



FORM NO. REG01525-01

FOR USE IN SERVICE MANUAL:
G342 ENGINE, REG01523

Systems Operation Testing & Adjusting

G342 Engine



WARNING

IMPORTANT SAFETY NOTICE

Proper repair is important to the safe and reliable operation of a machine. This Service Manual outlines basic recommended procedures, some of which require special tools, devices or work methods. Although not necessarily all inclusive, a list of additional skills, precautions and knowledge required to safely perform repairs is provided in the SAFETY section of this Manual.

Improper repair procedures can be dangerous and could result in injury or death.

READ AND UNDERSTAND ALL SAFETY PRECAUTIONS AND WARNINGS BEFORE PERFORMING REPAIRS ON THIS MACHINE

Basic safety precautions, skills and knowledge are listed in the SAFETY section of this Manual and in the descriptions of operations where hazards exist. Warning labels have also been put on the machine to provide instructions and identify specific hazards which if not heeded could cause bodily injury or death to you or other persons. These labels identify hazards which may not be apparent to a trained mechanic. There are many potential hazards during repair for an untrained mechanic and there is no way to label the machine against all such hazards. These warnings in the Service Manual and on the machine are identified by this symbol:



WARNING

Operations that may result only in machine damage are identified by labels on the machine and in the Service Manual by the word **NOTICE**.

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

IMPORTANT

The information, specifications and illustrations in this book are on the basis of information available at the time it was written. The specifications, torques, pressures of operation, measurements, adjustments, illustrations and other items can change at any time. These changes can effect the service given to the product. Get the complete and most current information before you start any job. Caterpillar Dealers have the most current information which is available. For a list of the most current modules and form numbers available for each Service Manual, see the SERVICE MANUAL CONTENTS MICROFICHE REG1139F.

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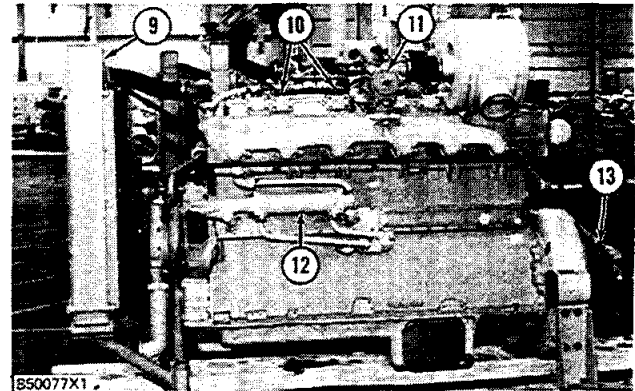
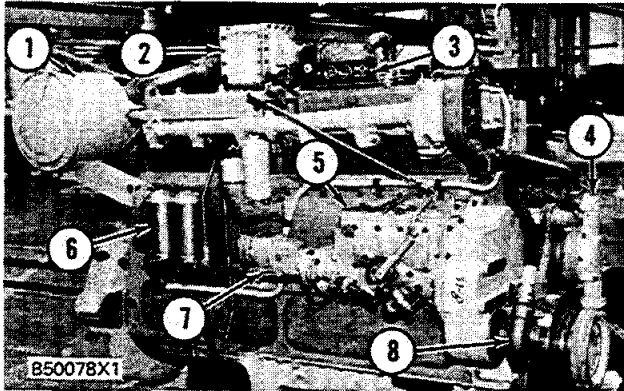
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SPECIFICATIONS

NOTE: For Specifications with illustrations, make reference to ENGINE SPECIFICATIONS FOR G342 ENGINE, Form No. REG01526. If the Specifications in Form No. REG01526 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.

GENERAL INFORMATION



G342 ENGINE ARRANGEMENT

1. Air cleaner. 2. Aftercooler. 3. Instrument panel. 4. Water pump. 5. Governor. 6. Oil filter. 7. Magneto. 8. Auxiliary water pump. 9. Radiator. 10. Ignition transformer (six). 11. Carburetor. 12. Oil cooler. 13. Power take-off clutch.

The G342 is a inline 6 cylinder engine. The engine has a 5.75 in. (146 mm) bore and a 8 in. (203 mm) stroke.

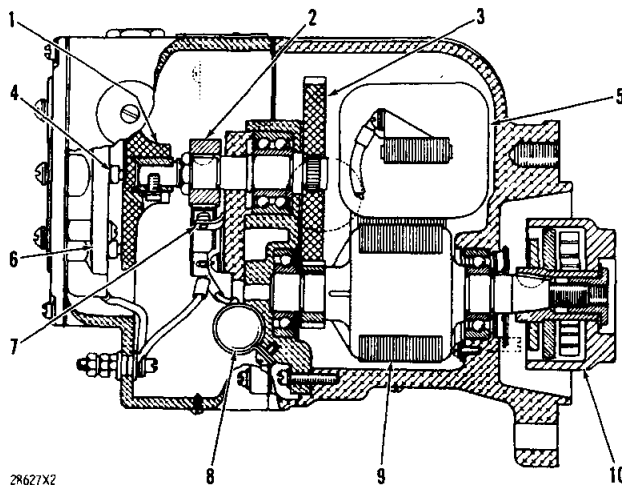
The engine has a displacement of 1246 cu. in. (20.4 liter). The firing order is 1, 5, 3, 6, 2, 4. The engine weight is approximately 5,250 lbs. (2381 kg).

IGNITION SYSTEM

The ignition system has five basic components: A magneto, ignition transformers for each cylinder, a wiring harness, spark plugs and an instrument panel.

SPARK GAP MAGNETO

The magneto is an alternating current generator that produces the electric source (and stops it at the right time) necessary for spark ignition engines. The basic components of the spark gap magneto are the transformer, rotor, contact breaker, distributor, and condenser.



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CROSS SECTION OF SPARK GAP MAGNETO

1. Distributor disc. 2. Cam. 3. Distributor gear and shaft assembly. 4. Brush and spring assembly. 5. Transformer. 6. Distributor block. 7. Contact points. 8. Condenser. 9. Rotor. 10. Impulse coupling.

Transformer (5) has a primary coil made of heavy wire. One end of the primary coil is connected to ground on the transformer core. The other end of the primary coil is connected to contact points (7).

Rotor (9) is a permanent magnet. When the rotor turns, one pole of the magnet in the rotor moves under the core of transformer (5). A flow having the characteristics of the magnet (flux) moves from this pole of the magnet to the opposite pole of the magnet through the layers of the metal core. There is an increase in the flux in the core until the pole is exactly under the core. The flux is then at its largest strength. As the rotor turns more it moves out from under the core and there is a decrease in the flux. The rotor turns so that the opposite pole is under the transformer core. Now the flux must change its direction of flow through the transformer coil. The flux gets larger and then smaller in the opposite direction. The flux direction changes each time the rotor makes a revolution. This flux in the core is all around the wires in the coil of the transformer and causes electricity in the wires.

Cam (2) opens contact points (7) at the point in the alternating current cycle when the voltage in the primary coil is large.

When the points open the circuit is broken and the flux around the primary coil wires suddenly falls (collapses) through the primary coil. This sudden collapse of flux causes the largest voltage (peak voltage) in the primary coil.

At peak voltage the contact on distributor disc (1) is in a position to make a complete circuit through brush and spring assembly (4) in the distributor block and through the low tension leads to the ignition transformers.

Condenser (8) prevents a spark that can cause damage to contact points (7). The electrical energy which normally makes a spark across the gap in the contact points goes into the condenser. When the contact points open wider, the electrical energy in the condenser moves back into the primary coil and adds to the voltage.

When there is an increase of rpm of the rotor, there is an increase in strength of spark at the spark plug electrodes. An impulse coupling (10) is used to cause an increase in rotor rpm as the engine is started. The impulse coupling is not engaged when the engine is in operation.

SOLID STATE MAGNETO (FAIRBANKS MORSE)

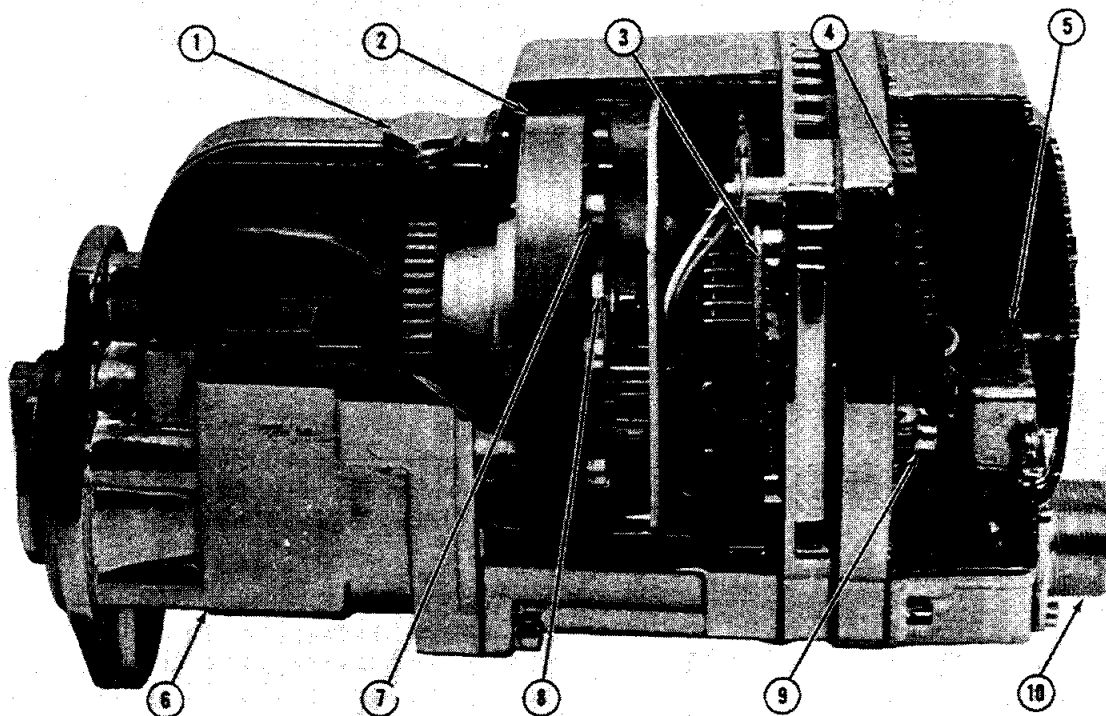
The solid state type magneto makes (generates) current in the alternator section of the magneto. Low tension current is held in the capacitor and then released. Distribution is then made through the distribution board (4). This system has no contact points, contactors, or brushes. There is no spark inside the magneto and only minimum wear. An ignition spark of high tension is made by the transformer to start the air fuel mixture burning under all operating conditions.

The alternator makes a voltage as the magnet rotor is turned by the engine through a drive coupling. The alternating current is sent through a rectifier and held in a capacitor (5). A zener diode, on the power board is the regulator of the capacitor voltage for proper ignition.

As the pulser rotor (8) moves by each pulser coil (trigger circuit) (7), a voltage is made and sent to the electronic switch (silicon controlled rectifier) (9) for the cylinder ready for ignition. The switch is then turned on and permits the capacitor (5) to release the voltage (discharge). Then the voltage

goes through the distribution board (4) and to the transformer. The transformer causes a spark (impulse) of high voltage and low current. This is sent

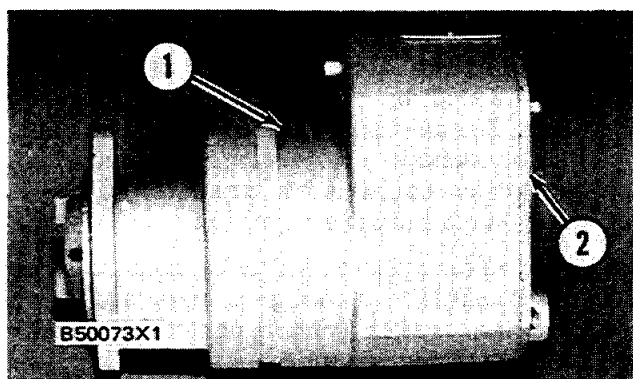
across the electrodes of the spark plug. As the pulser rotor moves by each pulser coil, the same development of spark (impulse) is made.



CUTAWAY VIEW OF SOLID STATE MAGNETO (FAIRBANKS MORSE)
(Typical Illustration)

1. Timing bolt. 2. Pulser coil assembly. 3. Plate and power board assembly. 4. Distribution board. 5. Capacitor. 6. Alternator housing. 7. Pulser coil (trigger circuit). 8. Pulser rotor. 9. Electronic switch (silicon controlled rectifier). 10. Plug connector.

SOLID STATE MAGNETO (ALTRONIC)

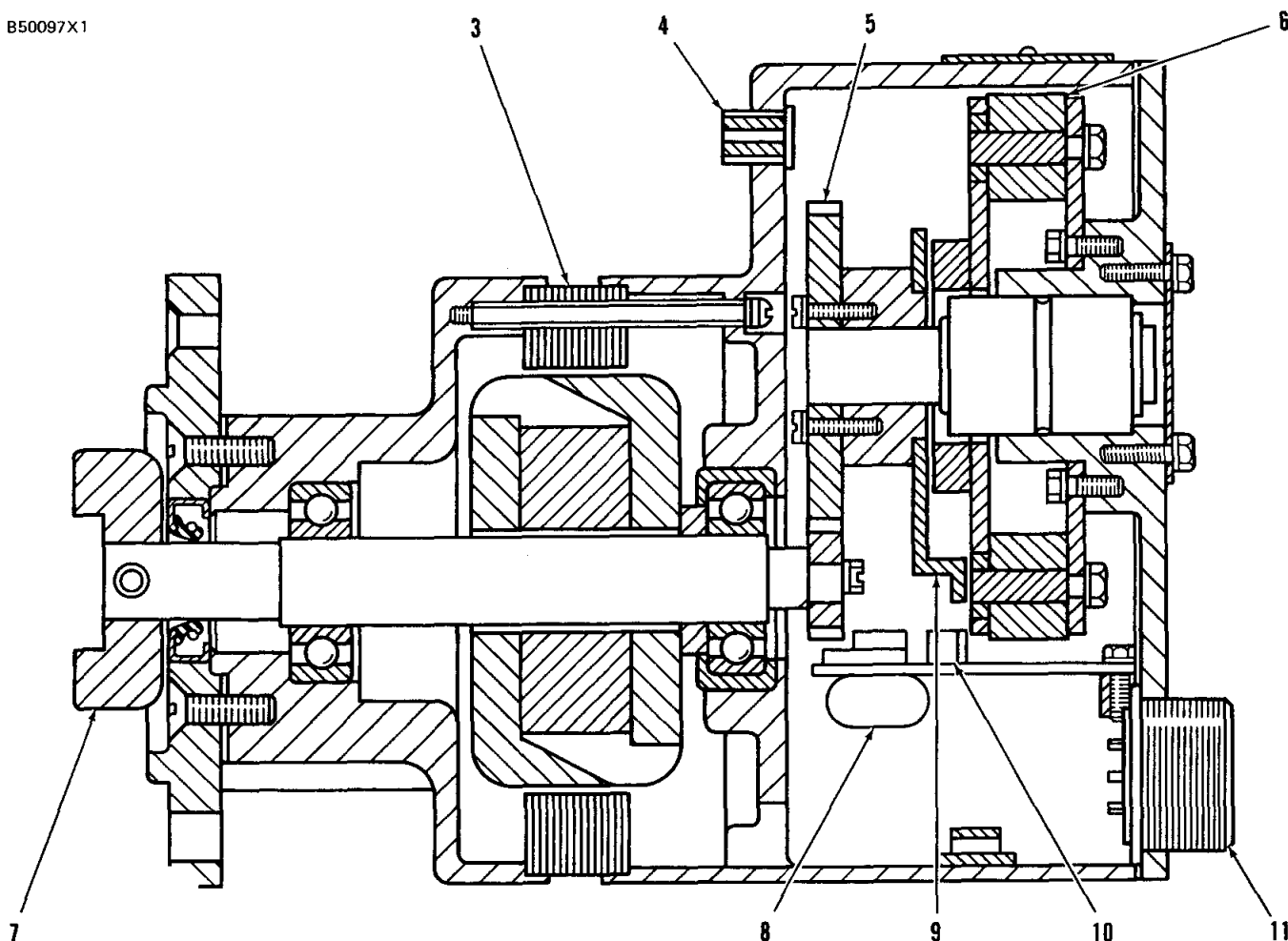


SOLID STATE MAGNETO (ALTRONIC)

1. Alternator section. 2. Electronic firing section.

The Altronic magneto is made of a permanent magneto alternator section (1) and brakerless electronic firing circuit (2). There are no brushes or distributor contacts.

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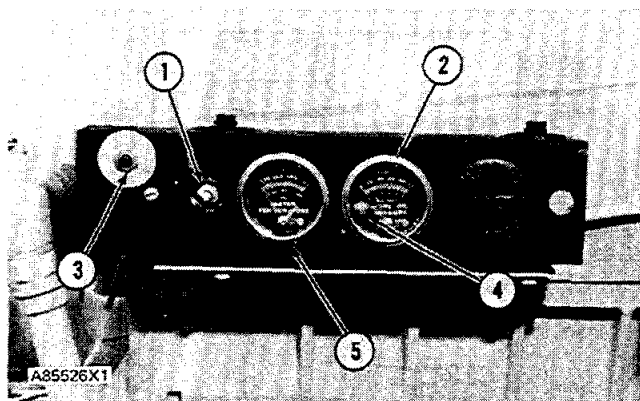
CROSS SECTION OF SOLID STATE MAGNETO (ALTRONIC)

3. Alternator. 4. Vent. 5. Speed reduction gears. 6. Pick-up coil. 7. Drive tang. 8. Energy storage capacitor. 9. Rotating timer arm. 10. SCR solid state switch. 11. Output connector.

The engine turns magneto drive tang (7). The drive tang turns alternator (3), speed reduction gears (5) and rotating timer arm (9). As the alternator is turned it provides power to charge energy storage capacitor (8). There are separate pick-up coils (6) and SCR (silicon controlled rectifier) solid state switches (10) for each engine cylinder. The timer

arm passes over pick-up coils (6) in sequence. The pick-up coils turn on solid state switches (10) which release the energy stored in capacitor (8). This energy leaves the magneto thru output connector (11). The energy travels thru the wiring harness to the ignition coils where it is transformed to the high voltage needed to fire the spark plugs.

INSTRUMENT PANEL



INSTRUMENT PANEL

1. Stop switch. 2. Gauge for the oil pressure. 3. Reset button for the magnetic switch. 4. Reset button for the gauge for oil pressure. 5. Gauge for the water temperature.

The instrument panel has a magnetic switch, manual stop switch (1), oil pressure gauge (2), and a water temperature gauge (5) which are connected to the magneto. The protection shut-off valve for the gas supply line is also operated by the instrument panel.

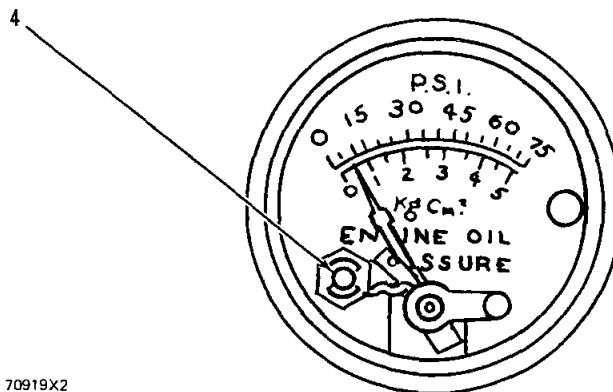
When the magnetic switch is activated it connects the magneto to ground and stops the engine. This is the normal way to stop the engine. If the water temperature gets too high or if the oil pressure gets too low the magnetic switch is activated.

Before a cold engine is started, push in reset button (3) for the magnetic switch and reset button (4) for the gauge for the oil pressure. This prevents the connection of the magneto to ground because of low oil pressure. When the engine starts, normal oil pressure releases the switch from reset position. The gauge switch is then ready to stop the engine when the oil pressure is low.

When the gauge switch for the water temperature has correct operation, a hot engine can not be started.

When the reset button for the magnetic switch is held in, the gauge switches for the oil pressure and water temperature can not make connection of the magneto to ground.

The protection shut-off valve for the gas line needs manual setting to open it after the engine has stopped.



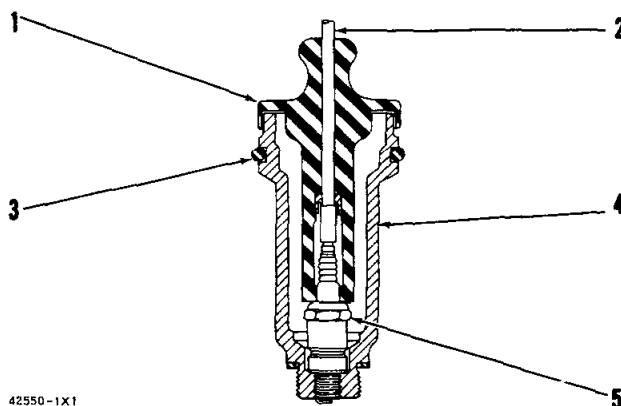
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OIL PRESSURE GAUGE

4. Reset button for the gauge for oil pressure.

SPARK PLUGS AND ADAPTERS

Spark plugs for this natural gas engine use two ground electrodes. This permits the spark plug to operate longer before adjustment or replacement is needed.



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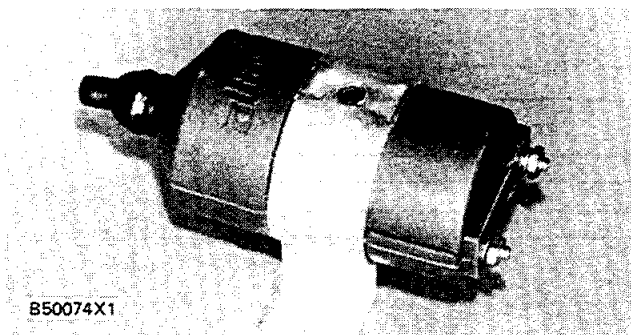
SPARK PLUG AND ADAPTER

1. Cover. 2. High tension wire. 3. Seal. 4. Spark plug adapter. 5. Spark plug.

A cover (1) is used over the spark plug adapter. High tension wire (2) goes through cover (1) to the connection (terminal) portion of spark plug (5). This keeps water, dirt and other foreign material out of spark plug adapter (4).

IGNITION TRANSFORMER

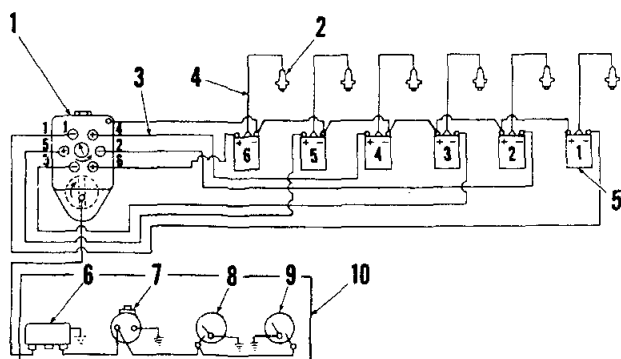
The ignition transformer causes an increase of the magneto voltage. This is needed to send a spark (im-



IGNITION TRANSFORMER
(Typical Example)

pulse) across the electrodes of the spark plugs. For good operation, the connections (terminals) must be clean and tight. The wiring diagram shows how all wires are to be connected to the plug connection at the magneto.

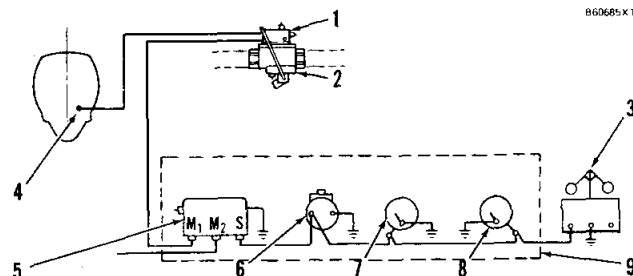
WIRING DIAGRAMS



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IGNITION SYSTEM DIAGRAM FOR
SPARK GAP MAGNETO

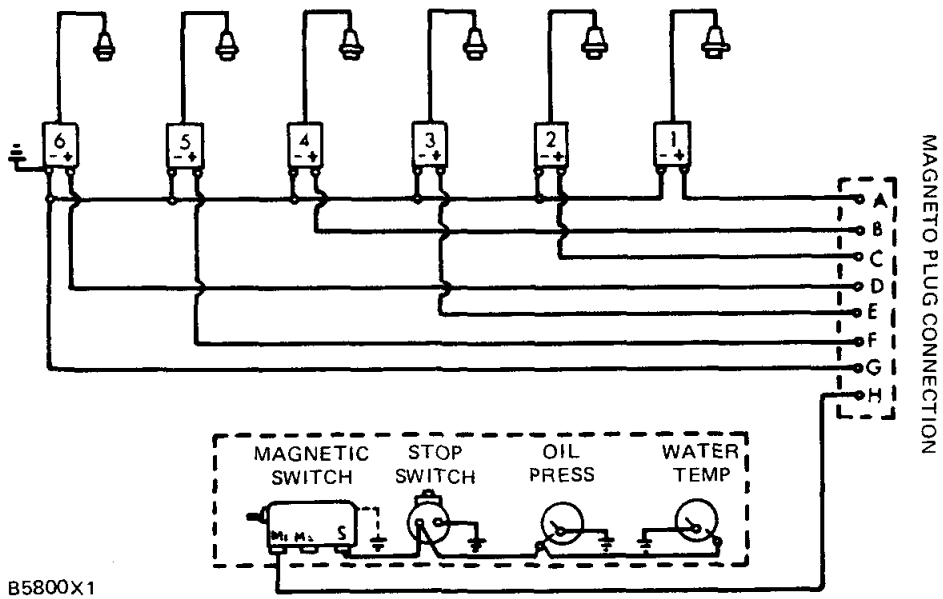
1. Magneto. 2. Spark plugs. 3. Low tension leads. 4. High tension leads. 5. Transformers. 6. Magnetic switch. 7. Manual stop switch. 8. Switch of the gauge for the oil pressure. 9. Switch of the gauge for the water temperature. 10. Instrument panel.



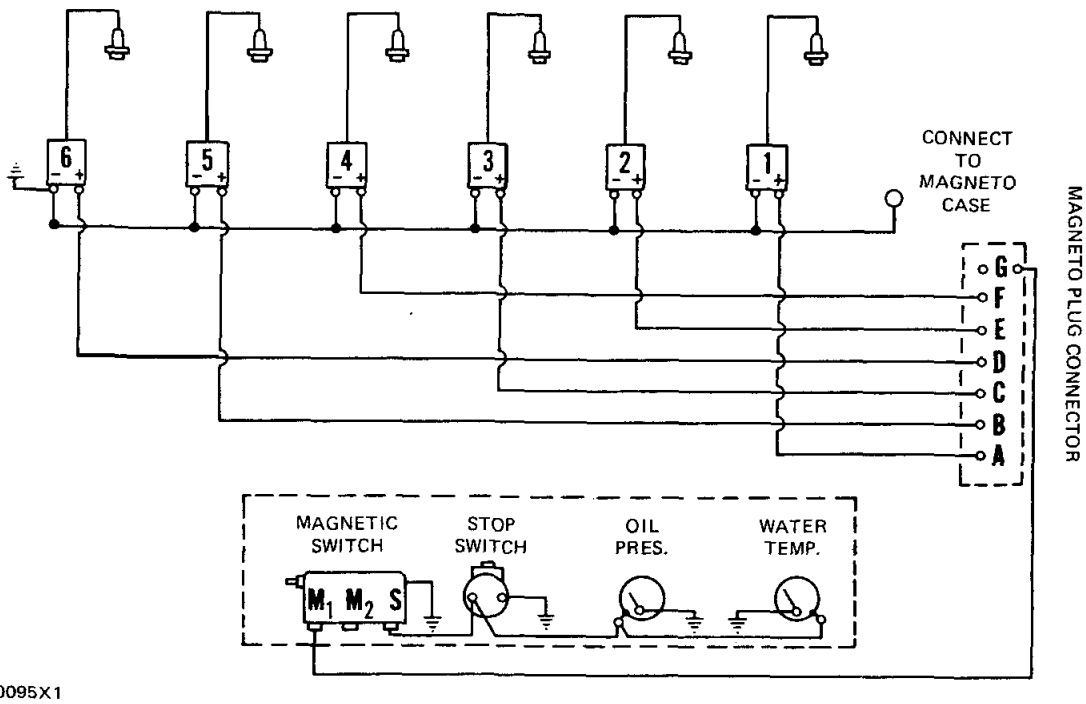
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WIRING DIAGRAM WITH OVERSPEED
CONTACTOR AND GAS VALVE

1. Solenoid. 2. Gas valve. 3. Overspeed contactor. 4. Shut-off stud for breaker point magneto or H pin for Fairbanks Morse Solid State Magneto or G pin for Altronic Magneto. 5. Magnetic switch. 6. Stop switch. 7. Switch of the gauge for the oil pressure. 8. Switch of the gauge for the water temperature. 9. Engine instrument panel.

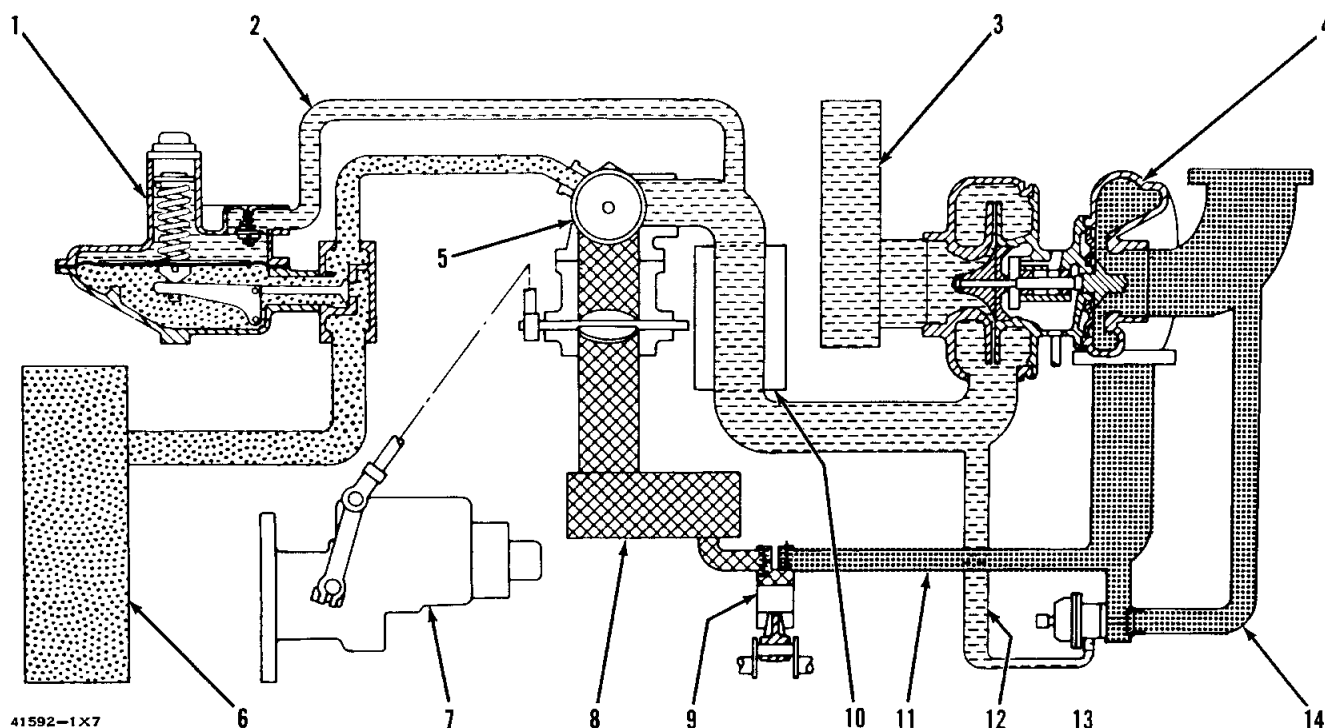


IGNITION SYSTEM DIAGRAM FOR SOLID STATE MAGNETO (FAIRBANKS MORSE)



IGNITION SYSTEM DIAGRAM FOR SOLID STATE MAGNETO (ALTRONIC)

GAS, AIR INLET AND EXHAUST SYSTEM



GAS, AIR INLET AND EXHAUST SYSTEM
(Typical Illustration)

1. Gas pressure regulator. 2. Balance line. 3. Air cleaner. 4. Turbocharger. 5. Carburetor. 6. Gas supply. 7. Governor. 8. Inlet manifold. 9. Cylinder. 10. Aftercooler. 11. Exhaust manifold. 12. Air tube. 13. Differential pressure regulator. 14. Exhaust bypass.

In addition to components shown in the diagram, some installations have a shut-off valve attachment in the supply line for the gas. The valve is electrically operated from the ignition system and can also be manually operated to stop the engine. After the engine is stopped, manual setting is needed to start the engine.

Engine installations using propane gas have system components the same as illustrated above. In addition, on some engines, a Thermac valve for reduction of pressure, and a load adjusting valve, between the gas pressure regulator and carburetor, are used. Later engines with a propane or dual fuel system have a vacuum regulator in place of the gas pressure regulator and Thermac valve. This vacuum regulator permits an adjustment to be made for differences in BTU content of the gas being used.

Changes in engine load and fuel burnt cause changes in rpm of the turbine wheels and impellers of the turbocharger (4).

When the turbocharger gives a pressure boost to the inlet air, the temperature of the air goes up. A water cooled aftercooler (10), is installed between the turbocharger (4) and the air inlet manifold (8)

to cylinders. The aftercooler causes a reduction of air temperature from the turbochargers.

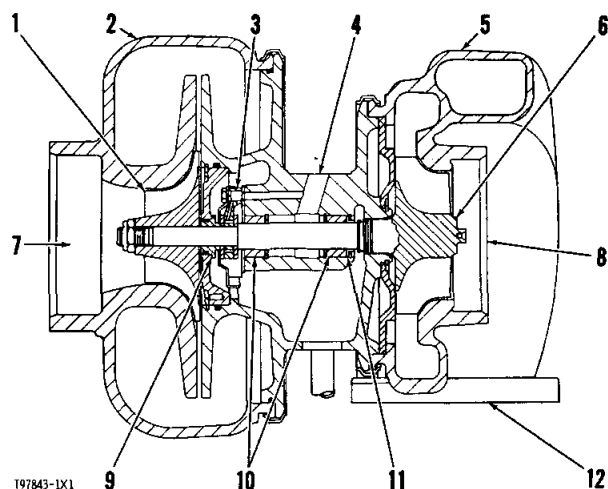
TURBOCHARGER (Engines so Equipped)

The turbocharger is on the exhaust outlet of the engine exhaust manifold. The energy that normally would be lost from the exhaust gases is used to turn the turbocharger.

As the engine starts, the flow of exhaust gases from the exhaust manifold goes through inlet (12) to the turbine wheel (6). The turbine wheel and compressor impeller (1) are on a common shaft. The exhaust gases flow over the turbine wheel making it and the impeller turn.

Air from the air cleaner flows through inlet (7) to the center of the impeller. The rotating impeller puts a compression force on the air causing it to go into the carburetor.

The bearings of the turbocharger get pressure lubrication from engine oil. The oil goes in through port (4) and is sent through passages to give lubrication to the thrust bearing (3), sleeves (9 and 11), and the bearings (10).

