

Important Safety Information

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

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

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

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

The hazards are identified by the "Safety Alert Symbol" and followed by a "Signal Word" such as "DANGER", "WARNING" or "CAUTION". The Safety Alert "WARNING" label is shown below.



The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

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

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

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

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Perkins dealers or Perkins distributors have the most current information available.



When replacement parts are required for this product Perkins recommends using Perkins replacement parts.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

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Systems Operation Section

Engine Design

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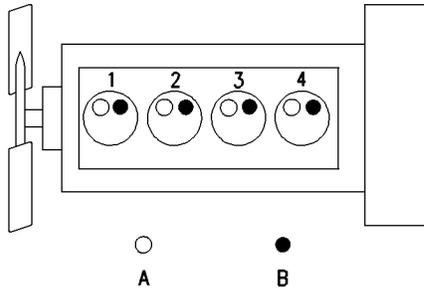


Illustration 1 g00984281

1104 example of the layout of the valves

- (A) Inlet valve
- (B) Exhaust valve

1104 Engine Specification

Type Four cylinder and four stroke
 Type of combustion Direct injection
 Bore 105 mm (4.133 inch)
 Stroke 127 mm (5.00 inch)
 Displacement 4.4 L (268 in³)
 Compression ratio
 Naturally aspirated 19.3:1
 Turbocharged 18.2:1
 Number of cylinders 4
 Cylinder arrangement In-line
 Firing order 1, 3, 4, 2

When the crankshaft is viewed from the front of the engine, the crankshaft rotates in the following direction. Clockwise

The front of the engine is opposite the flywheel end of the engine. The left side of the engine and the right side of the engine are determined from the flywheel end. Number 1 cylinder is the front cylinder of the engine.

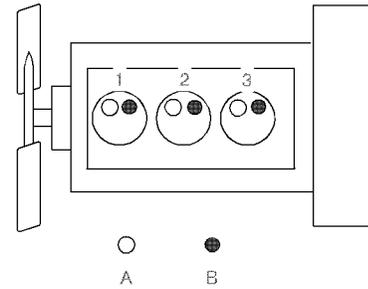


Illustration 2 g01014247

1103 example of the layout of the valves

- (A) Inlet valve
- (B) Exhaust valve

1103 Engine Specification

Type Three cylinder and four stroke
 Type of combustion Direct injection
 Bore 105 mm (4.133 inch)
 Stroke 127 mm (5.00 inch)
 Displacement 3.3 L (201 in³)
 Compression ratio
 Naturally aspirated 19.2:1
 Turbocharged 18.25:1
 Number of cylinders 3
 Cylinder arrangement In-line
 Firing order 1, 2, 3

When the crankshaft is viewed from the front of the engine, the crankshaft rotates in the following direction. Clockwise

The front of the engine is opposite the flywheel end of the engine. The left side of the engine and the right side of the engine are determined from the flywheel end. Number 1 cylinder is the front cylinder of the engine.

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General Information

Engine Description

Note: When you are ordering new parts, refer to the engine identification number in order to receive the correct parts. Refer to the Operation and Maintenance Manual, "Product Identification Information" for the correct numbers for your engine.

The engine cylinders are arranged in-line. The engines are controlled by a mechanically governed fuel injection pump.

The cylinder head assembly has one inlet valve and one exhaust valve for each cylinder. Each valve has one valve spring. The pistons have two compression rings and an oil control ring.

It is important to ensure the correct piston height so that the piston does not contact the cylinder head. The correct piston height also ensures the efficient combustion of fuel.

The 1104 engine crankshaft has five main journals. End play is controlled by thrust washers that are located on both sides of the center main bearing.

The 1103 engine crankshaft has four main journals. End play is controlled by thrust washers that are located on both sides of the number three main bearing.

The timing case has a hole that corresponds with a hole in the crankshaft. Use an alignment pin to find TC. The camshaft gear has a timing hole that corresponds with a timing hole in the timing case. The timing holes ensure that the camshaft and the crankshaft are in time with each other.

The crankshaft gear rotates the idler gear. The idler gear rotates the camshaft gear and the fuel injection pump gear. The idler gear for the engine oil pump is rotated by the crankshaft gear. This idler rotates the engine oil pump.

The fuel injection pump is a gear-driven pump that is mounted to the back of the front housing. The fuel transfer pump is electrically operated. The fuel transfer pump has an integral fuel filter. The fuel transfer pump is usually located on the left hand side of the cylinder block. Some applications may have the fuel transfer pump and the water separator (if equipped) relocated off the engine.

The oil pump is driven by an idler gear. The engine oil pump sends lubricating oil to the main oil gallery. The oil relief valve is internal to the oil pump.

Coolant from the bottom of the radiator passes through the water pump. The water pump is driven by the idler gear.

Lifting the Engine

NOTICE

Failure to follow recommended procedures for handling or transporting engines can lead to engine damage.

To avoid possible engine damage, use the following procedure.

When you are lifting or moving the engine, use the following procedures in order to prevent engine damage.

1. Do not tilt the engine to an extreme angle unless the lubricating oil is first drained from the oil pan.
2. Do not turn the engine onto a side or an end surface unless the lubricating oil is first drained from the oil pan.
3. If the oil is not drained prior to tilting the engine or turning the engine onto a side or an end surface, the lubricating oil from the oil pan can flow into the intake manifold and the cylinder bores. This situation could cause a hydraulic lock in the engine. Hydraulic lock can severely damage the engine.
4. The engine oil should be refilled to the correct level before the engine is started.

1104 Engine Model Views

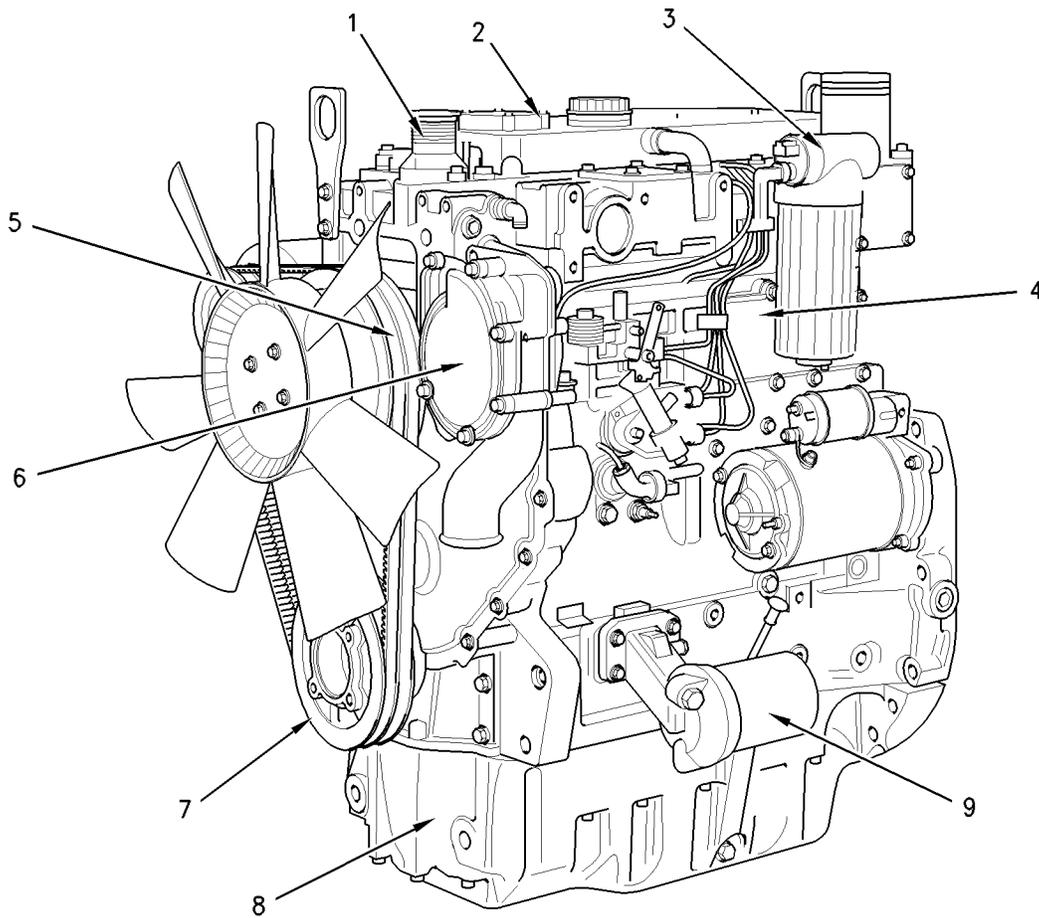


Illustration 3

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(1) Water temperature regulator housing
(2) Valve mechanism cover
(3) Fuel transfer pump and fuel filter

(4) Engine oil cooler
(5) Fan drive
(6) Water pump

(7) Crankshaft pulley
(8) Oil pan
(9) Engine oil filter

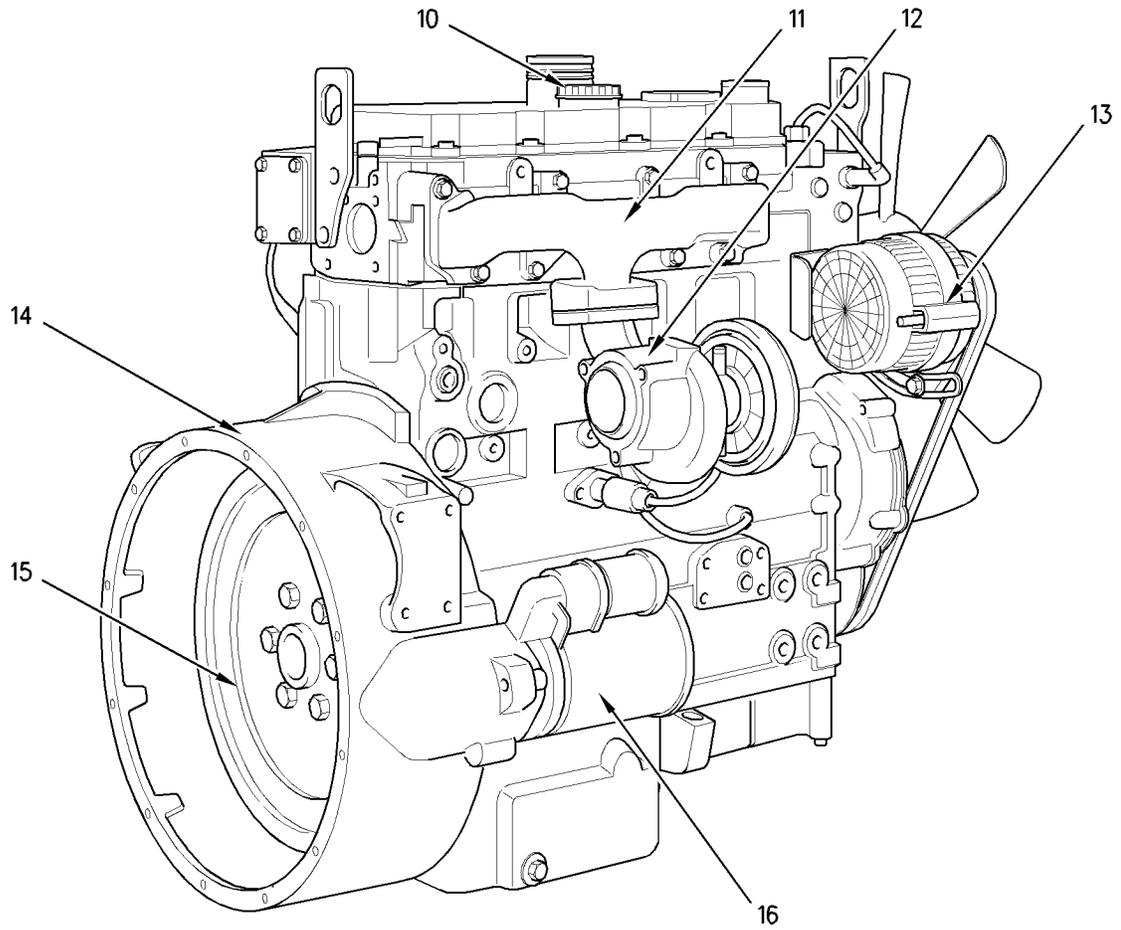


Illustration 4

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- (10) Engine oil filler cap
- (11) Exhaust manifold
- (12) Turbocharger

