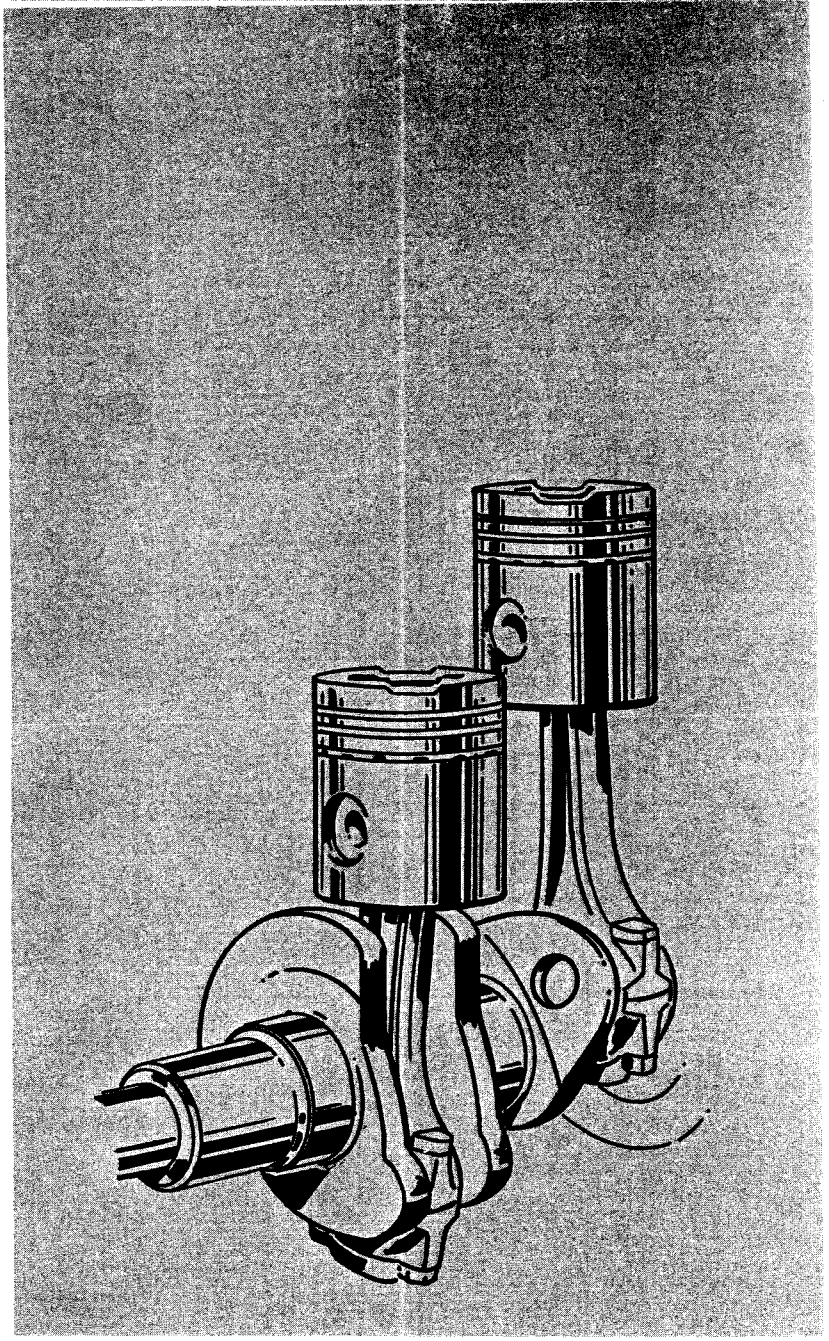


FORM NO. REG01349-01

FOR USE IN SERVICE MANUALS:
D4 TRACTOR, REG00632
D4 TRACTOR, SPECIAL APPLICATION, REG00784
D5 TRACTOR, REG00633
D5 TRACTOR, SPECIAL APPLICATION, REG00785
D6 TRACTOR, REG00530
D6 TRACTOR, SPECIAL APPLICATION, REG00871
D7 TRACTOR, REG00691
D7G TRACTOR, SENR7112
12G MOTOR GRADER, REG01544
NO. 12–NO. 14 MOTOR GRADER, REG00507
NO. 14G MOTOR GRADER, REG01542
NO. 112F MOTOR GRADER, REG00885
120G MOTOR GRADER, REG01654
NO. 120–NO. 140 MOTOR GRADERS, REG00762
130G–140G MOTOR GRADERS, REG01652
225 EXCAVATOR, REG01578
235 EXCAVATOR, REG01388
518 SKIDDER, REG00971
528 SKIDDER, REG01133
561 PIPELAYER, REG00913
571–572 PIPELAYERS, REG00699
571G–572G PIPELAYERS, SENR7120
627 TRACTOR-SCRAPER, REG00496
627 TRACTOR-SCRAPER, REG01609
637 TRACTOR-SCRAPER, REG00700
814 TRACTOR, 815-816 COMPACTORS, REG00786
920–930 WHEEL LOADERS, REG00514
941 TRAXCAVATOR, REG00527
950 WHEEL LOADER, REG00548
951 TRAXCAVATOR, REG00783
955 TRAXCAVATOR, REG00634
966 WHEEL LOADER, REG00484
977 TRAXCAVATOR, REG00635
980 WHEEL LOADER, REG00698

SERVICE MANUAL

3304 & 3306 VEHICLE ENGINES

SERIAL NUMBERS
3304: 78P
3306: 3N

NOTICE
This book also includes information for all 4.75" bore, four and six cylinder vehicle engines with vehicle serial numbers. This book supersedes Forms REG00502-05 and REG00511-03.

INTRODUCTION

This publication has instructions and procedures for the subject on the front cover. The information, specifications, and illustrations in this publication are on the basis of information that was current at the time this issue was written.

Correct operation, maintenance, test and repair procedures will give this product a long service life. Before starting a test, repair or rebuild job, the serviceman must read the respective sections of the Service Manual, and know all the components he will work on.

Your safety, and the safety of others, is at all times very important. When you see this symbol  or this symbol  in the manual, you must know that caution is needed for the procedure next to it. The symbols are warnings. To work safely, you must understand the job you do. Read all instructions to know what is safe and what is not safe.

It is very important to know the weight of parts. Do not lift heavy parts by hand. Use a hoist. Make sure heavy parts have a good stability on the ground. A sudden fall can cause an accident. When lifting part of a machine, make sure the machine has blocks at front and rear. Never let the machine hang on a hoist, put blocks or stands under the weight.

When using a hoist, follow the recommendation in the manual. Use correct lift tools as shown in illustrations to get the correct balance of the component you lift. This makes your work safer at all times.

40400X3

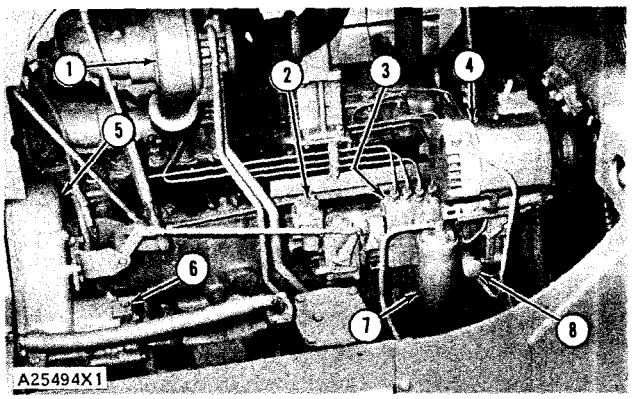
SPECIFICATIONS

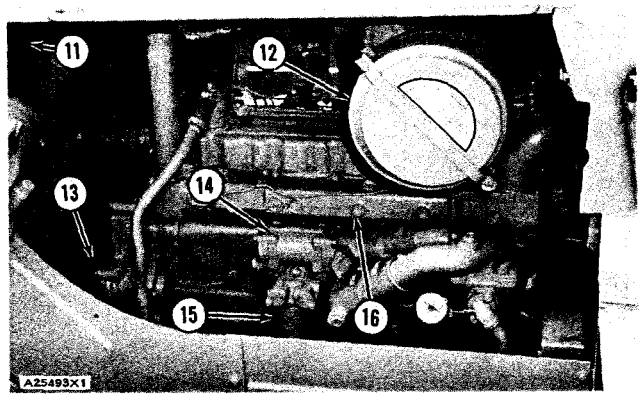
NOTE: For Specifications with illustrations, make reference to ENGINE SPECIFICATIONS for 3304 & 3306 VEHICLE ENGINES, Form No. REG01350. If the Specifications in Form REG01350 are not the same as in the Systems Operation and the Testing and Adjusting, look at the printing date on the back cover of each book. Use the Specifications given in the book with the latest date.

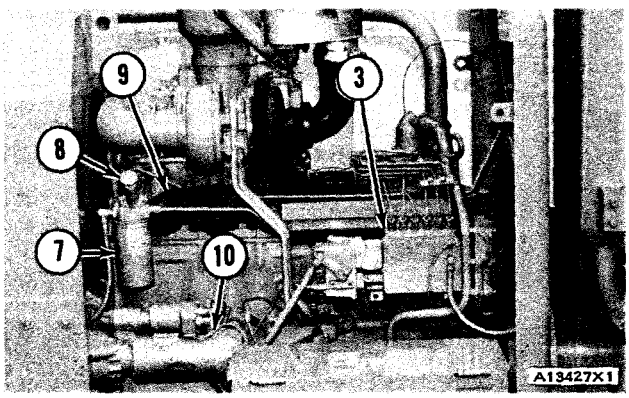
SYSTEMS OPERATION

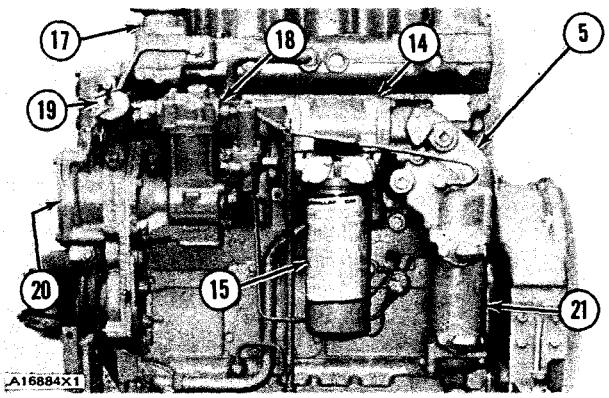
TESTING AND ADJUSTING

GENERAL INFORMATION









TYPICAL ENGINE ARRANGEMENTS

1. Turbocharger. 2. Fuel ratio control. 3. Fuel injection pump. 4. Alternator. 5. Flywheel housing. 6. Hydraulic pump. 7. Fuel filter. 8. Fuel priming pump. 9. Exhaust manifold. 10. Starting motor. 11. Fan. 12. Air cleaner. 13. Damper. 14. Engine oil cooler. 15. Engine oil filter. 16. Intake manifold. 17. Regulator housing. 18. Air compressor. 19. Oil filter. 20. Water pump. 21. Auxiliary oil cooler.

The 3304 and 3306 Vehicular Engines are part of a series of 4.75 in. (120.650 mm) bore, 6.00 in. (152.400 mm) stroke in-line engines. This book has the information for all the vehicular engines.

The 3304 Engine has four cylinders with a 425 cu.in. (7.0 litre) displacement. The firing order is 1, 3, 4, 2. The engine weight is approximately 1600 lb. (738 kg) without coolant or oil.

The 3306 Engine has six cylinders with a 638 cu.in. (10.5 litre) displacement. The firing order is 1, 5, 3, 6, 2, 4. The engine weight is approximately 1940 lb. (880 kg) without coolant or oil.

SLEEVE METERING FUEL SYSTEM

INTRODUCTION

The Sleeve Metering Fuel System is a pressure type fuel system. The name for the system is from the method used to control the amount of fuel in the fuel injection charge. This system has an injection pump and an injection valve for each cylinder. The injection pumps are in the fuel injection pump housing on the right side of the engine. The injection valves are in the precombustion chambers in the cylinder head.

FUEL SYSTEM TIMING

The timing of the 3304 Engine is 12° 30' before TC (top center).

The timing of the 3306 Engine is 13° 30' before TC (top center).

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.

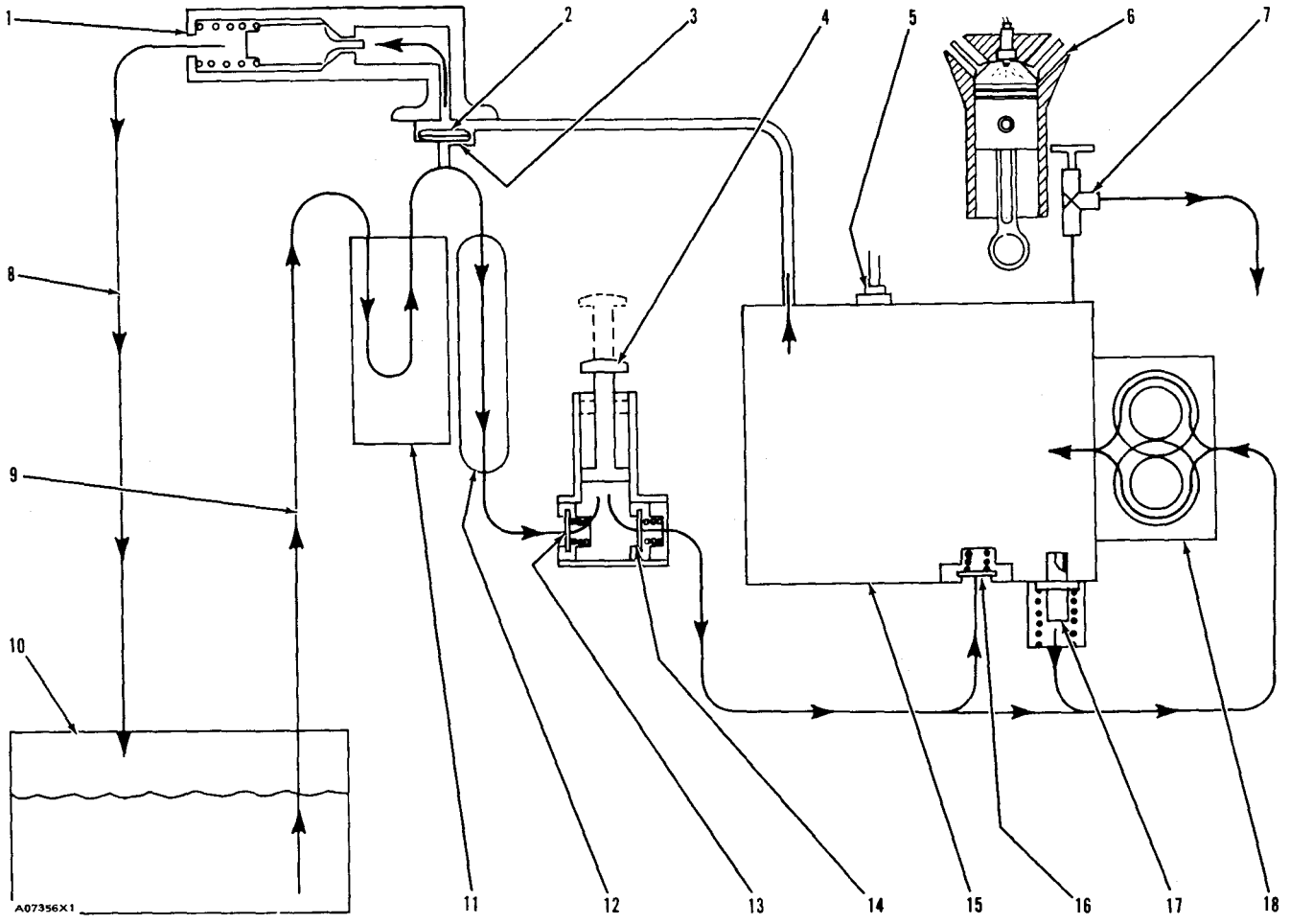
The water separator can remove 95% of the water in a fuel flow of up to 33 gph (125 l/hr) if the concentration of the water in the fuel is 10% or less. It is important to check the water level in the water separator frequently. The maximum amount of water which the water separator can hold is.0.8 pt. (0.4 l). At this point the water fills the glass to 3/4 full. Do not let the water separator have this much water before draining the water. After the water level is at 3/4 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 1/2 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 the valve in the drain line and the valve at the top of the water separator. Let the water drain until it is all out of the water separator. Close both valves.

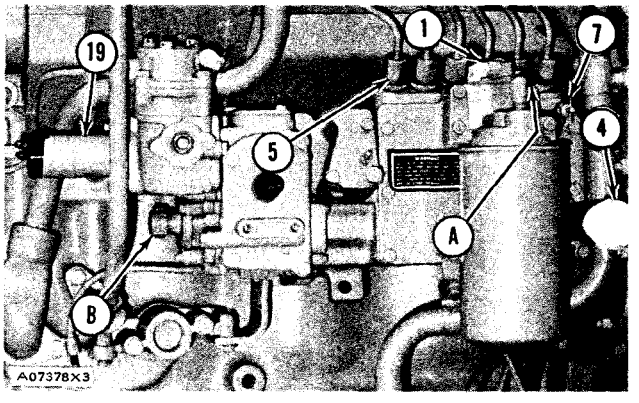
FUEL FLOW WITH ENGINE RUNNING

System With Siphon Break



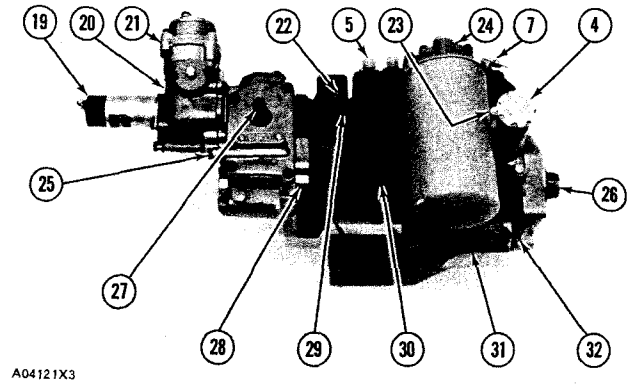
SCHEMATIC OF FUEL SYSTEM

1. Constant bleed valve. 2. Disc. 3. Siphon break orifice. 4. Priming pump. 5. Fuel injection pump. 6. Fuel injection valve. 7. Bleed valve. 8. Fuel return line. 9. Fuel supply line. 10. Fuel tank. 11. Fuel filter. 12. Channel. 13. Check valve. 14. Check valve. 15. Housing for the fuel injection pumps. 16. Check valve. 17. Bypass valve. 18. Transfer pump.



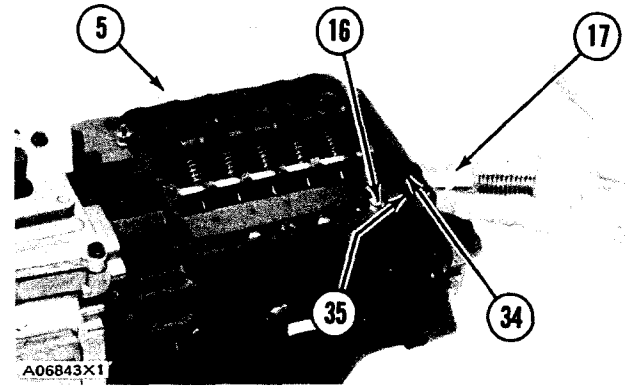
FUEL SYSTEM INSTALLED
(Typical Illustration)

1. Constant bleed valve. 4. Priming pump. 5. Fuel injection pump. 7. Bleed valve. 19. Shutoff solenoid. A. Connection for fuel supply line (9). B. Location for tachometer drive.



SLEEVE METERING FUEL INJECTION PUMP

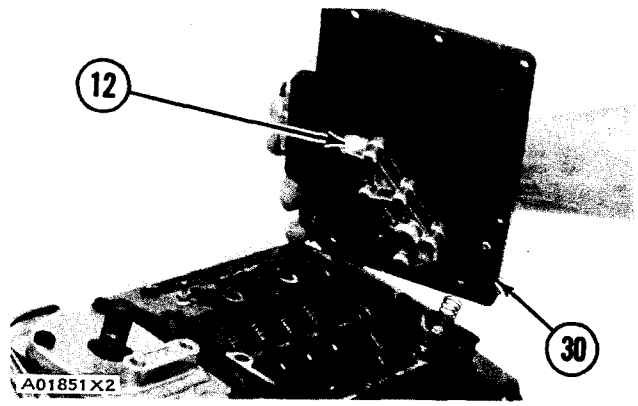
4. Priming pump. 5. Fuel injection pump. 7. Bleed valve. 19. Shutoff solenoid. 20. Shutoff housing. 21. Fuel ratio control. 22. Brass screw terminal. 23. Position for measurement of fuel pressure in housing. 24. Filter base. 25. Timing pin in storage position. 26. Drive sleeve. 27. Governor control shaft. 28. Cover for high idle stop and low idle stop. 29. Position for using timing pin. 30. Cover for housing. 31. 2P8315 Bracket Assembly. 32. Transfer pump drain.



SLEEVE METERING FUEL PUMP

5. Fuel injection pump. 16. Check valve. 17. Bypass valve. 34. Passage (to transfer pump inlet). 35. Passage to check valve.

When the engine is running, the transfer pump (18) pulls fuel from the tank (10), through the filter (11), and into channel (12) behind cover (30). From the channel, the fuel goes through check valve (13) into the bottom of the priming pump (4), through the priming pump, out check valve (14) and into passage (34) in the housing. The fuel in the passage is the supply for the transfer pump (18). The output of the transfer pump goes into the housing (15).



SLEEVE METERING FUEL PUMP

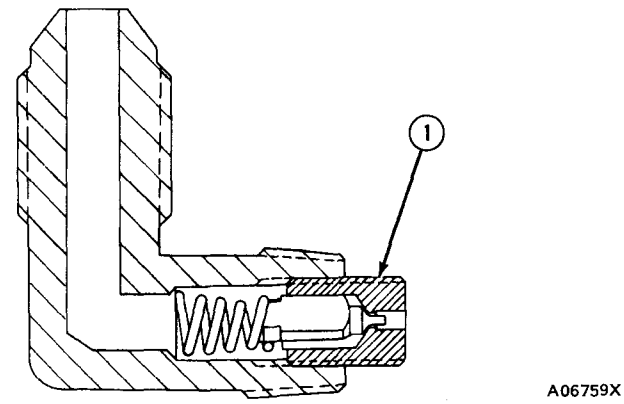
12. Channel. 30. Cover.

The fuel in the housing is the supply for the injection pumps and the lubricant for all the moving parts in the housing. Fuel can go from the housing in three ways.

1. The injection pumps (5) send some fuel to the cylinders during injection.

2. The constant bleed valve (1) lets approximately 9 gal./hr. (34.06 l/hr) of fuel go back to the fuel tank, through return line (8) when the pressure in the housing is 25 to 32 psi (1.8 to 2.3 kg/cm^2). This flow takes air and heat away from the housing.

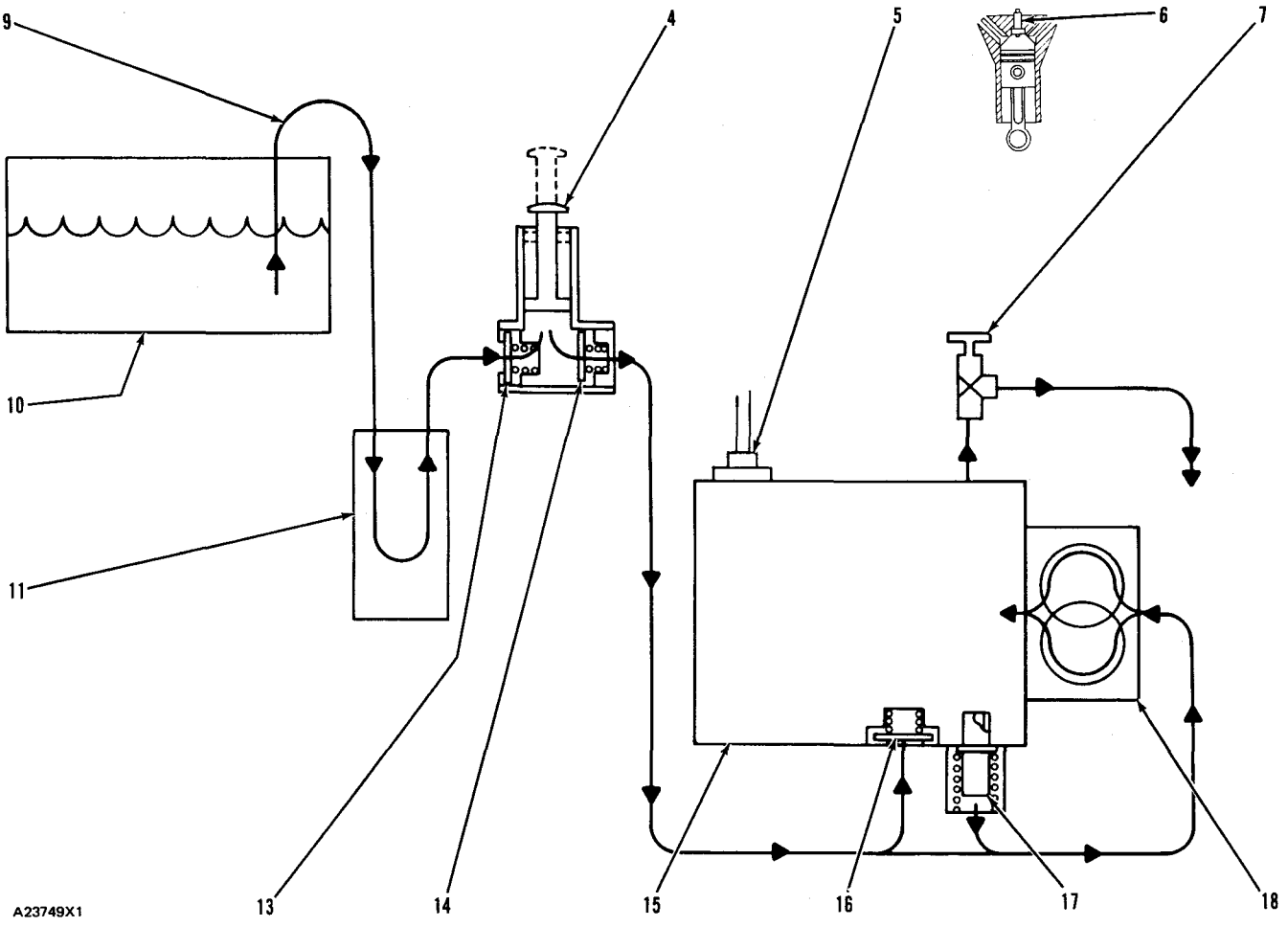
3. The fuel bypass valve (17) keeps the pressure of the fuel in the housing at 25 to 32 psi (1.8 to 2.3 kg/cm^2) at 2200 rpm. Fuel which goes through the bypass valve mixes with the fuel flow from the tank in passage (34). From here the mixture of fuel goes through the transfer pump and back into the housing.



CONSTANT BLEED VALVE

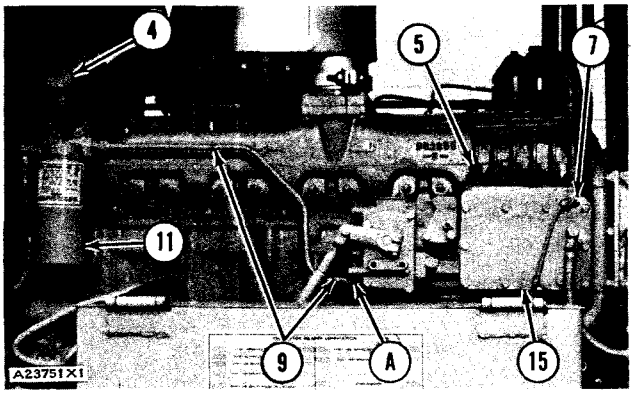
1. Constant bleed valve (in fitting).

System Without Siphon Break



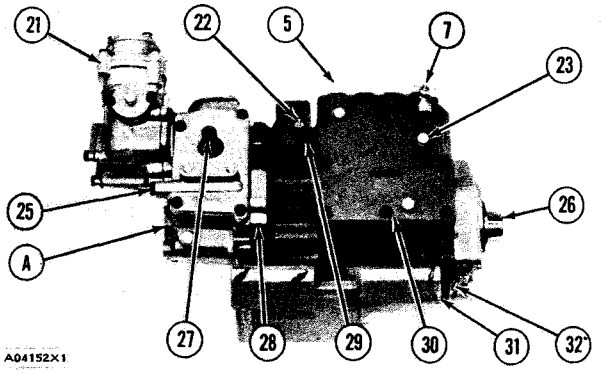
SCHEMATIC OF FUEL SYSTEM

4. Priming pump. 5. Fuel injection pump. 6. Fuel injection valve. 7. Bleed valve. 9. Fuel supply line. 10. Fuel tank. 11. Fuel filter. 13. Check valve. 14. Check valve. 15. Housing for the fuel injection pumps. 16. Check valve. 17. Bypass valve. 18. Transfer pump.



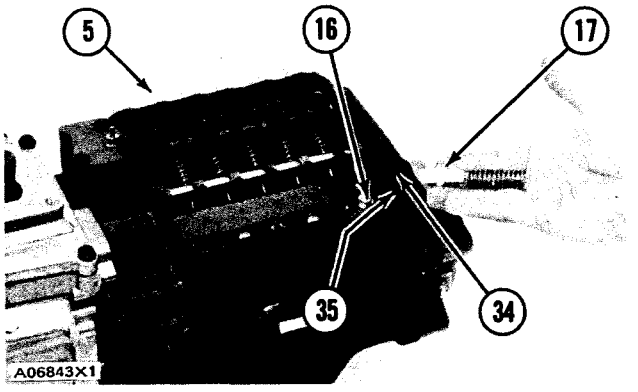
FUEL SYSTEM INSTALLED
(Typical Illustration)

4. Priming pump. 5. Fuel injection pump. 7. Bleed valve. 9. Fuel supply line. 11. Fuel filter. 15. Housing for the fuel injection pumps. A. Connection for fuel supply line (9).



SLEEVE METERING FUEL INJECTION PUMP

5. Fuel injection pump. 7. Bleed valve. 21. Fuel ratio control. 22. Brass screw terminal. 23. Position for measurement of fuel pressure in housing. 25. Timing pin in storage position. 26. Drive sleeve. 27. Governor control shaft. 28. Cover for high idle stop and low idle stop. 29. Position for using timing pin. 30. Cover for housing. 31. 2P8315 Bracket Assembly. 32. Transfer pump drain. A. Connection for fuel supply line (9).



SLEEVE METERING FUEL PUMP

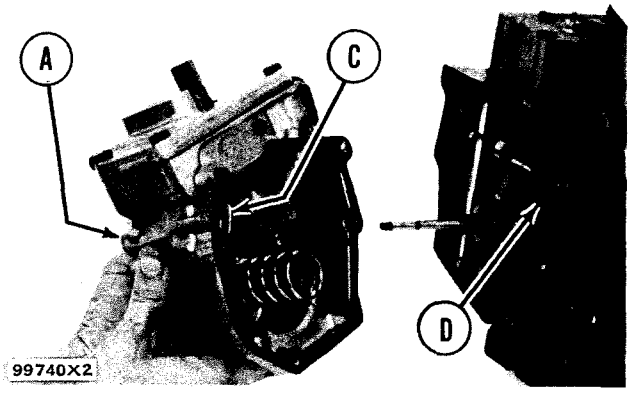
5. Fuel injection pump. 16. Check valve. 17. Bypass valve. 34. Passage (to transfer pump inlet). 35. Passage to check valve.

When the engine is running, the transfer pump (18) pulls fuel from the tank (10) through the filter (11). From the filter (11), the fuel goes through check valve (13) into the bottom of the priming pump (4), through the priming pump, out check valve (14) and through fuel supply line (9) to connection (A) on the governor housing. The fuel then goes through passages (C and D) inside the governor housing and the housing for the fuel injection pumps (15) to passage (34) in the housing. The fuel in the passage (34) is the supply for the transfer pump (18). The output of the transfer pump goes into the housing (15).

The fuel in the housing is the supply for the injection pumps and the lubricant for all the moving parts in the housing. Fuel can go from the housing in two ways.