**TURBOCHARGER**

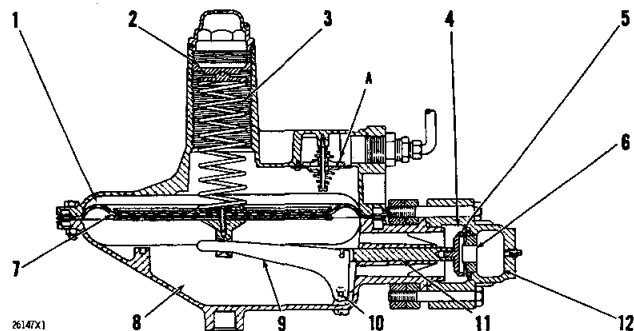
1. Compressor impeller. 2. Compressor housing. 3. Thrust bearing. 4. Inlet port for lubrication oil. 5. Turbine housing. 6. Turbine wheel. 7. Air inlet. 8. Exhaust outlet. 9. Sleeve. 10. Shaft journal bearing. 11. Sleeve. 12. Exhaust inlet.

AFTERCOOLER

The aftercooler is installed between the turbocharger and the carburetor. There is a water flow through the aftercooler to cool the hot air which is under compression from the turbocharger. The cool air going through the carburetor makes more oxygen available for combustion. More oxygen permits more fuel to be burned. This gives more power.

GAS PRESSURE REGULATOR

The gas pressure regulator is needed on engines equipped with turbochargers. Engines using inlet air that has only the pressure of the atmosphere (naturally aspirated) need a gas pressure regulator

**GAS PRESSURE REGULATOR**

1. Spring side chamber. 2. Adjustment screw. 3. Spring. 4. Outlet. 5. Valve disc. 6. Orifice. 7. Main diaphragm. 8. Lever side chamber. 9. Lever. 10. Pivot pin. 11. Valve stem. 12. Inlet. A. Vent valve.

if the pressure of the gas supply is more than the desired inlet pressure difference between the gas and air.

An adjustment can be made to the regulator by turning screw (2).

Gas goes through inlet (12), orifice (6), by valve disc (5), and through outlet (4). The outlet pressure is in chamber (8) on the lever side of diaphragm (7).

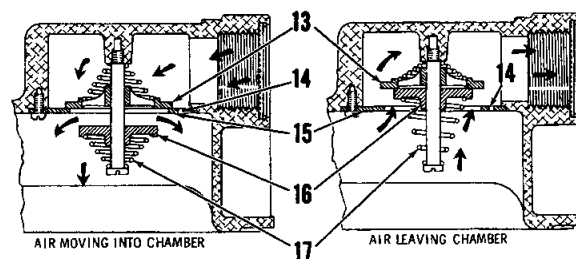
As the gas pressure in the chamber (8) becomes higher than the force of the spring (3) and the air pressure in the spring side chamber (1) (atmosphere on naturally aspirated engines; turbocharger boost on turbocharged engines), the diaphragm is pushed against the spring. This turns the lever (9) a pin (10) and causes the valve stem (11) to move to valve disc (5) to close orifice (6).

When orifice (6) is closed, gas is pulled from chamber (8). This causes a reduction in pressure in chamber (8) to a pressure less than that on the spring side of the diaphragm. The force of the spring and air pressure in the chamber (1) moves the diaphragm toward the lever. This turns the lever and opens the valve disc (5) permitting additional gas to fill chamber (8) and go to the carburetor.

When the pressure on either side of the diaphragm is the same, the regulator permits a set amount of gas flow to the carburetor.

Vent Valve

When the main diaphragm (7) moves toward the spring side of chamber (1), air goes out of chamber. This movement of air pushes the lower flapper (16) up taking upper flapper (13) with it. The air inside chamber (1) is then released. This is done rapidly enough to prevent any loss of time in the main diaphragm because of air compression.



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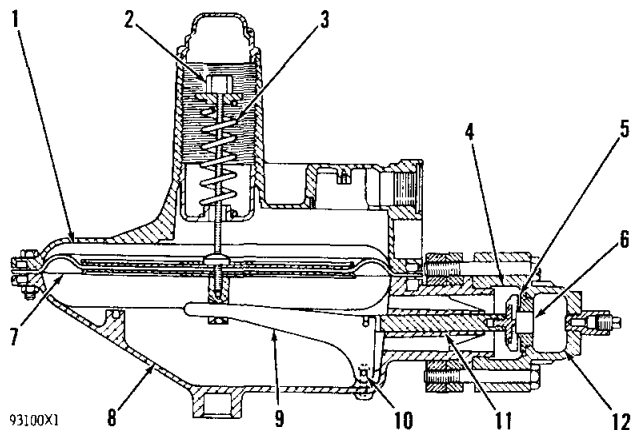
OPERATION OF THE VENT VALVE

13. Upper flapper. 14. Orifice. 15. Orifice plate. 16. Lower flapper. 17. Springs (two).

As the main diaphragm (7) moves toward the lever chamber (8), air moves in to fill the chamber (1). This pushed the upper flapper (13) against the orifice plate (15). Air going through the openings in upper flapper opens the lower flapper (16) and fills chamber (1).

VACUUM REGULATOR

The vacuum regulator on later engines controls the high BTU gases to a negative pressure (vacuum). Adjustment of the regulator is made by turning the adjustment nut (2).



VACUUM REGULATOR OPERATION

1. Spring side chamber. 2. Adjustment nut. 3. Spring. 4. Outlet. 5. Valve disc. 6. Orifice. 7. Diaphragm. 8. Lever side chamber. 9. Lever. 10. Pin. 11. Valve stem. 12. Inlet.

Gas goes through the inlet (12), orifice (6), by valve disc (5), and through the outlet (4). Vacuum is felt in the chamber (8) on the lever side of diaphragm (7).

When the vacuum in chamber (8) and air pressure in the spring side chamber (1) (atmosphere on naturally aspirated engines; turbocharger boost on turbocharged engines) becomes more than the force of the diaphragm spring (3) the diaphragm is pulled against the force of the spring. This turns (pivots) the lever (9) at pin (10) and causes the valve stem (11) to move the valve disc (5) to open orifice (6).

With the orifice open, gas supply under pressure is sent to the lever side of chamber (8). This causes a loss of vacuum, and permits the spring force to pull the diaphragm and lever to move the valve disc to close the orifice.

When the spring force is balanced by the combination of vacuum and air pressure force, the regulator sends gas to the carburetor at a specific amount.

BALANCE LINE

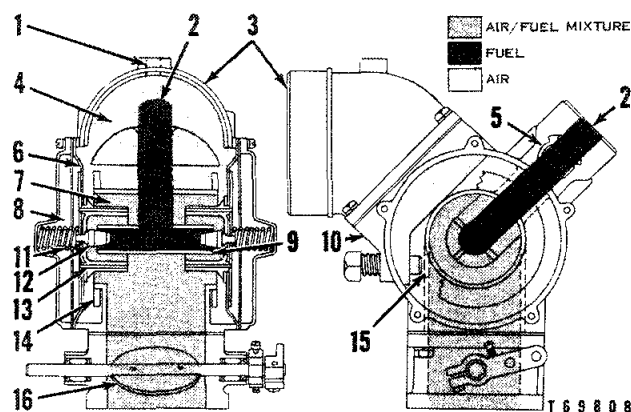
The balance line controls the correct pressure difference between the line pressure regulator and the carburetor inlet.

When the load on the engine changes, the boost pressure from the turbocharger changes in the inlet manifold. The balance line sends a signal of this change through the vent valve to the spring side chamber of the line pressure regulator. This pressure change causes the regulator diaphragm to move the line regulator valve to correct the gas pressure to the carburetor.

CARBURETOR

Air goes into the carburetor through air horn (3) and fills outer chamber (4). Air goes into inner chamber (7) (mixing chamber) by moving diaphragm (6) away from ring (14).

Fuel goes into the carburetor through fuel inlet (2), and goes by the power mixture adjustment (5) to the center of the carburetor and into tube (9) for the fuel outlet. Fuel valve (12) is fastened to diaphragm (6). With the diaphragm moved away from ring (14), fuel goes through fuel valve (12) and into chamber (7). The fuel and air mixture in inner chamber (7) goes down by throttle plate (16) and into the inlet manifold.



CARBURETOR OPERATION (Operating Position Shown)

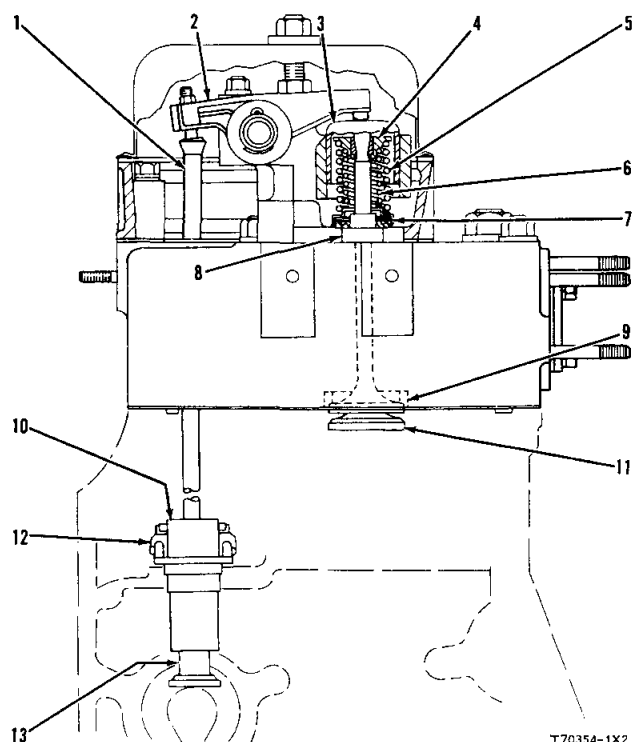
1. Balance line inlet. 2. Fuel inlet. 3. Air horn. 4. Outer chamber. 5. Power mixture adjustment. 6. Diaphragm. 7. Inner chamber. 8. Chamber. 9. Fuel outlet tube. 10. Carburetor body. 11. Spring. 12. Fuel valve. 13. Sensing holes. 14. Ring. 15. Idle adjustment opening. 16. Throttle plate.

With the engine stopped, spring (11) holds diaphragm (6) against ring (14) and holds fuel valve (12) closed. No air or fuel can go to inner chamber (7). As the engine is started, the vacuum in the cylinders, caused by the intake strokes of the pistons, make a low pressure condition in inner chamber (7). This low pressure is felt by chamber (8), behind the diaphragm, through holes (13). This permits the pressure in chamber (8) to balance with the low pressure condition in the inner chamber. As soon as the inlet pressure on the diaphragm (6) is higher than the spring force, the diaphragm moves out.

This also moves fuel valve (12) out and permits air and fuel to go into the inner chamber. A small volume of air is also measured into the inner chamber (7) through idle adjustment opening (15).

When the engine is running at a constant rpm, the diaphragm does not move from one position. This position is caused by the difference in pressure between the gas and the air. An adjustment can be made to this pressure difference by making an adjustment to the gas pressure regulator.

VALVES AND VALVE MECHANISM



VALVES AND VALVE MECHANISM

1. Push rod. 2. Rocker arm. 3. Sleeve. 4. Retainer. 5. Outer spring. 6. Inner spring. 7. Valve rotator. 8. Valve bushing (valve guide). 9. Insert. 10. Guide for valve lifter. 11. Valve. 12. Yoke. 13. Valve lifter (cam follower).

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 to open and close according to the firing order of the engine. Two valve springs for each valve help to hold the valves in the closed position.

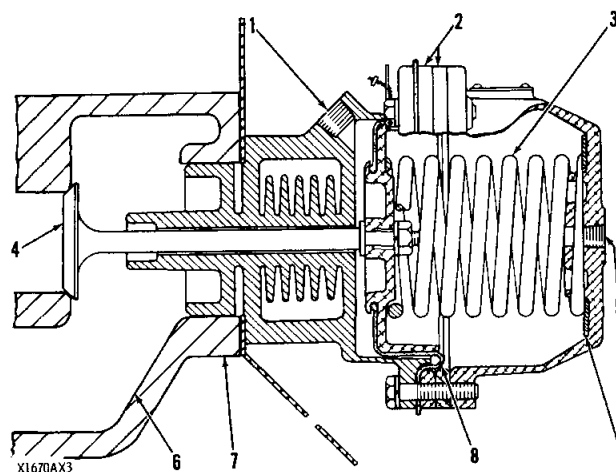
Valve rotators cause the valves to have rotation while the engine is running. This rotation of the valves keeps the deposit of carbon on the valves to a minimum and gives the valves longer service life.

DIFFERENTIAL PRESSURE REGULATOR

(Engines Equipped With Turbocharger)

The differential pressure regulator is installed on the turbine housing (7) of the turbocharger. It controls the amount of exhaust gases to the turbine wheel. The exhaust bypass valve (4) is activated directly by a pressure difference between the air pressure (atmosphere) and the pressure from the turbocharger outlet to the carburetor.

One side of the diaphragm (8) in the regulator feels the pressure of the atmosphere through



DIFFERENTIAL PRESSURE REGULATOR

1. Regulator control line connection. 2. Spacers. 3. Spring. 4. Bypass valve. 5. Breather location. 6. Bypass passage. 7. Turbine housing. 8. Diaphragm. 9. Shims.

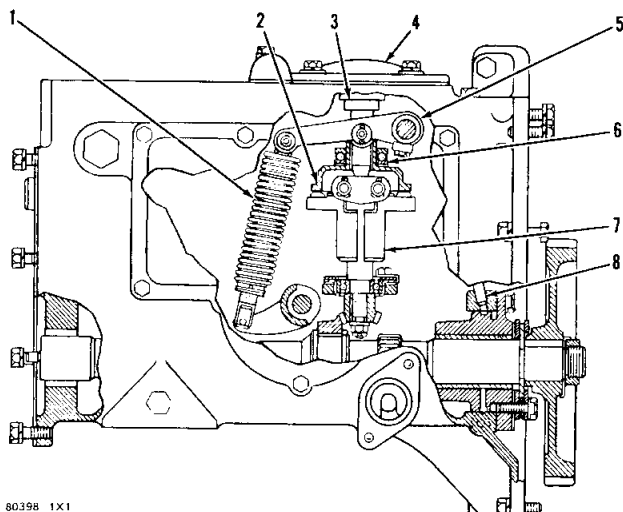
breather location (5). The other side of the diaphragm feels the air pressure from the outlet side of the turbocharger compressor through a control line at connection (1). When the outlet pressure to the carburetor gets to a value larger than the force of the pressure on the spring side, the diaphragm moves. This opens valve (4) and the exhaust gases go out the bypass passage (6), not to the turbocharger turbine wheel.

The bypass passage (6) is inside the turbine housing of the turbocharger. Under a constant load on the engine, the valve (4) does not move from one position. This permits just enough gas to go to the turbine wheel, turning it and giving the correct air pressure to the carburetor.

MECHANICAL GOVERNOR

The governor is in the housing for the accessory drive and governor. The governor control is connected to the control lever on the engine governor. The governor controls the amount of fuel needed to keep the engine at the desired rpm.

The governor has weights (7) which are on a shaft driven by the engine. Force of rotation (centrifugal force) of the weights on the retainer (2), bearing (6) and lever (5) puts a force against the force of governor spring assembly (1). These two forces move the lever (5) which is connected to the linkage to the carburetor.



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MECHANICAL GOVERNOR

1. Governor spring assembly. 2. Retainer. 3. Bearing. 4. Cover. 5. Lever assembly. 6. Bearing. 7. Governor weights. 8. Tube for oil.

The governor control controls only the tension of the governor spring assembly (1). Tension of the spring always pulls to give more fuel to the engine. The force of rotation (centrifugal force) of the gov-

ernor weights is always pushing to get a reduction of fuel to the engine. When these two forces are in balance the engine runs at desired rpm (governed rpm).

When there is an increase in the load on the engine, there is a reduction in the rpm of the engine. The rotation of the governor weights (7) gets slower (the governor weights move toward each other) and the force on the lever (5) is less. The governor spring assembly (1) moves the linkage to the carburetor to give more fuel to the engine. The engine rpm goes up until the force of rotation of the governor weights is fast enough to be in balance with the force of the governor spring assembly.

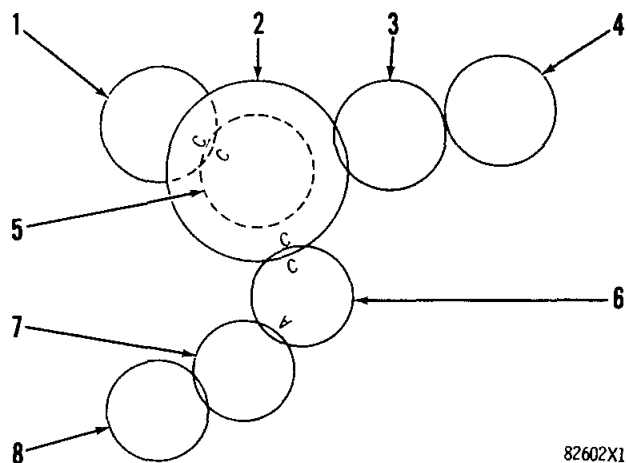
When there is a decrease in the engine load there will be an increase in the rpm of the engine and the rotation of the governor weights (7) will get faster. This moves the retainer (2), bearing (6) and lever (5) and puts more force against the governor spring assembly. This causes a reduction in the amount of fuel to the engine. Engine rpm goes down until the force of rotation (centrifugal force) of the governor weights is in balance with the force of the governor spring assembly. When these two forces are in balance the engine will run at the desired rpm (governed rpm).

Oil from the engine gives lubrication to the governor. Oil from the bearing assembly for the accessory shaft goes to cover (4) through tube (9). A passage in the cover gives oil to bearing (3). The governor shaft has oil holes in it to give lubrication to the bearing in retainer (3). The other parts of the governor get lubrication from oil thrown by parts (splash lubrication). Oil from the governor goes into the housing for the timing gear through an oil return hole in the front of the housing for the governor and magneto drive.

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 magneto and governor drive in the correct relation to each other. The timing gears are driven by the gear on the crankshaft.

The gear (6) on the crankshaft drives the large outer gear on the camshaft. This gear drives the idler gear (3) which drives the gear (4) for the water pump. The small inner gear (5) on the camshaft drives gear (1) for the governor and magneto drive. The gear (6) on the crankshaft also drives the idler gear (7) which drives gear (8) for the oil pump drive.



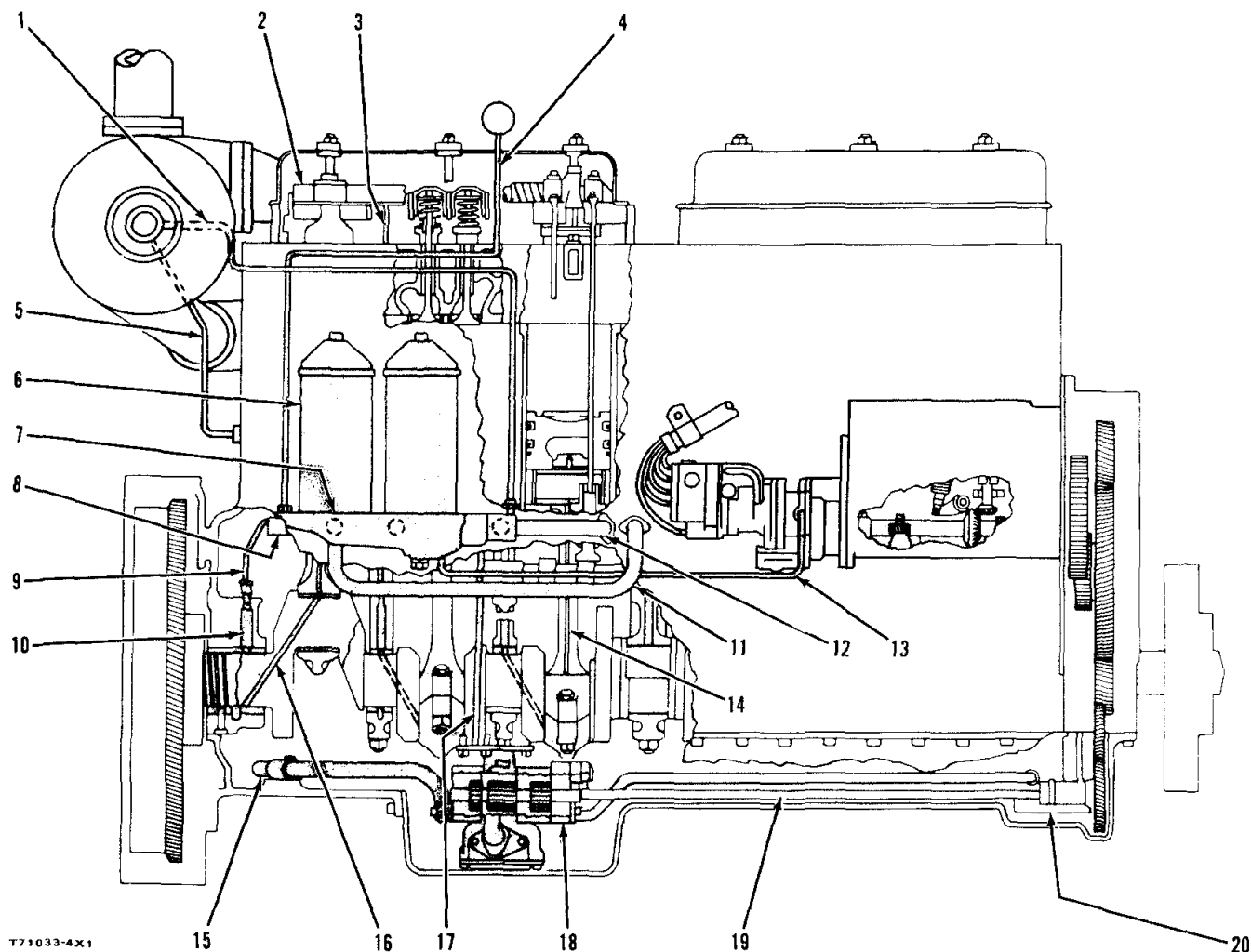
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TIMING GEARS

1. Gear for the governor and magneto drive. 2. Large outer gear on the camshaft. 3. Idler gear for the water pump. 4. Gear for the water pump. 5. Small inner gear on the camshaft. 6. Gear on the crankshaft. 7. Idler gear for the oil pump drive. 8. Gear for the oil pump drive.

NOTE: Timing mark "A" on gear (6) is not for the G342 Engine.

LUBRICATION SYSTEM



LUBRICATION SYSTEM

1. Oil supply line for turbocharger. 2. Rocker arm shaft. 3. Oil tube from oil manifold to rear rocker arm shaft (similar tube to front rocker arm shaft). 4. Tube for oil pressure gauge. 5. Oil return line from turbocharger. 6. Oil filters (two). 7. Oil filter base. 8. Oil manifold. 9. Tube. 10. Passage to main bearing. 11. Tube from oil cooler. 12. Tube to oil cooler. 13. Tube from oil filter base to magneto drive. 14. Passage in connecting rod. 15. Rear scavenger suction bell. 16. Passage in crankshaft. 17. Passage from oil pump to oil filter base. 18. Oil pump (three section). 19. Oil pump drive shaft. 20. Front scavenger suction bell.

FLOW OF OIL THROUGH THE ENGINE (Normal Operation)

The lubrication system uses a three section oil pump (18). The oil pump is in the oil pan and is driven by drive shaft (19) from the engine gears. Oil returns to the center of the oil pan through suction bells (15 and 20).

Oil is sent from the oil pan by the oil pump (18) through passage (17) to oil filter base (7). Oil from

the oil filter base goes through tube (12) to the oil cooler, (on the left side of the engine). Oil goes through the oil cooler from front to rear and returns to the filter base through tube (11). From the oil filter base the oil goes through the oil filters (6) and to the oil manifold (8).

A turbocharger lubrication valve, oil cooler bypass valve, and oil filter bypass valve are in the oil filter base. See the subject, FLOW OF OIL

THROUGH THE OIL COOLER AND OIL FILTERS.

Oil is sent from the oil manifold through tube (9) and passages (10) to each main bearing for the crankshaft.

Passages (16) send oil from the main bearings to the bearings for the connecting rods. Passages (14) in the connecting rods give lubrication for the piston pins and for the cooling of the piston.

A tube from the oil manifold gives oil to the timing gears. See the subject, LUBRICATION FOR THE TIMING GEARS.

Inside passages and tubes (3) send oil from the oil manifold to rocker arm shaft (2). This oil gives lubrication to the rocker arms, valve bushings (guides), push rods, and valve lifters (cam followers). Tube (13) sends oil to the magneto drive. Tube (4) sends oil to the gauge for the oil pressure.

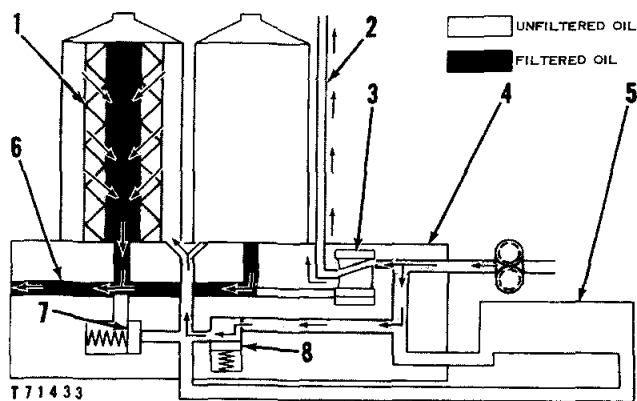
The bearings for the camshaft get oil by splash lubrication (oil thrown by other parts).

After the oil has given lubrication to the engine, it returns to the engine oil pan.

FLOW OF OIL THROUGH THE OIL COOLER AND OIL FILTERS

Oil filter bypass valve (7), oil cooler bypass valve (8), and turbocharger lubrication valve (3) are in the oil filter base.

When the oil is cold (when the engine is first started), the bypass valve for the oil cooler will open. Oil from the oil pump is sent through the opened bypass valve for the oil cooler to the oil filters (1). Oil goes through the oil filters and on to passage (6) to the oil manifold to give lubrication to the engine.



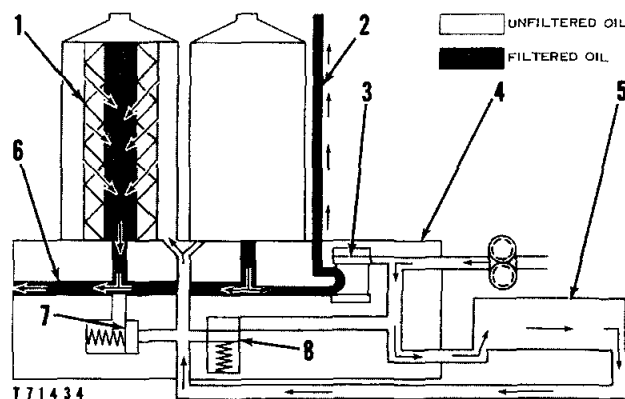
FLOW OF OIL (COLD OIL)

1. Oil filters (two). 2. Oil supply line for turbocharger. 3. Turbocharger lubrication valve. 4. Oil filter base. 5. Oil cooler. 6. Passage to oil manifold. 7. Oil filter bypass valve. 8. Oil cooler bypass valve.

As the temperature of the oil goes up, the bypass valve for the oil cooler will close and the oil will go through oil cooler (5) and then to the oil filters.

When the engine is started, the lubrication valve for the turbocharger will be open. The oil from the oil pump goes through line (2) to the turbocharger.

As the pressure of the oil through the oil filters goes up, the lubrication valve for the turbocharger will close and the oil will go through the oil filters and then to the turbocharger.



FLOW OF OIL (NORMAL OPERATION)

1. Oil filters (two). 2. Oil supply line for turbocharger. 3. Turbocharger lubrication valve. 4. Oil filter base. 5. Oil cooler. 6. Passage to oil manifold. 7. Oil filter bypass valve. 8. Oil cooler bypass valve.

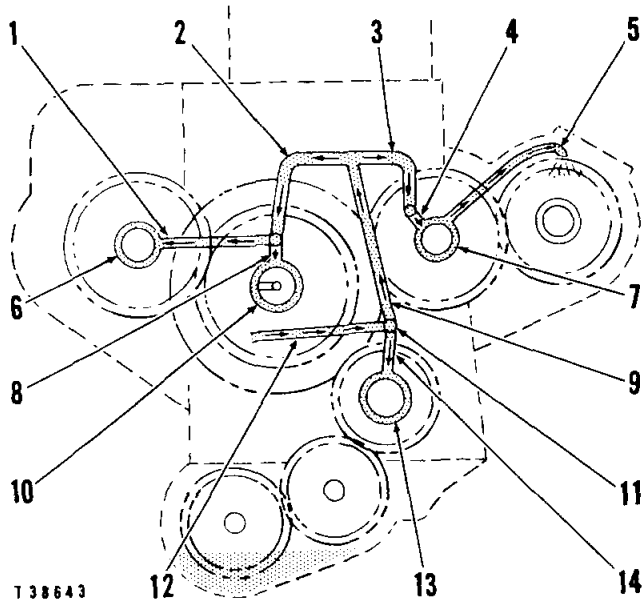
The bypass valve for the oil filters will open if the oil filters have a restriction. This allows the oil to go from the oil pump directly to passage (6). Only clean oil goes to the engine, unless the filters have a restriction or the viscosity of the oil is too high.

The bypass valves (7 and 8) makes it possible for the engine to have lubrication if the oil filters, oil cooler, or both the oil filters and oil cooler have a restriction.

LUBRICATION FOR THE TIMING GEARS

Oil under pressure comes from the oil manifold through tube (12) to passage (14), to the front bearing for the crankshaft (13), and to fitting (11).

Oil goes through tubes (9 and 2) to passages (8 and 1) in the cylinder block and gives lubrication to the bearing for the governor shaft (6), the governor, and the front bearing for the camshaft (10). Part of the oil goes through tube (3) and passage (4) to give lubrication to the bearing for water pump idler shaft (7). Tube (5) sends oil to the drive gear for the water pump.



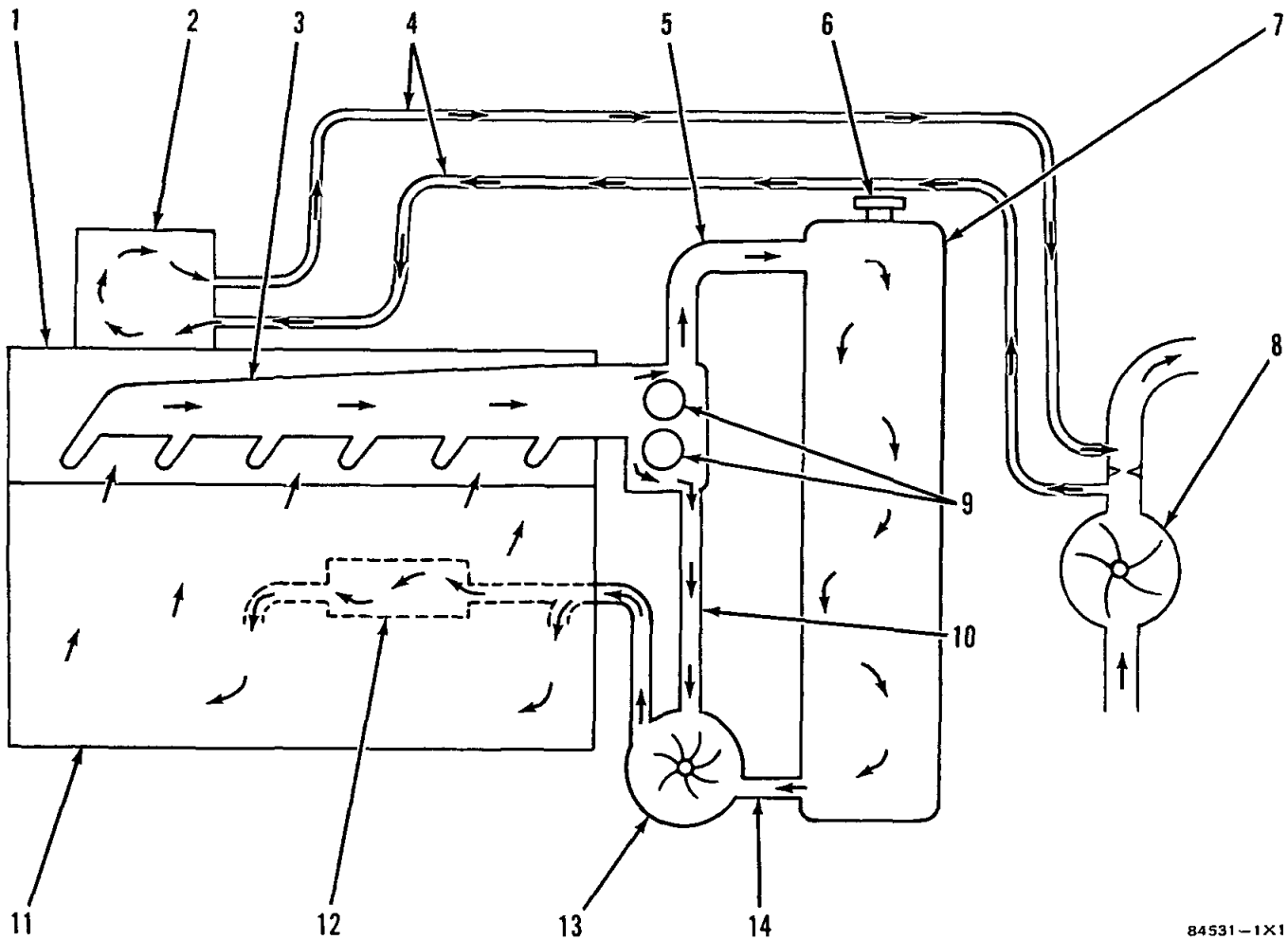
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TIMING GEAR LUBRICATION

1. Oil passage to bearing for governor drive shaft. 2. Oil tube to bearing for camshaft. 3. Oil tube to passage (4). 4. Oil passage to bearing for water pump idler shaft. 5. Oil tube to water pump gear. 6. Bearing for governor drive shaft. 7. Bearing for water pump idler shaft. 8. Passage in block. 9. Tube from oil passage in front of block. 10. Front bearing for camshaft. 11. Fitting. 12. Supply tube from oil manifold. 13. Front bearing for crankshaft. 14. Passage to front bearing for crankshaft.

COOLING SYSTEM

RADIATOR COOLED SYSTEM



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FLOW OF COOLANT IN RADIATOR COOLING SYSTEM

1. Cylinder head. 2. Aftercooler. 3. Water manifold. 4. Lines to and from aftercooler. 5. Radiator inlet line. 6. Radiator cap. 7. Radiator. 8. Auxiliary water pump. 9. Temperature regulators. 10. Bypass line. 11. Cylinder block. 12. Oil cooler. 13. Water pump. 14. Radiator outlet line.

Water pump (13) is gear driven by the engine timing gears. The water pump gets coolant from the bottom tank of radiator (7) and sends some of the coolant into cylinder block (11). The remainder of the coolant goes through oil cooler (12), to cool the oil for lubrication of the engine, and into the cylinder block.

The coolant then goes around the cylinder block, around the cylinder liners and up through the water ferrules and directors into cylinder head (1).

