ENGINE SERVICE MANUAL

EGES-415-2

2011

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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

1171898R4	International® MaxxForce® 11 and 13 *Engine Operation and Maintenance Manual*
EGES-415-1	International® MaxxForce® 11 and 13 *Engine Service Manual*
EGES-420–1	International® MaxxForce® 11 and 13 *Engine Diagnostic Manual*
EGED-425	International® MaxxForce® 11 and 13 Engine Performance Form
EGED-430–2	International® MaxxForce® 11 and 13 Engine Wiring Diagram
EGED-435	International® MaxxForce® 11 and 13 Signal Values (available on ISIS® only)

Technical Service Literature is revised periodically and mailed automatically to “Revision Service” subscribers. If a technical publication is ordered, the latest revision will be supplied.

NOTE: To order technical service literature, contact your International® dealer.

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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 and diagnostic test equipment
- 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

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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.

Obey Safety Instructions, Warnings, Cautions, and Notes in this manual. Not following warnings, cautions, and notes 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

- Shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.
- 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: 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.

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- Protect your eyes.
- Do not expose batteries to 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.

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Engine Identification

Engine Serial Number

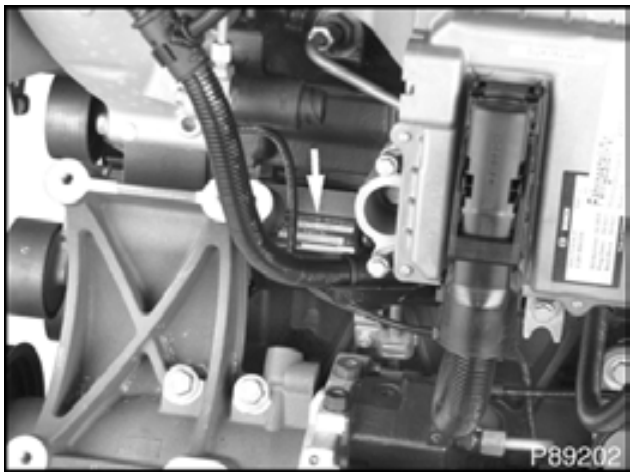

Figure 1 Engine serial number

The engine serial number is located on the upper left side of the crankcase below the cylinder head.

Engine Serial Number Examples

International® MaxxForce® 11: 105HM2DXXXXXXX

International® MaxxForce® 13: 124HM2DXXXXXXX

International® MaxxForce® 11: 105HM2YXXXXXXX

International® MaxxForce® 13: 124HM2YXXXXXXX

Engine Serial Number Codes

105 – Engine displacement
124 – Engine displacement
H – Diesel, turbocharged, Charge Air Cooler (CAC) and electronically controlled
M2 – Motor truck
D – Germany
Y – United States, Huntsville
7 digit suffix – Engine serial number sequence

Engine Emission Label

Figure 2 U.S. Environmental Protection Agency (EPA) exhaust emission label (example)

The U.S. Environmental Protection Agency (EPA) exhaust emission label is on top of the valve cover (front left side). The EPA label typically includes the following:

- Model year
- Engine family, model, and displacement
- Advertised brake horsepower and torque rating
- Emission family and control systems
- Valve lash specifications
- Engine serial number
- EPA, EURO, and reserved fields for specific applications

Engine Accessory Labels and Identification Plates

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

- Air compressor

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- Air conditioning compressor
- Alternator
- Aftertreatment Control Module (ACM)
- Cooling fan clutch
- Engine Control Module (ECM)
- Engine Interface Module (EIM)
- High pressure pump
- Power steering pump
- Starter motor
- Turbochargers

Engine Description

International® MaxxForce® 11 and 13 Diesel Engines	
Engine Configuration	4 stroke, inline six cylinder diesel
Advertised brake horsepower @ rpm	
• MaxxForce® 11	See EPA exhaust emission label
• MaxxForce® 13	See EPA exhaust emission label
Peak torque @ rpm	
• MaxxForce® 11	See EPA exhaust emission label
• MaxxForce® 13	See EPA exhaust emission label
Displacement	
• MaxxForce® 11	10.5 L (641 in^3)
• MaxxForce® 13	12.4 L (758 in^3)
Compression ratio	17.0:1
Stroke	
• MaxxForce® 11	155 mm (6.10 in)
• MaxxForce® 13	166 mm (6.54 in)
Bore (sleeve diameter)	
• MaxxForce® 11	120 mm (4.72 in)
• MaxxForce® 13	126 mm (4.96 in)
Total engine weight (dry weight without trim or accessories)	
• MaxxForce® 11	1018 kg (2244 lbs)
• MaxxForce® 13	1018 kg (2244 lbs)
Firing order	1-5-3-6-2-4
Engine rotation direction (facing flywheel)	Counterclockwise

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Aspiration	Dual turbocharged and charge air cooled
Combustion system	Direct injection turbocharged
Fuel system	High pressure common rail
Lube system capacity (including filter)	40 L (42 qts)
Lube system capacity (overhaul only, with filter)	44 L (46 qts)
Engine oil pressure at operating temperature with SAE 15W-40 oil	
• Low idle	138 - 172 kPa (20 - 25 psi)
• High idle	448 - 586 kPa (65 - 85 psi)
Idle speed (no load)	600 rpm
Thermostat operating temperature	83°C - 91°C (181°F - 196°F)

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Standard Features

The International® MaxxForce® 11 and 13 diesel engines are designed for increased durability, reliability, and ease of maintenance.

The cylinder head has four valves per cylinder with centrally located fuel injectors directing fuel over the pistons. This configuration provides improved performance and reduces emissions.

The overhead camshaft is supported by seven bearings in the cylinder head. The camshaft gear is driven from the rear of the engine. The overhead valve train includes roller rocker arms and dual valves that open using a valve bridge.

The MaxxForce® 11 engines use aluminum pistons, and the MaxxForce® 13 engines use one piece steel pistons. All pistons use an offset piston axis and centered combustion bowls. Crown markings show correct piston orientation in the crankcase.

The one piece crankcase can withstand high pressure loads during operation. The crankcase uses replaceable wet cylinder liners that are sealed by dual crevice seals.

The crankshaft has seven main bearings with fore and aft thrust controlled at the sixth bearing. One fractured cap connecting rod is attached at each crankshaft journal. The piston pin moves freely inside the connecting rod and piston. Piston pin circlips secure the piston pin in the piston. The rear oil seal carrier is part of the flywheel housing, and the front oil seal carrier is part of the front cover.

A gerotor lube oil pump is mounted behind the front cover and is driven by the crankshaft. Pressurized oil is supplied to engine components. All International® MaxxForce® 11 and 13 engines use an engine oil cooler and a cartridge-style engine oil filter element.

The distributor case serves as the mounting bracket for the refrigerant compressor. The pad mounting design of the alternator and refrigerant compressor brackets provide easy removal and improved durability.

The low pressure fuel supply pump draws fuel from the fuel tank through the fuel strainer element, and pumps it through the fuel filter housing assembly. The fuel filter housing assembly includes the filter element, fuel pressure sensor, and drain valve. Conditioned fuel is then pumped through the high pressure fuel pump towards the fuel injectors.

