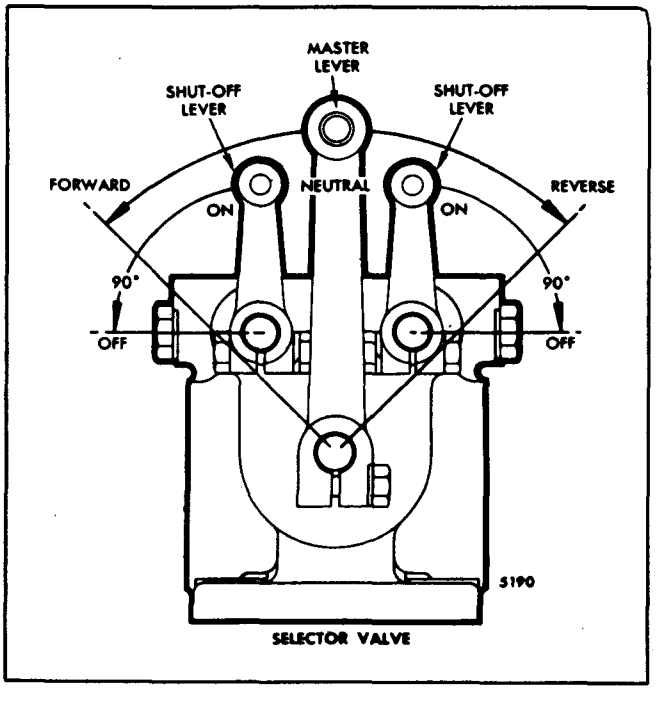


Fig. 17 - Lever Arrangement on Tandem Twin Engine Marine Gear Selector Valve

A strainer is used between the oil sump and the pump to remove harmful solids. The oil passes from the pump through a cooler to the control valve. From the control valve, the oil operates the forward or reverse clutch pistons and sprays oil into the reduction gear housing to lubricate the gear.

The constant flow control valve, incorporated with a pressure relief valve, controls the amount of oil pumped through the hydraulic system and is sensitive only to engine speed and operates independently of the pressure relief valve section which controls the pressure within the complete hydraulic system.

When the engine is in operation, the moving parts of the marine reverse gear are pressure lubricated while the reduction gear assembly is splash lubricated.

Shifting from forward to reverse drive through neutral may be made at any speed; however, it is advisable to shift at low engine speeds. For longest clutch life, reduce the engine speed to idle, make the shift and then increase the engine speed.

The marine gear selector control valve assembly on the tandem twin marine engine unit is provided with several levers (Fig. 17). The master control lever engages both marine gears in forward or reverse simultaneously. The smaller levers, one for each engine, operate the shut-off control valves for controlling the flow of oil to each individual engine marine gear. These levers are normally set in a vertical position ("on" position). To shut down one engine for service work or to conserve on power in a light load situation, place the master control lever in the neutral position and then turn the shut-off lever for that engine to the "off" position (90 degrees toward the engine). With the shut-off lever in the "off" position, the marine gear for that engine is locked out of engagement. The other engine can then continue to supply power to the gear box.

CAUTION: When the shut-off lever is turned to the **off** position, lock it in that position by wire or some other means to prevent vibration from moving it back up to the **on** position. This caution applies particularly when work is being done on the engine.

It is recommended that all sailing vessels and boats utilizing the Torqmatic marine gears (single or twin screw installations) have a locking (brake) device to prevent the propeller shaft from rotating while the sailing vessel is operating under sail, or the boat is operating with one engine shut-down or being towed.

With the engine shut-down, and the marine gear oil pump not operating, it cannot circulate lubricating oil through the reverse gear. Therefore, overheating and damage to the marine gear is possible unless rotation of the propeller shaft is prevented.

If the clutches cannot be engaged hydraulically, in an emergency, the forward drive may be engaged with three bolts as follows:

1. Remove the large pipe plug from the forward face of the flywheel housing.

2. With the throttle in the **stop** position, rotate the flywheel until one of the bolts aligns with the opening in the flywheel housing.

3. Remove the bolt from the flywheel.

4. Remove and save the jam nut, and replace the bolt finger-tight.

5. Remove and reinstall the remaining two bolts in the same manner.

6. Start at the first bolt and tighten all three bolts uniformly, thereby locking the clutch plate between the piston and the drive plate. Install the pipe plug in the flywheel housing.

NOTE: To prevent binding between the piston and the bore in the flywheel, the emergency engagement bolts must be tightened uniformly.

CAUTION: To prevent damaging the gear, do not use the reverse drive when the engagement bolts are engaged.

IMPORTANT: To reduce the possibility of overheating, add an additional gallon of oil if the forward clutch is engaged with the emergency engagement bolts and the hydraulic pump is inoperative.

TWIN DISC MARINE GEAR

A Twin Disc marine gear is used on 12V engines. This marine gear has two hydraulically operated multi-disc clutches to provide forward and reverse operation.

The marine gear has an oil sump capacity of approximately six gallons. An oil pump driven by the reverse shaft operates whenever the engine is operating. This pump draws oil from the sump through a suction strainer, protecting the pump from foreign particles in the oil. The oil discharged from the pump flows through an oil cooler, mounted on the side of the engine, and then returns to the marine gear housing. The oil upon entering the gear housing passes through an integral oil filter and then to the selector valve. A by-pass valve across the filter prevents the stoppage of oil flow to the selector valve in the event the filter becomes clogged. The operating oil pressure varies with the different Twin Disc gears as noted in the chart under *Operating Conditions.*

Some units incorporate a trolling valve which is mounted between the selector valve and the forward clutch. This valve is a relief valve with manual control over the relief valve spring. Movement of the trolling valve by the operator drops the forward clutch operating pressure to a point where the multi-disc clutch plates slip. Further movement of the valve increases the slippage. This permits very low propeller speeds necessary for some fishing operations. The entire oil spill from the trolling valve, in dropping the pressure, is directed through the plates of the forward slipping clutch. This provides a film of oil on which the plates ride and removes any heat generated.

The marine gear is driven by the engine through synthetic rubber caps molded in a gear tooth form. The rubber caps are mounted on the teeth of the spider gear and mesh with the flywheel drive ring. They cushion the drive from the engine to the marine gear.

Emergency Operation

In case of emergency shifting from forward to reverse at higher than normal engine speeds, the selector and pressure regulating valve should have a 1/2 second pause in neutral so that it can control the rate of pressure rise. This causes 3/4 to 1 1/2 second delay before full pressure is applied to the selected clutch. Thus, sudden shock on the gears and shafts is reduced. Complete reversal of the propeller is recommended only at reduced engine speeds.

Operating Conditions

Operating Oil Pressure			
Marine Gear	Temp	RPM	PSI
MG-506	180°F	1800	300-320
Minimum at Cruising Speed			270
MG-512			
Neutral	180°F	1800	60-65
Engaged	180°F	1800	185-195
MG-514			
Neutral	180°F	1800	60-65
Engaged	180°F	1800	185-215
MG-521			
Neutral	180°F	1800	50-60
Engaged	180°F	1800	190-210
MG-527			
Neutral	180°F	1800	75-120
Engaged	180°F	1800	188-220
Cooling and Lubricating Oil Pressure			
Marine Gear	Temp	RPM	PSI
MG-512	180°F	1800	18-20
MG-514	180°F	1800	18-20
MG-521	180°F	1800	25-30
MG-506	180°F	1800	7
	180°F	2400	12
	180°F	3000	13
MG-527	180°F	1800	25-30

Emergency Engagement

Should a failure impair the hydraulic system of the marine gear, the desired clutch, either forward or reverse, can be engaged manually. The manual engagement is accomplished by removing three pipe plugs, protruding from the rear of the transmission, in line with the desired clutch to be engaged. Then bar the engine output shaft over until the three emergency engagement bolts are in line with the holes. Alternately tighten the three bolts uniformly until the clutch is locked in engagement. Reinstall the pipe plugs.

The engine, when started with the selector valve in neutral, will drive the propeller through the engaged clutch. No attempt should be made to move the selector valve from the neutral position since engagement of the other clutch may cause damage.

SNOW-NABSTEDT MARINE GEAR

The Snow-Nabstedt marine gear is used on the 16V engines. The function of this unit is to change the rotation of the propeller shaft at will, without changing the rotation of the engine, and at the same time to transmit the power of the engine at engine speed to the reduction gear. The reduction gear transmits the power of the engine to the propeller shaft, and reduces the speed of the propeller for greater efficiency.

The unit consists of a common clutch drum which is bolted to the engine flywheel and contains two identical clutches. Each of these clutches consists of a series of alternate steel and sintered bronze discs which transmit power to the shaved and ground helical gearing through sturdy drive shafts.

The shafts and gearing are straddle mounted on ball or roller bearings. Large thrust bearings are used to absorb propeller thrust in both directions of rotation.

Two quill drive shafts are employed and each is splined into one of the clutches. These shafts drive the slow speed gear through one pinion for anti-engine rotation of the propeller shaft, or through a series of three pinions and a jack-shaft for engine rotation.

The pump drive shaft is keyed to the drive ring mounted on the engine flywheel and runs through the center of the inner quill shaft. This pump shaft drives a pump mounted on the back of the unit and turns whenever the engine is running. The oil is drawn from the housing sump which has ample capacity for lubrication, cooling and hydraulic operation of the unit. The oil system is entirely separate from the engine.

Operating Conditions

The operating pressure of the marine gear in neutral and during clutch engagements is 20-30 psi. The pressure with the clutch engaged is 110-150 psi.

TORQMATIC CONVERTERS

The Torqmatic converter is a self contained unit which transfers and multiplies the torque of the prime mover. This unit transmits the power through the action of oil instead of through gears and in addition to multiplying the torque also acts as a fluid coupling between the engine and the equipment to be powered. The converter will automatically adjust the output torque to load requirements.

There are various combinations of Torqmatic converters with features such as: an automotive or industrial flange on the shaft, a hydraulically operated lock-up clutch, a manual input disconnect clutch, and an accessory drive for either a governor or tachometer.

Check the oil level daily and, if the converter is equipped with an input disconnect clutch, additional checks and service will be necessary daily or at intervals determined by the type of operation.

Adjust the disconnect clutches as outlined under power take-off clutch adjustment.

Contact an authorized *Detroit Diesel Allison Service Outlet* for information on Torqmatic converters.

OPERATING INSTRUCTIONS

ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

The operator should read and follow these instructions before attempting to start the engine.

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

Air Cleaner

If the engine is equipped with oil bath air cleaners, fill the air cleaner oil cups to the proper level with engine lubricating oil. *Do not overfill.*

Cooling System

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

Open cooling system vent, if unit is so equipped. Remove the filler cap and fill the cooling system with clean, soft water or a protective solution consisting of high boiling point antifreeze if the engine will be exposed to freezing temperature. Keep the liquid level about 2 inches below the filler neck to allow for fluid expansion.

Use a quality rust inhibitor if only water is used in the cooling system. Refer to the *Coolant Recommendations.*

Close the vent after filling the cooling system.

On a marine engine, prime the raw water pump by removing the pipe plug in the inlet elbow and adding water. Open the sea cocks in the raw water system.

Lubrication System

The lubricating oil on the upper parts of new or overhauled engines, and engines which have been in storage, may not be enough when the engine is started. It is recommended that the upper engine parts be prelubricated by removing the valve rocker covers and pouring approximately two quarts of the same grade of oil as used in the crankcase over the rocker arms and push rods.

Fill the engine crankcase to the proper level with the heavy duty lubricating oil specified under *Lubricating Oil Specifications.*

Check the oil level in the crankcase with the dipstick on the side of the engine. Remove the dipstick, wipe the lower end with a clean cloth, insert and remove it again to check the oil level. Keep the oil at the proper level.

On new marine units that have an unmarked dipstick, mark the dipstick in accordance with the instructions on the tag wired to the dipstick.

Fuel System

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

If the unit is equipped with a fuel supply valve, it must be opened.

To ensure prompt starting, the fuel system between the pump and the fuel return manifold should be filled with fuel. If the engine has been out of service for a considerable length of time, the filter between the fuel pump and the injectors should be primed. The filter may be primed by removing the plug in the top of the filter cover and slowly filling the filter with fuel.

In addition to the above, on an engine equipped with a Hydrostarter, use a priming pump to make sure fuel lines, manifolds and injectors are full of fuel before attempting to start the engine.

> **NOTE:** The fuel system of a new engine is filled with fuel before leaving the factory. If the fuel is still in the system when preparing to start the engine, priming should be unnecessary.

Lubrication Fittings

Fill all of the grease cups and lubricate at all of the 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.

