OPERATION AND MAINTENANCE

CUMMINS

C SERIES DIESEL ENGINES

CUMMINS ENGINE COMPANY, INC. • COLUMBUS, INDIANA, U.S.A.

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Foreword

This manual is applicable to all Cummins 4 and 6-cylinder C Series engines. All of the engines in this series are treated in this one manual because the operating characteristics and service procedures are either identical or similar. Where different procedures are required, they are clearly indicated. Before you operate the engine and before you attempt any adjustments on it, familiarize yourself with the procedures described.

Unit replacement procedures are described, but unit rebuilding instructions are not included in this manual. Rebuild operations should be performed in a well-equipped shop by mechanics who are especially trained for rebuild work.

These facilities are available from your Cummins Distributor, or if you are equipped to do the complete rebuilding, you can obtain a C Series shop manual from your Cummins Distributor.

CUMMINS ENGINE COMPANY, INC.

COLUMBUS, INDIANA, U.S.A.

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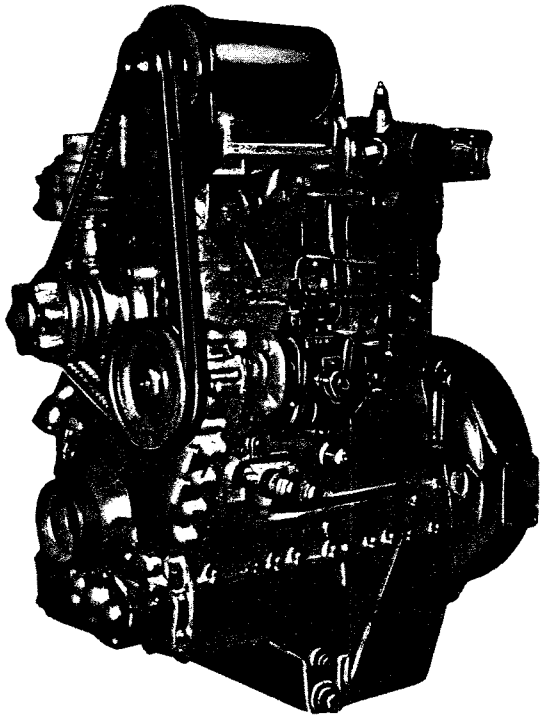


Fig. 1. Cummins C-105 Diesel Engine — Fuel Pump Side

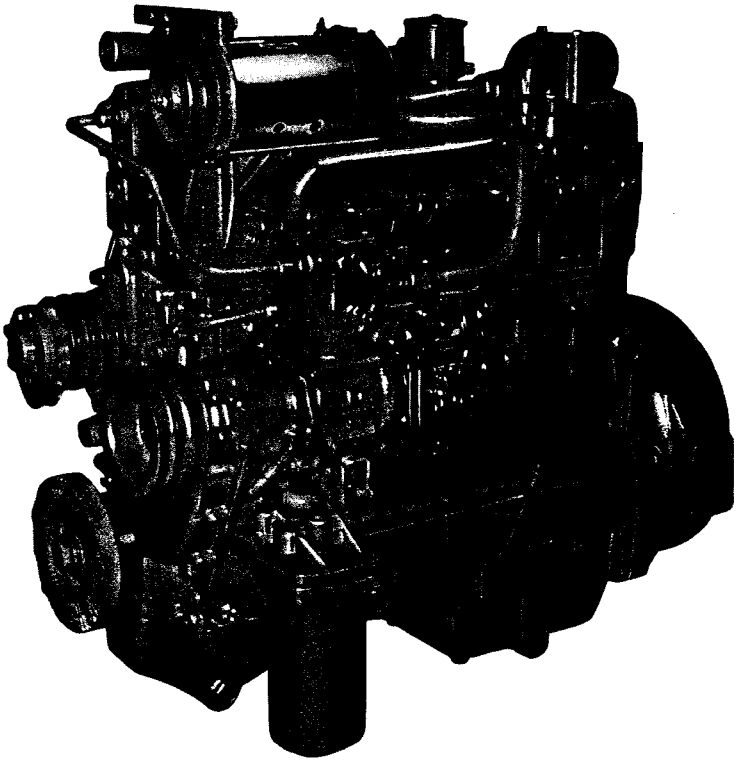


Fig. 2. Cummins C-160 Diesel Engine—Fuel Pump Side

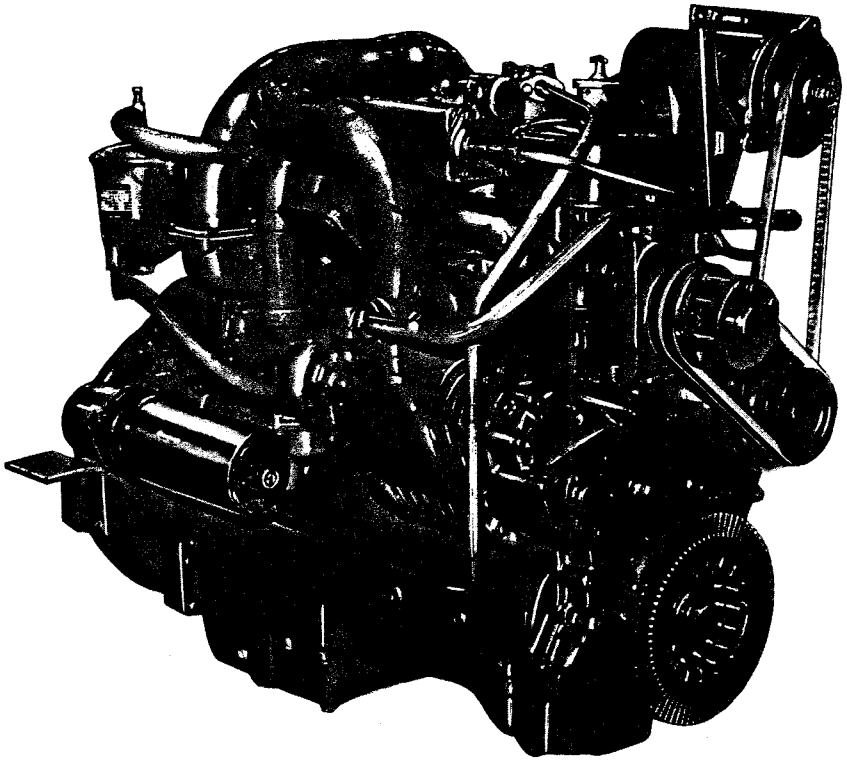


Fig. 3. Cummins C-180 Diesel Engine—Supercharger Side

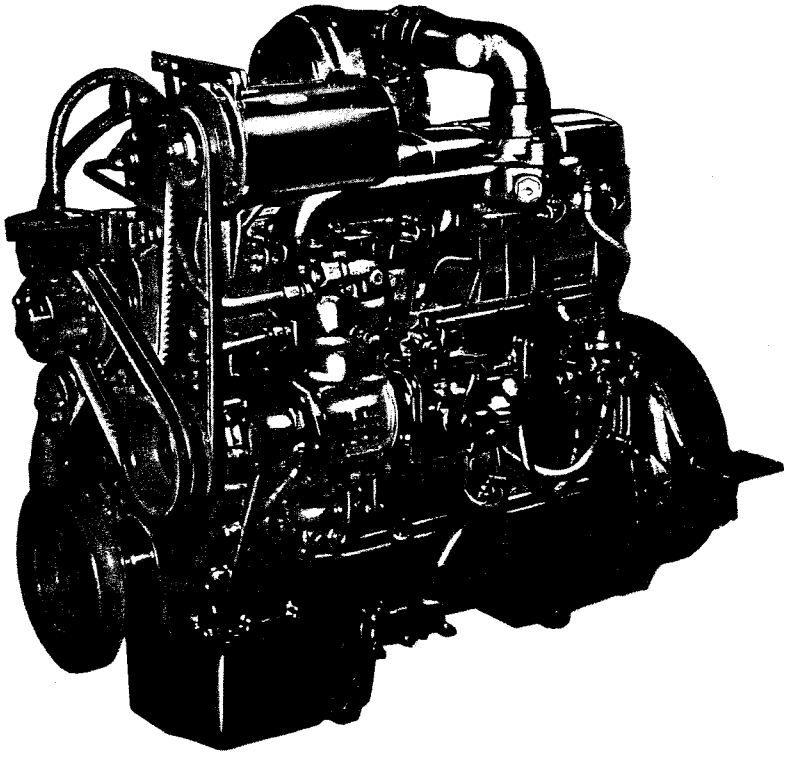


Fig. 4. Cummins C-175 TURBODIESEL Engine — Fuel Pump Side

CUMMINS

C SERIES DIESEL ENGINES

Section I

PRINCIPLES OF OPERATION

The most satisfactory service can be expected from a Cummins Diesel Engine when the operation and maintenance procedures are based upon a clear understanding of the engine working principles. Each part of the engine affects the operation of every other working part and of the engine as a whole.

Cummins C Series Diesel engines treated in this manual are four-stroke-cycle, high-speed, full-diesel engines. Horsepower ratings and other engine specifications for each model are tabulated at the end of this Section.

Diesel engines differ from other internal combustion engines in a number of ways. Compression ratios are higher than in spark-ignited engines. The charge taken into the combustion chamber through the intake consists of air only — with no fuel mixture. Injectors receive low pressure fuel from the fuel pump and deliver it into the individual combustion chambers at the right time in equal quantity and proper condition to burn. Ignition of fuel is caused by the heat of the compressed air in the combustion chamber.

THE CUMMINS DIESEL CYCLE

We can better understand the function of engine parts if we know what happens in the combustion chamber during each of the four piston strokes of the cycle. The four strokes and the order in which they occur are: Intake Stroke, Compression Stroke, Power Stroke and Exhaust Stroke.

INTAKE STROKE:

During the intake stroke, the piston travels downward, the intake valve is open, and the exhaust valve is closed.

The downstroke of the piston permits air from outside to enter the cylinder through the open intake valve port. The supercharger or turbocharger in-

creases air pressure in the engine intake manifold and forces it into the cylinder. The intake of air is never restricted by carburetion or mixing valves such as those used on spark-ignited, automotive-type gasoline engines.

The intake charge consists of air only with no fuel mixture.

COMPRESSION STROKE:

At the end of the intake stroke, the intake valve closes and the piston starts upward on the compression stroke. The exhaust valve remains closed.

At the end of the compression stroke, the air in the combustion chamber has been forced by the piston to occupy a space about one-fifteenth as great in volume as it occupied at the beginning of the stroke. Thus, we say the compression ratio is 15:1.

Compressing the air into a small space causes the temperature of that air to rise. Near the end of the compression stroke, the pressure of the air above the piston is approximately 500 to 600 pounds per square inch and the temperature of that air is approximately 1000° F.

During the last part of the compression stroke and the early part of the power stroke, a small metered charge of fuel is injected into the combustion chamber.

Almost immediately after the fuel charge is injected into the combustion chamber, the fuel is ignited by the hot air and starts to burn.

POWER STROKE:

During the power stroke, the piston travels downward and both intake and exhaust valves are closed.

By the time the piston reaches the end of the compression stroke, the burning fuel causes a further increase in the pressure above the piston. As more fuel is added and burns, the gases get hotter and hotter and expand more and more to push the piston downward and add impetus to crankshaft rotation.

EXHAUST STROKE:

During the exhaust stroke, the intake valve is closed, the exhaust valve is open, and the piston is on its upstroke.

Burned gases are forced out of the combustion chamber through the open exhaust valve port by the upward travel of the piston.

From the preceding description of the Cummins Diesel Cycle, it is apparent that the proper operation of the engine depends upon the two separate functions — first compression for ignition, and, second, that fuel be measured and injected into the compressed air in the cylinder in the proper quantity and at the proper time.

THE LUBRICATING SYSTEM

The working parts of Cummins C Series Engines are lubricated by force feed. The force is supplied by a gear-type lubricating pump located below the crankshaft and driven by an idler gear off the pinion gear. Oil is held in the sump in the oil pan, and is drawn from this sump by the lubricating oil pump. It is delivered to all working parts of the engine through lubricating oil lines and the oil header, the latter being drilled the full length of the block.

Various drillings through the block, cylinder head, crankshaft, and rocker levers complete the oil circulating passages.

Lubricating oil is forced through the crankshaft to lubricate the main and connecting rod bearings. In some engines, rifle drillings carry oil from the crankshaft through the connecting rods to lubricate the piston pin and bushing. Lubricating oil pressure is controlled by a regulator in the oil strainer head.

Filters and screens are provided throughout the lubricating system for proper cleaning of the lubricating oil.

The air compressor, supercharger or turbocharger and water-pump-drive all receive pressure lubrication from the engine oil supply.

The turbocharger is also cooled by lubricating oil.

The injector plunger in the injector and the working parts in the fuel pump are lubricated by fuel oil. The fuel oil used for lubrication of the injector plunger is returned to the fuel tank through drain lines.

The schematic diagrams, Pages 1-11 and 1-12, show direction of oil flow and the various units provided to clean and cool hot oil, and maintain a constant pressure of 30/50 psi in the header at governed engine rpm.

A by-pass valve is provided in the oil strainer as insurance against interruption of oil flow by a dirty or clogged strainer element.

THE FUEL SYSTEM

Cummins PT Fuel System is a completely new application of basic hydraulic principles to the diesel engine fuel system. It is a Cummins design for Cummins Diesels. The identifying letters, "PT," are an abbreviation for "pressure-time."

The principle of the PT Fuel System is based on the fact that by changing the pressure of a liquid flowing through a pipe you change the amount of liquid com-

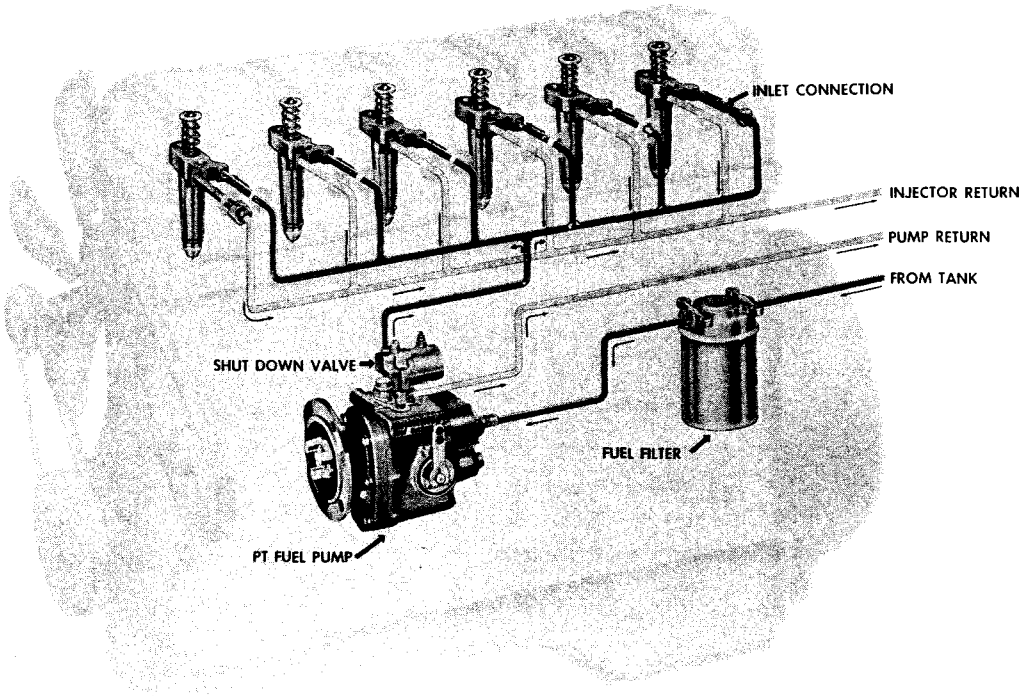


Fig. 1-1. PT fuel system—Fuel flow diagram, pressure regulated fuel pump

ing out of the open end. Increasing the pressure increases the flow or the amount of liquid delivered, and vice versa. In applying this simple principle to the diesel fuel system it is necessary to provide:

1. A fuel pump to draw fuel from the fuel tank and deliver it to individual injectors for each cylinder.
2. A means of controlling the pressure of the fuel being delivered by the fuel pump to the injectors so the individual cylinders will receive the right amount of fuel for the power required of the engine.
3. Fuel passages of the proper size and type so that the fuel will be distributed to all injectors and cylinders with equal pressure under all speed and load conditions.
4. Injectors to receive low-pressure fuel from the fuel pump and deliver it into the individual combustion chambers at the right time, in equal quantity and proper condition to burn.

The PT Fuel System consists of the fuel pump (with governor), the supply and drain lines, and the injectors. Each of these is described in detail in the paragraphs following.

FUEL PUMP:

The fuel pump is made up of three main units:

1. A gear pump which draws fuel from the supply tank and delivers it under pressure through the pump and supply lines to the individual injectors.
2. The pressure regulator which limits the pressure of the fuel to the injectors.
3. The governor and throttle which act independently of the pressure regulator to control fuel pressure to the injectors.

The fuel pump is coupled to the compressor or fuel pump drive which is driven from the engine gear train. The fuel pump main shaft turns at engine crankshaft speed, and drives the gear pump, governor and tachometer shaft.

The location of these units in the fuel pump housing is indicated in Figs. 1-2 and 1-3.

Gear Pump:

The gear pump is located at the rear of the fuel pump and is driven by the main shaft. This unit consists of a single set of gears to pick-up and deliver fuel throughout the fuel system. From the gear pump, fuel flows through the filter screen and to the pressure regulator.

Pressure Regulator:

The pressure regulator is a by-pass valve to regulate the fuel, under pressure, supplied to the injectors. By-passed fuel flows back to the suction side of the gear pump.

Throttle:

Fuel for the engine flows past the pressure regulator to the throttle shaft. Idle fuel passes around the shaft to the idle jet in the governor. For operation above idle, fuel passes through the throttling hole in the shaft and enters the governor through the primary jets.

