SERVICE MANUAL

INTERNATIONAL® DT 466, DT 570, HT 570

DIESEL ENGINE

SERVICE MANUAL

FORM EGES-265-2

Printed in the United States of America

SERVICE MANUAL

INTERNATIONAL® DT 466, DT 570, HT 570
DIESEL ENGINE (S/N 200001 AND ABOVE)

FORM EGES-265-2
2004 MODEL YEAR AND ABOVE

Table of Contents

Foreword

Navistar, Inc. is committed to continuous research and development to improve products and introduce technological advances. Procedures, specifications, and parts defined in published technical service literature may be altered.

This *Engine Service Manual* provides a general sequence of procedures for out-of-chassis engine overhaul (removal, inspection, and installation). For in-chassis service of parts and assemblies, the sequence may vary.

NOTE: Photo illustrations identify specific parts or assemblies that support text and procedures; other areas in a photo illustration may not be exact.

See vehicle manuals and Technical Service Information (TSI) bulletins for additional information.

Technical Service Literature

1171809R5	*DT 466, DT 570 and HT 570 Engine Operation and Maintenance Manual*
EGES-265–2	*DT 466, DT 570 and HT 570 Engine Service Manual*
EGES-270	*DT 466, DT 570 and HT 570 Engine Diagnostic Manual*
EGED-285	*DT 466, DT 570 and HT 570 Electronic Control Systems Diagnostic Form (Pad of 50)*
EGED-290	*DT 466, DT 570 and HT 570 Diagnostics Form (Pad of 50)*

Navistar, Inc. is committed to continuous research and development to improve products and introduce technological advances. Procedures, specifications, and parts defined in published technical service literature may be altered.

This *Engine Service Manual* provides a general sequence of procedures for out-of-chassis engine overhaul (removal, inspection, and installation). For in-chassis service of parts and assemblies, the sequence may vary.

NOTE: Photo illustrations identify specific parts or assemblies that support text and procedures; other areas in a photo illustration may not be exact.

See vehicle manuals and Technical Service Information (TSI) bulletins for additional information.

Service Diagnosis

Service diagnosis is an investigative procedure that must be followed to find and correct an engine application problem or an engine problem.

If the problem is engine application, see specific vehicle manuals for further diagnostic information.

If the problem is the engine, see specific *Engine Diagnostic Manual* for further diagnostic information.

Prerequisites for Effective Diagnosis

- Availability of gauges, diagnostic test equipment, and diagnostic software
- Availability of current information for engine application and engine systems
- Knowledge of the principles of operation for engine application and engine systems
- Knowledge to understand and do procedures in diagnostic and service publications

Technical Service Literature required for Effective Diagnosis

- *Engine Service Manual*
- *Engine Diagnostic Manual*
- Diagnostics Forms
- Electronic Control Systems Diagnostics Forms
- Service Bulletins

Safety Information

This manual provides general and specific maintenance procedures essential for reliable engine operation and your safety. Since many variations in procedures, tools, and service parts are involved, advice for all possible safety conditions and hazards cannot be stated.

Read safety instructions before doing any service and test procedures for the engine or vehicle. See related application manuals for more information.

Disregard for Safety Instructions, Warnings, Cautions, and Notes in this manual can lead to injury, death or damage to the engine or vehicle.

Safety Terminology

Three terms are used to stress your safety and safe operation of the engine: Warning, Caution, and Note

Warning: A warning describes actions necessary to prevent or eliminate conditions, hazards, and unsafe practices that can cause personal injury or death.

Caution: A caution describes actions necessary to prevent or eliminate conditions that can cause damage to the engine or vehicle.

Note: A note describes actions necessary for correct, efficient engine operation.

Safety Instructions

Work Area

- Keep work area clean, dry, and organized.
- Keep tools and parts off the floor.
- Make sure the work area is ventilated and well lit.
- Make sure a First Aid Kit is available.

Safety Equipment

- Use correct lifting devices.
- Use safety blocks and stands.

Protective Measures

- Wear protective safety glasses and shoes.
- Wear correct hearing protection.
- Wear cotton work clothing.
- Wear sleeved heat protective gloves.
- Do not wear rings, watches or other jewelry.
- Restrain long hair.

Vehicle

- Make sure the vehicle is in neutral, the parking brake is set, and the wheels are blocked before servicing engine.
- Clear the area before starting the engine.

Engine

- The engine should be operated or serviced only by qualified individuals.
- Provide necessary ventilation when operating engine in a closed area.
- Keep combustible material away from engine exhaust system and exhaust manifolds.
- Install all shields, guards, and access covers before operating engine.
- Do not run engine with unprotected air inlets or exhaust openings. If unavoidable for service reasons, put protective screens over all openings before servicing engine.
- Shut engine off and relieve all pressure in the system before removing panels, housing covers, and caps.
- If an engine is not safe to operate, tag the engine and ignition key.

Fire Prevention

- Make sure charged fire extinguishers are in the work area.

NOTE: Check the classification of each fire extinguisher to ensure that the following fire types can be extinguished.

1. Type A — Wood, paper, textiles, and rubbish
2. Type B — Flammable liquids
3. Type C — Electrical equipment

Batteries

- Always disconnect the main negative battery cable first.
- Always connect the main negative battery cable last.
- Avoid leaning over batteries.
- Protect your eyes.

- Do not expose batteries to open flames or sparks.
- Do not smoke in workplace.

Compressed Air

- Use an OSHA approved blow gun rated at 207 kPa (30 psi).
- Limit shop air pressure to 207 kPa (30 psi).
- Wear safety glasses or goggles.
- Wear hearing protection.
- Use shielding to protect others in the work area.
- Do not direct compressed air at body or clothing.

Tools

- Make sure all tools are in good condition.
- Make sure all standard electrical tools are grounded.
- Check for frayed power cords before using power tools.

Fluids Under Pressure

- Use extreme caution when working on systems under pressure.
- Follow approved procedures only.

Fuel

- Do not over fill the fuel tank. Over fill creates a fire hazard.
- Do not smoke in the work area.
- Do not refuel the tank when the engine is running.

Removal of Tools, Parts, and Equipment

- Reinstall all safety guards, shields, and covers after servicing the engine.
- Make sure all tools, parts, and service equipment are removed from the engine and vehicle after all work is done.

Table of Contents

Engine Identification

Engine Serial Number

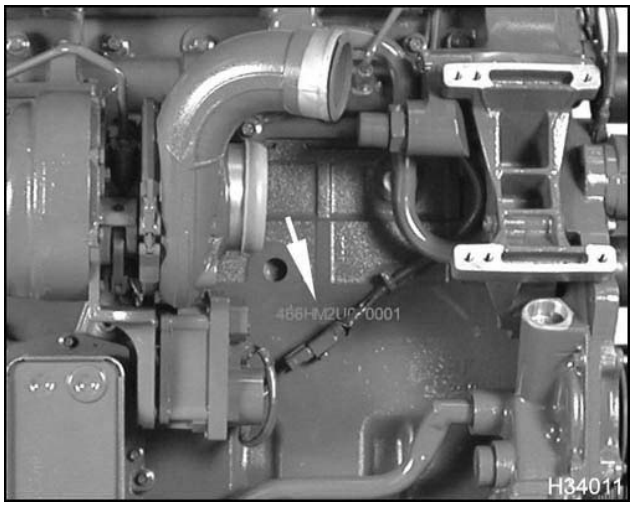


Figure 1 Engine serial number (right side front)

Figure 2 Engine serial number (right side rear)

Engine Serial Number Locations

- The engine serial number is stamped on a crankcase pad on the right side of the crankcase (front for earlier model years and rear for later model years).
- The engine serial number is also on the engine emission label.

Engine Serial Number Examples

DT 466 engine: 466HM2UXXXXXXX

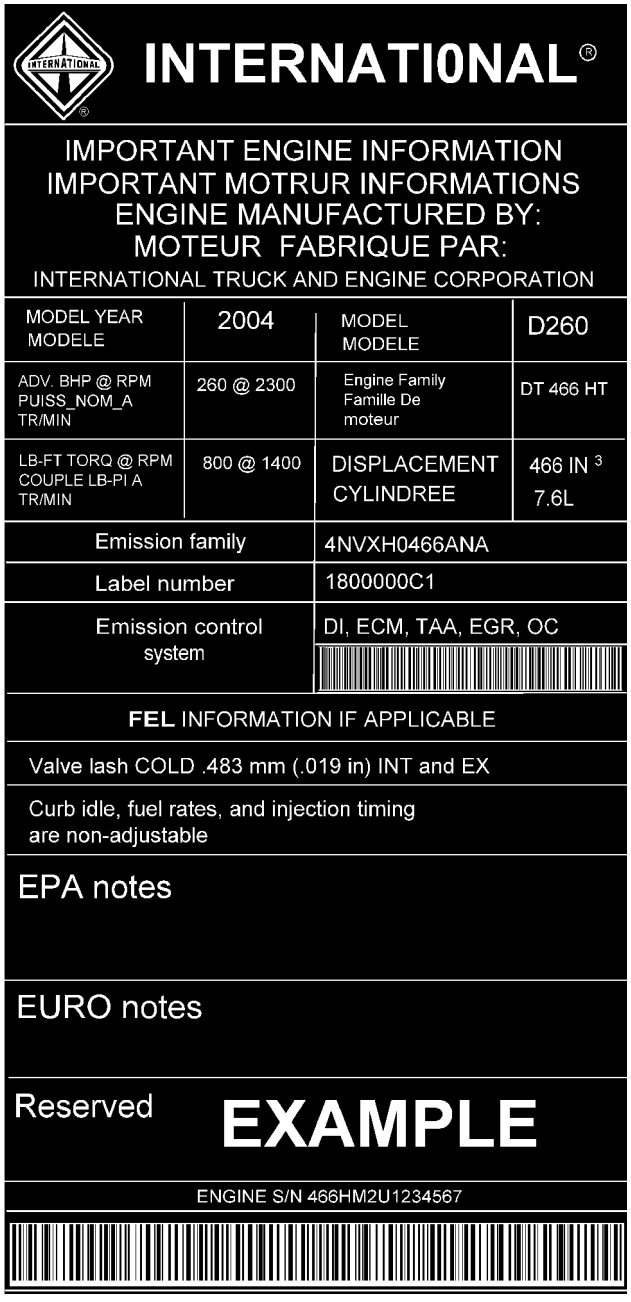
DT 570 engine: 570HM2UXXXXXXX

Engine Serial Number Codes

466 – Engine displacement
570 – Engine displacement
H – Diesel, turbocharged, Charge Air Cooler (CAC), and electronically controlled
M2 – Motor truck
U – United States
7 digit suffix – Engine serial number sequence beginning with 2,000,000

Engine Emission Label

A common emission label is issued for the International® DT 466 and DT 570 diesel engines.



H34005

Figure 3 Engine emission label (Example)

The Environmental Protection Agency (EPA) emission label is on top of the valve cover. The engine label includes the following:

- Model year
- Engine family, model, and displacement
- Advertised brake horsepower and torque rating
- Emission family and control systems
- U.S. Family Emission Limits (FEL), if applicable
- Valve lash specifications
- Engine serial number
- EPA, EURO, and reserved fields for specific applications

Engine Accessories

The following engine accessories may have manufacturer's labels or identification plates:

- Air compressor (for brake or suspension system)
- Air conditioning compressor
- Alternator
- Cooling fan clutch
- EVRT® electronically controlled turbocharger – International's version of a Variable Geometry Turbocharger (VGT)
- Power steering pump
- Starter motor

Labels or identification plates include information and specifications helpful to vehicle operators and technicians.

Engine Description

Table 1 International® DT 466 and DT 570 Features and Specifications

Engine	4 stroke, in-line six cylinder diesel
Configuration	Four valves per cylinder
Displacement	7.6 L (466 in^3)
Displacement	9.3 L (570 in^3)
Bore (sleeve diameter)	116.6 mm (4.59 in)
Stroke	
DT 466	119 mm (4.68 in)
DT 570	146 mm (5.75 in)
Compression ratio	
DT 466	16.5 : 1
DT 570	17.5 : 1
Aspiration	VGT turbocharged and Charge Air Cooled (CAC)
Rated power @ rpm	
DT 466*	210 bhp @ 2600 rpm
DT 570**	285 bhp @ 2200 rpm
Peak torque @ rpm	
DT 466*	520 lbf•ft @ 1400 rpm
DT 570**	800 lbf•ft @ 1200 rpm
Engine rotation (facing flywheel)	Counterclockwise
Combustion system	Direct injection turbocharged
Fuel system	International® electro-hydraulic generation 2 injection
Total engine weight (dry without accessories)	
DT 466	671 kg (1,480 lbs)
DT 570	708 kg (1,560 lbs)
Cooling system capacity (engine only)	12.8 L (13.5 qts US)
Lube system capacity (including filter)	28 L (30 qts US)
Lube system capacity (overhaul only, with filter)	34 L (36 qts US)
Firing order	1-5-3-6-2-4

* Base rating shown. See Appendix A in the *Engine Diagnostics Manual*.

**Base rating shown. See Appendix B in the *Engine Diagnostics Manual*.

Engine Features

Table 2

Standard Features	Optional Features
Four valves per cylinder	Air compressor
Dual timing sensors	Power steering pump
Replaceable piston and sleeve configuration	Front cover PTO access
Gerotor lube oil pump	Engine Fuel Pressure (EFP) sensor
International® common rail high-pressure injection system	Diamond Logic® engine brake
Variable Geometry Turbocharger (VGT)	Diamond Logic® exhaust brake
Exhaust Gas Recirculation (EGR)	Fuel heater
Water supply housing (Freon® compressor bracket)	Oil pan heater
Alternator bracket	Coolant heater assembly
Control modules	
Water In Fuel (WIF) separation	
Water In Fuel (WIF) sensor	
Inlet Air Heater (IAH) – single or dual element	

Standard Features

DT 466, DT 570, and HT 570 are in-line six cylinder engines (medium range). Engine displacements are 7.6 liters (466 cubic inches) for the DT 466 and 9.3 liters (570 cubic inches) for the DT 570, and HT 570. The firing order of the cylinders is 1–5–3–6–2–4.

The cylinder head has four valves per cylinder for improved air flow. Each fuel Injector is centrally located between the four valves and directs fuel over the piston bowl for improved performance and reduced emissions. The overhead valve train includes mechanical roller lifters, push rods, rocker arms, and dual valves that open using a valve bridge.

A one piece crankcase withstands high-pressure loads during diesel operation.

The lower end of the DT 570 and HT 570 engines (for ratings above 300 hp) includes a crankcase ladder designed to absorb additional loads generated by increased horsepower. Seven main bearings support the crankshaft for DT 466, DT 570, and HT 570 engines. Fore and aft thrust are controlled at the rear bearing. Four insert bushings support the camshaft for each engine. The rear oil seal carrier is part of the flywheel housing. The open crankcase breather assembly uses a road draft tube to vent crankcase pressure and an oil separator that returns oil to the crankcase.

The crankshaft (CKP) and camshaft (CMP) sensors are used by the ECM and IDM to calculate rpm, fuel timing, fuel quantity, and duration of fuel injection.

Two different kinds of pistons are used in the in-line engines:

- The DT 466 engine has one piece aluminum alloy pistons.
- The DT 570 and HT 570 engines have two piece articulated pistons with a steel crown.

All pistons are mated to fractured cap joint connecting rods. Replaceable wet cylinder sleeves are used with the pistons.

A gerotor lube oil pump, mounted to the front cover, is driven directly by the crankshaft. All engines use an oil cooler and spin-on oil filter.

A low-pressure fuel supply pump draws fuel from the fuel tank through a fuel filter assembly that includes a strainer, filter element, primer pump, drain valves,

and Water In Fuel (WIF) sensor. After filtering, fuel is pumped to the cylinder head fuel rail.

The International® common rail high-pressure injection system includes a cast iron oil manifold, fuel injectors, and a high-pressure oil pump.

The key feature of the VGT is actuated vanes in the turbine housing. The vanes modify flow characteristics of exhaust gases through the turbine housing. The benefit is the ability to control boost pressure for various engine speeds and load conditions. An additional benefit is lower emissions.

An EGR control valve regulates cooled exhaust gases entering the inlet air stream. Cool exhaust gas increases engine tolerance for EGR, while reducing smoke formed by gas dilution in the mixture. Three EGR coolers are available depending on applications.

A water supply housing (Freon® compressor bracket) is a coolant supply housing that includes an auxiliary water connection.

Three control modules monitor and control the electronic engine systems:

- Diamond Logic® engine controller – Electronic Control Module (ECM)
- Injector Drive Module (IDM)
- Exhaust Gas Recirculation (EGR) drive module

Water In Fuel (WIF) separation occurs when the filter element repels water molecules and water collects at the bottom of the element cavity in the fuel filter housing.

A Water In Fuel (WIF) sensor in the element cavity of the fuel filter housing detects water. When enough water accumulates in the element cavity, the WIF sensor sends a signal to the Electronic Control Module (ECM). A fuel drain valve handle on the housing can be opened to drain water from the fuel filter housing.

An Inlet Air Heater (IAH) – a single or dual element – warms the intake air entering the cylinder head.

Optional Features

An air compressor is available for applications requiring air brakes or air suspension.

A hydraulic power steering pump can be used with or without an air compressor.

The front cover includes a mounting flange for Power Take Off (PTO) accessories. The air compressor drive gear train, used with a spline adapter, provides power for front mounted PTO accessories.

An optional Engine Fuel Pressure (EFP) sensor detects low pressure caused by high fuel filter restriction and sends a signal to the ECM; the ECM illuminates the amber FUEL FILTER lamp on the instrument panel.

The Diamond Logic® engine brake is new for medium range diesel engines. This compression braking system uses a high-pressure rail assembly and the VGT for additional braking. The operator controls the engine brake for different operating conditions.

The Diamond Logic® exhaust brake system uses only the VGT to restrict exhaust flow for additional braking. The operator controls the exhaust brake for different operating conditions.

Options for vehicles and applications used in cold climates include the following:

- **Oil pan heater**

  The oil pan heater warms engine oil in the pan and ensures oil flow to the injectors.

- **Coolant heater**

  The coolant heater raises the temperature of coolant surrounding the cylinders for improved performance and fuel economy during start-up.

- **Fuel heater**

  The fuel heater (a 300 watt element) in the base of the fuel filter assembly heats the fuel for improved performance.

Engine Component Locations

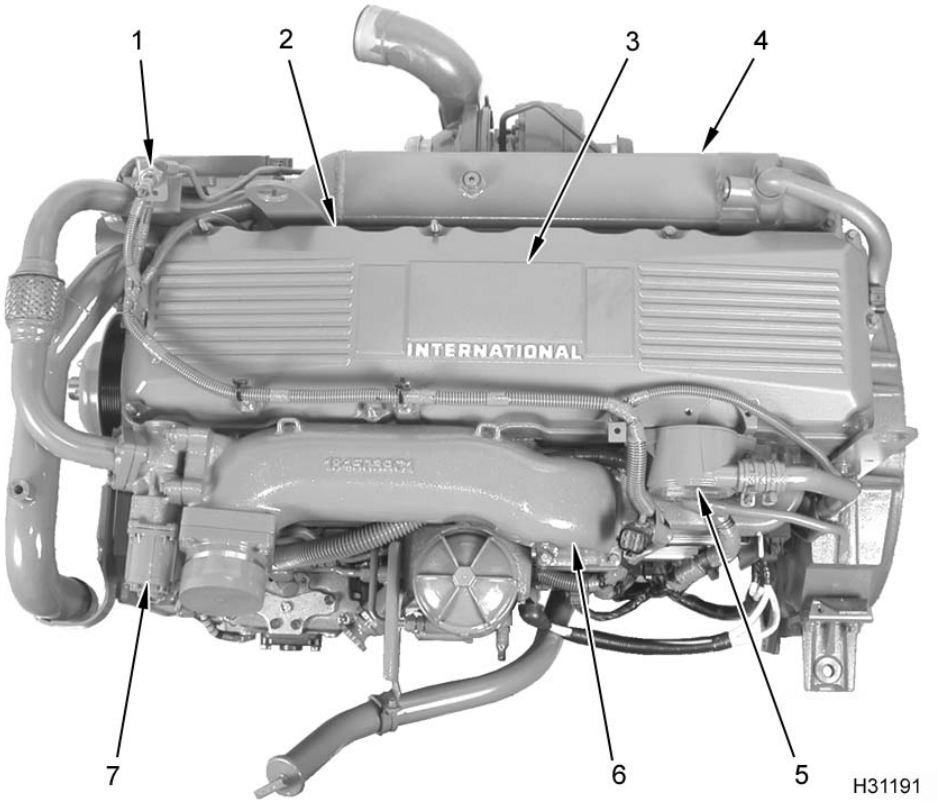


Figure 4 Component location – top

1. Exhaust Back Pressure (EBP) sensor
2. Valve cover
3. Exhaust emission label (location)
4. EGR cooler assembly
5. Breather assembly
6. Inlet and EGR mixer duct
7. EGR control valve

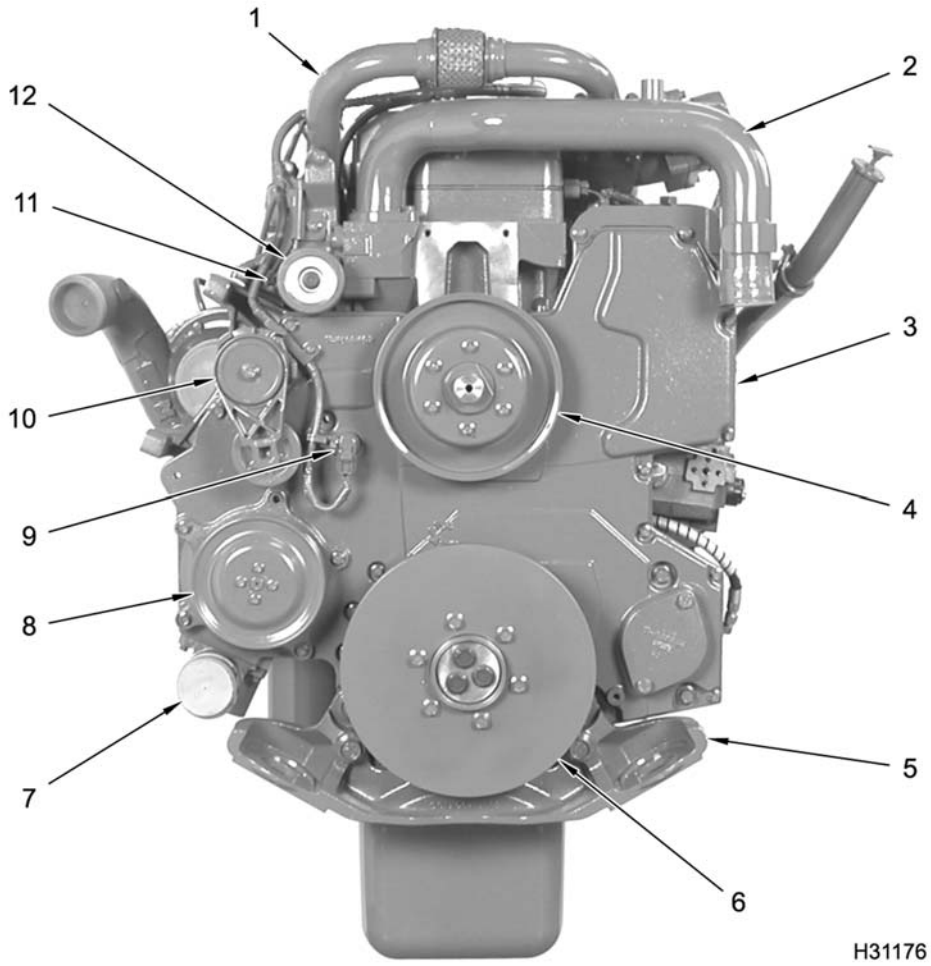


Figure 5 Component location – front

1. Exhaust gas crossover (EGR cooler to EGR valve)
2. Water outlet tube assembly (thermostat outlet)
3. Front cover (front half)
4. Fan drive pulley
5. Engine mounting bracket (front)
6. Vibration damper
7. Water inlet elbow
8. Water pump pulley
9. Camshaft Position (CMP) sensor
10. Auto tensioner assembly (belt)
11. ECT sensor (location)
12. Flat idler pulley assembly

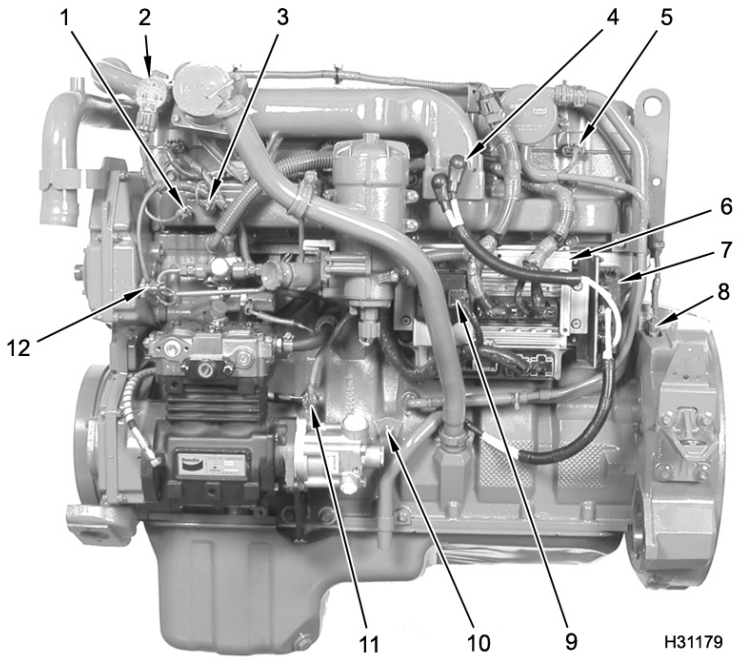


Figure 6 Component location, electrical– left

1. Manifold Absolute Pressure (MAP) sensor
2. EGR control valve
3. Manifold Air Temperature (MAT) sensor
4. Inlet Air Heater (IAH) cable – dual element
5. Valve cover gasket pass-through connector
   a. (Six) four wire connectors for fuel injectors
   b. (One) three wire connector for ICP sensor
   c. Engine brake application – (one) three wire connector for the BCP sensor and (one) three wire connector for the brake valve.
6. ECM and IDM module assembly
7. IAH relay
8. Crankshaft Position (CKP) sensor
9. EGR drive module
10. Ground stud
11. Engine Oil Pressure (EOP) sensor
12. Engine Oil Temperature (EOT) sensor

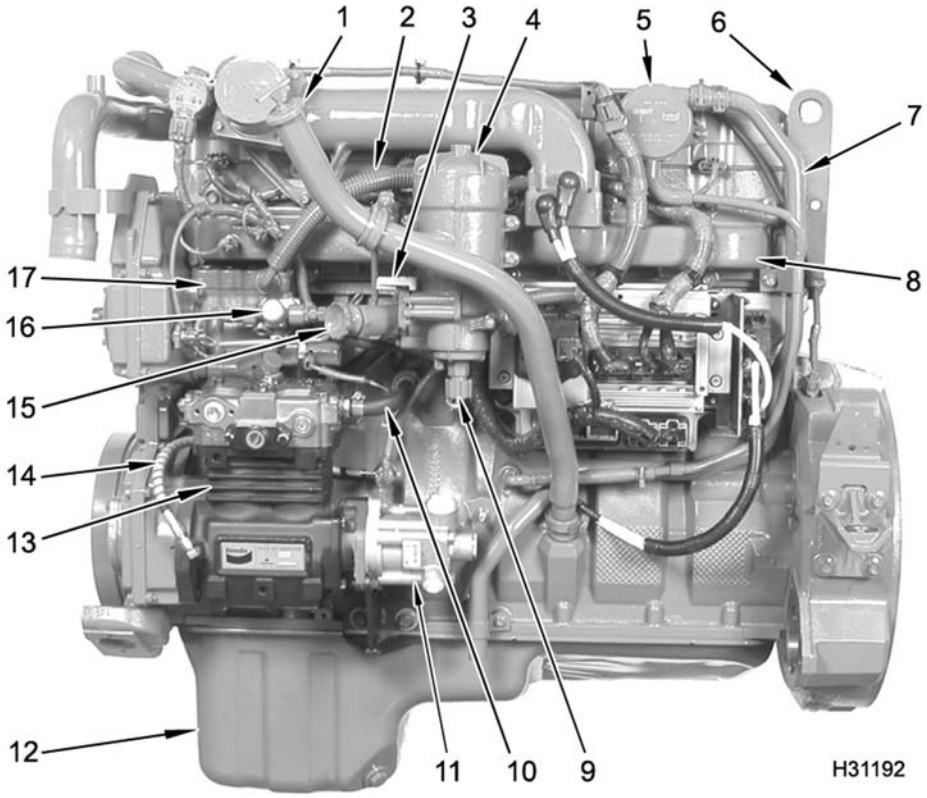


Figure 7 Component location, mechanical – left

1. Oil level gauge tube
2. High-pressure oil hose
3. Water drain valve (fuel)
4. Fuel filter header assembly
5. Breather assembly
6. Lifting eye
7. Vent and drain tube assembly
8. Intake manifold
9. Drain valve (fuel strainer)
10. Coolant line
11. Power steering pump
12. Oil pan assembly
13. Air compressor
14. Oil supply line
15. Fuel primer pump assembly
16. Low-pressure fuel supply pump
17. High-pressure oil pump assembly

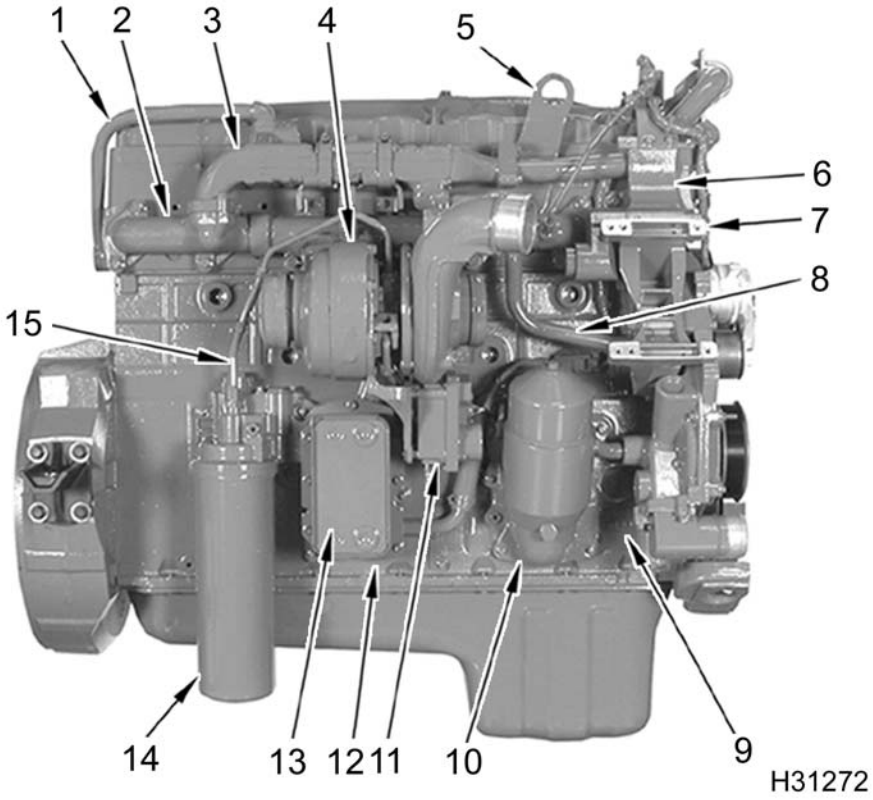


Figure 8 Component location – right

1. EGR cooler return tube assembly
2. Exhaust manifold assembly
3. EGR cooler assembly
4. Variable Geometry Turbocharger (VGT)
5. Engine lifting eye
6. Water supply housing (Freon® compressor bracket)
7. Alternator bracket
8. EGR cooler supply tube assembly
9. Crankcase
10. Secondary filtration filter (optional)
11. Turbocharger control module
12. Coolant drain plug (underneath location)
13. Oil cooler
14. Oil filter
15. Turbo oil inlet tube (supply)

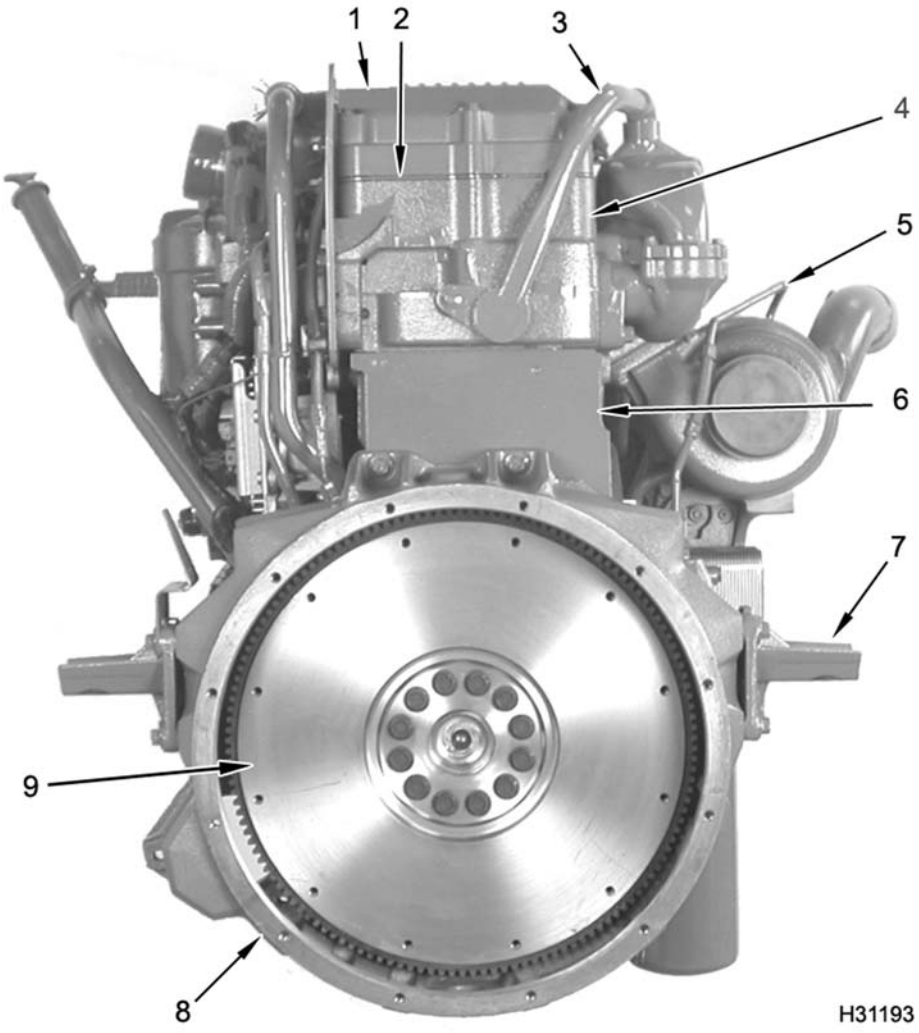


Figure 9 Component location – rear

1. Valve cover
2. Valve cover gasket with pass-through connectors
3. EGR cooler return tube assembly
4. Cylinder head assembly
5. Turbo oil inlet tube (supply)
6. Crankcase
7. Rear engine mount brackets (2)
8. Flywheel housing
9. Flywheel or flexplate assembly

Engine Systems

Engine System Diagram

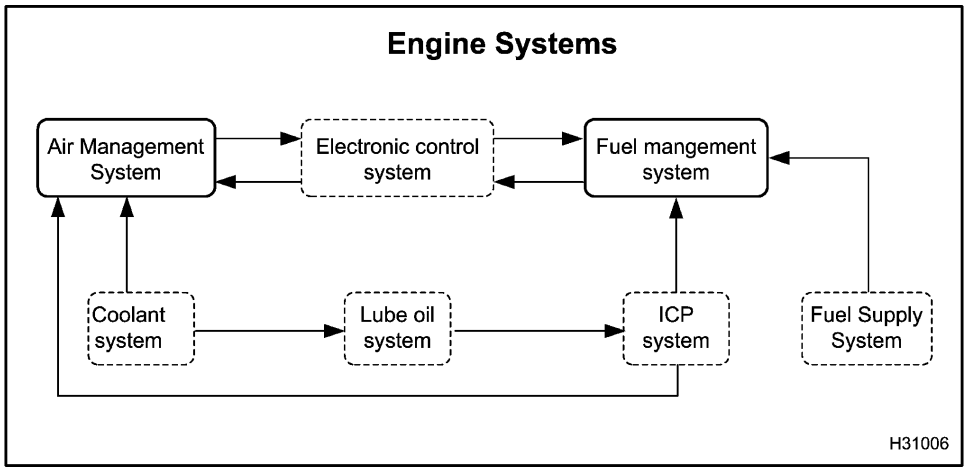


Figure 10 Engine systems

The primary engine systems are Air Management and Fuel Management which share some subsystems or have a subsystem that contributes to their operation.

- The Electronic Control system controls the Air Management System and Fuel Management System.
- The Coolant System provides heat transfer for EGR gases and lubrication oil.
- The Lube Oil System provides lubrication and heat transfer to engine components.
- The ICP system uses lube oil for hydraulic fluid to actuate the fuel injectors.
- The Fuel Supply System pressurizes fuel for transfer to the fuel injectors.

Air Management System

Air Management Components and Air Flow

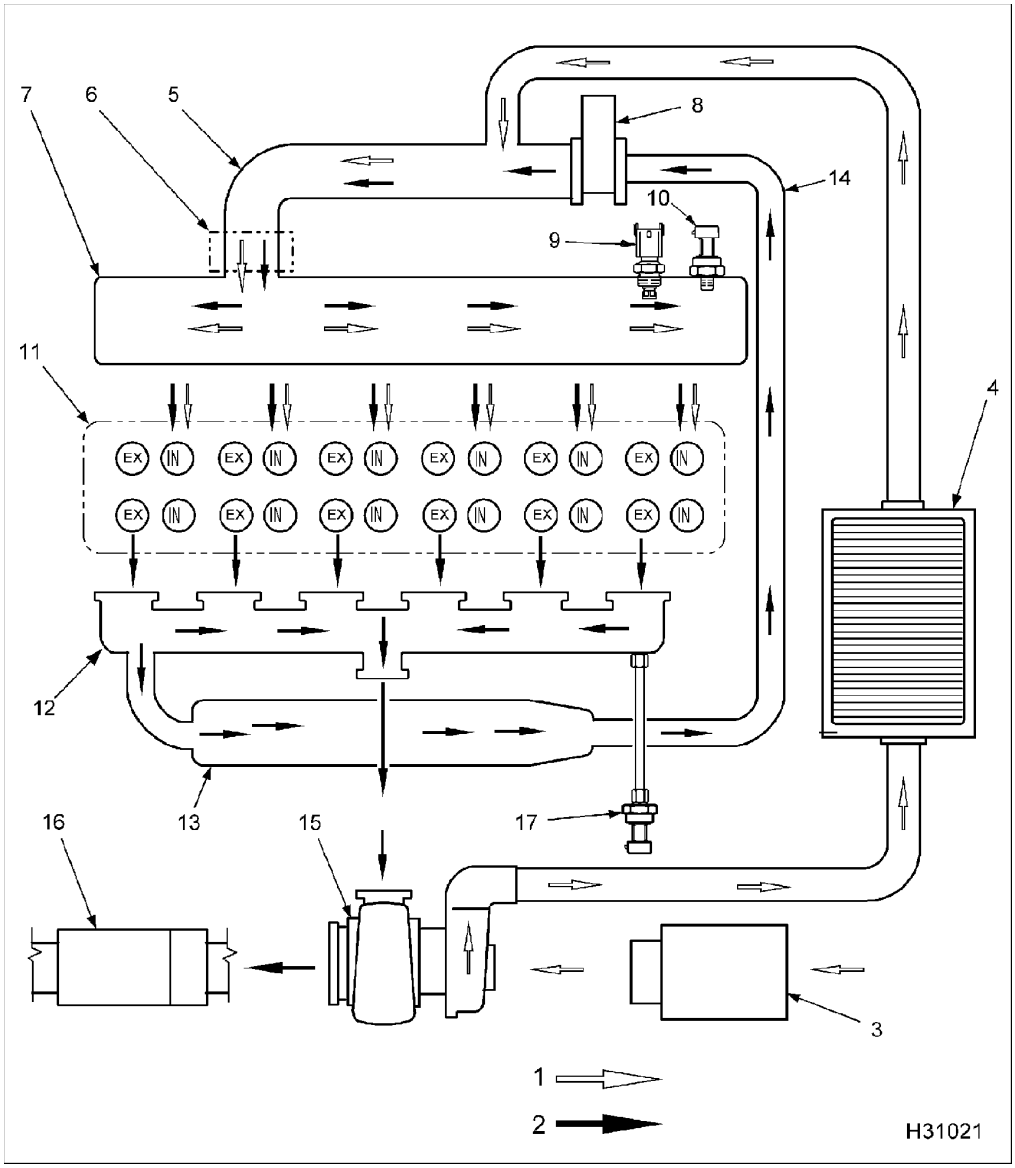


Figure 11 Air Management System (AMS)

1. Intake air
2. Exhaust gas
3. Air cleaner
4. Charge Air Cooler (CAC)
5. Inlet and EGR mixer duct
6. Inlet Air Heater (IAH) assembly – single or dual element
7. Intake manifold
8. EGR valve
9. Manifold Absolute Pressure (MAP) sensor
10. Manifold Air Temperature (MAT) sensor
11. Cylinder head
12. Exhaust manifold
13. EGR cooler
14. Exhaust gas crossover
15. Variable Geometry Turbocharger (VGT)
16. Muffler
17. Exhaust Back Pressure (EBP) sensor

The Air Management system includes the following:

- Air filter assembly
- Chassis mounted Charged Air Cooler (CAC)
- Variable Geometry Turbocharger (VGT)
- Inlet Air Heater (IAH) assembly – single or dual element
- Intake manifold
- Exhaust Gas Recirculation (EGR) system
- Exhaust system
- Inlet and EGR mixer duct
- Diamond Logic® engine brake
- Catalytic converter– dependent on application
- Catalyzed Diesel Particulate Filter (CDPF) – dependent on application

Air Flow

Air flows through the air filter assembly and enters the Variable Geometry Turbocharger (VGT). The compressor in the VGT increases the pressure, temperature, and density of the intake air before it enters the Charge Air Cooler (CAC). Cooled compressed air flows from the CAC into the EGR mixer duct.

- If the EGR control valve is open, exhaust gas will mix with filtered intake air and flow into the intake manifold.
- If the EGR control valve is closed, only filtered air will flow into the intake manifold.

After combustion, exhaust gas is forced through the exhaust manifold to the EGR cooler and VGT.

- Some exhaust gas is cooled in the EGR cooler and flows through the EGR control valve to the EGR mixer duct. When exhaust gas mixes with filtered air, nitrogen oxide (NOx) emissions and noise are reduced.
- The rest of the exhaust gas flows to the VGT, spins and expands through the turbine wheel, varying boost pressure.
- The VGT compressor wheel, on the same shaft as the turbine wheel, compresses the mixture of filtered air.

The VGT responds directly to engine loads. During heavy load, an increased flow of exhaust gases turns the turbine wheel faster. This increased speed turns the compressor impeller faster and supplies more air or greater boost to the intake manifold. Conversely, when engine load is light, the flow of exhaust gas decreases and less air is directed into the intake manifold.

Charge Air Cooler (CAC)

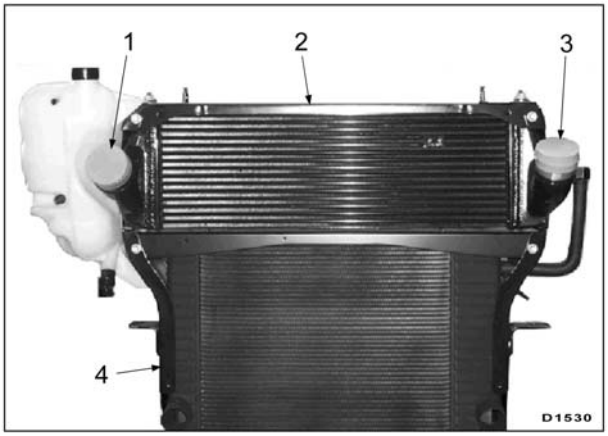


Figure 12 Charge Air Cooler (typical)

1. Air outlet
2. Charge Air Cooler (CAC)
3. Air inlet
4. Radiator

The CAC is mounted on top of the radiator. Air from the turbocharger passes through a network of heat exchanger tubes before entering the EGR mixer duct. Outside air flowing over the tubes and fins cools the charged air. Charged air is cooler and denser than the uncooled air; cooler and denser air improves the fuel-to-air ratio during combustion, resulting in improved emission control and power output.

Variable Geometry Turbocharger (VGT)

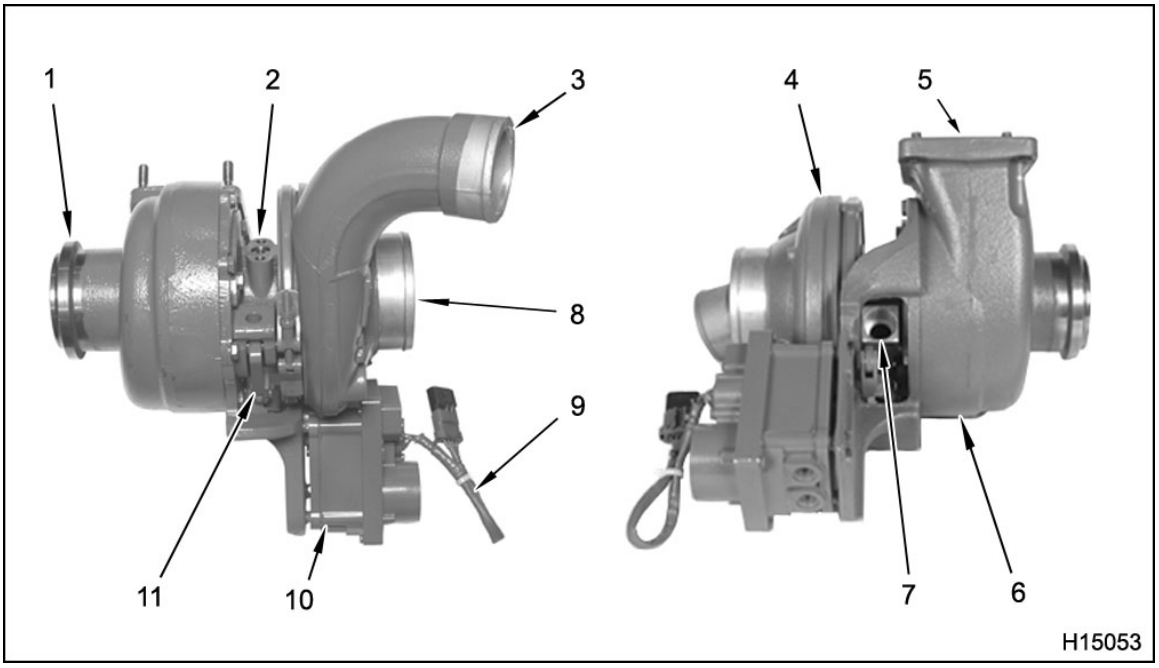


Figure 13 Variable Geometry Turbocharger (VGT)

1. Turbine outlet
2. Oil supply port
3. Compressor outlet
4. Compressor housing
5. Turbine inlet
6. Turbine housing
7. Oil drain port
8. Compressor inlet
9. Electrical connector and wire
10. Turbocharger control module
11. VGT linkage

The Variable Geometry Turbocharger (VGT) has actuated vanes in the turbine housing. The vanes modify flow characteristics of exhaust gases through the turbine housing. The benefit is the ability to control boost pressure for various engine speeds and load conditions. An additional benefit is lower emissions.

VGT Closed Loop System

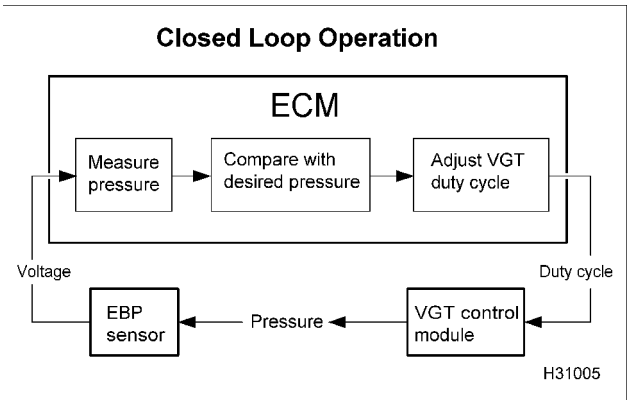


Figure 14 VGT closed loop system

The Variable Geometry Turbocharger (VGT) is a closed loop system that uses the Exhaust Back Pressure (EBP) sensor to provide feedback to the ECM. The ECM uses the EBP sensor to continuously

monitor EBP and adjust the duty cycle to the VGT to match engine requirements.

VGT Control

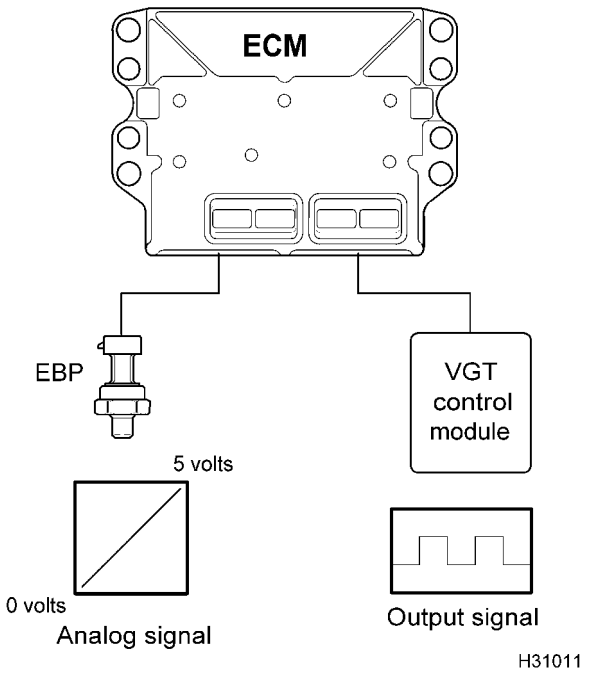


Figure 15 VGT control

The VGT actuator is a control module that contains a microchip and a DC motor. The VGT actuator is located below the turbocharger. The microchip operates a DC motor which rotates a crank lever controlling the vane position in the turbine housing. The position of the vanes is based off the pulse-width modulated signal sent from the ECM.

Actuated vanes are mounted around the inside circumference of the turbine housing. A unison ring links all the vanes. When the unison ring moves, all vanes move to the same position. Unison ring movement occurs when the crank lever in the control module moves.

Exhaust gas flow can be regulated depending on required exhaust back pressure for engine speed and load. As demand for EBP increases, the ECM increases the pulse-width modulation to the VGT control module. When EBP demand decreases, the ECM decreases the duty cycle to the control module.

Exhaust Gas Recirculation (EGR) System

The EGR system includes the following:

- EGR control valve
- EGR cooler
- Intake manifold
- Inlet and EGR mixer duct
- Exhaust manifold
- Exhaust gas crossover

The Exhaust Gas Recirculation (EGR) system reduces Nitrogen Oxide (NOx) emissions.

NO_x forms during a reaction between nitrogen and oxygen at high temperature during combustion. Combustion starts when fuel is injected into the cylinder before or slightly after the piston reaches top-dead-center.

EGR Flow

Some exhaust from the exhaust manifold flows into the EGR cooler. Exhaust from the EGR cooler flows through the exhaust gas crossover to the EGR valve.

When EGR is commanded, the EGR control valve opens allowing cooled exhaust gases to enter the EGR mixer duct to be mixed with filtered intake air.