The fuel injection system is direct common-rail. The system includes a high pressure pump, fuel rail, and fuel injectors. The injectors are installed in the cylinder head under the valve cover.

The International® MaxxForce® 11 and 13 engines use dual turbochargers with an air-to-liquid Charge Air Cooler (CAC) after each stage.

The cold start assist system warms the incoming air supply before, during, and a short period after cranking to aid cold engine starting and reduce white smoke during warm-up.

The Exhaust Gas Recirculation (EGR) system circulates cooled exhaust into the intake air stream in the air inlet duct. This cools the combustion process and reduces the formation of Nitrogen Oxides (NO_x) engine emissions.

An open crankcase breather system uses an engine mounted oil separator to return oil to the crankcase and vent the crankcase gasses to the atmosphere.

Optional Features

The engine retarder is available as an option for all engine displacements. The engine retarder is a compression release system that provides additional vehicle braking performance. The operator can control the engine retarder for different operating conditions.

Optional cold climate features available are an oil pan heater and a coolant heater. Both heaters use an electric element to warm engine fluids in cold weather conditions.

The oil pan heater warms engine oil to ensure optimum oil flow to engine components.

The coolant heater warms the engine coolant surrounding the cylinders. Warmed engine coolant increases fuel economy and aids start-up in cold weather conditions.

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Chassis Mounted Features

The aftertreatment system, part of the larger exhaust system, processes engine exhaust so that it meets tailpipe emission requirements.

- The Diesel Oxidation Catalyst (DOC) oxidizes hydrocarbons and carbon monoxide, provides heat for exhaust system warm-up, and aids in temperature management for the Diesel Particulate Filter (DPF) for passive DPF regeneration.
- The DPF temporarily stores carbon-based particulates then converts and stores them as non combustible ash.

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Engine Component Locations

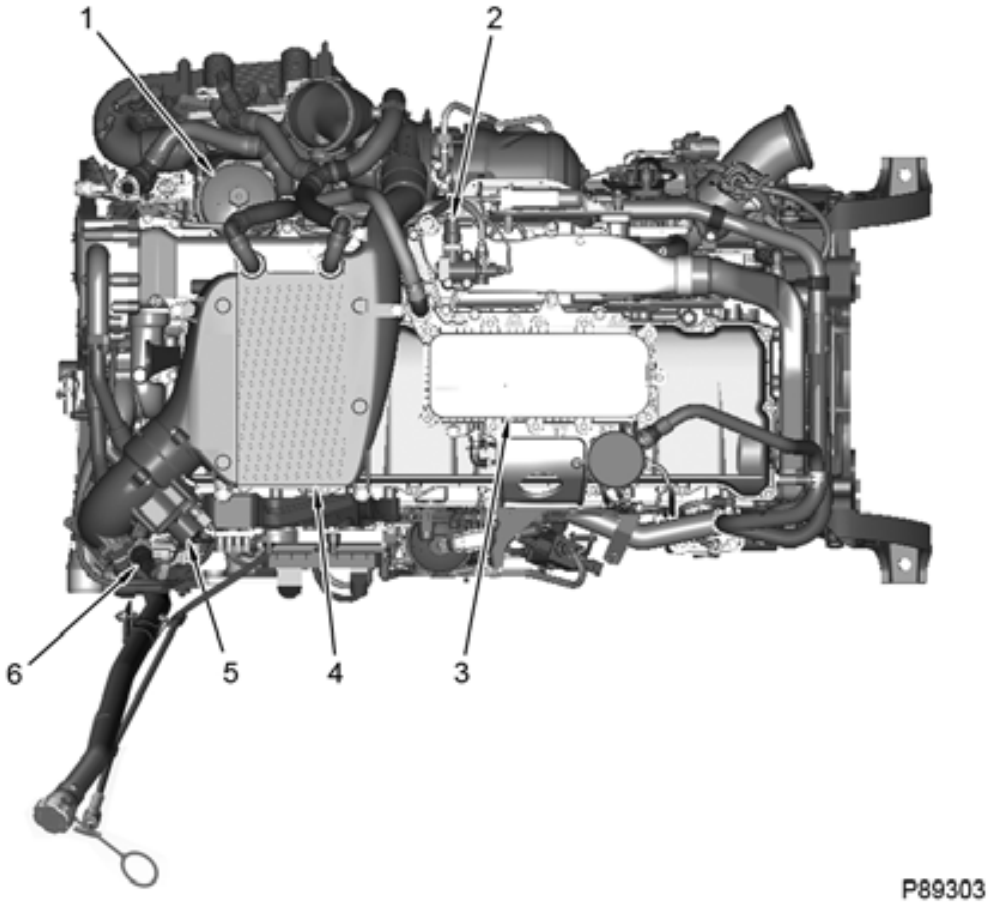

Figure 3 Component location – top

1. Oil module
2. Exhaust Gas Recirculation (EGR) control valve
3. Service breather assembly
4. High-pressure Charge Air Cooler (HPCAC)
5. Intake Throttle Valve (ITV)
6. Glow plug

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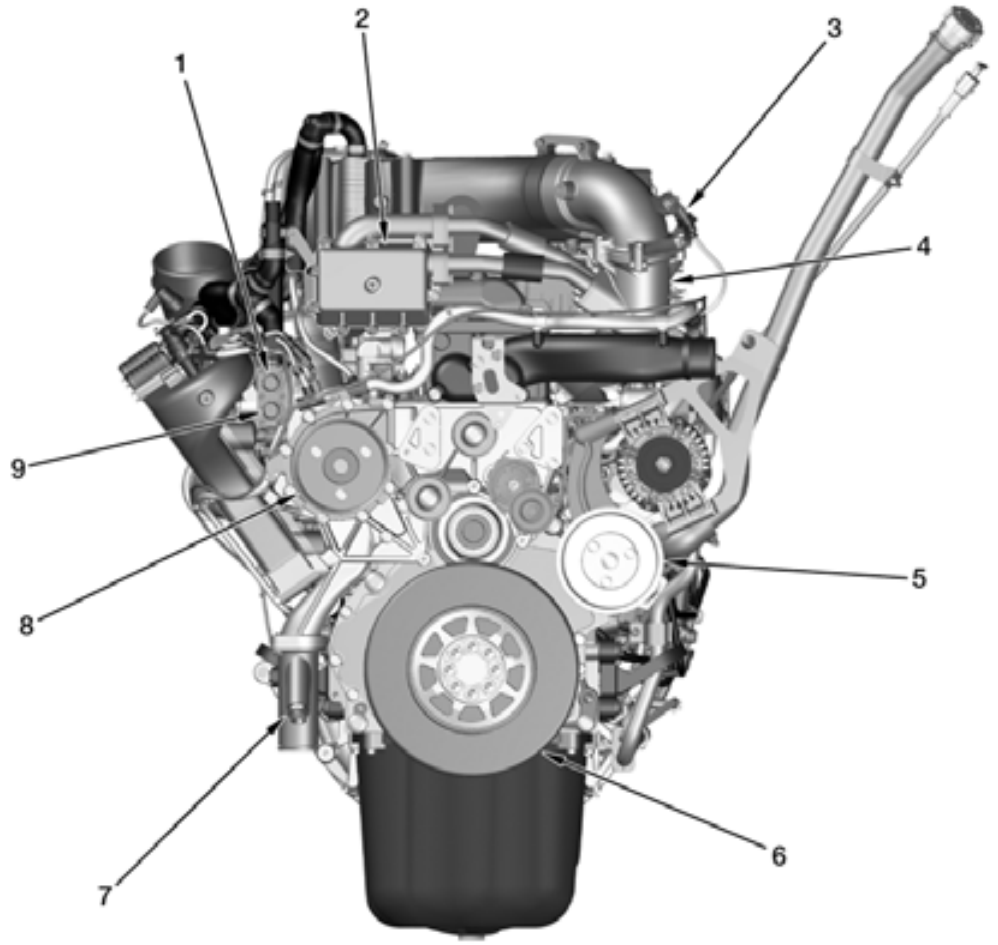