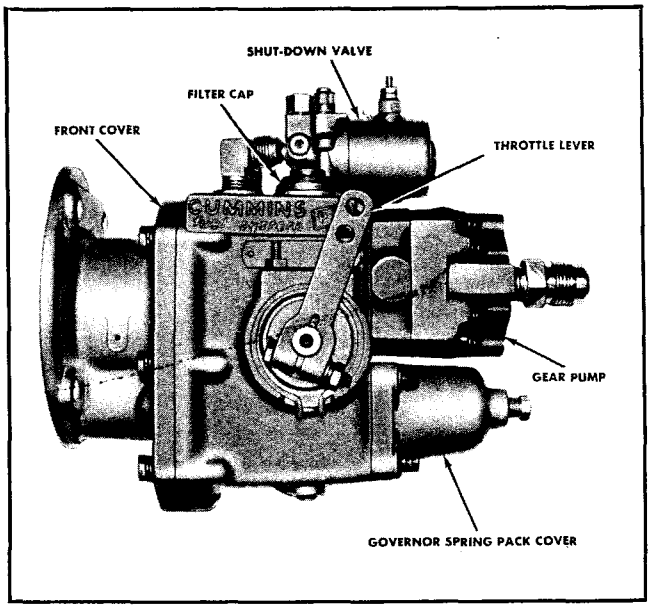


Fig. 1-2. Fuel pump units

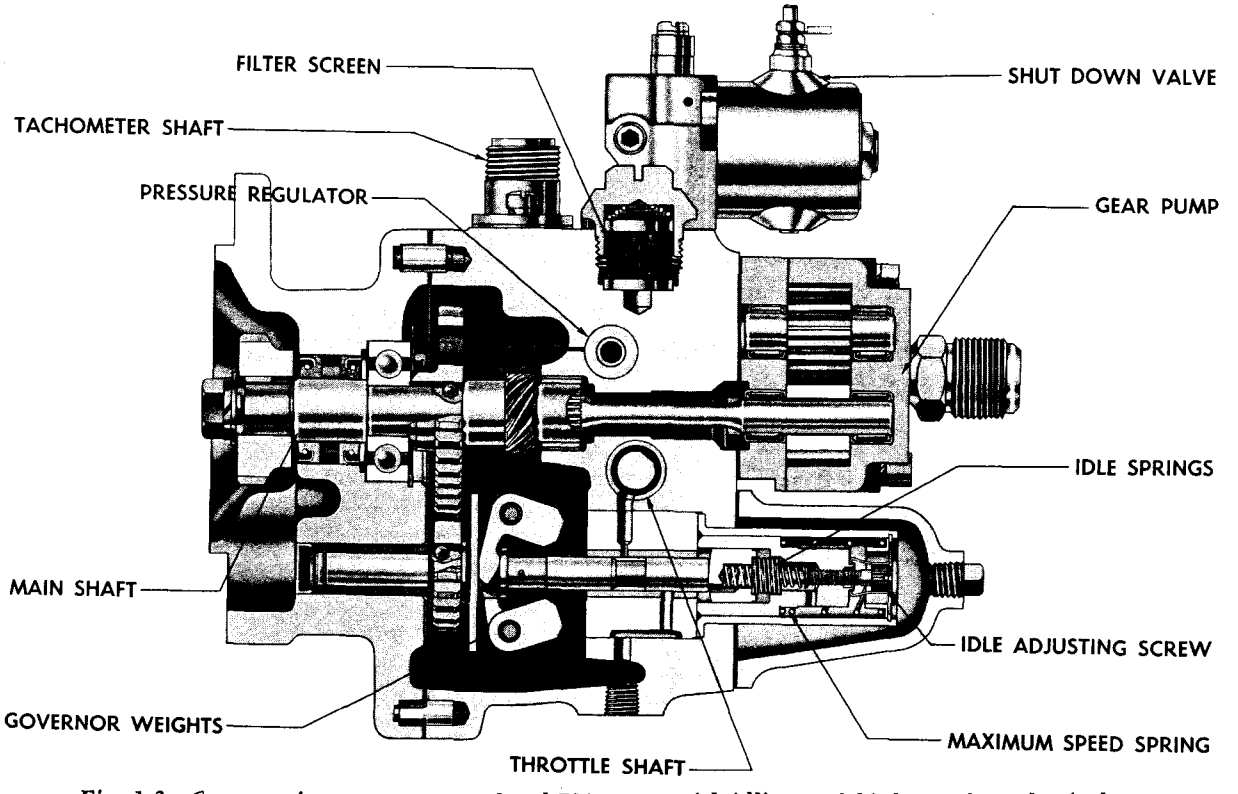


Fig. 1-3. Cross section, pressure regulated PT pump with idling and high-speed mechanical governor

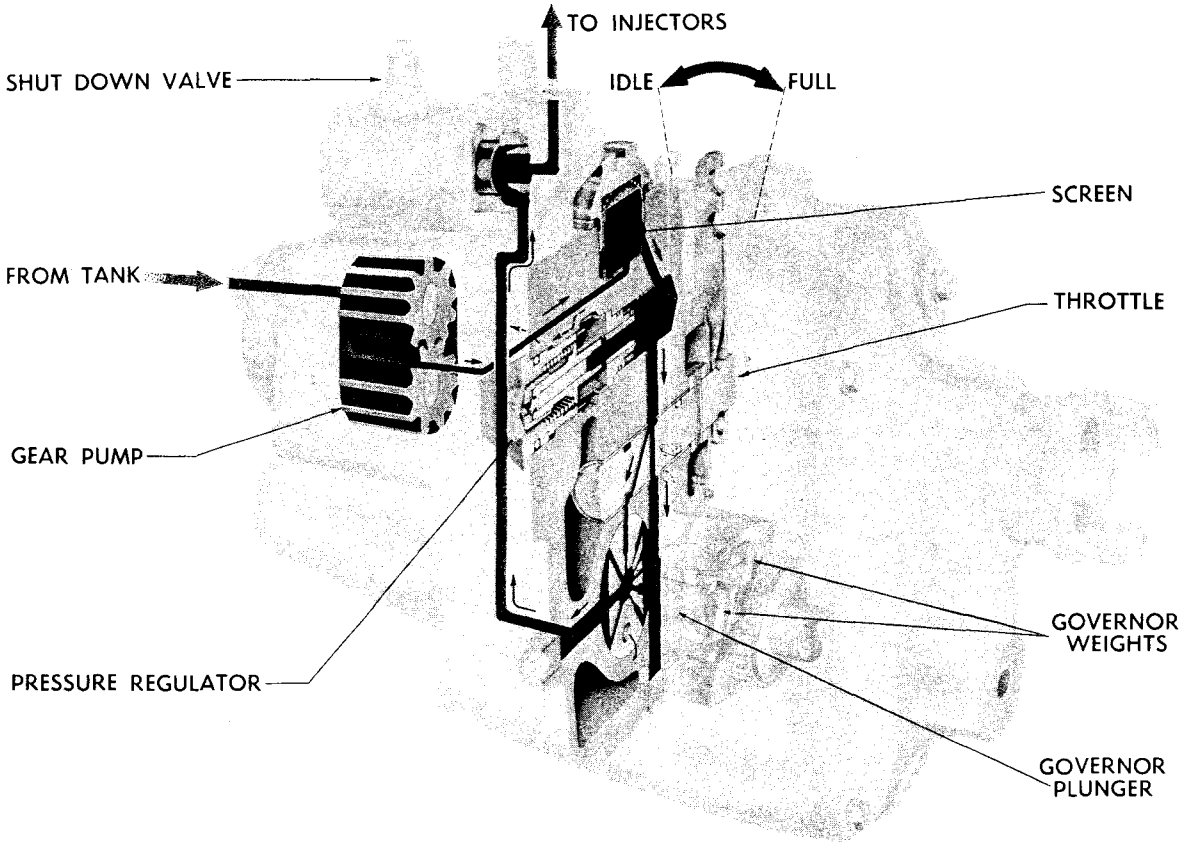


Fig. 1-4. Fuel flow through pressure regulated fuel pump

Governors:

Idling and High-Speed Mechanical Governor: Mechanical governor action is provided by a system of springs and weights, and has two functions. First, the governor maintains sufficient fuel for idling with the throttle control in idle position; and second, it cuts off fuel above maximum rated rpm. The idle springs in the governor spring pack position the governor plunger so the idle fuel jet is opened enough to permit passage of fuel to maintain engine idle speed.

During operation between idle and maximum speeds, fuel flows through the governor to the injectors in accord with the engine requirements as controlled by the throttle and limited by the pressure regulator. When the engine reaches governed speed, the governor weights move the governor plunger, and fuel passages to the fuel supply manifold are shut off. At the same time another passage opens and dumps the fuel to the supply manifold back into the main pump body. In this manner engine speed is controlled and limited by the governor regardless of throttle position. Fuel leaving the governor travels through the shut-down valve, inlet supply lines and on into the injectors.

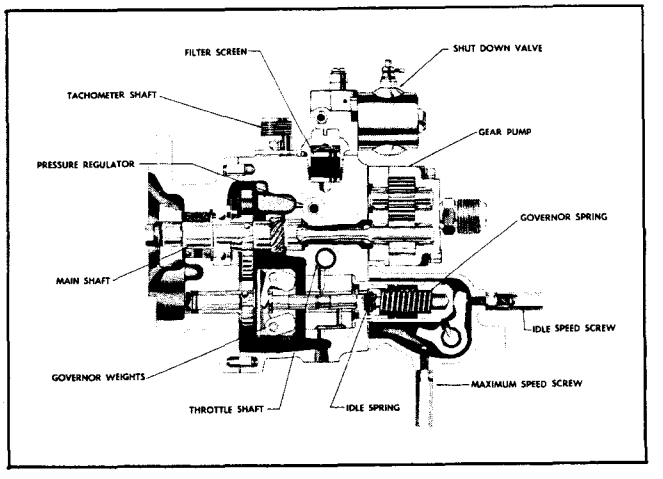


Fig. 1-5. Flange-mounted fuel pump with variable-speed governor

Variable-Speed Mechanical Governor: This governor is designed to meet the requirements of machinery on which the engine must operate at a constant speed, but where extremely close regulation is not necessary.

Adjustment for different rpm can be made by means of a lever control or adjusting screw. At full-rated speed, this governor has a speed droop between full-load and no-load of approximately eight percent. A cross-section of this governor is shown in Fig. 1-5.

As a variable-speed governor, this unit is suited to the varying speed requirements of cranes, shovels, etc., in which the same engine is used for propelling the unit and driving a pump or other fixed-speed machine.

As a constant-speed governor, this unit provides control for pumps, nonparalleled generators and other applications where close regulation (variation between no-load and full-load speeds) is not required.

Torque Converter Governor: When a torque converter is used to connect the engine with its driven unit, an auxiliary governor may be driven off the torque converter output shaft to exercise control over the engine governor and to limit converter output shaft speed. The engine governor and the converter governor must be adjusted to work together.

The PT torque converter governor is fundamentally two mechanical variable-speed governors in series — one driven by the engine and the other by the converter. See Figs. 1-5 and 1-6.

The engine governor, in addition to giving a variable engine speed acts as an overspeed and idle-speed governor while the converter-driven governor is controlling the engine. Each governor has its own control lever and speed adjusting screws.

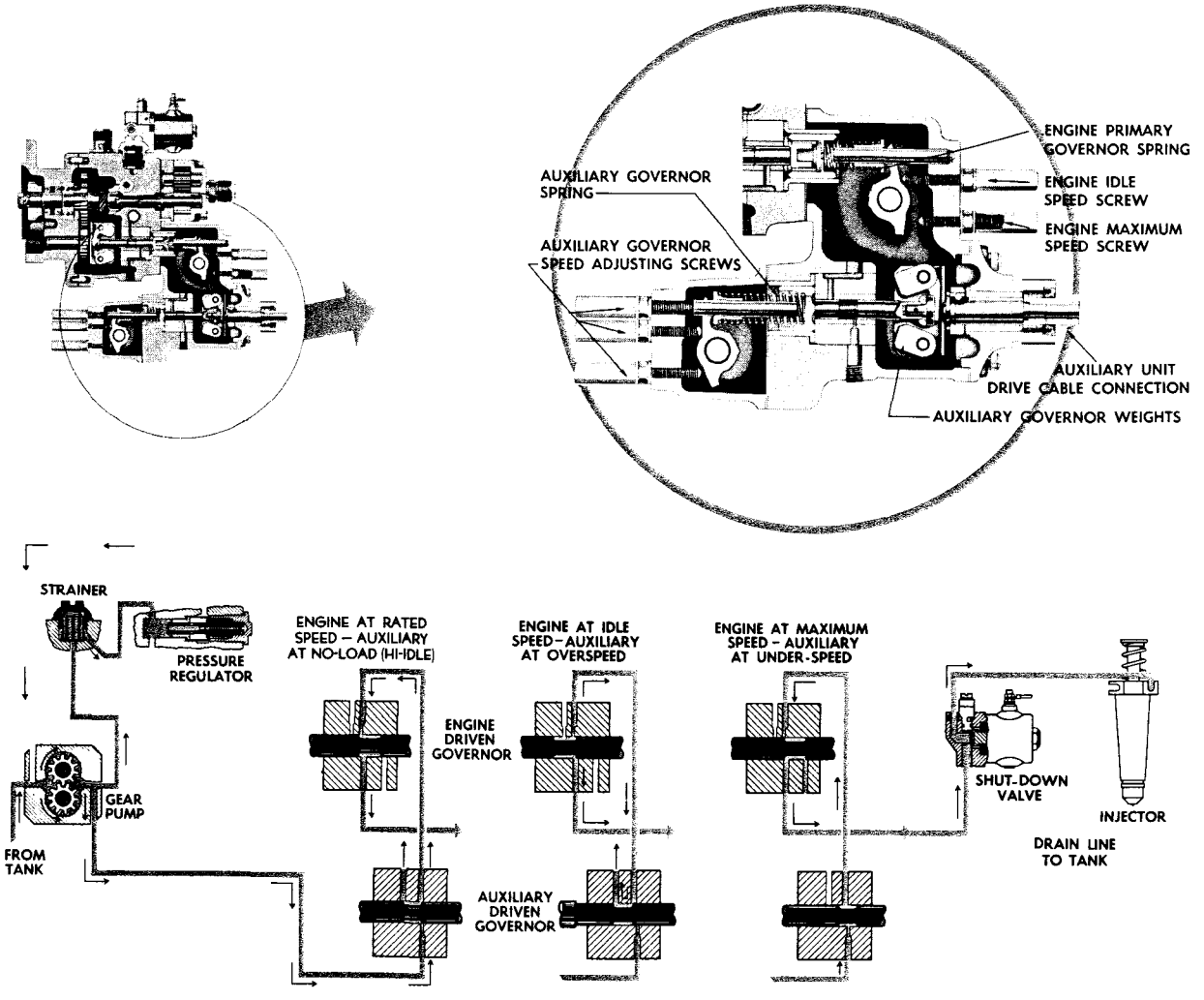


Fig. 1-6. Cross section and fuel flow through torque convertor governor and fuel pump

The converter driven governor works on the same principle as the standard engine governor except it cannot cut off fuel to the idle jet in the engine driven governor. This insures that if the converter tailshaft overspeeds it will not stop the engine.

Fig. 1-6 shows the position of the governor plungers under different engine and converter speed conditions.

INJECTORS:

Fuel circulates through the injector at all times except during a short period following injection into the cylinder. From the inlet connection, fuel flows down the inlet passage of the injector, around the injector plunger, between the body end and cup, up the drain passage to the drain connections and manifold and back to the supply tank.

As the plunger rises, the metering orifice is uncovered and part of the fuel is metered into the cup. At the same time, the rest of the fuel flows out of the drain orifice. The amount of fuel passing through the metering orifice and into the cup is controlled by fuel pressure, regulated by the fuel pump.

During injection, the plunger is forced downward until the metering orifice is closed and the fuel in the cup is injected into the cylinder. While the plunger is seated all fuel flow through the injector stops. Fig. 1-8.

Some injectors contain adjustable feed orifices located in the fuel inlet passages, Fig. 1-7. The size of this orifice regulates fuel flow to the injector.

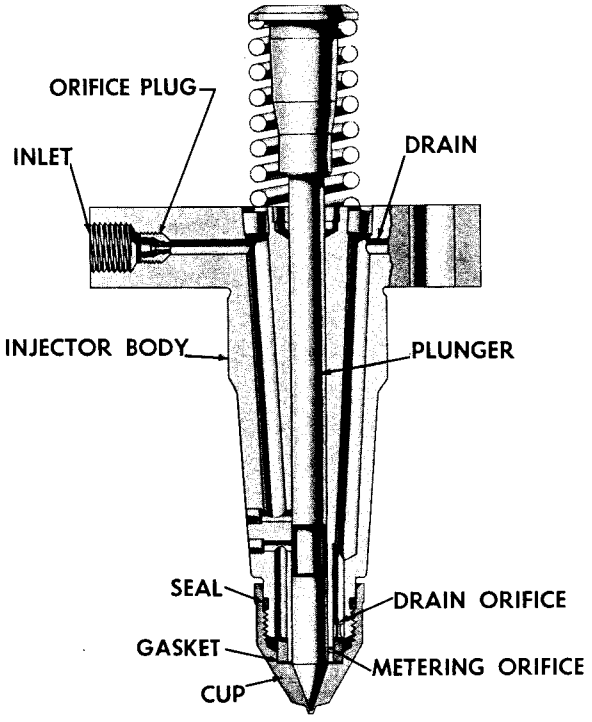


Fig. 1-7. Injector cross section

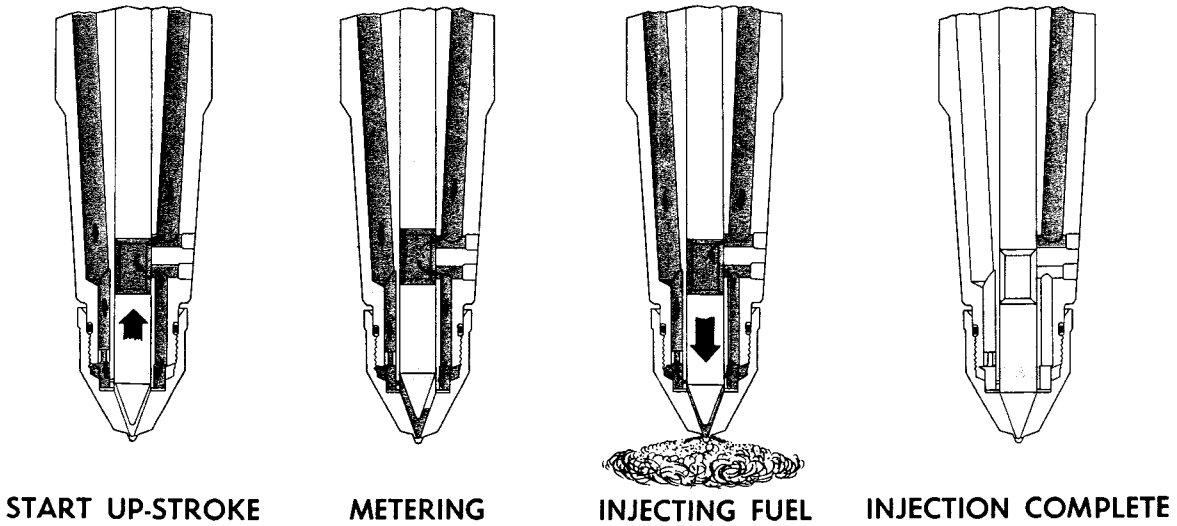


Fig. 1-8 Fuel injection cycle

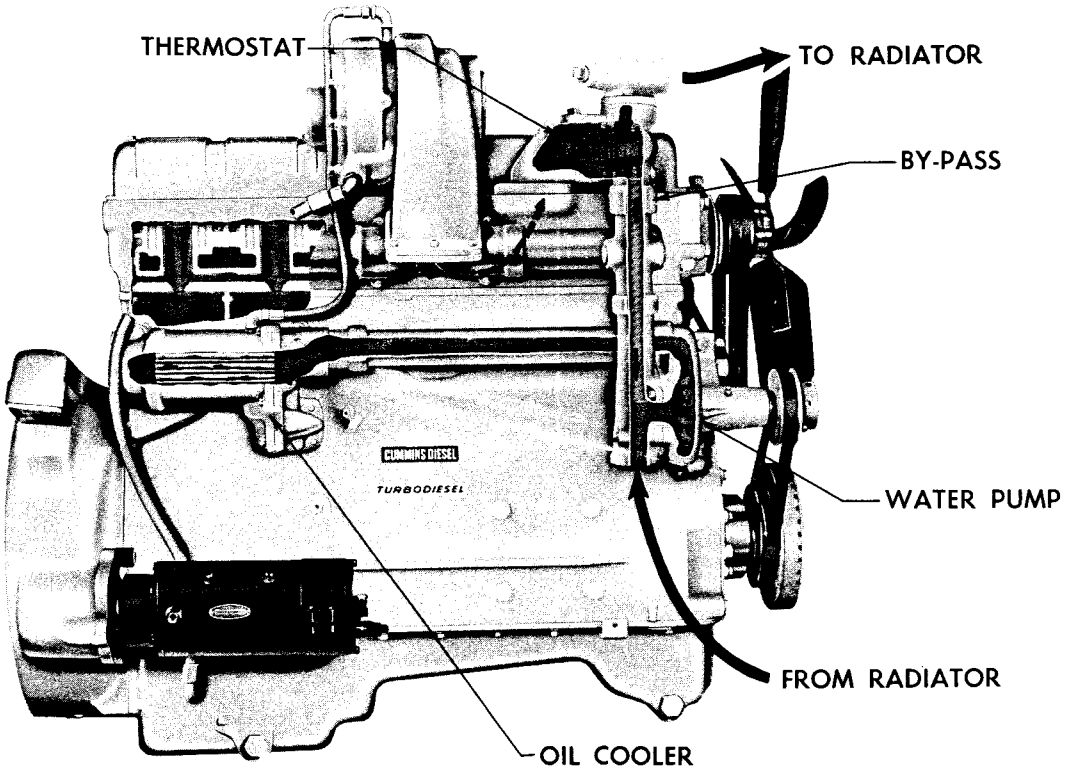


Fig. 1-9. C-175 TURBODIESEL cooling system

FUEL LINES AND VALVES:

Shut-Down Valve:

Manual Type: The shut-down valve is located on top of the fuel pump and is used to shut down the engine. This is a push-pull type valve. In other words, push in to permit fuel to flow to injectors; pull to shut off the fuel. It is important to keep this valve in the off position at all times the engine is not running.

