CATERPILLAR®

FORM NO. SENR2764-01

FOR USE IN SERVICE MANUALS:
225D,229D & 231D EXCAVATORS,
SENR4265
613C WHEEL TRACTOR SCRAPER,
SENR2760
V700,V800,V900 CH,V925,
V925 LH & V1100 CTH LIFT TRUCKS,
SENB8260

# Systems Operation Testing & Adjusting

## 3208 Vehicular Engine

79V1-Up

# Important Safety Information

Most accidents involving product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

**Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.**

**Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.**

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or other persons.

The hazards are identified by the "Safety Alert Symbol" and followed by a "Signal Word" such as "WARNING" as shown below.

**⚠ WARNING**

The meaning of this safety alert symbol is as follows:

**Attention! Become Alert! Your Safety is Involved.**

The message that appears under the warning, explaining the hazard, can be either written or pictorially presented.

Operations that may cause product damage are identified by NOTICE labels on the product and in this publication.

Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are therefore not all inclusive. If a tool, procedure, work method or operating technique not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the product will not be damaged or made unsafe by the operation, lubrication, maintenance or repair procedures you choose.

The information, specifications, and illustrations in this publication are on the basis of information available at the time it was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service given to the product. Obtain the complete and most current information before starting any job. Caterpillar dealers have the most current information available. For a list of the most current publication form numbers available, see the Service Manual Contents Microfiche, REG1139F.

# Index

## Systems Operation



## Testing And Adjusting



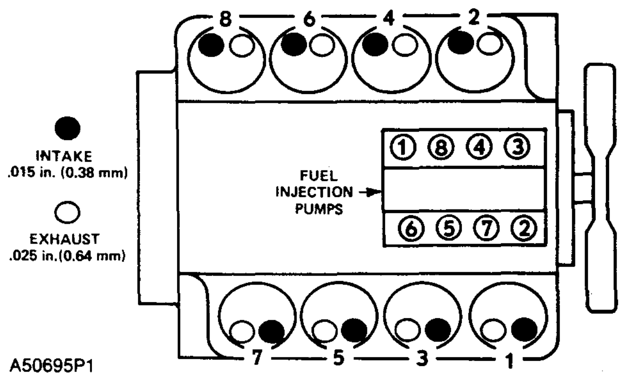
## Specifications

NOTE: For Specifications with illustrations, make reference to Specifications For 3208 Vehicular Engine, Form No. SENR2763. If the Specifications in Form SENR2763 are not the same as in the Systems Operation and the Testing And Adjusting, look at the printing date on the back cover of each book. Use the Specifications given in the book with the latest date.

A "C" in the left margin is an indication of a change from the former issue.

# Systems Operation

## Engine Design




Cylinder, Valve And Injection Pump Location

| | |
|---|---|
| Bore | 114.3 mm (4.5 in) |
| Stroke | 127.0 mm (5.0 in) |
| Number Of Cylinders | 8 |
| Cylinder Arrangement | 90°V |
| Firing Order (Injection Sequence) | 1,2,7,3,4,5,6,8 |
| Direction Of Rotation (As Seen From Flywheel End) | Counterclockwise |

## Fuel System

The sleeve metering fuel system is a pressure type fuel system. The name for the fuel system is from the method used to control the amount of fuel sent to the cylinders. This fuel system has an injection pump for each cylinder of the engine. It also has a fuel transfer pump on the front of the injection pump housing. The governor is on the rear of the injection pump housing.

The drive gear for the fuel transfer pump is on the front of the camshaft for the injection pumps. The carrier for the governor weights is bolted to the rear of the camshaft for the injection pumps. The injection pump housing has a bearing at each end to support the camshaft. The camshaft for the sleeve metering fuel system is driven by the timing gears at the front of the engine.

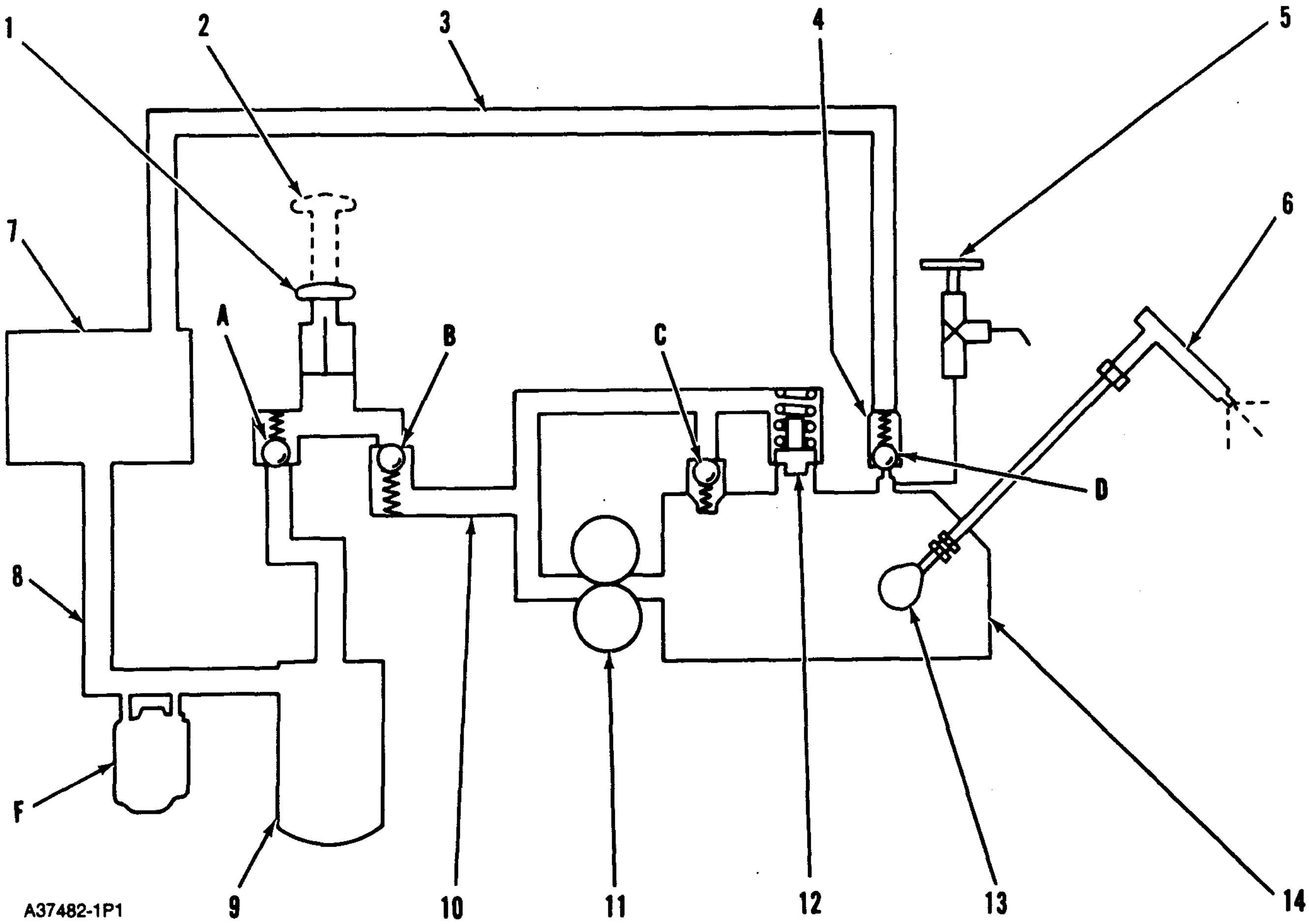
The injection pumps, lifters and rollers, and the camshaft are all inside of the pump housing. The pump housing and the governor housing are full of fuel at transfer pump pressure (fuel system pressure).

NOTICE

**Diesel fuel is the only lubrication for the moving parts in the transfer pump, injection pump housing and the governor. The injection pump housing must be full of fuel before turning the camshaft.**

This fuel system has governor weights, a thrust collar and two governor springs. Rotation of the shaft for governor control, compression of the governor springs, movement of connecting linkage in the governor and injection pump housing controls the amount of fuel sent to the engine cylinders.

Fuel from fuel tank (7) is pulled by fuel transfer pump (11) through water separator (F) (if so equipped) and fuel filter (9). From fuel filter (9) the fuel goes to housing for fuel injection pumps (14). The fuel goes in housing (14) at the top and goes through an inside passage to fuel transfer pump (11).




Schematic of Fuel System
(1) Fuel priming pump (closed position). (2) Fuel priming pump (open position). (3) Return line for constant bleed valve. (4) Constant bleed valve. (5) Manual bleed valve. (6) Fuel injection nozzle. (7) Fuel tank. (8) Fuel inlet line. (9) Fuel filter. (10) Fuel line to injection pump. (11) Fuel transfer pump. (12) Fuel bypass valve. (13) Camshaft. (14) Housing for fuel injection pumps. (A) Check valve. (B) Check valve. (C) Check valve. (D) Check valve. (F) Water separator.

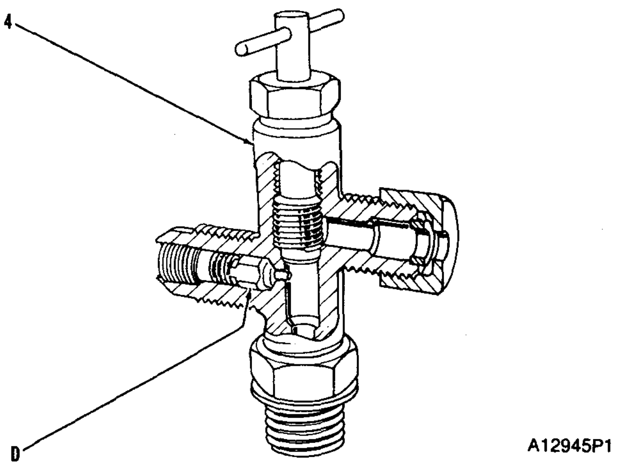
From fuel transfer pump (11), fuel under pressure, fills the housing for the fuel injection pumps (14). Pressure of the fuel in housing (14) is controlled by bypass valve (12). Pressure of the fuel at FULL LOAD is 205 ± 35 kPa (30 ± 5 psi). If the pressure of fuel in housing (14) gets too high, bypass valve (12) will move (open) to let some of the fuel return to the inlet of fuel transfer pump (11).

## Flow of Fuel Using the Priming Pump

When the handle of priming pump (2) is pulled out, negative air pressure in priming pump (2) opens check valve (A) and pulls fuel from fuel tank (7). Pushing the handle in closes check valve (A) and opens check valve (B). This pushes air and/or fuel into housing (14) through the fuel passages and check valve (C). More operation of priming pump (2) will pull fuel from fuel tank (7) until the fuel lines, fuel filter (9) and housing (14) are full of fuel. Do this until the flow of fuel from manual bleed valve (5) is free of air bubbles.

## Constant Bleed Valve

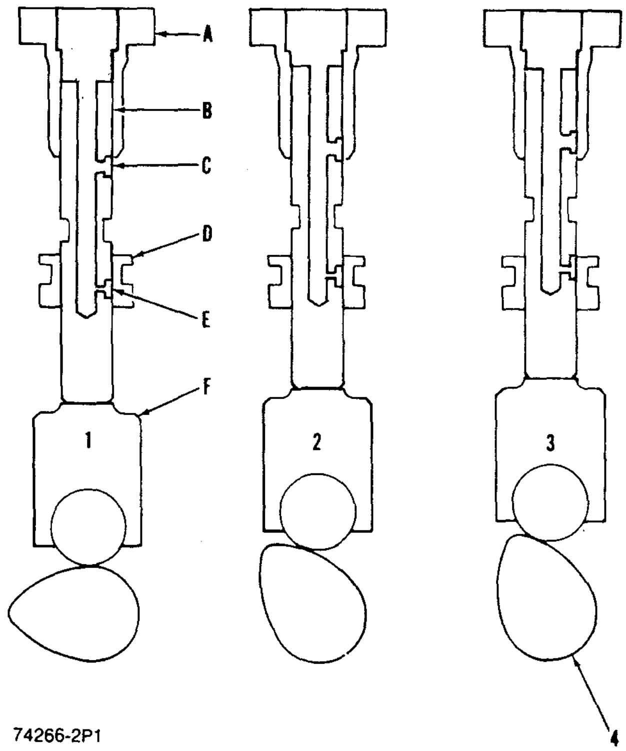
Constant bleed valve (4) lets approximately 9 gallons of fuel per hour go back to fuel tank (7). This fuel goes back to fuel tank (7) through return line for constant bleed valve (3). This flow of fuel removes air from housing (14) and also helps to cool the fuel injection pump. Check valve (D) makes a restriction in this flow of fuel until the pressure in housing (14) is at 55 ± 20 kPa (8 ± 3 psi).




Constant Bleed Valve
(4) Constant bleed valve. (D) Check valve.

## Operation of Fuel Injection Pumps

The main components of a fuel injection pump in the sleeve metering fuel system are barrel (A), plunger (B), and sleeve (D). Plunger (B) moves up and down inside the barrel (A) and sleeve (D). Barrel (A) is stationary while sleeve (D) is moved up and down on plunger (B) to make a change in the amount of fuel for injection.




Fuel Injection Sequence
(1,2,3) Injection stroke (positions) of a fuel injection pump.
(4) Injection pump camshaft. (A) Barrel. (B) Plunger. (C) Fuel inlet. (D) Sleeve. (E) Fuel outlet. (F) Lifter.

When the engine is running, fuel under pressure from the fuel transfer pump goes in the center of plunger (B) through fuel inlet (C) during the down stroke of plunger (B). Fuel can not go through fuel outlet (E) at this time because it is stopped by sleeve (D), (see position 1).

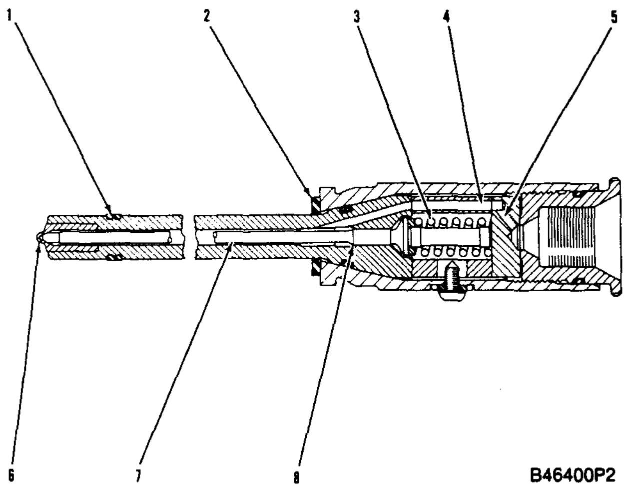
Fuel injection starts (see position 2) when plunger (B) is lifted up in barrel (A) enough to close fuel inlet (C). There is an increase in fuel pressure above plunger (B), when the plunger is lifted by camshaft (4). The fuel above plunger (B) is injected into the engine cylinder.

Injection will stop (see position 3) when fuel outlet (E) is lifted above the top edge of sleeve (D) by camshaft (4). This movement lets the fuel that is above, and in, plunger (B) go through fuel outlet (E) and return to the fuel injection pump housing.

When the sleeve (D) is raised on plunger (B), fuel outlet (E) is covered for a longer time, causing more fuel to be injected in the engine cylinders. If sleeve (D) is low on plunger (B), fuel outlet (E) is covered for a shorter time, causing less fuel to be injected.

## Operation of 7000 Series Fuel Injection Nozzle

The fuel injection nozzle goes through the cylinder head into the combustion chamber. The fuel injection pump sends fuel with high pressure to the fuel injection nozzle where the fuel is made into a fine spray for good combustion.




Fuel Injection Nozzle
(1) Carbon dam. (3) Seal. (3) Spring. (4) Passage. (5) Inlet passage. (6) Orifice. (7) Valve. (8) Diameter.

Seal (2) goes against the cylinder head and prevents leakage of compression from the cylinder. Carbon dam (1) keeps carbon out of the bore in the cylinder head for the nozzle.

Fuel with high pressure from the fuel injection pump goes into inlet passage (5). Fuel then goes into passage (4) to the area below diameter (8) of valve (7). When the pressure of the fuel that pushes against diameter (8) becomes greater than the force of spring (3), valve (7) lifts up. When valve (7) lifts, the tip of the valve comes off of the nozzle seat and the fuel will go through the four 0.29 mm (.011 in) orifices (6) into the combustion chamber.

The injection of fuel continues until the pressure of fuel against diameter (8) becomes less than the force of spring (3). With less pressure against diameter (8), spring (3) pushes valve (7) against the nozzle seat and stops the flow of fuel to the combustion chamber.

## Electric Fuel Pump (613C)

An electric fuel pump is mounted at the fuel tank on the scraper. A switch in the operator's compartment is used to turn on the pump when needed.

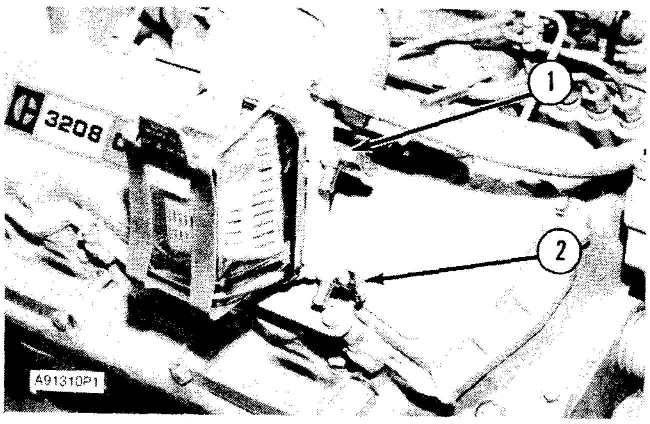
Hold the switch in the on position to operate the pump. The pump will push fuel to the fuel filters and the fuel injection pump housing. Any air will go through the return line to the fuel tank or through the manual bleed line.

## C Water Separator

Some engines have a water separator. The water separator is installed between the fuel tank and the rest of the fuel system. For efficiency in the action of the water separator the fuel flow must come directly from the fuel tank and through the water separator. This is because the action of going through a pump or valves before the water separator lowers the efficiency of the water separator.

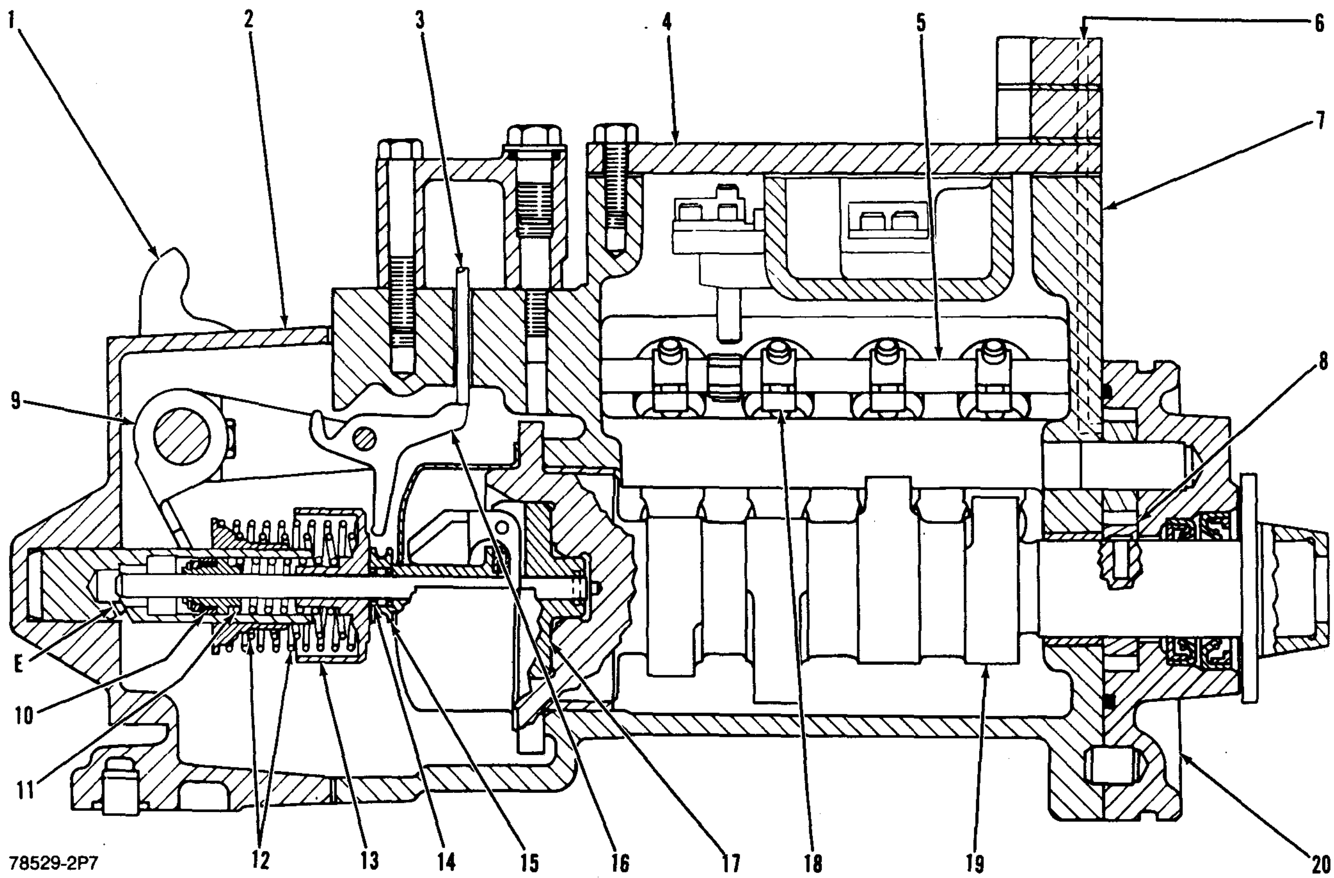
The water separator can remove 95% of the water in a fuel flow of up to 125 liter/hr (33 gph) if the concentration of the water in the fuel is 10% or less. It is important to check the water level in the water separator frequently. The maximum amount of water which the water separator can hold is 0.4 liter (.8 pt). At this point the water fills the glass to ¾ full. Do not let the water separator have this much water before draining the water. After the water level is at ¾ full, the water separator loses its efficiency and the water in the fuel can go through the separator and cause damage to the fuel injection pump.

Drain the water from the water separator every day or when the water level gets to ½ full. This gives the system protection from water in the fuel. If the fuel has a high concentration of water, or if the flow rate of fuel through the water separator is high, the water separator fills with water faster and must be drained more often. To drain the water separator, open drain valve (2) in the drain line and vent valve (1) at the top of the water separator. Let the water drain until it is all out of the water separator. Close both valves.




Water Separator
(1) Vent valve. (2) Drain valve.

## Governor

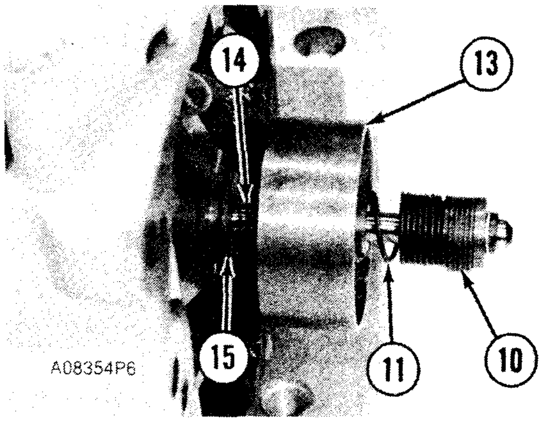



Cross Section of Fuel System
(1) Lever. (2) Governor housing. (3) Load stop pin (4) Cover. (5) Sleeve control shafts (two). (6) Inside fuel passage. (7) Housing for fuel injection pumps. (8) Drive gear for fuel transfer pump. (9) Lever on governor shaft. (10) Piston for dashpot governor. (11) Spring for dashpot governor. (12) Governor springs. (13) Spring seat. (14) Over fueling spring. (15) Thrust collar. (16) Load stop lever. (17) Carrier and governor weights. (18) Sleeve levers. (19) Camshaft. (20) Fuel transfer pump. (E) Orifice for dashpot.

Lever (1) for the governor is connected by linkage and governor springs (12) to the sleeve control shafts (5). Any movement of lever (9) will cause a change in the position of sleeve control shafts (5).

When lever (1) is moved to give more fuel to the engine, lever (9) will put governor springs (12) in compression and move thrust collar (15) forward. As thrust collar (15) moves forward, the connecting linkage will cause sleeve control shafts (5) to turn. With this movement of the sleeve control shafts, levers (18) will lift sleeves (21) to make an increase in the amount of fuel sent to the engine cylinders.

When starting the engine, the force of over fueling spring (14) is enough to push thrust collar (15) to the full fuel position. This lets the engine have the maximum amount of fuel for injection when starting. At approximately 400 rpm, governor weights (17) make enough force to push spring (14) together. Thrust collar (15) and spring seat (13) come into contact. From this time on, the governor works to control the speed of the engine.




Governor Parts
(10) Piston for dashpot governor. (11) Spring for dashpot governor. (13) Spring seat. (14) Over fueling spring. (15) Thrust collar.

When governor springs (12) are put in compression, the spring seat at the front of the governor springs will make contact with load stop lever (16). Rotation of the load stop lever moves load stop pin (3) up until the load stop pin comes in contact with the stop bar or stop screw. This stops the movement of thrust collar (15), the connecting levers, and sleeve control shafts (5). At this position, the maximum amount of fuel per stroke is being injected by each injection pump.

The carrier for governor weights (17) is held on the rear of camshaft (19) by bolts. When engine rpm goes up, injection pump camshaft (19) turns faster.

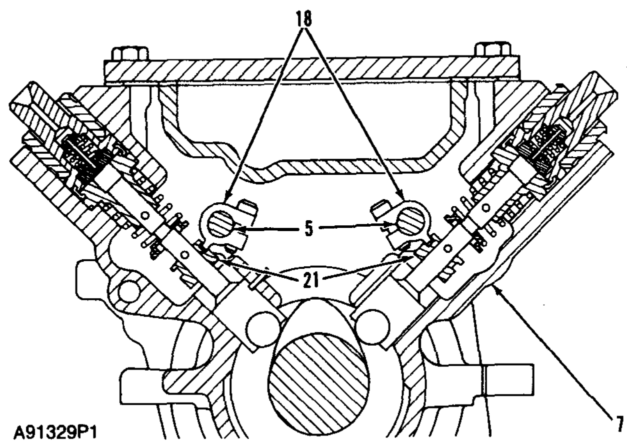
Any change of camshaft rpm will change the rpm and position of governor weights (17). Any change of governor weight position will cause thrust collar (15) to move. As governor weights (17) turn faster, thrust collar (15) is pushed toward governor springs (12). When the force of governor springs (12) is balanced by the centrifugal force of the governor weights, sleeves (21) of the injection pumps are held at a specific position to send a specific amount of fuel to the engine cylinders.

The parts of the dashpot work together to make the rpm of the engine steady. The dashpot works as piston (10) moves in the cylinder which is filled with fuel. The movement of piston (10) in the cylinder either pulls fuel into the cylinder or pushes it out. In either direction the flow of fuel is through orifice (E). The restriction to the flow of fuel by orifice (E) gives the dashpot its function.

When the load on the engine decreases, the engine starts to run faster and governor weights (17) put force against springs (12). This added force puts more compression on springs (12) and starts to put spring (11) in compression. Spring (11) is in compression because the fuel in the cylinder behind piston (10) can only go out through orifice (E). The rate of flow through orifice (E) controls how fast piston (10) moves. As the fuel is pushed out of the cylinder by piston (10), the compression of spring (11) becomes gradually less.

When springs (12) and spring (11) are both in compression, their forces work together against the force of weights (17). This gives the effect of having a governor spring with a high spring rate. A governor spring with a high spring rate keeps the engine speed from having oscillations during load changes.

When the load on the engine increases, the engine starts to run slower. Governor weights (17) puts less force against spring (12). Spring (12) starts to push seat (13) to give more fuel to the engine. Seat (13) is connected to piston (10) by spring (11). When seat (13) starts to move, the action puts spring (11) in tension. As piston (10) starts to move, a vacuum is made inside the cylinder. The vacuum will pull fuel into the cylinder through orifice (E). The rate of fuel flow through orifice (E) again controls how fast piston (10) moves. During this condition, spring (11) is pulling against springs (12). This makes the movement of seat (13) and springs (12) more gradual. This again gives the effect of a governor spring with a high spring rate.




Fuel System Components
(5) Sleeve control shafts. (7) Housing for fuel injection pumps. (18) Sleeve levers. (21) Sleeves.

When the governor control lever is turned toward the FUEL-OFF position with the engine running, there is a reduction of force on governor springs (12). The movement of the linkage in the governor will cause fuel control shafts (5) to move sleeves (21) down, and less fuel will be injected in the engine cylinders.

To stop the engine, turn the ignition switch to the "OFF" position. This will cause the shutoff solenoid to move linkage in the fuel pump housing. Movement of the linkage will cause sleeve levers (18) to move sleeves (21) down, and no fuel is sent to the engine cylinders. With no fuel going to the engine cylinders, the engine will stop.

## Fuel Ratio Control

The fuel ratio control limits the amount of fuel to the cylinders during an increase of engine speed (acceleration) to reduce exhaust smoke.

Bolt (3) in the fuel control limits the travel of the fuel control shaft in the FUEL ON direction only. As the engine accelerates, bolt (3) will not let the fuel control shaft go to the full fuel position. When the turbocharger gives enough air pressure to give good combustion in the cylinders, the inlet manifold pressure goes through a line into air chamber (1). The air pressure in air chamber (1) pushes on diaphragm (2) which moves bolt (3) down. When bolt (3) moves down, the fuel control shaft can move to the full fuel position.

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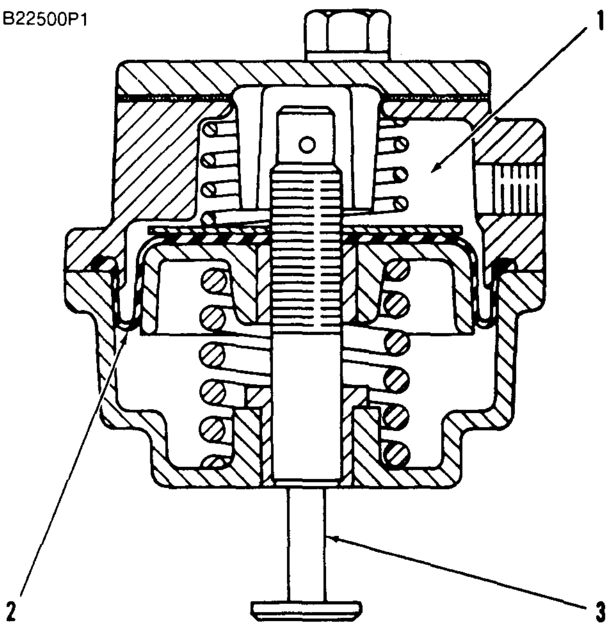
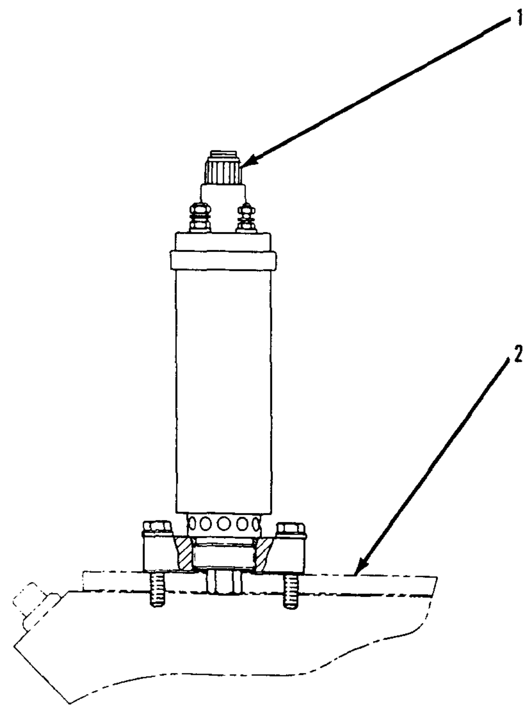



Fuel Ratio Control
(1) Air chamber. (2) Diaphragm. (3) Bolt.

## C Shutoff Solenoid (613C)

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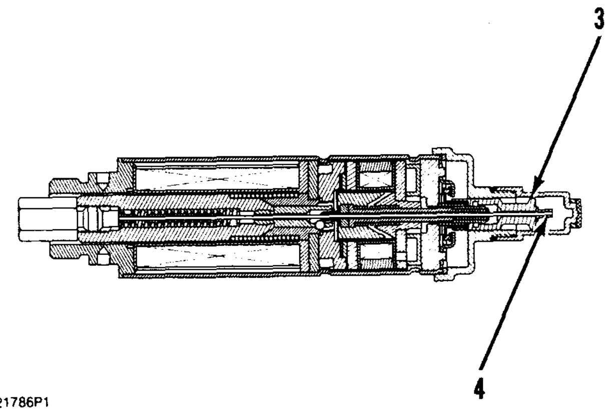
Shutoff Solenoid
(1) Threaded end cap. (2) Fuel injection pump housing.

The fuel shutoff mechanism is activated by a latching solenoid. A spring loaded plunger inside the solenoid acts on a lever assembly in the fuel injection pump housing. This lever assembly will cause sleeve control shafts to move sleeves to the fuel off position when the plunger of the solenoid is released electrically or manually at engine shutdown. At startup, the solenoid is energized to latch in the run position. The sleeve control shafts are then free to move to the fuel on position.

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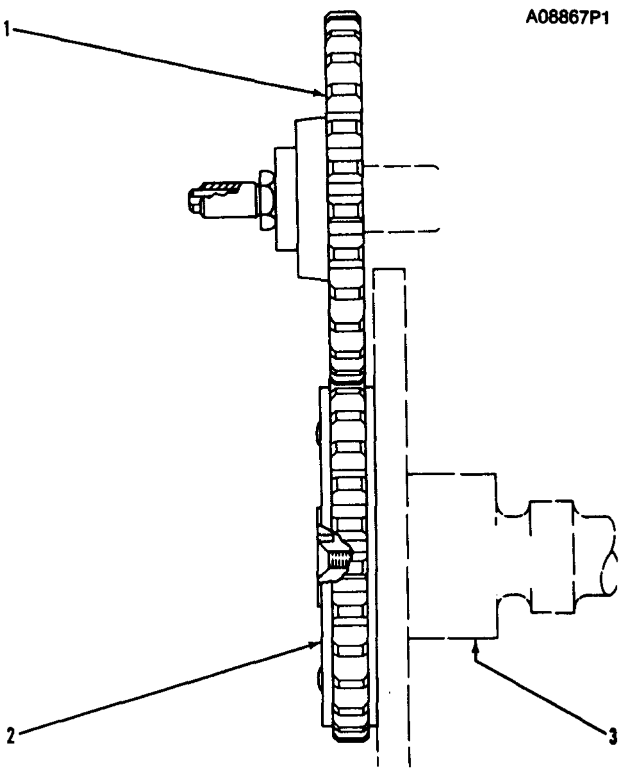
Shutoff Solenoid
(3) Ferrule. (4) Center rod.

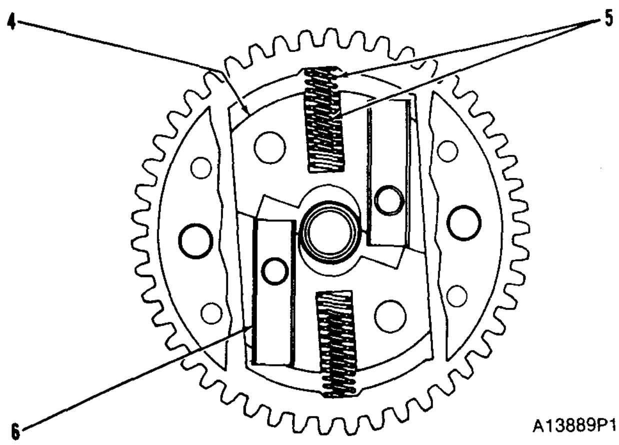
The engine can be manually shutdown by removing the threaded end cap (1) and pulling out on ferrule (3). To manually latch the solenoid in the run position, remove the end cap (1) and pull center rod (4) out with pliers.