- (13) Alternator
- (14) Flywheel housing
- (15) Flywheel

- (16) Starter motor

1103 Engine Model Views

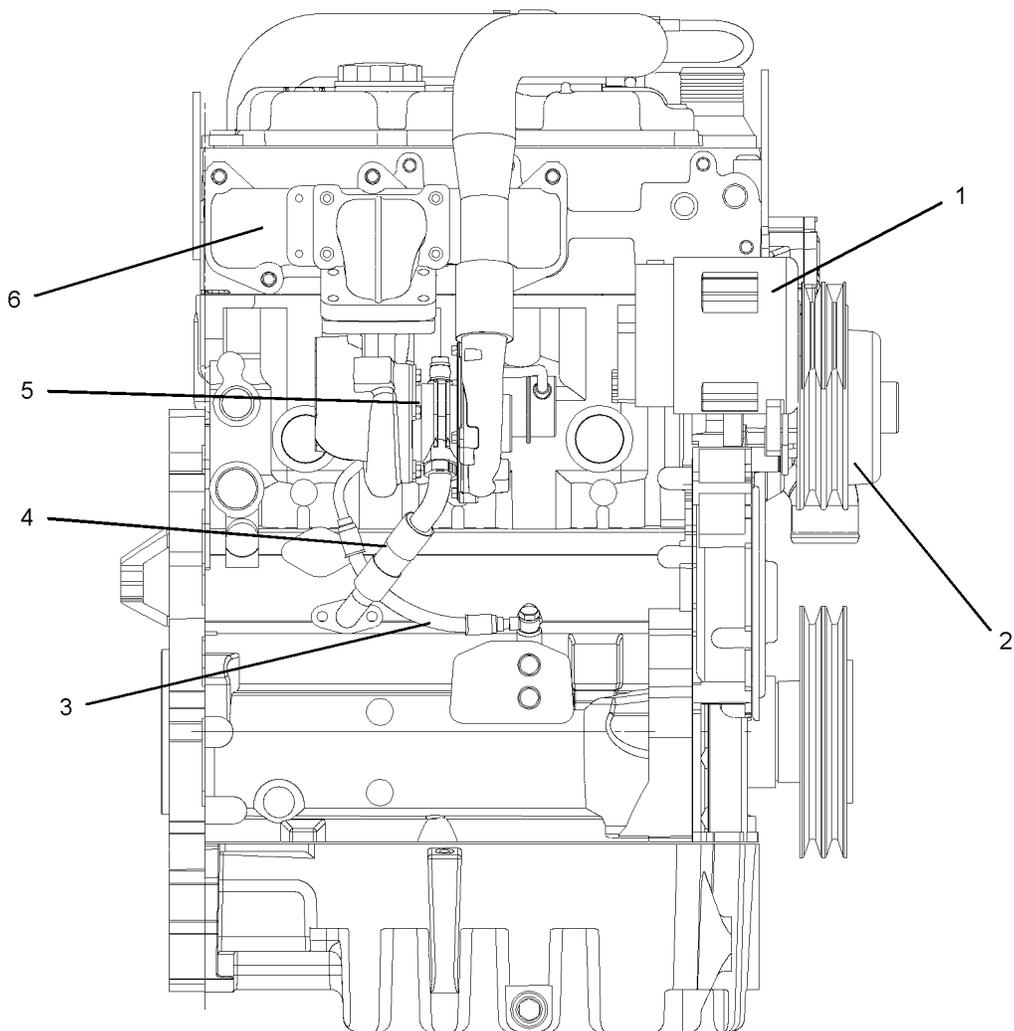


Illustration 5

(1) Alternator
(2) Fan pulley

(3) Turbocharger oil supply
(4) Turbocharger oil drain

(5) Turbocharger
(6) Exhaust manifold

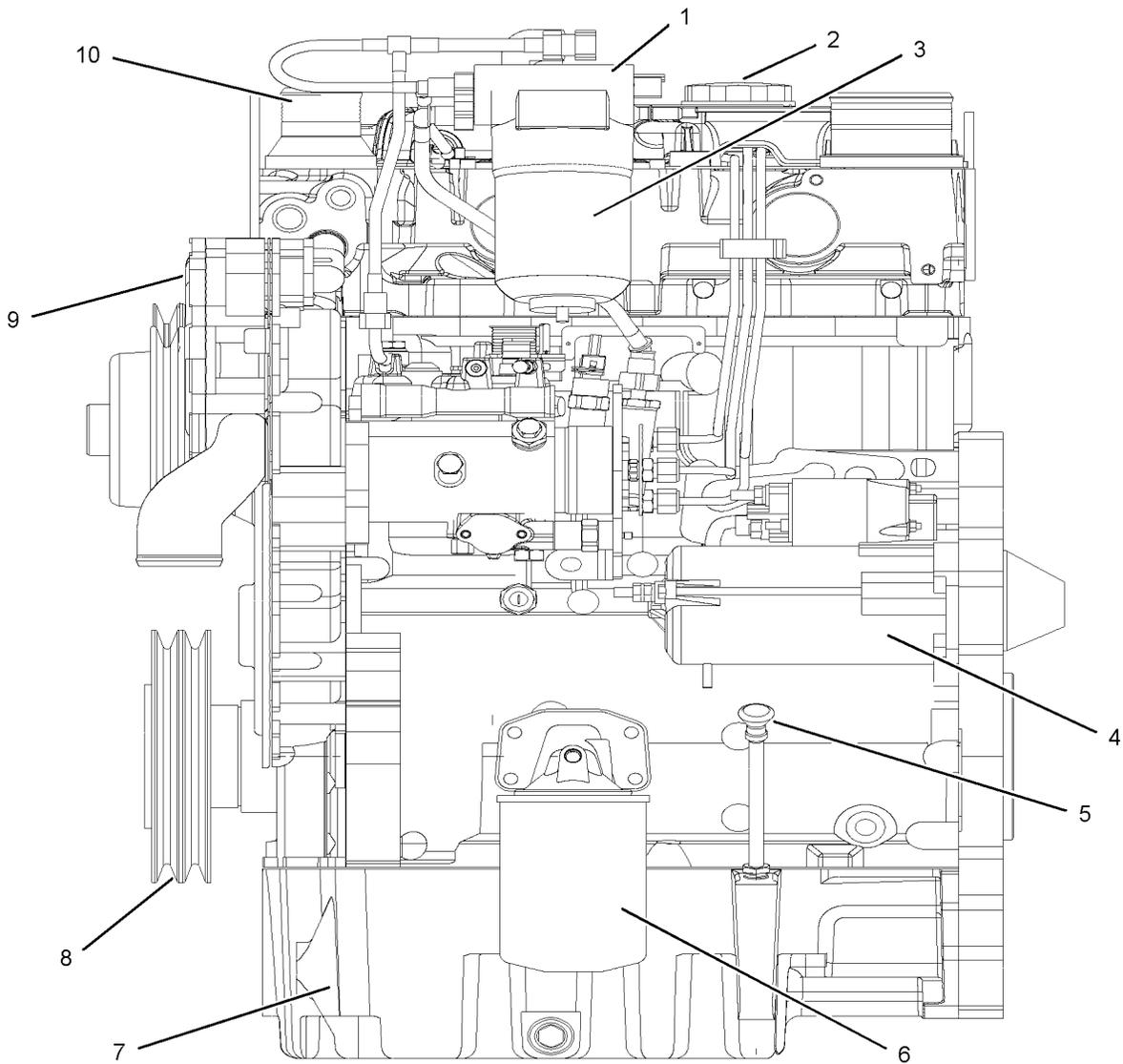


Illustration 6

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- | | |
|------------------------|--|
| (1) Fuel transfer pump | (6) Oil filter |
| (2) Oil filler cap | (7) Oil pan |
| (3) Fuel filter | (8) Crankshaft pulley |
| (4) Starter motor | (9) Water pump |
| (5) Dipstick | (10) Water temperature regulator housing |

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Fuel System

The Delphi DP210 fuel injection pump is installed on the 1104 engine and the 1103 engine. The Delphi STP fuel injection pump is installed on the 1103 engine only. The Bosch EPVE fuel injection pump is installed on the 1104 engine only.

The fuel transfer pump draws fuel from the fuel tank and through the water separator. When the fuel goes through the water separator, any water in the fuel will go to the bottom of the bowl. The fuel transfer pump sends the fuel at a low pressure to the fuel filter. From the fuel filter, the fuel goes through the supply line to the fuel injection pump.

The fuel injection pump sends fuel through the high pressure fuel line to each of the fuel injectors. The fuel injector sprays the fuel into the cylinder. Fuel that is not injected flows through the fuel return line to the top of the fuel filter, back to the fuel tank.

The engine must not be started until the fuel injection pump is full of fuel that is free of air. The fuel injection pump requires fuel for lubrication. The precision parts of the pump are easily damaged without lubrication.

The fuel system must be primed when any of the following conditions occur:

- The fuel filter is changed.
- The fuel line is removed.
- The fuel injection pump is removed.

Fuel System Components

Fuel Injection Pump

General Operation

The fuel injection pump is a pressurized system that is totally enclosed. The pump sends the correct amount of fuel under high pressure at the correct time through the fuel injectors to the individual cylinders. The fuel injection pump regulates the amount of fuel that is delivered to the fuel injectors. This action controls the engine rpm by the governor setting or the position of the throttle control.

The fuel lines to the fuel injectors are equal lengths. This ensures even pressure and correct injection timing at each fuel injector.

During operation, extra fuel is used as coolant and lubricant for moving parts of the pump. The extra fuel is circulated through the pump housing. The extra fuel is then returned to the fuel tank.

The Delphi DP210 and the Delphi STP fuel injection pumps must be serviced by an authorized Delphi technician. For repair information, contact your Perkins dealer or contact your Perkins distributor.

High idle and low idle of the fuel injection pump are factory set. Idle adjustments can not be made to the fuel pump. The Delphi DP210 fuel injection pump has a boost control. The Delphi DP210 and the Delphi STP fuel injection pumps have a engine stop solenoid. The Delphi DP210 and the Delphi STP fuel injection pumps have a feature that vents air from the pump.

The fuel injection pump has a cold starting aid. The cold starting aid advances the timing of the pump when the engine is cold. The cold starting aid is electrically operated.

Cold Start Advance Unit

The cold start advance unit holds the timing of the fuel injection pump in an advance position when the engine is cold.

The coolant switch for the cold start advance unit is on the rear of the timing case on the left side of the engine.

When the engine is cold, the sender unit is energized in order to advance the fuel injection pump timing for the cold start operation. When the correct temperature is achieved the sender unit is de-energized and the fuel injection pump timing is returned to the normal operating position.

If the switch fails in the closed position, the engine will run with advanced fuel injection timing. The engine will have higher cylinder pressure and engine damage may result.

If the switch fails in the open position the engine will run with the fuel injection timing in the normal operating position. The engine will be more difficult to start. When the engine is cold the engine might emit white smoke.

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Air Inlet and Exhaust System

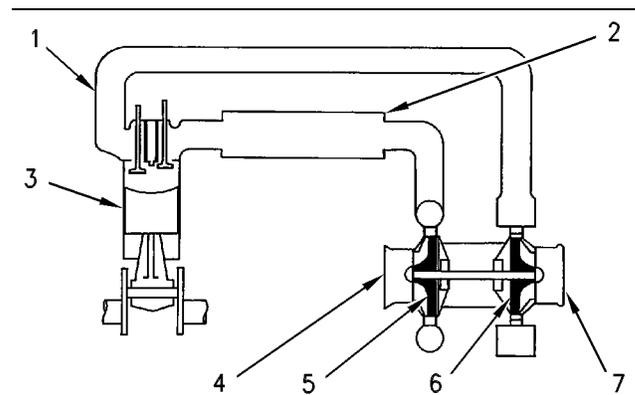


Illustration 7

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Air inlet and exhaust system (typical example)

- (1) Exhaust manifold
- (2) Intake manifold
- (3) Engine cylinders
- (4) Air intake
- (5) Turbocharger compressor wheel
- (6) Turbocharger turbine wheel
- (7) Exhaust outlet

Engines which are naturally aspirated pull outside air through an air cleaner directly into the inlet manifold (2). The air flows from the intake manifold to the engine cylinders (3). The fuel is mixed with the air in the engine cylinders. After the fuel combustion occurs in the engine cylinder, the exhaust gases flow directly to the outside air through the exhaust manifold (1).

Turbocharged engines pull outside air through an air cleaner into the air intake (4) of the turbocharger. The suction is caused by the turbocharger compressor wheel (5). Then, the turbocharger compressor wheel compresses the air. The air flows through the intake manifold (2) which directs an even distribution of the air to each engine cylinder (3). Air is pulled into the engine cylinder (3) during the intake stroke of the piston. Then, the air is mixed with fuel from the fuel injectors.

Each piston makes four strokes:

1. Intake
2. Compression
3. Power
4. Exhaust

The sequence of the strokes by all of pistons in all of the engine cylinders provide constant air flow to the inlet system during the engine operation.

The exhaust stroke and the timing of the valve mechanism pushes combustion gases out of the open exhaust valve through the exhaust manifold (1). The exhaust gases flow through the blades of the turbocharger turbine wheel (6) which causes the turbine wheel and the compressor wheel to turn. Then, the exhaust gases flow through the exhaust outlet (7) of the turbocharger to the outside.

The air inlet system is also equipped with a crankcase ventilation system. The intake strokes of the pistons pull in atmospheric air to the crankcase.

Turbocharger

Note: The turbocharger is not serviceable.

A turbocharger increases the temperature and the density of the air that is sent to the engine cylinder. This condition causes a lower temperature of ignition to develop earlier in the compression stroke. The compression stroke is also timed in a more accurate way with the fuel injection. Surplus air lowers the temperature of combustion. This surplus air also provides internal cooling.

A turbocharger improves the following aspects of engine performance:

- Power output is increased.
- Fuel efficiency is increased.
- Engine torque is increased.
- Durability of the engine is increased.
- Emissions of the engine are increased.

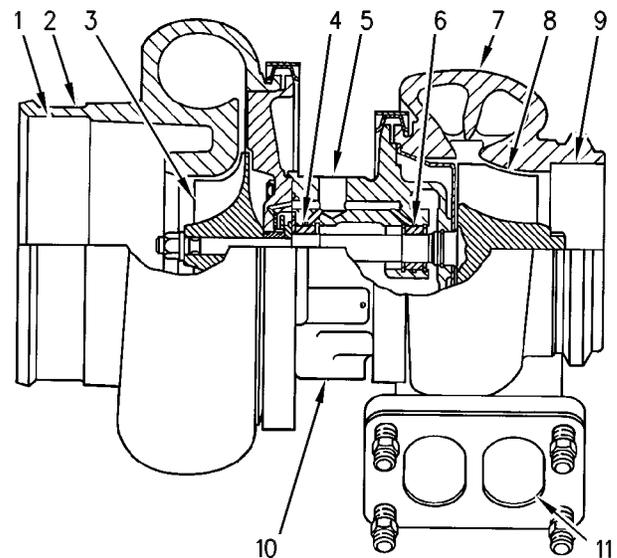


Illustration 8

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Components of a turbocharger (typical example)

- (1) Air intake
- (2) Compressor housing
- (3) Compressor wheel
- (4) Bearing
- (5) Oil inlet port
- (6) Bearing
- (7) Turbine housing
- (8) Turbine wheel
- (9) Exhaust outlet
- (10) Oil outlet port
- (11) Exhaust inlet

A turbocharger is installed between the exhaust and intake manifolds. The turbocharger is driven by exhaust gases which flow through the exhaust inlet (11). The energy of the exhaust gas turns the turbine wheel (8). Then, the exhaust gas flows out of the turbine housing (7) through the exhaust outlet (9).

The turbine wheel and the compressor wheel (3) are installed on the same shaft. Therefore, the turbine wheel and the compressor wheel rotate at the same rpm. The compressor wheel is enclosed by the compressor housing (2). The compressor wheel compresses the intake air (1). The intake air flows into the engine cylinders through the inlet valves of the cylinders.

The oil from the main gallery of the cylinder block flows through the oil inlet port (5) in order to lubricate the turbocharger bearings (4) and (6). The pressurized oil passes through the bearing housing of the turbocharger. The oil is returned through the oil outlet port (10) to the oil pan.

Some turbochargers have a wastegate. The wastegate is controlled by the boost pressure. This allows some of the exhaust to bypass the turbocharger at higher engine speeds. The wastegate is a type of valve that automatically opens at a preset level of boost pressure in order to allow exhaust gas to flow around the turbine. The wastegate allows the design of the turbocharger to be more effective at lower engine speeds.

The wastegate is controlled by a diaphragm. One side of this diaphragm is open to the atmosphere. The other side of this diaphragm is open to the manifold pressure.

Cylinder Head And Valves

The valves and the valve mechanism control the flow of the air and the exhaust gases in the cylinder during engine operation. The cylinder head assembly has two valves for each cylinder. Each valve has one valve spring. The ports for the inlet valves are on the left side of the cylinder head. The ports for the exhaust valves are on the right side of the cylinder head. Steel valve seat inserts are installed in the cylinder head for both the inlet and the exhaust valves. The valve seat inserts can be replaced.

The valves move along valve guides. The valve guides can be replaced. The exhaust valve guide has a counterbore in order to prevent the seizure of the valve stem. The seizure of the valve stem is caused by a buildup of carbon under the head of the valve.

The inlet and the exhaust valves are opened and closed by the rotation and movement of the following components:

- Crankshaft
- Camshaft
- Valve lifters
- Pushrods
- Rocker arms
- Valve springs

The camshaft gear is driven by the crankshaft gear. The camshaft and the crankshaft are timed together. When the camshaft turns, the valve lifters are moved up and down. The pushrods move the rocker arms. The movement of the rocker arms open the valves. The opening and closing of the valves is timed with the firing sequence of the engine. The valve springs push the valves back to the closed position.

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Lubrication System

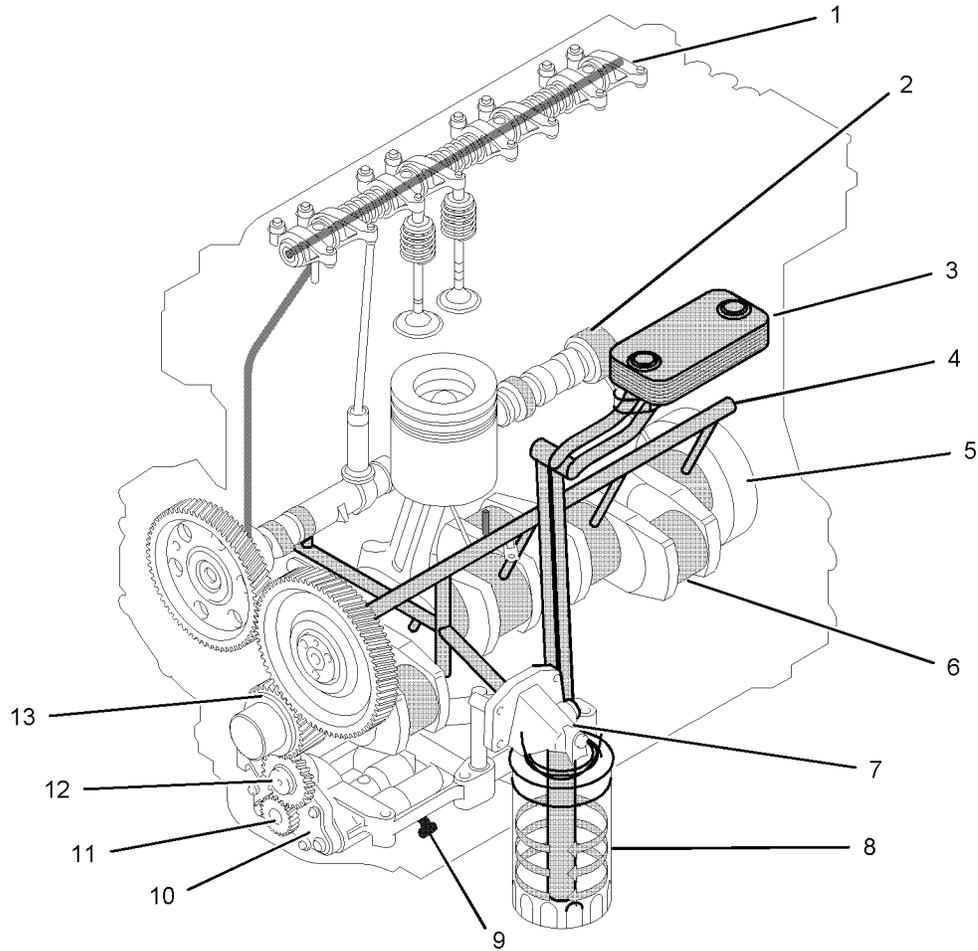


Illustration 9
Flow diagram of the lubrication system for the 1104 engine

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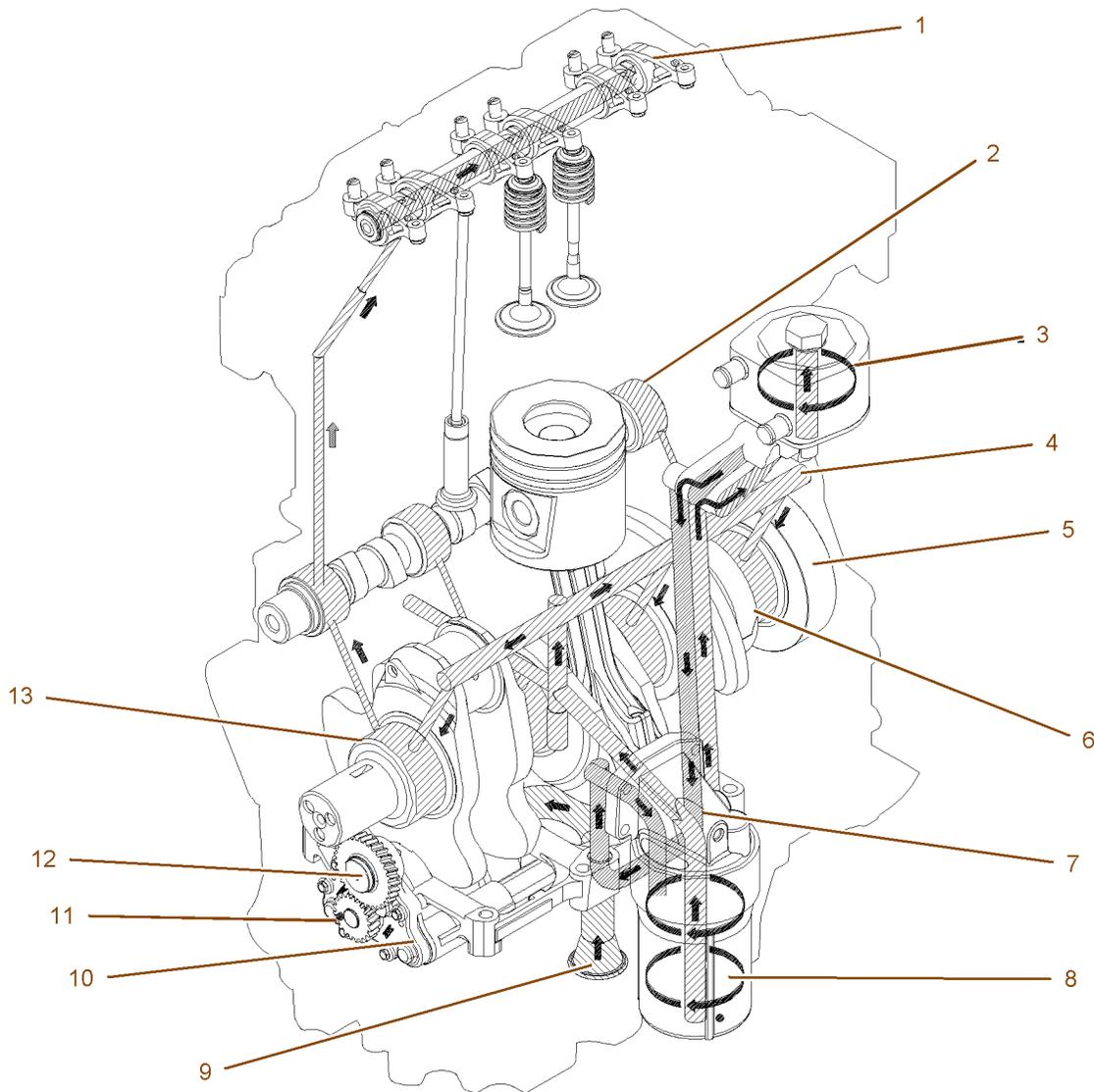