EGR Control Valve

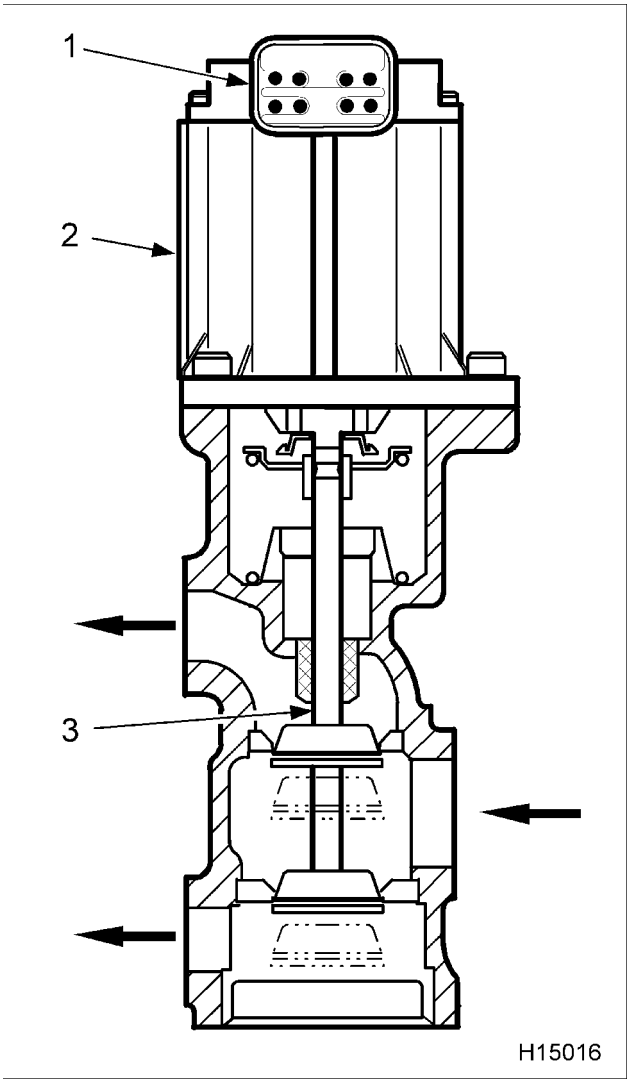


Figure 16 EGR control valve

1. Connector
2. DC motor with position sensor
3. Valve assembly

The EGR valve uses a DC motor to control the position of the valve assembly. The motor pushes directly on the valve assembly. The valve assembly has two valve heads on a common shaft.

The EGR actuator consists of three major components, a valve, an actuator motor, and Integrated Circuit (IC). The IC has three Hall effect position sensors to monitor valve movement. The

EGR actuator is located at the front of the engine on the intake manifold.

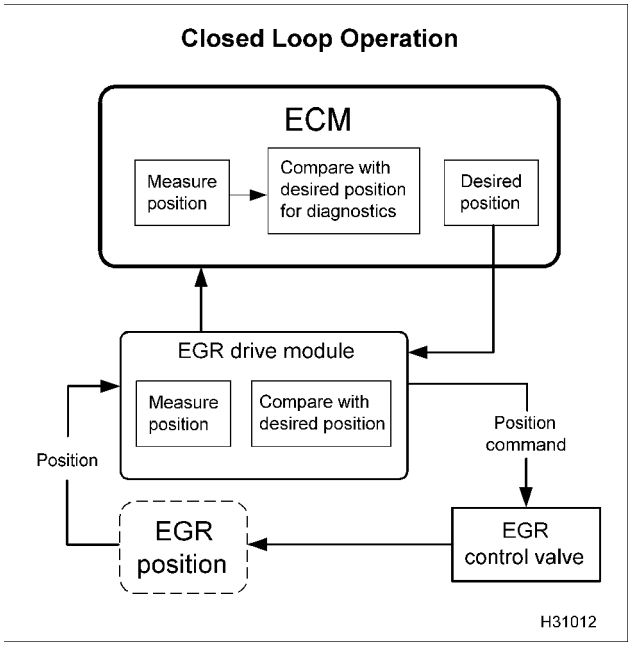


Figure 17 EGR closed loop operation with fault management

The EGR drive module controls the EGR actuator and is located on the left side of the engine on the ECM and Injector Driver Module (IDM).

The EGR drive module receives the desired EGR actuator position from the ECM across the CAN 2 datalink to activate the valve for exhaust gas recirculation. The EGR drive module provides feedback to the ECM on the valve position. The EGR drive module interprets the ECM command and sends the command using three pulse-width modulated signals to the valve actuator.

The system is closed loop control using the EGR position signals.

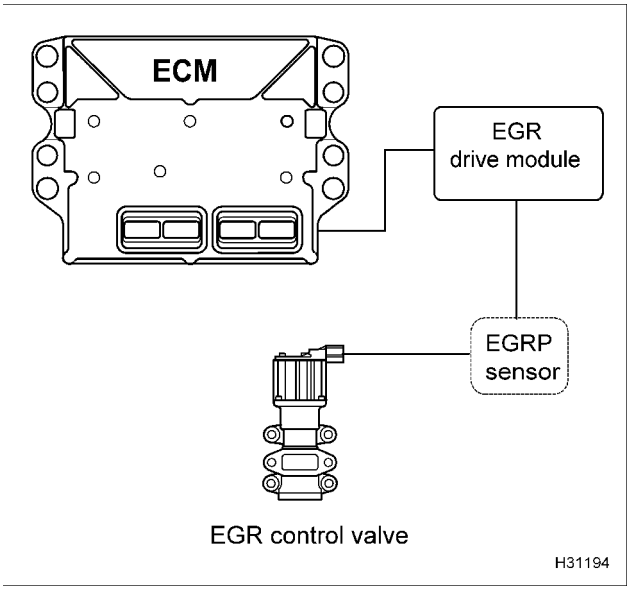


Figure 18 EGR control

Exhaust System

The exhaust system includes the following:

- Exhaust valves
- Exhaust manifold
- Diamond Logic® engine brake
- Variable Geometry Turbocharger (VGT)
- Exhaust piping
- Muffler and catalytic converter – dependent on application
- Catalyzed Diesel Particulate Filter (CDPF) – dependent on application

The exhaust system removes exhaust gases from the engine. Exhaust gases exit from exhaust valves, through exhaust ports, and flow into the exhaust manifold. Expanding exhaust gases are directed through the exhaust manifold. The exhaust manifold directs some exhaust gases into the Exhaust Gas Recirculation (EGR) cooler. Exhaust gases flowing into the turbocharger drive the turbine wheel. Exhaust gases exit the turbocharger and flow into the exhaust piping, through the muffler and catalytic converter or CDPF, depending on application, and out the discharge pipe to the atmosphere.

Fuel Management System

Fuel Management Components

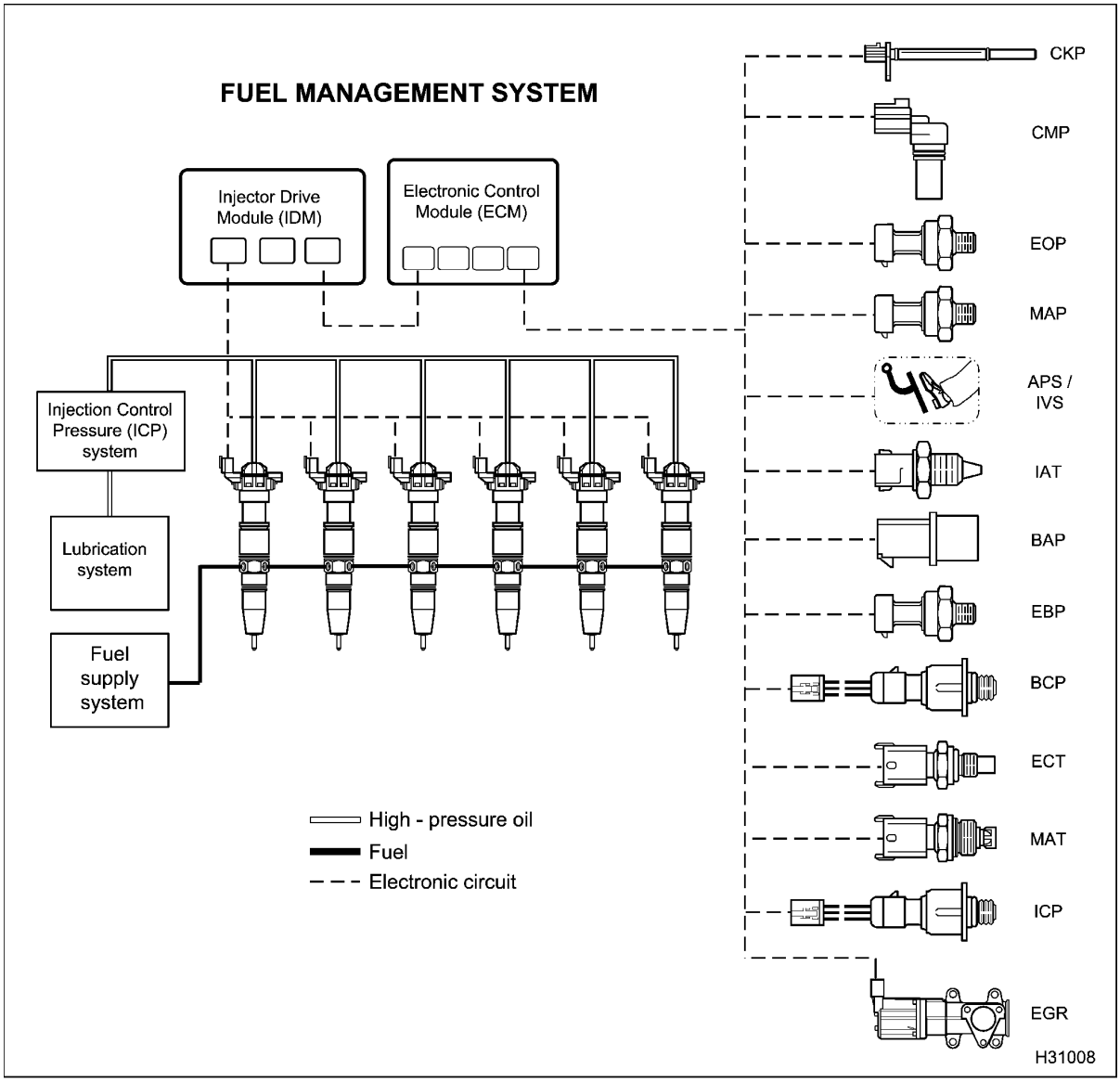


Figure 19 Fuel management system

The fuel management system includes the following:

- Injection Control Pressure (ICP) system
- Fuel supply system
- Fuel injectors
- Lubrication system
- Electronic control system

Injection Control Pressure (ICP) System Components and High-pressure Oil Flow

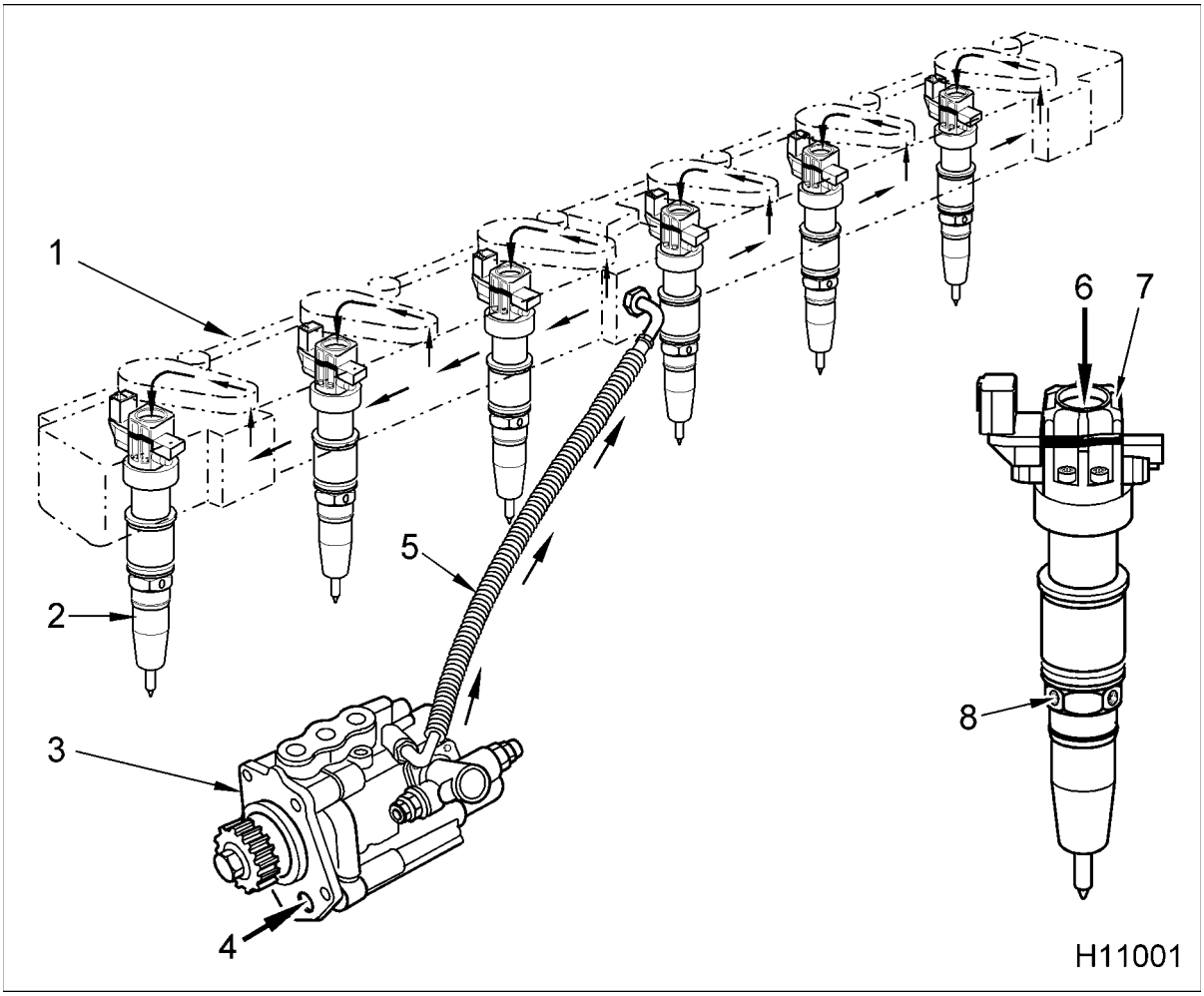


Figure 20 Injection Control Pressure (ICP) system

1. High-pressure oil manifold assembly
2. Fuel injector
3. High-pressure pump assembly
4. High-pressure oil inlet (pump)
5. High-pressure oil hose
6. High-pressure oil inlet (injector)
7. Oil exhaust port (2)
8. Fuel inlet (4)

High-pressure Oil Flow

The oil reservoir in the front cover provides a constant supply of oil to a high-pressure oil pump mounted to the backside of the front cover. Oil drawn from the oil reservoir is constantly refilled by the engine lubrication system.

The gear-driven, high-pressure oil pump delivers oil through a high-pressure oil hose, through a cylinder head passage into the high-pressure oil manifold beneath the valve cover. The manifold distributes to the top of each fuel injector.

When the OPEN coil for each injector is energized, the injectors use high-pressure oil to inject and atomize fuel in the combustion chambers. To end injection, the CLOSE coils are energized. Exhaust oil exits through two ports in the top of the fuel injectors, then drains back to sump.

Injection Control Pressure (ICP) Closed Loop System

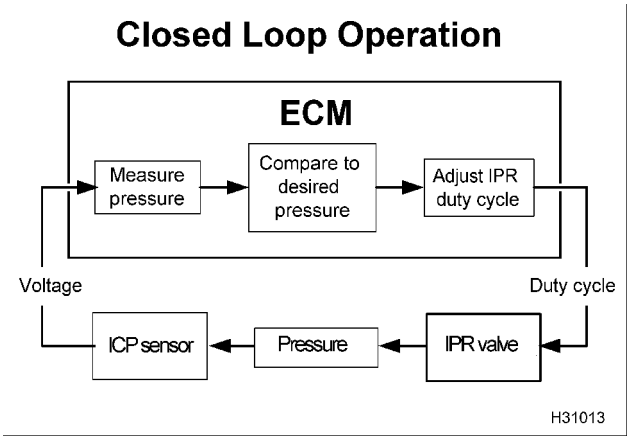


Figure 21 ICP closed loop system

The ICP is a closed loop system that uses the ICP sensor to provide feedback to the ECM. The ECM uses the ICP sensor to continuously monitor injection control pressure and adjust the duty cycle of the IPR valve to match engine requirements.

ICP System Control

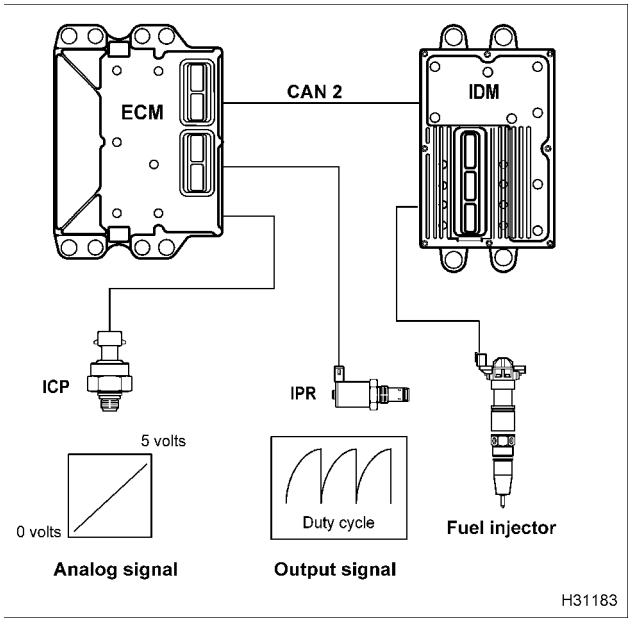


Figure 22 ICP control

ICP Operation

The IPR solenoid receives a pulse width modulated signal from the ECM that indicates the on and off time the control valve is energized. The pulse is calibrated to control ICP pressure in a range from 5 MPa (725 psi) up to 28 MPa (4,075 psi). Maximum pressure relief occurs at about 32 MPa (4,600 psi).

The IPR valve is mounted in the body of the high-pressure pump. The IPR valve maintains the desired ICP by dumping excess oil back to the crankcase sump.

As demand for ICP increases, the ECM increases the pulse - width modulation to the IPR solenoid. When ICP demand decreases, the ECM decreases the duty cycle to the solenoid, allowing more oil to flow from the drain orifice.

The ECM sets Diagnostic Trouble Codes (DTCs), if the ICP electrical signal is out of range. DTCs are also set if an ICP signal corresponds to an out of range value for injection control pressure for a given operating condition.

The ECM will ignore ICP signals that are out of range and the IPR valve will operate from programmed default values. This is called Open Loop operation.

The ICP sensor is installed under the valve cover, forward of the No. 6 fuel injector in the high-pressure oil rail.

Fuel Injectors

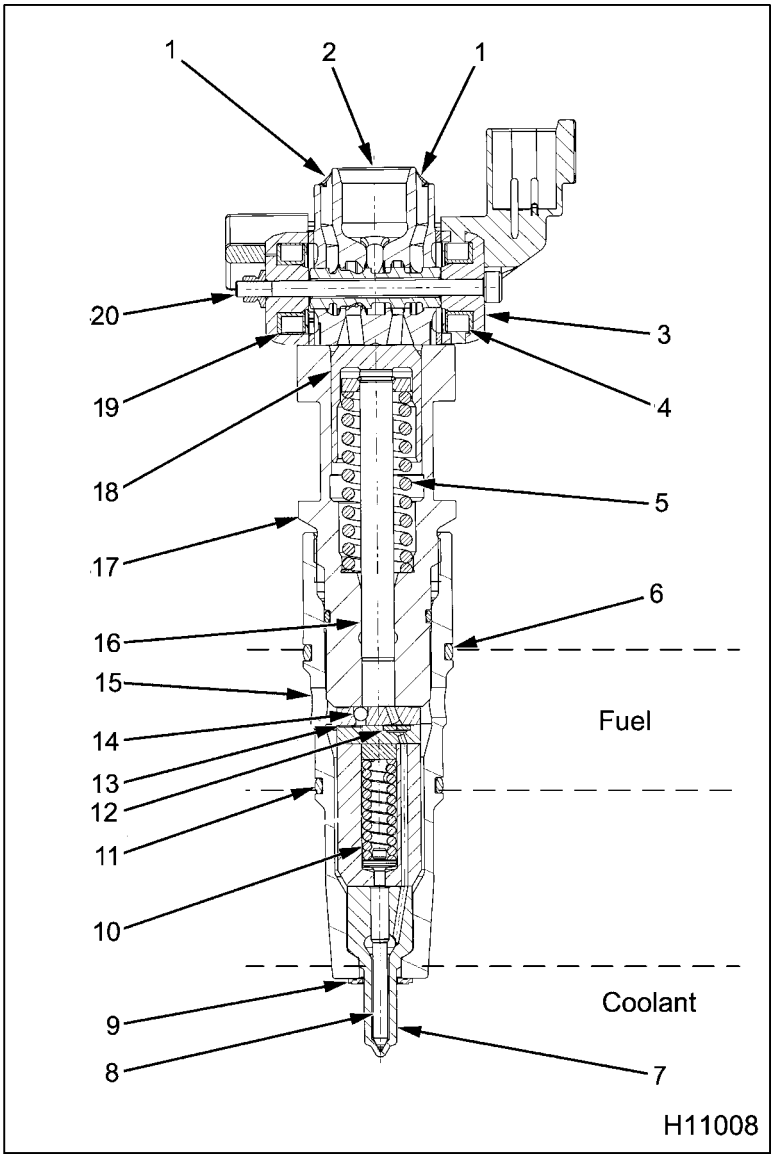


Figure 23 Fuel injector assembly

1. Exhaust port (oil)
2. Inlet port (oil)
3. Control valve body
4. OPEN coil
5. Intensifier piston spring
6. Upper O-ring
7. Nozzle assembly
8. Needle
9. Nozzle gasket
10. Valve Opening Pressure (VOP) spring
11. Lower O-ring
12. Reverse flow check
13. Edge filter
14. Fuel inlet check ball
15. Fuel inlet (4)
16. Plunger
17. Barrel
18. Intensifier piston
19. CLOSE coil
20. Spool valve (control valve)

Fuel Injector Features

Two 48 volt 20 amp coils control a spool valve that directs oil flow in and out of the injector. The injector coils are turned on for approximately 800 µs (microseconds or millionths of a second). Each injector has a single four pin connector that couples to the valve cover gasket assembly.

Injector Coils and spool valve

An OPEN coil and a CLOSE coil on the injector move the spool valve from side to side using magnetic force. The spool has two positions:

- When the spool valve is open, oil flows into the injector from the high-pressure oil rail.
- When the spool valve is closed oil exhausts from the top of the fuel injector and drains back to the crankcase.

Intensifier piston and plunger

When the spool valve is open, high-pressure oil enters the injector pushing down the intensifier piston and plunger. Since the intensifier piston is 7.1 times greater in surface area than the plunger, the injection pressure is also 7.1 times greater than ICP pressure on the plunger.

Plunger and barrel

Fuel pressure builds at the base of the plunger in the barrel. When the intensifier piston pushes the plunger down, the plunger increases fuel pressure in the barrel 7.1 times greater than ICP. The plunger has tungsten carbide coating to resist scuffing.

Injector needle

The injector needle opens inward, off its seat when fuel pressure overcomes the Valve Opening Pressure (VOP) of 28 MPa (4,075 psi). Fuel is atomized at high pressure through the nozzle tip.

Fuel Injector Operation

The injection operation has three stages:

- Fill stage
- Main injection
- End of main injection

Fill stage

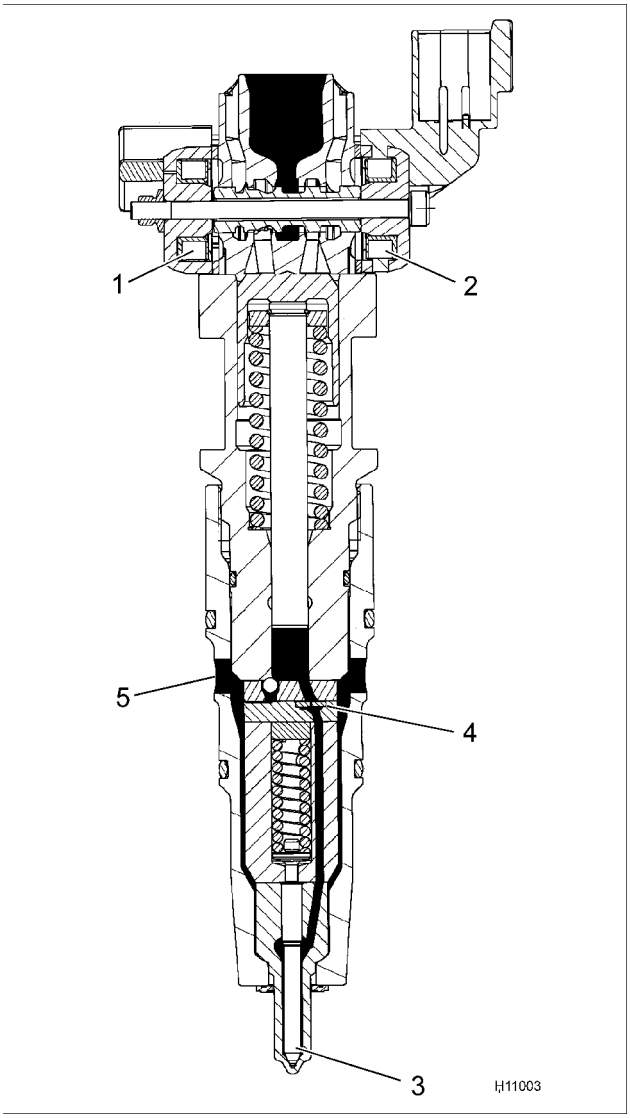


Figure 24 Fill stage

1. CLOSE coil (off)
2. OPEN coil (off)
3. Needle (seated)
4. Disk check (seated)
5. Fuel inlet (4)

During the fill stage both coils are de-energized and the spool valve is closed. High-pressure oil from the high-pressure oil rail is deadheaded at the spool valve.

Low-pressure fuel fills the four ports and enters through the edge filter on its way to the chamber

beneath the plunger. The needle control spring holds the needle onto its seat to prevent fuel from entering the combustion chamber.

Main injection (Step 1)

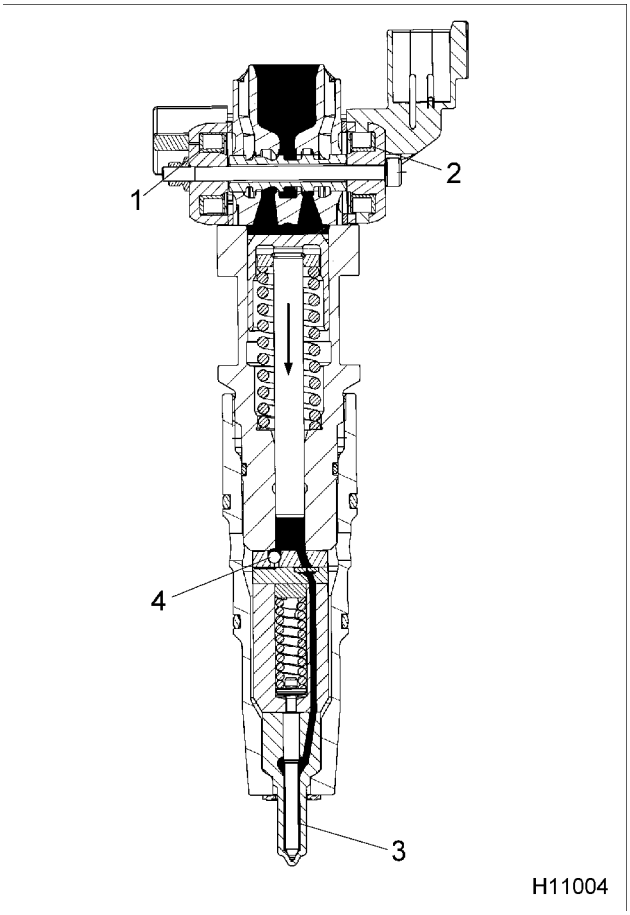


Figure 25 Main injection (Step 1)

1. CLOSE coil (off)
2. OPEN coil (on)
3. Needle (seated)
4. Fuel inlet check ball (seated)

A pulse width current energizes the OPEN coil. Magnetic force moves the spool valve open. High-pressure oil flows past the spool valve and onto the top of the intensifier piston. Oil pressure overcomes the force of the intensifier piston spring and the intensifier starts to move down. An increase in fuel pressure under the plunger seats the fuel inlet check ball, and fuel pressure starts to build on the needle.

Main injection (Step 2)

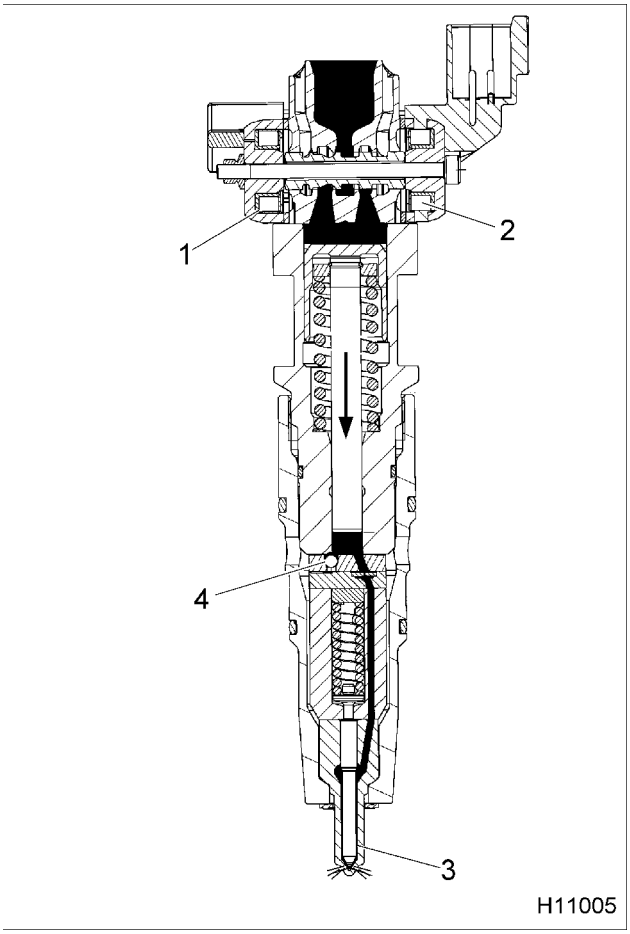


Figure 26 Main injection (Step 2)

1. CLOSE coil (off)
2. OPEN coil (off)
3. Needle (unseated – VOP)
4. Fuel inlet check ball (seated)

The pulse-width controlled current to the OPEN coil is shut off, but the spool valve remains open. High pressure oil from high pressure oil rail continues to flow past the spool valve. The intensifier piston and plunger continue to move and fuel pressure increases in the barrel. When fuel pressure rises above the VOP - about 28 MPa (4,075 psi) - the needle lifts of its seat and injection begins.

End of main injection (Step 1)

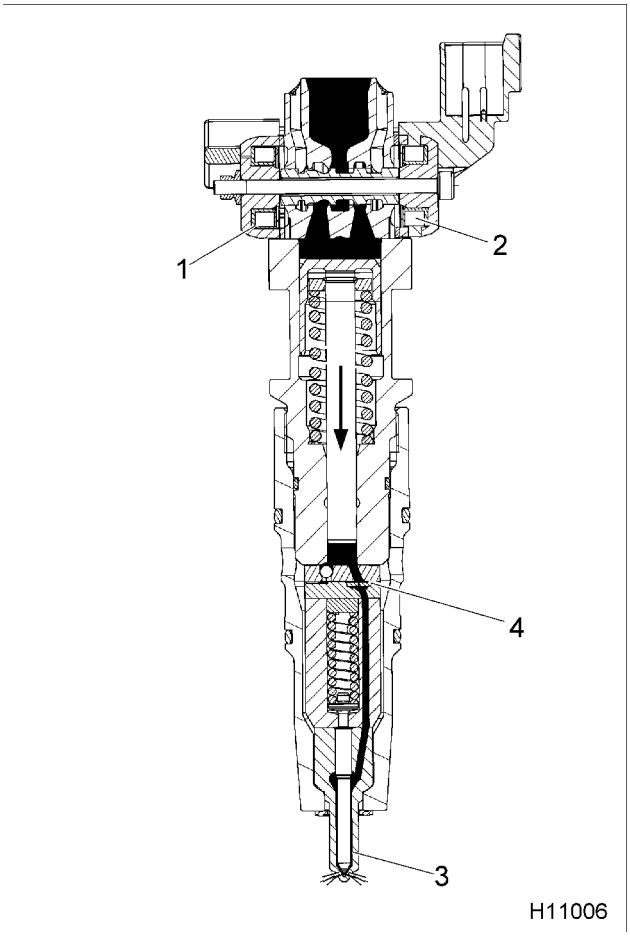


Figure 27 End of main injection (Step 1)

1. CLOSE coil (on)
2. OPEN coil (off)
3. Needle (unseated / closing)
4. Check disk (seated)

When the Injector Drive Module (IDM) determines that the correct injector on-time has been reached (the correct amount of fuel has been delivered), the IDM sends a pulse width controlled current to the CLOSE coil of the injector. The current energizes the CLOSE coil and magnetic force closes the spool valve. High-pressure oil is deadheaded against the spool valve.

End of main injection (Step 2)

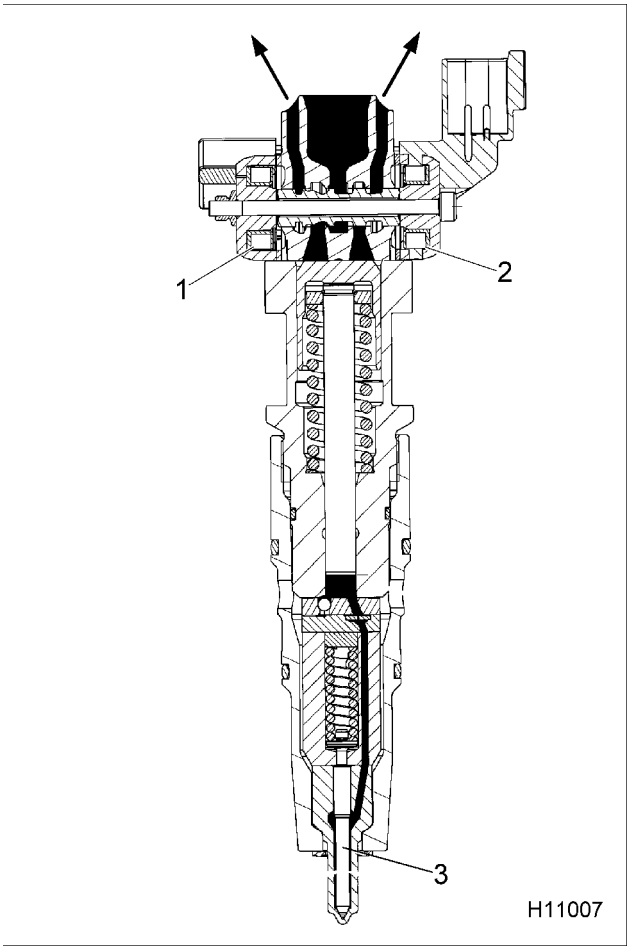


Figure 28 End of main injection (Step 2)

1. CLOSE coil (off)
2. OPEN coil (off)
3. Needle (seated)

The pulse width controlled current to close the coil is shut off, but the spool valve remains closed. The intensifier piston and plunger return to their initial positions. Oil above the intensifier piston flows past the spool valve through the exhaust ports. Fuel pressure decreases until the needle control spring forces the needle back onto its seat.

Fuel Supply System

Fuel System Components and Fuel Flow

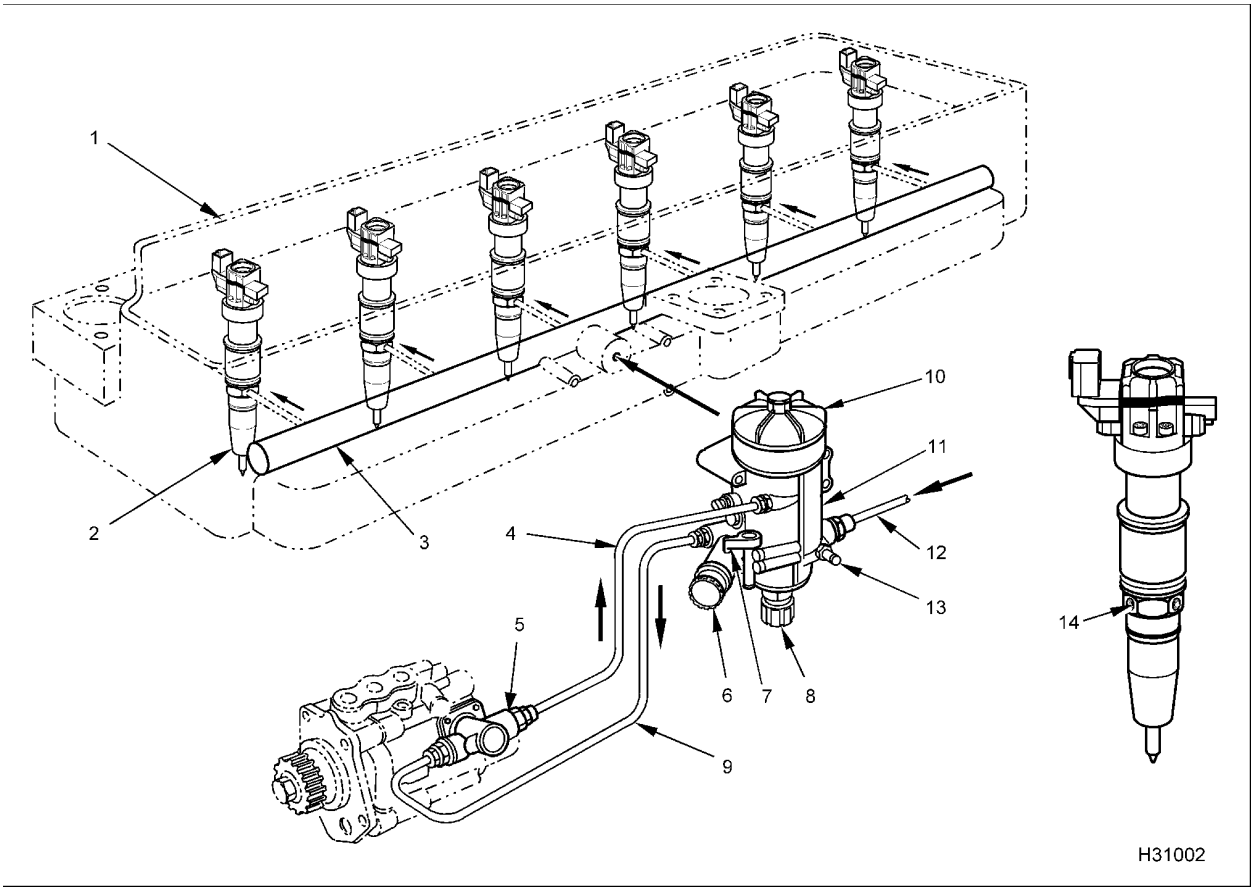


Figure 29 Fuel supply system

1. Cylinder head assembly
2. Fuel injector
3. Low-pressure fuel rail
4. Transfer pump outlet tube assembly
5. Low-pressure fuel supply pump
6. Primer pump assembly
7. Water drain valve
8. Drain valve (fuel)
9. Transfer pump inlet tube assembly
10. Fuel filter access cap
11. Fuel filter assembly
12. Fuel line from tank
13. Test fitting
14. Fuel inlet (4)

Fuel Flow Schematic

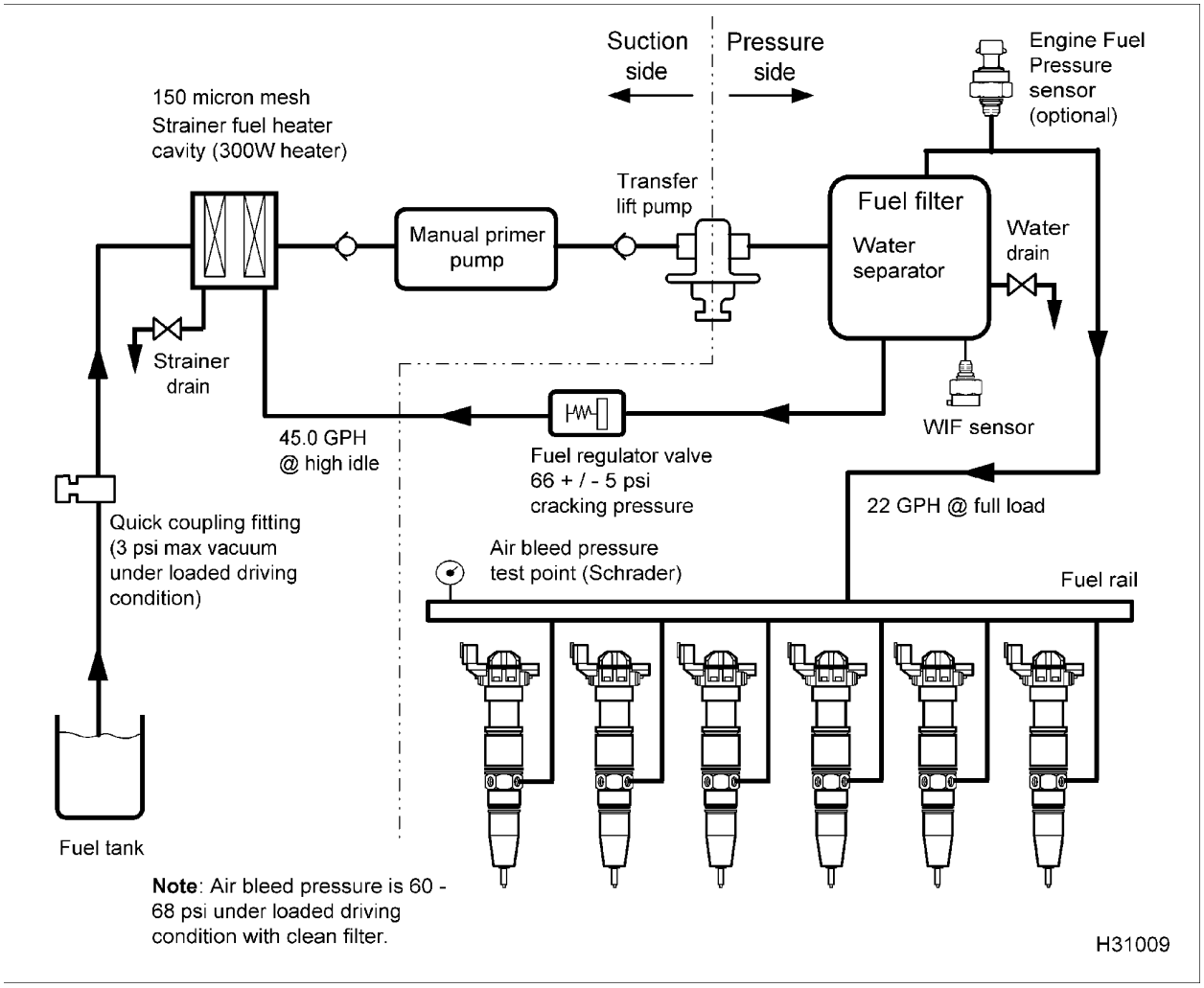


Figure 30 Fuel flow

The fuel filter housing includes the following components:

- 150 micron fuel strainer
- 300W fuel heating element (optional)
- Primer pump assembly
- Fuel filtering element
- Water separator
- Water In Fuel (WIF) sensor
- Water drain valve
- Fuel pressure regulator
- Engine Fuel Pressure (EFP) sensor (optional)

Fuel Flow

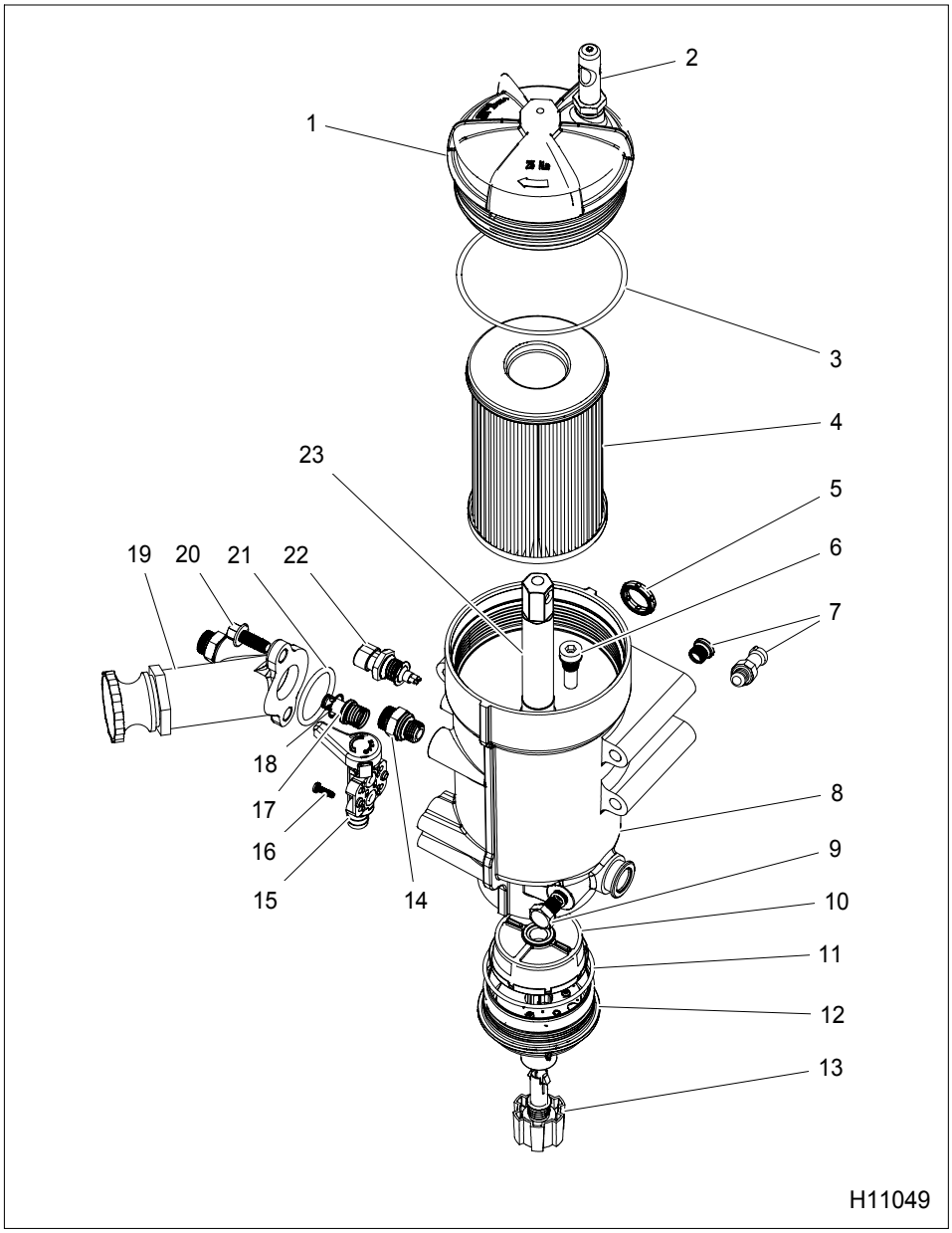


Figure 31 Fuel filter assembly

1. Housing cover assembly
2. M12 port fitting (factory fill)
3. O-ring seal
4. Fuel filter element
5. O-ring seal
6. Fuel pressure regulator assembly
7. Plug or EFP sensor (optional)
8. Fuel filter housing
9. M10 Plug assembly
10. Fuel strainer
11. Bowl O-ring seal
12. Fuel bowl (with heater option)
13. Drain valve
14. Fitting assembly, ⅜ tube
15. Water drain valve assembly
16. Self tapping screw (4)
17. Cartridge check valve
18. Retainer ring
19. Primer pump assembly
20. Bolt, M8 x 20 (2)
21. Primer pump seal
22. Water In Fuel (WIF) sensor
23. Stand pipe

NOTE: Early fuel filter assemblies may have an M10 Plug assembly (item 2) in the location of M12 port fitting (item 9). Item 2 is used by the assembly plants as a fuel fill.

- If item 2 is installed on housing cover assembly, it can be used to measure unfiltered fuel pressure.
- If item 2 is installed in item 9 location, it can be used to measure fuel inlet restriction.

The low-pressure fuel supply pump draws fuel from the fuel tank through a 150 micron strainer in the fuel filter assembly.

An optional electric heating element in the fuel filter housing warms incoming fuel to prevent waxing.

If water is in the fuel, the filter element repels water molecules, water collects at the bottom of the element cavity in the fuel filter housing, and a Water In Fuel (WIF) sensor in the element cavity detects water in the fuel. When enough water accumulates in the element cavity, the WIF sensor sends a signal to the Electronic Control Module (ECM); the ECM illuminates the amber WATER IN FUEL lamp on the instrument panel. A fuel drain valve handle on the housing can be opened to drain contaminants (usually water) from the fuel filter housing. Another drain valve in the bottom of the housing drains strainer cavity.

A built-in fuel regulator valve, calibrated to open at about 414 - 482 kPa (60 - 70 psi), regulates and relieves excessive pressure. During idle and light engine loads, when injector demand is low, most of the fuel is cycled between the fuel filter housing and low-pressure fuel pump. When engine demand increases, engine fuel consumption increases resulting in less fuel cycling. Under heavy loads fuel flows through the filter with little or no cycling.

Fuel is conditioned as it flows through a main filter and central post. The post prevents fuel from draining from the fuel rail during servicing.

An optional Engine Fuel Pressure (EFP) sensor detects low pressure caused by high fuel filter restriction and sends a signal to the ECM; the ECM illuminates the amber FUEL FILTER lamp on the instrument panel.

Fuel flows from the fuel filter housing into the fuel rail, through the fuel rail into six drilled holes (one for each injector) to each injector.

When the fuel injectors are activated, fuel flows (from fuel rail) into four inlets in each injector.