Figure 4 Component location – front

1. Coolant Mixer Valve (CMV)
2. Exhaust Gas Recirculation (EGR) module
3. Manifold Absolute Pressure/ Intake Air Temperature 2 (MAP/IAT2) sensor
4. Air inlet duct
5. Pulley (drive housing)
6. Vibration damper
7. Coolant heater (if equipped)
8. Pulley (water pump)
9. Coolant Flow Valve (CFV)

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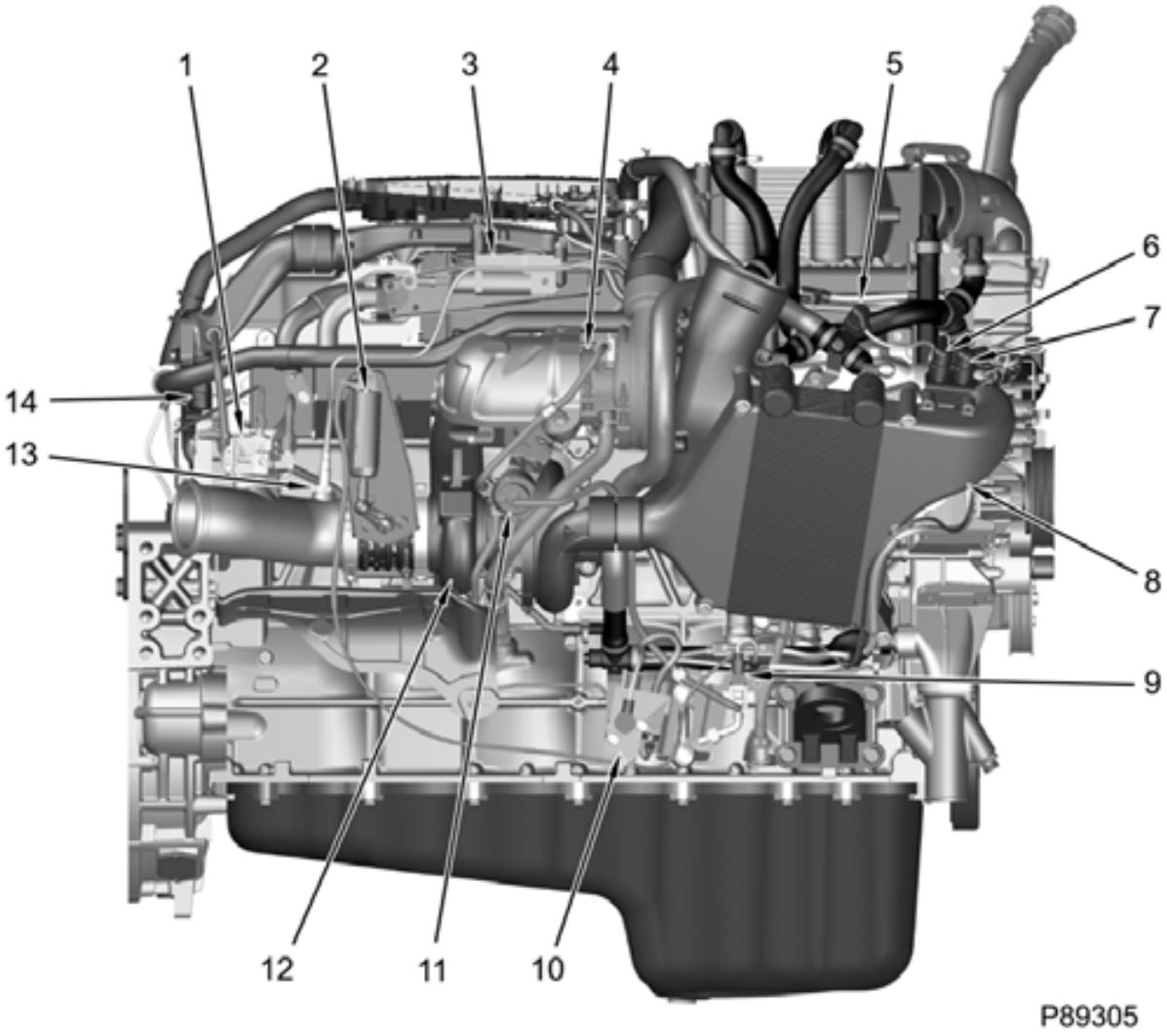

Figure 5 Component location – right

1. Aftertreatment Fuel Injector (AFI)
2. Exhaust manifold with butterfly
3. Exhaust Gas Recirculation (EGR) module
4. High-pressure turbocharger
5. Engine Coolant Temperature 2 (ECT2) sensor
6. Engine Oil Temperature (EOT) sensor adapter line
7. Engine Oil Pressure (EOP) sensor adapter line
8. Low-pressure Charge Air Cooler (LPCAC)
9. Boost Control Solenoid (BCS) valve
10. Retarder control
11. Boost control actuator
12. Low-pressure turbocharger
13. Exhaust Lambda Sensor (ELS)
14. Engine Coolant Temperature (ECT) sensor