## c Automatic Timing Advance Unit (If Equipped)




Automatic Timing Advance Unit
(1) Gear on camshaft for fuel injection pump. (2) Automatic timing advance unit. (3) Camshaft for the engine.

The automatic timing advance unit (2) is installed on the front of the camshaft (3) for the engine. The automatic timing advance unit (2) drives gear (1) on the camshaft for the fuel injection pump. This gear is the drive for the camshaft for the fuel injection pump.



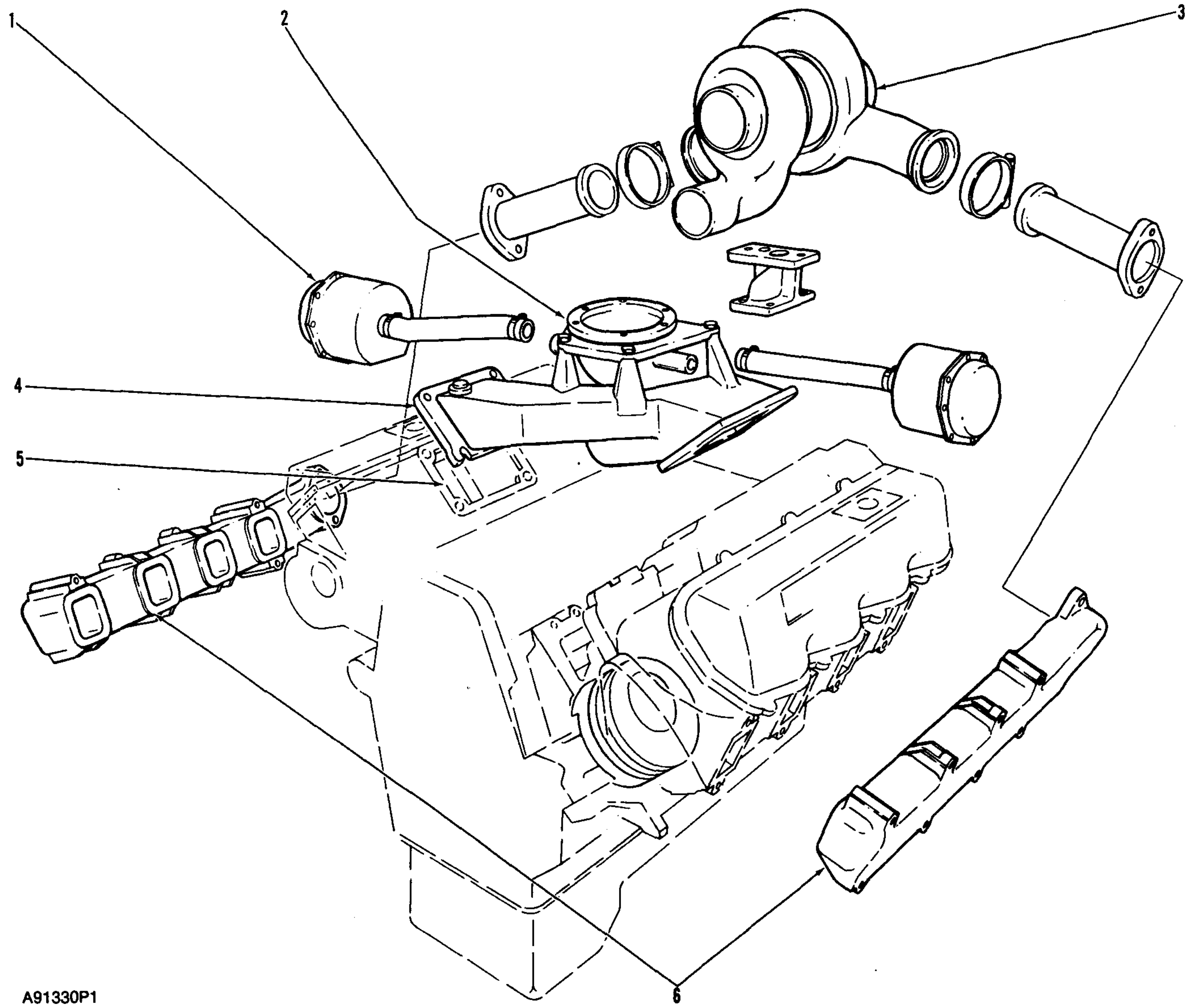

Automatic Timing Advance Unit
(4) Weights. (5) Springs. (6) Slides.

The weights (4) in the timing advance are driven by two slides (6) that fit into notches made on an angle in the weights. The slides (6) are driven by two dowels which are in the drive gear for the engine camshaft. As centrifugal force (rotation) moves weights (4) outward against the force of springs (5), The movement of the notches in weights (4) will cause the slides to make a change in the angle between the timing advance gear and the two drive dowels in the drive gear for the engine camshaft. Since the timing advance unit drives the gear (1) on the camshaft for the fuel injection pump, the fuel injection timing is also changed.

There are two different automatic timing advance units used on the 3208 Vehicular Engine. One unit will give 5° of timing advance, and the other gives 3.5° of timing advance. The timing advance unit begins to advance the timing at low idle rpm and stops advance at rated engine rpm. No adjustment can be made to the automatic timing advance unit.

Lubrication oil for the timing advance unit comes from drilled holes that connect with the front bearing for the engine camshaft.

# Air Inlet And Exhaust System




Air Inlet And Exhaust System
(1) Positive crankcase ventilation valves. (2) Air cleaner adapter. (3) Turbocharger. (4) Air inlet pipe. (5) Inlet manifold. (6) Exhaust manifold.

The 3208 Turbocharged Engine has a turbocharger located at the rear of the engine. The exhaust gases from all of the cylinders are used to turn the turbocharger. Air is pulled through the air cleaner and adapter by the turbocharger compressor wheel. The air goes from the turbocharger through air inlet pipe (4) to the inlet manifold in each cylinder head. The air enters the cylinders when the intake valves open.

The exhaust gases go out of the cylinders and into the exhaust ports when the exhaust valves open. The exhaust then goes through the exhaust manifolds (6) to the turbocharger. The exhaust gases enter the turbocharger turbine housing and cause the turbine wheel to turn. The exhaust gases leave the turbocharger through the exhaust outlet.

There is a positive crankcase ventilation valve on each valve cover. The ventilation valves are connected to the air cleaner adapter on the air inlet side of the turbocharger.

## Turbocharger

The turbocharger is located at the rear of the engine. All the exhaust gases from the diesel engine go through the turbocharger.

The exhaust gases enter the turbine housing (3) and go through the blades of turbine wheel (4) causing the turbine wheel and compressor wheel (1) to turn.

When compressor wheel (1) turns, it pulls filtered air from the air cleaner through compressor housing (2) air inlet. The air is put in compression by action of compressor wheel (1) and is pushed to the inlet manifold of the engine.

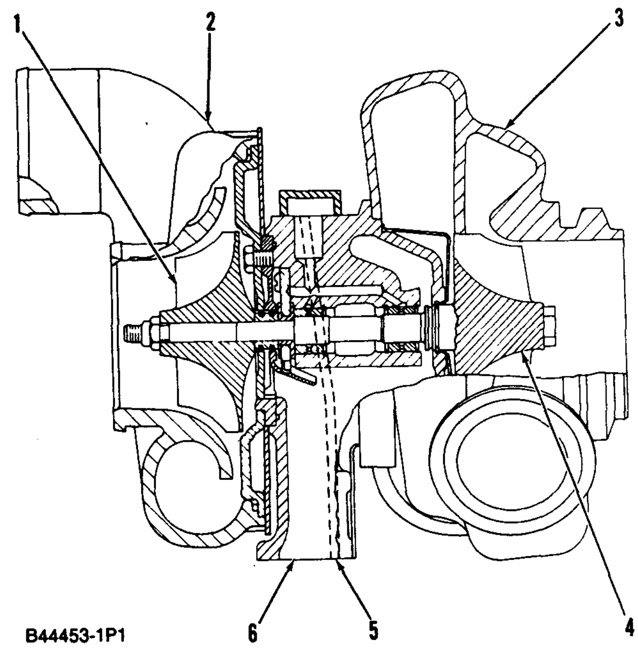
When the engine load increases, more fuel is injected into the engine cylinders. The volume of exhaust gas increases which causes the turbocharger turbine wheel and compressor impeller to turn faster. The increased rpm of the impeller increases the quantity of inlet air. As the turbocharger provides additional inlet air, more fuel can be burned. This results in more horsepower from the engine.

Maximum rpm of the turbocharger is controlled by the fuel setting, the high idle speed setting and the height above sea level at which the engine is operated.

NOTICE

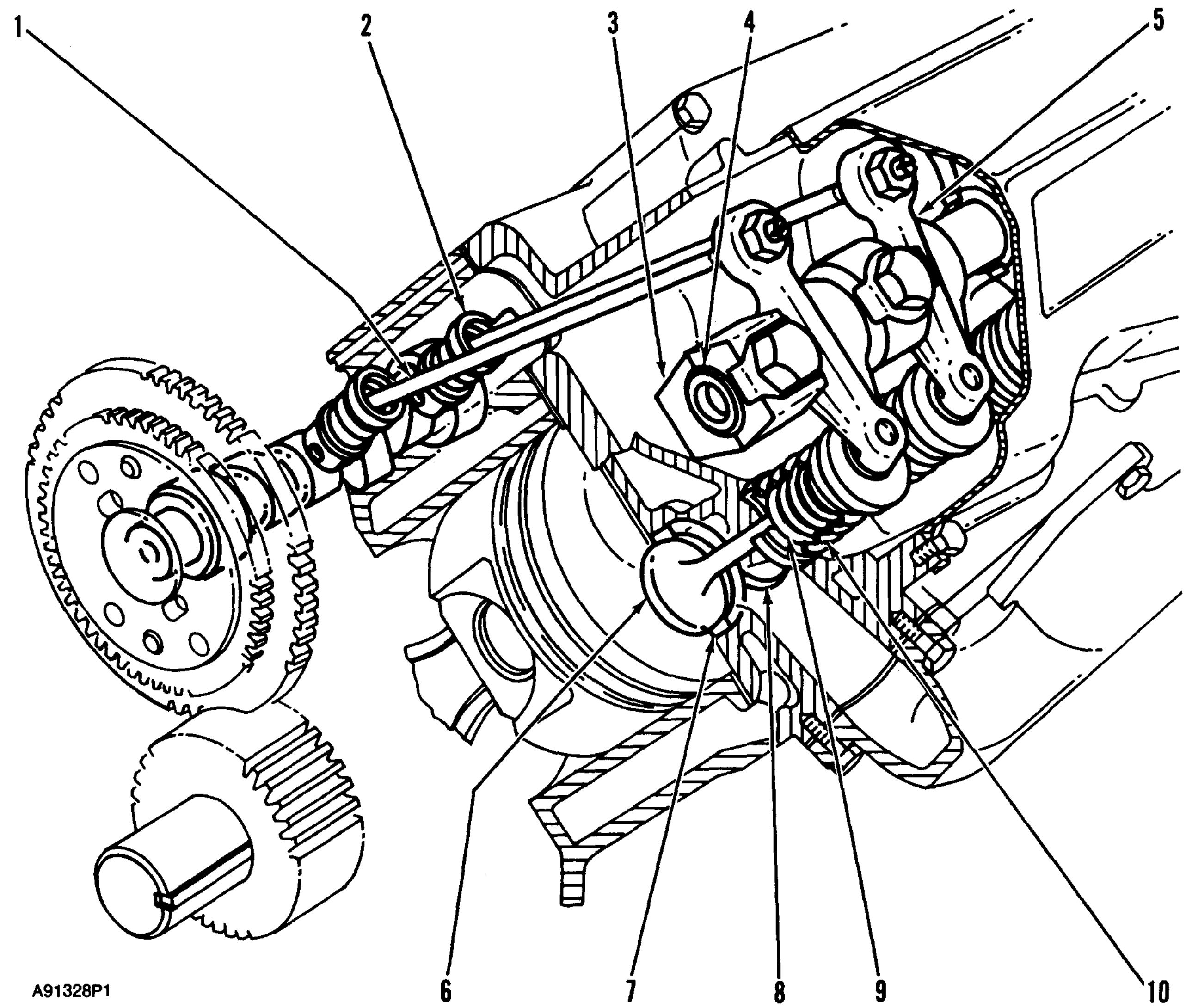
**If the high idle rpm or the fuel setting is higher than given in the Fuel Setting And Related Information Fiche (for height above sea level at which the engine is operated), there can be damage to engine or turbocharger parts.**

The bearings for the turbocharger use engine oil for lubrication. The oil comes in through the lubrication inlet passage (5) and goes through passages in the center section for lubrication of the bearings. Oil from the turbocharger goes out through the lubrication outlet passage (6) in the bottom of the center section and goes back to the engine oil pan.




Turbocharger
(1) Compressor wheel. (2) Compressor housing. (3) Turbine housing. (4) Turbine wheel. (5) Lubrication inlet passage. (6) Lubrication outlet passage.

# Cylinder Head And Valves



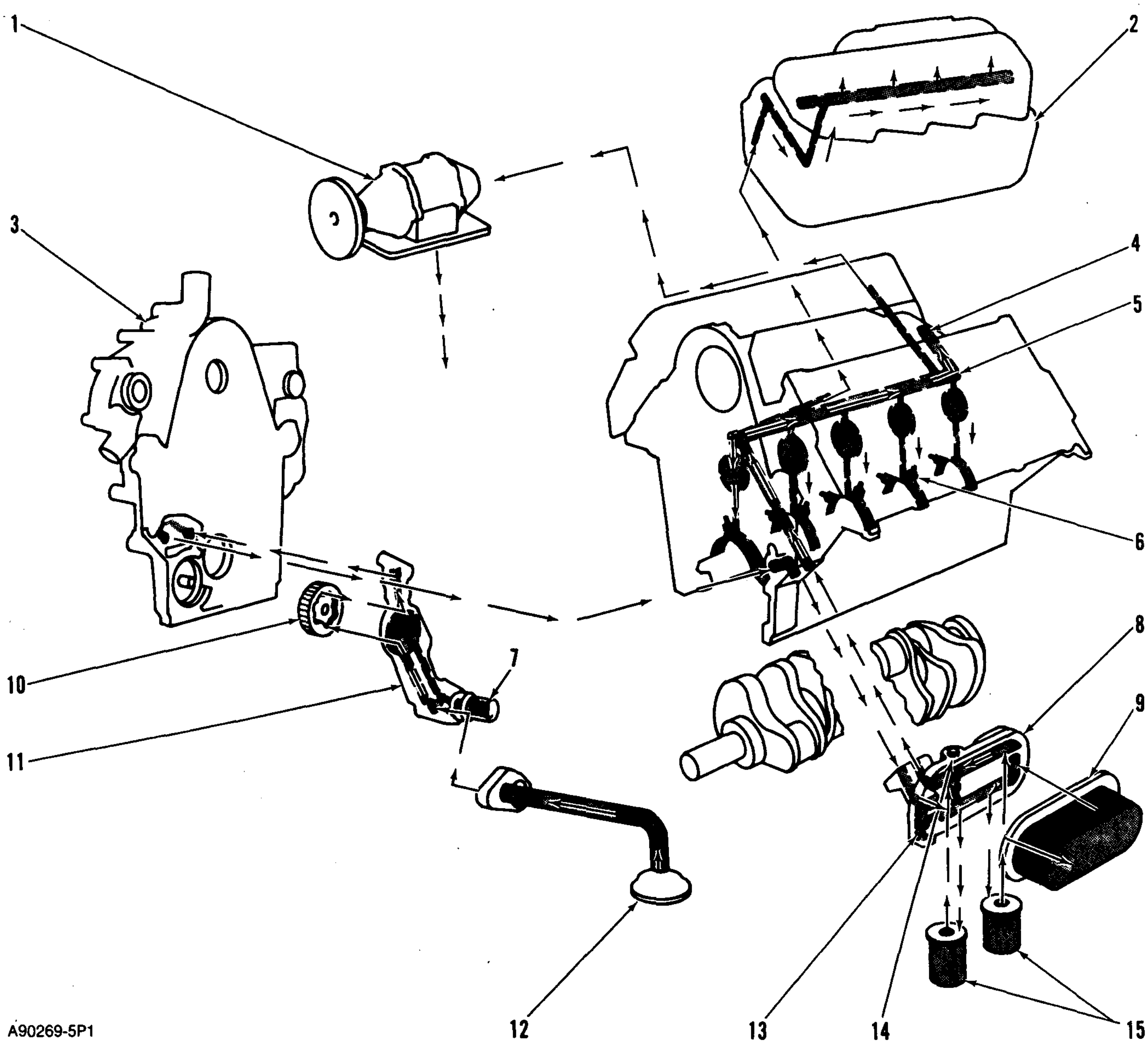

Cylinder Head and Valves
(Camshaft with roller lifter shown)
(1) Push rod. (2) Cam followers. (3) Guide support. (4) Rocker arm shaft. (5) Rocker arm. (6) Exhaust valve. (7) Valve seat insert. (8) Intake valve. (9) Inner valve spring. (10) Outer valve spring.

The valves and valve system components control the flow of inlet air and exhaust gases into and out of the cylinder during engine operation.

The intake and exhaust valves are opened and closed by movement of these components; crankshaft, camshaft, cam followers, push rods, rocker arms, and valve springs. Rotation of the crankshaft causes rotation of the camshaft. The camshaft gear is driven by, and timed to, a gear on the front of the crankshaft. When the camshaft turns, the cams on the camshaft also turn and cause the cam followers to go up and down. This movement makes the push rods move the rocker arms. The movement of the rocker arms will make the intake and exhaust valves in the cylinder head open and close according to the firing order (injection sequence) of the engine. Two valve springs for each valve help to hold the valves in the closed position.

There is one intake and one exhaust valve for each cylinder. The valve seat insert for the intake and exhaust valves can be replaced. The valve guide bore is machined in and is a part of the cylinder head.

# Lubrication System




Schematic of Lubrication System
(1) Vacuum pump or air compressor. (2) Cylinder head. (3) Front cover for the engine. (4) Oil passage (to turbocharger). (5) Oil manifold. (6) Piston cooling jet. (7) Oil pump bypass valve. (8) Base for the oil cooler. (9) Oil cooler. (10) Oil pump. (11) Cover for oil pump. (12) Suction bell for oil pump. (13) Oil cooler bypass valve. (14) Oil filters bypass valve. (15) Oil filters.

The lubrication system uses a six lobe, rotor type oil pump (10). Bolts hold the cover for the oil pump (11) on the front cover for the engine (3). The gear on the crankshaft drives the outer rotor. The outer rotor has rotation in a bearing in the front cover for the engine.

The inner rotor goes on a short shaft in the front cover for the engine. The inner rotor is driven by the outer rotor.

Oil pump bypass valve (7), in the cover for the oil pump (11) controls the pressure of the oil coming from oil pump (10). The pump can put more oil into the system than needed. When the pressure of the oil going into the engine is more than 380 to 550 kPa (55 to 80 psi) the bypass valve (7) will open. This permits the oil that is not needed to bypass the system.

Oil from the oil pan is pulled through the suction bell for the oil pump (12) by oil pump (10). The oil is sent by the pump to an oil passage in the front cover for the engine (3). Oil from this passage goes to the cylinder block and on to the base for the oil cooler (8). The base for the oil cooler is on the left side of the engine, near the front of the engine. Bypass valve (13) in the base for the oil cooler, will let the oil go around the oil cooler (9) when the oil is cold or if the restriction in the oil cooler is more than the other parts of the system. A difference in pressure of 85 to 105 kPa (12 to 15 psi) between the oil inlet and the oil outlet will open the bypass valve.

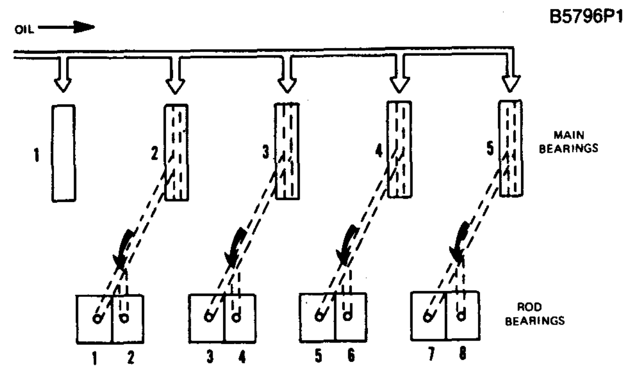
Oil from the oil cooler goes to the oil filters. Bypass valve (14) in the base for the oil cooler will let oil go around oil filters (15) if there is a restriction in the oil filters.

There are two pressure outlets in the base for the oil cooler. The pressure outlets are on the outlet side of the oil cooler and oil filters. The pressure outlets are for the sending unit and switch for the oil pressure.

Oil from the oil filters (15) goes through a passage in the cylinder block to oil manifold (5). The oil manifold is in the center of the cylinder block, above the camshaft, and goes the full length of the cylinder block. Oil goes from the oil manifold to the bearings for the camshaft. There are grooves in the bores in the cylinder block around the bearings for the camshaft. The bearing surfaces (journals) on the camshaft get lubrication from these grooves through a hole in the bearings for the camshaft.

Some of the oil goes around the grooves and down through passages to the main bearing bores. The main bearing bores in the cylinder block have grooves to let oil go to piston cooling jets (6) that spray oil to cool the pistons and lubricate the piston pin The remaining oil goes through a hole in the upper main bearing and into a groove in the bearing. This oil gives lubrication to the bearing surfaces (journals) of the crankshaft for the main bearings.

Oil gets into the crankshaft through holes in the bearing surfaces (journals) for the main bearings. Passages connect each bearing surface (journal) for the main bearing with the bearing surface (journal) for the connecting rod next to it.




Crankshaft Oil Schematic

NOTE: No. 1 main bearing surface (journal) does not have an oil passage to a connecting rod bearing surface (journal).

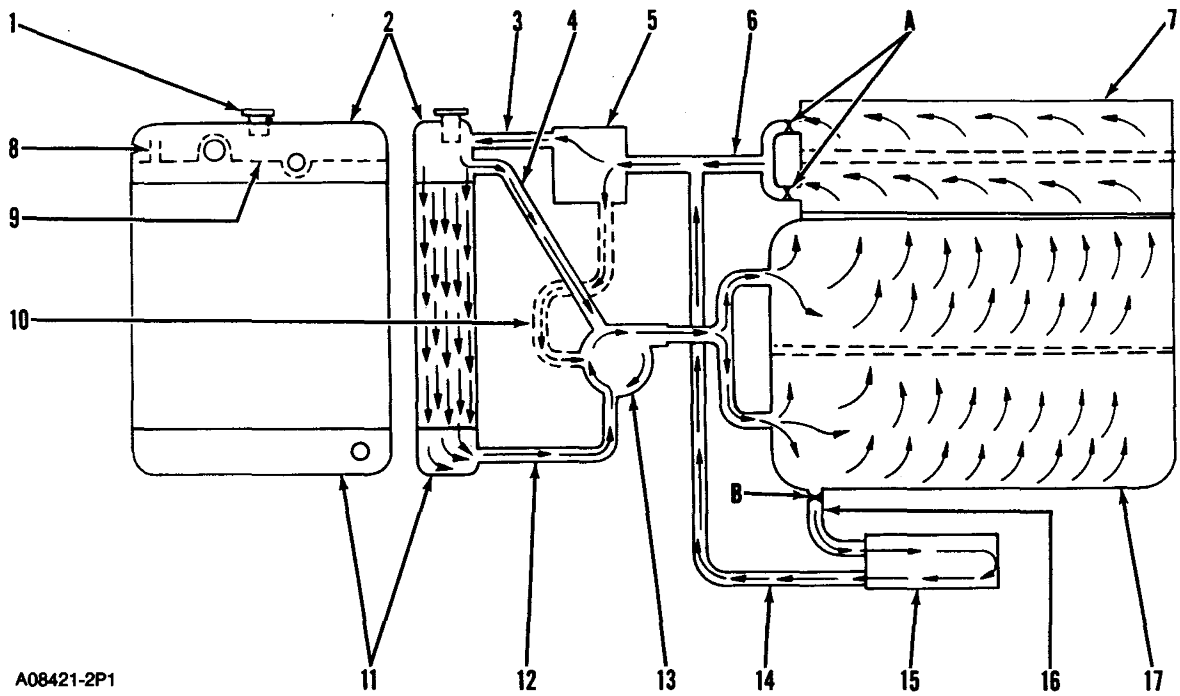
Oil passage (4) from the rear of oil manifold (5) goes up to the center housing of the turbocharger for lubrication of the bearings. Oil from the turbocharger drains back to the cylinder block and down to the oil pan.

Oil for the rocker arms comes from the oil manifold (5) through passages in the cylinder block. The passages in the cylinder block are in alignment with a passage in each cylinder head. The passage to the cylinder head on the left side is near the front of the cylinder block. The passage to the cylinder head on the right side is near the rear of the cylinder block.

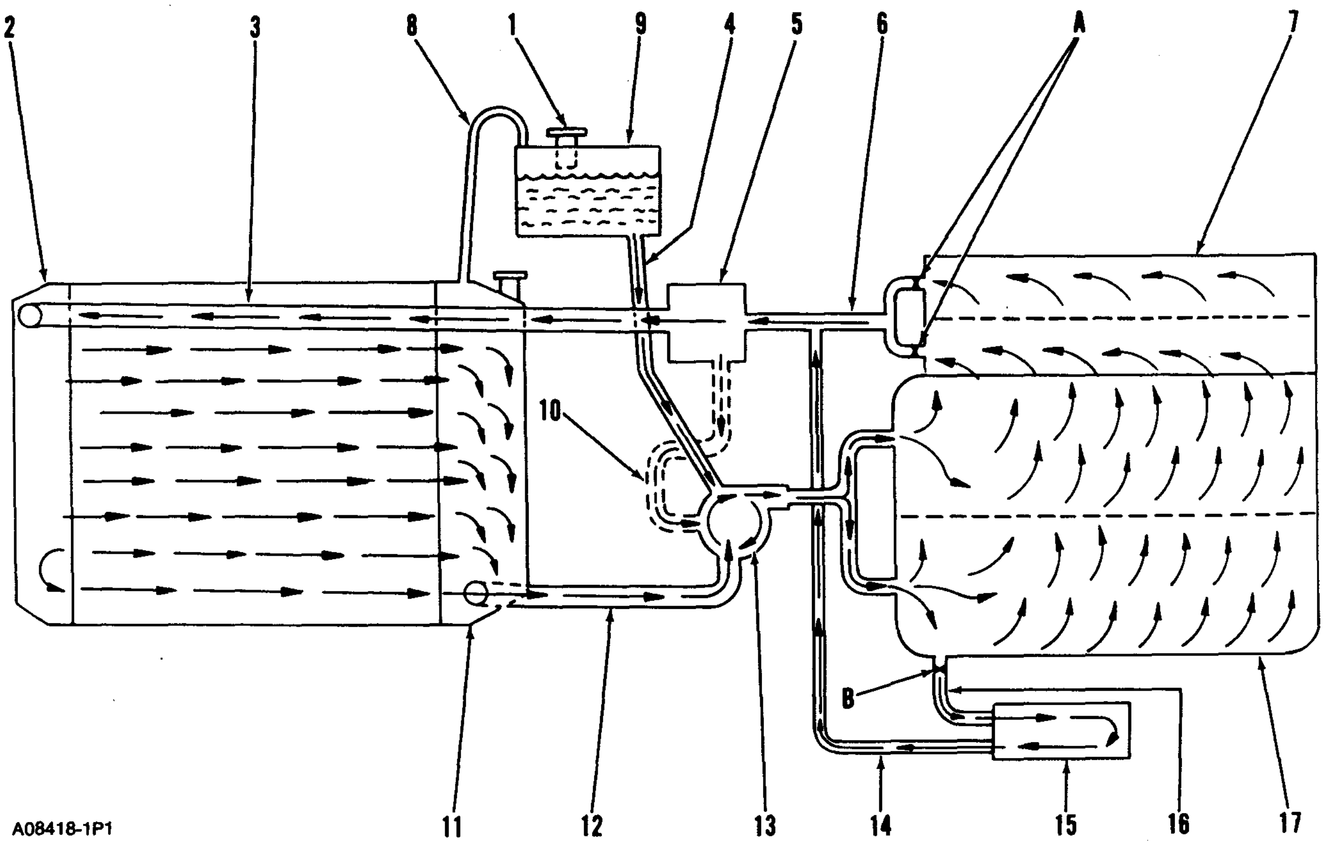
The passage in each cylinder head sends the oil into an oil hole in the bottom of the mounting surface of the bracket that holds the shaft for the rocker arms. The oil hole is in the front bracket on the left side and in the rear bracket on the right side. The oil then goes up through the bracket and into the center of the shaft for the rocker arms. Oil goes along the center of the shaft to the bearings for the rocker arms. From the rocker arms, the oil is pushed through small holes to give lubrication to the valves, push rods, cam followers, and camshaft lobes.

After the lubrication oil has done its work, it will return to the oil pan for the engine.

# Cooling System




Cooling System With Standard Vertical Radiator
(1) Radiator cap. (2) Radiator top tank. (3) Radiator top hose. (4) Shunt line. (5) Housing for water temperature regulators. (6) Return to housing for water temperature regulators. (7) Cylinder heads (two). (8) Vent tube. (9) Surge tank. (10) Inside bypass. (11) Radiator bottom tank. (12) Radiator bottom hose. (13) Water pump. (14) Outlet line for oil cooler. (15) Oil cooler. (16) Inlet line for oil cooler. (17) Cylinder block. (A) Orifices between cylinder heads and front cover. (B) Orifice in oil cooler inlet.




Cooling System With Cross Flow Radiator And Separate Surge Tank
(1) Radiator cap. (2) Radiator left side tank. (3) Radiator top hose. (4) Shunt line. (5) Housing for water temperature regulators. (6) Return to housing for water temperature regulators. (7) Cylinder heads (two). (8) Vent tube. (9) Surge tank. (10) Inside bypass. (11) Radiator right side tank. (12) Radiator bottom hose. (13) Water pump. (14) Outlet line for oil cooler. (15) Oil cooler. (16) Inlet line for oil cooler. (17) Cylinder block. (A) Orifices between cylinder heads and front cover for the engine. (B) Orifice in oil cooler inlet.

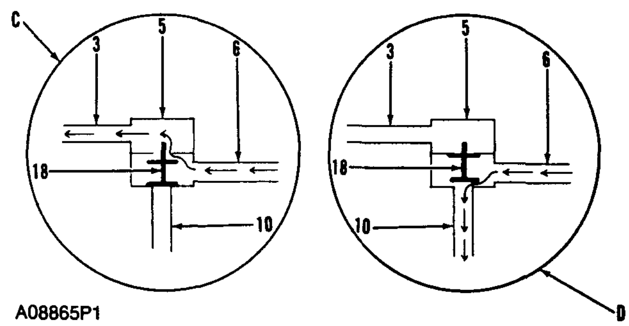
Water pump (13) is installed on the front face of the front cover for the engine and is driven by V-belts from the crankshaft pulley. The inlet opening of water pump (13) is connected to radiator bottom hose (12). The outlet flow of coolant from water pump (13) goes through inside passages in the front cover for the engine.

As the coolant goes from the water pump, it divides and goes through the inside passages in the front cover for the engine to cylinder block (17). Most of the coolant goes through cylinder block (17) and up to cylinder heads (7). From cylinder heads (7) the coolant goes forward through orifices (A) to the front cover for the engine.

Part of the coolant going to the left side (as seen from the flywheel) of cylinder block (17) goes through orifice (B) to inlet line (16) and on to oil cooler (15), to cool the oil for lubrication of the engine, and back to the front cover for the engine through outlet line (14).

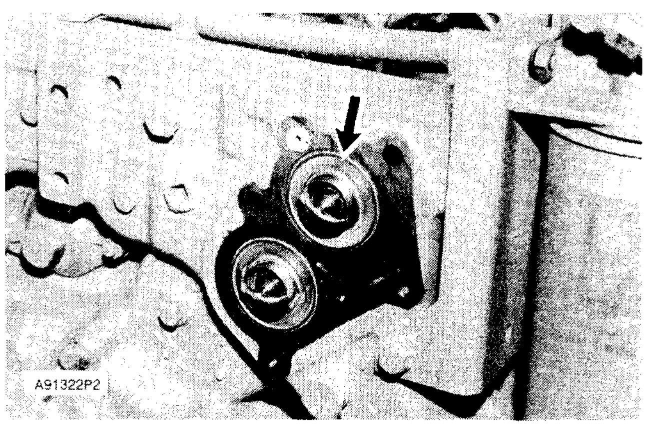
From the front cover for the engine, the coolant either goes to the inlet for water pump (13) or to the radiator.

If the coolant is cold (cool), the water temperature regulators (18) will be closed. The coolant will go through inside bypass (10) to water pump (13). If the coolant is warm, the water temperature regulators (18) will be open. When the water temperature regulators (18) are open, they make a restriction in the inside bypass (10) and the coolant goes through radiator top hose (3) and into radiator top tank (2) or left side tank (2). Coolant then goes through the core of the radiator to the radiator bottom tank (11) or radiator right side tank (11), where it is again sent through the cooling system. A small amount of coolant goes through inside bypass (10) when temperature regulators (18) are open.




Flow of Coolant
(3) Radiator top hose. (5) Housing (water temperature regulators). (6) Return to housing for water temperature regulators. (10) Inside bypass. (18) Water temperature regulators (two). (C) Flow with warm coolant. (D) Flow with cold coolant.

NOTE: The water temperature regulators (18) are an important part of the cooling system. They divide coolant flow between radiator (2) and inside bypass (10) as necessary to maintain the correct temperature. If the water temperature regulators are not installed in the system, there is no mechanical control, and most of the coolant will take the path of least resistance through bypass. This will cause the engine to overheat in hot weather. In cold weather, even the small amount of coolant that goes through the radiator is too much, and the engine will not get to normal operating temperatures.

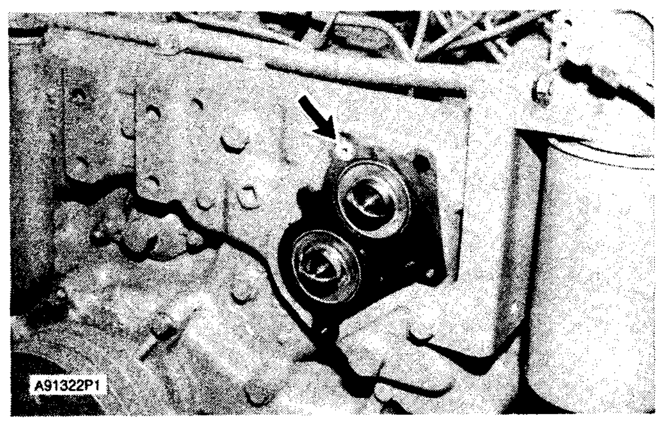



Location of Water Temperature Regulators

The vertical radiator is made with a top tank (2) above the core and a surge tank (9) either above or separate from the top tank. Vent tube (8) connects radiator top tank (2) and surge tank (9). The cross flow radiator is made with a left side tank (2) and a right side tank (11). The surge tank (9) is either a part of right side tank (11), separated by an inside baffle, or a tank separate from the radiator. Vent tube (8) connects the surge tank (9) to the radiator.