Illustration 10
Flow diagram of the lubrication system for the 1103 engine

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Pressure for the lubrication system is supplied by the oil pump (10). The crankshaft gear (13) drives a lower idler gear (12). The lower idler gear drives the oil pump gear (11). The pump has an inner rotor and an outer rotor. The axis of rotation of the rotors are off-center relative to each other. There is an interference fit between the inner rotor and the drive shaft.

The inner rotor has five lobes which mesh with the six lobes of the outer rotor. When the pump rotates, the distance increases between the lobes of the outer rotor and the lobes of the inner rotor in order to create suction. When the distance decreases between the lobes, pressure is created.

Lubricating oil from the oil pan flows through a strainer and a pipe (9) to the suction side of the engine oil pump. The lubricating oil flows from the outlet side of the pump through a passage to the oil filter head (7). The oil then flows from the filter head through a passage to a plate type oil cooler for the 1104 engine, or a modine oil cooler (3) for the 1103 engine. The integral oil cooler is located on the left side of the cylinder block. The modine oil cooler is located on the left side of the cylinder block.

From the oil cooler, the oil returns through a passage to the oil filter head. The oil then flows from the filter head to the bypass valve and from the bypass valve to the oil filter (8).

The oil flows from the oil filter through a passage that is drilled across the cylinder block to the oil gallery (4). The oil gallery is drilled through the total length of the left side of the cylinder block. If the oil filter is on the right side of the engine, the oil flows through a passage that is drilled across the cylinder block to the pressure gallery.

Lubricating oil from the oil gallery flows through high pressure passages to the main bearings of the crankshaft (5). Then, the oil flows through the passages in the crankshaft to the connecting rod bearing journals (6). The pistons and the cylinder bores are lubricated by the splash of oil and the oil mist.

Lubricating oil from the main bearings flows through passages in the cylinder block to the journals of the camshaft. Then, the oil flows from the second journal of the camshaft (2) at a reduced pressure to the cylinder head. The oil then flows through the center of the rocker shaft (1) to the rocker arm levers. The valve stems, the valve springs and the valve lifters are lubricated by the splash and the oil mist.

The hub of the idler gear is lubricated by oil from the oil gallery. The timing gears are lubricated by the splash from the oil.

Turbochargers are lubricated by oil from a connection on the side of the cylinder block. An external line from the cylinder block supplies oil to the turbocharger. The oil then flows through a line to the oil pan.

Engines have piston cooling jets that are supplied with oil from the oil gallery. The piston cooling jets spray lubricating oil on the underside of the pistons in order to cool the pistons.

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Cooling System

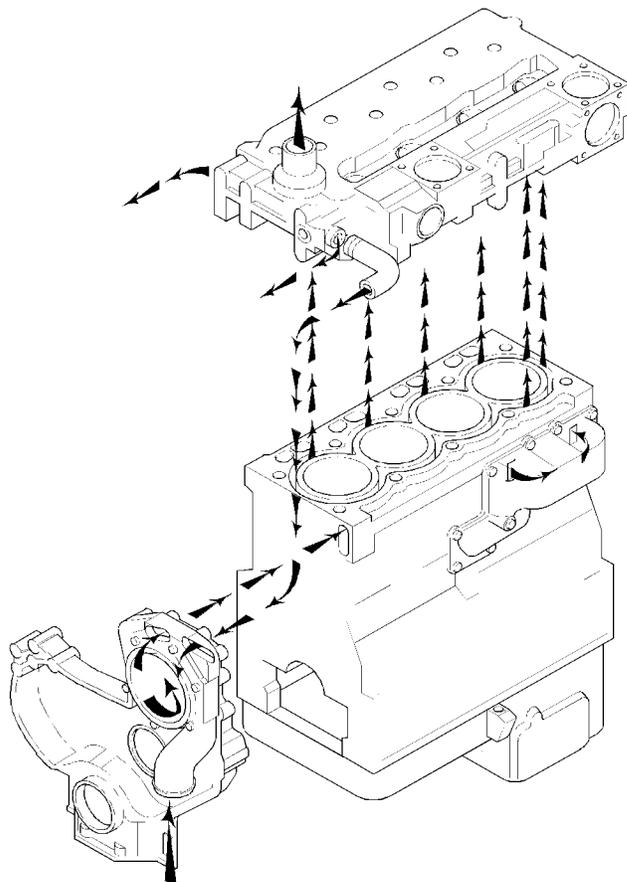


Illustration 11
Flow diagram of the cooling system for the 1104 engine

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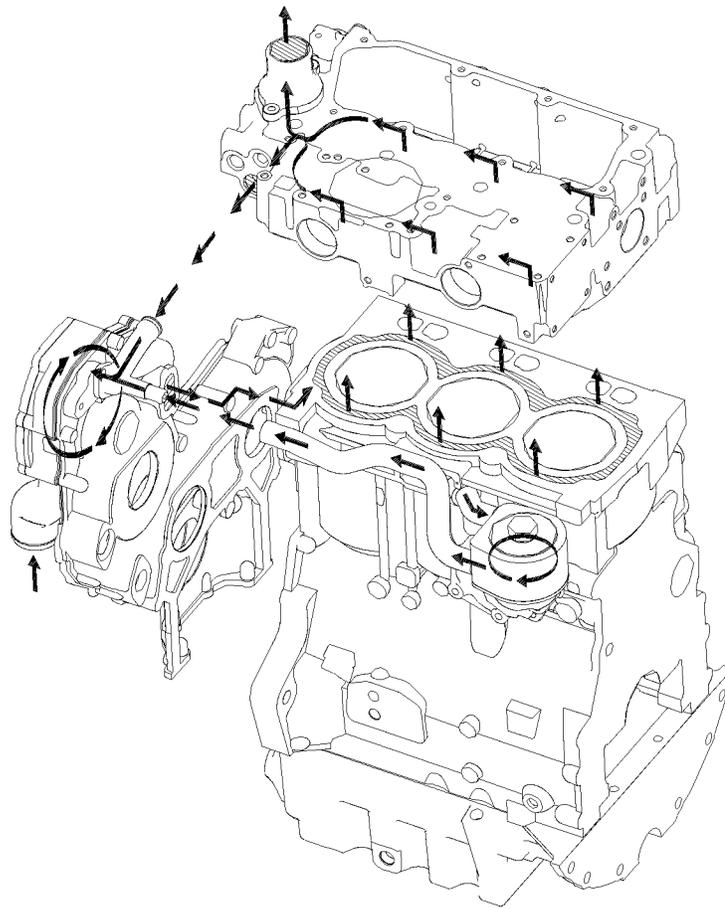


Illustration 12

Flow diagram of the cooling system for the 1103 engine

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The coolant flows from the bottom of the radiator to the centrifugal water pump. The water pump assists in the flow of the coolant through the system. The water pump is installed on the front of the timing case. The water pump is gear-driven by the fuel injection pump gear.

The water pump forces the coolant through a passage in the front of the timing case to the water jacket in the top left side of the cylinder block. The coolant continues to the rear of the cylinder block and some of the coolant passes into the oil cooler for the 1104 or into the modine oil cooler for the 1103. The oil cooler is located on the left side of the cylinder block with no external lines. The modine oil cooler is located on the left side of the cylinder block.

The coolant flows around the element of the oil cooler to the rear of the cylinder block. The coolant then passes from the rear of the cylinder block and into the rear of the cylinder head.

The coolant flows forward through the cylinder head and into the water temperature regulator housing. If the water temperature regulator is closed, the coolant goes directly through a bypass to the inlet side of the water pump. If the water temperature regulator is open, the bypass is closed and the coolant flows to the top of the radiator.

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Basic Engine

Cylinder Block and Cylinder Head

The cylinder block for the 1104 engine has four cylinders which are arranged in-line.

The cylinder block for the 1103 engine has three cylinders which are arranged in-line.

The cylinder block for the 1104 engine has five main bearings which support the crankshaft. Thrust washers on both sides of the center main bearing control the end play of the crankshaft.

The cylinder block for the 1103 engine has four main bearings which support the crankshaft. Thrust washers on both sides of the number three main bearing control the end play of the crankshaft.

A cylinder head gasket is used between the engine block and the cylinder head in order to seal combustion gases, water, and oil.

The engine has a cast iron cylinder head. The Inlet manifold is integral within the cylinder head. An inlet valve and an exhaust valve for each cylinder are controlled by a pushrod valve system. The ports for the inlet valves are on the left side of the cylinder head. The ports for the exhaust valves are on the right side of the cylinder head.

Pistons, Rings, and Connecting Rods

The pistons have a combustion chamber in the top of the piston in order to provide an efficient mix of fuel and air. The piston pin is off-center in order to reduce the noise level.

The pistons have two compression rings and an oil control ring. The groove for the top ring has a hard metal insert in order to reduce wear of the groove. The skirt has a layer of graphite in order to reduce wear.

The correct piston height is important in order to ensure that the piston does not contact the cylinder head. The correct piston height also ensures the efficient combustion of fuel which is necessary in order to conform to requirements for emissions.

Engines are equipped with connecting rods that are fracture split. The fracture split connecting rods are retained with torx screws. Connecting rods that are fracture split have the following characteristics:

- Higher integrity for the rod
- The splitting produces an accurately matched surface on each side for improved strength.
- Modern design

The connecting rod is matched to each cylinder. The piston height is controlled by the length of the connecting rod. Six different lengths of connecting rods are available in order to attain the correct piston height. The different lengths of connecting rods are made by machining the small end bearing off-center in order to form an eccentric bearing. The amount of the eccentricity of the bearing creates the different lengths of the connecting rods.

Each cylinder has a piston cooling jet that is installed in the cylinder block. The piston cooling jet sprays engine oil onto the inner surface of the piston in order to cool the piston.

Crankshaft

The crankshaft changes the combustion forces in the cylinder into usable rotating torque in order to power the engine. Vibration is caused by impacts from combustion along the crankshaft.

A gear at the front of the crankshaft drives the timing gears. The crankshaft gear turns the idler gear which then turns the following gears:

- Camshaft gear
- Fuel injection pump
- Lower idler gear which turns the gear of the lubricating oil pump

Lip type seals are used on both the front of the crankshaft and the rear of the crankshaft.

Camshaft

The engine has a single camshaft. The camshaft is driven by an idler gear in the front housing. The camshaft uses only one bearing on the front journal. The other journals rotate in the bore of the cylinder block. The front bearing and the camshaft bores in the cylinder block support the camshaft. As the camshaft turns, the camshaft lobes move the valve system components. The valve system components move the cylinder valves. The camshaft gear must be timed to the crankshaft gear. The relationship between the lobes and the camshaft gear causes the valves in each cylinder to open at the correct time. The relationship between the lobes and the camshaft gear also causes the valves in each cylinder to close at the correct time.

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Electrical System

The electrical system is a negative ground system.

The charging circuit operates when the engine is running. The alternator in the charging circuit produces direct current for the electrical system.

Starting Motor

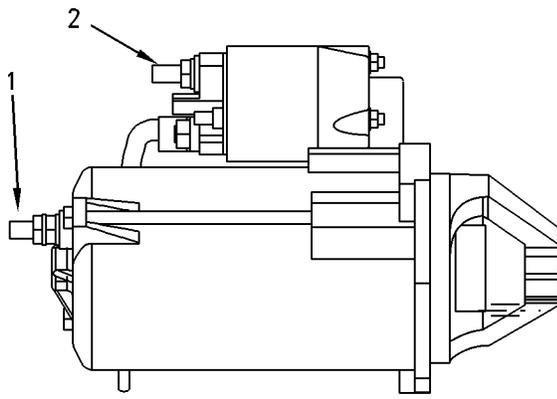


Illustration 13

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12 Volt Starting Motor

- (1) Terminal for connection of the battery cable
- (2) Terminal for connection of the ignition switch

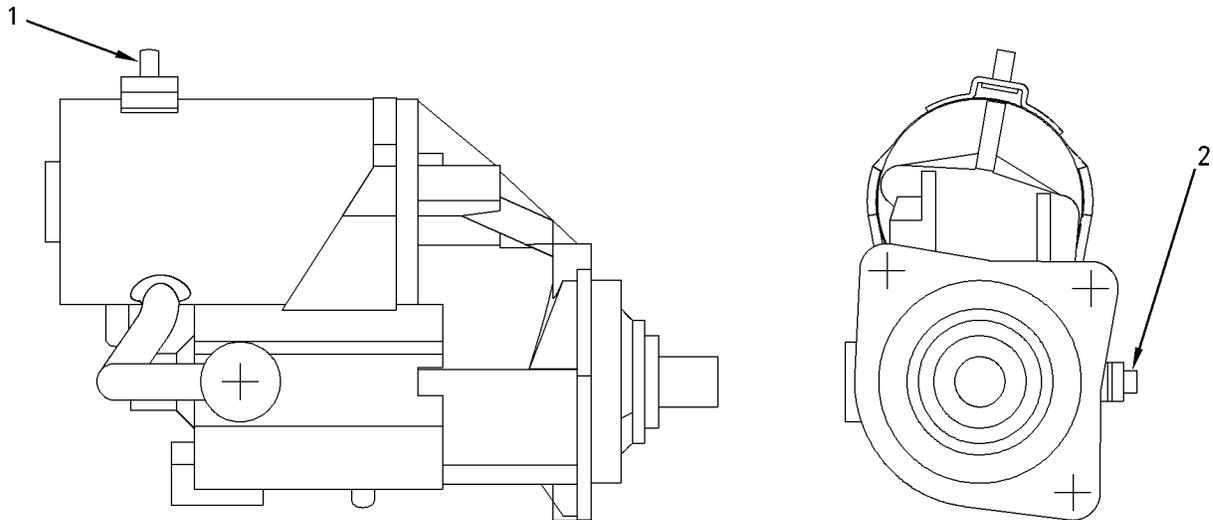


Illustration 14
24 Volt Starting Motor

g00956095

(1) Terminal for connection of the ignition switch

(2) Terminal for connection of the battery cable

The starting motor turns the engine flywheel. The rpm must be high enough in order to initiate a sustained operation of the fuel ignition in the cylinders.

The starting motor has a solenoid. When the ignition switch is activated, voltage from the electrical system will cause the solenoid to move the pinion toward the flywheel ring gear of the engine. The electrical contacts in the solenoid close the circuit between the battery and the starting motor barely before the pinion engages the ring gear. This causes the starting motor to rotate. This type of activation is called a positive shift.

When the engine begins to run, the overrunning clutch of the pinion drive prevents damage to the armature. Damage to the armature is caused by excessive speeds. The clutch prevents damage by stopping the mechanical connection. However, the pinion will stay meshed with the ring gear until the ignition switch is released. A spring in the overrunning clutch returns the clutch to the rest position.