Electric Solenoid Type: The electric solenoid shut-down valve permits the fuel to be shut off or turned on through the use of a switch key similar to that used in automotive ignition systems. Fig. 1-1.

Supply Lines:

Fuel supply lines must be held to a specified size to insure an even pressure and supply of fuel to each injector. From the supply lines, fuel enters the inlet connection to the injector. Fig. 1-1.

Inlet Connections:

The inlet connection connects the supply fuel manifold to the injector and contains a fine mesh screen at the large or cage end. This screen is the last protection against dirt entering the injector. There are no check valves in the inlet connection used in the PT fuel system. Fig. 1-1.

Drain Lines:

Not all the fuel entering the injector is burned in the cylinder. Part of the fuel circulates through the injector and is returned to the supply tank through the drain fittings, drain manifold and drain line. The drain lines must also be ample size to provide free drainage to the fuel tank. Fig. 1-1.

THE COOLING SYSTEM

Water is circulated by a centrifugal-type water pump mounted on the exhaust side of the engine, and driven by the supercharger or belts.

The water circulates around each of the wet-type cylinder liners, through the cylinder head and around the injector sleeves in the cylinder head. The injector sleeves, into which the injectors are mounted, are made of copper for fast dissipation of heat.

A single large thermostat is used to control the operating temperature of the engine.

The engine cooling solution is cooled by the radiator, or on marine engines, by the heat exchanger.

Where heat exchangers are used, a sea-water pump is mounted on the engine and circulates sea water inside the tubes of the heat exchanger. The engine's fresh water supply circulates around these tubes.

THE AIR SYSTEM

The supercharger and turbocharger force additional air into the combustion chambers so the engine can burn more fuel and develop more horsepower than if it were naturally-aspirated. C-180 is equipped with a supercharger while the C-175 and C-200 are turbocharged.

SUPERCHARGER:

A supercharger is a gear driven air pump which uses rotors instead of gears (like a gear type fluid pump) to force air into the engine cylinders. The supercharger is driven from the engine crankshaft through a gear train turning at about 1.8 engine speed. Fig. 1-10.

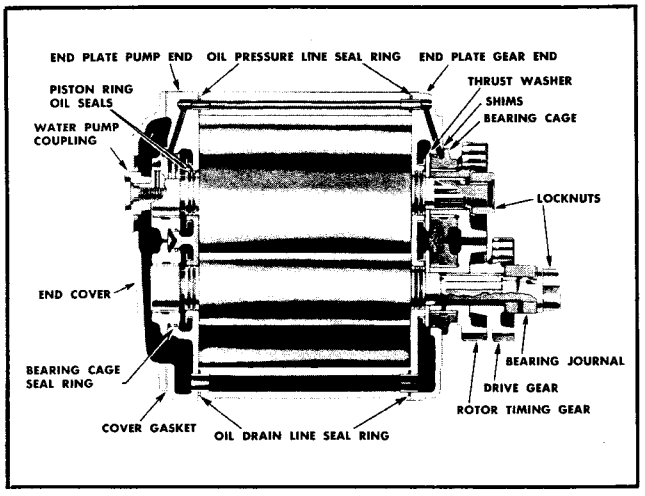


Fig. 1-10. Cutaway view of supercharger

TURBOCHARGER:

The turbocharger consists of a turbine wheel and a centrifugal blower impeller, or compressor wheel, separately encased but mounted on and rotating with a common shaft.

The power to drive the turbine wheel (which in turn drives the compressor) is obtained from the energy of the exhaust gases. The rotating speed of the turbine changes as the energy level of the exhaust gas changes so the engine is supplied with enough air to burn the fuel for its load requirement. Fig. 1-11.

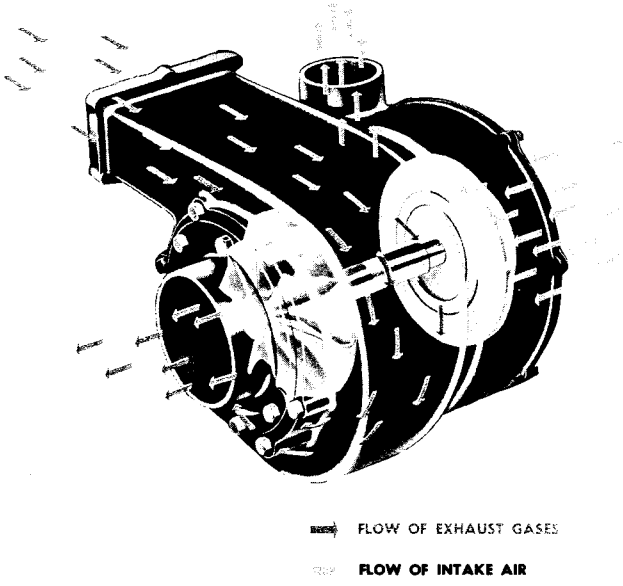


Fig. 1-11. Cutaway view of turbocharger

OTHER ENGINE UNITS

HYDRAULIC GOVERNOR:

Hydraulic governors are used on stationary power applications where it is desirable to maintain a constant speed with varying loads.

The Woodward SG hydraulic governor uses lubricating oil, under pressure, as an energy medium. It is supplied from a sump on the governor drive housing.

The governor acts through oil pressure to increase fuel delivery. An opposing spring in the governor control linkage acts to decrease fuel delivery.

In order that its operation may be stable, speed droop is introduced into the governing system. By speed droop is meant the characteristic of decreasing speed with increasing load. The desired magnitude of this speed droop varies with engine applications and may easily be adjusted to cover a range of approximately one-half of one percent to seven percent.

Assume that a certain amount of load is applied to the engine. The speed will drop, the flyballs will be forced inward and will lower the pilot valve plunger. This will admit oil pressure underneath the power piston, which will rise. The movement of the power

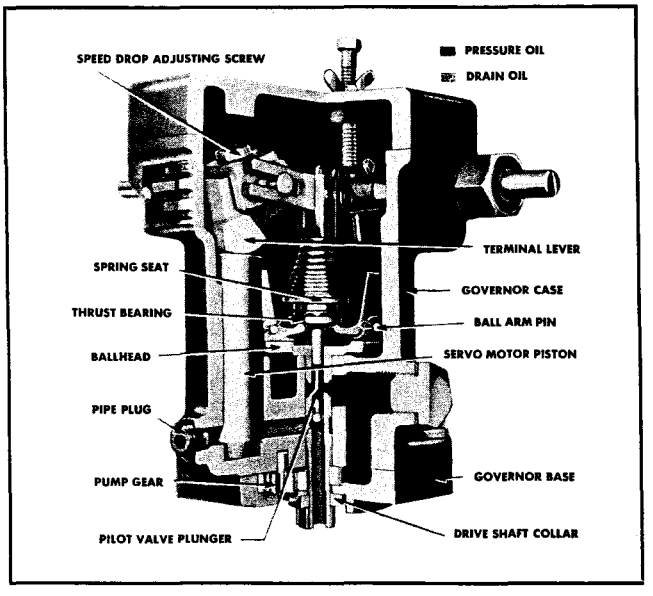


Fig. 1-12. Load off, speed increased position

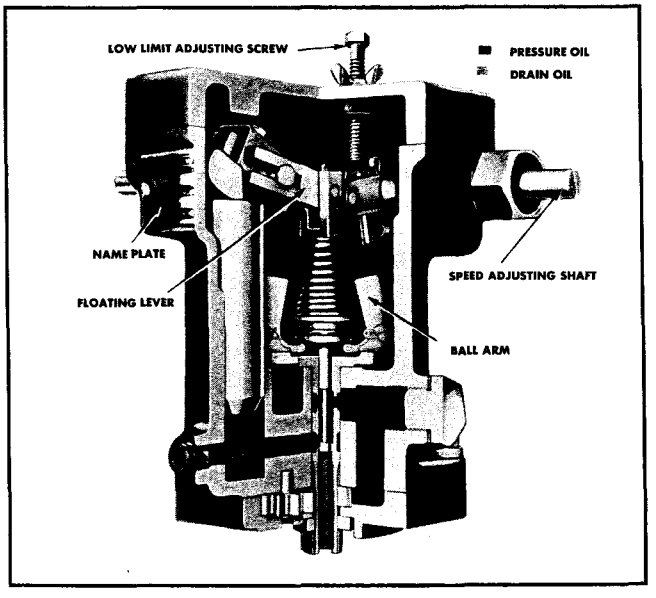


Fig. 1-13. Load on, speed decreased position

piston is transmitted to the terminal shaft by the terminal lever. Rotation of the terminal shaft causes the fuel setting on the engine to be increased. See Fig. 1-12.

If the governor is to be used for constant speed service, speed adjustment may be made by setting the low limit adjustment screw. Rotation of the speed adjustment shaft increases or decreases the compression on the speeder spring.

Rotating the speed adjusting shaft sufficiently far in the decrease speed direction opens the area under the power piston to drain and enables the fuel return spring to shut off the fuel completely, thus shutting down the engine.

BASIC ENGINE MODELS TREATED IN THIS MANUAL

Engine Models	Engine Breathing	Number Cylinders	Bore & Stroke	Cu. In. Displ.	Torque Ft. Lbs. @ RPM	Maximum HP @ RPM*
C-90	Natural	4	4 7/16 x 5	310	246 @ 1450	90 @ 2000
C-105	Natural	4	4 7/16 x 5	310	246 @ 1500	105 @ 2500
C-140	Turbocharged	4	4 7/16 x 5	310	325 @ 1700	140 @ 2500
C-160	Natural	6	4 7/16 x 5	464	376 @ 1400	160 @ 2500
C-175	Turbocharged	6	4 7/16 x 5	464	405 @ 1750	175 @ 2500
C-180	Supercharged	6	4 7/16 x 5	464	425 @ 1700	180 @ 2500
C-200	Turbocharged	6	4 7/16 x 5	464	465 @ 1700	200 @ 2500

* Based on 29.92" Hg. Barometric Pressure (Sea Level), 60° Fahrenheit Air Intake Temperature, Dry Air

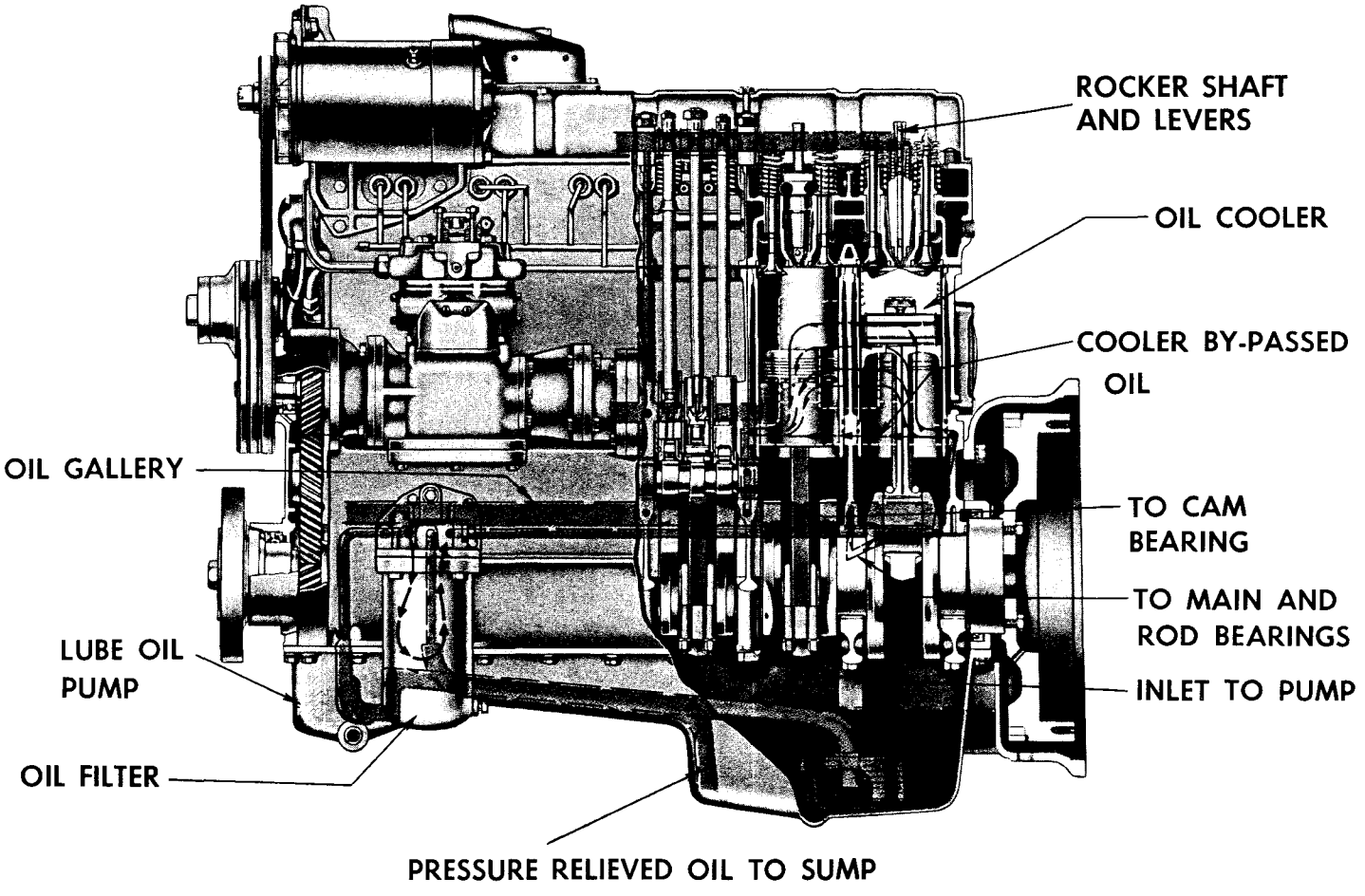


Fig. 1-14. Cross section of C-180 engine, side view

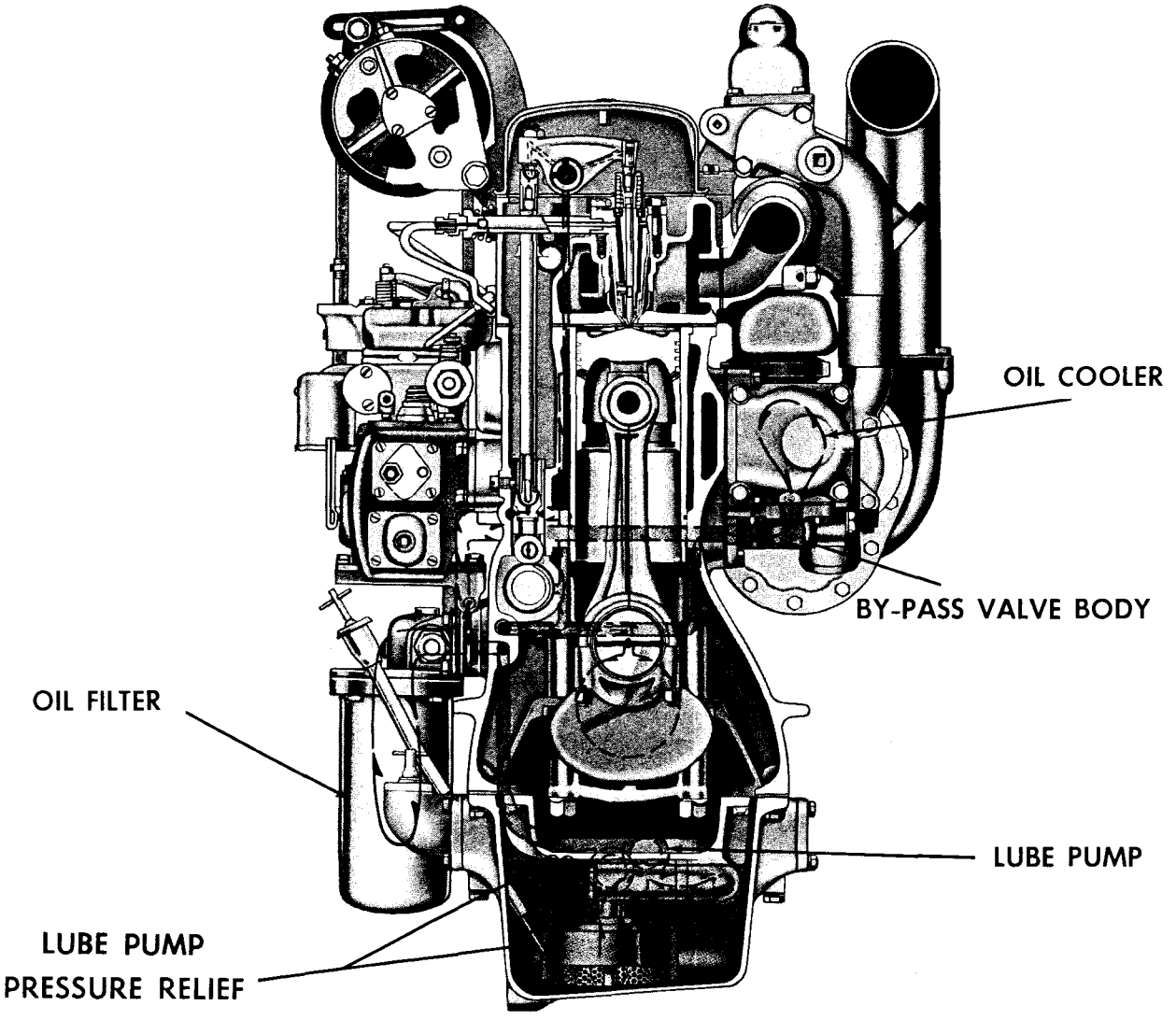


Fig. 1-15. Cross section of C-180 engine, end view

CUMMINS

C SERIES DIESEL ENGINES

Section II

OPERATING INSTRUCTIONS

The operator of the engine assumes the responsibility of engine care while it is being worked. This is an important job and one that will determine to a large degree the extent of profit from the operation.

There are comparatively few rules which the operator must observe to get the best service from the Cummins Diesel. However, if any of these rules are broken, a penalty is certain to follow. The penalty may be in lack of work accomplished because of lowered engine efficiency or it may be in down time and costly repair bills resulting from premature engine failure.

NEW ENGINE BREAK-IN

The way you operate your new engine during the first 50 to 100 hours' service will have an important effect on the life of the engine and its parts. Its moving parts are closely fitted for long service, and even though all Cummins engines are run on a dynamometer for several hours before they leave the factory, an additional period may be required before uniform oil films are established between all mating parts.