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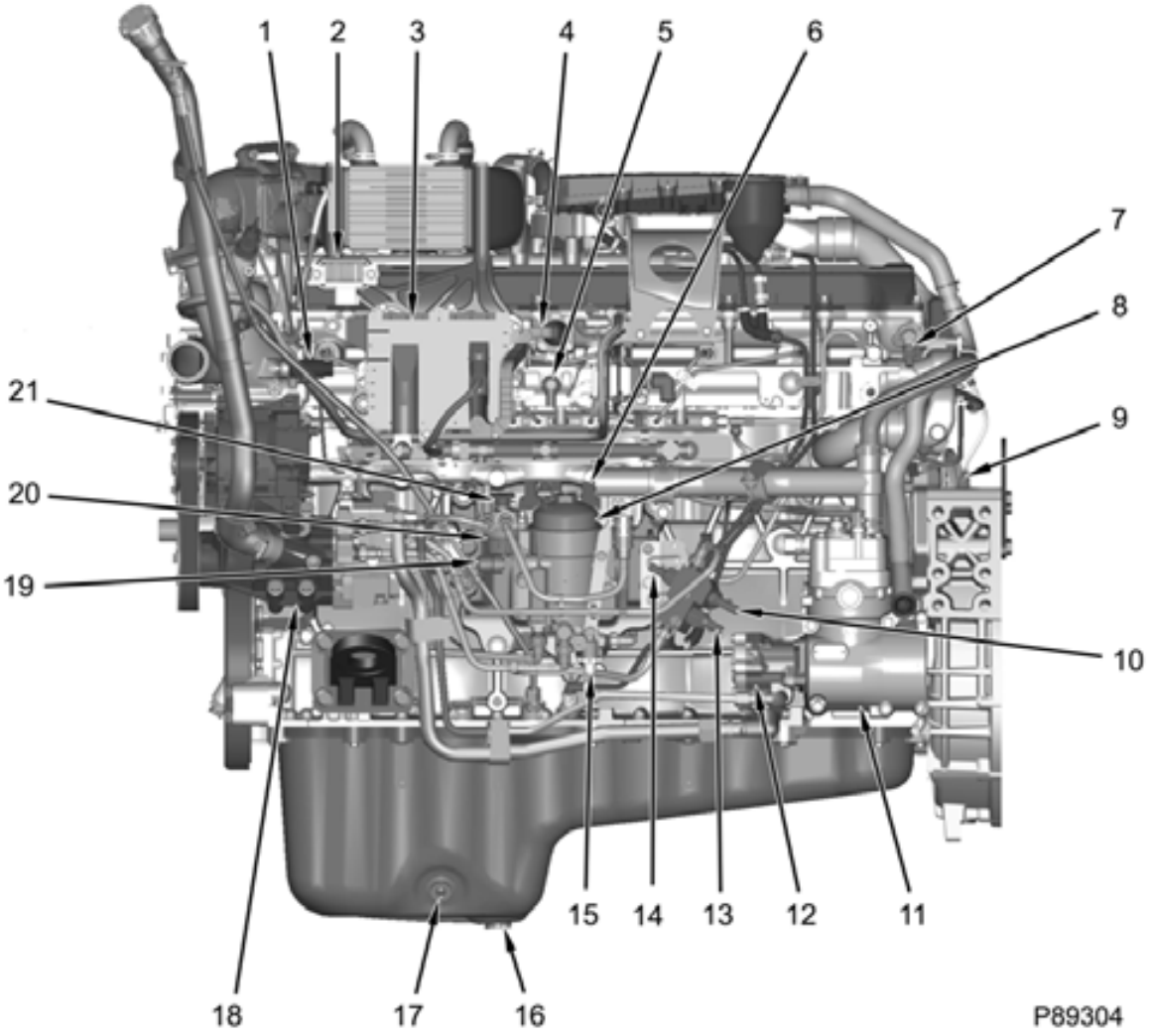

Figure 6 Component location – left

1. Cold Start Solenoid (CSS) valve
2. Cold Start Relay (CSR)
3. Engine Control Module (ECM)
4. Injector harness
5. Manifold Air Temperature (MAT) sensor
6. Engine Interface Module (EIM)
7. Camshaft Position (CMP) sensor
8. Fuel filter housing assembly
9. Crankshaft Position (CKP) sensor
10. Aftertreatment Fuel Pressure (AFP) sensor
11. Air compressor
12. Power steering pump
13. Aftertreatment Fuel Supply (AFS) valve
14. Aftertreatment Fuel Drain (AFD) valve
15. Water drain valve (from fuel filter)
16. Oil drain plug
17. Oil preheater (optional)
18. High-pressure pump
19. Engine Fuel Pressure (EFP) sensor
20. Fuel strainer cover
21. Fuel primer pump assembly

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Air Management System (AMS)

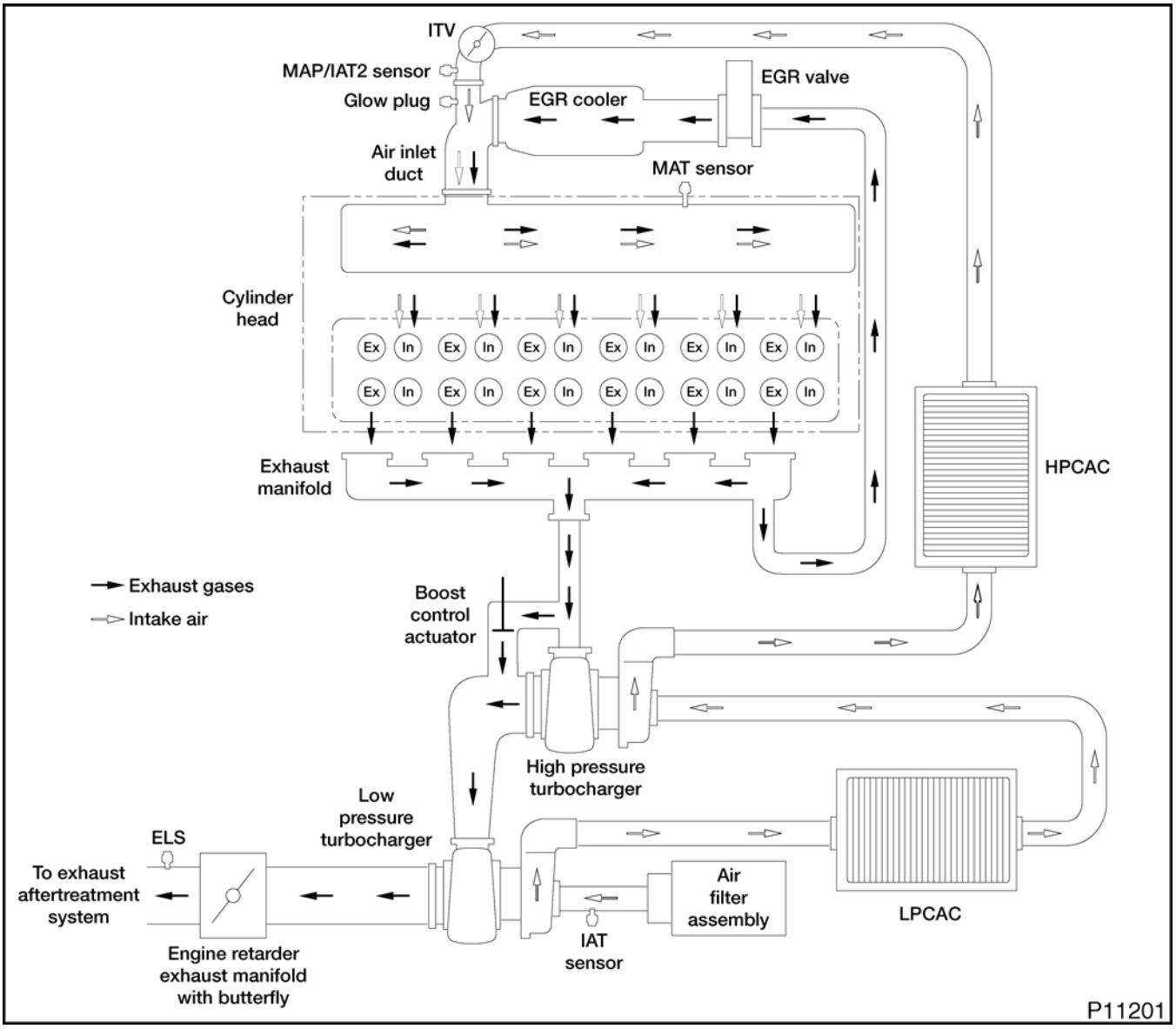

Figure 7 Air Management System (AMS)