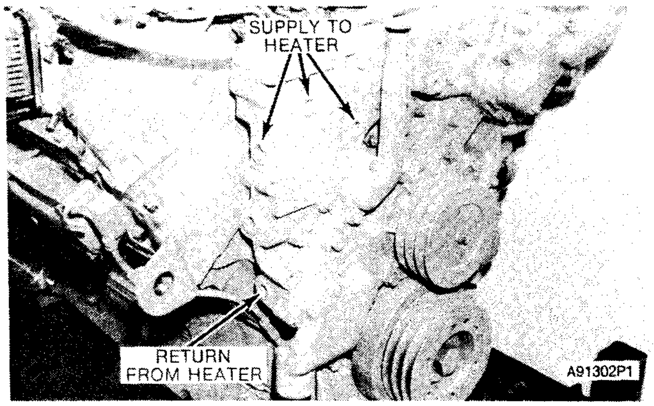
Surge tank (9) has a shunt line (4) that connects to the inlet of water pump (13). This shunt type system keeps a positive pressure on the inlet of water pump (13) at all times. When putting coolant in the cooling system, coolant from surge tank (9) goes through shunt line (4) to the inlet of water pump (13) and fills cylinder block (17) from the bottom. By filling the system from the bottom, any air in the system is pushed out through radiator top tank (2), through vent tube (8) into surge tank (9).

Radiator cap (1) is used to keep the correct pressure in the cooling system. This pressure keeps a constant supply of coolant to water pump (13). If this pressure goes too high, a valve in radiator cap (1) moves (opens) to get a reduction of pressure. When the correct pressure is in the cooling system, the valve in radiator cap (1) moves down (to the closed position).




Location of Vent Valve

The vent valve is located in the front housing next to the temperature regulators. The vent valve is used to let the air out of the cooling system when the cooling system is filled. When the engine is in operation, the vent valve will close and not let coolant go through. This will help increase the temperature of the coolant at low engine loads.



Locations of Heater Connections

C The front housing has several plugs that give access to water passages inside the housing. For the correct access points to install heater hoses, see the LOCATIONS OF HEATER CONNECTIONS picture.

# Basic Block

## Cylinder Block

The cylinders are a part of the cylinder block. There are no replaceable cylinder liners. The cylinders can be machined (bored) up to 1.02 mm (.040 in) oversize for reconditioning. The cylinders in the block are at a 90° angle to each other. There are five main bearings in the block to support the crankshaft.

## Cylinder Head

There is one cylinder head for each side (bank) of the engine. One intake and one exhaust valve is used for each cylinder. The valve guides are a part of the cylinder head and can not be replaced. Valve seat inserts are used for the intake and exhaust valves and can be replaced.

## Pistons, Rings and Connecting Rods

The pistons have two rings which are located above the piston pin bore. There is one compression ring and one oil control ring. The oil ring is made in one piece and has an expansion spring behind it. The compression ring is also one piece and goes into an iron band that is cast into the piston.

The piston pin is held in the piston by two snap rings which go into the piston pin bore.

The piston pin end of the connecting rod is tapered to give more bearing surface at the area of highest load. The rod is installed on the piston with the boss on the connecting rod on the same side as the crater in the piston. The connecting rod bearings are held in location with a tab that goes into a groove in the connecting rod.

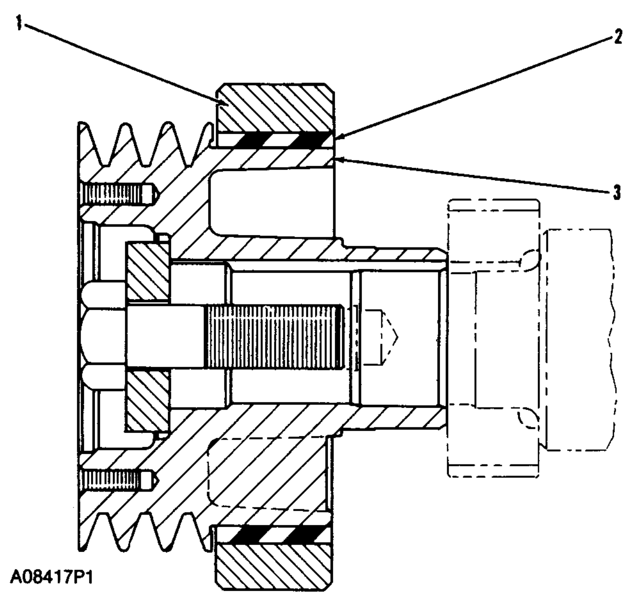
## Crankshaft

The force of combustion in the cylinders is changed to usable rotating power by the crankshaft. The crankshaft can have either six or eight counterweights. A gear on the front of the crankshaft turns the engine camshaft gear and the engine oil pump. The end play of the crankshaft is controlled by the thrust bearing on No. 4 main bearing.

## Vibration Damper

The twisting of the crankshaft, due to the regular power impacts along its length, is called twisting (torsional) vibration. The vibration damper is installed on the front end of the crankshaft. It is used for reduction of torsional vibrations and stops the vibration from building up to amounts that cause damage.

The damper is made of a flywheel ring (1) connected to an inner hub (3) by a rubber ring (2). The rubber makes a flexible coupling between the flywheel ring and the inner hub.



Cross Section of a Vibration Damper
(1) Flywheel ring. (2) Rubber ring. (3) Inner hub.

# Electrical System

The electrical system has three separate circuits; the charging circuit, the starting circuit and the low amperage circuit. Some of the electrical system components are used in more than one circuit. The battery (batteries), circuit breaker, ammeter, cables and wires from the battery are all common in each of the circuits.

The charging circuit is in operation when the engine is running. An alternator makes electricity for the charging circuit. A voltage regulator in the circuit controls the electrical output to keep the battery at full charge.

NOTICE

**Never operate the alternator without the battery in the circuit. Making or breaking an alternator connection with heavy load on the circuit can cause damage to the regulator.**

The starting circuit is in operation only when the start switch is activated.

The low amperage circuit and the charging circuit are both connected to the same side of the ammeter. The starting circuit connects to the opposite side of the ammeter.

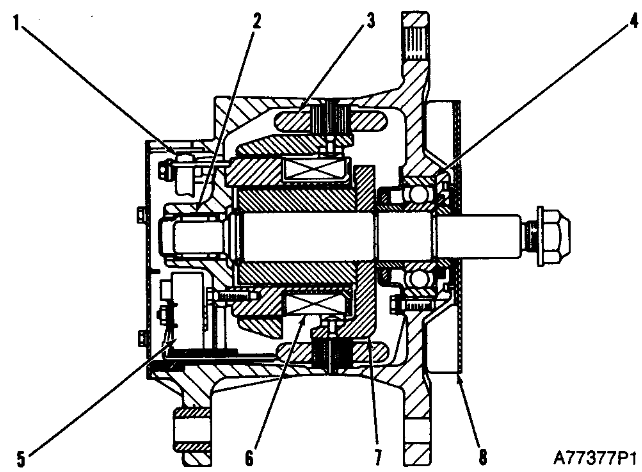
## Charging System Components

### Alternator (Delco-Remy)

The alternator is driven by V-belts from the crankshaft pulley. This alternator is a three phase, self-rectifying charging unit, and the regulator is part of the alternator.

This alternator design has no need for slip rings or brushes, and the only part that has movement is the rotor assembly. All conductors that carry current are stationary. The conductors are the field winding, stator windings, six rectifying diodes and the regulator circuit components.

The rotor assembly has many magnetic poles like fingers with air space between each opposite pole. The poles have residual magnetism (like permanent magnets) that produce a small amount of magnet-like lines of force (magnetic field) between the poles. As the rotor assembly begins to turn between the field winding and the stator windings, a small amount of alternating current (AC) is produced in the stator windings from the small magnetic lines of force made by the residual magnetism of the poles. This AC current is changed to direct current (DC) when it passes through the diodes of the rectifier bridge. Most of this current goes to charge the battery and to supply the low amperage circuit, and the remainder is sent on to the field windings. The DC current flow through the field windings (wires around an iron core) now increases the strength of the magnetic lines of force. These stronger lines of force now increase the amount of AC current produced in the stator windings. The increased speed of the rotor assembly also increases the current and voltage output of the alternator.

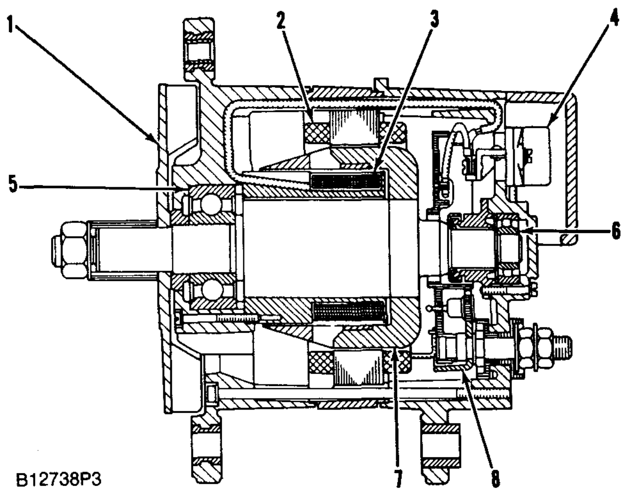



Delco-Remy Alternator
(1) Regulator. (2) Roller bearing. (3) Stator winding. (4) Ball bearing (5) Rectifier bridge. (6) Field winding. (7) Rotor assembly. (8) Fan.

### C Alternator (Bosch)

The alternator is driven by V-belts from the crankshaft pulley. This alternator is a three phrase, self-rectifying charging unit, and the regulator is part of the alternator.

The 7N9720 Alternator has an output of 37A. The 9G9538 Alternator has an output of 50A.




Bosch Alternator
(1) Fan. (2) Stator winding. (3) Field winding. (4) Regulator. (5) Ball bearing. (6) Roller bearing. (7) Rotor. (8) Rectifier assembly.

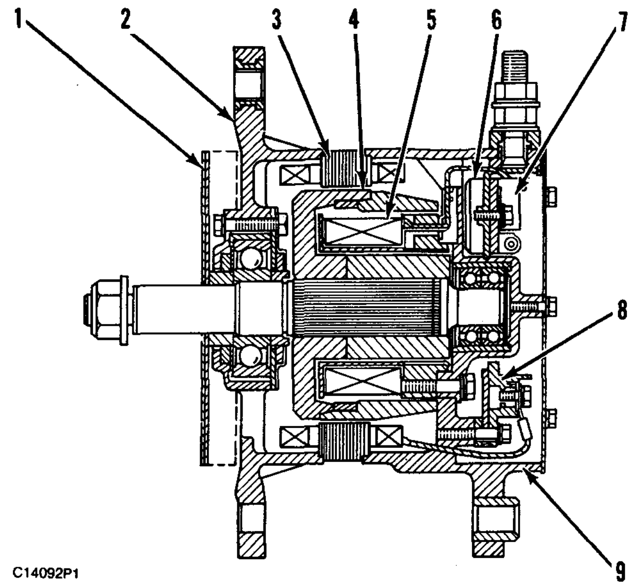
This alternator design has no need for slip rings or brushes, and the only part that has movement is the rotor assembly. All conductors that carry current are stationary. The conductors are: the field winding, stator windings, six rectifying diodes, and the regulator circuit components.

The rotor assembly has many magnetic poles like fingers with air space between each opposite pole. The poles have residual magnetism (like permanent magnets) that produce a small amount of magnet-like lines of force (magnetic field) between the poles. As the rotor assembly begins to turn between the field winding and the stator windings, a small amount of alternating current (AC) is produced in the stator windings from the small magnetic lines of force made by the residual magnetism of the poles. This AC current is changed to direct current (DC) when it passes through the diodes of the rectifier bridge. Most of this current goes to charge the battery and to supply the low amperage circuit, and the remainder is sent to the field windings. The DC current flow through the field windings (wires around an iron core) now increases the strength of the magnetic lines of force. These stronger lines of force now increase the amount of AC current produced in the stator windings. The increased speed of the rotor assembly also increases the current and voltage output of the alternator.

The voltage regulator is a solid state (transistor, stationary parts) electronic switch. It feels the voltage in the system and switches on and off many times a second to control the field current (DC current to the field windings) for the alternator to make the needed voltage output.

## C Alternator (Nippondenso)

The Nippondenso alternator has three-phase, full-wave rectified output. It is brushless. The rotor and bearings are the only moving parts. There is a 24 volt, 9G4574 Alternator with 35 amp output and a 24 volt, 6T7223 Alternator with a 50 amp output.




Nippondenso Alternator Components
(1) Fan. (2) Front frame assembly. (3) Stator assembly. (4) Rotor assembly. (5) Field winding (coil) assembly. (6) Regulator assembly. (7) Condenser (suppression capacitor). (8) Rectifier assembly. (9) Rear frame assembly.

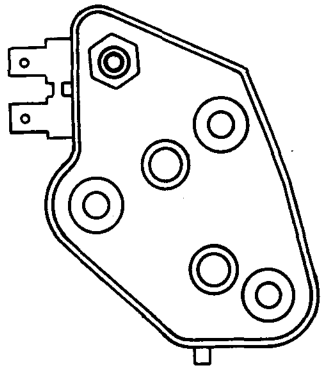
When the engine is started and the rotor turns inside the stator windings, three-phase alternating current (AC) and rapidly rising voltage is generated.

A small amount of alternating current (AC) is changed (rectified) to pulsating direct current (DC) by the exciter diodes on the rectifier assembly. Output current from these diodes adds to the initial current which flows through the rotor field windings from residual magnetism. This will make the rotor a stronger magnet and cause the alternator to become activated automatically. As rotor speed, current and voltages increase, the rotor field current increases enough until the alternator becomes fully activated.

The main battery charging current is charged (rectified) from AC to DC by the other positive and negative diodes in the rectifier and pack (main output diodes) which operate in a full wave linkage rectifier circuit.

Alternator output is controlled by a regulator.

### C Alternator Regulator (Delco-Remy)

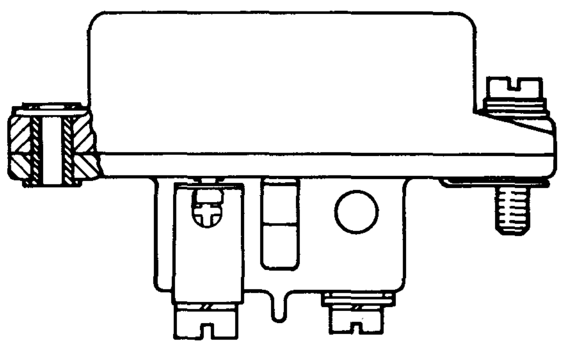


C12725P1

Regulator (Delco-Remy)

The voltage regulator is a solid state (transistor, stationary parts) electronic switch. It feels the voltage in the system and switches on and off many times a second to control the field current (DC current to the field windings) for the alternator to make the needed voltage output.

### C Alternator Regulator (Bosch)

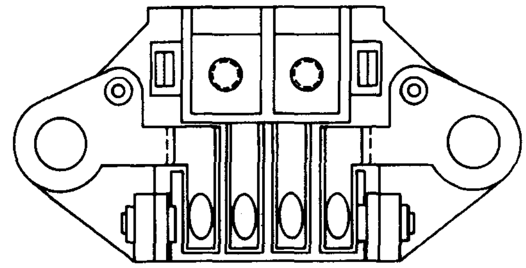


B12749P1

Regulator (Bosch)

The voltage regulator is an electronic switch. It feels the voltage in the system and gives the necessary field current (current to the field windings of the alternator) for the alternator to make the needed voltage. The voltage regulator controls the field current to the alternator by switching on and off many times a second.

### C Alternator Regulator (Nippondenso)



C10874P1

Regulator (Nippondenso)

The voltage regulator is a solid state electronic switch. It feels the voltage in the system and gives the necessary field current (current to the field windings of the alternator) for the alternator to make the needed voltage. The voltage regulator controls the field current to the alternator by switching on and off many times a second. There is no voltage adjustment for this regulator.

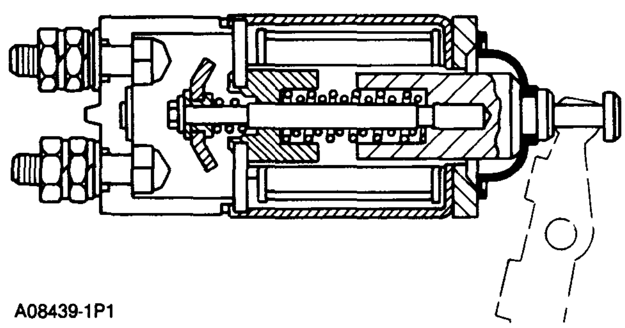
## Starting System Components

### Solenoid

A solenoid is a magnetic switch that does two basic operations:

a. Closes the high current starter motor circuit with a low current start switch circuit.

b. Engages the starter motor pinion with the ring gear.



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Typical Solenoid Schematic

The solenoid switch is made of an electromagnetic (one or two sets of windings) around a hollow cylinder.

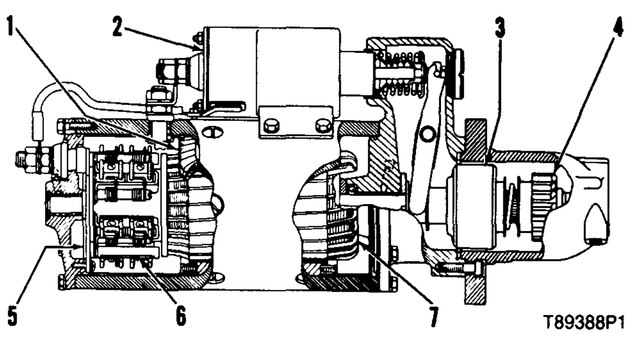
There is a plunger (core) with a spring load inside the cylinder that can move forward and backward. When the start switch is closed and electricity is sent through the windings, a magnetic field is made that pulls the plunger forward in the cylinder. This moves the shift lever (connected to the rear of the plunger) to engage the pinion drive gear with the ring gear. The front end of the plunger then makes contact across the battery and motor terminals of the solenoid, and the starter motor begins to turn the flywheel of the engine.

When the start switch is opened, current no longer flows through the windings. The spring now pushes the plunger back to the original position, and, at the same time, moves the pinion gear away from the flywheel.

When two sets of windings in the solenoid are used, they are called the hold-in winding and the pull-in winding. Both have the same number of turns around the cylinder, but the pull-in winding uses a larger diameter wire to produce a greater magnetic field. When the start switch is closed, part of the current flows from the battery through the hold-in windings, and the rest flows through the pull-in windings to motor terminal, then through the motor to ground. When the solenoid is fully activated (connection across battery and motor terminal is complete), current is shutoff through the pull-in windings. Now only the smaller hold-in windings are in operation for the extended period of time it takes to start the engine. The solenoid will now take less current from the battery and heat made by the solenoid will be kept at an acceptable level.

### Starter Motor

The starter motor is used to turn the engine flywheel fast enough to get the engine running.




Starter Motor
(1) Field. (2) Solenoid. (3) Clutch. (4) Pinion. (5) Commutator. (6) Brush assembly. (7) Armature.

The starter motor has a solenoid. When the start switch is turned to the START position, the solenoid will be activated electrically. The solenoid core will now move to push the starter pinion, by a mechanical linkage, to engage with the ring gear on the flywheel of the engine. The starter pinion will engage with the ring gear before the electric contacts in the solenoid close the circuit between the battery and the starter motor. When the circuit between the battery and the starter motor is complete, the pinion will turn the engine flywheel. A clutch gives protection for the starter motor so that the engine, when it starts to run, can not turn the starter motor too fast. When the start switch is released, the starter pinion will move away from the flywheel ring gear.

### C Magnetic Switch

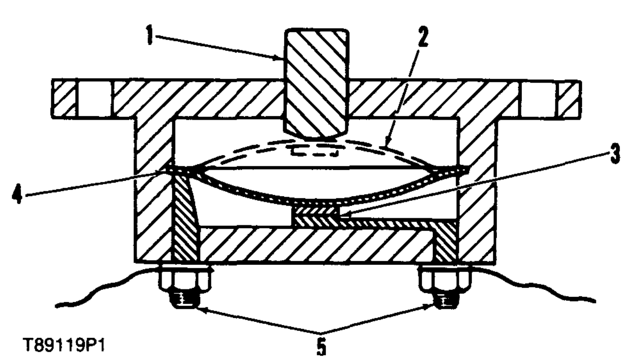
A magnetic switch (relay) is sometimes used for the starter solenoid circuit. Its operation electrically is the same as the solenoid. Its function is to reduce the current load on the start switch and control current to the starter solenoid.

## Other Components

### Circuit Breaker

The circuit breaker is a switch that opens the battery circuit if the current in the electrical system goes higher than the rating of the circuit breaker.

A heat activated metal disc with a contact point completes the electric circuit through the circuit breaker. If the current in the electrical system gets too high, it causes the metal disc to get hot. This heat causes a distortion of the metal disc which opens the contacts and breaks the circuit. A circuit breaker that is open can be reset after it cools. Push the reset button to close the contacts and reset the circuit breaker.




Circuit Breaker Schematic
(1) Reset button. (2) Disc in open position. (3) Contacts. (4) Disc. (5) Battery circuit terminals.

# Testing and Adjusting

## Troubleshooting

Troubleshooting can be difficult. On the following pages there is a list of possible problems. To make a repair to a problem, make reference to the cause and correction.

This list of problems, causes and corrections, will only give an indication of where a possible problem can be, and what repairs are needed. Normally, more or other repair work is needed beyond the recommendations in the list. Remember that a problem is not normally caused only by one part, but by the relation of one part with other parts. This list can not give all possible problems and corrections. The service personnel must find the problem and its source, then make the necessary repairs.

### Troubleshooting Index

1. Engine Will Not Start.
2. Misfiring Or Running Rough.
3. Stall At Low rpm.
4. Sudden Changes In Engine rpm.
5. Not Enough Power.
6. Too Much Vibration.
7. Loud Combustion Noise.
8. Loud Noise (Clicking) From Valve Compartment.
9. Oil In Cooling System.
10. Mechanical Noise (Knock) In Engine.
11. Fuel Consumption Too High.
12. Loud Noise From Valves Or Valve Drive Components.
13. Little Movement Of Rocker Arm And Too Much Valve Clearance.
14. Valve Spring Lock Is Free.
15. Oil At The Exhaust.
16. Little Or No Valve Clearance.
17. Engine Has Early Wear.
18. Coolant In Lubrication Oil.
19. Too Much Black Or Gray Smoke.
20. Too Much White Or Blue Smoke.
21. Engine Has Low Oil Pressure.
22. Engine Uses Too Much Lubrication Oil.
23. Engine Coolant Is Too Hot.
24. Starter Motor Does Not Turn.
25. Alternator Gives No Charge.
26. Alternator Charge Rate Is Low Or Not Regular.
27. Alternator Charge Is Too High.
28. Alternator Has Noise.
29. Exhaust Temperature Is Too High.

**Problem 1. Engine Will Not Start**

**Probable Cause:**

1. Empty Fuel Tank
   Put fuel in fuel tank.

2. Bad Quality Fuel
   Remove the fuel from the fuel tank. Install a new fuel filter element. Put a good grade of clean fuel in the fuel tank.

3. Dirty Fuel Filter
   Install new fuel filter.

4. Dirty Or Broken Fuel Lines
   Clean or install new fuel lines as necessary.

5. Linkage To Sleeve Control Shaft Is Held In Shutoff Position
   Check the operation of the shutoff solenoid and the shutoff linkage. Solenoid must pull up to compress spring for fuel turn on. Check governor linkage for free movement. Sleeves must turn freely on pump plungers in all positions of sleeve control shaft. The thrust collar must turn freely on the governor shaft at all positions between shutoff and full load. If linkage does not move freely under these conditions, clean all parts thoroughly. Inspect all parts for wear and make replacement where needed.

6. Fuel Pressure Is Too Low
   Replace the fuel filter. Inspect the bypass valve for free movement. Install a new bypass valve if necessary.

7. Air In The Fuel System
   Find the air leak in the fuel system and correct it. Remove air from the fuel system. Make reference to REMOVING AIR FROM FUEL SYSTEM in Testing and Adjusting.

8. Fuel System Not Timed Correctly To Engine
   Make adjustment to timing if necessary.

9. Constant Bleed Valve Stays Open (not enough fuel pressure for starting)
   Replace constant bleed valve.

10. No Over Fueling Spring
    Install an over fueling spring.

11. Fuel Ratio Control Has A Defect
    Check fuel ratio control setting. Adjust if necessary. Check operation of solenoid.

**Problem 2. Misfiring Or Running Rough**

**Probable Cause:**

1. Fuel Pressure Is Low
   Make sure there is enough fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system. Check fuel pressure. The outlet pressure of the fuel transfer pump at full load speed is 205 ± 35 kPa ( 30 ± 5 psi).
   If fuel pressure is lower than above pressure, install a new fuel filter element. Inspect the fuel bypass valve for free movement. Install a new fuel bypass valve if necessary.

2. Air In The Fuel System
   Find the air leak in the fuel system and correct it. Remove air from the fuel system. Make reference to REMOVING AIR FROM FUEL SYSTEM in Testing and Adjusting.

3. Leak Or Break In Fuel Line Between Injection Pump And Injection Valve
   Install a new fuel line.

4. Wrong Valve Clearance
   Make adjustment according to Testing and Adjusting.

5. Defect In Fuel Injection Nozzle
   Run engine at rpm that gives maximum misfiring or rough running. Then loosen a fuel line nut on the injection line for each cylinder, one at a time. Find the cylinder where loosening the fuel line nut does not change the way the engine runs. Test the fuel injection nozzle for that cylinder. Install new parts where needed.

6. Wrong Fuel Injection Timing
   Make adjustment to timing.

**Problem 3. Stall At Low rpm**

**Probable Cause:**

1. Fuel Pressure Is Low
   Make sure there is enough fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system. Check fuel pressure. The outlet pressure of the fuel transfer pump at full load speed is 205 ± 35 kPa (30 ± 5 psi).
   If fuel pressure is lower than above pressure, install a new fuel filter element. Inspect the bypass valve for free movement. Install a new bypass valve if necessary.

2. Idle rpm Too Low
   Make adjustment to governor so idle rpm is the same as given in the Fuel Setting And Related Information Fiche.

3. Defect In Fuel Injection Nozzle
   Install a new fuel injection nozzle.

4. Wrong Valve Clearance
   Make adjustment according to Testing and Adjusting.

5. Spring For Dashpot Governor Installed Wrong
   Install spring correctly.

**Problem 4. Sudden Changes In Engine rpm**

**Probable Cause:**

1. Air In the Fuel System
   Find the air leak in the fuel system and correct it. Remove air from the fuel system. Make reference to REMOVING AIR FROM FUEL SYSTEM in Testing and Adjusting.

2. Broken Torsion Spring On Sleeve Control Shaft
   Install new parts as needed.

3. Linkage In Governor Does Not Move Freely
   Clean all linkage and inside of governor housing. Install new parts for those parts that have damage.

4. Governor Springs Not Completely On Spring Seat
   Put springs completely on spring seat.

5. Spring For Dashpot Governor Installed Wrong
   Install spring correctly

**Problem 5. Not Enough Power**

**Probable Cause:**

1. Bad Quality Fuel
   Remove the fuel from the fuel tank. Install a new fuel filter element. Put a good grade of clean fuel in the fuel tank.

2. Fuel Pressure Is Low
   Make sure there is fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system. Check fuel pressure. The outlet pressure of the fuel transfer pump at full load speed is 205 $\pm$ 35 kPa (30 $\pm$ 5 psi).
   If fuel pressure is lower than above pressure, install a new fuel filter element. Inspect the fuel bypass valve for free movement. Install a new fuel bypass valve if necessary.

3. Air In The Fuel System
   Find the air leak in the fuel system and correct it. Remove air from the fuel system. Make reference to REMOVING AIR FROM FUEL SYSTEM in Testing and Adjusting.

4. Leaks In Air Inlet System
   Check the pressure in the air inlet manifold. Look for restrictions in the air cleaner.

5. Wrong Fuel Setting
   Make adjustments as necessary.

6. Governor Linkage
   Make adjustment to get full travel of linkage. Install new parts for those that have damage or defects.

7. Defect In Timing Advance Unit
   Replacement of timing advance unit is needed.

8. Wrong Valve Clearance
   Make adjustment according to Testing and Adjusting.

9. Defect In Fuel Injection Nozzle
   Run engine at rpm that gives maximum misfiring or rough running. Then loosen a fuel line nut on the injection line for each cylinder, one at a time. Tighten each fuel line nut before loosening the next one. Find the cylinder where loosening the fuel line nut does not change the way the engine runs. Test the fuel injection nozzle for that cylinder. Install new parts where needed.

10. Wrong Fuel Injection Timing
    Make adjusting to timing.

11. Fuel Shutoff Solenoid or Shutoff Linkage Causing A Restriction In The Travel Of The Shaft For The Sleeves
    Check for correct full power with solenoid removed. If the engine has full power with the solenoid removed, the problem is in the solenoid or the shutoff linkage. Check for free travel of the linkage.

12. Constant Bleed Valve Stays Closed
    Replace constant bleed valve.

13. Turbocharger Has Carbon Deposit
    Inspect and repair turbocharger as necessary.

14. Fuel Ratio Control Has A Defect
    Check fuel ratio control setting. Adjust if necessary. Check diaphragm in fuel ratio control.

**Problem 6. Too Much Vibration**

**Probable Cause:**

1. Loose Bolt Or Nut Holding Pulley Or Damper
   Tighten bolt or nut.

2. Pulley Or Damper Has A Defect
   Install a new pulley or damper.

3. Engine Supports Are Loose, Worn, Or Have A Defect
   Tighten all mounting bolts. Install new components if necessary.

4. Misfiring Or Running Rough
   Make Reference to PROBLEM 2.

**Problem 7. Loud Combustion Noise (Sound)**

**Probable Cause:**

1. Bad Quality Fuel
   Remove the fuel from the fuel tank. Install a new fuel filter element. Put a good grade of clean fuel in the fuel tank.

2. Defect In Fuel Injection Nozzle
   Install a new fuel injection nozzle.

3. Wrong Fuel Injection Timing
   Make adjustment to timing.

**Problem 8. Loud Noise (Clicking) From Valve Compartment**

**Probable Cause:**

1. Broken Valve Spring(s) Or Locks
   Install new parts where necessary. Broken locks can cause the valve to slide into the cylinder. This will cause much damage.

2. Loose Bolts Holding Rocker Arm Assembly
   Tighten to 24 ± 7 N•m (18 ± 5 lb ft).

3. Too Much Valve Clearance
   Make adjustment according to Testing and Adjusting.

**Problem 9. Oil In Cooling System**

**Probable Cause:**

1. Defect In Core Of Oil Cooler
   Install a new core in the oil cooler.

2. Defect In Head Gasket
   Install a new head gasket.

**Problem 10. Mechanical Noise (Knock) In Engine**

**Probable Cause:**

1. Failure Of Bearing For Connecting Rod
   Inspect the bearing for the connecting rod and the bearing surface on the crankshaft. Install new parts where necessary.

2. Damage To Crankshaft
   Make replacement of the crankshaft.

3. Defect In Attachment
   Repair or install new components.

**Problem 11. Fuel Consumption Too High**

**Probable Cause:**

1. Fuel System Leaks
   Replacement of parts is needed at points of leakage.

2. Defect In Timing Advance Unit
   Replacement of timing advance unit is needed.

3. Wrong Fuel Injection Timing
   Make adjustment to timing.

4. Fuel Setting Too High
   Make adjustment to the fuel setting. Make reference to the Fuel Setting And Related Information Fiche.

**Problem 12. Loud Noise From Valve Or Valve Drive Components**

**Probable Cause:**

1. Broken Valve Spring(s)
   Make replacement of parts with damage.

2. Broken Camshaft
   Make replacement of parts with damage. Clean engine thoroughly.

3. Broken Timing Advance Gear
   Make replacement of timing advance unit.

**Problem 13. Little Movement Of Rocker Arm And Too Much Valve Clearance**

**Probable Cause:**

1. Not Enough Lubrication
   Check lubrication in valve compartment. There must be a strong flow of oil at high engine rpm, but only a small flow at low rpm. Oil passages must be clean, especially those sending oil to the cylinder head.

2. Rocker Arm Parts Worn
   If there is too much wear, install new parts or rocker arms. Make adjustment of valve clearance according to Testing and Adjusting.

3. End Of Valve Stem Worn
   If there is too much wear, install new valves. Make adjustment of valve clearance according to Testing and Adjusting.

4. Too Much Valve Clearance
   Make adjustment according to Testing and Adjusting.

5. Worn Push Rods
   If there is too much wear, install new push rods, Make adjustment of valve clearance according to Testing and Adjusting.

6. Cam Followers Worn
   If there is too much wear, install new cam followers. Make adjustment of valve clearance according to Testing and Adjusting.

7. Worn Cams On Camshaft
   Check valve clearance. Check for free movement of valves or bent valve stems. Install new components as necessary. Make adjustment of valve clearance according to Testing and Adjusting.

8. Loose Bolts Holding Rocker Arm Assembly
   Tighten to 24 ± 7 N•m (18 ± 5 lb ft).

**Problem 14. Valve Spring Lock Is Free**

**Probable Cause:**

1. Broken Locks
   Broken locks can cause the valve to slide into the cylinder. This will cause much damage.

2. Broken Valve Spring(s)
   Install new valve spring(s).

**Problem 15. Oil At The Exhaust**

**Probable Cause**

1. Too Much Oil In The Valve Compartment
   Look at both ends of the rocker arm shaft. Be sure that there is a plug in each end.

2. Worn Valve Guides
   Reconditioning of the cylinder head is needed.

3. Worn Piston Rings
   Inspect and install new parts as needed.

**Problem 16. Little Or No Valve Clearance**

**Probable Cause**

1. Worn Valve Seat Or Face Of Valve
   Reconditioning of cylinder head is needed. Make adjustment of valve clearance according to Testing and Adjusting.

**Problem 17. Engine Has Early Wear**

**Probable Cause:**

1. Dirt In Lubrication Oil
   Remove dirty lubrication oil. Install a new oil filter element. Put clean oil in the engine.

2. Air Inlet Leaks
   Inspect all gaskets and connections. Make repairs if leaks are found.

3. Fuel Leakage Into Lubrication Oil
   This will cause high fuel consumption and low engine oil pressure. Make repairs if leaks are found. Install new parts where needed.

**Problem 18. Coolant In Lubrication Oil**

**Probable Cause:**

1. Failure Of Oil Cooler Core
   Install a new core for the oil cooler.

2. Failure Of Cylinder Head Gasket
   Install a new cylinder head gasket. Tighten the bolts holding the cylinder head, according to the Specifications.

3. Crack Or Defect In Cylinder Head
   Install a new cylinder head.

4. Crack Or Defect In Cylinder Block
   Install a new cylinder block.

5. Failure Of Front Cover Gasket
   Install a new front cover gasket.

**Problem 19. Too Much Black Or Gray Smoke**

**Probable Cause:**

1. Not Enough Air For Combustion
   C Check air cleaner for restrictions [Max. 762 mm (30 in) of water].

2. Bad Fuel Injection Nozzle(s)
   Install new fuel injection nozzle(s).

3. Wrong Fuel Injection Timing
   Make adjustment to timing.

4. Fuel Ratio Control Has A Defect
   Check fuel ratio control setting. Adjust if necessary. Check for broken springs.

**Problem 20. Too Much White Or Blue Smoke**

**Probable Cause:**

1. Too Much Lubrication Oil In Engine
   Remove extra oil. Find where extra oil comes from. Put correct amount of oil in engine. Do not put too much oil in engine.

2. Misfiring Or Running Rough
   Make reference to Problem 2.

3. Wrong Fuel Injection Timing
   Make adjustment to timing.

4. Worn Valve Guides
   Reconditioning of cylinder head is needed.

5. Worn Piston Rings
   Install new parts as necessary.

6. Defect In Timing Advance Unit
   Replacement of timing advance unit is needed.

7. Failure Of Turbocharger Oil Seal
   Check air inlet pipes for oil. Repair turbocharger if necessary.

**Problem 21. Engine Has Low Oil Pressure**

**Probable Cause:**

1. Defect In Oil Pressure Gauge
   Install new gauge.

2. Dirty Oil Filter Or Oil Cooler
   Check the operation of bypass valve for the filter. Install new oil filter elements if needed. Clean or install new oil cooler core. Remove dirty oil from engine. Put clean oil in engine.