During the first 50 to 100 hours' service:

1. Operate most of the time at one-half to three-quarters throttle. Do not operate at maximum horsepower for more than five or ten minutes at a time.
2. Do not idle the engine for long periods, because this will cause cylinder walls to glaze before the piston rings seat properly, and the engine will continue to use too much lubricating oil.
3. Keep a close watch on your instruments. Back off on throttle if oil temperature reaches 200° F. or if water temperature exceeds 185° F.
4. Drive in a gear low enough so you can accelerate under any condition.

PRE-STARTING CHECKS

CHECK LUBRICATING OIL SUPPLY:

1. A dip stick oil gauge is located on the side of the engine. The dip stick supplied with the engine has a high "H" and low "L" level mark to indicate lubricating oil supply. The dip stick must be kept with the

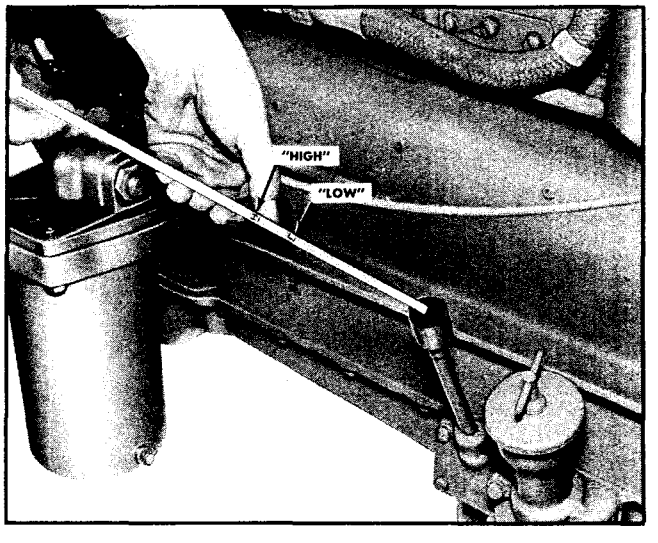


Fig. 2-1. Checking lubricating oil supply

oil pan, or engine, with which it was originally supplied. Cummins oil pans differ in capacity with different type installations and oil pan parts numbers.

2. Keep oil level as near the high level mark as possible. Never operate the engine with oil level below the low level mark.

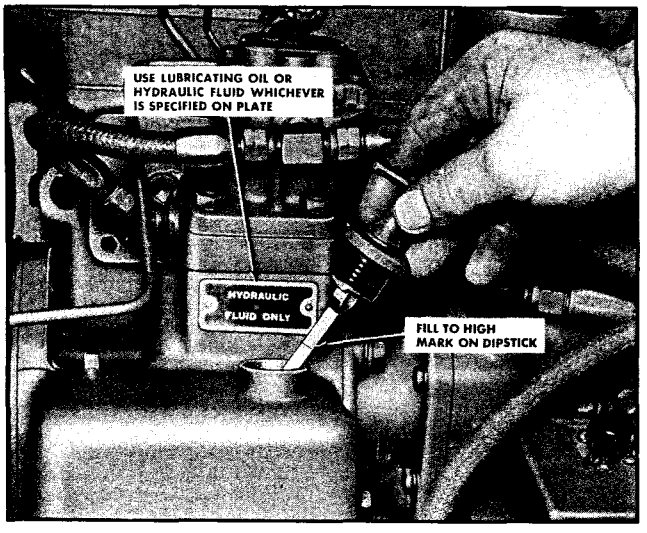


Fig. 2-2. Oil level in hydraulic governor sump

CHECK HYDRAULIC GOVERNOR, IF USED:

1. Many engines used in stationary power applications are equipped with hydraulic-governed fuel pumps. This governor uses lubricating oil (of the same weight as used in the engine) as an energy medium.

2. Oil level in governor sump must be at full mark on dipstick. Fig. 2-2.

CHECK AIR CONNECTIONS:

Check the air connections to the compressor and brake equipment, if used, and to the air cleaners.

CHECK ENGINE COOLANT SUPPLY:

1. Remove the radiator cap and check the engine coolant supply. Add coolant as needed to completely fill the system.

2. There are several recognized methods of protecting engine cooling systems from rust and corrosion. These methods are described on Page 3-16. under "Coolant Treatment."

CHECK INJECTOR PLUNGER AND VALVE ADJUSTMENTS:

If valve and injector adjustments have been disturbed by any maintenance work, it is important that they be properly adjusted before starting the engine. Otherwise, adjustments are required only at every fourth oil change, or "D" check.

CHECK FUEL SUPPLY AND CONNECTIONS:

Make sure there is an adequate supply of good clean No. 2 diesel fuel. See "Fuel Oil Specifications," Page 3-14.

STARTING THE ENGINE

There is no mystery about starting a Cummins Diesel Engine. Starting requires:

1. An air supply to the combustion chambers.
2. A fuel supply to the combustion chambers.
3. Compression of the air for ignition.

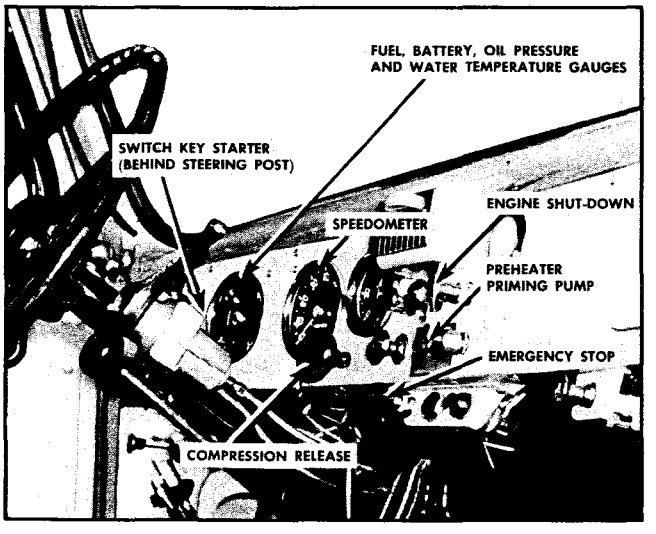


Fig. 2-3. Instrument panel

NORMAL STARTING PROCEDURE:

1. Set throttle for idle speed.
2. Release the clutch.
3. If you have a manual fuel shut-off valve, open it.
4. Pull the compression release on those engines so equipped.
5. Press the starter button or turn switch-key to "start" position. A manual over-ride button is provided on the forward end of the electric shut-

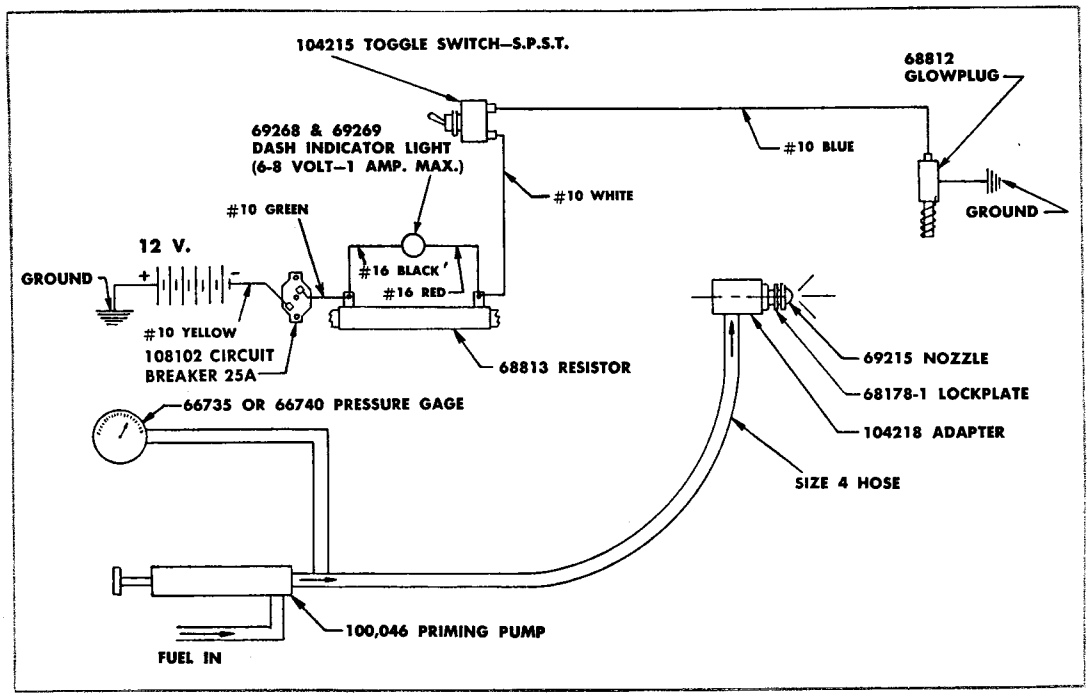


Fig. 2-4. Preheater wiring diagram

down valve above the fuel pump. It allows the valve to be opened in case of electric power failure. To use, push in button and lock by turning to right.

6. After three or four seconds of cranking, close the compression release (if so equipped) and continue to crank until the engine fires.

On some generator sets where main generator current is used to actuate the pump shut-off valve you must start the engine by using the manual override button, and then disengage the button to allow the engine safety circuit to take over pump and engine control. This arrangement is usually used with air starting systems.

CAUTION: DO NOT CRANK ENGINE FOR MORE THAN 30 SECONDS CONTINUOUSLY OR YOU MAY BURN OUT THE CRANKING MOTOR. IF ENGINE DOES NOT FIRE WITHIN THE FIRST 30 SECONDS, WAIT TWO TO FIVE MINUTES BEFORE RE-CRANKING.

USE THE PREHEATER FOR COLD WEATHER STARTING:

An intake air preheater arrangement is available as an aid in starting the engine when the ambient temperature is 50° F. or below. This equipment consists of a hand priming pump to pump fuel into the intake manifold, a glow plug electrically heated by the battery, and a switch to turn on the glow plug when fuel is pumped into the intake manifold. The fuel burns in the intake manifold and heats the intake air.

CAUTION: DO NOT USE ETHER IN CONJUNCTION WITH THE PREHEATER.

To use the preheater for cold starting follow this starting procedure:

1. Set throttle in idle position. *Do not accelerate engine during the starting procedure.*
2. Turn glow plug toggle switch to "ON" position. Red indicator light must be on.
3. After red light has been on for 20 seconds, start cranking the engine. As soon as engine begins rotating, operate the preheater priming pump to maintain 80 to 100 psi fuel pressure. Use of primer before the 20-second interval will wet glow plug and prevent heating.

NOTE: On engines equipped with an oil pressure safety switch, the fuel by-pass switch must be in "start" position before operating priming pump.

4. If engine does not start within 20 seconds, stop cranking. Wait 30 seconds, and repeat cranking operation.

NOTE: On engines with an oil pressure safety switch hold the fuel by-pass switch in "start" position

until engine oil pressure reaches 7 to 10 psi; then move to "run" position.

5. After engine starts, pump primer slowly to keep engine *idling* smoothly. In cold weather this may require 4 to 5 minutes, or longer. *Do not accelerate engine.*
6. After engine has warmed up until it does not falter between primer strokes, stop pumping. Close primer and lock. Turn off glow plug toggle switch. (Red indicator light will go off.)

Failure to Start:

1. If the engine gives no indication of starting during the first three full strokes of the preheater pump, check the intake manifold for heat. If there is no heat, check electric wiring. If wiring is all right, remove ⅛" pipe plug from manifold near glow plug and check flame while a helper performs the preceding steps 2, 3 and 4.

2. If no flame is observed, close glow plug manual switch 15 seconds and observe glow plug through ⅛" pipe plug hole. The glow plug should be white hot; if not, connect glow plug to a six-volt source and check amperage which should be 30 (minimum). If glow plug is all right, check manual switch and resistor and replace if necessary.

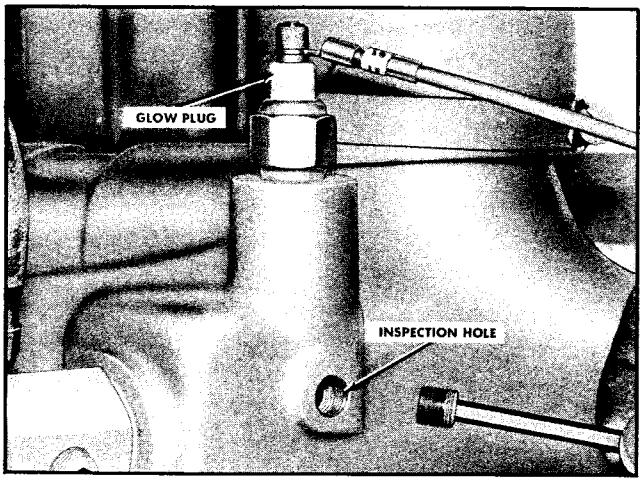


Fig. 2-5. Inspect glow plug

3. If glow plug is white-hot, and no flame is observed, remove the fuel nozzle and clean.

OTHER COLD STARTING AIDS:

Ether Compound Metering Equipment

This consists of an ether compound metering chamber to release ether into the air intake and aid in cold starting. To start engine:

1. Close shut-off cock. If properly installed, spring will hold it closed.
2. Remove cap, insert ether capsule then push cap down sharply, puncturing capsule. Tighten cap.
3. Wait 30 seconds. Engage starter, then open shut-off valve.

CAUTION: DO NOT OPEN SHUT-OFF VALVE BEFORE CRANKING ENGINE.

4. After engine starts, close shut-off valve.
5. Discard empty capsule, reassemble primer.

Use of Ether Without Metering Equipment

If engine is *not* equipped with preheater or ether metering equipment, two men can use the following method as a cold starting aid. One will crank the engine — the other will apply ether to air intake.

CAUTION: ETHER IS HIGHLY FLAMMABLE. DO NOT USE WITH PREHEATER OR NEAR OPEN FLAME. DO NOT BREATHE ETHER FUMES.

1. Pour three tablespoonfuls of ether on a cloth; hold cloth close to air cleaner or spray ether into air cleaner from spray can while operator cranks the engine.

CAUTION: DO NOT USE TOO MUCH ETHER. THIS WILL CAUSE EXCESSIVELY HIGH PRESSURES AND DETONATION.

2. Ether fumes will be drawn into the intake air manifold and the cold engine should start without difficulty.

CAUTION: BE SURE CLOTH IS OUTSIDE THE AIR CLEANER AND CAN NOT BE DRAWN INTO THE ENGINE.

ENGINE WARM UP

WARM UP ENGINE BEFORE APPLYING LOAD:

When the engine is started, it takes a while to get the lubricating oil film re-established between shafts and bearings and between pistons and liners. The most favorable clearances between moving parts are obtained only after all engine parts reach normal operating temperature.

Avoid seizing pistons in liners and running dry shafts in dry bearings by bringing the engine up to operating speed gradually as it warms up. Allow the engine to run at 800 to 1000 rpm long enough to bring water temperature to at least 130° F. before engaging the load. During this time make all the necessary outside checks; load distribution, brakes, fifth wheel, air and electric couplings, tires, etc. During the next 10 to 15 minutes, or until water temperature reaches 160°/165° F. operate at partial load and at not more than 1800 rpm.

APPLY LOAD GRADUALLY:

Always start the load moving in a gear low enough so you can accelerate to governed rpm, then catch the next gear as you decelerate. Do not skip gears while you are getting up to cruising speed.

Shock loads take their toll of tires and transmissions as well as being hard on the engine. Apply load gradually.

ENGINE SPEEDS

OPERATE AT REDUCED RPM FOR CRUISING OR CONTINUOUS-DUTY:

The governed full-load rpm of C Series engines is shown in the table below. This maximum-speed rating is for intermittent duty only, and it must be reduced for continuous duty.

TABLE: ENGINE SPEEDS

Governed Full Load RPM		Cruising or Continuous Duty RPM
C-90	2000	1675 to 1725
C-105	2500	2100 to 2150
C-140	2500	2100 to 2150
C-160	2500	2100 to 2150
C-175	2500	2100 to 2150
C-180	2500	2100 to 2150
C-200	2500	2100 to 2150

When you are operating a truck on a level highway, or cruising, hold engine rpm at approximately 85 percent of governed rpm. See table. This will give you adequate power for cruising and economical fuel mileage.

Engine governors are set for reduced rpm for continuous-duty operation.

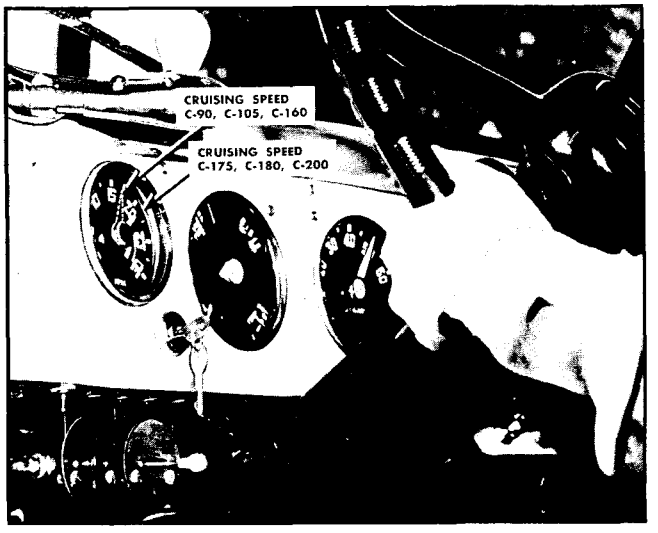


Fig. 2-6. Cruise at 85% governed rpm

Governed Speeds:

All Cummins engines are equipped with governors to prevent speeds in excess of maximum ratings.

The governor has two functions: First, it provides the exact amount of fuel needed for idling when the throttle is in idling position. Second, it overrides the throttle and shuts off fuel if engine rpm exceeds the maximum rated speed.

THE INSTRUMENT PANEL

OPERATE BY YOUR INSTRUMENTS:

It makes no difference whether your engine is in a truck, in a boat or on some other type operation; you need to use the panel board instruments. The instruments tell you at all times what you need to do to get the most satisfactory service from your engine.

USE THE TACHOMETER:

Governed engine speed is the maximum rpm which a properly adjusted governor will allow the engine to turn under full-load.

Never override the governor, or allow engine to exceed the governed rating while out of gear, operating at partial load, or driving down hill.