The AMS includes the following:

- Air filter assembly
- Low pressure turbocharger
- Low Pressure Charge Air Cooler (LPCAC)
- High pressure turbocharger
- High Pressure Charge Air Cooler (HPCAC)
- Intake Throttle Valve (ITV)
- Air inlet duct
- Cold start assist
- Exhaust and intake valves
- Exhaust Gas Recirculation (EGR)
- Exhaust system
- Engine retarder exhaust manifold with butterfly
- Diesel Particulate Filter (DPF) – aftertreatment

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Air Flow

Air flows through the air filter assembly and enters the low pressure turbocharger. The low pressure turbocharger increases the pressure, temperature, and density of the intake air before it enters the LPCAC. Cooled compressed air flows from the LPCAC into the high pressure turbocharger. The high pressure turbocharger increases the intake air pressure up to 345 kPa (50 psi). The hot compressed air flows into the HPCAC where it is cooled, and then through the Intake Throttle Valve (ITV) and air inlet duct.

If the EGR control valve is open, exhaust gas passes through the EGR system into air inlet duct where it is mixed with the filtered intake air. This mixture flows through the air inlet duct into the intake manifold and cylinder head. The intake manifold is an integral part of the cylinder head casting.

If the EGR control valve is closed, only filtered intake air flows through the ITV, air inlet duct, and into the intake manifold.

During cold weather, the cold start assist system rapidly heats the intake air by injecting and igniting small quantities of fuel into the air inlet duct.

After combustion, gases exit through the cylinder head exhaust valves and ports. The exhaust gas is forced through the exhaust manifold where, depending on the EGR throttle valve position, is split between the EGR system and the exit path through the high pressure turbocharger, low pressure turbocharger and engine retarder exhaust manifold.

The engine retarder exhaust manifold contains a butterfly valve that is actuated by an external actuator. When the engine retarder control is applied, the butterfly valve restricts flow and increases exhaust backpressure. The increased backpressure actuates the engine retarder. When the butterfly valve is opened, the backpressure is released and the exhaust valves return to normal operation.

The exhaust gases flow from the engine retarder exhaust manifold through the vehicle aftertreatment system, to the exhaust tail pipe.

Air Management Components

Turbochargers

The International® MaxxForce® 11 and 13 engines are equipped with an electronically controlled two stage turbocharging system. This system provides high levels of charge air pressure to improve the engine performance and to help reduce emissions. Because of its ability to generate very high charge air pressure levels, and to avoid Charge Air Cooler (CAC) overloading conditions, the system is fitted with a spring loaded boost control valve. The boost control valve is actuated by compressed air regulated to 296 kPa (43 psi). The compressed air flow to the boost control actuator is controlled by an electronically controlled Boost Control Solenoid (BCS) valve based on the Pulse Width Modulated (PWM) signal supplied by the Engine Control Module (ECM). The high and low pressure turbochargers are installed as an assembly on the exhaust manifold, on right side of engine.

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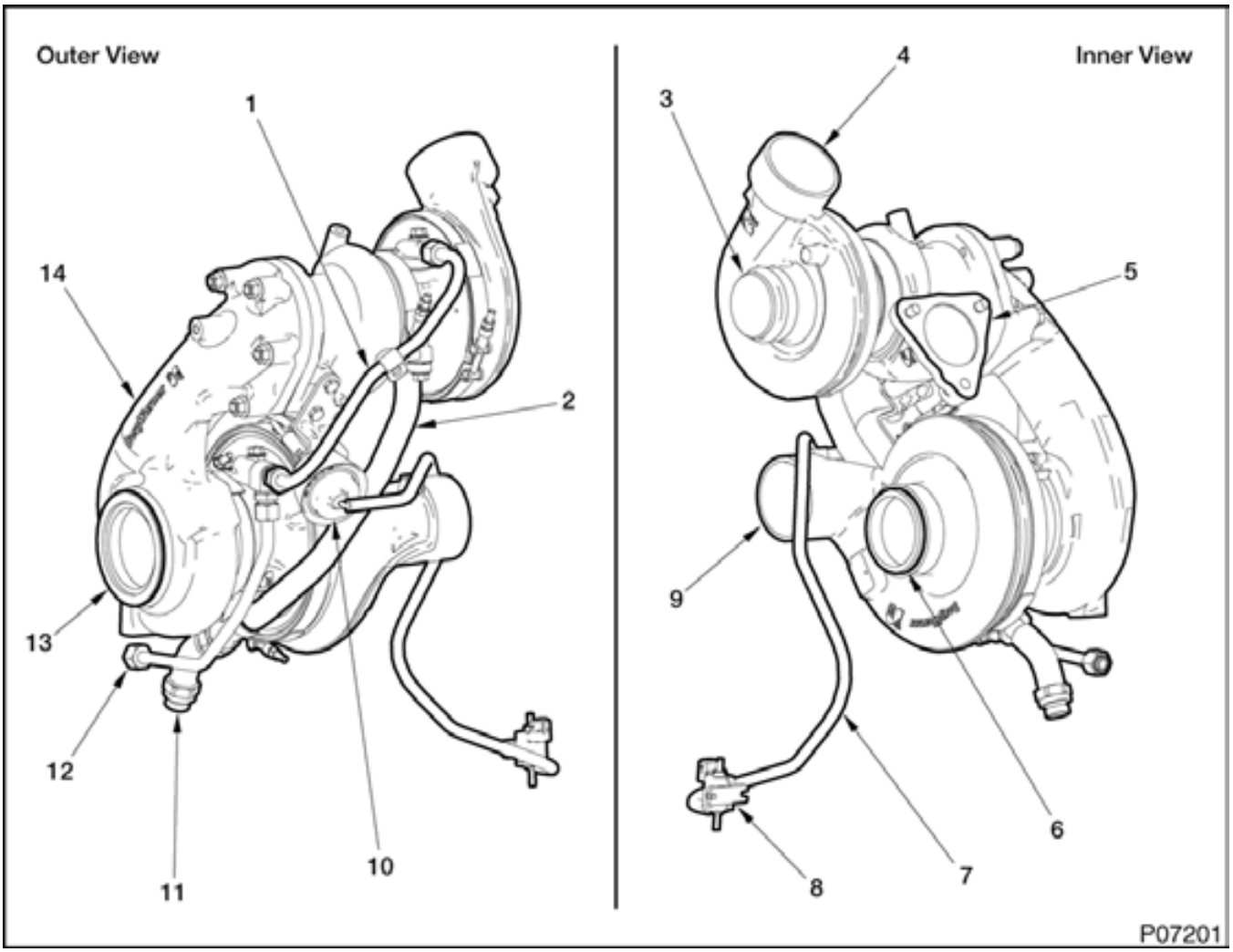

Figure 8 Low and high pressure turbocharger components

1. High pressure turbocharger oil pressure pipe
2. High pressure turbocharger oil return pipe
3. High pressure compressor inlet
4. High pressure compressor outlet
5. High pressure turbine inlet
6. Low pressure compressor inlet
7. Boost control actuator control hose
8. Boost Control Solenoid (BCS) valve
9. Low pressure compressor outlet
10. Boost control actuator
11. Low pressure turbocharger oil return pipe
12. Low pressure turbocharger oil pressure pipe
13. Low pressure turbine outlet
14. High pressure turbine outlet to low pressure turbine inlet tube

The low and high pressure turbochargers are installed inline on the right side of the engine. The high pressure turbocharger is connected directly to the exhaust manifold through the high pressure turbine inlet. The high pressure turbocharger is equipped with a boost control actuator that regulates the turbocharger boost by controlling the amount of exhaust gases that pass through the high pressure turbine. When the boost demand is low, the boost control actuator opens, allowing part of the exhaust gas flow to bypass the high pressure turbine. Cooled compressed air from the Low Pressure Charge Air Cooler (LPCAC) enters the high pressure compressor, where it is further compressed and directed into the High Pressure Charge Air Cooler (HPCAC).