3. Diesel Fuel In Lubrication Oil
   Find the place where diesel fuel gets into the lubrication oil. Make repairs as needed. Remove the lubrication oil that has diesel fuel in it. Install a new oil filter element. Put clean oil in the engine.

4. Too Much Clearance Between Rocker Arm Shaft And Rocker Arms
   Check lubrication in valve compartment. Install new parts as necessary.

5. Oil Pump Suction Pipe Has A Defect
   Replacement of pipe is needed.

6. Relief Valve For Oil Pump Does Not Operate Correctly
   Clean valve and housing. Install new parts as necessary.

7. Oil Pump Has A Defect
   Make repair or replacement of oil pump if necessary.

8. Too Much Clearance Between Crankshaft And Crankshaft Bearings
   Check the oil filter for correct operation. Install new parts if necessary.

9. Too Much Clearance Between Camshaft And Camshaft Bearings
   Install new camshaft and camshaft bearings if necessary.

**Problem 22. Engine Uses Too Much Lubrication Oil**

**Probable Cause:**

1. Too Much Lubrication Oil In Engine
   Remove extra oil. Find where extra oil comes from. Put correct amount of oil in engine. Do not put too much oil in engine.

2. Oil Leaks
   Find all oil leaks. Make repairs as needed.

3. Oil Temperature Is Too High
   Check operation of oil cooler. Install new parts if necessary. Clean the core of the oil cooler. Check oil cooler bypass valve.

4. Too Much Oil To Intake Valve Guides
   Make reference to PROBLEM 15.

5. Worn Valve Guides
   Make reference to PROBLEM 15.

6. Worn Piston Rings
   Install new parts as necessary.

7. Failure Of Turbocharger Oil Seal
   Inspect turbocharger and repair if necessary.

**Problem 23. Engine Coolant Is Too Hot**

**Probable Cause:**

1. Restriction To Air Flow Through Radiator Or Restriction To Flow Of Coolant Through The Heat Exchanger
   Remove all restrictions of flow.

2. Not Enough Coolant In System
   Add coolant to cooling system.

3. Pressure Cap Has A Defect
   Check operations of pressure cap. Install a new pressure cap if necessary.

4. Combustion Gases In Coolant
   Find out where gases get into the cooling system. Make repairs as needed.

5. Water Temperature Regulators (Thermostats) Or Temperature Gauge Has A Defect
   Check water temperature regulators for correct operation. Check temperature gauge operation. Install new parts as necessary.

6. Water Pump Has A Defect
   Install a new water pump.

7. Too Much Load On The System
   Make a reduction to the load.

8. Wrong Fuel Injection Timing
   Make adjustment to timing.

9. Shunt Line Has A Defect
   Make repairs as needed.

10. Drive Belts Loose
    Adjust drive belts.

**Problem 24. Starter Motor Does Not Turn**

**Probable Cause:**

1. Battery Has Low Output
   Check condition of battery. Charge battery or make replacement as necessary.

2. Wiring Or Switch Has A Defect
   Make repairs or replacement as necessary.

3. Starter Motor Solenoid Has A Defect
   Install a new solenoid.

4. Starter Motor Has A Defect
   Make repair or replacement of starter motor.

**Problem 25. Alternator Gives No Charge**

**Probable Cause:**

1. Loose Drive Belt For Alternator
   Make an adjustment to put the correct tension on the drive belt.

2. Charging Or Ground Return Circuit Or Battery Connections Have A Defect
   Inspect all cables and connections. Clean and tighten all connections. Make replacement of parts that have a defect.

3. Alternator Brushes Have A Defect
   Install new brushes.

4. Rotor (Field Coil) Has A Defect
   Install a new rotor.

**Problem 26. Alternator Charge Rate Is Low Or Not Regular**

**Probable Cause:**

1. Loose Drive Belt For Alternator
   Make an adjustment to put the correct tension on the drive belt.

2. Charging Or Ground Return Circuit Or Battery Connections Have A Defect
   Inspect all cables and connections. Clean and tighten all connections. Make replacement of parts that have a defect.

3. Alternator Regulator Has A Defect
   Make repair or replacement of alternator regulator.

4. Alternator Brushes Have A Defect
   Install new brushes.

5. Rectifier Diodes Have A Defect
   Make replacement of rectifier diode that has a defect.

6. Rotor (Field Coil) Has A Defect
   Install a new rotor.

**Problem 27. Alternator Charge Too High**

**Probable Cause:**

1. Alternator Or Alternator Regulator Has Loose Connections
   Tighten all connections to alternator or alternator regulator.

2. Alternator Regulator Has A Defect
   Install a new alternator regulator.

**Problem 28. Alternator Has Noise**

**Probable Cause:**

1. Drive Belt For Alternator Is Worn Or Has A Defect
   Install a new drive belt for the alternator.

2. Loose Alternator Drive Pulley
   Check key groove in pulley for wear. If groove is worn, install a new pulley. Tighten pulley nut according to Specifications.

3. Drive Belt and Drive Pulley For Alternator Are Not In Alignment
   Make an adjustment to put drive belt and drive pulley in correct alignment.

4. Worn Alternator Bearings
   Install new bearings in the alternator.

**Problem 29. Exhaust Temperature Is Too High**

**Probable Cause:**

1. Air Inlet Or Exhaust System Has A Restriction
   Remove restriction.

2. Wrong Fuel Injection Timing
   Make an adjustment to the timing.

3. Air Inlet System Has A Leak
   Check pressure in inlet system. Find leaks and correct.

4. Exhaust System Has A Leak
   Find cause of exhaust leak and correct.

# Fuel System

Either too much fuel or not enough fuel for combustion can be the cause of a problem in the fuel system.

Many times work is done on the fuel system when the problem is really with some other part of the engine. The source of the problem is difficult to find, especially when smoke comes from the exhaust. Smoke that comes from the exhaust can be caused by a bad fuel injection valve, but it can also be caused by one or more of the reasons that follow:

a. Not enough air for good combustion.
b. An overload at high altitude.
c. Oil leakage into combustion chamber.
d. Not enough compression.

## Fuel System Inspection

A problem with the components that send fuel to the engine can cause low fuel pressure. This can decrease engine performance.

1. Check the fuel level in the fuel tank. Look at the cap for the fuel tank to make sure the vent is not filled with dirt.
2. Check the fuel lines for fuel leakage. Be sure the fuel supply line does not have a restriction or a bad bend.
3. Install a new fuel filter. Clean the fuel screen located in the inlet valve of the fuel transfer pump.
4. Remove any air that may be in the fuel system. Open the drain valve on the fuel injection pump housing. Operate the fuel priming pump until fuel without air comes from the drain lines. Close the drain valve.

To remove air from the fuel injection lines, loosen the fuel line nuts ½ turn. Move the governor lever to the low idle position. Crank engine with the starter motor until fuel without air comes from the fuel line connections. Tighten the fuel line nuts.

## Check Engine Cylinders Separately

An easy check can be made to find the cylinder that runs rough (misfires) and causes black smoke to come out of the exhaust pipe.

Run the engine at the speed that is the roughest. Loosen the fuel line nut at a fuel injection pump. This will stop the flow of fuel to that cylinder. Do this for each cylinder until a loosened fuel line is found that makes no difference in engine performance. Be sure to tighten each fuel line nut after the test before the next fuel line nut is loosened. Check each cylinder by this method. When a cylinder is found where the loosened fuel line nut does not make a difference in engine performance, test the injection pump and fuel injection nozzle for that cylinder.

Temperature of an exhaust manifold port, when the engine runs at low idle speed, can also be an indication of the condition of a fuel injection nozzle. Low temperature at an exhaust manifold port is an indication of no fuel to the cylinder. This can possibly be an indication of a nozzle with a defect. Extra high temperature at an exhaust manifold port can be an indication of too much fuel to the cylinder, also caused by a nozzle with a defect.

The most common defects found with the fuel injection nozzles are:

1. Carbon on tip of the nozzle or in the nozzle orifice.
2. Orifice wear.
3. Dirty nozzle screen.

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NOTICE

Do not test or disassemble nozzles unless you have the correct service tools.

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c **Testing Fuel Injection Nozzles**

Before fuel injection nozzle can be tested, nozzle must be cleaned. Refer to Special Instruction, Form No. SEHS8627 for use of the 8S2245 Nozzle Cleaning Tool Group.

Perform the following tests using the 5P4150 Nozzle Testing Group to determine if nozzle performance is acceptable.

Valve Opening Pressure Test.
Tip Leakage Test.
Orifice Restriction Test.
Bleedscrew Leakage Test.

Refer to Special Instruction, Form No. SEHS7292 for operation of the 5P4150 Nozzle Testing Group.

## Fuel Injection Lines

Fuel from the fuel injection pumps goes to the fuel injection nozzles through the fuel injection lines.

When fuel injection lines are disconnected or removed, always put caps or plugs on the ends to keep dirt out of the lines. When fuel injection lines are installed, be sure all clamps and dampers are installed in their original location.

Each fuel injection line of an engine has a special design and must be installed in a certain location. When fuel injection lines are removed from an engine, put identification marks or tags on the fuel lines as they are removed, so they can be put in the correct location when they are installed.

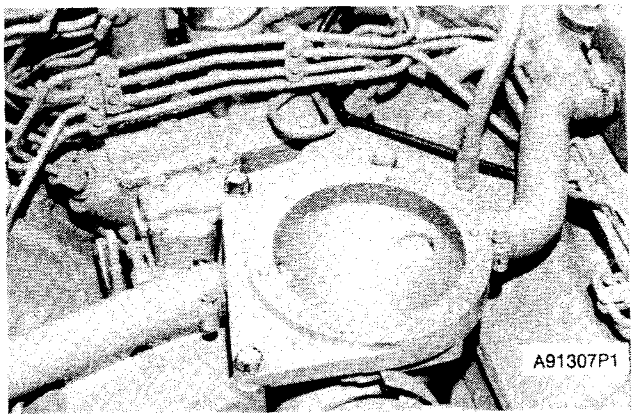
The nuts that hold a fuel injection line to an injection nozzle and injection pump must be tightened to the correct torque. If the nut is loose, fuel will leak from the connection. If the nut is tightened too tight, the inside diameter of the line will become smaller and cause a restriction to the flow of fuel in the line. Use a torque wrench and a 5P0144 Fuel Line Socket to tighten the fuel injection line nuts to 41 ± 7 N•m (30 ± 5 lb ft).

## Fuel Injection Pumps

When injection pumps, sleeves and lifters are removed from the injection pump housing, keep the parts of each pump together so they can be installed back in their original location.

Be careful when disassembling injection pumps. Do not damage the surface on the plunger. The plunger, sleeve and barrel for each pump are made as a set. Do not put the plunger of one pump in the barrel or sleeve of another pump. If one part is worn, install a complete new pump assembly. Be careful when putting the plunger in the bore of the barrel or sleeve.

When an injection pump is installed correctly, the plunger is through the sleeve and the adjustment lever is engaged with the groove on the sleeve. The bushing that holds the injection pump in the pump housing must be kept tight. Tighten the bushing to 80 ± 7 N•m (60 ± 5 lb ft). Damage to the housing will result if the bushing is too tight. If the bushing is not tight enough, the pump will leak.




Air Inlet Pipe

NOTICE

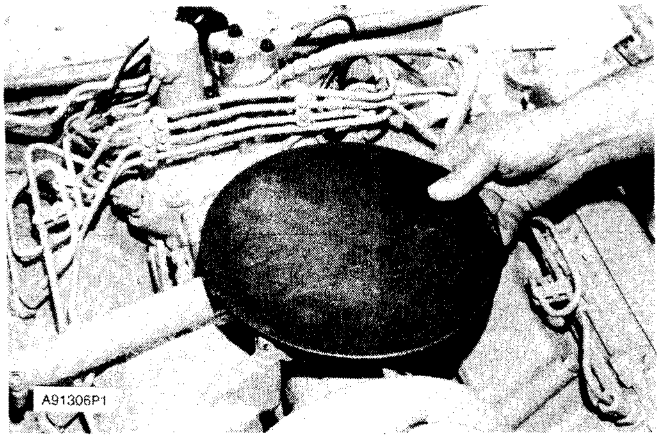
**If the sleeves on one or more of the fuel injection pumps have been installed wrong, damage to the engine is possible if cautions are not taken at first starting. When the fuel injection pumps have been removed and installed with the fuel injection pump housing on engine, take the cautions that follow to stop the engine, if it starts to overspeed (run out of control).**

a. Remove the air cleaner leaving the air inlet pipe open as shown.
b. Set the governor control at low idle.

**WARNING**

**Be careful when plate is put against air inlet opening. Due to excessive suction, the plate can be pulled quickly against air inlet pipe. To avoid crushed fingers, do not put fingers between plate and air inlet pipe.**

c. Start the engine, and if engine starts to overspeed (run out of control), put a steel plate over the air inlet as shown to stop the engine.

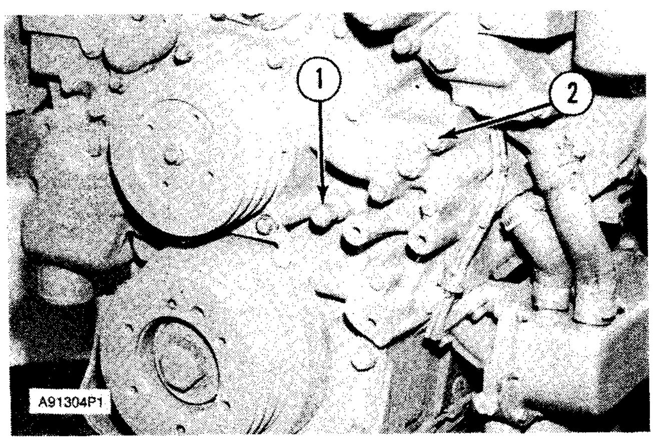



Stopping the Engine

## Finding Top Center Compression Position for No. 1 Piston

No. 1 piston at top center (TDC) on the compression stroke is the starting point for all timing procedures.

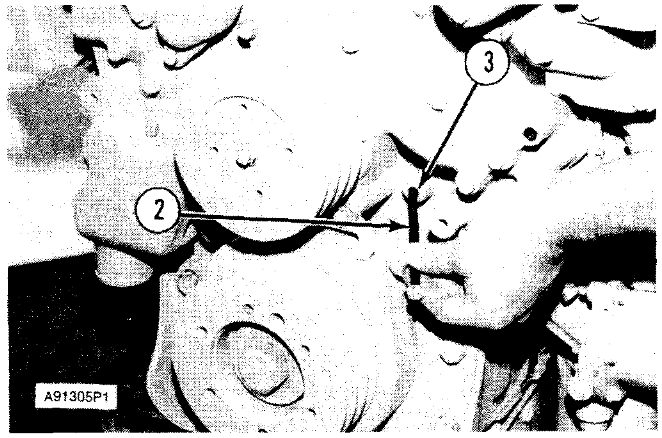
1. Remove fitting (1) from the timing hole (3) in the front cover. Put bolt (2) in timing hole (3).




Fitting and Bolt Location
(1) Fitting. (2) Bolt.

2. Turn the crankshaft **counterclockwise** (as seen from rear of engine) until bolt (2) will go into the hole in the drive gear for the camshaft.

3. Remove the valve cover on the right side of the engine (as seen from rear of engine). The two valves at the right front of the engine are the intake and exhaust valves for No. 1 cylinder.




Installing Bolt
(2) Bolt. (3) Timing hole.

4. The intake and exhaust valves for No. 1 cylinder must now be closed and the timing pointer will be in alignment with the TDC-1 on the damper assembly. The No. 1. piston is now at top center on the compression stroke.

## Fuel System Adjustments

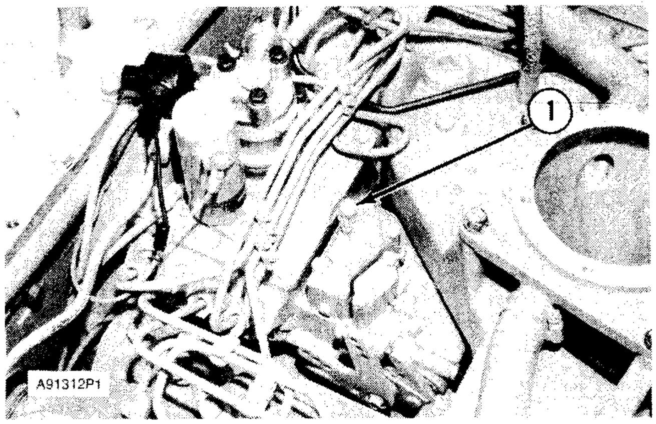
### Checking Fuel Injection Pump Timing; On Engine

The timing of the fuel injection pump can be checked and changed if necessary, to make compensation for movement in the taper sleeve drive or worn timing gears. The timing can be checked and if necessary, changed using the following method.

### Checking Timing by Timing Pin Method

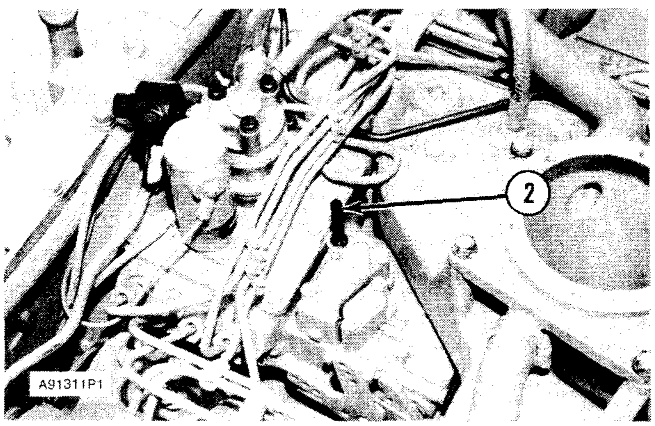
| Tools Needed | | |
|---|---|---|
| 6V4069 | Puller | 1 |
| 3P1544 | Timing Pin | 1 |

1. Remove bolt (1) from the timing pin hole.



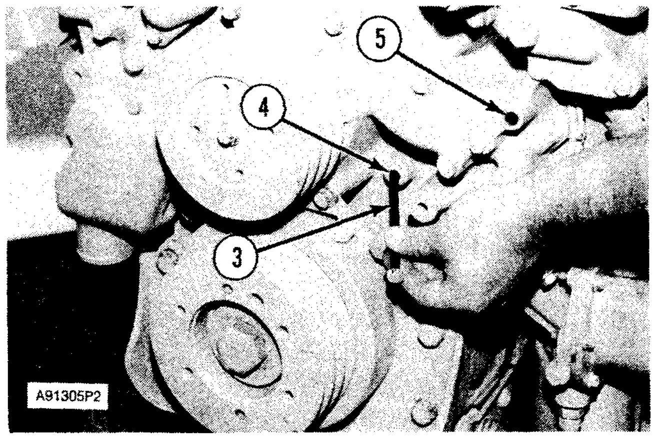
Timing Hole Bolt
(1) Bolt.

2. Turn the crankshaft **counterclockwise** MDNM (as seen from rear of engine) until timing pin (2) goes into the notch in the camshaft for the fuel injection pumps.



Timing Pin Installed
(2) 3P1544 Timing Pin.

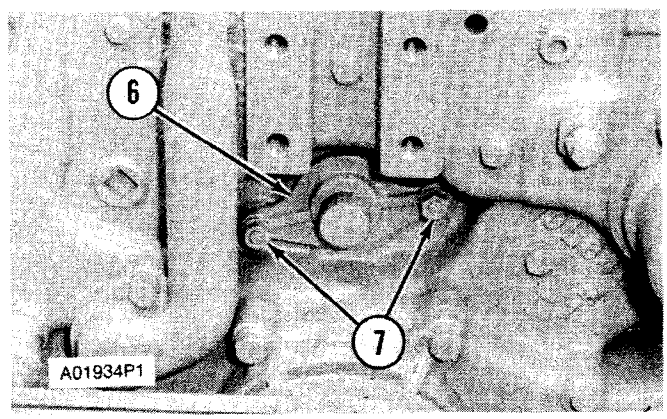
3. Remove the fitting from timing hole (4) in the front cover. Put bolt (3) through the front cover and into the hole with threads in the timing gear. The bolt from hole (5) can be used.



Installing Bolt
(3) 1D4539 Bolt, 5/16 in-18 NC, 63.5 mm (2.5 in) long. (4) Timing hole. (5) Hole.

4. If the timing pin is in the notch in the camshaft for the fuel injection pumps, and bolt (3) goes into the hole in the timing gear through timing hole (4), the timing of the fuel injection pump is correct.

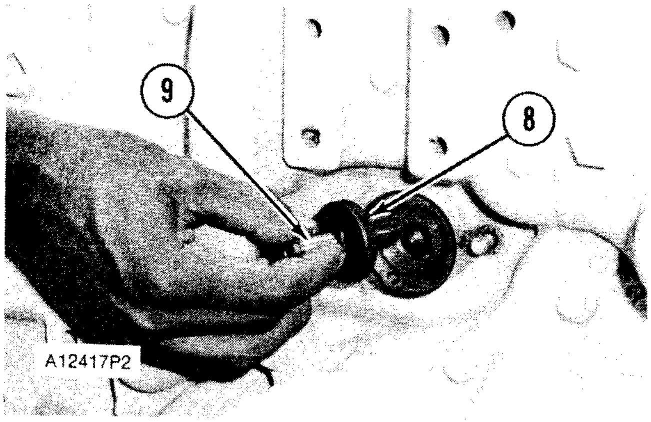
NOTE: If bolt (3) does not go in the hole in the timing gear with timing pin (2) in the notch in the camshaft, use the procedure that follows.



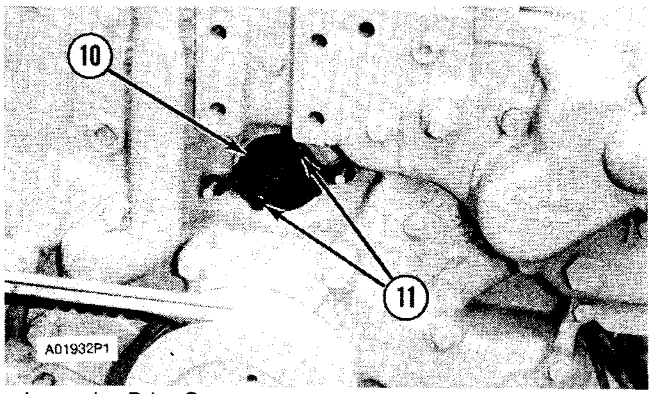
Location of Cover
(6) Cover for the tachometer drive assembly. (7) Nuts.

a. Remove nuts (7) and the cover for the tachometer drive assembly (6).
b. Remove the tachometer drive shaft (9) and washer (8) from the camshaft for the fuel injection pumps.

NOTE: Tachometer drive shaft (9) and washer (8) are removed as an assembly.

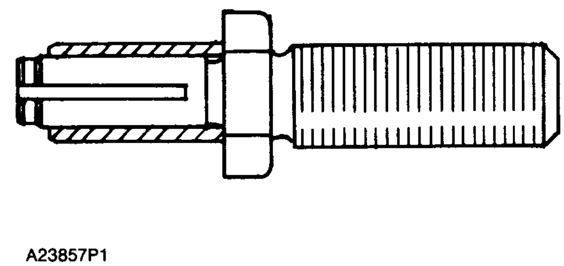



Location of Bolt
(8) Washer. (9) Tachometer drive shaft.




Loosening Drive Gear
(10) 6V4069 Puller. (11) Bolts.

c. Put 6V4069 Puller (10) on the camshaft for the fuel injection pumps. Tighten bolts (11) until the drive gear on the camshaft for the fuel injection pumps comes loose.
d. Remove the 6V4069 Puller.
e. Turn the crankshaft **counterclockwise** (as seen from rear of engine) until bolt (3) goes into the hole in the timing gear. With timing pin (2) in the notch in the camshaft for the fuel injection pumps, and bolt (3) in the hole in the timing gear, the timing for the engine is correct.
f. Install washer (8) and tachometer drive shaft (9). Tighten tachometer drive shaft to 149 ± 14 N•m (110 ± 10 lb ft). Remove timing pin (2).

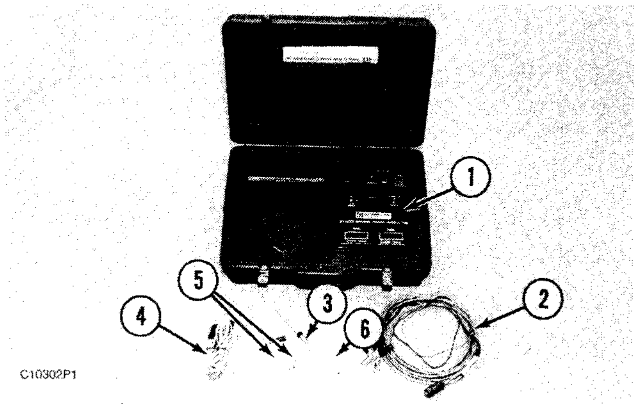



Tachometer Drive Shaft

g. Turn the crankshaft two complete revolutions **counterclockwise** (as seen from rear of engine) and put timing pin (2) and bolt (3) in again. If timing pin (2) and bolt (3) can not be installed do Steps a through f again.
h. Remove bolt (3) from the timing gear and install in hole (5). Install the plug in timing hole (4). Remove timing pin (2) and install bolt (1). Install cover for the tachometer drive assembly (6).

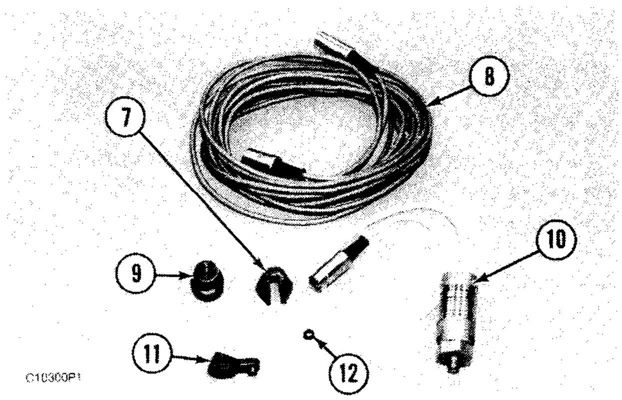
## Checking Engine Timing and Automatic Timing Advance Unit With 8T5300 Timing Indicator Group and 8T5301 Diesel Timing Adapter Group

| Tools Needed | | |
|---|---|---|
| 8T5300 | Timing Indicator Group | 1 |
| 8T5301 | Diesel Timing Adapter Group | 1 |




8T5300 Timing Indicator Group
(1) 8T5250 Engine Timing Indicator. (2) 5P7366 Cable Assembly. (3) 6V2197 Magnetic Transducer. (4) 5P7362 Cable. (5) 6V2199 & 6V3093 Transducer Adapters. (6) 8K4644 Fuse.

The 8T5300 Timing Indicator Group must be used with an 8T5301 Diesel Timing Adapter Group.




8T5301 Diesel Timing Adapter Group
(7) 5P7437 Adapter. (8) 6V2198 Cable. (9) 5P7436 Adapter. (10) 6V7910 Transducer. (11) 5P7435 Adapter. (12) 6V3016 Washer.

**⚠ WARNING**

**A high pressure fuel line must be disconnected. To avoid personal injury or fire from fuel spray, the engine must be stopped before the fuel line is disconnected.**

See Special Instruction, Form No. SEHS8580 for information required to calculate the timing curve. For the correct timing specifications to use, see the Engine Information Plate for the performance specification number and make reference to the Fuel Setting And Related Information Fiche.

Some engines do not have the mechanical advance (Serial #79V11322-79V12756). Caterpillar recommends that the service personnel use a worksheet like Form No. SEHS8140 to make the graph for the timing check. On an engine without the mechanical advance the timing can be measured at only one engine speed.

When checking the dynamic timing on an engine that has a mechanical advance, Caterpillar recommends that the service personnel calculate and plot the dynamic timing specifications first on a worksheet like Form No. SEHS8140. These worksheets are available in pads of 50 sheets, order one Form No. SEHS8140.

NOTE: For more information on acceptable tolerances for dynamic fuel injection timing, see Service Magazine dated 4-1-85 and 10-28-85.

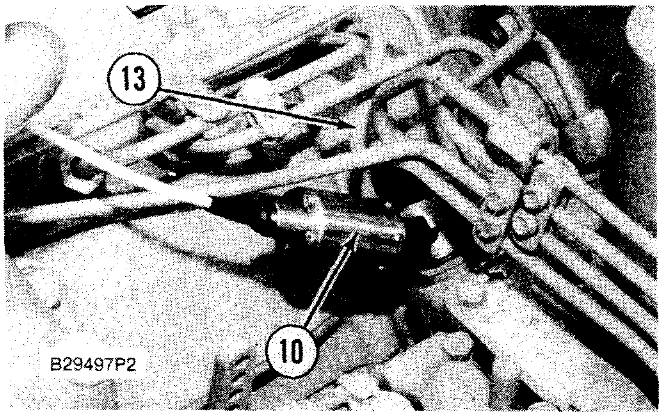
After the timing values are calculated and plotted, the dynamic timing should be checked with the 8T5300 Timing Indicator Group and the 8T5301 Diesel Timing Adapter Group. To do this, the service personnel must operate the engine from 1000 rpm (base rpm) to high idle and from high idle to 1000 rpm (base rpm). Unstable readings are often obtained below 1000 rpm. He must record the dynamic timing at each 100 rpm and at the specified speeds during both acceleration and deceleration. Then he should plot the results on the worksheet.

Inspection of the plotted values will show if the fuel injection timing is within specification and if it is advancing correctly.

1. Make reference to Special Instruction, Form No. SEHS8580 for complete service information and use of 8T5300 Timing Indicator Group.

2. Loosen all fuel line clamps that hold No. 1 fuel injection line and disconnect fuel injection line (13) for No. 1 cylinder at the fuel injection pump. Slide the nut up and out of the way. Put 5P7436 Adapter (9) in its place and turn adapter (9) onto the fuel pump bonnet until the top of the bonnet threads are approximately even with the bottom of the "window" in the adapter.

3. Put the 5P7435 Adapter (11) on 6V7910 Transducer (10) and put the end of the 5P7435 Adapter (11) in the "window" of the 5P7436 Adapter (9).

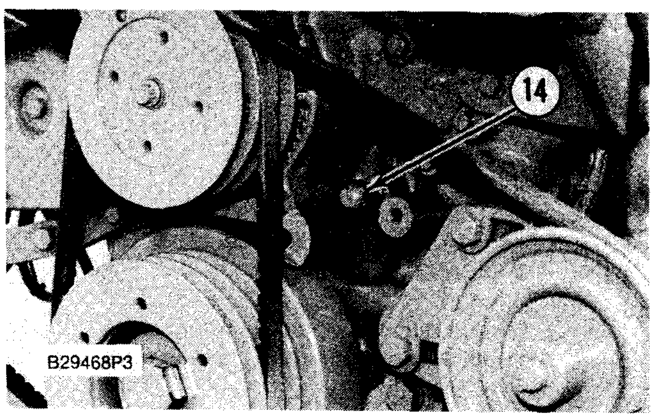



Transducer in Position
(10) Injection transducer. (13) Fuel injection line for No. 1 cylinder.

4. Put fuel injection line (13) on top of 5P7435 Adapter (11). Install 5P7437 Adapter (7) and tighten to 40 N•m (30 lb ft).

5. Remove fitting (14) from the front housing. Install transducer adapter (5) into hole fitting (14) was removed from. Tighten only a small amount.

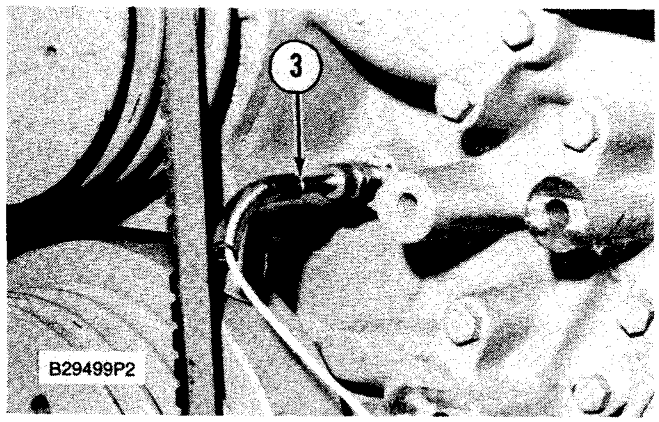
6. Push the TDC magnetic transducer (3) into the transducer adapter (5) until it makes contact with the camshaft gear. Pull it back out 1.6 mm (.06 in) and lightly tighten the knurled locknut.




Location of Fitting
(14) Fitting.

7. Connect the cables from the transducers to the Engine Timing Indicator. Make a calibration check of the indicator. For calibration procedure, make reference to Special Instruction, Form No. SEHS8580.

NOTICE
Be sure all test equipment cables are routed so they will not come into contact with the V-belts or other rotating components.




Transducer in Position
(3) TDC magnetic transducer.

**⚠ WARNING**

**Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.**

8. Start the engine and let it reach operating temperature. Then run the engine at approximately one-half throttle for eight to ten minutes before measuring timing.

9. Run the engine at the speeds required to check low idle, timing advance and high idle. Record the engine timing indicator readings. If the engine timing is not correct, make reference to Fuel System Adjustments: On Engine, Fuel Injection Pump Timing (Timing Pin Method) for static adjustment of the fuel injection pump drive.

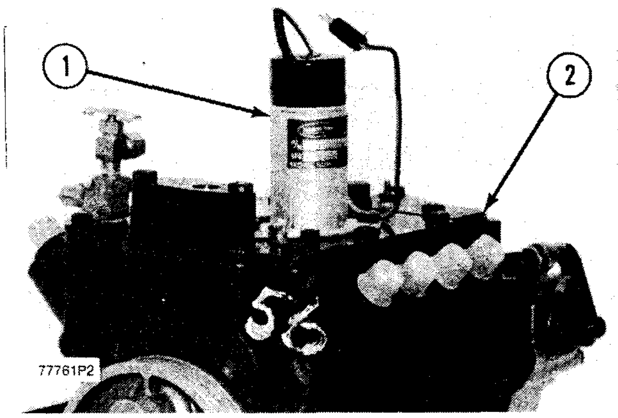
10. If the timing advance is still not correct, or if the operation of the advance is not smooth, make a repair or replacement of the automatic advance unit. There is no adjustment to the unit.

## Fuel Setting

| Tools Needed | | |
|---|---|---|
| 5P4203 | Field Service Tool Group | 1 |

The procedure that follows for fuel setting can be done with the housing for the fuel injection pumps either on or off the engine.

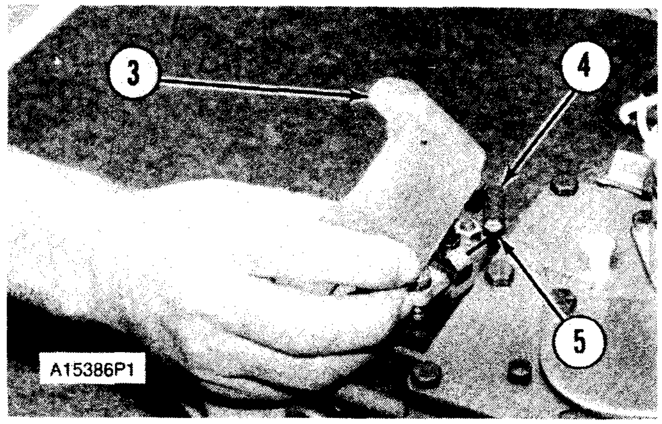
NOTE: If the fuel injection pump group is equipped with a fuel ratio control, the control must be removed before the fuel setting is checked or adjusted.




Removal of Covers
(1) Shutoff solenoid. (2) Top cover.