Engine Lubrication System

Lubrication System Components and Oil Flow

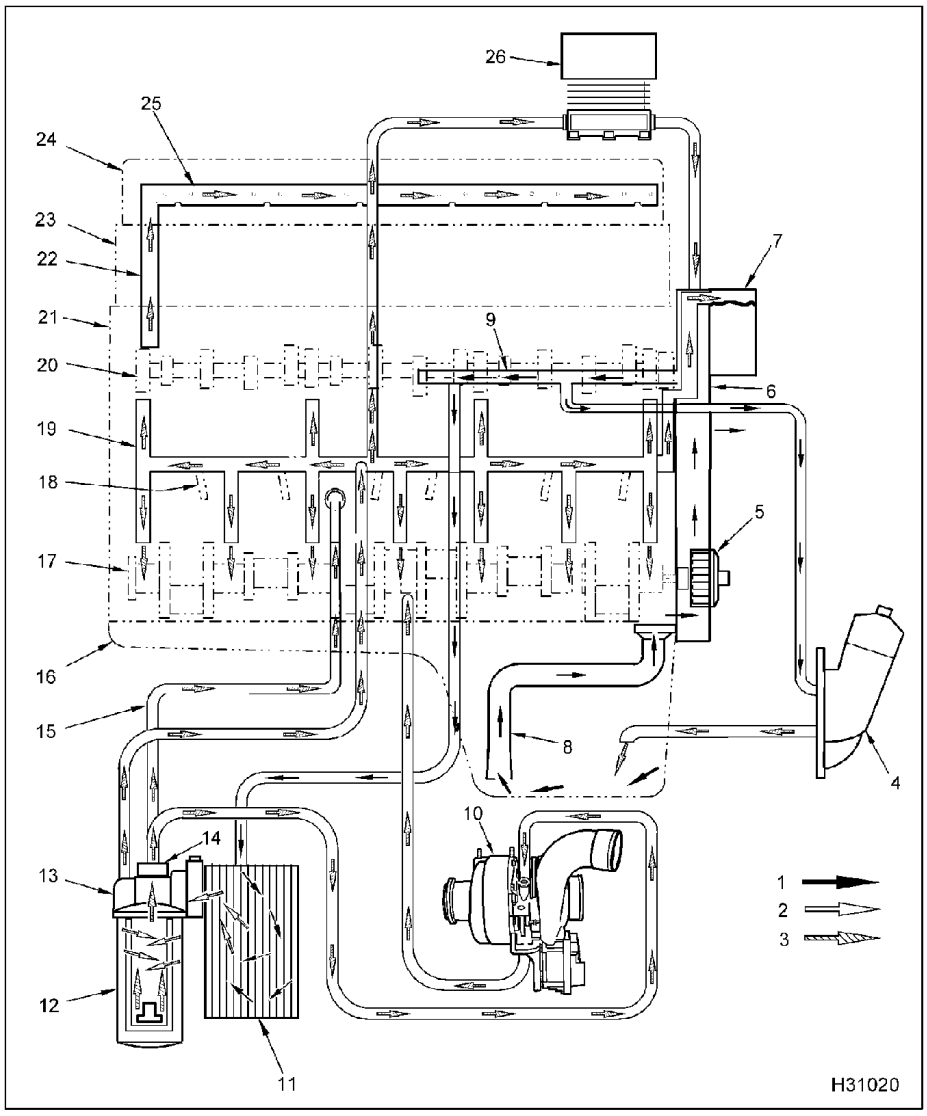


Figure 32 Lubrication system

1. Unfiltered oil
2. Cooled unfiltered oil
3. Filtered oil
4. Secondary filtration filter (optional)
5. Gerotor oil pump
6. Front cover
7. Reservoir for high-pressure oil pump
8. Pick-up tube
9. Unfiltered oil gallery
10. Variable Geometry Turbocharger (VGT)
11. Oil cooler
12. Oil filter
13. Oil cooler / filter header assembly
14. Oil pressure regulator relief valve
15. Regulator relief valve drain to crankcase
16. Oil pan assembly
17. Crankshaft
18. Piston cooling jet (6)
19. Main filtered oil gallery
20. Camshaft
21. Crankcase
22. Vertical gallery
23. Cylinder head
24. Valve cover
25. Rocker arm assembly
26. Air compressor

Oil Flow Diagram

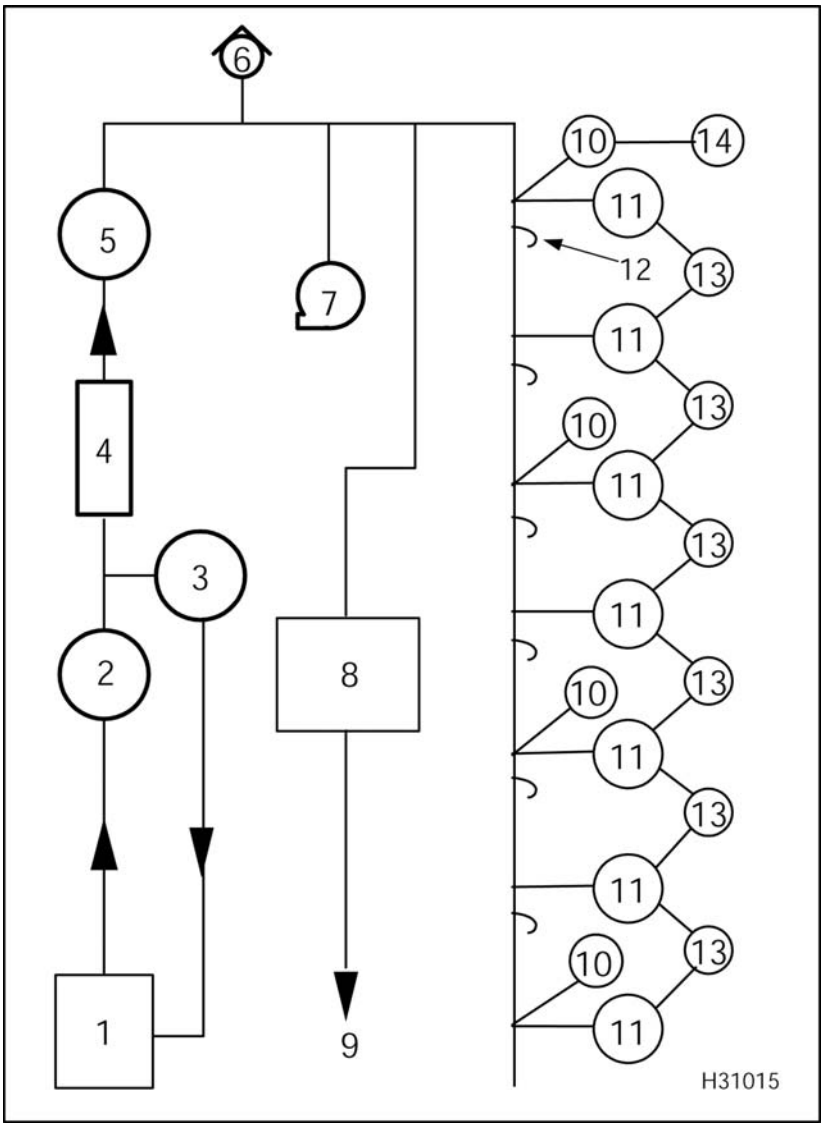


Figure 33 Lubrication system

1. Sump
2. Oil pump
3. Secondary filtration filter (optional)
4. Oil cooler
5. Oil filter
6. Regulator valve
7. Variable Geometry Turbocharger (VGT)
8. Oil reservoir for high-pressure pump
9. To high-pressure oil system
10. Cam bearings
11. Main bearings
12. Piston cooling tubes (6)
13. Connecting rods
14. Rocker arm shaft

The gerotor oil pump, driven by the engine crankshaft, draws unfiltered oil from the oil pan through an oil pick-up tube into the inlet port of the front cover. Unfiltered oil (under pressure) flows through the outlet port in the front cover into the unfiltered oil gallery in the crankcase.

The unfiltered oil gallery has one exit port to the header of the oil cooler. The oil is then internally

diverted to the oil cooler plate stack or bypassed in the oil cooler/filter module.

An oil temperature control valve, in the oil cooler/filter header, senses inlet oil temperature. During engine start-up, when the oil is cold the oil temperature control valve allows unfiltered oil to bypass the oil cooler plate stack. When the unfiltered oil reaches engine operating temperature, the oil temperature control valve routes unfiltered oil to the oil cooler. Oil flows through both the oil cooler core and bypass gallery when the valve is partially open.

Unfiltered oil at full flow moves through plates in the oil cooler. Engine coolant flows through the plates to cool the surrounding oil.

The cooled, unfiltered oil leaving the oil cooler stack mixes with the uncooled, unfiltered oil (that bypassed the oil cooler). The oil mixture flows through the oil filter (from element outside to element inside). The oil filter bypass valve in the header ensures full flow of oil to the engine should the filter element become plugged. Oil bypass occurs within the module when differential filter pressure reaches 345 kPa (50 psi) .

Cooled, filtered oil flows to and past the oil pressure regulator valve, in the oil cooler module. The oil pressure regulator valve maintains correct operating oil pressure.

The pressure regulator valve opens at 379 kPa (55 psi) and dumps excess oil into the crankcase. The filtered oil continues to the main oil gallery for distribution throughout the engine.

Connecting rod bearings are fed through drilled passages in the crankshaft from main to rod journals, receiving pressurized oil from the main bearings.

Camshaft journals are fed through passages drilled vertically in the main bearing webs. Pressurized oil from the main gallery, through piston cooling jets, lubricates and cools the pistons.

Valve rocker arms are lubricated through an annulus on the outside of the rear camshaft bushing. The oil passes up and through the vertical gallery in the rear of the crankcase, through a passage in the cylinder head. Oil continues through rocker arm shaft pedestal and into the rocker arm shaft. Oil continues flowing through drillings in the rocker arm shaft to the rocker arms. The oil then drains to the oil pan through push rod holes.

Filtered oil from the main gallery flows up through a passage in the front of the crankcase and front cover into the oil reservoir for the high-pressure oil pump.

The turbocharger receives filtered oil through an external tube connected to the oil cooler header. Oil drains back to the oil pan through a tube connected to the crankcase.

The air compressor (if equipped) receives filtered oil from the main oil gallery through an external tube connected to the left side of the crankcase. Oil drains to the front cover and back to the oil pan.

The front gear train is splash lubricated with oil draining from the high-pressure reservoir and the air compressor (if equipped).

Cooling System

Cooling System Components and Coolant Flow

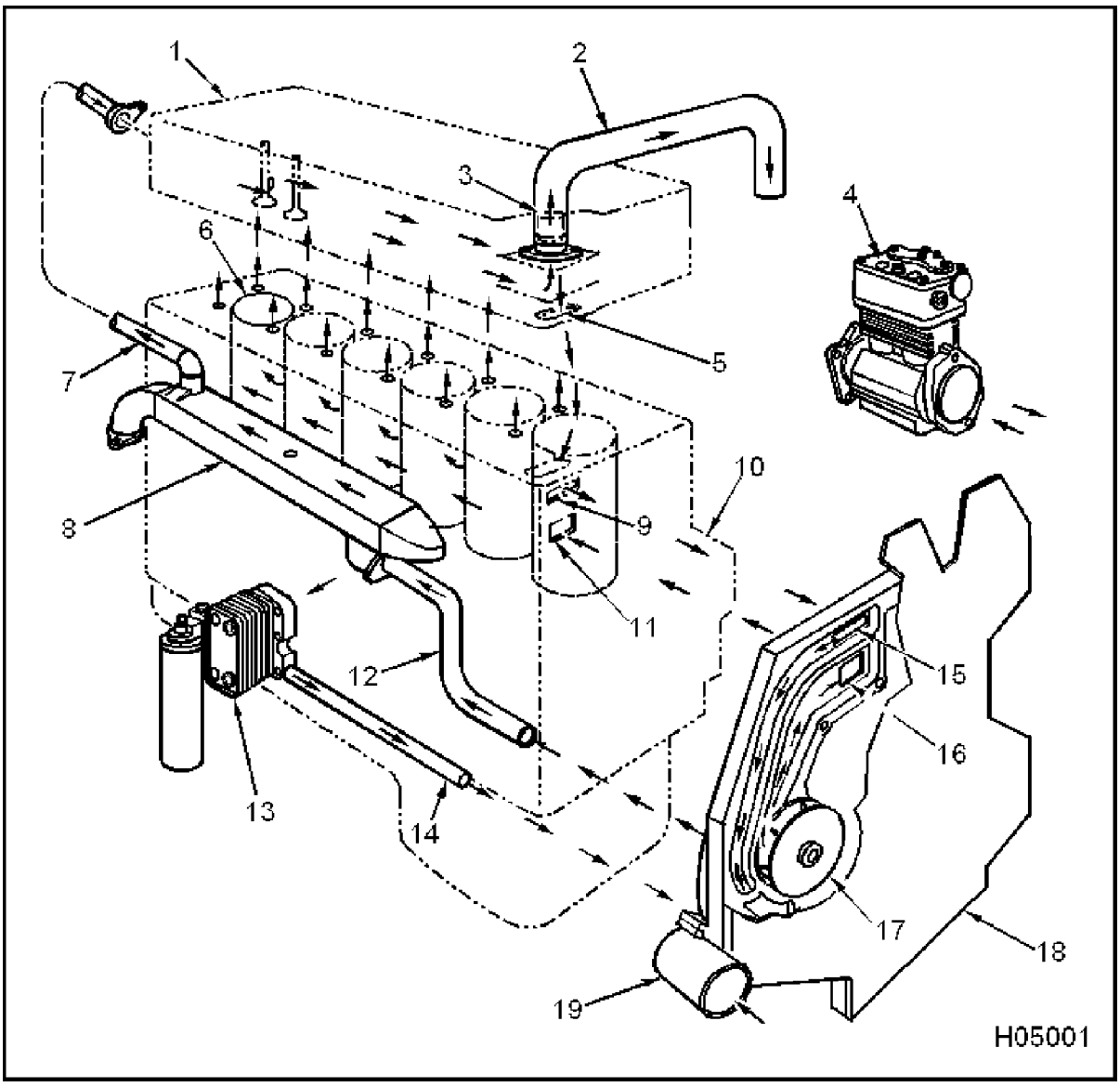


Figure 34 Engine cooling system

1. Cylinder head assembly
2. Water outlet tube assembly (thermostat outlet)
3. Thermostat assembly
4. Air compressor
5. Water return from cylinder head to crankcase
6. Cylinder sleeve
7. EGR coolant return tube assembly
8. EGR cooler
9. Water outlet from crankcase to front cover
10. Crankcase
11. Water inlet to crankcase
12. EGR cooler supply tube
13. Oil system module assembly
14. Oil cooler tube
15. Water inlet to front cover and water pump
16. Water supply from front cover to crankcase
17. Water pump impeller assembly
18. Front cover
19. Water inlet elbow

Cooling System Flow

The cooling system keeps the engine within a designated temperature range. The major components of the cooling system include the following:

- Radiator and fan combination (chassis components)
- Water pump assembly
- Thermostat assembly
- Oil system module assembly
- EGR cooler assembly

A belt-driven, centrifugal water pump set into the front cover has three passages. One passage channels coolant from the water pump to the crankcase, the second returns coolant to the water pump, and the third (a bypass) channels coolant back to the water pump when the thermostat is closed.

Incoming coolant flows from the bottom of the radiator through a water inlet elbow to the front cover and water pump. Coolant is pumped to the crankcase through a passage in the front cover and crankcase.

Water jackets in the crankcase direct coolant from front to rear, distributing coolant evenly to the lower sections of the cylinder sleeves. Coolant flow is directed tangent to each cylinder sleeve, causing a swirling motion up to the cylinder head. The swirling action improves heat absorption.

Coolant flows from the cylinder sleeve areas in three ways:

- Coolant flows into the oil system module assembly through the right side of the crankcase, passes through the oil system module, and returns through a tube to the front cover.
- Coolant is routed through hoses to and from the air compressor on the left side of the crankcase.
- Coolant exits the crankcase at the upper end of each cylinder sleeve bore, distributed evenly through metering holes in the cylinder head. Coolant then flows through the cylinder head (back to front) to the thermostat.

The EGR cooler receives coolant from the front cover. Coolant flows from the front of the cooler and exits the rear of the cooler into the rear of the cylinder head. A deaeration port is on top of the EGR cooler.

Thermostat Operation

The thermostat has two outlets. One directs coolant to the radiator when the engine is at operating temperature. The other directs coolant to the water pump until the engine reaches operating temperature. The thermostat begins to open at 88 °C (190 °F) and is fully open at 96 °C (205 °F).

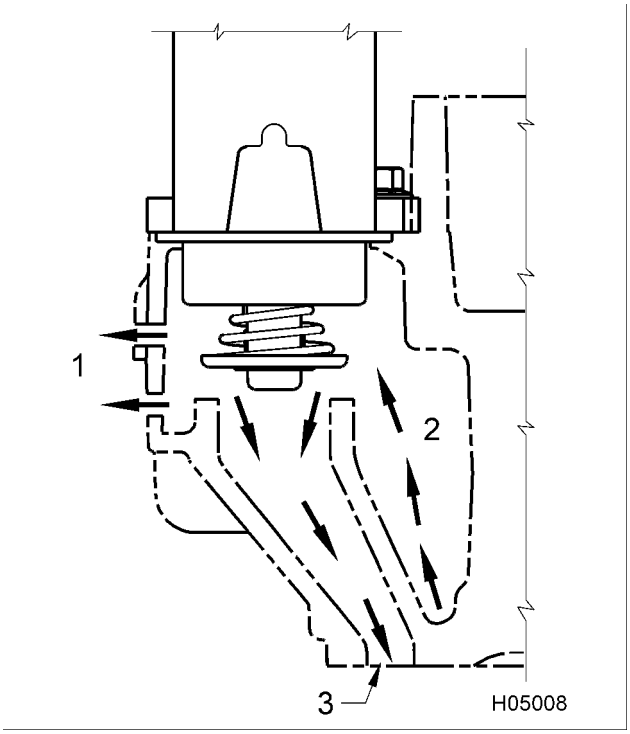


Figure 35 Thermostat closed

1. Coolant flow to heater port
2. Coolant in from engine
3. Bypass to water pump

When engine coolant is below 88 °C (190 °F), the thermostat is closed, blocking flow to the radiator. Coolant is forced to flow through a bypass port back to the water pump.

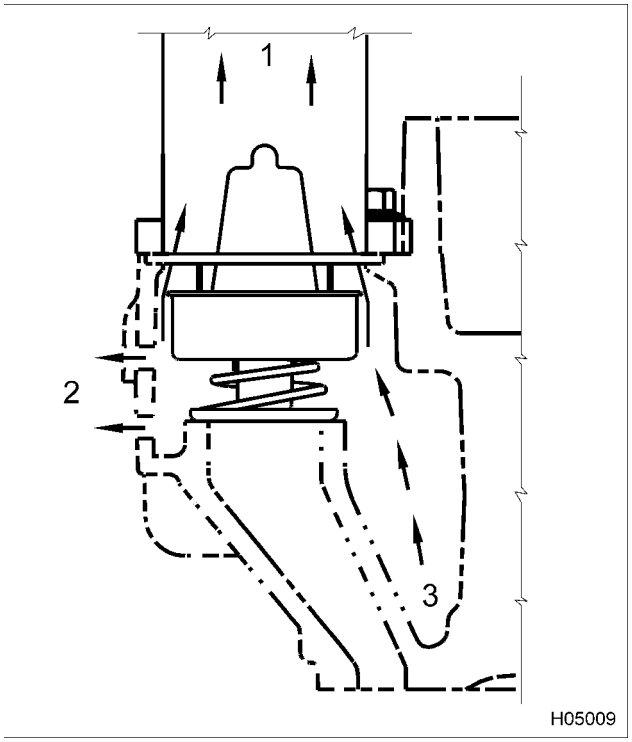


Figure 36 Thermostat open

1. Coolant out to radiator
2. Coolant flow to heater port
3. Coolant in from engine

When coolant temperature reaches the nominal opening temperature at 88 °C (190 °F), the thermostat opens allowing some coolant to flow to the radiator. When coolant temperature exceeds 96 °C (205 °F), the lower seat blocks the bypass port directing full coolant flow to the radiator.

Electronic Control System

Electronic Control System Components

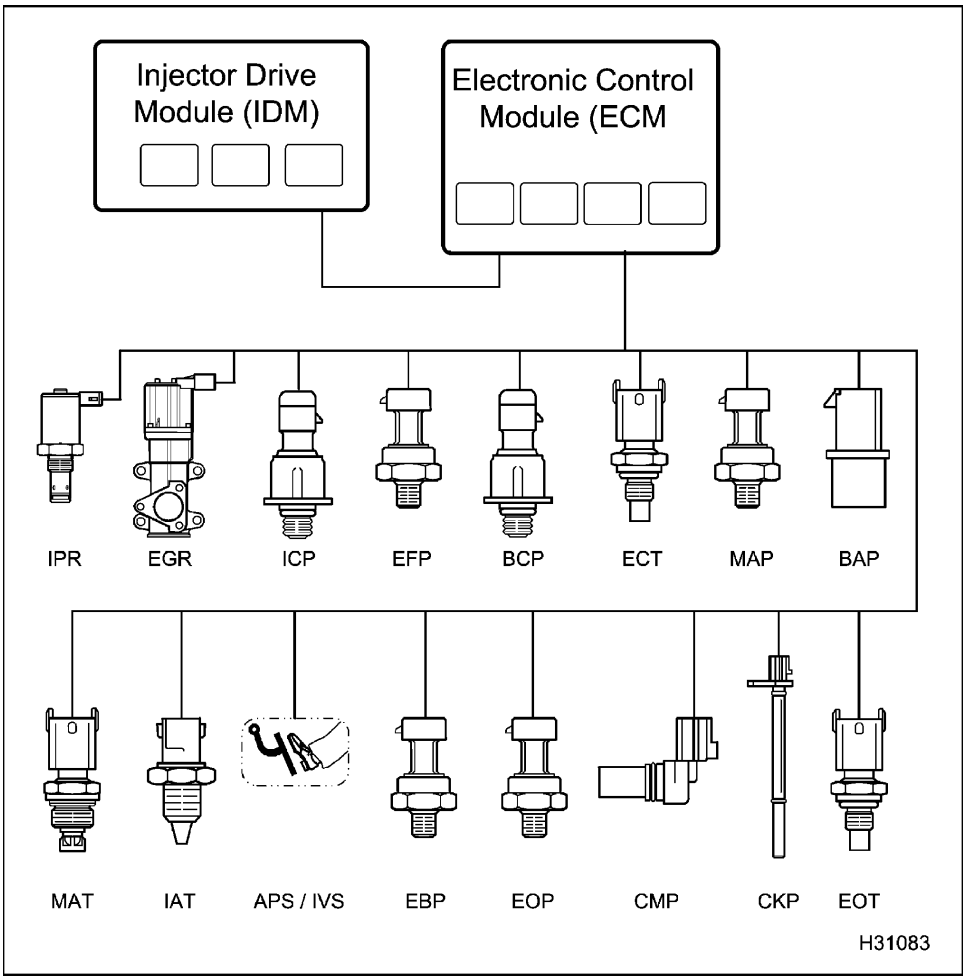


Figure 37 Electronic Control System

Operation and Function

The Electronic Control Module (ECM) monitors and controls engine performance to ensure maximum performance and adherence to emissions standards. The ECM has four primary functions:

- Provides Reference Voltage (V_{REF})
- Conditions input signals
- Processes and stores control strategies
- Controls actuators

1. Reference voltage (V_{REF})

The ECM supplies a 5 volt V_{REF} signal to input sensors in the electronic control system. By comparing the 5 volt V_{REF} signal sent to the sensors with their respective returned signals, the ECM determines pressures, positions, and other variables important to engine and vehicle functions.

The ECM supplies two independent circuits for V_{REF}:

- V_{REF} A supplies 5 volts to engine sensors
- V_{REF} B supplies 5 volts to vehicle sensors

2. Signal conditioner

The signal conditioner in the internal microprocessor converts analog signals to digital signals, squares up sine wave signals, or amplifies low intensity signals to a level that the ECM microprocessor can process.

3. Microprocessor

The ECM microprocessor stores operating instructions (control strategies) and value tables (calibration parameters). The ECM compares stored instructions and values with conditioned input values to determine the correct operating strategy for all engine operations.

Continuous calculations in the ECM occur at two different levels or speeds: Foreground and Background.

- Foreground calculations are much faster than background calculations and are normally more critical for engine operation. Engine speed control is an example.
- Background calculations are normally variables that change at a slower rates. Engine temperature is an example.

Diagnostic Trouble Codes (DTCs) are generated by the microprocessor, if inputs or conditions do not comply with expected values.

Diagnostic strategies are also programmed into the ECM. Some strategies monitor inputs continuously and command the necessary outputs to achieve the correct performance of the engine.

Microprocessor memory

The ECM microprocessor includes Read Only Memory (ROM) and Random Access Memory (RAM).

ROM

ROM stores permanent information for calibration tables and operating strategies. Permanently stored information cannot be changed or lost by turning the ignition key OFF or when ECM power is interrupted. ROM includes the following:

- Vehicle configuration, modes of operation, and options
- Engine Family Rating Code (EFRC)
- Engine warning and protection modes

RAM

RAM stores temporary information for current engine conditions. Temporary information in RAM is lost when the ignition key is turned to OFF or when ECM power is interrupted. RAM information includes the following:

- Engine temperature
- Engine rpm
- Accelerator pedal position

4. Actuator control

The ECM controls the actuators by applying a low level signal (low side driver) or a high level signal (high side driver). When switched on, both drivers complete a ground or power circuit to an actuator.

Actuators are controlled in three ways, determined by the kind of actuator.

- A duty cycle (percent time on/off)
- A controlled pulse width
- Switched on or off

ECM Control of Engine Operation

The ECM controls engine operation with the following:

- Variable Geometry Turbocharger (VGT) control module
- EGR control module and control valve
- Diamond Logic® engine brake
- IPR valve
- Inlet Air Heater (IAH) assembly

Variable Geometry Turbocharger (VGT) control module

The VGT control module controls vane position in the turbine housing. Vane position is controlled by a switching voltage source in the ECM. The ground circuit is supplied directly from the battery ground at all times.

The actuator control is set by a pulse width modulated signal in response to engine speed, desired fuel quantity, boost or exhaust back pressure and altitude.

Exhaust Gas Recirculation (EGR) Control Valve

The EGR valve controls the flow of exhaust gases into the inlet and EGR mixer duct.

The EGR drive module controls the EGR actuator.

The EGR drive module receives the desired EGR actuator position from the ECM across the CAN 2 datalink to activate the valve for exhaust gas recirculation. The EGR drive module provides feedback to the ECM on the valve position.

The EGR drive module constantly monitors the EGR actuator. When an EGR control error is detected, the EGR drive module sends a message to the ECM and a DTC is set.

Brake Shut-off Valve

The brake shut-off valve controls pressure in the oil gallery of the high-pressure oil rail. When the engine brake is activated, the ECM provides power to activate the brake shut-off valve to allow oil from the injector oil gallery to flow to the brake oil gallery. High oil pressure activates the brake actuator pistons to open the exhaust valves.

Injection Pressure Regulator (IPR)

The IPR valve controls pressure in the Injection Control Pressure (ICP) system. The IPR valve is a variable position valve controlled by the ECM. This regulated pressure actuates the fuel injectors. The valve position is controlled by switching the ground circuit in the ECM. The voltage source is supplied by the ignition switch.

Inlet Air Heater (IAH)

The IAH system warms the incoming air supply prior to cranking to aid cold engine starting and reduce white smoke during warm-up.

The ECM is programmed to energize the IAH elements through the IAH relays while monitoring certain programmed conditions for engine coolant temperature, engine oil temperature, and atmospheric pressure.

Injection Drive Module (IDM)

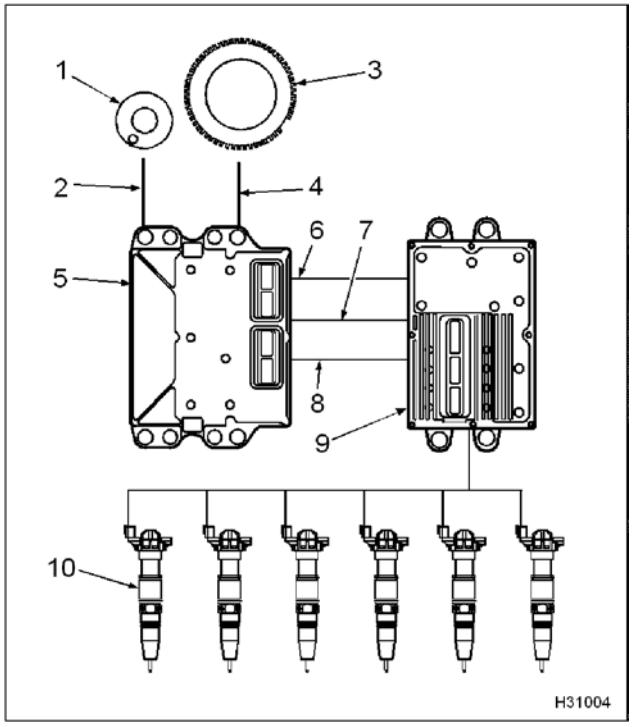


Figure 38 Injection Drive Module (IDM)

1. Camshaft with peg
2. Camshaft Position (CMP) signal
3. Crankshaft position sensor timing disk
4. Crankshaft Position (CKP) signal
5. Electronic Control Module (ECM)
6. Camshaft Position Output (CMPO) signal
7. Crankshaft Position Output (CKPO) signal
8. Controller Area Network (CAN 2) communication
9. Injection Drive Module (IDM)
10. Fuel injectors

The IDM has three functions:

- Electronic distributor for injectors
- Power source for injectors
- IDM and injector diagnostics

Electronic Distributor for Injectors

The IDM distributes current to the injectors. The IDM controls fueling to the engine by sending high voltage pulses to the OPEN and CLOSE coils of the injector. The IDM uses information from the ECM to determine the timing and quantity of fuel for each injector.

The ECM uses CMP and CKP input signals to calculate engine speed and position. The ECM conditions both input signals and supplies the IDM with CMP and CKP output signals. The IDM uses CMP and CKP output signals to determine the correct sequence for injector firing.

The ECM sends information (fuel volume, EOT, and ICP) through the CAN 2 link to the IDM; the IDM uses this information to calculate the injection cycle.

Injector power source

The IDM creates a constant 48 volt (DC) supply to all injectors by making and breaking a 12 volt source across a coil in the IDM. The 48 volts created by the collapsed field is stored in capacitors until used by the injectors.

The IDM controls when the injector is turned on and how long the injector is active. The IDM first energizes the OPEN coil, then the CLOSE coil. The low side driver supplies a return circuit to the IDM for each injector coil (open and close). The high side driver controls the power supply to the injector. During each injection event, the low and high side drivers are switched on and off for each coil.

IDM and injector diagnostics

The IDM determines if an injector is drawing enough current. The IDM sends a fault to the ECM, indicating potential problems in the wiring harness or injector, and the ECM will set a DTC. The IDM also does self-diagnostic checks and sets a DTC to indicate failure of the IDM.

On demand tests can be done using the Electronic Service Tool (EST). The EST sends a request to the ECM and the ECM sends a request to the IDM to do a test. Some tests generate a DTC when a problem exists. Other tests require the technician to evaluate parameters, if a problem exists.

Engine and Vehicle Sensors

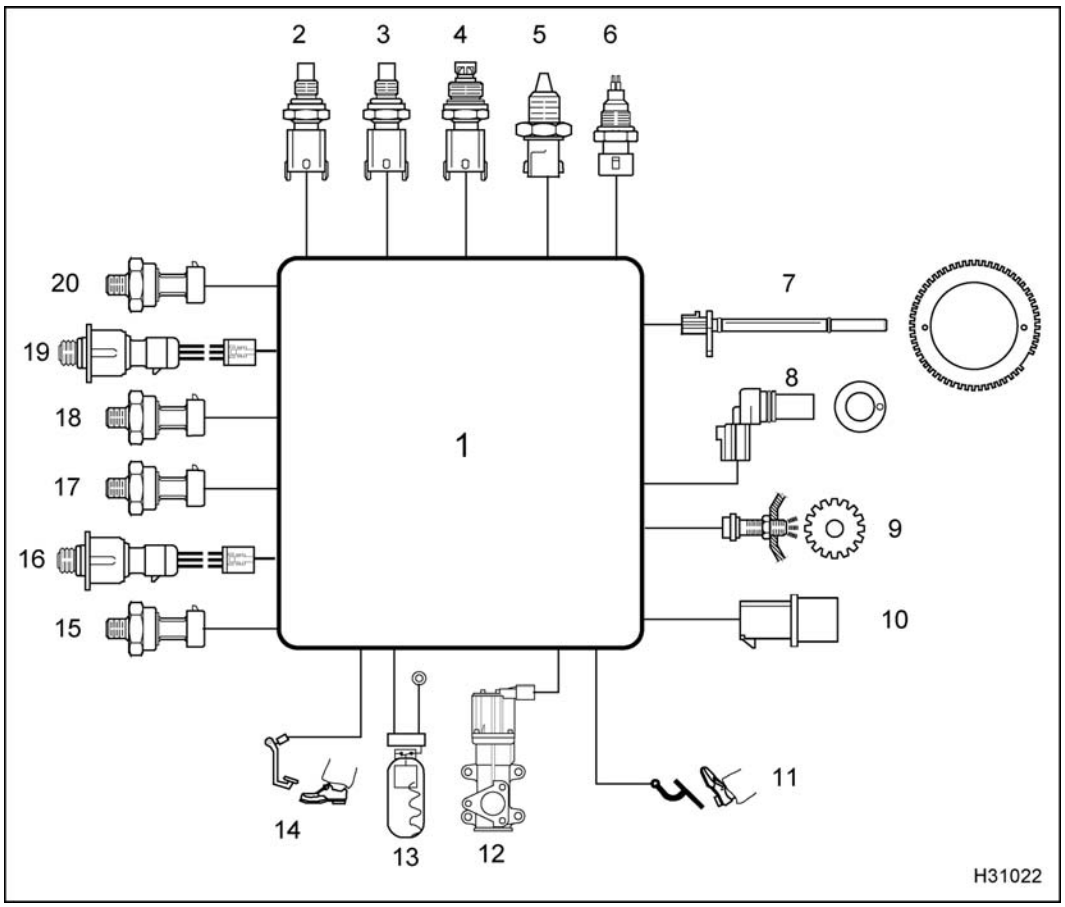


Figure 39 Engine and vehicle sensors

1. Electronic Control Module (ECM)
2. Engine Oil Temperature (EOT)
3. Engine Coolant Temperature (ECT)
4. Manifold Air Temperature (MAT)
5. Intake Air Temperature (IAT)
6. Water In Fuel (WIF) sensor
7. Crankshaft Position (CKP)
8. Camshaft Position (CMP)
9. Vehicle Speed Sensor (VSS)
10. Barometric Absolute Pressure (BAP)
11. Accelerator Position Sensor (APS)
12. Exhaust Gas Recirculation valve Position (EGRP)
13. Engine Coolant Level (ECL)
14. Driveline Disengagement Switch (DDS)
15. Manifold Absolute Pressure (MAP)
16. Brake Control Pressure (BCP)
17. Engine Oil Pressure (EOP)
18. Engine Fuel Pressure (EFP) sensor
19. Injection Control Pressure (ICP)
20. Exhaust Back Pressure (EBP)

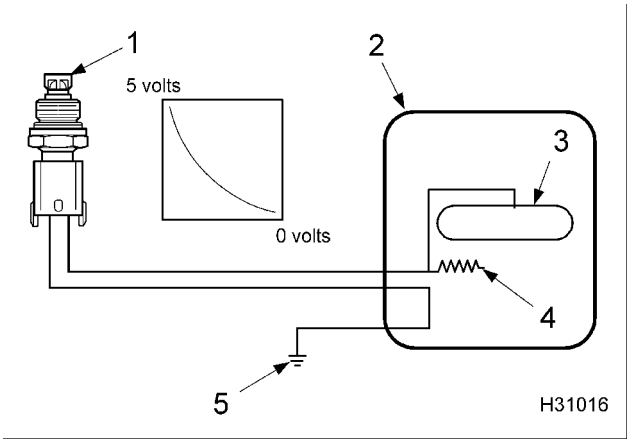


Figure 40 Thermistor

1. Temperature sensor
2. Electronic Control Module (ECM)
3. Microprocessor
4. Voltage Reference (Vref)
5. Ground

Thermistors

- ECT
- EOT
- IAT
- MAT

A thermistor sensor changes its electrical resistance with changes in temperature. Resistance in the thermistor decreases as temperature increases, and increases as temperature decreases. Thermistors work with a resistor that limits current in the ECM to form a voltage signal matched with a temperature value.

The top half of the voltage divider is the current limiting resistor inside the ECM. A thermistor sensor has two electrical connectors, signal return and ground. The output of a thermistor sensor is a nonlinear analog signal.

Engine Coolant Temperature (ECT)

The ECM monitors the ECT signal and uses this information for the instrument panel temperature gauge, coolant compensation, Engine Warning Protection System (EWPS), and intake heater operation. The ECT is a backup, if the EOT is out of range. The ECT sensor is installed in the water supply housing (Freon® compressor bracket), left of the flat idler pulley assembly.

Engine Oil Temperature (EOT)

The ECM monitors the EOT signal to control fuel quantity and timing when operating the engine. The EOT signal allows the ECM and IDM to compensate for differences in oil viscosity for temperature changes. This ensures that power and torque are available for all operating conditions. The EOT sensor is installed in the rear of the front cover, outboard of the high-pressure oil pump assembly.

Intake Air Temperature (IAT)

The ECM monitors the IAT signal to control timing and fuel rate during cold starts. The IAT sensor is chassis mounted on the air filter housing.

Manifold Air Temperature (MAT)

The ECM monitors the MAT signal for EGR operation. The MAT sensor is installed right of the MAP sensor in the intake manifold.

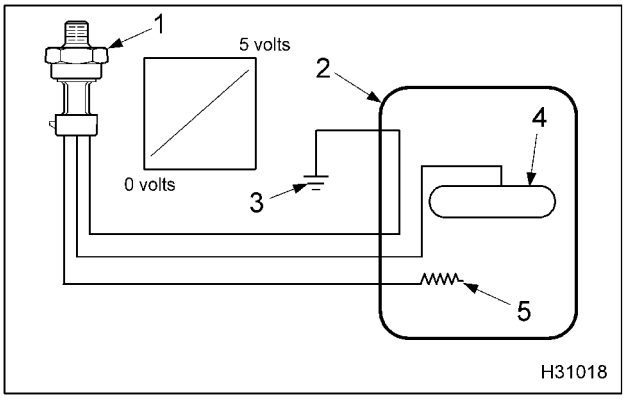


Figure 41 Variable capacitance sensor

1. Pressure sensor
2. Electronic Control Module (ECM)
3. Ground
4. Microprocessor
5. Voltage reference (V_{REF})

Variable Capacitance Sensors

- BAP
- EBP
- EFP

- EOP
- MAP

Variable capacitance sensors measure pressure. The pressure measured is applied to a ceramic material. The pressure forces the ceramic material closer to a thin metal disk. This action changes the capacitance of the sensor.

The sensor is connected to the ECM by three wires:

- V_{REF}
- Signal return
- Signal ground

The sensor receives the V_{REF} and returns an analog signal voltage to the ECM. The ECM compares the voltage with pre-programmed values to determine pressure.

The operational range of a variable capacitance sensor is linked to the thickness of the ceramic disk. The thicker the ceramic disk the more pressure the sensor can measure.

Barometric Absolute Pressure (BAP)

The ECM monitors the BAP signal to determine altitude, adjust timing, fuel quantity, and inlet air heater operation. The BAP sensor is located in the cab.

Exhaust Back Pressure (EBP)

The EBP sensor measures exhaust back pressure so that the ECM can control the VGT and EGR systems. The sensor provides feedback to the ECM for closed loop control of the Variable Geometry Turbocharger (VGT). The EBP sensor is installed in a bracket mounted on the water supply housing (Freon® compressor bracket).

Engine Fuel Pressure (EFP)

The ECM uses the EFP sensor signal to monitor engine fuel pressure and give an indication when the fuel filter needs to be changed. The EFP sensor is installed in the rear of the fuel filter assembly (crankcase side).

Engine Oil Pressure (EOP)

The ECM monitors the EOP signal, and uses this information for the instrument panel pressure gauge and EWPS. The EOP sensor is installed in the left side of the crankcase below and left of the fuel filter housing.

Manifold Absolute Pressure (MAP)

The ECM monitors the MAP signal to determine intake manifold pressure (boost). This information is used to control fuel rate and injection timing. The MAP sensor is installed left of the MAT sensor in the intake manifold.

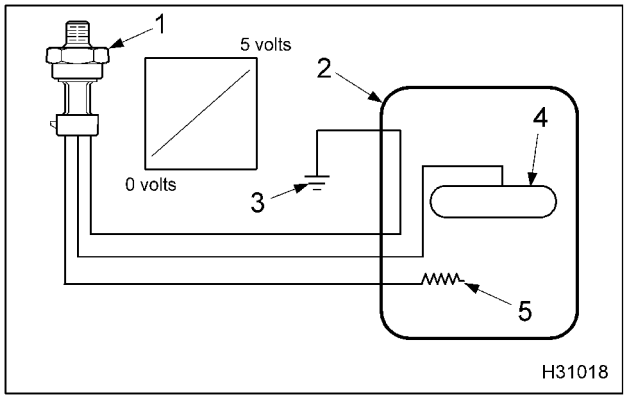


Figure 42 Micro Strain Gauge sensor

1. Pressure sensor
2. Electronic Control Module (ECM)
3. Ground
4. Microprocessor
5. Voltage reference (V_{REF})

Micro Strain Gauge (MSG) Sensors

- BCP
- ICP

A Micro Strain Gauge (MSG) sensor measures pressure. Pressure to be measured exerts force on a pressure vessel that stretches and compresses to change resistance of strain gauges bonded to the surface of the pressure vessel. Internal sensor electronics convert the changes in resistance to a ratiometric voltage output.

The sensor is connected to the ECM by three wires:

- V_{REF}
- Signal return
- Signal ground

The sensor receives the V_{REF} and returns an analog signal voltage to the ECM. The ECM compares the voltage with pre-programmed values to determine pressure.

Brake Control Pressure (BCP)

The ECM monitors the BCP signal to determine the oil pressure in the brake gallery of the high-pressure oil rail. The BCP sensor is under the valve cover, forward of the No. 2 fuel injector in the high-pressure oil rail.

Injection Control Pressure (ICP)

The ECM monitors the ICP signal to determine the injection control pressure for engine operation. The ICP signal is used to control the IPR valve. The ICP sensor provides feedback to the ECM for Closed Loop ICP control. The ICP sensor is under the valve cover, forward of the No. 6 fuel injector in the high-pressure oil rail.

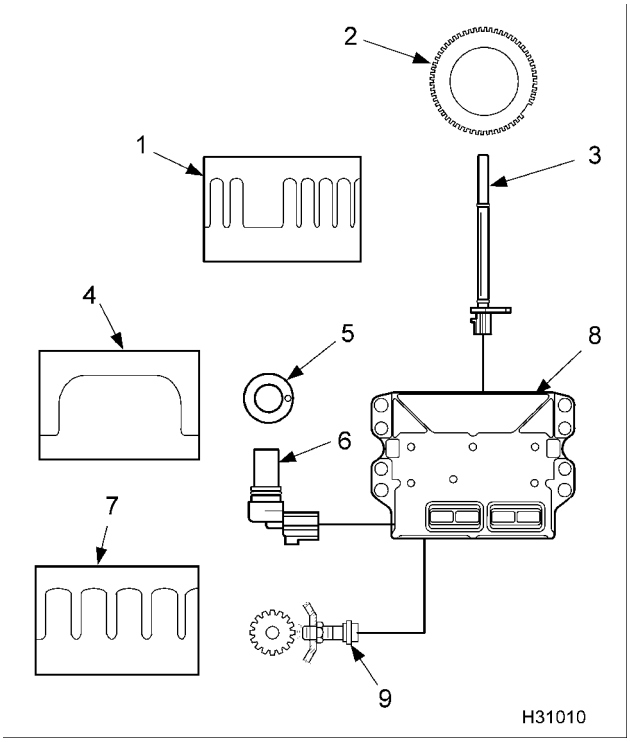


Figure 43 Magnetic pickups

1. Crankshaft Position (CKP) signal
2. Crankshaft position sensor timing disk
3. Crankshaft Position (CKP) sensor
4. Camshaft position (CMP) signal
5. Camshaft with peg
6. Camshaft position (CMP) sensor
7. Vehicle speed signal
8. Electronic Control Module (ECM)
9. Vehicle Speed Sensor (VSS)

Magnetic pickup sensors

- CKP
- CMP
- VSS

A magnetic pickup sensor generates an alternating frequency that indicates speed. Magnetic pickups have a two wire connection for signal and ground. This sensor has a permanent magnetic core surrounded by a wire coil. The signal frequency is generated by the rotation of gear teeth that disturb the magnetic field.

Crankshaft Position (CKP) sensor

The CKP sensor provides the ECM with a signal that indicates crankshaft speed and position. As the crankshaft turns the CKP sensor detects a 60 tooth timing disk on the crankshaft. Teeth 59 and 60 are missing. By comparing the CKP signal with the CMP signal, the ECM calculates engine rpm and timing requirements. The CKP is installed in the top left side of the flywheel housing.

NOTE: This long CKP sensor, used with International® DT 466, DT 570, and HT 570 diesel engines, is the Camshaft Position (CMP) sensor used with other International® diesel engines.

Camshaft Position (CMP)

The CMP sensor provides the ECM with a signal that indicates camshaft position. As the cam rotates, the sensor identifies the position of the cam by locating a peg on the cam. The CMP is installed in the front cover, above and to the right of the water pump pulley.

NOTE: This short CMP sensor, used with International® DT 466, DT 570, and HT 570 diesel engines, is the Crankshaft Position (CKP) sensor used with other International® diesel engines.

Vehicle Speed Sensor (VSS)

The VSS provides the ECM with transmission tail shaft speed by sensing the rotation of a 16 tooth gear on the rear of the transmission. The detected sine wave signal (AC), received by the ECM, is used with tire size and axle ratio to calculate vehicle speed. The VSS is on left side of the transmission.

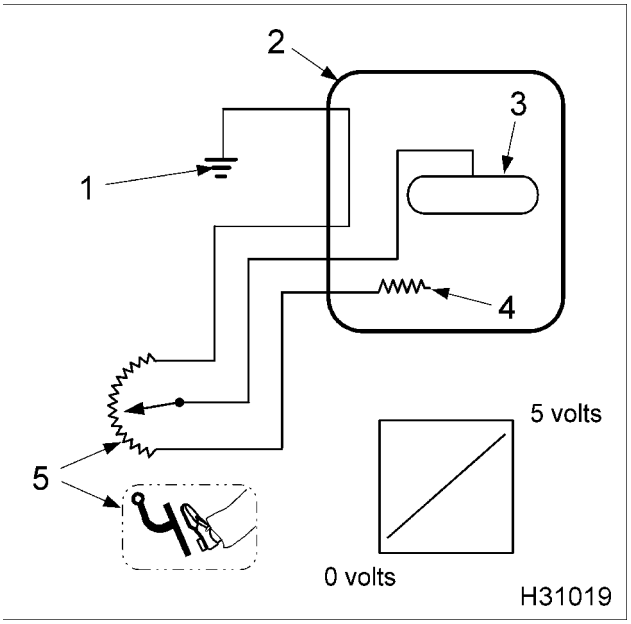


Figure 44 Potentiometer

1. Ground
2. Electronic Control Module (ECM)
3. Microprocessor
4. Voltage reference (V_{REF})
5. Accelerator Position Sensor (APS)

Potentiometers

- APS

A potentiometer is a variable voltage divider that senses the position of a mechanical component. A reference voltage is applied to one end of the potentiometer. Mechanical rotary or linear motion moves the wiper along the resistance material, changing voltage at each point along the resistive material. Voltage is proportional to the amount of mechanical movement.

Accelerator Position Sensor (APS)

The APS provides the ECM with a feedback signal (linear analog voltage) that indicates the operator's demand for power. The APS is mounted in the accelerator pedal. A remote accelerator or throttle device can be used in addition to the accelerator pedal.

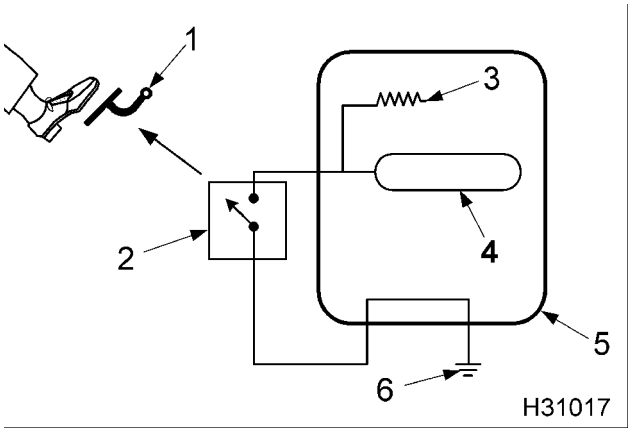


Figure 45 Switch

1. Accelerator pedal
2. Idle Validation Switch (IVS)
3. Voltage source with current limiting resistor
4. Microprocessor
5. ECM
6. Ground

Switches

- DDS
- ECL
- IVS
- WIF

Switch sensors indicate position. They operate open or closed, allowing or preventing the flow of current. A switch sensor can be a voltage input switch or a grounding switch. A voltage input switch supplies the ECM with a voltage when it is closed. A grounding switch grounds the circuit when closed, causing a zero voltage signal. Grounding switches are usually installed in series with a current limiting resistor.

Driveline Disengagement Switch (DDS)

The DDS determines if a vehicle is in gear. For manual transmissions, the clutch switch serves as the DDS. For automatic transmissions, the neutral indicator switch functions as the DDS.

Engine Coolant Level (ECL)

ECL is part of the Engine Warning Protection System (EWPS). The ECL switch is used in plastic deaeration tank. When a magnetic switch is open, the tank is full.

If engine coolant is low, the red ENGINE lamp on the instrument panel is illuminated.

Idle Validation Switch (IVS)

The IVS is a redundant switch that provides the ECM with a signal that verifies when the APS is in the idle position.

Water In Fuel (WIF)

A Water In Fuel (WIF) sensor detects water in the fuel. When enough water accumulates at the bottom of the housing, the WIF sensor sends a signal to the Electronic Control Module (ECM); the ECM sets a Diagnostic Trouble Code (DTC) and illuminates the amber WATER IN FUEL lamp on the instrument panel. The WIF is installed in the base of the fuel filter housing.

Diamond Logic® Engine Brake System

The Diamond Logic® engine brake system is available for all engine displacements.

Engine Brake Components

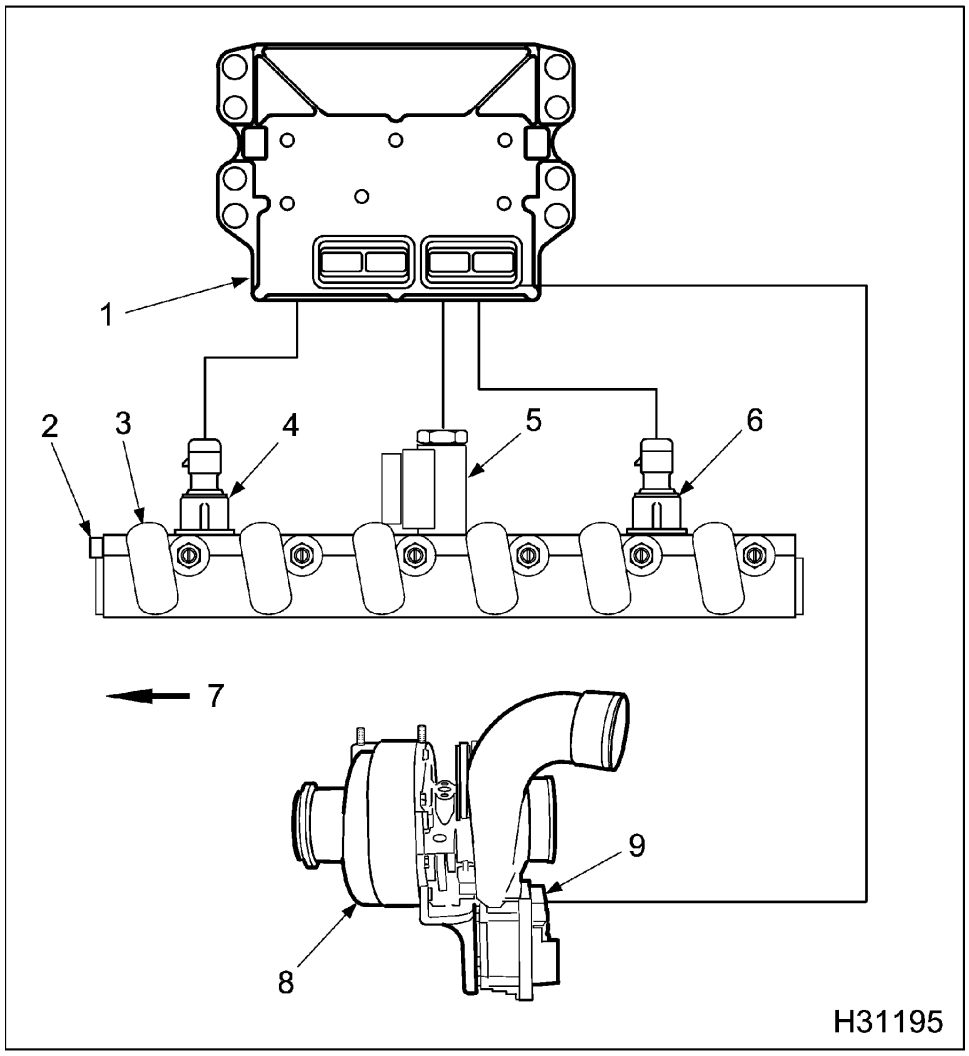


Figure 46 Diamond Logic® engine brake – system

1. ECM
2. Brake pressure relief valve
3. High-pressure oil rail
4. Brake Control Pressure (BCP) sensor
5. Brake shutoff valve assembly
6. Injection Control Pressure (ICP) sensor
7. Front of engine
8. Variable Geometry Turbocharger (VGT)
9. Turbocharger control module

The Diamond Logic® engine brake, a compression release brake system, provides the following:

- Significant noise reduction
- Improved engine braking
- High durability
- Compatibility with cruise control system
- Lower operating cost and longer service life for brake shoes

The Diamond Logic® engine brake is available for all engine displacements. The operator can select one of three brake settings, depending on terrain and driving conditions. See vehicle *Operator's Manual* for complete operating instructions.