Alternator

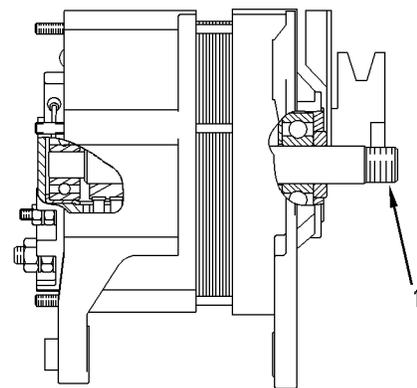


Illustration 15

g00303424

(1) Shaft for mounting the pulley

The alternator produces the following electrical output:

- Three-phase
- Full-wave
- Rectified

The alternator is an electro-mechanical component. The alternator is driven by a belt from the crankshaft pulley. The alternator charges the storage battery during the engine operation.

The alternator converts the mechanical energy and the magnetic energy into alternating current and voltage. This conversion is done by rotating a direct current electromagnetic field on the inside of a three-phase stator. The electromagnetic field is generated by electrical current flowing through a rotor. The stator generates alternating current and voltage.

The alternating current is changed to direct current by a three-phase, full-wave rectifier. Direct current flows to the output terminal of the alternator. The rectifier has three exciter diodes. The direct current is used for the charging process.

A regulator is installed on the rear end of the alternator. Two brushes conduct current through two slip rings. The current then flows to the rotor field. A capacitor protects the rectifier from high voltages.

The alternator is connected to the battery through the ignition switch. Therefore, alternator excitation occurs when the switch is in the ON position.

Testing and Adjusting Section

Fuel System

i01804057

Fuel System - Inspect

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

1. Check the fuel level in the fuel tank. Ensure that the vent in the fuel cap is not filled with dirt.
2. Check all fuel lines for fuel leakage. The fuel lines must be free from restrictions and faulty bends. Verify that the fuel return line is not collapsed.
3. Inspect the fuel filter for excess contamination. If necessary, install a new fuel filter. Determine the source of the contamination. Make the necessary repairs.
4. Service the primary fuel filter (if equipped).
5. Remove any air that may be in the fuel system. Refer to Testing and Adjusting, "Fuel System - Prime".

i01854200

Air in Fuel - Test

This procedure checks for air in the fuel system. This procedure also assists in finding the source of the air.

1. Examine the fuel system for leaks. Ensure that the fuel line fittings are properly tightened. Check the fuel level in the fuel tank. Air can enter the fuel system on the suction side between the fuel transfer pump and the fuel tank.

WARNING

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

2. Install a suitable fuel flow tube with a visual sight gauge in the fuel return line. When possible, install the sight gauge in a straight section of the fuel line that is at least 304.8 mm (12 inches) long. Do not install the sight gauge near the following devices that create turbulence:

- Elbows
- Relief valves
- Check valves

Observe the fuel flow during engine cranking. Look for air bubbles in the fuel. If there is no fuel that is present in the sight gauge, prime the fuel system. Refer to Testing and Adjusting, "Fuel System - Prime" for more information. If the engine starts, check for air in the fuel at varying engine speeds. When possible, operate the engine under the conditions which have been suspect.

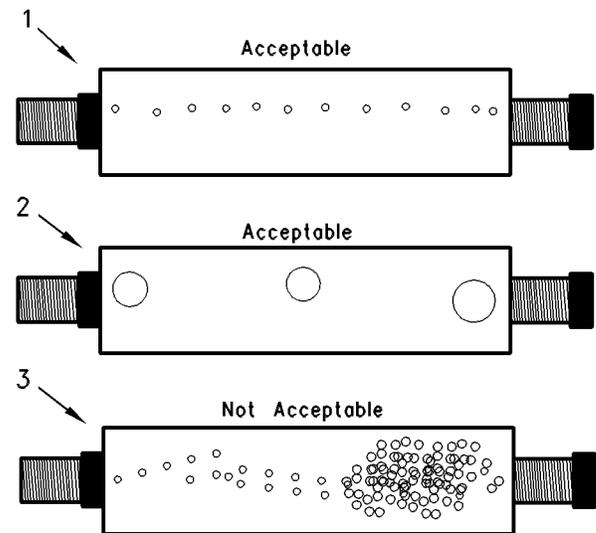


Illustration 16

g00578151

- (1) A steady stream of small bubbles with a diameter of approximately 1.60 mm (0.063 inch) is an acceptable amount of air in the fuel.
- (2) Bubbles with a diameter of approximately 6.35 mm (0.250 inch) are also acceptable if there is two seconds to three seconds intervals between bubbles.
- (3) Excessive air bubbles in the fuel are not acceptable.

3. If excessive air is seen in the sight gauge in the fuel return line, install a second sight gauge at the inlet to the fuel transfer pump. If a second sight gauge is not available, move the sight gauge from the fuel return line and install the sight gauge at the inlet to the fuel transfer pump. Observe the fuel flow during engine cranking. Look for air bubbles in the fuel. If the engine starts, check for air in the fuel at varying engine speeds.

If excessive air is not seen at the inlet to the fuel transfer pump, the air is entering the system after the fuel transfer pump. Refer to the Testing and Adjusting, "Fuel System - Prime".

If excessive air is seen at the inlet to the fuel transfer pump, air is entering through the suction side of the fuel system.

WARNING

To avoid personal injury, always wear eye and face protection when using pressurized air.

NOTICE

To avoid damage, do not use more than 55 kPa (8 psi) to pressurize the fuel tank.

4. Pressurize the fuel tank to 35 kPa (5 psi). Do not use more than 55 kPa (8 psi) in order to avoid damage to the fuel tank. Check for leaks in the fuel lines between the fuel tank and the fuel transfer pump. Repair any leaks that are found. Check the fuel pressure in order to ensure that the fuel transfer pump is operating properly. For information about checking the fuel pressure, see Testing and Adjusting, "Fuel System Pressure - Test".
5. If the source of the air is not found, disconnect the supply line from the fuel tank and connect an external fuel supply to the inlet of the fuel transfer pump. If this corrects the problem, repair the fuel tank or the stand pipe in the fuel tank.

i01893344

Finding Top Center Position for No. 1 Piston

Table 1

Required Tools		
Part Number	Part Description	Qty
27610211	Crankshaft timing pin	1
27610212	Camshaft timing pin	1

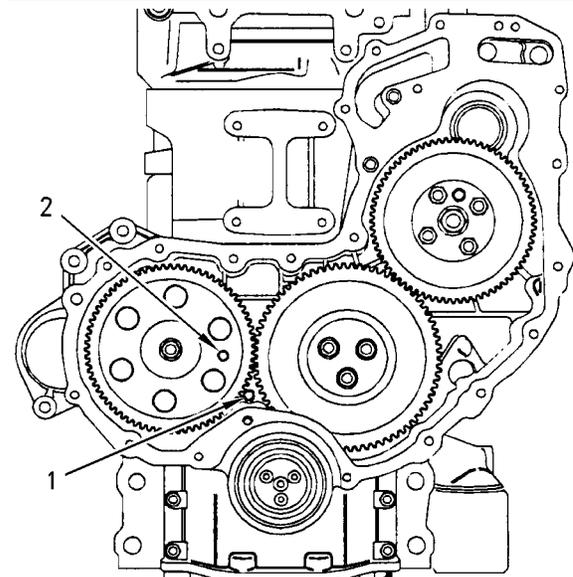


Illustration 17

g00923080

- (1) Hole for crankshaft pin
- (2) Hole for camshaft pin

1. Remove the valve mechanism cover, the glow plugs, and the cover for the front housing.

Note: The crankshaft timing pin can be inserted with the crankshaft pulley still on the engine.

2. Rotate the crankshaft in the normal direction of the engine until the inlet valve of the No. 4 cylinder has just opened and the exhaust valve of the No. 4 cylinder has not completely closed.
3. Carefully rotate the crankshaft in the normal direction of the engine in order to align the hole in the crankshaft with the hole in the cylinder block and the timing case. Insert the 27610211 Crankshaft Timing Pin fully into the hole in the crankshaft web.
4. Insert the 27610212 Camshaft Timing Pin through the hole in the camshaft gear and into the body of the timing case. The engine is set at the top center position for No. 1 piston.

Note: The camshaft gear can rotate a small amount when the pin is installed.

5. Remove the timing pins from the camshaft gear and the crankshaft web.

i02074847

Fuel Injection Pump Timing - Check

Delphi DP210 and the Delphi STP Fuel Injection Pumps

Note: The Delphi DP210 and the Delphi STP fuel injection pump timing cannot be checked. If you suspect that the fuel injection pump timing is incorrect, contact your Perkins dealer or your Perkins distributor for further information.

The Delphi DP210 and the Delphi STP fuel injection pumps must be serviced by an authorized Delphi technician. For repair information, contact your Perkins dealer or your Perkins distributor. The internal adjustment for the pump timing is tamper proof. High idle and low idle are factory set. Idle adjustments can not be made to the fuel pump.

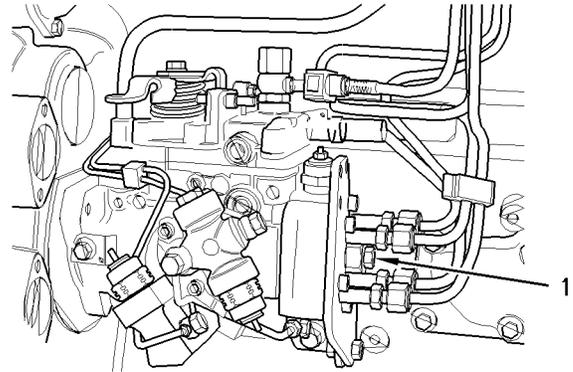


Illustration 18
(1) Plug

g00988405

Bosch EPVE Fuel Injection Pump

Note: The Bosch EPVE fuel injection pump is only installed on the 1104 engine.

Table 2

Required Tools		
Part Number	Part Description	Qty
27610248	Bosch EPVE fuel injection pump timing adapter	1

1. Set the number one piston at the top center piston on the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for the No. 1 Piston" for the procedure.
2. Remove the high pressure fuel lines from the fuel injection pump.

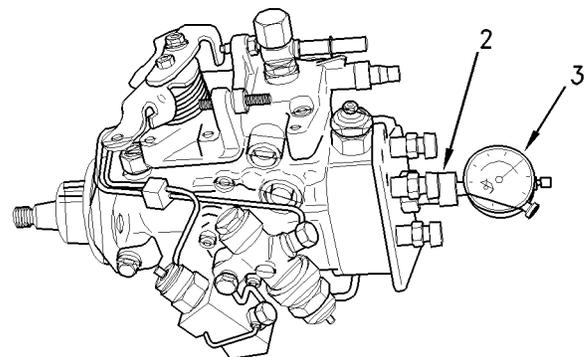


Illustration 19

g00988406

- (2) Bosch EPVE fuel injection pump timing adapter
- (3) Dial indicator

3. Remove the plug (1) and the washer from the rear of the fuel injection pump and install 27610248 fuel injection pump timing adapter (2). Install a suitable dial indicator (3) into 27610248 fuel injection pump timing adapter. Set the dial indicator to approximately 3 mm (0.1181 inch).
4. Rotate the crankshaft counterclockwise until the dial indicator (3) indicates that the plunger of the fuel injection pump is at the bottom of the stroke. Set the dial indicator (3) to zero.

5. Rotate the crankshaft clockwise, until the crankshaft timing pin can be pushed into the hole in the crankshaft web.
6. With the engine set at the Top Center Position for the No. 1 piston, check the reading on the dial indicator (3). Refer to Specifications, "Fuel Injection Pump" for the correct reading for the plunger.
7. If the fuel injection pump timing is correct remove the dial indicator (3). Remove 27610248 fuel injection pump timing adapter from the fuel injection pump. Install a new washer to the plug and install the plug in the back of the fuel injection pump. Refer to Specifications, "Fuel Injection Pump" for the correct torque.
8. Install the high pressure fuel lines on the fuel injection pump. Eliminate all air from the fuel system. Refer to Testing and Adjusting, "Fuel System - Prime".
9. If the fuel injection pump timing is incorrect, refer to Testing and Adjusting, "Fuel Injection Pump Timing - Adjust".

Note: This procedure must only be carried out by a person with the correct training.

Note: Do not rotate the fuel injection pump if the fuel injection pump shaft is locked.

1. Set the number one piston at the top center on the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for the No. 1 Piston" for the procedure.
2. Remove the rocker shaft. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrods".
3. Remove the high pressure fuel lines from the fuel injection pump.

i02074850

Fuel Injection Pump Timing - Adjust

Delphi DP210 and the Delphi STP Fuel Injection Pumps

The Delphi DP210 and the Delphi STP fuel injection pumps must be serviced by an authorized Delphi technician. For repair information, contact your Perkins dealer or your Perkins distributor. The internal adjustment for the pump timing is tamper proof. High idle and low idle are factory set. Idle adjustments can not be made to the fuel pump.

Bosch EPVE Fuel Injection Pump

Note: The Bosch EPVE fuel injection pump is only installed on the 1104 engine.

Table 3

Required Tools		
Part Number	Part Description	Qty
27610248	Bosch EPVE fuel injection pump timing adapter	1

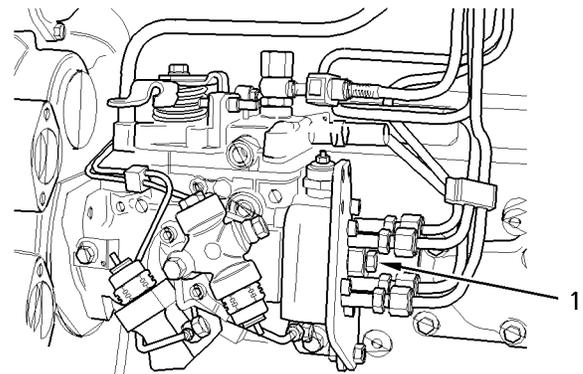


Illustration 20

g00996226

(1) Plug

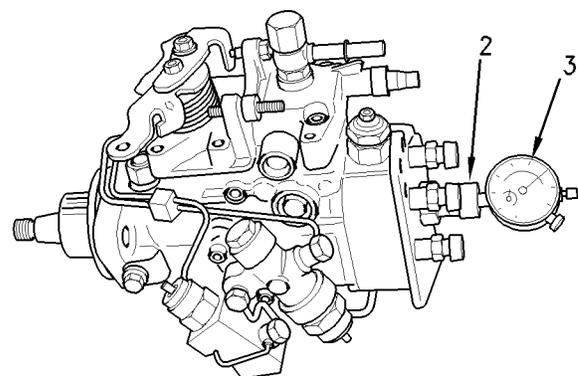


Illustration 21

g00996227

(2) Bosch EPVE fuel injection timing adapter
(3) Dial indicator

4. Remove the plug (1) and the washer from the rear of the fuel injection pump and install 27610248 fuel injection pump timing adapter (2). Install a suitable dial indicator (3) into 27610248 fuel injection pump timing adapter. Set the dial indicator to approximately 3 mm (0.1181 inch).
5. Ensure that the timing pins have been removed from the engine.
6. Rotate the crankshaft counterclockwise when the crankshaft is viewed from the front of the engine. Carefully rotate the crankshaft until the dial indicator (3) indicates that the plunger of the fuel injection pump is at the bottom. Set the dial indicator (3) to zero.
7. Rotate the crankshaft clockwise, until the required lift on the plunger is achieved. Refer to Specifications, "Fuel Injection Pump" for the correct reading.

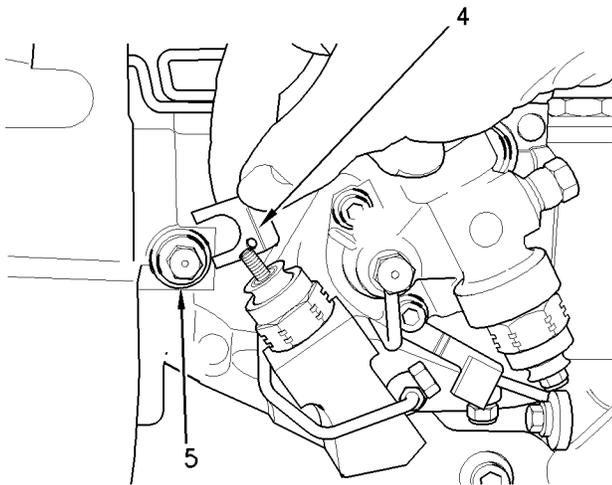


Illustration 22

g00996240

- (4) Washer
(5) Locking screw

8. Lock the fuel injection pump shaft.
In order to lock the shaft of the Bosch EPVE fuel injection pump, loosen the locking screw (5) and remove the washer (4). Tighten the locking screw to 31 N·m (23 lb ft). Ensure that the needle of the dial indicator has not moved.
9. Remove the water pump. Refer to Disassembly and Assembly, "Water Pump - Remove and Install".
10. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

11. Remove the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection pump - Remove".

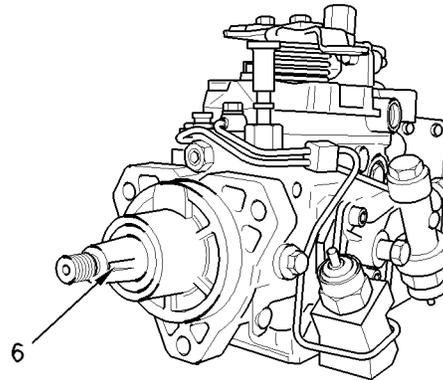


Illustration 23

g00996242

- (6) Keyway

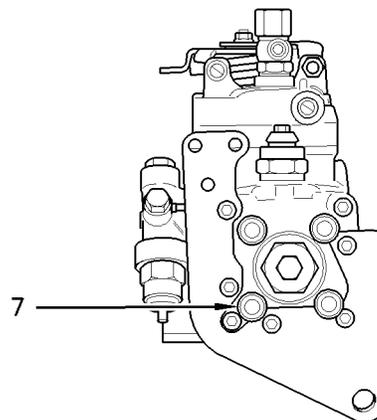


Illustration 24

g00996245

- (7) Outlet

Note: A key should not be installed in the keyway (6).