Transmission

Fill the hydraulic marine gear, Torqmatic converter or reduction gear to the proper level with the lubricant

specified under *Lubrication and Preventive Maintenance.*

Turbocharger

Disconnect the turbocharger oil inlet line and pump clean engine oil into the turbocharger, thus making sure the bearings are oiled for the initial start.

Drive Belts

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

Storage Battery

Check the battery; the top should be clean and dry, the terminals tight and protected with a coat of petroleum jelly and the electrolyte must be at the proper level.

NOTE: When necessary, check the battery with a hydrometer; the reading should be 1.265 or higher. However, hydrometer readings should always be corrected for the temperature of the electrolyte.

Clutch

Disengage the clutch or clutches if the unit is so equipped.

Generator Set

A generator set should be connected and grounded in accordance with the applicable local electrical codes.

The instructions for connecting the load terminals are contained in the generator connection diagram or control cabinet wiring diagram.

CAUTION: The base of a generator set must be grounded.

STARTING

Before starting the unit 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.*

If a manual or an automatic shut-down system is incorporated in the unit, the control must be set in the open position before starting the engine.

NOTE: On engines with dual air shut-down housings, both shut-off valves must be in the open position before starting the engine.

A blower will be seriously damaged if operated with the air shut-off valve in the closed position.

The engine will require the use of a cold weather starting aid if the ambient temperature is below 40° F. Refer to *Cold Weather Starting Aids.*

Initial Engine Start (Electric)

Start an engine equipped with an electric starting motor as follows: Set the throttle in the **IDLE** position. Press the starting motor switch firmly. If the engine fails to start within 30 seconds, release the starting switch and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

CAUTION: To prevent serious damage to the starter, if the engine does not start, do not press the starter switch again while the starter motor is running.

On twin units, move the master throttle lever to **IDLE** and engage the starting motors, one at a time.

Initial Engine Start (Hydrostarter)

An engine equipped with a Hydrostarter may be started as follows:

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

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

NOTE: During cold weather add starting fluid at the same time the Hydrostarter motor lever is

Ambient Temperature	Pressure Gage Reading
Above 40°F.	1500 psi
40°F. to 0°F.	2500 psi
Below 0°F.	3300 psi

TABLE 1

moved. Do not wait to add the fluid after the engine is turning over.

Push the Hydrostarter control lever to simultaneously engage the starter pinion with the flywheel ring gear and to open the control valve. Close the valve as soon as the engine starts to conserve the accumulator pressure and to avoid excessive over-running of the starter drive clutch assembly.

RUNNING

Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no oil pressure indicated within 10 to 15 seconds, stop the engine and check the lubricating system. The pressure should not fall below 25 psi at 1200 rpm or 30 psi at 2100 rpm, and normal operating pressure should be higher.

Warm-Up

Run the engine at part throttle and no-load for approximately five minutes, allowing it to warm up before applying a load. If the engine is operating a power generator, refer to the warm-up procedure for power generator units.

If the unit is in operation in a closed room, start the ventilating fan or open the doors and windows, as weather conditions permit, so ample air is available for the engine.

Temperature

Normal engine coolant temperature is 160° to 185° F.

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 the leaks.

Crankcase

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

Use only the heavy-duty lubricating oils as specified under *Lubricating Oil Specifications.*

Clutch

Do not engage the clutch (with a sintered iron clutch plate) at engine speeds over 850 rpm. A clutch with an asbestos or vegetable fiber clutch plate must not be engaged at speeds over 1000 rpm.

Cooling System

Remove the radiator or heat exchanger tank cap *slowly* after the engine has reached normal operating temperature and check the engine coolant level. The coolant level should be near the top of the opening. If necessary, add clean soft water or a high boiling point type antifreeze (refer to *Engine Coolant*).

Marine Gear

Check the marine gear oil pressure. The Torqmatic Marine Gear oil pressure taken at the control valve assembly for the hydraulic system is between 130 to 155 psi in forward and 110 to 150 psi in reverse.

Turbocharger

Make a visual inspection of the turbocharger for leaks and excessive vibration. Stop the engine immediately if there is an unusual noise in the turbocharger.

Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings and rapid accumulation of sludge in the engine.

NOTE: When prolonged engine idling is necessary, maintain at least 800 rpm.

STOPPING

Throttle

Release the load and decrease the engine speed. Allow the engine to run at half speed or lower with no- load for four or five minutes before closing the throttle and stopping the engine. If the engine is operating a power generator, refer to the stopping procedure for power generator units.

NOTE: The emergency shut-down system should never be used to stop the engine, except in an

emergency. To do so can cause oil to be sucked past the oil seals and into the blower housing.

Fuel System

If the unit is equipped with a fuel valve, close it. Fill the fuel tank; a full tank reduces condensation.

Exhaust System

Open the drain or valve, if one is used in the exhaust line or silencer, to drain the condensation.

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 with the dipstick. Add oil, if necessary, to bring it to the proper level.

Transmission

Check the oil level and, if necessary, add sufficient oil to bring it to the proper level.

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 unit has been in operation.

Make any routine adjustments and minor repairs needed to correct difficulties which became apparent to the operator during the last run.

ALTERNATING CURRENT POWER GENERATOR SET

OPERATING INSTRUCTIONS

These instructions cover the fundamental procedures for operating an alternating current power generator set. The operator should read these instructions before attempting to operate the generator set.

PREPARATION FOR STARTING

Before attempting to start a new or an overhauled engine or an engine which has been in storage, perform all of the operations listed under *Preparation for Starting Engine First Time.* Before a routine start see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart.*

In addition to the *Engine Operating Instructions,* the following instructions also apply when operating an alternating current power generator set.

1. Before the first start, check the generator main bearing oil reservoir. If necessary, add sufficient lubricating oil of the same grade that is used in the engine crankcase to bring it to the proper level on the sight gage. *Do not overfill.*

2. Check the interior of the generator for dust or moisture. Blow out dust with low pressure air (25 psi maximum). If there is moisture on the interior of the generator, it must be dried before the set is started. Refer to the appropriate Delco Products Maintenance Bulletin.

3. The overspeed trip solenoid lever located at the air inlet housing must be in the open or reset position.

4. Refer to Fig. 1 and place the circuit breaker (10) in the **off** position.

5. Place the field switch (7) in the **off** position.

6. Place the synchronizing lamp switch (6) in the **off** position.

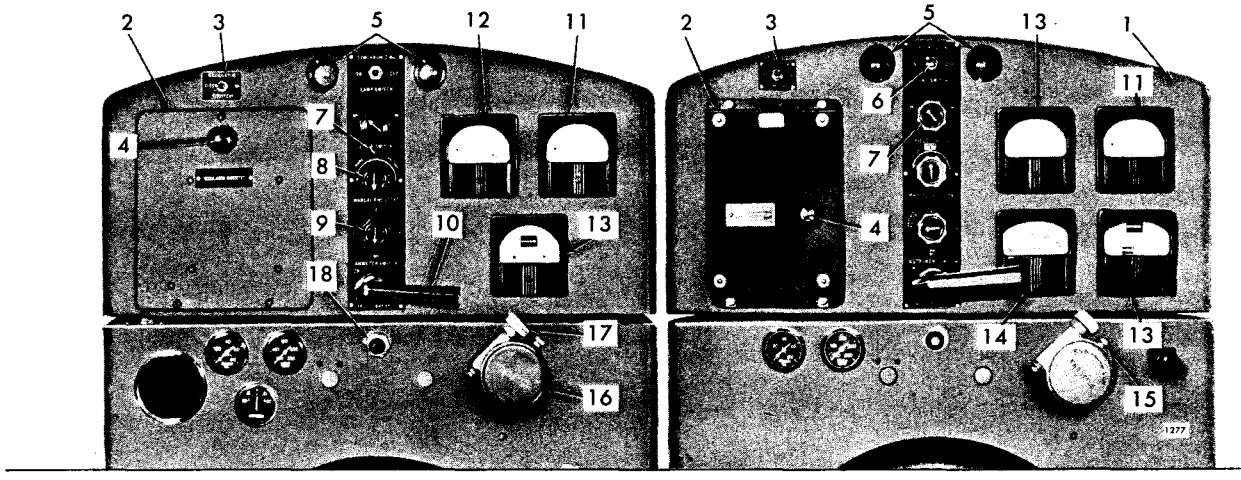
7. Place the voltage regulator switch (3) in the **off** or **manual** position.

8. Turn the field rheostat knob (8) clockwise to its lower limits.

9. Make sure the power generator set has been cleared of all tools or other objects which might interfere with its operation.

STARTING

If the generator set is operated in a closed space, start the ventilating fan or open the doors and windows, as weather permits, to supply ample air to the engine.



1. Cabinet--Control
2. Regulator--Voltage
3. Switch--Voltage Regulator
4. Control--Voltage Regulator Rheostat
5. Lamps--Synchronizing
6. Switch--Synchronizing Lamp
7. Switch--Field
8. Control--Manual Field Rheostat
9. Switch--Selector
10. Control--Circuit Breaker
11. Ammeter
12. Voltmeter
13. Frequency Meter
14. Kilowatt Meter
15. Button--Throttle
16. Control--Throttle
17. Knob--Vernier Throttle
18. Button--Engine Starter

Fig. 1 - Typical Alternating Current Generator Control Cabinets

The engine may require the use of a cold weather starting aid if the ambient temperature is below 40° F. Refer to *Cold Weather Starting Aids.*

Press the throttle button (15) and turn the throttle control (16), Fig. 1, counterclockwise to a position midway between **run** and **stop**. Then press the starter button (18) firmly.

If the engine fails to start within 30 seconds, release the starter button and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

CAUTION: To prevent serious damage to the starter if the engine does not start, do not press the starter switch again while the starter motor is rotating.

RUNNING

If the oil pressure is observed to be normal, increase the throttle setting to cause the engine to run at its synchronous speed.

PREPARING GENERATOR FOR LOAD

After the engine has warmed up (or the oil pressure has stabilized), prepare the generator set for load as follows:

1. Bring the engine up to rated speed. Then place the field switch (7), Fig. 1, in the **on** position.

2. Turn the voltage regulator switch (3) **on.**

3. Turn the instrument selector switch (9) to the desired position.

4. Turn the field rheostat (8) slowly in a counterclockwise direction to raise the voltage, while watching the voltmeter, until the rheostat reaches the end of its travel. The voltage regulator will take control of the generator voltage as the field rheostat reaches the end of its travel.

5. If the power generator unit is equipped with a frequency meter, adjust the engine speed with the vernier throttle knob (17) until the desired frequency is indicated on the meter.

6. Adjust the voltage regulator rheostat (4) to obtain the desired voltage.

7. Make sure all power lines are clear of personnel, then place the circuit breaker control (10) in the **on** position.

NOTE: Perform Step 7 only if the set is not being paralleled with an existing power source. If the set is being paralled with a power source already on the line, read and follow the instructions under *Paralleling* before turning the circuit breaker control to the **on** position.

PARALLELING

If the load conditions require an additional set to be placed on the line, the following instructions will apply to power generator sets of *equal capacity,* with one set in operation on the line.

1. Prepare the set to be paralleled as outlined under *Preparation for Starting, Starting, Running* and Items 1 through 6 under *Preparing Generator for Load.*

2. Check the voltmeter (12), Fig. 1; the voltage must be the same as the line voltage. Adjust the voltage regulator rheostat control (4) if the voltages are not the same.

3. Place the synchronizing lamp switch (6), of the generator set to be paralleled, in the **on** position.

4. Turn the vernier throttle knob (17) until both sets are operating at approximately the same frequency, indicated by the slow change in the brilliancy of the synchronizing lamps.

5. When the synchronizing lamps glow and then go out at a very slow rate, time the dark interval. Then, in the middle of this interval turn the circuit breaker control to the **on** position. This places the incoming set on the line, with no load. The proper share of the existing load must now be placed on this set.

6. The division of the kilowatt load between the alternating current generators operating in parallel depends on the power supplied by the engines to the generators as controlled by the engine governors and is practically independent of the generator excitation. Divide the kilowatt load between the sets by turning the vernier throttle knob (17) counterclockwise on the incoming set and clockwise on the set that has been carrying the load (to keep the frequency of the sets constant) until both kilowatt meters indicate that each set is carrying its proper percentage of the total K.W. load. Refer to Item 8 if the sets are not equipped with kilowatt meters.

7. The division of the reactive KVA load depends on the generator excitation as controlled by the voltage regulator. Divide the reactive load between the sets by turning the voltage regulator rheostat control on the incoming set (generally counterclockwise to raise the voltage) until the ammeters read the same on both sets and the sum of the readings is minimum.

> **NOTE:** The generator sets are equipped with a resistor and current transformer connected in series with the voltage coil of the regulator (cross-current compensation) which equalizes most but not all of the reactive KVA load between the generators.