Coolant moves through the cylinder head and into water manifold (3). The coolant goes through the water manifold to temperature regulators (9) at the front of the water manifold. If the coolant is

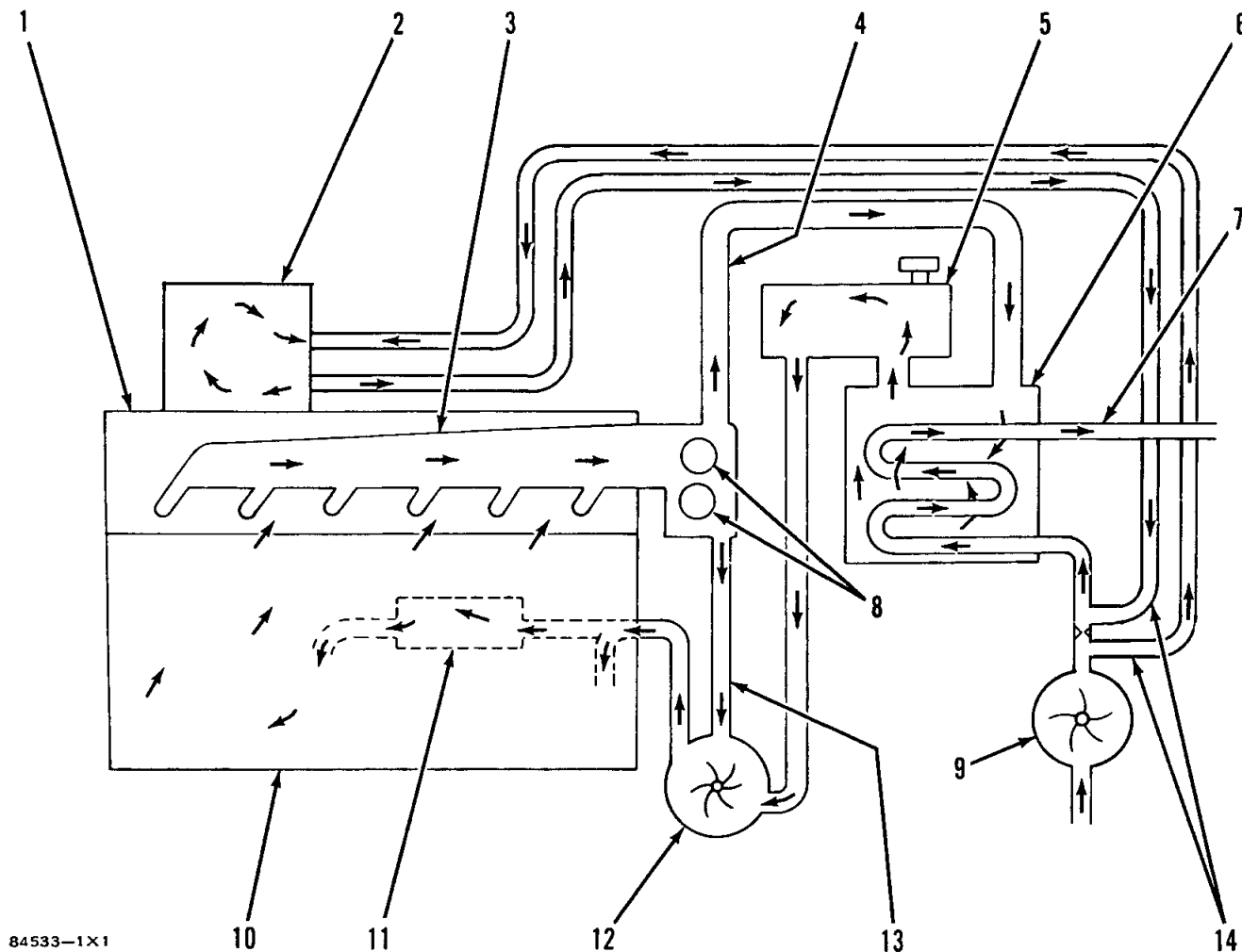
cold (cool), the temperature regulators will be closed. The coolant will go through bypass line (10) to the water pump. If the coolant is warm, the temperature regulators will be open and the coolant will go through line (5) and into the top tank of the radiator. Coolant then goes through the core of the radiator to the bottom tank, where it is again sent through the cooling system. A small part of the coolant goes through bypass line (10) when the temperature regulators are open.

Radiator cap (6) is used to keep the correct pressure in the cooling system. This pressure keeps a constant supply of coolant to the water pump. If this pressure goes too high, a valve in the radiator cap moves (opens) to get a reduction of pressure.

When the correct pressure is in the cooling system, the valve in the radiator cap moves down (to the closed position).

If the engine is equipped with a turbocharger and aftercooler, the auxiliary water pump (8) takes water from an outside source and sends it through lines (4) to the aftercooler (2).

HEAT EXCHANGER COOLED SYSTEM



FLOW OF COOLANT IN HEAT EXCHANGER COOLED SYSTEM

1. Cylinder head. 2. Aftercooler. 3. Water manifold. 4. Coolant outlet line. 5. Expansion tank. 6. Heat exchanger. 7. Outlet line for sea water. 8. Temperature regulators. 9. Auxiliary water pump. 10. Cylinder block. 11. Oil cooler. 12. Water pump. 13. Bypass line. 14. Lines to and from aftercooler.

Water pump (12) is gear driven by the engine timing gears. The water pump gets coolant from expansion tank (5) and sends some of the coolant into cylinder block (10). The remainder of the coolant goes through oil cooler (11), to cool the oil for lubrication of the engine, and then into the cylinder block.

The coolant then goes around the cylinder block, around the cylinder liners and up through the water ferrules and directors into cylinder head (1).

Coolant moves through the cylinder head and into water manifold (3). The coolant goes through the water manifold to temperature regulators (8) at the front of the water manifold. If the coolant is cold (cool), the temperature regulators will be closed. The coolant will go through bypass line (13) to the water pump. If the coolant is warm, the temperature regulators will be open and the coolant will go through line (4) and into heat exchanger (6). The coolant goes through the heat exchanger where it is cooled. The coolant goes

BASIC BLOCK

CYLINDER BLOCK, LINERS AND HEADS

Earlier engines did not have spacer plates. The block was counterbored for the cylinder liner flange.

On later engines a steel spacer plate is used between the cylinder head and the block to eliminate liner counterbore and to provide maximum liner flange support area (the liner flange sits directly on the cylinder block).

Engine coolant flows around the liners to cool them. Three O-ring seals at the bottom and a filler band at the top of each cylinder liner form a seal between the liner and the cylinder block.

The engine has two cylinder heads. Two vertical valves (one intake and one exhaust), controlled by a push rod valve system, are used for each cylinder. Each valve has a rotator to extend valve life. Replaceable valve guides are pressed into the cylinder head.

CAMSHAFT

The engine has a single camshaft that is driven at the front end. It is supported by four bearings. As the camshaft turns, each cam (lobe) (through the action of valve systems components) moves either the exhaust valve or the intake valve for each cylinder. The camshaft gear must be timed to the crankshaft gear. The relation of the cams (lobes) to the camshaft gear cause the valves in each cylinder to open and close at the correct time.

CRANKSHAFT

The crankshaft changes the combustion forces in the cylinder into usable rotating torque which powers the machine. Vibration, caused by combustion impacts along the crankshaft, is kept small by a vibration damper on the front of the crankshaft.

There is a gear at the front of the crankshaft to drive the timing gears which drive the camshaft, oil pump, water pump and governor. Pressure oil is supplied to all bearing surfaces through drilled holes in the crankshaft. The crankshaft is supported by seven main bearings. The center main bearing controls the end play of the crankshaft.

PISTONS

The cast aluminum piston has four rings. The top ring or compression ring is seated in an iron

band that is cast into the piston. The center two rings or intermediate rings seat directly in grooves machined in the piston. The lower ring is the oil ring. Holes in the oil ring groove return oil removed from the cylinder walls to crankcase. All four rings are above the piston pin bore.

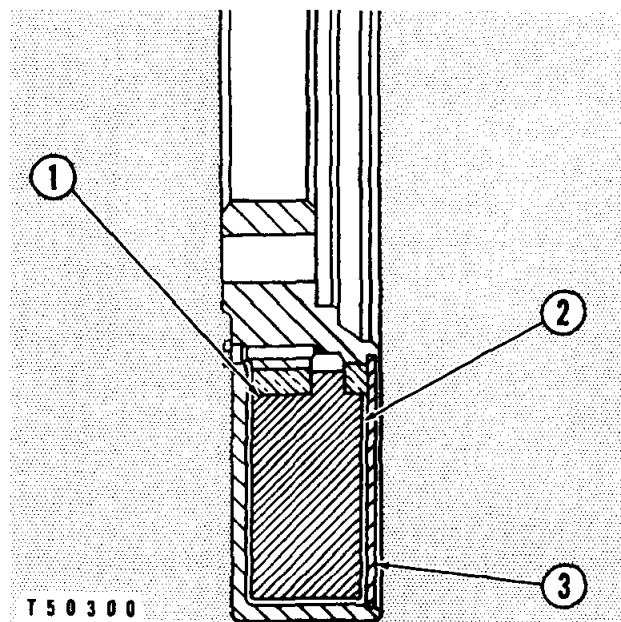
The full-floating piston pin is held in place by two snap rings which fit in grooves in the pin bore.

VIBRATION DAMPER

Viscous Type Damper

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

The damper is made of a weight (1) in a metal case (3). The small space (2) between the case and weight is filled with a thick fluid. The fluid permits the weight to move in the case to cause a reduction of vibrations of the crankshaft.



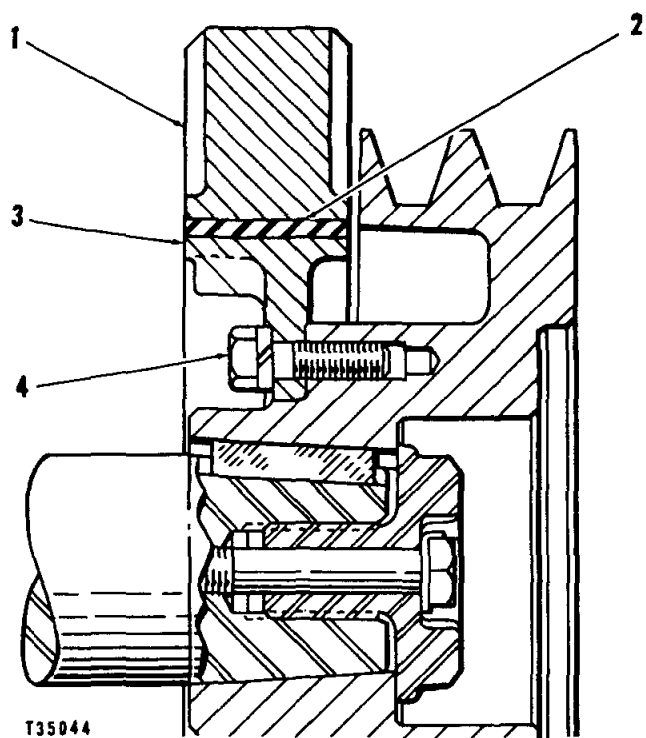
CROSS SECTION OF A TYPICAL
VIBRATION DAMPER

1. Solid cast iron weight. 2. Space between weight and case. 3. Case.

Rubber Ring Type Damper

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

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



CROSS SECTION OF A VIBRATION DAMPER

1. Flywheel ring. 2. Rubber ring. 3. Inner hub. 4. Bolt.

ELECTRICAL SYSTEM

The electrical system has three separate circuits: the charging circuit, the starting circuit and the low amperage circuit. Some of the electrical system components are used in more than one circuit. The battery (batteries), disconnect switch, 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 or a generator makes electricity for the charging circuit. A voltage regulator in the circuit controls the electrical output to keep the battery at full charge.

NOTICE

The disconnect switch, if so equipped, must be in the ON position to let the electrical system function. There will be damage to some of the charging circuit components if the engine is running with the disconnect switch in the OFF position.

If the engine has a disconnect switch, the starting circuit can operate only after the disconnect switch is put in the ON position.

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

The low amperage circuit and the charging circuit are both connected through the ammeter. The starting circuit is not connected through the ammeter.

CHARGING SYSTEM COMPONENTS

Alternator (Delco-Remy)

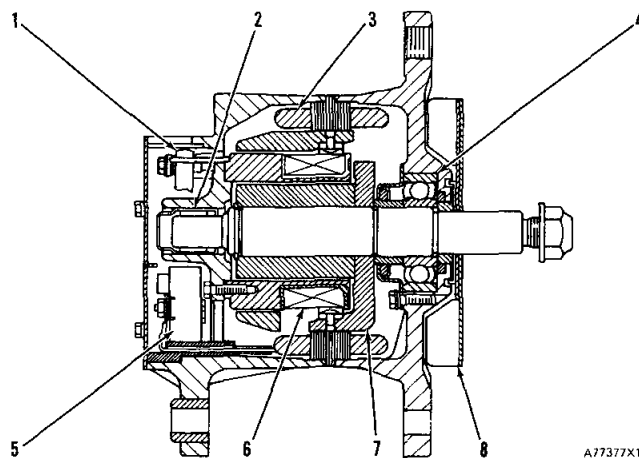
The alternator is driven by V-type belts from the crankshaft pulley. This alternator is a three phase, self-rectifying charging unit, and the regulator is part of the alternator.

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

The rotor assembly has many magnetic poles like fingers with air space between each opposite pole. The poles have residual magnetism (like permanent magnets) that produce a small amount of magnet-like lines of force (magnetic field) between the poles. As the rotor assembly begins to turn between the field winding and the stator windings, a

small amount of alternating current (AC) is produced in the stator windings from the small magnetic lines of force made by the residual magnetism of the poles. This AC current is changed to direct current (DC) when it passes through the diodes of the rectifier bridge. Most of this current goes to charge the battery and to supply the low amperage circuit, and the remainder is sent on to the field windings. The DC current flow through the field windings (wires around an iron core) now increases the strength of the magnetic lines of force. These stronger lines of force now increase the amount of AC current produced in the stator windings. The increased speed of the rotor assembly also increases the current and voltage output of the alternator.

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



DELCO-REMY ALTERNATOR
(Typical Example)

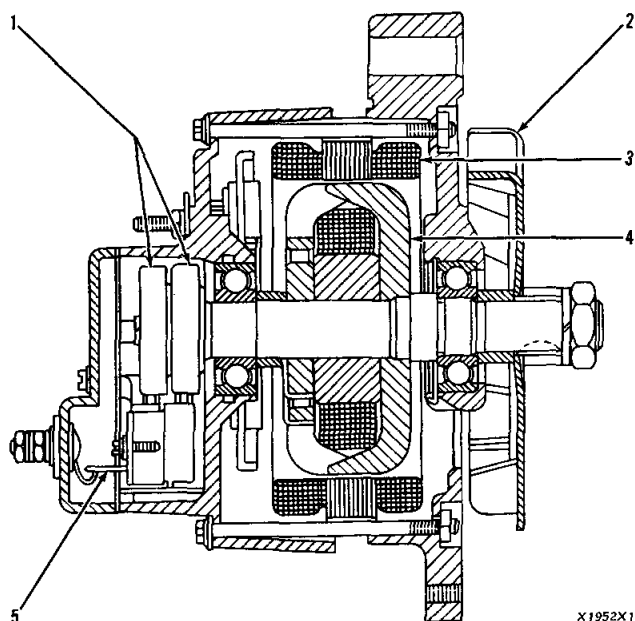
1. Regulator. 2. Roller bearing. 3. Stator winding. 4. Ball bearing. 5. Rectifier bridge. 6. Field winding. 7. Rotor assembly. 8. Fan.

Alternator (Motorola)

The alternator is a three phase, self-rectifying charging unit that is driven by V-type belts. The only part of the alternator that has movement is the rotor assembly. Rotor assembly (4) is held in position by a ball bearing at each end of the rotor shaft.

The alternator is made up of a front frame at the drive end, rotor assembly (4), stator assembly (3), rectifier assembly, brushes and holder assembly (5), slip rings (1) and rear end frame. Fan (2) provides heat removal by the movement of air thru the alternator.

Rotor assembly (4) has field windings (wires around an iron core) that make magnetic lines of force when direct current (DC) flows thru them. As the rotor assembly turns, the magnetic lines of force are broken by stator assembly (3). This makes alternator current (AC) in the stator. The rectifier assembly has diodes that change the alternating current (AC) from the stator to direct current (DC). Most of the DC current goes to charge the battery and make a supply for the low amperage circuit. The remainder of the DC current is sent to the field windings thru the brushes.

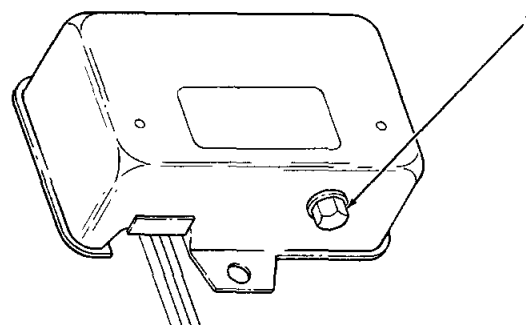


ALTERNATOR

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

Voltage Regulator (Motorola)

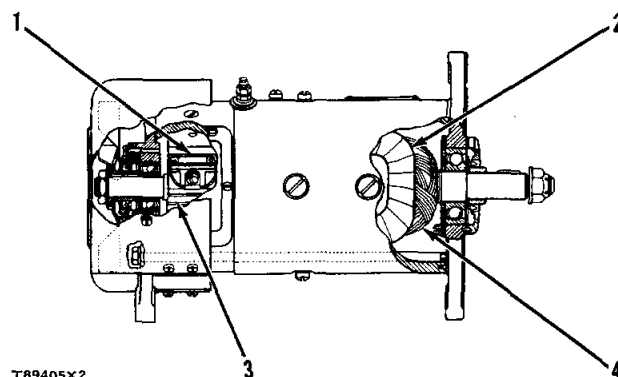
The voltage regulator is not fastened to the alternator, but is mounted separately and is connected to the alternator with wires. The regulator is a solid state (transistor, stationary parts) electronic switch. It feels the voltage in the system and switches on and off many times a second to control the field current (DC current to the field windings) for the alternator to make the needed voltage output. There is a voltage adjustment for this regulator to change the alternator output.



ALTERNATOR REGULATOR (MOTOROLA)

1. Cap for adjustment screw.

Generator



CUTAWAY VIEW OF A GENERATOR

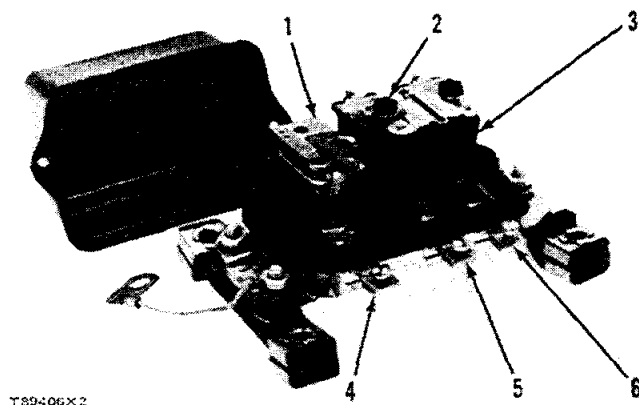
1. Brush assembly. 2. Field. 3. Commutator. 4. Armature.

The generator is turned by a gear system from the drive gear for the water pump. The generator keeps charge in the battery and gives a supply of current to operate the electrical components.

Generator Regulator

The generator regulator controls the output of the generator. The regulator has three controls: the cutout relay (1), the voltage regulator (3) and the current regulator (2). Each control has contact points which are operated by electrically activated magnets (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 in the opposite direction of the force of the electromagnets.



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GENERATOR REGULATOR

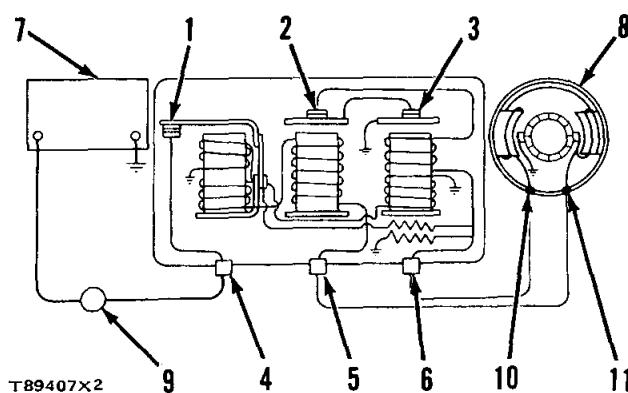
1. Cutout relay. 2. Current regulator. 3. Voltage regulator. 4. Battery terminal. 5. Generator terminal. 6. Field terminal.

The cutout relay prevents the battery from making a motor of a generator that is not making enough voltage. Generator voltage that is 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 give a supply of electricity to the battery and components of the electrical system.

The voltage regulator prevents the generator from making high voltage that would cause damage to the electrical components. Generator voltage that is a small amount more than the battery voltage opens the regulator points causing the generator output to be less. Low generator voltage permits the spring to close the regulator points and the generator voltage is high again. This action of the voltage 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 (2) prevents too much current from being made by the generator so the generator will constantly be making voltage the same as the battery voltage. When the generator makes current the same as the current regulator setting, the regulator contact points open. These open points cause the generator current to be lower. The low current permits the spring to close the points and the generator current is high again. The opening and closing of the current regulator points causes limited current from the generator. The points can open and close as often as 200 times per second.

When the loads on the generator are low and the battery needs very little charge, the voltage regulator contact points (3) are operating. When the electric loads are high, current regulator contact points are operating. The contact points of the two units will never open at the same time.



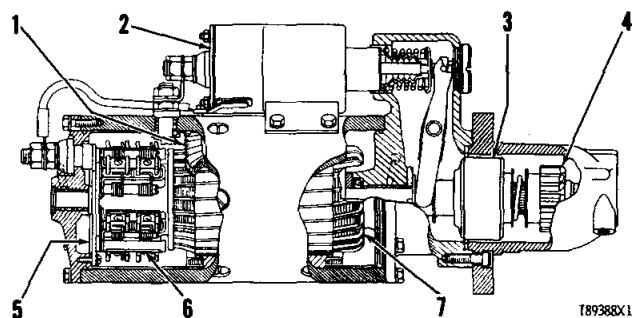
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**SCHEMATIC OF WIRING
DIAGRAM OF GENERATOR REGULATOR**

1. Cutout relay. 2. Current regulator. 3. Voltage regulator. 4. Battery terminal. 5. Generator terminal. 6. Field terminal. 7. Battery. 8. Generator. 9. Ammeter. 10. Field connection. 11. Armature connection.

STARTING SYSTEM COMPONENTS**Starter Motor**

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



T89388X1

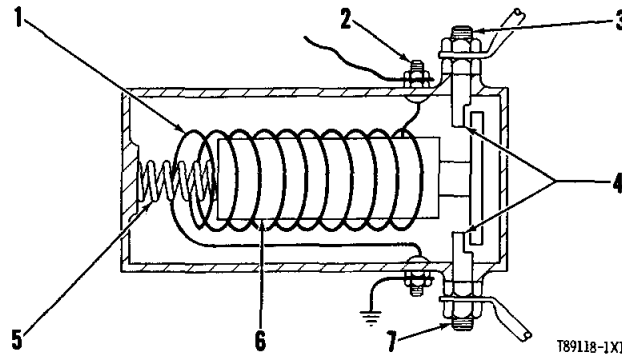
STARTER MOTOR

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

The starter 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 starter motor. When the start switch is released, the starter pinion will move away from the ring gear of the flywheel.

Solenoid

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.



SCHEMATIC OF A SOLENOID

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

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.

WIRING DIAGRAMS

There are many wiring diagrams for these engines. The diagrams are together by the type of electrical system. The diagrams for the charging systems are together by the alternator type.

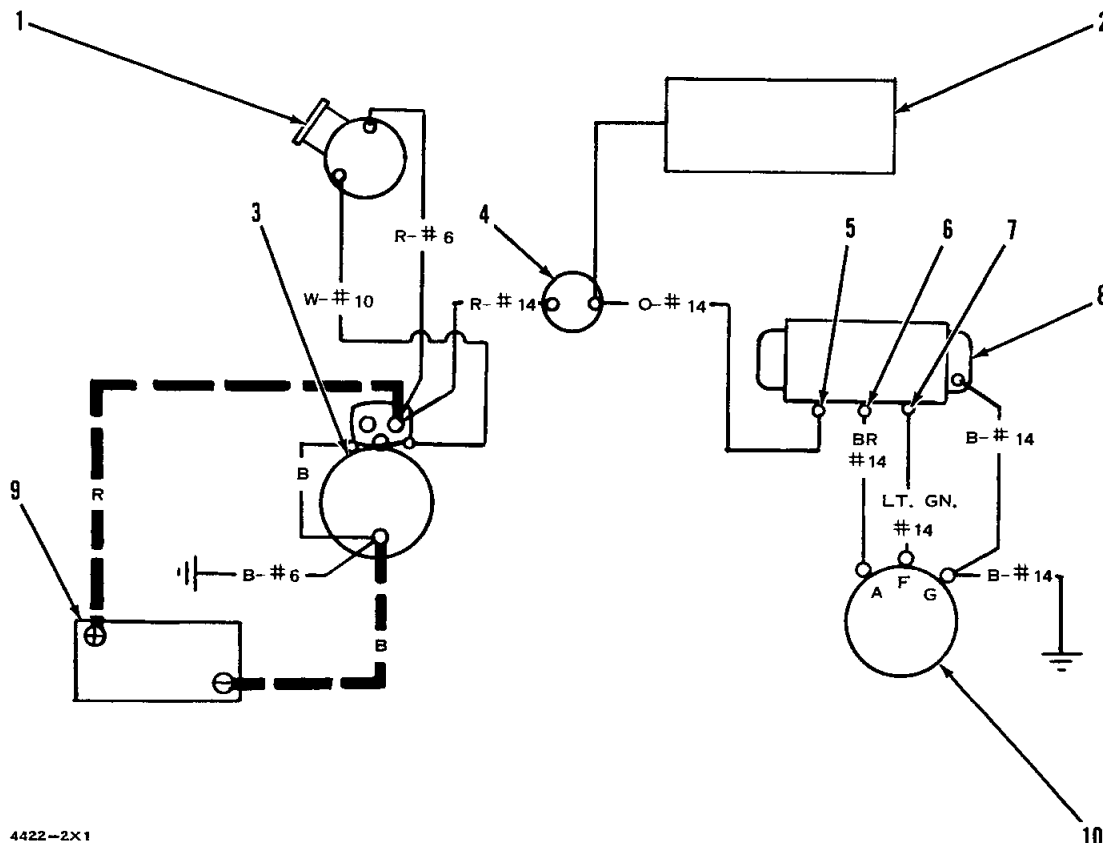
These engines can have electric, air, or hydraulic starting and charging systems. These engines can also have combinations of these systems. Be sure that the diagram is correct for the engine.

COLOR CODE	MAXIMUM RECOMMENDED TOTAL BATTERY CABLE LENGTH		WIRES MARKED # X		
B - Black W - White R - Red O - Orange BR - Brown LT GN - Light Green PU - Purple W/B [White with W/S [Black Stripe	CABLE SIZE	ELECTRIC STARTING		CHARGING UNIT OUTPUT	WIRE SIZE
	0 00 000 0000	12 VOLT	24-32 VOLT	0-18 amps.	# 14
		4.0 FEET	15.0 FEET	19-30 amps.	# 10
		5.0 FEET	18.0 FEET	31-45 amps.	# 8
		6.0 FEET	21.0 FEET	46-65 amps.	# 6
		7.5 FEET	27.0 FEET	NUMBER FOLLOWING COLOR CODE IS RECOMMENDED WIRE SIZE	
x3560—1 X 1					

X3560-1X1

Negative Ground Systems

These systems are used in applications when it is not necessary to prevent radio distortion and/or chemical changes (electrolysis) of grounded components.

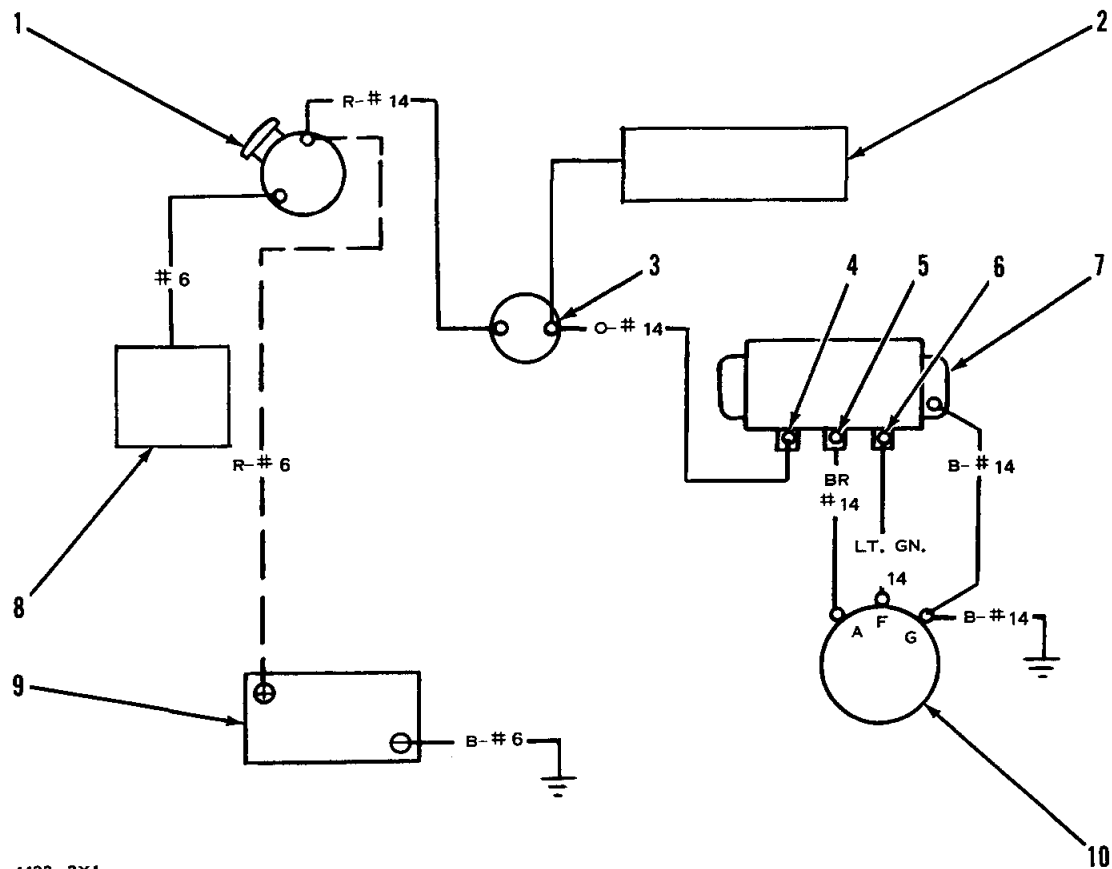


4422-2X1

**NEGATIVE GROUND 24V, 15 AMP, SYSTEM
(DELCO REMY GENERATOR)**

1. Start button. 2. Lights, alarm and other loads. 3. Starting motor. 4. Ammeter. 5. Battery terminal. 6. Generator terminal. 7. Field terminal. 8. Generator regulator. 9. Battery. 10. Generator.

Negative Ground Systems (Cont.)



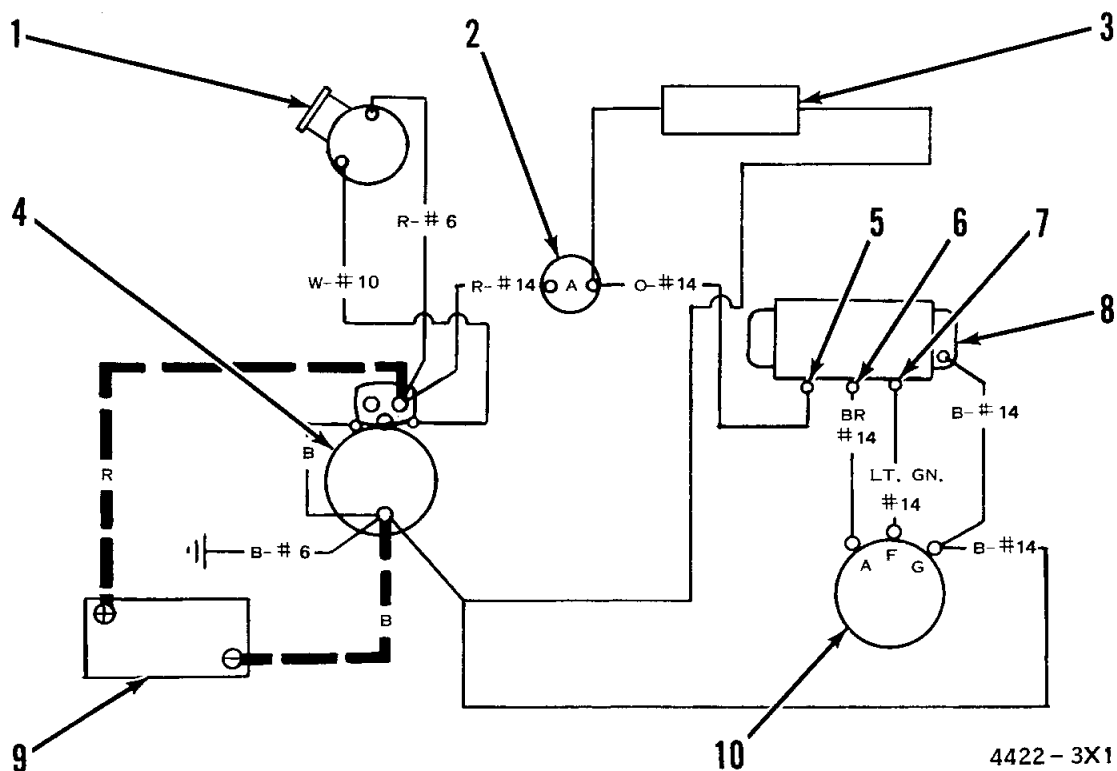
4423-2X1

**NEGATIVE GROUND 24V, 15 AMP, SYSTEM FOR USE WITH
AIR OR HYDRAULIC STARTING (DELCO REMY GENERATOR)**

1. Start button. 2. Lights, alarm and other loads. 3. Ammeter. 4. Battery terminal. 5. Generator terminal. 6. Field terminal. 7. Generator regulator. 8. Control relay for air motor. 9. Battery. 10. Generator.

Insulated Systems

These systems are most often used in applications where radio interference is not desired or where conditions are such that grounded components will have corrosion from chemical change (electrolysis).

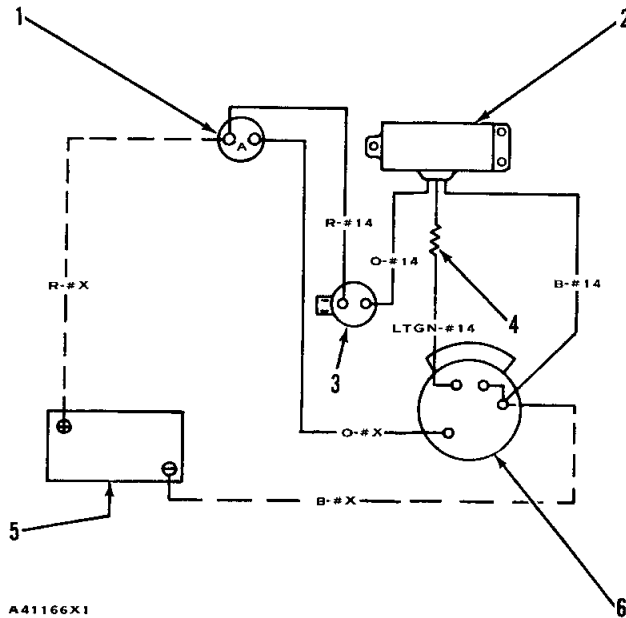


**INSULATED 24V, 15 AMP, SYSTEM
(DELCO REMY GENERATOR)**

1. Start button. 2. Ammeter. 3. Lights, alarm and other loads. 4. Starter motor. 5. Battery terminal. 6. Generator terminal. 7. Field terminal. 8. Generator regulator. 9. Battery. 10. Generator.