1. The injection pumps (5) send some fuel to the cylinders during injection.

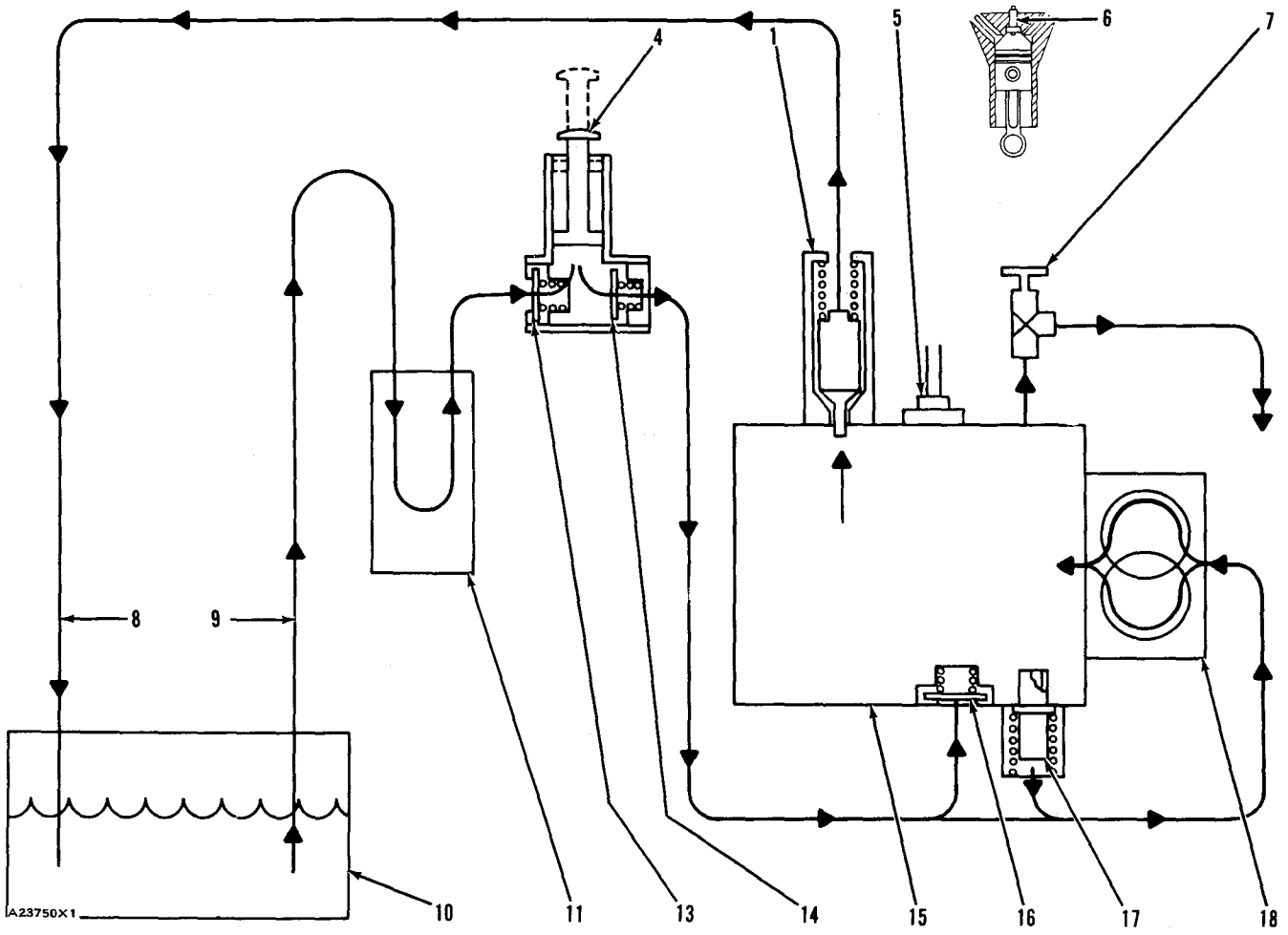
2. The fuel bypass valve (17) keeps the pressure of the fuel in the housing at 25 to 32 psi (1.8 to 2.3 kg/cm^2) at 2200 rpm. Fuel which goes through the bypass valve mixes with the fuel flow from the tank in passage (34). From here the mixture of fuel goes through the transfer pump and back into the housing.



FUEL FLOW THROUGH HOUSINGS

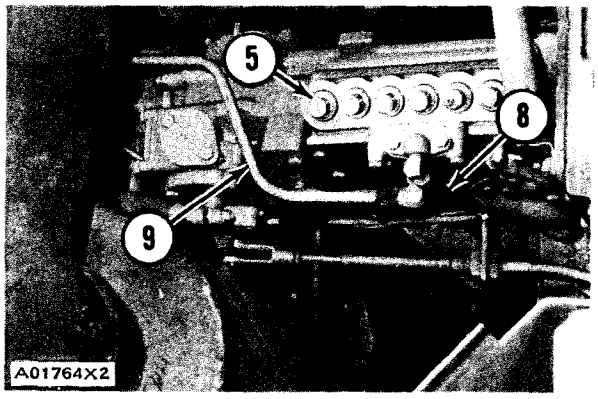
A. Connection for fuel supply line (9). C. Passage. D. Passage.

System With Return Line



SCHEMATIC OF FUEL SYSTEM

1. Constant bleed valve. 4. Priming pump. 5. Fuel injection pump. 6. Fuel injection valve. 7. Bleed valve. 8. Fuel return line. 9. Fuel supply line. 10. Fuel tank. 11. Fuel filter. 13. Check valve. 14. Check valve. 15. Housing for the fuel injection pumps. 16. Check valve. 17. Bypass valve. 18. Transfer pump.

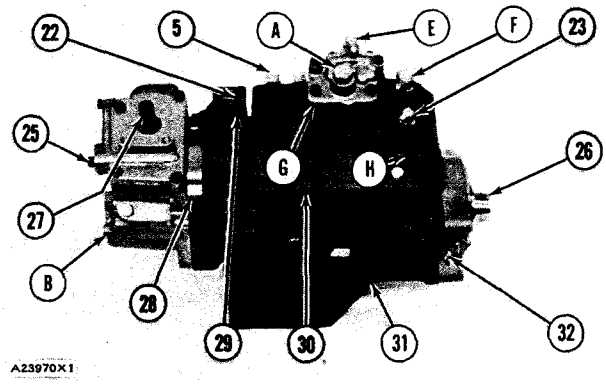


FUEL SYSTEM INSTALLED
(Typical Illustration)

5. Fuel injection pump. 8. Fuel return line. 9. Fuel supply line.

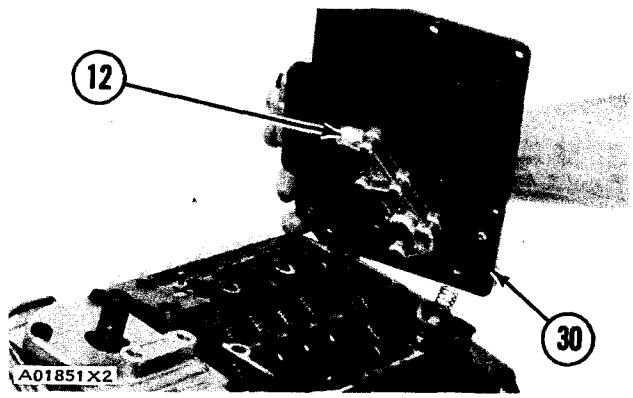
When the engine is running, the transfer pump (18) pulls fuel from the tank (10), through the filter (11), and into check valve (13), into the bottom of the priming pump (4), through the priming pump (4), out check valve (14) and into fuel line (9). Fuel line (9) goes into connection (A) on the cover (30) or connection (A) on the governor housing. If the fuel goes into connection (A) on the cover (30), it goes into channel (12) behind cover (30). From the channel, the fuel goes through a hole in cover (30) into cover (H), and back through another hole in cover (30) into passage (34).

If the fuel goes into connection (A) on the governor housing, it goes through the connecting passages (C & D) inside the governor housing and the housing for the fuel injection pumps (15) to passage (34).



SLEEVE METERING FUEL INJECTION PUMP
(Typical Illustration)

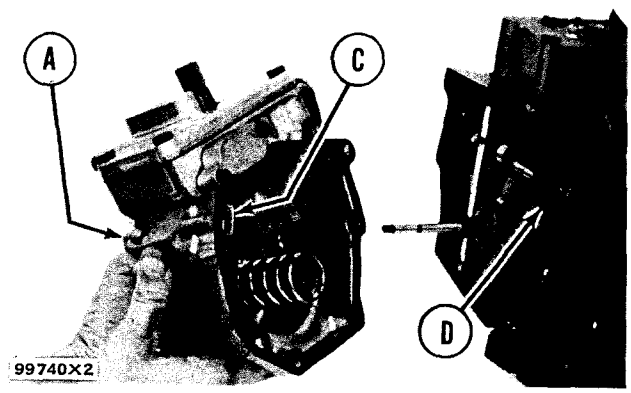
5. Fuel injection pump. 22. Brass screw terminal. 23. Position for measurement of fuel pressure in housing. 25. Timing pin in storage position. 26. Drive sleeve. 27. Governor control shaft. 28. Cover for high idle stop and low idle stop. 29. Position for using timing pin. 30. Cover for housing. 31. 2P8315 Bracket Assembly. 32. Transfer pump drain. A. Connection for fuel supply line (9). E. Connection for fuel return line (8). F. Connection for line to bleed valve (7). G. Housing (on some vehicles). H. Cover.



SLEEVE METERING FUEL PUMP

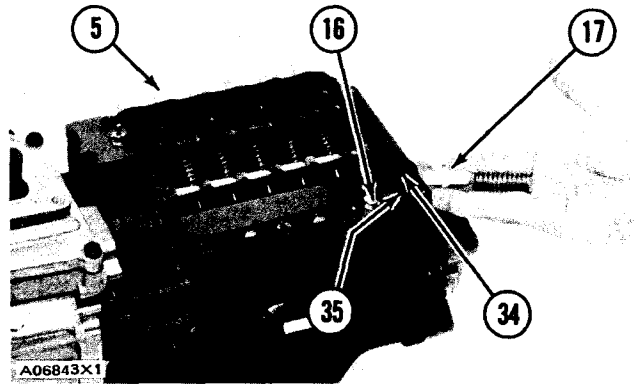
12. Channel. 30. Cover.

The fuel in the passage (34) is the supply for the transfer pump (18). The output of the transfer pump goes into the housing (15).



FUEL FLOW THROUGH HOUSINGS

A. Connection for fuel supply line (9). C. Passage. D. Passage.



SLEEVE METERING FUEL PUMP

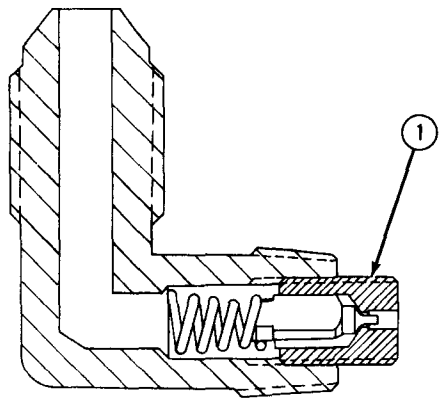
5. Fuel injection pump. 16. Check valve. 17. Bypass valve. 34. Passage (to transfer pump inlet). 35. Passage to check valve.

The fuel in the housing is the supply for the injection pumps and the lubricant for all the moving parts in the housing. Fuel can go from the housing in three ways.

1. The injection pumps (5) send some fuel to the cylinders during injection.

2. The constant bleed valve (1) lets approximately 9 gal./hr (34.06 l/hr) of fuel go back to the fuel tank, through return line (8) when the pressure in the housing is 25 to 32 psi (1.8 to 2.3 kg/cm^2). This flow takes air and heat away from the housing.

3. The fuel bypass valve (17) keeps the pressure of the fuel in the housing at 25 to 32 psi (1.8 to 2.3 kg/cm^2) at 2200 rpm. Fuel which goes through the bypass valve mixes with the fuel flow from the tank in passage (34). From here the mixture of fuel goes through the transfer pump and back into the housing.



CONSTANT BLEED VALVE

1. Constant bleed valve (in fitting).

FUEL FLOW USING THE PRIMING PUMP AND BLEED VALVE

System With Siphon Break

When the priming pump handle is pulled out, negative air pressure in the pump makes check valve (13) open and pulls fuel from the tank. Pushing the handle in closes valve (13) and opens valve (14). This pushes air and/or fuel into the housing through passage (35) and check valve (16). More operation of the priming pump will pull fuel from the tank until line (9), filter (11) and housing (15) are full of fuel. At this time the fuel flow from the bleed valve (7) will have no air bubbles.

System Without Siphon Break

When the priming pump handle is pulled out, negative air pressure in the pump makes check valve (13) open and pulls fuel from the tank. Pushing the handle in closes valve (13) and opens valve (14). This pushes air and/or fuel into the fuel supply line (9) to connection (A) on the governor housing. The fuel then goes through passages (C & D) inside the governor housing and the housing for the fuel injection pumps (15) to passage (35) and through check valve (16) into the housing for the fuel injection pumps (15). More operation of the priming pump will pull fuel from the tank until line (9), filter (11) and housing (15) are full of fuel. At this time the fuel flow from the bleed valve (7) will have no air bubbles.

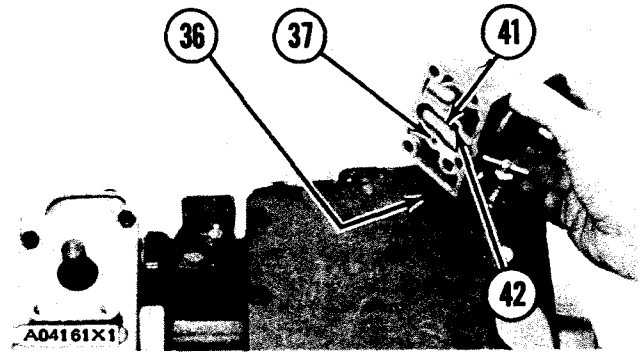
System With Return Line

When the priming pump handle is pulled out, negative air pressure in the pump makes check valve (13) open and pulls fuel from the tank. Pushing the handle in closes valve (13) and opens valve (14). This pushes air and/or fuel into the housing through passage (35) and check valve (16). More operation of the priming pump will pull fuel from the tank until line (9), filter (11) and housing (15) are full of fuel. At this time the fuel flow from the bleed valve (7) will have no air bubbles.

FUEL FLOW AFTER ENGINE STOPS RUNNING

(System With Siphon Break)

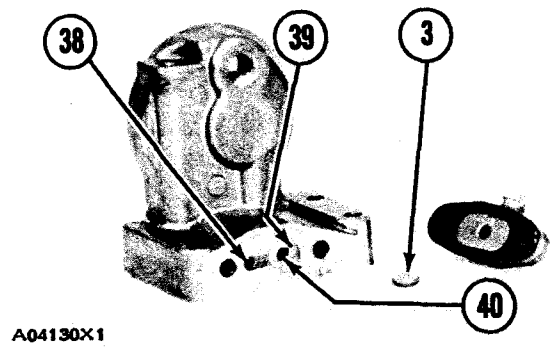
When the engine is running, the pressure in the housing holds some air in the fuel in a mixture. When the engine stops, the air comes out of the fuel and goes to the top of the housing. With no pressure in the housing, the constant bleed valve (1) closes. The air goes out of the housing through



SIPHON BREAK HOUSING

36. Hole. 37. Passage. 41. Passage. 42. Passage.

hole (36) in the cover and into passages (37) and (38) in the filter base. The air goes under disc (3) through scratch (39) and down through passages (40), (41), (42). Then the air goes through the top of the filter and follows the fuel back to the tank. The remainder of the fuel stays in the housing and filter.



SIPHON BREAK FUEL FILTER BASE

3. Disc. 38. Passage. 39. Scratch. 40. Passage.

When the engine starts the next time, the fuel in the housing and in the filter will be the supply for the engine until the transfer pump pulls the fuel from the tank.

System Without Siphon Break

The system is only used on vehicles which have the fuel tank above the fuel injection pump. When the engine stops running the fuel stays where it is in the housing for the fuel injection pumps (15).

System With Return Line

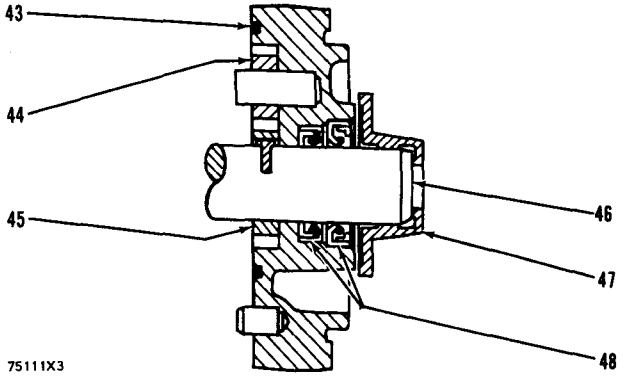
This system has a housing which works like the siphon break fuel filter base, if the fuel tank is above the fuel injection pump. The only difference

is the fuel filter (11) and priming pump (4) are not installed on the cover (30) of the fuel injection pump.

Make a reference to the story for System With Siphon Break.

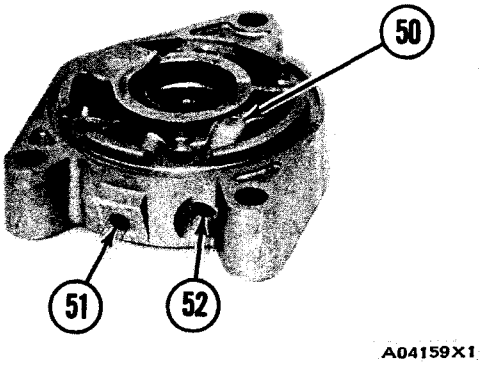
If the fuel tank is above the fuel injection pump, the constant bleed valve (1) is installed directly in the cover (30).

FUEL TRANSFER PUMP



FUEL TRANSFER PUMP

43. Seal. 44. Driven gear. 45. Drive gear. 46. Camshaft for the fuel injection pump. 47. Drive sleeve. 48. Lip-type seals.



FUEL TRANSFER PUMP BODY

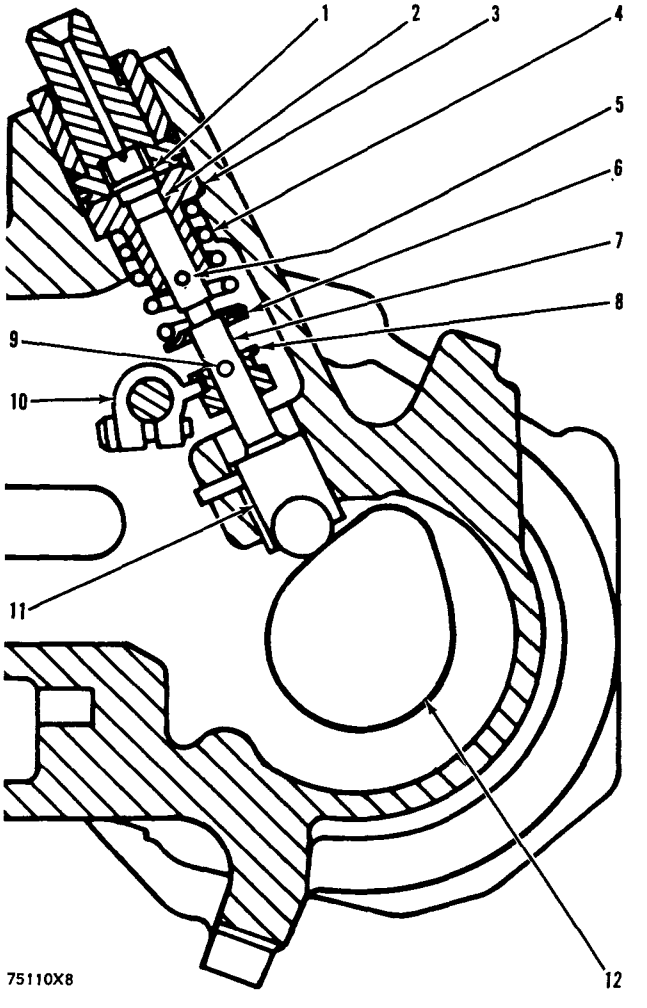
50. Outlet for lubrication oil to automatic timing advance unit. 51. Transfer pump drain. 52. Inlet for lubrication oil for automatic timing advance unit.

The fuel transfer pump (18) is on the front end of the housing for the fuel injection pumps. The output of the pump is more than the engine needs for combustion. The camshaft (46) for the fuel injection pump turns the drive gear (45) in the transfer pump. Two lip-seals (48) on the camshaft keep the fuel in the transfer pump apart from the engine oil in the compartment for the timing gears. The area between the two seals is connected to the transfer pump drain (51). The drain has two functions. One function is to be an outlet for fuel or lubrication oil leakage. The other function is to give a visual indication of seal or bearing failure before the failure can be a cause for any more failures.

FUEL PRIMING PUMP

The priming pump can be on the cover of the sleeve metering fuel system or at another place with the fuel filter. The purpose of the pump is to fill the fuel system with fuel. Operation of the pump with the bleed valve (7) open will remove air from the fuel injection pump housing.

FUEL INJECTION PUMP OPERATION

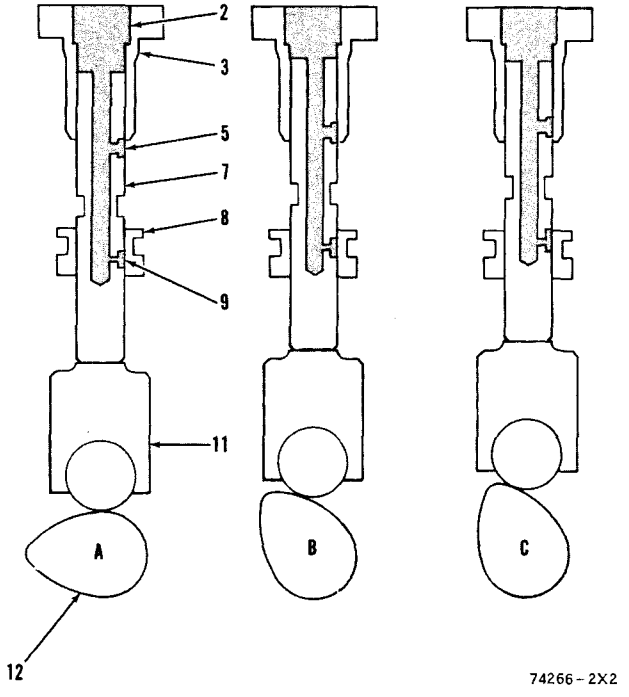


FUEL INJECTION PUMP OPERATION

1. Reverse flow check valve. 2. Chamber. 3. Barrel. 4. Spring. 5. Fuel inlet (fill port). 6. Retainer. 7. Plunger. 8. Sleeve. 9. Fuel outlet (spill port). 10. Sleeve control lever. 11. Lifter. 12. Camshaft.

The main components of a fuel injection pump in the sleeve metering fuel system are: plunger (7), barrel (3), and sleeve (8). The plunger moves up and down inside the barrel and sleeve. The barrel is stationary while the sleeve is moved up and down around the plunger to make a change in the amount of fuel for injection.

The plunger, barrel, and sleeve are a fitted set and they must be kept together. Lifter (11) and plunger (7) are lifted through a full stroke by each revolution of the camshaft (12). The force of spring (4) on plunger (7) through retainer (6) holds the lifter against the camshaft through the full stroke cycle.



FUEL INJECTION PUMP OPERATION

2. Chamber. 3. Barrel. 5. Fuel inlet (fill port). 7. Plunger. 8. Sleeve. 9. Fuel outlet (spill port). 11. Lifter. 12. Camshaft. A. Before injection. B. Start of injection. C. End of injection.

Before Injection

Before the engine can start or run correctly, the housing and fuel injection lines must be full of fuel and the sleeve (8) must be high enough on the plunger to close the fuel outlet (9) (spill port) during part of the stroke cycle. Chamber (2) fills with fuel through the fuel inlet (5) (fill port) which is under the level of the fuel in the housing.

Injection

Injection starts after the rotation of the camshaft lifts plunger (7) far enough into barrel (3) to close fuel inlet (5). At this time, both the fuel inlet and fuel outlet are closed. As more rotation of the camshaft lifts the plunger farther into the chamber of the barrel, the fuel in the chamber is put under more and more pressure. This pressure is felt by reverse flow check valve (1) and the fuel injection valve. When the pressure is high enough to open the fuel injection valve, injection starts. Injection stops when the rotation of the camshaft has lifted the plunger far enough to open fuel outlet (9). This puts the fuel outlet above the top of sleeve (8).

When the fuel outlet opens, it lets pressure off of the fuel in the chamber. The pressure of the fuel in the line closes the reverse flow check valve (1). With no more flow of fuel, injection valve at the other end of the line closes. This makes the injection complete. The volume of fuel in the injection charge is equal to the volume of the plunger which is lifted into the barrel between the start of injection and the end of injection.

After Injection

After injection has stopped, the camshaft lifts the plunger the rest of the way to the top of the stroke. The plunger is pushed out of the chamber by spring (4). The fuel in the housing fills the space in the chamber through the fuel outlet (9) until the sleeve closes it on the down stroke. More rotation of the camshaft lets the spring push the plunger down farther which opens fuel inlet (5). Fuel fills the rest of the chamber through the fuel inlet (5). Then the stroke cycle starts again.

SLEEVE POSITION

The position of the sleeve on the plunger controls the amount of fuel for injection. When the position of the sleeve on the plunger is low enough that it does not cover the fuel outlet during any part of the stroke, the pump can not make pressure for injection. This is the "fuel off" position for the sleeve.

If the sleeve is in a higher position on the plunger, the pump can make pressure for injection. This is the "fuel on" position. As the sleeve position is made higher, more fuel is put into the injection charge.

ADJUSTMENTS TO THE SLEEVE METERING FUEL SYSTEM

Fuel Pump Calibration

For good engine performance, it is very important to make the setting of all of the injection pumps be the same. The procedure for this is called Fuel Pump Calibration. See the Testing and Adjusting section of this book.

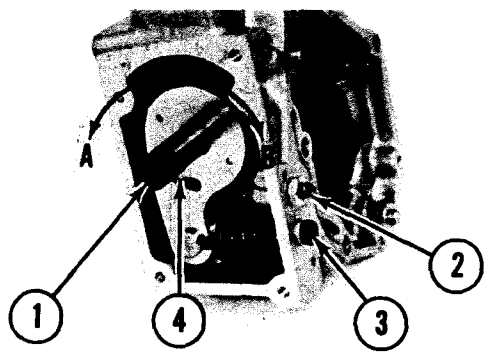
Fuel System Setting

The maximum injection charge is controlled by the Fuel System Setting. The correct procedure and tooling lists for adjustments to the fuel system are in the Testing and Adjusting section of this book. The correct measurement for the fuel system setting is in RACK SETTING INFORMATION and on the ENGINE INFORMATION plates on the side of the engine.

FUEL SYSTEM OPERATION

Engine Running

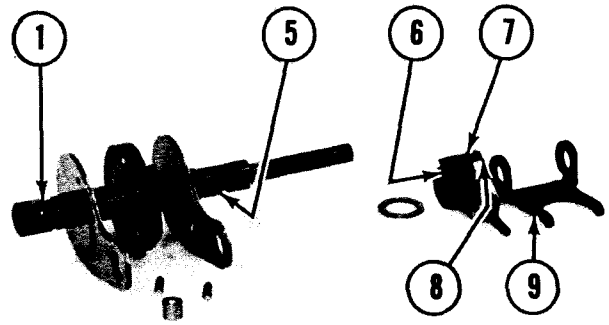
When the engine is running, any movement of the governor control shaft (1) makes a change in the speed of the engine. Counterclockwise movement (A) causes an increase in engine speed until the movement is held by the high idle stop (2). Clockwise movement (B) makes a decrease in engine speed until the movement is held by the low idle stop (3). More clockwise movement (B) moves the linkage beyond the detent (4) in the control. Still more clockwise movement (B) causes the pumps to stop injection and, because no fuel goes to the cylinders, the engine stops.



A00180X2

FUEL SYSTEM OPERATION

1. Governor control shaft. 2. High idle stop. 3. Low idle stop. 4. Detent. A. Counterclockwise movement. B. Clockwise movement.

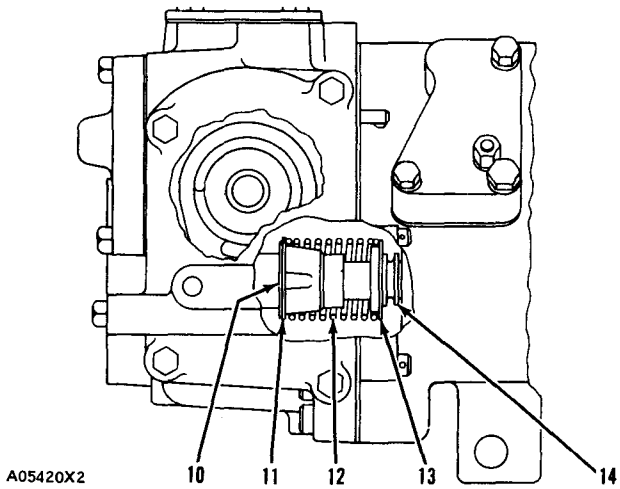


A00179X2

GOVERNOR CONTROL SHAFT

1. Governor control shaft. 5. Groove. 6. Tooth. 7. Lever. 8. Edge of lever (7). 9. Lever.

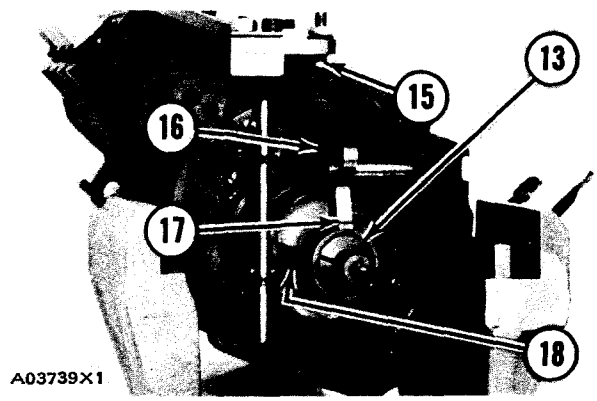
Governor control shaft (1) has a groove (5) which fits a tooth (6) in lever (7). Any movement of shaft (1) moves lever (7) in the same direction. If the shaft and lever have counterclockwise movement (A), an edge (8) of lever (7) comes into contact with lever (9).



A05420X2

FUEL SYSTEM OPERATION

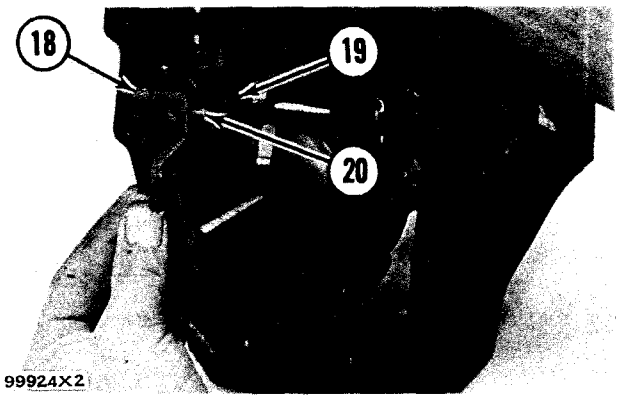
10. Seat. 11. Washer. 12. Governor spring. 13. Seat. 14. Riser.



A03739X1

FUEL SYSTEM OPERATION

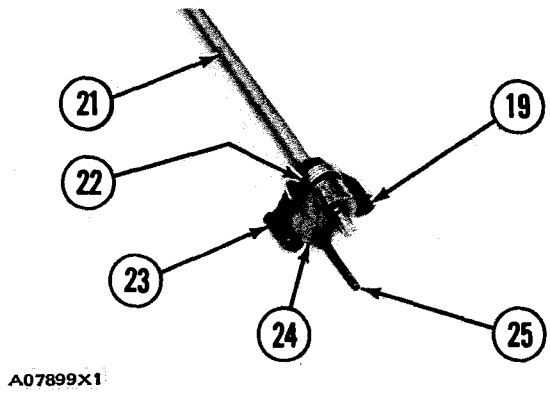
13. Seat. 15. Load stop. 16. Load stop pin. 17. Lever. 18. Lever.