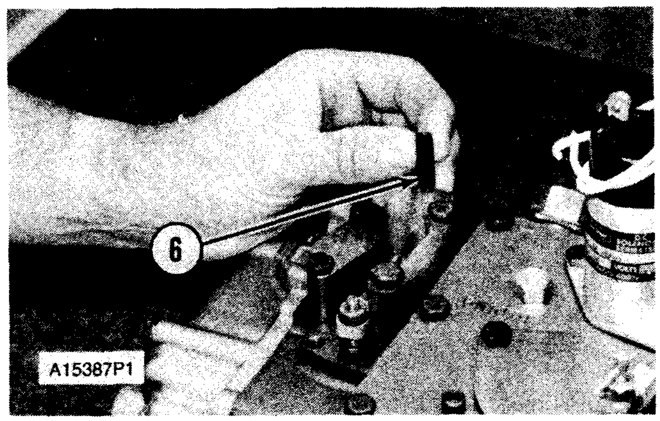
NOTICE
**Before any service work is done on this fuel system, the outside of the housing for the fuel injection pumps and all parts connected to it must be especially clean.**

1. Remove fuel shutoff solenoid (1) and fuel ratio control if so equipped, and cover (2).
2. Put the 5P0298 Zero Set Pin (5), with 17.8507 on it, in the pump housing.
3. Put adapter (3) and spring (4) over zero set pin (5). Use a 1D4533 Bolt and a 1D4538 Bolt to fasten adapter (3) to the housing for the fuel injection pumps.



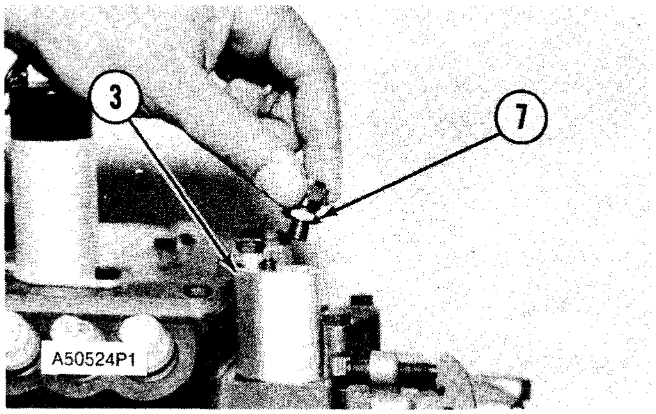

Installation of Cover
(3) 5P6602 Adapter. (4) 3J6956 Spring. (5) 5P0298 Zero Set Pin, with 17.8507 on it.

4. Put screw (6) in the hole over pin (5) and spring (4).



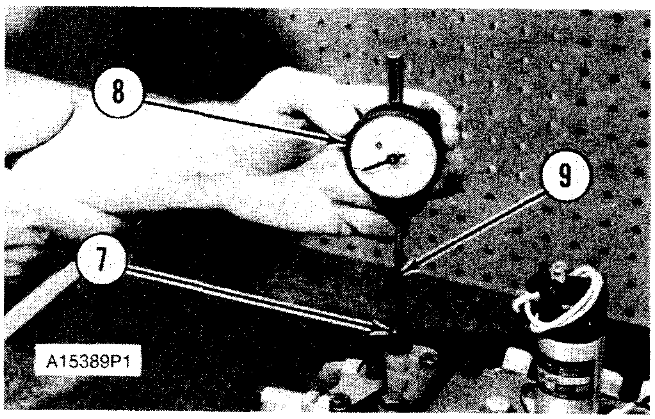

Installation of Screw
(6) 8S7271 Screw.

5. Turn screw (6) **clockwise** until pin (5) is held against the housing for the fuel injection pump. DO NOT tighten screw (6) too tight.
6. Put clamp (7) in adapter (3).
7. Move the governor control lever to FULL LOAD position.

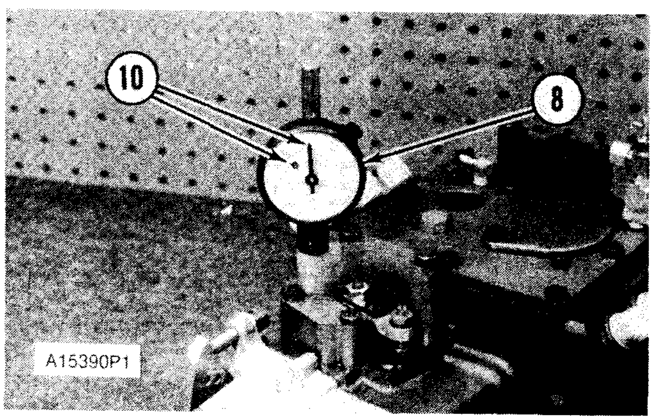


Installation of Clamp
(3) Adapter. (7) 3P1565 Collet Clamp.

8. Put 5P6531 Point (9) on dial indicator (8). Put the indicator assembly in clamp (7).



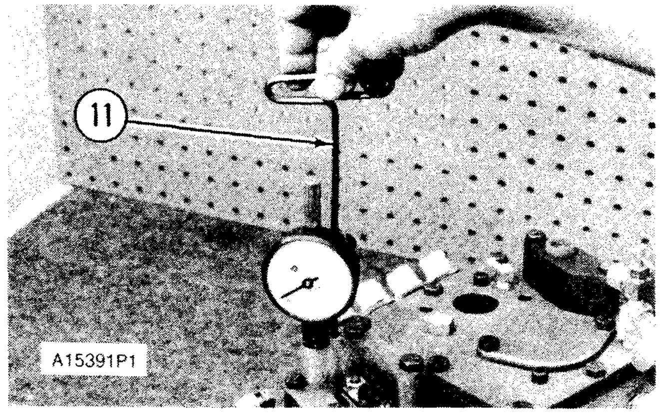
Installation of Dial Indicator
(7) 3P1565 Collet Clamp. (8) 3P1567 Dial Indicator. (9) 5P6531 Contact Point, 57.2 mm (2.25 in) long.



Indicator Set on Zero
(8) 3P1567 Dial Indicator. (10) Pointers.

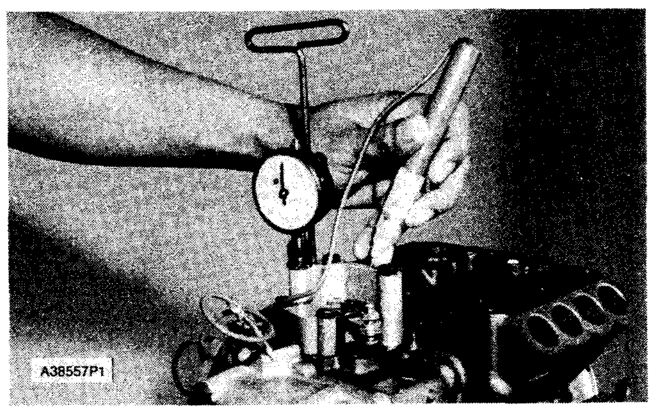
9. Adjust dial indicator (8) so both pointers (10) are on "0" (zero).

10. Use wrench (11) to turn the 8S7271 Screw (6) **counterclockwise** . Turn screw (6) six or more turns.



Loosening Screw (6)
(11) 5P4205 Wrench.

11. Put the clip end of the 8T0500 Circuit Tester to a good ground. Put the other end of the 8T0500 Circuit Tester on the load stop contact.



8T0500 Circuit Tester

12. Move the governor control lever to the LOW IDLE position.

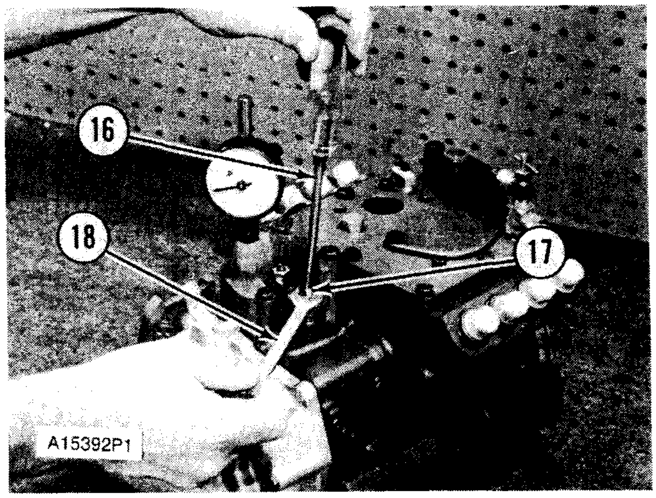
13. Move the governor control lever slowly toward the HIGH IDLE position until the continuity light just comes on. Make a note of the reading on dial indicator (8). Do this step several times to make sure the reading is correct.

14. Make a comparison of this reading and the fuel setting in the Fuel Setting And Related Information Fiche.

15. If the reading on dial indicator (8) is not correct, do the following.

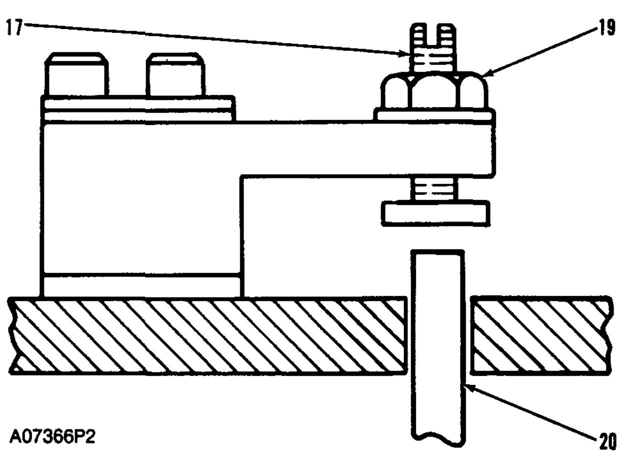
### Load Stop Adjustment

a. Use wrench (18) and loosen locknut (19).

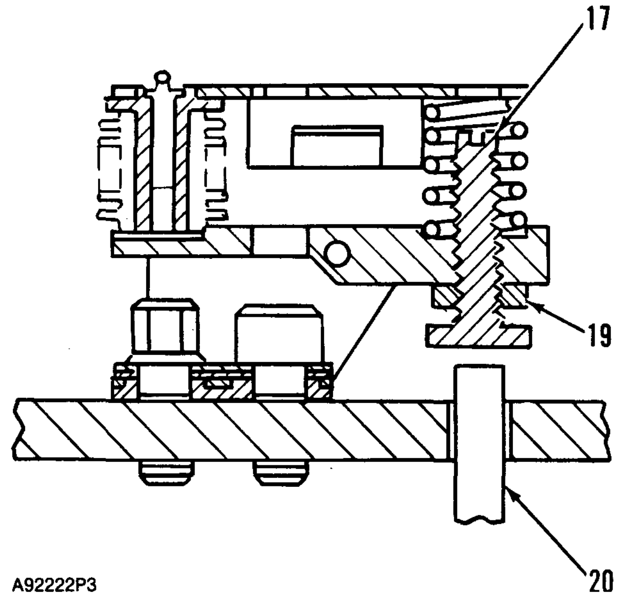



Adjustment of Fuel Setting
(16) Screwdriver. (17) Adjustment screw. (18) Wrench.

b. Use screwdriver (16) to turn adjustment screw (17) until the reading on dial indicator (8) is the same as the dimension given in the Fuel Setting And Related Information Fiche.
c. When the adjustment is correct, tighten locknut (19). Check the adjustment again by doing Steps 11 through 15 again.




Adjustment Screw for Fuel Setting
(17) Adjustment screw. (19) Locknut. (20) Load stop pin.




Adjustment Screw for Fuel Setting
(17) Adjustment screw. (19) Locknut. (20) Load stop pin.

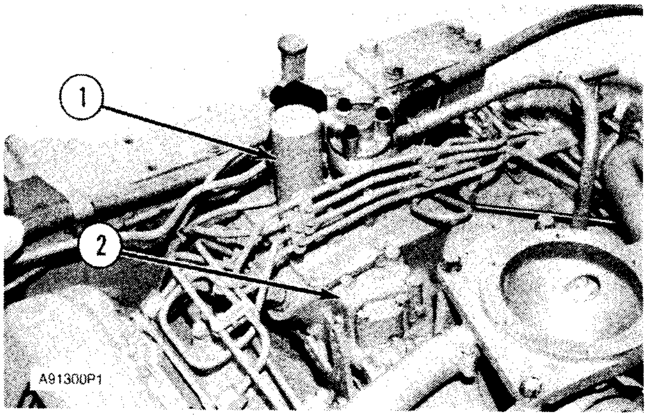
NOTE: The same tools that are used in this procedure are also used for the fuel ratio control adjustment.

## Fuel Ratio Control Adjustment

NOTE: The same tools are needed for the fuel ratio control adjustment that were used for the fuel setting. Make reference to FUEL SETTING for the tools needed and instructions to install the tools.

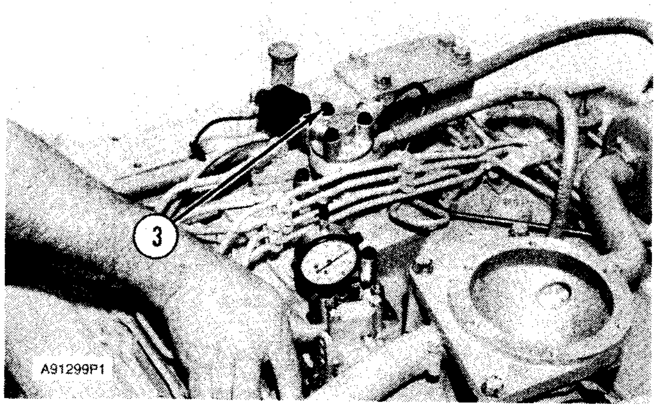
NOTE: The fuel setting must be correct before an adjustment is made to the fuel ratio control. Make reference to FUEL SETTING.

1. Remove shutoff solenoid (1) and cover (2). Install tools and "zero" dial indicator as shown in FUEL SETTING Steps 2-10.



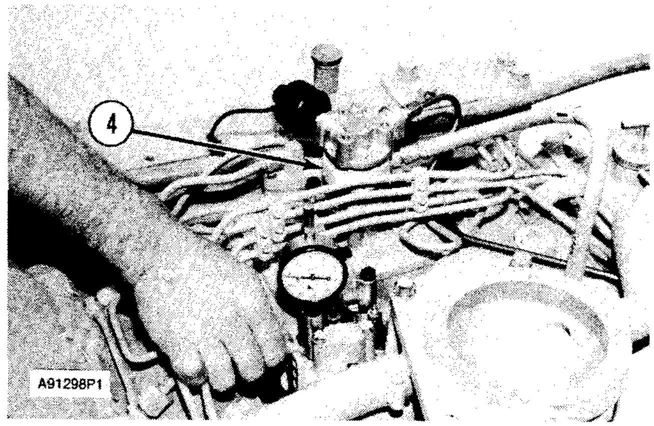
Removal of Covers
(1) Shutoff solenoid. (2) Cover.

2. To check the fuel ratio control setting, move the governor lever slowly to the high idle position. Make a record of the reading on the dial indicator. Compare the reading with the specification given in the Fuel Setting And Related Information Fiche.



Checking Fuel Ratio Control Setting
(3) Bolts.

3. If an adjustment is needed, remove three bolts (3) from the fuel ratio control. Hold the governor lever in the high idle position and turn flange (4) until the fuel ratio control setting is correct.



Adjustment of Fuel Ratio Control Setting
(4) Flange.

4. Move governor lever to low idle and again move the lever slowly to high idle to check the fuel ratio control setting.

5. Install bolts (3). Flange (4) can be turned a small amount to give alignment for bolts (3).

6. Remove tools and install cover (2) and shutoff solenoid (1).

## Crossover Levers

| Tools Needed | | |
|---|---|---|
| 3P1546 | Calibration Pin | 1 |
| 5P4206 | Wrench | 1 |
| 5P4209 | Gauge | 1 |
| 5P7253 | Socket Assembly | 1 |

### Checking Crossover Levers

NOTE: The crossover levers normally do not need checking unless one or more of the following conditions exist (after the timing is checked and the other corrections shown in TROUBLESHOOTING have been made):

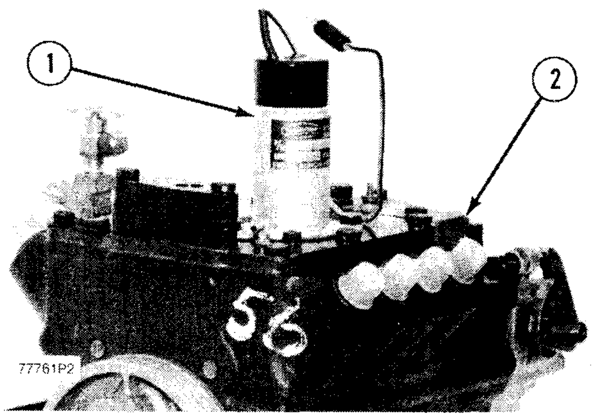
A. The engine produces too much black smoke.
B. The engine runs rough because fuel delivery is not even.
C. Some cylinders continue to fire at fuel shutoff position.
D. The complete injection group is being reconditioned.

NOTICE

Before any service work is done on this fuel system, the outside of the injection pump housing and all parts connected to it must be clean.

1. Remove the fuel shutoff solenoid (1) and fuel ratio control if so equipped and top cover (2) of the fuel pump housing and the cover over the torque control group.

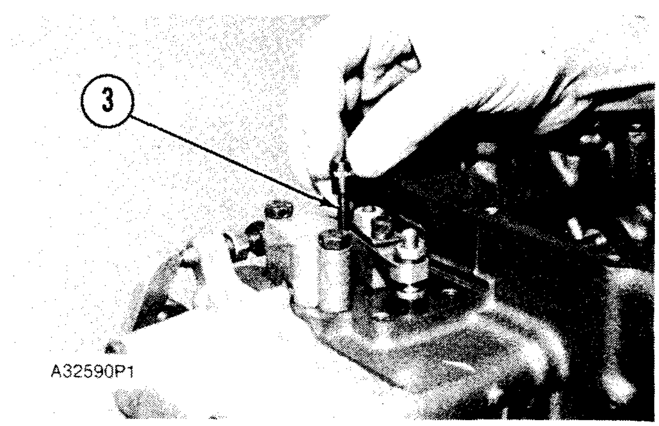
2. Remove the fuel that is in the injection pump housing and the governor housing.



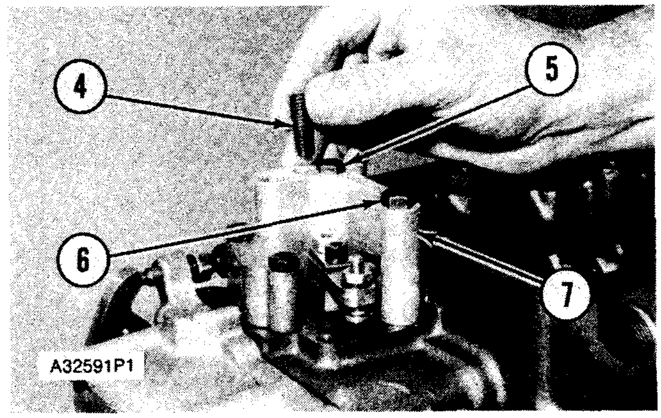
Removal of Covers
(1) Shutoff solenoid. (2) Top cover.

3. Put the 3P1546 Calibration Pin (3) in calibration hole as shown.

4. Install the 5P6602 Adapter (7) as shown. Fasten it in position with a 1D4533 Bolt (5) and a 1D4538 Bolt (6).

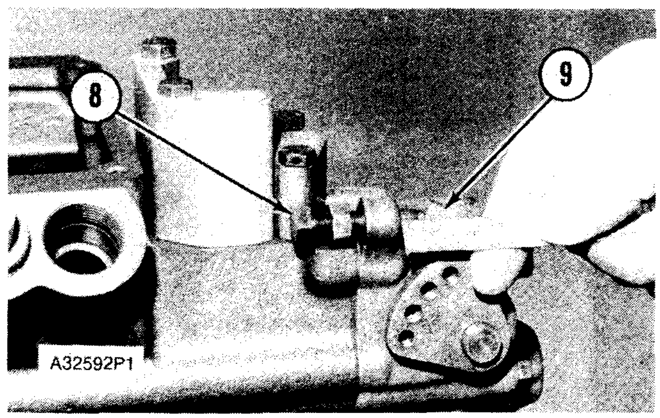


Installing Calibration Pin
(3) 3P1546 Calibration Pin, with 15.9410 on it.



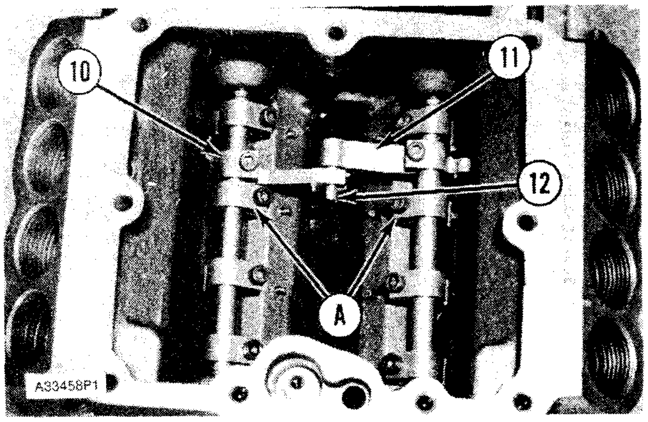
Installing 5P6602 Adapter and 8S7271 Screw
(4) Screw. (5) 1D4533 Bolt. (6) 1D4538 Bolt. (7) 5P6602 Adapter.

5. Put the 8S7271 Screw (4) (setscrew) in the hole over the calibration pin (3). Tighten the setscrew (4) to 2.3 to 2.8 N•m (20 to 25 lb in) with the 2P8264 Socket.



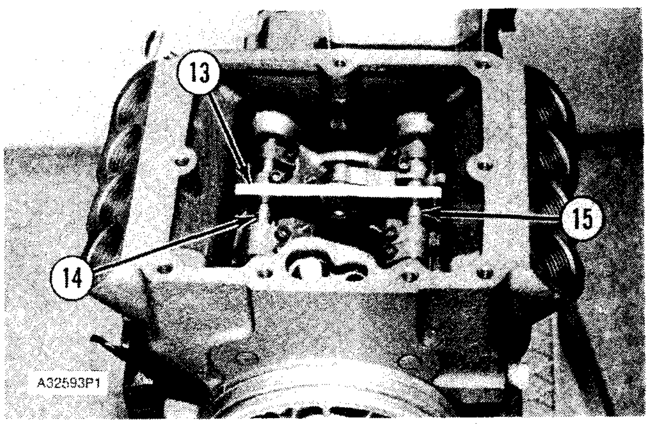
Adjustment of Low Idle Screw
(8) Low idle screw. (9) Lever.

6. Adjust low idle screw (8) to position lever (9) to 8.9 ± 1.0 mm (.35 ± .04 in) from governor housing boss.




Crossover Levers
(10) Crossover lever. (11) Crossover lever. (12) Dowel pin.
(A) Sleeve levers.

7. Loosen the bolts that hold sleeve levers (A) and slide levers (A) out of the way.

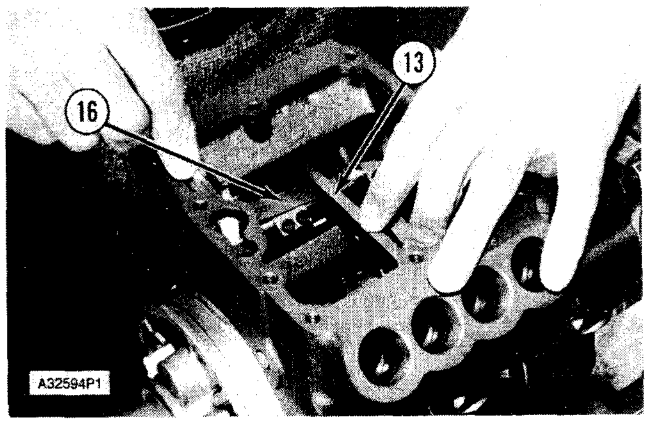



Installing 5P4209 Gauge
(13) 5P4209 Gauge. (14) Shaft. (15) Shaft.

8. Put gauge (13) on shafts (14) and (15). Slide gauge (13) toward crossover levers (10) and (11) until dowel pin (12) goes into hole in gauge (13).

9. If dowel pin (12) must be lifted to go into the hole in gauge (13), the levers must be adjusted. See ADJUSTMENT OF CROSSOVER LEVERS.

10. If gauge (13) must be lifted more than 0.20 mm (.008 in) to let dowel pin (12) go into the hole in gauge (13), see ADJUSTMENT OF CROSSOVER LEVERS.




Checking Clearance of Crossover Lever
(13) 5P4209 Gauge. (16) Feeler gauge.

11. To check the maximum clearance of 0.20 mm (.008 in) that is acceptable under one side of gauge (13), hold the center and one side of gauge (13) against sleeve lever shaft (15). Use a feeler gauge to check clearance.

NOTE: After the checking of the crossover levers is complete, the two fuel injection pumps must be calibrated where sleeve levers have been moved to install 5P4209 Gauge. See FUEL PUMP CALIBRATION.

**Adjustment of Crossover Levers**

1. Remove the fuel shutoff solenoid (1) top cover (2) of the fuel pump housing and the cover over the torque control group.

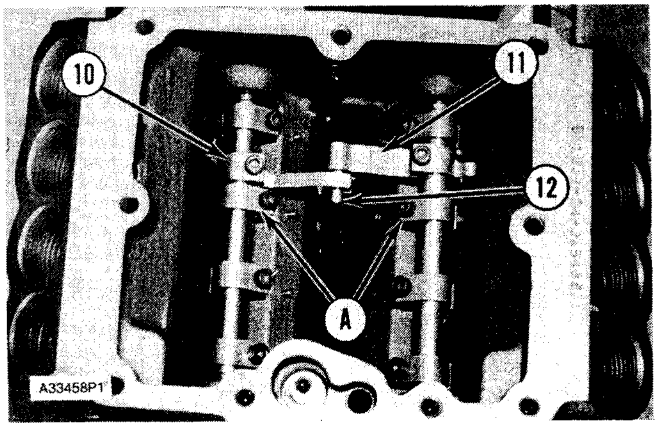
2. Remove the fuel that is in the injection pump housing and the governor housing.

3. Put the 3P1546 Calibration Pin (3) in calibration hole.

4. Install the 5P6602 Adapter (7). Fasten it in position with a 1D4533 Bolt (5) and a 1D4538 Bolt (6).

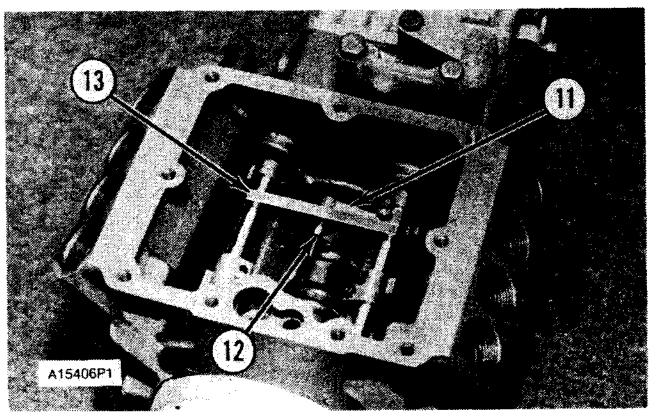
5. Put the 8S7271 Screw (4) (setscrew) in the hole over the calibration pin (3). Tighten the setscrew (4) to 2.3 to 2.8 N•m (20 to 25 lb in) with the 2P8264 Socket.

6. Adjust low idle screw (8) to position lever (9) to 8.9 ± 1.0 mm (.35 ± .04 in) from governor housing boss.



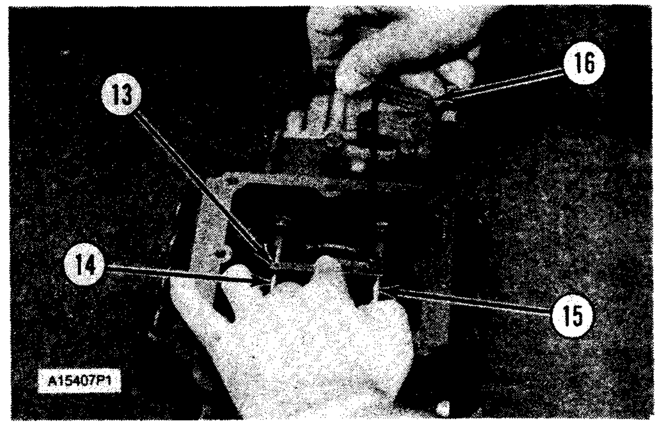
Crossover Levers
(10) Crossover lever. (11) Crossover lever. (12) Dowel pin.
(A) Sleeve levers.

7. Loosen the bolts that hold sleeve levers (A) and slide levers (A) out of the way.



5P4209 Gauge Installed
(11) Crossover lever. (12) Dowel pin. (13) 5P4209 Gauge.

8. Loosen the bolts that hold crossover lever (10) and (11) and move lever (10) off dowel pin (12).



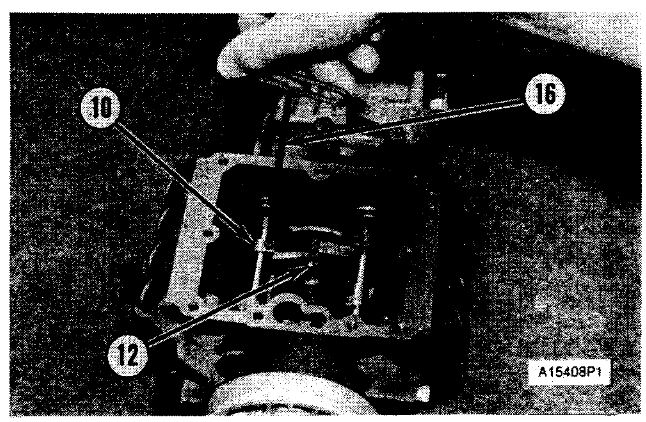
Adjustment of Crossover Levers
(13) Gauge. (14) Shaft. (15) Shaft. (16) 5P4206 Wrench.

9. Put gauge (13) on shafts (14) and (15), put crossover lever (11) in a position so dowel pin (12) will fit in gauge hole. Hold gauge (13) down and torque the bolt that holds crossover lever (11) to 2.75 ± 0.25 N•m (24 ± 2 lb in).

10. Check adjustment again with the 5P4209 Gauge (13). Put gauge (13) on shafts (14 and 15), slide gauge toward crossover lever (11) to engage dowel pin (12) into hole in gauge (13).

11. If dowel pin (12) must be lifted to go into gauge, the lever must be adjusted again. If gauge (13) is lifted, a maximum of 0.20 mm (.008 in) clearance is acceptable under one side of gauge (13). Use a feeler gauge to check clearance.

12. Slide crossover lever (10) on to dowel pin (12). Torque the bolt that holds crossover lever (10) to 2.8 ± 0.2 N•m (24 ± 2 lb in).



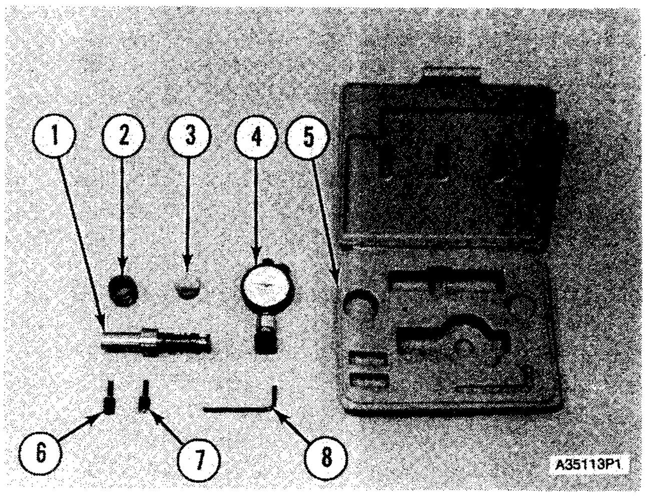
Tightening Bolt
(10) Crossover lever. (12) Dowel pin. (16) Wrench.

13. Check the adjustment again with the 5P4209 Gauge.

NOTE: After the adjustment of the crossover levers is completed, all of the fuel injection pumps must be calibrated. See FUEL PUMP CALIBRATION.

## Fuel Pump Calibration

| Tools Needed | | |
|---|---|---|
| 5P4203 | Tool Group | 1 |
| 8S2243 | Wrench | 1 |
| 5P6602 | Adapter | 1 |
| 5P4205 | Wrench | 1 |
| 1D4533 | Bolt | 1 |
| 1D4538 | Bolt | 1 |
| 8S7271 | Screw | 1 |
| 5P7253 | Socket Assembly | 1 |
| 5P4206 | Wrench | 1 |
| 6V0190 | Clamp | 1 |
| 3P2200 | Sleeve Metering Calibration Tool Group | 1 |



3P2200 Tool Group
(1) 3P1540 Calibration Pump. (2) 4N0218 Bushing. (3) 1P7379 Microgauge. (4) 3P1568 Dial Indicator with 3P2226 Collet. (5) 5P6510 Box. (6) 3P1545 Calibration Pin with 17.3734 on it, (in-line engines). (7) 3P1546 Calibration Pin with 15.9410 on it, (Vee engines). (8) 1S9836 Wrench.

### Checking Fuel Pump Calibration

The following procedure for fuel pump calibration can be done with the housing for the fuel injection pumps on or off the engine.

---

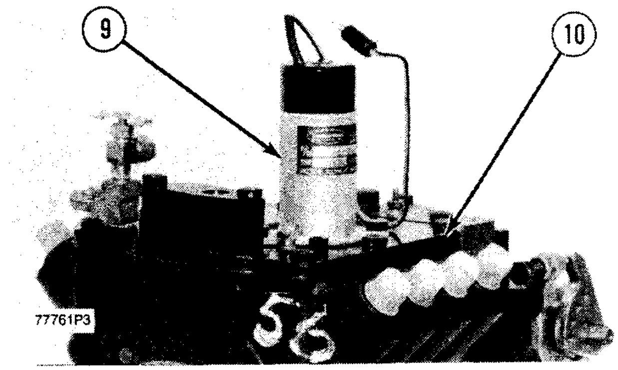
NOTICE

Before any service work is done on this fuel system, the outside of the injection pump housing and all parts connected to it must be clean.

---

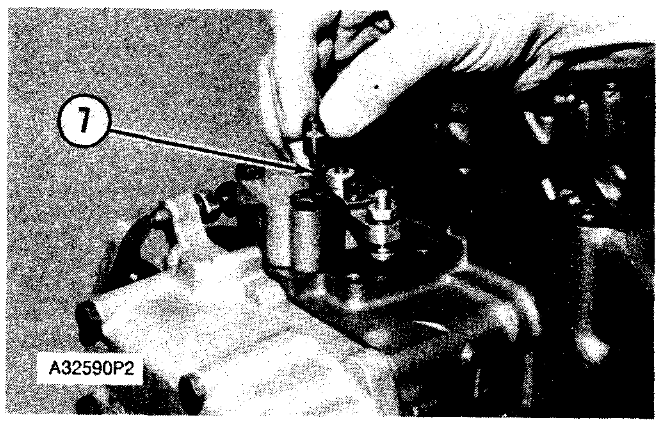
1. Remove the fuel shutoff solenoid (9), top cover (1) of the fuel pump housing and the cover over the torque control group.

2. Remove the fuel that is in the injection pump housing and the governor housing.



Removal of Covers
(9) Shutoff solenoid. (10) Top cover.

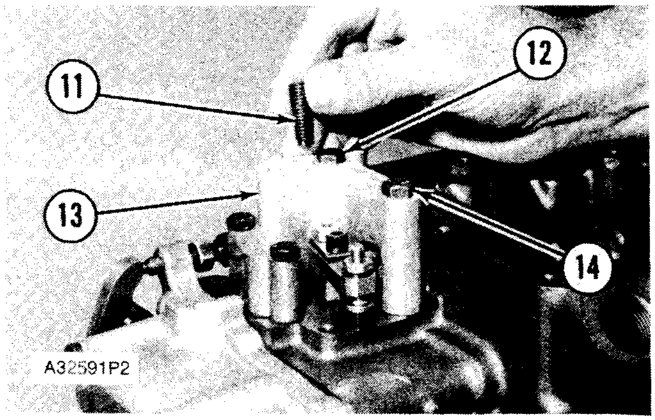
3. Install 3P1546 Calibration Pin (7), with 15.9410 on it, in the calibration hole.