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The low pressure turbocharger is installed directly to the output of the high pressure turbine. The exhaust gases enter the low pressure turbocharger through the low pressure turbine inlet and exit through the low pressure turbine outlet. Fresh air from the air filter enters the low pressure compressor where it is compressed and directed into the LPCAC.

Low Pressure Charge Air Cooler (LPCAC)

The LPCAC is installed between the low pressure and the high pressure turbochargers. The LPCAC air inlet is connected to the low pressure compressor outlet and uses engine coolant to regulate the charge air temperature. The LPCAC air outlet is connected to the compressor inlet on the high pressure turbocharger.

High Pressure Charge Air Cooler (HPCAC)

The HPCAC is installed between the high pressure turbocharger and the Intake Throttle Valve (ITV). The HPCAC air inlet is connected to the high pressure compressor outlet and uses engine coolant to regulate the charge air temperature. The HPCAC air outlet is connected directly to the ITV body.

Boost Control Solenoid (BCS) Valve

The BCS valve controls the boost control actuator position by regulating the compressed air based on a Pulse Width Modulated (PWM) signal received from the Engine Control Module (ECM).

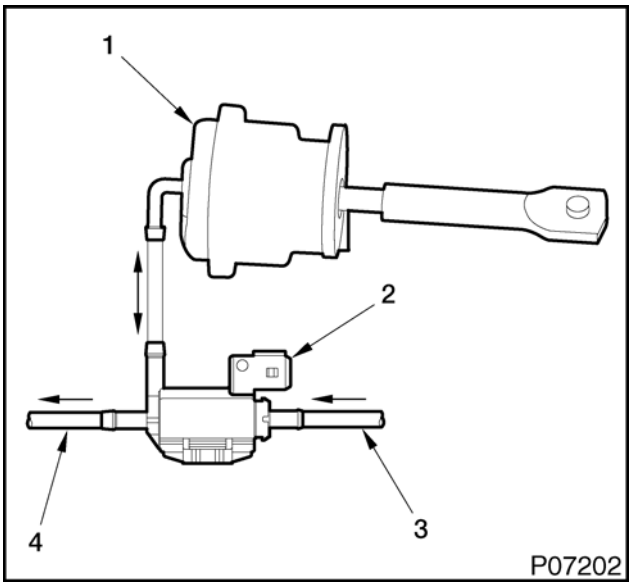

Figure 9 BCS valve operation

1. Boost control actuator
2. BCS valve
3. Compressed regulated air supply
4. Vent to atmosphere

With no PWM signal, the BCS valve is open and air is supplied to the boost control actuator maintaining it in the open position. When an increase in the charge air pressure is required, the ECM supplies PWM voltage to close the BCS valve. The limit values of the PWM signal are between approximately 9%, corresponding to a fully opened BCS valve, and 100%, corresponding to a closed BCS valve. When the BCS valve closes it interrupts the air supply to the boost control actuator and at the same time relieves the air pressure from the boost control actuator by allowing it to vent to the atmosphere. The boost control actuator then closes, resulting in increased charge air pressure.

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Exhaust Gas Recirculation (EGR) System

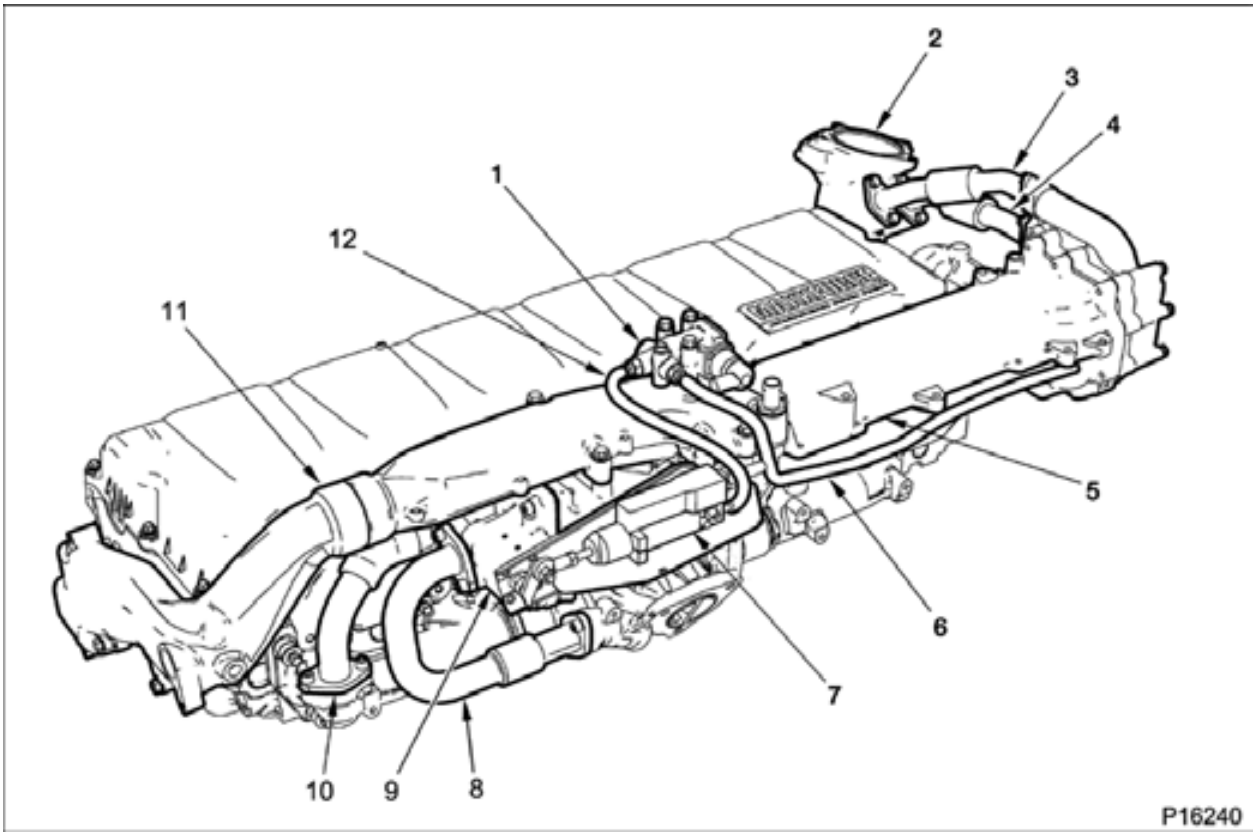

Figure 10 EGR system

1. EGR control valve
2. Air inlet duct
3. Front inner EGR tube
4. Front outer EGR tube
5. EGR module
6. Air supply line assembly
7. EGR throttle valve actuator
8. Rear outer EGR tube
9. EGR throttle valve
10. Rear inner EGR tube
11. Coolant elbow
12. EGR control valve - EGR cooler module air line assembly