FUEL SYSTEM OPERATION

18. Lever. 19. Hole. 20. Pin.

More counterclockwise movement (A) pushes lever (9) against seat (10), washer (11), governor spring (12), seat (13), and riser (14). The movement of seat (13) pushes against lever (17) which works like a bellcrank and pushes load stop pin (16) up. The load stop pin (16) can be pushed up until it is in contact with the load stop (15). This is the limit for the movement toward maximum fuel for injection. At the same time the lower end of lever (18) is in the groove in riser (14). As the riser moves, lever (18) works like a bellcrank and moves pin (20) which is in the top end of the lever. The outer end of pin (20) has the shape of a ball. It fits in a hole (19) in the bottom part of lever (23). The turning of lever (23) makes lever (24) turn the fuel control shaft (21) through spring (22). This makes an increase in the fuel for injection to the cylinder.

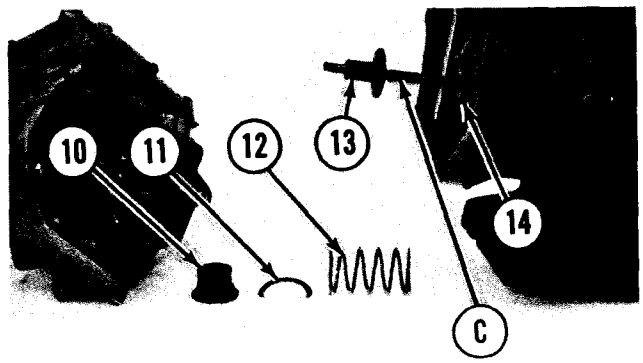


FUEL CONTROL SHAFT

19. Hole. 21. Fuel control shaft. 22. Spring. 23. Lever. 24. Lever. 25. Pin.

Starting the Engine

When starting the engine, the governor control shaft is in the middle position. The linkages in the housing work in almost the same manner as when the engine is running. The only difference is in the function of a spring (C) which is between seat (13) and riser (14). When the engine is running, the force from the weights in the governor is enough to cause compression of spring (C) until the seat (13) and riser (14) are in contact. For starting, the force of spring (C) is enough to push the riser to the full fuel position. This lets the engine have the maximum amount of fuel for injection for starting. The limit for the amount of fuel for injection is the position of the air-fuel ratio control.



FUEL SYSTEM OPERATION

10. Seat. 11. Washer. 12. Governor spring. 13. Seat. 14. Riser. C. Spring.

Before the speed of the engine is up to low idle speed, the governor weights make enough force to push spring (C) together and riser (14) and seat (13) come into contact. From this time on, the governor works to control engine speed.

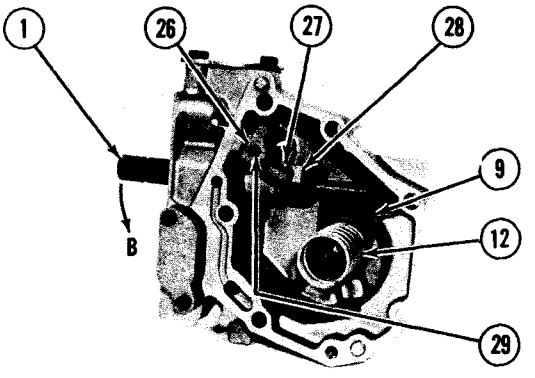
Stopping the Engine Manually

Maximum clockwise movement (B) of the governor control shaft stops the engine. If the governor control shaft (1) is not at the low idle position, clockwise movement (B) lets lever (9) move back away from the governor spring (12). Less compression in governor spring (12) lets riser (14) and seat (13) move away from the weight end of the shaft. The lower end of lever (18) is in the groove in riser (14). As the riser moves, lever (18) works like a bellcrank and moves pin (20) which is in the top end of the lever. The outer end of pin (20) has the shape of a ball. It fits in a hole (19) in the bottom part of lever (23). The turning of lever (18) makes lever (23) push against lever (24) which turns the fuel control shaft (21).

This makes a decrease in the amount of fuel for injection to the cylinder.

When the governor control shaft (1) is in the low

idle position, more clockwise movement (B) makes pin (27) in the end of lever (28) move against lever (26). Lever (26) works as a bellcrank. As it turns from the pressure of pin (27) the other end of the lever (21) moves against the pin (25) in lever (24). Lever (24) is tight on the fuel control shaft (21) and more movement in that direction causes the pumps to stop injection and, because no fuel goes to the cylinders, the engine stops.



A03729X1

FUEL SYSTEM OPERATION

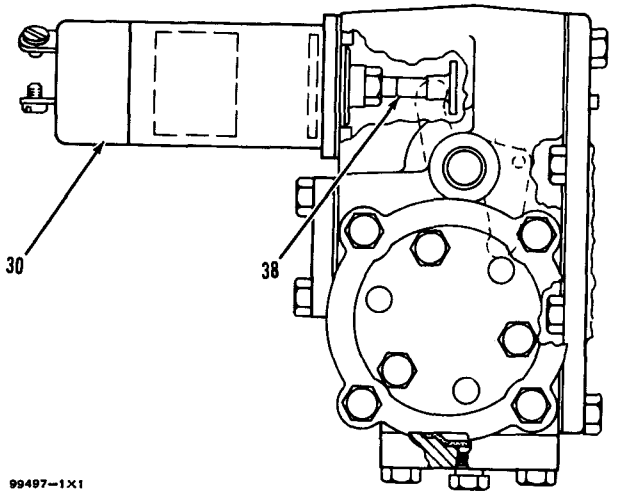
1. Governor control shaft. 9. Lever. 12. Governor spring. 26. Lever. 27. Pin. 28. Lever. 29. Shaft. B. Clockwise movement.

Pushing the operator governor control lever past the detent stops the engine on track type machines.

Pulling up on the foot pedal past the detent stops the engine on wheel type machines.

NOTE: The engine on the scraper part of scrapers has a contact switch which activates the shutoff solenoid.

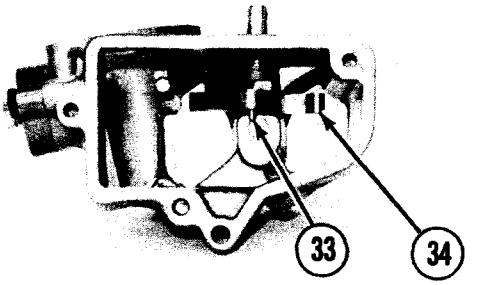
Stopping the Engine With Shutoff Solenoid



99497-1X1

SHUTOFF SOLENOID

30. Solenoid. 38. Shaft.

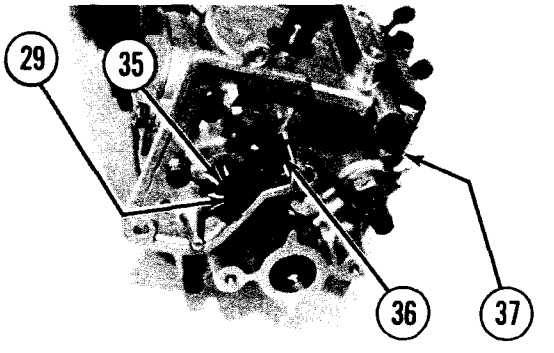


A04147X2

SHUTOFF HOUSING

33. Pin. 34. Lever.

The shutoff solenoid (30) can stop the engine without changing the position of the governor control. When the operator pushes the contact switch, electrical current goes into the windings of the solenoid (30). This current makes an electromagnetic force which pulls in the piston of the solenoid (30). The piston has a shaft (38) which pulls against one end of lever (34). Lever (34) has a pin (33) which comes in contact with edge (35) of lever (36) and pushes lever (36) in the direction shown.

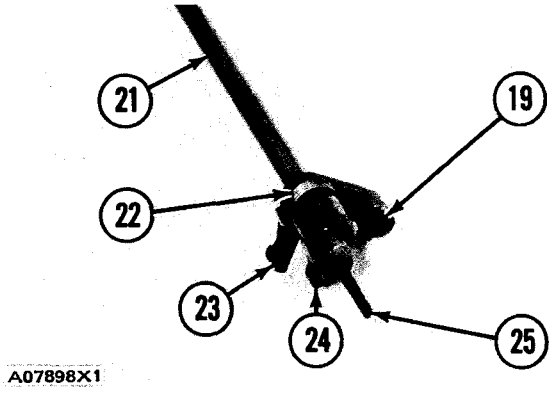


AO4318X7

FUEL SYSTEM OPERATION

29. Shaft. 35. Edge. 36. Lever. 37. Housing.

Lever (36) is tight on shaft (29) which is through housing (37). On the other end of shaft (29), lever (26) moves in the same direction. Lever (26) pushes against pin (25) in lever (24). Lever (24) is tight on the end of the fuel control shaft (21). The turning of lever (26) makes lever (24) turn the fuel control shaft (21) in the same direction. This stops the engine by putting the sleeves low on the plungers so there is no injection. This movement is independent of governor action because a spring (22) connects lever (23) and lever (24) on the fuel control shaft (21). Lever (24) can



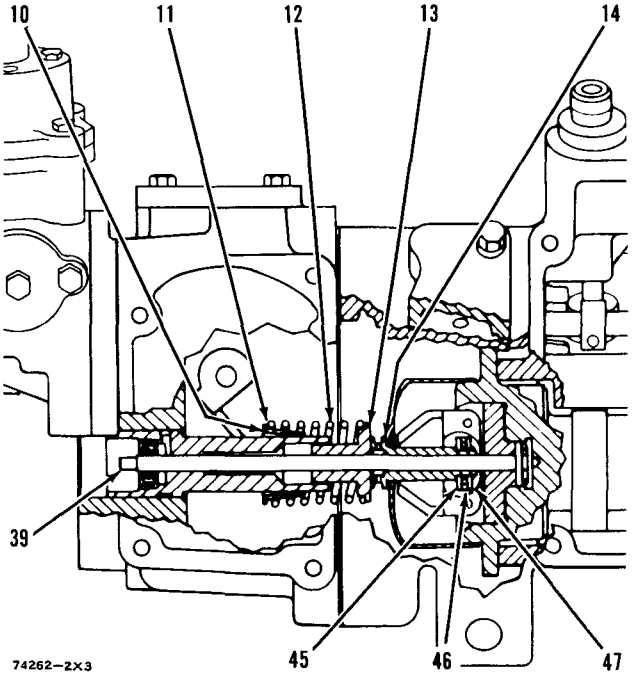
FUEL CONTROL SHAFT

19. Hole. 21. Fuel control shaft. 22. Spring. 23. Lever. 24. Lever. 25. Pin.

turn the fuel control shaft to the fuel off position by bending spring (22) without changing the position of the parts of the governor first.

GOVERNOR

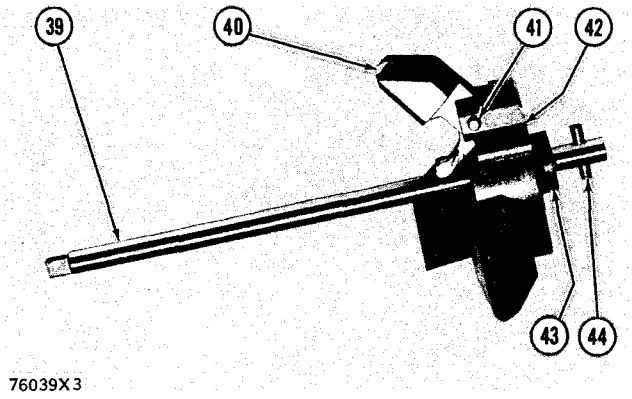
The governor for the Sleeve Metering Fuel System is of the mechanical type. It works to keep the speed of the engine from changing when there is an increase or decrease in load when the engine is running with governor control shaft stationary.



GOVERNOR

10. Seat. 11. Washer. 12. Governor spring. 13. Seat. 14. Riser. 39. Tachometer drive shaft. 45. Race. 46. Bearing. 47. Race.

The carrier (42) for weights (40) is held on one end of the camshaft by bolts. The tachometer drive shaft (39) is through the center of the governor parts. The shaft has a radial hole through the



GOVERNOR

39. Tachometer drive shaft. 40. Weight. 41. Pin. 42. Carrier. 43. Slot. 44. Pin.

driven end. A pin (44) is through this hole and fits into the slot (43) in the carrier on both sides of the shaft.

The weights (40) are connected to the carrier (42) by pins (41). The weights (40) and pins (41) work like bellcranks and pivots. When the camshaft and carrier (42) turn, the outer parts of the weights (40) move out from the center. The inner parts push against race (47), bearing (46), and race (45) (thrust bearing). The thrust bearing removes the turning movement but puts the thrust against the shoulder of riser (14). The riser (14) is against seat (13) which is against governor spring (12).

Governor spring (12) and washer (11) are in compression between seat (10) and seat (13). Seat (10) is held in position by lever (9) on the governor control shaft (1). There is a balance between the forces from the weights (39) and the governor spring (12) as long as the load on the engine does not change.

When there is a decrease in the load on the engine the engine starts to make an increase in speed. The weights in the governor turn faster causing the outer parts of the weights to move out farther. This puts more force against the thrust bearing. The thrust bearing pushes riser (14) which puts more compression on governor spring (12). At the same time the lower end of lever (18) is in the groove in riser (14).

The movement of riser (14) moves lever (18) to make a decrease in the amount of fuel for injection. With less fuel, the engine has a decrease in speed. The governor has this action again and again until the governor is in balance. When the governor is in balance the engine speed will be the same as it was before there was a decrease in load.

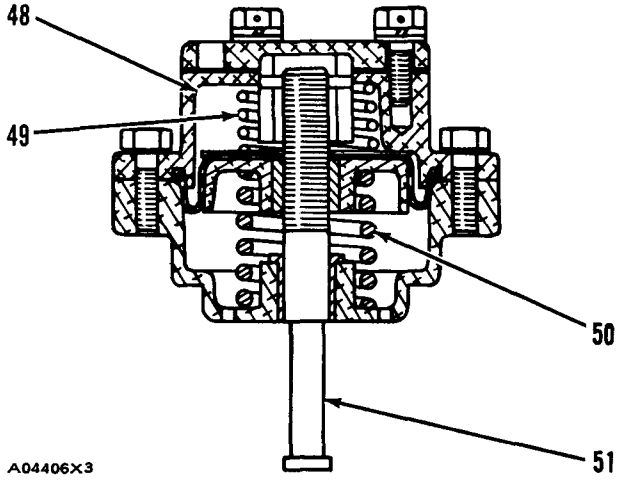
If there is an increase in the load on the engine, the engine starts to make a decrease in speed. The

weights in the governor turn slower. The thrust from the weights against the riser will be less, so the spring pushes the riser to the right.

The movement of the riser (14) makes lever (18) move the fuel control shaft (21) to make an increase in the amount of fuel for injection. With more fuel, the engine runs faster. The governor has this action again and again until the governor is in balance. When the governor is in balance the engine speed is the same as it was before the engine had an increase in load.

FUEL RATIO CONTROL

The fuel ratio control will limit the amount of fuel for injection during an increase in engine speed (acceleration). The purpose is to keep the amount of smoke in the exhaust gas at a minimum.



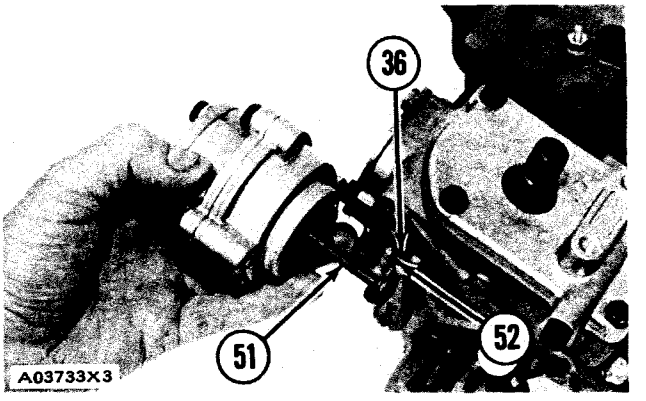
FUEL RATIO CONTROL

48. Chamber. 49. Spring. 50. Spring. 51. Bolt.

When the engine is running, air pressure from the inlet manifold is in the chamber (48) of the control. The combination of the force from the air pressure and spring (49) makes a balance with spring (50). The balance controls the position of bolt (51). When the governor control is moved to make an increase in engine speed, the linkage moves to turn the fuel control shaft (21) to put more fuel into each injection.

Lever (18) puts turning force on the fuel control shaft (21) through spring (22) and lever (23). Lever (23) is connected through linkage to lever. Lever (36) is held by bolt (51) of the fuel ratio control through pin (52).

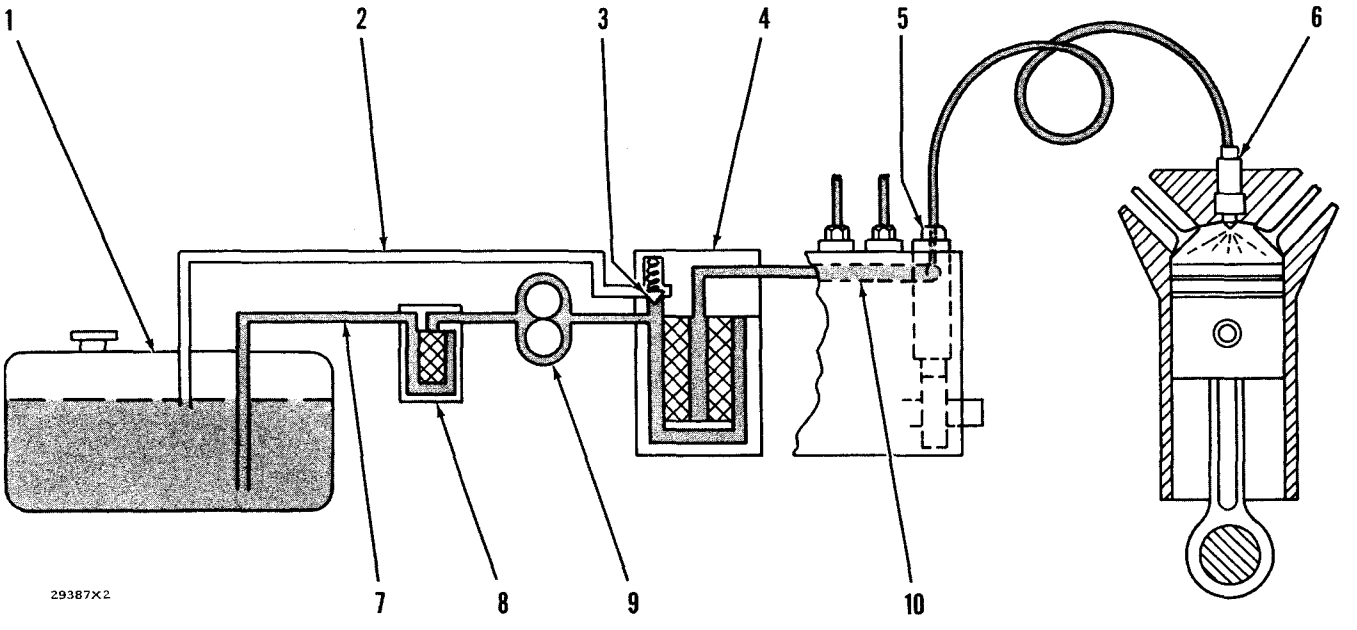
When the adjustment of the fuel ratio control is correct there will be enough increase in the fuel for injection to make the engine accelerate rapidly. If the adjustment is correct, there will not be too much smoke in the exhaust when the engine accelerates.



FUEL RATIO CONTROL

36. Lever. 51. Bolt. 52. Pin.

SCROLL FUEL SYSTEM



SCROLL FUEL SYSTEM SCHEMATIC

1. Fuel tank. 2. Fuel return line to fuel tank. 3. Bypass valve. 4. Main fuel filter. 5. Fuel injection pump. 6. Precombustion chamber. 7. Fuel supply line. 8. Primary fuel filter. 9. Fuel transfer pump. 10. Fuel manifold in the fuel injection pump housing.

The fuel system is a pressure-type with a separate injection pump and injection valve for each cylinder. Fuel is injected into a precombustion chamber, not directly into the cylinder.

A transfer pump supplies fuel to the manifold from which the injection pumps get fuel. Before the fuel is delivered to the manifold, it is filtered first by a primary filter which removes dirt particles, and later by a final filter which removes more minute particles.

The transfer pump can supply more fuel than is required for injection, so a bypass valve is used to limit the maximum pressure within the supply system.

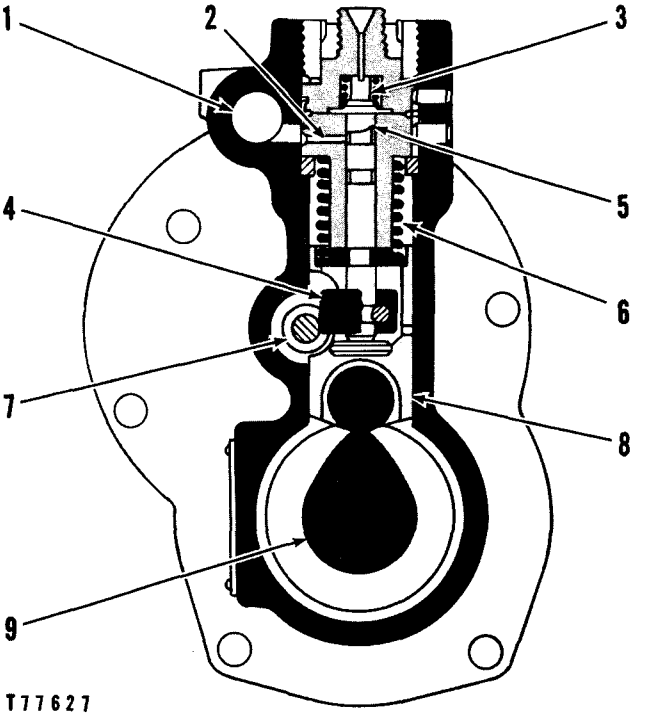
The injection pumps receive fuel from the manifold and forces it under high pressure to the injection valves. The injection valves spray atomized fuel into the precombustion chambers.

An air vent valve in the system permits removal of air. Air is removed by opening the valve and pressurizing the fuel system. The system can be pressurized by using the priming pump. The vent valve must be open until a stream of fuel, without air bubbles, flows from the vent line.

FUEL INJECTION PUMP OPERATION

The injection pump plungers and the lifters are lifted by lobes on the camshaft and always make a full stroke. The lifters are held against the cam lobes by spring force applied to the plungers.

The amount of fuel pumped each stroke is varied by turning the plunger in the barrel. Action of the governor moves the fuel rack which turns the pump gear segment on the bottom of the pump plunger.



FUEL INJECTION PUMP

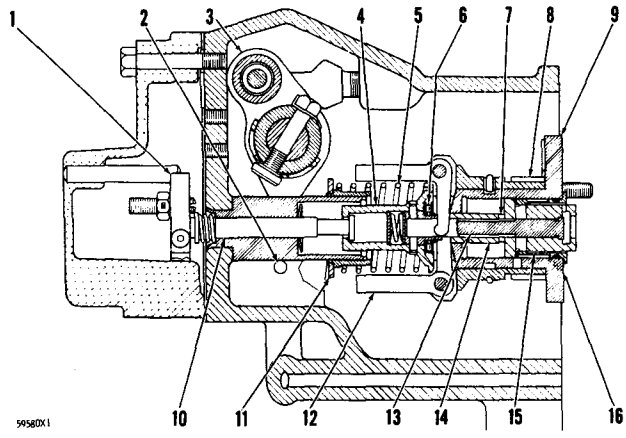
1. Fuel manifold. 2. Inlet port. 3. Check valve. 4. Gear segment. 5. Pump plunger. 6. Spring. 7. Fuel rack. 8. Lifter. 9. Camshaft.

GOVERNOR OPERATION

When the engine is operating, the balance between the centrifugal force of revolving weights (12) and the force of spring (5) controls the movement of valve (13). The valve directs pressure oil to either side of rack-positioning piston (14). Depending on the position of the valve (13), piston (14) will move the rack to increase or decrease fuel to the engine to compensate for load variation.

Pressurized lubrication oil, directed through passages in the fuel injection pump housing, enters passage (16) in the governor cylinder. The oil encircles sleeve (15) within the cylinder. Oil is then directed through a passage in piston (14) where it contacts valve (13).

When engine load increases, engine rpm decreases and revolving weights (12) slow down. The weights move toward each other and allow governor spring (5) to move valve (13) forward. As valve (13) moves, an oil passage around valve (13) opens to pressure oil. Oil then flows through passage (7) and fills the chamber behind piston (14). The pressure forces the piston and rack forward, increasing the amount of fuel to the engine. Engine rpm increases until the revolving weights rotate fast enough to balance the force of the governor spring.



HYDRAULIC GOVERNOR

1. Collar. 2. Speed limiter plunger. 3. Lever assembly. 4. Seat. 5. Governor spring. 6. Thrust bearing. 7. Oil passage. 8. Drive gear (weight assembly). 9. Cylinder. 10. Bolt. 11. Spring seat. 12. Weight. 13. Valve. 14. Piston. 15. Sleeve. 16. Oil passage. The governor valve is shown in the position when the force of the weights and the force of the spring are balanced.

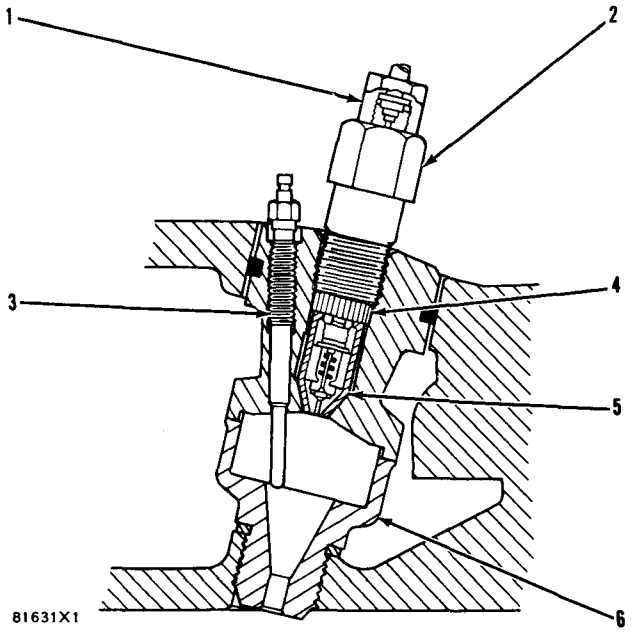
When engine load decreases, engine rpm increases, revolving weights (12) speed-up, and the toes on the weights move valve (13) rearward, allowing the oil behind piston (14) to flow through a drain passage opened at the rear of the piston. At the same time, the pressure oil between sleeve (15) and piston (14) forces the piston and rack rearward, decreasing the amount of fuel to the engine. Engine rpm decreases until the revolving weights balance the force of the governor spring.

When the engine is started, speed limiter plunger (2) restricts the movement of the governor control linkage. When operating oil pressure is reached, the plunger in the speed limiter retracts and the governor control can be moved to the HIGH IDLE position.

When the engine rpm is at LOW IDLE, a spring-loaded plunger within the lever assembly in the governor bears against the shoulder of the low idle adjusting screw. To stop the engine, the plunger must be forced past the shoulder on the adjusting screw.

Oil from the engine lubrication system lubricates the governor weight bearing. The various other parts are splash lubricated. The oil from the governor drains into the fuel injection pump housing.

FUEL INJECTION VALVE



CROSS SECTION OF THE PRECOMBUSTION CHAMBER AND FUEL INJECTION VALVE

1. Fuel injection line. 2. Nut. 3. Glow plug. 4. Body. 5. Nozzle assembly. 6. Precombustion chamber.

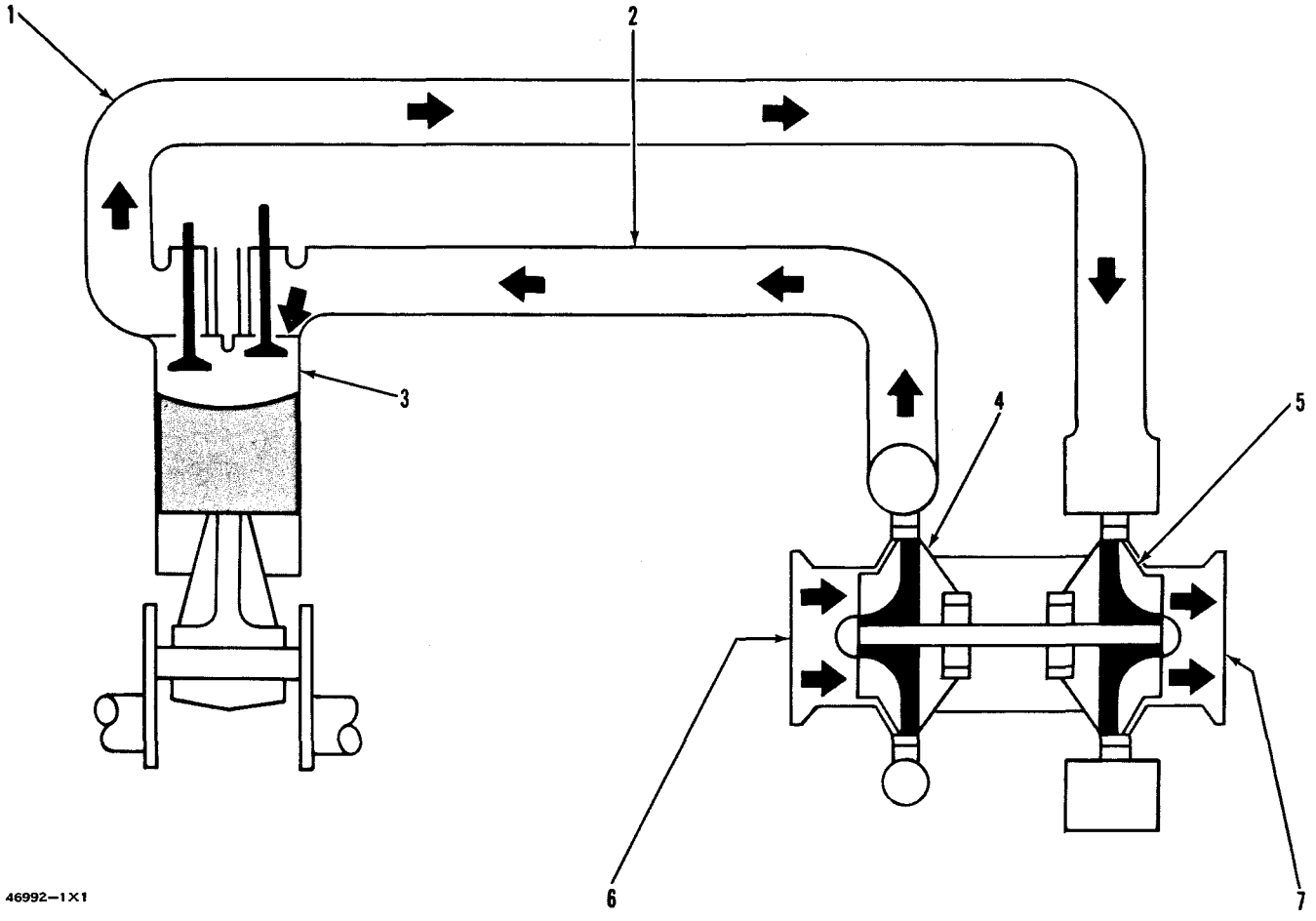
Fuel, under high pressure from the injection pumps, is sent through the fuel lines to the fuel injection valves. When the fuel under high pressure goes into the nozzle assembly, the check valve inside the nozzle opens and the fuel goes into the precombustion chamber. The injection valve changes the fuel to many very small drops of fuel. This gives the fuel the correct characteristics for good combustion.

GLOW PLUGS

Glow plugs are an aid for cold weather starting. During cold weather starting, the pressure in the cylinders made by the compression stroke is not enough to start combustion of the fuel injection charge. Activating the glow plugs for the correct length of time heats the precombustion chambers to the temperature which is necessary for combustion when the engine is turned for starting. After combustion starts and the starting motor is no longer necessary to keep the engine running, more operation of the glow plugs heats the precombustion chambers until the engine is running smoothly.