Engine Brake Concept

The engine brake system retards vehicle speed during deceleration or braking. During deceleration and braking, the vehicle wheels drive the engine; the engine acts as an energy absorber.

Engine Brake Operation

To absorb energy, the Diamond Logic® engine brake combines bleeding off compressed intake air, VGT controlling exhaust back pressure, and vehicle driven piston movement.

- Energy is absorbed during the compression stroke, when intake air is compressed and forced through a slightly open exhaust valve, providing compressed air flow to the VGT.
- VGT turbine vanes create the desired energy absorbing, back pressure and intake boost.
- At the top of the compression stroke energy dissipates, pressure to force the piston down is eliminated, and energy is absorbed by the vehicle drive pulling the piston down.

Engine Brake Control

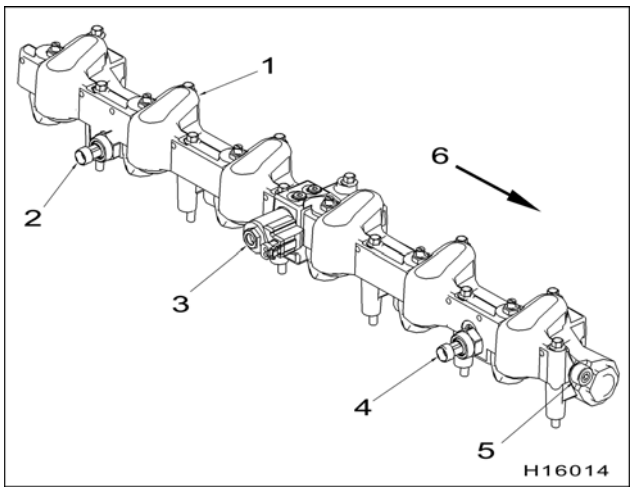


Figure 47 High-pressure oil rail

1. High-pressure oil rail
2. ICP sensor
3. Brake shutoff valve assembly
4. BCP sensor
5. Brake pressure relief valve
6. Front of engine

The high-pressure oil rail uses high-pressure oil from the injection control pressure system to open exhaust valves.

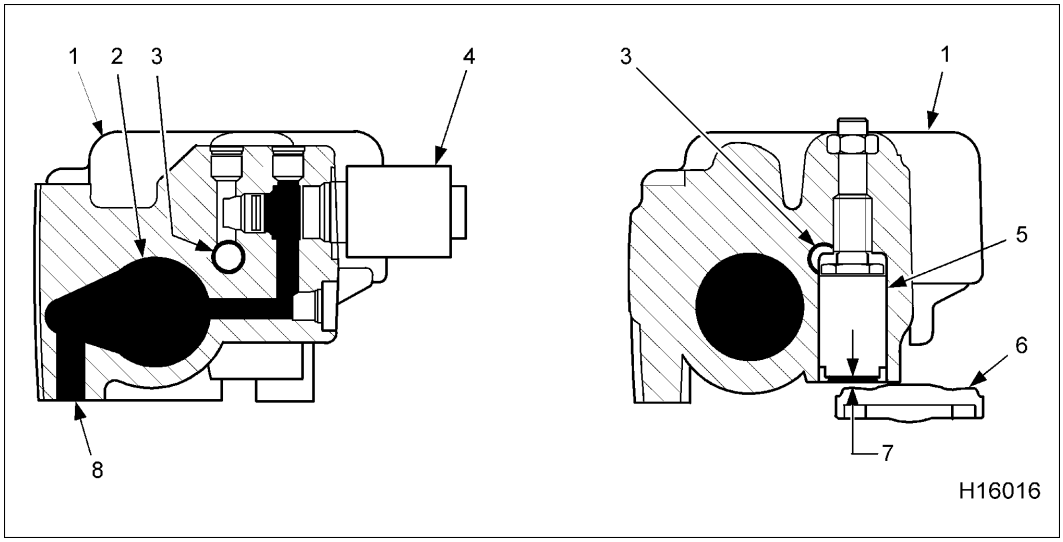


Figure 48 Brake shutoff valve and brake actuator– OFF

1. High-pressure oil rail
2. Injector oil gallery
3. Brake oil gallery
4. Brake shutoff valve assembly
5. Brake actuator piston assembly
6. Exhaust valve bridge
7. Valve lash (actuator retracted)
8. Oil inlet

During normal engine operation, oil in the high-pressure rail goes to the fuel injectors only. A brake shutoff valve, mounted in the high-pressure oil rail, is closed to prevent oil from entering the brake gallery.

Operation of Diamond Logic® Engine Brake in Braking Mode

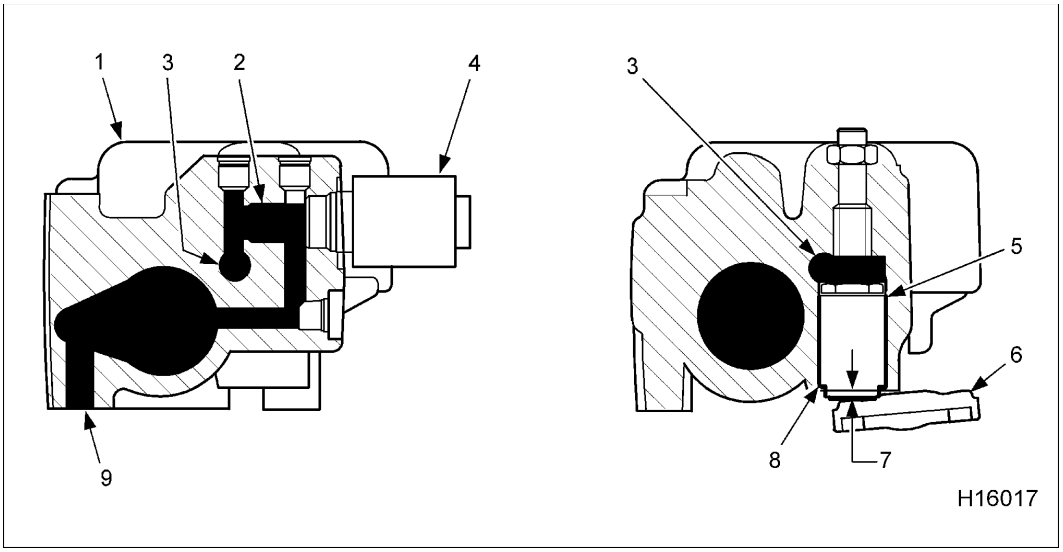


Figure 49 Brake shutoff valve and brake actuator– ON

1. High-pressure oil rail
2. High-pressure oil flow to brake oil gallery
3. Brake oil gallery
4. Brake shutoff valve assembly
5. Brake actuator piston assembly
6. Exhaust valve bridge
7. Valve lash (actuator deployed)
8. Normal oil seepage
9. Oil inlet

The ECM monitors the following criteria to make sure certain conditions are met.

- ABS (inactive)
- RPM (greater than 1200)
- APS (less than 5%)
- Idle validation
- EOT (greater than or equal to 60 °C [140 °C])
- Operator input switches (On/Off) (power selection – Low, Med, High)

If On is selected, and the above criteria is met, the engine brake will activate.

When the engine brake is activated, the ECM provides the power to activate the brake shutoff valve to allow oil from the injector oil gallery to flow to the brake oil gallery. High oil pressure activates the brake actuator pistons to open the exhaust valves.

During an ABS event, the engine brake is deactivated. The engine brake is activated once the ABS event is over.

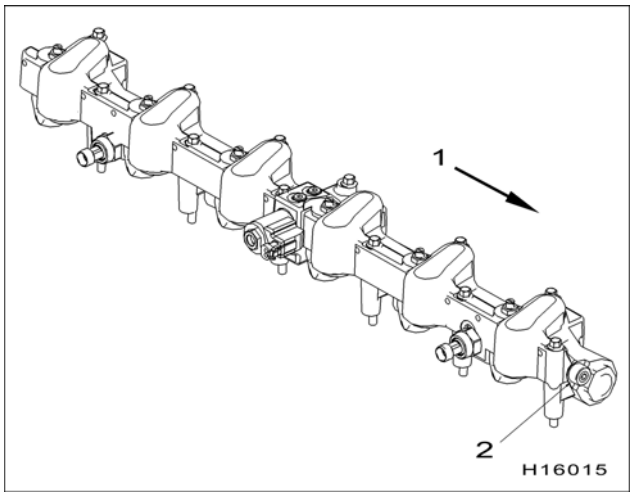


Figure 50 Brake pressure relief valve in high-pressure oil rail

1. Front of engine
2. Brake pressure relief valve

The ECM removes the ground source from the brake shutoff valve to deactivate the engine brake. Residual brake gallery pressure initially bleeds from the actuator bore. When brake gallery pressure reaches 1000 psi, the brake pressure relief valve opens, and oil drains back to sump.

Table of Contents

Engine Preparation

Cleaning the Engine

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.

WARNING: To prevent personal injury or death, read all safety instructions in the "Safety Information" section of this manual.

WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

WARNING: To prevent personal injury or death, disconnect ground (-) cable from battery before doing service or diagnostic procedures.

WARNING: To prevent personal injury or death, allow engine to cool before working with components.

WARNING: To prevent personal injury or death, do not let engine fluids stay on your skin. Clean skin and nails using hand cleaner and wash with soap and water. Wash or discard clothing and rags contaminated with engine fluids.

1. Cap all openings to prevent water and degreased agents from entering any engine components internally.
2. Cover any exposed electrical pin connectors and ECM, IDM, and EGR modules using plastic and duct tape.
3. Use an appropriate detergent mixed in the correct ratio of water and apply to engine using a hot water pressure washer or similar cleaning equipment.

Draining Engine Fluids

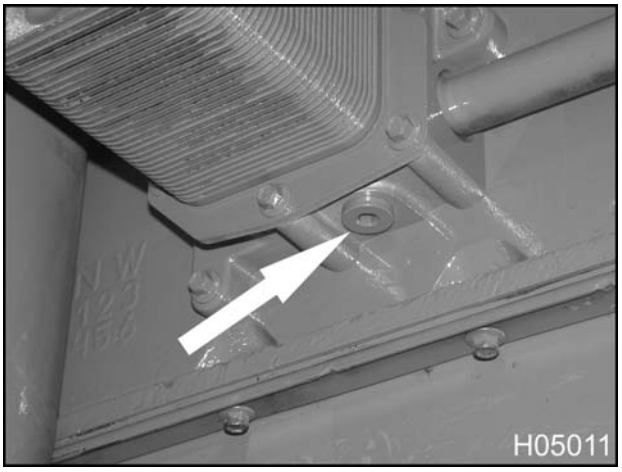


Figure 51 Coolant drain plug location

1. Place a coolant drain pan beneath the coolant drain plug. Remove coolant drain plug (M18) and O-ring from the bottom of the oil system module. Discard O-ring. Open radiator cap to allow system to drain quicker.
2. After draining coolant, install new O-ring on plug and install in module. Torque plug to the standard torque value (General Torque Guidelines, page 445). Dispose of used coolant according to applicable laws

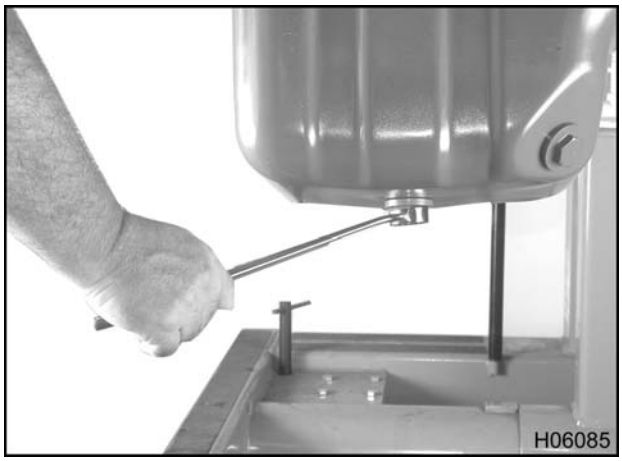


Figure 52 Draining the oil

3. Place a oil drain pan beneath the oil drain plug to collect the oil.
4. Remove oil pan drain plug (M25) and O-ring. Drain engine oil and dispose of used engine oil according to applicable laws.
5. Discard O-ring, inspect drain plug and replace if necessary. Place a new O-ring onto drain plug and install to oil pan. See special torque value (Table 3).

Component Removal

Turbocharger Oil Inlet Tube

1. Loosen turbocharger oil inlet tube assembly nut from fitting on top of oil filter header.
2. Remove two mounting bolts (M8 x 20) securing the turbocharger and oil inlet tube assembly to the top of the turbocharger central housing. Remove turbocharger oil inlet tube assembly. Discard flange O-ring.
3. Remove turbocharger oil drain tube bracket and bolt (M8 x 16) at crankcase.

Turbocharger

WARNING: To prevent personal injury or death, inspect turbocharger with engine off, and turbocharger not spinning. Turbocharger components may be extremely hot. Turbocharger wheels are very sharp and spin at high speeds.

WARNING: To prevent personal injury or death, support turbocharger assembly during removal and installation.

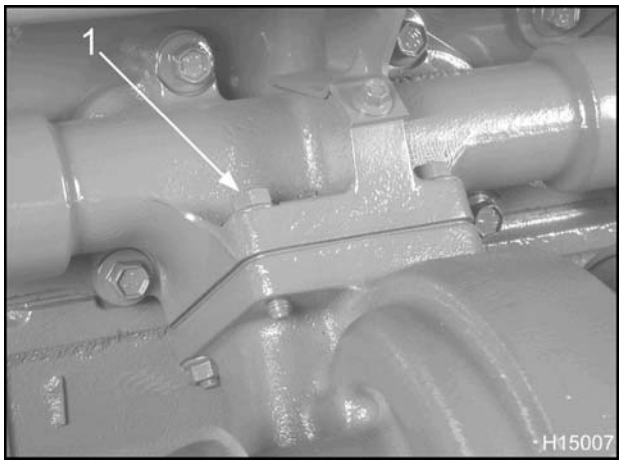


Figure 53 Turbocharger mounting nuts

1. Nut, M10 (4)

NOTE: To aid in the disassembly of the turbocharger, loosen four nuts (M10) between 1/8 and 1/4 of a turn then tap each nut using a socket or flat punch and hammer. This will knock the “peaks” of the stud threads off the “ramps” of the special Spiralock® nuts, thus allowing the nuts to unthread with considerable ease.

NOTE: Remove turbocharger and oil drain tube as an assembly. The oil drain tube is trapped between the turbocharger and crankcase.

1. Remove four nuts (M10 flange head) securing turbocharger assembly to exhaust manifold flange.

2. Remove turbocharger assembly, oil drain tube, and turbo mounting O-ring from engine. Discard oil drain tube O-rings.
3. Cap all openings on turbocharger assembly.

NOTE: If plastic caps are not available, use duct tape to cover openings.

Oil Filter

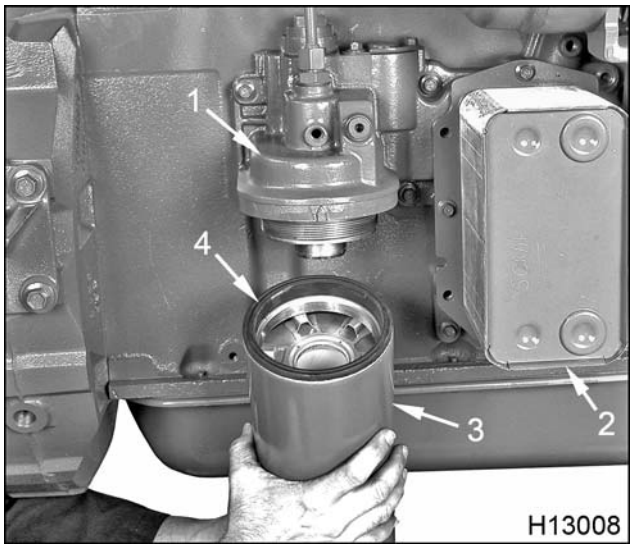


Figure 54 Removing the oil filter

1. Oil filter header
2. Oil cooler
3. Oil filter (spin-on)
4. Oil filter gasket

Remove oil filter from oil cooler filter header. Discard oil filter.

Oil System Module

1. Remove one bolt (M8 x 16) securing oil cooling drain tube assembly to crankcase.
2. Remove eight bolts (M8 x 30) securing oil system module to crankcase.
3. Remove oil system module and oil cooler drain tube as an assembly from crankcase and discard O-rings. The oil cooler drain tube is trapped between the oil system module and the front cover.

Mounting Adapter Plate and Engine

Adapter Plate

⚠ WARNING: To prevent personal injury or death, use a chain hoist rated for the weight of the engine, follow manufacturer's installation and safety instructions, and attach safety latch lifting hooks to lifting eyes on the engine.

⚠ WARNING: To prevent serious personal injury, possible death or damage to the engine or vehicle, use only metric grade 10.9 or SAE grade 8 bolts when mounting adapter plate to engine as well as the engine stand. See instructional literature included with adapter plate for specific directions of its safe use.

1. Match Engine Mounting Plate (Table 4) with bolt holes on right side of engine to determine adapter plate orientation to the Engine Stand (Table 4).

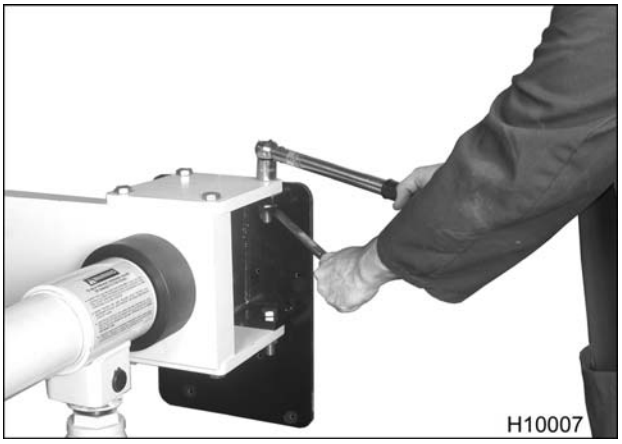


Figure 55 Installing the adapter plate to engine stand

2. Install recommended Engine Mounting Plate (Table 4) to engine stand and secure by using eight (grade 8) bolts and nuts. Tighten bolts to the standard torque value (General Torque Guidelines, page445).

Engine

1. Remove oil system module and oil cooler drain tube as an assembly from crankcase and discard O-rings. The oil cooler drain tube is trapped between the oil system module and the front cover.
2. Raise or lower engine to approximate height of Engine Stand (Table 4).
3. Align engine stand and Engine Mounting Plate (Table 4) to engine, rotating stand and / or raising engine to match adapter plate. Secure one bolt and rotate stand if necessary to thread remaining bolts.
4. Use metric grade 10.9 bolts to secure engine to Engine Mounting Plate (Table 4). Tighten bolts to the standard torque value (General Torque Guidelines, page445).

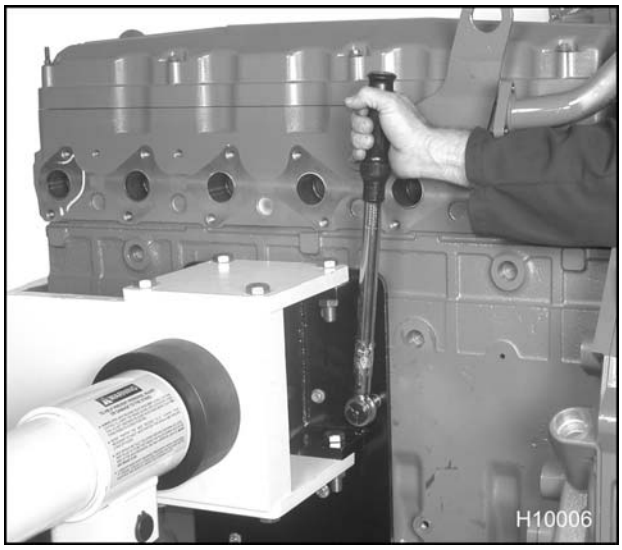


Figure 56 Torquing engine mounting bolts

5. Slowly release tension from engine hoist.
6. remove hoist safety chain hooks from engine lifting eyes.

Special Torque

Table 3 Engine Mounting Special Torques

Oil pan drain plug (M25)	68 N·m (50 lbf·ft)

Special Service Tools

Table 4 Special Tools

Engine Mounting Plate	ZTSE4649
Engine Stand	OTC1750A

Table of Contents

Description

For the procedures in this manual, the term Variable Geometry Turbocharger (VGT) will be used. See (Variable Geometry Turbocharger (VGT), page 21) for complete description of the EVRT® electronically controlled turbocharger.

This “EVRT® Electronically Controlled Turbocharger” section is for basic removal, exterior inspection and cleaning, and installation of the complete VGT assembly. See additional specific procedures in Appendix E for the following VGT components: turbocharger actuator, turbocharger actuator linkage, turbocharger actuator flange and pivot shaft, and turbine vane assembly

Instruction Sheets in Appendix E

- Installation of Turbocharger Actuator (1171855R1 Turbo Actuator Service Kit (SRA), page497). This service kit provides instructions for replacement of the turbocharger actuator without removal of the turbocharger from the engine.
- Installation of Turbocharger Actuator Linkage (1171908R1 Turbocharger VGT Linkage Kit, page 499). This service kit provides instructions for replacement of the turbocharger actuator linkage without removal of the turbocharger from the engine.
- Installation of Turbocharger Actuator Flange and Pivot Shaft (1171915R2 Turbocharger Actuator Flange and Pivot Shaft Kit, page 508). This service kit provides instructions for replacement of internal turbocharger actuator flange and pivot shaft. These procedures require removal of the turbocharger from the engine.
- Cleaning Turbine Vane Assembly (1171913R1 Turbine Vane Assembly Cleaning Kit, page 503). This service kit provides instructions for cleaning the turbine vane area inside the housing when vanes become stuck due to excessive oil deposits. These procedures require removal of the turbocharger from the engine.

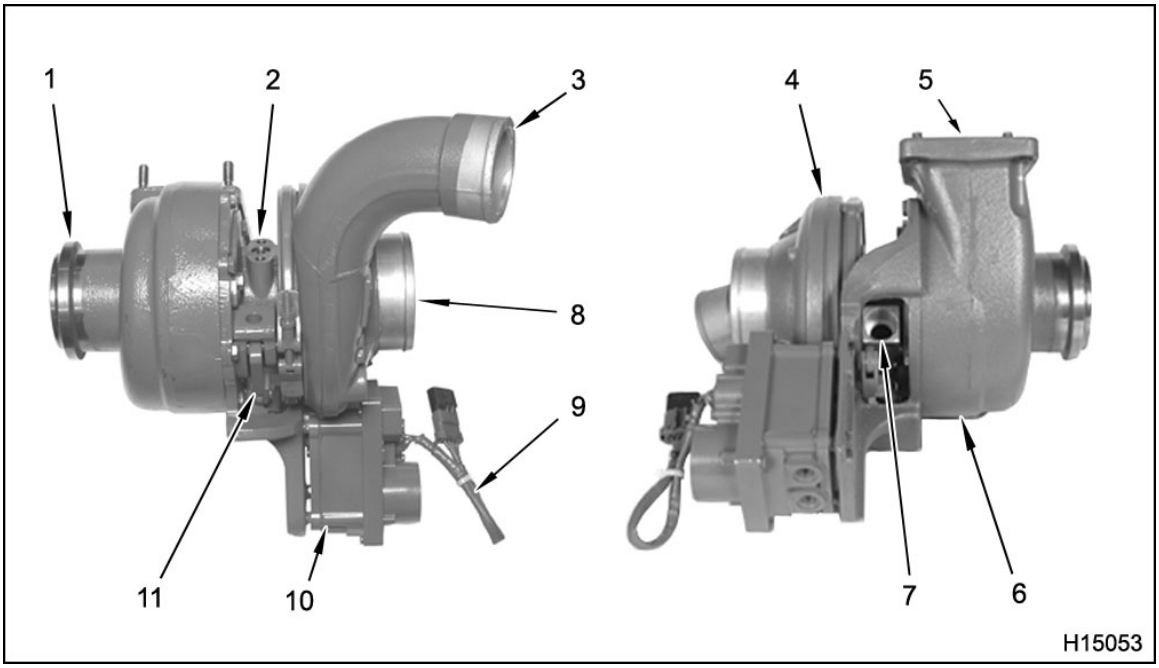


Figure 57 Variable Geometry Turbocharger (VGT) components

1. Turbine outlet
2. Oil supply port
3. Compressor outlet
4. Compressor housing
5. Turbine inlet
6. Turbine housing
7. Oil drain port
8. Compressor inlet
9. Electrical connector and wire
10. Turbocharger control module
11. VGT linkage

Removal

Variable Geometry Turbocharger (VGT) Assembly

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.

WARNING: To prevent personal injury or death, read all safety instructions in the "Safety Information" section of this manual.

WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

WARNING: To prevent personal injury or death, allow engine to cool before working with components.

WARNING: To prevent personal injury or death, disconnect ground (-) cable from battery before doing service or diagnostic procedures.

WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

WARNING: To prevent personal injury or death, support turbocharger assembly during removal and installation.

WARNING: To prevent personal injury or death, do not let engine fluids stay on your skin. Clean skin and nails using hand cleaner and wash with soap and water. Wash or discard clothing and rags contaminated with engine fluids.

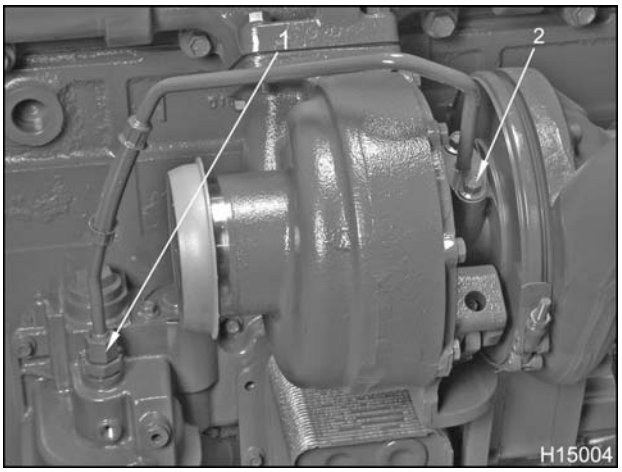


Figure 58 Oil inlet tube assembly

1. Nut
2. Bolt, M8 x 20 (2)

1. Remove turbo oil inlet tube assembly nut from fitting on top of oil filter header.
2. Remove two M8 x 20 bolts from turbo oil inlet tube assembly. Remove tube assembly, and discard O-ring.

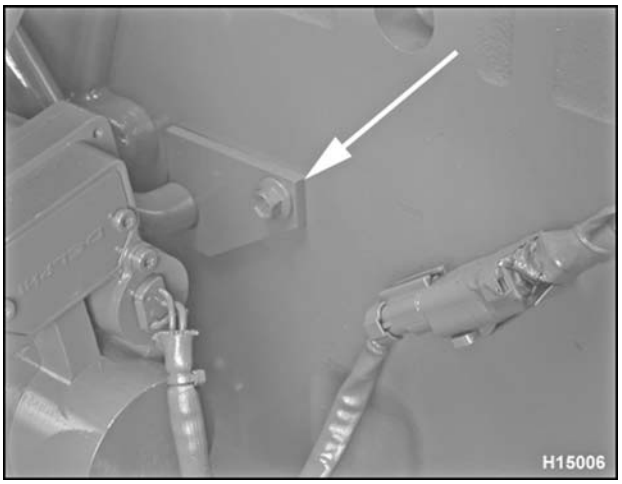


Figure 59 Oil drain tube bracket and bolt

3. Remove the M8 x 16 bolt from the turbo oil drain tube bracket.
4. Disconnect electrical harness from VGT actuator.

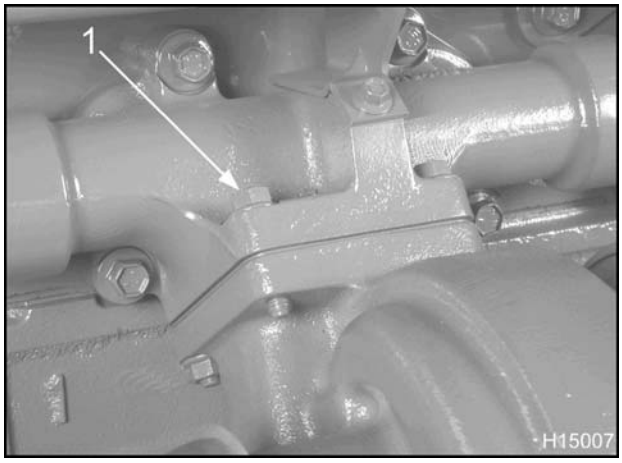


Figure 60 VGT mounting

1. M10 Spiralock® nut (4)

NOTE: To aid removal of the turbocharger, loosen four M10 nuts 1/4 turn then tap each nut using a socket or flat punch and a hammer. This will knock the “peaks” of the threads down, allowing the nuts to unthread easily.

WARNING: To prevent personal injury or death, support turbocharger assembly during removal and installation.

5. Remove three of four M10 Spiralock® nuts holding the VGT assembly to the exhaust manifold.
6. Support the VGT assembly, remove the fourth M10 nut, and remove the VGT assembly and turbocharger oil drain tube as a combined unit.
7. Remove the oil drain tube from VGT assembly and discard the oil drain tube O-rings.
8. Remove and discard the turbocharger mounting gasket.
9. Discard used M10 Spiralock® nuts.

Cleaning

Turbocharger and Related Parts

WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

1. Use soap and water to clean piping between VGT and air cleaner assembly. Use filtered compressed air to dry piping.
2. Use filtered compressed air to clean the air inlet piping and connecting hoses.
3. Use a suitable solvent and a nylon brush to clean the oil inlet tube and oil drain tube. Use filtered compressed air to dry the tubes. Replace any damaged tubes.
4. Clean remaining gasket material from mounting surface of the turbine housing and exhaust manifold.

Inspection

Checking Turbine and Compressor

WARNING: To prevent personal injury or death, inspect turbocharger with engine off, and turbocharger not spinning. Turbocharger components may be extremely hot. Turbocharger wheels are very sharp and spin at high speeds.

1. Position VGT on a workbench so that the shaft is horizontal.

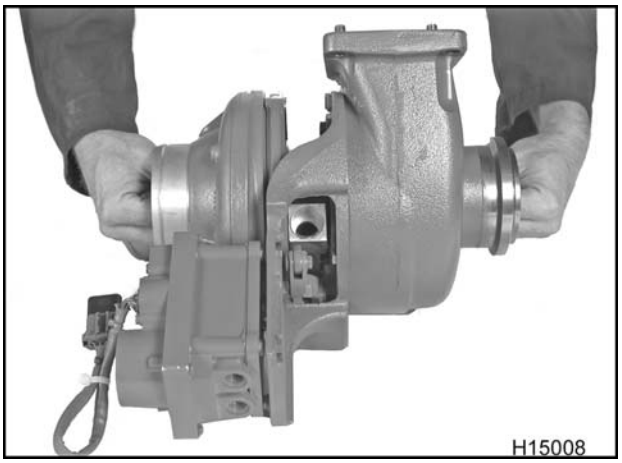


Figure 61 Checking shaft rotation

2. Turn shaft by hand and check for wheel rub within each housing.

   The wheels must rotate freely. If there is any rubbing or interference, replace the VGT assembly.

NOTE: Do not straighten bent blades.

3. Check the compressor impeller and turbine wheel. If there are deposits on the blades or any blades are bent, broken or eroded, replace the VGT assembly.

Checking Rotation of Actuator Shaft

1. Place VGT assembly onto a clean workbench.
2. Position VGT assembly so that actuator linkage can be easily accessed and viewed.
3. Move the actuator shaft through its entire travel. The actuator shaft should rotate 90° and return under spring tension (Table 5).

Installation

Variable Geometry Turbocharger (VGT) Assembly

1. Position VGT on a workbench so the oil supply port faces up.
2. Prelube the VGT assembly by adding oil to the oil supply port while rotating the turbine shaft. Continue to add oil until oil comes out the oil drain port.
3. Place a new turbocharger mounting gasket onto turbocharger flange studs.
4. Place a new O-ring onto each end of the turbocharger oil drain tube and lubricate with clean engine oil.

CAUTION: To prevent serious personal injury, possible death, or damage to the engine or vehicle, exercise special care not to cut or damage oil drain tube O-rings.

5. Install oil drain tube into turbocharger side and then move turbocharger and oil drain tube into cylinder block as a unit.

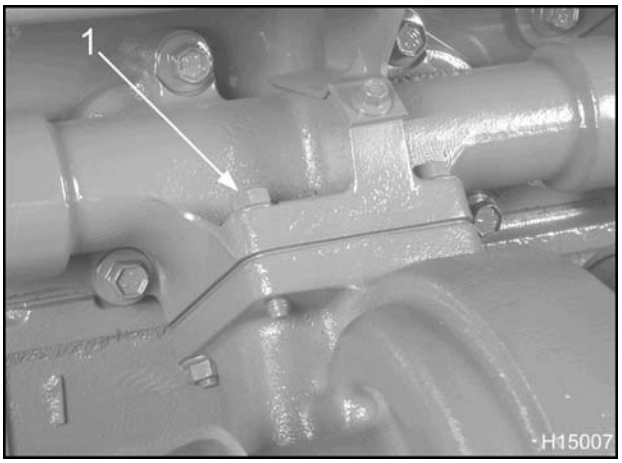


Figure 62 VGT mounting

1. M10 Spiralock® nut (4)

WARNING: To prevent personal injury or death, support turbocharger assembly during removal and installation.

6. Lift VGT assembly onto engine and insert VGT mounting studs into the exhaust manifold flange.

Install two new M10 Spiralock® nuts on the VGT mounting studs.

7. Install two new M10 Spiralock® nuts on the exhaust manifold studs.
8. Verify the oil drain tube is seated in the crankcase oil drain port.
9. Tighten four M10 Spiralock® nuts to the special torque (Table 6).

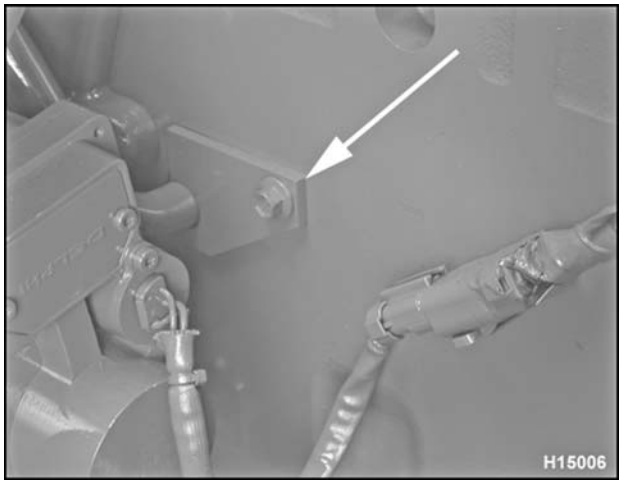


Figure 63 Oil drain tube bracket and bolt

10. Align oil drain tube bracket with bolt (M8 x 16) and hole and tighten bolt to the standard torque value (General Torque Guidelines, page445).
11. Place a new turbo oil inlet O-ring over oil inlet flange located on top of the VGT central housing.

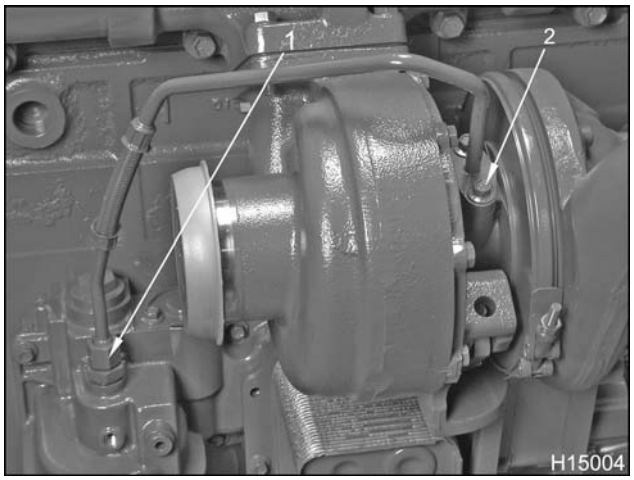


Figure 64 Oil inlet tube assembly

1. Nut
2. Bolt, M8 x 20 (2)

12. Thread two bolts (M8 x 20) through turbo oil inlet tube assembly at the top of the VGT. Do not tighten these bolts yet.
13. Thread oil inlet tube assembly nut onto fitting located on top of oil filter header.
14. Tighten two bolts (M8 x 20) at the top of the oil inlet tube assembly to the standard torque value (General Torque Guidelines, page445).
15. Tighten oil inlet tube assembly nut to the standard torque value (General Torque Guidelines, page 445).
16. Connect electrical harness to VGT actuator.

Specifications

Table 5 VGT Specifications

VGT axial linkage shaft	Must strike open and closed stops in actuator, 90° rotation

Special Torque

Table 6 VGT Special Torques

VGT Spiralock® nuts (M10)	71 N·m (52 lbf·ft)

Table of Contents

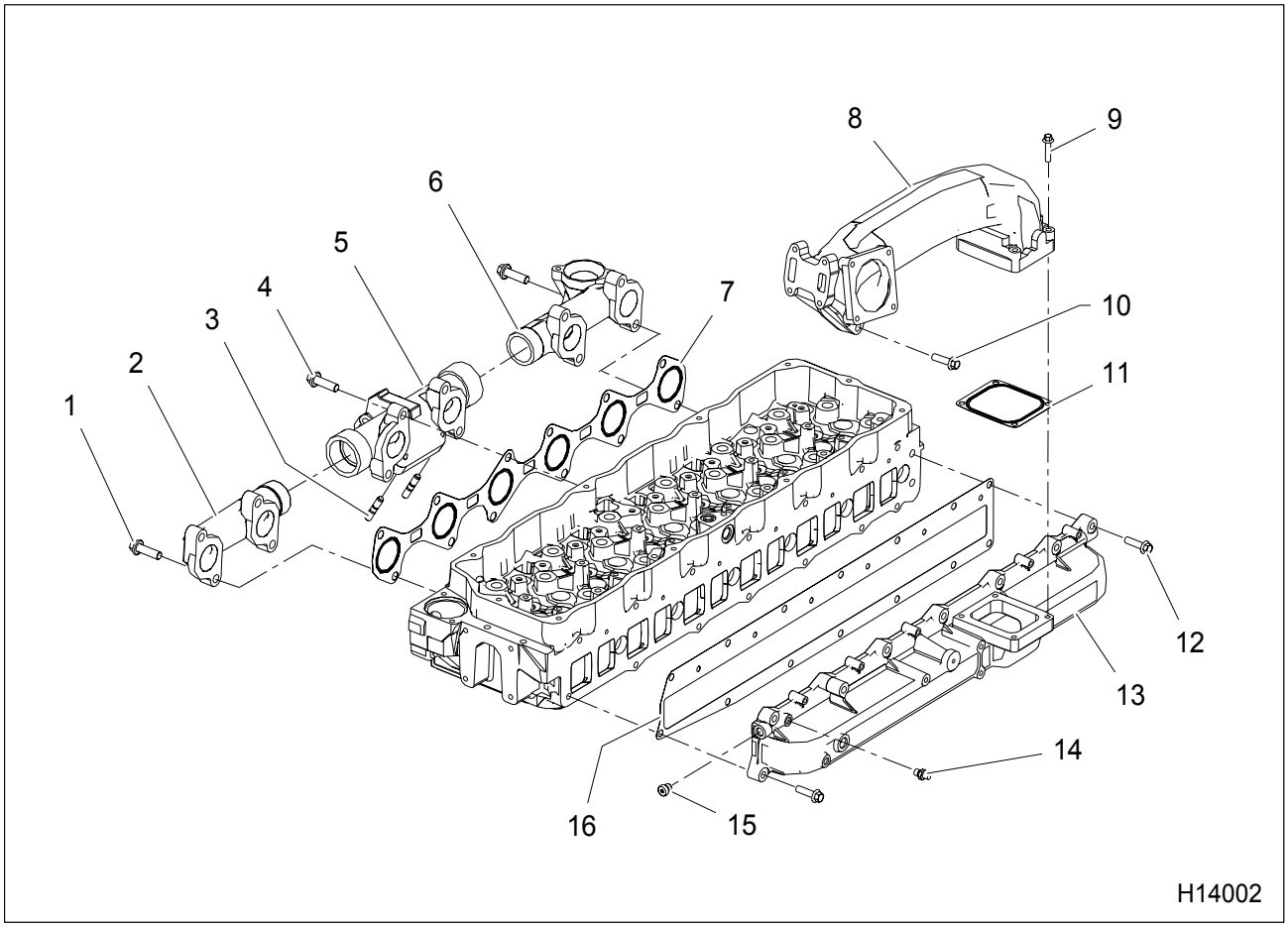


Figure 65 Intake manifold, inlet and EGR mixer, and exhaust manifold assemblies

1. Exhaust manifold flange head bolt, M12 x 35 (11)
2. Manifold, exhaust front
3. Stud, M10 (2)
4. Manifold, exhaust center (low or high mount turbo versions)
5. Exhaust manifold and EGR bracket flange head bolt, M12 x 120 (1)
6. Manifold, exhaust rear (short or long EGR cooler version)
7. Exhaust manifold gasket
8. Inlet and EGR mixer duct
9. EGR mixer flange bolt, M8 x 60 (4)
10. EGR mixer support bolt, M10 x 90
11. Intake manifold to mixer gasket
12. Intake manifold bolt, M10 x 35 (13)
13. Intake manifold
14. Fuel (Schrader) valve
15. Intake manifold plug (2)
16. Intake manifold gasket

Removal

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.

WARNING: To prevent personal injury or death, read all safety instructions in the "Safety Information" section of this manual.

WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

WARNING: To prevent personal injury or death, allow engine to cool before working with components.

WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

WARNING: To prevent personal injury or death, do not let engine fluids stay on your skin. Clean skin and nails using hand cleaner and wash with soap and water. Wash or discard clothing and rags contaminated with engine fluids.

NOTE: For information regarding the removal or installation of adjacent components, refer to the following service procedures located in other sections of this manual:

- VGT turbo
- EGR valve
- Fuel filter assembly
- Crankcase breather
- Oil fill tube assembly

Exhaust Manifold

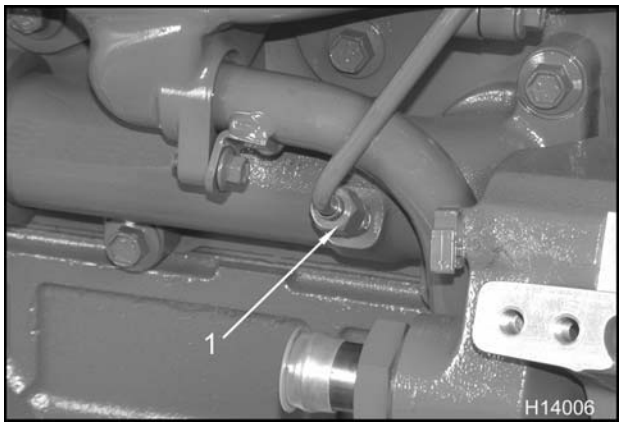


Figure 66 EBP tubing nut

1. EBP tubing nut

1. Disconnect the EBP tubing nut at exhaust manifold.

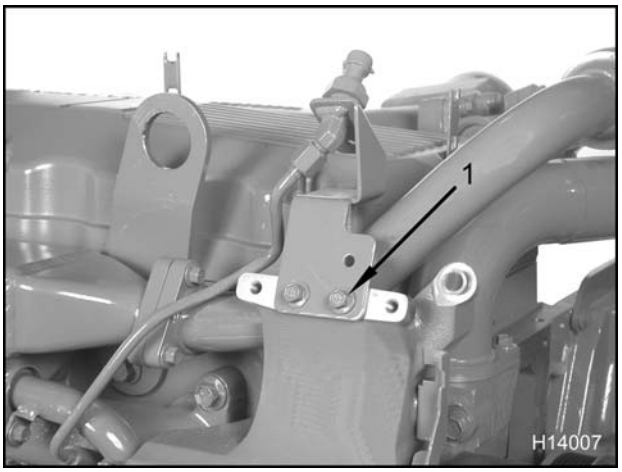


Figure 67 Removing EBP tubing bracket

1. EBP tubing bracket bolt (2)

2. Remove EBP tubing bracket bolts at water housing (Freon® compressor bracket).
3. Lift the EBP tubing and bracket assembly from the engine.

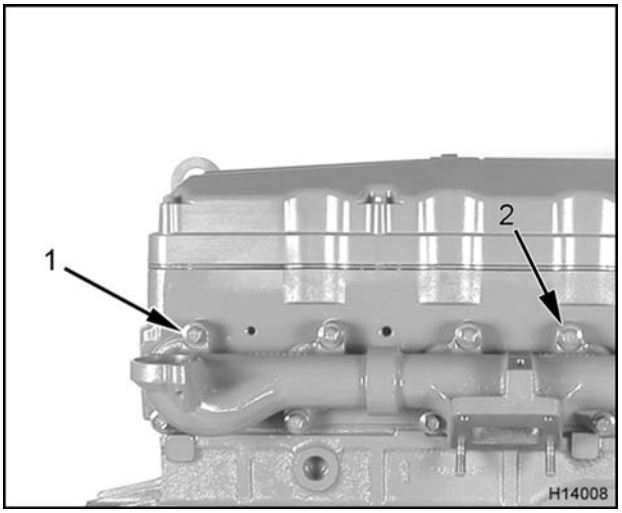


Figure 68 Exhaust manifold mounting bolts

1. Exhaust manifold mounting bolt, M12 x 35 (11)
2. Exhaust manifold mounting bolt, M12 x 120

4. Remove 11 mounting bolts (M12 x 35) and one mounting bolt (M12 x 120) securing the three-piece exhaust manifold to the cylinder head.

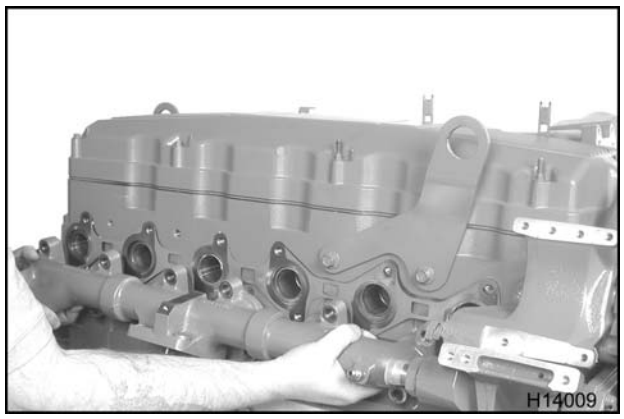


Figure 69 Removing exhaust manifold

5. Remove exhaust manifold from the engine and discard the one piece gasket.

Inlet and EGR Mixer Duct

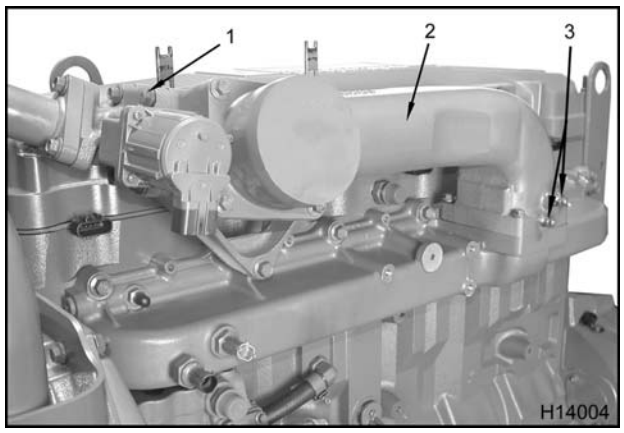


Figure 70 Inlet and EGR mixer duct related components

1. EGR valve mounting bolt (4)
2. Inlet and EGR mixer duct
3. Inlet Air Heater (IAH) connections

1. Remove four EGR valve mounting bolts at the EGR valve to mixer duct connection.
2. Remove EGR valve and discard gasket.

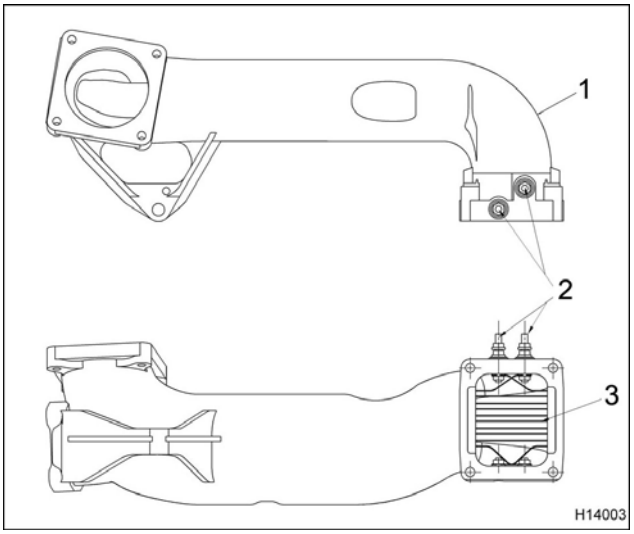


Figure 71 Intake air heater – dual element

1. Inlet and EGR mixer
2. Intake air heater cable locations
3. Intake air heater element

See (TSI-05-12-35 New 1500 Watt Single Grid Intake Air Heater Production Option, page 466).

3. Disconnect Inlet Air Heater (IAH) cable(s).

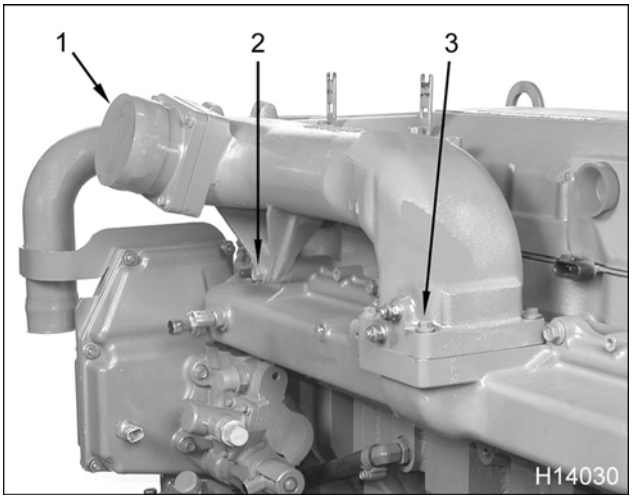


Figure 72 Inlet and EGR mixer duct bolts

1. Inlet adapter
2. Inlet and EGR mixer support bolt, M10 x 90
3. Inlet mixer bolt, M8 x 60 (4)

4. Remove the inlet and EGR mixer duct bolts.

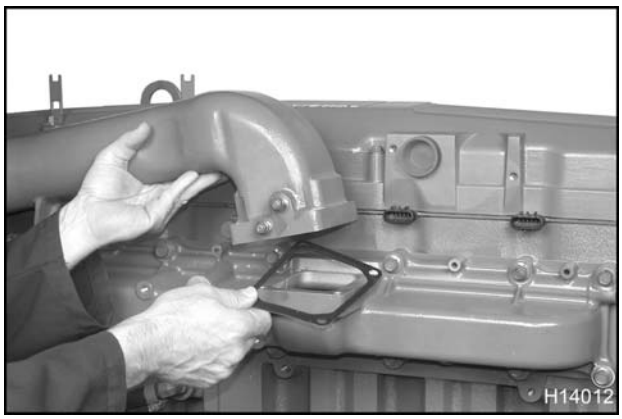


Figure 73 Inlet and EGR mixer duct gasket

5. Lift inlet and EGR mixer duct away from the intake manifold. Remove gasket and discard.

Aluminum Air Inlet Adapter and Inlet Air Heater Option

See (1171846R1 Aluminum Air Inlet Adapter, page 492).

Intake Manifold

1. Disconnect wire from MAP and MAT sensor connectors.
2. Disconnect injector harness anchor points.
3. Pull out wiring harness and connectors.
4. Disconnect the high-pressure oil hose at pump.