EGR System Overview

The EGR system reduces Nitrogen Oxides (NO_x) engine emissions by introducing cooled exhaust gas into the air inlet duct. NO_x forms during a reaction between nitrogen and oxygen at high temperatures during combustion. An Exhaust Lambda Sensor (ELS) located in the exhaust pipe, monitors the oxygen content in the exhaust gas and provides input to the Engine Control Module (ECM) to control the EGR throttle valve.

The ECM monitors signals from the Manifold Air Temperature (MAT) sensor and Engine Coolant Temperature (ECT) sensor to control the EGR system. The EGR is switched off (EGR throttle valve closed) if any of the following conditions are present:

- Charge air temperatures is below 10°C (50°F)
- Charge air temperature exceeds 70°C (158°F)
- Engine coolant temperature exceeds 95°C (203°F)
- During engine retarder control operation
- Acceleration/high engine load

EGR Flow

Exhaust gas from the exhaust manifold flows through the rear EGR tubes to EGR throttle valve. When

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the EGR is activated, the EGR throttle valve opens and allows exhaust gas to enter the EGR module for cooling. Cooled exhaust gas flows through the front EGR tubes into the air inlet duct where it is mixed with filtered intake air.

EGR Control

The EGR system consists of an EGR module, EGR control valve, and Exhaust Lambda Sensor (ELS). The EGR module contains an EGR throttle valve which consists of an air actuator cylinder, mounting bracket, and valve. Within the air actuator cylinder is an Exhaust Gas Recirculation Position (EGRP) sensor.

The EGR throttle valve is installed at the rear of the EGR module on the right side of engine valve cover and limits the exhaust gas flow into the EGR cooler.

The EGR actuator cylinder uses compressed air controlled by the EGR control valve to move and hold position of an exhaust gas flapper valve internal to the EGR module. The EGRP sensor located inside the actuator cylinder, monitors and provides an EGR valve position signal to the ECM.

The EGR control valve is connected to the truck compressed air system and regulates the air supply to the EGR throttle valve based on the Pulse Width Modulated (PWM) signal from the ECM.

The ELS is installed in the exhaust pipe in front of the aftertreatment fuel injector. The ELS has a heater element that heats the sensor to its normal operating temperature of 780°C (1436°F). During initial engine warm-up the ELS heater element is activated only after the engine coolant reaches 40°C (104°F) and the exhaust gas temperature exceeds 100°C (212°F) for more than 30 seconds.

EGR Open Loop System

During the engine warm-up period and before the ELS reaches its normal operating temperature, the EGR system operates in open loop. In open loop, the EGR system is controlled by the ECM based on the charge air temperature, engine coolant temperature, engine speed, and load conditions. The EGR actuator provides feedback to the ECM on current valve position through the EGRP sensor.

EGR Closed Loop System

After the ELS reaches its operating temperature, the EGR system switches to closed loop operation. In closed loop, the EGR system is controlled by the ECM based on the ELS readings.

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Aftertreatment (AFT) System

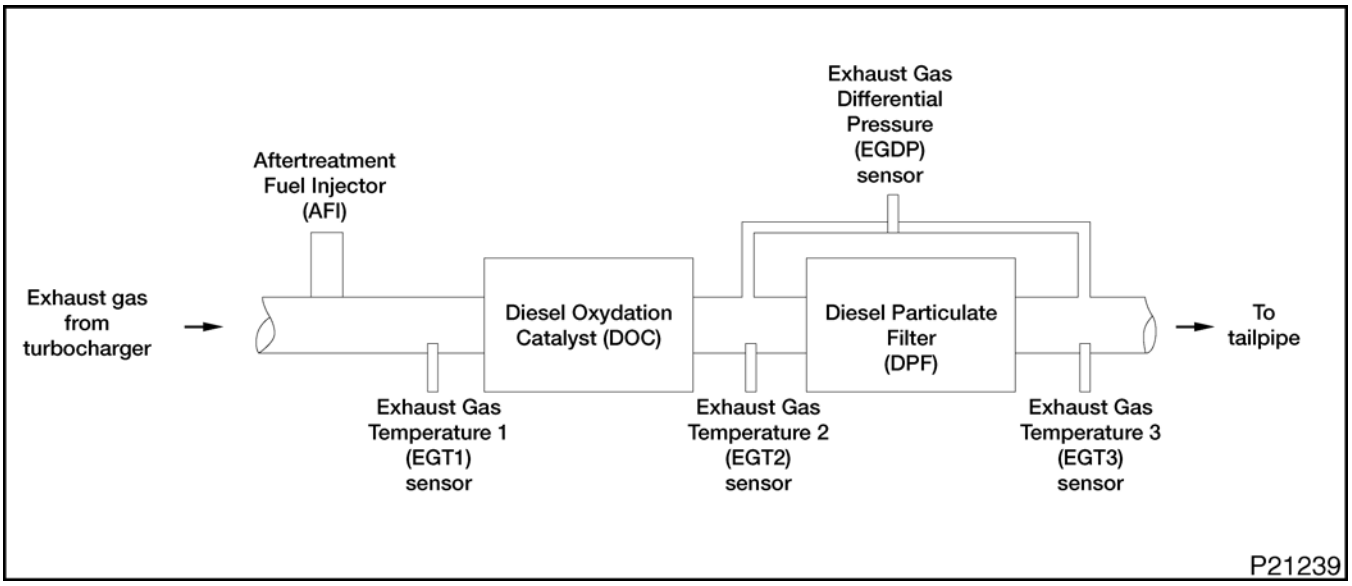

Figure 11 AFT system overview

The AFT system, part of the larger exhaust system, processes engine exhaust to meet emissions requirements. The AFT system traps particulate matter (soot) and prevents it from leaving the tailpipe.

The AFT system performs the following functions:

- Monitors exhaust gases and controls engine operating parameters for emission processing and failure recognition
- Cancels regeneration in the event of catalyst or sensor failure
- Monitors the level of soot accumulation in the Diesel Particulate Filter (DPF) and adapts engine operating characteristics to compensate for increased backpressure
- Controls engine operating parameters to make regeneration automatic
- Maintains vehicle and engine performance during regeneration

Aftertreatment Fuel Injection

The aftertreatment system injects fuel into the exhaust gas to increase the temperature necessary for DPF regeneration. Control of the aftertreatment fuel injection is done by the Aftertreatment Control Module (ACM). The ACM receives data from the aftertreatment sensors directly and determines when regeneration is required.