AIR INLET AND EXHAUST SYSTEM

ENGINES WITH TURBOCHARGERS

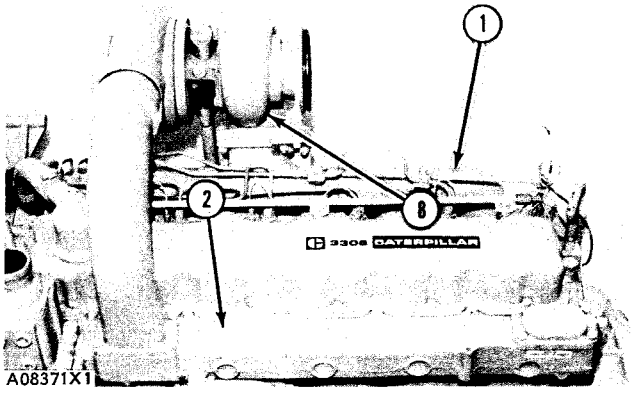


AIR INLET AND EXHAUST SYSTEM

1. Exhaust manifold. 2. Inlet manifold. 3. Engine cylinder. 4. Turbocharger compressor wheel. 5. Turbocharger turbine wheel. 6. Air inlet. 7. Exhaust outlet.

The air inlet and exhaust system components are: air cleaner, inlet manifold, cylinder head, valves and valve system components, exhaust manifold, and turbocharger.

Clean inlet air from the air cleaner is pulled through the air inlet (6) of the turbocharger by the turning compressor wheel (4). The compressor wheel causes a compression of the air. The air then goes to the inlet manifold (2) of the engine. When the intake valves open, the air goes into the engine cylinder (3) and is mixed with the fuel for combustion. When the exhaust valves open, the exhaust gases go out of the engine cylinder and into the exhaust manifold (1). From the exhaust manifold, the exhaust gases go through the blades of the turbine wheel (5). This causes the turbine wheel and compressor wheel to turn. The exhaust gases then go out the exhaust outlet (7) of the turbocharger.



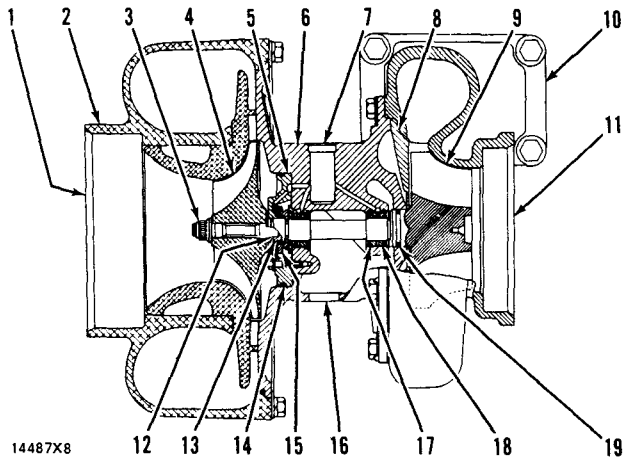
AIR INLET AND EXHAUST SYSTEM
(Typical Example)

1. Exhaust manifold. 2. Inlet manifold. 8. Turbocharger.

TURBOCHARGER

The turbocharger is installed on the exhaust manifold. All the exhaust gases from the engine go through the turbocharger.

The exhaust gases go through the blades of the turbine wheel. This causes the turbine wheel and compressor wheel to turn which causes a compression of the inlet air.



TURBOCHARGER
(Typical Illustration)

1. Air inlet. 2. Compressor housing. 3. Nut. 4. Compressor wheel. 5. Thrust plate. 6. Center housing. 7. Lubrication inlet port. 8. Shroud. 9. Turbine wheel and shaft. 10. Turbine housing. 11. Exhaust outlet. 12. Spacer. 13. Ring. 14. Seal. 15. Collar. 16. Lubrication outlet port. 17. Ring. 18. Bearing. 19. Ring.

When the load on the engine goes up more fuel is put into the engine. This makes more exhaust gases and will cause the turbine and compressor wheels of the turbocharger to turn faster. As the turbocharger turns faster, it gives more inlet air and makes it possible for the engine to burn more fuel and will give the engine more power.

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

⚠ WARNING: If the high idle rpm or the fuel system setting is higher than given in the book RACK SETTING INFORMATION (for the 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 under pressure for lubrication. The oil comes in through the oil inlet port and goes through passages in the center section for lubrication of the bearings. Oil from the turbocharger goes out through the oil outlet port in the bottom of the center section and goes back to the engine lubricating system.

The fuel system adjustment is done at the factory for a specific engine application. The governor housing and turbocharger are sealed to prevent changes in the adjustment of the rack and the high idle speed setting.

AFTERCOOLER

An air to air aftercooler is on the 980 WHEEL LOADER.

The air flow on this engine is from the turbocharger, through the air to air aftercooler which is next to the radiator and into the inlet manifold. The purpose of the aftercooler is to cool the air going into the inlet manifold for more combustion efficiency and power.

ENGINES WITHOUT TURBOCHARGERS

The air inlet and exhaust system components are: air cleaner, inlet manifold, cylinder head, valves and valve system components and exhaust manifold.

When the engine is running, each time a piston moves through the intake stroke, it pulls air into the cylinder. The air flow is through the air filter, inlet manifold, passages in the cylinder head and past the open inlet valve into the cylinder. Too much restriction in the inlet air system makes the efficiency of the engine less.

When the engine is running, each time a piston moves through the exhaust stroke, it pushes hot exhaust gases from the cylinder. The exhaust gas flow is out of the cylinder between the open exhaust valve and the exhaust valve seat. Then it goes through passages in the cylinder head, through the exhaust manifold and out through the exhaust pipe. Too much restriction in the exhaust system makes the efficiency of the engine less.

VALVES AND VALVE MECHANISM

The valves and valve mechanism control the flow of air and exhaust gases in the cylinder during engine operation.

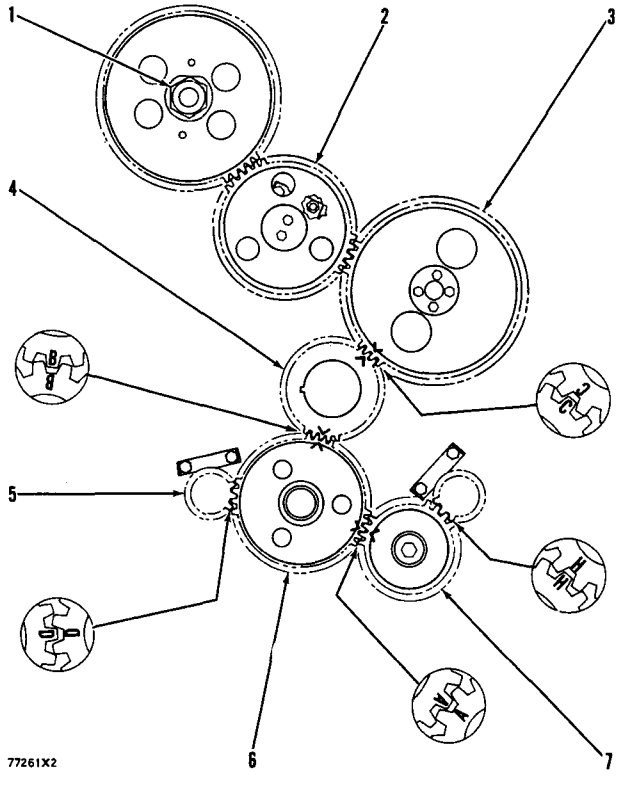
The intake and exhaust valves are opened and closed by movement of these components; crankshaft, camshaft, valve lifters (cam followers), push rods, rocker arms, and valve springs. Rotation of the crankshaft causes rotation of the camshaft. The camshaft gear is driven by, and timed to, a gear on

the front of the crankshaft. When the camshaft turns, the cams on the camshaft also turn and cause the valve lifters (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 according to the firing order (injection sequence) of the engine. A valve spring for each valve pushes the valve back to the closed position.

Valve rotators cause the valves to have rotation while the engine is running. This rotation of the valves keeps the deposit of carbon on the valves to a minimum and gives the valves longer service life.

TIMING GEARS

The timing gears are at the front of the cylinder block. Their cover is the housing for the timing gears. The timing gears keep the rotation of the crankshaft, camshaft, and fuel injection pump in the correct relation to each other. The timing gears are driven by the crankshaft gear.

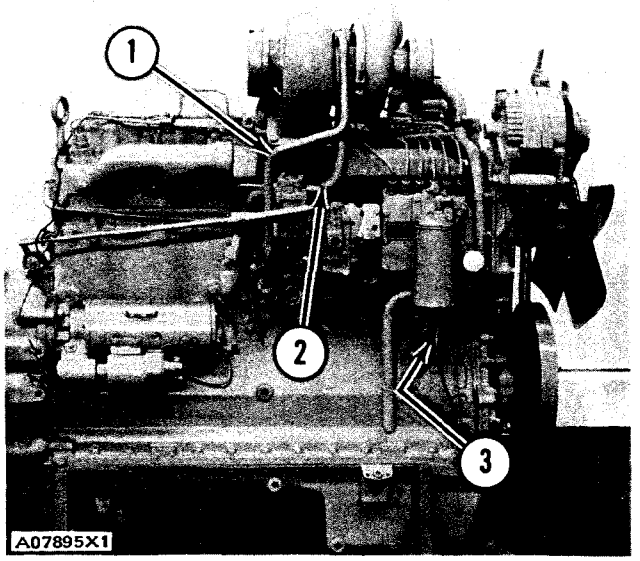


TIMING GEARS

1. Drive gear for fuel injection pump. 2. Idler gear for fuel injection pump. 3. Camshaft gear. 4. Crankshaft gear. 5. Balancer shafts (3304 Engines only). 6. Idler gear for oil pump. 7. Drive gear for oil pump.

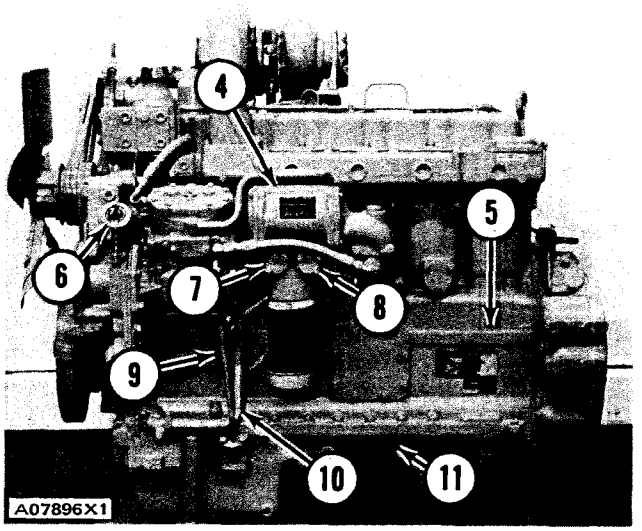
LUBRICATION SYSTEM

LUBRICATION SYSTEM COMPONENTS



LUBRICATION SYSTEM COMPONENTS
(Typical Example)

1. Supply line for turbocharger. 2. Return line for turbocharger. 3. Supply line for automatic timing advance unit.



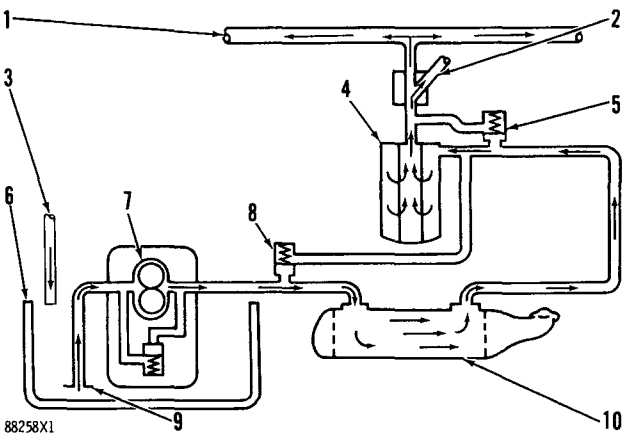
LUBRICATION SYSTEM COMPONENTS
(Typical Example)

4. Oil cooler. 5. Oil manifold in cylinder block. 6. Oil filter cap. 7. Bypass valve for oil cooler. 8. Bypass valve for oil filter. 9. Oil supply line for air compressor. 10. Oil line to cooler and filter. 11. Oil pan.

The lubrication system has the following components: oil pan, oil pump, oil cooler, oil filter, oil passages in the cylinder block, and lines to engine components and attachments such as turbocharger, air compressor and others.

OIL FLOW THROUGH THE OIL FILTER AND OIL COOLER

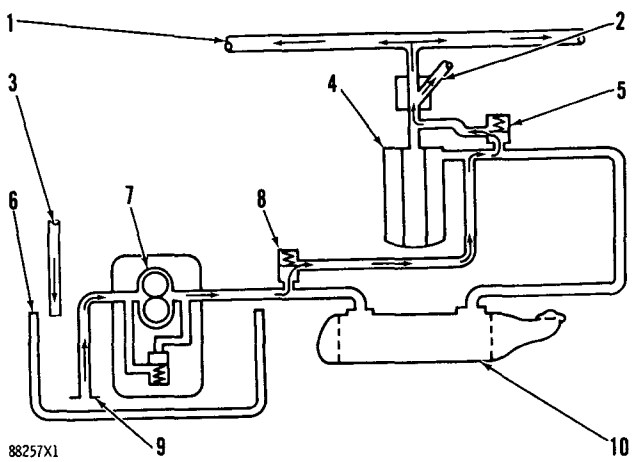
With the engine warm (normal operation), oil comes from the oil pan (6) through the suction bell (9) to the oil pump (7). The oil pump sends warm oil to the oil cooler (10) and then to the oil filter (4). From the oil filter, oil is sent to the oil manifold (1) in the cylinder block.



FLOW OF OIL (ENGINE WARM)

1. Oil manifold in cylinder block. 2. Oil supply line to turbocharger. 3. Oil return line from turbocharger. 4. Oil filter. 5. Bypass valve for the oil filter. 6. Oil pan. 7. Oil pump. 8. Bypass valve for the oil cooler. 9. Suction bell. 10. Oil cooler.

With the engine cold (starting conditions), oil comes from the oil pan (6) through the suction bell (9) to the oil pump (7). When the oil is cold, an oil pressure difference in the bypass valve (installed in the oil filter housing) causes the valves to open.



FLOW OF OIL (ENGINE COLD)

1. Oil manifold in cylinder block. 2. Oil supply line to turbocharger. 3. Oil return line from turbocharger. 4. Oil filter. 5. Bypass valve for the oil filter. 6. Oil pan. 7. Oil pump. 8. Bypass valve for the oil cooler. 9. Suction bell. 10. Oil cooler.

These bypass valves give immediate lubrication to all components when cold oil with high viscosity causes a restriction to the oil flow through the oil cooler (10) and oil filter (4). The oil pump then sends the cold oil through the bypass valve for the oil cooler (8) and through the bypass valve for the oil filter (5) to the oil manifold (1) in the cylinder block.

When the oil gets warm, the pressure difference in the bypass valves decrease and the bypass valves close. Now there is a normal oil flow through the oil cooler and oil filter.

OIL FLOW IN THE ENGINE

There is a bypass valve in the oil pump. This bypass valve controls the pressure of the oil coming from the oil pump. The oil pump can put more oil into the system than is needed. When there is more oil than needed, the oil pressure goes up and the bypass valve opens. This lets the oil that is not needed go back to the inlet oil passage of the oil pump.

NOTE: The later oil pumps have a different kind of spring in the bypass valve in the oil pump. These bypass valves are not adjustable.

The output of the oil pump goes to the oil manifold in the cylinder block. The oil manifold is the source for oil under pressure for the engine and its attachments. Connecting drilled passages from the oil manifold are the way for the oil to get to the main bearings, timing gear bearings, and the bearings for the rocker arm shaft.

The flow of oil which goes to the main bearings is divided. Some of the oil is the lubricant between the main bearings and the bearing surfaces (journals) of the crankshaft. Some of the oil goes through passages drilled in the crankshaft. This oil is the lubricant between the connecting rod bearings and the bearing surfaces (journals) of the crankshaft. The rest of the oil goes out through orifices in the block near the main bearings. This oil is both a coolant and a lubricant for the pistons, piston pins, cylinder walls and the piston rings.

Oil also goes through connecting passages in the cylinder block and cylinder head. This oil is the lubricant for the rocker arm shaft and bearings and for the rocker arms. Some of the oil is the lubricant for the valve stems. The rest of the oil drains on the cylinder head where it is the lubricant for the push rods and valve lifters and the cams for the camshaft.

On the 3306 Engines, this oil is the lubricant for the intermediate and rear camshaft bearings.

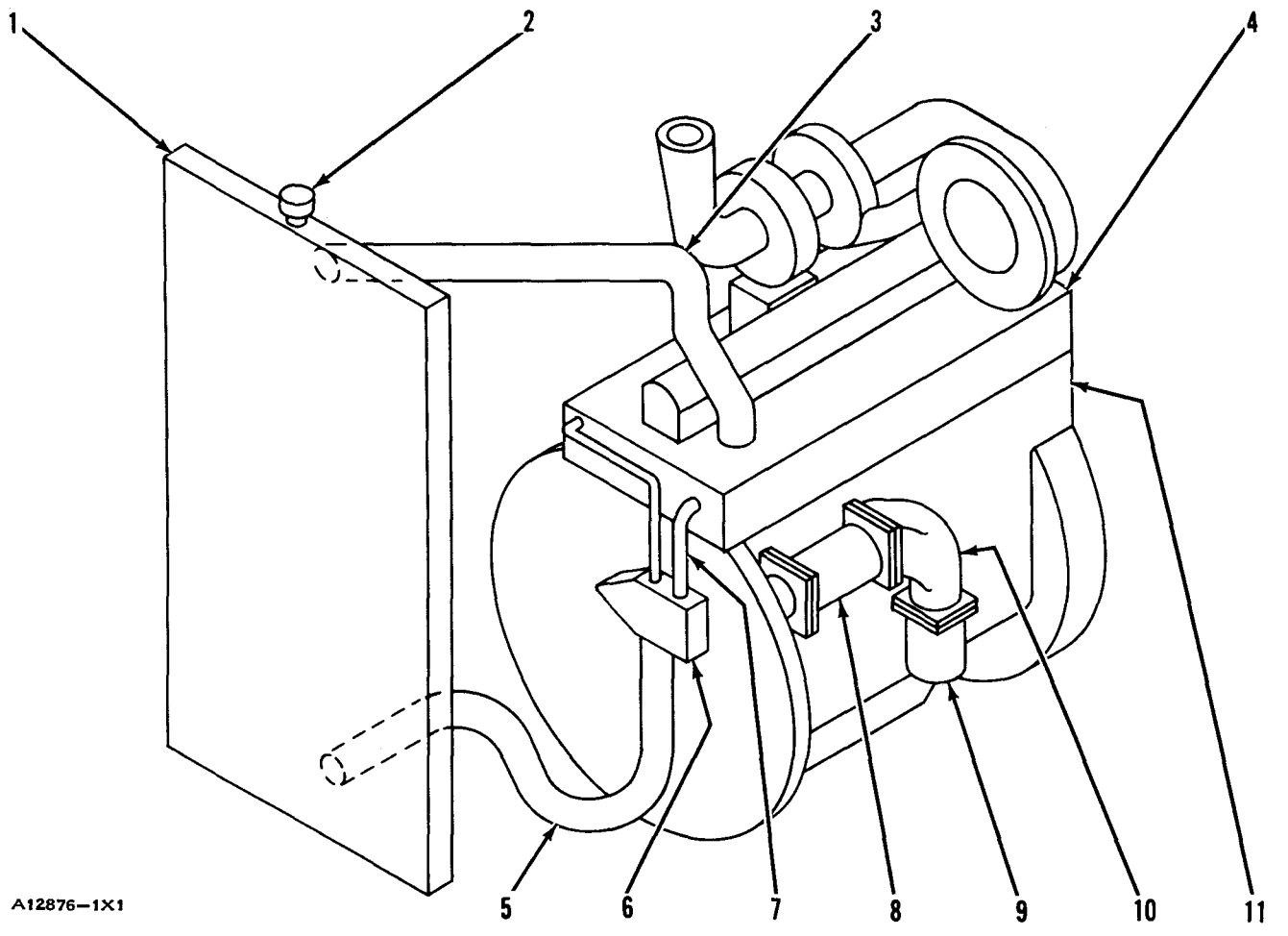
On the 3304 Engines, the bearings for the camshaft get lubrication oil under pressure through passages drilled in the cylinder block to the oil manifold.

All the timing gear bearings get lubricant under pressure from the oil manifold through connecting drilled passages.

Oil goes to the components and attachments on the outside of the engine through supply lines which connect to the oil manifold. These components and attachments are: turbocharger, air compressor and others.

After the lubricating oil has done its work, it goes back to the engine oil pan.

COOLING SYSTEM



1. Radiator. 2. Pressure cap. 3. Inlet line for radiator. 4. Cylinder head. 5. Supply line for water pump. 6. Water pump. 7. Internal bypass (shunt) line. 8. Engine oil cooler. 9. Oil cooler for torque converter or hydraulic systems. 10. Bonnet. 11. Cylinder block.

The water pump (6) is on the left front side of the engine. It is gear driven by the timing gears. Coolant from the bottom of the radiator (1) goes to the water pump inlet. The rotation of the impeller in the water pump (6) pushes the coolant through the system.

All of the coolant flow from the water pump (6) in the standard system, goes through the engine oil cooler (8). The bonnet (10) on the outlet side of the engine oil cooler (8) connects to the side of the cylinder block (11).

On engines with an additional oil cooler (9), a different bonnet (10) is on the engine oil cooler (8). This bonnet (10) sends the coolant flow through the other cooler which is for torque converters or hydraulic systems. The flow goes through one side on the way into the cooler. At the bottom of the cooler the flow turns and goes back up through the other side and into the bonnet (10) again. Then the bonnet (10) sends the coolant into the cylinder block (11).

Inside the cylinder block (11) the coolant goes around the cylinder liners and up through the water directors into the cylinder head (4). The water directors send the flow of coolant around the valves and the passages for exhaust gases in the cylinder head (4). The coolant goes to the front of the cylinder head (4). Here the water temperature regulator controls the direction of the flow. If the coolant temperature is less than normal for engine operation, the water temperature regulator is closed. The only way for the coolant to get out of the cylinder head (4) is through the internal bypass (shunt) line (7). The coolant from this line goes into the water pump (6) which pushes it through

the cooling system again. The coolant from the internal bypass (shunt) line (7) also works to prevent cavitation (air bubbles) in the coolant. When the coolant gets to the correct temperature, the water temperature regulator opens and coolant flow is divided. Some goes through the radiator (1) for cooling. The rest goes through the internal bypass (shunt) line (7) to the water pump (6). The proportion of the two flows is controlled by the water temperature regulator.

CAUTION: DO NOT RUN THE ENGINE WITHOUT A WATER TEMPERATURE REGULATOR. Overheating (engine gets too hot) will result because not enough coolant goes through the radiator when the water temperature regulator is removed.

The internal bypass (shunt) line (7) has another function when the cooling system is being filled. It lets the coolant go into the cylinder head (4) and cylinder block (11) without going through the water pump (6).

The radiator (1) has a pressure cap (2). This cap controls pressure in the cooling system.

980 WHEEL LOADER

The cooler for the torque converter oil is next to the radiator.

COOLING SYSTEM COMPONENTS

Water Pump

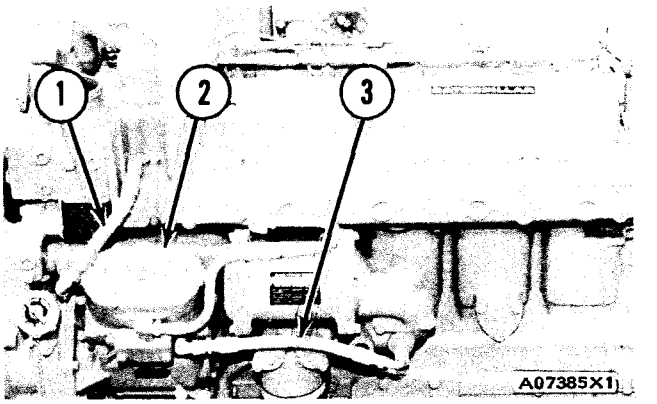
The centrifugal-type water pump has two seals, one prevents leakage of water and the other prevents leakage of lubricant.

An opening in the bottom of the pump housing allows any leakage at the water seal or the rear bearing oil seal to escape.

Fan

The fan is driven by two V-belts, from a pulley on the crankshaft. Belt tension is adjusted by moving the clamp assembly which includes the fan mounting and pulley.

COOLANT FOR AIR COMPRESSOR

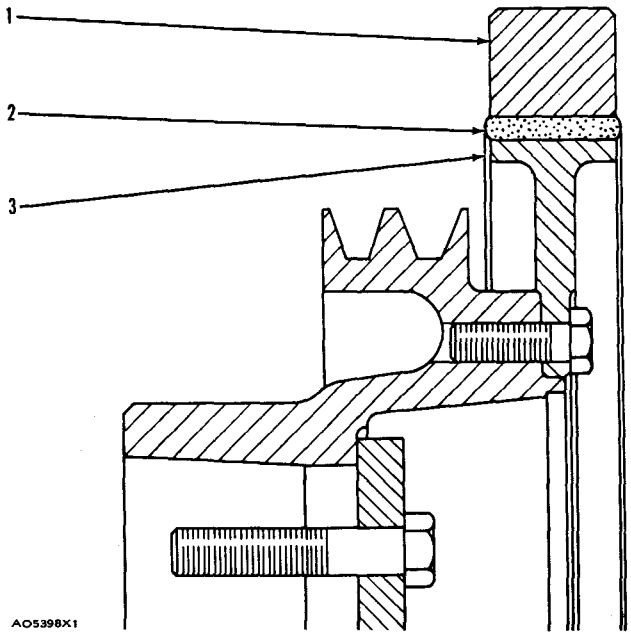


COOLANT FLOW IN AIR COMPRESSOR

1. Outlet hose. 2. Air compressor. 3. Inlet hose.

The coolant for the air compressor (2) comes from the cylinder block through hose (3) and into the air compressor. The coolant goes from the air compressor through hose (1) back into the front of the cylinder head.

BASIC BLOCK



CROSS SECTION OF A VIBRATION DAMPER
(Typical Example)

1. Flywheel ring. 2. Rubber ring. 3. Inner hub.

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.

ELECTRICAL SYSTEM

The electrical system can have 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.

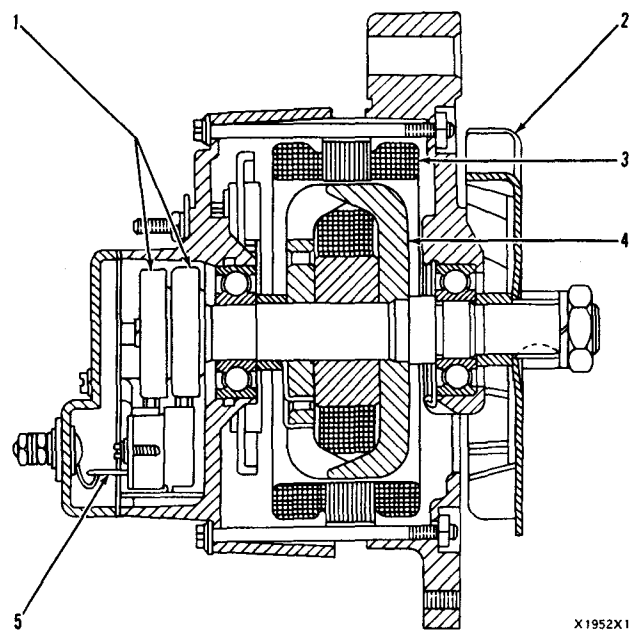
The starting circuit is in operation only when the start switch is activated.

The starting circuit can have a glow plug for each cylinder of the diesel engine. Glow plugs are small heating units in the precombustion chambers. Glow plugs make ignition of the fuel easier when the engine is started in cold temperature.

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 (Motorola)



ALTERNATOR

1. Slip rings. 2. Fan. 3. Stator. 4. Rotor. 5. Brush assembly.

The alternator is a three phase, self rectifying charging unit. The alternator is driven from an auxiliary drive by two V type belts.

The alternator has three main parts: a "rotating" (turning, radial motion) rotor (4) which makes magnetic lines of force; a stationary stator (3) in which alternating current (AC) is made; and stationary rectifying diodes that change alternating current (AC) to direct current (DC).

The alternator field current goes through the brushes. The field current is 2 to 3 amperes. The rectifying diodes will send current from the alternator to the battery or load, but will not send current from the battery to the alternator.

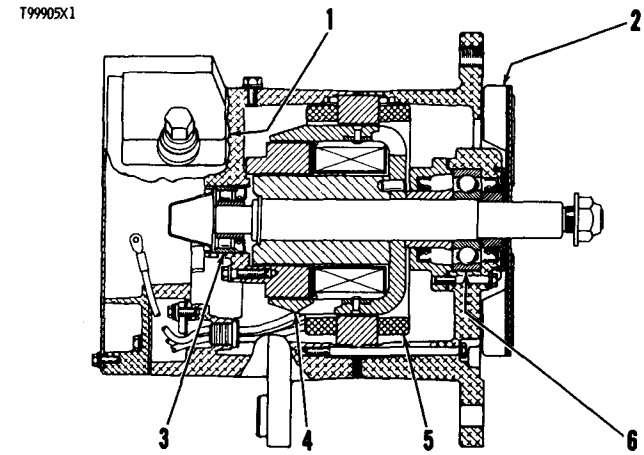
Regulator (Motorola)

The voltage regulator is a transistorized electronic switch. It feels the voltage in the system at the switch for oil pressure and gives the necessary field current to keep the needed system voltage. The voltage regulator has two basic circuits, the load circuit and the control circuit.

The load circuit has a positive potential from the input lead of the regulator to the rotor (field) winding. The control circuit makes the load circuit go off and on at a rate that will give the needed charging voltage.

Alternator (Delco-Remy)

The alternator is a three phase, self rectifying charging unit. The regulator for the alternator is part of the alternator. The alternator is driven from an auxiliary drive by two V type belts.



5S9088 ALTERNATOR

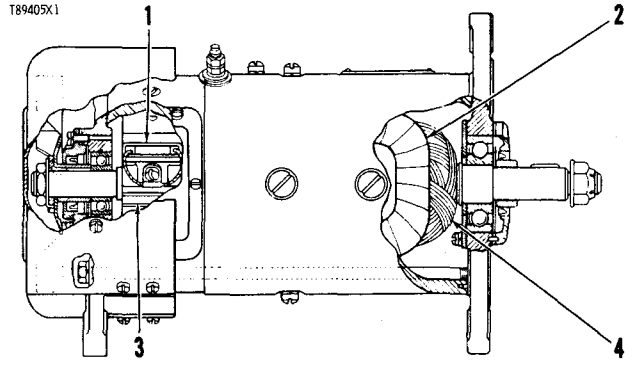
1. Regulator. 2. Fan. 3. Roller bearing. 4. Rotor. 5. Stator windings. 6. Ball bearing.

The only part in the alternator which has movement is the rotor. The rotor is held in position by a ball bearing at the drive end and a roller bearing at the rectifier end.

The compartment for the regulator is sealed. The regulator controls the alternator output according to the needs of the battery and the other components in the electrical system.

Generator

The generator is belt driven by the diesel engine. The generator keeps the battery charged and supplies current to operate the electrical components.