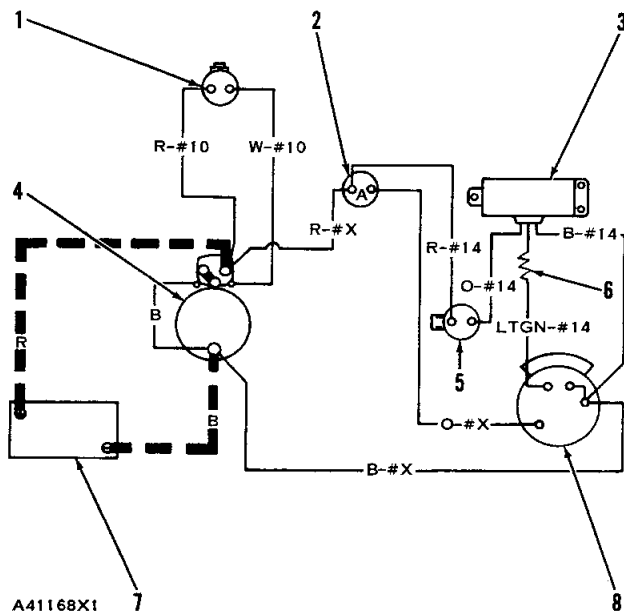
Insulated Systems (Cont.)

(Motorola Alternator)



CHARGING SYSTEM

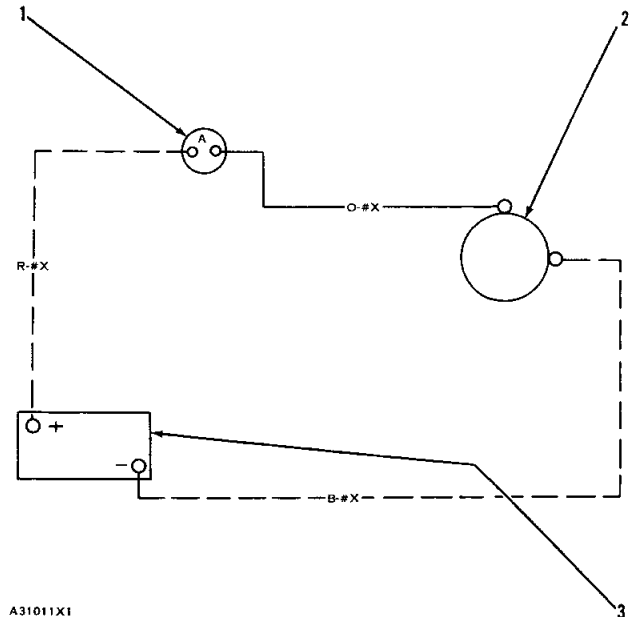
1. Ammeter. 2. Regulator. 3. Pressure switch (N.O.). 4. Resistor (Installed only on 30 and 32 volt systems. On 12 and 24 volt systems, the alternator and regulator are connected without the resistor). 5. Battery. 6. Alternator.



CHARGING SYSTEM WITH ELECTRIC STARTER MOTOR

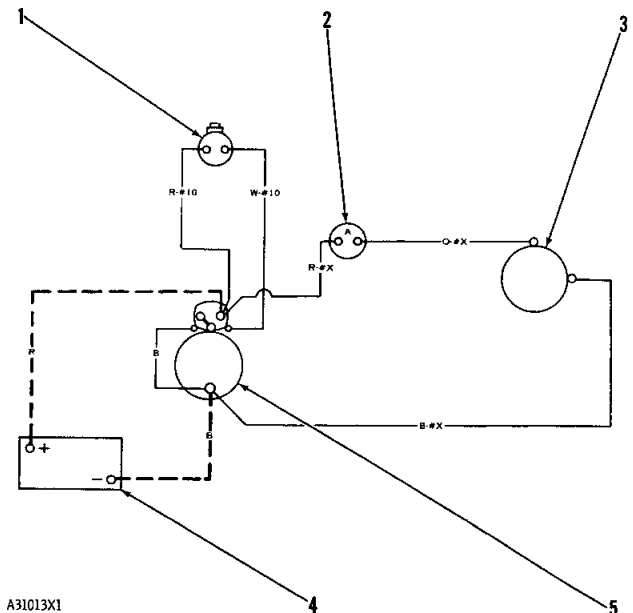
- 1. Start switch. 2. Ammeter. 3. Regulator. 4. Starter motor. 5. Pressure switch (N.O.). 6. Resistor (installed only on 30 and 32 volt systems. On 12 and 24 volt systems, the alternator and regulator are connected without the resistor). 7. Battery. 8. Alternator.**

**(Delco-Remy Alternator)
(Regulator Inside Alternator)**



CHARGING SYSTEM

- 1. Ammeter. 2. Alternator. 3. Battery.**

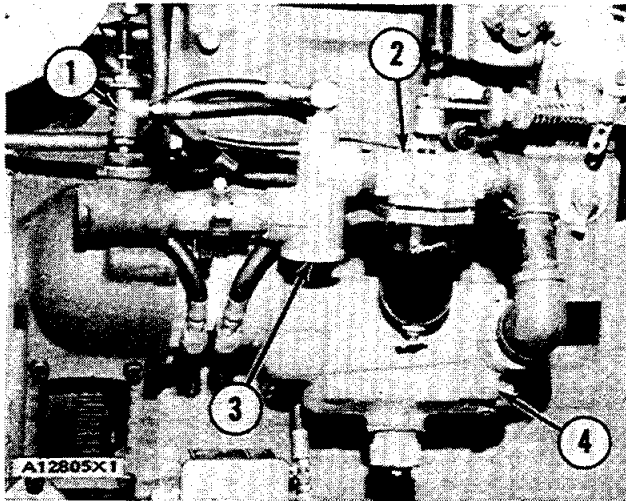


CHARGING SYSTEM WITH ELECTRIC STARTER MOTOR

1. Start switch. 2. Ammeter. 3. Alternator. 4. Battery.
5. Starter motor.

AIR STARTING SYSTEM

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



AIR STARTING SYSTEM
(Typical Example)

1. Starter control valve. 2. Oiler. 3. Relay valve. 4. Air starting motor.

The air starting motor is on the right side of the engine. Normally the air for the starting motor is from a storage tank which is filled by an air compressor installed on the left front of the engine. The air storage tank holds 10.5 cu. ft. (297 liter) of air at 250 psi (1720 kPa) when filled.

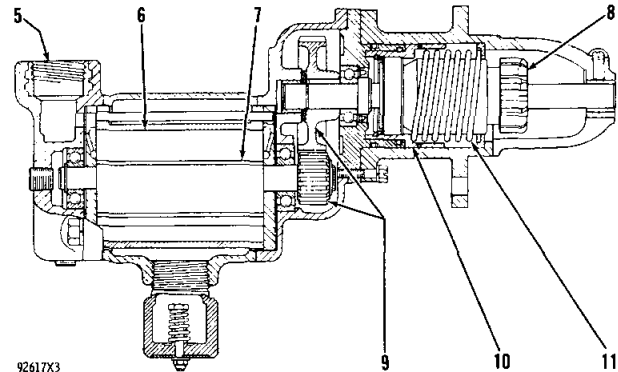
For engines which do not have heavy loads when starting, the regulator setting is approximately 100 psi (690 kPa). This setting gives a good relationship between cranking speeds fast enough for easy starting and the length of time the air starting motor can turn the engine before the air supply is gone.

If the engine has a heavy load which can not be disconnected during starting, the setting of the air pressure regulating valve needs to be higher in order to get high enough speed for easy starting.

The air consumption is directly related to speed, the air pressure is related to the effort necessary to turn the engine flywheel. The setting of the air pressure regulator can be up to 150 psi (1030 kPa) if necessary to get the correct cranking speed for a heavily loaded engine. With the correct setting, the air starting motor can turn the heavily loaded engine as fast and as long as it can turn a lightly loaded engine.

Other air supplies can be used if they have the correct pressure and volume. For good life of the air starting motor, the supply should be free of dirt and water. The maximum pressure for use in the air starting motor is 150 psi (1030 kPa). Higher pressures can cause safety problems. The 1L5011

Regulating and Pressure Reducing Valve Group has the correct characteristics for use with the air starting motor. Most other types of regulators do not have the correct characteristics. Do not use a different style of valve in its place.



AIR STARTING MOTOR

5. Air inlet. 6. Rotor. 7. Vanes. 8. Pinion. 9. Gears. 10. Piston. 11. Pinion spring.

The air from the supply goes to relay valve (3). The starter control valve (1) is connected to the line before the relay valve (3). The flow of air is stopped by the relay valve (3) until the starter control valve (1) is activated. Then air from the starter control valve (1) goes to the piston (10) behind the pinion (8) for the starter. The air pressure on the piston (10) puts the spring (11) in compression and puts the pinion (8) in engagement with the flywheel gear. When the pinion is in engagement, air can go out through another line to the relay valve (3). The air activates the relay valve (3) which opens the supply line to the air starting motor.

The flow of air goes through the oiler (2) where it picks up lubrication oil for the air starting motor.

The air with lubrication oil goes into the air motor. The pressure of the air pushes against the vanes (7) in the rotor (6). This turns the rotor which is connected by gears (9) to the starter pinion (8) which turns the engine flywheel.

When the engine starts running the flywheel will start to turn faster than the starter pinion (8). The pinion (8) retracts under this condition. This prevents damage to the motor, pinion (8) or flywheel gear.

When the starter control valve (1) is released, the air pressure and flow to the piston (10) behind the starter pinion (8) is stopped, the pinion spring (11) retracts the pinion (8). The relay valve (3) stops the flow of air to the air starting motor.

TROUBLESHOOTING

Troubleshooting can be difficult. The TROUBLESHOOTING INDEX gives a list of possible problems. To make a repair to a problem, make reference to the cause and corrections on the pages that follow.

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 is only a guide and can not give all possible problems and corrections. The serviceman must find the problem and its source, then make the necessary repairs.

TROUBLESHOOTING INDEX

Item	Problem	Item	Problem
1.	Engine Crankshaft Will Not Turn When Start Switch is On.	25.	Starter Motor Does Not Turn.
2.	Engine Will Not Start.	26.	Alternator Gives No Charge.
3.	Misfiring or Running Rough.	27.	Alternator Charge Rate Is Low or Not Regular.
4.	Stall at Low rpm.	28.	Alternator Charge Too High.
5.	Sudden Changes In Engine Speed.	29.	Alternator Has Noise.
6.	Not Enough Power.	30.	Solenoid Does Not Stop Engine.
7.	Too Much Vibration.	31.	Short Spark Plug Life.
8.	Loud Combustion Noise (Knock).	32.	Preignition.
9.	Loud Noise (Clicking) From Valve Compartment.	33.	Detonation.
10.	Oil In Cooling System.	34.	Gas Supply Line Shutoff Valve Failure.
11.	Mechanical Noise (Knock) In Engine.	35.	Instrument Panel Gauge Switches Do Not Stop Engine.
12.	Gas Consumption Too High.	36.	Instrument Panel Gauge Switches Prevent Engine Start.
13.	Loud Noise From Valves or Valve Drive Components.	37.	Failure of Overspeed Contactor Switch to Shutoff Engine.
14.	Little Movement of Rocker Arm and Too Much Valve Clearance.	38.	Overspeed Contactor Stops Engine at Low Speed.
15.	Valve Rotocoil or Spring Lock is Free.	39.	Air Starting Motor Turns Slowly.
16.	Oil at the Exhaust.	40.	Troubleshooting Solid State Magneto. (Fairbanks Morse)
17.	Little or No Valve Clearance.	40A.	Missing on One or More Cylinders.
18.	Engine Has Early Wear.	40B.	Engine Dead and Has No Spark.
19.	Coolant in Lubrication Oil.	41.	Troubleshooting Solid State Magneto. (Altronic)
20.	Exhaust Temperature is Too High.	41A.	Missing on One or More Cylinders.
21.	Too Much White or Blue Smoke.	41B.	Engine Dead and Has No Spark.
22.	Engine Has Low Oil Pressure.		
23.	Engine Uses Too Much Lubrication Oil.		
24.	Engine Coolant Is Too Hot.		

1. ENGINE CRANKSHAFT WILL NOT TURN WHEN START SWITCH IS ON.

Cause	Correction
Battery Has Low Output	Make Reference to Item 26.
Wiring or Switches Have Defect	Make Reference to Item 26.
Starting Motor Solenoid Has A Defect	Make Reference to Item 25.
Starting Motor Has A Defect	Make Reference to Item 25.
Inside Problem Prevents Engine Crankshaft From Turning	If the crankshaft can not be turned after the driven equipment is disconnected, remove the spark plugs and check for fluid in the cylinders while the crankshaft is turned. 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, or wrong pistons installed in the engine and valves making contact with pistons.

2. ENGINE WILL NOT START

Cause	Correction
Slow Cranking Speed	Make Reference to Item 26.
No Gas to Engine	Check gas supply and pressure regulator. Reset shutoff valve in the supply line. Check carburetor throttle and linkage between carburetor and governor.
Wrong Ignition Timing	Make adjustment to magneto timing.
Ignition System Failure	Check the ignition transformers for loose connection, moisture, short or open circuits. Check the low and high tension wires. Check the spark plugs for correct type and spark plug adapters. Check the magneto. Repair or replace any component that shows signs of failure.
Gas Line Pressure Regulator Not Working	Clean balance line. Check inlet and outlet regulator pressures.
Carburetor Not Working	Check all carburetor adjustments. Be sure that throttle plate is open and that governor permits it to open fully. Check the BTU content of the fuel based on lower heat value (LHV). If it is too low, a higher fuel pressure (correct spring in the regulator), or a special carburetor may be needed. Inspect the fuel-air diaphragm for leaks, dirt or wet fuel. Check the governor high idle and carburetor stop screw for low idle adjustments.
Slow Cranking Speed	Cranking speed must be at least 100 rpm. Check condition of starting system. Make reference to Item 25.
Switch of the Gauge Panel Broken	Hold in reset button of the magnetic switch while cranking to cut out (override) gauge switches.

3. MISFIRING OR RUNNING ROUGH

Cause	Correction
Ignition System Failure	Make Reference to Item 2.
Low Gas Pressure	Check for leaks in gas supply. Check the line pressure regulator, shutoff valve and solenoid. If two or more engines are used, be sure the common supply line is large enough. Regulator pressure should not change over the normal load range. Inspect the regulator diaphragm for leaks and valve for correct seat contact. Check gas pressure before and after the line pressure regulator. Check for restriction in balance line for carburetor to regulator. Set valve clearances.
Wrong Valve Clearance	Make adjustment according to Specifications.
Bent or Broken Push Rod	Replacement of push rod is necessary.

4. STALL AT LOW RPM

Cause	Correction
Idle rpm Too Low	Make adjustment to the throttle stop screw at the carburetor.
Too Much Load	Be sure the attachments do not put too much load on the engine. Make a reduction in load and/or make adjustment to throttle stop. If necessary, disconnect attachments and test engine.

5. SUDDEN CHANGES IN ENGINE SPEED

Cause	Correction
Governor Failure	Look for damaged or broken springs, linkage or other components. Check governor-to-carburetor linkage or other components. Check for correct spring.
Wrong Adjustment or Valve Leakage	Make adjustment to the valves. If necessary, make replacement of the valves.
Governor Springs Not Fully On Spring Seat	Put springs fully on spring seat.
Governor or Linkage Adjustment Incorrect	Check to see if linkage between governor and carburetor operates smoothly and has no free play. Make adjustment to the governor and linkage as necessary.
Low Gas Pressure	Make reference to Item 3.

6. NOT ENOUGH POWER

Cause	Correction
Low Gas Pressure or Gas Line Pressure Regulator Failure	Make reference to Item 3.
Carburetor Adjustment or Carburetor Not Working	Make reference to Item 2.
Leaks in Air Induction System	Check air cleaner for restriction. Check inlet manifold pressure on turbocharged engines.
Too Much Valve Clearance	Set to correct clearance.
Failure of Ignition Wires	Check for damage to wires arcing, or bare wire. Check rubber boot over spark plugs for cracks or moisture.
Transformer Failure	Check for loose connections, moisture, short or open circuits.
Bad Spark Plugs	Check type of plug used. Install correct type. Inspect for gas leaks and/or cracked porcelain. Clean and set gap of the plugs. Install new plugs if badly worn.
Wrong Ignition Timing	Make adjustment to magneto timing. Tighten any loose wires.
Spark Plug Adapters Leak	Check for water leakage into cylinder, or combustion gases in coolant. Install new adapters.
Boost Limit Control Failure	Check the valve movement.
Too Much Carbon In Turbocharger or Turbocharger Turns Too Slow	Inspect and install a new turbocharger as necessary.
Deposits in the Combustion Chamber	Make a compression test on all cylinders. Any cylinder which has great difference from the others should be inspected and cleaned.
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.

7. TOO MUCH VIBRATION

Cause	Correction
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.
Misfiring or Running Rough	Make Reference to Item 3.

8. LOUD COMBUSTION NOISE (KNOCK)

Cause	Correction
Gas Octane Rating Too Low	Use recommended gas.
Detonation	Make reference to Item 33.
Preignition	Make reference to Item 32.

9. LOUD NOISE (CLICKING) FROM VALVE COMPARTMENT

Cause	Correction
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 that send 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.

10. OIL IN COOLING SYSTEM

Cause	Correction
Defect In Core of Oil Cooler	Install a new oil cooler.
Defect of Head Gasket or Water Seals	Install a new head gasket and new water seals in spacer plate.

11. MECHANICAL NOISE (KNOCK) IN ENGINE

Cause	Correction
Failure of Bearing For Connecting Rod	Inspect the bearing for the connecting rod and the bearing surface on the crankshaft. Install new parts where necessary.
Damaged Timing Gears	Install new parts where necessary.
Defect in Attachment	Repair or install new components.
Broken Crankshaft	Install a new crankshaft. Check other components for damage.

12. GAS CONSUMPTION TOO HIGH

Cause	Correction
Gas System Leaks	Replacement of parts is needed at points of leakage.
Spark Plugs Not Firing	Check spark and install new plugs if necessary.
Wrong Ignition Timing	Make adjustment to magneto timing.

13. LOUD NOISE FROM VALVES OR VALVE DRIVE COMPONENTS

Cause	Correction
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.

14. LITTLE MOVEMENT OF ROCKER ARM AND TOO MUCH VALVE CLEARANCE

Cause	Correction
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 that send oil to the cylinder head.
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 Cams 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 Specifications.

15. VALVE ROTOCOIL OR SPRING LOCK IS FREE

Cause	Correction
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).

16. OIL AT THE EXHAUST

Cause	Correction
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	Do not let the engine run for long periods of time at low idle.
Turbocharger Leak	Check turbocharger oil seals.

17. LITTLE OR NO VALVE CLEARANCE

Cause	Correction
Worn Valve Seat or Face of Valve	Reconditioning of cylinder head is needed. Make adjustment of valve clearance according to Specifications.

18. ENGINE HAS EARLY WEAR

Cause	Correction
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.

19. COOLANT IN LUBRICATION OIL

Cause	Correction
Failure of Oil Cooler Core	Install a new oil cooler.
Failure of Cylinder Head Gasket or Water Seals	Install a new cylinder head gasket and new water seals in the spacer plate. Tighten the bolts that hold 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 Seals for Cylinder Liners	Make a replacement of the seals.

20. EXHAUST TEMPERATURE IS TOO HIGH

Cause	Correction
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.
Wrong Ignition Timing	Make adjustment to magneto timing.

21. TOO MUCH WHITE OR BLUE SMOKE

Cause	Correction
Too Much Lubrication Oil in Engine	Remove extra oil. Find where extra oil comes from. Put correct amount of oil in engine.
Misfiring or Running Rough	Make reference to Item 3.
Wrong Timing	Make adjustment to magneto timing.
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.

22. ENGINE HAS LOW OIL PRESSURE

Cause	Correction
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 a new oil cooler. Remove dirty oil from engine. Put clean oil in 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.
Orifices For Piston Cooling Not Installed	Be sure orifices are installed in the cylinder block.

23. ENGINE USES TOO MUCH LUBRICATION OIL

Cause	Correction
Too Much Lubrication Oil in Engine	Remove extra oil. Find where extra oil comes from. Put correct amount of 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 or install a new oil cooler.
Too Much Oil in Valve Compartment	Make Reference to Item 16.
Worn Valve Guides	Make Reference to Item 16.
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.

24. ENGINE COOLANT IS TOO HOT

Cause	Correction
Restriction To Air Flow Through Radiator or Restriction To Flow of Coolant Through the Heat Exchanger	Remove all restrictions to flow.
Not Enough Coolant in System	Add coolant to cooling system.
Pressure Cap Has Defect	Check operation of pressure cap. Install a new pressure cap if necessary.
Combustion Gases in Coolant	Find out where gases get into the cooling system. Make repairs as needed.
Water Temperature Regulator (Thermostat) or Temperature Gauge Has A Defect	Check water temperature regulator 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 Ignition Timing	Make adjustment to timing.

25. STARTER MOTOR DOES NOT TURN

Cause	Correction
Battery Has Low Output	Check condition of battery. Charge battery or make replacement as necessary.
Wires or Switch Has Defect	Make repairs or replacement as necessary.
Starter Motor Solenoid Has A Defect	Install a new solenoid.
Starter Motor Has A Defect	Make repair or replacement of starter motor.
Inside of Engine Problem	Make reference to Item 1.

26. ALTERNATOR GIVES NO CHARGE

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

27. ALTERNATOR CHARGE RATE IS LOW OR NOT REGULAR

Cause	Correction
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.

28. ALTERNATOR CHARGE TOO HIGH (AS SHOWN BY BATTERY NEEDS TOO MUCH WATER)

Cause	Correction
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.

29. ALTERNATOR HAS NOISE

Cause	Correction
Drive Belt for Alternator is Worn or Has A Defect	Install a new drive belt for the alternator.
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.

30. SOLENOID DOES NOT STOP ENGINE

Cause	Correction
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.
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.

31. SHORT SPARK PLUG LIFE

Cause	Correction
Wrong Polarity of Connections at Transformers	Check wiring diagrams in SYSTEMS OPERATION. Make change to the connection of wires to the primary coil of transformers.
Wrong Magneto Timing (Ignition Sequence)	Make adjustment to magneto timing.
Wrong Spark Plugs	Install correct spark plugs.

32. PREIGNITION

Cause	Correction
Worn Spark Plugs	Clean and make adjustment to the plug gap. If worn install new plugs.
Water Leakage in Cylinder or Combustion Gas	Inspect spark plug adapter gasket. Check spotface for adapter in head for roughness. Install a new adapter to correct torque.

33. DETONATION

Cause	Correction
Wrong Magneto Timing	Make adjustment to magneto timing.
Deposits in Combustion Chamber	Remove deposits from combustion chambers.
High Ambient Air Temperature	Check for high engine room temperature or high temperature of water to aftercooler.
Too Much Load	Make a reduction in the load.
Restrictions in Aftercooler	Inspect, clean or install new aftercooler as necessary.
Fuel to Air Ratio Too "Rich"	Check and make adjustment to gas regulator setting.

34. GAS SUPPLY LINE SHUTOFF VALVE FAILURE

Cause	Correction
Defect in Solenoid	Install new solenoid.
Wrong Electrical Rated Solenoid	Install new solenoid valve with correct valve.
Defect in Wiring and/or Connections	Correct the defect in wiring and connections.

35. INSTRUMENT PANEL GAUGE SWITCHES DO NOT STOP ENGINE

Cause	Correction
Loose Connection or Defect In Wiring	Check the wiring and tighten the connections at overspeed shutoff, water temperature gauge, oil pressure gauge, magnetic switch, stop switch, valve solenoid in gas supply line and magneto.
Defect in Magnetic Switch	Install a new magnetic switch.
Defect in Gauge Switches or Overspeed Shutoff	Make adjustment to or install new gauge or overspeed shutoff.
Defect in Valve Solenoid In The Gas Supply Line	Install a new solenoid valve.

36. INSTRUMENT PANEL GAUGE SWITCHES PREVENT ENGINE START

Cause	Correction
Defective Wiring	Check for wiring contact to ground.
Magnetic Switch Failure	Check wiring in panel for ground and gauge switches for failure.
High Water Temperature or Oil Pressure Gauge Switches not Reset or Failure of Switches	Permit engine to cool. Engage switches. Make adjustment or install new switches.

37. FAILURE OF OVERSPEED CONTACTOR SWITCH TO SHUTOFF ENGINE

Cause	Correction
Wrong Electrical Connections	Check connection, wiring and correct where necessary.
Wrong Adjustment	Make adjustment or install new contactor switch.

38. OVERSPEED CONTACTOR STOPS ENGINE AT LOW SPEED

Cause	Correction
Wrong Adjustment	Make adjustment or install new contactor switch if necessary.

39. AIR STARTING MOTOR TURNS SLOWLY

Cause	Correction
Low Supply Air Pressure	Make an increase to the air supply pressure.
Pressure Regulator Adjustment Not Correct	Make an adjustment to the air pressure regulator.
Oiler Not Working Correctly	Clean, make an adjustment to, and fill oiler.

40. TROUBLESHOOTING SOLID STATE MAGNETO (FAIRBANKS MORSE)

40A. Missing on One or More Cylinders

1. Use a 1P1790 Firing Indicator to find which cylinder(s) is missing.

Note: The brightness of the neon bulb used in this tool indicates the required voltage of the spark plug only. It does not reflect the output of the magneto.

2. Find which wire, in the primary magneto harness, (wire from magneto to transformer), is connected to the problem cylinder. See Wiring Diagrams in SYSTEMS OPERATION.
3. Stop the engine and disconnect the magneto harness connector from the magneto.

Note: All ohmmeters must be "zeroed" (adjusted to read zero when the leads are connected together) before using. Follow instructions with your meter.

All meters have a percentage of error because of the type of meter movement used. This error can be from 3 to 5%. A variation between meters is normal.

4. Using an ohmmeter having a scale of RX1, connect the probes between the pin of the problem cylinder, (pin in wiring harness), and a good ground. Read the resistance. The resistance should be between .3 and .6 ohms. If reading is within specification the primary circuit is not defective. Proceed to Step 7.

A reading of less than .3 ohms indicates grounded primary wire or shorted primary in the transformer.

A reading of more than .6 ohms indicates poor connections, defective primary in transformer, or poor ground connection.

5. To locate the defect, disconnect the primary wire from the transformer, (wire from magneto). Connect the ohmmeter to the primary stud of the transformer and ground. Check resistance again. Correct reading is .3 to .6 ohms.

Correct reading: defect in primary harness wire or connector in harness.

Incorrect reading: defective transformer or poor ground.

6. Connect the ohmmeter across the primary terminals of the transformer. Read the resistance. Correct reading is .3 to .6 ohms.

Correct reading: poor ground.

Incorrect reading: defective transformer.

7. With the magneto harness still disconnected, remove the spark plug high tension lead from the spark plug. Do not remove the transformer.

8. Using a scale of RX 100 or RX1000, connect the ohmmeter between the spark plug connector and ground. The resistance should be between 11,000 to 13,000 ohms.

Correct reading: defective spark plug or magneto.

Incorrect reading: defective spark plug high tension lead, transformer or ground.

9. Remove the spark plug high tension lead from the transformer. Read resistance between high tension outlet of the transformer to ground. The resistance should be between 11,000 to 13,000 ohms.

Correct reading: defective spark plug high tension lead and/or connections.

Incorrect reading: defective transformer or ground.

10. Connect ohmmeter between the high tension outlet of the transformer and ground terminal of the transformer. The correct reading is 11,000 to 13,000 ohms.

Correct reading: defective ground.

Incorrect reading: defective transformer.

40B. Engine Dead and Has No Spark

1. At a convenient place, break the connection between the "H" wire of the magneto harness and the shutdown circuit. Try to start the engine.

Engine Starts: Defect in shutdown circuit.

Repair as required.

Engine Does Not Start: Proceed to Step 2.

2. Connect an ohmmeter, using high scale, between the "H" wire, at the place you made the break, and ground.

A reading of "Infinite": "H" lead not grounded.

Any resistance: Grounded "H" lead or defective magneto.

Note: For this test, any reading over 500,000 ohms is to be considered infinite.

3. Remove harness connector from magneto. Connect an ohmmeter, using high scale, between "H" pin in the harness connector and ground. Be sure to touch only the "H" pin when making this test.

A reading of "Infinite": "H" lead not grounded. Defective magneto. Replace the magneto.

Any resistance: "H" lead grounded. Repair as required.

NOTICE

Be sure to reconnect "H" lead to shutdown circuit after repairs are made. Failure to do so will leave the engine unprotected and damage could result.

41. TROUBLESHOOTING SOLID STATE MAGNETO (ALTRONIC)

41A. Missing on One or More Cylinders

1. Use a 1PI790 Firing Indicator to find which cylinder(s) is missing.

Note: The brightness of the neon bulb used in this tool indicates the required voltage of the spark plug only. It does not reflect the output of the magneto.

2. Find which wire, in the primary magneto harness, (wire from magneto to transformer), is connected to the problem cylinder. See Wiring Diagrams in SYSTEMS OPERATION.

3. Stop the engine and disconnect the magneto harness connector from the magneto.

Note: All ohmmeters must be "zeroed" (adjusted to read zero when the leads are connected together) before using. Follow instructions with your meter.

All meters have a percentage of error because of the type of meter movement used. This error can be from 3 to 5%. A variation between meters is normal.

4. Using an ohmmeter having a scale of RX1, connect the probes between the pin of the problem cylinder, (pin in wiring harness), and a good ground. Read the resistance. The resistance should be between .1 and .2 ohms. If reading is within specification the primary circuit is not defective. Proceed to Step 7.

A reading of less than .1 ohm indicates grounded primary wire or shorted primary in the transformer.

A reading of more than .2 ohms indicates poor connections, defective primary in transformer, or poor ground connection.

5. To locate the defect, disconnect the primary wire from the transformer, (wire from magneto). Connect the ohmmeter to the primary stud of the transformer and ground. Check resistance again. Correct reading is .1 to .2 ohms.

Correct reading: defect in primary harness wire or connector in harness.

Incorrect reading: defective transformer or poor ground.

6. Connect the ohmmeter across the primary terminals of the transformer. Read the resistance. Correct reading is .1 to .2 ohms.

Correct reading: poor ground.

Incorrect reading: defective transformer.

7. With the magneto harness still disconnected, remove the spark plug high tension lead from the spark plug. Do not remove the transformer.

8. Using a scale of RX 100 or RX1000, connect the ohmmeter between the spark plug connector and ground. The resistance should be between 5,000 to 8,000 ohms.

Correct reading: defective spark plug or magneto.

Incorrect reading: defective spark plug high tension lead, transformer or ground.

9. Remove the spark plug high tension lead from the transformer. Read resistance between high tension outlet of the transformer to ground. The resistance should be between 5,000 to 8,000 ohms.

Correct reading: defective spark plug high tension lead and/or connections.

Incorrect reading: defective transformer or ground.

10. Connect ohmmeter between the high tension outlet of the transformer and ground terminal of the transformer. The correct reading is 5,000 to 8,000 ohms.

Correct reading: defective ground.

Incorrect reading: defective transformer.

41B. Engine Dead and Has No Spark

1. Disconnect the M₁ terminal of the magnetic switch on the engine instrument panel. Try to start the engine.

Engine Starts: Defect in shutdown circuit. Repair as required.

Engine Does Not Start: Proceed to Step 2.

2. Connect an ohmmeter between the wire that was removed from the magnetic switch M₁ terminal and ground.

An ohmmeter reading of infinite (500,000 ohms or greater).

- a. The wire is not grounded.
- b. Possible defective magneto.

A resistance indication on the ohmmeter.

- a. Grounded wire between instrument panel and magneto.
- b. Defective magneto.

3. Remove the wiring harness connector from the magneto. Connect an ohmmeter between the G pin in the wiring harness connector and ground.

- a. Any resistance indication means that the wire is grounded. Replace or repair as required.
- b. A reading of infinite indicates that the wire is not grounded. Defective magneto. Repair or replace the magneto.

NOTICE

Be sure to reconnect the wire to the magnetic switch and the connector to the magneto after the repairs are made.

IGNITION SYSTEM

To make a test of the magneto on the engine, check the condition (intensity) of the spark at the spark plug. Remember that the condition of the instrument panel components: magnetic switch, stop switch, oil pressure gauge and water temperature gauge have an effect on the output of the magneto. A defect in, or an activated overspeed shutoff contact or gas line solenoid valve can cause an indication of a defect in the magneto.

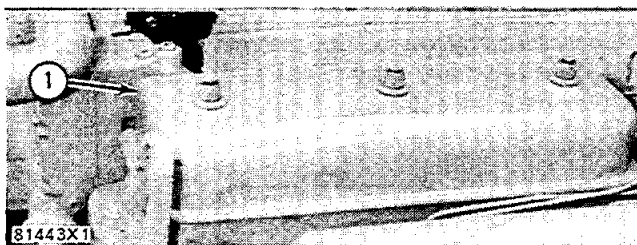
A test of the magneto off the engine can be used to find a defect in the electrical components. The 2P2340 Magneto Test Bench is used to make the tests. Special Instruction Form No. GEG02059 gives the complete test procedure.

FINDING TOP CENTER COMPRESSION POSITION FOR NO. 1 PISTON

Tools Needed: 2P8300 Engine Turning Tool Group.

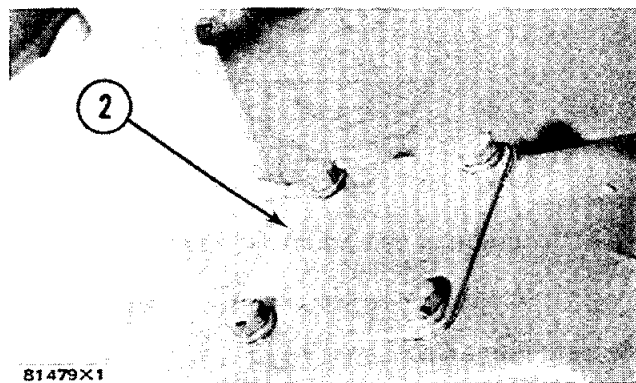
No. 1 piston at top center (TC) on the compression stroke is the starting point for all timing procedures.

1. Remove valve cover (1) at the front of the engine.



LOCATION OF VALVE COVER

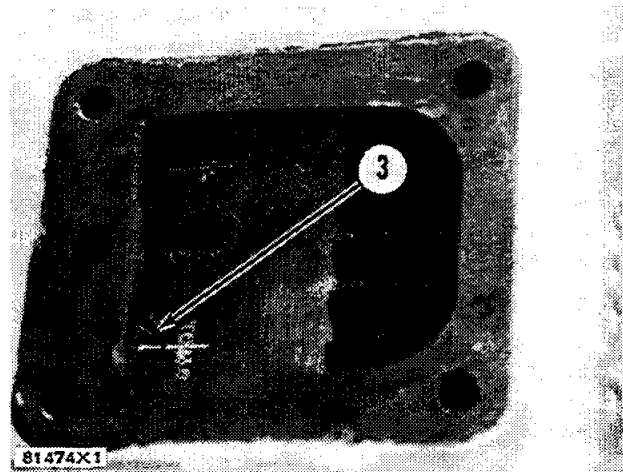
1. Valve cover.