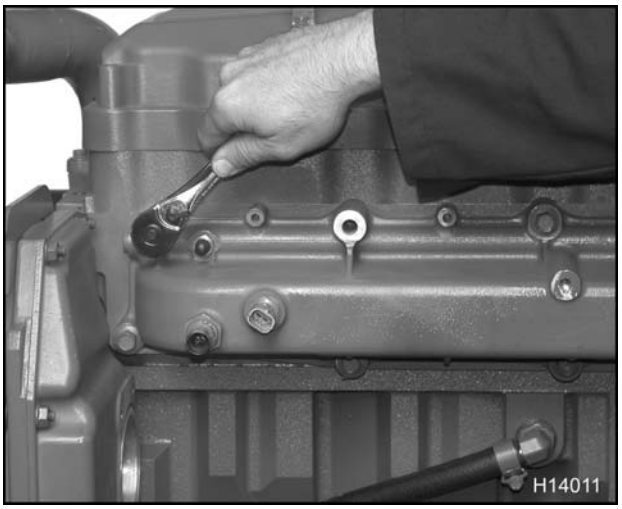


Figure 74 Intake manifold mounting bolts

5. Remove 13 intake manifold mounting bolts (M10 x 35).
6. Remove intake manifold and gasket from the engine. Discard gasket.

Cleaning and Inspection

Exhaust Manifold

1. Clean exhaust manifold thoroughly with a suitable non-caustic solvent. Scrape off excess scale and rust from manifold surfaces.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

2. After cleaning, blow dry exhaust manifold using filtered compressed air.
3. Inspect manifold for cracks or damage. Replace manifold as necessary.
4. Check for warpage as follows:
   a. Install exhaust manifold without the gasket to a cleaned cylinder head mating surface. Torque 12 mounting bolts (M12 x 35) to the special torque value (Table 8).

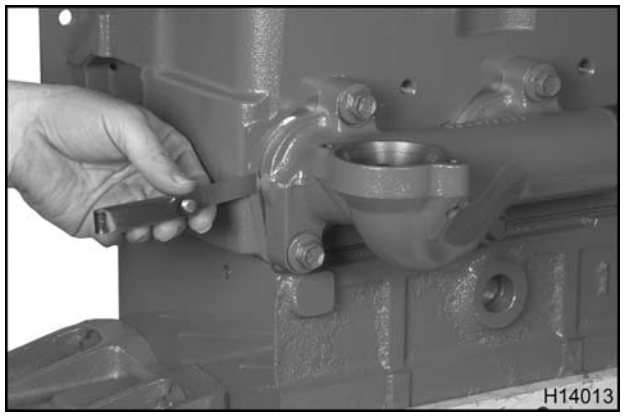


Figure 75 Checking exhaust manifold for cracks and warpage

   b. Use a 0.25 mm (0.010 in) feeler gauge to measure the gap between the mating surfaces of the manifold and engine. If the feeler gauge passes through the gap, the manifold must be resurfaced.

      NOTE: A maximum of 0.64 mm (0.025 in) of material can be ground off to correct warpage.

   c. Remove 12 bolts (M12 x 35) and manifold.
   d. If the warpage cannot be corrected by grinding manifold mating surface, replace manifold.

Intake Manifold

CAUTION: To prevent engine damage, do not attempt to grind or machine the intake manifold to compensate for a warped condition.

1. Clean intake manifold thoroughly with a suitable non-caustic solvent.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

2. After cleaning, blow dry using filtered compressed air.
3. Check manifold for cracks and damage. Replace intake manifold as necessary.

Installation

Exhaust Manifold

CAUTION: To prevent engine damage, make sure exhaust manifold gasket and exhaust manifold are aligned before tightening bolts to the specified torque value.

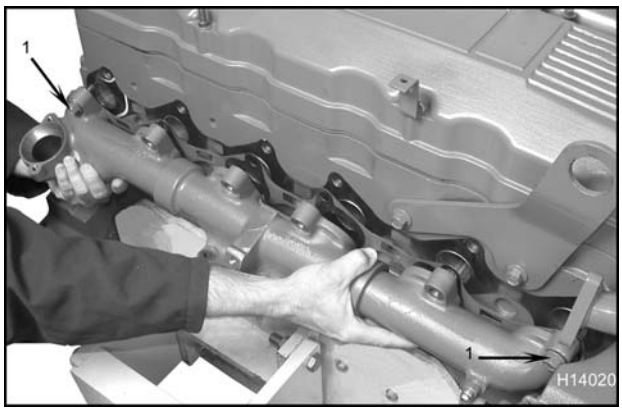


Figure 76 Installing exhaust manifold

1. Bolts installed holding gasket

1. Apply anti-seize compound to all 11 bolt (M12 x 35) threads and one bolt (M12 x 120) used with the EGR cooler bracket.
2. Insert an exhaust manifold bolt (M12 x 35) at each end of the assembled exhaust manifold. Place the exhaust manifold gasket over these two bolts. This will ensure a proper alignment of the exhaust manifold and gasket.

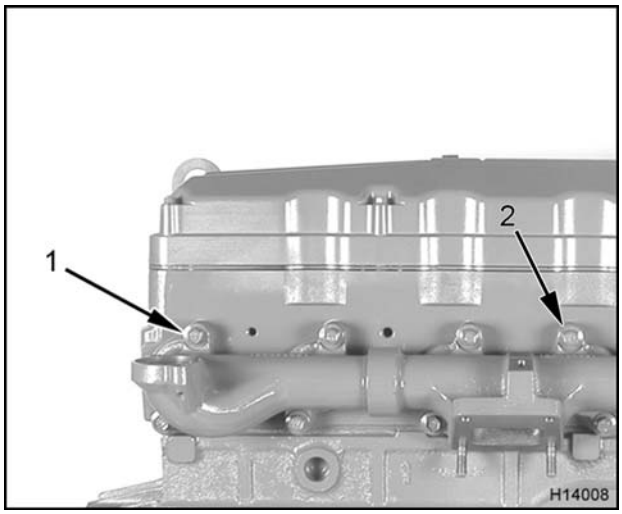


Figure 77 Exhaust manifold mounting bolts

1. Exhaust manifold mounting bolt, M12 x 35 (11)
2. Exhaust manifold mounting bolt, M12 x 120

3. Install assembled exhaust manifold with a new gasket to cylinder head.

NOTE: Refer to the EGR Cooler and Tubing Section for instructions assembling the EGR cooler.

4. Torque the exhaust manifold bolts in the following three step sequence.

Exhaust Manifold Torque Sequence

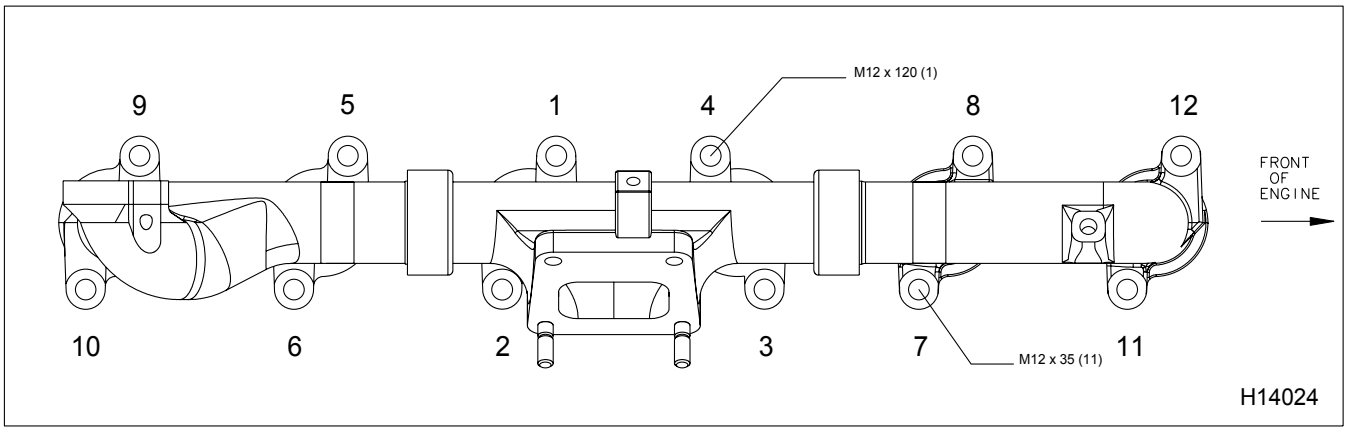


Figure 78 Exhaust manifold torque sequence

a. Torque all bolts in sequence 1 through 12 to 27 N·m (20 lbf·ft).

b. Torque all bolts in sequence 1 through 12 to 54 N·m (40 lbf·ft).

c. Torque all bolts in sequence 1 through 12 to 109 N·m (80 lbf·ft).

CAUTION: To prevent engine damage, make sure that the EGR cooler bracket bolt (M12 x 120) has a final torque value of 116 N·m (85 lbf·ft). This applies only to this bolt (number 4 in the sequence).

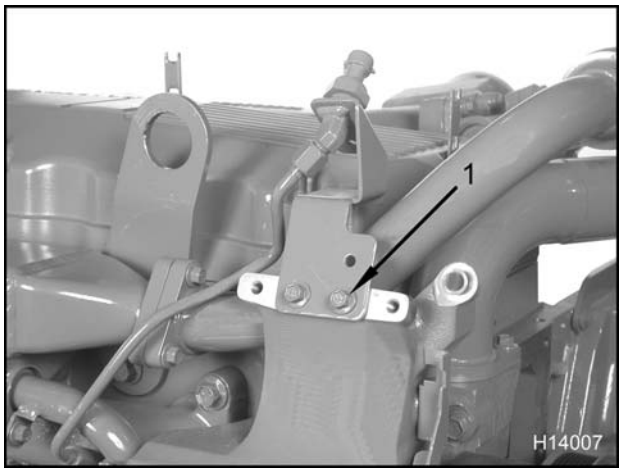


Figure 79 Installing EBP tubing bracket

1. EBP tubing bracket bolts, M8 x 20 (2)

5. Install EBP tubing bracket assembly and bolts onto the water supply housing (Freon® compressor bracket) and finger tighten.

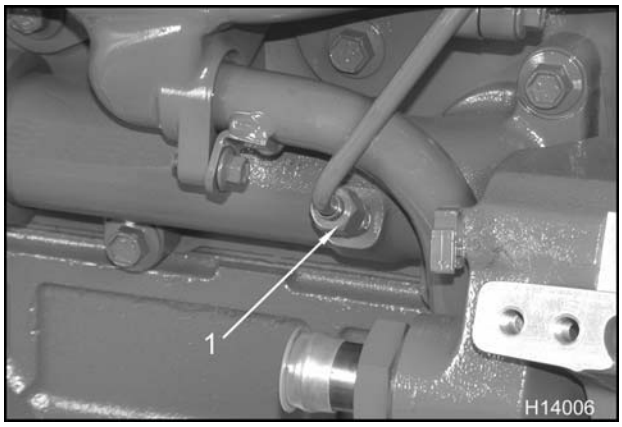


Figure 80 Installing EBP tubing nut

1. EBP tubing nut

6. Torque tubing nut to the standard torque value (General Torque Guidelines, page445).
7. Torque EBP tubing bracket bolts to the standard torque value (General Torque Guidelines, page 445).
8. Install the EBP sensor connector.

Intake Manifold

Figure 81 Aligning intake gasket to manifold

1. Insert an intake manifold bolt (M10 x 35) into each end of the intake manifold (both top holes). Place intake manifold gasket over these two bolts to ensure proper alignment between the manifold and gasket.
2. Install the intake manifold and gasket to the cylinder head by starting the two top end bolts by hand.

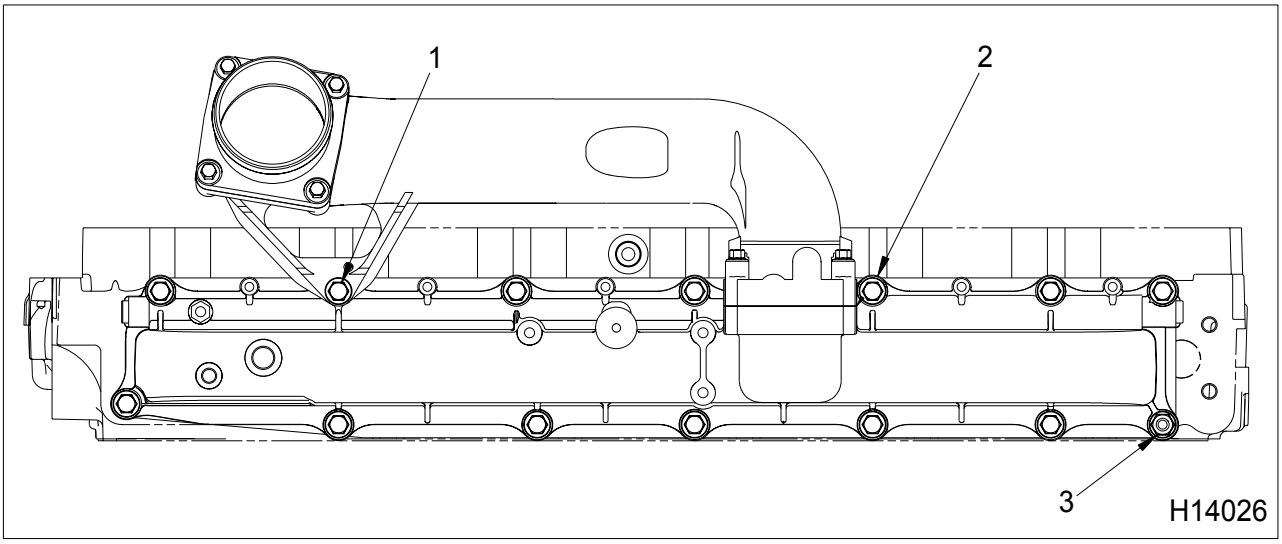


Figure 82 Intake manifold and inlet duct bolt configuration

1. Inlet and EGR mixer support bolt, M10 x 90
2. Bolt, M10 x 35 (12)
3. Bolt / Stud, M10 x 35 / 20

3. Place bolt / stud, (M10 x 35 / 20) into the rear most bolt hole along the bottom finger tight.
4. Install the remaining short intake manifold mounting bolts (M10 x 35) finger tight, in their correct positions. One bolt hole should remain open for later installation of the inlet and EGR mixer support and bolt.
5. Connect injectors and anchor harness.
6. Connect harness to MAP and MAT sensors.

Inlet and EGR Mixer Duct

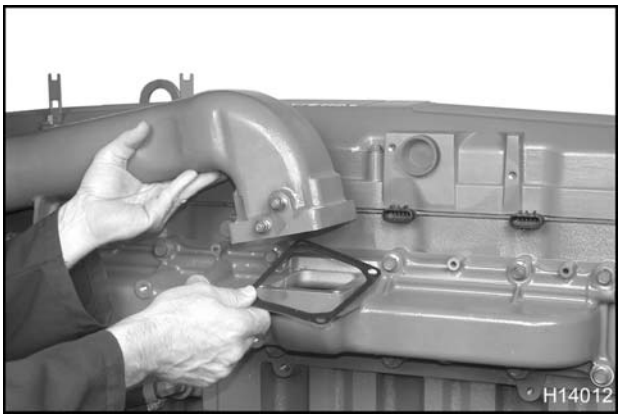


Figure 83 Inlet and EGR mixer gasket

1. Install inlet and EGR mixer with new gasket.

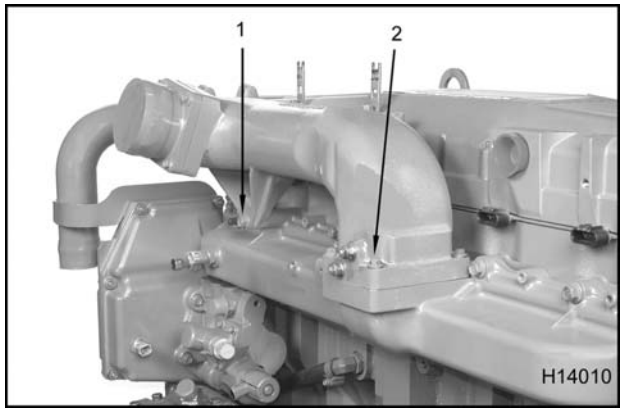


Figure 84 Mounting the inlet and EGR mixer

1. Inlet and EGR mixer support bolt, M10 x 90
2. Inlet mixer bolts, M8 x 60 (4)

2. Install four bolts (M8 x 60) that hold the inlet and EGR mixer to the intake manifold, but do not tighten.
3. Thread the inlet and EGR mixer duct support bolt (M10 x 90) finger tight.

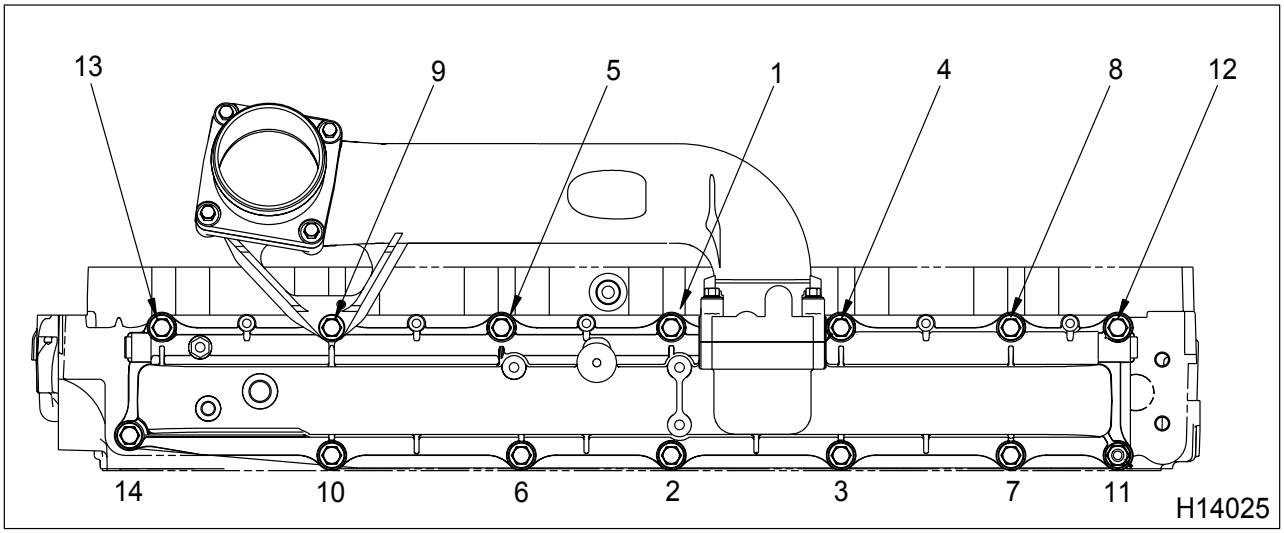


Figure 85 Intake manifold torque sequence

4. Torque intake manifold bolts including the inlet and EGR mixer support bolt (M10 x 90) to the standard torque value (General Torque Guidelines, page 445) and in the recommended sequence.

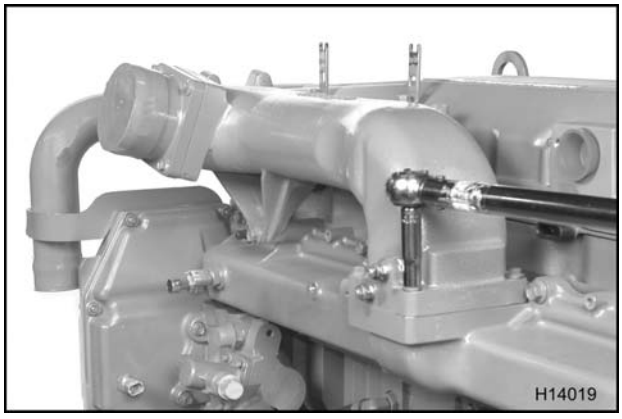


Figure 86 Torque the inlet and EGR mixer bolts

5. Torque four inlet mixer bolts (M8 x 60) to the standard torque value (General Torque Guidelines, page 445).
6. Install fuel assembly valve if removed, and tighten to the special torque value (Table 8).
7. Install intake plug assemblies, if removed (M12) and tighten to the special torque value (Table 8).

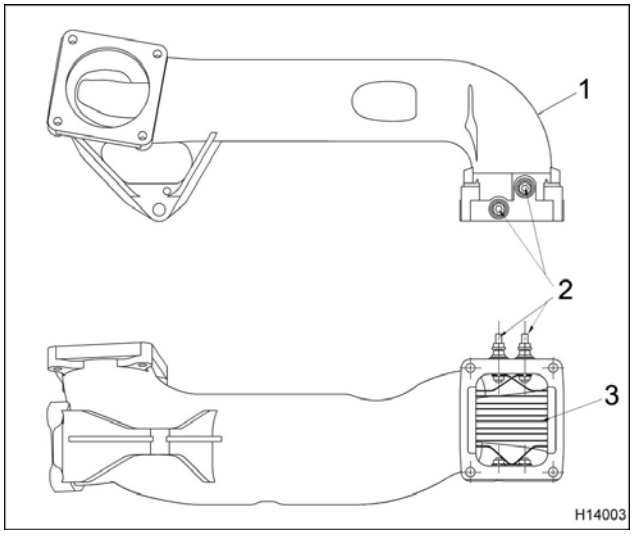


Figure 87 Intake air heater – dual element

1. Inlet and EGR mixer
2. Intake air heater cable locations
3. Intake air heater element

See (TSI-05-12-35 New 1500 Watt Single Grid Intake Air Heater Production Option, page 466).

8. Connect Inlet Air Heater (IAH) cable(s).

Specifications

Table 7 Exhaust Manifold Specifications

Allowable warpage (max.)	0.10 mm (0.004 in) overall
Flange thickness (min.)	21.59 mm (0.850 in)

Special Torque

Table 8 Intake Manifold, Inlet and EGR Mixer, and Exhaust Manifold Special Torques

Exhaust manifold mounting torque and sequence.	See “Exhaust manifold torque sequence” (page 85).
Fuel assembly valve	15 N·m (132 lbf·in)
Intake manifold mounting bolts	40 N·m (30 lbf·ft)
Intake plug assembly	25 N·m (18 lbf·ft)

Table of Contents

Description

EGR COOLANT SYSTEM

The original production version of the complete EGR coolant system and first EGR cooler return configuration, beginning model year 2004, starts at the front of this section.

Over the production life of the International® DT 466, DT 570 and HT 570 Diesel Engines, the EGR coolant return system was modified according to the following EGR cooler return configurations:

- Deeper O-ring location in EGR coolant return tube plus retaining clip
- EGR coolant return tube adapter and EGR coolant hose
- Round EGR coolers and EGR coolant hose
- Service kits to convert from original or first modification of EGR coolant return tube design changes to a more robust EGR coolant return hose design.

See specific EGR coolant return system modifications, listed in the Table of Contents in this section for service procedures.

EGR System Components (Beginning Model Year 2004)

Removal of EGR System Components

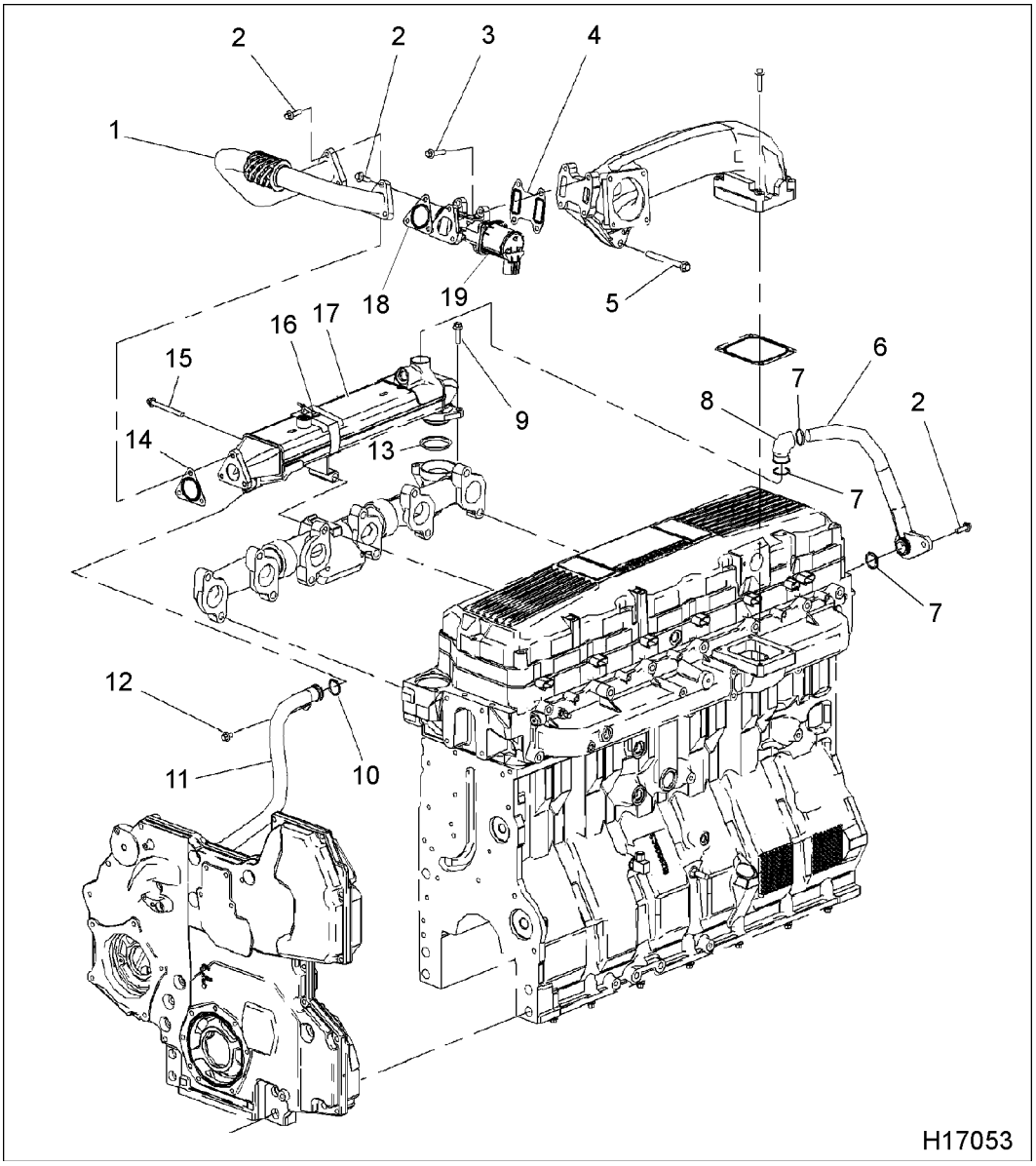


Figure 88 EGR system

1. EGR tube assembly
2. Bolt, M8 x 25 (7)
3. Bolt, M8 x 35 (4)
4. Gasket
5. Bolt, M10 x 90
6. EGR cooler return tube
7. O-ring (3)
8. EGR cooler return elbow
9. Bolt, M8 x 30 (2)
10. O-ring (2)
11. EGR cooler supply tube
12. EGR cooler supply tube retaining bolt, M8 x 16
13. Gasket, hot side
14. Gasket, cool side
15. Bolt, M12 x 120
16. EGR cooler bracket clamp
17. EGR cooler assembly
18. EGR cooler assembly gasket
19. EGR valve assembly

Table 9 EGR Cooler – Applications

EGR Cooler Length (inches)	Engine Model	Rated Brake Horsepower (bhp)
11.5	DT 466	225 and below
17.0	DT 466	245 and above
	DT and HT 570	295 and below
21.0	DT and HT 570	300 and above

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.

WARNING: To prevent personal injury or death, read all safety instructions in the "Safety Information" section of this manual.

WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

WARNING: To prevent personal injury or death, make sure that the engine has cooled before removing components.

WARNING: To prevent personal injury or death, do not let engine fluids stay on your skin. Clean skin and nails using hand cleaner and wash with soap and water. Wash or discard clothing and rags contaminated with engine fluids.

WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

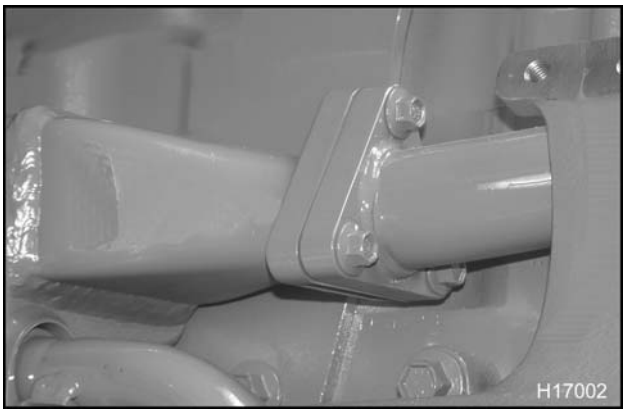


Figure 89 EGR tube assembly at EGR cooler

1. Remove three bolts (M8 x 25) from the EGR tube assembly at the EGR cooler assembly.

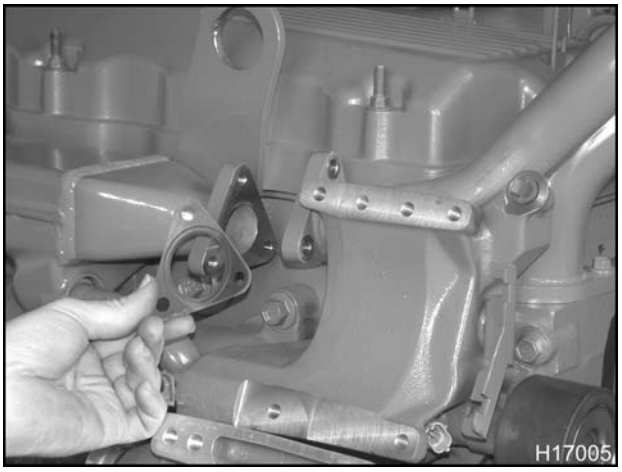


Figure 90 Removing the gasket

2. Pull tube assembly away and discard gasket.

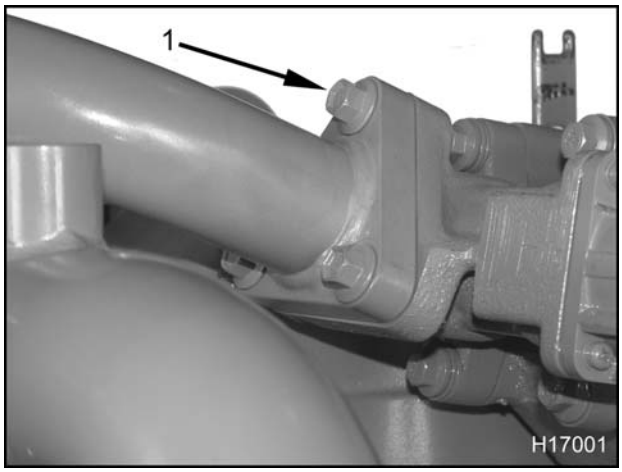


Figure 91 EGR tube assembly at EGR valve

1. Bolt, M8 x 25 (3)

3. Remove three bolts (M8 x 25) securing the EGR tube assembly at the EGR valve assembly.

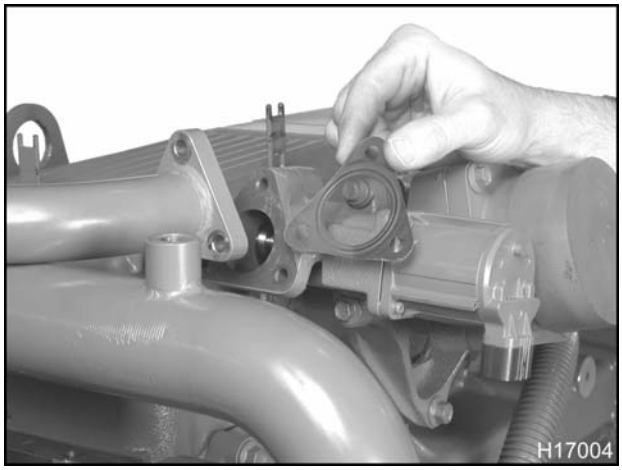


Figure 92 Removing the EGR tube assembly gasket

4. Remove EGR tube assembly and discard gasket.
5. Disconnect wiring harness connector at EGR valve assembly.

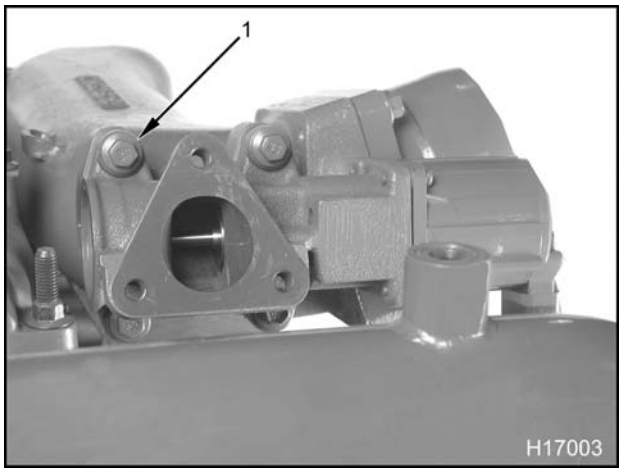


Figure 93 EGR valve retaining bolts

1. Bolt, M8 x 35 (4)

6. Remove four bolts (M8 x 35) securing the EGR valve assembly to the EGR mixer duct.

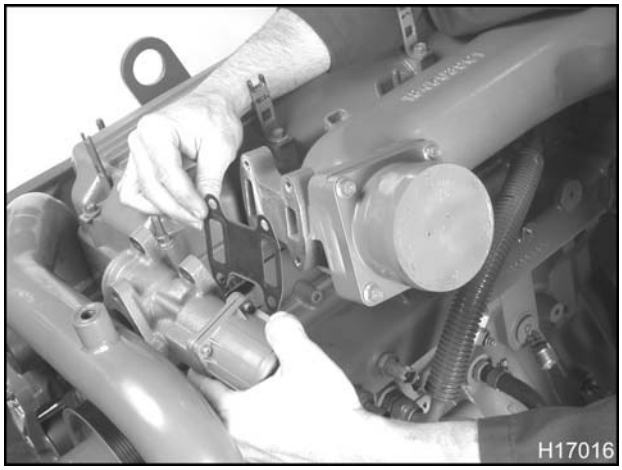


Figure 94 Removing the EGR valve to EGR mixer gasket

7. Remove and discard gasket between EGR valve assembly and EGR mixer.

NOTE: Do not attempt to remove the EGR cooler supply tube from the engine until the EGR cooler assembly has been removed. The EGR cooler supply tube is trapped between the EGR cooler and the rear half of the front cover.

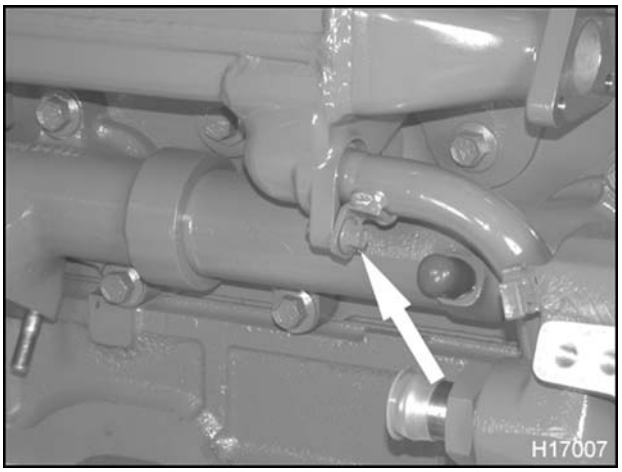


Figure 95 EGR cooler supply tube assembly retaining bolt

8. Remove the EGR cooler supply tube assembly retaining bolt (M8 x 16).

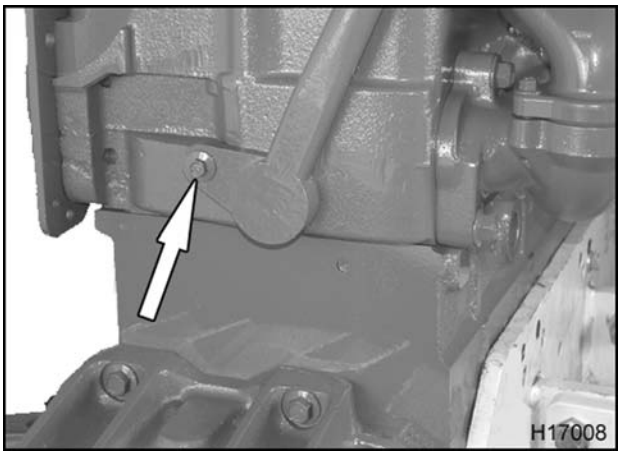


Figure 96 EGR cooler return tube assembly retaining bolt

9. Remove the EGR cooler return tube assembly retaining bolt (M8 x 25).

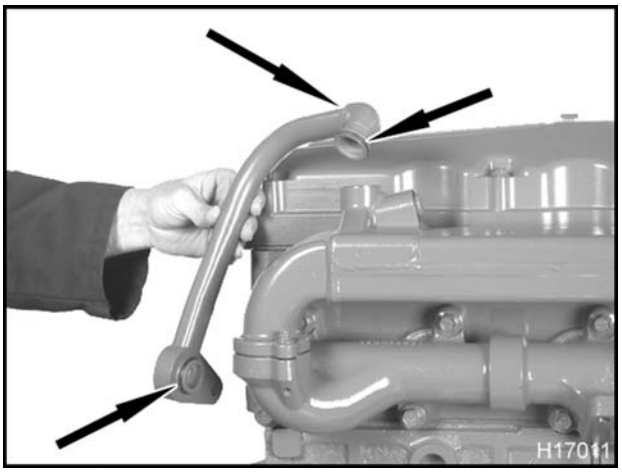


Figure 97 EGR cooler return tube and elbow O-rings

10. Remove the EGR cooler return tube assembly and elbow from engine and discard all O-rings.

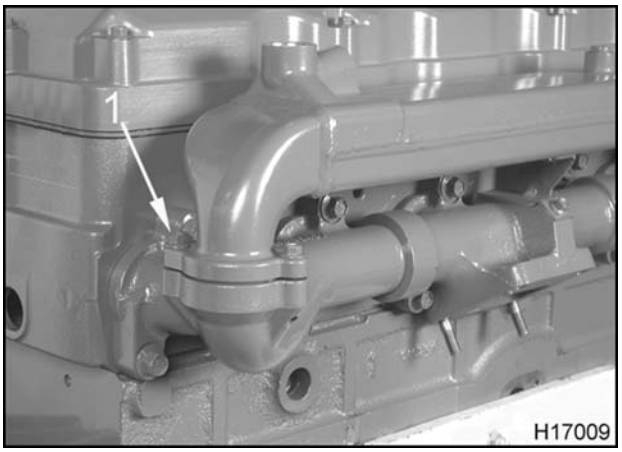


Figure 98 EGR cooler retaining bolts at exhaust manifold

1. Bolt, M8 x 30 (2)

11. Remove two bolts (M8 x 30) retaining the EGR cooler to the exhaust manifold.

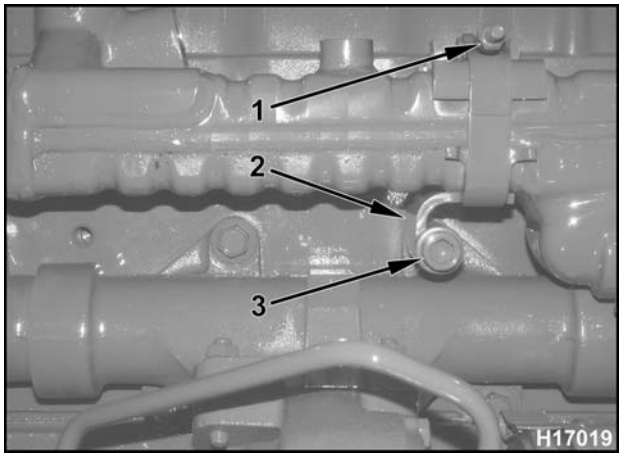


Figure 99 EGR cooler mounting bracket hardware

1. EGR cooler bracket clamp
2. EGR cooler mounting bracket
3. Bolt, M12 x 120

12. Remove M12 x 120 bolt from EGR cooler mounting bracket and exhaust manifold.
13. Remove the EGR cooler bracket clamp.

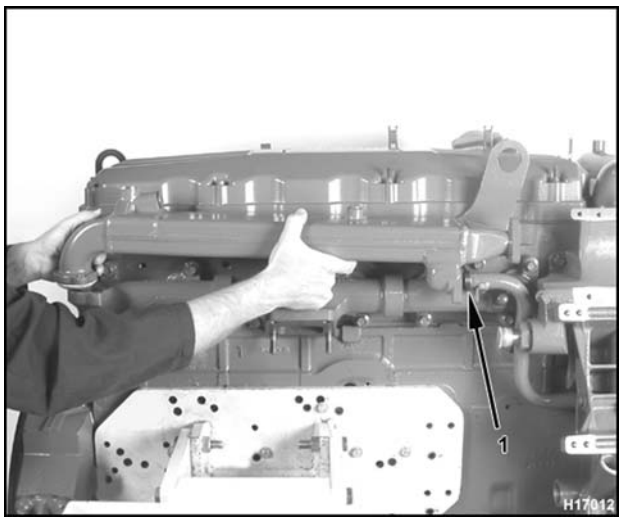


Figure 100 Removing the EGR cooler assembly

1. O-ring gasket

14. Remove the EGR cooler assembly by pulling out from EGR cooler supply tube and discard O-ring gasket.
15. Discard gasket between EGR cooler assembly and exhaust manifold.

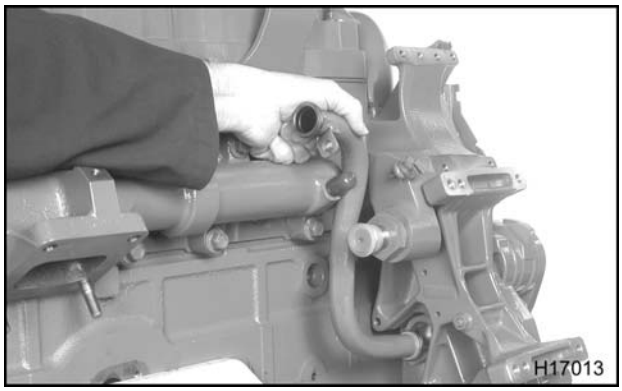


Figure 101 EGR cooler supply tube

16. Remove EGR cooler supply tubing from rear half of front cover. Discard O-ring from end of tube.

Cleaning EGR System Components

1. Clean off any gasket material and carbon deposits between the EGR cooler and exhaust manifold mating surfaces.
2. Clean mating surfaces between EGR cooler and exhaust gas crossover.
3. Clean mating surfaces between exhaust gas crossover and EGR valve.
4. Clean mating surfaces between EGR valve and intake mixer duct.

Inspection of EGR Cooler

1. Bolt EGR cooler pressure test plates (Table 11) to each end of the EGR cooler assembly.

WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

2. Connect air pressure to EGR cooler pressure test plate and regulate pressure to not more than 207 kPa (30 psi).

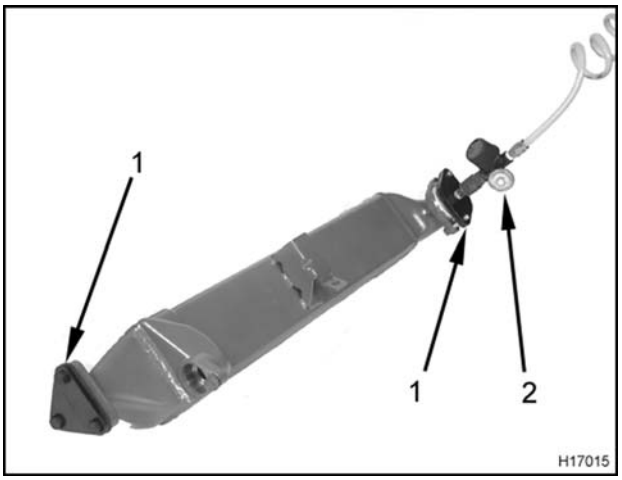


Figure 102 EGR cooler pressure test

1. EGR cooler pressure test plates (2)
2. Air pressure regulator

3. Submerge assembly into a tank of water. Watch for air bubbles coming out of the coolant ports. Discard EGR cooler if any air bubbles are produced from any ports.

Installation EGR System Components

NOTE: Assemble the following parts in order, but do not torque any bolts until all components have been installed and bolts threaded finger tight.

1. Install new O-rings onto each end of the EGR cooler supply tube.

Figure 103 EGR cooler supply tube

2. Install the EGR cooler supply tube into the open port in rear half of front cover.

3. Install a new gasket between the EGR cooler assembly and exhaust manifold.

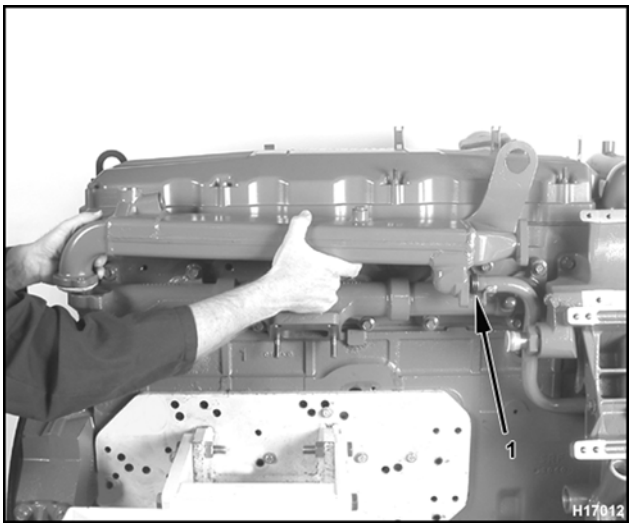


Figure 104 Installing the EGR cooler assembly

1. O-ring gasket

4. Install EGR cooler assembly by pushing in towards the EGR cooler supply tube. Make sure EGR cooler supply tube fully engages the EGR cooler assembly. The cooler tube should be trapped between the EGR cooler and the rear half of the front cover.

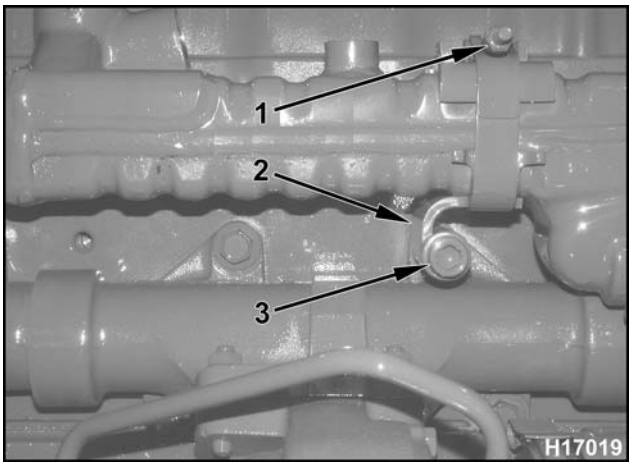


Figure 105 EGR cooler support bracket retaining bolt

1. EGR cooler bracket clamp
2. EGR cooler mounting bracket
3. Bolt, M12 x 120

5. Install M12 x 120 bolt through the EGR cooler support bracket and exhaust manifold to support and secure the EGR cooler assembly. Hand tighten bolt.
6. Install the EGR cooler into the mounting bracket and close EGR cooler bracket clamp.

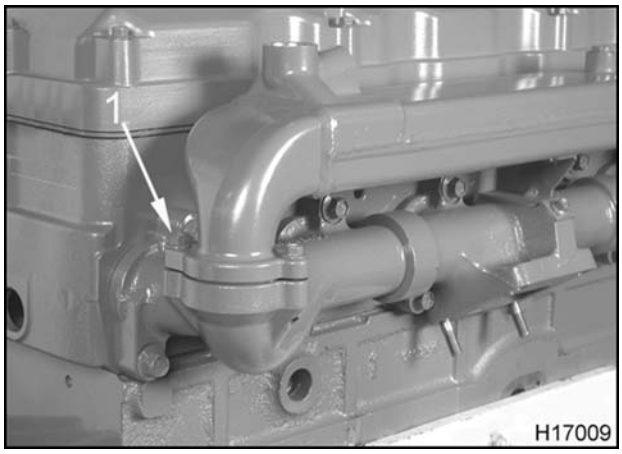


Figure 106 EGR cooler retaining bolts at exhaust manifold

1. Bolt, M8 x 30 (2)

7. Place EGR gasket between EGR cooler and exhaust manifold.
8. Install two EGR cooler retaining bolts (M8 x 30). Thread bolts finger tight at the exhaust manifold.