CUTAWAY VIEW OF A GENERATOR

1. Brush assembly. 2. Field. 3. Commutator. 4. Armature.

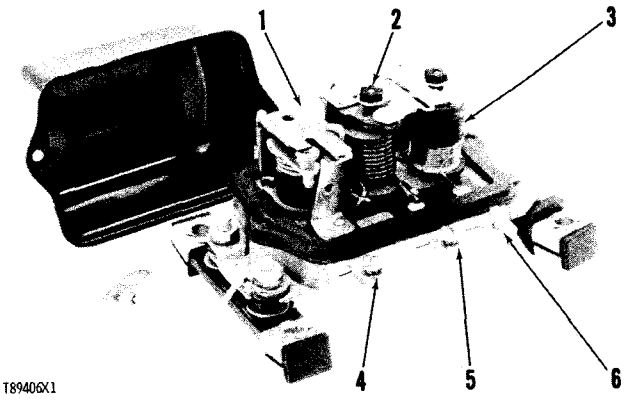
Generator Regulator

The generator regulator controls the output of the generator. The regulator incorporates three controls: the cutout relay, the voltage regulator and the current regulator. Each control has contact points which are operated by electromagnets.

Springs hold the cutout relay points open and the voltage regulator and current regulator contact points closed. The spring tension for each unit is a force opposing the force of the electromagnets.

The cutout relay prevents the battery from motorizing a generator that is not producing enough voltage. Generator voltage approximately equal to battery voltage will close the cutout relay points. This closes the circuit between the generator and the battery. The generator can now supply the battery and the components of the electrical system with power.

The voltage regulator prevents the generator from producing damaging high voltage. Generator voltage slightly higher than battery voltage opens the regulator points causing the generator output voltage to lower. Low generator voltage allows the spring to close the regulator points and generator voltage is again high. The action of the voltage

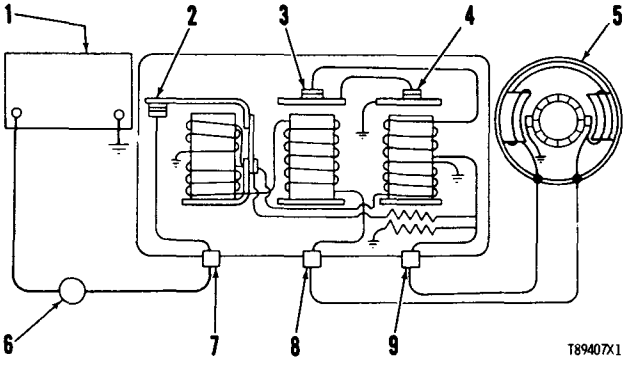


GENERATOR REGULATOR

1. Cutout relay. 2. Current regulator. 3. Voltage regulator. 4. Battery terminal. 5. Generator terminal. 6. Field terminal.

regulator points, opening and closing, controls the output voltage of the generator. The points can open and close as often as 200 times per second.

The current regulator limits the current produced by the generator to allow the generator to continue producing voltage equal to battery voltage. When the generator produces current equal to the current regulator setting, the regulator contact points open. Open points lower the generator current. Low current allows the spring to close the points and generator current is again high. The opening and closing of the current regulator points, limits the current produced by the generator. The points can open and close as often as 200 times per second.



REGULATOR WIRING SCHEMATIC
(Typical "A" Circuit illustrated)

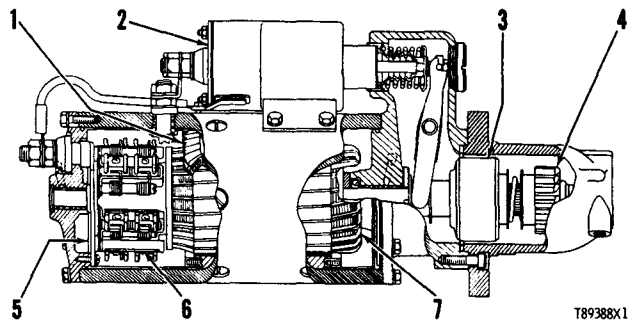
1. Battery. 2. Cutout relay. 3. Current regulator. 4. Voltage regulator. 5. Generator. 6. Ammeter. 7. Battery terminal. 8. Generator terminal. 9. Field terminal.

When generator electric loads are low and the battery requires very little charging, the VOLTAGE REGULATOR contact points are operating. When electric loads are high, the CURRENT REGULATOR contact points are operating. The contact points of the two units, will never open at the same time.

STARTING SYSTEM COMPONENTS

Starting Motor

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

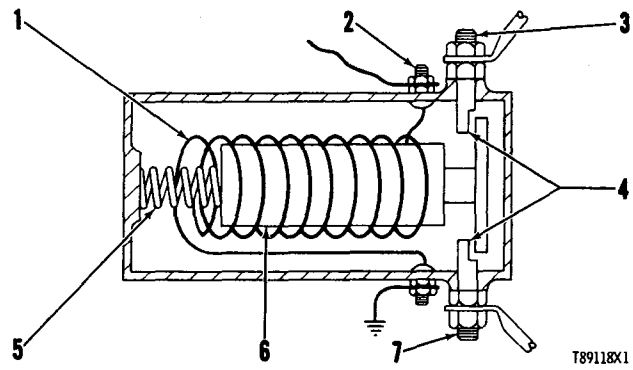


STARTING MOTOR

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

The starting motor has a solenoid. When the start switch is activated, electricity from the electrical system will cause the solenoid to move the starter pinion 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 starting motor. When the start switch is released, the starter pinion will move away from the ring gear of the flywheel.

Solenoid



SCHEMATIC OF A SOLENOID

1. Coil. 2. Switch terminal. 3. Battery terminal. 4. Contacts. 5. Spring. 6. Core. 7. Component terminal.

A solenoid is a magnetic switch that uses low current to close a high current circuit. The solenoid has an electromagnet with a core (6) which moves. There are contacts (4) on the end of core (6). The contacts are held in the open position by spring (5) that pushes core (6) from the magnetic center of coil (1). Low current will energize coil (1) and make a magnetic field. The magnetic field pulls core (6) to the center of coil (1) and the contacts close.

Magnetic Switch

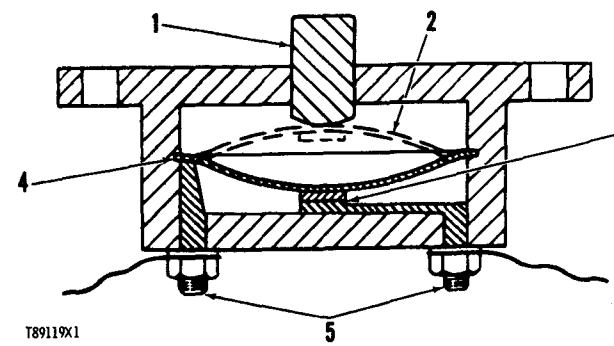
A magnetic switch (relay) is used sometimes for the starter solenoid or glow plug circuit. Its operation electrically, is the same as the solenoid. Its function is to reduce the low current load on the start switch and control low current to the starter solenoid or high current to the glow plugs.

OTHER COMPONENTS

Circuit Breaker

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

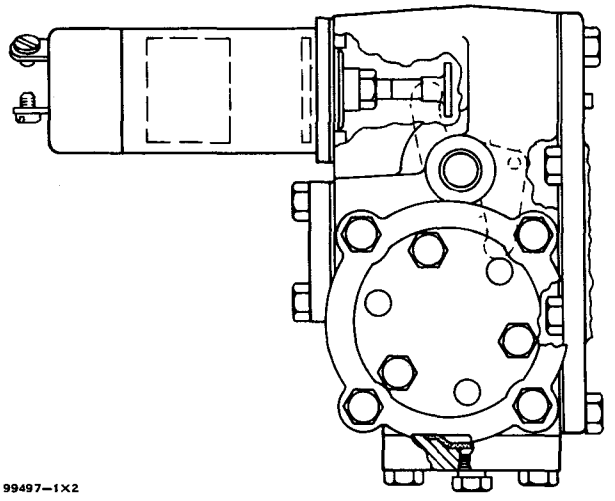
A heat activated metal disc with a contact point completes the electric circuit through the circuit breaker. If the current in the electrical system gets too high, it causes the metal disc to get hot. This heat causes a distortion of the metal disc which opens the contacts and breaks the circuit. A circuit 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.

Shutoff Solenoid



ACTIVATE TO SHUTOFF SOLENOID

When activated, the activate to shutoff solenoid moves the fuel control shaft to the fuel off position. The solenoid can be activated by any one of several sources. The most common is the manually operated momentary switch activated by the operator.

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 serviceman must find the problem and its source, then make the necessary repairs.

Item	Problem
1.	Engine Crankshaft Will Not Turn When Start Switch is On.
2.	Engine Will Not Start.
3.	Misfiring or Running Rough.
4.	Stall at Low rpm.
5.	Sudden Changes In Engine rpm.
6.	Engine Speed Does Not Go Higher Than 1000 to 1200 rpm.
7.	Not Enough Power.
8.	Governor Control Does Not Hold In High Idle Position.
9.	Too Much Vibration.
10.	Loud Combustion Noise (Knock).
11.	Loud Noise (Clicking) From Valve Compartment.
12.	Oil In Cooling System.
13.	Mechanical Noise (Knock) In Engine.
14.	Fuel Consumption Too High.
15.	Loud Noise From Valves or Valve Drive Components.
16.	Little Movement of Rocker Arm and Too Much Valve Clearance.
17.	Valve Rotocoil or Spring Lock is Free.
18.	Oil at the Exhaust (Slobber.)
19.	Little or No Valve Clearance.
20.	Engine Has Early Wear.
21.	Coolant In Lubrication Oil.
22.	Too Much Black or Gray Smoke.
23.	Too Much White or Blue Smoke.
24.	Engine Has Low Oil Pressure.
25.	Engine Uses Too Much Lubrication Oil.
26.	Engine Coolant Is Too Hot.
27.	Starting Motor Does Not Turn.
28.	Alternator Gives No Charge.
29.	Alternator Charge Rate Is Low or Not Regular.
30.	Alternator Charge Too High.
31.	Alternator Has Noise.
32.	Exhaust Temperature Too High.
33.	Solenoid Does Not Stop Engine.

Problem	Cause	Correction
1. ENGINE CRANKSHAFT WILL NOT TURN WHEN START SWITCH IS ON	Battery Has Low Output	Make Reference to Item 28.
	Wiring or Switches Have Defect	Make Reference to Item 28.
	Starting Motor Solenoid Has A Defect	Make Reference to Item 27.
	Starting Motor Has A Defect	Make Reference to Item 27.
	Inside Problem Prevents Engine Crankshaft From Turning	If the crankshaft can not be turned after disconnecting the driven equipment, remove the fuel nozzles and check for fluid in the cylinders while turning the crankshaft. If fluid in the cylinders is not the problem, the engine must be disassembled to check for other inside problems. Some of these inside problems are bearing seizure, piston seizure, wrong pistons installed in the engine, and valves making contact with pistons.

Problem	Cause	Correction
2. ENGINE WILL NOT START	Slow Cranking Speed	Make Reference to Item 27.
	No Fuel In The Housing For The Fuel Injection Pumps (Sleeve Metering Fuel System)	Fill the housing for the fuel injection pumps with fuel using the priming pump. Remove the air from the housing for the fuel injection pumps with the bleed valve. Loosen the bolts that hold the torque spring or stop bar cover. This will let out any air that is in the governor housing. After all air is out of fuel system, tighten bolts that hold torque spring or stop bar cover. Close manual bleed valve. Loosen each fuel line nut at the injection pumps and turn the engine until all the air is out of the fuel injection lines. Tighten fuel line nuts according to the SPECIFICATIONS.
	Dirty Fuel Filter	Install new fuel filter.
	Fuel Has "Cloud Point" Higher Than Atmospheric Temperature ("Cloud Point" = Temperature Which Makes Wax Form In Fuel.)	Drain the fuel tank lines, and fuel injection pump housing. Change the fuel filter. Fill the tank with fuel which has the correct "cloud point" and remove the air from the system with the priming pump and bleed valve.
	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.
	Dirty or Broken Fuel Lines	Clean or install new fuel lines as necessary.
	Fuel Pressure Is Low (Sleeve Metering Fuel System)	At starting rpm, the minimum fuel pressure from fuel transfer pump must be 2 psi (0.14 kg/cm^2). If fuel pressure is less than 2 psi (0.14 kg/cm^2), change the fuel filter element. Look for air in the fuel system. If fuel pressure is still low, inspect the constant bleed valve and pressure relief valve. Install a new fuel transfer pump.
	Fuel Pressure Is Low (Scroll Fuel System)	Check fuel supply line for leaks or kinks, air in fuel system, sticking, binding, or defective fuel bypass valve. Replace fuel filter. Check fuel pressure. Fuel transfer pump should supply fuel to engine at the following pressures: Full Load: minimum of 25 psi (1.76 kg/cm^2) High Idle: minimum of 30 psi (2.11 kg/cm^2)

Problem	Cause	Correction
2. ENGINE WILL NOT START (CONT.)	No Fuel To Cylinders	Put fuel in fuel tank. "Prime" (remove the air and/or low quality fuel from the fuel system).
	Slipping Fuel Injection Pump Drive (Scroll Fuel System Only)	The fuel injection pump is driven by the accessory drive gear through a tapered sleeve. If this sleeve is not tightened properly the accessory drive shaft will not rotate. Check this by removing the fuel transfer pump, cranking the engine, and observing through the fuel transfer pump mounting opening to see if the shaft rotates. If the shaft fails to rotate, remove the small cover from the front of the timing gear cover and tighten the accessory drive gear retaining nut. If tightening eliminates the slipping, retime the fuel injection pump to the engine before starting. If the accessory drive shaft rotates during above step, it is possible that the tapered sleeve has slipped. Reset the accessory drive shaft timing.
	Wrong Fuel Injection Timing	Make adjustment to timing.
	Shutoff Solenoid Holding Fuel Control Shaft in Fuel Off Position	Operate the control for the shutoff solenoid and see if the solenoid makes a noise (clicking sound). If this sound can be heard and the engine will not start, remove the solenoid. Now see if the engine will start. If the engine starts, the shutoff solenoid is bad. Replacement of the solenoid is necessary.
	Linkage to Sleeve Control Shaft is Held in Shutoff Position (Sleeve Metering Fuel System Only)	Check governor linkage for free movement. Sleeves must turn freely on pump plungers in all positions of sleeve control shaft. Thrust collar must turn freely on the governor shaft during all positions of the riser lever between shutoff and full load. On 4 and 6 cylinder fuel systems, the bellcrank and sleeve control shaft assembly must fall of its own weight when the bellcrank is disconnected from the thrust collar and the center line of the injection pumps is in the vertical position. If linkage does not move freely under these conditions, clean all parts thoroughly. Inspect all parts for wear and make replacement where needed.
	Over Fuel Spring Not Installed	Install over fuel spring.

Problem	Cause	Correction
3. MISFIRING OR RUNNING ROUGH	Air In The Fuel System	Find the air leak in the fuel system and correct it. Loosen each fuel line nut at the injection pumps and open the manual bleed valve. (On sleeve metering fuel systems, also loosen the bolt in the hole for the timing pin. This will let out any air that is in the governor housing.) Work the priming pump or turn the engine with the starting motor until there are no more air bubbles in the fuel coming from these places. Tighten the timing pin bolt and fuel line nuts according to the SPECIFICATIONS. Close manual bleed valve.
	Fuel System Not Timed Correctly to Engine	Make adjustment to timing.
	Fuel Pressure is Low (Sleeve Metering Fuel System)	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 must be as follows: High Idle 30 ± 5 psi (2.11 ± 0.35 kg/cm^2) Low Idle 18 ± 5 psi (1.27 ± 0.35 kg/cm^2) Cranking 2 psi (0.14 kg/cm^2) minimum If fuel pressure at high idle is lower than 20 psi (1.41 kg/cm^2), install a new filter element. If fuel pressure is still low, install a new fuel transfer pump. Check if the orifice check valve is working correctly. Check if pressure relief valve is working correctly.
	Fuel Pressure is Low (Scroll Fuel System)	Check fuel supply line for leaks or kinks, air in fuel system, sticking, binding, or defective fuel bypass valve. Replace fuel filter. Check fuel pressure. Fuel transfer pump should supply fuel to engine at the following pressures: Full Load: minimum of 25 psi (1.76 kg/cm^2) High Idle: minimum of 30 psi (2.11 kg/cm^2)
	Leak or Break in Fuel Line Between Injection Pump and Injection Valve	Install a new fuel line.

Problem	Cause	Correction
3. MISFIRING OR RUNNING ROUGH (CONT.)	Constant Bleed Valve Fitting Stays Open, Too Much Fuel By-passed, Not Enough Fuel Pressure For Starting	Install a new orifice check valve.
	Defect in Fuel Injection Valve(s) or Injection Pump(s)	Run engine at rpm that gives maximum misfiring or rough running. Then loosen a fuel line nut on the injection valve 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 injection pump and injection valve for that cylinder. Install new parts where needed.
	Wrong Valve Clearance	Make adjustment according to Specifications.
	Bent or Broken Push Rod	Replacement of push rod is necessary.
4. STALL AT LOW RPM	Fuel Pressure is Low (Sleeve Metering Fuel System)	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 must be as follows: High Idle 30 ± 5 psi (2.11 ± 0.35 kg/cm^2) Low Idle 18 ± 5 psi (1.27 ± 0.35 kg/cm^2) Cranking 2 psi (0.14 kg/cm^2) minimum If fuel pressure at high idle is lower than 20 psi (1.41 kg/cm^2), install a new fuel filter element. If fuel pressure is still low, install a new fuel transfer pump.
	Fuel Pressure is Low (Scroll Fuel System)	Check fuel supply line for leaks or kinks, air in fuel system, sticking, binding, or defective fuel bypass valve. Replace fuel filter. Check fuel pressure. Fuel transfer pump should supply fuel to engine at the following pressures: Full Load: minimum of 25 psi (1.76 kg/cm^2) High Idle: minimum of 30 psi (2.11 kg/cm^2)
	Idle rpm Too Low	Make adjustment to governor so idle rpm is the same as given in RACK SETTING INFORMATION.

Problem	Cause	Correction
4. STALL AT LOW RPM (CONT.)	Defect in Fuel Injection Valve(s)	Install a new fuel injection valve.
	Defect in Fuel Injection Pump(s)	Install new parts if needed.
5. SUDDEN CHANGES IN ENGINE SPEED	Air In The Fuel System	Find the air leak in the fuel system and correct it. Loosen each fuel line nut at the injection pumps and open the manual bleed valve. (On sleeve metering fuel systems, also loosen the bolt in the hole for the timing pin. This will let out any air that is in the governor housing.) Work the priming pump or turn the engine with the starting motor until there are no more air bubbles in the fuel coming from these places. Tighten the timing pin bolt and fuel line nuts according to the SPECIFICATIONS. Close manual bleed valve.
	Broken Torsion Spring on Sleeve Control Shaft	Install new parts as needed.
	Linkage In Governor Does Not Move Freely	Clean all linkage and inside of governor housing. Install new parts for those parts that have damage.
	Governor Springs Not Fully On Spring Seat	Put springs fully on spring seat.
6. ENGINE SPEED DOES NOT GO HIGHER THAN 1000 TO 1200 RPM	Speed Limiter Is Not Working Correctly	Check engine oil pressure at oil inlet to speed limiter. Check for a restriction of travel of the plunger in the speed limiter.
7. NOT ENOUGH POWER	Air In The Fuel System	Find the air leak in the fuel system and correct it. Loosen each fuel line nut at the injection pumps and open the manual bleed valve. (On sleeve metering fuel systems, also loosen the bolt in the hole for the timing pin. This will let out any air that is in the governor housing.) Work the priming pump or turn the engine with the starting motor until there are no more air bubbles in the fuel coming from these places. Tighten the timing pin bolt and fuel line nuts according to the SPECIFICATIONS. Close manual bleed valve.

Problem	Cause	Correction
7. NOT ENOUGH POWER (CONT.)	Fuel Pressure Is Too Low	Install a new fuel filter. Inspect the fuel bypass valve for free movement. Install a new fuel bypass valve if necessary.
	Solenoid or Shutoff Linkage Stopping Full Sleeve Shaft Travel	Check for correct full power with solenoid removed. If engine has power then, problem is in solenoid or shutoff housing linkage. Check for free travel of shutoff housing linkage.
	Constant Bleed Valve Stays Open or Closed	Install new parts if needed.
	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.
	Fuel Pressure is Low (Sleeve Metering Fuel System)	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 must be as follows: High Idle 30 ± 5 psi (2.11 ± 0.35 kg/cm^2) Low Idle 18 ± 5 psi (1.27 ± 0.35 kg/cm^2) Cranking 2 psi (0.14 kg/cm^2) minimum If fuel pressure at high idle, is lower than 20 psi (1.41 kg/cm^2), install a new fuel filter element. If fuel pressure is still low, install a new fuel transfer pump.
	Fuel Pressure is Low (Scroll Fuel System)	Check fuel supply line for leaks or kinks, air in fuel system, sticking, binding or defective fuel bypass valve. Replace fuel filter. Check fuel pressure. Fuel transfer pump should supply fuel to engine at the following pressures: Full Load: minimum of 25 psi (1.76 kg/cm^2) High Idle: minimum of 30 psi (2.11 kg/cm^2)
	Leaks in Air Inlet System	Check the pressure in the air intake manifold. Look for restrictions in the air cleaner.

Problem	Cause	Correction
7. NOT ENOUGH POWER (CONT.)	Governor Linkage	Make adjustment to get full travel of linkage. Install new parts for those that have damage or defects.
	Wrong Valve Clearance	Make adjustment according to Specifications.
	Defect in Fuel Injection Valve(s) or Fuel Injection Pump(s)	Run engine at rpm that gives maximum misfiring or rough running. Then loosen a fuel line nut on the injection pump 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 injection pump and injection valve for that cylinder. Install new parts where needed.
	Wrong Fuel Injection Timing	Make adjustment to timing.
	Fuel Setting or Fuel Ratio Control Setting Too Low	Make reference to RACK SETTING INFORMATION.
	Turbocharger Has Carbon Deposits or Other Causes of Friction	Make inspection and repair of turbocharger as necessary.
8. GOVERNOR CONTROL DOES NOT HOLD IN THE HIGH IDLE POSITION	The Force of the Friction Springs is Too Low (Sleeve Metering Fuel System Only)	Install a new friction spring.
9. TOO MUCH VIBRATION	Loose Bolt or Nut Holding Pulley or Damper	Tighten bolt or nut.
	Pulley or Damper Has A Defect	Install a new pulley or damper.
	Fan Blade Not in Balance	Loosen or remove fan belts and operate engine for a short time at the rpm that the vibration was present. If vibration is not still present, make a replacement of the fan assembly.
	Engine Supports Are Loose, Worn, or Have a Defect	Tighten all mounting bolts. Install new components if necessary.

Problem	Cause	Correction
9. TOO MUCH VIBRATION (CONT.)	Misfiring or Running Rough	Make Reference to Item 3.
	Balancer Shafts Not Correctly Timed (Four Cylinder Engines Only)	Put the balancer shafts in correct timing.
10. LOUD COMBUSTION NOISE (KNOCK)	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.
	Defect in Fuel Injection Valve(s)	Install a new fuel injection valve(s).
	Defect in Fuel Injection Pump(s)	Install new fuel injection pump(s).
	Wrong Fuel Injection Timing	Make adjustment to timing.
11. LOUD NOISE (CLICKING) FROM VALVE COMPARTMENT	Damage to Valve Spring(s) or Locks	Install new parts where necessary. Locks with defects can cause the valve to slide into the cylinder. This will cause much damage.
	Not Enough Lubrication	Check lubrication in valve compartment. There must be a strong flow of oil at engine high rpm, but only a small flow of oil at low rpm. Oil passages must be clean, especially those sending oil to the cylinder head.
	Too Much Valve Clearance	Make adjustment according to Specifications.
	Damage to Valves	Make a replacement of the valve(s) and make an adjustment as necessary.
12. OIL IN COOLING SYSTEM	Defect In Core of Oil Cooler	Install a new core in the oil cooler.
	Defect in Head Gasket	Install a new head gasket.

Problem	Cause	Correction
13. MECHANICAL NOISE (KNOCK) IN ENGINE	Failure of Bearing For Connecting Rod	Inspect the bearing for the connecting rod and the bearing surface on the crankshaft. Install new parts when necessary.
	Damage to Timing Gears	Install new parts where necessary.
	Damage to Crankshaft	Make replacement of the crankshaft.
	Air Compressor Rod or Piston Failure	Repair air compressor as necessary.
14. FUEL CONSUMPTION TOO HIGH	Fuel System Leaks	Large changes in fuel consumption may be the result. Inspect the fuel system for leaks and make repairs as necessary.
	Fuel and Combustion Noise (Knock)	Small increases in fuel consumption may be the result of fuel nozzles with defects, rough running, or factors causing loss of power. See Item 3 and Item 7.
	Wrong Fuel Injection Timing	Make an adjustment to fuel injection timing.
15. LOUD NOISE FROM VALVES OR VALVE DRIVE COMPONENTS	Damage to Valve Spring(s)	Make replacement of parts with damage.
	Damage to Camshaft	Make replacement of parts with damage. Clean engine thoroughly.
	Damage to Valve Lifter	Clean engine thoroughly. Make a replacement of the camshaft and valve lifters. Look for valves that do not move freely. Make an adjustment to valve clearance according to Specifications.
	Damage to Valve(s)	Make a replacement of the valve(s) and make an adjustment as necessary.
16. LITTLE MOVEMENT OF ROCKER ARM AND TOO MUCH VALVE CLEARANCE	Too Much Clearance	Make adjustment according to Specifications.
	Not Enough Lubrication	Check lubrication in valve compartment. There must be a strong flow of oil at engine high rpm, but only a small flow at low rpm. Oil passages must be clean, especially those sending oil to the cylinder head.

Problem	Cause	Correction
16. LITTLE MOVEMENT OF ROCKER ARM AND TOO MUCH VALVE CLEARANCE (CONT.)	Rocker Arm Worn at Face That Makes Contact With Valve	If there is too much wear, install new rocker arms. Make adjustment of valve clearance according to the Specifications.
	End of Valve Stem Worn	If there is too much wear, install new valves. Make adjustment of valve clearance according to Specifications.
	Worn Push Rods	If there is too much wear, install new push rods. Make adjustment of valve clearance according to the Specifications.
	Valve Lifters Worn	If there is too much wear, install new valve lifters. Make adjustment of valve clearance according to the Specifications.
	Damage to Valve Lifters	Install new valve lifters. Check camshaft for wear. Check for free movement of valves or bent valve stem. Clean engine thoroughly. Make adjustment of valve clearance according to Specifications.
	Worn Lobes on Camshaft	Check valve clearance. Check for free movement of valves or bent valve stems. Check for valve lifter wear. Install a new camshaft. Make adjustment of valve clearance according to the Specifications.
17. VALVE ROTOCOIL OR SPRING LOCK IS FREE	Damage to Locks	Locks with damage can cause the valve to fall into the cylinder. This will cause much damage.
	Damage to Valve Spring(s)	Install new valve spring(s).
18. OIL AT THE EXHAUST (SLOBBER)	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.
	Worn Valve Guides	Reconditioning of the cylinder head is needed.
	Worn Piston Rings	Inspect and install new parts as needed.
	Running Engine Too Long At Low Idle	Don't let the engine run for long periods of time at low idle.
19. LITTLE OR NO VALVE CLEARANCE	Worn Valve Seat or Face of Valve	Reconditioning of cylinder head is needed. Make adjustment of valve clearance according to the Specifications.

Problem	Cause	Correction
20. ENGINE HAS EARLY WEAR	Dirt in Lubrication Oil	Remove dirty lubrication oil. Install a new oil filter element. Put clean oil in the engine.
	Air Inlet Leaks	Inspect all gaskets and connections. Make repairs if leaks are present.
	Fuel Leakage Into Lubrication Oil	This will cause high fuel consumption and low engine oil pressure. Make repairs if leaks are present. Install new parts where needed.
21. COOLANT IN LUBRICATION OIL	Failure of Oil Cooler Core	Install a new core for the oil cooler.
	Failure of Cylinder Head Gasket	Install a new cylinder head gasket. Tighten the bolts holding the cylinder head, according to the Specifications.
	Crack or Defect in Cylinder Head	Install a new cylinder head.
	Crack or Defect in Cylinder Block	Install a new cylinder block.
	Failure of Cylinder Liners Seals	Make a replacement of the seals.
22. TOO MUCH BLACK OR GRAY SMOKE	Not Enough Air For Combustion	Check air cleaner for restrictions. Check inlet manifold pressure. Inspect turbocharger for correct operation.
	Bad Fuel Injection Valve(s)	Install new fuel injection valve(s).
	Wrong Fuel Injection Timing	Make adjustment to timing.
	Defect in Fuel Ratio Control	Make adjustment to or install new control.
23. TOO MUCH WHITE OR BLUE SMOKE	Too Much Lubricating 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.
	Misfiring or Running Rough	Make Reference to Item 3.
	Wrong Fuel Injection Timing	Make adjustment to timing.

Problem	Cause	Correction
23. TOO MUCH WHITE OR BLUE SMOKE (CONT.)	Worn Valve Guides	Reconditioning of cylinder head is needed.
	Worn Piston Rings	Install new piston rings.
	Failure of Turbocharger Oil Seal	Check inlet manifold for oil and make repair to turbocharger if necessary.
24. ENGINE HAS LOW OIL PRESSURE	Defect in Oil Pressure Gauge	Install new gauge.
	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.
	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.
	Too Much Clearance Between Rocker Arm Shaft and Rocker Arms	Check lubrication in valve compartment. Install new parts as necessary.
	Oil Pump Suction Pipe Has A Defect	Replacement of pipe is needed.
	Relief Valve for Oil Pump Does Not Operate Correctly	Clean valve and housing. Install new parts as necessary.
	Oil Pump Has A Defect	Make repair or replacement of oil pump if necessary.
	Too Much Clearance Between Camshaft and Camshaft Bearings	Install new camshaft and camshaft bearings if necessary.
	Too Much Clearance Between Crankshaft and Crankshaft Bearings	Check the oil filter for correct operation. Install new parts if necessary.
	Too Much Bearing Clearance for Idler Gear	Inspect bearings and make replacement as necessary.

Problem	Cause	Correction
24. ENGINE HAS LOW OIL PRESSURE (CONT.)	Orifices For Piston Cooling Or Plugs Not Installed	Install the correct parts. NOTE: Make a reference to Oil Lines in the parts book to find this information.
25. ENGINE USES TOO MUCH LUBRICATION OIL	Too Much Lubricating 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.
	Oil Leaks	Find all oil leaks. Make repairs as needed.
	Oil Temperature is Too High	Check operation of oil cooler. Install new parts if necessary. Clean the core of the oil cooler.
	Too Much Oil In Valve Compartment	Make Reference to Item 18.
	Worn Valve Guides	Make Reference to Item 18.
	Worn Piston Rings and Cylinder Liners	Install new parts if necessary.
	Failure of Seal Rings in Turbocharger	Check inlet manifold for oil and make repair to turbocharger if necessary.
	Worn Piston Rings in Air Compressor	Repair or replace air compressor as necessary.
26. ENGINE COOLANT IS TOO HOT	Restriction To Air Flow Through Radiator	Remove all restrictions to air flow.
	Restriction To Flow Of Coolant Through the Radiator	Remove all restrictions to flow of coolant through radiator.
	Not Enough Coolant in System	Add coolant to cooling system.
	Pressure Cap Has A Defect	Check operation of pressure cap. Install a new pressure cap if necessary.

Problem	Cause	Correction
26. ENGINE COOLANT IS TOO HOT (CONT.)	Combustion Gases in Coolant	Find out where gases get into the cooling system. Make repairs as needed.
	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.
	Water Pump Has A Defect	Make repairs to the water pump as necessary.
	Too Much Load On The System	Make a reduction in the load.
	Wrong Fuel Injection Timing	Make adjustment to timing.
	Torque Converter or Transmission Not Operating Correctly Causing an Increase in the Coolant Temperature	Make corrections for torque converter or transmission running too hot.
27. STARTING MOTOR DOES NOT TURN	Battery or Supply System For Starting Motor Has Low Output	Check condition of battery or supply system. Charge battery or supply system or make replacement as necessary.
	Wiring or Switch Has Defect	Make repairs or replacement as necessary.
	Starting Motor Solenoid Has a Defect	Install a new solenoid.
	Starting Motor Has A Defect	Make repair or replacement of starting motor.
28. ALTERNATOR GIVES NO CHARGE	Loose Drive Belt For Alternator	Make an adjustment to put the correct tension on the drive belt.