8. When the load is unity power factor (lighting and a few small motors only), follow the instructions in Item 6 above until both ammeters read the same.

9. When the load is 80 per cent power factor lagging (motor and a few lights only), turn the vernier throttle knob (17) on the incoming set until the ammeter on that set reads approximately 40 per cent of the total current load.

10. Rotate the voltage regulator rheostat control (4) on the incoming set (generally counterclockwise to raise the voltage) until the ammeters read the same on both sets.

> **NOTE:** If a load was not added during paralleling, the total of the two ammeter readings should be the same as the reading before paralleling. Readjust the voltage regulator rheostat (4) on the incoming set, if necessary.

11. To reset the load voltage, turn the voltage regulator rheostat controls slowly on each set. It is necessary to turn the controls the same amount and in the same direction to keep the reactive current equally divided.

Power generator sets with different capacities can also be paralleled by dividing the load proportionately to their capacity.

STOPPING

The procedure for stopping a power generator set or taking a set out of parallel is as follows:

1. Turn off all the load on the generator when stopping a single engine unit. Shift the load from the generator when taking a set out of parallel operation by turning the vernier throttle knob (17), Fig. 1, until the ammeter (11) reads approximately zero.

2. Place the circuit breaker control (10) in the **off** position.

3. Turn the field rheostat (8) to the fully clockwise position.

4. Turn the voltage regulator switch (3) to the **off** position.

5. Place the field switch (7) in the **off** position.

6. Press the throttle button (15) and turn the throttle control (16) to **stop** to shut down the engine.

> **NOTE:** When performing a tune-up on a unit that will be operated in parallel with another set, adjust the speed droop as specified in *Engine Tune-Up.*

LUBRICATION AND PREVENTIVE MAINTENANCE

To obtain the long life and the best performance from a Detroit Diesel engine, the Operator must adhere to the following schedule and instructions on lubrication and preventive maintenance.

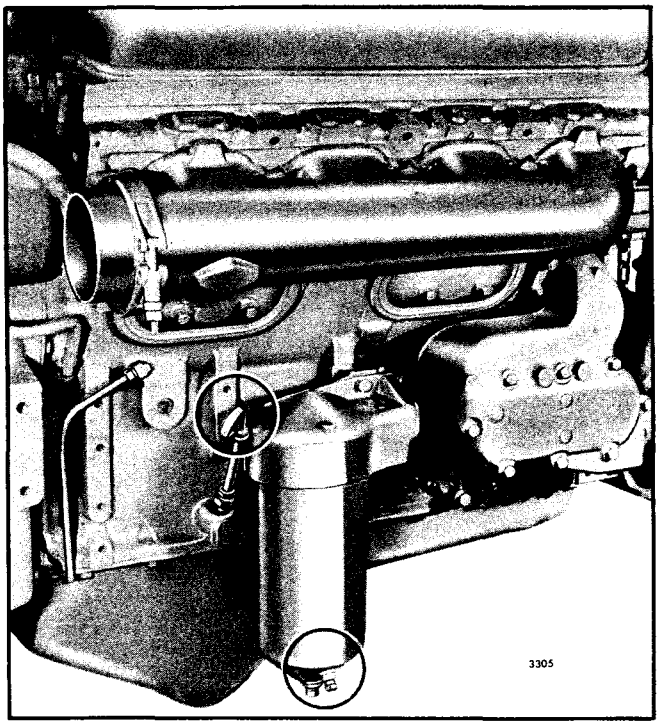
The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out instructions given under *Preparation for Starting Engine First Time* under *Operating Instructions.*

The time intervals given in the chart on the following page are actual operating hours or miles of an engine. 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, therefore, will drain readily.

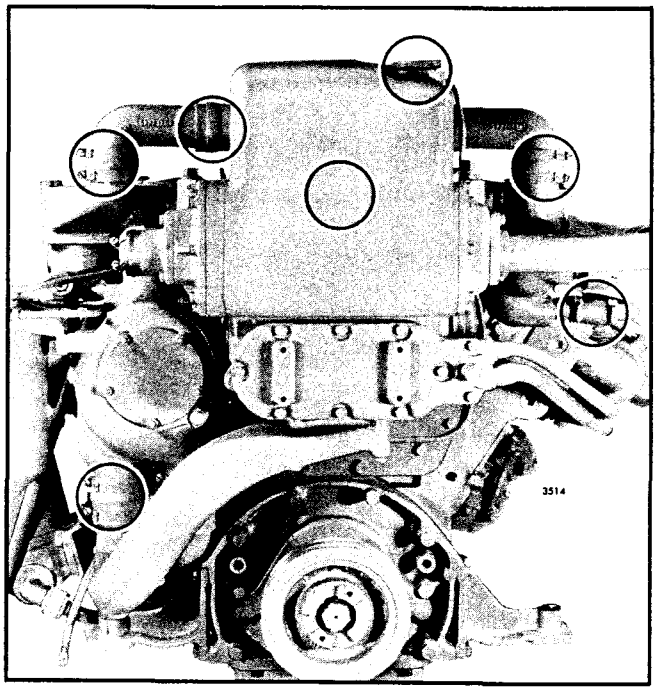
All authorized *Detroit Diesel Allison Service Outlets* are prepared to service engines with the viscosity and grade of lubricants recommended on the following pages.

LUBRICATION AND PREVENTIVE MAINTENANCE CHART	Time Interval								
Item Operation	Hours		8	50	100	200	300	500	1,000	2,000
	Miles	Daily	240	1,500	3,000	6,000	9,000	15,000	30,000	60,000
1. Engine Oil		X								
2. Oil Filter*										
3. Coolant and Filter		X						X	X	
4. Hoses								X		
5. Radiator									X	
6. Heat Exchanger Electrodes and Core								X	X	
7. Raw Water Pump		X								
8. Fuel Tank		X						X		
9. Fuel Strainer and Filter							X			
10. Air Cleaners			X			X		X		
11. Air Box Drains									X	
12. Ventilating System									X	
13. Blower Screen									X	
14. Starting Motor*										
15. Battery-Charging Generator					X	X				
16. Battery					X					
17. Tachometer Drive					X					
18. Throttle and Clutch Controls						X				
19. Engine Tune-Up*										
20. Drive Belts			X			X				
21. Overspeed Governor								X		
22. Fan Hub Bearings*										
23. Shut-Down System							X			
24. Hydrostarter System*										
25. Air Compressor Air Strainer						X				
26. Turbocharger*										
27. Thermo-Modulated Fan*										
28. Power Generator					X		X			
29. Power Take-Off			X	X				X		
30. Torqmatic Converter		X		X					X	
31. Marine Gear		X				X †			X **	
32. Reduction Gear (Single Engine Units)			X	X				X	X	
33. Reduction Gear (Multiple Engine Units)		X				X				

*See items on following pages ** Twin Disc Marine Gear † Allison Torqmatic Marine Gear



Items 1 and 2



Items 3 and 4

Item 1

Check the oil level daily before starting the engine. Add oil, if necessary, to bring it to the proper level on the dipstick.

Select the proper grade of oil in accordance with the instructions given in the *Lubricating Oil Specifications.*

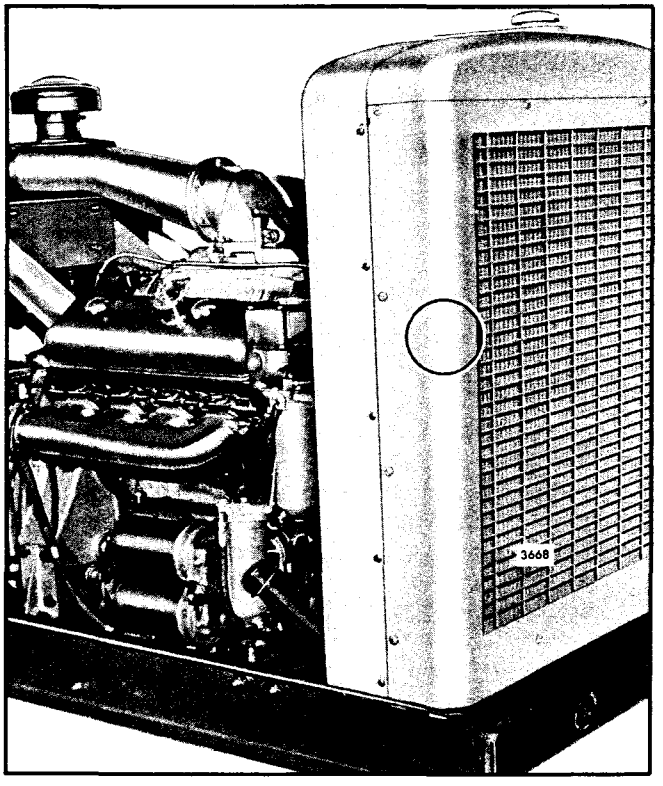
It is recommended that new engines be started with 100 hour oil change periods. The drain interval may then be gradually increased or decreased, following the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the oil sample analysis) until the most practical oil change period for the particular service has been established.

Item 2

Install new oil filter elements and gaskets each time the engine oil is changed. Check for oil leaks after starting the engine. If the engine is equipped with a governor oil filter, change the element every 1000 hours.

Item 3

Check the coolant level daily and maintain it near the top of the heat exchanger tank or radiator upper tank.



Item 5

Clean the cooling system every 1,000 hours or 30,000 miles using a good radiator cleaning compound in accordance with the instructions on the container. After the cleaning operation, rinse the cooling system thoroughly with fresh water; then, fill the system with soft water, adding a good grade of rust inhibitor or a high boiling point type antifreeze (refer to *Engine Coolant*). 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.

If the cooling system is protected by a coolant filter and conditioner, the filter element should be changed every 500 hours or 15,000 miles.

Item 4

Inspect all of the cooling system hoses at least once every 500 hours or 15,000 miles for signs of deterioration. Replace the hoses if necessary.

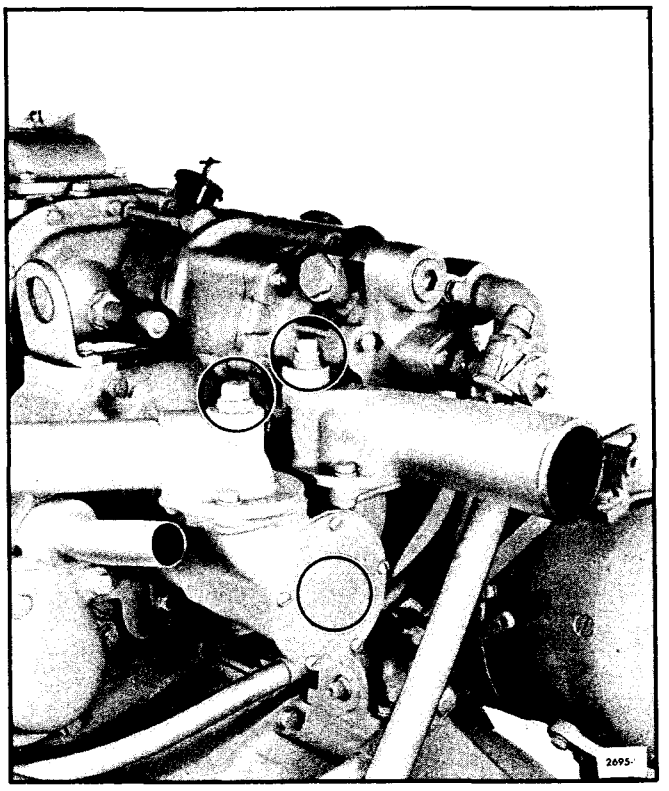
Item 5

Inspect the exterior of the radiator core every 1,000 hours or 30,000 miles and, if necessary, clean it with a quality grease solvent such as Oleum and dry it with compressed air. *Do not use fuel oil, kerosene or gasolines.* It may be necessary to clean the radiator more frequently if the engine is being operated in dusty or dirty areas.

Item 6

Every 500 hours, drain the water from the heat exchanger raw water inlet and outlet tubes. Then, remove the zinc electrode from the inlet side of the raw water pump and the heat exchanger. Clean the electrodes with a wire brush or, if worn excessively, replace with new electrodes. To determine the condition of a used electrode, strike it sharply against a hard surface; a weakened electrode will break.

Drain the cooling system, disconnect the raw water pipes at the outlet side of the heat exchanger and remove the retaining cover every 1,000 hours and inspect the heat exchanger core. If a considerable amount of scale or deposits are present, contact an authorized *Detroit Diesel Service Outlet.*



Items 6 and 7

Item 7

Check the prime on the raw water pump; the engine should not be operated with a dry pump. Prime the pump, if necessary, by removing the pipe plug provided in the pump inlet elbow and adding water. Reinstall the plug.