TIMING MARK COVER

2. Cover.

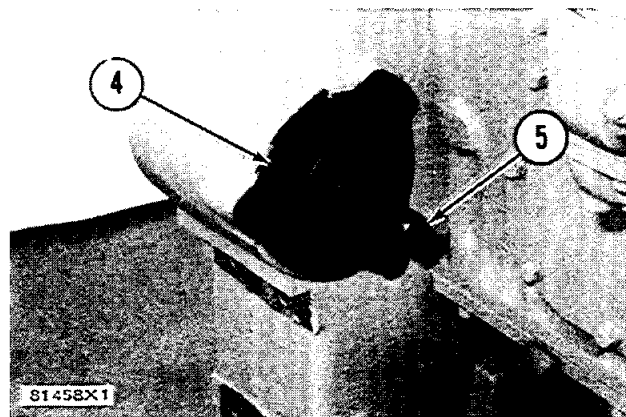
2. Remove cover (2) from the top of the housing for the flywheel.



TIMING MARKS ON FLYWHEEL

3. Pointer.

3. Turn the flywheel in the direction of engine rotation until No. 1 piston is at top center (TC) on the compression stroke. An indication is by pointer (3).
4. Look at the valves for No. 1 cylinder (the two valves at the front of the engine). The intake valve and exhaust valve for No. 1 cylinder must be closed.
5. If the intake and exhaust valves for No. 1 cylinder are not closed, turn the flywheel in the direction of engine rotation 360°. If both valves are now closed, this is top center (TC) compression position for No. 1 piston.



ENGINE TURNING TOOLS

4. 2P8294 Housing. 5. 2P8299 Pinion.

NOTE: If the flywheel is turned too far, turn it in the other direction a minimum of 60°, then turn the flywheel in the direction of engine rotation until No. 1 piston is at top center (TC) on compression stroke.

TIMING OF MAGNETO TO ENGINE (SPARK GAP)

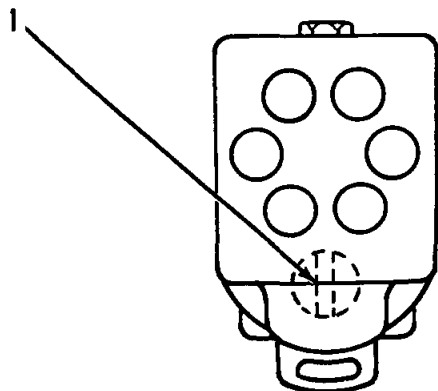
Tools Needed: 2P8300 Engine Turning Tool Group.

1. Turn the flywheel in direction of engine rotation until the No. 1 piston is coming up on the compression stroke. See subject Finding Top Center Compression Position for No. 1 Piston.
2. Turn the flywheel until the desired timing mark is directly under the flywheel pointer. See the Chart NO. 1 CYLINDER TIMING ANGLES (SPARK GAP) for the correct operating conditions.

NO. 1 CYLINDER TIMING ANGLES (SPARK GAP MAGNETO)		
Compression Ratio	Conditions	Degrees BTC on Compression Stroke
10.5:1	NA	20°
10.5:1	TA (90° Water)	12.5°
10.5:1	NA (Propane)	10°
7.5:1	NA	25°
7.5:1	TA (130° Water)	20°
7.5:1	NA (Wet Natural Gas and Butane)	15°

BTC = Before top center.

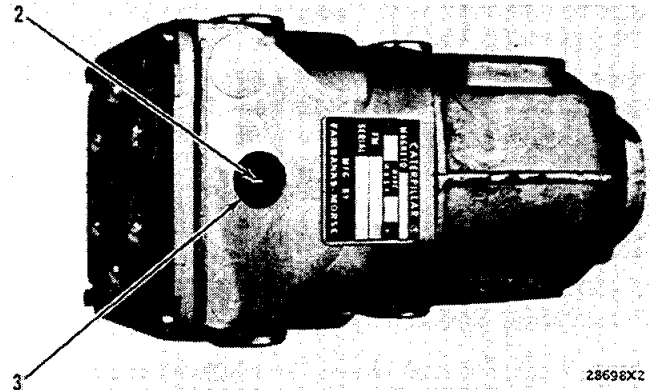
3. Put the magneto drive slot (1) in vertical position as shown in illustration. The drive coupling can be pulled to the rear, put in the correct position, and then pushed forward to engage with the gear teeth.



DRIVE TANG AND SLOT POSITION
(Seen from Rear of Engine)

1. Drive tang and slot.

4. Remove the timing nut and turn the magneto drive until the timing hole (2) is in the center of the hole (3).
5. Install the magneto. The drive tang and slot will engage.
6. Make the final timing adjustment by turning the magneto at the drive housing mounting. Use a timing light with the engine running to check the alignment of the correct mark on the flywheel with the pointer.

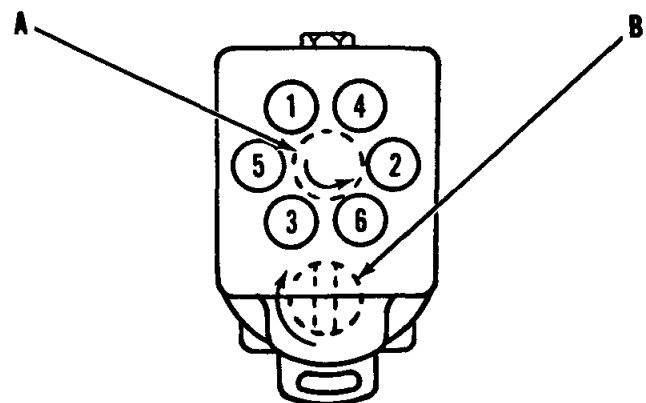


MAGNETO TIMING

2. Timing hole. 3. Hole in magneto housing for timing nut.

Firing Order

The firing order (ignition sequence) is 1, 5, 3, 6, 2, 4. The direction of the arrows in the illustration show the rotation of the magneto distributor disc (A) and the drive tang (B) as seen from the end cap cover (rear of engine).



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DIAGRAM OF MAGNETO NUMBERING
(Seen from rear of engine)

A. Magneto distributor disc. B. Drive tang.

Magneto Point Gap

Make the magneto point gap setting to .017 in. (0.43 mm).

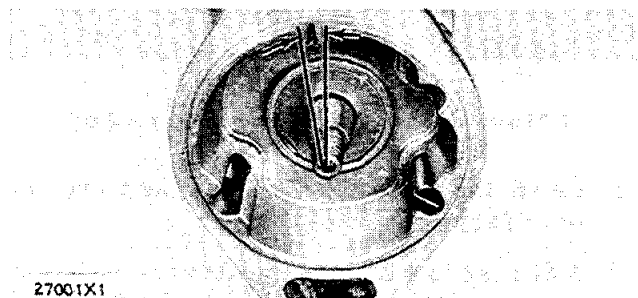
Magneto Edge Gap

The maximum ignition discharge is a result of breaking the primary circuit at the exact point in time that the voltage in the primary circuit is at the maximum value. At this point the contact points are just starting to open.

Field Method

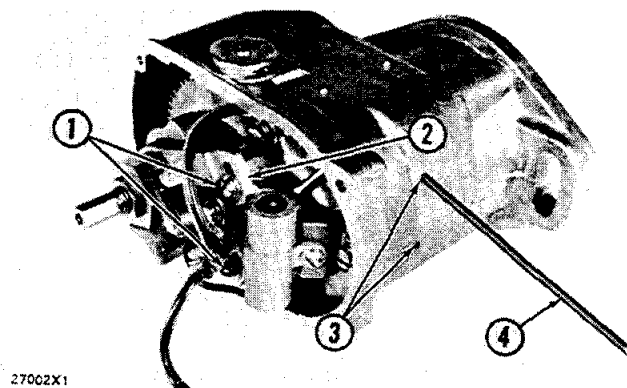
When the setting of the edge gap is needed and cannot be made with the use of 2P2340 Magneto Test Bench, a temporary setting can be made.

1. Check the contact points and make an adjustment to the proper gap, if needed.
2. Remove the impulse coupling.
3. Turn the rotor shaft so the keyway is up. Then turn the shaft approximately 15° in the direction of rotation.



POSITION OF SHAFT
(Counterclockwise Magneto)

4. Look at magneto from the drive end. Remove the set screw and put a 1/8 in. (3.175 mm) diameter rod (4) in the right timing hole (3). The left hole is used for clockwise rotation magnetos. Do not use it.
5. Loosen screws (1) for the support plate (2).



EDGE GAP ADJUSTMENT
(Counterclockwise Magneto)

1. Screws for the support plate. 2. Support plate. 3. Timing holes. 4. Rod.

6. Push rod (4) in until it is in contact with the rotor. Turn the rotor shaft in the direction opposite the normal rotation until the rod is tight between the rotor pole shoe and housing field.
7. With the rotor in this position, move the plate (2) either left or right until the contact points start to open. Tighten the screws (1) for the support plate.
8. Install the impulse coupling.

Shop Method

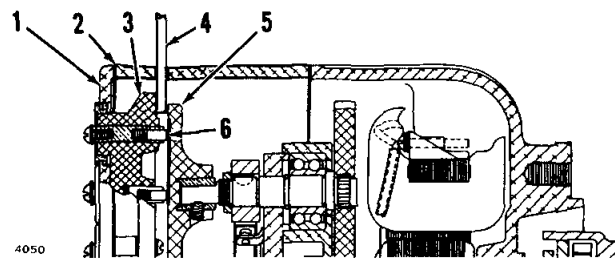
Tools Needed: 2P2340 Magneto Test Bench.

The method of making the edge gap setting with the most accuracy is with the 2P2340 Magneto Test Bench. The complete instructions for making the setting are in Special Instruction Form No. GEG-02059. The correct speed for rotation of the magneto is 1800 rpm.

Brush Spring Adjustment

Each time service is done on a magneto, a check must be made of the distance between the distributor block (3) and the face of the distributor disc (5). The correct gap gives the correct pressure on the brush and spring assembly (6). Remove the timing bolt and put a drill rod (4) between distributor block (3) and distributor disc (5). The clearance is .156 to .219 in. (3.96 to 5.56 mm).

To make an increase in clearance use additional gaskets (2) for the end cap cover. To make a decrease in clearance use number 10 washers between the distributor block (3) and end cap cover (1).



MAKING A CHECK OF THE BRUSH
SPRING ADJUSTMENT

1. End cap cover. 2. Gasket for the end cap cover. 3. Distributor block. 4. Drill rod. 5. Distributor disc. 6. Brush and spring assembly.

TIMING OF MAGNETO TO ENGINE (SOLID STATE FAIRBANKS MORSE)

1. Turn the crankshaft in the direction of engine rotation until the No. 1 piston is coming up on

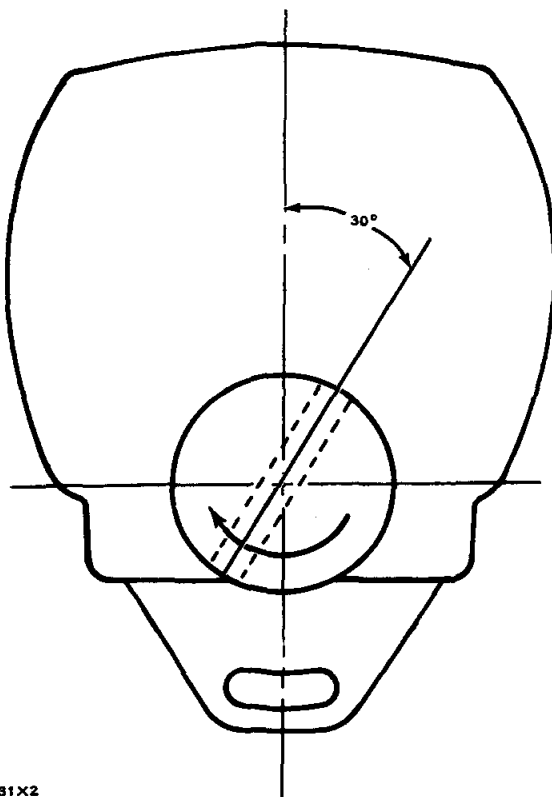
the compression stroke. See the subject Finding Top Center Compression Position for the No. 1 Piston.

- Turn the crankshaft until the desired timing mark is directly under the flywheel pointer. See the charts No. 1 Cylinder Timing Angles (Fairbanks Morse Solid State Magneto) for the correct operating conditions.

NOTE: After top center (ATC) timing with the engine stopped is needed under some conditions. When flywheels with no ATC marks are found, put marks on the outside diameter of the flywheel by using the same dimensions from the marks now on the flywheel.

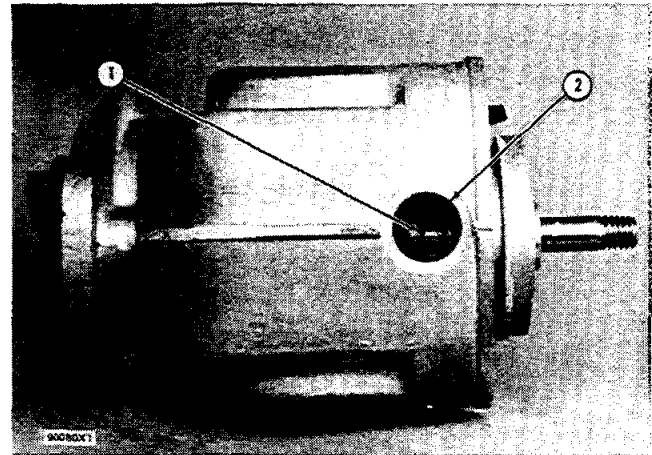
NO. 1 CYLINDER TIMING ANGLES (FAIRBANKS MORSE SOLID STATE MAGNETO)			
Compression Ratio	Conditions	Engine Stopped	Engine at Rated Speed
10.5:1	NA	TC	20° BTC
10.5:1	TA (90° Water)	7.5° ATC	12.5° BTC
10.5:1	NA (Propane)	10° ATC	10° BTC
7.5:1	NA	5° BTC	25° BTC
7.5:1	TA (130° Water)	TC	20° BTC
7.5:1	NA (Wet Natural Gas and Butane)	5° ATC	15° BTC

TC = Top center. BTC = Before top center.
ATC = After top center.



DRIVE TANG AND SLOT POSITION
(Viewed from the rear of the engine)

- Put the magneto drive slot in the position shown in the illustration. The drive coupling can be pulled to the rear, put in the correct position and then pushed forward to engage with the gear teeth.
- Remove the timing nut and turn the magneto drive until the timing hole (1) in the gear is in the center of the hole (2).



LOCATION OF TIMING HOLE

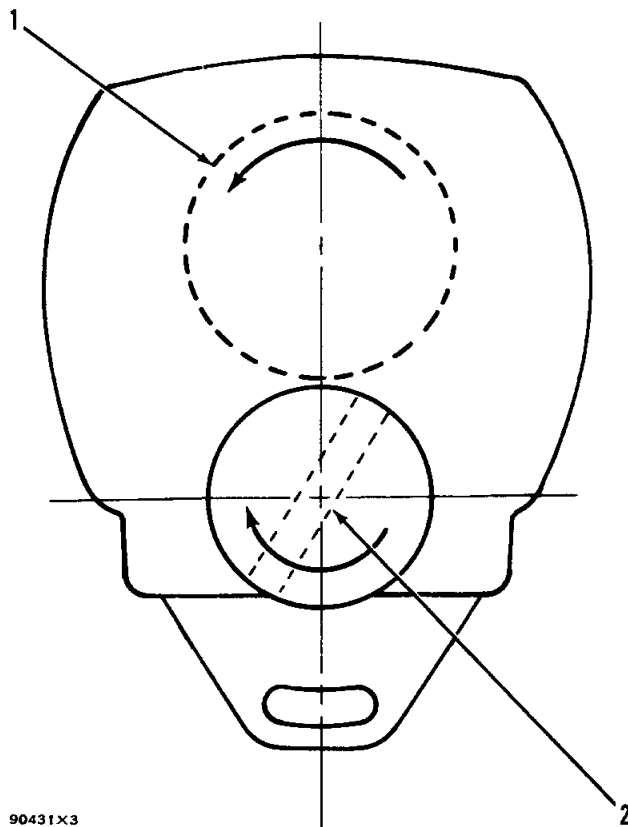
1. Timing hole in gear. 2. Hole in magneto housing.

- Install the magneto. The drive tang and slot will engage.
- Make the last timing adjustment with the engine running at the rated speed. See the FUEL SETTING INFORMATION. Use a timing light to check the alignment of the correct mark on the flywheel with the pointer. Turn the magneto at the drive housing mounting until the mark and pointer are in alignment.

NOTE: Timing must NOT be made at low idle because of the timing advance in the magneto.

Firing Order

The firing order (ignition sequence) is 1, 5, 3, 6, 2, 4. The direction of the arrows in the illustration shows the rotation of the pulser rotor assembly (1) and the drive tang (2) as seen from the rear of the engine.



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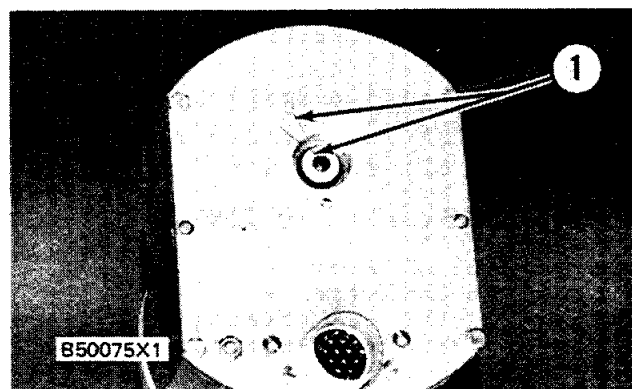
ROTATION OF PULSER ROTOR ASSEMBLY AND DRIVE TANG

1. Pulser rotor assembly. 2. Drive tang.

TIMING OF MAGNETO TO ENGINE (SOLID STATE ALTRONIC)

1. Turn the crankshaft in the direction of engine rotation until the No. 1 piston is coming up on the compression stroke. See the subject Finding Top Center Compression Position for the No. 1 Piston.
2. Turn the crankshaft until the desired timing mark is directly under the flywheel pointer. See the charts No. 1 Cylinder Timing Angles (Altronic Solid State Magneto) for the correct operating conditions.

NO. 1 CYLINDER TIMING ANGLES (ALTRONIC SOLID STATE MAGNETO)		
Compression Ratio	Conditions	Degrees BTC on Compression Stroke
10.5:1	NA	20°
10.5:1	TA (90° Water)	12.5°
10.5:1	NA (Propane)	10°
7.5:1	NA	25°
7.5:1	TA (130° Water)	20°
7.5:1	NA (Wet Natural Gas and Butane)	15°
BTC = Before top center.		

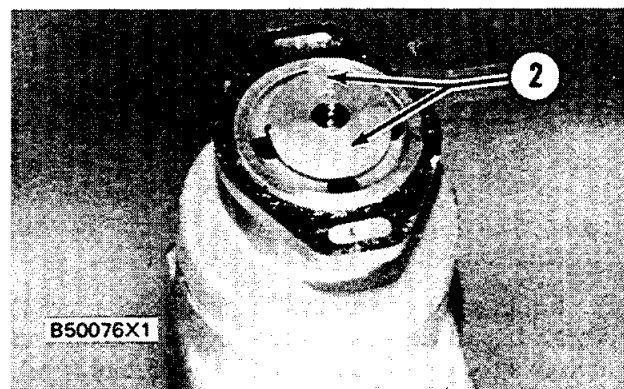


MAGNETO TIMING MARKS
(Typical Example)

1. Timing marks.

3. The magneto timing marks (1) must be in alignment when the No. 1 piston is at the correct BTC position.

4. If not correct, remove the magneto from the engine.



MAGNETO DRIVE TANG

2. Drive tang.

5. Put timing marks (1) in the correct position with drive tang (2) positioned as shown.
6. Position the magneto drive slots in proper position for timing. The drive coupling can be pulled out, then positioned and pushed in for engagement.
7. Install the magneto. The drive tang and slot will engage.
8. Make final timing adjustment by rotating the magneto at the drive housing mounting and with the use of a timing light when the engine is running at rated speed.

IGNITION TRANSFORMERS

See the subject WIRING DIAGRAM in the SYSTEMS OPERATION section for the way the transformers are connected to the magneto.

SPARK PLUGS AND ADAPTERS

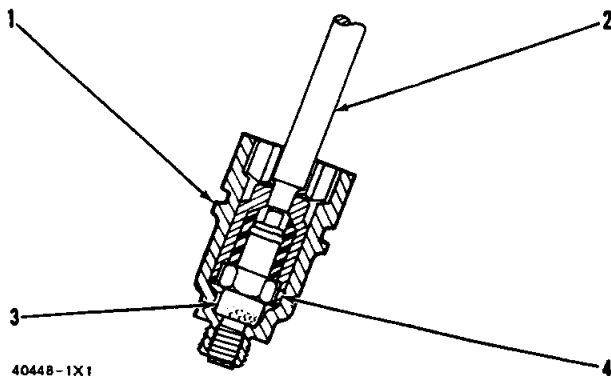
Tools Needed: 8S7227 Wrench.
8H3538 Socket.
1P1790 Firing Indicator.
1P7424 Spark Plug Socket.

If the spark plug adapter does not have a covered seat, water leakage or detonation and preignition can be the result. Adapters are installed and removed with an 8S7227 Wrench and 8H3538 Socket.

Voltage to cause the spark will change with the spark plug condition and engine load. A new spark plug in an engine at low idle will take 3,000 to 6,000 volts. At full load, this voltage will be 8,000 to 10,000 volts. When the gap of the spark plug needs adjustment the voltage needed will be over 10,000 volts. Voltage needed will go higher if plug gap adjustment is not made. Spark plugs start to cause the engine to run rough (fire erratically) when the spark plug voltage needs go higher than 10,000 volts.

Spark plug gap must be kept at $.014 \pm .001$ in. (0.36 ± 0.03 mm). The use of 1P1790 Firing Indicator is an aid for finding ignition problems. Follow the instructions that come with the tool.

Put liquid soap on the seat groove of adapter (1) and seal. Install the adapter into cylinder head and tighten to a torque of 150 ± 10 lb. ft. (205 ± 14 N·m). Spark plugs (3) must be installed to a torque of 26 ± 4 lb. ft. (36 ± 5 N·m) with 1P7424 Spark Plug Socket (4).



40448-1X1

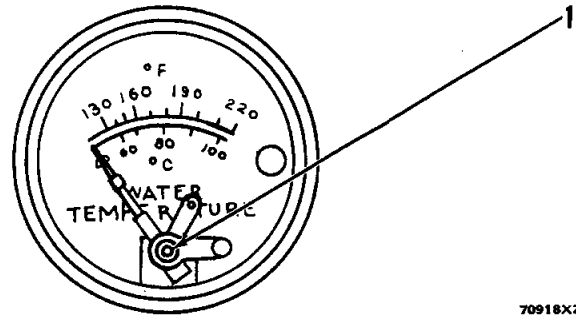
SPARK PLUG INSTALLATION

1. Adapter. 2. 3/8 in. Drive extension. 3. Spark plug. 4. 1P7424 Spark Plug Socket.

ADJUSTMENT OF GAUGE CONTACT POINT

The adjustment of the contact for the pressure gauge for oil is correct when the engine is stopped at 8 psi (55 kPa) oil pressure. The correct adjustment of the gauge for water temperature is when the engine is stopped at 210°F (99°C).

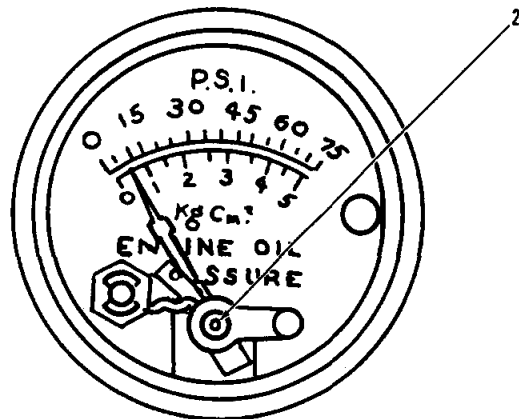
Adjustment of the gauges is made with a small hollow head screw wrench.



70918X2

WATER TEMPERATURE GAUGE

1. Adjustment screw.



70919X3

OIL PRESSURE GAUGE

2. Adjustment screw.

GAS, AIR INLET AND EXHAUST SYSTEM

RESTRICTION OF AIR INLET AND EXHAUST

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

Air flow through the air cleaner must not have a restriction of more than 15 in. (381 mm) of water difference in pressure.

Back pressure from the exhaust (pressure difference measurement between exhaust outlet elbow and atmosphere) must not be more than 34 in. (864 mm) for naturally aspirated and 27 in. (686 mm) for turbocharged engines measured between the turbocharger outlet and atmosphere.

CRANKCASE (CRANKSHAFT COMPARTMENT) PRESSURE

Broken or damaged pistons or piston rings can be the cause of too much pressure in the crankcase. This condition will cause the engine to run rough. There will also be more than the normal amount of fumes coming from the crankcase breather. This crankcase pressure can also cause the element for the crankcase breather to have a restriction in a very short time. It can also be the cause of oil leakage at gaskets and seals.

COMPRESSION

Tools Needed: 2P8300 Engine Turning Tool Group.

An engine that runs rough can have a leak at the valves, or valves that need adjustment. Run the engine at the speed that gives rough running. To find a cylinder that has low compression or does not have good ignition, remove spark plug wires one at a time. This will stop the flow of current to that cylinder. Do this for each cylinder until a removed wire is found that makes no difference in engine rough running. Be sure to install the wire for the spark plug after each cylinder test before the next wire is removed. This test can also be an indication that the spark plug is bad, so more checking of the cylinder will be needed.

Conditions of the valves, valve seats, pistons, piston rings and cylinder liners can be tested by putting air pressure in the cylinder. Special Instruction Form No. GMG00694 gives instructions for the test procedure. It also gives the list of parts needed from Parts Department to make the test.

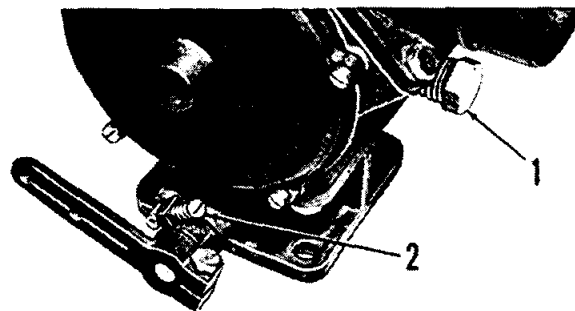
This test is a fast method of finding the cause of compression loss in a cylinder. Removal of the head and inspection of the valves and valve seats if necessary to find those small defects that do not normally cause a problem. Repair of these problems is normally done when reconditioning is done on the engine.

CARBURETOR

The carburetor and governor linkage adjustment is given in the subject GOVERNOR.

Turn the power mixture adjustment to center between "R" (rich) and "L" (lean). Make fuel mixture adjustments by changing the gas pressure from the line pressure regulator. See the subject GAS PRESSURE REGULATOR ADJUSTMENTS.

Turn idle adjustment screw (1) four full turns open (from the closed position).



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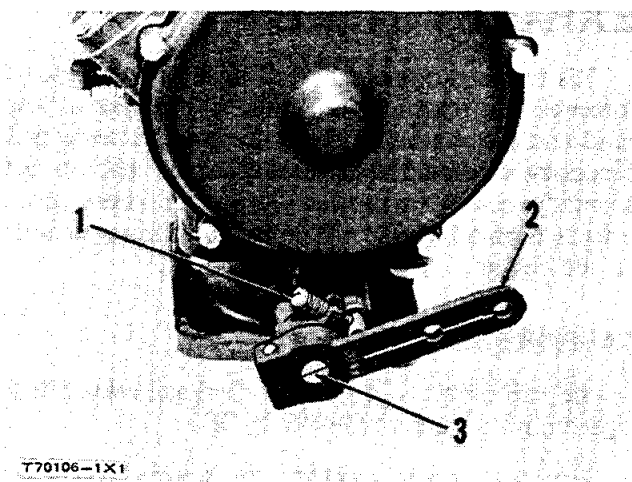
CARBURETOR ADJUSTMENTS

1. Idle adjustment screw. 2. Throttle stop screw.

Turn throttle stop screw (2), to obtain desired idle speed. See FUEL SETTING INFORMATION for low idle rpm.

Adjustment to the Low Idle (Engine Not Operating)

1. Disconnect governor linkage at the throttle shaft lever (2).
2. Turn the screw (1) out until the throttle will close before the screw makes contact with the stop. Slot (3) in the end of the throttle shaft shows the position of the throttle plate.
3. Turn the stop screw (1) so it will just make contact with the stop while the throttle plate is closed.

**THROTTLE VALVE SYNCHRONIZATION**

1. Throttle stop screw for low idle. 2. Throttle shaft lever. 3. Slot.
4. Move the control lever for the governor to the OFF position.
5. Make adjustments to the length of the linkage between governor and carburetor until both connections can be made while the throttle plate is completely closed, and the governor weight fully closed.
6. Connect the linkage to throttle shaft lever (2).
7. Start the engine and make a setting to the throttle stop screw (1) for the low idle.

PERFORMANCE EVALUATION

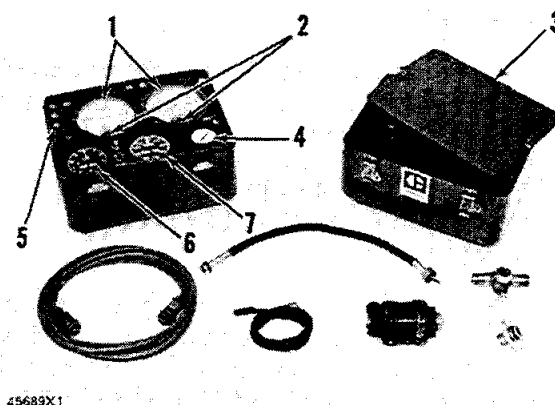
When an engine has no power, it is desirable to make a quick check with an instrument to find the approximate horsepower.

Use the 4S6553 Instrument Group to check engine rpm and the pressure in the inlet manifold. This instrument group has a tachometer for reading the engine rpm and a gauge for reading the pressure in the inlet manifold. Differential pressure gauges are used to make measurements of the gas pressure and air inlet pressure. Special Instruction Form No. SEHS7341 is with the tool group and gives instructions for the test procedures.

Correct engine operating adjustments must be made to get the correct results from the instruments and tests.

Correct analysis can be made of the engine operating efficiency by a check of the pressure of the inlet manifold and a comparison of that pressure with the information in the FUEL SETTING INFORMATION. This test is used if the engine horse-

power is too low, but with no other condition of engine problem.

**4S6553 INSTRUMENT GROUP**

1. 4S6992 Differential Pressure Gauges. 2. Zero adjustment screw. 3. Lid. 4. 8M2743 Gauge. 5. Pressure tap fitting. 6. 1P7443 Tachometer. 7. 4S6997 Manifold Pressure Gauge.

GAS LINE PRESSURE

Gas engines burn a wide range of gaseous fuels. BTU rating of a fuel is a measure of the power content of the fuel. The higher BTU rated fuels need less gas pressure to have the correct gas volume for a specific horsepower.

The BTU HHV (high heat value) of gaseous fuels is the unit of measurement of the total fuel heat content. The BTU LHV (low heat value) content is more important. The combustion procedure in a cylinder causes carbon dioxide and water, but the heat needed for the conversion of water into vapor is lost and cannot be used in the engine. The remainder of the heat that can be used from the fuel is the LHV, and, as a rule, is 10% less than the HHV of natural gas. When BTU HHV is given, remember to make a conversion to LHV so the correct settings can be made.

Low octane fuels burn so fast that an adjustment to the timing must be made to move it back (retard). With early timing and low octane fuel, the fast burning fuel burns too much before the piston goes over top center. The result of this is "knocking" (detonation).

A change to the fuel to air ratio is made by changing the gas pressure in relation to the air pressure. Too much gas makes a "rich mixture" and not enough gas makes a "lean mixture". Either will cause a loss of power. If the compression is too high and the fuel to air mixture is too rich, fuel ignition will be without the aid of the spark and at a time different than the timing setting. When Propane gas is used, the adjustment of the fuel to

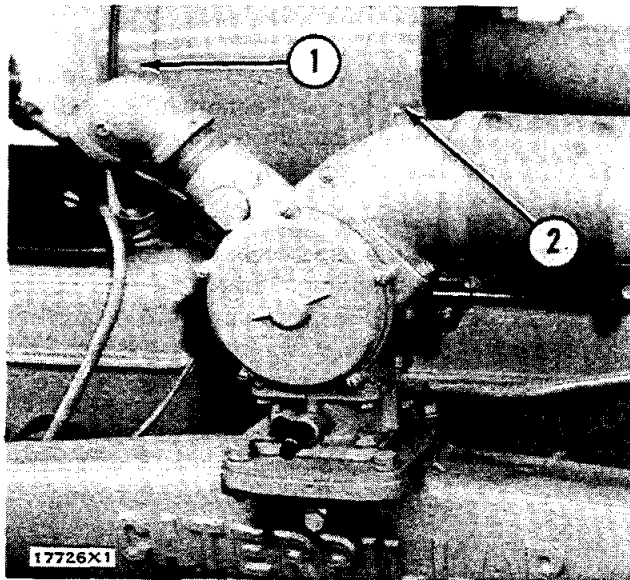
air setting must be made with much more precision than when natural gas is used.

Make an adjustment to (regulate) the pressure in main gas supply to the engine. Naturally aspirated engines need main gas supply line pressure of 3 to 20 psi (20 to 140 kPa). Turbocharged engines need more pressure, 12 to 20 psi (85 to 140 kPa); 20 psi (140 kPa) is the maximum pressure that can be used in this engine. If the main line pressure of the gas supply is more than 20 psi (140 kPa), another regulator is needed.

ADJUSTMENT TO GAS PRESSURE REGULATOR

Tools Needed: 4S6553 Instrument Group.

Before the engine can be started an adjustment to the gas pressure regulator must be made either when the engine is installed, when work is done on the regulator or when there is a change in the BTU content of the fuel. Adjustments can be made with either the 4S6553 Instrument Group or a water manometer.



PLUG REMOVAL

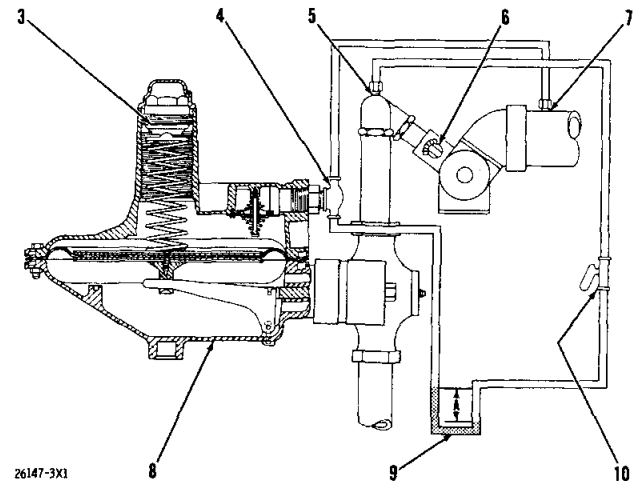
1. Plug on gas inlet line. 2. Plug on air inlet.

1. Remove plugs (1) and (2).
2. Turn the power mixture screw (6) adjustment to center between "R" (rich) and "L" (lean) position.
3. Connect one end of the manometer or one side of a differential gauge of the 4S6553 Instrument Group to the gas supply connection at (5) at the carburetor. Connect the other end of the manometer or other side of the differ-

ential gauge to the air inlet at (7). On engines with a balance line, connect the second end of the manometer or second side of the differential gauge either to a tee (4) installed at the balance line connection or to the balance line connection at the air inlet at (7) on the carburetor.

4. Open valve (10) if a manometer is used.

NOTE: If a manometer is used, the valve (10) must be closed while the engine is being stopped or started. This will prevent the manometer fluid from getting into the inlet of the carburetor (5).