Note: If the fuel injection pump is on the correct stroke, the keyway (6) is toward the outlet (7).

12. Set the number one piston at the top center piston on the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for the No. 1 Piston" for the procedure.
13. Install the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection pump - Install".
14. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".

15. Install the water pump. Refer to Disassembly and Assembly, "Water Pump - Remove and Install".
16. Install a new washer to the plug and install the plug in the back of the fuel injection pump. Refer to Specifications, "Fuel Injection Pump" for the correct torque.
17. Install the rocker shaft. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrods".
18. Install the high pressure fuel lines on the fuel injection pump. Eliminate all air from the fuel system. Refer to Testing and Adjusting, "Fuel System - Prime".

i01944302

Fuel Quality - Test

Use the following procedure to test for problems regarding fuel quality:

1. Determine if water and/or contaminants are present in the fuel. Check the water separator (if equipped). If a water separator is not present, proceed to Step 2. Drain the water separator, if necessary. A full fuel tank minimizes the potential for overnight condensation.
- Note:** A water separator can appear to be full of fuel when the water separator is actually full of water.
2. Determine if contaminants are present in the fuel. Remove a sample of fuel from the bottom of the fuel tank. Visually inspect the fuel sample for contaminants. The color of the fuel is not necessarily an indication of fuel quality. However, fuel that is black, brown, and/or similar to sludge can be an indication of the growth of bacteria or oil contamination. In cold temperatures, cloudy fuel indicates that the fuel may not be suitable for the operating conditions. Refer to Operation and Maintenance Manual, "Fuel Recommendations" for more information.
 3. If fuel quality is still suspected as a possible cause of problems regarding engine performance, disconnect the fuel inlet line, and temporarily operate the engine from a separate source of fuel that is known to be good. This will determine if the problem is caused by fuel quality. If fuel quality is determined to be the problem, drain the fuel system and replace the fuel filters. Engine performance can be affected by the following characteristics:

- Cetane number of the fuel
- Air in the fuel

- Other fuel characteristics

i02074852

Fuel System - Prime

If air enters the fuel system, the air must be purged before the engine can be started. Air can enter the fuel system when the following events occur:

- The fuel tank is empty or the tank has been partially drained during normal operation.
- The low pressure fuel lines are disconnected.
- A leak exists in the low pressure fuel system during engine operation.
- The fuel filter or the fuel pump is replaced.
- The high pressure fuel lines are disconnected.

Delphi DP210 and the Delphi STP

The Delphi DP210 and the Delphi STP fuel injection pumps will eliminate the air from the fuel system automatically. Position the starting switch to the RUN position for three minutes. Air in the fuel and the fuel lines will be purged from the system.

Bosch EVPE

The Bosch EPVE fuel injection pump will not eliminate air automatically from the fuel system. the following procedure must be used.

- Remove the valve mechanism cover.
- Turn the start switch to the RUN position for three minutes. Then return the start switch to the OFF position.
- Loosen the high pressure lines at the fuel injectors.
- Operate the starting motor until fuel free from air comes from the connections.
- Tighten the connections for the fuel injectors. Refer to Specifications, "Fuel Injection Lines".
- Operate the engine and check for leaks.
- Fit the valve mechanism cover.

i01944991

Fuel System Pressure - Test

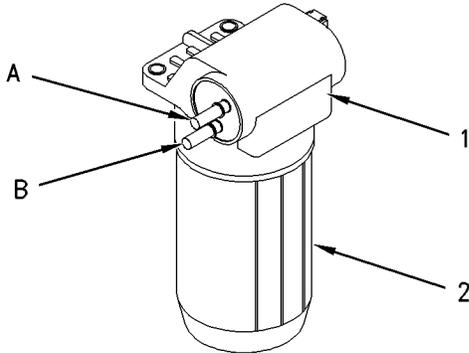


Illustration 25

g00928705

(A and B) Fuel outlet
(1) Fuel transfer pump
(2) Fuel filter

The pressure test measures the output pressure of the fuel transfer pump. Low fuel pressure and starting difficulty may be indications of problems with the fuel priming pump.

Check the Function of the Fuel Transfer Pump

1. Make a note of the location of the fuel lines from the fuel transfer pump. Remove the two lines from the outlets (A) and (B).
2. Connect two lengths of 5/16 inch rubber hose to outlets (A) and (B). Place the hoses into a suitable container that is capable of holding 3 L (3.17 qt) of fuel.
3. Energize the fuel transfer pump until a constant flow of fuel is running from the outlet for the supply for the fuel injection pump.

Note: The flow from the outlet for the return for the fuel tank will have a slower flow rate.

4. Measure the combined flow of both outlets with a stopwatch. Fuel flow should be a minimum of 2 L/min (0.53 US gpm).
5. If the combined flow is less than 2 L/min (0.53 US gpm), repair the pump or replace the pump.
6. Reconnect the outlet lines in the correct positions.
7. Start the engine and check for any leakage of fuel or air from the fuel lines.

Check the Function of the Pressure Regulator

1. Remove the fuel line from the outlet for the supply for the fuel injection pump (B).
2. Install a pipe with a tap for a pressure gauge. Connect a 0 to 80 kPa (0 to 12 psi) pressure gauge.
3. Start the engine and run the engine at idle for two minutes in order to remove any trapped air.
4. Record the pressure reading at idle and at rated speed. The pressure reading should be the following values:

Bosch EPVE

Idle 31 kPa (4.49 psi)
Rated speed 31 kPa (4.49 psi)

Delphi DP210

Idle 27.5 kPa (3.99 psi)
Rated speed 28 kPa (4.06 psi)

Note: Maximum pressure for the fuel injection pump is 80 kPa (12 psi).

5. Reconnect the fuel line. Run the engine at idle for two minutes in order to remove any trapped air.

Check for the following issues if the pressures are outside of the above specifications.

- All electrical connections are installed correctly.
- There are no leaks in the fuel lines or connections.
- The O-ring on the fuel filter housing (2) does not leak.

Air Inlet and Exhaust System

i01822825

Air Inlet and Exhaust System - Inspect

A general visual inspection should be made to the air inlet and exhaust system. Make sure that there are no signs of leaks in the system.

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

⚠ WARNING

Hot engine components can cause injury from burns. Before performing maintenance on the engine, allow the engine and the components to cool.

⚠ WARNING

Making contact with a running engine can cause burns from hot parts and can cause injury from rotating parts.

When working on an engine that is running, avoid contact with hot parts and rotating parts.

1. Inspect the engine air cleaner inlet and ducting in order to ensure that the passageway is not blocked or collapsed.
2. Inspect the engine air cleaner element. Replace a dirty element with a clean element.
3. Check for dirt tracks on the clean side of the engine air cleaner element. If dirt tracks are observed, contaminants are flowing past the element.

Wastegate - Test

⚠ WARNING

Hot engine components can cause injury from burns. Before performing maintenance on the engine, allow the engine and the components to cool.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

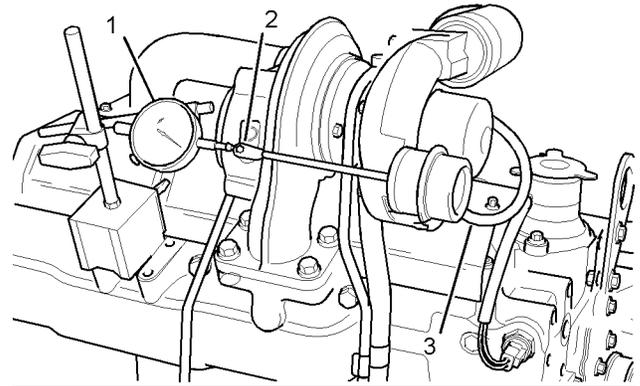


Illustration 26

g01009681

Note: The turbocharger is a nonserviceable item. The pressure for the wastegate can be checked, but not adjusted.

1. Use a suitable magnetic base dial indicator (1). Align the dial gauge to the actuator rod (2).
2. Remove the air hose to the actuator (3). Install an air line that can be adjusted in order to give the correct pressure.

Note: Do not exceed 205 kPa (30 psi) in order to check the actuator. Refer to the Specification, "Turbocharger" topic for information on the correct pressure setting for your actuator.

3. Carefully apply the air pressure until the air pressure has moved the rod 1 mm (0.0394 inch). Check that the air pressure is correct for your turbocharger.
4. For more information on installing a new turbocharger, contact your Perkins dealer or your Perkins distributor.

i01888954

Compression - Test

The cylinder compression test should only be used in order to compare the cylinders of an engine. If one or more cylinders vary by more than 350 kPa (51 psi), the cylinder and related components may need to be repaired.

A compression test should not be the only method which is used to determine the condition of an engine. Other tests should also be conducted in order to determine if the adjustment or the replacement of components is required.

Before the performance of the compression test, make sure that the following conditions exist:

- The battery is in good condition.
 - The battery is fully charged.
 - The starting motor operates correctly.
 - The valve lash is set correctly.
 - All fuel injectors are removed.
 - The fuel supply is disconnected.
1. Install a gauge for measuring the cylinder compression in the hole for a fuel injector.
 2. Operate the starting motor in order to turn the engine. Record the maximum pressure which is indicated on the compression gauge.
 3. Repeat Steps 1 and 2 for all cylinders.

i01958109

Engine Valve Lash - Inspect/Adjust

WARNING

To prevent possible injury, do not use the starter to turn the flywheel.

Hot engine components can cause burns. Allow additional time for the engine to cool before measuring valve clearance.

Refer to Systems Operation, "Engine Design" for the location of the cylinder valves.

If the valve lash requires adjustment several times in a short period of time, excessive wear exists in a different part of the engine. Find the problem and make necessary repairs in order to prevent more damage to the engine.

Not enough valve lash can be the cause of rapid wear of the camshaft and valve lifters. Not enough valve lash can indicate that the seats for the valves are worn.

Valves become worn due to the following causes:

- Fuel injectors that operate incorrectly
- Excessive dirt and oil are present on the filters for the inlet air.
- Incorrect fuel settings on the fuel injection pump.
- The load capacity of the engine is frequently exceeded.

Too much valve lash can cause broken valve stems, springs, and spring retainers. Too much valve lash can be an indication of the following problems:

- Worn camshaft and valve lifters
- Worn rocker arms
- Bent pushrods
- Broken socket on the upper end of a pushrod
- Loose adjustment screw for the valve lash

If the camshaft and the valve lifters show rapid wear, look for fuel in the lubrication oil or dirty lubrication oil as a possible cause.

Inspect Valve Lash

An adjustment is NOT NECESSARY if the measurement of the valve lash is in the acceptable range. Inspect the valve lash while the engine is stopped. The temperature of the engine does not change the valve lash setting.

Engine valve lash for the 1104 engine

Table 4

	Inlet Valves 1104	Exhaust Valves 1104
Valve Lash (Stopped Engine)	0.20 mm (0.008 inch)	0.45 mm (0.018 inch)
TC Compression Stroke	1,2	1,3
TC Exhaust Stroke ⁽¹⁾	3,4	2,4
Firing Order	1,3,4,2 ⁽²⁾	

(1) 360° from TC compression stroke

(2) The No. 1 cylinder is at the front of the engine.

Engine valve lash for the 1103 engine

Table 5

Valves	Inlet Valves	Exhaust Valves
Valve Lash	0.20 mm (0.008 inch)	0.45 mm (0.018 inch)
Valves	1, 3, 5	2, 4, 6
Firing order	1, 2, 3	

If the measurement is not within the acceptable clearance, adjustment is necessary. Refer to "Valve Lash Adjustment".

Valve Lash Adjustment for the 1104 engine

Note: The No. 1 cylinder is at the front of the engine.

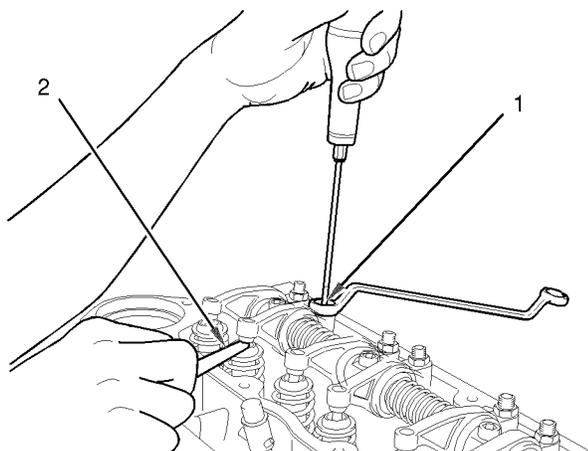


Illustration 27

g01016764

Setting the valve lash

(1) Adjustment screw

(2) Feeler gauge

! WARNING

Accidental engine starting can cause injury or death to personnel.

To prevent accidental engine starting, turn the ignition switch to the OFF position, place a do not operate tag at the ignition switch location and disconnect and tape the electrical connection to the stop solenoid that is located on the fuel injection pump.

Remove the valve mechanism cover and perform the following procedure in order to adjust the valve lash:

1. Put the No. 1 piston at the top center position on the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

Table 6

TC Compression Stroke	Inlet Valves	Exhaust Valves
Valve Lash	0.20 mm (0.008 inch)	0.45 mm (0.018 inch)
Cylinders	1,2	1,3

2. Adjust the valves according to Table 5.

- a. Lightly tap the rocker arm at the top of the adjustment screw with a soft mallet. This will ensure that the lifter seats against the camshaft.
- b. Loosen the adjustment locknut.
- c. Place the correct feeler gauge between the rocker arm and the valve stem. Then, turn the adjustment screw in a clockwise direction. Slide the feeler gauge between the rocker arm and the valve stem. Continue turning the adjustment screw until a slight drag is felt on the feeler gauge. Remove the feeler gauge.
- d. Tighten the adjustment locknut to a torque of 27 N·m (20 lb ft). Do not allow the adjustment screw to turn while you are tightening the adjustment locknut. Recheck the valve lash after tightening the adjustment locknut.

3. Rotate the engine by 360 degrees. The engine will be on TC compression stroke for cylinder 4.

Table 7

TC Exhaust Stroke ⁽³⁾	Inlet Valves	Exhaust Valve
Valve Lash	0.20 mm (0.008 inch)	0.45 mm (0.018 inch)
Cylinders	3,4	2,4

⁽³⁾ Position for No. 1 cylinder

4. Adjust the valves according to Table 7.

- a. Lightly tap the rocker arm at the top of the adjustment screw with a soft mallet. This will ensure that the lifter seats against the camshaft.
- b. Loosen the adjustment locknut.
- c. Place the correct feeler gauge between the rocker arm and the valve stem. Then, turn the adjustment screw in a clockwise direction. Slide the feeler gauge between the rocker arm and the valve stem. Continue turning the adjustment screw until a slight drag is felt on the feeler gauge. Remove the feeler gauge.
- d. Tighten the adjustment locknut to a torque of 27 N·m (20 lb ft). Do not allow the adjustment screw to turn while you are tightening the adjustment locknut. Recheck the valve lash after tightening the adjustment locknut.

Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

Valve Lash Adjustment for the 1103 engine

Note: The No. 1 cylinder is at the front of the engine.

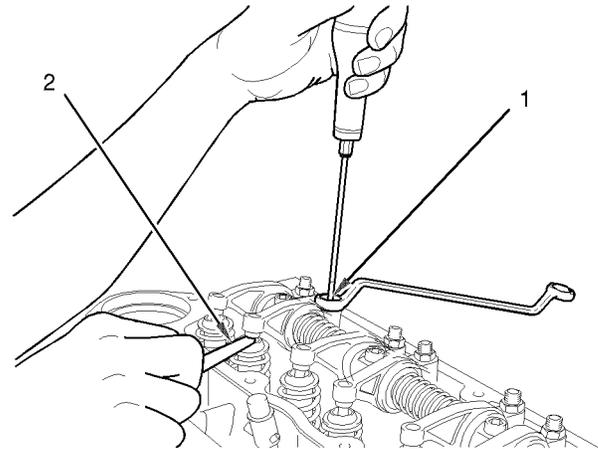


Illustration 28

g01016764

Setting the valve lash

- (1) Adjustment screw
- (2) Feeler gauge

Remove the valve mechanism cover and perform the following procedure in order to adjust the valve lash:

1. Put the No. 1 piston at the top center position on the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

Table 8

Valves	Inlet Valves	Exhaust Valves
Valve Lash	0.20 mm (0.008 inch)	0.45 mm (0.018 inch)
Valves	1, 3, 5	2, 4, 6

2. Rotate the crankshaft until the inlet valve for the cylinder 1 has just opened and the exhaust valve for the cylinder 1 is not completely closed. Then adjust the number 3 valve and the number 6 valve.
 - a. Adjust the valves according to Table 8.
 - b. Lightly tap the rocker arm at the top of the adjustment screw with a soft mallet. This will ensure that the lifter seats against the camshaft.
 - c. Loosen the adjustment locknut.