Item 8

Keep the fuel tank filled to reduce condensation to a minimum. Select the proper grade of fuel in accordance with the *Diesel Fuel Oil Specifications.* Open the drain at the bottom of the fuel tank every 500 hours or 15,000 miles to drain off any water or sediment.

Item 9

Install new elements every 300 hours or 9,000 miles 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

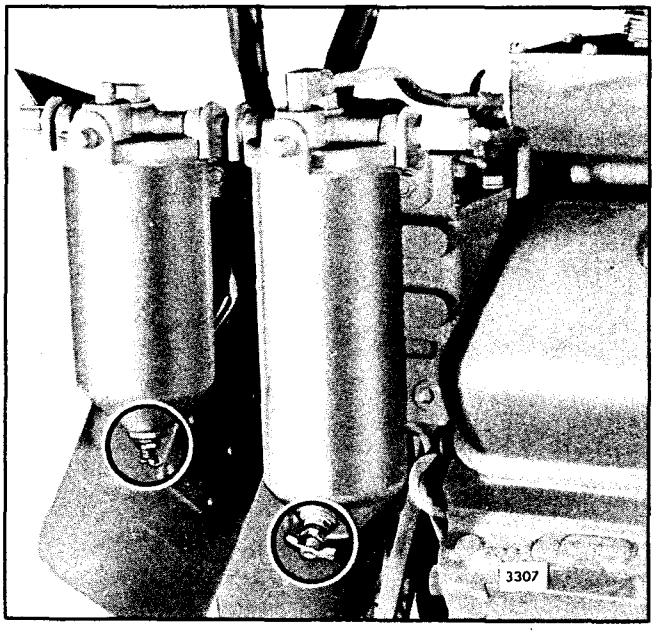
FUEL PRESSURE AT INLET MANIFOLD					
Speed (rpm)	1200	1800	2000	2100	2300
V-71, V-71N (6, 8, 12V) Normal	35-70	45-70		45-70	
8V-71T Normal 12V-71T Normal		45-70	45-70	45-60	45-70 45-60
16V-71 Normal 16V-71N Normal	35-50 35-70	45-70 45-70		45-70 45-70	
16V-71T Except Stand By Generator Set		45-70	45-70	45-70	
16V-71T With Stand By Generator Set		50-70			

TABLE 1

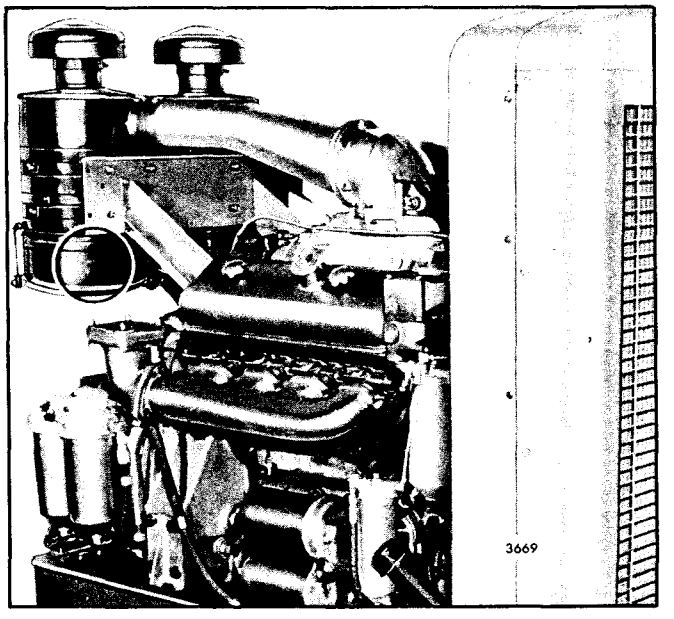
must not exceed 6 inches of mercury. At normal operating speeds (1600-2100 rpm), the fuel pressure is 45 to 70 psi. Change the fuel filter elements whenever the inlet restriction (suction) at the fuel pump reaches 12 inches of mercury at normal operating speeds and whenever the fuel pressure at the inlet manifold falls to 45 psi, refer Table 1.

Item 10

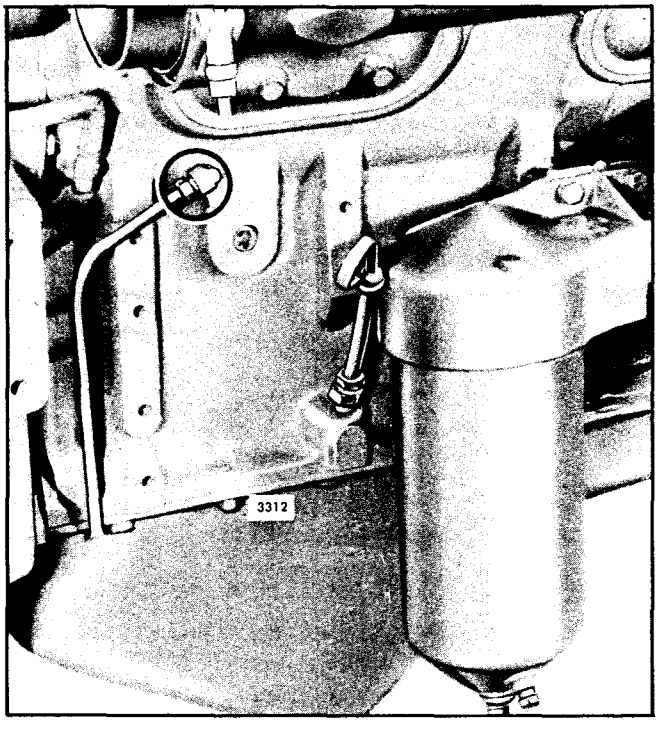
Remove the dirty oil and sludge from the oil bath type air cleaner cups and center tubes every 8 hours, or less if operating conditions warrant. Wash the cups and elements in clean fuel oil and refill the cups to the level mark with the same grade of *heavy duty* oil as



Item 9



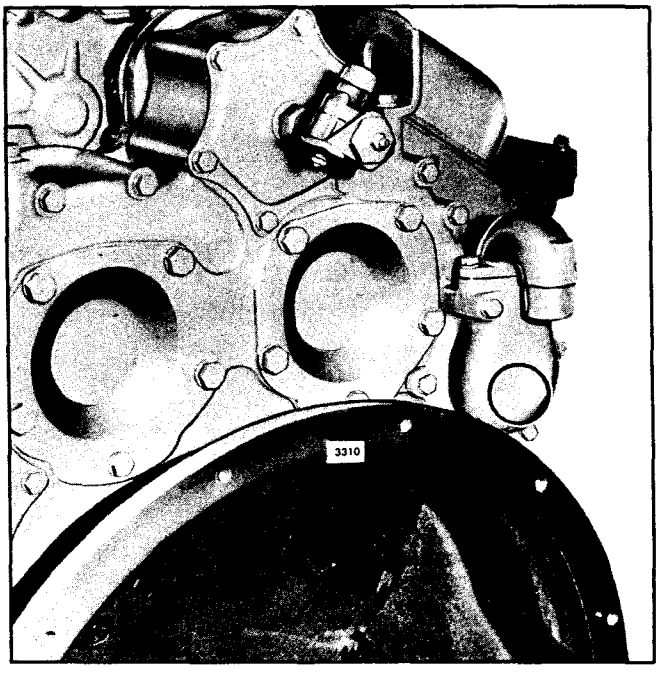
Item 10



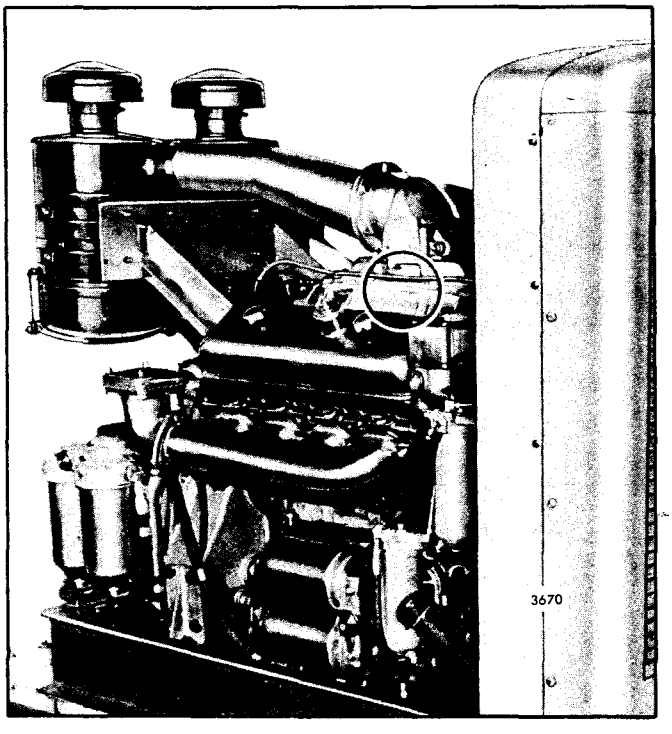
Item 11

used in the engine. The frequency of servicing may be varied to suit local dust conditions.

It is recommended that the body and fixed element in the heavy-duty oil bath type air cleaner be serviced every 500 hours, 15,000 miles or as conditions warrant.



Item 12



Item 13

Clean or replace the element in the dry-type air cleaner when the restriction indicator instrument indicates high restriction or when a water manometer reading at the air inlet housing indicates the maximum allowable air inlet restriction (refer to the *Air Inlet Restriction* chart in the *Trouble Shooting* section). Refer to the instructions in the *Air System* section for servicing the dry-type air cleaner.

Item 11

With the engine running, check for flow of air from the air box drain tubes every 1,000 hours or 30,000 miles. 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 12

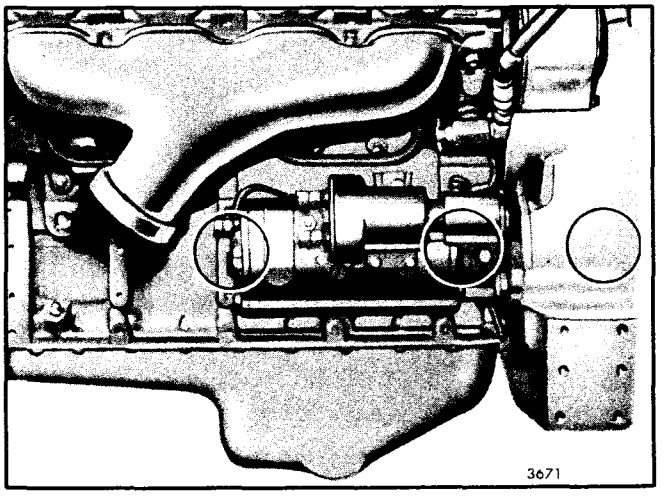
Clean the crankcase breather, if it is mounted on the flywheel housing, every 1,000 hours or 30,000 miles. Remove the crankcase breather from the engine and wash the steel mesh pads in fuel oil and dry them with compressed air. This cleaning period may be reduced or lengthened according to severity of service.

Item 13

Inspect the blower screen and gasket assembly every 1,000 hours or 30,000 miles and, if necessary, clean the screen in fuel oil and dry it with compressed air. Reinstall the screen and gasket assembly with the screen side of the assembly toward the blower. Inspect for evidence of blower seal leakage.

Item 14

The electrical starting motor is lubricated at the time of original assembly. Oil can be added to the oil wicks,



Item 14

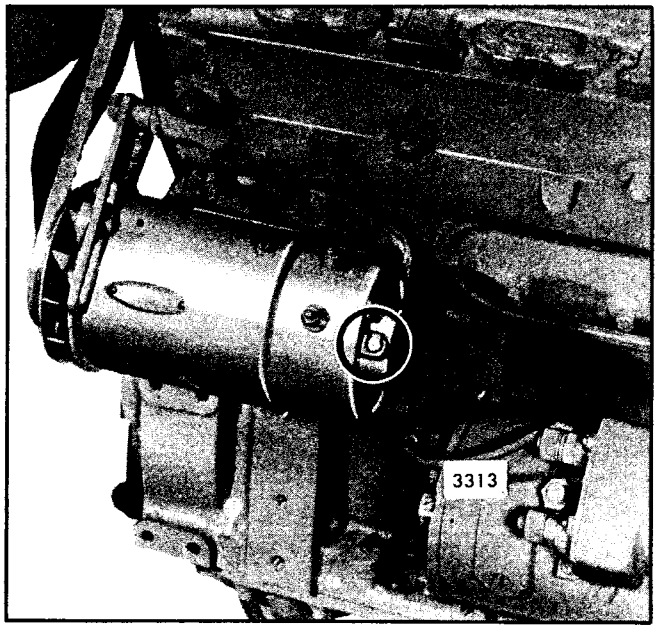
which project through each bushing and contact the armature shaft, by removing the pipe plugs on the outside of the motor. The wicks should be lubricated whenever the starting motor is taken off the engine or disassembled.