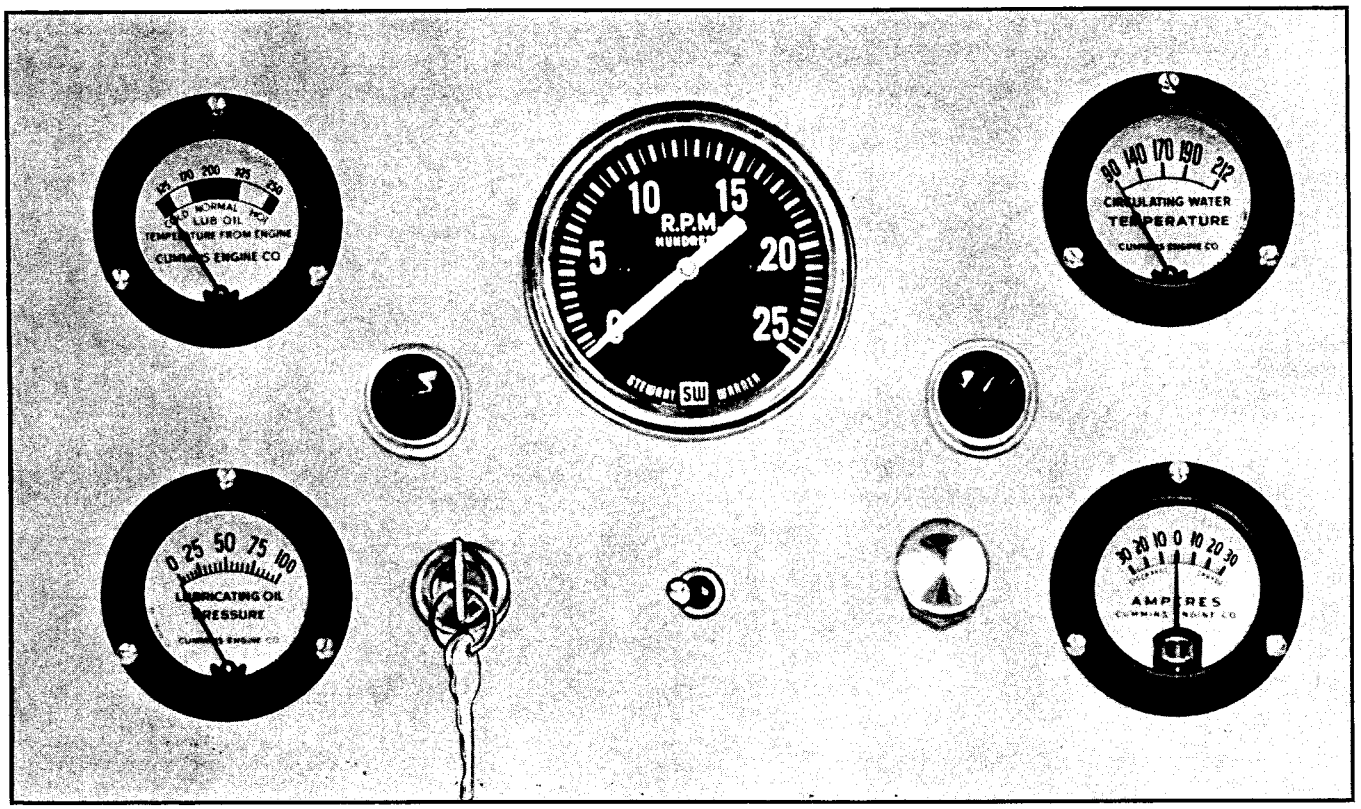


Fig. 2-7. Instrument Panel

Drive at partial throttle on a level highway to give you the road speed you require and with the tachometer showing rpm approximately 15% below governed speed.

Most of your miles will be this kind of driving. The engine will not be working hard, and you will be operating in the easy-shift range.

Many trucks are geared for higher maximum road speeds than schedules require, so drivers can cruise in high gear and at reduced engine rpm. This is good practice as long as the engine pulls its load at partial throttle.

THE OIL TEMPERATURE GAUGE INDICATES BEST DRIVING RANGE:

Your oil temperature guage normally should read between 180° F. and 200° F. for best lubrication. Under full-load conditions, a temperature of 225° F. for a short period is not to be considered cause for alarm.

Any sudden increase in oil temperature which is not caused by load increase is a warning of possible mechanical failure, and it should be investigated at once.

During warm-up period apply load gradually until oil temperature reaches 170° F. While oil is cold it does not do a good job of lubricating. Also, if you operate continuously with oil temperatures much below 170° F., you are likely to have crankcase dilution and acids in the lubricating oil which will accelerate wear tremendously.

KEEP WATER TEMPERATURE BETWEEN 165°F. AND 185°F.:

A water temperature of 165° F. to 185° F. is the best assurance that cylinder liners are heated to the proper temperature to support good combustion, and that working parts of the engine have expanded evenly for the most favorable oil clearances.

Engines should be warmed up slowly before applying full load so that pistons will not expand too fast for the cylinder liners. Most cases of piston and liner scoring start from throwing full load on a cold engine.

When water temperature is too low the cylinder walls retard heating of air during the compression stroke and delay ignition of fuel. This causes dilution

of lubricating oil, fuel knocks, incomplete combustion, exhaust smoke, and high fuel consumption.

Keep thermostats in the engine summer and winter, avoid long periods of idling, and do whatever else is required to keep water temperatures up to a minimum of 165° F. If necessary in cold weather, use radiator shutters or cover a part of the radiator to prevent over-cooling.

Of course there is also the problem of over heating but that requires mechanical correction. It may be caused by loose water pump belts, a clogged cooling system, or insufficient radiator capacity. Report cases of overheating to the maintenance department for correction.

KEEP AN EYE ON YOUR OIL PRESSURE GAUGE:

First of all your oil pressure gauge shows whether you have a supply of lube oil. A good operator will note loss of oil pressure immediately and shut down the engine before the bearings are ruined.

The oil pressure guage also indicates the condition of lubricating oil. If pressure drops between oil changes it may be due to dilution, to a clogged suction line, or to an internal oil leak. Always investigate and determine cause of decreased oil pressure.

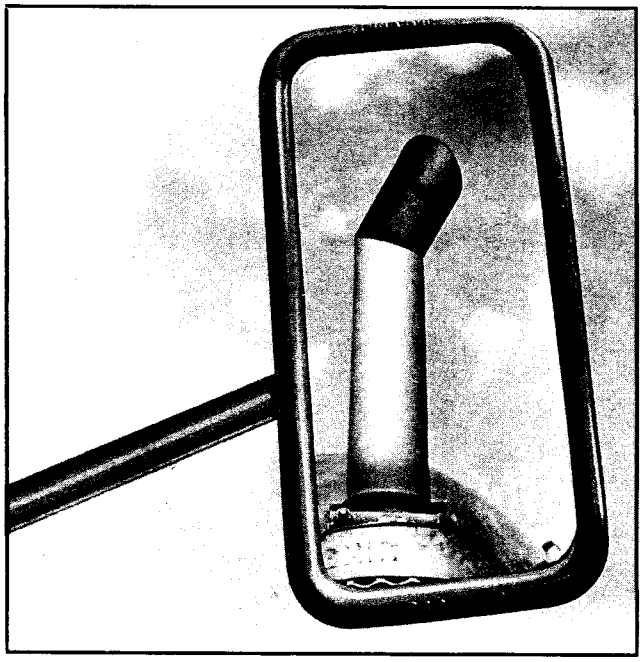


Fig. 2-8. Watch your exhaust

OBSERVE ENGINE EXHAUST:

One of the most valuable instruments is a rear view mirror which will let you observe the exhaust stack. A smoky exhaust may be due to a poor grade of fuel, dirty air cleaner, or poor mechanical conditions.

If your exhaust is smoky, change to a lower gear.

MAXIMUM HORSEPOWER REQUIREMENTS

Maximum horsepower is attained only at maximum, or governed, engine rpm. Whenever you pull down engine rpm by overload you start losing horsepower, and you continue to lose it as long as the engine continues to lose rpm. When you need full horsepower, operate your engine near the governor. This rule applies to any kind of application.

Torque converters and combinations of electric generators and motors often are applied to transmit power from the engine to its driven unit. When properly applied, these devices automatically compensate for load changes by trading shaft speed for increased torque without allowing engine rpm to be pulled down by more than 10% to 15%.

WHEN YOU NEED MORE POWER SHIFT TO A LOWER GEAR AND INCREASE ENGINE RPM:

Here is one rule that sums up everything you need to observe about proper selection of gears to give you the power you need and best performance from your equipment:

Always operate in a gear low enough to allow the engine to accelerate to, or maintain, governed RPM when you advance to full throttle.

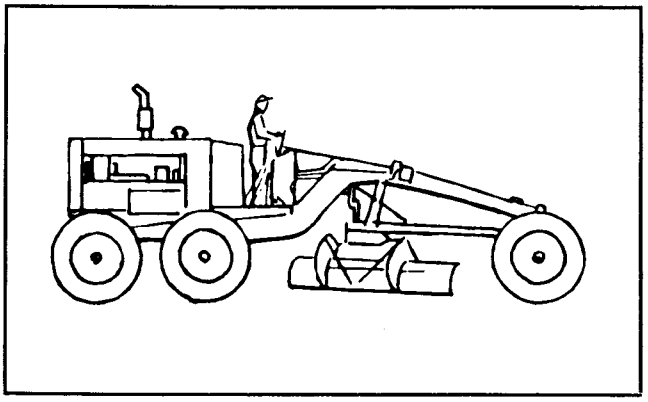


Fig. 2-9. Change gears for more power

When you approach a hill you know that you will require more torque at the wheels, so shift to a lower gear, and rev up the engine near the governor. This will give you the additional horsepower you need without loss of road speed.

SHIFT TO A LOWER GEAR WHEN THE LOAD PULLS DOWN ENGINE RPM AS MUCH AS 10%:

If the grade gets steeper and load starts to pull down engine rpm, just treat that part of the grade like another hill and shift to a still lower gear.

Never allow engine rpm to drop more than 10 percent below the governor at full-throttle before you start shifting. If you cannot catch the next gear at the 10 percent drop, let up on the throttle until you get the right rpm for the shift, but at full-throttle do not pull down engine rpm more than 10 percent.

The practice of shifting gears — next to safety observance — is the most important phase of good driving.

HIGH ALTITUDE OPERATION

You lose horsepower when you drive at high altitude because the air is too thin to burn as much fuel as at sea level. The loss is about 3 percent for each 1000 feet of altitude on all but turbocharged engines. See table, Page 1-10.

OPERATE IN LOWER GEARS AT HIGH ALTITUDE:

You are sure to have a smoky exhaust in the mountains unless you use a gear low enough so your engine will not demand full-fuel from the fuel system.

Smoke wastes fuel, burns valves and exhaust manifolds, and "carbons up" piston rings and injector spray holes. Shift gears as needed to avoid smoking, and to avoid overspeeding of turbocharger.

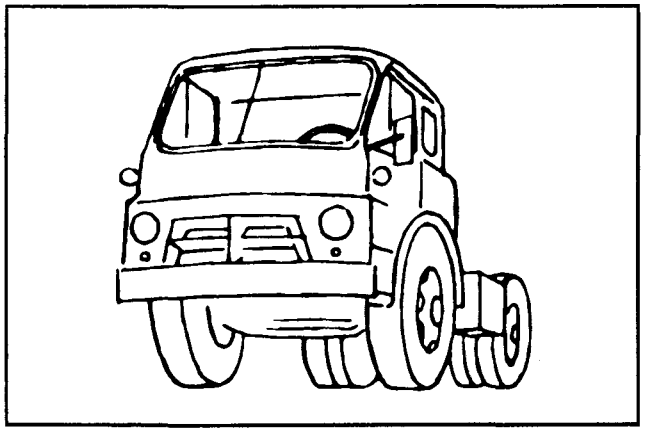


Fig. 2-10. Let engine idle

DOWN-HILL OPERATION

Your Cummins Diesel is effective as a brake on downhill grades, but do not overspeed the engine going downhill. The governor has no control over engine speed when it is being pushed by the loaded vehicle.

Never turn off the switch key while going down hill because, with the engine still in gear, fuel pressure will build up against the shut-off valve and may prevent it from opening when the switch key is again turned on.

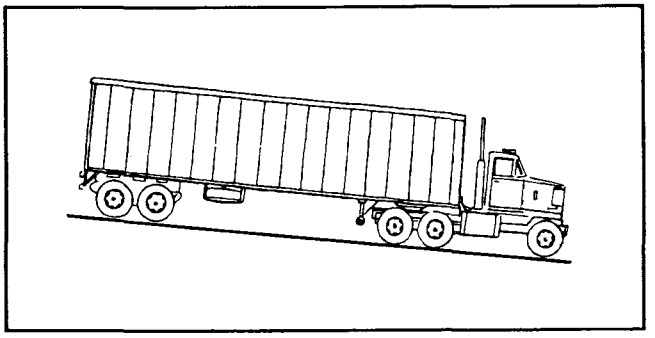


Fig. 2-11. Down-hill operation

USE BRAKES AS NEEDED TO PREVENT EXCESSIVE ENGINE SPEEDS:

Use a combination of brakes and gears to keep the vehicle under control at all times, and to keep engine rpm below its rated governed rpm.

ENGINE SHUT-DOWN

LET THE ENGINE IDLE A FEW MINUTES BEFORE SHUTTING IT DOWN:

It is important to idle an engine 3 to 5 minutes before shutting it down to allow lubricating oil and water to carry heat away from the combustion chamber, bearings, shafts, etc.

The turbocharger is the one unit containing bearings and seals that is subject to the high heat of combustion exhaust gases.

While the engine is running, the heat is carried away by oil and water circulation, but if the engine is stopped suddenly, the temperature of the turbocharger may rise as much as 100° F. above that reached during operation. The results of the extreme heat may be seized bearings or loose oil seals.

DO NOT IDLE THE ENGINE FOR EXCESSIVELY LONG PERIODS:

Long periods of idling are not good for the engine because operating temperatures will drop so low the fuel may not burn completely, and this will cause carbon to clog the injector spray holes and piston rings.

If engine coolant remains cold, raw fuel will wash lubricating oil off cylinder walls and dilute crankcase oil so all moving parts of the engine will suffer from poor lubrication.

If you are not using the engine, shut it down.

TURN SWITCH KEY TO "OFF" POSITION TO SHUT DOWN THE ENGINE:

The engine can be shut down completely by turning off the switch key on installations equipped with an electric solenoid valve, or by pulling out the manual shut-down lever.

Turning off switch key which controls electric shut-down valve always stops engine unless over-ride button on shut-down valve has been locked in open position. Refer to "Normal Starting Procedure," Page 2-2. Valve can not be reopened by switch key until after engine comes to complete stop.

Never leave switch key or over-ride button in valve-open or run position when engine is not running. With overhead tanks this would allow fuel to drain into cylinders causing a hydraulic lock.

DO NOT USE THE COMPRESSION RELEASE LEVER TO STOP THE ENGINE:

Some Cummins engines are equipped with a compression release lever. Pulling this lever lifts the intake valve push rods and opens the intake valves. The push rods will be pulled from their sockets, and extensive wear on the balls and sockets will result from using the compression release to stop the engine.

The compression release lever can be used as an aid in cranking, before starting, or while making injector and valve adjustments, but not to stop the engine.

STOP THE ENGINE IMMEDIATELY IF ANY PARTS FAIL:

Practically all failures give some warning to the operator before the parts "let go" and ruin the engine. Most engines are saved because alert operators heed warning signs (sudden drop in oil pressure, unusual noises, etc.) and immediately shut down the engine. A delay of ten seconds, after a bearing failure causes a knock, may result in a ruined crankshaft. Five seconds delay may be enough to cause a block to be perforated by a broken connecting rod.

Never try to make the next trip or another load after the engine warns you that something is wrong. It does not pay!

COLD WEATHER PROTECTION

ANTI-FREEZES:

For cold weather operation, we recommend use of permanent-type (ethylene-glycol) antifreeze with rust inhibitor.

DRAINING CYLINDER BLOCK:

To assure complete draining of the cylinder block and head, open the petcock on the water pump and the petcock on the side of the cylinder block midway to the rear of the engine and behind the water pump. If an air compressor is used, open the petcock beside the breather. See Fig. 2-12.

If the engine is to be stored, drain water from oil cooler, water cooled manifold, turbocharger and heat exchanger if these units are present. Failure to drain any of these units may cause serious damage in freezing weather.

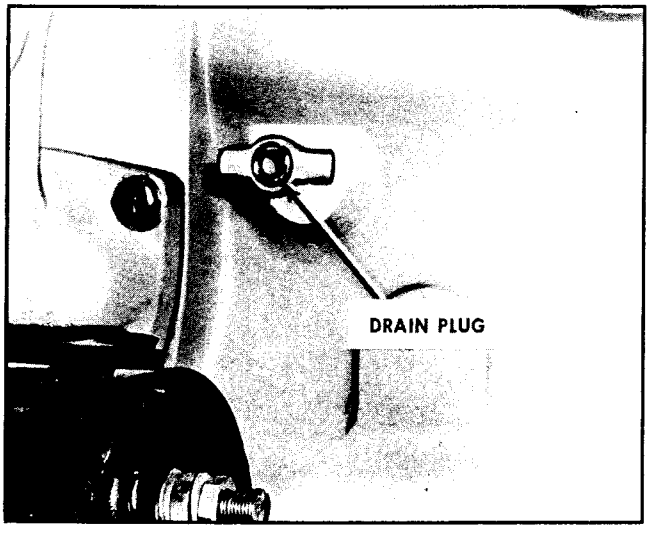


Fig. 2-12. Cylinder block drain plug

OPERATOR'S DAILY REPORT

MAKE A DAILY REPORT OF ENGINE OPERATION TO THE MAINTENANCE DEPARTMENT:

The engine must be maintained in top mechanical condition if the operator is to get the most satisfaction from its use. Engine adjustments, etc., are the work of the maintenance department. However, the maintenance department needs daily running reports from the operator to make necessary adjustments in the time allotted between runs and to make provisions for more extensive maintenance work as the reports indicate the necessity.

Comparison and intelligent interpretation of the day by day report will make it possible to eliminate practically all road failures and emergency repairs.

REPORT TO THE MAINTENANCE DEPARTMENT ANY OF THE FOLLOWING CONDITIONS:

Low lubricating oil pressure.

Low fuel pressures.

Abnormal water or oil temperature.

Unusual engine noise.

Excessive smoke.

GENERATOR SETS — PARALLEL OPERATION

In many cases where electric power is required, it may be advantageous to install two or more smaller generator sets instead of one single unit of higher rating. This condition also exists when it becomes necessary to increase the capacity of the existing plant by adding generator sets. When two or more generators are connected and operated together in such a way that they deliver electric energy to the system they are said to be operating in parallel. Parallel operation is considered successful when the generators deliver energy to the external system without delivering energy to each other.

To be suitable for parallel operation, the generating equipment selected must meet the following requirements:

1. The generator voltage and frequency ratings must be the same for all units.
2. The generators should have approximately the same waveform. Similar waveshapes are readily obtainable if machines are of similar type.
3. The generators should have similar voltage regulation characteristics.
4. The driving engines should have the same speed regulation characteristics. The governors should be adjusted to give the same speed droop when applying or removing the load.

CONNECTIONS

1. When two or more power units are to be operated in parallel they must be tied together electrically and connected to the load system. This interconnection is referred to as "The Bus."

2. The connecting cables or bus must be installed between the corresponding line terminals of each power unit. Thus L-1 on one unit will be connected to L1 on the second unit, L-2 to L2 and L3 to L3, etc. On 3-phase, 4-wire units, the L-0 terminals will also be connected together.

CAUTION: BOTH SETS MUST BE CONNECTED TO A COMMON GROUND. THIS IS MOST READILY ACHIEVED BY RUNNING A NO. 12 OR LARGER WIRE FROM THE GROUNDING TERMINAL ON THE HOUSING OF ONE SET TO THE GROUNDING TERMINAL ON THE OTHER SET. THIS WIRE SHOULD BE PROTECTED FROM MECHANICAL DAMAGE. IT NEED NOT BE INSULATED.

3. Bar positions on the sets' reconnection panels must be connected in the same way so that the output voltage of both sets will be the same.

4. Power units which are suitable for parallel operation will be equipped with necessary cross current compensation equipment to assure proper parallel operation.

INITIAL OPERATION:

Generator Test:

Before operating power units in parallel, each generator and regulator should be checked by starting and operating each unit individually.

1. Check engine, battery, generator and connecting cables in accordance with the operating procedure for single-unit operation as outlined in the technical manual belonging to the set in use.

CAUTION: WHEN CONDUCTING THESE PRELIMINARY TESTS NEVER CLOSE THE MAIN SWITCHES (OR CONTACTORS) OF BOTH SETS AT THE SAME TIME.

2. Check operation of the voltage regulators of each of the sets as described in the technical manual and adjust as described therein, if necessary.

Speed Droop Check:

Since it is important that both engines have the same speed droop characteristics, each set should be checked individually for speed droop and the governors adjusted, if necessary. This may be accomplished by using any load which does not exceed the rating of a single set. When a dummy load is not available, the use of the end item as a load may be resorted to if it is possible to put a steady load on the generator. Loads which vary, such as tracking antennas, should be avoided but acquisition antennas running at constant speed are acceptable loads.