- d. Place the correct feeler gauge between the rocker arm and the valve stem. Then, turn the adjustment screw in a clockwise direction. Slide the feeler gauge between the rocker arm and the valve stem. Continue turning the adjustment screw until a slight drag is felt on the feeler gauge. Remove the feeler gauge.
 - e. Tighten the adjustment locknut to a torque of 27 N·m (20 lb ft). Do not allow the adjustment screw to turn while you are tightening the adjustment locknut. Recheck the valve lash after tightening the adjustment locknut.
3. Rotate the engine by 360 degrees. Then adjust the number 1 valve and the number 5 valve. Then adjust the number 2 valve and the number 4 valve.
- a. Adjust the valves according to Table 8.
 - b. Lightly tap the rocker arm at the top of the adjustment screw with a soft mallet. This will ensure that the lifter seats against the camshaft.
 - c. Loosen the adjustment locknut.
 - d. Place the correct feeler gauge between the rocker arm and the valve stem. Then, turn the adjustment screw in a clockwise direction. Slide the feeler gauge between the rocker arm and the valve stem. Continue turning the adjustment screw until a slight drag is felt on the feeler gauge. Remove the feeler gauge.
 - e. Tighten the adjustment locknut to a torque of 27 N·m (20 lb ft). Do not allow the adjustment screw to turn while you are tightening the adjustment locknut. Recheck the valve lash after tightening the adjustment locknut.

Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

i01889422

Valve Depth - Inspect

Table 9

Required Tools		
Part Number	Part Description	Qty
21825617	Dial gauge	1
21825496	Dial gauge holder	1

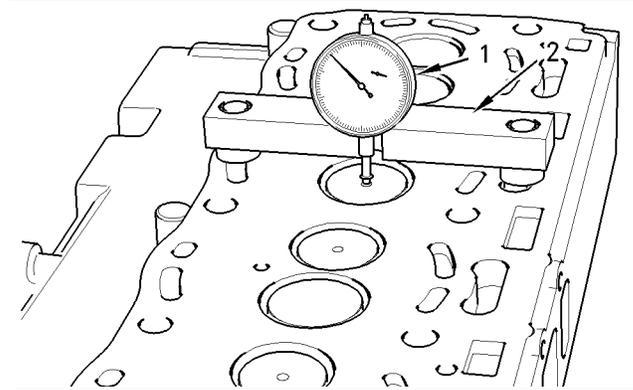


Illustration 29

g00983531

Measurement of the valve depth

(1) 21825617 Dial gauge

(2) 21825496 Dial gauge holder

1. Use the dial gauge (1) with the dial gauge holder (2) to check the depths of the inlet valves and the exhaust valves below the face of the cylinder head. Use the cylinder head face (3) to zero the dial gauge (1).
2. Position the dial gauge holder (2) and the dial gauge (1) in order to measure the valve depth. Measure the depth of the inlet valve and the exhaust valve before the valve springs are removed.

Refer to Specifications, "Cylinder Head Valves" for the minimum, the maximum, and the service wear limits for the valve depth below the cylinder head face.

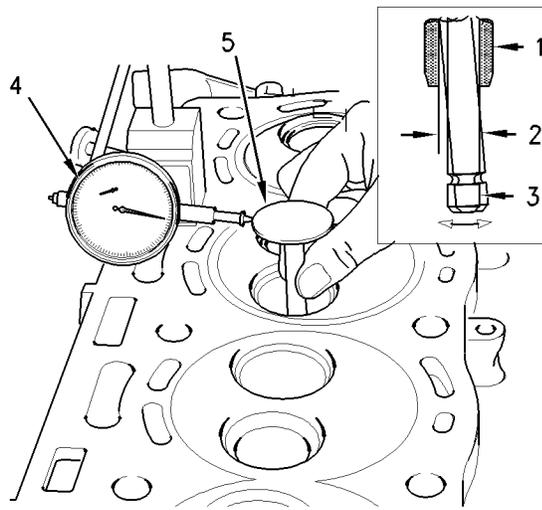
If the valve depth below the cylinder head face exceeds the service limit, use a new valve to check the valve depth. If the valve depth still exceeds the service limit, renew the cylinder head or renew the valve seat inserts (if equipped). If the valve depth is within the service limit with a new valve, renew the valves.

3. Inspect the valves for cracks and other damage. Check the valve stems for wear. Check that the valve springs are the correct length under the test force. Refer to Specifications, "Cylinder Head Valves" for the dimensions and tolerances of the valves and the valve springs.

i01938952

Valve Guide - Inspect

Perform this inspection in order to determine if a valve guide should be replaced.



Refer to Specifications, "Cylinder Head Valves" for the maximum clearance of the valve in the valve guide.

Illustration 30

g00986821

- (1) Valve guide
- (2) Radial movement of the valve in the valve guide
- (3) Valve stem
- (4) Dial indicator
- (5) Valve head

1. Place a new valve in the valve guide.
2. Place a suitable dial indicator with the magnetic base on the face of the cylinder head.
3. Lift the edge of the valve head to a distance of 15.0 mm (0.60 inch).
4. Move the valve in a radial direction away from the dial indicator. Make sure that the valve moves away from the dial indicator as far as possible. Position the contact point of the dial indicator on the edge of the valve head. Set the position of the needle of the dial indicator to zero.
5. Move the valve in a radial direction toward the dial indicator as far as possible. Note the distance of movement which is indicated on the dial indicator. If the distance is greater than the maximum clearance of the valve in the valve guide, replace the valve guide.

When new valve guides are installed, new valves and new valve seat inserts must be installed. Valve guides and valve seat inserts are supplied as an unfinished part. The unfinished valve guides and unfinished valve seat inserts are installed in the cylinder head. Then, the valve guides and valve inserts are cut and reamed in one operation with special tooling.

Lubrication System

i01854908

Engine Oil Pressure - Test

Low Oil Pressure

The following conditions will cause low oil pressure.

- The oil level is low in the crankcase.
- A restriction exists on the oil suction screen.
- Connections in the oil lines are leaking.
- The connecting rod or the main bearings are worn.
- The rotors in the oil pump are worn.
- The oil pressure relief valve is operating incorrectly.

A worn oil pressure relief valve can allow oil to leak through the valve which lowers the oil pressure. Refer to the Specifications Module, "Engine Oil Relief Valve" for the correct operating pressure and other information.

When the engine runs at the normal temperature for operation and at high idle, the oil pressure must be a minimum of 280 kPa (40 psi). A lower pressure is normal at low idle.

A suitable pressure gauge can be used in order to test the pressure of the lubrication system.

High Oil Pressure

High oil pressure can be caused by the following conditions.

- The spring for the oil pressure relief valve is installed incorrectly.
- The plunger for the oil pressure relief valve becomes jammed in the closed position.
- Excessive sludge exists in the oil which makes the viscosity of the oil too high.

i01893791

Engine Oil Pump - Inspect

If any part of the oil pump is worn enough in order to affect the performance of the oil pump, the oil pump must be replaced.

Perform the following procedures in order to inspect the oil pump for clearances and torques.

Refer to the Specifications Module, "Engine Oil Pump".

1. Remove the oil pump from the engine. Refer to the Disassembly and Assembly, "Engine Oil Pump - Remove". Remove the cover of the oil pump.
2. Remove the outer rotor. Clean all of the parts. Look for cracks in the metal or other damage.

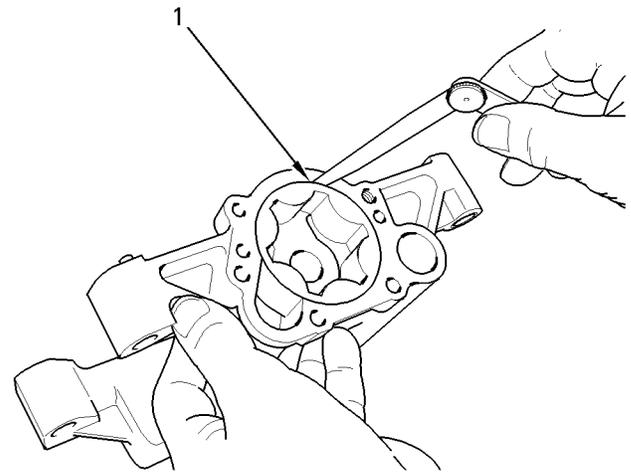


Illustration 31

g00985779

Clearance for the outer rotor body

(1) Measure the clearance of the outer rotor to the body.

3. Install the outer rotor. Measure the clearance of the outer rotor to the body (1).

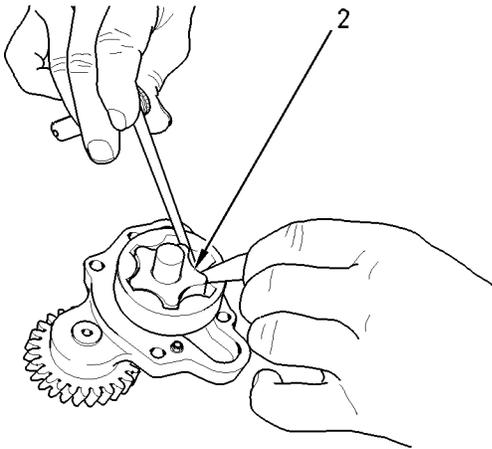


Illustration 32 g00985780

Clearance for the inner rotor

(2) Measure the clearance of the inner rotor to the outer rotor.

4. Measure the clearance of the inner rotor to the outer rotor (2).

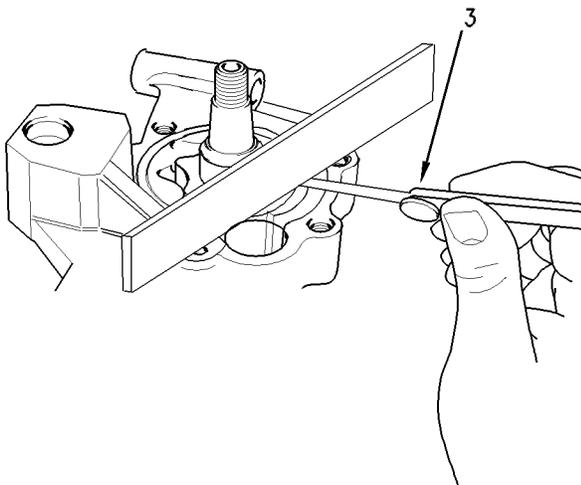


Illustration 33 g00989217

5. Measure the end play of the rotor with a straight edge and a feeler gauge (3).
6. Clean the top face of the oil pump and the bottom face of the cover. Install the cover on the oil pump. Install the oil pump on the engine. Refer to Disassembly and Assembly, "Engine Oil Pump - Install".

Excessive Bearing Wear - Inspect

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

An engine oil pressure indicator may show that there is enough oil pressure, but a component is worn due to a lack of lubrication. In such a case, look at the passage for the oil supply to the component. A restriction in an oil supply passage will not allow enough lubrication to reach a component. This will result in early wear.

Excessive Engine Oil Consumption - Inspect

Engine Oil Leaks on the Outside of the Engine

Check for leakage at the seals at each end of the crankshaft. Look for leakage at the gasket for the engine oil pan and all lubrication system connections. Look for any engine oil that may be leaking from 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. A dirty crankcase breather will cause the gaskets and the seals to leak.

Engine Oil Leaks into the Combustion Area of the Cylinders

Engine oil that is leaking into the combustion area of the cylinders can be the cause of blue smoke. There are several possible ways for engine oil to leak into the combustion area of the cylinders:

- Leaks between worn valve guides and valve stems
- Worn components or damaged components (pistons, piston rings, or dirty return holes for the engine oil)
- Incorrect installation of the compression ring and/or the intermediate ring
- Leaks past the seal rings in the turbocharger shaft

- Overfilling of the crankcase
- Wrong dipstick or guide tube
- Sustained operation at light loads

Excessive consumption of engine oil can also result if engine oil with the wrong viscosity is used. Engine oil with a thin viscosity can be caused by fuel leakage into the crankcase or by increased engine temperature.

i01945015

Increased Engine Oil Temperature - Inspect

Look for a restriction in the oil passages of the oil cooler (if equipped). The oil temperature may be higher than normal when the engine is operating. In such a case, the oil cooler may have a restriction. A restriction in the oil cooler will not cause low oil pressure in the engine.

Cooling System

i01892576

Cooling System - Check (Overheating)

Above normal coolant temperatures can be caused by many conditions. Use the following procedure to determine the cause of above normal coolant temperatures:

1. Check the coolant level in the cooling system. If the coolant level is too low, air will get into the cooling system. Air in the cooling system will cause a reduction in coolant flow and bubbles in the coolant. Air bubbles will keep the coolant away from the engine parts, which will prevent the transfer of heat to the coolant. Low coolant level is caused by leaks or incorrectly filling the expansion tank.
2. Check the mixture of antifreeze and water. The mixture should be 50 percent water and 50 percent 21825166 POWERPART antifreeze.
3. Check for air in the cooling system. Air can enter the cooling system in different ways. The most common causes of air in the cooling system are not filling the cooling system correctly and combustion gas leakage into the cooling system. Combustion gas can get into the system through inside cracks, a damaged cylinder head, or a damaged cylinder head gasket. Air in the cooling system causes a reduction in coolant flow and bubbles in the coolant. Air bubbles keep the coolant away from the engine parts, which prevents the transfer of heat to the coolant.
4. Check the sending unit. In some conditions, the temperature sensor in the engine sends signals to a sending unit. The sending unit converts these signals to an electrical impulse which is used by a mounted gauge. If the sending unit malfunctions, the gauge can show an incorrect reading. Also if the electric wire breaks or if the electric wire shorts out, the gauge can show an incorrect reading.
5. Check the radiator for a restriction to coolant flow. Check the radiator for debris, dirt, or deposits on the inside of the core. Debris, dirt, or deposits will restrict the flow of coolant through the radiator.
6. Check the filler cap. A pressure drop in the cooling system can cause the boiling point to be lower. This can cause the cooling system to boil. Refer to Testing and Adjusting, "Cooling System - Test".
7. Check the cooling system hoses and clamps. Damaged hoses with leaks can normally be seen. Hoses that have no visual leaks can soften during operation. The soft areas of the hose can become kinked or crushed during operation. These areas of the hose can cause a restriction in the coolant flow. Hoses become soft and/or get cracks after a period of time. The inside of a hose can deteriorate, and the loose particles of the hose can cause a restriction of the coolant flow.
8. Check for a restriction in the air inlet system. A restriction of the air that is coming into the engine can cause high cylinder temperatures. High cylinder temperatures require higher than normal temperatures in the cooling system.
9. Check for a restriction in the exhaust system. A restriction of the air that is coming out of the engine can cause high cylinder temperatures.
 - a. Make a visual inspection of the exhaust system.
 - b. Check for damage to exhaust piping. Check for damage to the exhaust elbow. If no damage is found, check the exhaust system for a restriction.
10. Check the water temperature regulator. A water temperature regulator that does not open, or a water temperature regulator that only opens part of the way can cause overheating. Refer to Testing and Adjusting, "Water Temperature Regulator - Test".
11. Check the water pump. A water pump with a damaged impeller does not pump enough coolant for correct engine cooling. Remove the water pump and check for damage to the impeller.
12. Consider high outside temperatures. When outside temperatures are too high for the rating of the cooling system, there is not enough of a temperature difference between the outside air and coolant temperatures. The maximum temperature of the ambient air that enters the engine should not exceed 50 °C (120 °F).
13. When a load that is applied to the engine is too large, the engine rpm does not increase with an increase of fuel. This lower engine rpm causes a reduction in coolant flow through the system. This combination of less air and less coolant flow during high input of fuel will cause above normal heating.

i01889427

i01876572

Cooling System - Inspect

This engine has a pressure type cooling system. A pressure type cooling system gives two advantages:

- The pressure type cooling system can operate safely at a higher temperature than the boiling point of water at a range of atmospheric pressures.
- The pressure type cooling system prevents cavitation in the water pump.

Cavitation is the sudden generation of low pressure bubbles in liquids by mechanical forces. The generation of an air or steam pocket is much more difficult in a pressure type cooling system.

Regular inspections of the cooling system should be made in order to identify problems before damage can occur. Visually inspect the cooling system before tests are made with the test equipment.

Visual Inspection Of The Cooling System

1. Check the coolant level in the cooling system.
2. Look for leaks in the system.
3. Inspect the radiator for bent fins and other restriction to the flow of air through the radiator.
4. Inspect the drive belt for the fan.
5. Inspect the blades of the fan for damage.
6. Look for air or combustion gas in the cooling system.
7. Inspect the radiator cap for damage. The sealing surface must be clean.
8. Look for large amounts of dirt in the radiator core. Look for large amounts of dirt on the engine.
9. Shrouds that are loose or missing cause poor air flow for cooling.

Cooling System - Test

Remember that temperature and pressure work together. When a diagnosis is made of a cooling system problem, temperature and pressure must be checked. The cooling system pressure will have an effect on the cooling system temperature. For an example, refer to Illustration 34. This will show the effect of pressure on the boiling point (steam) of water. This will also show the effect of height above sea level.