The Sprag overrunning clutch drive mechanism should be lubricated with a few drops of light engine oil whenever the starting motor is overhauled.

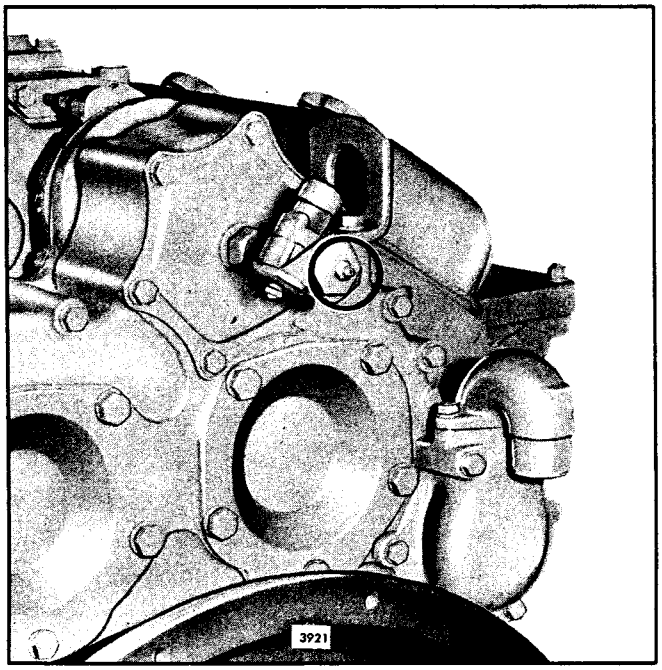
Item 15

Lubricate the alternator bearings or bushings with 5 or 6 drops of engine oil at the hinge cap oiler every 200 hours or 6,000 miles. Some alternators have a built-in supply of grease, while others use sealed bearings. In these latter two cases, additional lubrication is not necessary.

On A.C. alternators, the slip rings and brushes can be inspected through the end frame assembly. If the slip rings are dirty, they should be cleaned with 400 grain or finer polishing cloth. Never use emery cloth to clean the slip rings. Hold the polishing cloth against the slip rings with the generator in operation and blow away all dust after the cleaning operation. If the slip rings are rough or out of round, replace them. Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.



Item 15



Item 17

Item 16

Check the specific gravity of the electrolyte in each cell of the battery every 100 hours or 3,000 miles. In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. The electrolyte level should be maintained in accordance with the battery manufacturer's recommendations.

Item 17

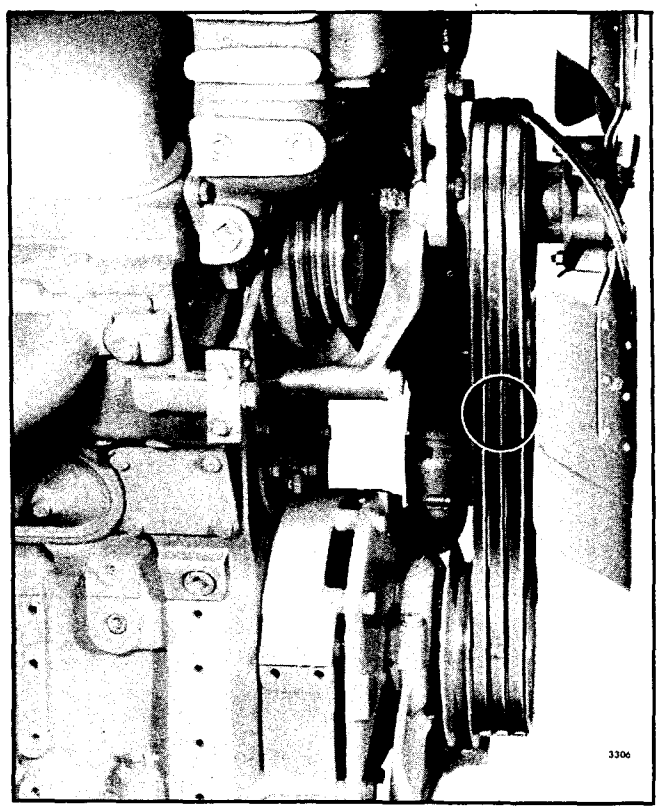
Lubricate the tachometer drive every 100 hours or 3,000 miles with an all purpose grease at the grease fitting. At temperatures above +30° F., use a No. 2 grade grease. Use a No. 1 grade grease below this temperature.

Item 18

Lubricate the throttle control mechanism every 200 hours or 6,000 miles with an all purpose grease. At temperatures above +30° F., use a No. 2 grade grease. Use a No. 1 grade grease below this temperature. Lubricate all other control mechanisms, as required, with engine oil.

Item 19

There is no scheduled interval for performing an



Item 20

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

Item 20

New drive belts will stretch after the first few hours of operation. Run the engine for 15 *seconds* to seat the belts and readjust the tension. Check the belts and retighten the fan drive, pump drive and battery-charging alternator drive belts after 1/2 hour or 15 miles and again after 8 hours or 240 miles of operation. Thereafter, check the tension of the drive belts every 200 hours or 6,000 miles and adjust, if necessary. Too tight a belt is destructive to the bearings of the driven part; a loose belt will slip.

"V" and "POLY V" BELT TENSION TABLE (1 lbs/belt)

Model	Fan Drive			Alternator or Generator Drive		
	10 Rib (L) Poly V Belt	2 or 3 Belts	Single Belt	Two 3/8" or 1/2" Belts	One 1/2" Belt	8 Rib (K) Poly V Belts
6, 8V-71		60-80	80-100	40-50	50-70	110-130
12V-71		70-90		40-50	50-70	
16V-71	310-360	90-120		40-50	50-70	

Belt tension is 50-70 for a single premium high capacity belt (.785" wide) used to drive a 12 cfm air compressor.

Adjust all V-belts with belt tension gage BT-33-73 FA or equivalent.

Adjust all Poly V-belts with belt tension gage *BT-33-AE6-40A (Burroughs) or equivalent J23586 (Kent Moore) *Range 60-400 lbs

TABLE 2

Replace all belts in a set when one is worn. Single belts of similar size should not be used as a substitute for a matched belt set; premature belt wear can result because of belt length variation. All belts in a matched belt set are within .032" of their specified center distances.

Adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 1/2" to 3/4". If a belt tension gage such as BT-33-73FA or equivalent is available, adjust the belt tension as outlined in Table 2.

> **NOTE:** When installing or adjusting an accessory drive belt, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

Tightent the 7/16"-14 (300M) pivot bolt to 72-77 lb-ft torque. Tighten the 7/16"-14 (280M) pivot bolt to 46-50 lb-ft torque.

Adjust Poly-V Fan Belt (16V-71)

The fan belt should be neither too tight nor too loose. Carelessness in making a belt adjustment can be dangerous. Too tight a belt imposes an undue load on the fan bearings and shortens the life of the belt. Too loose a belt allows slippage and lowers the fan speed, causes excessive belt wear and leads to overheating of the cooling system.

Before a Poly-V belt is installed, it is very important that the crankshaft pulley (10 grooves) and the fan drive pulley (11 grooves) are in alignment. The extra groove in the fan drive pulley can be on the inside or the outside of the pulley, depending upon alignment requirements.

Misalignment between the crankshaft pulley and the fan drive pulley cannot be more than .009" per inch of center line distance. A straight line can be determined by placing a straight edge on the rims of the pulleys. A spacer is available to facilitate pulley alignment, if necessary.

Poly-V belts require a special procedure for proper belt tension.

1. After the belts have been initially adjusted, run the engine under a light load for one-half hour.

2. Stop the engine and check the belt tension with the belt "hot"; use belt tension gage BT-33-86AE6-40A, or equivalent, which has a range of 60 to 400 pounds.

3. If the tension value is not between 280 and 360 pounds, re-adjust the belt tension.

CAUTION: Because the allowable load the crankshaft bearing can carry is critical, do not exceed the maximum tension value of 360 pounds.

4. Run the engine at full load for eight hours and then recheck the belt tension.

5. If the belt tension is too tight or too loose, keep the gage in place and adjust the belt tension, to the prescribed value, at the accessory mounting or adjusting bolts. Retighten all of the bolts to the proper torque.

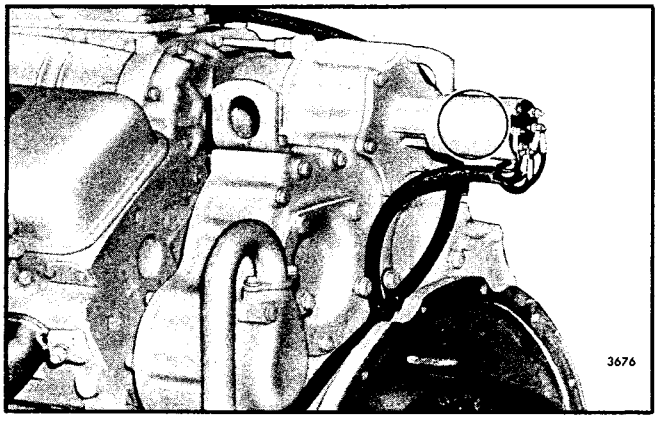
6. The belt tension should be rechecked every 200 hours of engine operation and readjusted, if necessary.

Item 21

Lubricate the overspeed governor, if it is equipped with a hinge cap oiler or oil cup, with 5 or 6 drops of engine oil every 500 hours. Avoid excessive lubrication and do not lubricate the governor while the engine is running.

Item 22

At a major engine overhaul, discard the bearings in the fan hub assembly used in radiator cooled engines. Pack the hub assembly, using new bearings, with Texaco Premium RB grease or an equivalent Lithium base multi-purpose grease.



Item 21

Item 23

Check the shut-down system every 300 operating hours or each month to be sure it will function when needed.

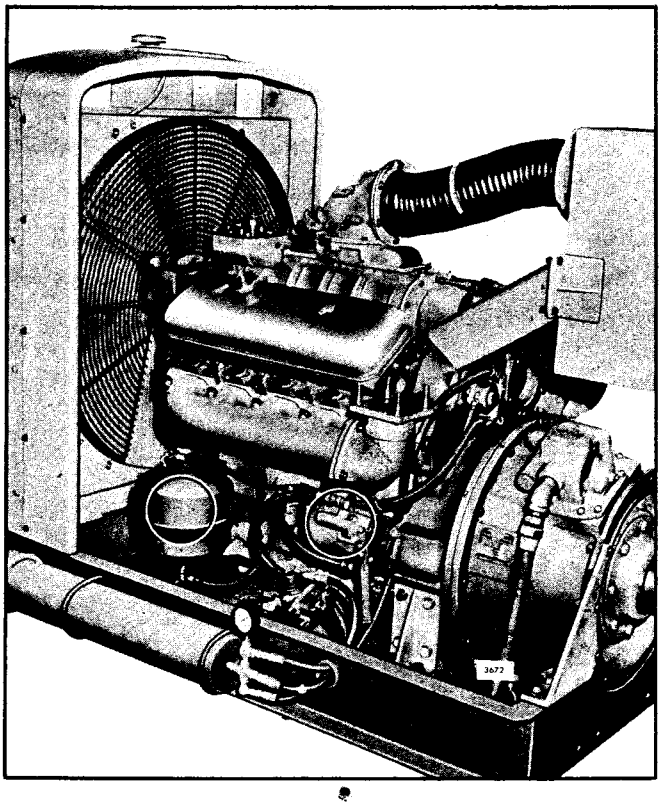
Item 24

On engines equipped with a Hydrostarter, refer to the *Hydraulic Starting System* in the section on *Engine Equipment* for preventive maintenance and lubrication.

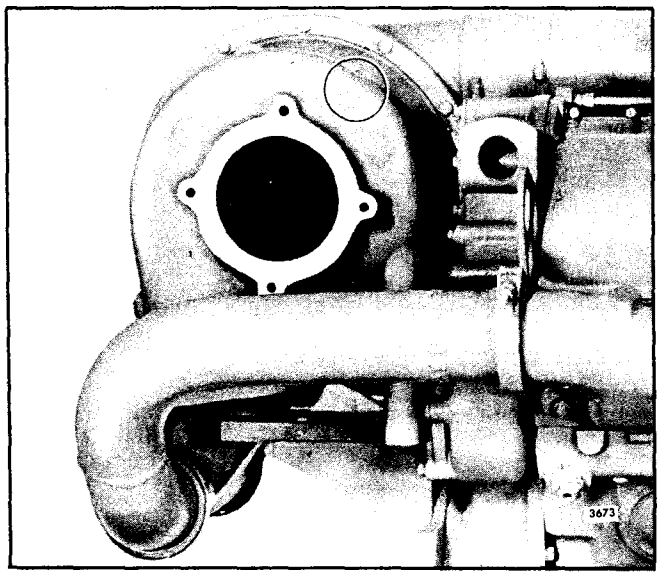
Item 25

To clean either the hair or polyurethane type air compressor air strainer element, saturate and squeeze it in fuel oil, or any other cleaning agent that would not be detrimental to the element, until dirt free. Then dip it in lubricating oil and squeeze it dry before placing it back in the air strainer.