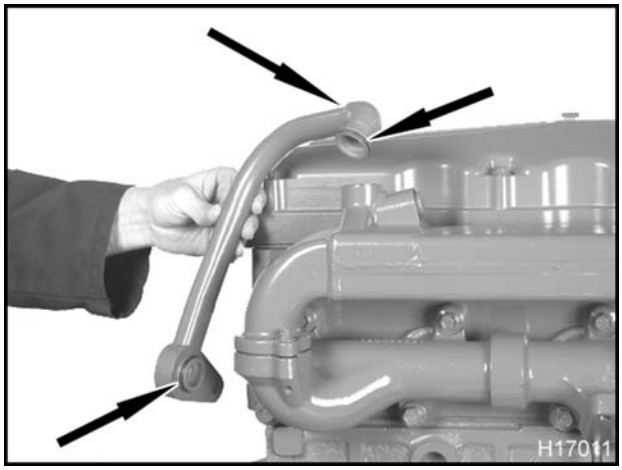


Figure 107 EGR cooler return tube O-rings

9. Install new O-rings onto each end of the EGR cooler return tube. Lubricate O-rings with P-80 or equivalent.

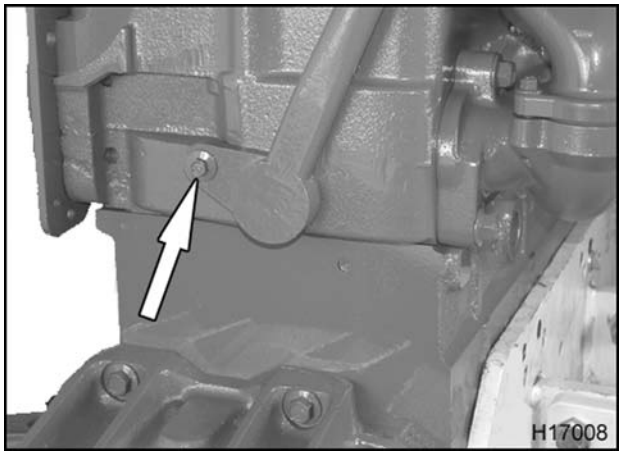


Figure 108 EGR cooler return tube assembly retaining bolt

10. Position the EGR cooler return tube assembly into place and install retaining bolt (M8 x 25) finger tight.

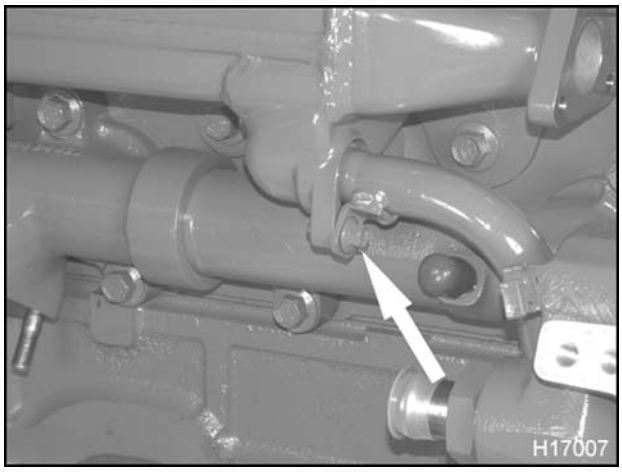


Figure 109 EGR cooler supply tube assembly retaining bolt

11. Install the EGR cooler supply tube assembly retaining bolt (M8 x 16) finger tight.

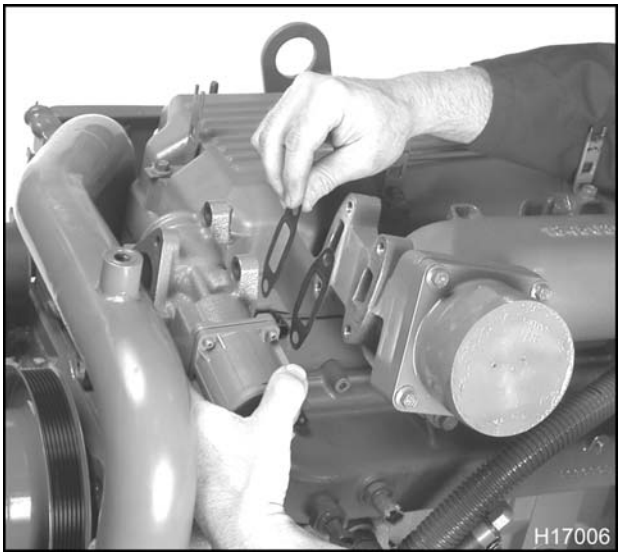


Figure 110 EGR valve gasket at EGR mixer duct

12. Place a new gasket between the EGR mixer duct and EGR valve assembly.

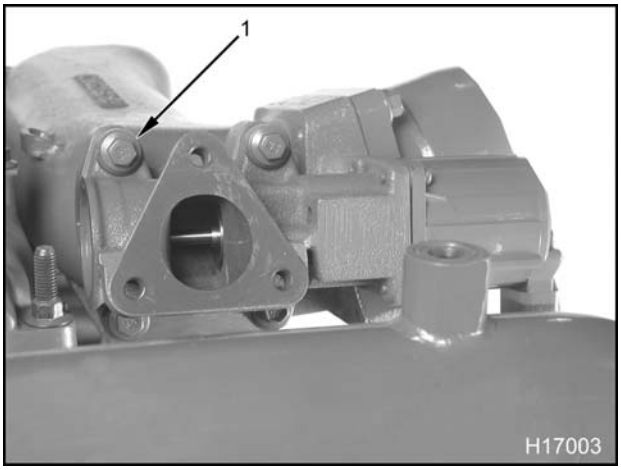


Figure 111 EGR valve mounting bolts

1. Bolt, M8 x 35 (4)

13. Secure EGR valve assembly with four bolts (M8 x 35) finger tight.

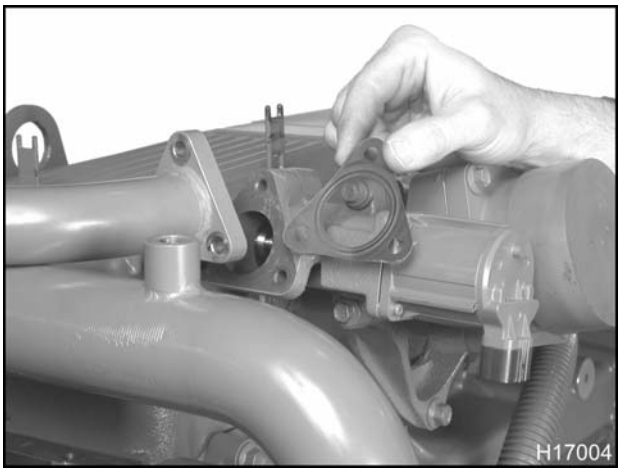


Figure 112 EGR gasket at EGR valve

14. Position a new gasket between the EGR tube assembly and EGR valve assembly.

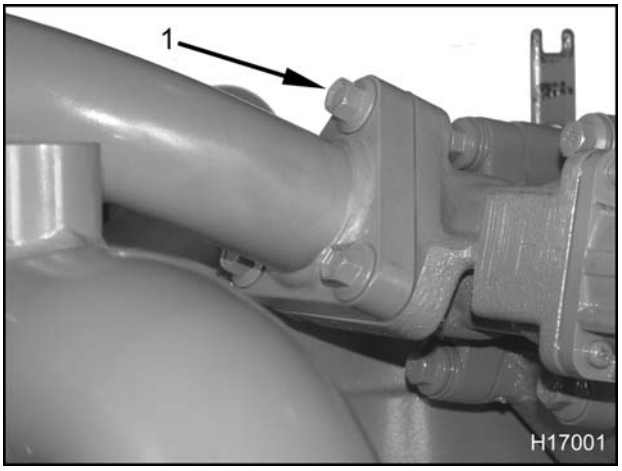


Figure 113 EGR tube assembly at EGR valve

1. Bolt, M8 x 25 (3)

15. Install three EGR tube assembly bolts (M8 x 25) finger tight.

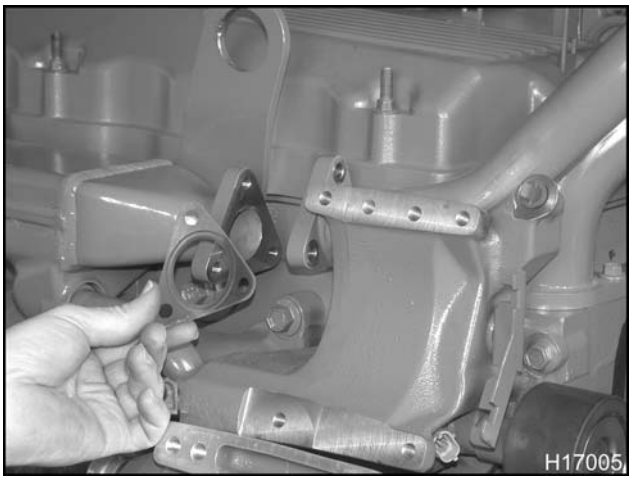


Figure 114 Installing a new gasket

16. Position a new gasket between the EGR tube assembly and EGR cooler.

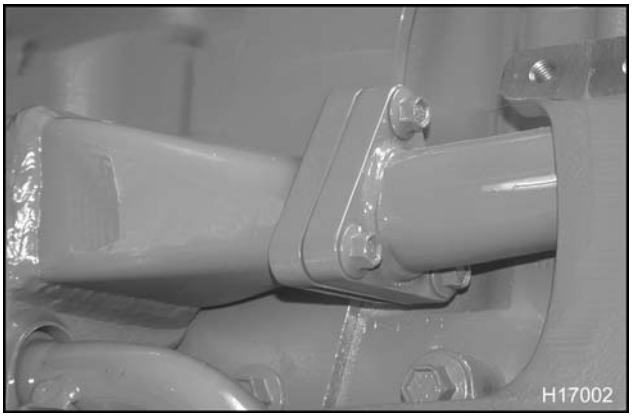


Figure 115 EGR tube assembly at EGR cooler

17. Install three bolts (M8 x 25) finger tight to join the EGR tube assembly at the EGR cooler assembly.
18. Tighten all EGR system component bolts to the standard torque (General Torque Guidelines, page445) in the following order:
    a. EGR cooler at exhaust manifold
    b. EGR tube assembly at EGR cooler
    c. EGR valve mounting bolts
    d. EGR tube assembly at EGR valve
    e. EGR cooler return tube assembly retaining bolt
    f. EGR cooler supply tube assembly retaining bolt
    g. EGR cooler support bracket retaining bolt

Modification 1 – Deeper O-ring Location into EGR Coolant Return Tube plus Retaining Clip

Removal of EGR Coolant Return Tube and Elbow

CAUTION: To prevent engine damage, do not mix the new longer leg EGR coolant return tube elbow with the original short adapter end EGR cooler return tube.

The EGR coolant return tube and mating elbow were redesigned as a production running change to locate the elbow O-ring one inch deeper into the EGR coolant return tube. Both the EGR coolant return tube and EGR coolant return elbow were redesigned to accomplish this. The EGR coolant return tube has a one inch longer arm to locate the O-ring one inch deeper into the EGR coolant return tube adapter end.

1. Drain coolant to a level below the cylinder head.
2. Remove bolt from EGR return tube located at back of cylinder head. Retain bolt for reuse with new EGR cooler return tube assembly.
3. If applicable, remove two set screws or retaining clip retaining the EGR cooler elbow.
4. Remove EGR return tube and elbow as an assembly by lifting it out of the EGR cooler.

Installation of EGR Coolant Return Tube and Elbow

1. Install two O-rings onto EGR cooler elbow and one O-ring onto pilot of EGR coolant return tube assembly.

CAUTION: To prevent engine damage, do not use engine oil or any other petroleum based products on EGR coolant return tube or elbow O-rings. These O-rings are not compatible with petroleum based lubricants.

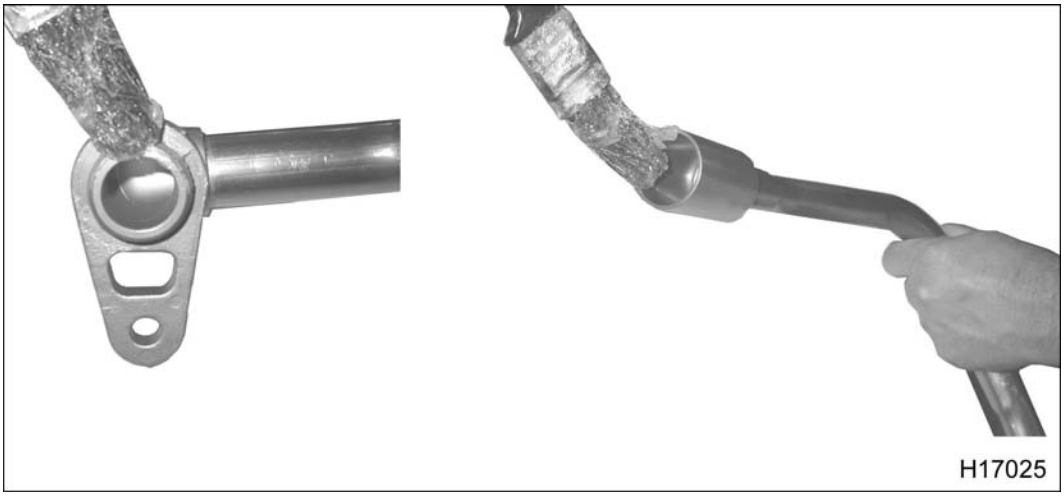


Figure 116 Brushing lubricant and sealant onto pilot end (left) and adapter end of EGR coolant return tube (right)

2. Using P-80 or equivalent, lubricate the pilot O-ring on one end and the adapter on the other end.

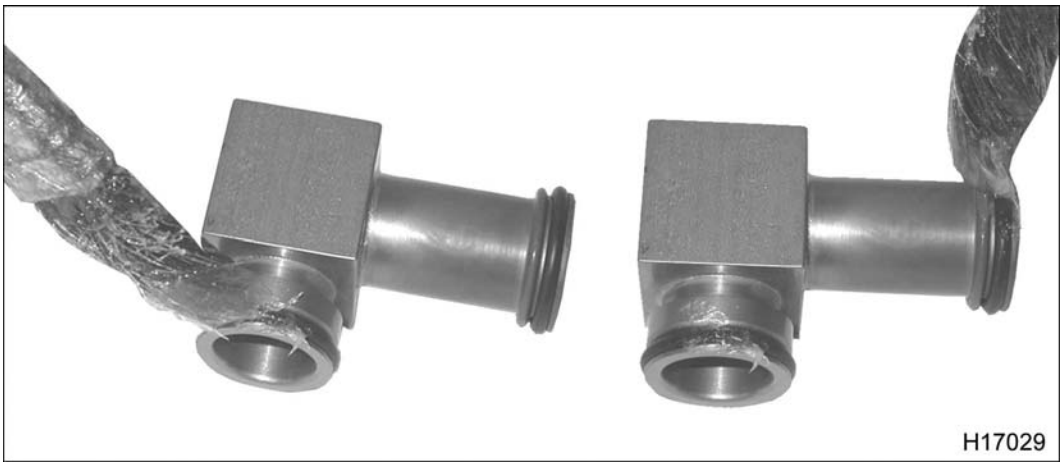


Figure 117 Lubricating both ends of the EGR cooler elbow

3. Using P-80 or equivalent, lubricate both O-rings on the EGR cooler elbow.

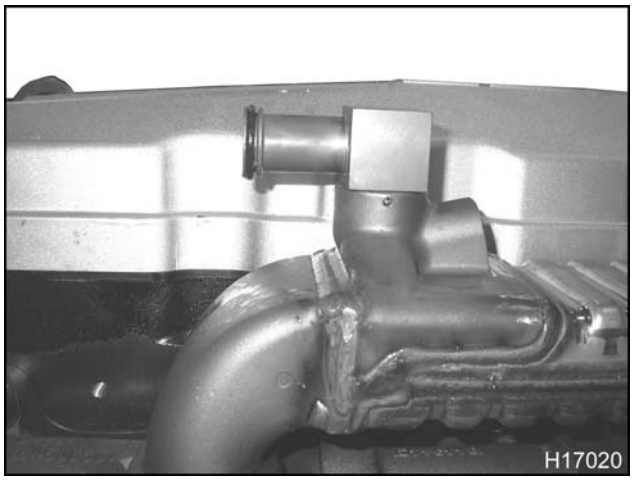


Figure 118 EGR cooler return elbow

4. Install EGR cooler return elbow into the EGR cooler assembly without wire retaining clip. The shorter arm of the elbow goes into EGR cooler.

Figure 119 EGR cooler return tube

5. Assemble EGR cooler return tube at the elbow end, pushing in until O-ring is well into tube adapter.

Figure 120 Installing the EGR cooler return tube

6. While holding the elbow and tube with one hand, swivel the EGR cooler return tube into position as needed, aligning the O-ring pilot into the cylinder head.
7. With palm of left hand, forcefully push the flange face forward into the cylinder head, fully engaging both ends while also maintaining alignment of elbow and return tube with right hand.

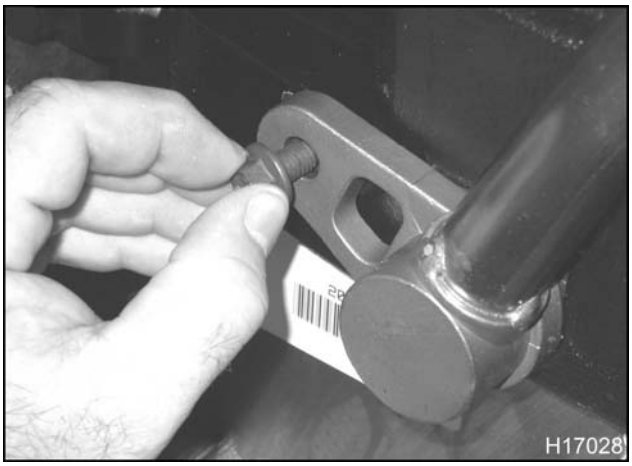


Figure 121 Installing the EGR return tube mounting bolt

8. Install EGR return tube mounting bolt (M8 x 25) into cylinder head (finger tight).

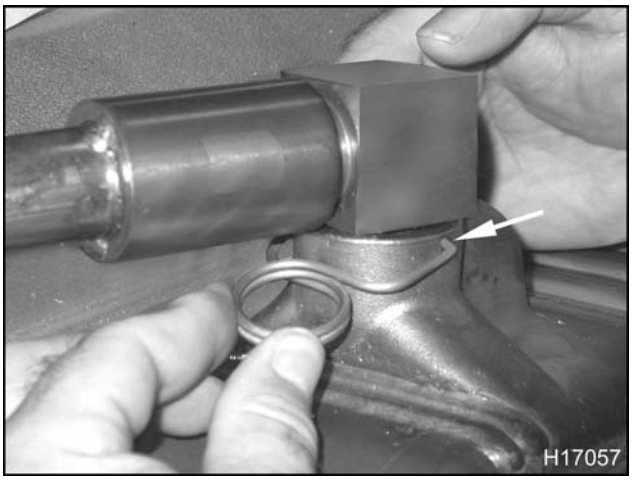


Figure 122 Installing the retaining clip (outboard hole first)

9. Ensure that EGR cooler elbow and return tube are straight. Hand seat elbow downward as far as possible and install wire retaining clip into outboard hole of EGR cooler and slide retaining clip around into remaining hole.

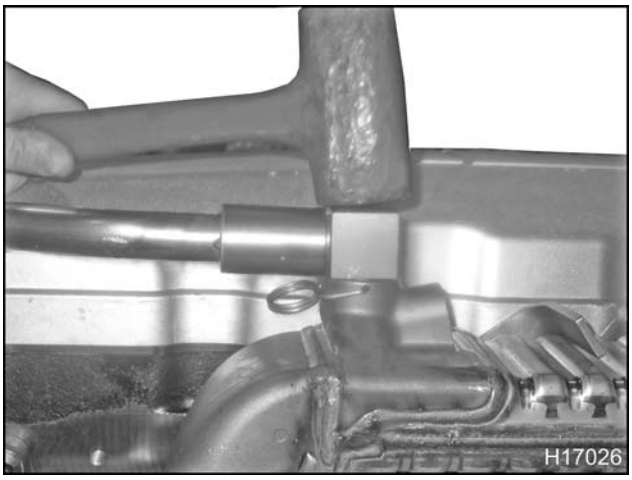


Figure 123 Seating the EGR cooler elbow and retaining clip

10. Tap top of EGR cooler elbow with rubber mallet to ensure retaining clip is fully engaged in elbow.

Figure 124 Torquing the EGR cooler return tube mounting bolt

11. Torque EGR cooler return tube mounting bolt to the standard torque value (General Torque Guidelines, page445).

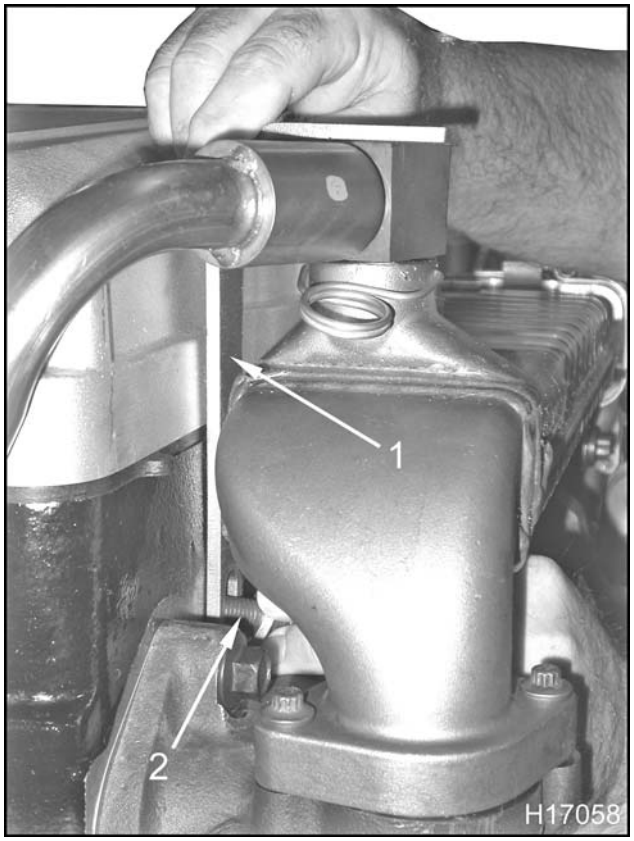


Figure 125 Installing the EGR elbow bracket and mounting hardware

1. Bracket
2. M10 x 25 Bolt and 3/8 flat washer

12. If equipped, slide elbow retaining bracket between cylinder head and EGR cooler assembly. Install flat washer and M10 x 25 bolt. Tighten bolt to the standard torque (General Torque Guidelines, page445).

Modification 2 – EGR Coolant Return Tube Adapter and EGR Coolant Hose

Removal of EGR Coolant Return Tube Adapter and EGR Coolant Hose

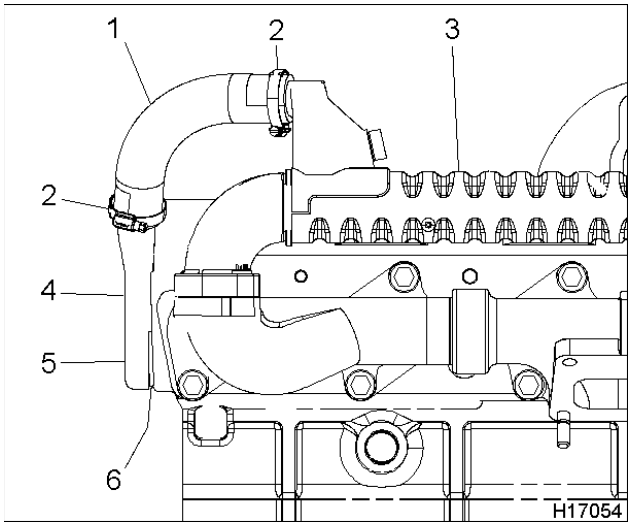


Figure 126 EGR coolant return tube adapter and EGR coolant hose

1. EGR coolant hose
2. Constant tension EGR hose clamp (2)
3. EGR cooler
4. EGR coolant return tube adapter
5. Bolt, M8 x 25 (in flange)
6. O-ring seal

1. Drain coolant.
2. Loosen two constant tension EGR hose clamps and remove EGR coolant hose from EGR coolant return tube adapter and EGR cooler.
3. Remove M8 x 25 EGR coolant return tube adapter bolt and pull EGR coolant return tube adapter straight out of the cylinder head. Discard O-ring.

Installation of EGR Coolant Return Tube Adapter and EGR Coolant Hose

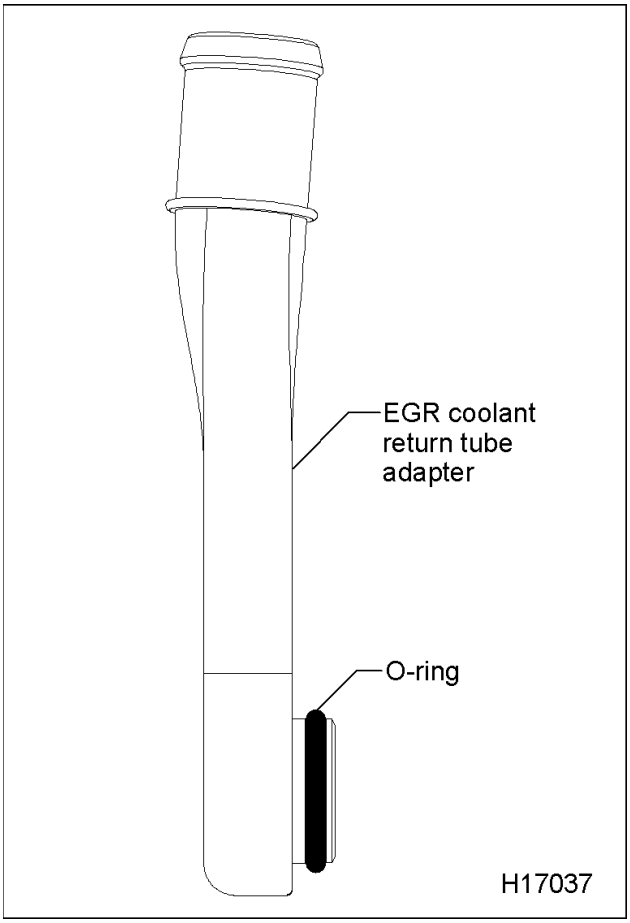


Figure 127 EGR cooler return tube adapter

1. Install a new O-ring onto new EGR cooler return tube adapter.

   CAUTION: To prevent engine damage, do not use engine oil or any other petroleum based products on EGR cooler return tube adapter O-ring. This O-ring is not compatible with petroleum based lubricants.
2. Using P-80 or equivalent, lubricate O-ring on adapter.

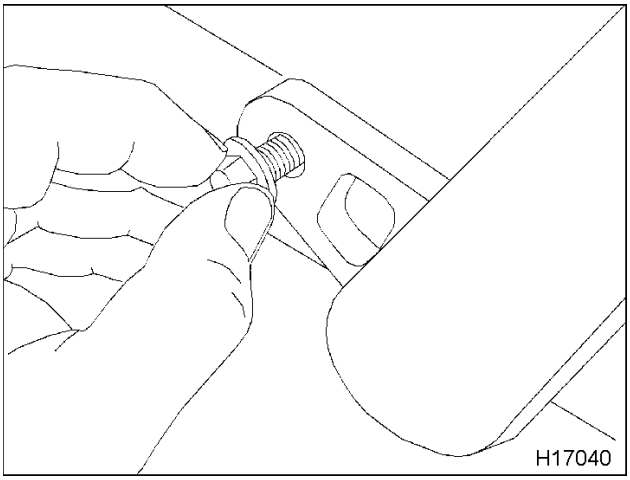


Figure 128 Installing the EGR return tube adapter mounting bolt

3. Position adapter into cylinder head coolant port and install EGR coolant return tube adapter bolt (M8 x 25). Tighten bolt to the standard torque (General Torque Guidelines, page445).

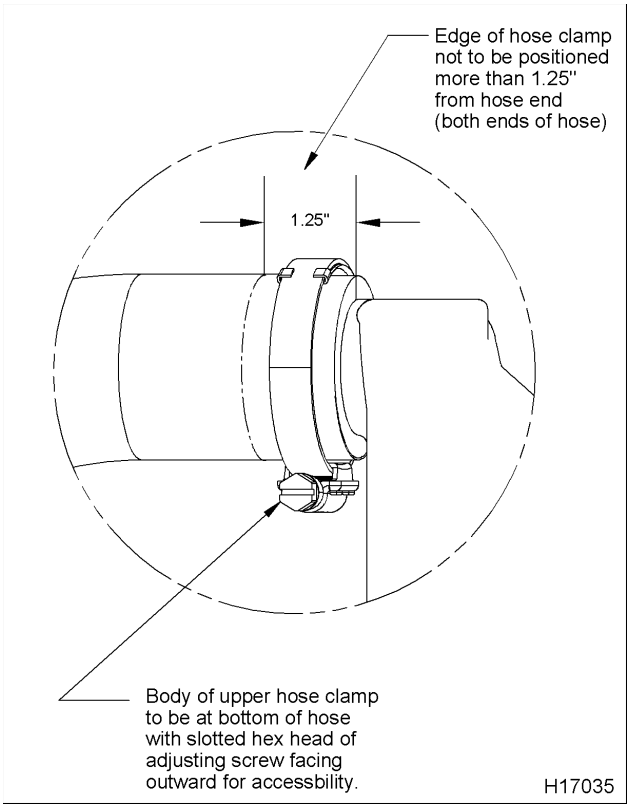


Figure 129 EGR upper hose clamp details

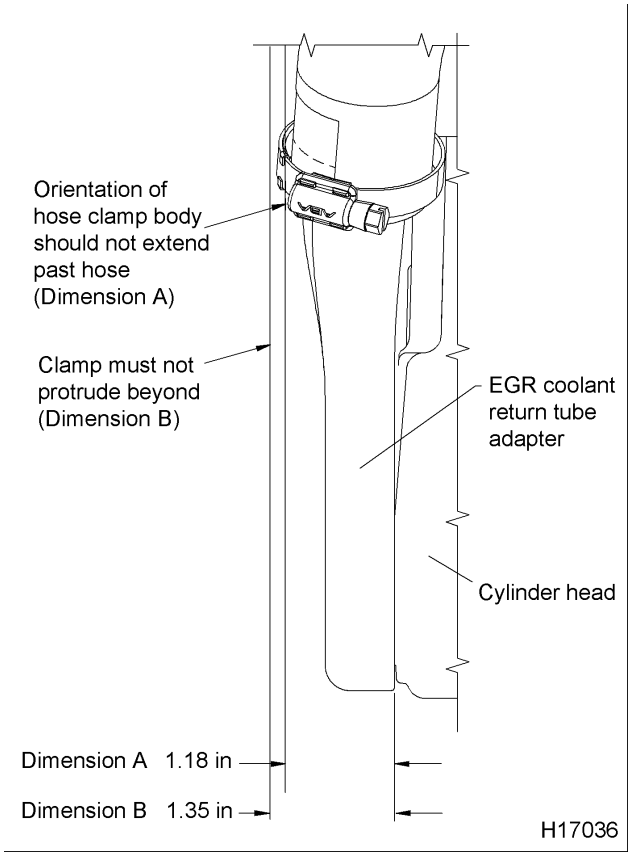


Figure 130 EGR lower hose clamp details

4. Position EGR coolant hose and two constant tension EGR hose clamps between EGR cooler and EGR cooler return tube adapter.
5. Tighten constant tension EGR hose clamps to the special torque (Table 10).
6. Fill engine with coolant and check for leaks.
7. Start engine and let engine warm up to operating temperature.
8. Shut down engine and let engine cool to ambient air temperature.
9. Retighten constant tension EGR hose clamps to the special torque (Table 10).

Modification 3 – Round EGR Cooler and EGR Return Hose

Removal

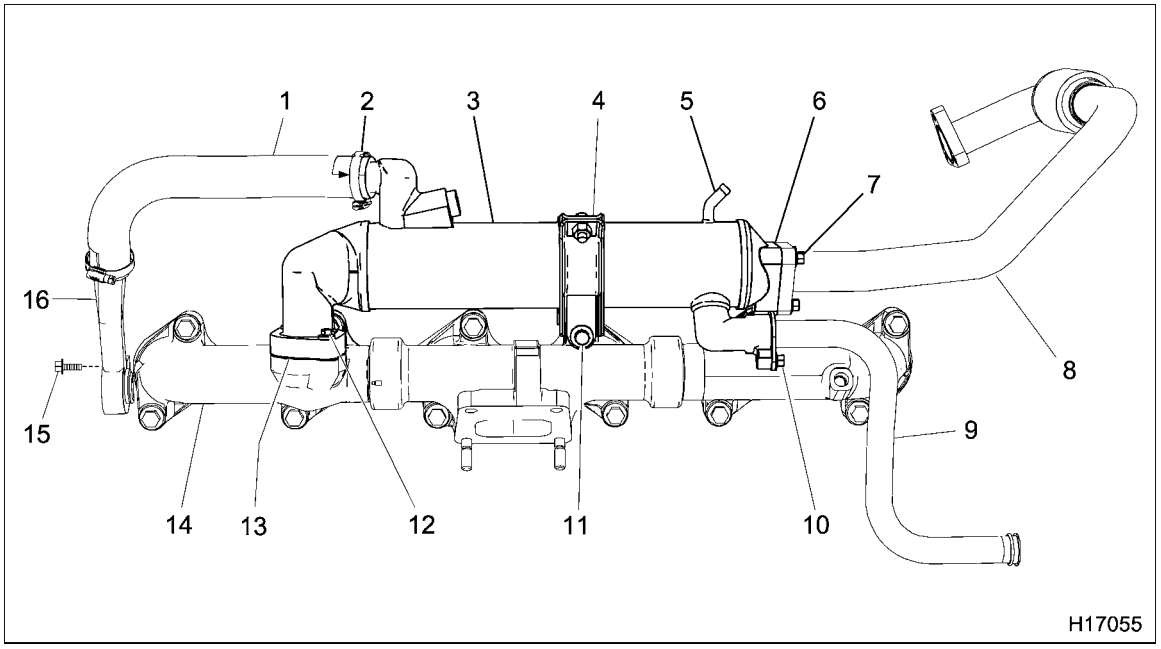


Figure 131 Round EGR cooler

1. EGR return hose
2. Constant tension EGR hose clamp (2)
3. EGR cooler
4. EGR cooler mounting bracket
5. Deaeration hose fitting
6. EGR tube to EGR valve gasket
7. EGR tube assembly bolt (M8 x 25) (3)
8. EGR tube assembly
9. EGR cooler supply tube assembly
10. EGR cooler supply tube retaining bolt (M8 x 16)
11. EGR cooler mounting bracket lower bolt (M12 x 120)
12. EGR rear mounting bolt (M8 x 30) (2)
13. EGR hot side gasket
14. Exhaust manifold
15. EGR coolant return adapter tube retaining bolt (M8 x 25)
16. EGR coolant return adapter tube

1. Drain engine cooling system.
2. Loosen and remove EGR cooler supply tube retaining bolt.
3. Loosen and remove three bolts holding EGR tube assembly to EGR cooler.
4. Loosen EGR return hose clamp and pull EGR return hose off of EGR cooler.
5. Loosen clamp holding deaeration hose to the deaeration hose fitting and pull hose off of EGR cooler.
6. Remove EGR rear mounting bolts.
7. Loosen and remove EGR cooler mounting bracket lower bolt.
8. Pull EGR cooler and mounting bracket away from exhaust manifold, EGR cooler supply tube, and EGR tube assembly.
9. Remove EGR cooler supply tube assembly from rear half of front cover. Remove and discard O-rings from ends of cooler supply tube and clean tube ends.
10. Remove old gaskets and clean gasket surfaces of EGR tube assembly and exhaust manifold.

Installation

1. Clean port in rear half of front cover which EGR cooler supply tube fits into.

   CAUTION: To prevent engine damage, do not use engine oil or any other petroleum based products on EGR cooler supply tube O-rings. These O-rings are not compatible with petroleum based lubricants.

2. Install new O-ring seals on EGR cooler supply tube assembly ends and reinstall tube into port in rear half of front cover.
3. Install new EGR hot side gasket on new EGR cooler.
4. Position EGR cooler on the engine and install two new EGR rear mounting bolts. Finger tighten bolts.
5. Reinstall EGR cooler mounting bracket lower bolt and finger tighten.
6. Push EGR cooler supply tube assembly into EGR cooler and finger tighten retaining bolt.
7. Install new EGR tube to EGR valve gasket and finger tighten three bolts holding EGR tube to EGR cooler.
8. Tighten EGR rear mounting bolts (M8 x 30) to the standard torque (General Torque Guidelines, page445).
9. Tighten EGR cooler mounting bracket lower bolt (M12 x 120) to the special torque (Table 10).
10. Tighten EGR cooler mounting bracket to the special torque (Table 10).
11. Tighten three bolts (M8 x 25) holding EGR tube assembly to EGR cooler to the standard torque (General Torque Guidelines, page445).
12. Tighten EGR cooler supply tube retaining bolt (M8 x 16) to the special torque (Table 10).
13. Push EGR return hose onto EGR cooler and tighten constant tension EGR hose clamps to the special torque value (Table 10).
14. Push deaeration hose onto EGR cooler deaeration fitting and tighten clamp.
15. Refill engine cooling system.
16. Start engine and let engine warm up to operating temperature.
17. Shut down engine and let engine cool to ambient air temperature.
18. Retighten constant tension EGR hose clamps to the special torque value (Table 10).

EGR Coolant Return Kits (Conversion from EGR Cooler Return Tube to Hose)

Removal of EGR Coolant Return

NOTE: See Technical Service Information (TSI) bulletin (TSI-07-12-12 EGR Coolant Return Kit, page 477) for Exhaust Gas Recirculation (EGR) kits.

1. Drain coolant to a level below the cylinder head.
2. Remove and save bolt from EGR cooler return tube flange.
3. Remove spring clip or set screws from EGR return tube elbow.
4. Remove old EGR return tube and elbow.

Installation of EGR Coolant Return Kit

CAUTION: To prevent engine damage, do not use engine oil or other petroleum products on EGR coolant return hose or O-rings.

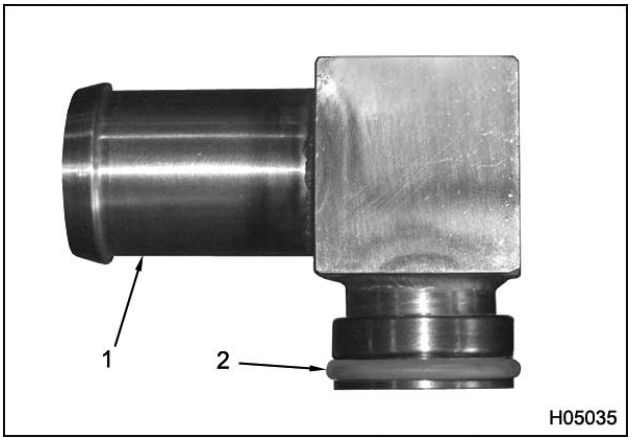


Figure 132 EGR coolant return elbow

1. EGR coolant return elbow
2. O-ring seal

1. Put O-ring seal on new EGR coolant return elbow.
2. Put O-ring seal on new EGR coolant return adapter tube.
3. Lubricate both O-rings with P-80 or equivalent.

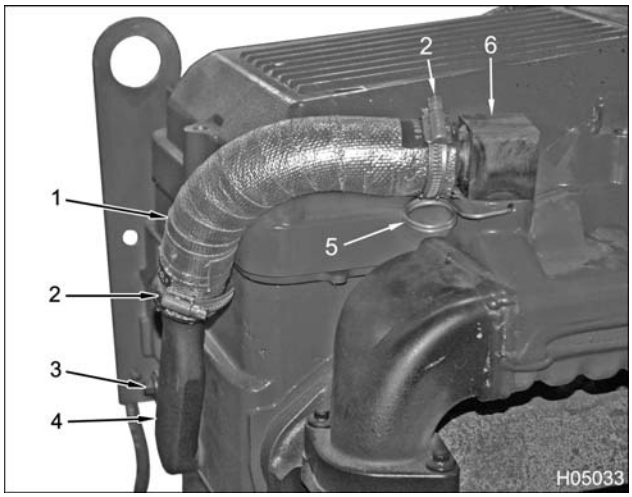


Figure 133 EGR coolant return

1. EGR coolant return hose
2. Constant tension EGR hose clamp
3. M8 x 25 bolt
4. EGR cooler return adapter tube
5. EGR elbow retaining clip
6. EGR coolant return elbow

4. Install EGR coolant return elbow.
5. Slide new EGR coolant return hose onto coolant return elbow and position hose clamp.
6. Put hose clamp on EGR coolant return hose, insert EGR cooler return adapter tube into hose, and position clamp.
7. Install M8 x 25 bolt (finger tight) to secure EGR cooler return adapter tube to cylinder head.
8. Install EGR elbow retaining clip (outboard hole first). Tap top of elbow with rubber mallet to ensure retaining clip is fully engaged.
9. Tighten M8 x 25 bolt to the standard torque (General Torque Guidelines, page 445).
10. Tighten constant tension EGR hose clamps to the special torque (Table 10).

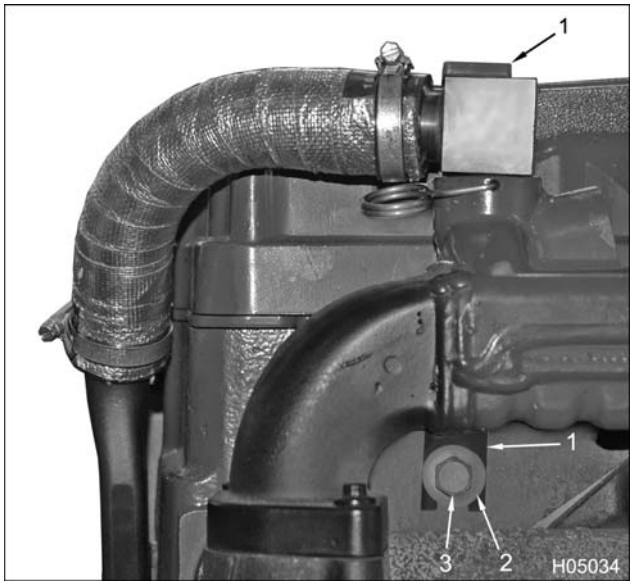


Figure 134 EGR cooler return bracket

1. EGR tube bracket
2. Flat washer, 3/8 in
3. Bolt, M10 x 1.5 x 25 mm

11. Position EGR cooler return bracket between cylinder head and EGR cooler.
12. Install 3/8 in flat washer and M10 Bolt.
13. Tighten M10 bolt to the standard torque (General Torque Guidelines, page445).
14. Refill engine cooling system.
15. Start engine and let engine warm up to operating temperature.
16. Shut down engine and let engine cool to ambient air temperature.
17. Retighten constant tension EGR hose clamps to special torque (Table 10).

Special Torque

Table 10 EGR Cooler Special Torques

Constant tension EGR hose clamps (if equipped)	3.4 N·m (30 lbf·in)
EGR cooler mounting bracket lower bolt, M12 x 120	116 N·m (85 lbf·ft)
EGR cooler mounting bracket	116 N·m (85 lbf·ft)
EGR cooler supply tube retaining bolt	15-22 N·m (11.3-16.2 lbf·ft)

Special Service Tools

Table 11 EGR System Special Service Tools

EGR cooler pressure test plates	ZTSE4636

Table of Contents

Description

The DT 466 and DT 570 cylinder heads are cast iron and feature four valves per cylinder.

The design of the cylinder head valve train focuses on component commonality between the intake and exhaust sides of the head. Shared parts include: valve bridges, guides, springs, retainer keys, rotators, and valve stem seals. These parts are also compatible between the 466 and 570 engine families.

The valve rotators create positive valve rotation for increased valve face life.

The valve stem seals are one piece design, easy to install, and have a hardened washer for valve spring seating.

The valve guides and valve seats are replaceable.

The bridge can be installed on the intake or exhaust in either direction, and still allow compression brake operation through the pad on top.

A single roller tappet transfers lifting forces through a push rod, rocker arm, and then onto a valve bridge where both valves are opened and closed simultaneously. This allows for a greater quantity of air to flow through the engine than comparably sized engines using only two valves per cylinder.

Phosphate coating has been carried over from past production to rocker arms for initial break-in and to extend life.

Pressurized oil is fed from the crankcase through the head at cylinder number 6 exhaust lower support. Oil then enters shaft and is distributed to all rocker arms.

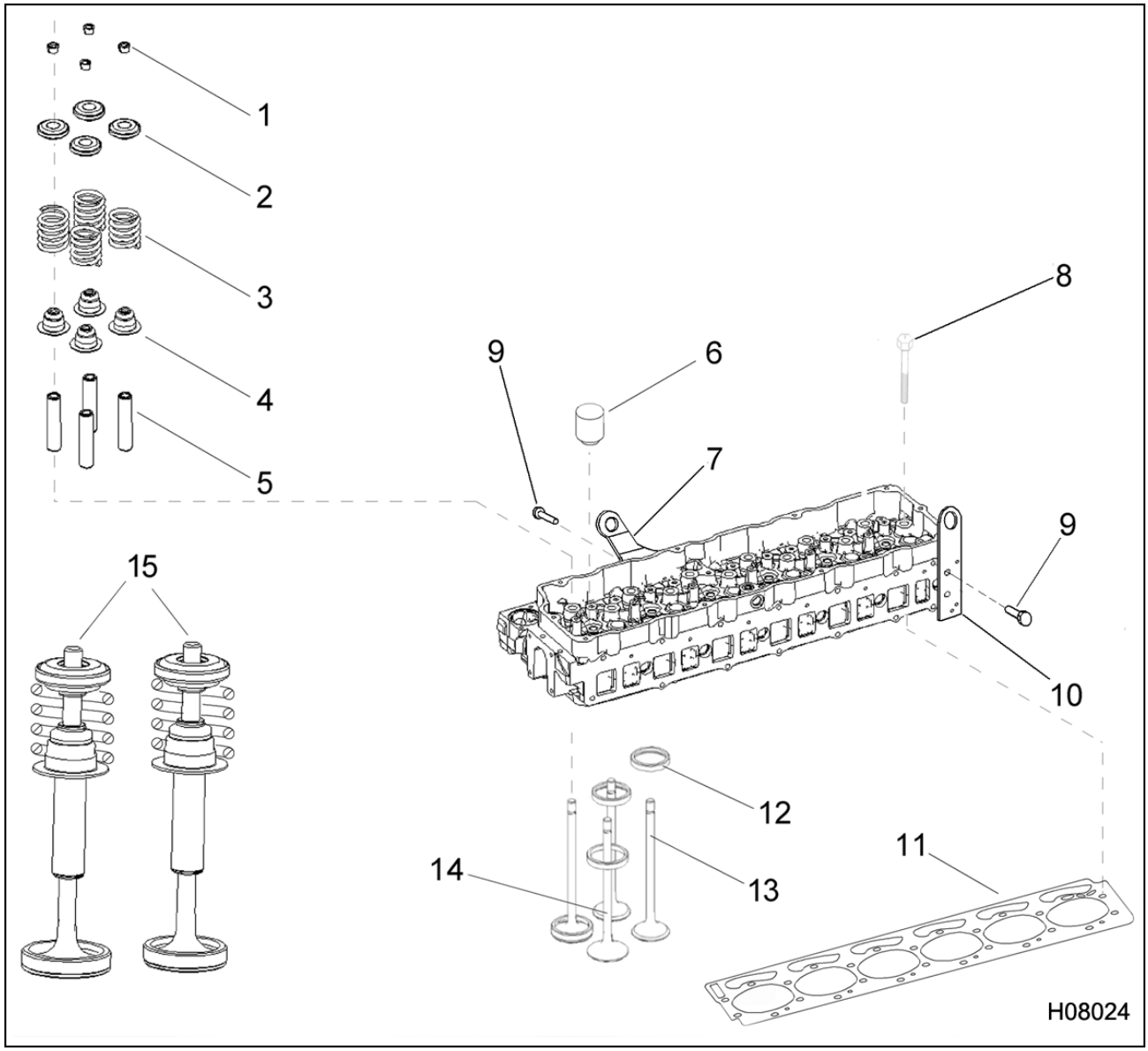


Figure 135 Cylinder head and valve train components

1. Valve spring retainer keys
2. Valve rotators
3. Valve springs
4. Valve stem seals
5. Valve guide inserts
6. Fuel injector sleeve
7. Front lifting eye
8. Cylinder head bolt, (26)
9. Bolt, M12 x 25 (4)
10. Rear lifting eye
11. Cylinder head gasket
12. Valve seat insert
13. Exhaust valve
14. Intake valve
15. Valve assemblies

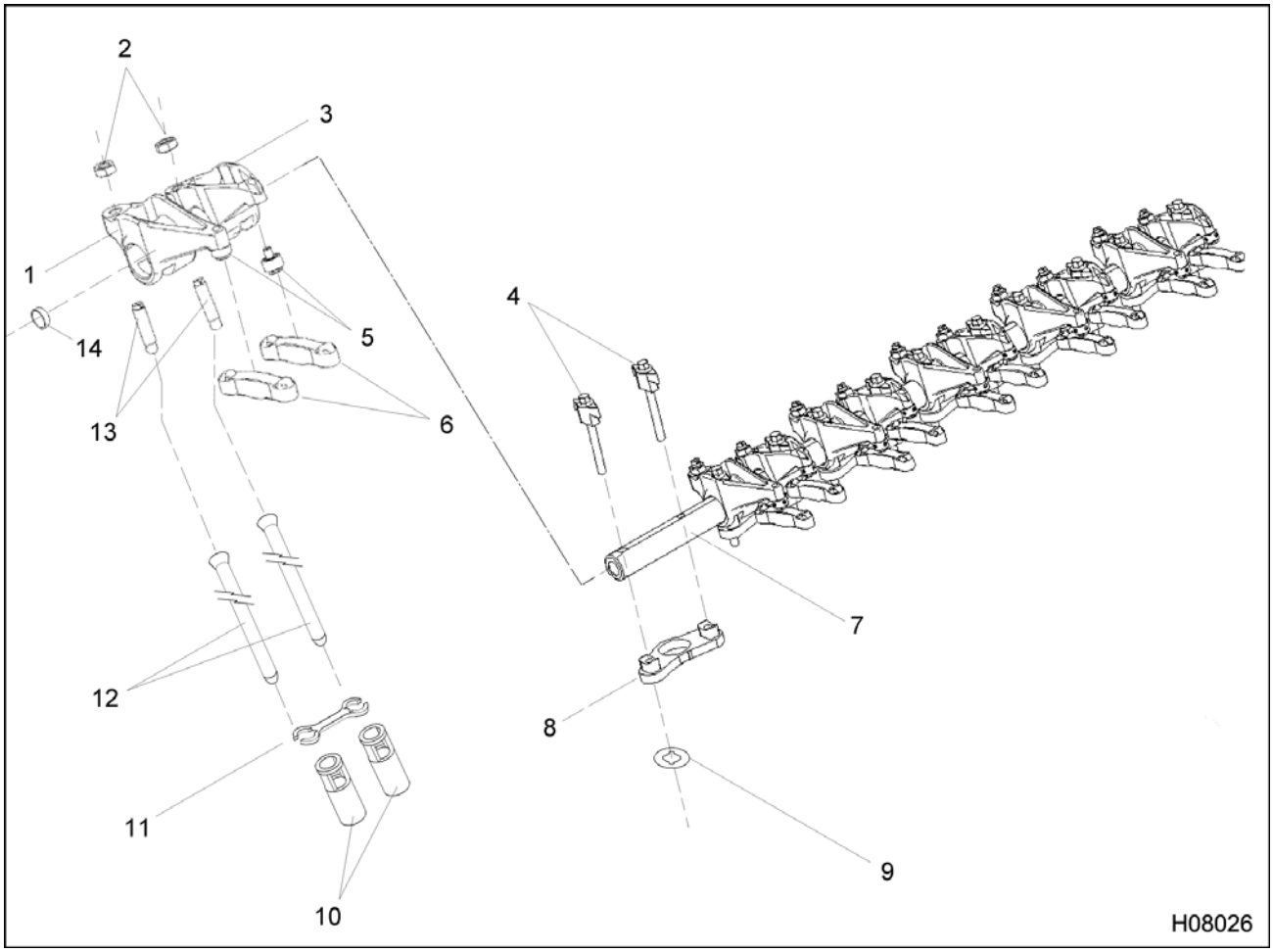


Figure 136 Valve train components

1. Intake rocker arm (6)
2. Valve lash adjustment nuts, M10 (12)
3. Exhaust rocker arm (6)
4. Rocker shaft clamp assembly (12)
5. Rocker pivots (12)
6. Valve bridge (12)
7. Rocker arm shaft
8. Rocker shaft support (6)
9. Lower support washer (6)
10. Roller tappets (12)
11. Roller tappet guide (6)
12. Push rods (12)
13. Valve lash adjuster screw, M10 (12)
14. Rocker shaft plug (2)

Removal

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.

WARNING: To prevent personal injury or death, read all safety instructions in the "Safety Information" section of this manual.

WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

WARNING: To prevent personal injury or death, allow engine to cool before working with components.

WARNING: To prevent personal injury or death, disconnect ground (-) cable from battery before doing service or diagnostic procedures.

WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

WARNING: To prevent personal injury or death, do not let engine fluids stay on your skin. Clean skin and nails using hand cleaner and wash with soap and water. Wash or discard clothing and rags contaminated with engine fluids.

CAUTION: To prevent engine damage, do not reuse cylinder head bolts; install new bolts.

NOTE: For information regarding the removal or installation of adjacent components, refer to the following service procedures located in other sections of this manual:

- VGT turbocharger
- Intake and exhaust manifolds
- EGR system components
- High-pressure oil manifold or Diamond Logic® Engine Brake (if equipped)
- Fuel filter assembly
- Fuel injector assembly
- Crankcase breather assembly
- Coolant outlet tube assembly
- Water supply housing

Valve Cover

1. If cylinder head is to be removed in chassis, drain coolant to a level below the head gasket joint.
2. Disconnect crankcase ventilation and drain tubing from breather assembly. The breather assembly can remain attached to the valve cover during the valve cover removal (Crankcase Ventilation System, page253).

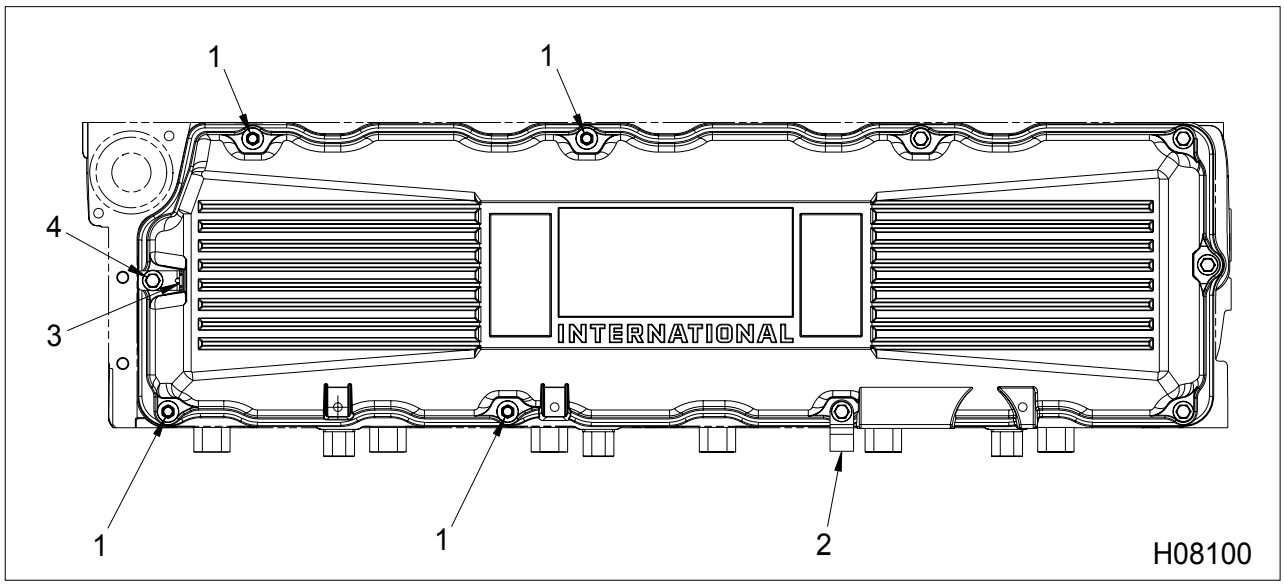


Figure 137 Valve cover assembly detail

1. Bolt / stud, M8 x 80 / 19 (4)
2. Extension bracket
3. Valve cover harness mounting bracket
4. Bolt, M8 x 80 (6)

3. Remove four valve cover bolt / studs (M8 x 80 / 19).
4. Remove six valve cover bolts (M8 x 80).
5. Lift valve cover off of cylinder head.