CHECKING THE GAS PRESSURE REGULATOR ADJUSTMENT

A. Positive pressure differential. 3. Adjustment screw. 4. Tee and manometer connection. 5. Gas supply connection at carburetor. 6. Power mixture adjustment. 7. Air inlet connection at carburetor. 8. Gas pressure regulator. 9. Manometer or 4S6553 Instrument Group. 10. Valve.

5. Open the main gas valve and make an adjustment to the gas pressure regulator to cause a differential reading of 5.5 in. (139.7 mm) of water. The regulator adjustment is made by removing the cap on the top of the regulator and turning the screw (3) clockwise to cause an increase in the output pressure, and counterclockwise to cause a decrease in the pressure.
6. Start the engine and make adjustments to the fuel to air ratio.

ADJUSTMENT TO THE FUEL TO AIR RATIO

For Engines With Loads Which Go Up With an Increase of the Engine Speed (Examples: Turbine Pumps, Fans)

1. See the subject Adjustment to the Gas Pressure Regulator for the correct procedure to get the engine started.

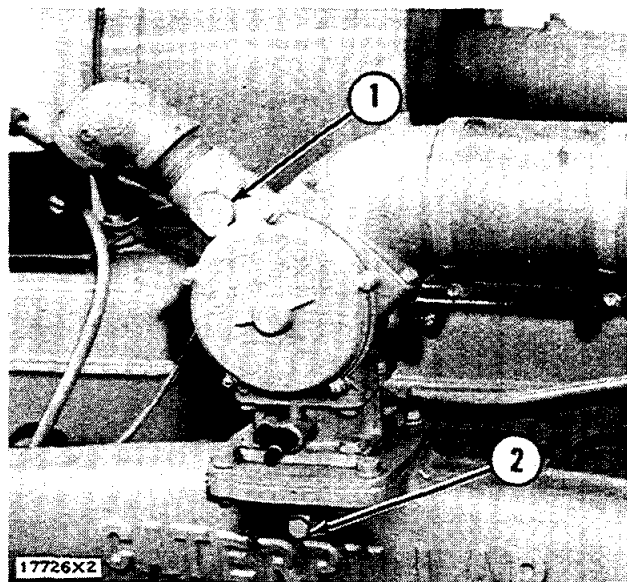
2. Install an accurate tachometer on the engine.
3. Remove the plug on the regulator so adjustment screw can be turned.

NOTE: On turbocharged engines, a special tool is necessary to prevent the turbocharger boost from leaking and giving a wrong reading on the gauge or manometer.

4. Start and run the engine with a constant load at an rpm that is more than 3/4 the Full Load Setting. See the FUEL SETTING INFORMATION.
5. Hold (clamp) the throttle lever in place so it will not move.
6. Remove the governor linkage from the throttle lever.
7. Change the gas pressure by making an adjustment to the adjustment screw to get maximum rpm.
8. After getting maximum rpm, make a 3% reduction in the value of this rpm by making an adjustment with the screw to remove some of the force of the regulator spring. This will make the fuel to air ratio more "lean" until the desired rpm is found. This is the correct fuel to air ratio setting.
9. Connect the governor linkage and remove the restriction on the throttle lever.

**For Engines Driving Loads at a Constant Speed and Constant Output
(Examples: Electric Sets, Piston Compressors)**

1. See the subject Adjustment to the Gas Pressure Regulator for the correct procedure to get the engine started.
2. Remove plug (2) from the inlet manifold.
3. Install a pressure gauge to the hole in the inlet manifold to give a reading of the inlet manifold pressure.
4. Install an accurate tachometer on the engine.
5. Start the engine and put a constant load on the engine. Run the engine at a speed between 1/2 and 3/4 of the Full Load rpm. See the FUEL SETTING INFORMATION. Permit the governor to keep the engine at a constant rpm.



CHECKING INLET MANIFOLD PRESSURE

1. Power mixture screw. 2. Plug in inlet manifold.

6. Make an adjustment to the spring compression in the regulator with the adjustment screw until the minimum pressure of the inlet manifold is found.

NOTE: On turbocharged engines a special tool is necessary to prevent the turbocharger boost from leaking and not putting the correct pressure on the top of the regulator diaphragm.

7. When the minimum inlet manifold pressure is found, make a decrease in the force of the spring on the diaphragm until there is an increase of 1 inch of mercury (25.4 mm of mercury) of the inlet manifold pressure. This is the correct fuel to air ratio setting.

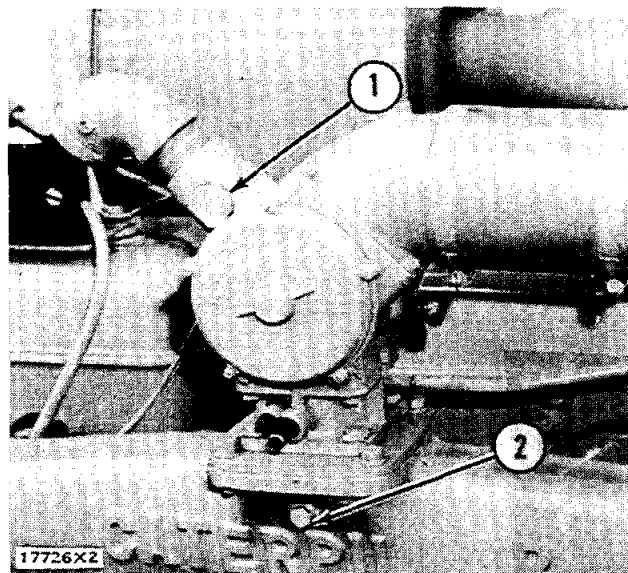
NOTE: Be sure that the engine rpm is constant while the adjustments are being made. Any sudden change in rpm will make the adjustments wrong.

Adjustment of the Power Mixture Screw

Normally the power mixture screw (1) setting is at the center position between "L" (lean) and "R" (rich) (2 1/2 spaces from the full lean position). A small adjustment of the power mixture screw (1) will cause a large change to the fuel to air ratio of the engine. The power mixture screw must not be moved after the adjustment has been made to the line pressure regulator.

However, if the adjustment screw in the regulator is such that a minimum compression is on the spring and the fuel and air mixture is still too "rich", turn the power mixture screw 1/8 to 1/4

space at a time toward the "L" (lean) to "lean" out the mixture. Each time the power mixture screw is moved an adjustment to the line pressure regulator must be made to get the correct balance point between the power mixture screw and the regulator.



POWER MIXTURE SCREW

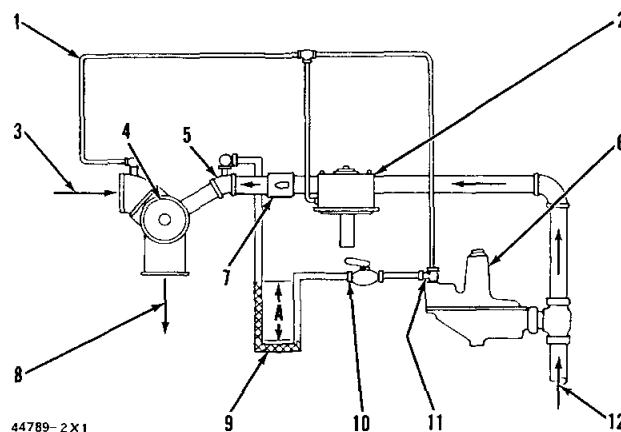
1. Power mixture screw. 2. Plug in inlet manifold.

ADJUSTMENT TO THE THERMAC PROPANE SYSTEM

Tools Needed: 4S6553 Instrument Group.

1. Connect one end of the water manometer (9) or one side of a differential gauge of the 4S6553 Instrument Group to the gas supply at (5) at the carburetor. Connect the other end of the manometer or other side of the differential gauge to the air inlet. On engines with a balance line connect the second end of the manometer or second side of the differential gauge to a tee installed either at the balance line connection on the vacuum regulator at (11) or to the balance line connection on the air inlet of the carburetor.
2. Open the main propane supply valve.
3. Make adjustment to the gas pressure regulator (6) to get a differential reading of 10 in. (254.0 mm) of water. The Thermac valve (2) will give a reduction to -1 in. (-25.4 mm) of water.
4. Start engine and make adjustment to the load adjusting valve (7) to get -2 in. (-50.8 mm) of water pressure differential (A) at full load.

5. Make adjustment to power mixture adjustment on the carburetor to 1/2 space to the "L" (lean) side of the center mark.

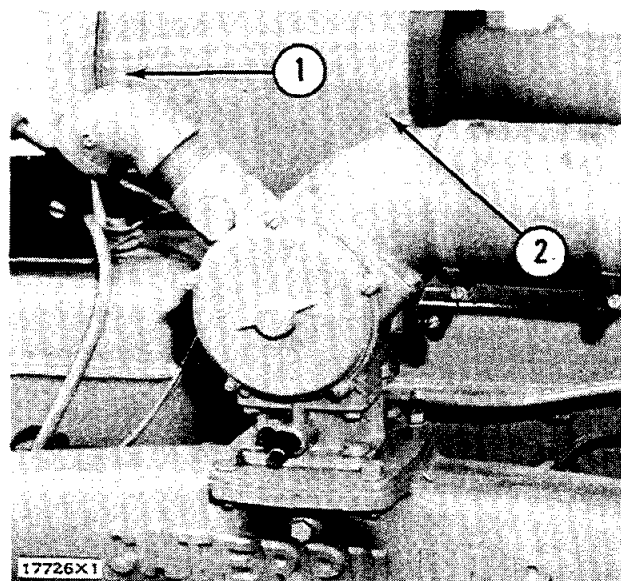
PROPANE GAS REGULATOR COMPONENTS
(THERMAC SYSTEM)

A. Negative pressure differential. 1. Balance line. 2. Thermac valve. 3. Inlet air. 4. Carburetor. 5. Gas supply at carburetor. 6. Gas pressure regulator. 7. Load adjusting valve. 8. Air fuel mixture. 9. Manometer or 4S6553 Instrument Group. 10. Valve. 11. Tee and manometer connection. 12. Propane gas supply.

ADJUSTMENT TO VACUUM REGULATOR (On Engines with Propane Gas)

Tools Needed: 4S6553 Instrument Group.

1. Remove plugs (1) and (2) from the carburetor.

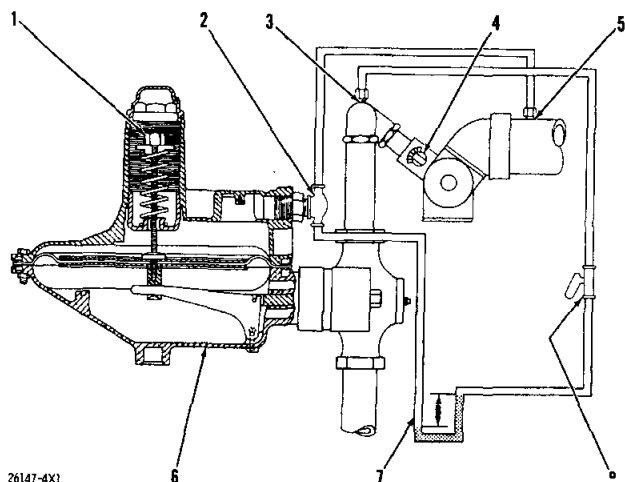


PLUG REMOVAL

1. Plug on gas inlet line. 2. Plug on the air inlet.

2. Connect one end of the water manometer or one side of a differential gauge of the 4S6553 Instrument Group to the gas supply connection at the carburetor (3). Connect the

other end of the manometer or other side of the differential gauge to the air inlet. On engines with a balance line connect the second end of the manometer or second side of the differential gauge to a tee (2) installed at the balance line connection on the vacuum regulator or to the balance line connection on the air inlet of the carburetor.



CHECKING THE VACUUM REGULATOR ADJUSTMENT

B. Negative pressure differential. 1. Adjustment nut. 2. Tee and manometer connection. 3. Propane supply connection at carburetor. 4. Power mixture adjustment. 5. Air inlet connection at carburetor. 6. Vacuum regulator. 7. Manometer or 4S6553 Instrument Group. 8. Valve.

NOTE: If a manometer is used, valve (8) must be closed while the engine is being stopped or started. This will prevent the manometer fluid from getting into the inlet of the carburetor.

3. Open the main propane supply valve. Start the engine and open valve (8). Make adjustment to the vacuum regulator to get the measurement (B) to -1 in. (-25.4 mm) of water at idle speed.
4. Make adjustment to the power mixture adjustment (4) to 1/2 space to the "L" (lean) side of the center mark.

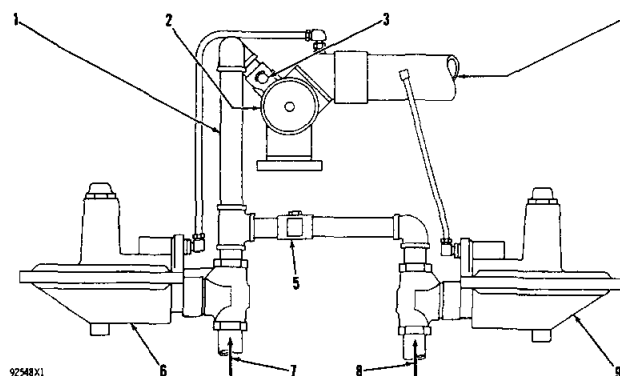
ADJUSTMENTS TO THE DUAL FUEL SYSTEM

Engines Using Natural Gas and Propane

Adjustments to the dual fuel system components must be made one at a time. Make an adjustment to the gas pressure regulator (6). See the subject ADJUSTMENT TO THE FUEL TO AIR RATIO. Be sure the adjustment procedure used is for the correct load application.

Make an adjustment to the vacuum regulator (9). Make reference to the subject ADJUSTMENT TO THE VACUUM REGULATOR. Make a setting

of the load adjusting valve (5) to the mark in the center between "L" (lean) and "R" (rich).



DUAL FUEL SYSTEM (NATURAL GAS AND PROPANE)

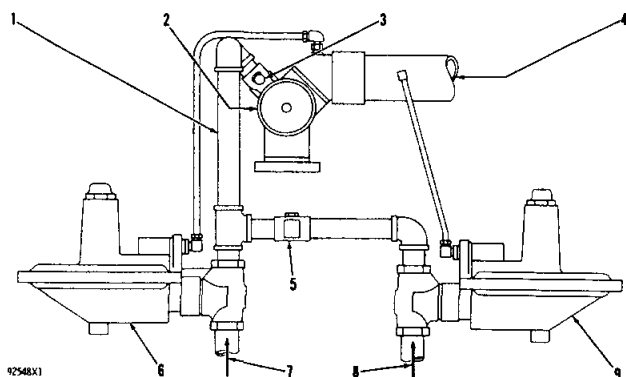
1. Gas supply at carburetor. 2. Carburetor. 3. Power mixture adjustment. 4. Air inlet. 5. Load adjusting valve. 6. Gas pressure regulator. 7. Natural gas supply. 8. Propane supply. 9. Vacuum regulator.

Engines Using Digester Gas and Natural Gas

If digester gas is used with natural gas in a dual fuel system a digester gas carburetor (2) must be used. The natural gas supply (8) is controlled by the vacuum regulator (9) and the digester gas supply is controlled by the gas pressure regulator (6).

1. Open the main supply valve for the digester gas.
2. Make adjustments to the gas pressure regulator (6) as given in the earlier subject ADJUSTMENTS TO THE FUEL TO AIR RATIO. Be sure to use the correct procedure for the load application of the engine.
3. Close the main supply valve for the digester gas and open the main supply valve for the natural gas.
4. Make a setting of the load adjusting valve (5) to one mark to the "L" (lean) side of center.
5. Make adjustments to the vacuum regulator (9) as given in the subject ADJUSTMENT TO THE FUEL TO AIR RATIO.

NOTE: When digester gas and natural gas are used in a dual fuel system the vacuum regulator adjustments are made using the same procedure as the adjustments for the gas pressure regulator. Be sure to use the correct procedure for the load application of the engine.



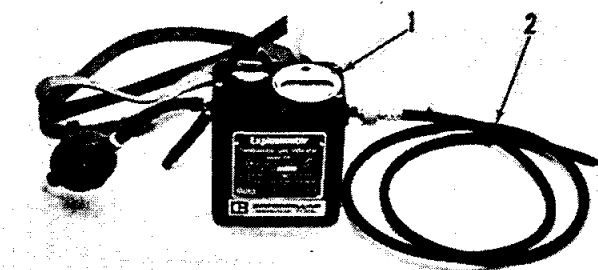
**DUAL FUEL SYSTEM
(NATURAL GAS AND DIGESTER GAS)**

1. Gas supply at carburetor. 2. Digester carburetor. 3. Power mixture adjustment. 4. Air inlet. 5. Load adjusting valve. 6. Gas pressure regulator. 7. Digester gas supply. 8. Natural gas supply. 9. Vacuum regulator.

HOW TO FIND GAS LEAKS

Combustion gases leaking from natural gas engines can be a danger to safety. To find gas leaks, use the 1P1830 Explosimeter Group. It is made up of the explosimeter instrument (1) a five foot sampling line (2) and several replacement parts which are in a carrying case.

After there has been work on the fuel system, use the explosimeter to check connections and any other place gas leaks can be.



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1P1830 EXPLOSIMETER

1. Explosimeter. 2. Sampling line.

The concentration of flammable gases is shown in percent explosive by the indicator.

Detailed operating and maintenance instructions are with the group.

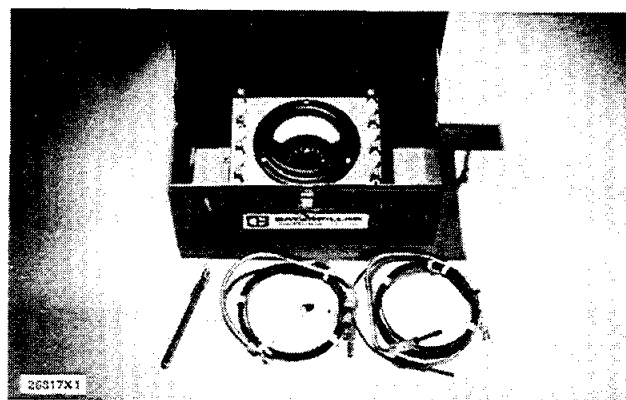
EXHAUST TEMPERATURE

Use the 1P3060 Pyrometer Group to check the exhaust temperature. Take temperature readings soon after the engine is installed. Regular checks are needed, and a record kept, to find any large increase or decrease in exhaust temperature.

Exhaust temperatures will not be the same for all engines of a similar type. Factors that have an affect on the exhaust temperatures are:

1. Restriction in the air inlet system
2. Restriction in the exhaust system
3. Temperature of the inlet air
4. Friction inside the engine
5. Fuel rate, fuel system condition or setting
6. Height of engine above sea level (altitude)
7. Size of valve openings
8. Condition of pyrometer thermocouple
9. Location of thermocouple

Checking the exhaust temperature, by itself, is not a complete method of making an analysis of an engine problem. A large or sudden temperature change will give an indication that something is wrong in the engine. Other checks must be made to find the cause. Special Instruction Form No. SMHS7179 is with the tool group and gives instructions for the test procedure.



1P3060 PYROMETER GROUP

CYLINDER HEAD

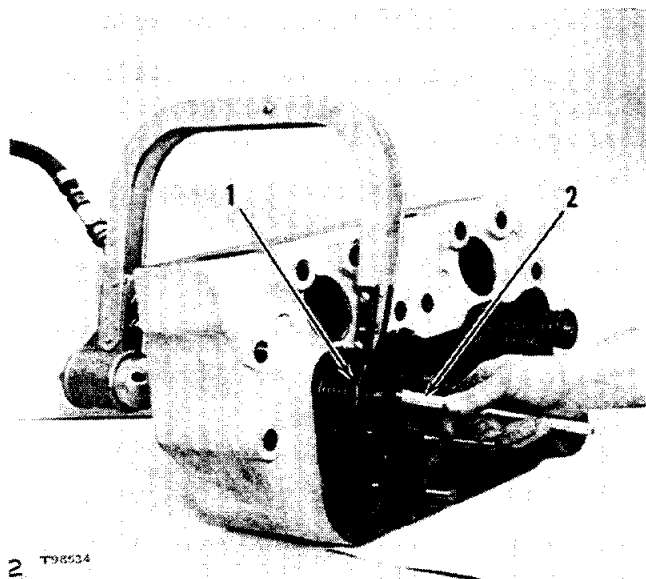
Spark Plug Adapters

Use a 8S7227 Wrench and 8H8538 Socket to remove and install the spark plug adapters. Put liquid soap on the bore in head and seal. Put 5P3931 Anti-Seize Compound on the threads.

Valves

The illustration shows the 5S1330 Valve Spring Compressor Assembly with 5S1329 Jaw (1) to put

the valve spring under compression. The 5S1322 Valve Keeper Installer (2) used with the compressor assembly makes installation of the valve keepers easier and faster.



COMPRESSION OF VALVE SPRINGS
(Typical Illustration)

1. 5S1329 Jaw. 2. 5S1322 Valve keeper installer.

The valves can also be removed with 7F4992 Valve Spring Compressor Group. The 7F4290 Adapter is installed on a rocker arm stud. When installing the valve springs with 7F4292 Group, use the FT196 Fabricated tool to hold the valves in place.

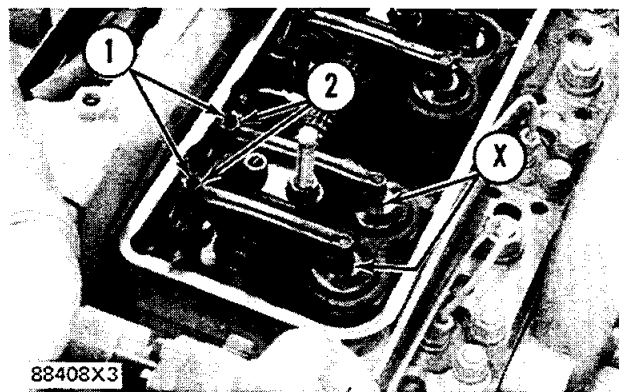
VALVE CLEARANCE

NOTE: Valve clearance is measured between the rocker arm and the valves.

VALVE CLEARANCE CHECK: ENGINE STOPPED

Exhaust025 to .031 in. (0.64 to 0.79 mm)
Intake013 to .019 in. (0.33 to 0.48 mm)

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



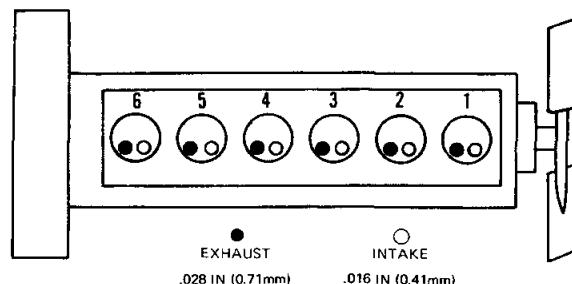
VALVE CLEARANCE ADJUSTMENT

1. Adjustment screw. 2. Locknut. X. Valve clearance.

VALVE CLEARANCE SETTING WITH ENGINE STOPPED

Exhaust028 in. (0.71 mm)
Intake016 in. (0.41 mm)

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. Make an adjustment to the valve clearance on the intake valves for cylinders 1, 2, and 4. Make an adjustment to the valve clearance on the exhaust valves for cylinders 1, 3 and 5.
3. Turn the flywheel 360° in the direction of engine rotation. This will put No. 6 piston at top center (TC) on the compression stroke.
4. Make an adjustment to the valve clearance on the intake valve for cylinders 3, 5, and 6. Make an adjustment to the valve clearance on the exhaust valves for cylinders 2, 4, and 6.
5. After valve adjustment is correct, tighten the nuts for the valve adjustment screws to 40 ± 5 lb. ft. (55 ± 7 N·m).



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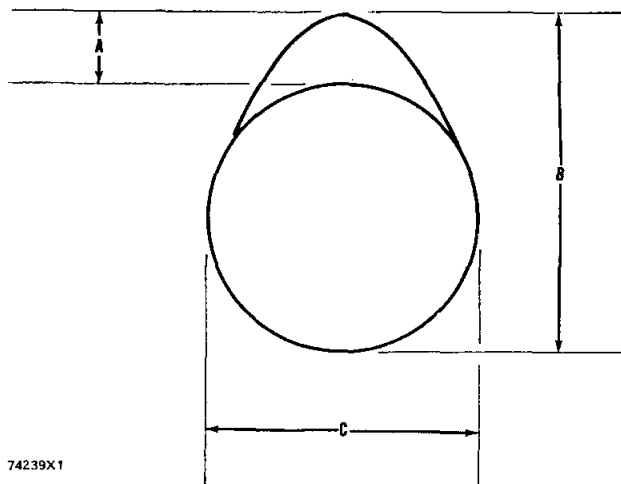
CYLINDER AND VALVE LOCATION

PROCEDURE FOR MEASURING CAMSHAFT LOBES

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

- A. Measure camshaft lobe height (B).
- B. Measure base circle (C).
- C. Subtract base circle (STEP B) from lobe height (STEP A). The difference is actual lobe lift (A).
- D. Specified camshaft lobe lift (A) is .4030 in. (10.236 mm).

Maximum permissible difference between actual lobe lift (STEP C) and specified lobe lift (STEP D) is .010 in. (0.25 mm).



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CAMSHAFT LOBE

A. Lobe lift. B. Lobe height. C. Base circle.

Valve Seat Inserts

Valve seat inserts are available with a larger outside diameter than the original size. The available inserts are in the chart.

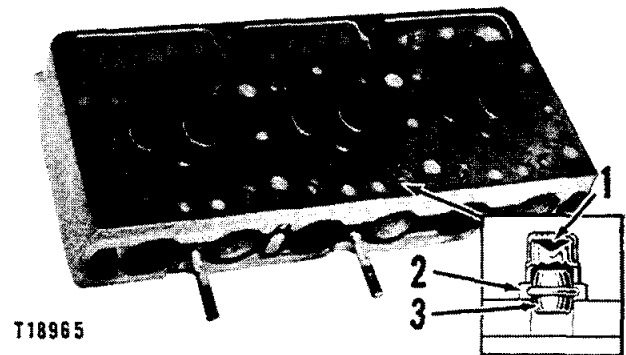
VALVE SEAT INSERT PART NUMBER			
	Original Size	.005 in. (0.13 mm) Larger Than The Original Size	.010 in. (0.25 mm) Larger Than The Original Size
Intake	9M8745	4S8912	4S8913
Exhaust	8M9810	4S8896	4S8897

Valve Guides

Install valve guides so the top of the guide is above the surface of the head 1.690 ± 0.020 in. (42.93 ± 0.51 mm). Use the 4H446 Driver Assembly and the 5P1727 Bushing to install the guides to the correct height. Be sure the small diameter of the guide is at the top of the bushing when installing the guides.

Water Directors

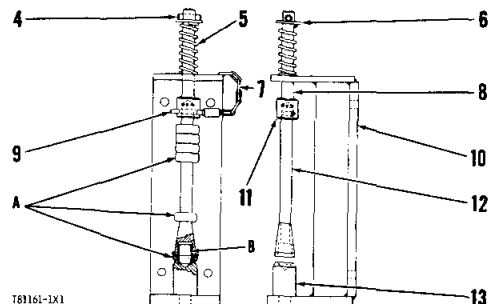
There are twelve water directors (1) installed in each cylinder head. They give the coolant the desired direction of flow. On the exhaust side, the coolant flow goes toward the precombustion chambers and the exhaust valve ports; and on the intake side, the coolant flow goes to the other side of the valve ports.



WATER DIRECTORS

1. Water director. 2. Seal. 3. Ferrule.

Water directors are installed with a press in the heads after the alignment of the notch on the director with the V-mark on the head.



FT117 SEAL AND FERRULE ASSEMBLY TOOL

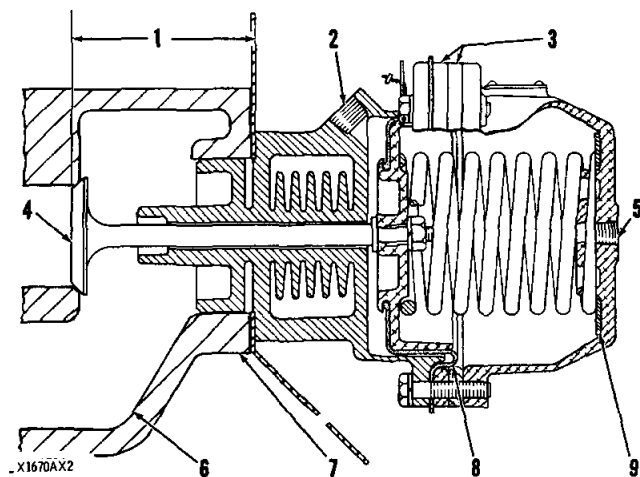
- | | |
|--------------------|-----------------------|
| 4. 5H3182 Pin. | 10. Bracket. |
| 5. 2A3672 Spring. | 11. Connecting Joint. |
| 6. Flat Washer. | 12. Lower Rod. |
| 7. Chain | 13. Base. |
| 8. Upper Rod. | A. Rubber Seals. |
| 9. Connecting Pin. | B. Ferrule. |

Replacement type seals (2) and ferrule (3) go between the head and top of the block. Put soap on the inner surface of the seal and put the seal over the flange on the ferrule before installing. Use the FT117 Seal and Ferrule Assembly Tool to install the seal on the ferrule

DIFFERENTIAL PRESSURE REGULATOR

The regulator has two .25 in. (6.4 mm) spacers (3) for altitude adjustment. Both spacers must be used for operation up to 1500 feet (457 m) altitude. Remove one for operating between 1500 and 4000 feet (457 and 1219 m). All spacers can be removed for operating between 4000 and 6500 feet (1219 and 1981 m). Make a small adjustment by adding or removing shims (9). The bolts of the regulator assembly must be sealed.

To test the regulator with both spacers (3) in place, and atmospheric pressure in spring compartment, use a pressure of 6.66 to 7.21 psi (46.1 to 50.0 kPa) in the chamber, through connection (2). Measurement at (1) must be 2.893 in. (73.5 mm). Special Instruction Form No. FE034610 shows the equipment for testing and adjusting this regulator. Use large enough lines to supply the volume of air needed. Use a Tee in the line to connect the gauge. The Tee must be installed so the gauge is at the opposite end of the Tee from the connection to the regulator. The supply pressure will be attached to the third side of the Tee.



REGULATOR

1. Measurements for testing regulator. 2. Pressure sensing port connection. 3. Spacers. 4. Bypass valve. 5. Breather location. 6. Bypass passage. 7. Exhaust regulator bypass housing. 8. Diaphragm. 9. Shims.

GOVERNOR ADJUSTMENTS

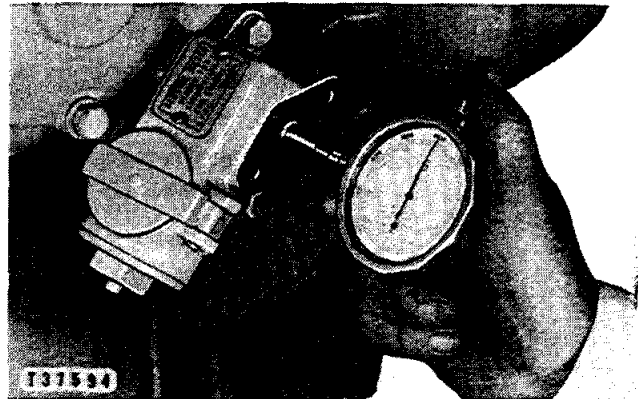
High Idle RPM

The engine idle rpm can be checked at the con-

nection for the tachometer drive on the service meter after the cover has been removed. The rpm will be one half of engine rpm.

NOTICE

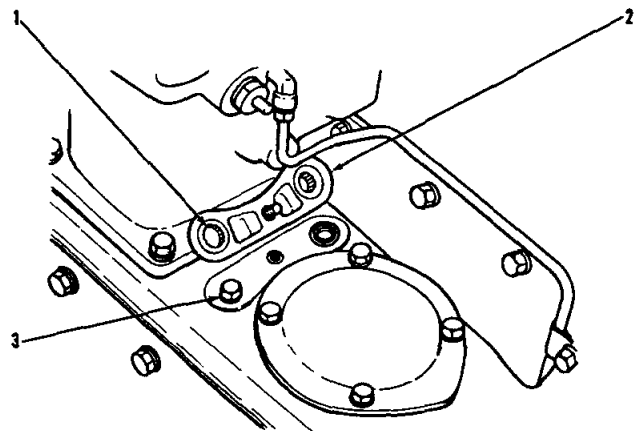
A mechanic with training in governor adjustments is the only one to make the adjustment to the high idle and low idle rpm. The correct high idle and low idle rpm is in the FUEL SETTING INFORMATION.



CHECKING ENGINE RPM

To make an adjustment to the high idle rpm use the following procedure:

1. Remove cover (2) from the top of the housing for the governor.
2. Turn adjustment screw (3) as necessary to change high idle rpm.



LOCATION OF ADJUSTMENTS

1. Retainer hole in cover. 2. Cover. 3. Adjustment screw for high idle.

3. After an 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. Use this procedure until the idle rpm is the same as the idle rpm given in the FUEL SETTING INFORMATION.

NOTE: Turning the adjustment screw counter-clockwise will cause the rpm to have an increase. Turning the adjustment screw clockwise will cause the rpm to have a decrease.

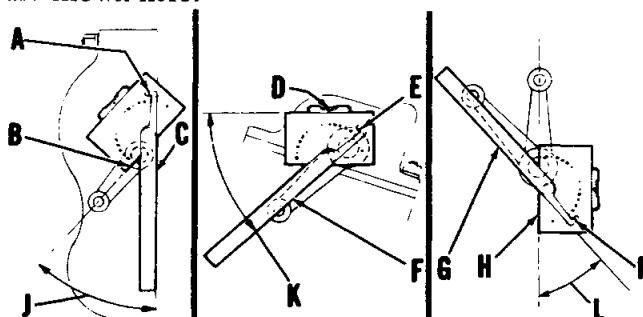
- When governor adjustment is correct, put the cover on the governor. Then put the cover on the service meter.

Low Idle RPM

The adjustment to the low idle rpm is made with the screw on the throttle shaft lever. See the subject CARBURETOR for the correct adjustment procedures.

Adjustment of Linkage to the Carburetor

Three basic uses of the 1P2385 Protractor tools are shown here.

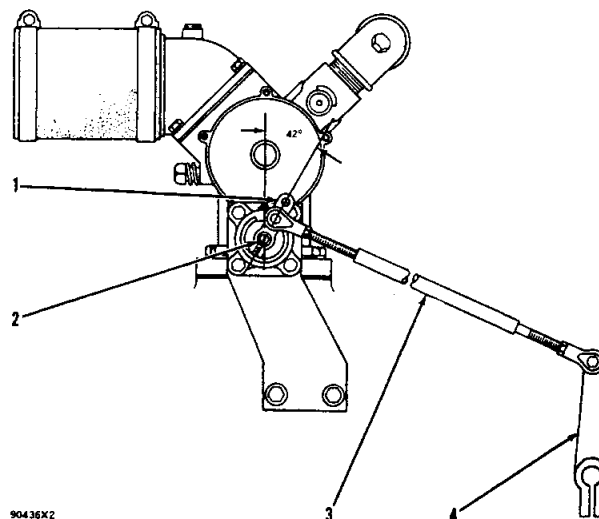


1P2385 PROTRACTOR TOOL USE

A. Indicator used for angle setting. B. Protractor plate edge in alignment with lever. C. Vertical housing face and extension arm are in alignment. D. Bubble in level. E. Indicator used for angle setting. F. Extension arm in alignment with lever. G. Extension arm in alignment with lever. H. Plate edge in alignment with second lever. I. Indicator used for angle setting. J. Angle between lever and vertical face of housing. K. Angle between level and lever. L. Angle between levers.