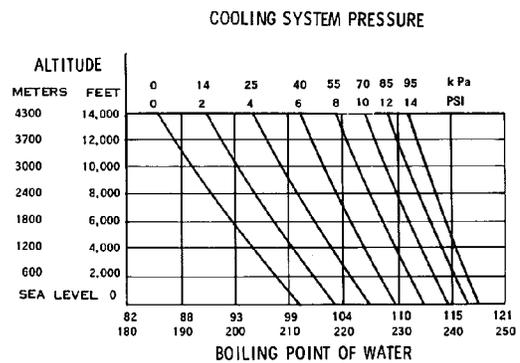


Illustration 34

g00286266

Cooling system pressure at specific altitudes and boiling points of water

WARNING

Personal injury can result from hot coolant, steam and alkali.

At operating temperature, engine coolant is hot and under pressure. The radiator and all lines to heaters or the engine contain hot coolant or steam. Any contact can cause severe burns.

Remove filler cap slowly to relieve pressure only when engine is stopped and radiator cap is cool enough to touch with your bare hand.

The coolant level must be to the correct level in order to check the coolant system. The engine must be cold and the engine must not be running.

After the engine is cool, loosen the pressure cap in order to relieve the pressure out of the cooling system. Then remove the pressure cap.

The level of the coolant should not be more than 13 mm (0.5 inch) from the bottom of the filler pipe. If the cooling system is equipped with a sight glass, the coolant should be to the correct level in the sight glass.

Making the Correct Antifreeze Mixtures

Do not add pure 21825166 POWERPART antifreeze to the cooling system in order to adjust the concentration of antifreeze. The pure antifreeze increases the concentration of antifreeze in the cooling system. The increased concentration increases the concentration of dissolved solids and undissolved chemical inhibitors in the cooling system.

The antifreeze mixture must consist of equal quantities of antifreeze and clean soft water. The corrosion inhibitor in the antifreeze will be diluted if a concentration of less than 50% of antifreeze is used. Concentrations of more than 50% of antifreeze may have the adverse effect on the performance of the coolant.

Checking the Filler Cap

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

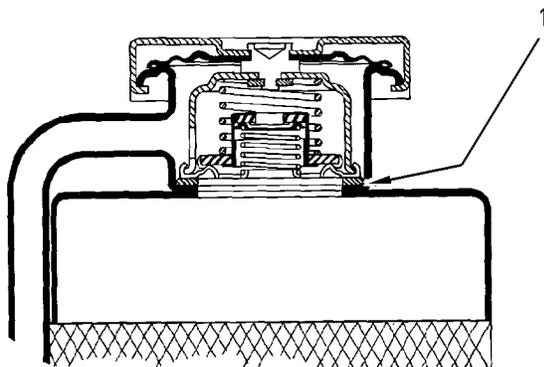


Illustration 35 g00296067

Typical schematic of filler cap

(1) Sealing surface between the pressure cap and the radiator

WARNING

Personal injury can result from hot coolant, steam and alkali.

At operating temperature, engine coolant is hot and under pressure. The radiator and all lines to heaters or the engine contain hot coolant or steam. Any contact can cause severe burns.

Remove filler cap slowly to relieve pressure only when engine is stopped and radiator cap is cool enough to touch with your bare hand.

To check for the amount of pressure that opens the filler cap, use the following procedure:

1. After the engine cools, carefully loosen the filler cap. Slowly release the pressure from the cooling system. Then, remove the filler cap.
2. Inspect the pressure cap carefully. Look for damage to the seal. Look for damage to the surface that seals. Remove any debris on the cap, the seal, or the sealing surface.

Carefully inspect the filler cap. Look for any damage to the seals and to the sealing surface. Inspect the following components for any foreign substances:

- Filler cap
- Seal
- Surface for seal

Remove any deposits that are found on these items, and remove any material that is found on these items.

3. Install the pressure cap onto a suitable pressurizing Pump.
4. Observe the exact pressure that opens the filler cap.
5. Compare the pressure to the pressure rating that is found on the top of the filler cap.
6. If the filler cap is damaged, replace the filler cap.

Testing The Radiator And Cooling System For Leaks

Use the following procedure to test the radiator and the cooling system for leaks.

WARNING

Personal injury can result from hot coolant, steam and alkali.

At operating temperature, engine coolant is hot and under pressure. The radiator and all lines to heaters or the engine contain hot coolant or steam. Any contact can cause severe burns.

Remove filler cap slowly to relieve pressure only when engine is stopped and radiator cap is cool enough to touch with your bare hand.

1. When the engine has cooled, loosen the filler cap to the first stop. Allow the pressure to release from the cooling system. Then remove the filler cap.

2. Make sure that the coolant covers the top of the radiator core.
3. Put a suitable pressurizing Pump onto the radiator.
4. Use the pressurizing pump to increase the pressure to an amount of 20 kPa (3 psi) more than the operating pressure of the filler cap.
5. Check the radiator for leakage on the outside.
6. Check all connections and hoses of the cooling system for leaks.

The radiator and the cooling system do not have leakage if all of the following conditions exist:

- You do NOT observe any leakage after five minutes.
- The dial indicator remains constant beyond five minutes.

The inside of the cooling system has leakage only if the following conditions exist:

- The reading on the gauge goes down.
- You do NOT observe any outside leakage.

Make any repairs, as required.

i01956505

Engine Oil Cooler - Inspect

WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

Engine oil cooler for the 1104 engine

Perform the following procedure in order to inspect the engine oil cooler (if equipped):

1. Place a container under the oil cooler in order to collect any engine oil or coolant that drains from the oil cooler.
2. Refer to Disassembly and Assembly, "Engine Oil Cooler - Remove" for removal of the engine oil cooler.
3. Thoroughly clean the flange face of the cover plate and the cylinder block.

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

4. Inspect the cooling plates for cracks and dents. Replace the cooling plates if cracks or dents exist.

If necessary, clean the outside and clean the inside of the cooling plates. Use a solvent that is not corrosive on copper. Ensure that no restrictions for the flow of lubricating oil exist in the cooling plates.

Dry the cooling plate with low pressure air. Flush the inside of the cooling plate with clean lubricating oil.

5. Refer to Disassembly and Assembly, "Engine Oil Cooler - Install" for installation of the engine oil cooler.
6. Ensure that the cooling system and the oil system of the engine are filled to the correct level. Operate the engine. Check for oil or coolant leakage.

Modine oil cooler for the 1103 engine

Perform the following procedure in order to inspect the modine oil cooler (if equipped):

1. Place a container under the modine oil cooler in order to collect any engine oil or coolant that drains from the modine oil cooler.
2. Refer to Disassembly and Assembly, "Engine Oil Cooler - Remove" for removal of the engine oil cooler.
3. Thoroughly clean the outside of the cooler plates with a suitable cleaning fluid.

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

4. Thoroughly clean the inside of the cooler plates with clean water.

Dry the cooling plate with low pressure air. Flush the inside of the cooling plate with clean lubricating oil.
5. Install the modine oil cooler. Refer to Disassembly and Assembly, "Engine Oil Cooler - Install".
6. Ensure that the cooling system and the oil system of the engine are filled to the correct level. Operate the engine. Check for oil or coolant leakage.

If the distance is less than the amount listed in the manual, replace the water temperature regulator. Refer to Disassembly and Assembly, "Water Temperature Regulator - Remove and Install".

Install the water temperature regulator. Refer to Disassembly and Assembly, "Water Temperature Regulator - Remove and Install".

i01889428

Water Temperature Regulator - Test

Note: Do not remove the water temperature regulator from the water temperature regulator housing in order to perform the test.

1. Remove the water temperature regulator housing which contains the water temperature regulator from the engine. Refer to Disassembly and Assembly, "Water Temperature Regulator - Remove and Install".
2. Heat water in a pan until the temperature of the water is equal to the fully open temperature of the water temperature regulator. Refer to Specifications, "Water Temperature Regulator" for the fully open temperature of the water temperature regulator. Stir the water in the pan. This will distribute the temperature throughout the pan.
3. Hang the water temperature regulator housing in the pan of water. The water temperature regulator housing must be below the surface of the water. The water temperature regulator housing must be away from the sides and the bottom of the pan.
4. Keep the water at the correct temperature for ten minutes.
5. After ten minutes, remove the water temperature regulator housing. Immediately measure the opening of the water temperature regulator. Refer to Specifications, "Water Temperature Regulator" for the minimum opening distance of the water temperature regulator at the fully open temperature.

Basic Engine

i01889476

Piston Ring Groove - Inspect

Inspect the Piston and the Piston Rings

1. Check the piston for wear and other damage.
2. Check that the piston rings are free to move in the grooves and that the rings are not broken.

Inspect the Clearance of the Piston Ring

1. Remove the piston rings and clean the grooves and the piston rings.

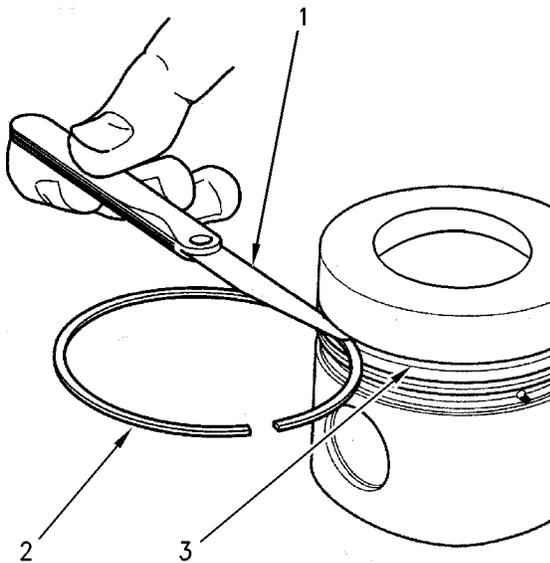


Illustration 36

g00905732

- (1) Feeler gauge
(2) Piston ring
(3) Piston grooves

2. Fit new piston rings (2) in the piston grooves (3).
3. Check the clearance for the piston ring by placing a suitable feeler gauge (1) between the piston groove (3) and the top of piston ring (2). Refer to Specifications, "Piston and Rings" for the dimensions.

Note: Some pistons have a tapered top groove and the piston ring is wedged. The clearance for the top piston ring cannot be checked by the above method when this occurs.

Inspect the Piston Ring End Gap

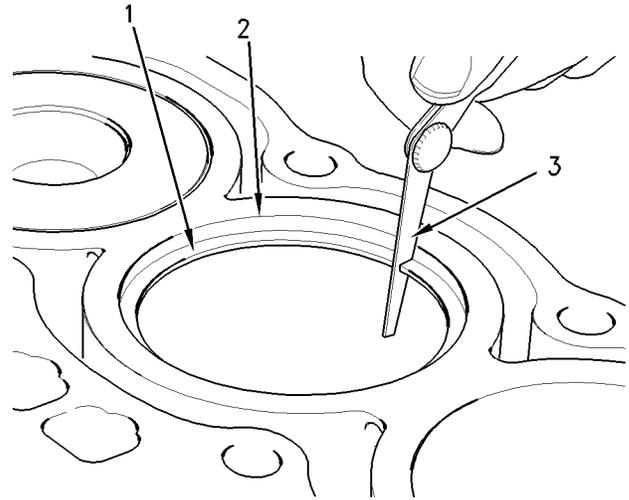


Illustration 37

g00983549

- (1) Piston ring
(2) Cylinder ring ridge
(3) Feeler gauge

1. Clean all carbon from the top of the cylinder bores.
2. Place each piston ring (1) in the cylinder bore just below the cylinder ring ridge (2).
3. Use a suitable feeler gauge (3) to measure the piston ring end gap. Refer to Specifications, "Piston and Rings" for the dimensions.

Note: The coil spring must be removed from the oil control ring before the gap of the oil control ring is measured.

i01946425

Connecting Rod - Inspect

This procedure determines the following characteristics of the connecting rod:

- The distortion of the connecting rod
- The parallel alignment of the bores of the connecting rod

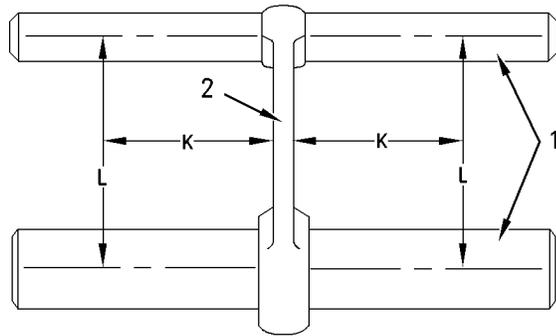


Illustration 38

g00927038

Inspection of the connecting rod parallel alignment.

- (1) Measuring pins
- (2) Connecting rod
- (L) Measure the distance between the center of the bore for the piston pin bearing and the center of the connecting rod bearing bore.
- (K) Measure the distance 127 mm (5.0 inch) from the connecting rod.

1. Use the appropriate tools in order to measure the distances for the connecting rod (2).

- Appropriate gauges for measuring distance
- Measuring pins (1)

Note: The connecting rod bearings should be removed before taking the measurements.

2. Measure the connecting rod for distortion and parallel alignment between the bores.

The measurements must be taken at distance (K). Distance (K) has a value of 127 mm (5.0 inch) from both sides of the connecting rod.

Measure length (L).

The total difference in measurements of length (L) from each side should not vary more than ± 0.25 mm (± 0.010 inch).

If the piston pin bearing is not removed, the limits are reduced to ± 0.06 mm (± 0.0025 inch).

3. Inspect the piston pin bearing and the piston pin for wear and other damage.
4. Measure the clearance of the piston pin in the piston pin bearing. Refer to Specifications, "Connecting Rod" for clearance dimensions.

i01748770

Connecting Rod Bearings - Inspect

Check the connecting rod bearings and the connecting rod bearing journal for wear or other damage.

Connecting rod bearings are available with a smaller inside diameter than the original size bearings. These bearings are for crankshafts that have been ground.

i01748792

Main Bearings - Inspect

Check the main bearings for wear or other damage. Replace both halves of the bearings and check the condition of the other bearings if a main bearing is worn or damaged.

Main bearings are available with a smaller inside diameter than the original size bearings. These bearings are for main bearing journals that have been ground.

i01946424

Cylinder Block - Inspect

1. Clean all of the coolant passages and the oil passages.
2. Check the cylinder block for cracks and damage.
3. The top deck of the cylinder block must not be machined. This will affect the piston height above the cylinder block.
4. Check the camshaft bearing for wear. If a new bearing is needed, use a suitable adapter to press the bearing out of the bore. Ensure that the oil hole in the new bearing faces the front of the block. The oil hole in the bearing must be aligned with the oil hole in the cylinder block. The bearing must be aligned with the face of the recess. Refer to Disassembly and Assembly, "Camshaft Bearings - Remove and Install".

i01905914

Cylinder Head - Inspect

1. Remove the cylinder head from the engine.
2. Remove the water temperature regulator housing.
3. Inspect the cylinder head for signs of gas or coolant leakage.
4. Remove the valve springs and valves.
5. Clean the bottom face of the cylinder head thoroughly. Clean the coolant passages and the lubricating oil passages. Make sure that the contact surfaces of the cylinder head and the cylinder block are clean, smooth and flat.
6. Inspect the bottom face of the cylinder head for pitting, corrosion, and cracks. Inspect the area around the valve seat inserts and the holes for the fuel injectors carefully.
7. Test the cylinder head for leaks at a pressure of 200 kPa (29 psi).

Refer to Specifications, "Cylinder Head" for the requirements of flatness.

Remachining the Cylinder Head

The bottom face of cylinder head can be resurfaced if any of the following conditions exist:

- The bottom face of the cylinder head is not flat within the specifications.
- The bottom face of the cylinder head is damaged by pitting, corrosion, or wear.

Note: The thickness of the cylinder head must not be less than 117.20 mm (4.614 inch) after the cylinder head has been machined.

If the bottom face of the cylinder head has been remachined, the recesses in the cylinder head for the valve seat inserts must be machined. The valve seat inserts must be ground on the side which is inserted into the cylinder head. Grinding this surface will ensure that no protrusion exists above the bottom face of the cylinder head. Refer to Specifications, "Cylinder Head Valves" for the correct dimensions.

i01889496

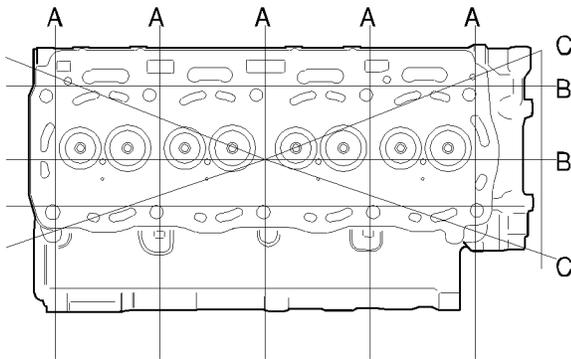


Illustration 39

g01012606

Flatness of the cylinder head (typical example)

- (A) Side to side
(B) End to end
(C) Diagonal

8. Measure the cylinder head for flatness. Measure the flatness of the cylinder head with a straight edge and with a feeler gauge.
 - Measure the cylinder head from one side to the opposite side (A).
 - Measure the cylinder head from one end to the opposite end (B).
 - Measure the cylinder head from one corner to the opposite corner (C).