For replacement of the air strainer element, contact the nearest Bendix Westinghouse dealer; replace with the polyurethane element, if available.



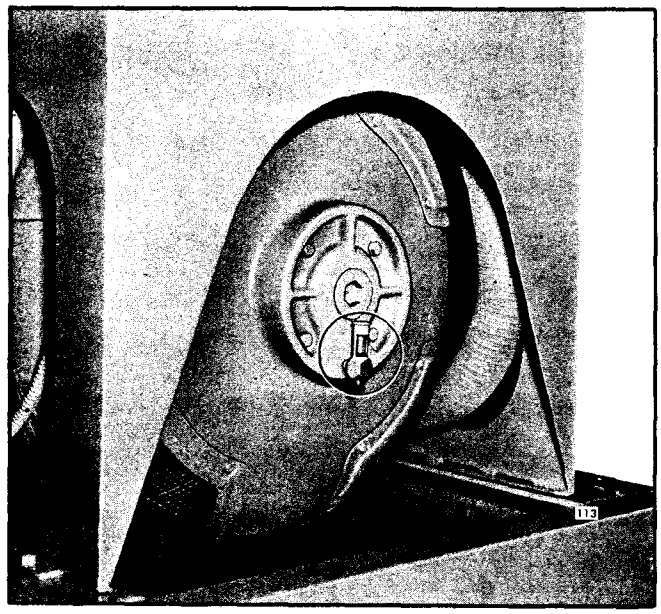
Item 24



Item 26

Item 26

There is no scheduled interval for performing an inspection on the Airesearch turbocharger. As long as the turbocharger is operating satisfactorily and there is no appreciable loss of power, only a periodic inspection is necessary. When service is required, contact an authorized *Detroit Diesel Allison Service Outlet.*



Item 28

Item 27

Check the fan drive fluid level every 75,000 to 100,000 miles to avoid improper operation and damage to the drive components.

The modulated fan drive has an inspection plug for checking the fluid level.

1. Check the fan drive fluid level after the unit has been idle for at least 1/2 hour.

2. Turn the fan drive so that the inspection plug is 3/4" below the horizontal center line, then allow the silicone fluid to drain down an additional five minutes.

3. Remove the inspection plug. If fluid begins to flow from the inspection hole, the drive has sufficient fluid. Replace the inspection plug.

4. If the fluid does not flow from the hole, proceed as follows:

a. Rotate the fan drive downward and observe when the fluid begins to flow from the hole. If it is necessary to lower the drain hole more than 2" below the horizontal center line, the fan drive should be removed from the engine, disassembled and inspected for possible damage to the components.

b. Turn the fan drive back so the inspection hole is 3/4" below the horizontal center line and add fluid until the overflow point is reached. Replace the inspection plug.

NOTE: Use only the manufacturer's Special 20 Cenistroke fluid.

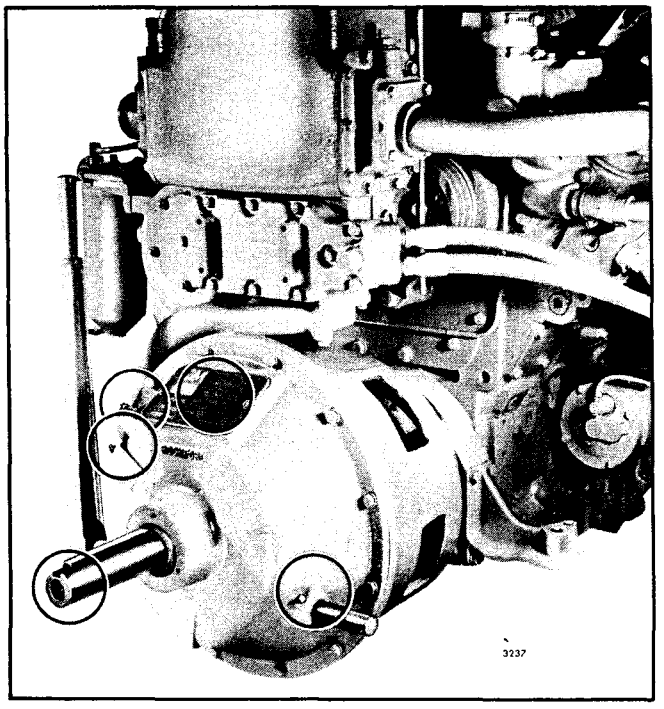
The fan drive bearing should be lubricated with a Medium Consistency Silicone Grease (Dow Corning No. 44, or equivalent). The bearing is lubricated through a grease fitting in the drive housing hub.

Item 28

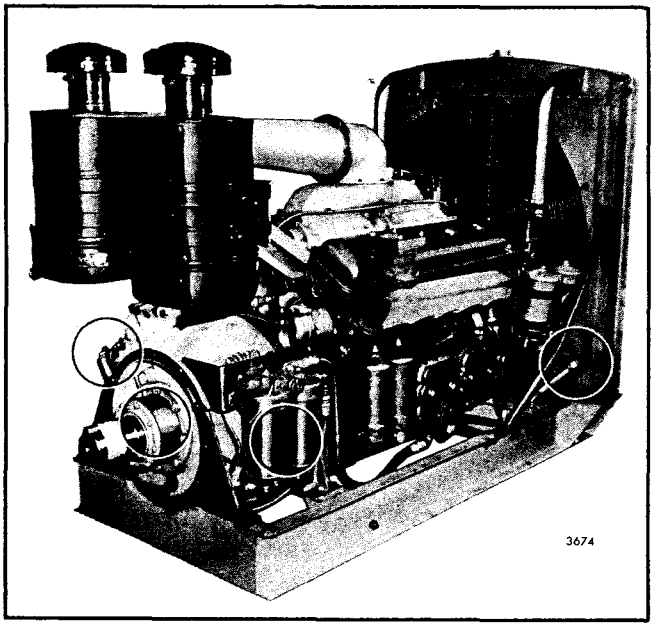
The power generator requires lubrication at only one point -- the ball bearing in the end frame.

If the bearing is oil lubricated, check the oil level in the sight gage every 300 hours; change the oil every six months. Use the same grade of oil as specified for the engine. Maintain the oil level to the line in the sight gage. *Do not overfill.* After adding oil, recheck the oil level after running the generator for several minutes.

If the bearing is grease lubricated, a new generator has sufficient grease for three years of normal service.



Item 29



Item 30

Thereafter, it should be lubricated at one year intervals. To lubricate the bearing, remove the filler and relief plugs on the side and the bottom of the bearing reservoir. Add grease until new grease appears at the relief plug opening. Run the generator a few minutes to vent the excess grease; then reinstall the plugs.

The following greases, or their equivalents, are recommended:

Keystone 44H .....Keystone Lubrication Co.
BRB Lifetime .....Socony Vacuum Oil Co.
NY and NJ926 or F927 .....NY and NJ Lubricant Co.

After 100 hours on new brushes, or brushes in generators that have not been in use over a long period, remove the end frame covers and inspect the brushes, commutator and collector rings. If there is no appreciable wear on the brushes, the inspection interval may be extended until the most practicable period has been established (not to exceed six months). To prevent damage to the commutator or the collector rings, do not permit the brushes to become shorter than 3/4 inch.

Keep the generator clean inside and out. Before removing the end frame covers, wipe off the loose dirt. The loose dirt and dust may be blown out with low pressure air (25 psi maximum). Remove all greasy dirt with a cloth.

Item 29

Lubricate all of the power take-off bearings with an all purpose grease such as Shell Alvania No. 2, or equivalent. Lubricate sparingly to avoid getting grease on the clutch facings.

Lubricate the clutch release bearing and the disconnect mechanical rear drive shaft shielded bearing every 8 hours. The clutch release bearing in the 18" diameter clutch is pre-lubricated and is not provided with a grease fitting, since no further lubrication is required.

Lubricate the power take-off main bearing, also the outboard bearing if the unit is so equipped, every 50 hours. Frequency of lubrication will depend on the working conditions of the bearing, shaft speeds and bearing loads. It may be necessary to lubricate this bearing more often than every 50 hours. Lubricate the front power take-off clutch pilot ball bearing through the fitting in the outer end of the drive shaft every 50 hours. One or two strokes with a grease gun should be sufficient.

Remove the inspection hole cover and lubricate the clutch release levers and link pins sparingly every 500 hours. Lubricate the clutch release shaft through the grease fittings on the front of the housing every 500 hours.

Check the clutch facing for wear every 500 hours. Adjust the clutch if necessary.

Prevailing Ambient Temperature	Recommended Oil Specification
Above - 10° F.	Hydraulic Transmission Fluid, Type C-2.
Below -10° F.	Hydraulic Transmission Fluid, Type C-2. Auxiliary preheat required to raise temperature in the sump to a temperature above -10° F.

TABLE 3

Item 30

Check the oil level in the Torqmatic converter and supply tank daily. The oil level must be checked while the converter is operating, the engine idling and the oil is up to operating temperature (approximately 200° F). If the converter is equipped with an input disconnect clutch, the clutch must be engaged.

Check the oil level after running the unit a few minutes. The oil level should be maintained at the proper level on the dipstick. If required, add hydraulic transmission fluid type "C-2" (see Table 3). *Do not overfill* the converter, as too much oil will cause foaming and high oil temperature.

The oil should be changed every 1,000 hours for Series 400 through 900 converters. Also, the oil should be changed whenever it shows traces of dirt or effects of high operating temperature as evidenced by discoloration or strong odor. If the oil shows metal contamination, contact an authorized *Detroit Diesel Allison Service Outlet* as this usually requires disassembly. Under severe operating conditions, the oil should be changed more often.

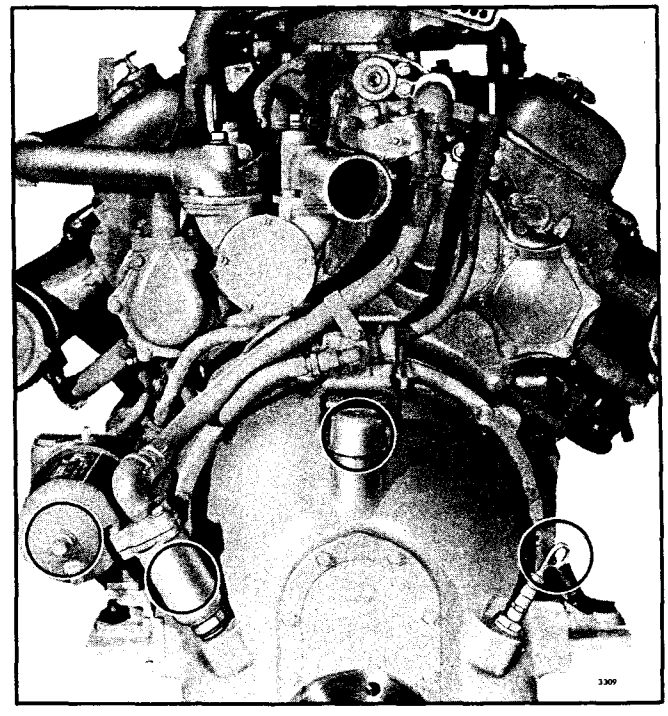
Lubricate the input clutch release bearing and ball bearing and the front disconnect clutch drive shaft bearing every 50 hours with an all purpose grease. Grease fittings are provided on the clutch housing. This time interval may vary depending upon the operating conditions. Over-lubrication will cause grease to be thrown on the clutch facing, causing the clutch to slip.

The strainer (in the Torqmatic transmission) and the hydraulic system filters should be replaced or cleaned with every oil change.