Problem	Cause	Correction
28. ALTERNATOR GIVES NO CHARGE (CONT.)	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 with defect.
	Brushes Have A Defect	Install new brushes.
	Rotor (Field Coil) Has A Defect	Install a new rotor.
29. ALTERNATOR CHARGE RATE IS LOW OR NOT REGULAR	Loose Drive Belt For Alternator	Make an adjustment to put the correct tension on the drive belt.
	Charging, Ground Return Circuit or Battery Connections Have A Defect	Inspect all cables and connections. Clean and tighten all connections. Make replacement of parts with defects.
	Alternator Regulator Has A Defect	Make an adjustment or replacement of alternator regulator.
	Alternator Brushes Have A Defect	Install new brushes.
	Rectifier Diodes Have A Defect	Make replacement of rectifier diode that has a defect.
	Rotor (Field Coil) Has A Defect	Install a new rotor.
30. ALTERNATOR CHARGE TOO HIGH (AS SHOWN BY LIGHTS BURNING OUT, BATTERY NEEDS TOO MUCH WATER)	Alternator or Alternator Regulator Has Loose Connections	Tighten all connections to alternator or alternator regulator.
	Alternator Regulator Has A Defect	Make an adjustment or replacement of alternator regulator.
31. ALTERNATOR HAS NOISE	Drive Belt For Alternator is Worn or Has A Defect	Install a new drive belt for the alternator.

Problem	Cause	Correction
31. ALTERNATOR HAS NOISE (CONT.)	Loose Alternator Drive Pulley	Check groove in pulley for key that holds pulley in place. If groove is worn, install a new pulley. Tighten pulley nut according to Specifications.
	Drive Belt and Drive Pulley For Alternator Are Not in Alignment	Make an adjustment to put drive belt and drive pulley in correct alignment.
	Worn Alternator Bearings	Install new bearings in the alternator.
	Armature or Rotor Shaft is Bent	Make a replacement of the component.
	Rectifiers in the Alternator Are Shorted	Make a replacement of the diode assembly.
32. EXHAUST TEMPERATURE IS TOO HIGH	Air Inlet System Has A Leak	Check pressure in the air inlet manifold. Look for restrictions at the air cleaner. Correct any leaks.
	Exhaust System Has A Leak	Find cause of exhaust leak. Make repairs as necessary.
	Air Inlet or Exhaust System Has A Restriction	Remove restriction.
	Fuel System Setting Or Calibration Not Correct	Make corrections as necessary.
	Wrong Fuel Injection Timing	Make an adjustment to the timing.
33. SOLENOID DOES NOT STOP ENGINE	Electrical Connections Are Not Correct	Correct electrical connections and wiring.
	Adjustment for Plunger Shaft is Not Correct	Make an adjustment to the plunger shaft.
	Wrong Plunger in Solenoid	Install the correct plunger in the solenoid.

Problem	Cause	Correction
33. SOLENOID DOES NOT STOP ENGINE (CONT.)	Not Enough Plunger Travel	Make an adjustment to the plunger shaft or make a replacement of the solenoid if necessary.
	Defect in Solenoid Wiring	Make a replacement of the solenoid.

SLEEVE METERING 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. Finding the source of the problem is difficult, especially when smoke is coming from the exhaust. Smoke coming from the exhaust can be caused by a bad fuel injection valve, but it can also be caused by the following:

a. Not enough air for good combustion.
b. An overload at high altitude.
c. Burning of too much oil.
d. Not enough compression.

FUEL SYSTEM INSPECTION

1. Look at the reading on the gauge for fuel pressure. Not enough fuel pressure is an indication of a problem with the components that send fuel to the engine.
2. 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.
3. Check the fuel lines for fuel leakage. Be sure the fuel supply line does not have a restriction or a bad bend.
4. Install a new fuel filter. Clean the primary fuel filter if so equipped.
5. Remove any dirt that may be in the fuel system.
6. Check fuel flow from orifice check valve. Flow should be about 8 oz. in 25 seconds (250 ml in 22 seconds) with the pressure in the housing for the fuel injection pumps at 30 ± 5 psi (2.11 ± 0.35 kg/cm^2).

TESTING FUEL INJECTION EQUIPMENT

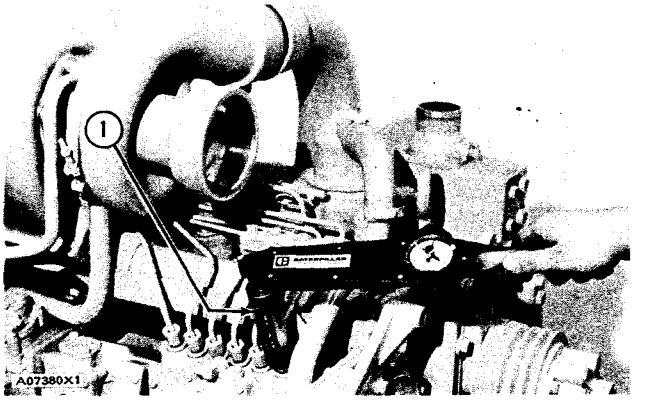
An easy check can be made to find the cylinder that is misfiring, or running rough, and causing black smoke to come out of the exhaust pipe.

Run the engine at the speed that gives misfiring. 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 misfiring. 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 running, test the injection pump and injection valve for that cylinder.

FUEL INJECTION LINES

Fuel from the fuel injection pumps is sent through the fuel injection lines to the fuel injection valves.

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.



TIGHTENING THE NUT OF A FUEL INJECTION LINE

1. 5P144 Fuel Line Socket.

The nuts that hold a fuel injection line to an injection valve and injection pump must be kept tight. Use a torque wrench and the 5P144 Fuel Line Socket (1) to tighten the fuel line nuts to 30 ± 5 lb.ft. (4.1 ± 0.7 mkg).

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.

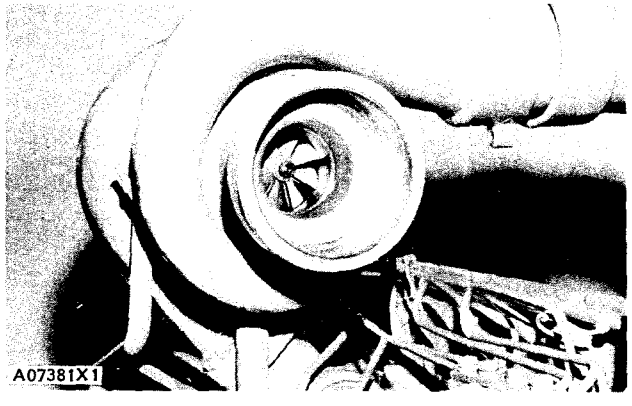
Be careful when disassembling injection pumps. Do not damage the surface on the plunger. The plunger, sleeve and barrel for each pump are made as a set. Do not put the plunger of one pump in the barrel or sleeve of another pump. If one part is

worn, install a complete new pump assembly. Be careful when putting the plunger in the bore of the barrel or sleeve.

Be sure that all the sleeves are installed correctly on the plungers. 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 70 ± 5 lb.ft. (9.7 ± 0.7 mkg). Damage to the housing will result if the bushing is too tight. If the bushing is not tight enough, the pump will leak.

⚠ WARNING: 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 following cautions when first starting the engine.

a. Remove the air cleaner leaving the air inlet pipe open as shown.



AIR INLET PIPE

STOPPING THE ENGINE

b. If the sleeve on pump has been installed wrong and the engine operates in a not regular way, put a steel plate over the air inlet opening as shown to stop the engine.

CHECKING THE FUEL INJECTION VALVES

Check the fuel injection valves for:

1. Too much carbon on the tip of the nozzle or in the nozzle orifice.
2. Wear of the orifice.
3. Nozzle screen being dirty or broken.

Use the Caterpillar Diesel Fuel Injection Test Bench to test the nozzle.

Check the seat of the nozzle and the seat in the precombustion chamber before installing the fuel injection valve. It is important to keep the correct torque on the nut that holds the fuel nozzle in the precombustion chamber. Tighten the nut to 105 ± 5 lb.ft. (14.5 ± 0.7 mkg). There will be damage to the nozzle if the nut is too tight. If the nut is not tight enough the nozzle can leak.

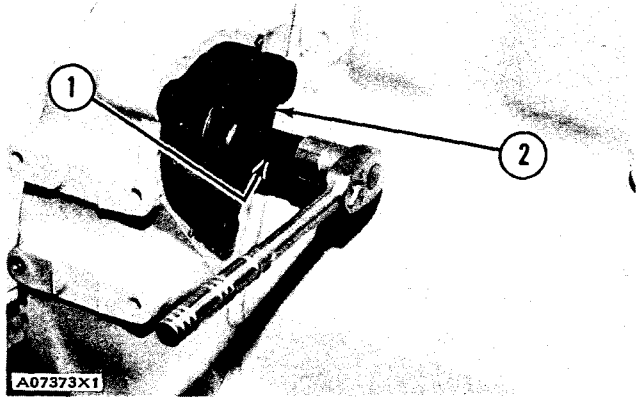
FINDING TOP CENTER COMPRESSION POSITION FOR NO. 1 PISTON

Tools Needed: 2P8298 Gear Assembly.
2P8294 Housing.

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

NOTE: The engine is seen from the flywheel end when direction of crankshaft rotation is given.

1. Remove starting motor.
2. Install tooling as shown.

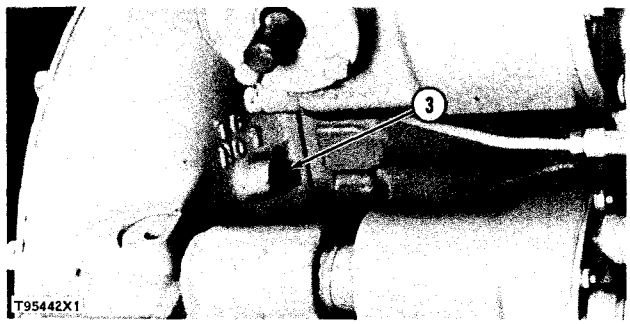


ENGINE TURNING TOOLS INSTALLED
1. 2P8298 Gear Assembly. 2. 2P8294 Housing.

3. To find top center (TC) compression stroke for No.1 piston, first turn the flywheel clockwise (opposite the direction of engine rotation) approximately 30 degrees. The reason for making this step is to be sure the play is removed from the timing gears when the engine is put on top center.

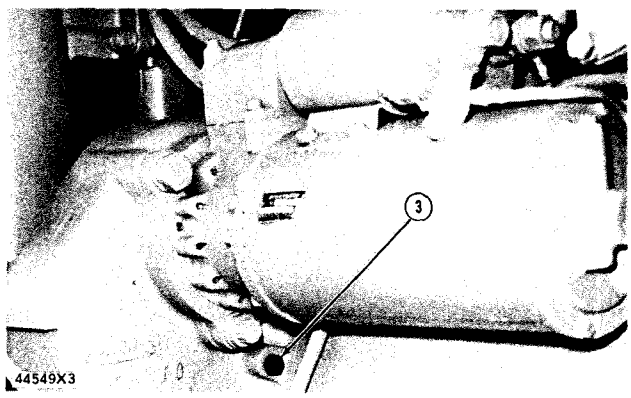
4. Turn the flywheel counterclockwise until a 3/8"-16 NC bolt (3) can be installed in the flywheel through the hole in the flywheel housing. The No.1 piston is on top center.

NOTE: If the flywheel is turned beyond the point where the 3/8"-16 NC bolt (3) can be installed in the flywheel turn the flywheel back (clockwise) a minimum of 30° before turning counterclockwise toward alignment again.



LOCATING TOP CENTER

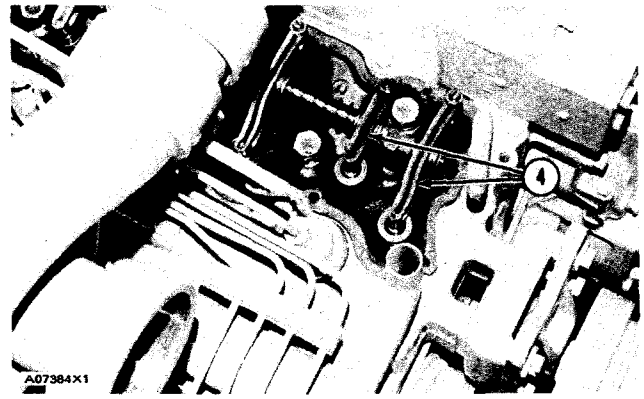
3. Bolt.



LOCATING TOP CENTER

3. Bolt.

5. To see if No.1 piston is on the compression stroke, look at the valves of No.1 cylinder. The valves will be closed if No.1 cylinder is on the compression stroke. You should be able to move the rocker arms (4) up and down with your hand.



VALVE COVER REMOVED

4. Rocker arms.

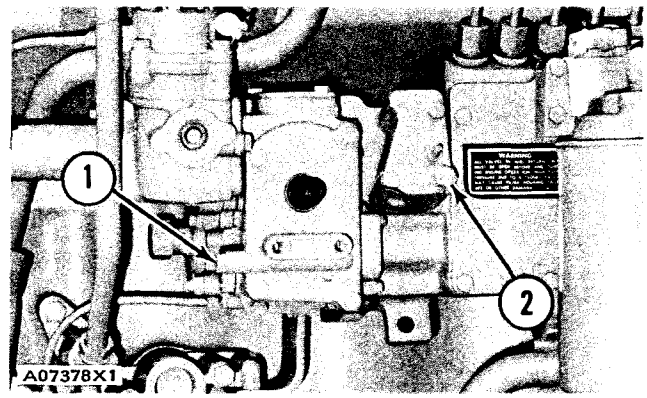
6. If No.1 piston is not on the compression stroke, remove the 3/8"-16 NC bolt (3) and turn the flywheel 360° counterclockwise. Install the 3/8"-16 NC bolt (3) as before. The No.1 piston is now at top center on the compression stroke (TC1).

FUEL SYSTEM ADJUSTMENTS

Checking Timing By Timing Pin Method

Tools Needed: 8S2264 Puller Group.
3/8"–24 NF bolts, 3 1/2" long.
3/8" Flat washer.
8B7560 Step Plate.

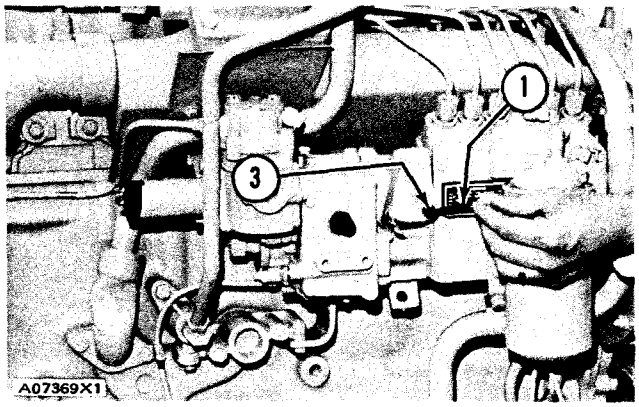
1. Put No. 1 piston at TC 1 compression position. Make a reference to FINDING TOP CENTER COMPRESSION POSITION FOR NO. 1 PISTON.
2. Remove bolt (2).
3. Remove timing pin (1) from the cover of the governor housing.



TIMING PIN

1. Timing pin. 2. Bolt.

4. Put timing pin (1) in hole (3). If timing pin goes into the notch in the camshaft, the timing of the fuel injection pump is correct.

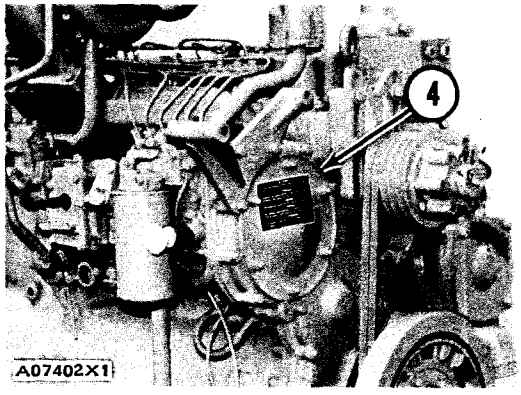


INSTALLING TIMING PIN

1. Timing pin. 3. Hole for timing pin.

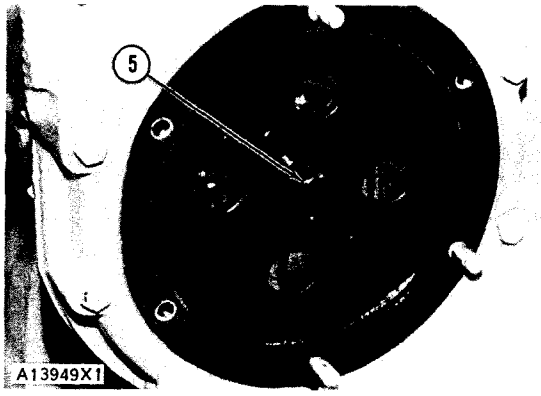
5. If the timing pin does not go into the notch in the camshaft with the No. 1 piston at top center, turn the engine until the pin goes into the notch.

6. Remove cover (4) from the front housing.



COVER

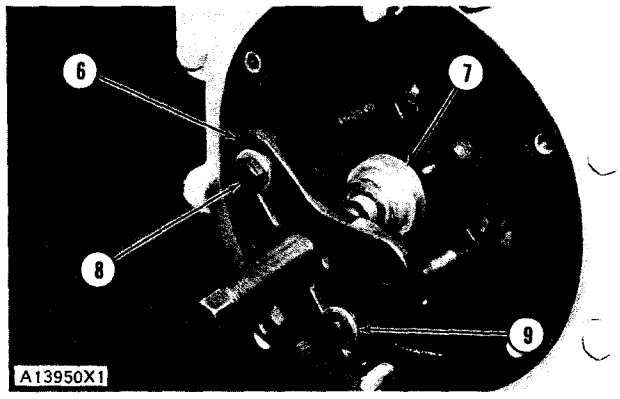
4. Cover.



DRIVE GEAR FOR THE FUEL INJECTION PUMP

5. Bolt.

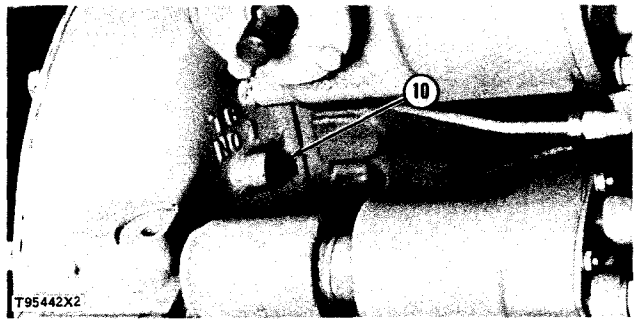
7. Loosen bolt (5) holding the drive gear for the fuel injection pump to the drive sleeve for fuel injection pump.



PULLER TOOLS INSTALLED

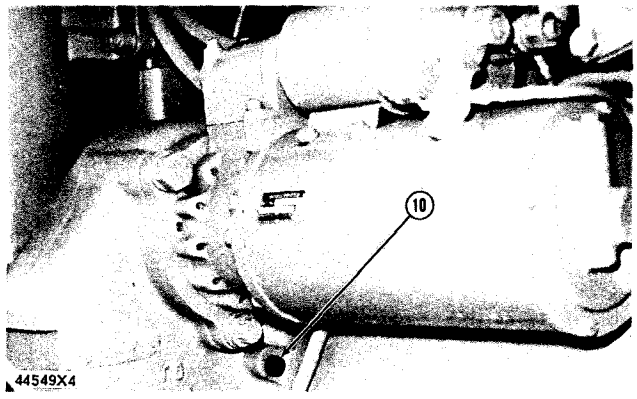
6. 8S2264 Puller Group. 7. 8B7560 Step Plate. 8. 3/8"–24 NF bolts, 3 1/2" long. 9. 3/8" I.D. Flat washer.

8. Install tools as shown and loosen the drive gear for the fuel injection pump from the drive sleeve for the fuel injection pump.



LOCATING TOP CENTER

10. Bolt.



LOCATING TOP CENTER

10. Bolt.

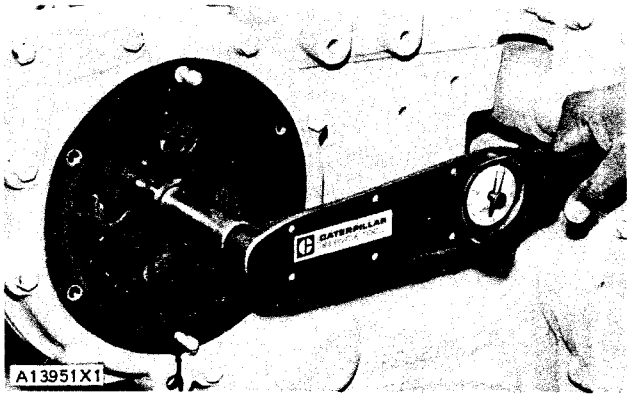
9. Remove the 3/8"-16 NC bolt (10) from the flywheel. Turn the flywheel clockwise at least 60° beyond the point where the 3/8"-16 bolt (10) can be installed.

10. Tighten the bolt (5) finger tight. Be sure that the timing pin (1) is in the notch in the camshaft. Turn the flywheel counterclockwise until the 3/8"-16 bolt (10) can be installed in the flywheel.

11. Tighten the bolt (5) to 110 ± 5 lb. ft. (15.2 ± 0.7 mkg). Remove the timing pin (1). Remove the 3/8"-16 bolt (10) from the flywheel.

12. Turn the engine flywheel two complete revolutions. If the timing pin (1) goes into the notch in the camshaft and the 3/8"-16 bolt (10) goes into the flywheel at the same time, the timing is correct.

13. If the timing pin (1) can not be installed, go through Steps 4 through 11 again.



TIGHTENING THE BOLT FOR THE DRIVE GEAR

Checking Timing by Fuel Flow Method

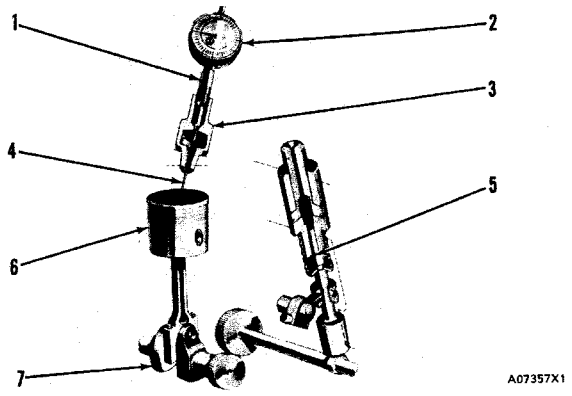
Tools Needed: 1P540 Flow Checking Tool Group.
3S2954 Engine Timing Indicator Group.
5P2371 Puller.

See Special Instruction (FM035709) for complete instructions for the fuel flow method of engine timing (injection sequence).

Travel of piston (6), from point of closing inlet port (5) to top center, can be found by using the tools listed under Tools Needed. Make a conversion of travel of piston (6) to degrees and determine if timing is correct.

1. Put No. 1 piston at top center (TC) on the compression stroke. Make reference to FINDING TOP CENTER COMPRESSION POSITION FOR NO. 1 PISTON.

2. Remove the fuel nozzle from the precombustion chamber for No. 1 cylinder.



MEASURING PISTON TRAVEL

1. 3S3263 Adapter Assembly. 2. 9M9268 Dial Indicator. 3. Precombustion chamber. 4. 3S3264 Rod. 5. Inlet port. 6. Piston. 7. Crankshaft.

3. Put the 3S3264 Rod in the 3S3263 Adapter Assembly. Put the 3S3263 Adapter Assembly in the precombustion chamber and tighten the adapter finger tight.

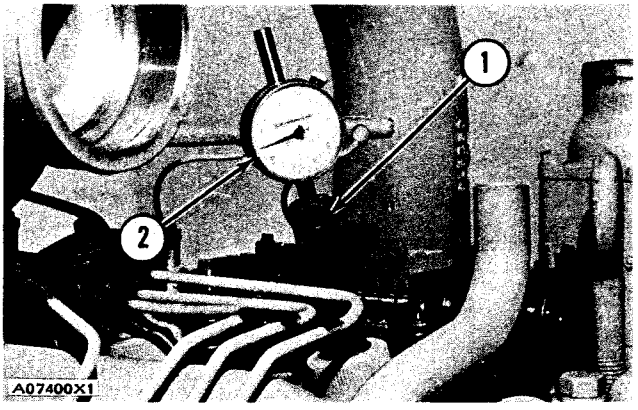
CAUTION: Do not use a wrench to tighten the adapter. There will be damage to the nozzle seat if the adapter is too tight.

4. Put the 9M9268 Dial Indicator in the adapter assembly. Make an adjustment to the dial indicator so both pointers are on "0" (zero).

5. Turn the crankshaft a minimum of 45° in the CLOCKWISE direction.

NOTE: The direction of rotation is given as seen from the flywheel end of the engine.

6. Turn the crankshaft in the counterclockwise direction until the No. 1 piston is at the top of its stroke. Adjust the dial indicator if necessary to put both of the dials at "0" (zero).

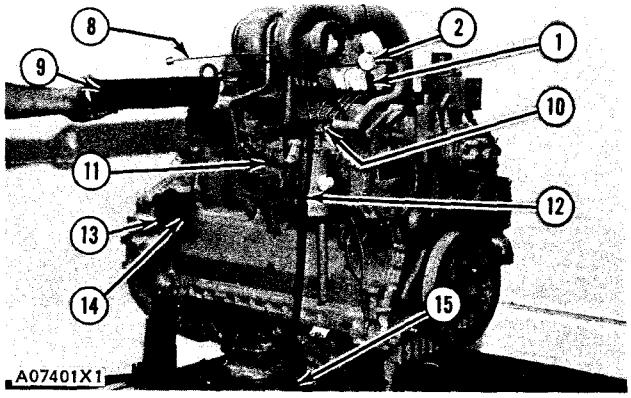


TIMING INDICATOR GROUP INSTALLED

1. 3S3263 Adapter Assembly. 2. 9M9268 Dial Indicator.

7. Disconnect the fuel line for No. 1 injection pump at the injection pump housing. Put the

7M1999 Tube Assembly (8) on No. 1 injection pump and tighten the nut. The position of the end of tube assembly (8) must be a little above horizontal as shown.



TYPICAL ARRANGEMENT FOR FUEL FLOW CHECK OF TIMING

1. 3S3263 Adapter Assembly. 2. 9M9268 Dial Indicator. 8. 7M1999 Tube Assembly. 9. Pan for holding fuel. 10. Orifice check valve. 11. Governor control shaft. 12. 5J4634 Hose Assembly. 13. 2P8294 Housing. 14. 2P8298 Gear Assembly. 15. 1P539 Pressure Tank.

8. Disconnect fuel supply line at the fuel filter. Use an adapter to connect the 5J4334 Hose Assembly to the fuel filter.

9. Disconnect the fuel return line from the orifice check valve. Put a cap on the orifice check valve.

10. Turn the crankshaft approximately 45° in a clockwise direction with the engine turning tools.

11. With 1 gal. (3.8 l) of clean fuel in the 1P539 Pressure Tank (5), move the governor control to full FUEL-ON position. Put 15 psi (1.1 kg/cm^2) of air pressure in the tank by using the hand pump or shop air.

CAUTION: If shop air is used, be sure to make an adjustment to the regulator so there is no more than 15 psi (1.1 kg/cm^2) air pressure in the tank.

12. Put a pan (9) under the end of tube assembly (8) for the fuel that comes out of the end of the line.

13. Turn the crankshaft slowly in counterclockwise direction. Do this until the flow of fuel coming from the end of the tube assembly (8) is 6 to 12 drops per minute. This is the point of closing inlet port.

14. Stop rotation of the crankshaft when the flow of fuel is 6 to 12 drops per minute. Take a reading of the measurement on the dial indicator.

15. Disconnect the 5J4634 Hose Assembly from the fuel filter.

16. Make a comparison of the reading on the dial indicator with the chart.

Timing Angle (Degrees Before Top Center)	Indicator Reading in.	Indicator Reading mm
10.5	.070	1.77
11.0	.077	1.95
11.5	.084	2.13
12.0	.092	2.33
*12.5	.099	2.51
13.0	.107	2.71
**13.5	.116	2.94
14.0	.124	3.14
14.5	.133	3.37
15.0	.142	3.60
15.5	.152	3.86

*Correct timing for 3304 Engines.
**Correct timing for 3306 Engines.

17. If the reading on the dial indicator (2) is the same as the chart, the timing of the fuel system is correct. If the reading on the dial indicator (2) is different from the chart make adjustment to the timing. Make reference to Checking Timing By Timing Pin Method for the correct method for adjusting the timing of the fuel system.

18. After adjusting the timing by the timing pin method, a check by the fuel flow method should show that the timing is correct. If the two methods do not give the same result, look for the reason and correct it.

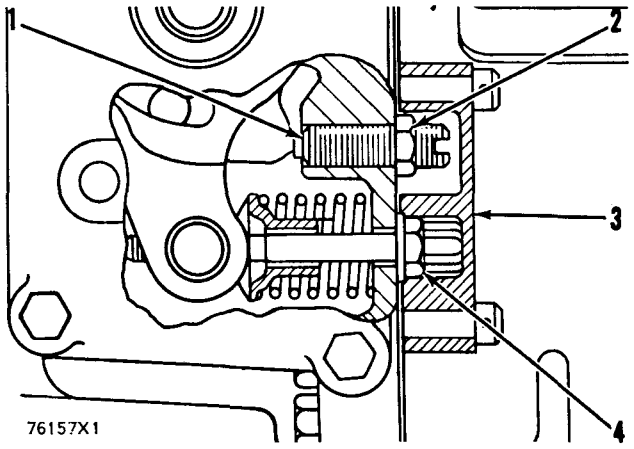
GOVERNOR ADJUSTMENTS

CAUTION: A mechanic that has the proper training is the only one to make the adjustment of low idle and high idle rpm. The correct low idle and high idle rpm, and the measurement for adjustment of fuel system setting are in the book RACK SETTING INFORMATION.

Check engine rpm with a tachometer that has good accuracy. If the low idle or high idle rpm needs an adjustment, use the following procedure:

1. Remove cover (3).

2. To make an adjustment to the high idle rpm, loosen locknut (2) and turn adjustment screw (1). Turning the screw in makes the engine run



LOCATION OF IDLE ADJUSTMENT SCREWS

1. High idle adjustment screw. 2. Locknut. 3. Cover. 4. Low idle adjustment bolt.

slower. Turning the screw out makes the engine run faster. Hold screw (1) and tighten locknut (2) after adjustment procedure is done.

3. To make an adjustment to the low idle rpm, turn bolt (4). Turning the bolt in makes the engine run faster. Turning the bolt out makes the engine run slower. Grooves in cover (3) hold bolt (4) and keep it from turning after adjustment is done and the cover is installed.
4. After each idle adjustment is made, move the governor lever to change the rpm of the engine. Now move the governor lever back to the point of first adjustment to check the idle adjustment. Keep doing the adjustment procedure until the low idle and high idle rpm are the same as given in RACK SETTING INFORMATION.

Checking Balance Point (Full Load Speed)

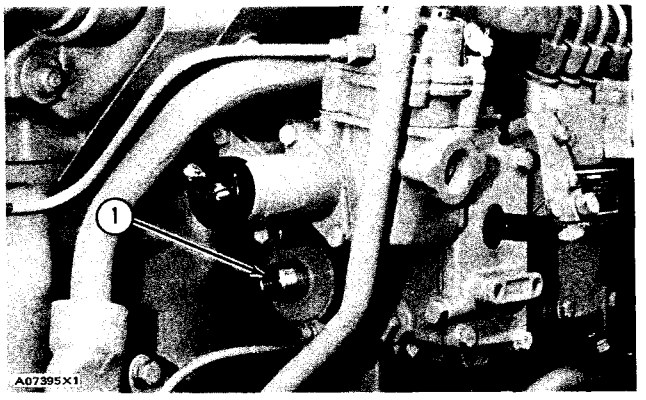
Checking the Balance Point of the engine is a fast way to make a diagnosis of engine performance.

The balance point for the engine is:

1. At full load speed.
2. The point where the load stop pin is against the load stop or torque spring.
3. The point where the engine gets the maximum amount of fuel.
4. The point where the engine has the most horsepower output.
5. The point where an increase in load on the engine puts the engine in a lug condition (a condition in which a small increase in load makes the engine speed get much less).