Piston Height - Inspect

Table 10

Required Tools		
Part Number	Part Description	Qty
21825617	Dial gauge	1
21825496	Dial gauge holder	1

If the height of the piston above the cylinder block is not within the tolerance that is given in the Specifications Module, "Piston and Rings", the bearing for the piston pin must be checked. Refer to Testing and Adjusting, "Connecting Rod - Inspect". If any of the following components are replaced or remachined, the piston height above the cylinder block must be measured:

- Crankshaft
- Cylinder head
- Connecting rod
- Bearing for the piston pin

The correct piston height must be maintained in order to ensure that the engine conforms to the standards for emissions.

Note: The top of the piston should not be machined. If the original piston is installed, be sure that the original piston is assembled to the correct connecting rod and installed in the original cylinder.

Six grades of length of connecting rods determine the piston height above the cylinder block. The grade of length of a connecting rod is identified by a letter or a color. The letter or the color is marked on the side of the connecting rod. Refer to Testing and Adjusting, "Connecting Rod - Inspect" and Specifications, "Connecting Rod" for additional information.

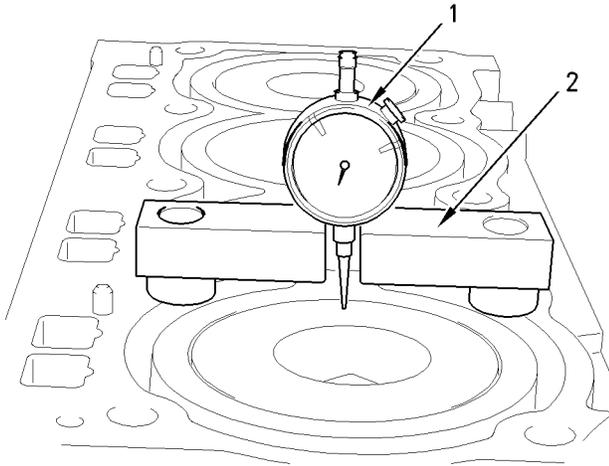


Illustration 40

g00983585

- (1) Dial gauge
- (2) Dial gauge holder

1. Use the dial gauge (1) and the dial gauge holder (2) in order to measure the piston height above the cylinder block. Use the cylinder block face to zero the dial gauge (1).
2. Rotate the crankshaft until the piston is at the approximate top center.
3. Position the dial gauge holder (2) and the dial gauge (1) in order to measure the piston height above the cylinder block. Slowly rotate the crankshaft in order to determine when the piston is at the highest position. Record this dimension. Compare this dimension with the dimensions that are given in Specifications, "Piston and Rings".

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Flywheel - Inspect

Alignment of the Flywheel Face

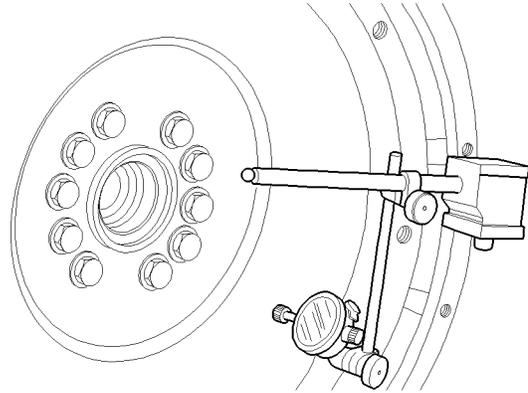


Illustration 41

g00987751

1. Install the dial indicator. Refer to Illustration 41.
2. Set the pointer of the dial indicator to 0 mm (0 inch).
3. Turn the flywheel. Read the dial indicator for every 90 degrees.

Note: During the check, keep the crankshaft pressed toward the front of the engine in order to remove any end clearance.

4. Calculate the difference between the lowest measurement and the highest measurement of the four locations. This difference must not be greater than 0.03 mm (0.001 inch) for every 25 mm (1.0 inch) of the radius of the flywheel. The radius of the flywheel is measured from the axis of the crankshaft to the contact point of the dial indicator.

Flywheel Runout

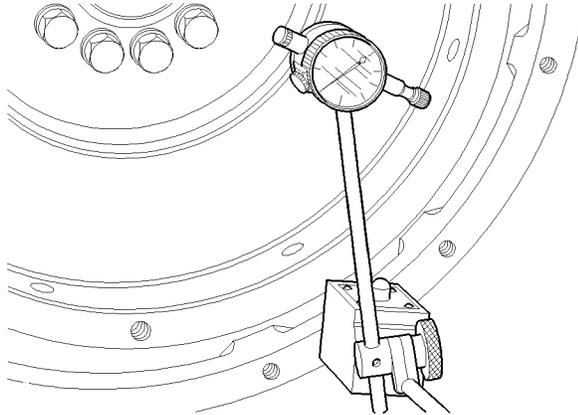


Illustration 42

g00987752

1. Install the dial indicator. Refer to Illustration 42.
2. Set the pointer of the dial indicator to 0 mm (0 inch).
3. Turn the flywheel. Read the dial indicator for every 90 degrees.
4. Calculate the difference between the lowest measurement and the highest measurement of the four locations. This difference must not be greater than 0.30 mm (0.012 inch).

Gear Group - Inspect

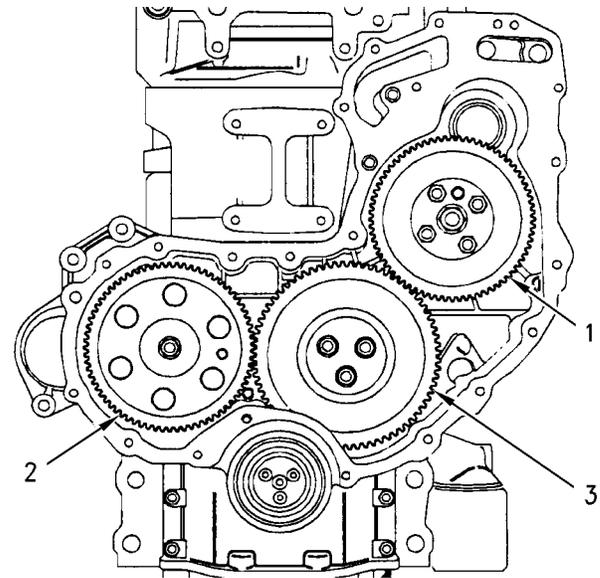


Illustration 43

g00918708

- (1) Fuel pump drive gear
- (2) Camshaft drive gear
- (3) Idler gear

Remove the front timing cover and inspect the gears. The timing marks on the gears indicate the front side of the gears. Inspect the gears for broken teeth or worn teeth.

Electrical System

i01899123

Alternator - Test

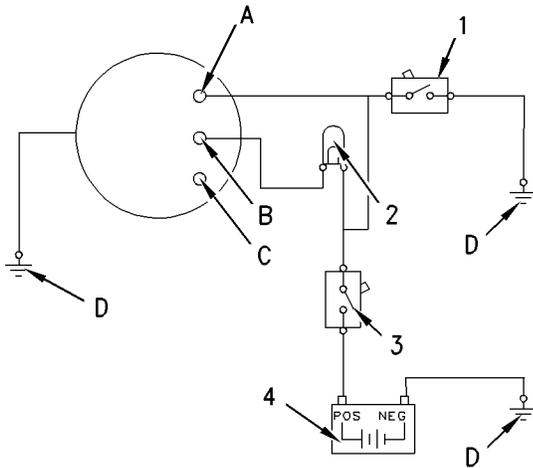


Illustration 44

g00931045

Typical wiring schematic for an alternator

- (A) Terminal "B+"
- (B) Terminal "D+"
- (C) Terminal "W"
- (D) Ground
- (1) Electrical switch
- (2) Dash light
- (3) Ignition switch
- (4) Battery

Warning Lamp Does Not Illuminate

The warning lamp for the charging system should illuminate when the ignition switch is in the ON position. Follow the steps below in order to test the system.

1. Check the light bulb. Replace the light bulb if the element is broken.
2. Use a suitable Multimeter to check the battery voltage. Check the battery voltage with the ignition switch OFF.
3. Check the voltage between the terminal (A) and ground. The measured voltage should equal the battery voltage.

4. Turn the ignition switch to the ON position. Check the voltage between terminal (B) and ground. If the voltage is more than 2 Volts the alternator needs to be replaced.

Warning Light is On When the Engine is Running

1. Start the engine and run the engine at fast idle.
2. Measure the voltage between terminal (A) and ground.
3. Measure the voltage between terminal (B) and ground.
4. The measured voltage for terminal (A) and terminal (B) should be 13 to 15 volts for a 12 volt system. The measured voltage for terminal (A) and terminal (B) should be 26 to 30 volts for a 24 volt system.
5. If the voltages do not match replace the alternator.
6. Increase the engine to high idle. Turn an electrical load ON.
7. Measure the voltage between terminal (A) and ground.
8. Measure the voltage between terminal (B) and ground.
9. The measured voltage for terminal (A) and terminal (B) should be 13 to 15 volts for a 12 volt system. The measured voltage for terminal (A) and terminal (B) should be 26 to 30 volts for a 24 volt system.
10. Replace the alternator if the voltage does not match.

i01899136

Battery - Test

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 both components must be tight.

⚠ WARNING

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

The battery circuit is an electrical load on the charging unit. The load is variable because of the condition of the charge in the battery.

NOTICE

The charging unit will be damaged if the connections between the battery and the charging unit are broken while the battery is being charged. Damage occurs because the load from the battery is lost and because there is an increase in charging voltage. High voltage will damage the charging unit, the regulator, and other electrical components.

The correct procedures to test the battery can be found in the manual that is supplied by the OEM.

i01945632

Electric Starting System - Test

General Information

All electrical starting systems have four elements:

- Ignition switch
- Start relay
- Starting motor solenoid
- Starting motor

Start switches have a capacity of 5 to 20 amperes. The coil of a start relay draws about 1 ampere between test points. The switch contacts of the start relay for the starting motor are rated between 100 and 300 amperes. The start relay can easily switch the load of 5 to 50 amperes for the starting motor solenoid.

The starting motor solenoid is a switch with a capacity of about 1000 amperes. The starting motor solenoid supplies power to the starter drive. The starting motor solenoid also engages the pinion to the flywheel.

The starting motor solenoid has two coils. The pull-in coil draws about 40 amperes. The hold-in coil requires about 5 amperes.

When the magnetic force increases in both coils, the pinion gear moves toward the ring gear of the flywheel. Then, the solenoid contacts close in order to provide power to the starting motor. When the solenoid contacts close, the ground is temporarily removed from the pull-in coil. Battery voltage is supplied on both ends of the pull-in coil while the starting motor cranks. During this period, the pull-in coil is out of the circuit.

Cranking of the engine continues until current to the solenoid is stopped by releasing the ignition switch.

Power which is available during cranking varies according to the temperature and condition of the batteries. The following chart shows the voltages which are expected from a battery at the various temperature ranges.

Table 11

Typical Voltage Of Electrical System During Cranking At Various Ambient Temperatures		
Temperature	12 Volt System	24 Volt System
-23 to -7°C (-10 to 20°F)	6 to 8 volts	12 to 16 volts
-7 to 10°C (20 to 50°F)	7 to 9 volts	14 to 18 volts
10 to 27°C (50 to 80°F)	8 to 10 volts	16 to 24 volts

The following table shows the maximum acceptable loss of voltage in the battery circuit. The battery circuit supplies high current to the starting motor. The values in the table are for engines which have service of 2000 hours or more.

Table 12

Maximum Acceptable Voltage Drop In The Starting Motor Circuit During Cranking		
Circuit	12 Volt System	24 Volt System
Battery post “-” to the starting motor terminal “-”	0.7 volts	1.4 volts
Drop across the disconnect switch	0.5 volts	1.0 volts
Battery post “+” to the terminal of the starting motor solenoid “+”	0.5 volts	1.0 volts
Solenoid terminal “Bat” to the solenoid terminal “Mtr”	0.4 volts	0.8 volts

Voltage drops that are greater than the amounts in Table 12 are caused most often by the following conditions:

- Loose connections
- Corroded connections
- Faulty switch contacts

Diagnosis Procedure

The procedures for diagnosing the starting motor are intended to help the technician determine if a starting motor needs to be replaced or repaired. The procedures are not intended to cover all possible problems and conditions. The procedures serve only as a guide.

Note: Do not crank the engine for more than 30 seconds. Allow the starter to cool for two minutes before cranking the engine again.

If the starting motor does not crank or cranks slow, perform the following procedure:

1. Measure the voltage of the battery.

Measure the voltage across the battery posts with the multimeter when you are cranking the engine or attempting to crank the engine. Do not measure the voltage across the cable post clamps.

- If the voltage is equal or greater than the voltage in Table 11, then go to Step 2.
- The battery voltage is less than the voltage in Table 11.

A low charge in a battery can be caused by several conditions.

- Deterioration of the battery
- A shorted starting motor
- A faulty alternator
- Loose drive belts
- Current leakage in another part of the electrical system

2. Measure the current that is sent to the starting motor solenoid from the positive post of the battery.

Note: If the following conditions exist, do not perform the test in Step 2 because the starting motor has a problem.

- The voltage at the battery post is within 2 volts of the lowest value in the applicable temperature range of Table 11.

- The large starting motor cables get hot.

Use a suitable ammeter in order to measure the current. Place the jaws of the ammeter around the cable that is connected to the “bat” terminal. Refer to the Specifications Module, “Starting Motor” for the maximum current that is allowed for no load conditions.

The current and the voltages that are specified in the Specifications Module are measured at a temperature of 27°C (80°F). When the temperature is below 27°C (80°F), the voltage will be lower through the starting motor. When the temperature is below 27°C (80°F), the current through the starting motor will be higher. If the current is too great, a problem exists in the starting motor. Repair the problem or replace the starting motor.

If the current is within the specification, proceed to Step 3.

3. Measure the voltage of the starting motor.

- Use the multimeter in order to measure the voltage of the starting motor, when you are cranking or attempting to crank the engine.
- If the voltage is equal or greater than the voltage that is given in Table 11, then the battery and the starting motor cable that goes to the starting motor are within specifications. Go to Step 5.
- The starting motor voltage is less than the voltage specified in Table 11. The voltage drop between the battery and the starting motor is too great. Go to Step 4.

4. Measure the voltage.

- Measure the voltage drops in the cranking circuits with the multimeter. Compare the results with the voltage drops which are allowed in Table 12.
- Voltage drops are equal to the voltage drops that are given in Table 12 or the voltage drops are less than the voltage drops that are given in Table 12. Go to Step 5 in order to check the engine.
- The voltage drops are greater than the voltage drops that are given in Table 12. The faulty component should be repaired or replaced.

5. Rotate the crankshaft by hand in order to ensure that the crankshaft is not stuck. Check the oil viscosity and any external loads that could affect the engine rotation.

- a. If the crankshaft is stuck or difficult to turn, repair the engine.
 - b. If the engine is not difficult to turn, go to Step 6.
6. Attempt to crank the starting motor.
- a. The starting motor cranks slowly.
Remove the starting motor for repair or replacement.
 - b. The starting motor does not crank.
Check for the blocked engagement of the pinion gear and flywheel ring gear.

Note: Blocked engagement and open solenoid contacts will give the same electrical symptoms.

i01911231

Glow Plugs - Test

Continuity Check of the Glow Plugs

The following test will check the continuity of the glow plugs.

1. Disconnect the power supply and the bus bar.
2. Use a suitable digital multimeter to check continuity (resistance). Turn the audible signal on the digital multimeter ON.
3. Place one probe on the connection for the glow plug and the other probe to a suitable ground. The digital multimeter should make an audible sound. Replace the glow plug if there is no continuity.
4. Check the continuity on all the glow plugs.

Checking The Operation of The Glow Plug

The following test will check the operation of the glow plugs.

1. Disconnect the power supply and the bus bar.
2. Connect the power supply to only one glow plug.
3. Place a suitable ammeter on the power supply wire.
4. Connect a suitable digital multimeter to the terminal on the glow plug and to a suitable ground.

5. Turn the switch to the ON position in order to activate the glow plugs.

Table 13

12 Volt System	
Amp	Time (sec)
30	Initial
21	4
14	8
10	20
9	60

Table 14

24 Volt System	
Amp	Time (sec)
12	Initial
8.5	8
7	20
6	60

6. Check the reading on all of the glow plugs.
7. If there is no reading on the ammeter check the electrical connections. If the readings on the ammeter are low replace the glow plugs. If there is still no reading replace the glow plugs.

i01955101

V-Belt - Test

Table 15

Belt Tension Chart			
Size of Belt	Width of Belt	Gauge Reading	
		Initial Belt Tension⁽¹⁾	Used Belt Tension⁽²⁾
1/2	13.89 mm (0.547 Inch)	535 N (120 lb)	355 N (80 lb)
Measure the tension of the belt that is farthest from the engine.			

(1) Initial Belt Tension refers to a new belt.

(2) Used Belt Tension refers to a belt that has been in operation for 30 minutes or more at the rated speed.

1. Check the belts for wear and check the belts for damage. Belts must always be changed as a pair.
2. Fit a suitable Burroughs gauge at the center of the longest free length of the belt and check the tension on both belts. Check and adjust the tension on the tightest belt. To adjust the belt tension, see Disassembly and Assembly Manual, "Alternator - Install".

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