Item 31

TORQMATIC MARINE GEAR (6 and 8V):

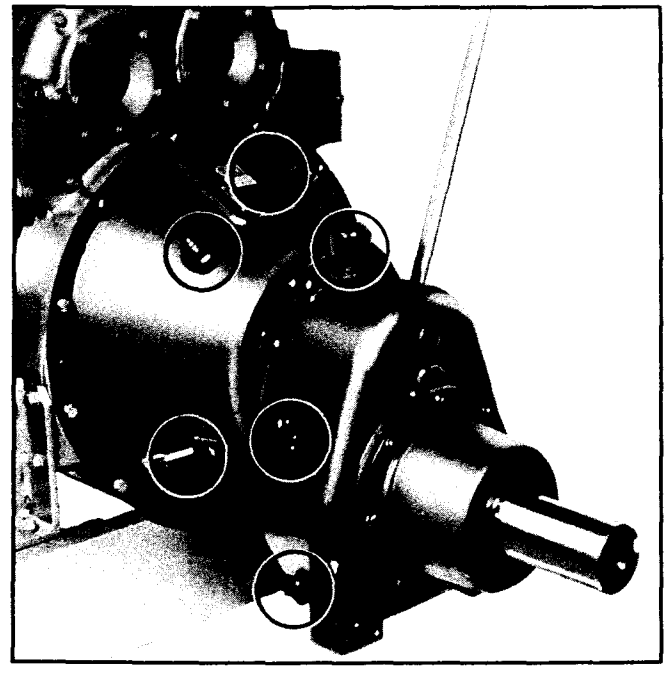
Check the oil level daily in the marine gear, with the engine running at idle speed, and add oil as required to bring it to the proper level on the dipstick. Use oil



Item 31

of the same *heavy duty* grade and viscosity that is used in the engine. Drain the oil every 200 hours and flush the gear with light engine oil.

NOTE: Series 3 oil should not be used in the marine gear.



Item 32

When refilling after an oil drain, bring the oil up to the proper level on the dipstick (approximately 6 quarts in the M type and 8 quarts in the MH type gear). Then, run the engine at light load for three or four minutes. Stop the engine and check the oil level again. Bring the oil level up to the proper level on the dipstick.

Every time the marine gear oil is changed, remove the oil strainer element, rinse it thoroughly in fuel oil, dry it with compressed air and reinstall it. Also, replace the full-flow oil filter element every time the marine gear oil is changed.

TWIN DISC MARINE GEAR (12V and 16V):

Check the oil level daily. Check the oil level with the engine running at low idle speed and the gear in neutral. Keep the oil up to the proper level on the dipstick. Use oil of the same *heavy-duty* grade and viscosity that is used in the engine.

Change the oil and the 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. Then stop the engine and check the oil level. If necessary, add oil to bring it up to the full mark on the dipstick.

SNOW NABSTEDT MARINE GEAR (16V):

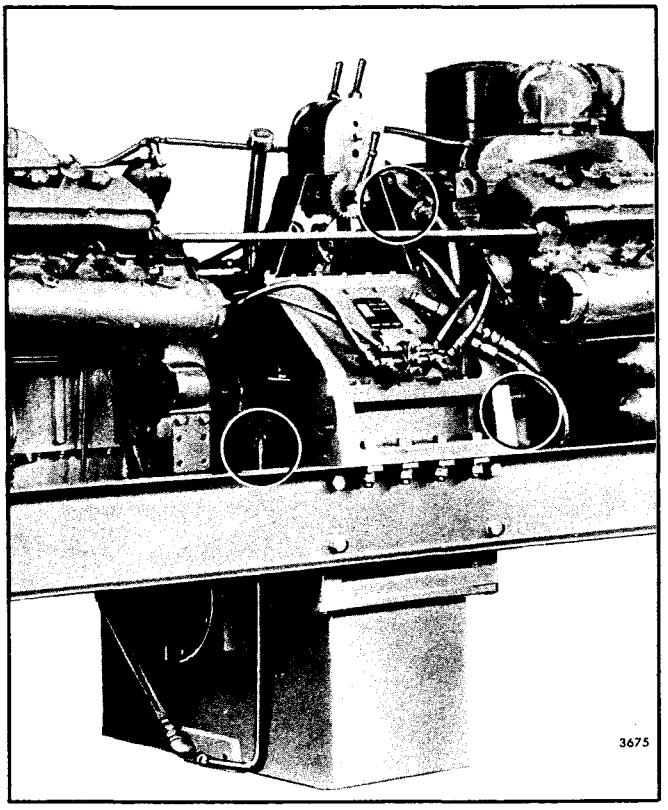
Check the oil level daily. If necessary, stop the engine. Also, turn the handle of the filter in the suction line daily, or more often if necessary. This is a knife edge filter, and a turn of the handle wipes the accumulated sediment from the edge of the filter discs.

Change the oil every 1,000 hours or at the end of each season, whichever occurs first. At each oil change, remove the plug from the bottom of the filter to drain the sediment. If the filter is extremely dirty, remove the screws holding the sediment bulb to the flange at the top of the filter and remove the bulb for thorough cleaning. When replacing the bulb, be sure to tighten the screws evenly and securely to prevent air leaks in the suction line. Use oil of the same *heavy duty* grade and viscosity that is used in the engine.

Item 32

ROCKFORD REDUCTION GEAR:

Check the oil level in the reduction gear every 8 hours and add oil as required to bring the oil to the proper level on the dipstick. Drain the oil every 1,000 hours, flush the housing with light engine oil, and refill to the proper level with the same grade and viscosity *heavy duty* oil that is used in the engine. This oil change period should be reduced under severe operating conditions.



Item 33

Lubricate the clutch release bearing through the grease fitting on the side of the housing every 8 hours of operation. The clutch release bearing in the 18" diameter clutch is pre-lubricated and is not provided with a grease fitting, since no further lubrication is required. Lubricate the front reduction clutch pilot ball bearing through the fitting in the outer end of the drive shaft every 50 hours. One or two strokes with a grease gun should be sufficient.

Remove the inspection hole cover and oil the clutch release levers and link pins sparingly every 500 hours. Lubricate the clutch release shaft through the grease fittings on the front of the housing every 500 hours.

Item 33

REDUCTION GEAR (24V and 32V):

The oil level in the reduction gear should be checked while the gear is in operation. Keep the oil level at the operating level on the dipstick.

Drain the oil every 200 hours of operation. Flush with light engine oil and refill to the proper level on the dipstick (approximately 21 gallons).

NOTE: Series 3 oil should not be used in the reduction gear.

Use oil of the same *heavy duty* grade and viscosity that is used in the engine.

Every time the oil is changed, remove the element from each oil strainer and rinse it thoroughly in clean fuel oil, dry it with compressed air and reinstall.

The filter element of each marine gear oil filter should be removed, the element shell cleaned, and a new element and gasket installed every time the reduction gear oil is changed.

When refilling after an oil drain, bring the oil up to the proper level on the dipstick; then, run the engines to fill the system with oil. Check the oil level on the reduction gear with the engines and gear operating. Bring the oil level up to the proper level on the dipstick. *Do not overfill.*

DETROIT DIESEL FUEL OIL SPECIFICATIONS

Detroit Diesel designs, develops, and manufactures commercial diesel engines to operate on diesel fuels classified by the A.S.T.M. as Designation D-975 (grades 1-D and 2-D). These grades are very similar to grades DF-1 and DF-2 of Federal Specification VV-F-800. Residual fuels and furnace oils, generally, are not considered satisfactory for Detroit Diesel engines. In some regions, however, fuel suppliers may distribute one fuel that is marketed as either diesel fuel (A.S.T.M. D-975) or domestic heating fuel (A.S.T.M. D-396) sometimes identified as furnace oil. In this case, the fuel should be investigated to determine whether the properties conform with those shown in the FUEL OIL SELECTION CHART, presented in this specification.

The FUEL OIL SELECTION CHART also will serve as a guide in the selection of the proper fuel for various applications. The fuels used must be clean, completely distilled, stable, and non-corrosive. DISTILLATION RANGE, CETANE NUMBER, and SULFUR CONTENT are three of the most important properties of diesel fuels that must be controlled to insure optimum combustion and minimum wear. Engine speed, load, and ambient temperature influence the selection of fuels with respect to distillation range and cetane number. The sulfur content of the fuel must be as low as possible to avoid excessive deposit formation, premature wear, and to minimize the sulfur dioxide exhausted into the atmosphere.

To assure that the fuel you use meets the required properties, enlist the aid of a reputable fuel oil supplier. The responsibility for clean fuel lies with the fuel supplier as well as the operator.

During cold weather engine operation, the cloud point (the temperature at which wax crystals begin to form in diesel fuel) should be 10° F below the lowest expected fuel temperature to prevent clogging of the fuel filters by wax crystals.

At temperatures below −20° F, consult an authorized Detroit Diesel service outlet, since particular attention must be given to the cooling system, lubricating system, fuel system, electrical system, and cold weather starting aids for efficient engine starting and operation.

STATEMENT OF POLICY ON FUELS AND LUBRICANTS

In answer to requests concerning the use of fuel and lubricating oil additives, the following excerpts have been taken from a policy statement of General Motors Corporation:

> *"It has been and continues to be General Motors policy to build motor vehicles that will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets. It is accordingly contrary to the policy of General Motors to recommend the regular and continued use of supplementary additives in such fuels and lubricants.*
>
> *"This policy should not be confused with the fact that certain supplementary additives may effectively and economically solve specific operating problems which occasionally arise in some vehicles. In such instances, supplementary additives may be developed on the basis of suitable tests to remedy such problems without otherwise causing harm to vehicles. These selected products are then given official GM part numbers and made available for use in appropriate service applications.*
>
> *"While General Motors Corporation assumes responsibility for the additives selected by it to remedy specific operating problems, it cannot, of course, accept responsibility for the many other additives which are constantly being marketed."*

Although the stated Corporation policy is self-explanatory, the following is emphasized: Detroit Diesel does not recommend or support the use of any supplementary fuel or lubricant additives. These include all products marketed as fuel conditioners, smoke suppressants, masking agents, reodorants, tune-up compounds, top oils, break-in oils, graphitizers and friction reducing compounds.

NOTE: The manufacturer's warranty applicable to Detroit Diesel engines provides in part that the provisions of such warranty shall not apply to any engine unit which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow the manufacturer's fuel or lubricating recommendations indicated above may not be within the coverage of the warranty.

FUEL OIL SELECTION CHART

Typical Application	General Fuel Classification	Final Boiling Point	Cetane No.	Sulfur Content
		(Max)	(Min)	(Max)
City Buses	No. 1-D	550° F	45	0.30%
All Other Applications	Winter No. 2-D	675° F	45	0.50%
	Summer No. 2-D	675° F	40	0.50%

NOTE: When prolonged idling periods or cold weather conditions below 32° F are encountered, the use of lighter distillate fuels may be more practical. The same consideration must be made when operating at altitudes above 5,000 ft.

DETROIT DIESEL LUBRICATING OIL SPECIFICATIONS*

OIL QUALITY

OIL QUALITY is the responsibility of the oil supplier. (The term oil supplier is applicable to refiners, blenders, and rebranders of petroleum products, and does not include distributors of such products).

There are hundreds of commercial crankcase oils marketed today. Obviously, engine manufacturers or users cannot completely evaluate the numerous commercial oils. The selection of a suitable lubricant in consultation with a reliable oil supplier, observance of his oil drain recommendations (based on used oil sample analysis and experience) and proper filter maintenance, will provide the best assurance of satisfactory oil performance.

Detroit Diesel lubricant recommendations are based on general experience with current lubricants of various types and give consideration to the commercial lubricants presently available.

RECOMMENDATION

Detroit Diesel engines have given optimum performance and experienced the longest service life with the following oil performance levels having the ash and zinc limits shown:

Former Military and Commercial Lube Identification	New API Letter Code Service Classification	SAE Grade †
MIL-L-2104B/1964 MS Supplement 1	CC/SC CB	30 or 40 30 or 40

† SAE 30 and 40 grades have both performed satisfactorily in Detroit Diesel engines. Obviously, the expected ambient temperatures and engine cranking capability must be considered by the engine owner/operator when selecting the proper grade of oil.

ASH LIMIT
The sulfated ash limit (A.S.T.M. D-874) of the above lubricants shall not exceed 1.000% by weight, except lubricants that contain only barium detergent-dispersant salts where 1.500% by weight is allowed. The majority of lubricants marketed under the performance levels shown above have a sulfated ash content between 0.55 to 0.85% by weight.

ZINC CONTENT
The zinc content, as zinc diorganodithiophosphate, shall be a minimum of 0.07% by weight.

RECOMMENDATIONS REGARDING THE USE OF CURRENT OIL PERFORMANCE LEVEL PRODUCTS MEETING PRESENT MILITARY LUBRICANT SPECIFICATIONS

The petroleum industry is currently marketing engine crankcase oils that may be identified as follows:

Military or Commercial Identification	API Letter Code Service Classification	Comment on Application and Performance
MIL-L-2104C	CD/SC	Supersedes MIL-L-45199B (Series 3) intended for diesel service.
MIL-L-46152	CC/SE	Supersedes MIL-L-2104B intended for gasoline engine passenger cars.
Universal	Numerous	Meets the performance criteria of all industry accepted tests and all current military specifications including MIL-L-2104C and MIL-L-46152.