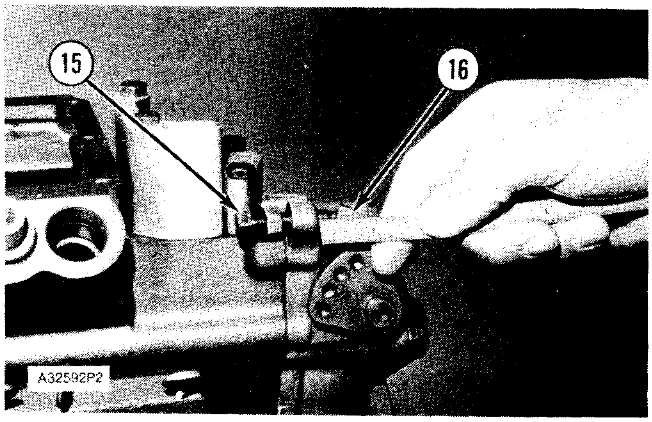
Installing Calibration Pin
(7) 3P1546 Calibration Pin, with 15.9410 on it.

4. Install 5P6602 Adapter (13) as shown. Fasten it in position on the injection pump housing with a 1D4533 Bolt (12) and a 1D4538 Bolt (14).

5. Put 8S7271 Screw (11) in the hole over calibration pin (7). Tighten screw (11) to 2.3 to 2.8 N•m (20 to 25 lb in).



Installing 5P6602 Adapter and 8S7271 Screw
(11) Screw. (12) 1D4533 Bolt. (13) 5P6602 Adapter. (14) 1D4538 Bolt.



Adjustment of Low Idle Screw
(15) Low idle screw. (16) Lever.

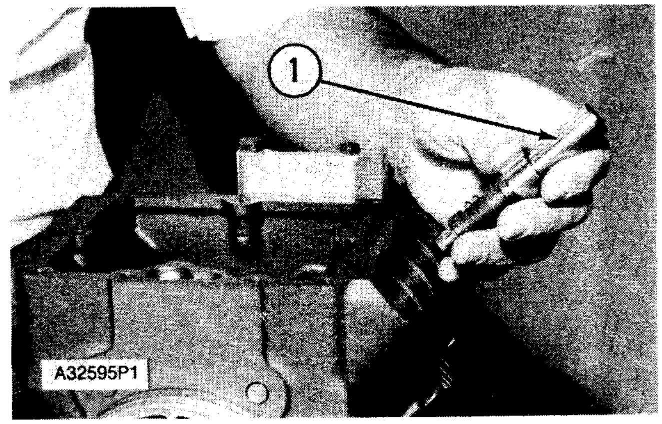
6. Adjust low idle screw (15) to position lever (16) to 8.9 ± 1.0 mm (.35 ± .04 in) from governor housing boss.

7. Use the 8S2243 Wrench and remove the fuel injection pumps to be checked.

NOTE: If pump is removed carefully, the sleeve will remain on the plunger. If the sleeve falls off the pump plunger during removal, find it immediately and replace it on the pump plunger before removal of another pump. The original sleeve must remain with the same pump plunger.

NOTE: When sleeve is installed on pump plunger, the narrower of the two lands on the sleeve must be toward top of pump (nearest the pump spring).

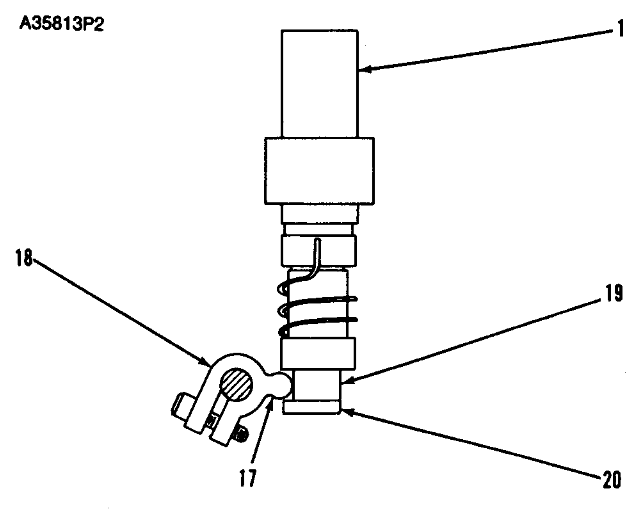
8. Clean the barrel and plunger of calibration pump (1). Put clean diesel fuel on the calibration pump for lubrication.



Installing Calibration Pump
(1) 3P1540 Calibration Pump.

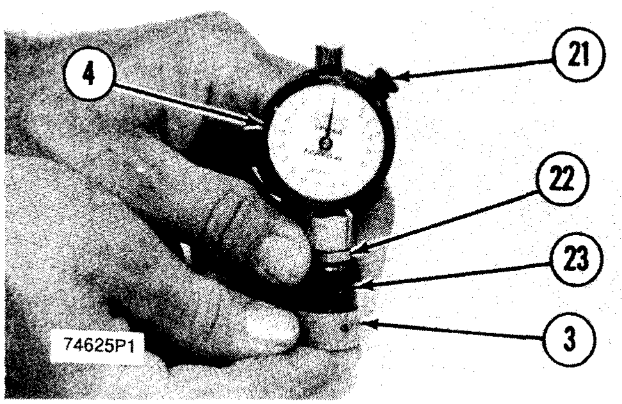
9. Put calibration pump (1) in the place of the pump to be checked with the flat place (20) on the plunger toward tang (17) on lever (18). When the calibration pump (1) is all the way in the bore, turn it 180° in either clockwise or counterclockwise direction. Tang (17) on lever (18) is now in groove (19) of calibration pump (1). Then install 4N0218 Bushing (2). Use the 8S2243 Wrench and a torque wrench to tighten the bushing to 80 ± 7 N•m (60 ± 5 lb ft).

NOTE: Turning calibration pump (1) 180° gives the same reference point for all measurements.



Calibration Pump Installed
(1) 3P1540 Calibration Pump. (17) Tang on lever. (18) Lever. (19) Groove of calibration pump. (20) Flat on plunger.

NOTE: Use 4N0218 Bushing (2) and calibration pump (1) together. The contact surfaces of the standard bushing, fuel injection pump and the housing for the fuel injection pumps are sealing surfaces. Keep them clean and free of scratches to prevent leaks.

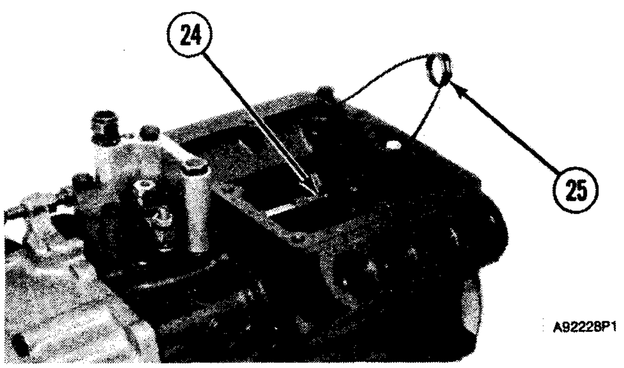


Putting Dial Indicator on Zero
(3) Microgauge. (4) 3P1568 Dial Indicator with 3P2226 Collet.
(21) Lockscrew. (22) Locknut. (23) 3P2226 Collet.

10. Put dial indicator (4) on microgauge (3) and hold them together tightly. Loosen lockscrew (21) and turn the face of dial indicator (4) to put the pointer at "0". Tighten lockscrew (21).

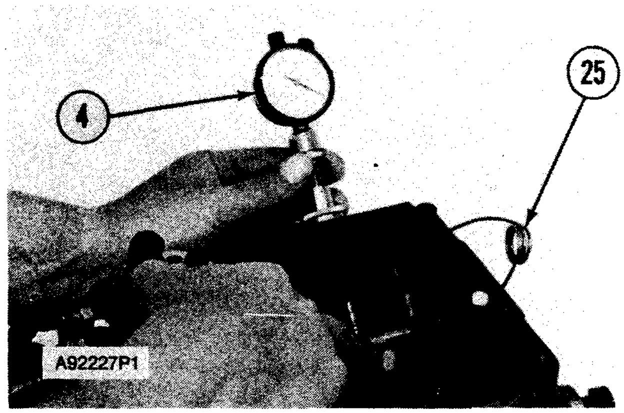
Remove dial indicator (4) from microgauge (3). Look at the face of dial indicator (4) and put dial indicator (4) on microgauge (3) again. The pointer must move through one to one and one half revolutions before stopping at exactly "0". If the number of revolutions is not correct, loosen the locknut on 3P2226 Collet (23), and adjust the position of the dial indicator until the adjustment is correct.

NOTE: If locknut (22) on the 3P2226 Collet is too tight, it can cause interference in the operation of the dial indicator.



6V0190 Clamp Installed
(24) Shaft. (25) 6V0190 Clamp.

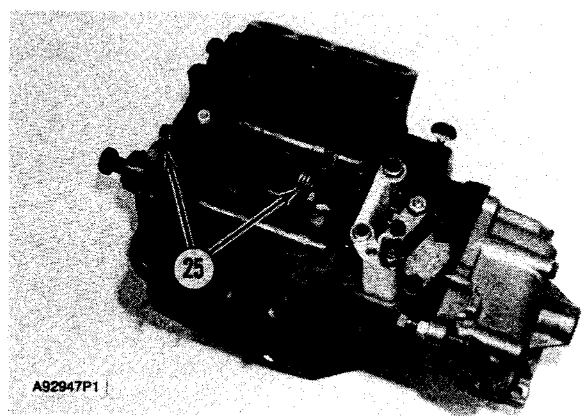
11. Put 6V0190 Clamp (25) in the position shown, next to the transfer pump end. Clamp (25) pushes shaft (24) down against the bottom of its bearing. The other end of shaft (24) is held down against its bearing by 3P1546 Calibration Pin (7) which is held by 8S7271 Screw (11). The combination of forces from clamp (25) and calibration pin (7) is necessary to hold shaft (24) in its normal operating position against the lifting force from the spring in calibration pump (1).



Dial Indicator Position
(4) 3P1568 Dial Indicator with 3P2226 Collet. (25) 6V0190 Clamp.

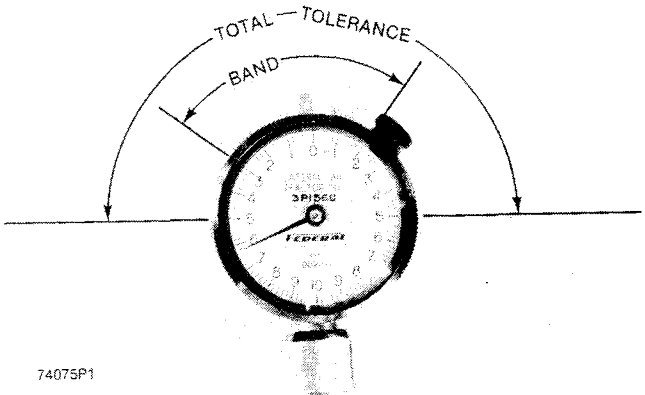
NOTE: When checking pumps on the "slave" side [side opposite from governor control lever (16)], put clamp (25) on both ends of sleeve shaft as shown.

12. Put dial indicator (4) on the calibration pump (1) as shown. Hold it tightly in place. Move shaft (24) toward the governor end to remove end play. To remove any clearance in the linkage, lift the crossover lever dowel and rapidly let it go. Do this several times. Then look at the reading on the dial indicator (4).



Installing Clamp on "Slave" Side
(25) 6V0190 Clamps.

13. If the dial indicator (4) reading is more than ± 0.050 mm from "0.000" (outside the TOTAL TOLERANCE), do Steps 17 through 20, ADJUSTING FUEL PUMP CALIBRATION.




Dial Indicator Reading
Desired reading for all pumps is "0.000".

**Maximum permissible tolerance for pump readings in any FUEL INJECTION PUMP GROUP IS 0.100 mm (−0.050 to + 0.050 mm on dial indicator).**

**Maximum permissible differences between any two pumps in the same FUEL INJECTION PUMP GROUP is 0.050 mm.**

**TOTAL TOLERANCE shows the maximum permissible range of pointer positions which are acceptable. If any reading is outside the range of TOTAL TOLERANCE, do ADJUSTING FUEL PUMP CALIBRATION for all pumps.**

**BAND is an example only. It shows a 0.050 mm range. This range shows the maximum permissible difference between any two readings for all the pumps. If any two readings are farther apart than the 0.050 mm range, do ADJUSTING FUEL PUMP CALIBRATION for all pumps.**

If the dial indicator (4) reading is near either end of the TOTAL TOLERANCE, check another pump. If the next reading is outside the TOTAL TOLERANCE or if the two readings have a difference of 0.050 mm or more, do the Steps 15 through 19, ADJUSTMENT OF FUEL PUMP CALIBRATION.

NOTE: The mechanic doing the checking must make the decisions of which and how many pumps to check according to the symptoms of the fuel injection pump being tested.

**14.** If dial indicator (4) readings for all the pumps are within the limits in Step 13, the calibration is acceptable. Remove the tooling, and install the parts which were removed.

NOTE: For troubleshooting purposes, if the dial indicator (4) reading is "0" or near "0", the calibration of the other pumps is probably in the tolerance.

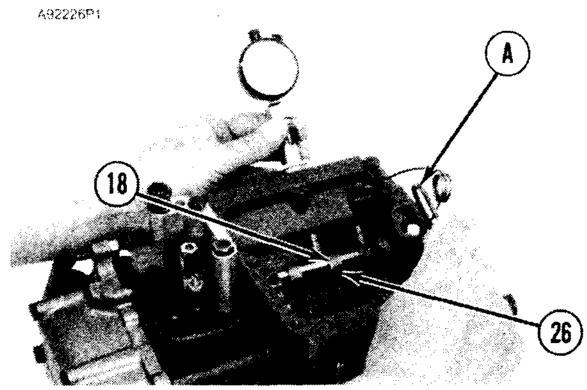
**Adjustment of Fuel Pump Calibration**

**15.** Remove all pumps with 8S2243 Wrench.

**16.** Clean the barrel and pump of calibration pump (1). Put clean diesel fuel on the calibration pump (1) for lubrication.

**17.** Install calibration pump (1) in the place of one of the pumps according to the procedure in Step 9.

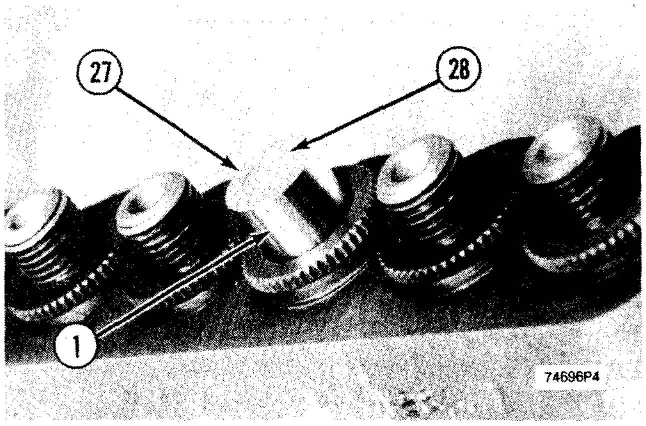
**18.** Loosen bolt (26) with 1S9836 Wrench (8) or 5P4206 Wrench. Turn the lever (18) on shaft (24) enough to move the top of plunger (28) of calibration pump (1) below top surface (27) of calibration pump (1). Tighten bolt (26) just enough for lever (18) to hold plunger (28) stationary.




5P4206 Wrench
(18) Lever. (26) Bolt. (A) 5P4206 Wrench.

NOTE: When bolt (26) has the correct torque, pushing with a small amount of force on lever (18) through the wrench moves plunger (28) in calibration pump (1).

**19.** Move shaft (24) toward the governor to remove end play. Then push down on lever (18) through the wrench until top of plunger (28) is almost even with top surface (27) of calibration pump (1) as shown.

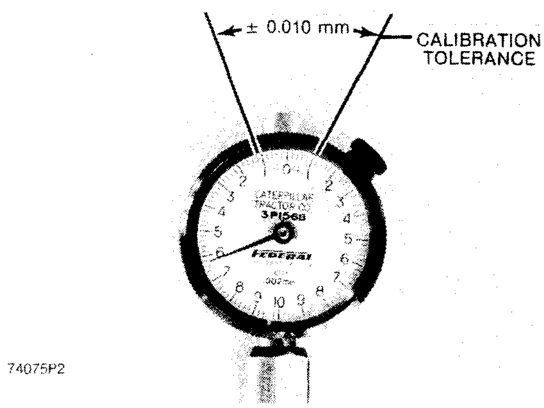


Plunger Position
(1) Calibration pump. (27) Top surface of calibration pump.
(28) Plunger.

**20.** Check dial indicator (4) according to Step 10. Then put dial indicator (4) in place over the center of calibration pump (1) and hold it there tightly. Now move plunger (28) of calibration pump (1) by pushing on lever (18) through the wrench. Stop moving the plunger when the dial indicator is at approximately 0.009 mm past "0.000". Tighten bolt (26) to 3.0 ± 0.5 N•m (27 ± 4 lb in).

NOTE: When moving plunger (28), make sure that the last direction of plunger (28) movement is in the up direction. If plunger (28) goes up too far, move plunger (28) down to a position below that desired. Then move plunger (28) up to the desired position.

NOTE: The action of tightening bolt (26) usually changes the reading on dial indicator (4) by approximately (0.010 mm) in the minus direction.

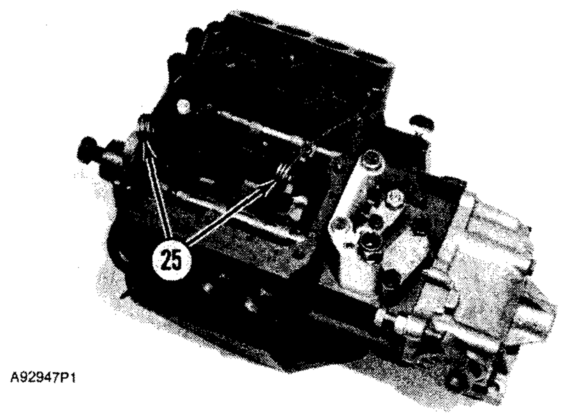


± 0.010 mm Calibration Tolerance

Move shaft (24) toward shutoff several times to remove clearance in the linkage. Dial indicator (4) reading must be (0.000 ± 0.010 mm) as shown.

When the pump calibration is correct make a record and then do the same procedure for all the other pumps.

NOTE: When calibrating pumps on the "slave" side [side opposite from governor control lever (16)], put clamp (25) on both ends of the sleeve shaft as shown in picture number A92947P1.



Installing Clamp on "Slave" Side
(25) 6V0190 Clamps.

## Governor Adjustments

NOTICE

**A mechanic with training in governor adjustments is the only one to make the adjustment to the set point rpm.**

Engine rpm must be checked with an accurate tachometer.

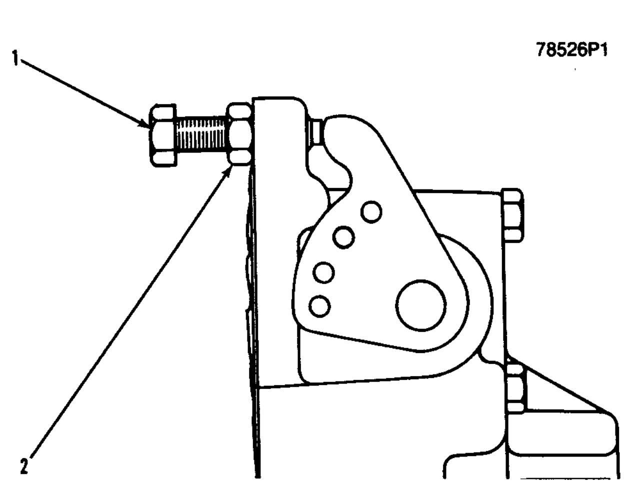
### Low Idle Adjustment

NOTE: The correct LOW IDLE rpm is given in the Fuel Setting And Related Information Fiche.

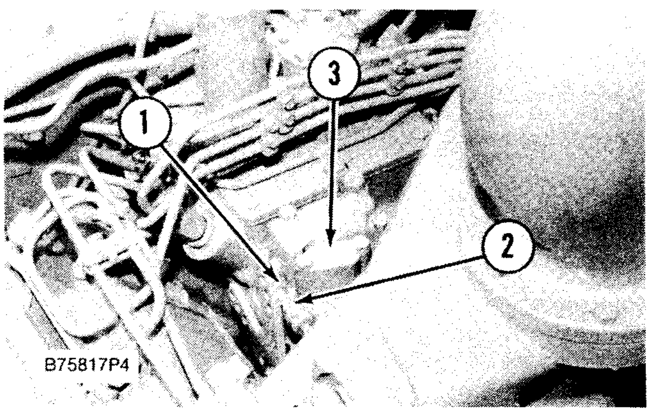
**⚠ WARNING**

**To help prevent an accident caused by parts in rotation, work carefully around an engine that has been started.**

Start the engine and run until the temperature of normal operation is reached. Check low idle rpm with no load on the engine. If an adjustment is necessary, use the procedure that follows:




Adjustment of Low Idle rpm
(1) Adjustment bolt for low idle. (2) Locknut.




Adjustment of Low Idle rpm
(1) Adjustment bolt for low idle. (2) Locknut. (3) Cover.

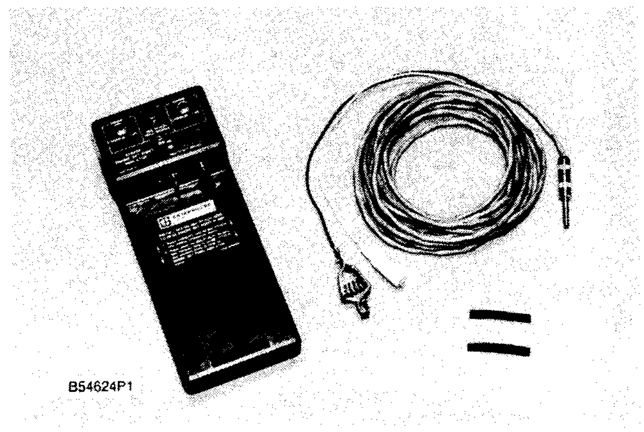
To adjust the LOW IDLE rpm, start the engine and run with the governor in the low idle position. Loosen locknut (2) for low idle screw (1). Turn the low idle screw to get the correct low idle rpm. Increase engine speed and return to low idle and check low idle speed again. Tighten the locknut.

### Checking Set Point (Balance Point)

The engine set point is an adjusted specification and is important to the correct operation of the engine. High idle rpm is NOT an adjusted specifications. Set point (formerly balance point) is full load rpm plus an additional 20 rpm. Set point is the rpm at which the fuel setting adjustment screw and stop or first torque spring just start to make contact. At this rpm the fuel setting adjustment screw and stop or first torque spring still have movement between them. When additional load is put on the engine, the fuel setting adjustment screw and stop or first torque spring will become stable against each other. Set point is controlled by the fuel setting and the high idle adjustment screw.

There is a new and more accurate method for checking the "set point," formerly called the balance point, of the engine. If the tools for the new method are not available, there is an alternate method for checking the "set point."

| | Tools Needed | |
|---|---|---|
| 6V4060 | Engine Set Point Indicator Group | 1 |




6V4060 Engine Set Point Indicator Group

The 6V4060 Engine Set Point Indicator Group with the 6V2100 Multitach can be used to check the set point. Special Instruction, Form No. SEHS7931 gives instructions for installation and use of this tool group.

### Alternate Method

| | Tools Needed | |
|---|---|---|
| 8T0500 | Circuit Tester | 1 |
| 6V3121 | Multitach Group | 1 |

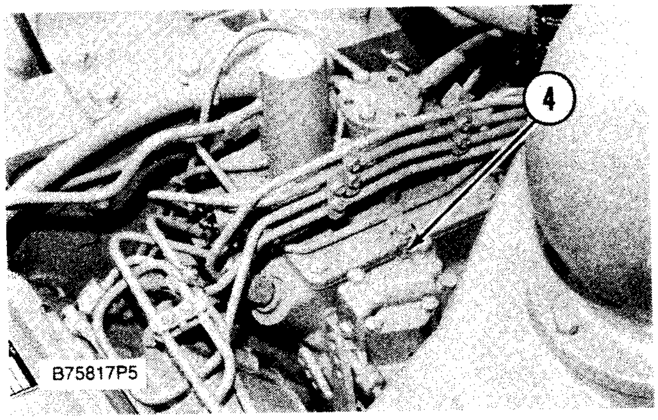
If the set point is correct and the high idle speed is within specifications, the fuel system operation of the engine is correct. The set point for the engine is:

A. At 20 rpm greater than full load speed.
B. The rpm where the fuel setting adjustment screw and stop or first torque spring just make contact.

Use the procedure that follows to check the set point. Make reference to TECHNIQUES FOR LOADING ENGINES in Special Instruction, Form No. SEHS7050.

1. Connect a tachometer which has good accuracy to the tachometer drive.

2. Connect the clip end of the 8T0500 Circuit Tester to the brass terminal screw (4) on the governor housing. Connect the other end of the tester to a place on the fuel system which is a good ground connection.




Terminal Location
(4) Brass terminal screw.

**⚠ WARNING**

**Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.**

3. Start the engine.

4. With the engine at normal conditions for operation, run the engine at high idle.

5. Make a record of the speed of the engine at high idle.

6. Add load on the engine slowly until the circuit tester light just comes on (minimum light output). This is the set point.

7. Make a record of the speed (rpm) at the set point.

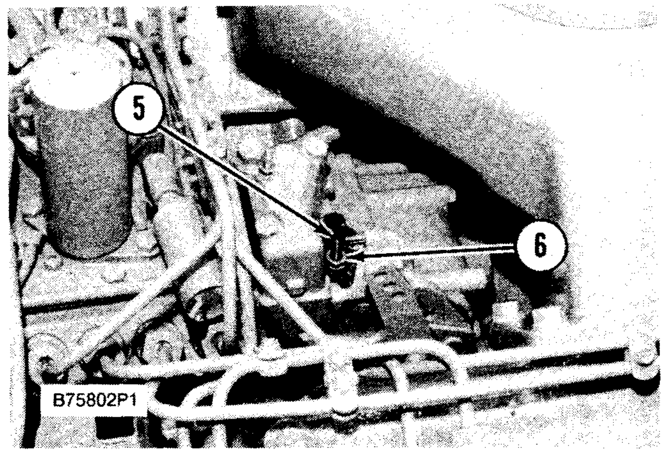
8. Repeat Step 6 several times to make sure that the reading is correct.

9. Stop the engine. Make a comparison of the records from Steps 5 and 7 with the information from the Engine Information Plate. If the Engine Information Plate is not available see the Fuel Setting And Related Information Fiche. The tolerance for the set point is ± 10 rpm. The tolerance for the high idle rpm is ± 50 rpm. If the readings from Steps 5 and 7 are within the tolerance, no adjustment is needed.

NOTE: It is possible in some applications that the high idle rpm will be less than the lower limit. This can be caused by high parasitic loads such as hydraulic pumps, compressors, etc.

### Adjusting Set Point (Balance Point)

1. If the set point and the high idle rpm are within tolerance, no adjustment is to be made.




Adjustment of Set Point
(5) Adjustment screw. (6) Locknut.

2. If the set point rpm is not correct, remove cover (3) and loosen locknut (6). Turn adjustment screw (5) to adjust the set point to the mid point of the tolerance.

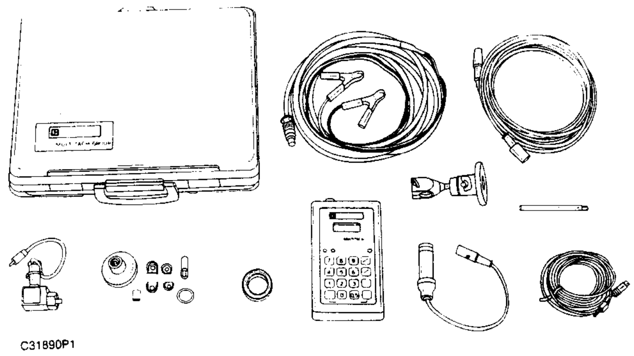
3. When the set point is correct, check the high idle rpm. The high idle rpm must not be more than the high limit of the tolerance.

If the high idle rpm is more than the high limit of the tolerance, check the governor spring and flyweights. If the high idle rpm is less than the low limit of the tolerance, check for excess parasitic loads and then the governor spring and flyweights.

## c Engine Speed Measurement

| Tools Needed | | |
|---|---|---|
| 6V3121 | Multitach Group or | 1 |
| 6V4950 | Injection Line Speed Pickup Group | 1 |

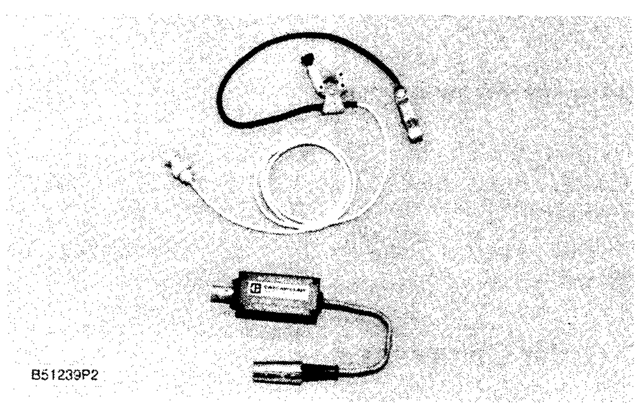
The 6V3121 Multitach Group can measure engine speed from a tachometer drive on the engine. It also has the ability to measure engine speed from visual engine parts in rotation.




6V3121 Multitach Group

Special Instruction, Form No. SEHS7807 is with the 6V3121 Multitach Group and gives instructions for the test procedure.

The 6V4950 Injection Line Speed Pickup Group is another diagnostic tool accessory that can be used with the 6V2100 Multitach. It can be used on all Caterpillar Diesel Engines equipped with 6 mm (.25 in) single wall fuel injection lines. With this pickup group, engine speed can be measured quickly, automatically and with an accuracy of ± 1 rpm.




6V4950 Injection Line Speed Pickup Group

Special Instruction, Form No. SEHS8029 is with the group and gives instructions for use of the 6V4950 Injection Line Speed Pickup Group.

# Air Inlet And Exhaust System

## Restriction of Air Inlet and Exhaust

There will be a reduction of horsepower and efficiency of the engine if there is a restriction in the air inlet or exhaust system.

Air flow through the air cleaner must not have a restriction (negative pressure difference measurement between atmospheric air and air that has gone through air cleaner) of more than 762 mm (30 in) of water.

Back pressure from the exhaust (pressure difference measurement between exhaust at outlet elbow and atmospheric air) must not be more than 686 mm (27 in) of water.

## Measurement of Pressure in Inlet Manifold

The efficiency of an engine can be checked by making a comparison of the pressure in the inlet manifold with the information given in the Fuel Setting and Related Information Fiche. This test is used when there is a decrease of horsepower from the engine, yet there is no real sign of a problem with the engine.

The correct pressure for the inlet manifold is given in the Fuel Setting and Related Information Fiche. Development of this information is done with these conditions:

a. 747 mm (29.4 in) of mercury barometric pressure.

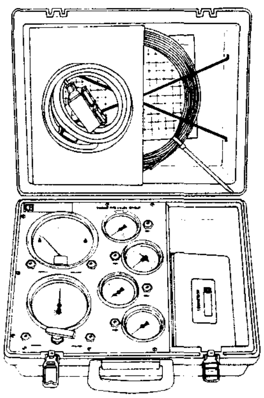
b. 29°C (85°F) outside air temperature.

c. 35 API rated fuel.

Any change from these conditions can change the pressure in the inlet manifold. Outside air that has higher temperature and lower barometric pressure than given above will cause a lower horsepower and a lower inlet manifold pressure measurement than given in the Fuel Setting and Related Information Fiche. Outside air that has a lower temperature and a higher barometric pressure will cause higher horsepower and a higher inlet manifold pressure measurement.

A difference in fuel rating will also change horsepower and the pressure in the inlet manifold. If the fuel is rated above 35 API, pressure in the inlet manifold can be less than given in the Fuel Setting and Related Information Fiche. If the fuel is rated below 35 API, the pressure in the inlet manifold can be more than given in the Fuel Setting and Related Information Fiche. BE SURE THAT THE AIR INLET AND EXHAUST DO NOT HAVE A RESTRICTION WHEN MAKING A CHECK OF PRESSURE IN THE INLET MANIFOLD.

Use the 1U5470 Engine Pressure Group to check the pressure in the inlet manifold.



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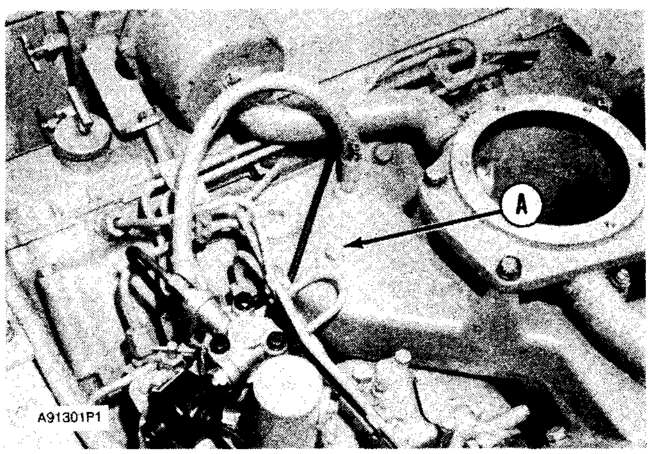
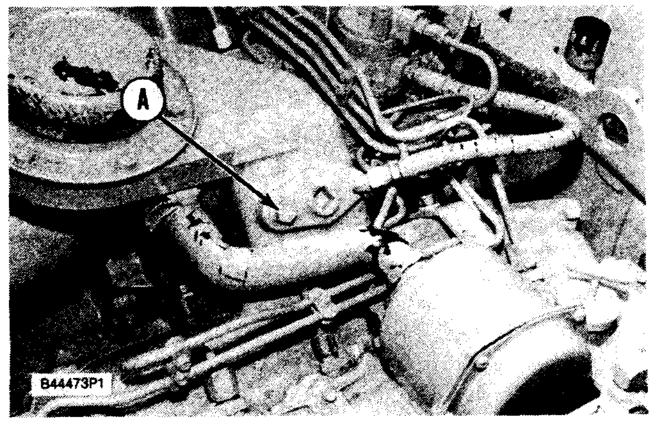
1U5470 Engine Pressure Group

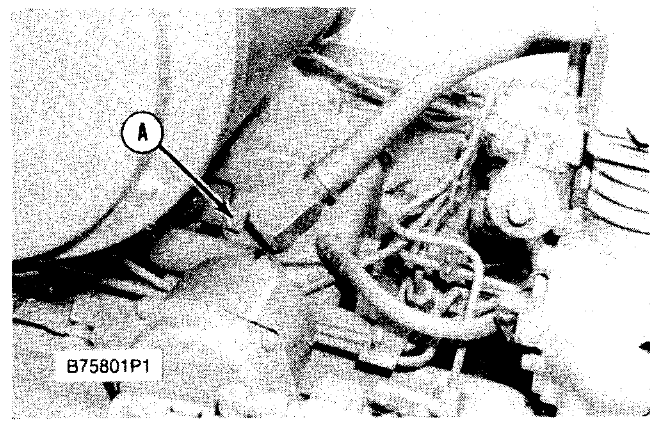
This tool group has a gauge to read pressure in the inlet manifold. Special Instruction, Form No. SEHS8907 is with the tool group and gives instructions for its use.