Procedure for Checking Balance Point

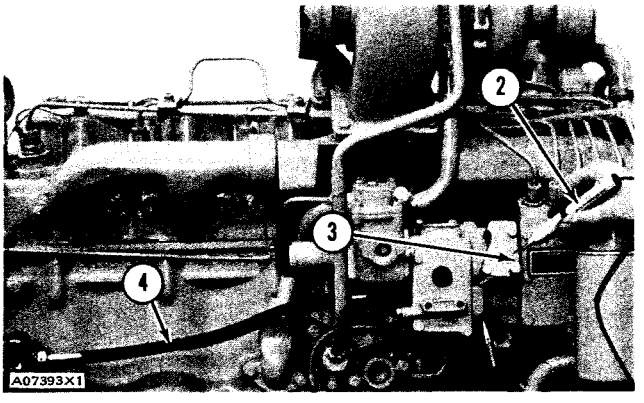
1. Connect a tachometer which has good accuracy to adapter (1) on the end of the fuel injection pump.



CHECKING BALANCE POINT

1. Adapter.

2. Connect a continuity light (2) to the brass terminal screw (3) on the cover for the load stop. Connect the other end of the light to a place on the fuel system which is a good electrical connection.
3. Start the engine.



CHECKING BALANCE POINT

2. Continuity light. 3. Brass terminal screw. 4. Tachometer drive shaft.

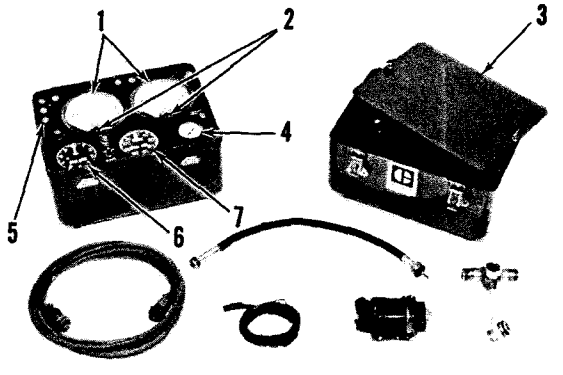
4. With the engine at operating temperatures, run the engine at high idle.
5. Make a record of the speed of the engine at high idle.
6. Add load on the engine slowly until the continuity light just comes on. This is the balance point.

7. Make a record of the speed at the balance point.
8. Repeat Step 6 several times to make sure that the reading is correct.
9. Stop engine. Make a comparison of the records from Steps 5 and 7 with the information from RACK SETTING INFORMATION.
10. If the high idle speed and balance point are correct, the fuel system is working correctly.
11. If there is a difference, make a change to the high idle to get the balance point correct.

CAUTION: Do not make the high idle speed more than the high idle speed plus the tolerance as given in Rack Setting Information.

Measuring Engine Speed

Most engines have a location where a tachometer drive adapter can be installed. On these engines, install the correct tooling and use the tachometer in the 4S6553 Engine Test Group, the 5P2150 Engine Horsepower Meter or the 1P5500 Portable Phototach Group.



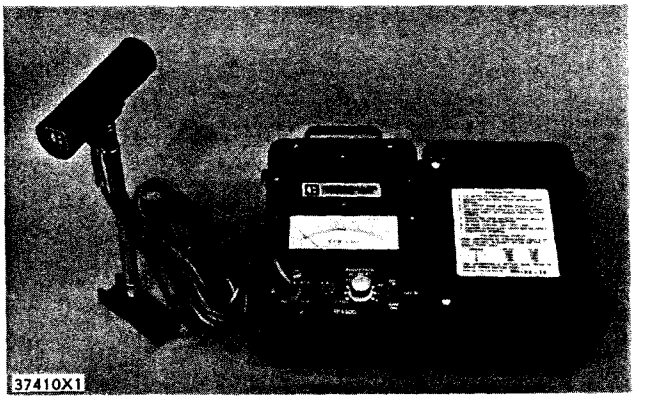
45689X1

4S6553 ENGINE TEST GROUP

1. 4S6992 Differential Pressure Gauges. 2. Zero adjustment screw. 3. Lid. 4. 8M2743 Gauge. 5. Pressure tap fitting. 6. 4S6991 Tachometer. 7. 4S6997 Manifold Pressure Gauge.

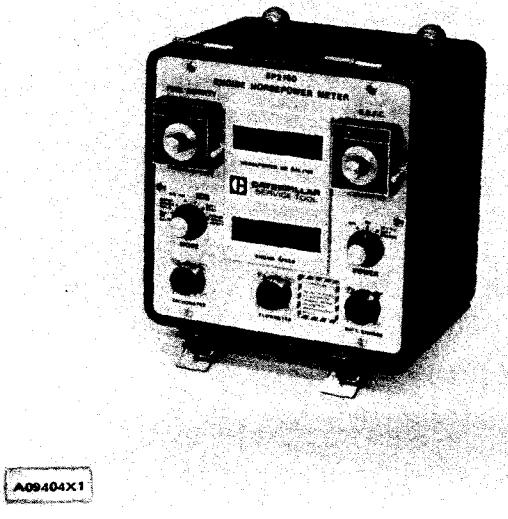
Special Instruction Form FEO36044 is with the 4S6553 Engine Test Group and gives instructions for the test procedure.

The 1P5500 Portable Phototach Group can measure engine speed from the tachometer drive on the engine. It also has the ability to measure engine speed from visible rotating parts of the engine. Special Instruction Form GMG00819 has instructions for its use.



37410X1

1P5500 PORTABLE PHOTOTACH GROUP



A09404X1

5P2150 ENGINE HORSEPOWER METER

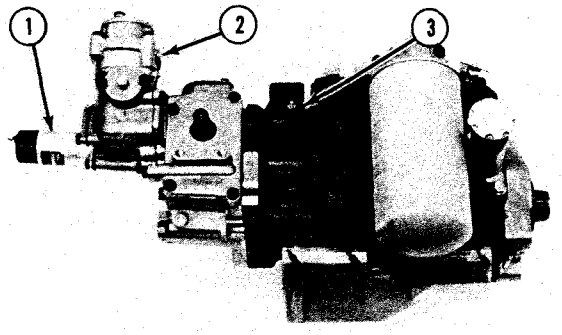
The 5P2150 Engine Horsepower Meter can measure engine speed from the tachometer drive on the engine. Special Instruction Form GEG02402 has instructions for its use.

FUEL SYSTEM SETTING

Tools Needed: 5P4203 Field Service Tool Group or 3P1550 Field Service Tool Group.

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

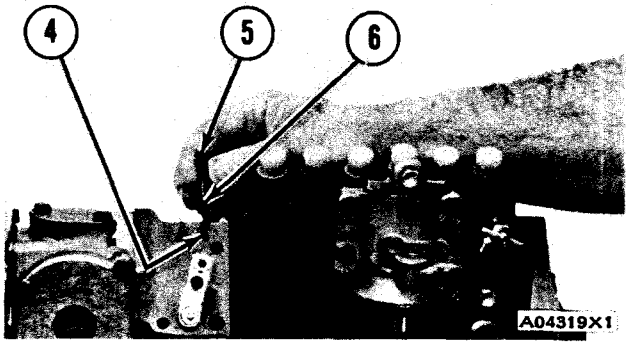
1. Disconnect the governor control linkage.
2. Remove the shutoff solenoid (1).
3. Remove the fuel ratio control (2).
4. Remove cover (3).



A04120X2

FUEL SYSTEM SETTING

1. Shutoff solenoid. 2. Fuel ratio control. 3. Cover.



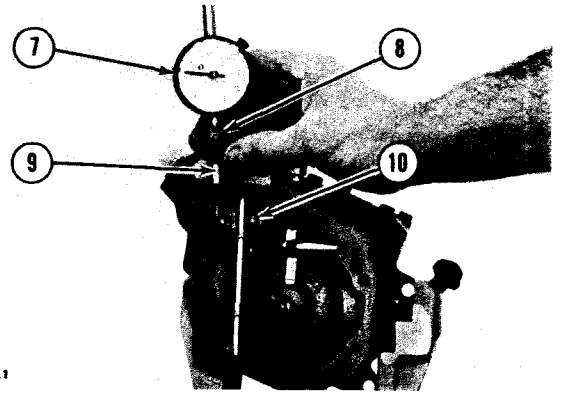
INSTALLATION OF PIN AND SPRING

4. Hole. 5. Spring. 6. 5P299 Pin, with 19.2831 on it.

5. Put 5P299 Pin (6) into hole (4).

6. Put cover (14) and spring (5) over pin (6). Use two 1D4533 Bolts and 1D4538 Bolt with flatwashers to hold cover (14) to the injection pump housing.

7. Put 8S7271 Screw in the hole over pin (6) and spring (5). Tighten the screw until, the pin is held against the injection pump housing.



A04316X1

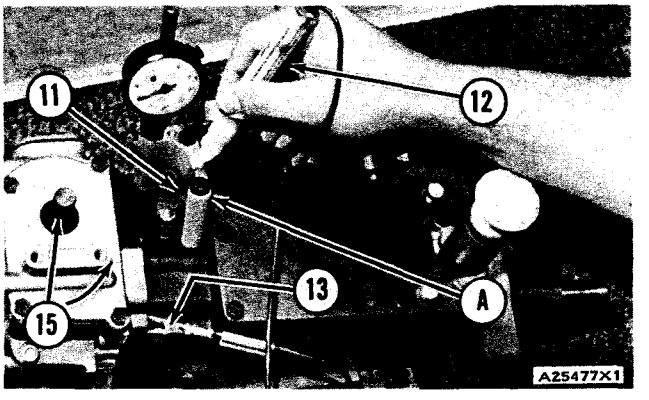
DIAL INDICATOR IN CONTACT WITH FUEL CONTROL SHAFT

7. Dial indicator. 8. Clamp. 9. Magnetic point. 10. Fuel control shaft.

8. Put clamp (8) in cover (14). Put 3P1569 Magnetic Point or 5P4809 Point on indicator (7) and install indicator (7) in clamp (8).

NOTE: If the indicator automatically goes to the extended position, use the 5P4809 Point. If the indicator does not automatically go to the extended position, use the 3P1569 Magnetic Point.

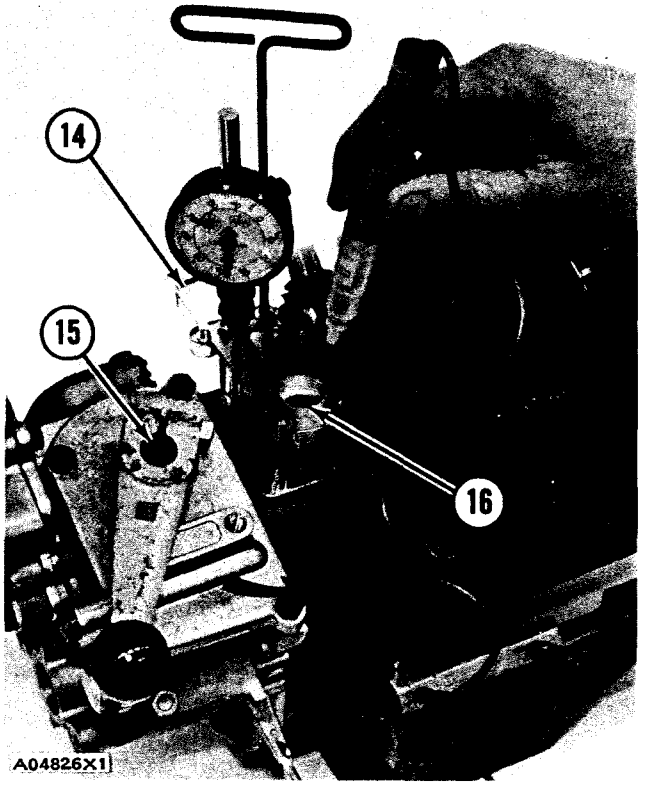
9. Turn the governor control shaft (15) in the direction shown and hold it at the full load position.



5P4226 ADAPTER INSTALLED

11. Contact. 12. 8S4627 Circuit Continuity Tester Light. 13. Clip. 15. Governor control shaft. A. 5P4226 Adapter.

NOTE: 5P4226 Adapter (A) is a replacement for cover (14) for fuel setting.



FUEL SYSTEM SETTING

14. Cover. 15. Governor control shaft. 16. Hole.

10. Make an adjustment to put both dials of the dial indicator (7) at zero.

11. Connect the clip end (13) of continuity light (12) to a good electrical ground. Put the other end of continuity light (12) in contact with the contact (11) as shown.

12. Turn the 8S7271 Screw counterclockwise. Turn it slowly until the continuity light just goes on.

13. Make a record of the reading on the dial indicator (7).

14. Do this procedure several times to make sure that the reading is correct.

15. Make a comparison of this reading and the FUEL SYSTEM SETTING from RACK SETTING INFORMATION. If the reading is not the same, make sure the governor control shaft is in the full load position. Then do Steps 7 through 14 again.

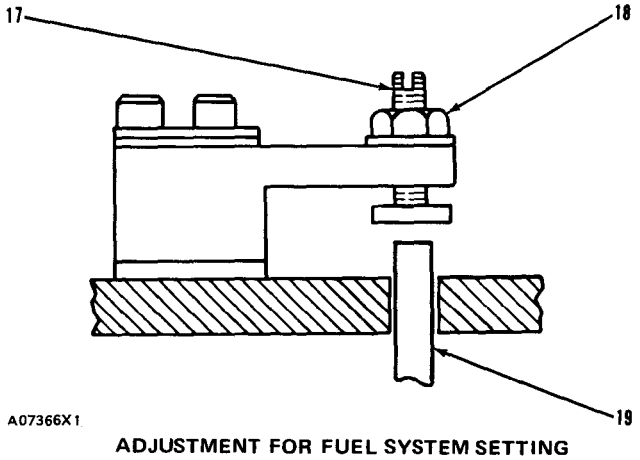
NOTE: The arrangement of the tooling for checking the fuel ratio control is the same as for checking the fuel setting. Make a reference to Fuel Ratio Control Setting at this point if a check of the fuel ratio control setting is desired.

16. If the reading on the dial indicator is not correct, do the following:

Load Stop Adjustment:

(Solid Load stop pin or Coil spring torque spring)

a. Put the 3P2210 Socket on locknut (18) through hole (16). Loosen the locknut and turn the torque control screw (17) with a screwdriver until the reading on the dial indicator (7) is correct. Tighten the locknut (18).



ADJUSTMENT FOR FUEL SYSTEM SETTING

17. Torque control screw. 18. Locknut. 19. Load stop pin or coil spring torque spring.

b. Check the adjustment by doing Steps 7 through 14 again.

c. When the adjustment is correct, install the fuel ratio control (2).

d. Remove the tooling and install the cover (3) and shutoff solenoid (1).

Leaf Type Torque Spring:

a. Write down the dimension that is on the dial indicator.

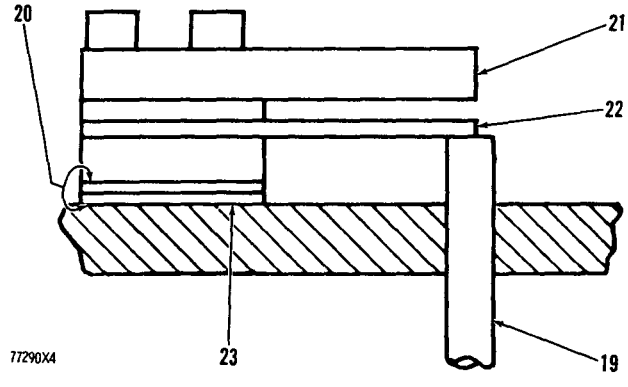
b. Write down the dimension given in the RACK SETTING INFORMATION.

c. Remove the test tools [cover (14), spring (5) and dial indicator (7)] from the injection pump housing.

d. Install or remove shims at location (20) to get the correct dimension as given in the RACK SETTING INFORMATION. The difference between the dimensions in (a) and (b) is the thickness and amount of shims to remove or install to get the correct setting.

e. Install correct amount of shims (23) torque spring (22) and stop bar (21) on the injection pump housing. Install the test tools on the injection pump housing and do the test procedure again. Remember the tester light must come on when the correct dimension is on the dial indicator.

f. Do the test procedure until the dimension on the dial indicator is the same as the dimension given in the RACK SETTING INFORMATION. After fuel system setting is correct, remove the fuel system setting tools and install cover (3).



LEAF TYPE TORQUE SPRING

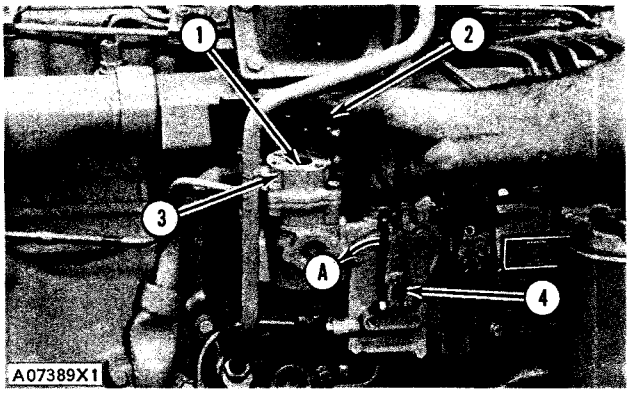
19. Load stop pin. 20. Location of shims. 21. Stop bar. 22. Leaf type torque spring. 23. Shims.

FUEL RATIO CONTROL SETTING

NOTE: The following procedure can be done with the fuel system either on or off the engine. In either way, damage to the fuel system can be the result if dirt gets into the fuel system.

The adjustment of the Fuel Setting must be correct before making checks or adjustments to the Fuel Ratio Control.

Make a reference to Fuel System Setting for the correct procedure for checking and making adjustments to the Fuel System Setting.



MAKING ADJUSTMENT TO FUEL RATIO CONTROL

1. Bolt. 2. Cover. 3. Body. 4. Governor control shaft. A. Direction for full fuel position.

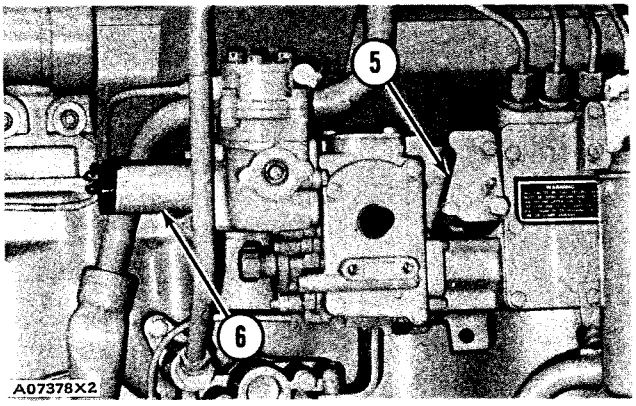
1. With the tooling still installed from the procedure Fuel System Setting, turn the 8S7271 Screw in until the 5P299 Pin is against the fuel injection housing.
2. Make an adjustment if necessary to make the reading of both dials on the dial indicator be zero.
3. Turn 8S7271 Screw out 6 or more turns. Move the governor control shaft to the full load position. The reading on the dial indicator must be the same as the Fuel Ratio Control Setting on the ENGINE INFORMATION plates or in Rack Setting Information.

NOTE: The reading on the dial indicator has a tolerance of ± .004 in. (± 0.10 mm). This tolerance is for the turning of bolt (1) for the alignment of the bolt holes in the cover (2).

4. If the reading is not correct, remove the cover (2). Turn the bolt (1) with the cover (2) until the reading on the dial indicator is correct. Be sure that the governor control shaft (4) is turned to the full fuel position.
5. Install cover (2).

NOTE: If the bolt holes in the cover (2) are not in alignment with bolt holes in the body (3), turn the bolt (1) with the cover (2) to put the bolt holes in the cover in alignment with the nearest holes on the body (3).

6. Remove the tooling and install cover (5), shutoff solenoid (6) and governor control linkage.



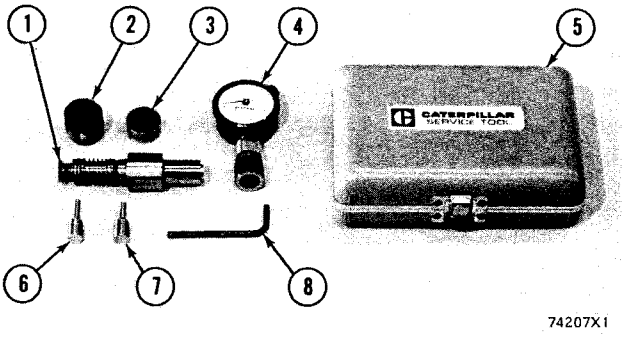
FUEL SYSTEM

5. Cover. 6. Shutoff solenoid.

FUEL PUMP CALIBRATION

Tools Needed: 3P2200 Tool Group. The following tools from 3P1550 Tool Group are also needed: 8S2243 Wrench, 2P8331 Cover, 4B4276 Washer (two), 8S7271 Screw, 1D4533 Bolt (two), 1D4538 Bolt, 3K6896 Washer, 3J6956 Spring, 2H3740 Bolt.

Refer to Special Instruction (FM035709) for complete and detailed instructions for fuel pump calibration.



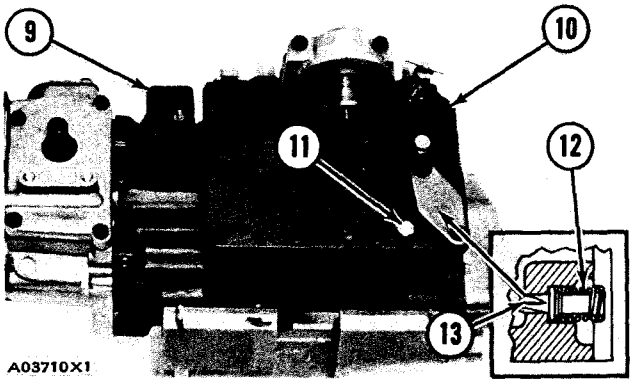
3P2200 TOOL GROUP

1. 3P1540 Calibration Pump. 2. 4N218 Bushing. 3. 1P7379 Microgage. 4. 3P1568 Dial Indicator with 3P2226 Base. 5. 2P5519 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.

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

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

1. Remove plug (11) from the cover (10) of the housing for the fuel injection pumps.



REMOVAL OF COVERS

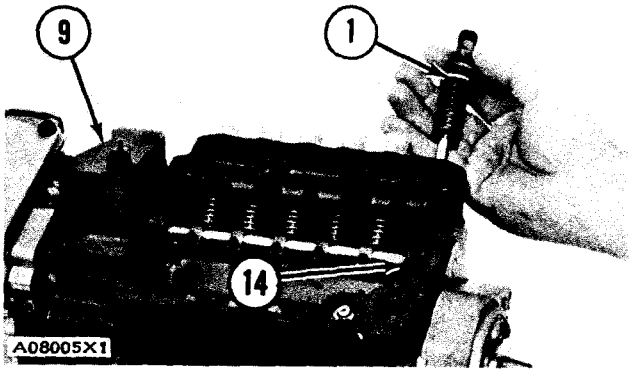
9. Cover. 10. Cover for injection pump housing. 11. Plug. 12. Spring for bypass valve. 13. Bypass valve.

2. Hold a container under the pump housing for the fuel that comes out of the hole for plug (11).

3. Remove cover (10).

NOTE: Cover (10) has a bypass valve and spring behind it in the injection pump housing.

4. Use the 8S2243 Wrench and remove the injection pump that is going to be calibrated.

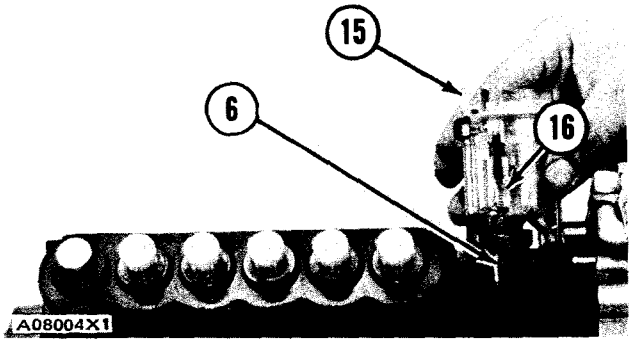


INSTALLING 3P1540 CALIBRATION PUMP

1. 3P1540 Calibration pump. 9. Cover. 14. Lever.

5. Put calibration pump (1) in the injection pump housing with flat on plunger of pump toward tang on lever (14). When calibration pump (1) is all the way in the bore, turn the calibration pump approximately 45° so the tang on lever (14) fits in groove in the plunger. Install 4N218 Bushing. Tighten bushing to 70 ± 5 lb.ft. (9.7 ± 0.7 mkg).

6. Remove cover (9).



INSTALLING CALIBRATION PIN

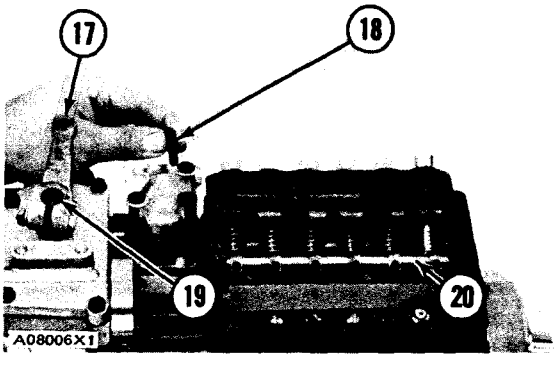
6. 3P1545 Calibration Pin with 17.3734 on it. 15. 2P8331 Cover. 16. 3J6956 Spring.

7. Put the 3P1545 Calibration Pin, (6) with 17.3734 on it, in calibration hole as shown.

8. Put the 2P8331 Cover (15) over the calibration pin (6). DO NOT put a gasket under the 2P8331 Cover (15). Use two 1D4533 bolts, two 4B4276 Washers and a 1D4538 Bolt to hold 2P8331 Cover (15) on the injection pump housing.

9. Put the screw (18) in the hole over calibration pin (6). Tighten the screw just enough to hold the calibration pin (6) against the top of the injection pump housing.

10. Disconnect the governor control linkage from the end of lever (17). If there is no lever on the governor control shaft (19), install a lever for test purposes.



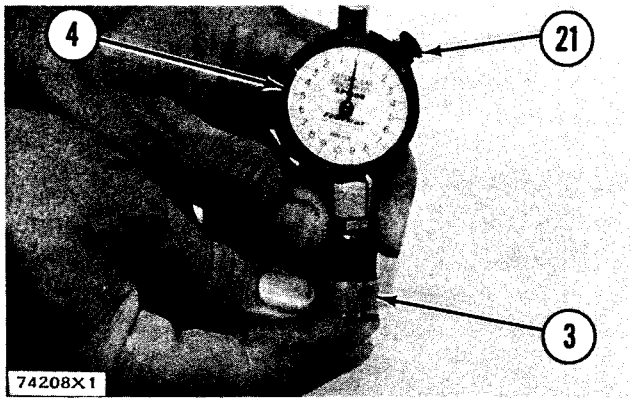
INSTALLING 8S7271 SCREW

17. Lever. 18. 8S7271 Screw. 19. Governor control shaft. 20. Sleeve control shaft.

11. Move lever (17) in counterclockwise direction

to put the sleeve control shaft in the full load position.

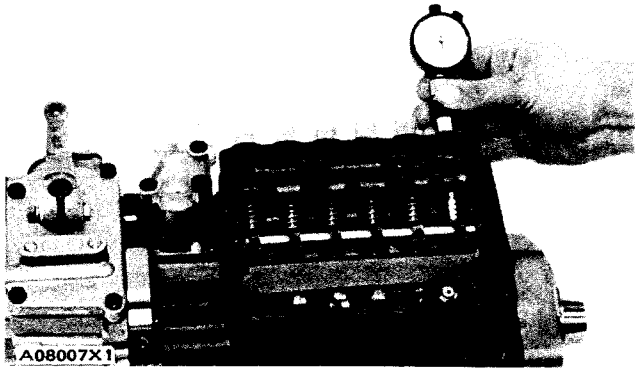
12. Put dial indicator (4) on microgage (3) and make an adjustment so the dial is on zero. Hold the indicator on zero with lockscrew (21). Check the adjustment again and make sure the pointer on dial indicator is set correctly and not one revolution off.



PUTTING DIAL INDICATOR ON ZERO

3. 1P7379 Microgage. 4. 3P1568 Indicator with 3P2226 Base. 21. Lockscrew.

13. With governor lever in FULL LOAD position, put dial indicator (4) on calibration pump and hold it tightly in place. Look at the dimension on the dial indicator. If the dimension is 0 ± 0.005 mm, lever (16) is calibrated correctly for that pump. If the dimension is not correct check again by doing Steps 11 and 12 again.

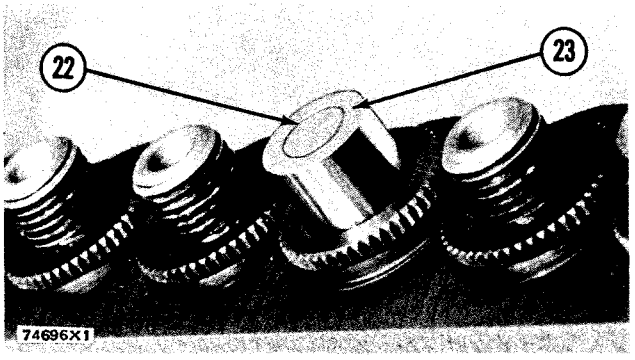


CHECKING PUMP CALIBRATION

If a pump needs adjustment use the following procedure.

NOTE: The governor control lever must be held in the FULL LOAD position for accuracy in checking and making adjustments to the fuel pump calibration.

a. Use wrench (8) to loosen the screw that holds lever (14) on shaft (20). Loosen the screw just enough so lever (14) can be moved (up or down) on shaft (20).



POSITION OF PLUNGER

22. Plunger. 23. Top surface of calibration pump.

NOTE: Move the lever and put plunger (22) of the calibration pump almost even with top surface (23) of the calibration pump.

b. With wrench (8) in the screw for lever (14) and dial indicator held tightly on top of the calibration pump, use wrench (8) to move lever (14) until the dimension on the dial indicator is zero.

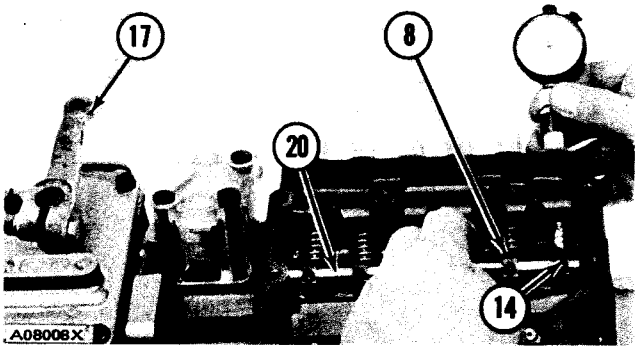
NOTE: To keep from having error, move the lever (14) so the top of plunger (22) is below the top surface (23) of calibration pump. Then slowly move the lever (14) so the plunger (22) moves up until the dimension on the dial indicator is zero.

Tighten the screw to 24 ± 2 lb. in. (27.7 ± 2.3 cm.kg).

c. After the screw is tightened, use the dial indicator to check the adjustment again.

14. The calibration of each pump can be checked using this same procedure. The 1P7379 Microgage must be used to put the dial indicator on zero before the calibration of each pump is checked.

15. If a pump is checked and an adjustment is made, check adjustment again after the lever screw is tightened.



CALIBRATION OF AN INJECTION PUMP

8. 1S9836 Wrench. 14. Lever. 17. Lever. 20. Sleeve control shaft.

SCROLL FUEL SYSTEM

Difficulty within the fuel system can be classed in one of two groups: lack of fuel or too much fuel for proper combustion.

Many times the fuel system is blamed when the fault lies elsewhere, especially when smoky exhaust is the problem. Smoky exhaust can be the result of a faulty fuel injection valve, but it can also be caused by lack of air for complete combustion, overloading at high altitude, excessive oil burning or lack of compression.