32231-1X1

- Put governor lever (4) in fuel off position.
- Turn control shaft (2) so that the throttle plate is in the closed position. This is low idle.
- Install lever (1) on control shaft (2) so the angle from vertical is 42° .
- Make an adjustment to the rod (3) so it is the correct length when installed on levers (1 and 4). Install the end on lever (1) so it is in the hole 1 in. (25.4 mm) from the center of the control shaft (2).



ADJUSTMENT OF LINKAGE TO THE CARBURETOR

1. Lever on carburetor control shaft. 2. Carburetor control shaft. 3. Rod. 4. Governor control lever.

LUBRICATION SYSTEM

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

TOO MUCH OIL CONSUMPTION
OIL PRESSURE IS LOW
OIL PRESSURE IS HIGH
TOO MUCH COMPONENT WEAR

TOO MUCH OIL CONSUMPTION

Oil Leakage on Outside of Engine

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

Oil Leakage Into Combustion Area of Cylinders

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

1. Oil leakage between worn valve guides and valve stems.
2. Worn or damaged piston rings or dirty oil return holes.
3. There can be a leakage of oil past the ring seals at the impeller end of the turbocharger shaft.
4. Compression ring not installed correctly.

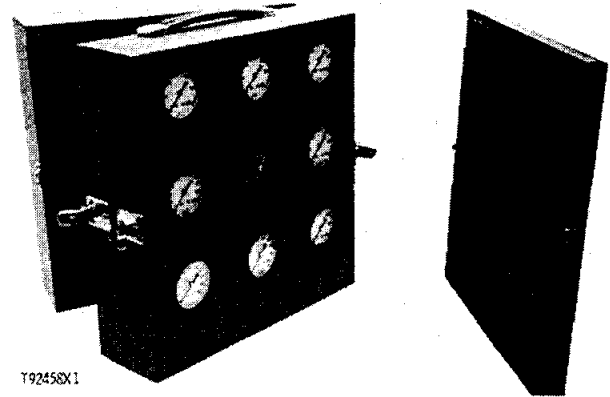
Too much oil consumption can also be the result of using oil with the wrong viscosity. Oil with a thin (low) viscosity can be caused from fuel getting in the crankcase, or by the engine getting too hot.

OIL PRESSURE IS LOW

An oil pressure gauge that has a defect may give an indication of low oil pressure.

When the engine is running at full load rpm with SAE 10 oil, temperature at $200 \pm 10^\circ \text{F}$ ($93 \pm 6^\circ \text{C}$), the oil pressure measured at the clean side of the oil filter at the oil filter base will be $43 \pm 7 \text{ psi}$ ($295 \pm 50 \text{ kPa}$).

A lower pressure reading, $18 \pm 7 \text{ psi}$ ($125 \pm 50 \text{ kPa}$), is normal at low idling speeds. An 8M2744 Gauge, which is part of 7S8875 Hydraulic Test Box, can be used for checking pressure in the system.



7S8875 HYDRAULIC TEST BOX

Crankcase Oil Level

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

Oil Pump Does Not Work Correctly

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

Oil Filter and Oil Cooler Bypass Valve

If the bypass valve for the oil filter is held in the open position (unseated) and the oil filter has a restriction, a reduction in oil pressure will be the result.

The bypass valve is in the oil filter base. The bypass valve will cause the flow of oil to go around the filter elements when there is a reduction to the flow through the elements.

If the oil cooler has a restriction, the oil cooler bypass valve in the oil filter base will open. This will cause the flow of oil to go around the oil cooler.

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

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

Oil Cooler

Look for a restriction in the oil passage of the oil cooler.

If the oil cooler has a restriction the oil temperature will be higher than normal when the engine is running. The oil pressure of the engine will become low if the oil cooler has a restriction.

OIL PRESSURE IS HIGH

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

TOO MUCH COMPONENT WEAR

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

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

Turbocharger Component Wear

When the gauge for oil pressure shows the correct oil pressure and bearing failure or wear is present in the turbocharger, check the operation of the turbocharger lubrication valve. The valve can be in the open position and permit oil that is not clean to give lubrication to the turbocharger.

COOLING SYSTEM

The engine has a pressure type cooling system. A pressure type cooling system gives two advantages. The first advantage is that the cooling system can operate safely at a temperature that is higher than the normal point where water changes to steam. The second advantage is that this type system prevents cavitation (air in inlet of pump) in the water pump. With this type system it is more difficult for an air or steam pocket to form in the cooling system.

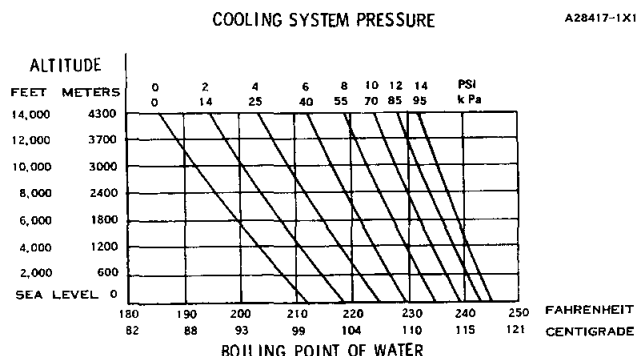
The cause for an engine getting too hot is generally because regular inspections of the cooling system were not done. Make a visual inspection of the cooling system before testing with testing equipment.

VISUAL INSPECTION OF THE COOLING SYSTEM

1. Check coolant level in the cooling system.
2. Look for leaks in the system.
3. Look for bent radiator fins. Be sure that air flow through the radiator does not have a restriction.
4. Inspect the drive for the fan.
5. Check for damage to the fan blades.
6. Look for air or combustion gas in the cooling system.
7. Inspect the pressure cap and the sealing surface for the cap. The sealing surface must be clean.
8. Look for large amounts of dirt in the radiator core and on the engine.

TESTING THE COOLING SYSTEM

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



Checking Coolant Temperatures

Tools Needed: 9S9102 Thermistor Thermometer Group.

The 9S9102 Thermistor Thermometer Group is used in the diagnosis of overheating (engine running too hot) or overcooling (engine running too cool) problems. This group can be used to check the different parts of the cooling system. The complete testing procedure is in Special Instruction Form No. SMHS7140.

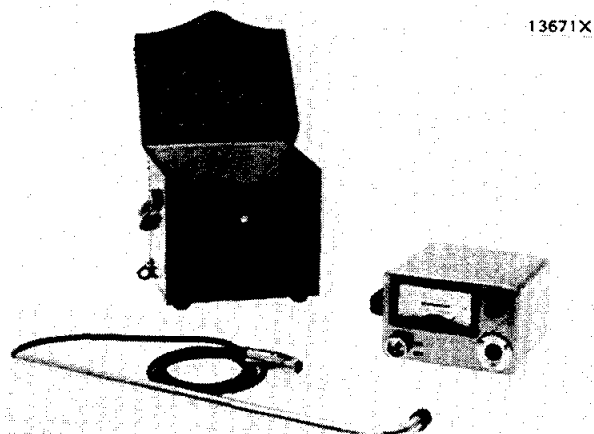


9S9102 THERMISTOR THERMOMETER GROUP

Checking Radiator Air Flow

Tools Needed: 9S7373 Air Meter Group.

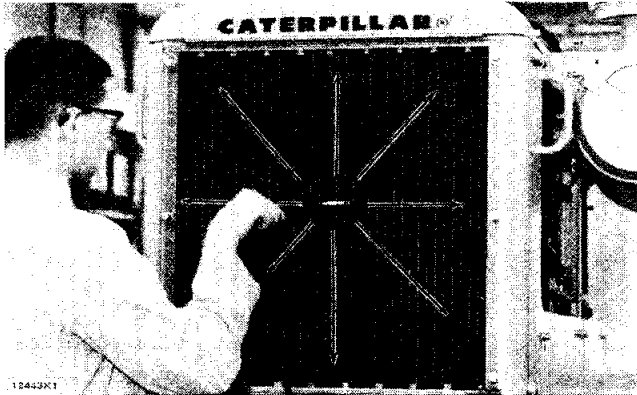
The 9S7373 Air Meter Group is used to check the air flow through the radiator core. Overheating can be caused by installing the wrong fan guard, low fan speed, or a restriction in the radiator core (clogging). The meter will give aid in finding a restriction in the core. The testing procedure and the correct readings are in Special Instruction Form No. SMHS7063.



9S7373 AIR METER GROUP

⚠ WARNING

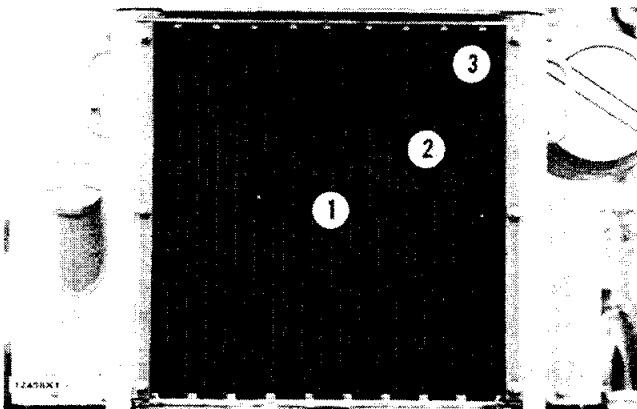
Make all checks at engine **LOW IDLE** and on the side of the radiator opposite the fan. Wear eye protection.



**CHECKING AIR FLOW IN CROSS AND
DIAGONAL LINES**
(Typical Illustration)

Take readings in a cross and diagonal pattern. Make a comparison of the readings in each line the same distance from the center of the fan. Permit differences for restrictions such as guards, braces and engine components which will cause a change in the rate of air flow.

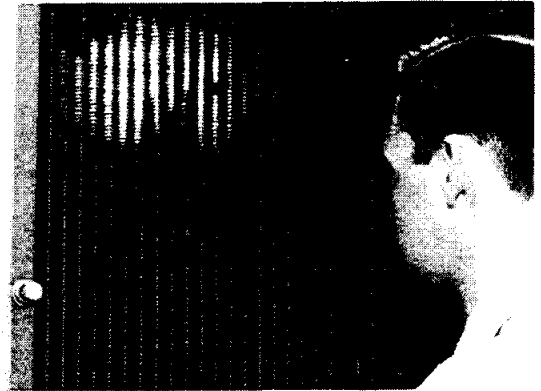
NOTE: All readings are taken at engine **LOW IDLE**.



AIR FLOW
(Typical Illustration)

1. Fan hub area. 2. Fan blade area. 3. Area outside fan blade.

If the readings are not within the ranges, stop the engine, put a strong light behind the core and inspect for a restriction. If the restriction is from dirt, remove by steam cleaning. If the restriction is from bent fins use 2H1822 Radiator Fin Comb to make the fins straight.

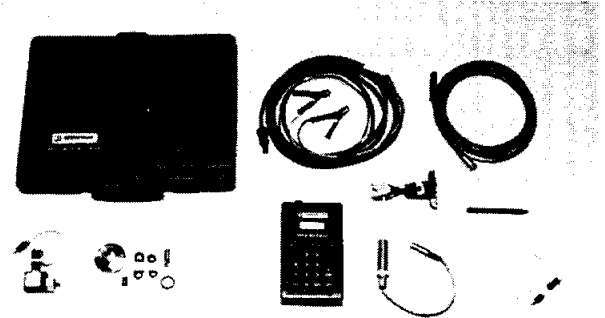


INSPECTING RADIATOR CORE FOR RESTRICTION
(Typical Illustration)

Checking Fan Speed

Tools Needed:
6V3121 Multitach Group

The 6V3121 Multitach Group can measure fan speed by the use of the photo pickup and reflective tape. Special Instruction Form No. SEHS7807 has instructions for its use.



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6V3121 MULTITACH GROUP

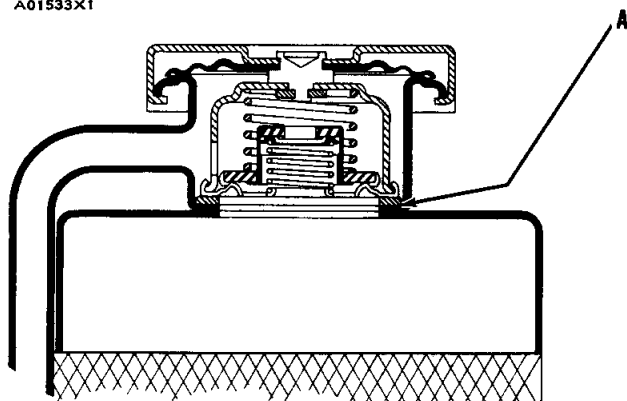
Pressure Cap

One cause for a pressure loss in the cooling system can be a bad seal on the pressure cap of the system. Inspect the pressure cap carefully. Look for damage to the seal or the sealing surface. Any foreign material or deposits on the cap, seal or sealing surface must be removed.

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

1. Remove the pressure cap from the radiator.

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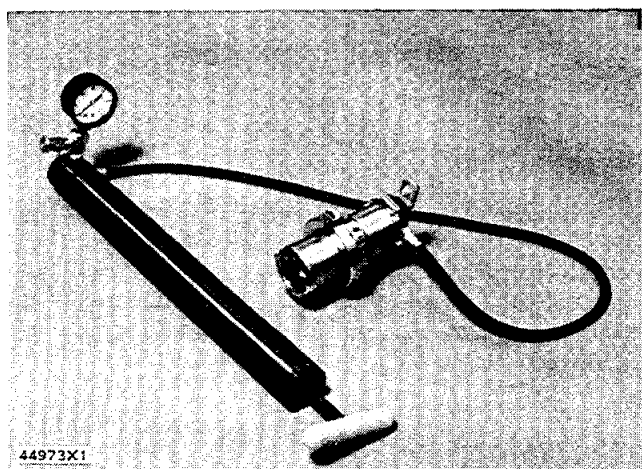
SCHEMATIC OF PRESSURE CAP

A. Sealing surface of cap and radiator.

WARNING

Always stop the engine to inspect the cooling system. Loosen the pressure cap to the first stop and let the pressure out of the cooling system, then remove the pressure cap. Hot coolant and steam can cause personal injury. Let coolant become cool before it is drained.

2. Put the pressure cap on the 9S8140 Cooling System Pressurizing Pump Group.
3. Look at the gauge for the exact pressure that makes the pressure cap open.



9S8140 COOLING SYSTEM PRESSURIZING PUMP GROUP

4. Make a comparison of the reading on the gauge with the correct pressure at which the pressure cap must open.

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

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

Testing Radiator and Cooling System for Leaks (Systems That Use Pressure Cap)

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

1. Remove the pressure cap from the radiator.

WARNING

Always stop the engine to inspect the cooling system. Loosen the pressure cap to the first stop and let the pressure out of the cooling system, then remove the pressure cap. Hot coolant and steam can cause personal injury. Let coolant become cool before it is drained.

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

Water Temperature Regulators

1. Remove the regulator from the engine.
2. Heat water in a pan until the temperature is correct for opening the regulator according to the chart. Move the water around in pan to make it all be the same temperature.
3. Hang the regulator in the pan of water. The regulator must be below the surface of the water and it must be away from the sides and bottom of the pan.
4. Keep the water at the correct temperature for 10 minutes.
5. Remove the regulator from the water. Immediately make a measurement of the distance the regulator is open.
6. If the regulator is open to a distance less than given in the chart, install a new regulator.

WATER TEMPERATURE REGULATORS				
Part No.	Minimum Open Distance		Temperature	
	in.	mm	° F	° C
9N2894	.375	9.53	197°	92°
9S9160	.375	9.53	187°	86°
4L7615	.375	9.53	180°	82°

NOTE: When installing a regulator inspect seal for defects and change if necessary.

9S9102 Thermistor Thermometer Group

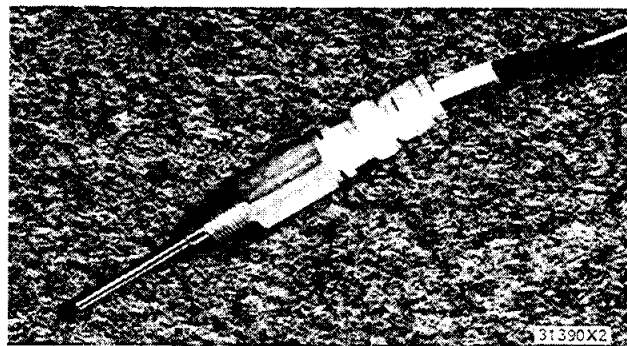
The 9S9102 Thermistor Thermometer Group is

used in the diagnosis of overheating (engine running too hot) or overcooling (engine running too cool) problems. This group can be used to check the different parts of the cooling system. The complete testing procedure is in Special Instruction Form No. SMHS7140.



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9S9102 THERMISTOR THERMOMETER GROUP



PROBE FOR CHECKING

31390X2

The probe must be installed in the coolant of the system being tested.

NOTICE

Do not tighten the probe more than 30 lb. ft. (40 N·m) torque.

Check temperatures in the locations listed in the chart. Look at the chart to see if these comparisons are within the range in the chart. Make the needed checks if the temperatures are not within the ranges.

PROBE LOCATIONS	TEMPERATURES	PROBLEM	CHECK FOR
Top Tank and Bottom Tank or Heat Exchanger Inlet and Expansion Tank	Maximum 15°F (8°C) difference.	Overheating	Defect in Water Pump. Collapsed Hoses. Restriction in Radiator Core Tubes. Restrictions in Heat Exchanger Tubes. Low Coolant Level.
Regulator Housing and Ambient* or Regulator Housing and Sea Water Source	Standard Capacity Maximum 100°F (56°C) difference.** Large Capacity Radiator Maximum 85°F (47°C) difference.** With 85°F (28.5°C) sea water. Maximum 85°F (47°C) difference.***	Overheating	Engine Operated with too Great a Load. Radiator Core with Restriction to Air Flow. Restrictions in Heat Exchanger Tubes. Bent Radiator Fins. Low Fan Speed. Damaged Fan Guard.
Oil Manifold	Maximum 235°F (113°C) oil to bearings.	Overheating	Oil Cooler Core with Restrictions. Heat Exchanger Core with Restrictions. High Ambient * Temperature or High Sea Water Temperature.
Top Tank and Regulator Housing or Expansion Tank and Regulator Housing	Maximum 2°F (1°C) difference with regulators open.	Overcooling	Temperature Regulator will not Close. Regulator Seals Leaking. Coolant Flow Past the Regulator Flange. Low Ambient * Temperature with Light Loads. Low Sea Water Temperature with Light Loads.
		Overheating	Temperature Regulators will not Open.
*Ambient (air temperature away from the machine and not in direct sunlight). **If ambient temperature is low a greater differential can be expected. ***If temperature of sea water source is less than 85°F (28.5°C) a greater differential can be expected.			

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V-BELT TENSION CHART										
BELT SIZE	WIDTH BELT TOP		WIDTH TOP OF PULLEY GROOVE		BELT TENSION "INITIAL"*		BELT TENSION "USED"***		BORROUGHS GAUGE NUMBERS	
					GAUGE READING		GAUGE READING			
	in.	mm	in.	mm	lb.	N	lb.	N	OLD GAUGE NO.	NEW GAUGE NO.
3/8	.422	10.72	.380	9.65	100 ± 5	445 ± 22	90 ± 5	400 ± 22	BT-33-73F	BT-33-95
1/2	.547	13.89	.500	12.70	120 ± 5	534 ± 22	90 ± 10	400 ± 44	BT-33-96-4-16	BT-33-95
5V	.625	15.88	.600	15.24	120 ± 5	534 ± 22	90 ± 10	400 ± 44	BT-33-72-4-15	BT-33-72C
11/16	.688	17.48	.625	15.88	120 ± 5	534 ± 22	90 ± 10	400 ± 44	BT-33-72-4-15	BT-33-72C
3/4	.750	19.05	.690	17.53	120 ± 5	534 ± 22	90 ± 10	400 ± 44	BT-33-72-4-15	BT-33-72C
15/16	.938	23.83	.878	22.30	120 ± 5	534 ± 22	90 ± 10	400 ± 44	BT-33-72-4-15	BT-33-72C
MEASURE TENSION OF BELT FARTEST FROM THE ENGINE										
***"INITIAL" BELT TENSION is for a new belt.										
***"USED" BELT TENSION is for a belt which has more than 30 minutes of operation at rated speed of engine.										
A10232X5										

A10232X5

BASIC BLOCK

CONNECTING RODS AND PISTONS

Use the 7B7974 Piston Ring Expander to remove or install piston rings.

Use the 5P3527 Piston Ring Compressor to install pistons into cylinder block.

Tighten the connecting rod bolts in the following step sequence:

1. Put 2P2506 Thread Lubricant on threads and nut seat.
2. Tighten both nuts 75 ± 5 lb. ft. (100 ± 7 N•m).
3. Put a mark on each nut and cap.
4. Tighten each nut 60° from the mark.

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

CONNECTING ROD AND MAIN BEARINGS

Bearings are available with .025 in. (0.64 mm) and .050 in. (1.27 mm) smaller inside diameter than the original size bearings. These bearings are for crankshafts that have been "ground" (made smaller than the original size).

PISTON RING GROOVE GAUGE

Pistons With Straight Sides in Ring Grooves

A 5P3519 Piston Ring Groove Gauge is available for checking ring grooves with straight sides. For instructions on the use of the gauge, see the **GUIDE-LINE FOR REUSABLE PARTS; PISTONS AND CYLINDER LINERS**, Form No. SEBF8001.



5P3519 PISTON RING GROOVE GAUGE

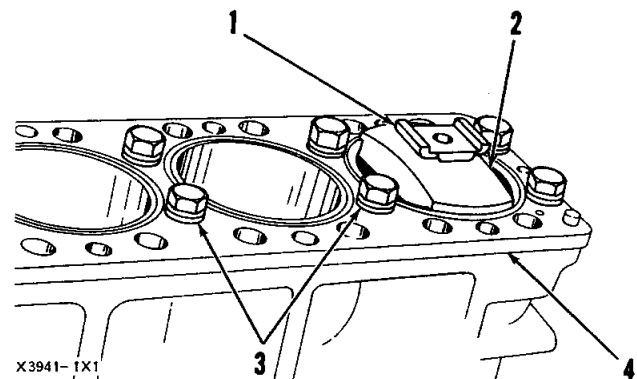
CYLINDER LINER PROJECTION For Engines With Spacer Plates

Tools Needed: 1P2397 Adapter Plate.
8B7548 Push-Puller Crossbar and three 3H465 Plates.
7/8"-9 NC Bolts, 3 in. (76.2 mm) long.
7/8"-9 NC Bolts, 7 in. (177.8 mm) long.
7M7875 Head Bolt Washers.
8S3140 Cylinder Block Counterboring Tool Arrangement.
1P5510 Liner Projection Tool Group.

Check liner projection above spacer plate (4) as follows:

1. Make certain that spacer plate (4) and the cylinder liner flange are clean.
2. Install the gasket and spacer plate (4) on the cylinder block. Use 7/8 in.-9 NC bolts, 3 in. (76.2 mm) long, with two 7M7875 Washers (3) on each bolt to secure spacer plate (4) to the cylinder block. Place two bolts with washers on each side of the cylinder liner. Tighten the bolts evenly, in four steps; 10 lb. ft. (14 N•m), 25 lb. ft. (35 N•m), 50 lb. ft. (70 N•m) and finally to 70 lb. ft. (95 N•m).

NOTE: To avoid moving bolts and washers as each liner is checked, install two bolts with washers on each side of each cylinder liner, along the entire length of the spacer plate.



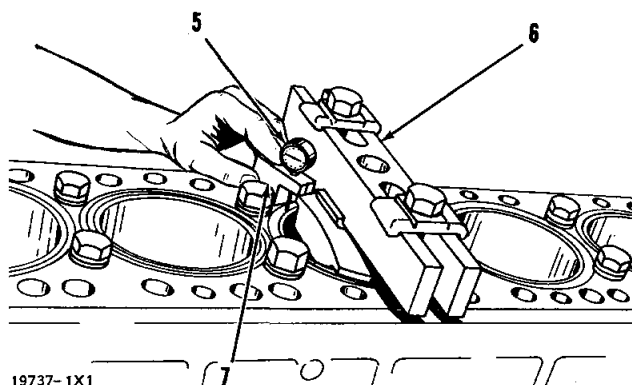
SECURING SPACER PLATE TO CYLINDER BLOCK
(Typical Example)

1. 3H465 Plate. 2. 1P2397 Adapter Plate. 3. Cylinder head bolt washers. 4. Spacer plate.

3. Invert 3H465 Plate (1) from an 8B7548 Push Puller, in the center of adapter plate (2). Center crossbar (6) on the inverted 3H465 Plate. Using two 7/8 in.-9 NC bolts 7 in. (177.8 mm) long and two 3H465 Plates, secure the crossbar

to the cylinder block as illustrated. Tighten the bolts evenly, in four steps; 5 lb. ft. (7 N•m), 15 lb. ft. (20 N•m), 25 lb. ft. (35 N•m) and finally to 50 lb. ft. (70 N•m). Distance from bottom edge of crossbar to top plate, must be the same on both sides of cylinder liner.

4. Zero the dial indicator using the back of 1P5507 Gauge with dial indicator (5) mounted in 1P2402 Gauge Body (7).
5. Measure liner projection as close as possible to the clamping area and at four locations around the liner. The liner projection must be within $.005 \pm .003$ in. (0.13 ± 0.08 mm) and the four measurements should not vary more than .002 in. (0.05 mm). The average projection between adjacent cylinders for the same cylinder head must not vary more than .002 in. (0.05 mm).



MEASURING LINER HEIGHT PROJECTION
(Typical Example)

5. Dial indicator. 6. Crossbar. 7. 1P2402 Gauge Body.

NOTE: If liner projection varies from point to point around the liner, rotate the liner to a new position within the bore. If still not within specified limits move liner to a different bore.

NOTE: Measure and check the following dimensions when installing new parts. With all dimensions correct, proceed with the listed Steps.

- a. Spacer plate thickness, $.486 \pm .001$ in. (12.34 ± 0.03 mm).
- b. Spacer plate gasket thickness, $.008 \pm .001$ in. (0.20 ± 0.03 mm). (All surfaces must be clean and dry when installing gasket).
- c. Cylinder liner flange thickness, $.4990 \pm .0008$ in. (12.675 ± 0.020 mm).

Liner projection can be adjusted by machining the contact face of the cylinder block with use of the 8S3140 Cylinder Block Counterboring Tool Arrangement. Form FM055228 is part of the cyl-

inder block counterboring tool arrangement and gives tool arrangement and tool usage information.

The counterboring depth ranges from a minimum of .030 in. (0.76 mm) to a maximum of .045 in. (1.14 mm). Put a .030 in. (0.76 mm) shim directly beneath the liner flange. If more than one shim is installed put the other shims under the .030 in. (0.76 mm) shim.

Shims of various thicknesses also are available to adjust liner projection.

ADJUSTMENT SHIMS FOR LINER PROJECTION				
SHIM THICKNESS, COLOR CODE, AND PART NUMBER				
.007 in. (0.18 mm)	.008 in. (0.20 mm)	.009 in. (0.23 mm)	.015 in. (0.38 mm)	.030 in. (0.76 mm)
BLACK 5S8143	RED 5S8144	GREEN 5S8145	BROWN 5S8146	BLUE 5S8147

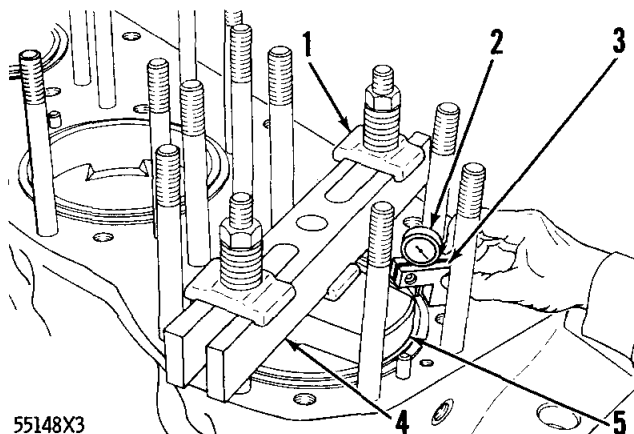
CYLINDER LINER PROJECTION

For Engines Without Spacer Plates

Tools Needed: 1P2397 Puller Plate.
8B7548 Push Puller Crossbar and three 3H465 Plates.
8S3140 Cylinder Block Counterboring Tool Arrangement.
1P5510 Liner Projection Tool Group.

1. Make sure that the bore in block and the cylinder liner flange are clean.
2. Use a 1P2397 Puller Plate (5), three 3H465 Plates (1) and the crossbar (4) from the 8B7548 Push Puller, to hold the liner down with stud nuts for the cylinder head.
3. Tighten the nuts to 50 lb. ft. (70 N•m). Tighten the nuts evenly in four steps; 5 lb. ft. (7 N•m), 15 lb. ft. (20 N•m), 25 lb. ft. (35 N•m), then to 50 lb. ft. (70 N•m). The distance from bottom edge of the crossbar, to the cylinder block must be the same on both sides of the cylinder liner.
4. Use a 1P5510 Liner Projection Tool Group as illustrated, to measure liner projection. Special Instruction Form No. SMHS7727 is with the tool. Liner projection must be .004 to .008 in. (0.10 to 0.20 mm). The maximum difference in height of liners next to each other under the same cylinder head is .002 in. (0.05 mm). The maximum difference between high and low measurements made at four places around each cylinder is .002 in. (0.05 mm). Shims are available for adjustment of the liner projection.

ADJUSTMENT SHIMS FOR LINER PROJECTION				
SHIM THICKNESS, COLOR CODE, AND PART NUMBER				
.007 in. (0.18 mm)	.008 in. (0.20 mm)	.009 in. (0.23 mm)	.015 in. (0.38 mm)	.030 in. (0.76 mm)
BLACK 5S8143	RED 5S8144	GREEN 5S8145	BROWN 5S8146	BLUE 5S8147

**MEASURING LINER PROJECTION**

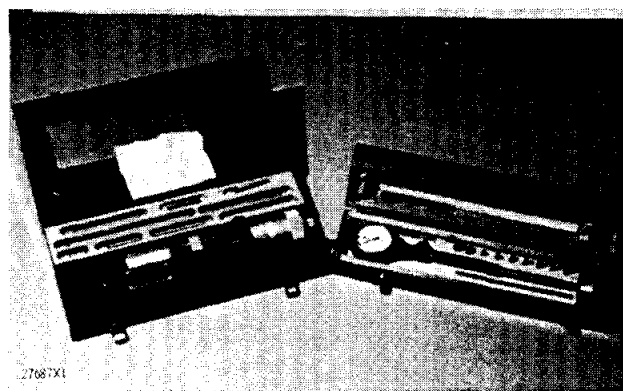
1. 3H465 Plate. 2. Dial Indicator. 3. 1P2402 Gauge Body.
4. Crossbar. 5. 1P2397 Puller Plate.

5. Use the 8S3140 Counterboring Tool Arrangement to bore the block deeper if needed. Maximum depth of the bore is .538 in. (13.67 mm). Special Instruction Form No. FM055228 gives an explanation of the use of the 8S3140 Counterboring Tool Arrangement.

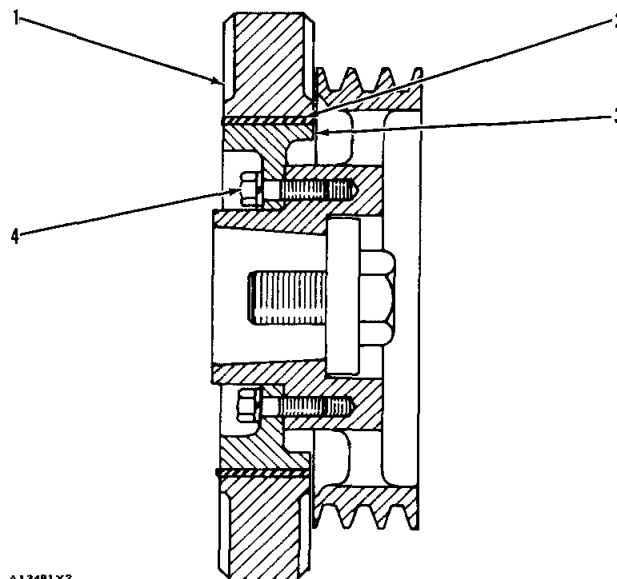
CYLINDER BLOCK

Tools Needed: 1P4000 Line Boring Tool Group.
1P3537 Dial Bore Gauge Group.

The bore in the block for main bearings can be checked with main bearing caps installed without bearings. Tighten the nuts holding the caps to the torque shown in the SPECIFICATIONS. Alignment error in the bores must not be more than .003 in. (0.08 mm). Special Instruction Form No. SMHS7606 gives the use of 1P4000 Line Boring Tool Group to machine the main bearing bores. 1P3537 Dial Bore Gauge Group can be used to check the size of the bores. Special Instruction Form No. GMG00981 is with the group.

**1P3537 DIAL BORE GAUGE GROUP****VIBRATION DAMPER**

Damage to or failure of the damper will cause an increase in vibrations and can result in damage to the crankshaft.

**VIBRATION DAMPER**

1. Flywheel ring. 2. Rubber ring. 3. Inner hub. 4. Bolt.

The damper needs replacement when the holes for the bolts have wear and the fit between the bolts and the holes is loose.

FLYWHEEL AND FLYWHEEL HOUSING

Tools Needed: 8S2328 Dial Indicator Group.

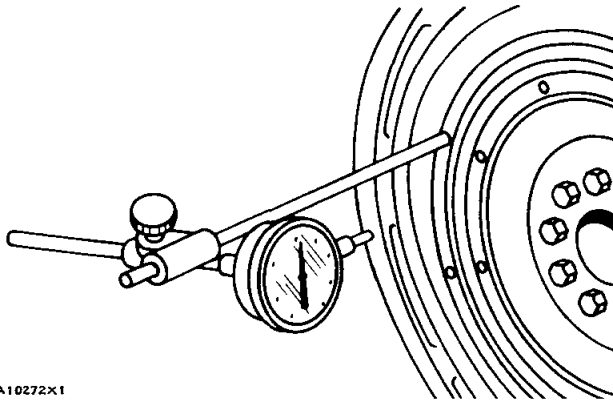
Flywheel Ring Gear

Heat the ring gear to a maximum of 600° F (316° C) to install. Install the ring gear so the chamfer on the gear teeth is next to the starter pinion when the flywheel is installed.

Face Runout (axial eccentricity) of the Flywheel Housing

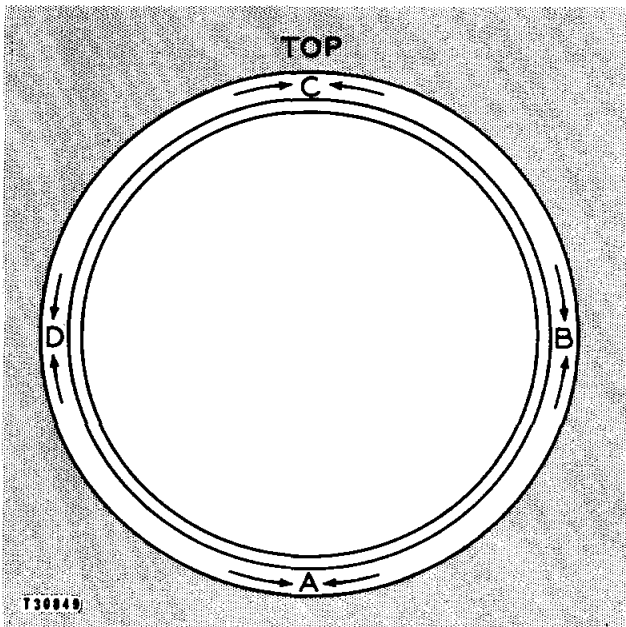
If any method other than given here is used, always remember bearing clearances must be removed to get correct measurements.