Detroit Diesel does not have sufficient experience with any of the above described lubricants to recommend their use. Some oil suppliers have reported satisfactory performance of the above identified products marketed by them. If an owner/operator intends to use any of the above described products, it is recommended he obtain evidence from the oil supplier that the lubricant has performed satisfactorily in Detroit Diesel engines. The above products may be satisfactory for use in Detroit Diesel engines under the following conditions:

1. The sulfated ash (A.S.T.M. D-874) limit of the above lubricants shall not exceed 1.000% by weight, except lubricants that contain only barium detergent-dispersant salts where 1.500% by weight is allowed.

2. The zinc content, as zinc diorganodithiophosphate, shall be a minimum of 0.07% by weight.

3. Sufficient evidence of satisfactory performance in Detroit Diesel engines has been provided to Detroit Diesel and/or the customer.

LUBRICANTS NOT RECOMMENDED

The following lubricants are NOT recommended because of a history of poor performance in Detroit Diesel engines:

Military or Commercial Identification	API Letter Code Service Classification	Comment on Performance
MIL-L-2104B/1968 MS	CC/SD	Excessive ash deposits formed
MIL-L-45199B (Series 3)	CD	Excessive ash deposits formed
Multigrade oils	Numerous	History of poor performance in most heavy duty diesel engines

COLD WEATHER OPERATION

Cold weather starting will be facilitated when immersion type electrical coolant heaters can be used. Other practical considerations, such as the use of batteries, cables and connectors of adequate size, generators or alternators of ample capacity, proper setting of voltage regulators, ether starting aids, oil and coolant heater systems, and proper fuel selection will accomplish starting with the use of SAE 30 or SAE 40 oils. For complete cold weather starting information, consult an authorized Detroit Diesel service outlet. Ask for Engineering Bulletin No. 38 entitled: "Cold Weather Operation"

NORTH SLOPE & OTHER EXTREME SUB-ZERO OPERATIONS

Some new special arctic lubricants have recently been developed for Military use in extremely cold climates. The oils that have shown best cold temperature performance may be described as multigrades having a synthetic base stock and low volatility characteristics. At this time a new Military arctic oil specification is being developed. The good oil performers have passed the oil performance criteria defined in (tentative) Federal Test Method 354 of Federal Test Standard 791. The lubricants may be used where continuous sub-zero temperatures prevail and where engines are shut down for periods longer than eight (8) hours. These are not comparable to the performance of SAE 30 or 40 oils at operating conditions and should be considered only as a last resort when engine cranking is a severe problem and auxiliary heating aids are not available.

OIL CHANGES

The oil change period is dependent on the operating conditions (e.g. load factor, etc.) of an engine that will vary with the numerous service applications. It is recommended that new engines be started with 150 hour oil change periods. For highway vehicles this corresponds to approximately 4,500 miles, and for "city" service vehicles, approximately 2,500 miles. The drain interval may then be gradually increased, or decreased with experience on a specific lubricant while also considering the recommendations of the oil supplier (analysis of the drained oil can be helpful here) until the most practical oil drain period for the particular service has been established.

Solvents should not be used as flushing oils in running engines. Dilution of the fresh refill oil supply can occur, which may be detrimental.

Full flow oil filtration systems have been used in Detroit Diesel engines since they have been manufactured. For the best results, the oil filter element should be replaced each time the oil is changed.

NEW ENGINE OIL CLASSIFICATION SYSTEM

A relatively new engine oil classification system has been introduced to industry that describes the criteria required to meet each performance level. A simplified cross-reference of oil and current commercial and military specifications is shown below.

CROSS-REFERENCE OF LUBE OIL CLASSIFICATION SYSTEMS

API Code Letters	Comparable Military or Commercial Industry Spec.
CA	MIL-L-2104A
CB	Supplement 1
CC	MIL-L-2104B (see Note 1 below)
CD	MIL-L-45199B (Series 3)
‡	MIL-L-46152 (supersedes MIL-L-2104B for Military only)
■	MIL-L-2104C (supersedes MIL-L-45199B for Military only)
SA	none
SB	none
SC	1964 MS oils — Auto passenger car
SD	1968 MS oils — Auto passenger car
SE	1972 MS oils — Auto passenger car

NOTE 1: MIL-L-2104B Lubricants are currently marketed and readily available for Commercial use. MIL-L-2104B oils are obsolete for Military service applications only.

‡ Oil performance meets or exceeds that of CC and SE oils.
■ Oil performance meets or exceeds that of CD and SC oils.

For complete descriptions, consult the following publications:

1. Society of Automotive Engineers (SAE) Technical Report J-183a.
2. Federal Test Method Standard 791a.

PUBLICATION AVAILABLE SHOWING COMMERCIAL "BRAND" NAME LUBRICANTS

A list of "brand" name lubricants distributed by the majority of worldwide oil suppliers can be purchased from the Engine Manufacturers Association (EMA). The publication is titled, "EMA Lubricating Oils Data Book for Heavy Duty Automotive and Industrial Engines." The publication shows the brand names, oil performance levels, viscosity grades, and sulfated ash contents of most "brands" marketed.

ENGINE MANUFACTURERS ASSOCIATION
111 EAST WACKER DRIVE
CHICAGO, ILLINOIS 60601

ENGINE COOLANT

Engine coolant is considered as any solution which is circulated through the engine to provide the means for heat transfer from the various engine components. In general, water containing various materials in solution is used for this purpose.

The function of the coolant is basic in the design and the successful operation of the engine and must be carefully selected and properly maintained.

COOLANT REQUIREMENTS

A suitable coolant solution must meet the following five 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.

Normally requirements 1 through 4 are satisfied by combining a suitable water with reliable inhibitors. When operating conditions dictate the need for freeze protection, a solution of suitable water and an ethylene glycol type antifreeze containing adequate inhibitors will provide a satisfactory coolant.

WATER

Any water, whether of drinking quality or not, will produce a corrosive environment in the cooling system. Also, scale deposits may form on the internal surfaces of the cooling system due to the mineral content of the water. 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 (1) chlorides, (2) sulfates, (3) total hardness and (4) dissolved solids. These materials are objectionable for a number of reasons: chlorides and/or sulfates will accelerate corrosion, while hardness (percentage of magnesium and calcium present) will cause 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 but not necessarily all the materials which make up dissolved solids. Water, within the limits specified in Tables 1 and 2 of Figure 1, is satisfactory as an engine coolant when proper inhibitors are added.

CORROSION INHIBITORS

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. Depletion of all types of inhibitors occur through normal operation and therefore strength levels must be maintained by the addition of inhibitors at prescribed intervals. Always follow the supplier's recommendations on inhibitor usage and handling.

Chromates

Sodium chromate and potassium dichromate are two of the best and more commonly used *water* system corrosion inhibitors. However, the restrictive use of these materials, due to ecology considerations, has de-emphasized their use in favor of non-chromates. Care should be exercised in handling these materials due to their toxic nature.

Chromate inhibitors must *not* be used in ethylene glycol antifreeze solutions. Chromium hydroxide, commonly called "green slime", can result from the use of chromate inhibitors with permanent type antifreeze. This material deposits on the cooling system passages, reducing the heat transfer rate and will result in engine overheating. Engines which have operated with a chromate inhibited water must be chemically cleaned before the addition of ethylene glycol type 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: 1-1/4% of soluble

TABLE 1

	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

Refer to Table 2 for evaluation of water intended for use in a coolant solution.

TABLE 2

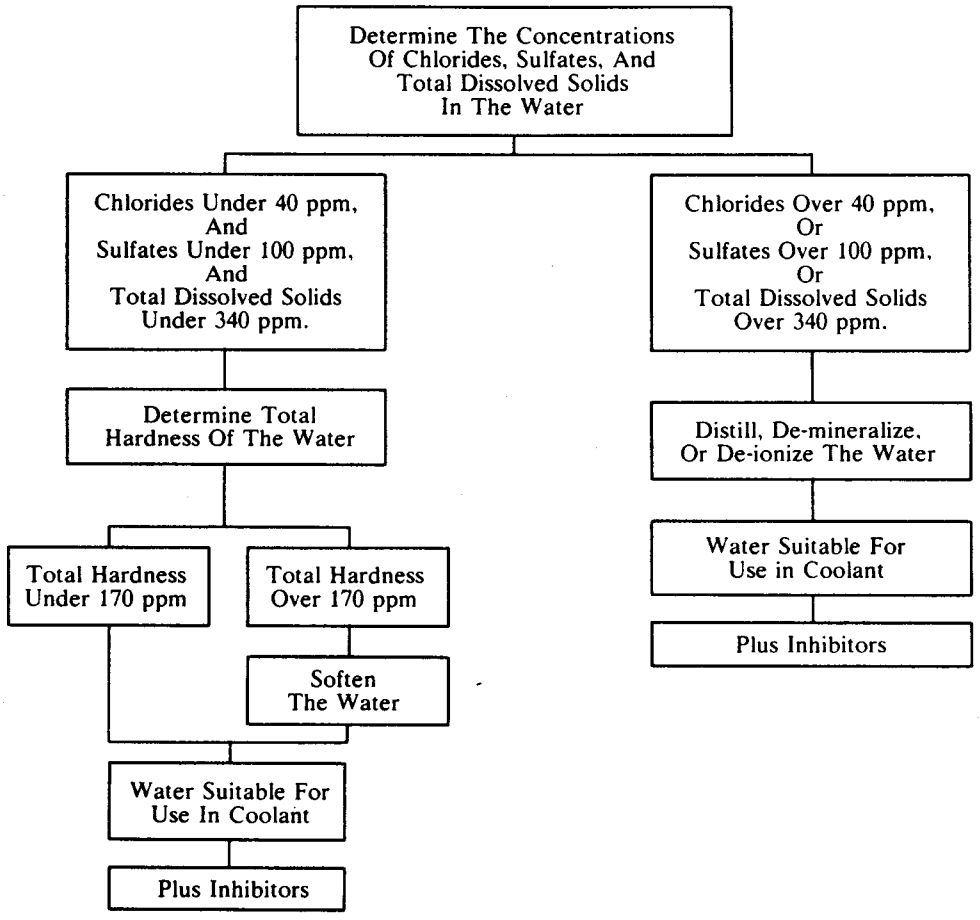


Figure 1

oil in the cooling system increases fire deck temperatures 6% and a 2-1/2% concentration raises fire deck temperature up to 15%. Soluble oil is *not* recommended as a corrosion inhibitor.

Non-Chromates

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

COOLANT INHIBITOR CHART

Inhibitor or Inhibitor System	Corrosion Inhibitor Type	Complete Inhibitor System	Inhibitor Compatability		
			Water	Ethylene Glycol Base Antifreeze	*Methoxy Propanol Base Antifreeze
Sodium chromate	Chromate	No	Yes	No	No
Potassium dichromate	Chromate	No	Yes	No	No
Perry filter elements:					
5020 (type OS)	Chromate	Yes	Yes	No	No
S-453 (Spin-on)	Chromate	Yes	Yes	No	No
5030 (type OS)	@Non-chromate	Yes	Yes	Yes	No
S-331 (Spin-on)	@Non-chromate	Yes	Yes	Yes	No
5070 (type OS)	#Non-chromate	Yes	Yes	Yes	No
S-473 (Spin-on)	#Non-chromate	Yes	Yes	Yes	No
Lenroc filter element	Non-chromate	Yes	Yes	Yes	No
Fleetguard filter elements:					
DCA (canister)	Non-chromate	Yes	Yes	Yes	No
DCA (Spin-on)	Non-chromate	Yes	Yes	Yes	No
AC filter elements:					
DCA (canister)	Non-chromate	Yes	Yes	Yes	No
DCA (Spin-on)	Non-chromate	Yes	Yes	Yes	No
Luber-Finer filter elements:					
LW-4739 (canister)	Non-chromate	Yes	Yes	Yes	No
LFW-4744 (spin-on)	non-chromate	Yes	Yes	Yes	No
Nalcool 2000 (liquid)	Non-chromate	Yes	Yes	Yes	No
Perry LP-20 (liquid)	Non-chromate	Yes	Yes	Yes	No
Lubercool (liquid)	Non-chromate	Yes	Yes	Yes	No
Dowtherm cooling system conditioner	Non-chromate	Yes	Yes	Yes	Yes

*Dowtherm 209, or equivalent.
@Perry "Year Around" formula.
#Perry "Universal" formula.

Figure 2

INHIBITOR SYSTEMS

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

Coolant Filter Elements

Replaceable elements are available with various chemical inhibitor systems. Care should be used in the