Location for Pressure Test
(A) Remove fitting and install test fitting.




Location for Pressure Test
(A) Remove fitting and install test fitting.




Location for Pressure Test
(A) Remove fitting and install test fitting.

## Exhaust Temperature

Use the 1U8865 Infrared Thermometer to check exhaust temperature. The Operator's Manual, Form No. NEHS0510, for the 1U8865 Infrared Thermometer gives complete operating and maintenance instructions for this tool.

## Cylinder Compression

An engine that runs rough can have a leak at the valves, or valves that need adjustment. Run the engine at the speed that gives rough running. To find a cylinder that has low compression or does not have good fuel ignition, loosen a fuel line nut at a fuel injection pump. This will stop the flow of fuel to that cylinder. Do this for each cylinder until a loosened fuel line is found that makes no difference in engine rough running. Be sure to tighten each fuel line nut after the test before the next fuel line nut is loosened. This test can also be an indication that the fuel injection is wrong, so more checking of the cylinder will be needed.

An analysis of the engine cylinder condition can be done with controlled pressure air through the cylinder head. Special Instruction, Form No. GMG00694 explains the procedure.

1. Remove the fuel injection nozzle.
2. Adapt an air hose to 1P5564 Adapter. Install the 1P5564 Adapter in the fuel injection nozzle opening in the cylinder head.
3. Start crankshaft rotation until the piston in the cylinder being inspected is at TC on the compression stroke. In this position, the valves of this cylinder will be against their seats.
4. Force the air into the cylinder and then check for air leakage. An air leak from the exhaust opening is an indication of exhaust valve leakage and an air leak from the air cleaner inlet is an indication of intake valve leakage. If the air leakage is into the crankcase during this test, the piston or piston rings can be the cause.

## Valve Clearance Setting

Check and adjust the valve clearance with engine stopped.

Valve clearance is measured with a thickness gauge between the top of the valve stem and the rocker arm.

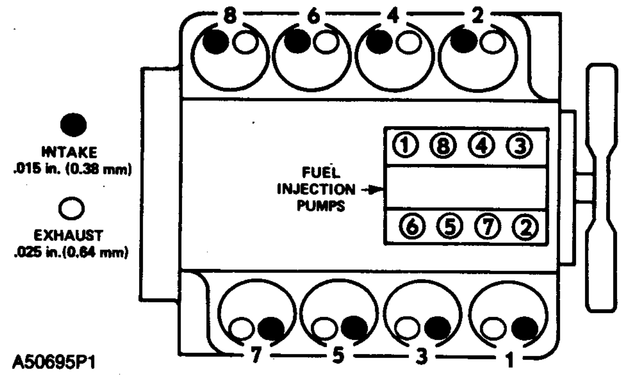
| VALVE CLEARANCE CHECK: ENGINE STOPPED | |
|---|---|
| Exhaust | Intake |
| 0.56 to 0.71 mm<br>(.022 to .028 in) | 0.30 to 0.46 mm<br>(.012 to .018 in) |

NOTE: When the valve lash (clearance) is checked, adjustment is NOT NECESSARY if the measurement is in the range given in the chart for VALVE CLEARANCE CHECK: ENGINE STOPPED. If the measurement is outside this range, adjustment is necessary. See the chart for VALVE CLEARANCE SETTING: ENGINE STOPPED, and make the setting to the nominal (desired) specifications in this chart.

| VALVE CLEARANCE SETTING: ENGINE STOPPED | |
|---|---|
| Exhaust | Intake |
| 0.64 mm<br>(.025 in) | 0.38 mm<br>(.015 in) |

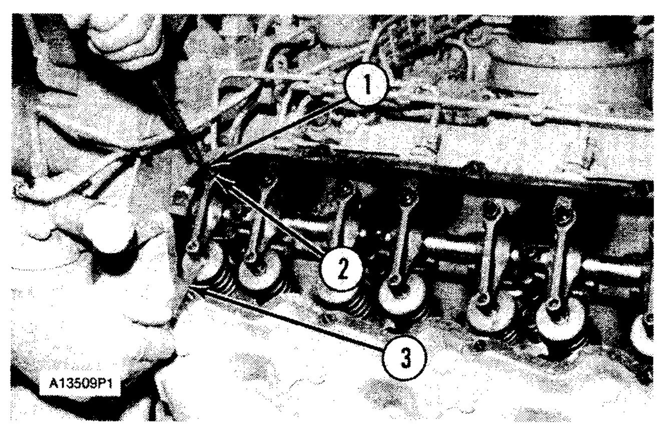
To check and make adjustment to the valve lash, use the procedure that follows:

1. Remove the valve covers.




Cylinder, Valve and Pump Location

2. Turn the crankshaft **counterclockwise** (as seen from rear of engine) until No. 1 piston is at top center on the compression stroke. The TDC-1 mark on the damper assembly will be in alignment with the timing pointer.
3. Make adjustment to the valves for No. 1 and No. 2 cylinders. To make the adjustment, loosen locknut (2). Turn the adjustment screw (1) until the feeler gauge (3) will go between the end of the valve stem and the rocker arm.



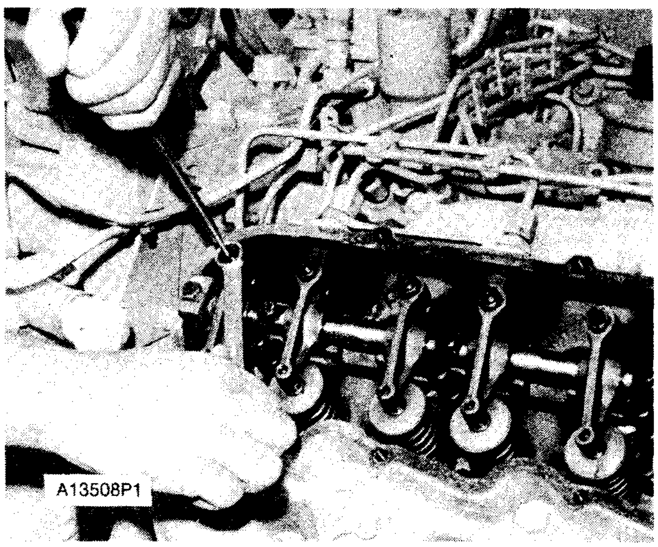

Valve Lash Adjustment
(1) Adjustment screw. (2) Locknut. (3) Feeler gauge.

4. After the adjustment is complete, hold adjustment screw (1) and tighten locknut (2) to 33 ± 7 N•m (24 ± 5 lb ft). After the locknut is tightened, check the adjustment again.

5. Turn the crankshaft 180° **counterclockwise** (as seen from rear of engine). The VS mark on the damper assembly will be in alignment with the timing pointer. Make adjustment to the valves for No. 3 and No. 7 cylinders.

6. Turn the crankshaft 180° counterclockwise (as seen from rear of engine). The TDC-1 mark on damper assembly will be in alignment with the timing pointer. Make adjustment to the valves for No. 4 and No. 5 cylinders.

7. Turn the crankshaft 180° **counterclockwise** (as seen from rear of engine). The VS mark on damper assembly will be in alignment with the timing pointer. Make adjustment to the valves for No. 6 and No. 8 cylinders.




Tightening Locknut

When the adjustment of the valve lash needs to be done several times in a short period of time, it can be an indication of wear in a different part of the engine. Find the problem and make any necessary repairs to prevent more damage to the engine.

Not enough valve lash, if not corrected, can be the cause of rapid wear of the camshaft and cam followers. Not enough valve lash can also be an indication of the seats for the valves being bad. Some reasons for the seats for the valves becoming bad are fuel injection nozzles with defects, restrictions to the inlet air or dirty air filters, wrong fuel setting, or using the engine on loads that are too large for the engine.

Too much valve lash, if not corrected, can be the cause for broken valve stems, push rods, or spring retainers. A fast increase in valve lash can be an indication of any of the following:

a. Camshaft and cam follower with wear.
b. Rocker arms with wear.
c. Push rods that are bent.
d. Loose adjustment screw for the valve lash.
e. Broken socket on the upper end of the push rod.

If the camshaft and cam followers show signs of rapid wear, look for fuel in the lubrication oil or dirty lubrication oil as a possible cause when making the necessary repairs.

## Procedure for Measuring Camshaft Lobes

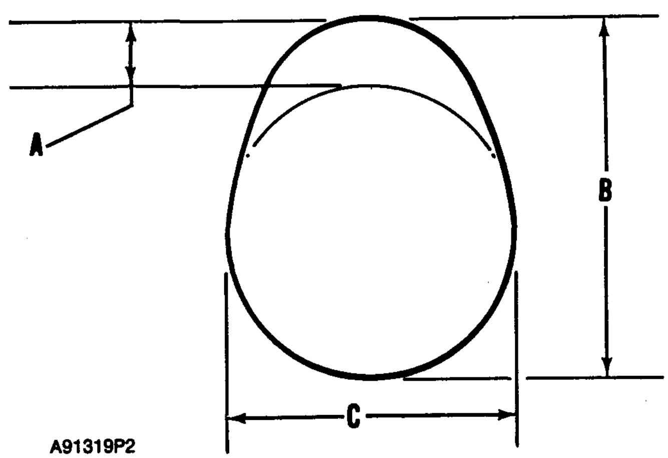
To find lobe lift (A) of camshaft, use the procedure that follows:

1. Measurement lobe height (B) of one exhaust and one intake lobe.

2. Measure base circle (C) of one exhaust and one intake lobe.

3. Subtract base circle (C) dimension (STEP 2) from lobe height (B) dimension (STEP 1). The difference is actual lobe lift (A).

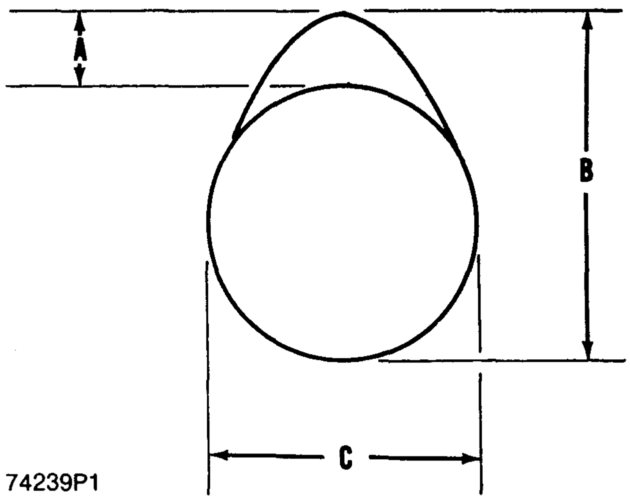
4. The specified (new) lobe lift (A) is:




Camshaft Lobe (Roller Lifters)
(A) Lobe lift. (B) Lobe height. (C) Base circle.

Camshaft with Roller Lifters:

(a) Exhaust lobe ........................ 9.40 mm (.370 in)
(b) Intake lobe ........................... 9.33 mm (.367 in)




Camshaft Lobe (Flat Face Lifters)
(A) Lobe lift. (B) Lobe height. (C) Base circle.

Camshaft with Flat Face Lifters:

(a) Exhaust lobe ........................ 9.40 mm (.370 in)
(b) Intake lobe ........................... 9.06 mm (.357 in)

5. The maximum permissible difference between actual lobe life (STEP 3) and specified lobe lift (STEP 4) is 0.25 mm (.010 in).

# Lubrication System

One of the problems in the list that follows will generally be an indication of a problem in the lubrication system for the engine.

**Too Much Oil Consumption**

**Oil Pressure Is Low**

**Oil Pressure Is High**

**Too Much Bearing Wear**

**Increased Oil Temperature**

## Too Much Oil Consumption

### Oil Leakage on Outside of Engine

Check for leakage at the seals at each end of the crankshaft. Look for leakage at the oil pan gasket and all lubrication system connections. Check to see if oil comes out of the crankcase breather. This can be caused by combustion gas leakage around the pistons. A dirty crankcase breather will cause high pressure in the crankcase, and this will cause gasket and seal leakage.

### Oil Leakage Into Combustion Area of Cylinders

Oil leakage into the combustion area of the cylinders can be the cause of blue smoke. There are four possible ways for oil leakage into the combustion area of the cylinders:

1. Oil leakage between worn valve guides and valve stems.
2. Worn or damaged piston rings, or dirty oil return holes.
3. Compression ring not installed correctly.
4. Oil leakage past the seal rings in the impeller end of the turbocharger shaft.

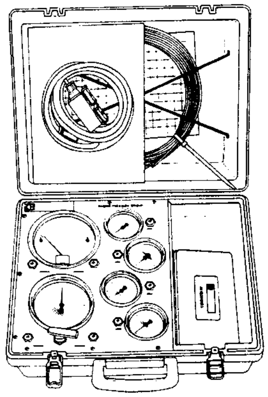
Too much oil consumption can also be the result if oil with the wrong viscosity is used. Oil with a thin viscosity can be caused by fuel leakage into the crankcase, or by increased engine temperature.

## Measuring Engine Oil Pressure

| Tools Needed | | |
|---|---|---|
| 1U5470 | Engine Pressure Group | 1 |

An oil pressure gauge that has a defect can given an indication of low oil pressure.

The 1U5470 Engine Pressure Group can be used to check engine oil pressure.

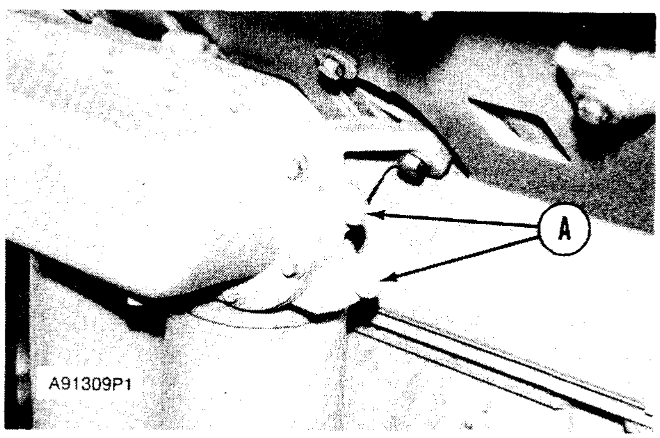


1U5470 Engine Pressure Group

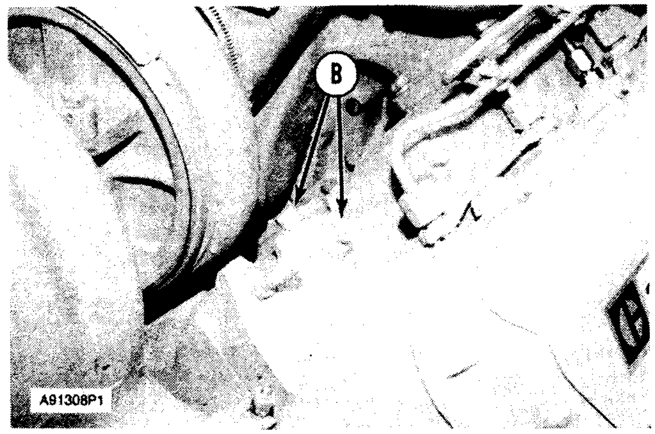
This tool group has a gauge to read oil pressure in the engine. Special Instruction, Form No. SEHS8907 is with the tool group and gives instructions for the test procedure.

1. Be sure that the engine is filled to the correct level with SAE 10W-30 oil. If any other viscosity of oil is used, the information in the Engine Oil Pressure Graph does not apply.

2. Connect the 1U5470 Engine Pressure Group to the main oil manifold at location (A) or location (B).




Oil Pressure Test Location
(A) Oil pressure test location at oil cooler.




Oil Pressure Test Location
(B) Oil pressure test location at rear of right cylinder head.

3. Run the engine to get the oil temperature at 93 ± 6°C (200 ± 10°F).

4. Keep the oil temperature constant with the engine at the rated rpm from the chart, and read the pressure gauge.

| ENGINE OIL PRESSURE AT 2800 rpm 10W30 OIL AT 93 ± 6°C (200 ± 10°F) | |
|---|---|
| **Test Location** | **Pressure** |
| A | 380 to 550 kPa (55 to 80 psi) |
| B | 345 to 520 kPa (50 to 75 psi) |

If the results do not fall within the pressure range given in the chart, find the cause and correct it. Engine failure or a reduction in engine life can be the result if engine operation is continued with oil pressure outside this range.

## Oil Pressure Is Low

### Crankcase Oil Level

Check the level of the oil in the crankcase. Add oil if needed. It is possible for the oil level to be too far below the oil pump supply tube. This will result in the oil pump not having the ability to supply enough lubrication to the engine components.

### Oil Pump Does Not Work Correctly

The inlet screen of the supply tube for the oil pump can have a restriction. This will result in cavitation and a loss of oil pressure. Air leakage in the supply side of the oil pump will also cause cavitation and loss of oil pressure. If the pressure regulating valve for the system is held in the open (unseated) position, the lubrication system can not get to maximum pressure. Oil pump gears that have too much wear will cause a reduction in oil pressure.

### Oil Filter and Oil Cooler

A dirty oil filter will cause a reduction in oil pressure. When the oil filter is filled with dirt, a restriction of oil flow through the filter and a reduction of filtered oil pressure is the result.

The bypass valve will cause the flow of oil to go around the filter elements when there is a reduction to the flow through the elements. When the bypass valve is open, oil that is not filtered is permitted to flow through the engine. To correct this problem, install a new Caterpillar filter.

Look for a restriction in the oil passages of the oil cooler. If the oil cooler has a restriction, the oil cooler bypass valve in the oil filter base will open. This will cause the flow of oil to go around the oil cooler. The oil temperature will be higher than normal when the engine is running. The oil pressure of the engine will become low if the oil cooler has a restriction.

### Too Much Clearance at Engine Bearings or Open, Broken or Disconnected Oil Line or Passage in Lubrication System

Components that are worn and have too much bearing clearance can cause oil pressure to be low. Low oil pressure can also be caused by an oil line or oil passage that is open, broken or disconnected.

## Oil Pressure Is High

Oil pressure will be high if the bypass valve for the oil pump can not move from the closed position.

## Too Much Bearing Wear

When some components of the engine show bearing wear in a short time, the cause can be a restriction in the oil passage. A broken oil passage can also be the cause.

If the gauge for oil pressure shows the correct oil pressure, but a component is worn because it is not getting enough lubrication, look at the passage for oil supply to that component. A restriction in a supply passage will not let enough lubrication get to a component and this will cause early wear.

## Increased Oil Temperature

Look for a restriction in the oil and coolant passages of the oil cooler. If the oil cooler has a restriction, the oil temperature will be higher than normal when the engine is operated. The oil pressure of the engine will not get low just because the oil cooler has a restriction.

Also check the oil cooler bypass valve to see if it is held in the open position (unseated). This condition will let the oil through the valve instead of the oil cooler, and oil temperature will increase.

# Cooling System

This engine has a pressure type cooling system. A pressure type cooling system gives two advantages. The first advantage is that the cooling system can have safe operation at a temperature that is higher than the normal boiling (steam) point of water. The second advantage is that this type system prevents cavitation (low pressure bubbles suddenly made in liquids by mechanical forces) in the water pump. With this type system, it is more difficult for an air or steam pocket to be made in the cooling system.

The cause for increased engine temperature is generally because regular inspections of the cooling system were not made. Make a visual inspection of the cooling system before a test is made with test equipment.

## Visual Inspection of the Cooling System

**1.** Check coolant level in the cooling system.

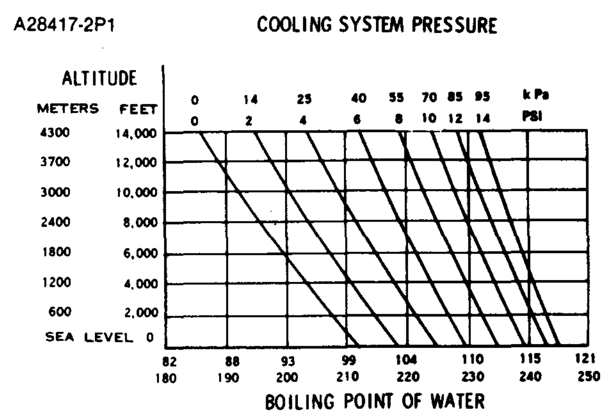
**2.** Look for leaks in the system.

NOTE: Water pump seals. A small amount of coolant leakage across the surface of the "face-type" seals is normal, and required, to provide lubrication for this type of seal. A hole is provided in the water pump housing to allow this coolant/seal lubricant to drain from the pump housing. Intermittent leakage of small amounts of coolant from this hole is not an indication of water pump seal failure. Replace the water pump seals only if a large amount of leakage, or a constant flow of coolant is observed draining from the water pump housing.

3. Look for bent radiator fins. Be sure that air flow through the radiator does not have a restriction.
4. Inspect the drive belts for the fan.
5. Check for damage to the fan blades.
6. Look for air or combustion gas in the cooling system.
7. Inspect the filler cap and the surface that seals the cap. This surface must be clean.

## Testing the Cooling System

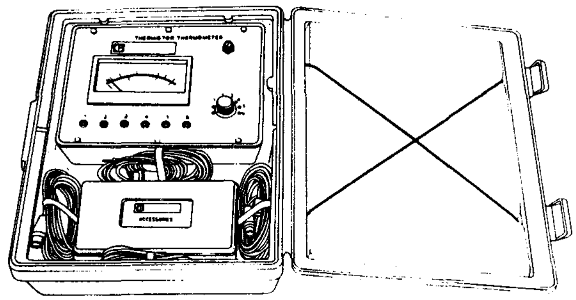
Remember that temperature and pressure work together. When a diagnosis is made of a cooling system problem, temperature and pressure must both be checked. Cooling system pressure will have an effect on cooling system temperatures. For an example, look at the chart to see the effect of pressure and height above sea level on the boiling (steam) point of water.




### C Test Tools for Cooling System

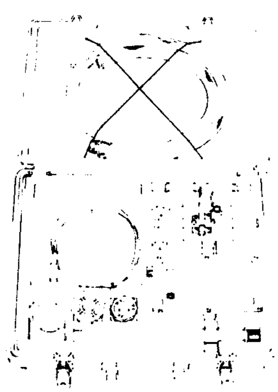
| Tools Needed | | |
|---|---|---|
| 8T0470 | Thermistor Thermometer Group | 1 |
| 8T2700 | Blowby/Air Flow Indicator Group | 1 |
| 6V3121 | Multitach Group | 1 |
| 9S8140 | Cooling System Pressurizing Pump Group | 1 |

The 8T0470 Thermistor Thermometer Group is used in the diagnosis of overheating (engine hotter than normal) or overcooling (engine cooler than normal) problems. This group can be used to check temperatures in several different parts of the cooling system. The testing procedure is in Special Instruction, Form No. SEHS8446.


C31893P1

8T0470 Thermistor Thermometer Group

The 8T2700 Blowby/Air Flow Indicator Group is used to check the air flow through the radiator core. The test procedure is in Special Instruction, Form No. SEHS8712.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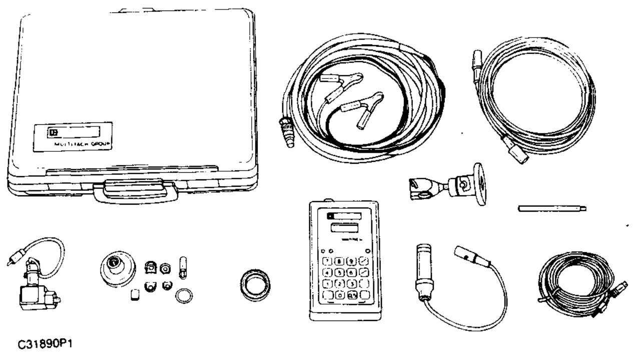
8T2700 Blowby/Air Flow Indicator Group

The 6V3121 Multitach Group is used to check the fan speed. The testing procedure is in Special Instruction, Form No. SEHS7807.




6V3121 Multitach Group

## Checking Pressure Cap

| Tools Needed | | |
|---|---|---|
| 9S8140 | Cooling System Pressurizing Pump Group | 1 |

One cause for a pressure loss in the cooling system can be a bad seal on the radiator pressure cap.

**⚠ WARNING**

**DO NOT loosen the filler or pressure cap on a hot engine. Steam or hot coolant can cause severe burns.**

After the engine is cool, loosen the pressure cap and let the pressure out of the cooling system. Then remove the pressure cap.

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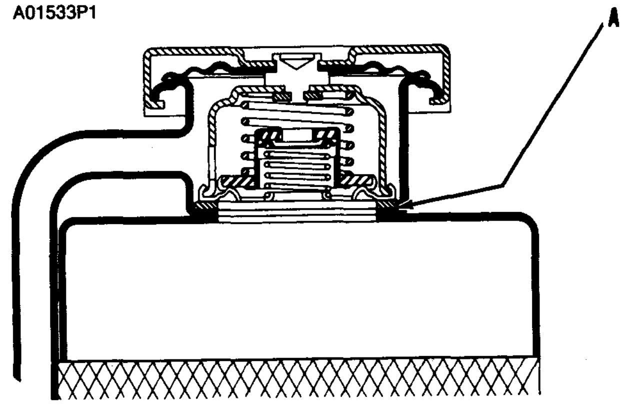



Typical Schematic of Pressure Cap
(A) Sealing surface of cap and radiator.

Inspect the pressure cap carefully. Look for damage to the seal or to the surface that seals. Any foreign material or deposits on the cap, seal or surface that seals, must be removed.

The 9S8140 Cooling System Pressurizing Pump Group is used to test pressure caps and to pressure check the cooling system for leaks.

**⚠ WARNING**

**DO NOT loosen the filler or pressure cap on a hot engine. Steam or hot coolant can cause severe burns.**

To check the pressure cap for the pressure that makes the pressure cap open, use the procedure that follows:

1. Remove the pressure cap from the radiator.
2. Put the pressure cap on the 9S8140 Cooling System Pressurizing Pump Group.
3. Look at the gauge for the exact pressure that makes the pressure cap open.
4. Make a comparison of the reading on the gauge with the correct pressure at which the pressure cap must open.

NOTE: The correct pressure that makes the pressure cap open is on the pressure cap and is also in the SPECIFICATIONS SECTION.

5. If the pressure cap is bad, install a new pressure cap.

## Testing Radiator and Cooling System for Leaks

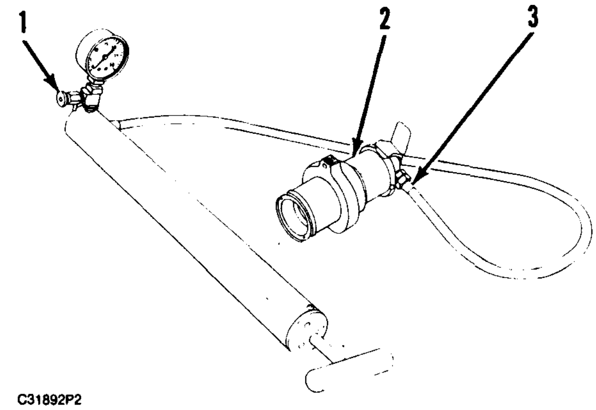
| Tools Needed | | |
|---|---|---|
| 9S8140 | Cooling System Pressurizing Pump Group | 1 |

To test the radiator and cooling system for leaks, use the procedure that follows:

**⚠ WARNING**

**DO NOT loosen the filler or pressure cap on a hot engine. Steam or hot coolant can cause severe burns.**

1. Remove the pressure cap from the radiator.
2. Make sure the coolant is over the top of the radiator core.
3. Put the 9S8140 Cooling System Pressurizing Pump Group on the radiator.
4. Operate the pump group and get a pressure reading on the gauge that is 20 kPa (3 psi) more than the pressure marked on the pressure cap.
5. Check the radiator for outside leakage.
6. Check all connections and hoses for the cooling system for outside leakage.
7. If you do not see any outside leakage and the pressure reading on the gauge is still the same after 5 minutes, the radiator and cooling system does not have leakage. If the reading on the gauge goes down and you do not see any outside leakage, there is leakage on the inside of the cooling system. Make repairs as necessary.



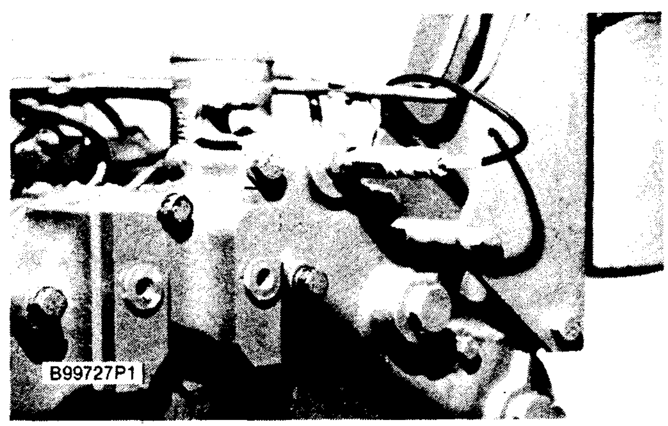

9S8140 Cooling System Pressurizing Pump Group
(1) Release valve. (2) Adapter. (3) Hose.

**⚠ WARNING**

**If a pressure indication is shown on the gauge, to avoid personal injury push release valve (1) to release all pressure in the system before removal of hose (3) from radiator.**

### Gauge for Water Temperature

| Tools Needed | | |
|---|---|---|
| 8T0470 | Thermistor Thermometer Group or | 1 |
| 2F7112 | Thermometer and 6B5072 Bushing | 1 |




8T0470 Thermistor Thermometer Group Installed (Typical Example)

If the engine gets too hot and a loss of coolant is a problem, a pressure loss in the cooling system could be the cause. If the gauge for water temperature shows that the engine is getting too hot, look for coolant leakage. If a place can not be found where there is coolant leakage check the accuracy of the gauge for water temperature. A temperature gauge of known accuracy can be installed at the plug locations to make this check. Also, the 8T0470 Thermistor Thermometer Group or the 2F7112 Thermometer and 6B5072 Bushing can be used.

**⚠ WARNING**

**Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.**

Start the engine and run it until the temperature is at the desired range according to the test gauge or thermometer. If necessary, put a cover over part of the radiator or cause a restriction of the coolant flow. The reading on the gauge for water temperature must be the same as the test gauge or thermometer within the tolerance range in the attachment specification charts for water temperature gauges.

### Water Temperature Regulators

1. Remove the regulator from the engine.
2. Heat water in a pan until the temperature is 92°C (197°F). Move the water around in the pan to make it all the same temperature.
3. Hang the regulator in the pan of water. The regulator must be below the surface of the water and it must be away from the sides and bottom of the pan.
4. Keep the water at the correct temperature for 10 minutes.
5. After ten minutes, remove the regulator and immediately measure the distance the regulator has opened. See the Specifications for the correct opening distance.

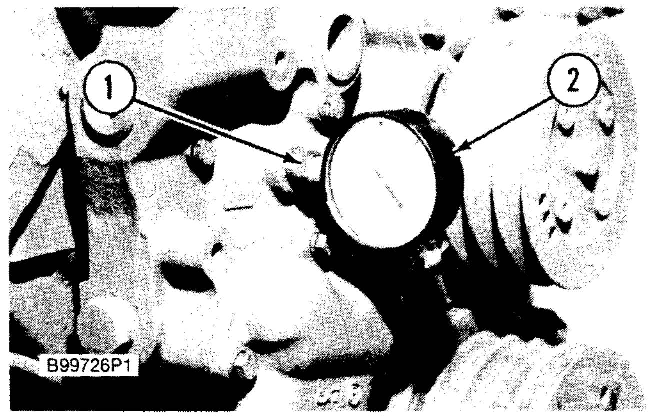
## C Water Pump Pressure Check

| Tools Needed | | |
|---|---|---|
| 6V7775 | Pressure Gauge | 1 |
| 3B7722 | Bushing | 1 |

The pressure at the outlet for the water pump tells if the shunt system and water pump are operating correctly. To check the pump pressure, install pressure gauge (2) in the front cover. The pressure must be minimum of 105 kPa (15 psi) at 2800 rpm.

If the pump pressure is less than the minimum pressure: First, check the vent tube between the radiator top tank and the surge tank; it must have an inside diameter of approximately 4.8 mm (.19 in).

Second check to see that the shunt line has a minimum inside diameter of 19.1 mm (.75 in).




Gauge Installed
(Typical Example)
(1) 3B7722 Bushing. (2) 6V7775 Pressure Gauge.

c **Belt Tension Chart**

| BELT TENSION CHART | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| BELT SIZE | WIDTH BELT TOP | | WIDTH TOP OF PULLEY GROOVE | | BELT TENSION "INITIAL"* GAUGE READING | | BELT TENSION "USED"** GAUGE READING | | BORROUGHS GAUGE NUMBERS | |
| | mm | in. | mm | in. | N | lb | N | lb | OLD GAUGE NO. | NEW GAUGE NO. |
| 3/8 | 10.72 | .422 | 9.65 | .380 | 445 ± 22 | 100 ± 5 | 400 ± 22 | 90 ± 5 | BT-33-95 | BT-33-97 |
| 1/2 | 13.89 | .547 | 12.70 | .500 | 534 ± 22 | 120 ± 5 | 400 ± 44 | 90 ± 10 | BT-33-95 | BT-33-97 |
| 5V | 15.88 | .625 | 15.24 | .600 | 534 ± 22 | 120 ± 5 | 400 ± 44 | 90 ± 10 | BT-33-72-4-15 | BT-33-72C |
| 11/16 | 17.48 | .688 | 15.88 | .625 | 534 ± 22 | 120 ± 5 | 400 ± 44 | 90 ± 10 | BT-33-72-4-15 | BT-33-72C |
| 3/4 | 19.05 | .750 | 17.53 | .690 | 534 ± 22 | 120 ± 5 | 400 ± 44 | 90 ± 10 | BT-33-72-4-15 | BT-33-72C |
| 15/16 | 23.83 | .983 | 22.30 | .878 | 534 ± 22 | 120 ± 5 | 400 ± 44 | 90 ± 10 | BT-33-72-4-15 | BT-33-72C |
| 8K | 27.92 | 1.099 | | | 800 ± 22 | 180 ± 5 | 489 ± 44 | 110 ± 10 | | BT-33-109 |
| MEASURE TENSION OF BELT FARTHEST FROM THE ENGINE | | | | | | | | | | |

*"INITIAL" BELT TENSION is for a new belt.
**"USED" BELT TENSION is for a belt which has more than 30 minutes of operation at rated speed of engine. A10232-4P1

# Basic Block

## Connecting Rods and Pistons

Use the 5F9059 Piston Ring Expander to remove or install piston rings.

Use the 5P3524 Piston Ring Compressor to install pistons into cylinder block.

Tighten the connecting rod nuts in the following step sequence:

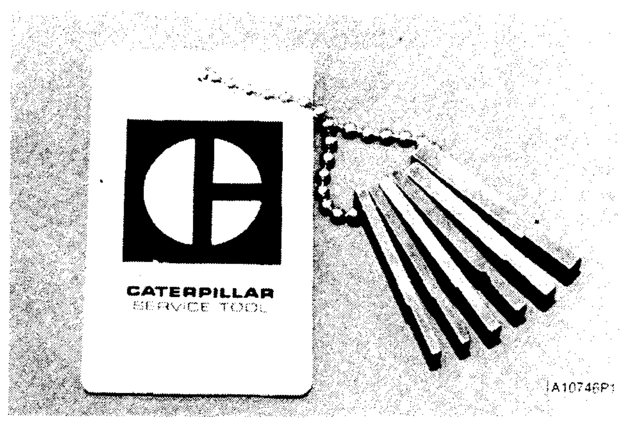
1. Put 2P2506 Thread Lubricant on bolt threads and seating surfaces of cap and nut.
2. Tighten both nuts to 41 ± 4 N•m (30 ± 3 lb ft).
3. Put a mark on each nut and cap.
4. Tighten each nut 60° from the mark.

The connecting rod bearings should fit tightly in the bore in the rod. If bearing joints or backs are worn (fretted), check for bore size as this is an indication of wear because of looseness.