1. Fasten a dial indicator to the crankshaft flange so the anvil of the indicator will touch the face of the flywheel housing.



A10272X1

8S2328 DIAL INDICATOR GROUP INSTALLED



T30040

CHECKING FACE RUNOUT OF THE FLYWHEEL HOUSING

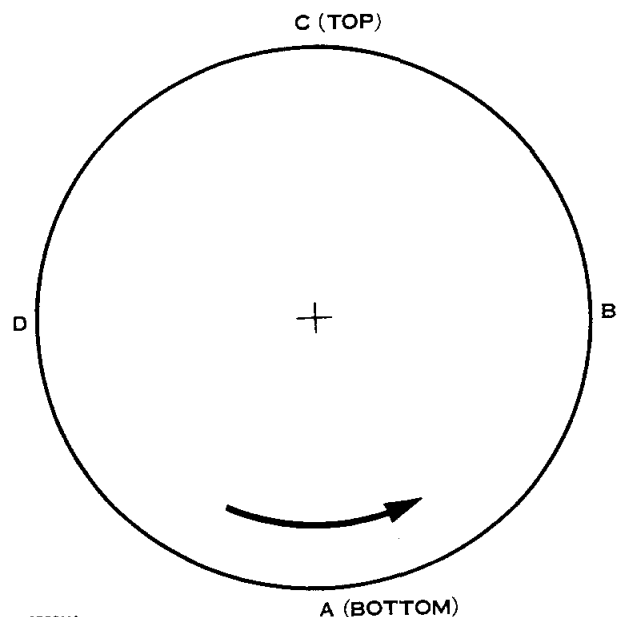
A. Bottom. B. Right side. C. Top. D. Left side.

2. Force the crankshaft to the rear before reading the indication at each point.
3. With dial indicator set at .000 in. (0.0 mm) at location (A), turn the crankshaft and read the indicator at locations (B), (C) and (D).
4. The difference between lower and higher measurements taken at all four points must not be more than .012 in. (0.30 mm), which is the maximum permissible face runout (axial eccentricity) of the flywheel housing.

Bore Runout (radial eccentricity) of the Flywheel Housing

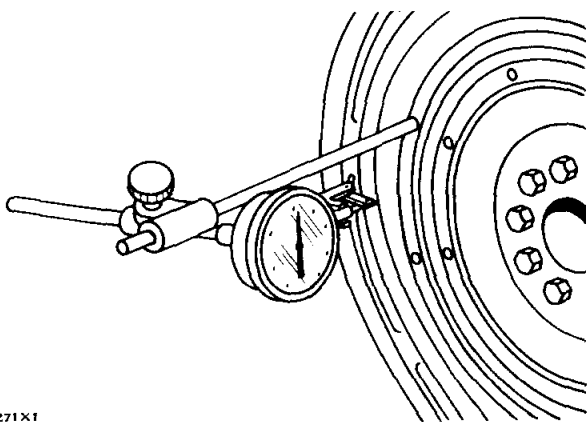
NOTE: Write the dial indicator measurements with their positive (+) and negative (−) notation (signs). This notation is necessary for making the calculations in the chart correctly.

1. With the dial indicator in position at (C), adjust the dial indicator to "0" (zero). Push the crankshaft up against the top bearing. Write the measurement for bearing clearance on line 1 in column (C).



A10233X1

CHECKING BORE RUNOUT OF THE FLYWHEEL HOUSING



A10271X1

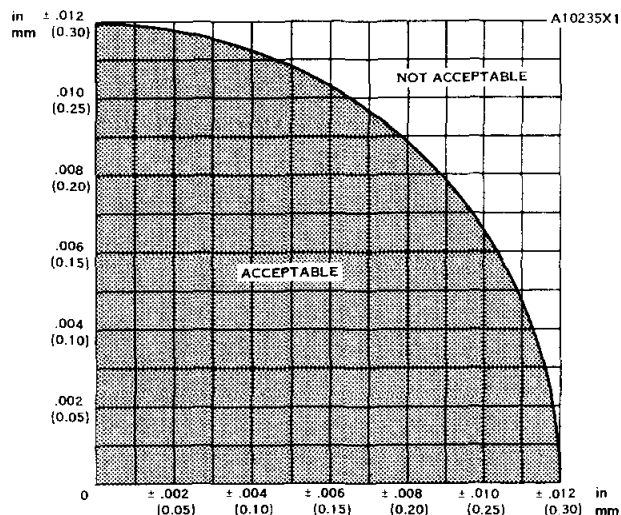
8S2328 DIAL INDICATOR GROUP INSTALLED

2. Divide the measurement from Step 1 by 2. Write this number on line I in columns (B) & (D).
3. Turn the crankshaft to put the dial indicator at (A). Adjust the dial indicator to "0" (zero).
4. Turn the crankshaft counterclockwise to put the dial indicator at (B). Write the measurement in the chart.
5. Turn the crankshaft counterclockwise to put the dial indicator at (C). Write the measurement in the chart.
6. Turn the crankshaft counterclockwise to put the dial indicator at (D). Write the measurement in the chart.
7. Add lines I & II by columns.
8. Subtract the smaller number from the larger number in line III in columns (B) & (D). The result is the horizontal "eccentricity" (out of round). Line III, column (C) is the vertical eccentricity.

CHART FOR DIAL INDICATOR MEASUREMENTS					
		Position of dial indicator			
	Line No.	A	B	C	D
Correction for bearing clearance	I	0			
Dial Indicator Reading	II	0			
Total of Line I & 2	III	0	**	*	**
*Total Vertical eccentricity (out of round). **Subtract the smaller No. from the larger No. The difference is the total horizontal eccentricity.					

A10234X1

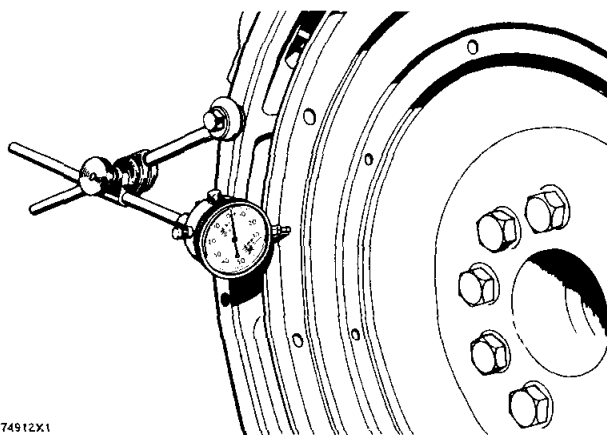
9. On the graph for total eccentricity find the point of intersection of the lines for vertical eccentricity and horizontal eccentricity.

**GRAPH FOR TOTAL ECCENTRICITY**

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

Face Runout (axial eccentricity) of the Flywheel

1. Install the dial indicator as shown. Force the crankshaft the same way before the indicator is read so the crankshaft end clearance (movement) is always removed.
2. Set the dial indicator to read .000 in. (0.0 mm).
3. Turn the flywheel and read the indicator every 90°.
4. The difference between the lower and higher measurements taken at all four points must not be more than .006 in. (0.15 mm), which is the maximum permissible face runout (axial eccentricity) of the flywheel.

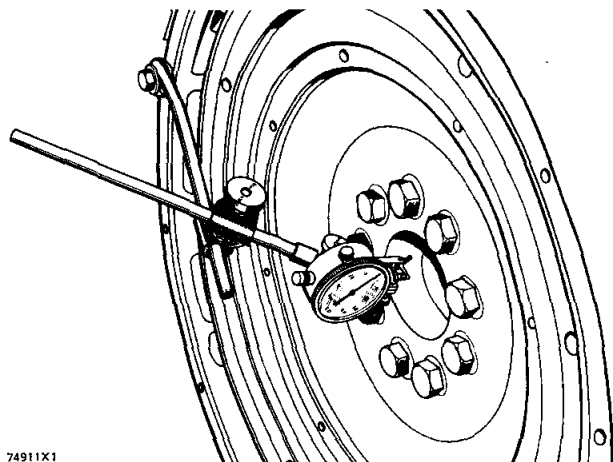


74912X1

CHECKING FACE RUNOUT OF THE FLYWHEEL

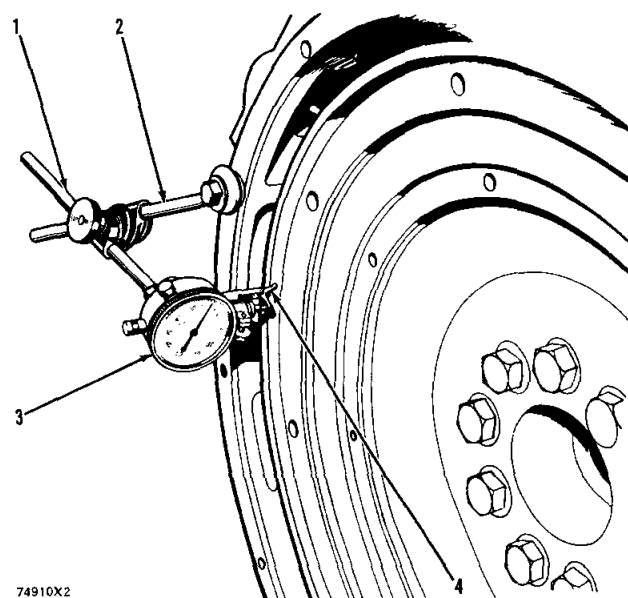
Bore Runout (radial eccentricity) of the Flywheel

1. Install the dial indicator (3) and make an adjustment of the universal attachment (4) so it makes contact as shown.
2. Set the dial indicator to read .000 in. (0.0 mm).
3. Turn the flywheel and read the indicator every 90°.
4. The difference between the lower and higher measurements taken at all four points must not be more than .006 in. (0.15 mm), which is the maximum permissible bore runout (radial eccentricity) of the flywheel.
5. Runout (eccentricity) of the bore for the pilot bearing for the flywheel clutch, must not exceed .005 in. (0.13 mm).



74911X1

**CHECKING FLYWHEEL CLUTCH
PILOT BEARING BORE**



74910X2

CHECKING BORE RUNOUT OF THE FLYWHEEL

1. 7H1945 Holding Rod. 2. 7H1645 Holding Rod. 3. 7H1942 Indicator. 4. 7H1940 Universal Attachment.

ELECTRICAL SYSTEM

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

The service manual TESTING AND ADJUSTING ELECTRICAL COMPONENTS, Form No. REG00636 has complete specifications and procedures for the components of the starting circuit and the charging circuit.

BATTERY

Tools Needed: 5P300 Electrical Tester.
9S1990 or 1P7400 Battery Charger Tester.
5P957 or 5P3414 Coolant and Battery Tester.

NOTE: Make reference to Special Instruction Form No. SEHS7006 and to the instructions inside of the cover of the tester, when testing with the 5P300 Electrical Tester.

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

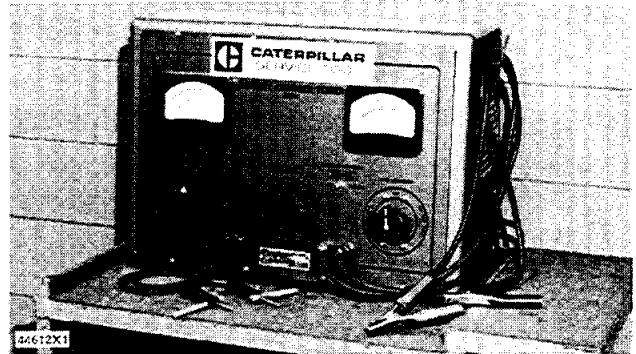
WARNING

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

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

4.5 V; an 8 V battery will show 6 V; a 12 V battery will show 9 V. Each cell of a battery in good condition must show 1.6 V on either a 6, 8 or 12 V battery.

Make reference to Special Instruction Form No. SEHS6891 when checking with the 9S1990 or 1P7400 Battery Charger Tester.



9S1990 BATTERY CHARGER TESTER

CHARGING SYSTEM

Tools Needed: 5P300 Electrical Tester.

NOTE: Make reference to Special Instruction Form No. SEHS7006 and to the instructions inside of the cover of the tester, when testing with the 5P300 Electrical Tester.

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

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

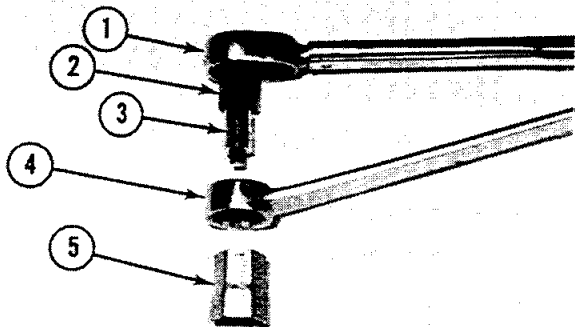
Before starting the on engine testing, the charging system and battery must be checked as given in the Steps below.

1. Battery must be at least 75% (1.240 Sp. Gr.) full charged and held tightly in place. The battery holder must not put too much stress on the battery.

2. Cables between the battery, starter and engine ground must be the correct size. Wires and cables must be free of corrosion and have cable supports clamps to prevent stress on battery connections (terminals).
3. Leads, junctions, switches and panel instruments that have direct relation to the charging circuit must give correct circuit control.
4. Inspect the drive components for the charging unit to be sure they are free of grease and oil and have the ability to operate the charging unit.

Delco-Remy Alternator; Pulley Nut Tightening

Tighten nut that holds the pulley to a torque of 75 ± 5 lb. ft. (100 ± 7 N·m) with the tools shown.



862612X1

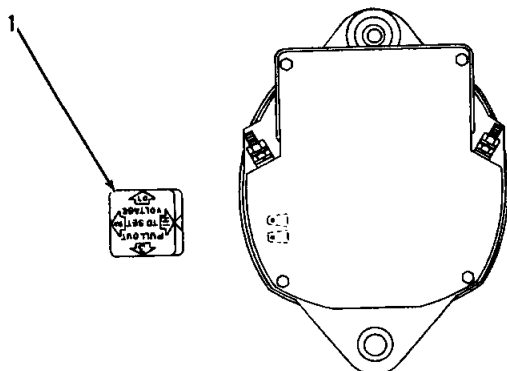
TOOLS TO TIGHTEN ALTERNATOR PULLEY NUT

1. 5P7425 Torque Wrench.
2. 8S1588 Adapter ($\frac{1}{2}$ " female to $\frac{3}{4}$ " male drive).
3. FT1697 Socket.
4. 8H8517 Combination Wrench ($1\frac{1}{4}$ ").
5. FT1696 Wrench.

Alternator Regulator Adjustment

When an alternator is charging the battery too much or not enough, an adjustment can be made to the charging rate of the alternator.

Alternator Regulator (Delco-Remy)

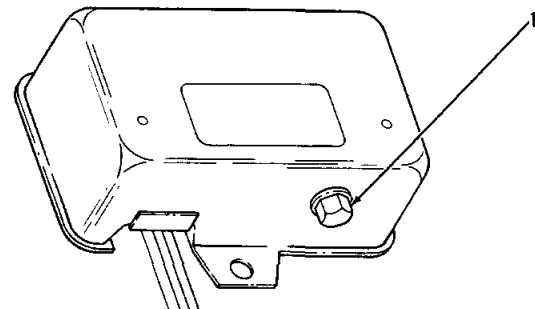


97213X1

ALTERNATOR REGULATOR ADJUSTMENT

1. Voltage adjustment cap.

To make an adjustment to the voltage output on these alternators, remove the voltage adjustment cap (1) from the alternator, turn the cap 90° , and install it again into the alternator. The voltage adjustment cap has four positions: HI, LO, and two positions between the high and the low setting.



A18833X1

ALTERNATOR REGULATOR (MOTOROLA)

1. Cap for adjustment screw.

When the alternator is either charging the battery too much or not enough, an adjustment can be made to the alternator charging rate. To make an adjustment to the voltage output, remove cap (1) from the alternator regulator and change the regulator adjustment with a screwdriver.

To increase the voltage turn the adjustment screw clockwise. The adjustment screw under the cap (1) has five positions (number 1 is the last position clockwise).

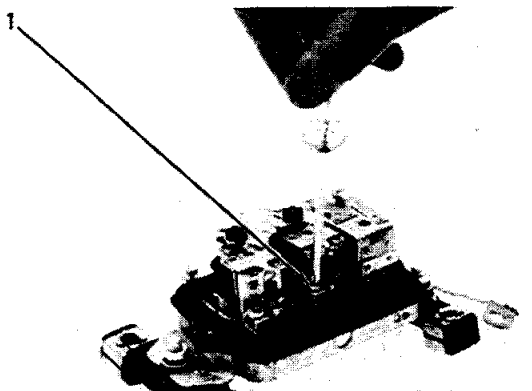
24V REGULATOR					
Adjustment Position	1	2	3	4	5
Regulator Voltage	29.25 $\pm .35$	28.6 $\pm .3$	28.0 $\pm .3$	27.4 $\pm .3$	26.8 $\pm .3$

Generator

NOTE: Make reference to Special Instruction Form No. SEHS7006 and to the instructions inside of the cover of the tester, when testing with the 5P300 Electrical Tester.

When the generator is giving the battery too large or too small a charge, use a 5P300 Electrical Tester to check if the voltage regulator control, the current regulator control, or both need adjustment. To get a correct test the regulator cover must not be removed and the regulator must be at operating temperature.

The voltage regulator and current regulator controls have a spring tension adjustment screw. To cause an increase in generator voltage or current turn adjusting screw (1), to put more spring force on the correct control. Make the spring force less to cause a decrease in generator output. After the regulator adjustment has been made test the generator output with the regulator cover installed.



T89394X2

GENERATOR OUTPUT ADJUSTMENT

1. Adjustment screw.

STARTING SYSTEM

Tools Needed: 5P300 Electrical Tester.

NOTE: Make reference to Special Instruction Form No. SEHS7006 and to the instructions inside of the cover of the tester, when testing with the 5P300 Electrical Tester.

Use a D.C. Voltmeter to find starting system components which do not function.

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

If the solenoid for the starter motor will not operate, it is possible that the current from the battery does not get to the solenoid. Fasten one lead of the voltmeter to the connection (terminal) for the battery cable on the solenoid. Put the other lead to a good ground. No voltmeter reading shows there is a broken circuit from the battery. More testing is necessary when there is a reading on the voltmeter.

The solenoid operation also closes the electric circuit to the motor. Connect one lead of the voltmeter to the solenoid connection (terminal) that is fastened to the motor. Put the other lead to a good ground. Activate the starter solenoid and look at the voltmeter. A reading of battery voltage shows the problem is in the motor. The motor must be removed for more testing. No reading on the voltmeter shows that the solenoid contacts do not close. This is an indication of the need for repair to the solenoid or an adjustment to be made to the starter pinion clearance.

Make a test by fastening one voltmeter lead to the connection (terminal) for the small wire at the solenoid and the other lead to the ground. Look at the voltmeter and activate the starter solenoid. A voltmeter reading shows that the problem is in the solenoid. No voltmeter reading shows that the problem is in the heat-start switch or wiring.

Fasten one voltmeter lead to the heat-start switch at the connection (terminal) for the wire from the battery. Fasten the other lead to a good ground. No voltmeter reading indicates a broken circuit from the battery. Make a check of the circuit breaker and wiring. If there is voltmeter reading, the malfunction is in the heat-start switch or in the wiring.

Fasten one lead of the voltmeter to the battery wire connection of the starter switch and put the other lead to a good ground. A voltmeter reading indicates a failure in the switch.

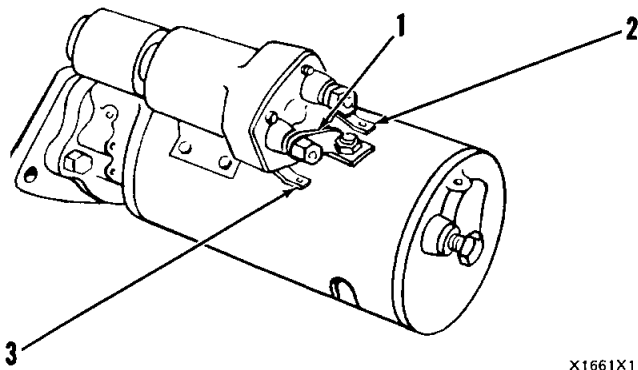
A starter motor that operates too slow can have an overload because of too much friction in the engine being started. Slow operation of the starter motor can also be caused by shorts, loose connections, and/or dirt in the motor.

Pinion Clearance Adjustment (Delco-Remy)

When the solenoid is installed, adjust the pinion clearance. Make the adjustment with the starter motor removed.

Bench test and adjust the pinion clearance at installation of solenoid as follows:

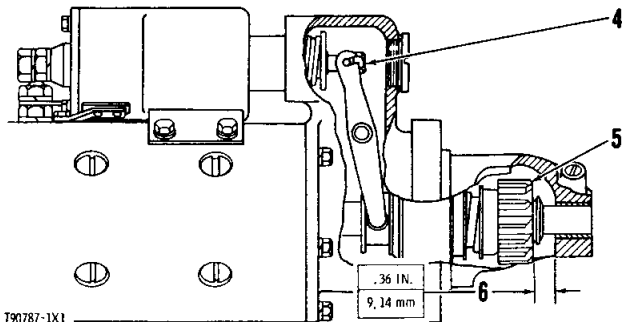
1. Install the solenoid without connector (1) from the MOTOR terminal on solenoid to the motor.
2. Connect a battery, of the same voltage as the solenoid, to the terminal (2), marked SW.
3. Connect the other side of battery to ground terminal (3).



X1661X1

CONNECTIONS FOR CHECKING PINION CLEARANCE

1. Connector from MOTOR terminal on solenoid to motor.
2. SW terminal. 3. Ground terminal.



T90787-1X1

PINION CLEARANCE ADJUSTMENT

4. Shaft nut. 5. Pinion. 6. Pinion clearance.

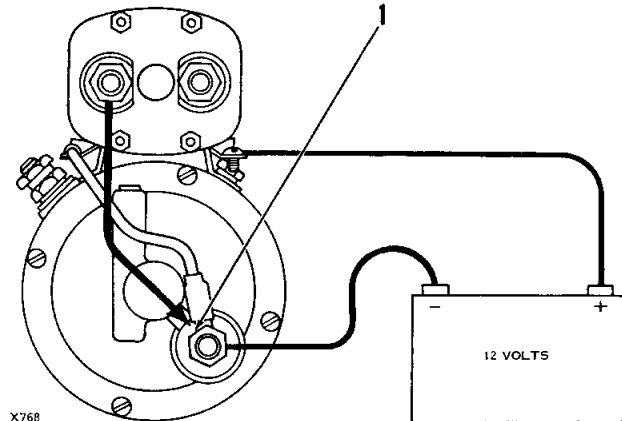
4. **MOMENTARILY** flash a jumper wire from the solenoid terminal marked MOTOR to the ground terminal. The pinion will shift into cranking position and will remain there until the battery is disconnected.
5. Push pinion towards commutator end to eliminate free movement.
6. Pinion clearance (6) is .33 to .39 in. (8.3 to 9.9 mm).
7. To adjust clearance remove the plug and turn shaft nut (4).

Pinion Clearance Adjustment (Prestolite)

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

End Play For The Armature

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

Pinion Clearance Adjustment

X768

CONNECTIONS FOR ADJUSTMENT OF THE PINION CLEARANCE

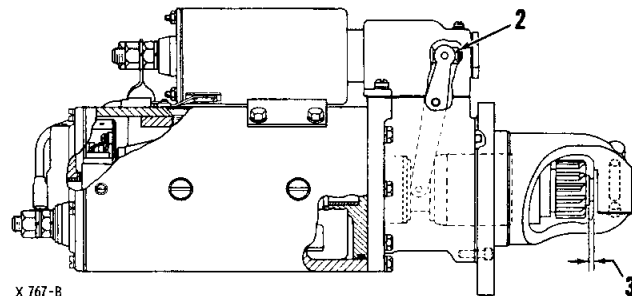
1. Stud.

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

Disconnect the wire.

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

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



X 767-B

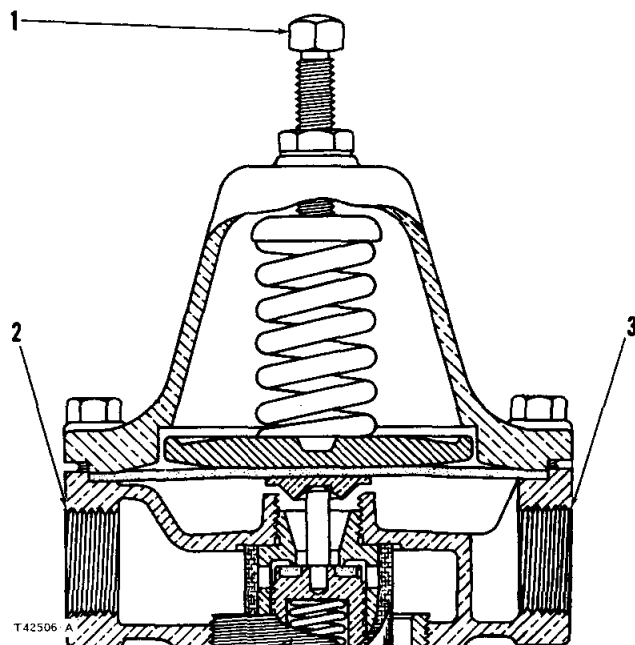
PINION CLEARANCE ADJUSTMENT

2. Adjusting nut. 3. Distance.

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

AIR STARTING SYSTEM

Pressure Regulating Valve



**PRESSURE REGULATING VALVE
(TYPICAL ILLUSTRATION)**

1. Adjustment screw. 2. Regulator inlet. 3. Regulator outlet.

Use the procedure that follows to check and adjust the pressure regulating valve.

1. Drain the line to the pressure regulating valve or drain the air storage tank.
2. Disconnect the regulator from the starter control valve.
3. Connect an 8M2885 Pressure Gauge to the regulator outlet.
4. Put air pressure in the line or tank.
5. Check the pressure.
6. Adjust the pressure regulating valve to 100 to 150 psi (690 to 1030 kPa).
7. Remove the air pressure from the line or tank.
8. Remove the 8M2885 Pressure Gauge and connect the air pressure regulator to the line to the air starting motor.

Each engine application will have to be inspected to get the most acceptable starting results. Some of the factors that affect regulating valve pressure setting are: attachment loads pulled by engine during starting, ambient temperature conditions, oil viscosity, capacity of air reservoir, and condition of engine (new or worn).

The advantages of setting the valve at the higher pressures are increased torque for starting motor and faster rotation of engine. The advantage of setting the valve at the lower pressures is longer time of engine rotation for a given reservoir capacity of supply air.

Lubrication

Always use an air line lubricator with these Starters.

For temperatures above 32° F (0° C), use a good quality SAE 10 motor oil.

For temperatures below 32° F (0° C), use diesel fuel.

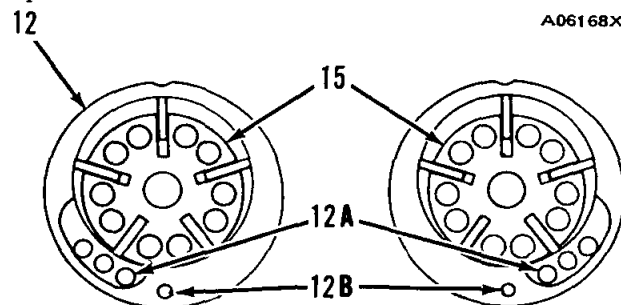
To maintain the efficiency of the starting motor flush it at regular intervals. Put approximately 1 pt. (0.5 litre) of diesel fuel into the air inlet of the starting motor and operate the motor. This will remove the dirt, water and oil mixture (gummy coating) from the vanes of the motor.

Air Starting Motor

The cylinder (12) must be assembled over the rotor (15) and on the front end plate (16) so the dowel hole (12B) and the inlet passages (12A) for the air are as shown in the rear view illustration of the cylinder and rotor. If the installation is not correct, the starter drive (42) will turn in the wrong direction.

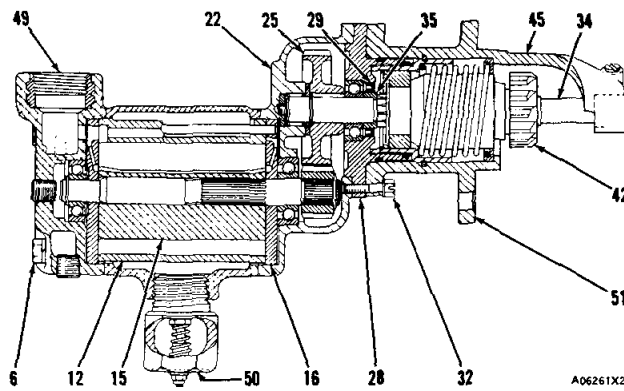
Tighten the bolts (6) of the rear cover in small increases of torque for all bolts until all bolts are tightened to 20 to 25 lb. ft. (25 to 35 N·m).

Put a thin layer of lubricant on the lip of the seal (29) and on the outside of the collar (35), for installation of drive shaft (34). After installation of the shaft through the cover (28), check the lip of the grease seal (29). It must be turned correctly toward the drive gear (25). If the shaft turned the seal lip in the wrong direction, remove the shaft and install again. Use a tool with a thin point to turn the seal lip in the correct direction.



**REAR VIEW OF THE CYLINDER AND ROTOR
FOR CLOCKWISE ROTATION**

12. Cylinder. 12A. Air inlet passages. 12B. Dowel hole. 85
15. Rotor.

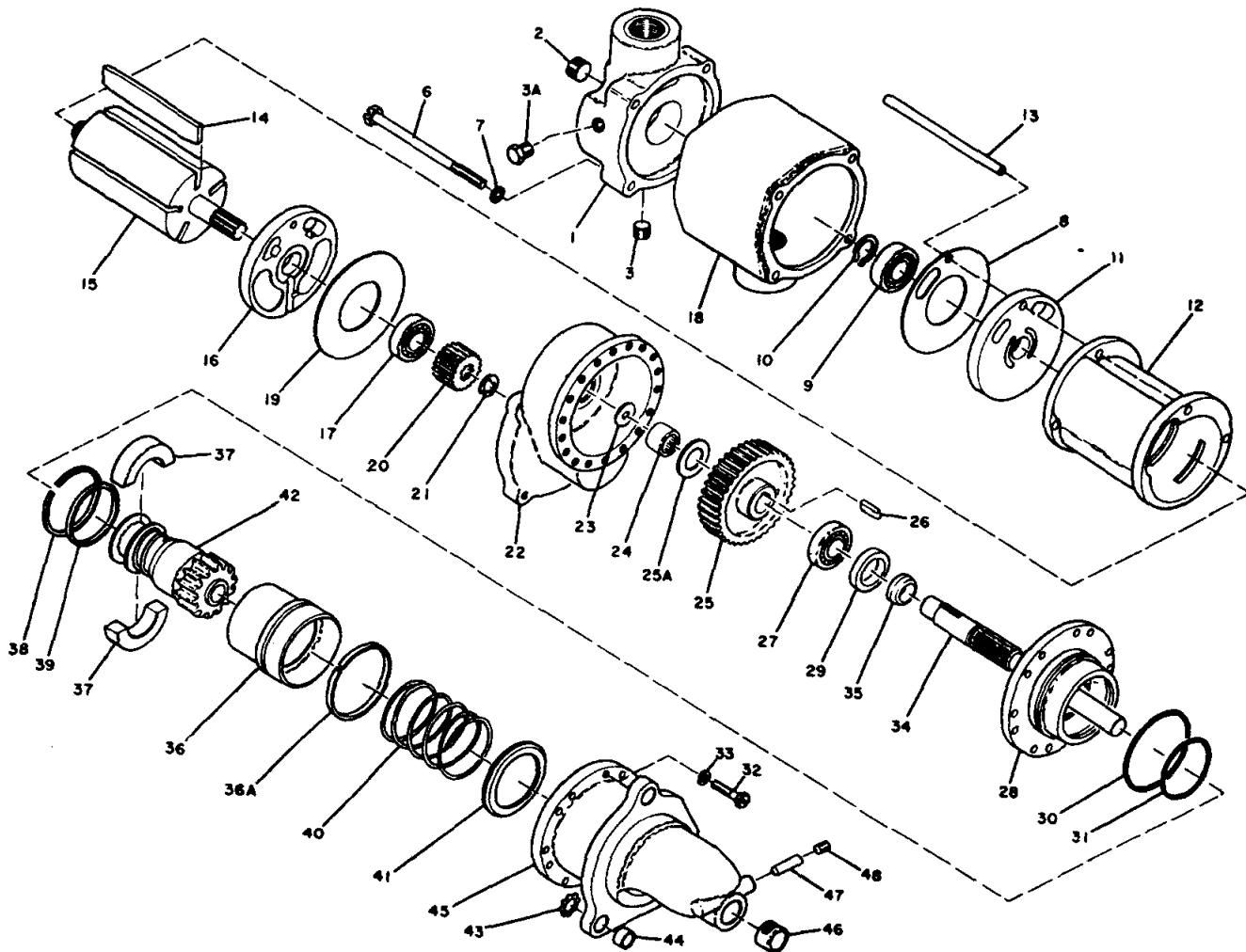
**AIR STARTER (INGERSOLL-RAND)**

6. Bolt. 12. Cylinder. 15. Rotor. 16. Front end plate. 22. Gear case. 25. Drive gear. 28. Gear case cover. 42. Starter drive (pinion). 45. Drive housing. 49. Air inlet. 50. Deflector (air outlet). 51. Mounting flange on the drive housing.

Tighten the bolts (32) of the drive housing in small increases of torque for all bolts until all bolts are tightened to 100 lb. in. (11.3 N·m).

Check the motor for correct operation. Connect an air hose to the air inlet (49) and make the motor turn slowly. Look at the drive pinion (42) from the front of the drive housing (45). The pinion must turn clockwise.

Connect an air hose to the small hole with threads in the drive housing (45), near the gear case (22). When a little air pressure goes to the drive housing, the drive pinion (42) must move forward to the engaged position. Also, the air must get out through the other hole with threads nearer the mounting flange (51).



**COMPONENTS OF THE AIR STARTER
(INGERSOLL-RAND, SIZE 150 BMP, MODEL C OR E)**

1. Motor housing cover. 2. Plug. 3. Plug. 3A. Plug. 6. Bolt (capscrew). 7. Lockwasher. 8. Gasket. 9. Rotor rear bearing. 10. Bearing retainer. 11. Rear end plate. 12. Cylinder. 13. Dowel. 14. Rotor vane. 15. Rotor. 16. Front end plate. 17. Rotor front bearing. 18. Motor housing. 19. Gear case gasket. 20. Rotor pinion. 21. Rotor pinion retainer. 22. Gear case. 23. Bearing ejecting washer. 24. Rear bearing for the drive shaft. 25. Drive gear. 25A. Thrust washer. 26. Key for the drive gear. 27. Front bearing for the drive shaft. 28. Gear case cover. 29. Grease seal for the drive shaft. 30. Cover seal. 31. Piston seal. 32. Bolt. 33. Lockwasher. 34. Drive shaft. 35. Drive shaft collar. 36. Piston. 36A. Piston ring. 37. Shift ring. 38. Shift ring retainer. 39. Shift ring spacer. 40. Piston return spring. 41. Return spring seat. 42. Starter drive (pinion). 43. Lockwasher. 44. Bushing for the bolts. 45. Drive housing. 46. Drive housing bushing. 47. Oiler felt for the bushing. 48. Oiler plug.