1. Start one machine and adjust to standard no load speed (62 cycles for 60 cycle machines and 415 cycles for 400 cycle machines).
2. Adjust set to rated voltage operating under automatic voltage regulator control. Load set with as much steady state load as is available, up to the rated capacity of the machine.
3. Determine the frequency at which the set is operating under load.
4. Shut down first machine and repeat steps 1 and 2 above, on second machine.
5. In accordance with the instructions contained in the technical manual, adjust the governor droop characteristic of the second machine so that the set will be operating at the same frequency as the first machine when loaded with the same load.

PRELIMINARY TESTS:

Before operating two sets in parallel for the first time, two preliminary electrical tests should be made.

Phase Rotation Test:

Only generators connected together with the proper phase rotation (phase sequence) can be operated in parallel.

1. Connect units to bus as directed in paragraph "Connections" above.
2. Start both units leaving main switch or contactor on both sets open.

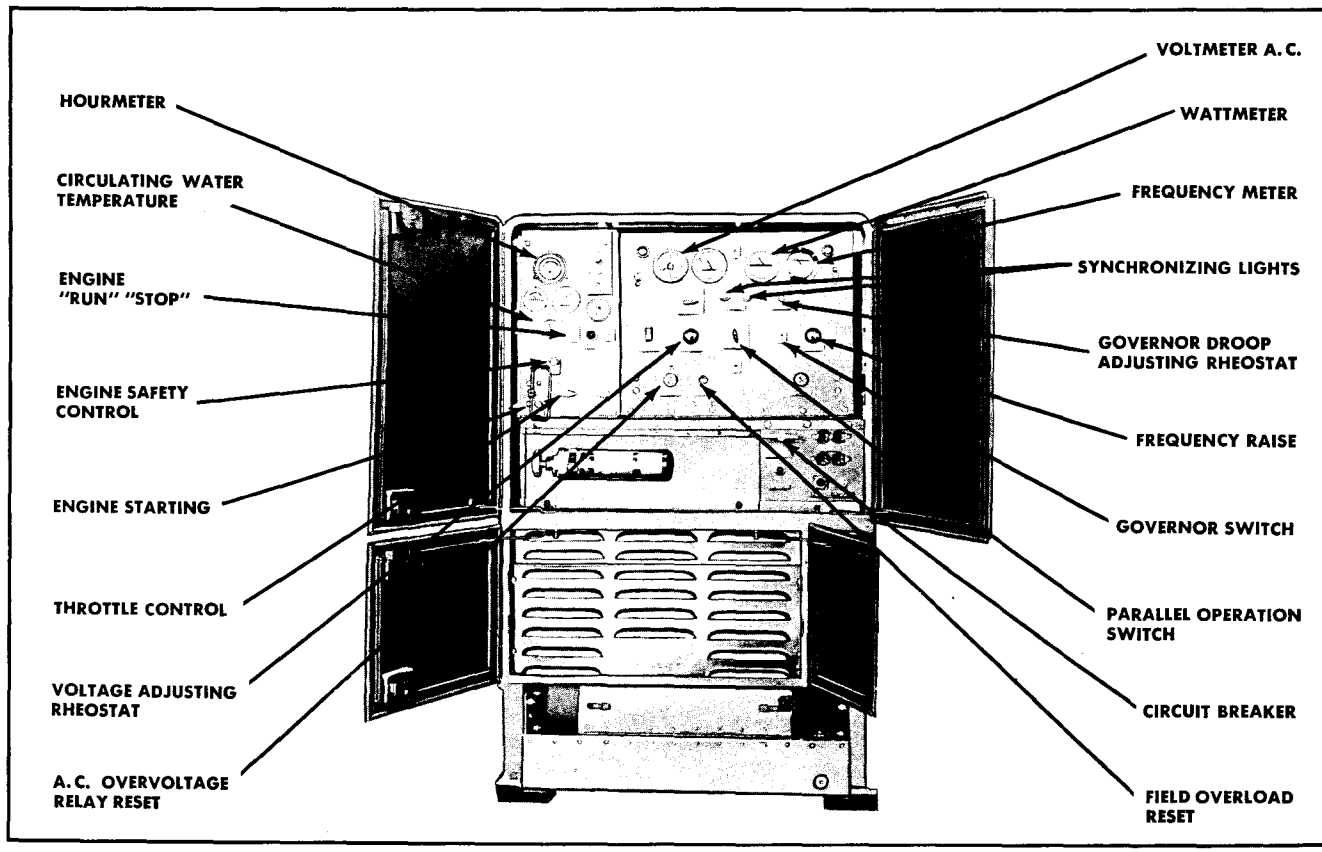


Fig. 2-13. Typical switch gear control panel

3. Adjust voltage on both sets to rated value by means of automatic voltage regulator rheostat.

4. Adjust both sets to same frequency (no load).

5. Close main switch on one set and turn on synchronizing lamp switch on the other machine.

6. If the phase sequence on both generators is the same, both synchronizing lights will light and go dark simultaneously. If the machines do not have the same phase sequence, at no time will both lamps be dark simultaneously; instead, the lamps in the different legs will darken successively. In the latter case, the phase rotation of the machines can be matched by interchanging two (any two) cables at the one load terminal pane.

CAUTION: NEVER WORK ON LOAD OR BUS LINES UNLESS BOTH SETS ARE SHUT DOWN.

Cross Current Compensation:

When two generators are operated in parallel, supplying a load whose power factor is other than unity, each generator must supply its proper share of reactive (wattless) KVA. If one generator carries more than its share of wattless current, overheating of the generator may take place. The voltage regulator functions to hold the voltage constant. In addition, when sets are operated in parallel, the voltage regulators function to provide proper division of wattless KVA load between generators. They also serve to prevent useless circulating currents from flowing between the two machines. For these purposes, cross current compensation equipment is provided with the regulators.

Polarity Test: Proper functioning of the cross current compensating equipment depends on the connections to the current transformers being made correctly. If the polarity of the transformer secondaries is incorrect, the compensation will aggravate current unbalance instead of restoring the proper division.

To determine if the connections are correct.

1. Start both machines as directed in paragraph "Preliminary Tests" above. Close the parallel operation (cross current compensator) switches on both sets and adjust voltage and frequency.

2. Adjust speed of either of sets so that synchronizing lights blink slower and slower (about once every two seconds). When both lights are dark, close the open breaker.

3. Some circulating current will flow between the two machines as indicated on the ammeters. If it does not or if it is very great, turn the voltage regulator rheostat on either set to cause about 10 percent of rated current to flow between the sets.

4. Turn off the parallel operation (cross current compensating switch) on one set. If the current rises, the circuit is connected correctly. If the current falls, the leads to the current transformer secondaries must be reversed on that set.

5. Repeat operation on second machine.

Adjustment:

1. After the proper polarity of the compensation circuit has been established, the amount of compensation should be adjusted. For single, non-parallel operation, the voltage regulator can be adjusted for a negligible voltage droop. As soon as compensation is connected in the regulator circuit, a droop in the ac voltage, held by the voltage regulator, is introduced when a load with a power factor other than unity is applied or increased during operation. Depending upon how much resistance is used across the current transformers, the ac voltage will drop from 2 to 5 percent when the load varies from zero to rated load. It should be noted that voltage droop due to compensation will only occur when the load has a power factor other than unity; on unity power factor (pure resistance) loads, this compensation droop is negligible.

2. Increasing the compensating resistance will increase the compensating effect toward equalizing the division of current between generators, but at the same time the voltage droop will increase which is an undesirable effect. Therefore, it is advisable to use just enough compensation to obtain satisfactory parallel operation. Generally, parallel operation is considered successful if the differences between the currents of the two generators (as indicated by the load ammeter) is less than 10 percent of the rated current of one machine when the load is anything from 20 percent to 100 percent of rated load.

3. The compensating resistor (or resistors) are set at the factory for load and power factor conditions normally encountered in the field. This setting will usually provide satisfactory parallel operation and will eliminate cross currents. The voltage droop during parallel operation will be negligible. It is recommended that the setting of the compensating resistor not be changed unless the load conditions are so abnormal that the compensation is inadequate. Once set and found satisfactory the resistor setting should be left unchanged.

SYNCHRONIZING:

Once the preliminary tests have been performed and adjustments made, the settings will remain correct as long as the respective wire and cable connections remain unchanged. It is not necessary to make these tests every time the alternators are to be paralleled. It is, however, necessary to synchronize each and every time the generators are to be paralleled.

1. Make sure both main switches (breakers or contactors) are open.
2. Start both sets and adjust to frequency, without load, by adjusting governor controls. (Nominally this setting will be about 62 cycles for 60 cycle sets and 415 cycles for 400 cycle sets.)
3. Operate both sets on their automatic voltage regulators. Adjust both sets to the same voltage.
4. Throw both cross current compensation (parallel operation) switches to the "ON" position.
5. Close the breaker on one of the sets.
6. Turn on the synchronizing lamp switch on the other set. The synchronizing lamps will flash on and off rapidly at a frequency depending on the difference in speeds of the two units.
7. Adjust the speed of the unit whose breaker is open until the lamps flash on and off slowly (about once every two seconds). After making a speed adjustment it may be necessary to wait a few seconds until lamp fluctuations slow up.
8. When the lamps are dark, close the main breaker of the set.
9. Open the synchronizing lamp switch.

NOTE: The above procedure can be followed if one of the sets is already on the line. Follow the above directions with the loaded set taken to be the one with the closed main switch.

LOAD DIVISION:

After the units are operating in parallel, the load should be divided proportionally to the generator ratings. In the case of the addition of a set to one already carrying a load, this involves the shifting of part of the load to the second generator. In the case of two units of the same size, each should carry half of the load. On ac generators, the load can be shifted from one generator to another *only* by speed control, not by manipulating the voltage regulator rheostat. Such manipulation will only change the power factor of the alternator and hence the current output of the machines, causing undesirable cross current.

1. Increase the load on the machine with the lesser amount of the total load by increasing the governor throttle control. This increase will be indicated on the wattmeter.
2. When the two loads are correct as indicated by the wattmeters, check the frequency as indicated on either sets' frequency meter. If the frequency is too high, it will be necessary to readjust both governor controls to feed less fuel to the machines. Conversely, if the combined speed is too low, opening the governor controls on both machines will increase the frequency. When raising or lowering the frequency, care must be taken to readjust the load division so that the wattmeter readings are equal (or proportional to set size if the sets are not the same size).

ELIMINATING WATTLESS CURRENT:

After the KW load has been proportionally divided, the reactive (wattless) load should also be divided proportionally. Assuming that both generators have the same rating, both generators should show the same load amperes. This indicates cross currents and should be eliminated by adjustment of the voltage regulator rheostats on the sets.

1. Slowly turn the voltage adjusting knob on one of the units first clockwise, then counterclockwise. One movement or the other should result in decreasing the ammeter readings. Adjust until both ammeters are at the lowest point at which they both read the same value on similar sets. On different size sets, the proportional load division described previously will have to be considered.
2. After adjustment, it may be found that the output voltage is too high or too low. If too low, turn the voltage regulator rheostat on one of the sets up slightly and repeat the operation of the preceding paragraph using the rheostat on the other set for balancing. Conversely, if the voltage is too high, turn down one of the rheostats and balance with the other.

ADJUSTMENTS:

Once the proper load distribution between the units is established, little or no adjustment of the load distribution should be required when the load is increased or decreased. Such adjustments as may be necessary should be carried out as indicated in the preceding paragraphs. Proportional division of the KW load is assured by the speed regulation characteristics of the units. The proportional division of the wattless load

will be maintained by the cross current compensation feature of the voltage regulators.

REMOVING A GENERATOR FROM THE LINE:

To remove a generator operating in parallel, reduce the load carried by that machine by manipulating the speed control until the KW indication on the wattmeter is very small, then open the main switch or contactor on that machine. Turning the speed control in the *decrease* speed direction will decrease the load carried by that generator.

CUMMINS

C SERIES DIESEL ENGINES

Section III

MAINTENANCE OPERATIONS

Maintenance is the key to lower operating costs. A diesel engine — like any other engine or machine — requires maintenance to keep it running. Most diesel engines are purchased and used for the sake of revenue, and any loss of efficiency or failure reduces the revenue as well as requiring additional funds for repair.

Investigate any successful operation where engines are used and you will find a good maintenance program in effect.

Preventive maintenance performed on schedule is the easiest as well as the least expensive type of maintenance. It permits the maintenance department to do the work in the shop on schedule rather than out on the job under poor working conditions and at unusual hours.

THE MAINTENANCE SCHEDULE MUST FIT THE JOB

The maintenance schedule on the next page is based on engine work output as measured by its fuel consumption. It also has been adapted to a suggested schedule of "hours" or "miles" of operation.

A maintenance schedule based on fuel consumption is the most accurate because the amount of wear in an engine is proportional to the work performed. Work is measured in horsepower and is obtained from the fuel that is burned. Therefore, based on your particular operation you may find it desirable to reduce or extend the number of miles or hours between maintenance operations.

PREVENTIVE MAINTENANCE SHOULD BE APPLIED TO ALL THE ENGINE SYSTEMS

By necessity, all engine owners practice preventive maintenance to some degree. To be effective and profitable, the maintenance program must apply to all the engine systems, and maintenance work must be performed before the engine is damaged by unfavorable conditions resulting from lack of maintenance.

Preventive maintenance consists of doing the things that will prevent on-the-job failures and expensive progressive damage to the unit. Maintenance work is profitable work.

MAINTENANCE SCHEDULE FOR C SERIES ENGINES

Engine Serial No. _____ **Mileage or Hours** _____

Check Being Made _____ **Time Spent on Check** _____

Date _____ **Parts Order No.** _____

Mechanic _____

		Check As Performed		GALLONS FUEL CONSUMED				
				750	1500	3000	6000	18000
				HOURS				
				150	300	600	1200	3600
				MILEAGE				
			Daily	4500	9000	18000	36000	108000
		✓	A	B	C	D	E	
LUBRICATING SYSTEM	Check Oil Level		●	●	●	●	●	
	Check Leaks and Correct		●	●	●	●	●	
	Change Oil			●	●	●	●	
	Clean Filter Element (Screen Type)			●	●	●	●	
	Change Filter Element (Bag Type)			●	●	●	●	
	Record Oil Pressure			●	●	●	●	
	Lubricate Generator			●	●	●	●	
	Change Oil in Aneroid Control			●	●	●	●	
	Lubricate Cranking Motor				●	●	●	
	Change By-Pass Filter Element				●	●	●	
	Flush Crankcase						●	
FUEL SYSTEM	Fill Fuel Tanks		●	●	●	●	●	
	Check Leaks and Correct		●	●	●	●	●	
	Drain Sediment from Filter and Tanks			●	●	●	●	
	Check Hydraulic Governor Oil Level			●	●	●	●	
	Clean Fuel Pump Screen and Magnet			●	●	●	●	
	Change Filter Element				*	●	●	
	Clean Injectors					●	●	
	Adjust Injectors and Valves					●	●	
	Clean Injector Inlet Screens					●	●	
	Check Fuel Rate					●	●	
	Change Hydraulic Governor Oil						●	
COOLING SYSTEM	Fill Cooling System		●	●	●	●	●	
	Check Leaks and Correct		●	●	●	●	●	
	Check and Adjust Belt Tension				●	●	●	
	Check Corrosion Resistor				●	●	●	
	Check Thermal Controls					●	●	
	Check Engine Coolant					●	●	
	Check Fan Hub and Drive Pulley					●	●	
	Check Sea Water Pump				*	●	●	
	Clean Cooling System				SPRING & FALL			
AIR SYSTEM	Check Air Cleaner Oil Level		●	●	●	●	●	
	Clean Pre-Cleaner		●	●	●	●	●	
	Check Air and Vapor Line Connections		●	●	●	●	●	
	Clean Composite-Type Air Cleaner		*	●	●	●	●	
	Clean Dry-Type Cleaner Element			●	●	●	●	
	Change Air Cleaner Oil			●	●	●	●	
	Clean Crankcase Breather (Oil-Bath Type)		*	●	●	●	●	
	Clean Crankcase Breather (Horsehair Element)		*	●	●	●	●	
	Change Crankcase Breather (Paper Element)		*	●	●	●	●	
	Clean Air Compressor Breather		*	*	●	●	●	
	Clean Tray Screen			*	●	●	●	
	Check Air Piping			*	●	●	●	
	Check for Supercharger/Turbocharger Oil Leaks					●	●	
	Tighten Turbocharger Mounting Nuts					●	●	
	Check Inlet Air Restriction				*	●	●	
	Replace Composite-Type Cleaner Element				*	●	●	
	Replace Dry-Type Cleaner Element				*	●	●	
	Clean Oil-Bath Air Cleaner				*	●	●	
	Clean Aneroid Air Filter				*	●	●	
	Tighten Manifold Nuts or Cap Screws						●	
	Clean Turbocharger Compressor Wheel & Diffuser					*	●	
	Check Turbocharger Bearing Clearances						●	
OTHER	Check Operator's Report		●	●	●	●	●	
	Retighten Cylinder Head Capscrews (1st "B" only)			●				
	Blow Dust from Generator and Cranking Motor			*	*	●	●	
	Clean and Tighten Electric Connections					●	●	
	Check Generator Brushes and Commutator					●	●	
	Steam Clean Engine					●	●	
	Tighten Mounting Bolts and Nuts					●	●	
	Check Engine Blow-By					●	●	
	Check Crankshaft End Clearance						●	

MAJOR INSPECTION SEE PAGE 3-27

* Under extremely dusty or dirty conditions, perform checks as indicated.

SCHEDULED MAINTENANCE OPERATIONS

The material in this maintenance section is so arranged that you can immediately set up your maintenance program and follow the procedures step by step. The instructions are complete for each operation and the necessary forms are shown which you may have your printer reproduce.

The maintenance schedule form on the facing page lists the operations for each engine system in progressive form. You can have your local printer reproduce this sheet at very little expense so you can use it as a check-off form for all periodic inspections.

MAINTENANCE OPERATIONS:

The maintenance operations are described for each system following the reproduction of that portion of the chart starting with Page 3-4.

Space is provided above the letters heading each check column for gallons fuel consumed, mileage or hour intervals corresponding to schedule you use in your operation. For example, if your average mileage is 6 mpg, the "B" check should be made at 4,500 miles and you would insert 4,500 above the "B", etc.

This section should be studied carefully by the maintenance mechanic until he is familiar with the procedure; afterward, he will use the form only as a check-off sheet.

MAJOR INSPECTION:

After 18,000 gallons fuel consumption, or equivalent mileage, the engine should be given a major inspection. This is not considered routine maintenance, and for that reason, it is described separately on Page 3-27.

ENGINE MAINTENANCE OPERATIONS SUMMARY:

The summary sheet shown on Page 3-29 has space provided for the complete maintenance data which is obtained from the maintenance schedule checklist and parts requisitions.

After determining the maintenance schedule periods as described above, insert these figures in the engine maintenance operations summary sheet on Page 3-29 For example, if your "B" check is at 4,500 miles, place 4,500 after "B", 9,000 after "C" 13,500 after the second "B", 18,000 after "D", etc. If your maintenance schedule is based on hours of operation or gallons of fuel consumed, fill in the appropriate data in the spaces provided.

This record will show complete operating expense for the engine and illustrate the value of the preventive maintenance program.