WARNING: To prevent personal injury or death, disconnect the main battery negative terminal before disconnecting or connecting electrical components.

6. Disconnect all electrical and injector connectors at valve cover gasket.
7. Remove valve cover gasket.

Removing Rocker Arm Assembly

1. Remove high-pressure oil rail. See (Figure 640) .

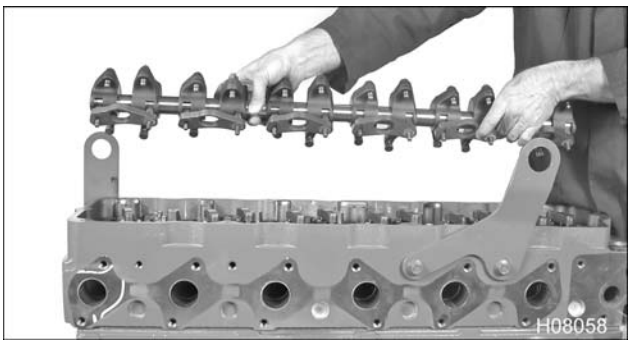


Figure 138 Removing rocker arm assembly

2. Loosen all rocker arm adjusting screws and nuts. This will avoid possible valve train damage during installation.
3. Loosen but do not remove 12 rocker shaft clamp bolts.
4. Lift the rocker arm shaft assembly up and away from the cylinder head and set aside.

   NOTE: There are six nylon washers, one for each rocker shaft support, that are for assembly purposes. Make sure that you have these washers for installing the rocker arm shaft.

Figure 139 Removing the valve bridge

5. If removing valve bridges, mark all valve bridges for installation (original orientation) later on.

Measuring Camshaft Lift

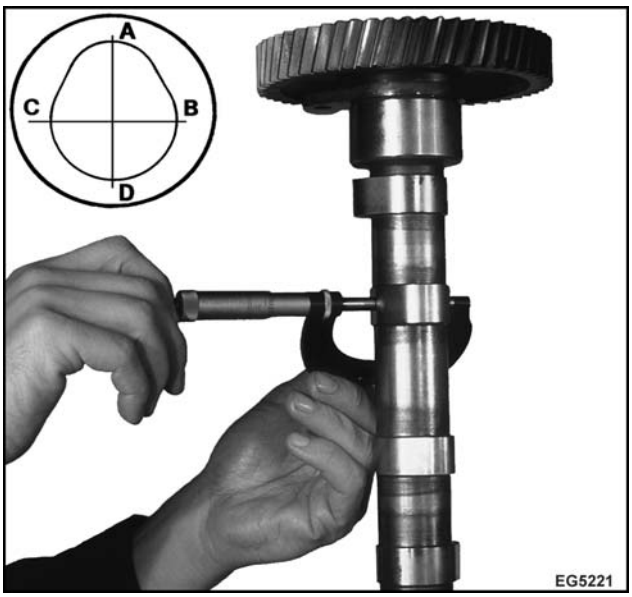


Figure 140 Measuring cam lobes with micrometer

NOTE: If a complete engine overhaul is scheduled, camshaft lobe wear can be determined by measuring lobes (Checking Camshaft Lobes and Journals, page 263) with a micrometer after the camshaft is removed.

At this stage of disassembly, determine the appropriate stage of camshaft inspection. If this is not a complete engine overhaul, measure camshaft lobe lift now using the following procedure.

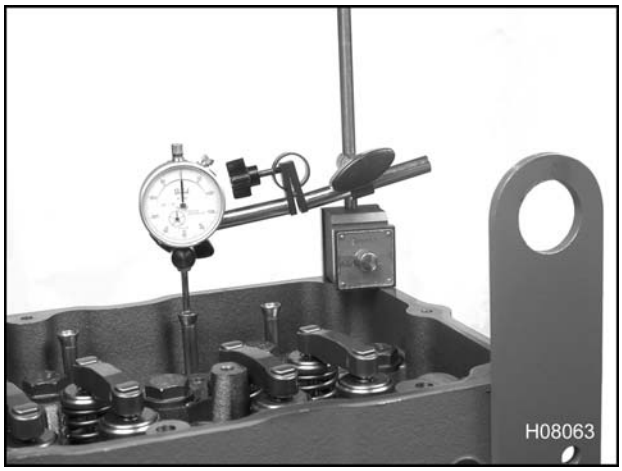


Figure 141 Mounting magnetic base dial indicator

1. Mount a magnetic base dial indicator onto the cylinder head.
2. Place dial indicator tip on top of push rod and rotate engine until push rod is at its lowest point of travel (base circle), then “zero” indicator.

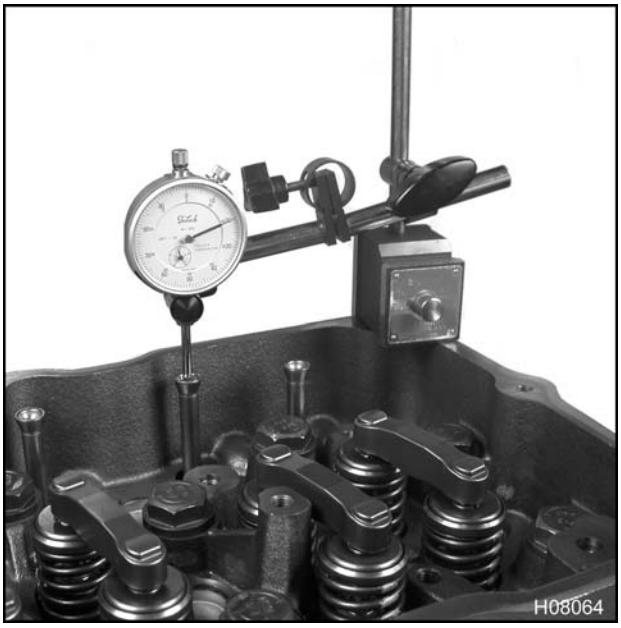


Figure 142 Recording camshaft lobe reading

3. Rotate the crankshaft and bring push rod to its highest point of travel. Record indicator reading.
4. Repeat this procedure for all lobes.
5. For specifications on camshaft lobe (Table 13).

Removing Rocker Arms

NOTE: Mark rocker arms and rocker shaft supports for location to ensure correct placement for later reassembly.

1. Place the rocker arm assembly on a clean flat surface. Mark each rocker arm before removal to aid in assembly of the rocker arm shaft later on.
2. Remove the 12 rocker shaft clamps.

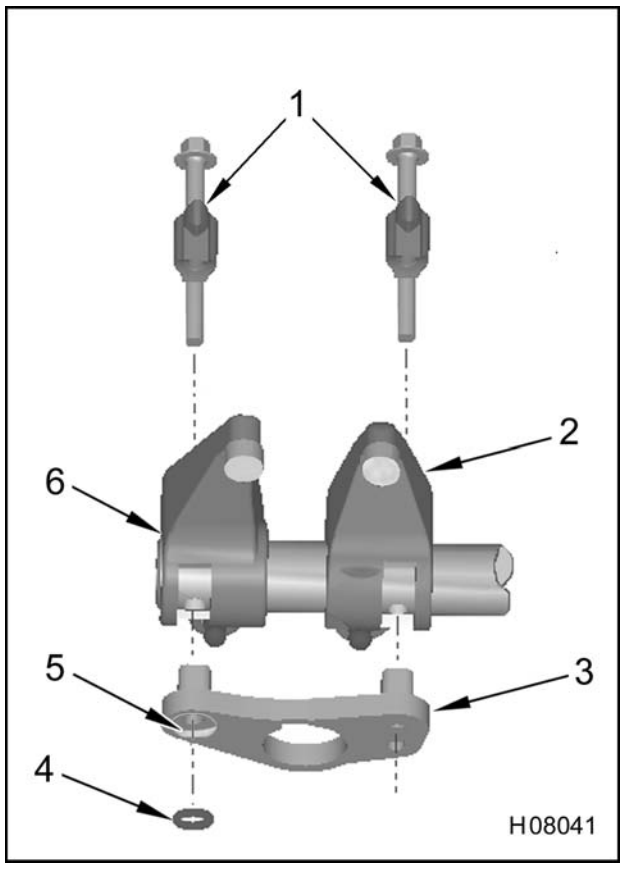


Figure 143 Rocker arm configuration

1. Clamp bolt assembly
2. Exhaust rocker arm
3. Rocker arm shaft support
4. Lower support washer
5. Machined recessed
6. Intake rocker arm

3. Slide rocker arm assembly components off shaft.
4. Tag all pushrods with cylinder number and valve association (intake or exhaust).
5. Remove all pushrods.

Removing Cylinder Head

CAUTION: To prevent engine damage, remove injectors before cylinder head removal (High-pressure Oil Rail Assembly, page 340).

1. Remove and discard 26 cylinder head mounting bolts (M15 x 180).

WARNING: To prevent serious personal injury, possible death, or damage to the engine or vehicle, chain must be equipped with safety hooks. See safety section in front of manual.

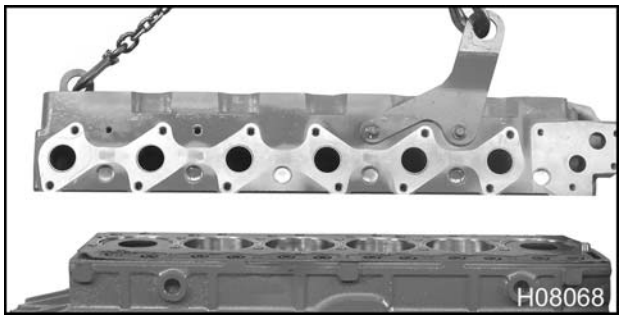


Figure 144 Removing cylinder head from crankcase

2. Attach appropriate hoist and lifting hooks to lifting eyes. Carefully lift the cylinder head from the crankcase.
3. After cylinder head been placed on a workbench surface, remove both lifting eyes and four bolts (M12 x 25) from cylinder head.

Figure 145 Removing cylinder head gasket

NOTE: Place the cylinder head on wood blocks to protect the valves and bottom deck surface.

4. Remove the cylinder head gasket from the crankcase. Discard the gasket.

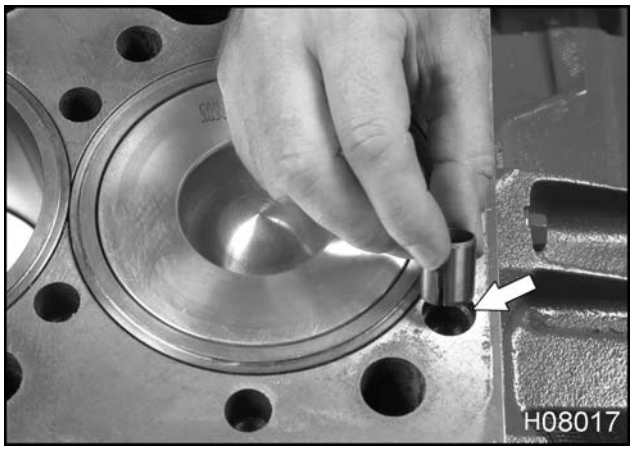


Figure 146 Removing alignment dowels

5. Remove the alignment dowels from the top of the crankcase, only if damaged.

Roller Tappets

Figure 147 Roller tappets and guide

Remove each roller tappet and guide from tappet bore and mark with cylinder number, valve association (intake or exhaust), and roller orientation.

Cleaning

Cylinder Head

CAUTION: To prevent engine damage, leave the valves installed within the cylinder head. This protects the valve seats during the cleaning process.

1. Use a rotary wire brush or a sanding block with mineral spirits to remove any deposits and gasket material from the gasket surface of the cylinder head.
2. Use an appropriately sized brush to clean all mounting bolt holes in the cylinder head.
3. Wash rocker arm assemblies, hydraulic lifters, and push rods in a suitable solvent and dry them thoroughly. Replace any bolts that have damaged threads.

CAUTION: To prevent engine damage, do not use chlorinated solvents on bolts or crankcase tapped holes. Parts should be clean, dry, and free of any chemical residuals other than engine oil.

Inspection

Valve Train Components

Engine valve train load carrying requirements have resulted in the release of several different push rod and tappet configurations. The main differences are improved geometry designs and materials.

For information on push rod and tappet compatibility for different engine model year configurations, see (TSI-06-12-14 Update Valve Train Components – Push Rod and Tappet Compatibility, page469) .

Push Rods

WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

1. Thoroughly clean each push rod using a suitable solvent and dry rods using filtered compressed air .
2. Inspect each push rod for wear at both ends. If push rod is worn, install new push rod.

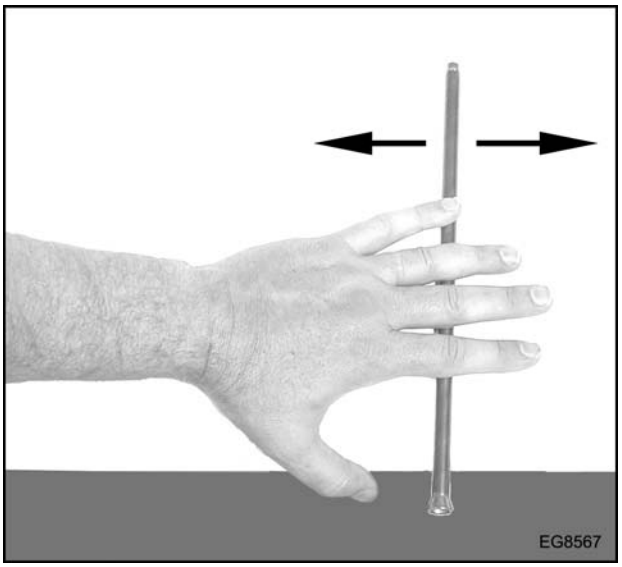


Figure 148 Check push rods for straightness

3. Check all push rods for straightness by rolling push rods on a flat surface with the cap end over the edge of the flat surface.
4. Measure push rod runout with a feeler gauge (page150) between the flat surface and push rod.
5. If specifications (page154) are exceeded, install new push rod.

Rocker Shaft

CAUTION: To prevent engine damage, if it is necessary to replace the rocker shaft, all of the rocker arms must be replaced. Reusing rocker arms on a new shaft will not allow for an adequate break-in period, causing premature failure of the rocker arm assembly.

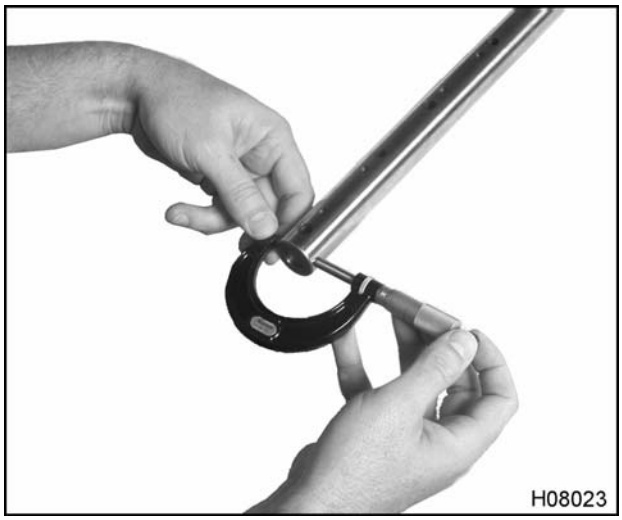


Figure 149 Measuring rocker arm shaft

1. Check the rocker shaft for scoring, pitting and wear. Replace rocker shaft and all of the rocker arms as required.

NOTE: It is normal to see a slight polishing at the rocker arm area.

2. Use an outside micrometer to measure a non-contact area of the rocker shaft. This dimension will be used as a baseline for the shaft diameter.
3. Use an outside micrometer to measure each of the 12 lever contact areas of the rocker shaft. If the difference between the baseline and any of the measurements is greater than 0.03 mm (0.001 in), replace the rocker shaft and all of the rocker arms.
4. To ensure that oil supply holes are open, insert a small wire or another suitable tool.
5. Check the cup plugs at each end of the rocker shaft. Do not disturb the cup plugs unless they are damaged. If replacement is required, pry out the plugs and press in new plugs.

Rocker Arms

1. Inspect arms for scoring, pitting, or signs of excessive wear. If the bore has visible damage, replace the rocker arm. Be sure to inspect the lower half of the rocker arm. The most significant wear will occur at this location. Rocker arms may be reused in their original locations if the phosphate coating is worn off and the shaft was not replaced.

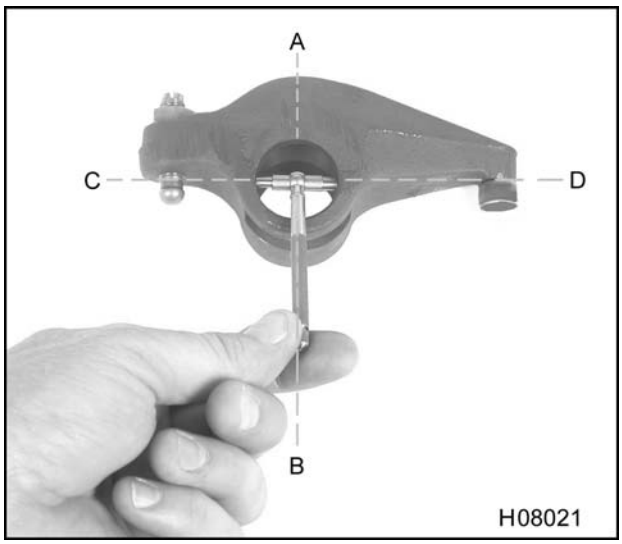


Figure 150 Measuring the rocker arm bore

NOTE: The purpose of the black phosphate coating on the rocker arm is to provide a break-in lubricant between the rocker shaft and rocker arm bore. It is normal to see the black phosphate coatings worn off of the bottom of the lever arm in the shaft and bore contact area. Rocker arms must be labeled and installed in their original locations to maintain the proper wear pattern.

2. Use a telescoping gauge and outside micrometer to measure the rocker arm bore diameter at two locations. Measure the diameter at **A-B** and **C-D**. If the difference between the diameters is greater than or equal to 0.03 mm (0.001 in), replace the rocker arm.
3. Inspect the valve bridge contact pivot on the rocker arm for scoring, pitting, or signs of excessive wear.
4. Inspect the valve lash adjuster for signs of wear. Replace the adjuster screw if excessive wear is found.

Cylinder Head Warpage

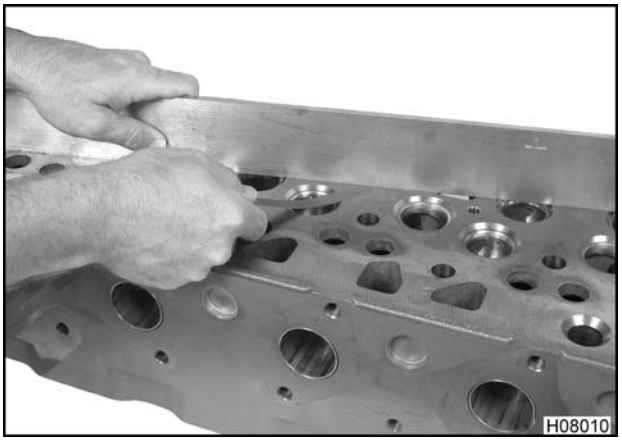


Figure 151 Checking for warpage

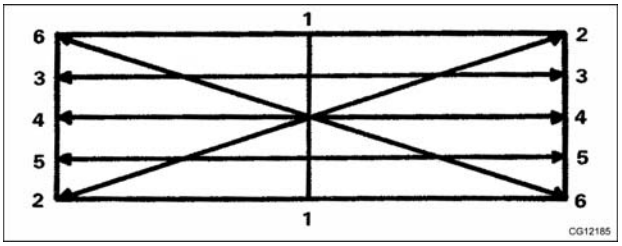


Figure 152 Checking pattern

Use a straightedge and feeler gauge to check the gasket surface of the cylinder head for warpage. Use the checking pattern that is shown. If warpage is present as indicated by a feeler gauge measurements exceeding cylinder head gasket surface flatness specifications, check thickness of cylinder head.

Cylinder Head Thickness

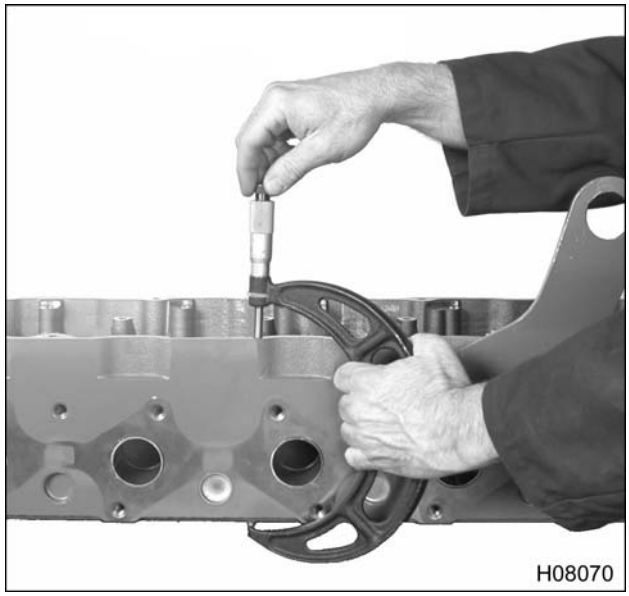


Figure 153 Checking cylinder head thickness

Use a 6-7 inch outside micrometer to measure the thickness of the cylinder head at six locations (four corners and two center points). Cylinder head thickness must equal or exceed the minimum specification after resurfacing. If the minimum specification after resurfacing cannot be met, replace cylinder head.

Valve Seat Leakage

NOTE: This test does not check for the condition of the valve guides or the valve stem-to-valve guide clearance.

1. Position the cylinder head on wood blocks with the gasket surface facing down.
2. Squirt mineral spirits into the intake and exhaust valve ports and wait 5 minutes.
3. Use an inspection mirror to check valve seat area for leakage of the mineral spirits past the valve seats.

   NOTE: If leakage occurs, the valves must be reconditioned.

Cylinder Head Cracking

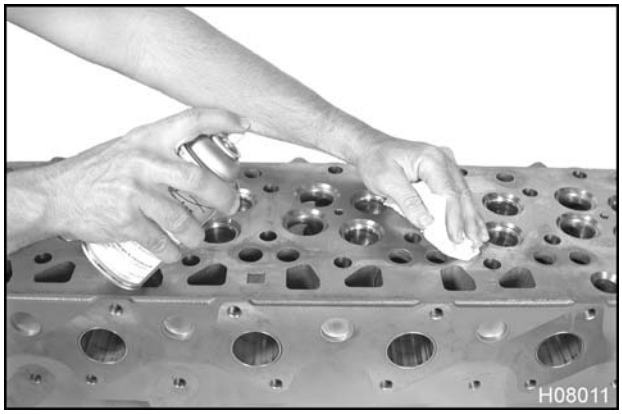


Figure 154 Spraying brake cleaner on cylinder head

NOTE: The cylinder head cracking inspection can be performed with or without valves installed.

1. Spray brake cleaner on the gasket surface of the cylinder head and wipe it dry.

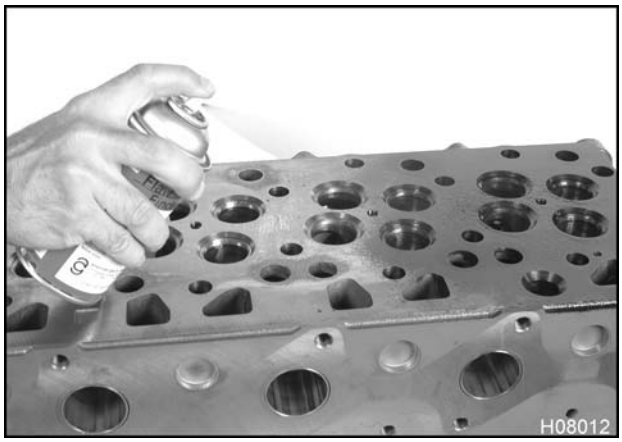


Figure 155 Spraying dye penetrant on cylinder head

2. Spray dye penetrant on the gasket surface of the cylinder head. Leave the dye penetrant on for 1-10 minutes.

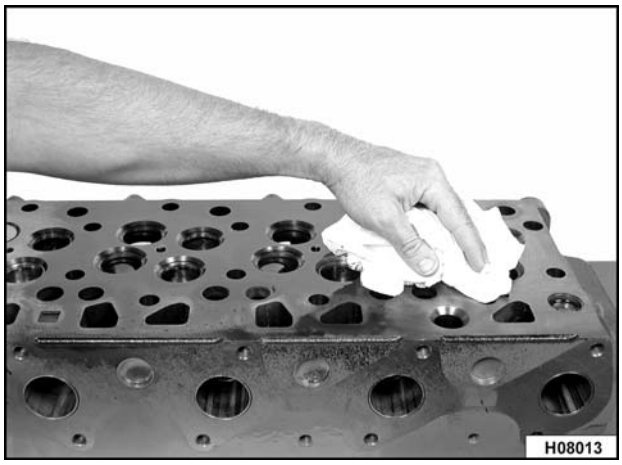


Figure 156 Wiping dye penetrant off cylinder head

3. Wipe off dye penetrant. The dye will remain in any cracks in the cylinder head.

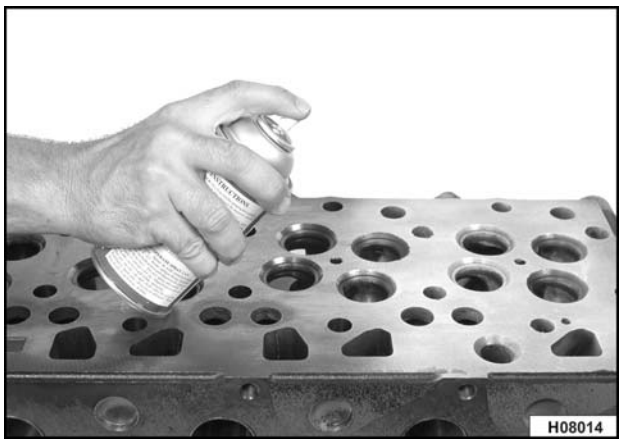


Figure 157 Spraying developer on cylinder head

4. Spray developer on the gasket surface of the cylinder head. Allow the developer to dry for 5-15 minutes.

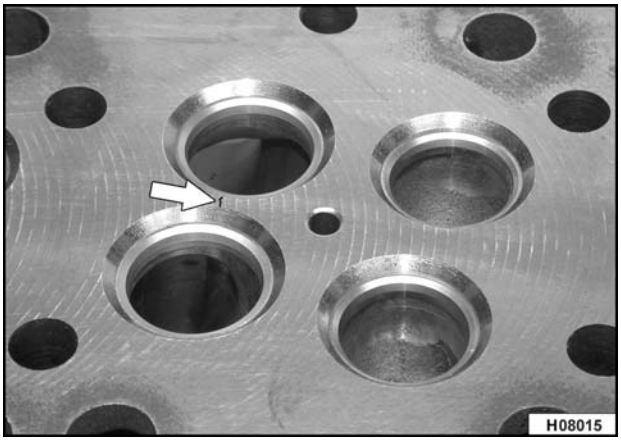


Figure 158 Crack in cylinder head

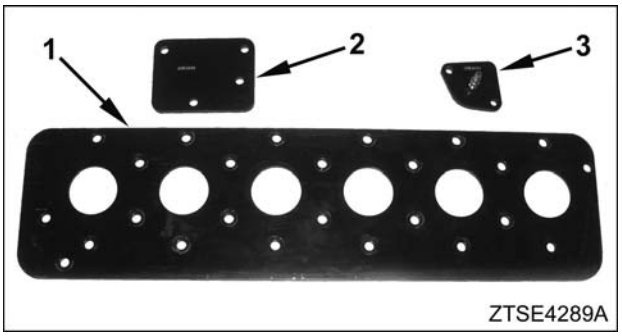


Figure 159 Cylinder head pressure test tools

1. Cylinder head test plate (bolts not shown)
2. Water supply housing pressure adapter
3. Thermostat opening pressure adapter- cylinder head

NOTE: Any cracks will show up as purple lines against the white developer. If any cracks are present, replace the cylinder head.

Pressure Check Cylinder Head

Pressure testing the cylinder head will reveal cracks in ports or sleeve leakage which cannot be observed using dye penetrant. Pressure-test the cylinder head as follows:

1. Install fuel injectors into cylinder head injector bores and secure. Refer to Fuel Injectors (Fuel Injectors, page352) for installation procedure.
2. Remove the valves, using a valve spring compressor. See “Reconditioning” in this section for valve removal instructions.
3. Pressure test the cylinder head using the cylinder head pressure test tools (Table 17).
4. Fasten the pressure plate to the cylinder head gasket surface using the 24 mounting bolts and nuts supplied with the kit.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

5. Remove thermostat and install air regulator. Secure to cylinder head with two mounting bolts.
6. Remove the pipe plug next to the thermostat opening. Fill cylinder head with hot water and reinstall pipe plug
7. Install a hose fitting to the cylinder head at the removed plug. Apply 124–138 kPa (18–20 psi) air pressure and inspect for leaks at the:
   - Fuel injector nozzle sleeve area
   - Ports
   - Upper deck
   - Lower deck

If leakage is observed at any port or the upper and lower deck, replace the cylinder head.

Reconditioning

Removing Valves from Cylinder Head

WARNING: To prevent serious personal injury, possible death, or damage to the engine or vehicle, wear safety glasses when removing valves or valve spring retainer keys.

1. Install a valve spring compressor tool over the valve, see Cylinder head and valve special service tools (Table 17). Compress the valve spring.

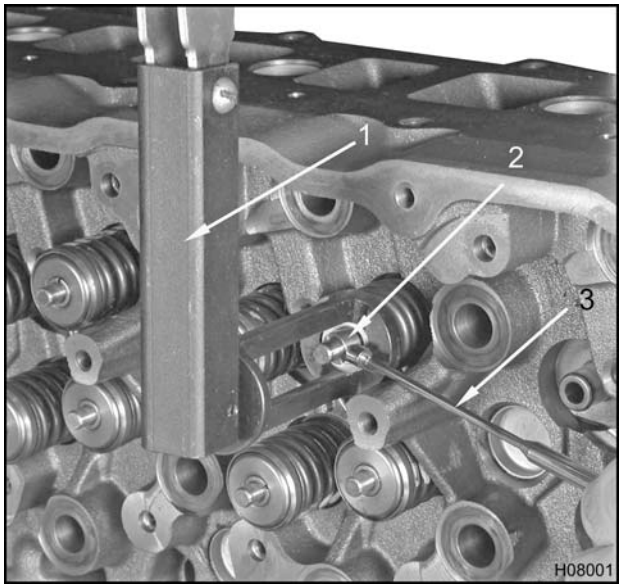


Figure 160 Removing valve spring retainer keys

1. Valve spring compressor tool
2. Valve spring retainer key
3. Magnet

2. Use a magnet to remove the valve spring retainer keys.

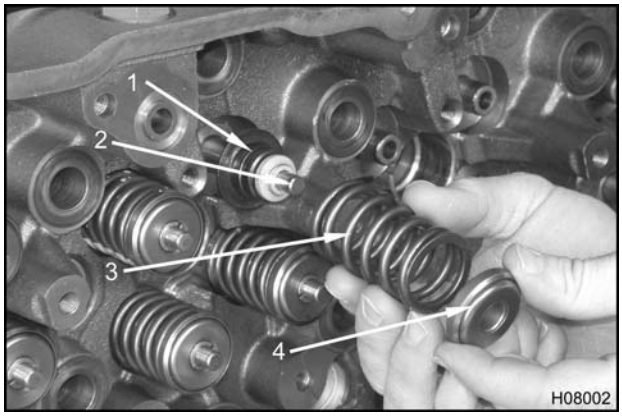


Figure 161 Removing valve rotator, spring, and valve stem seal

1. Valve stem seal
2. Valve stem
3. Valve spring
4. Valve rotator

3. Remove valve spring compression tool, valve rotator, and spring.
4. Remove and discard valve stem seal.
5. Remove valve from the cylinder head.
6. Repeat steps 1-5 for all 24 valve locations.

Inspecting Valve Guides

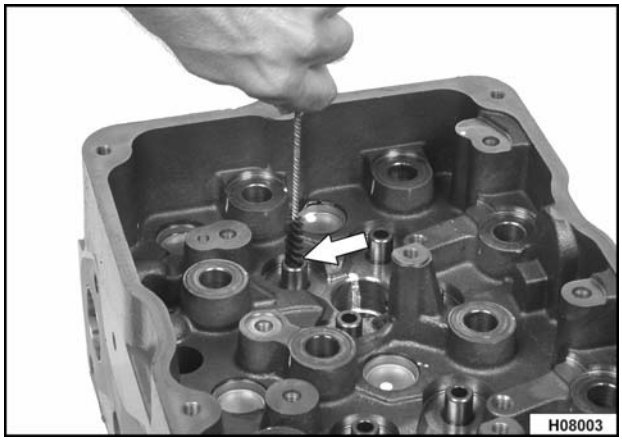


Figure 162 Cleaning valve guides

1. After removing valves, use soap, water, and a nylon brush to clean valve guides.

2. Position an inspection light at the bottom of the valve guide bores. Inspect bores for signs of burning or cracking. Replace any valve guides that are damaged.

Figure 163 Measuring valve guide with ball gauge

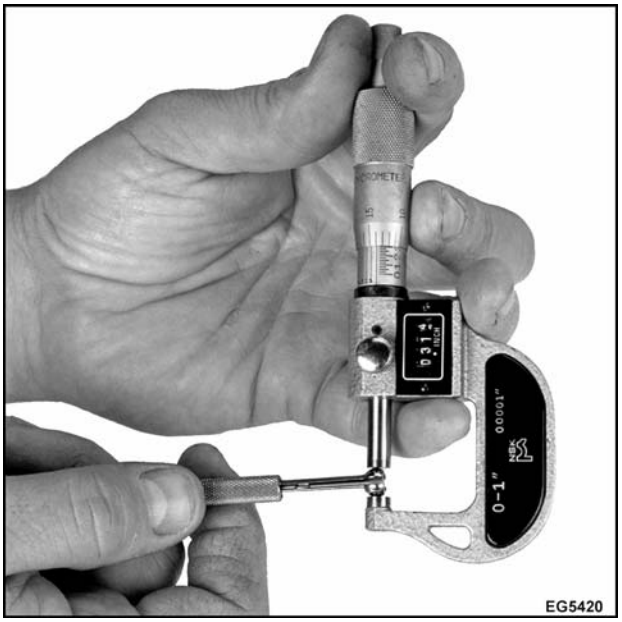


Figure 164 Measuring ball gauge with an outside micrometer

3. Use a ball gauge and an outside micrometer to measure the inside diameter of each valve guide.

   If inside diameter of valve guide exceeds specifications, replace valve guide.

4. Measure the valve guides within 0.64 mm (0.025 in) of each end and 90 degrees from the crankshaft center line. Record the readings in order to determine the valve-to-guide running clearance later.

Replacing Valve Guides

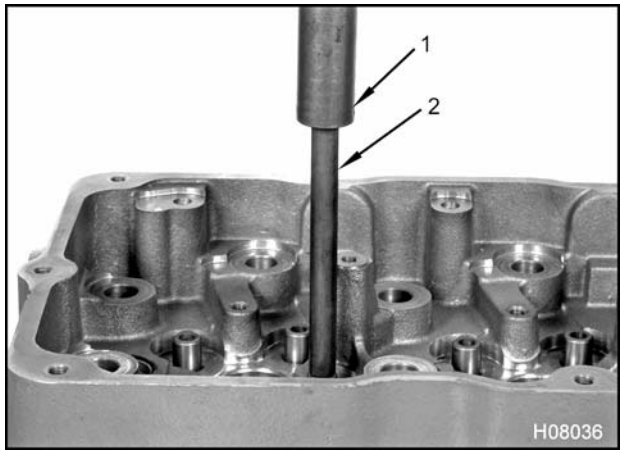


Figure 165 Pressing out valve guide insert

1. Arbor press ram
2. Valve guide removal tool

1. Secure the cylinder head on a press table. Align the valve guide to be replaced with the center of the press ram.
2. Insert the valve guide removal tool into the valve guide from the top side of the cylinder head. Press out the valve guide insert.

CAUTION: To prevent engine damage, do not use a hammer or any other tool to remove or install the valve guide inserts into the cylinder head.

NOTE: Chilling the valve guide inserts first may facilitate installation.

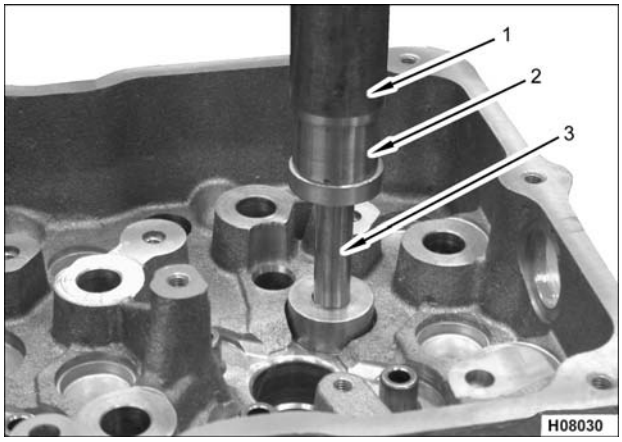


Figure 166 Pressing in the valve guide insert

1. Arbor press ram
2. Valve guide installation tool
3. Valve guide insert

3. Lubricate a new valve guide insert with clean engine oil. Use the valve guide installation sleeve to install the valve guide insert until the installation sleeve bottoms out against the cylinder head.

NOTE: Do not ream the inside diameter of the valve guide after installation. Service valve guides are provided in a finish reamed condition.

4. After installing the valve guide insert, debur the valve guide by using the valve guide deburring tool.

Inspecting Valves

1. Remove all carbon deposits from the valve stems and valve heads.
2. Inspect each valve for burn marks, warpage, scuffing and bending. Replace any damaged valves.

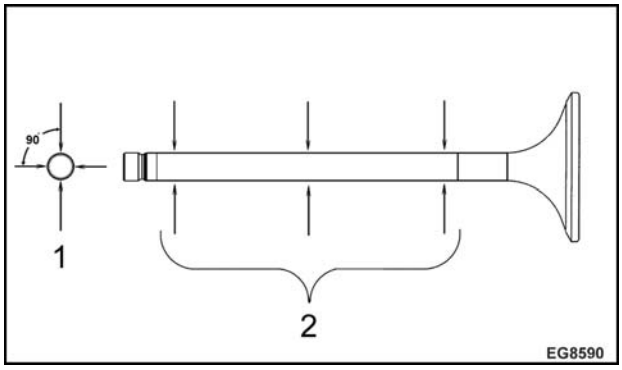


Figure 167 Measuring valve stem diameter

1. Two measurements 90 degrees apart
2. Valve stem diameter measurement locations

3. To check for wear, use a micrometer to measure the diameter of each valve stem.
4. Measure the valve stem diameter at two locations that are approximately equidistant. At each location, take two measurements that are 90 degrees apart. Average the two measurements at each location and record the readings.

   If the average of measurements at any of the two locations exceed the valve stem diameter specification, replace the valve.
5. Inspect the valve stem tip for scoring, pitting, or signs of excessive wear.
6. Using the valve stem diameter and valve guide inside diameter measurements, recorded earlier (see “Inspecting Valve Guides”) determine valve stem-to-guide running clearance. See “Specifications”. Replace the valve or valve guides as required.

NOTE: Subtract the average valve stem diameter from the average valve guide inner diameter (determined earlier).

Valve Guide – Valve Stem = Running Clearance.

Refacing Valves

Valve Face

NOTE: If the valves are in serviceable condition, they may be refaced to the specified angles, as required.

CAUTION: To prevent engine damage, maintain the minimum valve face margin across the entire valve face. An insufficient valve face margin will not provide proper heat dissipation, ultimately causing the valve to warp or break.

NOTE: Make sure that there is sufficient coolant in the valve grinding machine reservoir. Turn coolant pump on before grinding.

1. Use the dressing stud attachment on the grinder to dress the cutting stone.

Figure 168 Grinding valve face

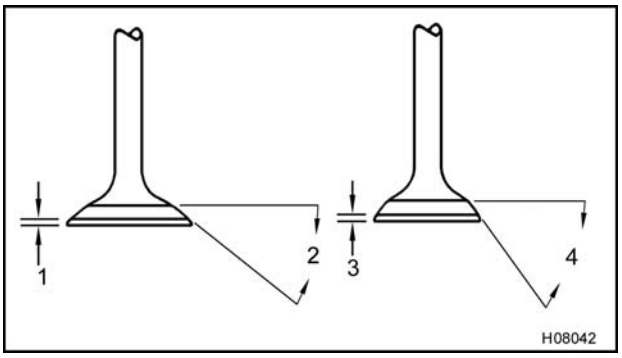


Figure 169 Valve face angles

1. Intake margin
2. Intake valve angle
3. Exhaust margin
4. Exhaust valve angle

NOTE: Intake valves and exhaust valves have different valve face margins.

2. Install valve in the grinder and set the grinder to the specified angle.
3. Turn on coolant and grinder.

NOTE: Removal of too much material may reduce the margin below minimum specifications.

4. Grind the valve face. Only remove the minimum amount of material necessary.

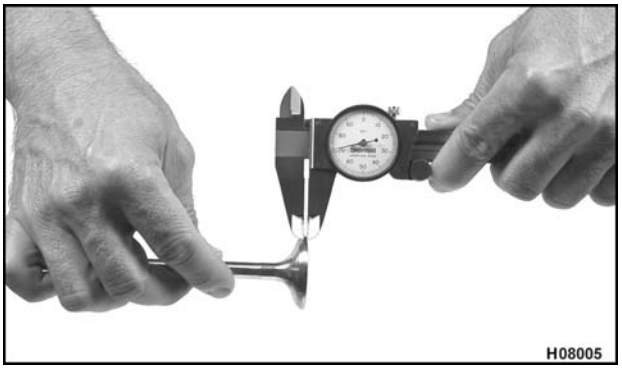


Figure 170 Measuring valve face margin

5. Use a caliper to measure the valve face margin at four locations. If any of the measurements are less than the minimum specification (Table 13), replace valve.

Valve Stem Tip

CAUTION: To prevent engine damage, leave a sufficient amount of material so that the valve bridge does not contact the valve retainer keys or valve rotator during operation. Refacing the tip of the valve stem provides a new wear surface for the valve bridge.

1. Use the dressing stud attachment on the grinder to dress the cutting stone.

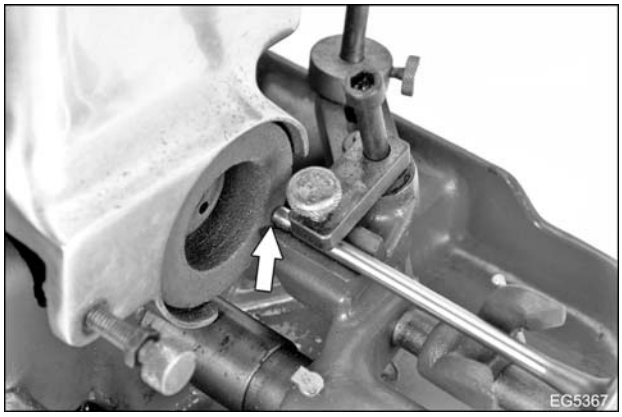


Figure 171 Grinding valve stem

2. Install the valve in the grinder so that the tip of the valve stem is close to the grinding stone.
3. Briefly touch the tip of the valve stem to the grinding stone. Only remove the minimum amount of material that is necessary.

Checking Valve Face-to-Valve Seat Contact

Figure 172 Applying Prussian Blue® to valve face

1. After refacing a valve, spread a thin film of Prussian Blue® on the valve face and insert the valve in the valve guide.

Figure 173 Turning valve on valve seat

2. Apply pressure on the center of the valve head while turning the valve 90 degrees on the valve seat.
3. Remove the valve from the cylinder head. Check the impression that was made on the valve seat and valve face. Prussian Blue should appear around the entire contact surface of the valve seat and valve face.
4. Perform this check several times to rule out any errors. If the Prussian Blue® contact impression is good, proceed to valve installation. If the Prussian Blue® contact impression is not good, continue with resurfacing valve seats.

Resurfacing Valve Seats

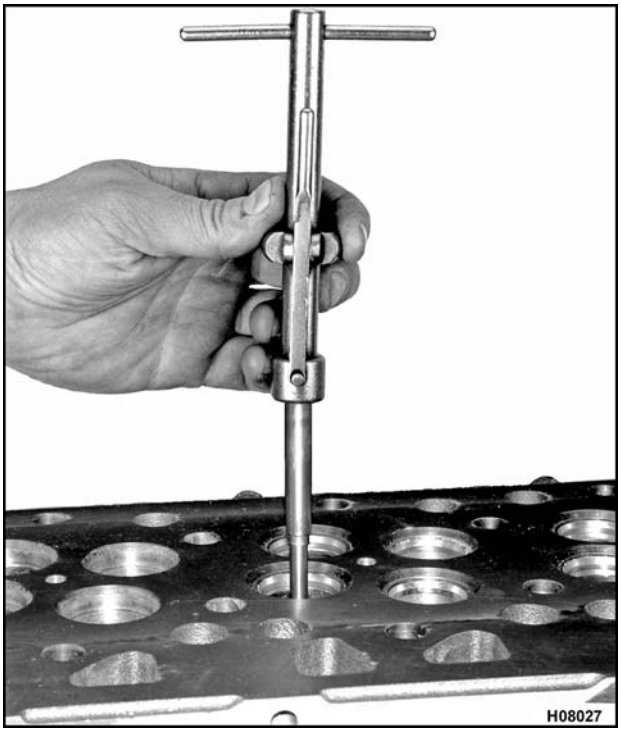


Figure 174 Installing valve guide pilot

1. Lightly lubricate the correct size of grinding pilot. Install the pilot into the valve guide.
2. Choose the correct angle grinding stone and dress the stone. See “Specifications” for the correct valve seat angle.
3. Install the grinding stone over the pilot.

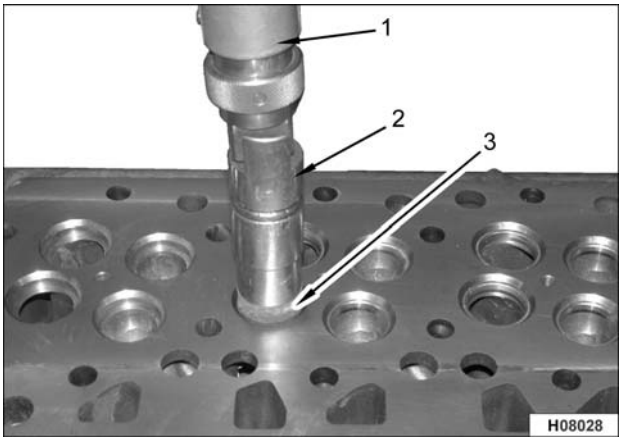


Figure 175 Grinding the valve seat

1. Motor and drive
2. Holder
3. Grindstone

4. Turn on the power and gently apply the weight of the grinding motor to the grindstone. Raise the grinding stone frequently to prevent overheating. Grind the valve seat to a smooth even finish, paying attention to achieving an acceptable uniform width (Table 15).

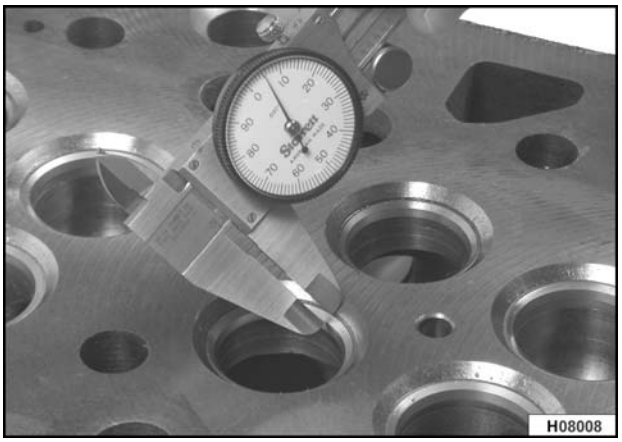


Figure 176 Checking valve seat width

5. Use a caliper to check the valve seat width. If the valve seat width exceeds specifications, the valve seat may be corrected by grinding with a 15 degree or smaller angle stone.

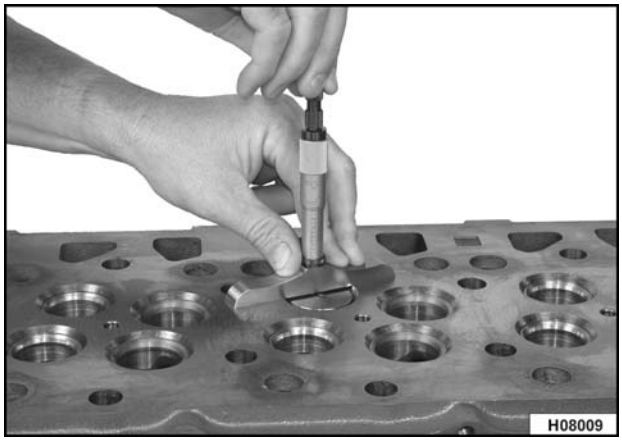


Figure 177 Checking valve recession

6. Install valve in guide. Use a depth micrometer to check valve recession. If valve recession is excessive, install a new valve or replace valve seat as necessary. If the valve protrudes above the surface of the cylinder head, regrind the valve seat. After grinding the valve seat, check valve seat width again. Also check the valve face-to-valve seat contact (Checking Valve Face-to-Valve Seat Contact, page134).
7. Use an appropriate dial indicator to check the valve seat runout. If runout exceeds specifications, replace valve seat.

Replacing Valve Seats

Removal

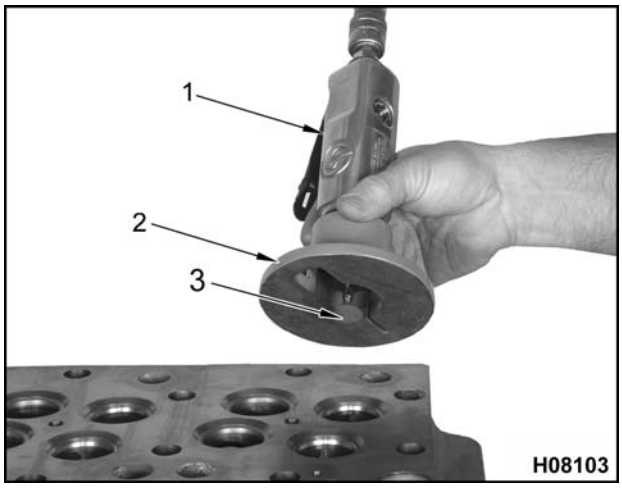


Figure 178 Grinding group tool

1. Air motor
2. Grinding base
3. Grinding wheel

1. Use grinding group tool (Table 17) to cut a groove in the valve seat insert.

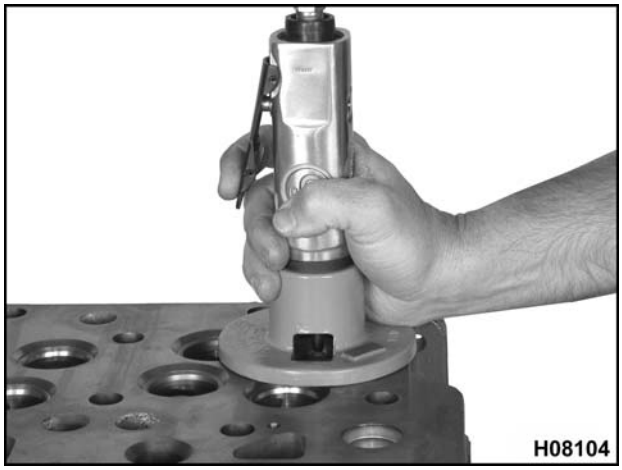


Figure 179 Grinding groove in valve seat

2. Position the appropriate size extractor in the valve seat.

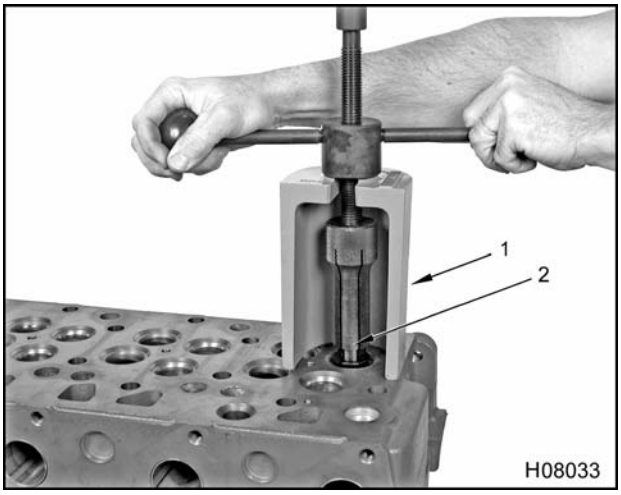


Figure 180 Removing the valve seat insert

1. Lifting bridge
2. Valve seat remover (collet)

3. Expand collet by threading the shaft into the valve seat remover until it is tight inside the valve seat. Turn T-handle on shaft to pull the valve seat insert from cylinder head.