## 5P3519 Piston Ring Groove Gauge

A 5P3519 Piston Ring Groove Gauge is available for checking ring grooves with straight sides. For instructions on the use of the gauge, see the GUIDELINE FOR REUSABLE PARTS: PISTONS, Form No. SEBF8049.

NOTE: The 5P3519 Piston Ring Groove Gauge is used to check the top ring groove only.




Piston Ring Groove Gauge

## Connecting Rod and Main Bearings

Bearings are available with a smaller inside diameter than the original size bearings. These bearings are for crankshafts that have been "ground" (made smaller than the original size). Main bearings are available with a larger outside diameter than the original size bearings. These bearings are for cylinder blocks that have had the bore for the main bearings "bored" (made larger than the original size).

## Flywheel and Flywheel Housing

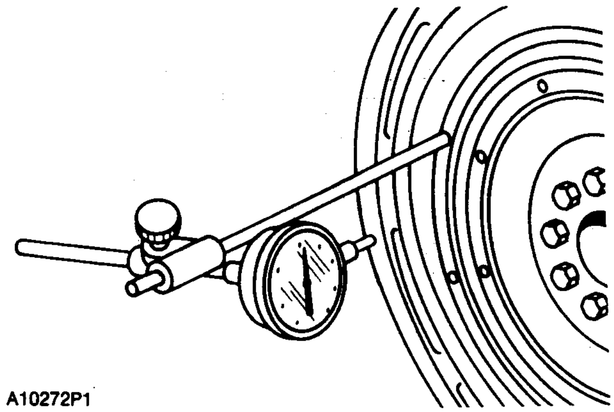
| Tools Needed | | |
|---|---|---|
| 8T5096 | Dial Indicator Group | 1 |

Heat the ring gear to install it. Do not heat to more than 204°C (400°F). Install the ring gear so the chamfer on the gear teeth is next to the starter pinion when the flywheel is installed.

### Face Runout (axial eccentricity) of the Flywheel Housing

If any method other than given here is used, always remember bearing clearances must be removed to get correct measurements.

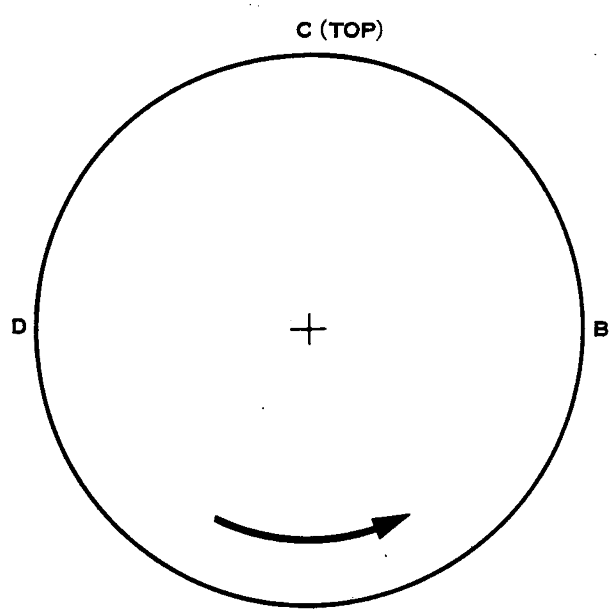
1. Fasten a dial indicator to the crankshaft flange so the anvil of the indicator will touch the face of the flywheel housing.
2. Force the crankshaft to the rear before reading the indicator at each point.



A10272P1

8T5096 Dial Indicator Group

3. With the dial indicator set at 0.00 mm (.000 in) at location (A), turn the crankshaft and read the indicator at locations (B), (C) and (D).
4. The difference between lower and higher measurements taken at all four points must not be more than 0.25 mm (.010 in), which is the maximum permissible face runout (axial eccentricity) of the flywheel housing.



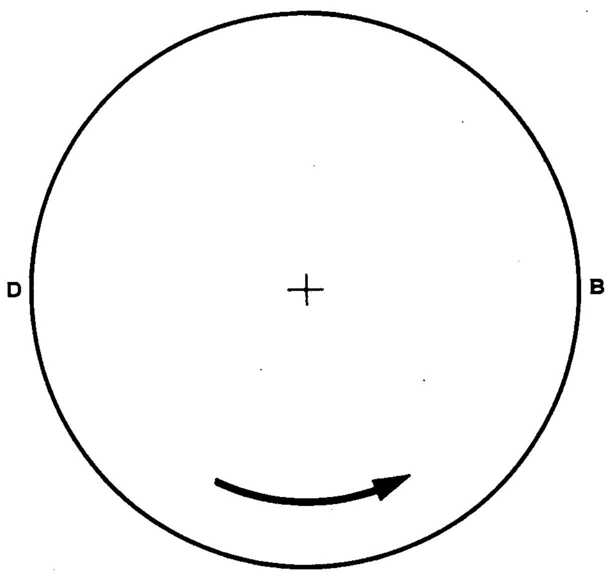

A10233P1

Checking Face Runout of the Flywheel Housing
(A) Bottom. (B) Right side. (C) Top. (D) Left side.

## Bore Runout (radial eccentricity) of the Flywheel Housing

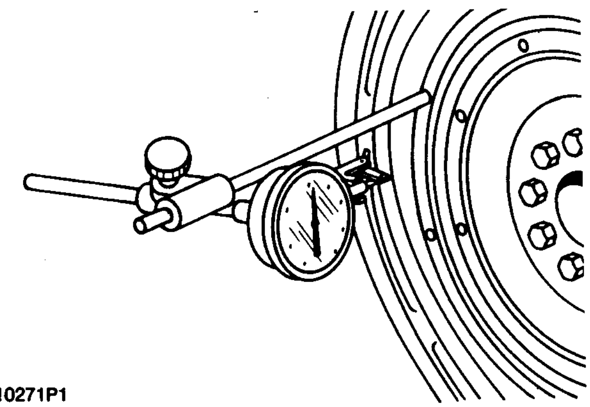
1. With the dial indicator in position at (C), adjust the dial indicator to 0.00 mm (.000 in). Push the crankshaft up against the top bearing. Write the measurement for bearing clearance on line 1 in column (C).

2. Divide the measurement from Step 1 by 2. Write this number on line 1 in columns (B) & (D).




A10233P1

Checking Bore Runout of the Flywheel Housing



A10271P1

8T5096 Dial Indicator Group Installed

3. Turn the crankshaft to put the dial indicator at (A). Adjust the dial indicator to 0.00 mm (.000 in).

4. Turn the crankshaft **counterclockwise** to put the dial indicator at (B). Write down the measurement in the chart.

NOTE: Write the dial indicator measurements with their positive (+) and negative (–) notation (signs). This is necessary for making the calculations in the chart correctly.

5. Turn the crankshaft **counterclockwise** to put the dial indicator at (C). Write the measurement in the chart.

6. Turn the crankshaft **counterclockwise** to put the dial indicator at (D). Write the measurement in the chart.

7. Add lines I & II by columns.

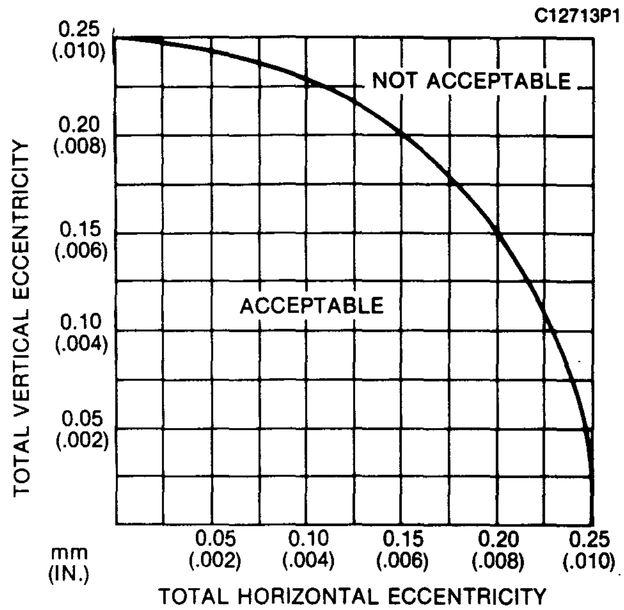
8. Subtract the smaller number from the larger number in line III in columns (B) & (D). The result is the horizontal "eccentricity" (out of round). Line II, column (C) is the vertical eccentricity.

| CHART FOR DIAL INDICATOR MEASUREMENTS | | | | | |
|---|---|---|---|---|---|
| | Position of dial indicator | | | | |
| | Line No. | A | B | C | D |
| Correction for bearing clearance | I | 0 | | | |
| Dial Indicator Reading | II | 0 | | | |
| Total of Line 1 & 2 | III | 0 | ** | * | ** |

*Total Vertical eccentricity (out of round).
**Subtract the smaller No. from the larger No. The difference is the total horizontal eccentricity.

A10234P1

9. On the graph for total eccentricity find the point of intersection of the lines for vertical eccentricity and horizontal eccentricity.



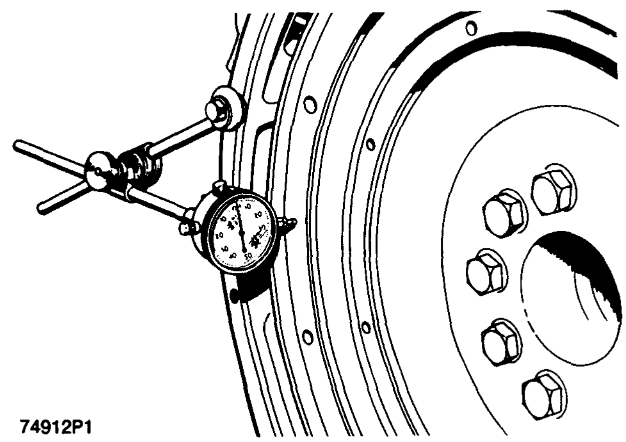

Graph for Total Eccentricity

10. If the point of intersection is in the range marked "Acceptable" the bore is in alignment. If the point of intersection is in the range marked "Not Acceptable" the flywheel housing must be changed.

### Face Runout (axial eccentricity) of the Flywheel

1. Install the dial indicator as shown. Force the crankshaft the same way before the indicator is read so the crankshaft end clearance (movement) is always removed.

2. Set the dial indicator to read 0.00 mm (.000 in).



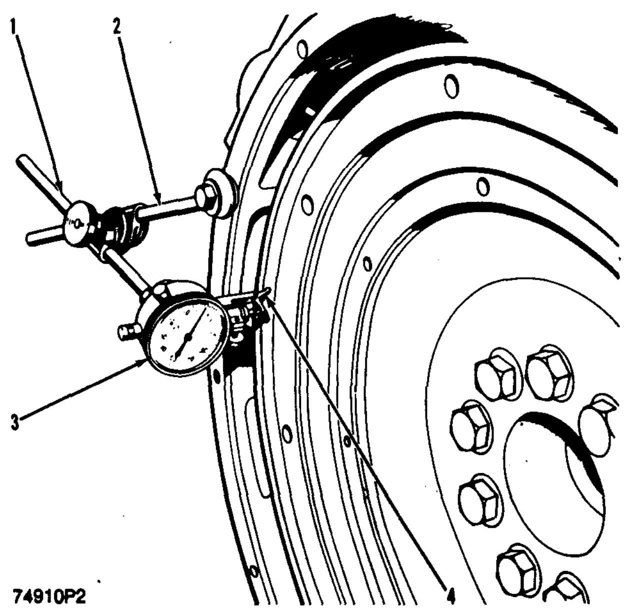

Checking Face Runout of the Flywheel

3. Turn the flywheel and read the indicator every 90°.

4. The difference between the lower and higher measurements taken at all four points must not be more than 0.15 mm (.006 in), which is the maximum permissible face runout (axial eccentricity) of the flywheel.

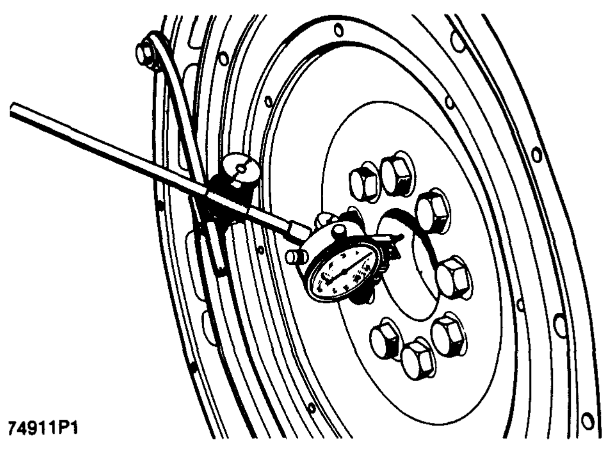
### Bore Runout (radial eccentricity) of the Flywheel

1. Install the dial indicator (3) and make an adjustment of the universal attachment (4) so it makes contact as shown.




74910P2

Checking Bore Runout of the Flywheel
(1) 7H1945 Holding Rod. (2) 7H1645 Holding Rod. (3) 7H1942 Indicator. (4) 7H1940 Universal Attachment.



74911P1

Checking Flywheel Clutch Pilot Bearing Bore

2. Set the dial indicator to read 0.00 mm (.000 in).
3. Turn the flywheel and read the indicator every 90°.
4. The difference between the lower and higher measurements taken at all four points must not be more than 0.15 mm (.006 in), which is the maximum permissible bore runout (radial eccentricity) of the flywheel.
5. Runout (eccentricity) of the bore for the pilot bearing for the flywheel clutch, must not exceed 0.13 mm (.005 in).

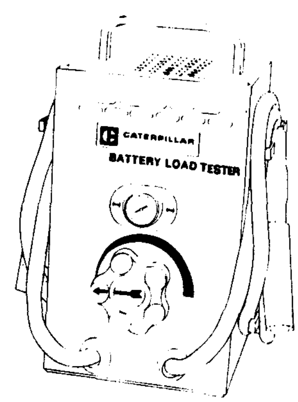
# Electrical System

## C Test Tools For Electrical System

| Tools Needed | | |
|---|---|---|
| 6V4930 | Battery Load Tester | 1 |
| 8T0900 | AC/DC Clamp-On Ammeter | 1 |
| 6V7070 | Heavy-Duty Digital Multimeter or | 1 |
| 6V7800 | Regular-Duty Digital Multimeter | 1 |

Most of the tests of the electrical system can be done on the engine. The wiring insulation must be in good condition, the wire and cable connections must be clean and tight, and the battery must be fully charged. If the on-engine test shows a defect in a component, remove the component for more testing.

The service manual Testing and Adjusting Electrical Components, Form No. REGO0636 has complete specifications and procedures for the components of the starting circuit and the charging circuit.



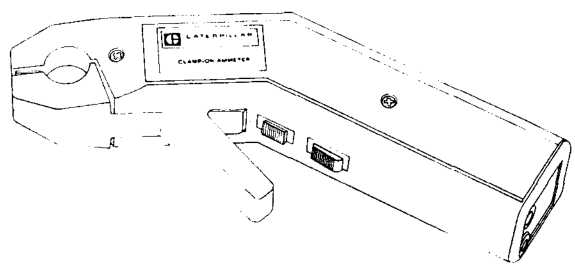

C31887P1

6V4930 Battery Load Tester

The 6V4930 Battery Load Tester is a portable unit in a metal case for use under field conditions and high temperatures. It can be used to load test all 6, 8 and

12V batteries. This tester has two heavy-duty load cables that can easily be fastened to the battery terminals, and a load adjustment knob on the front panel permits a current range up to a maximum of 700 amperes. The tester also has a thermometer to show when the safe operating temperature limit of the unit has been reached.

NOTE: Make reference to Special Instruction, Form No. SEHS8268 for complete information for use of the 6V4930 Battery Load Tester.



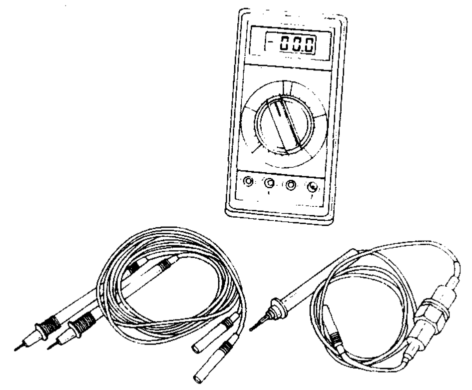
C31895P1

8T0900 AC/DC Clamp-On Ammeter

The 8T0900 AC/DC Clamp-On Ammeter is a completely portable, self-contained instrument that allows electrical current measurements to be made without breaking the circuit or disturbing the insulation on conductors. A digital display is located on the ammeter for reading current directly in a range from 1 to 1200 amperes. If an optional 6V6014 Cable is connected between this ammeter and one of the digital multimeters, current readings of less than 1 ampere can then be read directly from the display of the multimeter.

A lever is used to open the jaws over the conductor [up to a diameter of 19 mm (.75 in)], and the spring loaded jaws are then closed around the conductor for current measurement. A trigger switch that can be locked in the ON or OFF position is used to turn on the ammeter. When the turn-on trigger is released, the last current reading is held on the display for 5 seconds. This allows accurate measurements to be taken in limited access areas where the digital display is not visible to the operator. A zero control is provided for DC operation, and power for the ammeter is supplied by batteries located inside the handle.

NOTE: Make reference to Special Instruction, Form No. SEHS8420 for more complete information for use of the 8T0900 Clamp-On Ammeter.



C31896P1

6V7070 Heavy-Duty Digital Multimeter

The 6V7070 Heavy-Duty Digital Multimeter is a completely portable, hand held instrument with a digital display. This multimeter is built with extra protection against damage in field applications, and is equipped with seven functions and 29 ranges. The 6V7070 Multimeter has a instant ohms indicator that permits continuity checks for fast circuit inspection. It also can be used for troubleshooting small value capacitors.

The 6V7800 Regular-Duty Multimeter (a low cost option to the Heavy-Duty Multimeter) is also available; however, the 6V7800 Multimeter does not have the 10A range or the instant ohms feature of the 6V7070 Multimeter.

NOTE: Make reference to Special Instruction, Form No. SEHS7734 for more complete information for use of the 6V7070 and 6V7800 Multimeters.

## Battery

**⚠ WARNING**

**Never disconnect any charging unit circuit or battery circuit cable from battery when the charging unit is operated. A spark can cause an explosion from the flammable vapor mixture of hydrogen and oxygen that is released from the electrolyte through the battery outlets. Injury to personnel can be the result.**

The battery circuit is an electrical load on the charging unit. The load is variable because of the condition of the charge in the battery. Damage to the charging unit will result if the connections (either positive or negative) between the battery and charging unit are broken while the charging unit is in operation. This is because the battery load is lost and there is an increase in charging voltage. High voltage will damage, not only the charging unit, but also the regulator and other electrical components.

Load test a battery that does not hold a charge when in use. To do this, put a resistance across the main connections (terminals) of the battery. For a 6, 8 or 12V battery, use a test load of three times the ampere/hour rating (the maximum test load on any battery is 500 amperes). Let the test load remove the charge (discharge) of the battery for 15 seconds and with the test load still applied, test the battery voltage. A 6V battery in good condition will show 4.5V; and 8V battery will show 6V; a 12V battery will show 9V. Each cell of a battery in good condition must show 1.6V on either a 6, 8 or 12V battery.

## Charging System

The condition of charge in the battery at each regular inspection will show if the charging system operates correctly. An adjustment is necessary when the battery is constantly in a low condition of charge or a large amount of water is needed (more than one ounce of water per cell per week or per every 50 service hours).

When it is possible, make a test of the charging unit and voltage regulator on the engine, and use wiring and components that are a permanent part of the system. Off-engine (bench) testing will give a test of the charging unit and voltage regulator operation. This testing will give an indication of needed repair. After repairs are made, again make a test to give proof that the units are repaired to their original condition of operation.

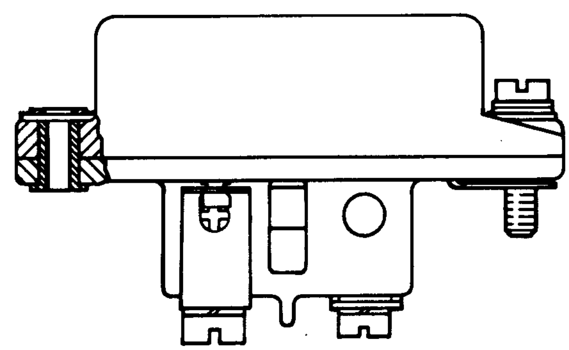
Before the start of on-engine testing, the charging system and battery must be checked as shown in the steps that follow:

1. Battery must be at least 75% (1.225 Sp Gr) fully charged and held tightly in place. The battery holder must not put too much stress on the battery.
2. Cables between the battery, starter and engine ground must be the correct size. Wires and cables must be free of corrosion and have cable support clamps to prevent stress on battery connections (terminals).
3. Leads, junctions, switches and panel instruments that have direct relation to the charging circuit must give correct circuit control.
4. Inspect the drive components for the charging unit to be sure they are free of grease and oil and have the ability to operate the charging unit.

### C Alternator Regulator Adjustment

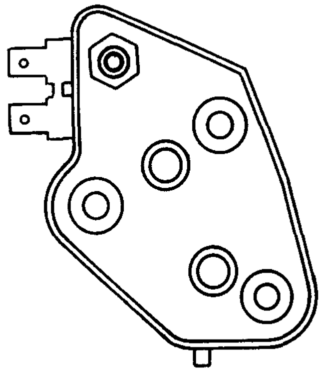
When an alternator is charging the battery too much or not enough, an adjustment can be made to the charging rate of the alternator. Make reference to Specifications to find all testing specifications for all alternators and regulators.

Bosch Regulators (9G7567)
Delco-Remy Regulators (3T6354)
Nippondenso Regulators (7T2798)



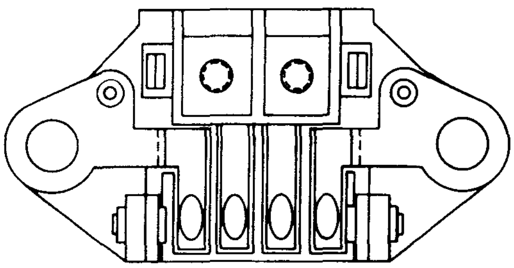
B12749P1

Bosch Regulators (9G7567)



C12725P1

Delco-Remy Regulators (3T6354)



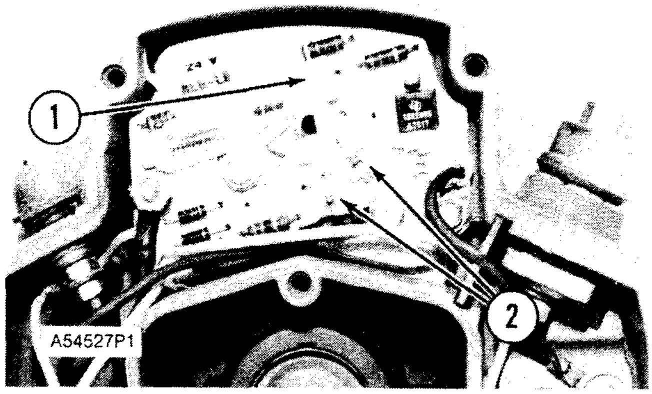
C10874P1

Nippondenso Regulators (7T2798)

No adjustment can be made to change the rate of charge on these alternator regulators. If rate of charge is not correct, a replacement of the regulator is necessary.

### Alternator Regulator Adjustment (Delco-Remy)

1. Remove the covers from the end of the alternator to get access to the voltage regulator.




Delco-Remy Regulator Adjustment
(1) Potentiometer adjustment screw. (2) Transistor pins.

2. Remove the rubber from the potentiometer so that the small screw can be seen.

3. Connect a voltmeter across the batteries to measure the regulation of the voltage.

NOTE: The batteries must have a good charge for this measurement.

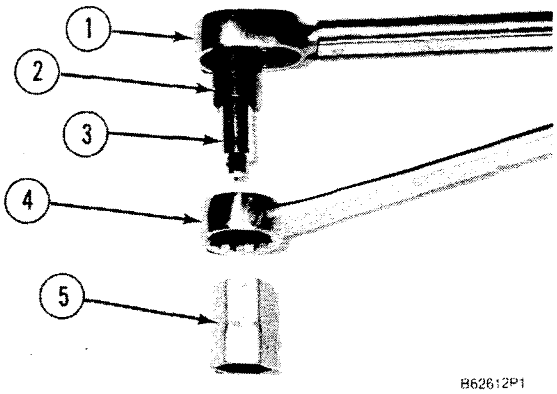
4. Operate the alternator at medium speed for 30 seconds and take a measurement of the voltage. The voltage must be 27.5 ± 1.0 volts. Turn the small screw **counterclockwise** to get less voltage output and **clockwise** to get more voltage output.

5. After adjustment has been made, put a thin layer of 3S6252 Silicone Rubber Sealant on the adjustment screw and install the covers.

NOTE: Make sure the location of the wires to the voltage regulator is not over the transistor pins. The transistor pins could make holes in the insulation for the wires and cause a short circuit.

### Alternator Pulley Nut Tightening (Delco-Remy)

Tighten nut that holds the pulley to a torque of 102 ± 7 N•m (75 ± 5 lb ft) with the tools shown.




Tools To Tighten Alternator Pulley Nut
(1) 8T9293 Torque Wrench. (2) 8S1588 Adapter (½" female to ⅜" male). (3) 2P8267 Socket Assembly. (4) 8H8517 Combination Wrench (1-⅛"). (5) 8T5314 Socket.

## Starting System

Use the multimeter in the DCV range to find starting system components which do not function.

Move the start control switch to activate the starter solenoid. Starter solenoid operation can be heard as the pinion of the starter motor is engaged with the ring gear on the engine flywheel.

If the solenoid for the starter motor will not operate, it is possible that the current from the battery did not get to the solenoid. Fasten one lead of the multimeter to the connection (terminal) for the battery cable on the solenoid. Put the other lead to a good ground. A zero reading is an indication that there is a broken circuit from the battery. More testing is necessary when there is a voltage reading on the multimeter.

The solenoid operation also closes the electric circuit to the motor. Connect one lead of the multimeter to the solenoid connection (terminal) that is fastened to the motor. Put the other lead to a good ground. Activate the starter solenoid and look at the multimeter. A reading of battery voltage shows the problem is in the motor. The motor must be removed for further testing. A zero reading on the multimeter shows that the solenoid contacts do not close. This is an indication of the need for repair to the solenoid or an adjustment to be made to the starter pinion clearance.

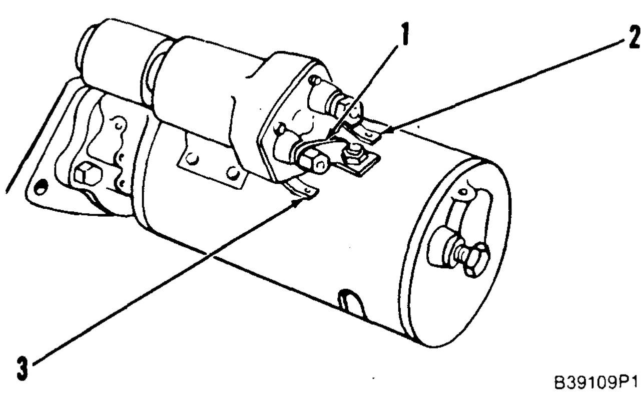
Make a test with one multimeter lead fastened to the connection (terminal) for the small wire at the solenoid and the other lead to the ground. Look at the multimeter and activate the starter solenoid. A voltage reading shows that the problem is in the solenoid. A zero reading is an indication that the problem is in the start switch or the wires for the start switch.

Fasten one multimeter lead to the start switch at the connection (terminal) for the wire from the battery. Fasten the other lead to a good ground. A zero reading indicates a broken circuit from the battery. Make a check of the circuit breaker and wiring. If there is a voltage reading, the problem is in the start switch or in the wires for the start switch.

A starter motor that operates too slow can have an overload because of too much friction in the engine being started. Slow operation of the starter motor can also be caused by a short circuit, loose connections and/or dirt in the motor.

### Pinion Clearance Adjustment (Delco-Remy)

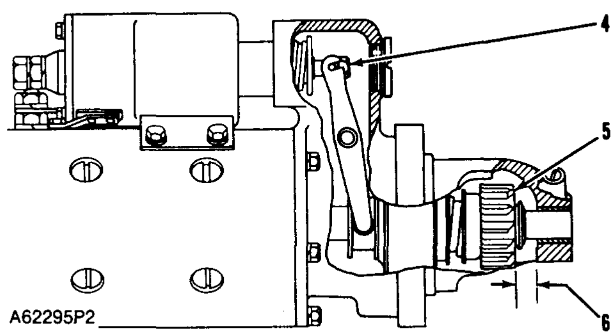
When the solenoid is installed, make an adjustment of the pinion clearance. The adjustment can be made with the starter motor removed.




Connection for Checking Pinion Clearance
(1) Connector from MOTOR terminal on solenoid to motor. (2) SW terminal. (3) Ground terminal.

1. With the solenoid installed on the starter motor, remove connector (1).
2. Connect a battery, of the same voltage as the solenoid, to the terminal (2), marked SW.
3. Connect the other side of the battery to ground terminal (3).

4. Connect for a moment a wire from the solenoid connection (terminal) marked MOTOR to the ground connection (terminal). The pinion will shift to crank position and will stay there until the battery is disconnected.




Pinion Clearance Adjustment
(4) Shaft nut. (5) Pinion. (6) Pinion clearance.

5. Push the pinion toward the commutator end to remove free movement.

6. Pinion clearance (6) must be 8.3 to 9.9 mm (.33 to .39 in).

7. To adjust pinion clearance, remove plug and turn nut (4).

8. After the adjustment is completed, install the plug over adjustment nut (4) and install connector (1) between the MOTOR terminal on the solenoid and the starter motor.

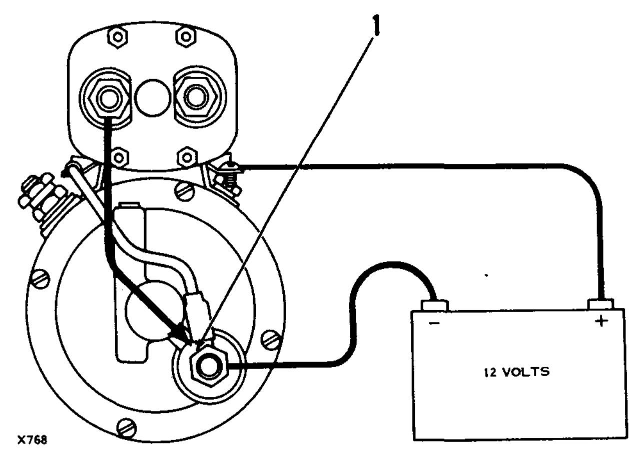
### Pinion Clearance Adjustment (Prestolite)

There are two adjustments on this type motor. They are end play for the armature and pinion clearance.

#### End Play For The Armature

The correct end play for the armature is 0.13 to 0.76 mm (.005 to .030 in). The adjustment is made by adding or removing thrust washers on the commutator end of the armature shaft.

#### Pinion Clearance Adjustment

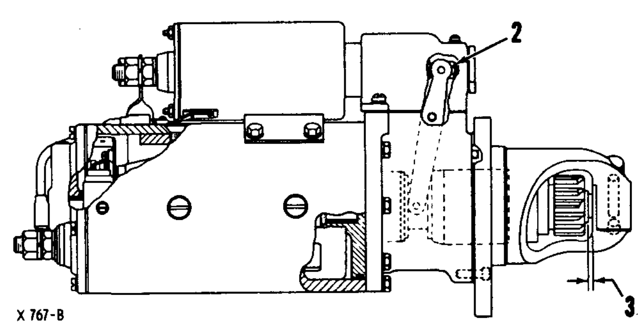



Connections For Adjustment Of The Pinion Clearance
(1) Stud.

1. To adjust the pinion distance, connect the 24V solenoid to a 12V battery (12V solenoid to a 6V battery) as shown. For a short moment, connect a wire from the "motor" stud of the solenoid to the stud at (1) in the commutator end. This moves the solenoid and drive into the cranking position.

Disconnect the wire.

NOTE: The drive is in the cranking position until the battery is disconnected.




Pinion Clearance Adjustment
(2) Adjustment nut. (3) Distance.

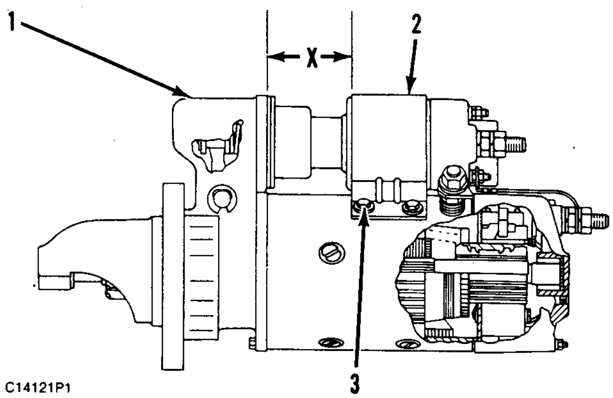
2. Push the drive toward the commutator end of the motor to eliminate any slack movement in the linkage and measure the distance between the outside edge of the drive sleeve and the thrust washer. The distance (3) must be 0.51 to 1.27 mm (.020 to .050 in).

3. Remove the plug. Turn the adjustment nut (2) in or out as necessary to get this distance.

4. Install the plug.

## C Starter Motor Adjustments (Bosch)

### Solenoid Position Adjustment




Solenoid Assembly
(1) Intermediate housing. (2) Solenoid mounting bracket. (3) Bolts. (X) 62.5 + 0.2 - 0.5 mm (2.46 + .008 - .020 in).

The solenoid position on the starter motor controls the pinion clearance. If the solenoid position dimension is correct, the pinion clearance is correct. The adjustment can be made with the starter motor removed.

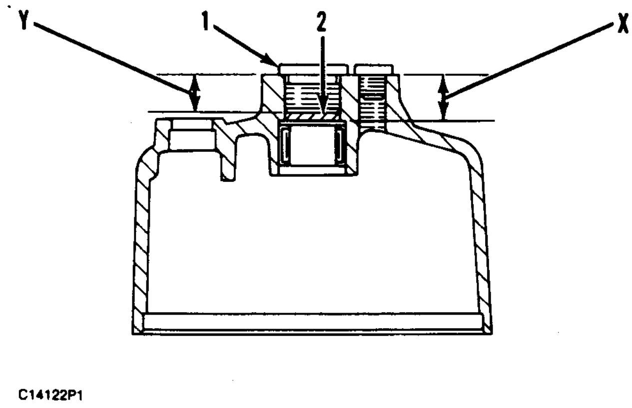
1. Check distance (X) between intermediate housing (1) and solenoid bracket (2).

2. If distance (X) is not correct, loosen bolts (3) and move the solenoid until distance (X) is correct. Bracket (2) has elongated holes.

3. Tighten bolts (3) after the adjustment is correct to a torque of 7 to 10 N•m (5 to 7 lb ft).

### Armature End Plate Adjustment

The armature end plate adjustment is made during assembly of the starter motor.




Starter Motor End Cover
(1) Plug. (2) Spacer. (X) Distance between armature and face of end cover. (Y) Length of plug threads.

1. Remove center plug (1) and spacer (2) from the end cover.

2. Force the armature assembly into the drive housing up against the spacer.

3. Measure distance (X) from the end cover to the armature assembly.

4. Measure length of threads (Y) of plug (1).

5. Subtract measurement (Y) from measurement (X). This difference is the armature end play. The allowable end play is 0.1 to 0.3 mm (.004 to .012 in). The end play can be adjusted with different spacers (2). The thickness of each is as follows:
   1.5 mm (.059 in)
   1.7 mm (.067 in)
   1.9 mm (.075 in)
   2.1 mm (.083 in)
   2.3 mm (.090 in)
   2.5 mm (.100 in)

6. Install correct spacer (2). Put 9S3263 Thread Lock on threads of plug (1) and install it into the end cover.

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