LUBRICATING SYSTEM MAINTENANCE

	OPERATION	√	A	B	C	D	E
LUBRICATING SYSTEM	Check Oil Level		●	●	●	●	●
	Check Leaks and Correct		●	●	●	●	●
	Change Oil			●	●	●	●
	Clean Filter Element			●	●	●	●
	Change Filter Element			●	●	●	●
	Record Oil Pressure			●	●	●	●
	Lubricate Generator			●	●	●	●
	Change Oil in Aneroid Control			●	●	●	●
	Lubricate Cranking Motor				●	●	●
	Change By-Pass Filter Element				●	●	●
	Flush Crankcase						●

Perform the operations at the intervals shown in the chart above. The instructions follow the same order as listed in the chart.

CHECK OIL LEVEL:

The dip stick oil gauge located on the side of the engine has a high "H" and a low "L" level mark to indicate lubricating oil supply. The dip stick must be kept with the oil pan, or engine, with which it was originally supplied. Cummins oil pans differ in capacity with different type installations and oil pan parts numbers.

Keep oil level as near the high level mark as possible, and never operate the engine with oil level below the low level mark. Fig. 3-1.

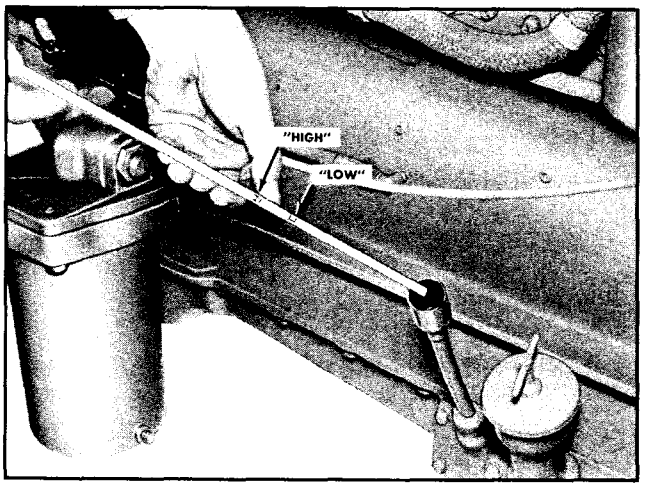


Fig. 3-1. Lubricating oil level

CHECK LEAKS AND CORRECT:

Check for evidence of external oil leakage. Tighten capscrews, fittings, connections, or replace gaskets as necessary to correct.

CHANGE OIL:

The kind of oil used, the efficiency of the filtering system and the condition of the engine must be considered in determining when the oil needs changing.

NOTE: The schedule for oil change periods at 750 gallons fuel consumption is based on a lubricating oil system (crankcase and full-flow filter) capacity of 4 to 6 gallons PLUS a by-pass filter of approximately 3 gallons.

CAUTION: ON ENGINES NOT EQUIPPED WITH 3 GALLON BY-PASS FILTER, OIL CHANGE PERIODS MUST BE REDUCED BY ONE-THIRD.

The safest method for determining oil change period is by lubricating oil analysis. See "Lubricating Oil Specifications," Page 3-8.

CHANGE FILTER ELEMENT:

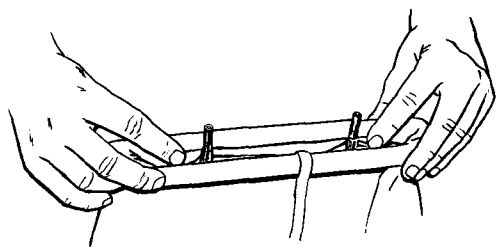
Bag-Type:

1. Remove filter element from case. Wipe case clean with clean cloths.
2. Turn used bag inside out and inspect for bearing metal, grit, etc. If metal is found in the bag, inspect connecting rod and main bearings at once.

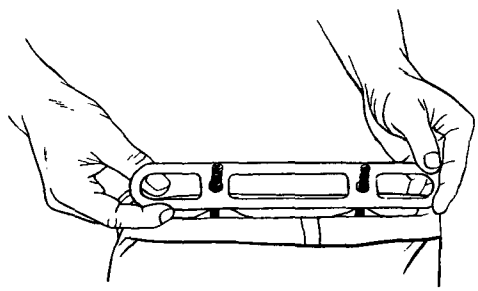
CAUTION: DO NOT ATTEMPT TO WASH USED FILTER BAGS.

3. Wash all parts thoroughly except bag. Replace gaskets.
4. Install new filter bag as shown in following sketches.

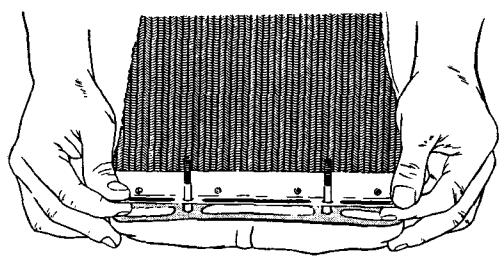
1. **Install ring in filter bag with studs protruding. Fold top of bag inward over ring about 1/2 inch; tuck bag snugly around ring stud bases to assure good seat.**



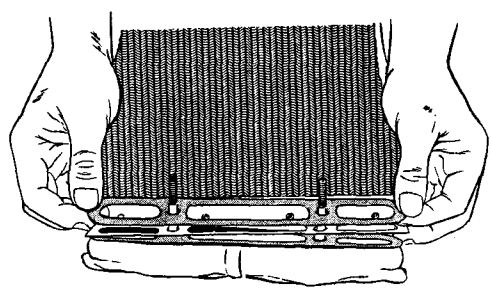
2. **Install gasket over studs and against bag.**



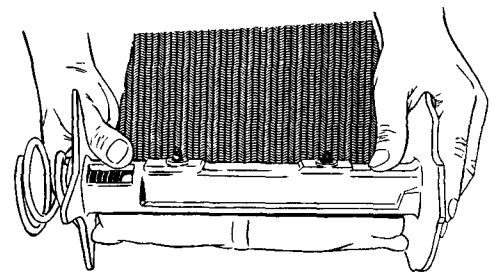
3. **Install retainer attached to wire mesh spacer over studs.**



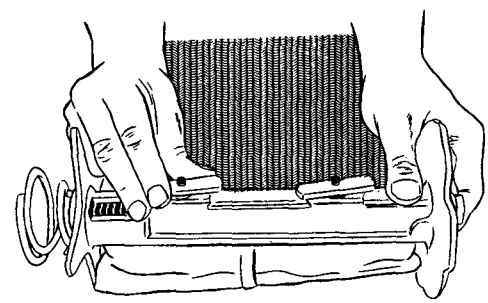
4. **Install second gasket over studs and down against spacer retainer.**



5. **Insert ring studs in spool through oil channel.**



6. **Install wing nuts over studs and tighten until nuts are parallel with spool.**



7. **Place filter assembly on clean flat surface with wire mesh spacer on top and filter bag on bottom. Roll bag and spacer around spool so that spacer is between bag and studs.**

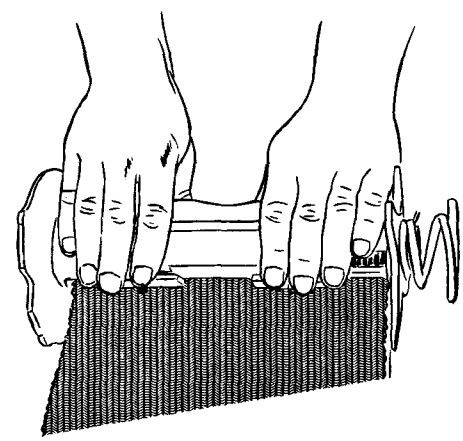


Fig. 3-2. Installing oil filter bag

CLEAN FILTER ELEMENT:

Screen-Type:

1. Loosen capscrew at bottom of filter case and lower case to remove case and filter assembly.

CAUTION: DO NOT LOSE THE NEOPRENE SEAL RING.

2. Lift the filter pack assembly from capscrew and case. Plug open tube ends of filter with cork stoppers to keep dirt out of pack assembly.

3. Inspect element for dirt, sludge, metal particles, grit, etc. If filter is full of dirt and sludge, it has probably been inoperative. This is a definite indication of inadequate maintenance.

4. If dirty element contains bearing metal, it is an indication of a possible bearing failure in the near future. *This calls for an immediate inspection of the connecting rod and main bearing shells.*

5. Clean assembly by washing in cleaning solvent. Drain or blow off cleaning fluid.

6. Clean inside of case thoroughly in solvent and dry with compressed air. The capscrew has a retainer ring to prevent washer and spring from being lost. Do not remove capscrew, ring, washer or spring.

7. Remove cork stoppers and reassemble filter.

8. Replace rubber seal ring between case and cover.

9. Fill filter case with clean lubricating oil. This will aid in priming lubricating system.

10. Tighten capscrews to 75 to 100 inch pounds. *Extreme tightening will distort case and cut rubber seal ring.*

NOTE: Many operators find it profitable to carry an extra filter element in stock as a service replacement unit and allow dirty element to soak in solvent overnight. This saves cleaning time.

RECORD OIL PRESSURE:

Start the engine and bring up speed and temperatures slowly until the oil temperature gauge reads 140° F. and record the oil pressure. A comparison of pressure at idling speed with previous readings will give an indication of progressive wear of lubricating oil pump, bearings, shafts, etc. These readings are more accurate and reliable when taken immediately after an oil change.

LUBRICATE GENERATOR:

Use SAE 20 lubricating oil to lubricate the battery charging generator bearings. Fig. 3-3. Avoid over oiling which would damage wire insulation.

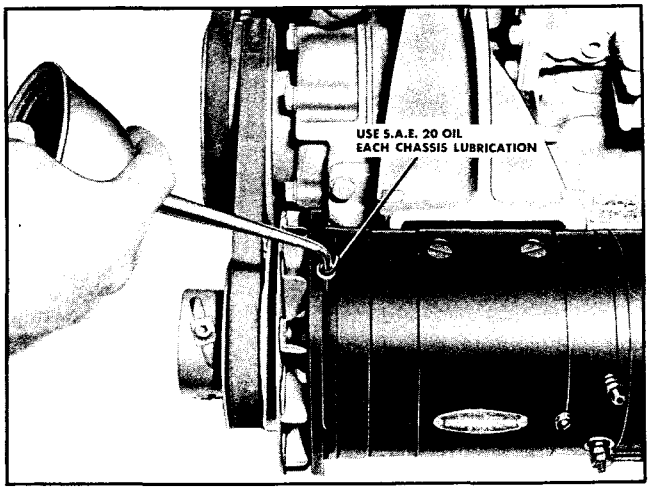


Fig. 3-3. Generator lubrication

CHANGE OIL IN ANEROID CONTROL:

1. At each "B" check, remove the plug from the bottom of the aneroid control and drain the oil.

2. Replace drain plug, and loosen vent line to crankcase at the control.

3. Fill control with clean engine lubricating oil through the vent tube hole (until oil fills to vent plug hole level) and reinstall vent tube.

4. On aneroid controls with an air filter mounted in the old vent line tap, remove filter and fill with oil; replace filter when aneroid is filled.

5. Latest aneroid controls have a special boss for mounting the air filter and are filled through an oil cup mounted in the old vent line tap.

LUBRICATE CRANKING MOTOR:

Add a few drops of clean SAE 30 weight lubricating oil to the bearings of the cranking motor.

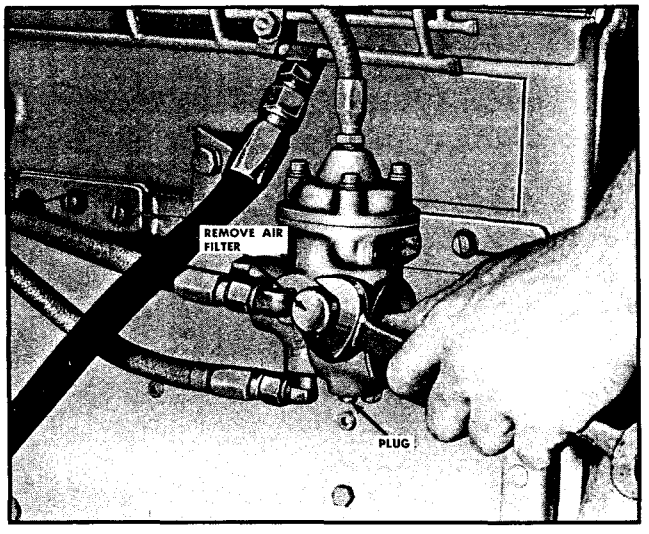


Fig. 3-4. Lubricate aneroid

CHANGE BY-PASS FILTER ELEMENT:

If the engine is equipped with a by-pass filter the element should be changed as follows:

1. Remove drain plug from bottom of housing and drain oil.
2. Remove clamping ring capscrew and lift off the cover.
3. Unscrew T-handle pack holddown assembly and lift out pack or packs.
4. Clean housing and replace drain plug.
5. Install new pack or packs.
6. Replace T-handle pack holddown assembly in filter and tighten down to stop. Inspect the T-handle assembly to see that the metering hole in the orifice plug is open.
7. Check to see that the "O" ring gasket is clean and in position on the housing flange. Replace "O" ring if damaged.
8. Replace cover and clamping ring and tighten down the capscrew until the clamping lugs come together.
9. Add an extra two and one-half gallons of engine oil to the crankcase to fill the filter case and element.
10. Loosen the vent plug in the cover and start the engine. Close vent plug when oil reaches vent.

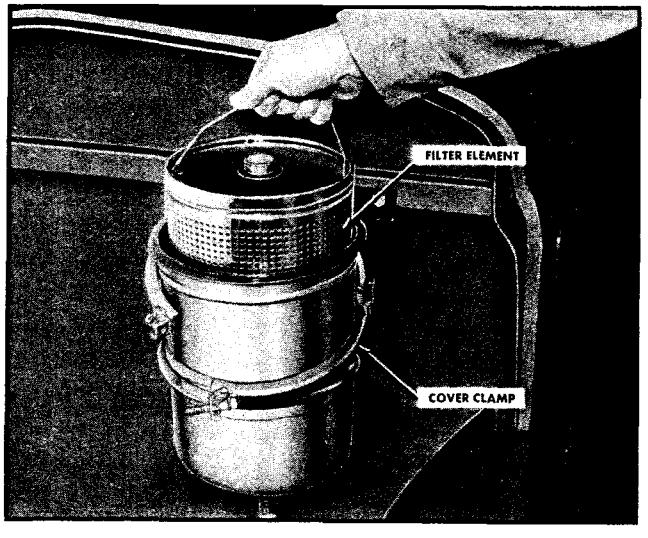


Fig. 3-5. By-pass filter element

FLUSH CRANKCASE:

Inspect crankcase and upper rockers for sludge. If a good grade heavy-duty oil has been used and operating temperatures kept between 160° and 180°F., there will be no sludge and flushing will not be necessary. If inspection reveals sludge:

1. Drain crankcase and fill with four parts fuel oil and one part lubricating oil. Keep flushing oil level in oil level operating range.
2. Remove lubricating oil filter elements and install clean elements or elements used for flushing operation only.
3. Cover radiator and operate engine at 800 rpm *no-load*. Bring water temperature to 180°F. Flushing oil must be hot to cut sludge thoroughly.
4. Drain flushing oil. Allow to drain at least 30 minutes. Unless all flushing oil is drained it will dilute the new lubricating oil.
5. Install new filter elements and fill crankcase with proper grade of lubricating oil.

LUBRICATE WATER PUMP AND FAN HUB:

Disassemble, clean and repack the water pump and fan hub bearings at each "F" check. Use a multi-purpose industrial grease meeting the specifications outlined under "Lubricant Specifications," Page 3-8. Be sure all traces of old grease are removed before repacking grease cavities. Pack and maintain water pump and fan hub grease cavities 1/2 to 2/3 full of grease meeting these specifications.

NOTE: Do not over-grease bearings. Excessive lubrication is as harmful as inadequate lubrication.

LUBRICANT SPECIFICATIONS

LUBRICATING OIL

Lubricating oil used in Cummins Engines when ambient temperatures are above 0°F. should meet quality requirements of U. S. Military Specification Mil-L-2104A. The responsibility for meeting these specifications, the quality of the product, and its performance in service must necessarily rest with the oil supplier. Cummins Engine Company, Inc. does not recommend any specific brand of lubricating oil.

The Internal Combustion Engine Institute (Chicago 6, Illinois) has published, in their booklet "Lubricating Oils For Industrial Engines," numerous oil brand names which meet the performance standards of Mil-L-2104A. These brands are satisfactory for use in Cummins Engines.

In the same booklet, "Supplement 1" and "Series 3" oils are listed for use where more severe lubrication requirements must be met such as extremely low temperatures, frequent starting and stopping, or where high-sulphur content fuel is used.

When ambient temperature is consistently below 0°F., SAE #5W oils which meet the requirements of Mil-L-10295 may be used in Cummins engines. Caution must be exercised when using SAE #5W oil above 0° F. Satisfactory lubrication can be obtained up to 30°F. if engine load is reduced, work periods are shortened, and lubricating oil pressure remains constant. Do not use SAE #5W oil above 30° F. Contact your local oil supplier for his recommendations.

Multi-viscosity oils which meet or exceed the requirements of U. S. Military Specification Mil-L-2104A in all the viscosity grades they are represented to cover, are satisfactory for use in Cummins Engines.

VISCOSITY:

SAE 5W WHEN AMBIENT TEMPERATURE IS BELOW 0° F.
SAE 10W WHEN AMBIENT TEMPERATURE IS BETWEEN 0° F. AND 32° F.
SAE 20W WHEN AMBIENT TEMPERATURE IS BETWEEN 32° F. AND 90° F.
SAE 30W WHEN AMBIENT TEMPERATURE IS ABOVE 90° F.

Oil which is best for general operation is also best for the "break-in" period. No change in oil viscosity or type is needed for new or newly rebuilt engines.

Do not mix brands or grades of lubricating oil in the engine. Choose carefully the best oil available and continue to use that brand in the proper viscosity and type, consistent with weather conditions and engine wear.

GREASE

Greases used to lubricate water pump and fan hub bearings must be a multi-purpose industrial grease suitable for service at all temperatures ranging from 0° F. to 450° F. It must be a smooth texture grease free of lumps, crusts, undesirable fillers and abrasives.

Physical and chemical properties must meet or exceed the following specifications:

Thickener by Weight	5
Mineral Oil Viscosity	
S. U. S. at 100° F. (ASTM D88-53)	500-550
Work Penetration at 77° F.	265-295
Dropping Point Minimum, 0° F.	None
Oxygen Bomb Test	
PSI Drop, 100 hours max.	4.5
Induction Period, hours, min.	500
Metal Corrosion Characteristics	Pass

Contact your lubricant supplier for greases meeting these specifications.

CAUTION: DO NOT MIX GRADES OR BRANDS OF GREASE. BEARING DAMAGE MAY RESULT.

FUEL SYSTEM MAINTENANCE

	OPERATION	√	A	B	C	D	E
FUEL SYSTEM	Fill Fuel Tanks		●	●	●	●	●
	Check Leaks and Correct		●	●	●	●	●
	Drain Sediment from Filter and Tanks			●	●	●	●
	Check Hydraulic Governor Oil Level			●	●	●	●
	Clean Fuel Pump Screen and Magnet			●	●	●	●
	Change Filter Element				*	●	●
	Clean Injectors					●	●
	Adjust Injectors and Valves					●	●
	Clean Injector Inlet Screens					●	●
	Check Fuel Rate					●	●
	Change Hydraulic Governor Oil						●

Perform the operations at the intervals shown in the chart above. The instructions follow the same order as listed in the chart.

FILL FUEL TANKS:

Do not miss an opportunity to filter or strain the fuel before or while putting it in the tank.

See "Fuel Oil Specifications," Page 3-14.

CHECK LEAKS AND CORRECT:

1. Check for evidence of external fuel leakage. Tighten capscrews, fittings, and connections, or replace gaskets as necessary to correct.
2. Check for air leaks in fuel by placing a sight gauge in the line between fuel filter and pump. Bubbles over ½ inch long or "milky" appearance indicates an air leak. Find and correct.