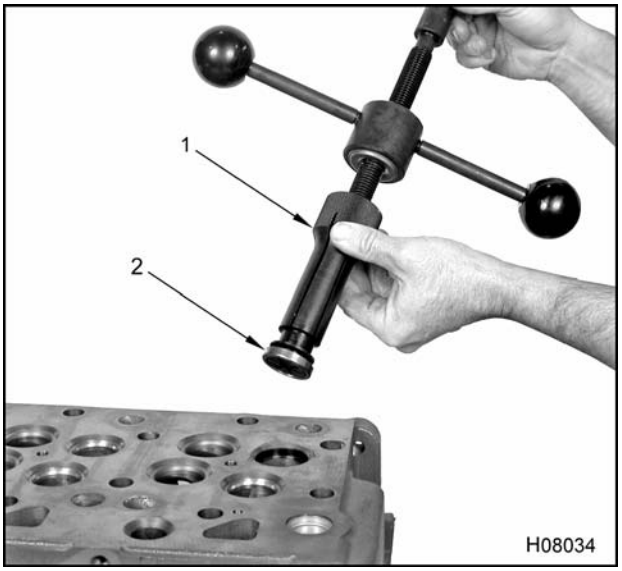


Figure 181 Valve seat insert removed

1. Collet
2. Valve seat insert

4. Unlock the collet by loosening the threaded shaft. Discard valve seat insert.

Installation

1. Use a micrometer to measure the diameter of the valve seat insert counterbore at two locations, 90° apart. Average the two measurements to determine the appropriate size valve seat insert to install.

Table 12 Valve Seat Insert Selection Chart

Available inserts (int. and exh.)	Ave. dia. of intake counterbore	Ave. dia. of exhaust counterbore
Standard	40.119 - 40.170 mm (1.5795 - 1.5815 in)	37.478 - 37.529 mm (1.4755 - 1.4775 in)
Oversize - 0.05 mm (0.002 in)	40.170 - 40.221 mm (1.5815 - 1.5835 in)	37.529 - 37.579 mm (1.4775 - 1.4795 in)

2. Chill the valve seat insert in a freezer for 30 minutes. This will prevent the outer layer of metal from being shaved off during installation.

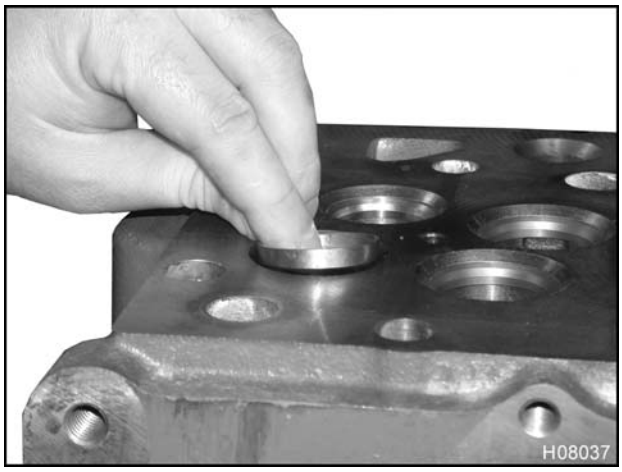


Figure 182 Placing chilled valve seat into head

3. Align insert over counterbore to avoid misalignment.

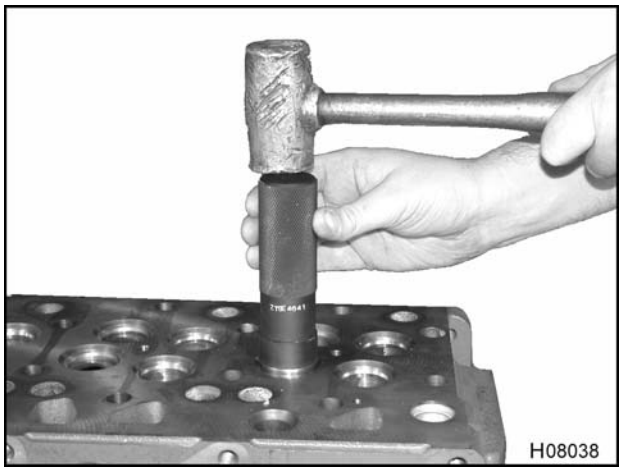


Figure 183 Driving valve seat into place

4. Using a hammer and valve seat installation tool drive the valve seat into place until it is fully seated. See Cylinder head and valve special service tools (Table 17).
5. Grind new valve seats to the specified angles and widths, see Cylinder Head Specifications (Table 15) in this section.

Inspecting Valve Springs

1. Clean all of the valve springs in a suitable solvent.

CAUTION: To prevent engine damage, do not wire brush or grind valve springs. Disruption of surface may result in fatigue cracks and spring failure.

2. Check the valve springs for rust, cracks, and pitting. Replace any damaged valve springs.

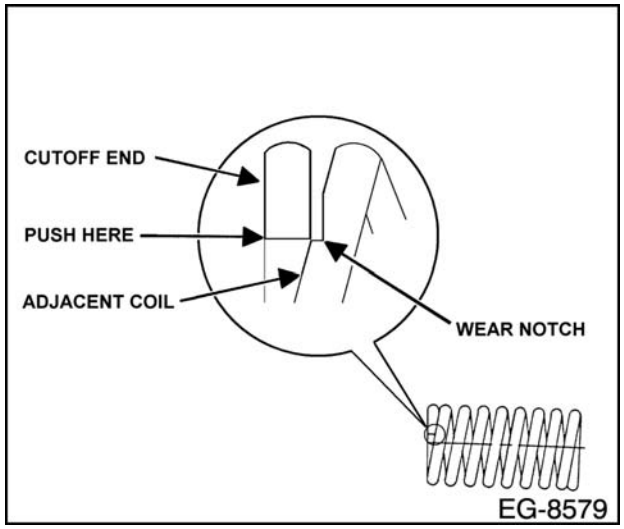


Figure 184 Valve spring inspection

3. Check both ends of each valve spring at the contact point between the cutoff end of the last coil and the adjacent coil. If the cutoff end has worn a notch in the adjacent coil, replace the spring.

NOTE: These wear notches can also be detected by compressing the spring and listening for a clicking sound.

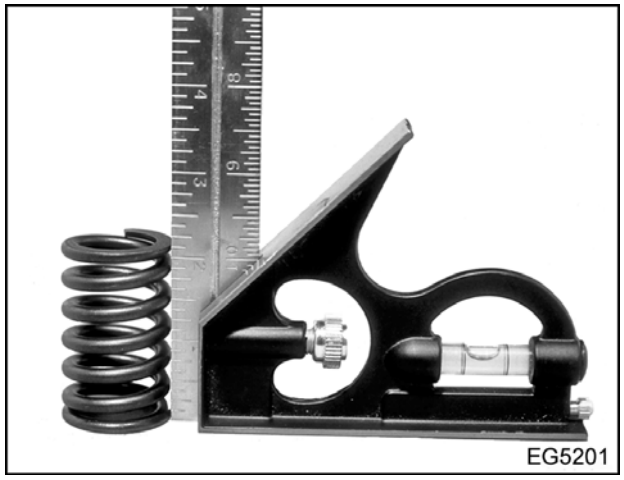


Figure 185 Checking perpendicularity and flatness of valve spring

NOTE: Valve springs that are not perpendicular to a flat surface place an unequal lateral load on the valve stem during operation, causing premature valve guide wear.

4. Use a square to check flatness and perpendicularity of spring ends. If the end of any valve spring is not flat and square, replace spring.

Figure 186 Measuring valve spring tension

5. Use a Valve Spring Compressor (Table 17) to measure the valve spring tension. Measure the maximum and minimum lengths of the spring at the appropriate test loads (valve closed and valve open). Replace any valve spring that does not meet valve spring specifications (Table 14).

Inspecting Valve Rotators

1. Clean all valve rotators in a suitable solvent.

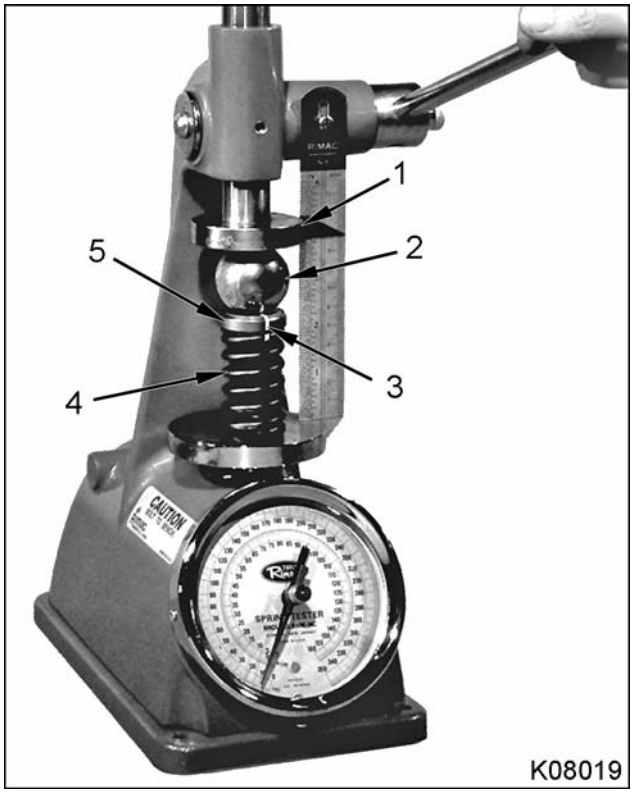


Figure 187 Checking valve rotator

1. Ram
2. Steel ball bearing
3. Paint reference line
4. Spring
5. Valve rotator

2. Lubricate the valve rotator with clean engine oil. Place the valve spring and rotator in spring tester.
3. Place a ball bearing between the valve rotator and the ram of the spring tester. The ball bearing must be large enough to prevent the ram from touching any part of the rotator.
4. Paint a reference line on the valve rotator and spring.
5. Compress the valve spring rapidly with even pressure and observe the valve rotator as it turns. Replace any valve rotator that does not turn.

Inspecting Valve Spring Retainer Keys

1. Clean all valve spring retainer keys with a suitable solvent.
2. Check the inside and outside of the valve spring retainer keys for wear. Replace any worn retainer keys.

Replacing Fuel Injector Sleeves

Removal

NOTE: If the fuel injector sleeve is being removed while the engine is in-chassis, place a cup plug in the bore before removal to prevent debris from entering the cylinder bore.

1. Insert the fuel injector sleeve removal tool into the fuel injector bore.
2. Turn the removal tool to cut threads into the fuel injector sleeve. Remove the tool from the bore.
3. Install the fuel injector sleeve puller tool into the bore and tighten. Make sure that the puller tool is threaded all the way into the fuel injector sleeve.
4. Install a slide hammer onto the puller tool. Remove the fuel injector sleeve from the bore.

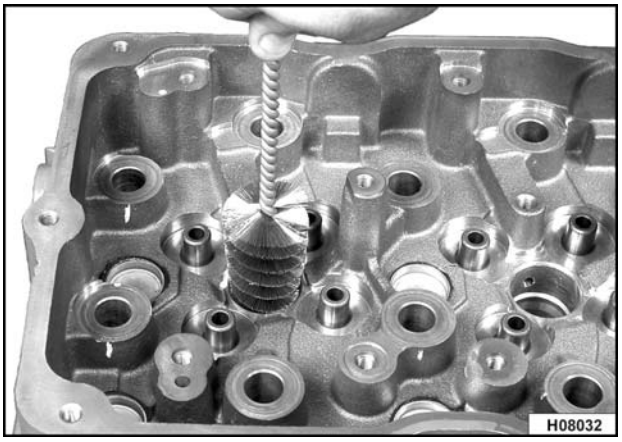


Figure 188 Cleaning fuel injector bore

5. Use a stiff wire brush to clean deposits and hardened sealant from the fuel injector bore.
6. Insert a small stiff nylon brush tool into oil gallery for cleaning.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

7. Use compressed air to clean out all fuel and oil galleries of debris.

Installation

1. Inspect installation tool for a bent pilot shaft or any nicks where sleeve will seat

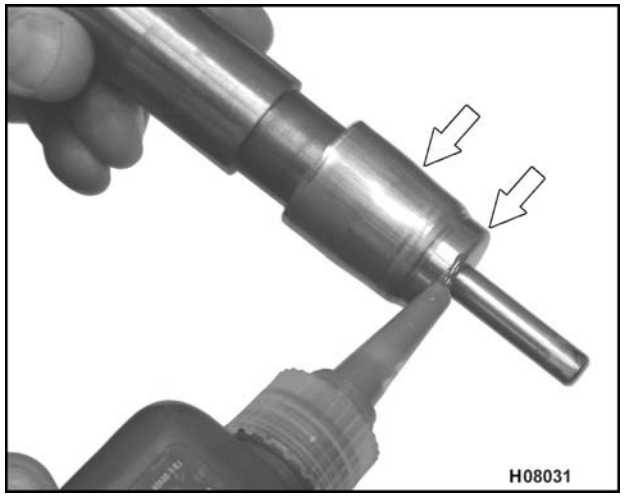


Figure 189 Applying Loctite® 620 sealant to fuel injector sleeve

2. Place a new fuel injector sleeve on the end of the installation tool. See cylinder head and valve special service tools (Table 17).

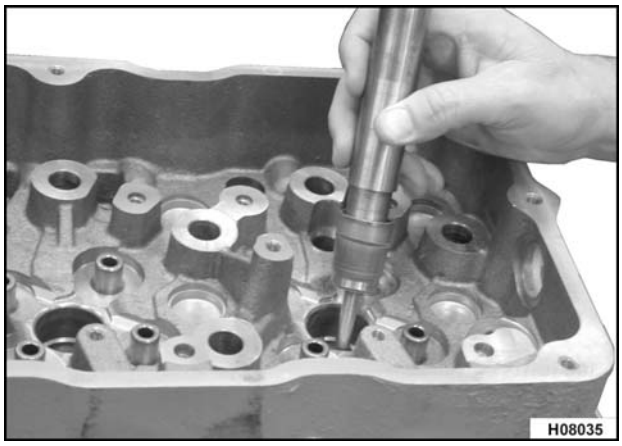


Figure 190 Installing fuel injector sleeve into bore

3. Apply Loctite® 620 around the outside diameter at the bottom of the sleeve and around the beginning of the taper at the middle of the sleeve.

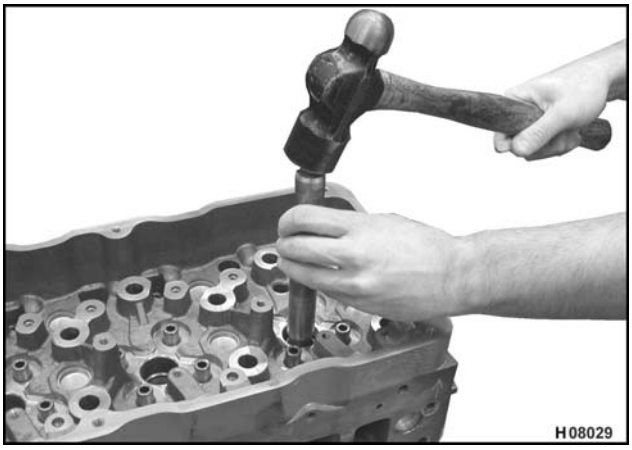


Figure 191 Installing fuel injector sleeve

4. Install the sleeve and installation tool into the fuel injector bore.
5. Use a hammer to drive the fuel injector sleeve into the bore. Remove the installation tool when the sleeve is seated.
6. Use a soft nylon brush to clean the fuel injector sleeve after installation.
7. Inspect the inside surfaces of the installed fuel injector sleeve. If nicks and scratches are evident, replace the sleeve again. Make sure that the installation tool is not causing such damage. Use a different installation tool, if necessary.

Installing Valves

Cleaning

WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

1. Clean the valve faces and seats with a suitable cleaning solvent. Dry all components using filtered compressed air.
2. To clean valve guides, coat a brush with soap and water. Insert the brush into each valve guide bore and rotate in one direction with an up and down motion. Dry the valve guide bores using filtered compressed air.
3. Insert a large nylon brush in the rear of the fuel rail gallery to loosen any dirt and deposits. Blow out any debris using filtered compressed air.

Assembly

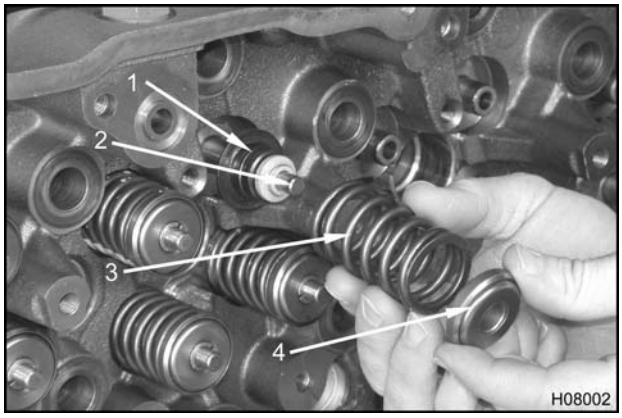


Figure 192 Installing valve stem seal, spring, and valve rotator

1. Valve stem seal
2. Valve stem
3. Valve spring
4. Valve rotator

1. Lubricate the valve stems with clean engine oil and insert into the valve guides.

2. Lubricate the inside diameter of the new valve stem seals with clean engine oil. Install the seals over the valve stems and valve guides. Make sure that the seals are completely seated against the cylinder head spring pockets.
3. Install the valve springs over the valve stem seals.
4. Then install the valve rotators on top of the valve springs.

WARNING: To prevent serious personal injury or possible death, wear safety glasses before using the valve spring compressor.

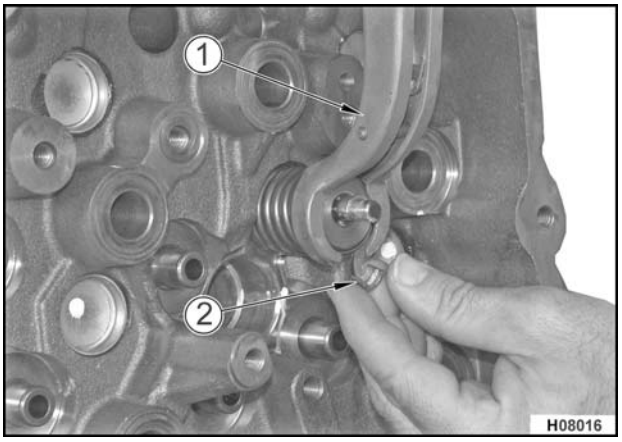


Figure 193 Installing valve spring retainer keys

1. Valve spring compressor tool
2. Valve spring retainer key

5. Install a valve spring compressor tool over the valve. See cylinder head and valve special service tools (Table 17). Compress the valve spring.
6. Install the valve spring retainer keys.

Installation

Roller Tappets

Figure 194 Roller tappets and guide

1. Lubricate roller tappets with clean engine oil.
2. Install each roller tappet and guide into tappet bore. Install used roller tappets in their original locations, revolving in the same direction as before removal.

Installing the Cylinder Head

NOTE: Before cylinder head installation, check cylinder sleeve protrusion (Checking Cylinder Sleeve Protrusion, page 229).

1. Install two lifting eyes with four bolts (M12 x 25) onto cylinder head. Tighten bolts to the standard torque value (General Torque Guidelines, page 445).
2. Clean and dry the cylinder head gasket surface. Also use the correct size tap to clean head bolt holes in the crankcase.

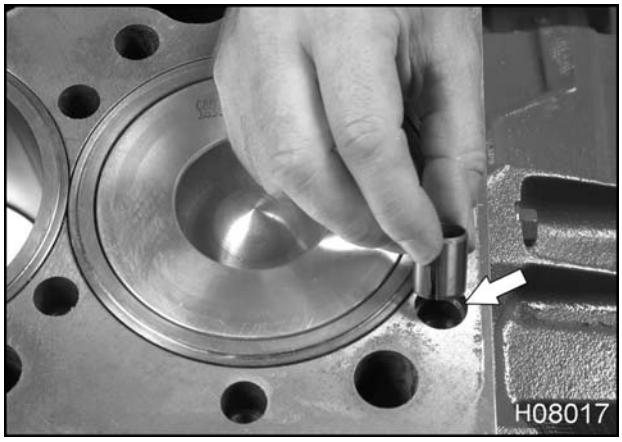


Figure 195 Installing alignment dowels

3. Install or verify that alignment dowels are in the top of the crankcase.

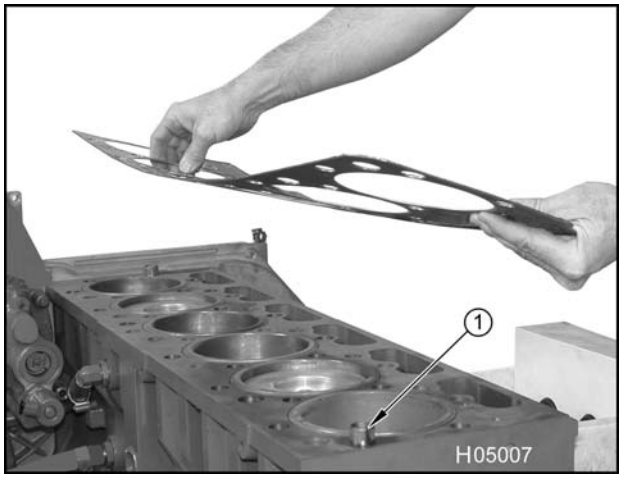


Figure 196 Installing cylinder head gasket

1. Alignment dowels

4. Install a new cylinder head gasket over the alignment dowels.

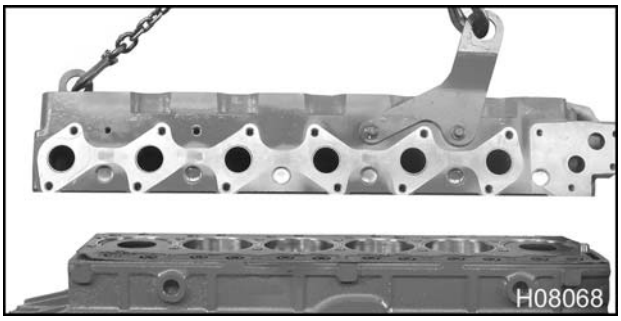


Figure 197 Lowering cylinder head onto crankcase

5. Attach an appropriate hoist and lifting hooks to the lifting eyes. Carefully lower the cylinder head onto the crankcase.

Torque-to-Yield Procedure for Cylinder Head Bolts

CAUTION: To prevent engine damage, do not reuse cylinder head bolts; install new bolts.

NOTE: Do not use chlorinated solvents on cylinder head bolts. Parts should be clean, dry, and free of chemicals other than engine oil.

1. Lightly lubricate threads and bolt flange of new 26 cylinder head bolts with clean engine oil.
2. Install all new cylinder head bolts finger tight.

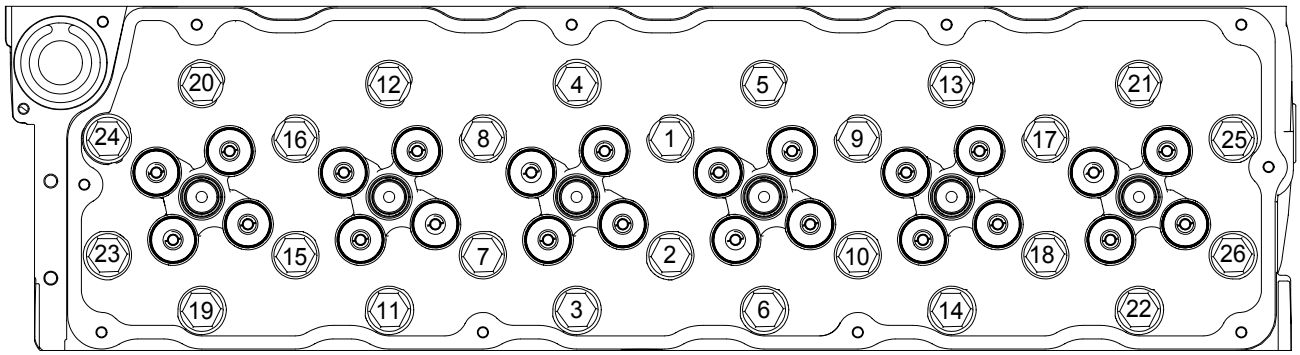


Figure 198 Torque sequence A for cylinder head bolts

3. Tighten each cylinder head bolt to 204 N·m (150 lbf·ft) in cylinder head torque sequence A.

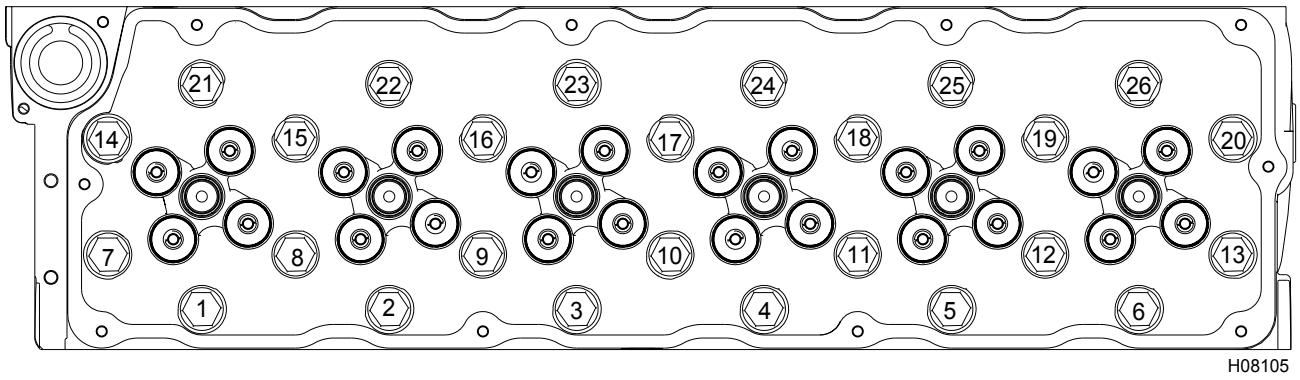


Figure 199 Torque sequence B for cylinder head bolts

4. Tighten each cylinder head bolt to 204 N·m (150 lbf·ft) in cylinder head torque sequence B.

NOTE: It is necessary to tighten cylinder head bolts in both sequence A and B to obtain uniform head bolt torque.

CAUTION: To prevent engine damage, use permanent marker to identify internal engine components and their orientation. Do not use paint or temporary markers.

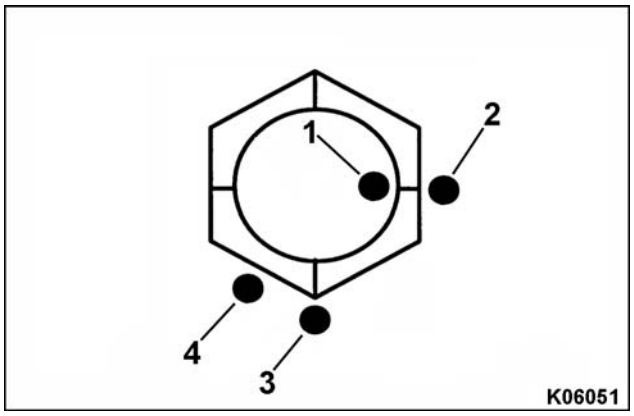


Figure 200 Cylinder head and head bolt torque markings

1. Mark on cylinder head bolt
2. Mark on cylinder head surface next to head bolt mark
3. Mark on cylinder head surface 90° CW from head bolt mark
4. Mark on cylinder head surface 120° CW from head bolt mark

5. Using permanent marker, place a mark on each head bolt and put another mark on the head bolt socket directly in line with the mark on each head bolt. Put another mark on the cylinder head surface next to the head bolt mark. (Figure 200) Items 1 and 2
6. Place a mark on the cylinder head surface 90 degrees clockwise (CW) from each head bolt mark. (Figure 200) Item 3
7. Place a mark on the cylinder head surface 120 degrees (two hex flats) CW from each head bolt mark. (Figure 200) Item 4
8. Install head bolt socket on head bolt to be torqued (Cylinder head bolt torque sequence B) and align mark on socket with the mark on the head bolt.

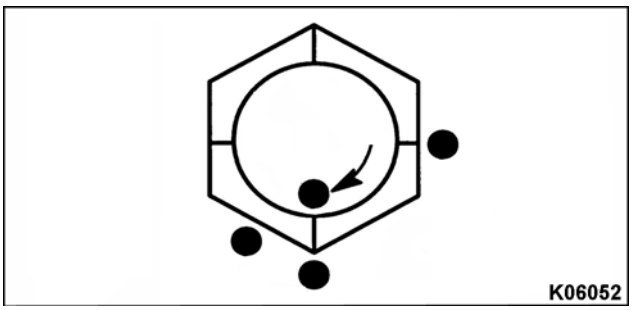


Figure 201 Head bolt rotated 90° CW

9. Rotate cylinder head bolt 90 degrees CW (1/4 turn). The marks on the head bolt socket, head bolt, and cylinder head surface should align.
10. Repeat steps 8 and 9 for each cylinder head bolt in cylinder head bolt torque sequence B.

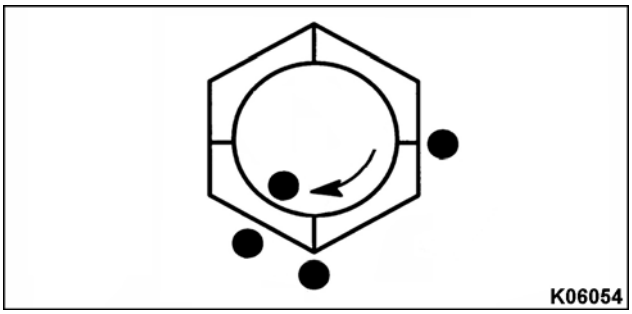


Figure 202 Head bolt rotated 120° CW

11. Rotate each cylinder head bolt an additional 30 degrees CW in cylinder head bolt torque sequence B for a total of 120 degrees (two hex flats). The marks on the head bolt socket, head bolt, and cylinder head surface should align.

Valve Train Components

Engine valve train load carrying requirements have resulted in different push rod and tappet configurations. The main differences are noted by improved geometry designs and materials.

For information on push rod and tappet compatibility for different engine model year configurations, see (TSI-06-12-14 Update Valve Train Components – Push Rod and Tappet Compatibility, page469).

A small geometry adjuster kit provides a replacement large geometry rocker shaft assembly with small geometry adjuster screws that can be used with existing small geometry push rods and tappets. See (TSI-06-12-21 Update Valve Train Components – Adjuster Screws, page474).

Installing Rocker Arms

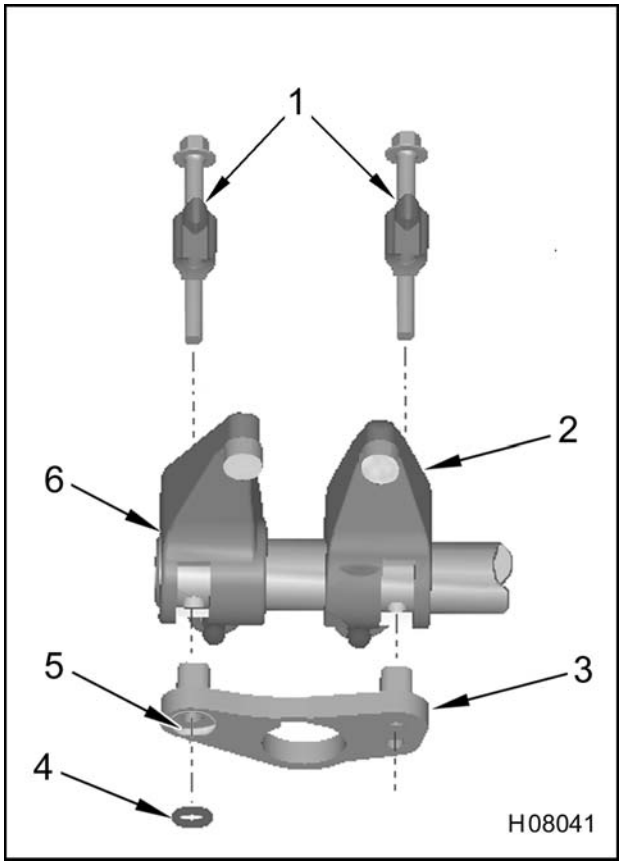


Figure 203 Rocker arm configuration

1. Clamp bolt assembly
2. Exhaust rocker arm
3. Rocker arm shaft support
4. Lower support washer
5. Machined recessed
6. Intake rocker arm

1. Install push rods.
2. Slide each of the 12 rocker arms onto the rocker shaft in the order they were removed (rocker arms should have been marked for this occasion).

NOTE: Ensure that the rocker arm shaft has the big **T** stamped facing up (Figure 204).

3. Place a bolt and clamp assembly through each rocker arm shaft support and align shaft with bolt hole in cylinder head (Figure 203).
4. Install plastic washer (assembly aid) onto each intake rocker arm retaining bolt.

Installing the Rocker Arm Assembly

1. Place valve bridges across each set of valves. These should be marked if removed. The recessed holes set over the valve stems.

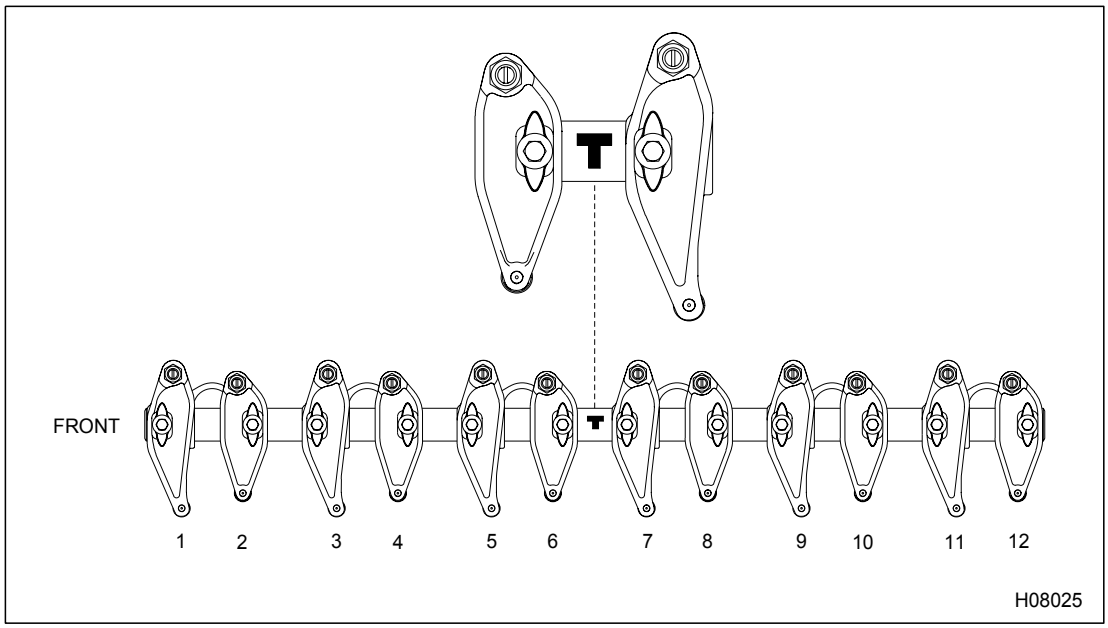


Figure 204 Rocker arm orientation

2. Align rocker arm assembly with bolts over mounting holes and thread hand tight.

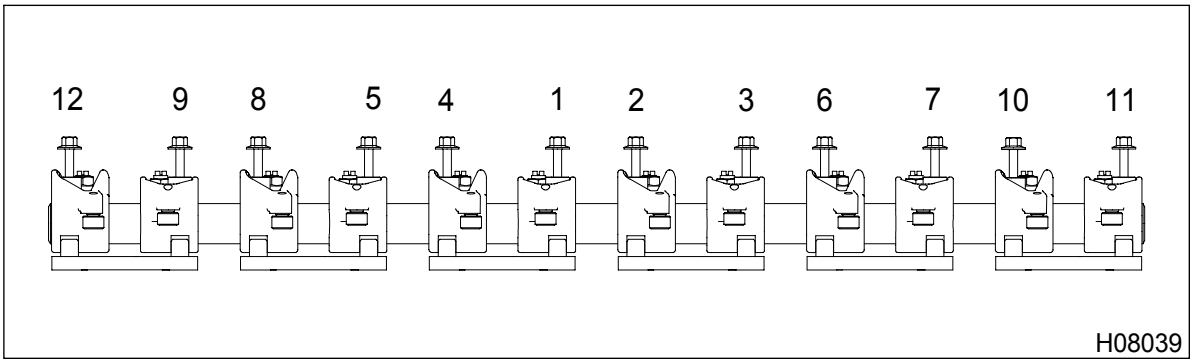


Figure 205 Rocker arm torque sequence

3. Torque bolts in two passes in the sequence illustrated above and to the specified value.
   a. Torque rocker arm clamp assembly bolts to 27 N·m (20 lbf·ft) for the first pass.
   b. Torque rocker arm clamp assembly bolts to 37 N·m (27 lbf·ft) for the final pass.

Valve Lash for Intake and Exhaust Valves

During the procedure to adjust valve lash, the crankshaft is rotated two times:

- Six adjustments are made when piston 1 is at Top Dead Center (TDC) compression.
- Six adjustments are made when piston 6 is at Top Dead Center (TDC) compression.

If the engine is equipped with the Diamond Logic® engine brake, corresponding brake actuator lash (Adjusting Valve Lash, page 150) can be adjusted before and after rotating the crankshaft the second time.

Adjusting Valve Lash

1. Remove valve cover (Valve Cover, page120).
2. Turn the crankshaft in the direction of engine rotation to remove gear lash. Position piston 1 at TDC compression by observing cylinder 6 rocker arms in overlap as the vibration damper timing mark approaches the TDC mark on the front cover. Cylinder 6 exhaust valve will be closing (coming up) and the intake valve will be starting to open (going down).
3. If piston 1 is at TDC compression, see Chart 1 (page151) and do steps 4 and 5 for cylinders 1, 3, and 5.

Chart 1

Valve and brake lash adjustments (inches) with piston 1 at TDC compression (Chart 1)											
Cylinder 1		Cylinder 2		Cylinder 3		Cylinder 4		Cylinder 5		Cylinder 6	
intake 1	exhaust 2	intake 3	exhaust 4	intake 5	exhaust 6	intake 7	exhaust 8	intake 9	exhaust 10	intake 11	exhaust 12
0.019	0.019	0.019			0.019	0.019			0.019		
Brake 0.019				Brake 0.019				Brake 0.019			

Valve and brake lash adjustments with piston 1 at TDC compression

Chart 2

Valve and brake lash adjustments (inches) with piston 6 at TDC compression (Chart 2)											
Cylinder 1		Cylinder 2		Cylinder 3		Cylinder 4		Cylinder 5		Cylinder 6	
intake 1	exhaust 2	intake 3	exhaust 4	intake 5	exhaust 6	intake 7	exhaust 8	intake 9	exhaust 10	intake 11	exhaust 12
			0.019	0.019			0.019	0.019		0.019	0.019
		Brake 0.019				Brake 0.019				Brake 0.019	

Valve and brake lash adjustments with piston 6 at TDC compression

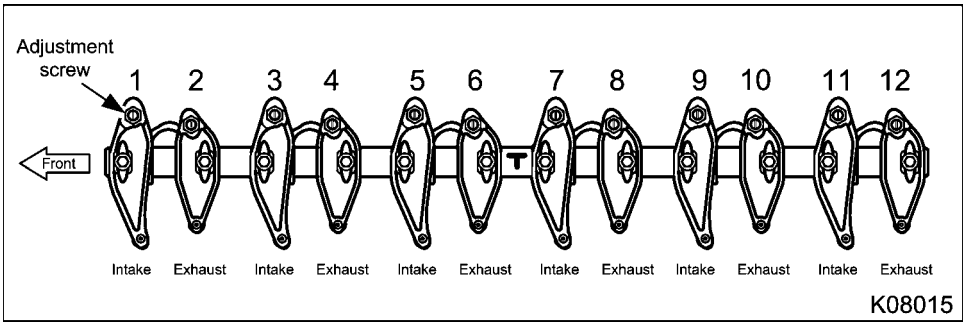


Figure 206 Valve lash adjustment

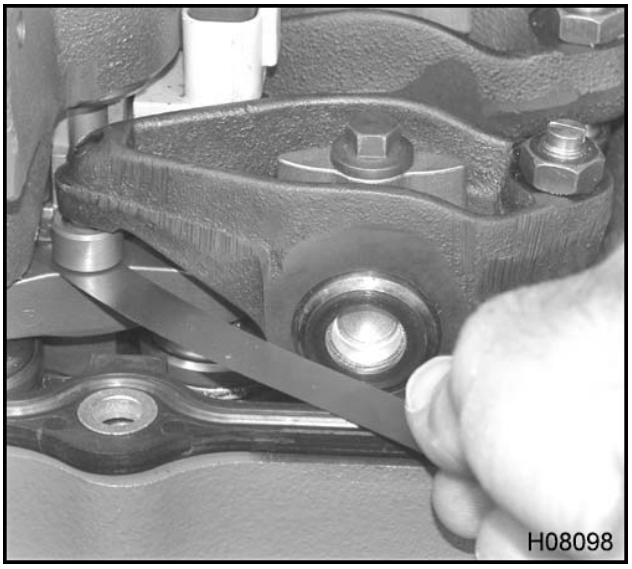


Figure 207 Feeler gauge between the pivot foot and valve bridge

4. Measure valve lash when engine is cold. Put 0.048 mm (0.019 in) feeler gauge (Table 56) between the pivot foot and valve bridge. A light drag on the feeler gauge should be felt. on the feeler gauge. If adjustment is required, loosen locknut and turn valve adjustment screw until a light drag if felt.
5. Once valve lash is set, tighten valve adjustment screw locknut to Special Torque (Table 55) and remove feeler gauge. Recheck valve lash. A light drag should be felt on the feeler gauge. If drag is too tight or loose, repeat steps 4 and 5.

   If engine is equipped with a Diamond Logic® engine brake, corresponding brake actuator lash can be adjusted before rotating crankshaft.
6. Turn crankshaft 360° in the direction of engine rotation to remove gear lash. Position piston 6 at TDC compression by observing cylinder 1 rocker arms in overlap as the vibration damper timing mark approaches the TDC mark on the front cover.
7. If piston 6 is at TDC compression, see Chart 2 (page151) and do steps 4 and 5 for cylinders 2, 4, and 6.

High-pressure Oil Rail Assembly

1. Install high-pressure oil rail assembly. See (High-pressure Oil Rail Assembly, page353).

Valve Cover

1. Install valve cover gasket.
2. Connect all electrical and injector connectors to the valve cover gasket, if disconnected.
3. Install valve cover onto cylinder head.

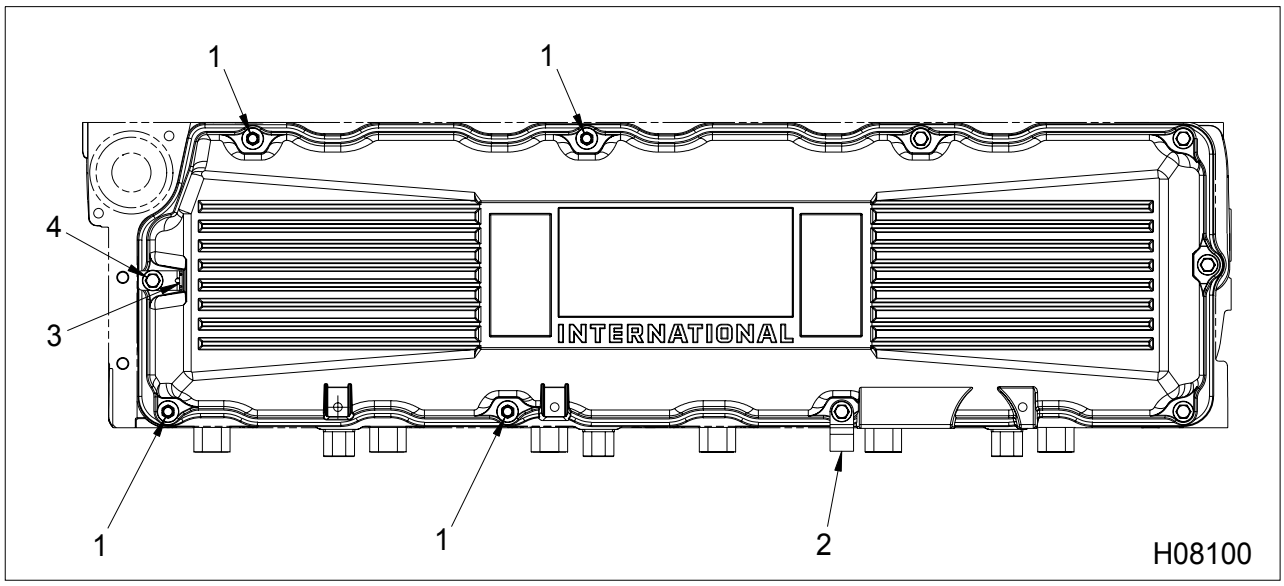


Figure 208 Valve cover assembly detail

1. Bolt / stud, M8 x 80 / 19 (4)
2. Extension bracket
3. Valve cover harness mounting bracket
4. Bolt, M8 x 80 (6)

4. Install four valve cover bolt / studs (M8 x 80 / 19) finger tight.
5. Install six valve cover bolts (M8 x 80) finger tight.
6. Tighten all bolts and studs to the standard torque value (General Torque Guidelines, page445).
7. Add any necessary brackets to the appropriate studs.
8. Connect crankcase ventilation piping (Crankcase Ventilation System, page274).
9. Add coolant (if cylinder head was removed in chassis).

Specifications

Table 13 Valve Specifications

Camshaft lobe lift	**Intake:** 6.68 mm (0.263 in)
	Exhaust: 6.91 mm (0.272 in)
Valve face angle	**Intake:** 59.75 - 60.00°
	Exhaust: 44.75 - 45.00°
Valve face margin (min.)	**Intake:** 1.32 mm (0.052 in)
	Exhaust: 1.16 mm (0.046 in)
Valve face-to-valve stem runout (max.)	0.038 mm (0.0015 in)
Valve lash (cold), intake and exhaust	0.48 mm (0.019 in)
Valve stem diameter (new condition)	**Intake:** 7.928 ± 0.0089 mm (0.3121 ± 0.00035 in)
	Exhaust: 7.908 ± 0.0089 mm (0.3113 ± 0.00035 in)
Valve stem-to-valve guide clearance (max.)	**Intake:** 0.10 mm (0.004 in)
	Exhaust: 0.11 mm (0.005 in)

Table 14 Valve Spring Specifications

Intake and Exhaust Valve Springs	
Free length	52.35 mm (2.061 in)
Solid height (max.)	27.43 mm (1.080 in)
Valve closed test length @ 410.1 ± 24.5 N (92.2 ± 5.5 lbf) test load	40 mm (1.575 in)
Valve closed test length @ 764.2 ± 48.9 N (171.8 ± 11.0 lbf) test load	29.3 mm (1.155 in)

Table 15 Cylinder Head Specifications

Cylinder head gasket surface flatness	0.10 mm (0.004 in.) per 229 mm (9.0 in)
Cylinder head thickness	**New:** 160.48 mm (6.318 in)
	Minimum: 159.97 mm (6.298 in)
Exhaust valve seat insert counterbore diameter	**Standard:** 37.503 ± 0.003 mm (1.477 ± 0.001 in)
	Oversize: 0.05 mm (0.002 in) 37.55 ± 0.03 mm (1.478 ± 0.001 in)
Exhaust valve seat outside diameter	**Standard:** 37.56 mm (1.479 in)
	Oversize: 0.05 mm (0.002 in) 37.61 mm (1.481 in)
Intake valve seat insert counterbore diameter	**Standard:** 33.50 ± 0.03 mm (1.319 ± 0.001 in)

Table 15 Cylinder Head Specifications (cont.)

	Oversize: 0.05 mm (0.002 in) 35.55± 0.03 mm (1.321 ± 0.001 in)
Intake valve seat outside diameter	**Standard:** 40.20 mm (1.583 in)
	Oversize: 0.05 mm (0.002 in) 40.25 mm (1.585 in)
Push rod runout (maximum)	0.508 mm (0.020 in)
Valve guide bore diameter	14.308 ± 0.017 mm (0.5633 ± 0.0007 in)
Valve guide bore out-of-round (max.)	0.005 mm (0.0002 in)
Valve guide bore taper (max.)	0.013 mm (0.0005 in)
Valve guide height from cylinder head spring pocket (intake)	16.53 ± 0.13 mm (0.651 ± 0.005 in)
Valve guide insert inside diameter (installed)	7.98 - 8.00 mm (0.314 - 0.315 in)
Valve guide insert interference fit dimension	0.043 mm (0.0017 in)
Valve guide insert outside diameter	14.351 ± 0.010 mm (0.5650 ± 0.0004 in)
Valve guide length (overall)	65.71 mm (2.587 in)
Valve recession	**Intake:** 1.02 mm (0.040 in)
	Exhaust: 1.40 mm (0.055 in)
Valve seat angles	**Intake:** 59.75 - 60°
	Exhaust: 44.75 - 45°
Valve seat runout (max.)	0.05 mm (0.002 in)
Valve seat width	1.91 - 2.16 mm (0.075 - 0.085 in)

Special Torque

Table 16 Cylinder Head and Valve Train Special Torques

BCP sensor	20 - 30 N·m (15 - 22 lbf·ft)
Cylinder head mounting bolts torque and sequence	
Fuel injector mounting bolt	41 N·m (30 lbf·ft)
High-pressure oil hose fitting	46 N·m (34 lbf·ft)
ICP sensor	20 - 30 N·m (15 - 22 lbf·ft)
Rocker arm bolts torque and sequence	(Installing Rocker Arms, page148)
Valve adjustment locknut	27 N·m (20 lbf·ft)

Special Service Tools

Table 17 Cylinder Head Special Service Tools

Cylinder head test plate	ZTSE4289A
Dye penetrant kit	Obtain locally
Feeler gauge	Obtain locally
Injector sleeve brush set (set of 2)	ZTSE4304
Injector sleeve installer	ZTSE4642
Injector sleeve remover	ZTSE4643
Pressure regulator	Obtain locally
Slide hammer puller set	ZTSE1879
Small hole gauge set	Obtain locally
Straightedge	Obtain locally
Thermostat opening pressure adapter	ZTSE4647
Valve guide deburring tool	ZTSE4393
Valve guide installer	ZTSE1943
Valve guide remover	ZTSE4377
Valve seat extractor kit (universal)	ZTSE1951C
Valve seat grinder	ZTSE1631A
Valve seat grinding stones 45° (exhaust)	Obtain locally
Valve seat grinding stones 60° (intake)	Obtain locally
Valve seat installer	ZTSE4641
Valve seat remover (collet)	ZTSE4640
Valve spring compressor	ZTSE1846
Valve spring compressor jaws	ZTSE4652
Water supply housing pressure adapter	ZTSE4648