VISUAL INSPECTION

1. Observe the fuel pressure gauge reading. Lack of pressure indicates difficulty in the supply side of the system.
2. Check the fuel level in the supply tank and the fuel tank cap vent for being plugged.
3. See that the vent valve is closed.
4. Check for leakage in the fuel supply lines and components or for a kinked or restricted supply line.
5. Replace the fuel filter element and clean the primary fuel filter if so equipped.
6. Inspect the fuel bypass valve to see that it moves freely and that dirt is not holding the plunger off its seat. Be certain the spring has correct tension.
7. Bleed the fuel system to remove trapped air.

TESTING FUEL INJECTION EQUIPMENT

A simple check can be made to determine which cylinder is misfiring or causes puffing black smoke. With the engine running at a speed which makes the defect most pronounced, momentarily loosen the fuel line nut on an injection pump sufficiently to "cut out" the cylinder. Check each cylinder in the same manner. If one is found where loosening makes no difference in the irregular operation or causes puffing black smoke to cease, the pump and valve for only that cylinder need be tested.

Checking Fuel Injection Valve

Examine fuel injection valves for:

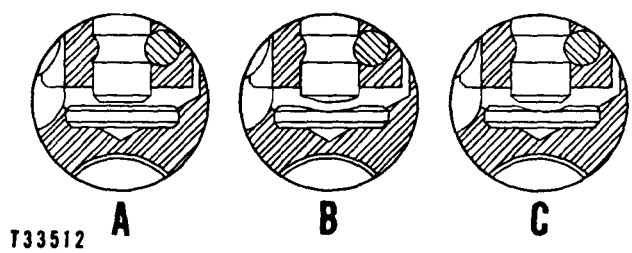
1. Excessive carbon on tip of nozzle or in orifice.
2. Erosion of the orifice.
3. Screen plugged with dirt.

The condition of a capsule-type nozzle assembly can be tested on the Caterpillar Diesel Fuel Injection Test Apparatus, and the rate of leakage of the nozzle assembly can be determined.

Checking Fuel Injection Pump Lifter Washer and Pump Plunger

The timing dimension should be checked and adjusted, if necessary, by setting the fuel injection pump timing dimension with the fuel injection pump off the engine. This will assure that the point of the fuel injection is correct. If the timing dimension is too small, injection will begin early, and if too great, injection will be late.

When pump plunger wear becomes excessive, the lifter washer may also be worn so it will not make full contact with the end of a new plunger. To avoid rapid wear on the end of the new plunger, replace the lifters having washers showing visible wear.



WEAR BETWEEN LIFTER WASHER AND PLUNGER
Fig. A illustrates the contact surfaces of a new pump plunger and a new lifter washer. In Fig. B the pump plunger and lifter washer have worn considerably. Fig. C shows how the flat end of a new plunger makes poor contact with a worn lifter washer, resulting in rapid wear to both parts.

A pump can maintain a satisfactory discharge rate and yet be unserviceable because of delayed timing resulting from wear on the lower end of the plunger. When testing a pump which has been in use for a long time, check the plunger length with a micrometer. Discard the pump if the plunger measures less than the minimum length (worn) dimension.

FUEL PUMP PLUNGER	
Length (new)	2.5934 ± .0015 in. (65.872 ± 0.038 mm)
Minimum permissible length (worn)	2.5869 in. (65.707 mm)

Inspect the upper diameter of the plunger for wear. Performance of pumps worn in this manner can be checked as described in the Instructions for Fuel Injection Test Apparatus.

:UEL INJECTION SERVICE

Fuel Injection Valve

When installing a fuel injection valve, always :heck the seats of both the nozzle and the precombustion chamber. The nozzle assembly should be only finger-tight on the body. It is important to maintain the nozzle retaining nut torque to 105 ± 5 lb. ft. (14.5 ± 0.7 mkg). EXCESSIVE TORQUE will damage the nozzle. LESS TORQUE will allow the nozzle to leak and may cause the nozzle case to bulge or split.

Fuel Injection Pump

Use an 8S4613 Wrench and 8S2244 Extractor to remove and install fuel injection pumps.

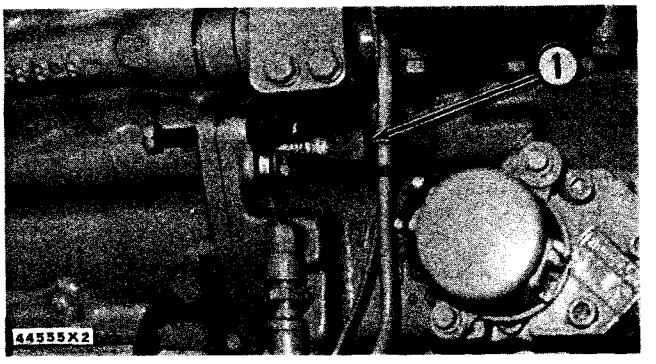
When removing fuel injection pumps, spacers and lifters the components should be kept together and marked so they can be installed in their respective locations.

While disassembling fuel injection pumps, exercise considerable care to prevent damage to the plunger surfaces. The barrel and the plunger are matched and are not interchangeable. Use extreme care when inserting the plunger into the bore of the barrel.

Fuel Pump Installation

The installation of fuel injection pumps requires that the lifter be at a low point and the fuel rack be centered or at "zero" position. To center or "zero" the rack, install the 7S7113 Rack Setting Gauge and set it at .000 in., retract the speed limiter, and move the rack in "fuel on" direction until it contacts the gauge. To install the pump, sight down the pump and align notches in bonnet and barrel with slot in the pump gear segment. Slot is 180° from pump gear segment center tooth. Position the notches in bonnet and barrel to align with dowels in the housing. Install the pump. Keep a downward force (by hand) on the pump and install bushing finger-tight, until flush with top of housing. If the bushing can not be assembled this far finger-tight, remove the pump. Align components and install again. Tighten the retaining bushing to 150 ± 10 lb. ft. (20.7 ± 1.4 mkg). With less torque the pump will leak. If the torque value is greater, the housing can be damaged.

Total rack travel, approximately .800 in. (20.32 mm), will be reduced if the pump is installed one or more teeth off in either the "fuel on" or "fuel off" side of its gear segment. The only way to check for correct installation of pumps with engine stopped is to measure full rack travel with the entire governor removed, including piston and valve mechanism.



RACK SETTING GAUGE INSTALLED

1. 7S7113 Rack Setting Gauge. A 9S240 Rack Positioning Tool Group can also be used.

NOTE: With the fuel injection pump housing removed, full rack travel can be checked with the 7S7113 Rack Setting Gauge but, FT960 Adapter Assembly must be used.

EXAMPLE OF RACK TRAVEL

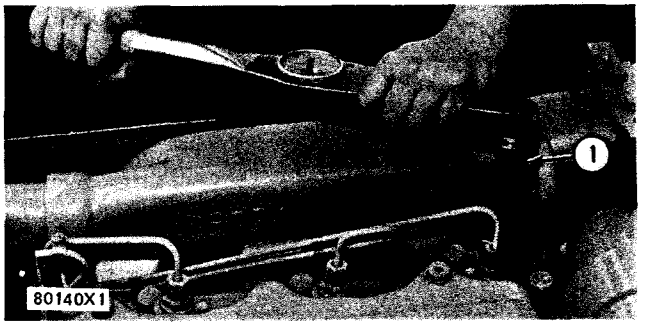
TEETH OFF	TOTAL RACK TRAVEL		TRAVEL FROM CENTER POSITION		TOTAL TRAVEL REDUCTION	
	in.	mm	in.	mm	in.	mm
0	.8	20.3	.4	10.2	0	0.0
1	.6	15.2	.3	7.6	.2	5.1

Similar results can be obtained for 2 & 3 teeth off, however, reduction in rack travel is greater but not proportional.

Fuel Injection Lines

Fuel from the fuel injection pumps is sent through the fuel injection lines to the fuel injection valves.

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.



TIGHTENING THE NUT OF A FUEL INJECTION LINE
(Typical Example)

1. 5P144 Fuel Line Socket.

The nuts that hold a fuel injection line to an injection valve and injection pump must be kept tight. Use a torque wrench and the 5P144 Fuel Line Socket (1) to tighten the fuel line nuts to 30 ± 5 lb. ft. (4.1 ± 0.7 mkg).

Fuel Bypass Valve

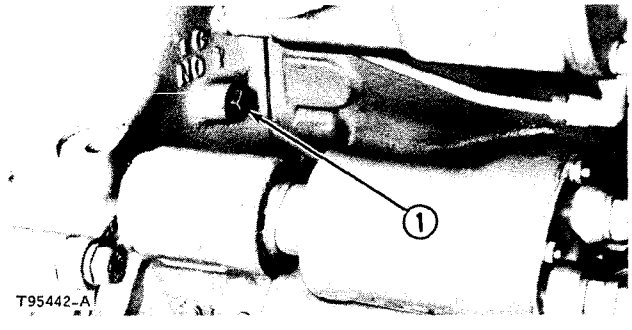
The fuel bypass valve should control fuel pressure to the fuel injection pump at full speed to a pressure of 25 to 32 psi (1.8 to 2.2 kg/cm^2).

LOCATING TOP CENTER COMPRESSION POSITION FOR NO.1 PISTON

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

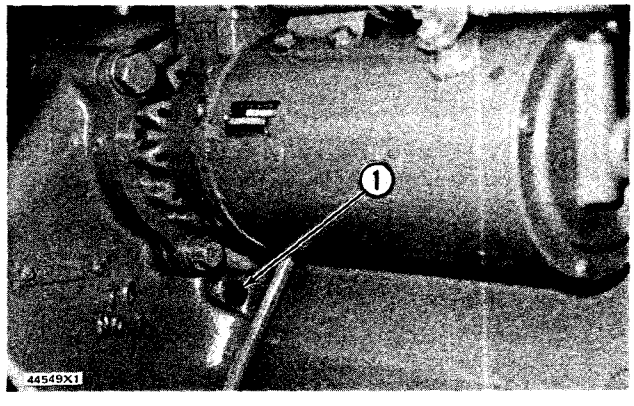
Remove the valve and rocker arm cover (the two valves at the front of the engine are the inlet and exhaust valves for No.1 cylinder). Remove the plug on the front of the flywheel housing.

Rotate the crankshaft counterclockwise (as viewed from the flywheel end) at least 60°, until both the inlet and exhaust valves of No.1 cylinder are closed.



LOCATING TOP CENTER

1. Bolt.



LOCATING TOP CENTER

1. Bolt.

Insert a 3/8" - 16 NC bolt (1), of proper length, in the timing plug hole in the flywheel housing, and screw the bolt into the threaded hole in the flywheel. The No.1 piston is now positioned at top center (TC) on compression.

FUEL SYSTEM ADJUSTMENTS

Checking Fuel Injection Pump Timing; On Engine

The timing dimension should be checked and reset, if necessary, to account for slipped accessory drive shaft tapered sleeve or worn timing gears. The timing dimension can be checked in either of the following manners.

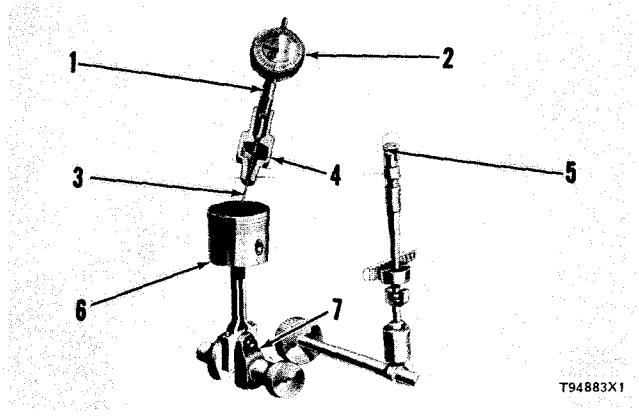
Checking with 1P540 Flow Checking Tool Group and 3S2954 Timing Indicator Group

Tools Needed: 1P540 Flow Checking Tool Group
3S2954 Timing Indicator Group
9M9268 or 9S215 Dial Indicator

Before performing flow check, locate (TC) compression position for No.1 piston.

Refer to Special Instruction (FM035709) for complete and detailed instructions for the fuel flow method of engine timing.

Travel of piston (6), from point of closing inlet port (5) to top center, can be found by using the 3S2954 Timing Indicator Group. Convert the travel of piston (6) into degrees to determine if engine timing is correct.



MEASURING PISTON TRAVEL

1. 3S3263 Adapter. 2. 9M9268 or 9S215 Dial Indicator. 3. 3S3264 Rod. 4. Precombustion chamber. 5. Inlet port. 6. Piston. 7. Crankshaft.

The 1P540 Flow Checking Tool Group is used to pressurize the fuel system. Maintain 10 to 15 psi (0.70 to 1.05 kg/cm^2) fuel pressure with the 1P539 Tank Assembly. This can be done with hand pump provided with the tank assembly, or connecting shop air to the tank assembly.

Consult chart to find angle corresponding to indicator reading. At the indicator reading and timing angle specified, fuel flow from the injection

pump should be reduced to 6 to 12 drops per minute [point of closing inlet port (5)].

INDICATOR READING		TIMING ANGLE
.077 in.	1.95 mm	11°
.092 in.	2.33 mm	12°
*.099 in.	2.51 mm	12.5°
.107 in.	2.71 mm	13°
**.116 in.	2.94 mm	13.5°
.124 in.	3.14 mm	14°
.142 in.	3.60 mm	15°

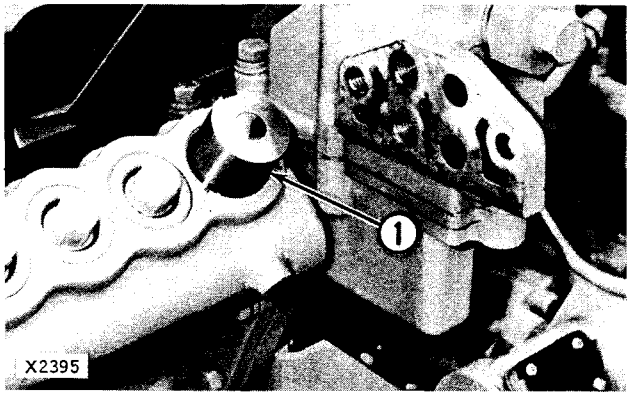
*Specified timing for 4 cylinder engine
**Specified timing for 6 cylinder engine

Checking with 8S4620 or 8S4618 Gauge

Tools Needed: 8S4618 Fuel Pump Lifter Gauge or 8S4620 Fuel Pump Lifter Gauge, 8S5417 Timing Fixture Plate, 8S4613 Wrench, 8S2244 Extractor

1. Locate (TC) compression position for No.1 piston.

2. Remove No.1 fuel injection pump with 8S4613 Wrench and 8S2244 Extractor. Insert fuel pump lifter gauge (1) into fuel pump bore (4).

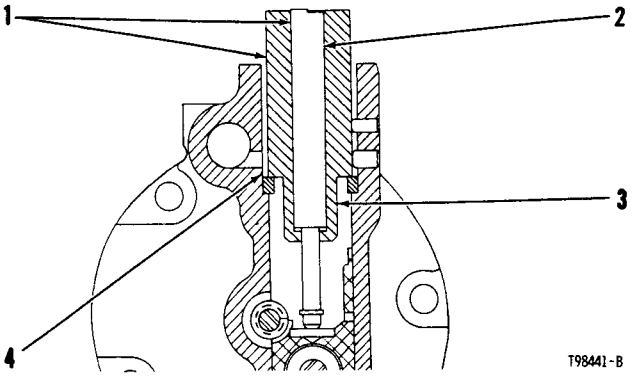


FUEL PUMP LIFTER GAUGE INSTALLED

1. 8S4620 Gauge for four cylinder engines and 8S4618 Gauge for six cylinder engines.

3. With gauge seated in fuel pump bore, the higher step of the plunger (2) must be slightly above the top surface of the gauge body (3). The lower step of the plunger must be just below the top surface of the gauge body.

NOTE: If plunger (2) of gauge (1) is in the position as stated in Step 3, rotate the crankshaft in the direction of normal rotation and observe the movement of plunger (2). Plunger (2) must rise. If plunger (2) does not rise, refer to ACCESSORY DRIVE SHAFT TIMING.



FUEL PUMP LIFTER GAUGE INSTALLED

1. Fuel pump lifter gauge. 2. Plunger. 3. Gauge body. 4. Fuel pump bore.

4. If the plunger in the gauge is not in the position stated in Step 3, check the accessory drive shaft timing. See ACCESSORY DRIVE SHAFT TIMING.

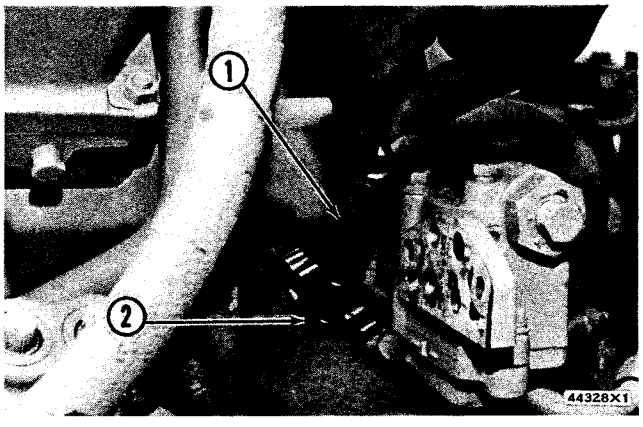
5. If the accessory drive shaft timing is correct and the lifter gauge plunger was not in the position stated in Step 3, the pump timing dimension setting must be corrected. See FUEL INJECTION PUMP TIMING DIMENSION SETTING; OFF ENGINE.

Checking with 8S7167 Gauge

Tools Needed: 8S7167 Gauge
6F6922 Depth Micrometer, 4 to 5 in. (101.6 to 127.0 mm) rod
8S4613 Wrench, 8S2244 Extractor

1. Locate (TC) compression position for No.1 piston.

2. Remove No.1 fuel injection pump with 8S4613 Wrench and 8S2244 Extractor. Insert gauge (2) into the housing fuel pump bore.



CHECKING TIMING DIMENSION SETTING
(Typical Example)

1. 6F6922 Depth Micrometer, 4 to 5 in. (101.6 to 127.0 mm) rod. 2. 8S7167 Gauge.

3. The correct timing dimension setting using depth micrometer (1) is:
Four cylinder: 4.2216 ± .0020 in. (107.229 ± 0.051 mm).
Six cylinder: 4.2179 ± .0020 in. (107.135 ± 0.051 mm).
4. If the timing dimension setting measurement is not correct, check the accessory drive shaft timing. See ACCESSORY DRIVE SHAFT TIMING.
5. If the accessory drive shaft timing is correct and the timing dimension setting measurement was incorrect, the timing setting must be corrected. See FUEL INJECTION PUMP TIMING DIMENSION SETTING; OFF ENGINE.

Fuel Injection Pump Timing Dimension Setting; Off Engine

Tools Needed: 1F8747 Timing Plate, 8S7167 Gauge 8S4613 Wrench and 8S2244 Extractor 6F6922 Depth Micrometer, 4 to 5 in. (101.6 to 127.0 mm) rod

The off engine method will result in correct fuel injection timing only if the pump housing is installed on a new engine or an engine with new timing gears, accessory drive shaft and fuel pump camshaft. The off engine setting adjusts for wear in the fuel injection pump housing only. The accessory drive shaft timing adjusts for wear in the timing gears, accessory drive shaft and fuel pump camshaft coupling.

1. Install the pointer assembly on the fuel injection pump housing.
2. Place 1F8747 Timing Plate on the drive end of the camshaft. Secure the plate to the camshaft.
3. Refer to the chart and select the timing plate degree setting for the lifter being checked or set. Set the timing plate by rotating it counterclockwise until the proper degree setting aligns with the pointer assembly. Lock in position with the lockscrew.

LIFTER SETTING IN DEGREES (OFF ENGINE)		
LIFTER NO. (Numbered consecutively front to rear)	TIMING PLATE DEGREES	
	4 Cyl.	6 Cyl.
1	179°	178.5°
2	89°	58.5°
3	269°	298.5°
4	359°	118.5°
5		238.5°
6		358.5°

NOTE: Fuel injection pump removal is made with an 8S4613 Wrench and 8S2244 Extractor.

4. The fuel injection pump timing dimension (off engine), using the 8S7167 Gauge and the 6F6922 Depth Micrometer is 4.2675 ± .0020 in. (108.395 ± 0.051 mm).
5. The spacer must be changed to change the timing dimension. See the SPACER CHART.

SPACER NO.	SPACER THICKNESS	
5M2697	.170"	4.32 mm
2M4208	.174"	4.42 mm
2M4209	.178"	4.52 mm
2M4210	.182"	4.62 mm
2M4211	.186"	4.72 mm
2M4212	.190"	4.83 mm
5M2691	.194"	4.93 mm
5S7189	.198"	5.03 mm

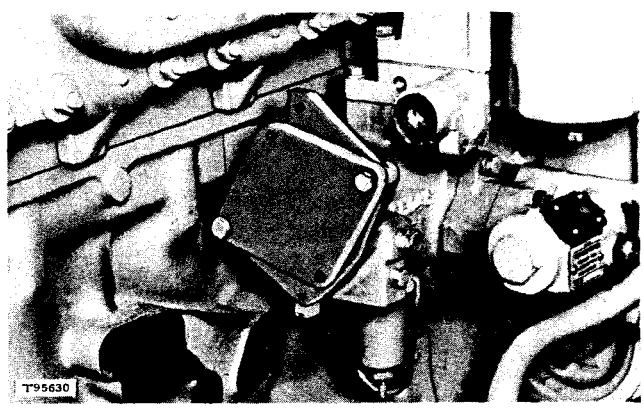
6. If all timing dimensions are to be checked or reset, continue the same procedure in the firing order of the engine. Recheck each timing dimension after the adjustment has been made.

NOTE: The accessory drive shaft must be positioned correctly in relation to the engine crankshaft, before the fuel injection pump housing is installed.

Accessory Drive Shaft Timing

Tools Needed: 8S5417 Timing Fixture Plate 8S2264 Puller Group 8S8375 Sleeve 8B7561 Step Plate

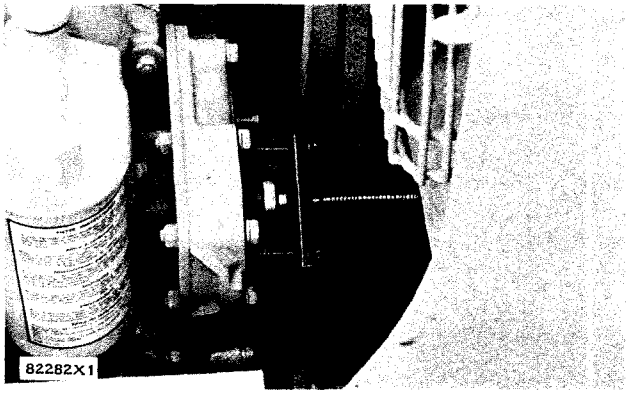
1. Put No.1 piston at top center (TC) on the compression position. Make reference to LOCATING TOP CENTER COMPRESSION POSITION FOR NO.1 PISTON.
2. Remove the injection pump housing from the engine.
3. Install the 8S5417 Timing Fixture Plate on the rear face of the accessory housing, dowels aligned and bolts installed as illustrated.



8S5417 TIMING FIXTURE PLATE INSTALLED

NOTE: If the timing fixture plate can be installed, the timing is correct. If the timing fixture plate can not be installed, use the following procedure.

4. Loosen the alternator and remove the belt (or belts) from the alternator pulley.
5. Remove the small cover from the front housing.
6. Remove the nut and washer that hold the accessory drive gear on the accessory drive shaft.
7. Use the tools as illustrated and make the accessory drive gear loose on the accessory drive shaft.



TOOLS INSTALLED
(3306 Engine Illustrated)

Tools Needed: 8S2264 Puller Group, 8S8375 Sleeve, 8B7561 Step Plate, two 3/8 in. 24-NF Bolts, 3.50 in. (88.9 mm) long and two flat washers.

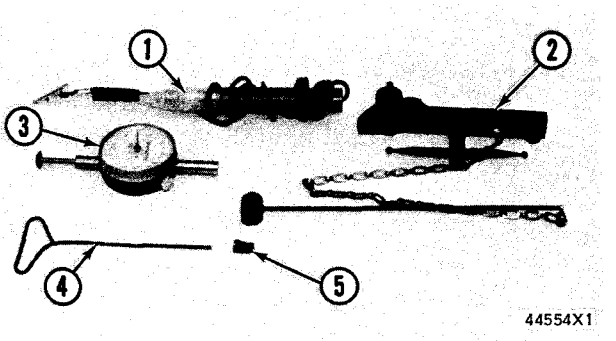
NOTE: Remove the fan guard if it prevents installing the 8S2264 Puller Group.

8. Remove the puller tools and turn the accessory drive shaft in the direction necessary to install the 8S5417 Timing Fixture Plate.
9. With the 8S5417 Timing Fixture Plate installed correctly, put the washer on the accessory drive shaft with the large diameter against the gear. Install the nut and tighten the nut to 100 ± 10 lb. ft. (13.8 ± 1.4 mkg).
10. Remove the 8S5417 Timing Fixture Plate and install cover (1).
11. Turn the camshaft of the injection pump so it is in alignment with the end of the accessory drive shaft. Install the injection pump housing on the engine. Make all necessary connections and installation of components that were removed or disconnected.
12. The injection pump camshaft is now timed to No.1 cylinder.

FUEL RACK SETTING

Rack Positioning Tool, Dial Indicator and Circuit Tester Method:

Tools Needed: 9S240 Rack Positioning Tool Group and 4B9820 Wrench



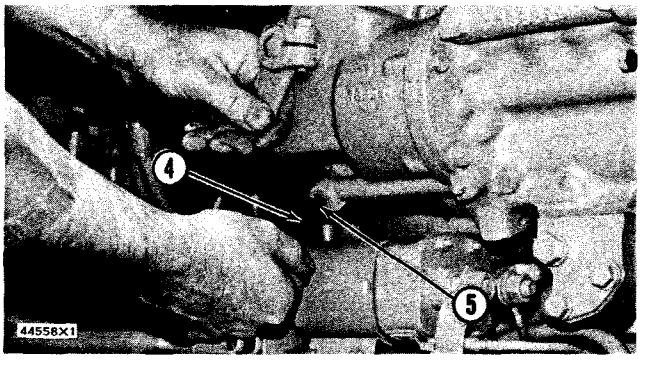
PARTS OF 9S240 RACK POSITIONING TOOL GROUP

1. 8S4627 Circuit Tester. 2. 9S238 Rack Positioning Bracket Group. 3. 9S215 Dial Indicator. 4. 9S8521 Rod. 5. 9S8518 Plug.

The 9S238 Rack Positioning Bracket Group makes it possible to measure rack position, during normal operation of the engine. The ability to observe rack position during operation, can provide most of the needed data to determine actual horsepower output and diagnose the cause for lack of power.

CAUTION: Do not attempt to adjust rack setting with engine running. Always stop the engine before adjusting rack setting.

1. Refer to the RACK SETTING INFORMATION to obtain the correct rack setting dimension.
2. Disconnect the governor control linkage, at the most convenient location, so the governor control lever moves freely throughout its entire length of travel.



DEPRESSING PLUNGER
(Typical Example)

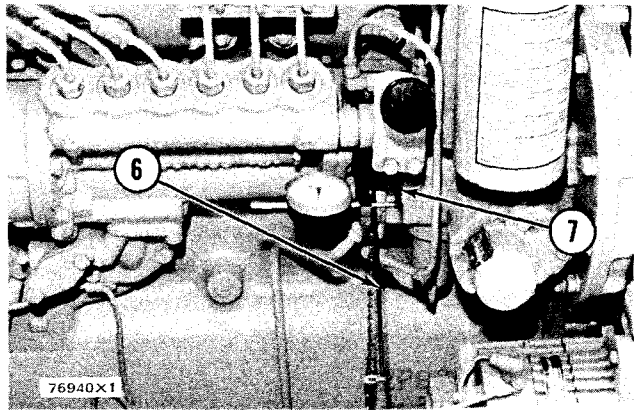
4. 9S8521 Rod (for manually depressing speed limiter plunger). 5. 9S8518 Plug (rod guide).

NOTE: The speed limiter restricts rack travel until the plunger is manually depressed.

3. Remove the fuel ratio control from the rear of the governor and/or the rear cover, then remove the fuel rack cover and gasket from the front flange of the accessory drive housing.

4. Install rack positioning bracket group and dial indicator, over the opening for fuel rack cover on front flange of accessory drive housing.

5. Place the spacer (6) over the rod in the bracket. Adjust the dial on the indicator to read zero when the hole attachment (7) is against the rod and the rod is against the spacer.



DIAL INDICATOR ADJUSTED TO ZERO READING
(Typical Example)

6. Spacer. 7. Hole attachment.

6. Before starting the engine, be sure the rack moves freely throughout its entire length of travel. The speed limiter will restrict rack travel until the engine is operating with proper oil pressure, or the plunger is manually depressed.

7. Attach one end of the 8S4627 Circuit Tester to the brass screw terminal on the outside of the governor housing.

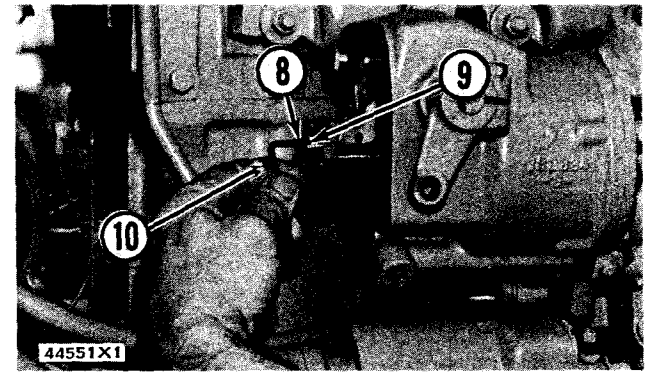
8. With the speed limiter depressed, move the governor control lever toward the fuel-on direction until the tester light comes on bright.

9. Slowly, move the governor control lever toward the shutoff position until the light goes out.

10. Now, again slowly move the governor control lever toward the fuel-on position, until the tester light just barely comes on (a dim light); adjusting screw (8) in rack collar is now just touching the stop bar or torque spring. Rack setting dimension is read directly from the 9S215 Dial Indicator.

11. To adjust the rack setting, loosen locknut (9) and with wrench (10), adjust screw (8) to obtain the correct rack setting dimension. Rack travel can be read directly 9S215 Dial Indicator.

NOTE: Turn screw (8) clockwise to decrease rack travel. Never adjust rack travel by adding or removing shims.



ADJUSTING RACK SETTING
(Typical Example)

8. Adjusting screw. 9. Locknut. 10. 4B9820 Wrench.

12. After the rack has been adjusted, tighten locknut (9) to 11 ± 1 lb. ft. (1.5 ± 0.14 mkg).

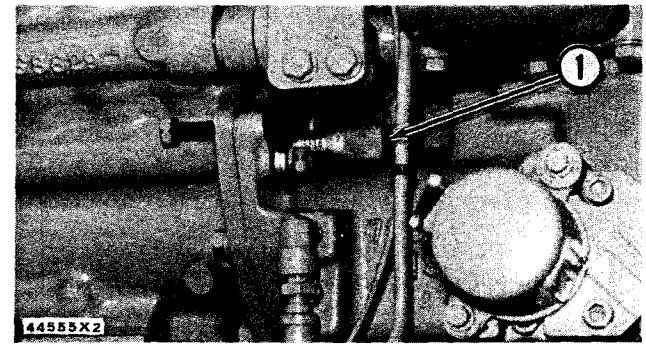
Rack Setting Gauge Method:

Tools Needed: 7S7113 Rack Setting Gauge
8S4627 Circuit Tester
FT960 adapter Assembly

Use a 7S7113 Rack Setting Gauge to check the fuel rack setting.

1. Remove the rack cover from the front of the accessory drive housing rear flange and the cover from the rear of the governor housing.

2. Install the 7S7113 Rack Setting Gauge over the front end of the fuel rack.



GAUGE INSTALLED

1. 7S7113 Rack Setting Gauge.

3. Set gauge to the proper rack setting. Refer to the RACK SETTING INFORMATION for correct setting.

4. To adjust the rack, refer to the topic RACK POSITIONING TOOL, DIAL INDICATOR AND CIRCUIT TESTER METHOD and follow Steps 7 through 12.