DRAIN SEDIMENT FROM FILTER AND TANKS:

Loosen the drain cock at the bottom of the fuel filter case and drain out any accumulated water and sediment.

Tighten the drain cock and refill the filter case with clean fuel.

CHECK HYDRAULIC GOVERNOR OIL LEVEL:

If the fuel pump has a hydraulic governor, clean lubricating oil of the same grade as used in the engine must be carried in the governor sump.

The level should be maintained half-way up on the inspection glass or to high level on dip-stick oil guage.

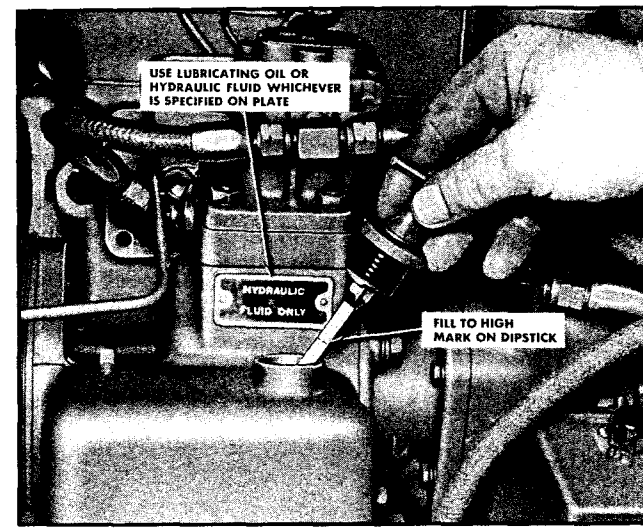


Fig. 3-6. Hydraulic governor oil level

CLEAN FUEL PUMP SCREEN AND MAGNET:

Remove and clean fuel pump filter screen and magnet at each "D" check. To clean:

1. Loosen and remove cap at top of fuel pump. Remove spring. Lift out filter screen assembly. Fig. 3-7.
2. Separate screen retainer and magnet. On some units magnet and screen are one integral unit.

NOTE: Some filter screens do not contain a magnet. If not, magnet can be obtained from any Cummins Distributor. Magnetic action in filter screen will remove any metal particles that may enter fuel system.

3. Clean screen and magnet in cleaning solvent and dry with compressed air.
4. Reassemble magnet in screen; replace screen retainer with hole down.
5. Install filter screen assembly in fuel pump. Replace spring on top of filter screen assembly.
6. Replace cap; tighten to 20/25 foot-pounds.

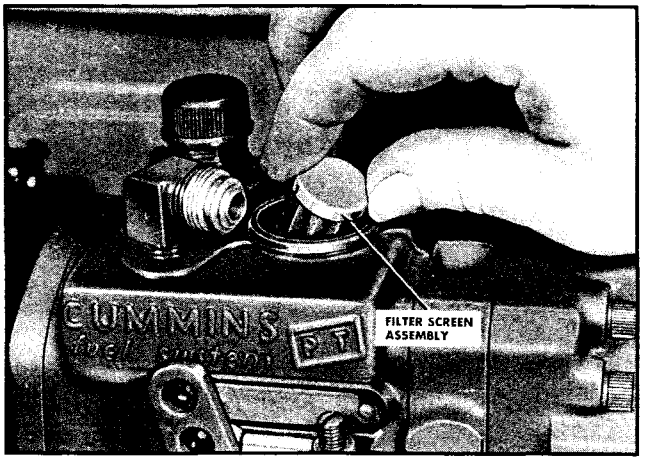


Fig. 3-7. Filter screen in fuel pump

CHANGE FILTER ELEMENT:

Ordinarily, the element should be changed at 1500 gallons fuel consumption. This is not always necessary, however, if the restriction on the inlet side of the pump is satisfactory.

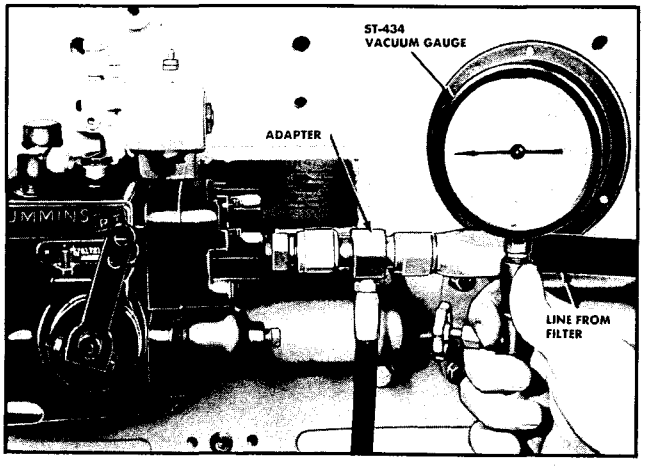


Fig. 3-8. Checking fuel restriction

To check restriction, attach ST-434 vacuum gauge to fuel pump with adapter. Fig. 3-8. Run engine at full speed and load. If restriction exceeds 8 inches mercury, change element or correct other cause of restriction. When fuel restriction reaches 8 inches mercury, engine loses power.

Change fuel filter element as described below.

Replaceable Element:

1. Loosen hex nut at top of filter head.
2. Remove dirty element and old filter head gasket. Fig. 3-10.
3. Check fuel filter mounting bracket. If bent or twisted, install new bracket.
4. Clean sediment from filter case.
5. Install new gasket in filter head.
6. Insert new element in filter case and fill with clean fuel oil.
7. Install case and element to filter head.
8. Tighten hex nut to 20/25 ft. lbs.
9. Check fittings in filter head for leaks. See that fittings are tightened to 30/40 ft. lbs.

Throw-away Element:

1. Unscrew fuel filter; discard.
2. Check mounting bracket. If bent or twisted, install new bracket.
3. Coat seal gasket with clean fuel oil.
4. Install new element; tighten by hand until seal touches filter head, then tighten additional 45° to 90°. Fig. 3-9.

CAUTION: MECHANICAL TIGHTENING WILL DISTORT OR CRACK FILTER HEAD.

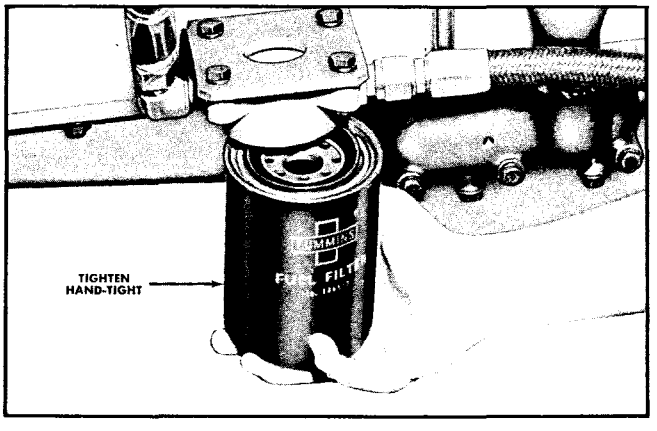


Fig. 3-9. Changing throw-away fuel filter element

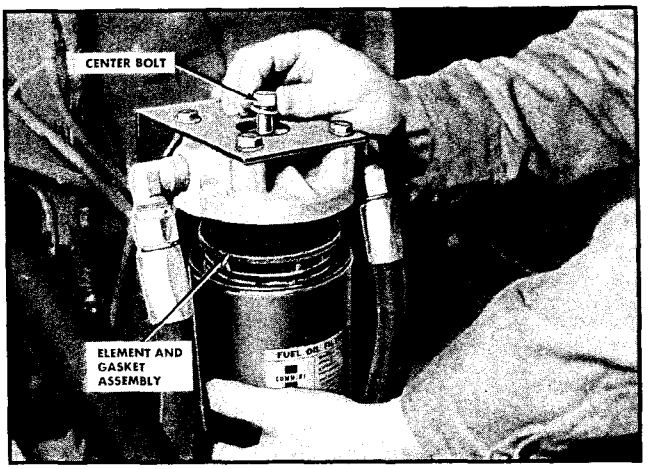


Fig. 3-10. Change replaceable fuel filter element

CLEAN INJECTORS:

Clean injectors regularly to prevent restriction of fuel delivery to combustion chambers.

In some applications, it may be advantageous to clean injectors by reverse flushing. Reverse flushing provides a method for cleaning injectors without removing them from the engine.

This method may not always be effective. If not, remove injectors (see page 4-9) and clean in approved solvent.

To reverse flush injectors, perform as follows on a warm engine:

1. Loosen half of injector adjusting screws one turn from bottom or one and one-fourth turns from set position.
2. Lock with jam nut.
3. Start engine; accelerate with *maximum* throttle from idle to high-idle *10 to 15 times.*
4. Readjust loosened injectors to standard settings.
5. Perform same operation on remaining injectors.

When injector is set with adjusting screw backed off, metering orifice will not be closed during injection. High injection pressure will force part of fuel to back-flow through orifice, removing carbon deposits.

NOTE: Difficult starting, intense smoking and sluggishness are characteristic during this operation.

ADJUST INJECTORS AND VALVES:

It is essential that injectors and valves be in correct adjustment at all times for the engine to operate properly. One controls engine breathing; the other controls fuel delivery to the cylinders.

Adjust valves and injectors at "D" and "E" checks. Final adjustment must be made when the engine is at operating temperature. Injectors should always be adjusted before valves. The procedure is as follows:

Injector Adjustment:

1. On engines with compression release levers, pull lever back and block in open position. This lifts all intake valves so the crankshaft may be turned without working against compression. *While actual valve adjustments are being made, compression release lever must be in running position.*
2. Bar engine, in direction of rotation, to No. 1 top-center firing position. In this position, intake and exhaust valves for No. 1 cylinder are closed.

CAUTION: DO NOT ROTATE ENGINE BY PULLING ON FAN BLADES.

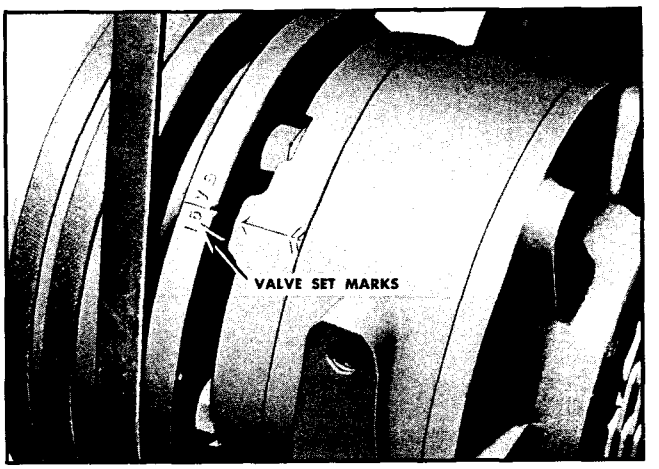


Fig. 3-11. Valve set marks

3. Continue rotating crankshaft until valve set mark on fan drive pulley aligns with timing mark on gear case cover. (1-6 VS on 6 cylinder and 1-4 VS on 4 cylinder engines.)

When these marks align, the engine is in position to adjust valves and injector plunger for No. 1 cylinder. See Fig. 3-11.

4. Firing order is as follows:
   Six-cylinder: 1-5-3-6-2-4
   Four-cylinder: 1-2-4-3
5. Check intake and exhaust valve position of cylinder to be adjusted. See that valves are closed and rocker levers free.
6. Check threads on adjusting screw and nut. See that they are clean, well-oiled and free-turning.
7. Turn injector adjusting screw down until plunger contacts cup. Turn adjusting screw an additional 15° to squeeze oil from cup.

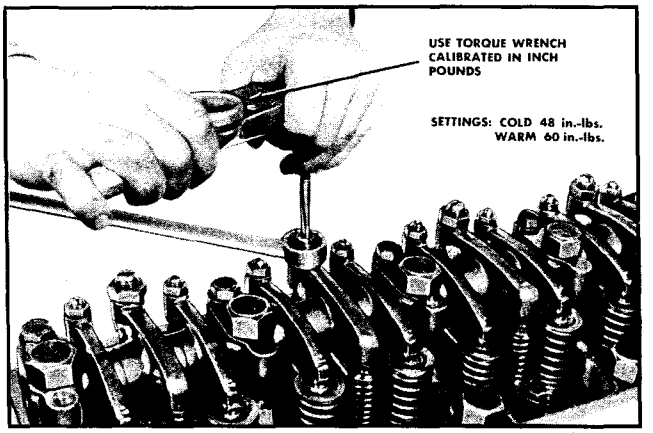


Fig. 3-12. Adjusting injector plunger

8. Loosen adjusting screw one turn.
9. Tighten adjusting screw to "cold" setting shown in Table — Injector Adjustment. Use a torque wrench equipped with a screw driver adapter, graduated in inch-pound divisions, and having a maximum capacity of 150 inch-pounds. See Fig. 3-12.
10. Tighten locknut to 70/80 foot-pounds.
11. Make final adjustment when engine is at operating temperature. Injector settings are:

Warm Setting (140°F.): 60 inch-pounds.

Crosshead Adjustments:

On engines having four-valve heads, it is necessary to adjust the crossheads *before* making valve adjustments.

1. Loosen the valve crosshead adjusting locknut. Loosen the adjusting screw one turn.
2. Use light finger pressure at rocker lever contact surface "A" to hold the crosshead in contact with the valve stem "B". Turn down the crosshead adjusting screw until it touches the valve stem "C".

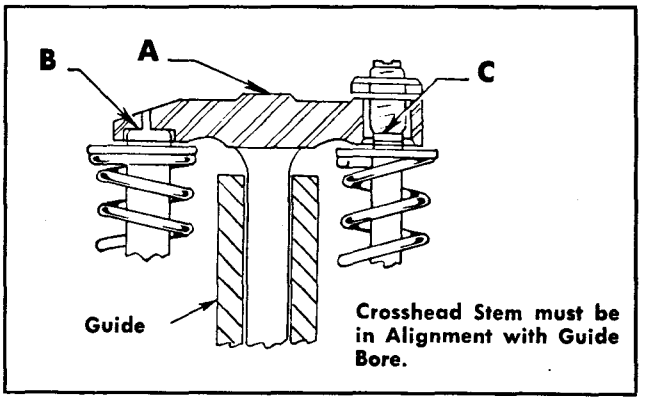


Fig. 3-13. Alignment of crosshead stem and guide

3. For new crossheads and guides, advance the crosshead adjusting screw an additional one-third hex (20°) to straighten the stem in its guide and to compensate for slack in threads. With worn crossheads and guides, it may be necessary to advance the screw as much as one-half hex (30°) in order to straighten the stem in its guide.
4. Tighten adjusting screw in this position to 25/30 foot-pounds. Adjust both intake and exhaust valve crossheads in this manner.

NOTE: If ST-669 is used to adjust crossheads, tighten locknut to 22/26 foot pounds to compensate for torque arm length of ST-669.

Valve Adjustment:

The same crankshaft position used in setting the injectors is used for setting the intake and exhaust valves. *Set valves after injectors are adjusted.*

Fig. 3-14. Adjusting valves

1. Loosen the locknut and adjusting screw. Insert a feeler gauge between the rocker lever and top of the valve stem or crosshead and turn screw down until the lever just touches the feeler gauge.
2. Lock adjusting screw in position with jam nut. Recheck valve clearance after tightening jam nut. Valve clearances are:

Intake valves: .017
Exhaust valves: .027

3. Continue turning crankshaft in direction of rotation, performing adjustments, until all valves are adjusted correctly.
4. Make final valve adjustment after engine oil temperature reaches 140° F.

NOTE: Two crankshaft revolutions are necessary to set all injector plungers and valves. Injectors and valves can be adjusted for only one cylinder at any one "VS" setting.

INJECTOR AND VALVE ADJUSTMENT WITH ST-669:

Injectors:

Use ST-669 Adjustment Tool with standard ½ inch drive sockets and torque wrenches.

1. Repeat procedure outlined in Steps 1 through 8 under "Injector Adjustment."
2. Place ST-669 over rocker lever locknut and adjusting screw. Place torque wrench calibrated in foot-pounds in torque arm of ST-669 and loosen locknut.
3. Loosen adjusting screw using torque wrench calibrated in inch-pounds in screwdriver handle adaptor socket.
4. Tighten adjusting screw to 48 inch-pounds (cold setting).
5. Holding adjusting screw firmly with screwdriver handle, tighten locknut to 60/70 foot-pounds. Make final adjusting screw adjustment (60 inch-pounds) when engine is at operating temperature.

Valves:

1. Place ST-669 over valve adjusting screw and locknut. Loosen locknut with torque wrench in torque arm of ST-669.
2. Loosen adjusting screw with screwdriver handle of ST-669.
3. Place feeler gauge between rocker lever and crosshead or valve stem. See "Valve Adjustment" for proper valve clearance. Tighten adjusting screw until proper valve clearance is obtained.
4. Holding adjusting screw with screwdriver handle, tighten locknut to 60/70 foot-pounds.

NOTE: Lower torque setting is necessary to compensate for torque arm length on ST-669.

5. Perform remaining procedures as outlined under Steps 2 through 4, "Valve Adjustment."

CLEAN INJECTOR INLET SCREENS:

Each fuel inlet connection has a fine mesh screen at the large end. This screen is the last protection against dirt entering the injector.

To clean: Remove the strainer screen; wash in solvent and dry with compressed air. Reassemble as removed. See Fig. 3-15.

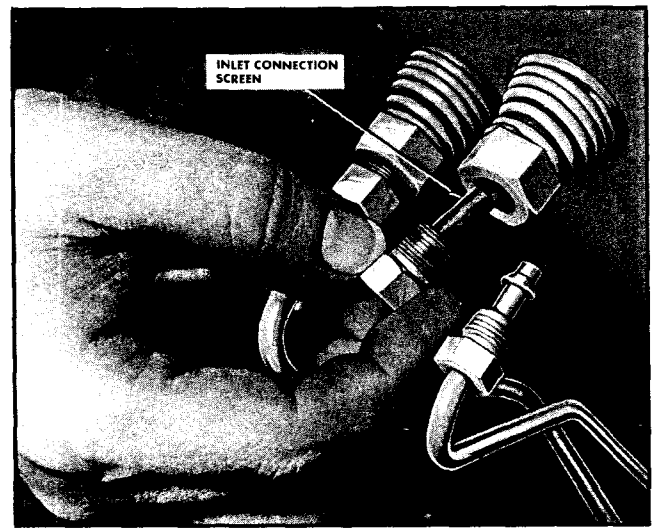


Fig. 3-15. Injector inlet screen

CHECK FUEL RATE:

The best way to check pump settings is on a fuel pump test stand; however, where a test stand is not available, a pump can be checked on the engine. The most accurate check with the pump on an engine is made while operating at full-load and rated speed using an engine dynamometer and a full-flow meter available as service tool ST-502.

A less accurate method is to take "snap readings" of fuel manifold pressure with ST-435 Pressure Gauge while accelerating the engine from idling to governed rpm. (While operating in this manner the fuel manifold pressure is at maximum.)

Checking Fuel Rate in Pounds per Hour:

1. Make sure fuel restriction is less than 8 inches mercury, measured with a vacuum gauge.
2. Adjust valves and injectors.
3. Attach ST-502 Flow Meter to fuel supply line between fuel pump and tank.
4. Read fuel rate at top of float on ST-502 while engine is pulling full load.
5. If rate is different than specified, adjust by adding or removing shims under pressure regulator nylon adjusting plunger.

Checking Maximum Fuel Manifold Pressure:

1. To check manifold pressure, connect ST-435 to shut-off valve. Remove pipe plug from shut-off valve to connect pressure gauge line. At governed speed (just before governor cuts in) maximum manifold pressure will be attained.