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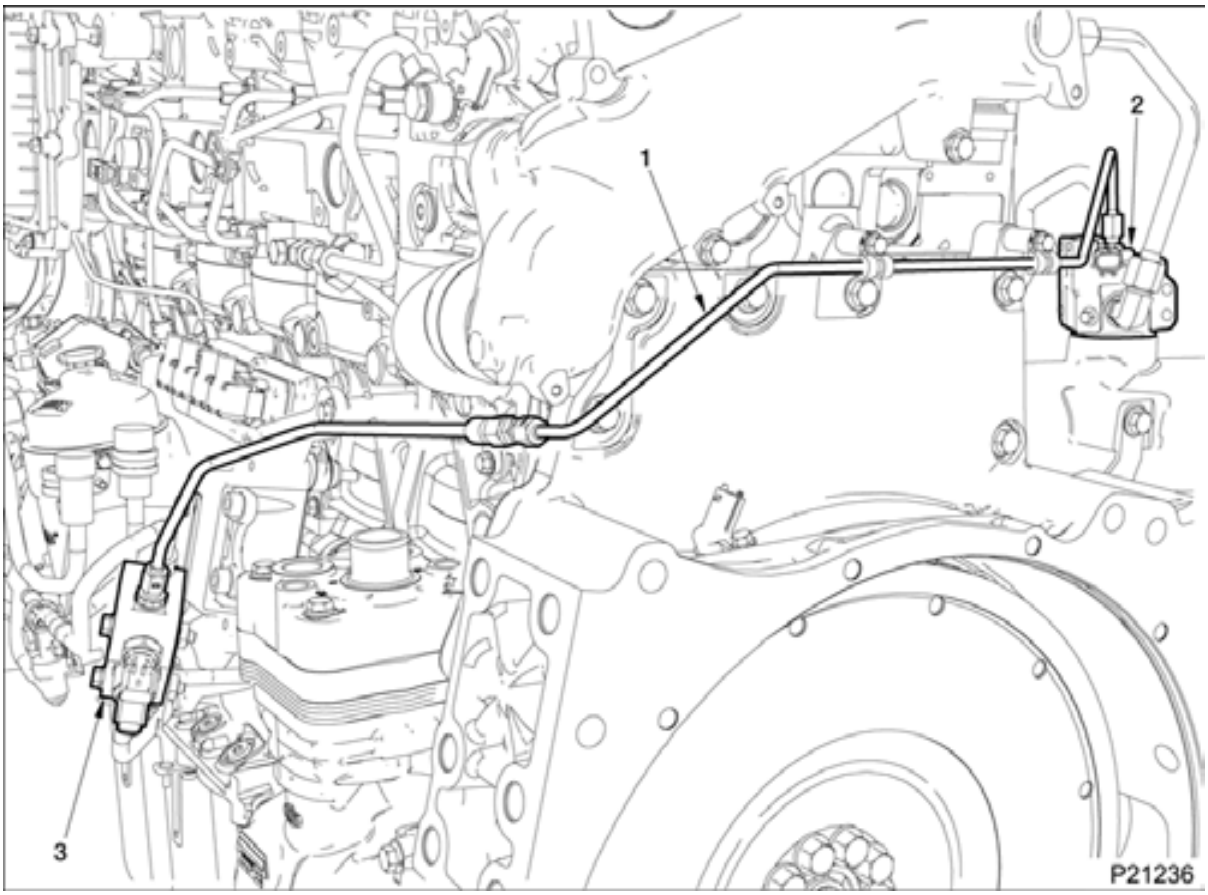

Figure 12 Aftertreatment fuel injection components

1. Fuel supply assembly
2. Aftertreatment Fuel Injector (AFI)
3. Hydrocarbon (HC) cut-off valve

Hydrocarbon (HC) Cut-off Valve

The HC cut-off valve is installed on the left side of the engine in front of the air compressor. The HC cut-off valve is connected to the clean side of the low pressure fuel system as well as to the fuel return line, and controls the fuel flow to the AFI.

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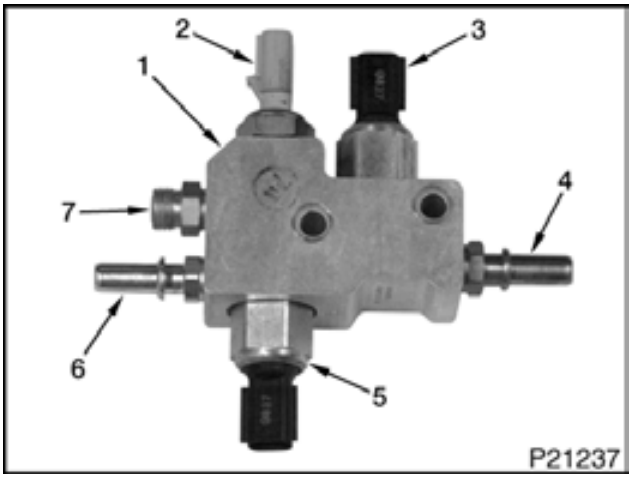

Figure 13 HC cut-off valve

1. HC cut-off valve
2. Aftertreatment Fuel Pressure (AFP) sensor
3. Aftertreatment Fuel Supply (AFS) valve
4. Fuel supply from fuel filter housing assembly
5. Aftertreatment Fuel Drain (AFD) valve
6. Fuel return to tank
7. Fuel supply to AFI

The AFS valve controls the fuel supply to the AFI when regeneration is required. The AFS valve is controlled by the ACM.

The AFP sensor monitors the fuel pressure in the aftertreatment fuel system and provides a signal to the ACM.

The AFD valve is used to relieve the pressure from the aftertreatment fuel system. A fuel overpressure can occur due to fuel thermal expansion inside the AFI fuel supply line. When the fuel pressure increases, the ACM commands the AFD to open and relieve the fuel pressure into the fuel return to tank line.

Aftertreatment Fuel Injector (AFI)

The AFI is located on the right side of the engine and is installed on the turbo exhaust pipe after the Exhaust Lambda Sensor (ELS).

Pressurized fuel is supplied to the AFI from the HC cut-off valve through the fuel supply assembly. When the conditions required for regeneration are met, the ACM sends a voltage to the AFI solenoid valve to open and inject fuel into the turbo exhaust pipe.

To protect the AFI internal components, continuous engine coolant flow through the AFI is maintained by external coolant supply and return lines.

Diesel Particulate Filter (DPF)

The DPF does the following:

- Captures and temporarily stores carbon-based particulates in a filter
- Allows for oxidation (regeneration) of stored particulates once loading gets to a particular level (pressure drop)
- Provides the required exhaust back pressure drop for engine performance
- Stores non-combustible ash

Diesel Oxidation Catalyst (DOC)

The DOC does the following:

- Oxidizes hydrocarbons and carbon monoxide (CO) in exhaust stream
- Provides heat for exhaust system warm-up
- Aids in system temperature management for the DPF
- Oxidizes NO into NO_2 for passive DPF regeneration

Aftertreatment System Conditions and Responses

The operator is alerted of system status either audibly or with instrument panel indicators. Automatic or manual regeneration is required when levels of soot exceed acceptable limits. For additional information see the applicable vehicle Operator's Manual and the vehicle visor placard.

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Fuel Management System

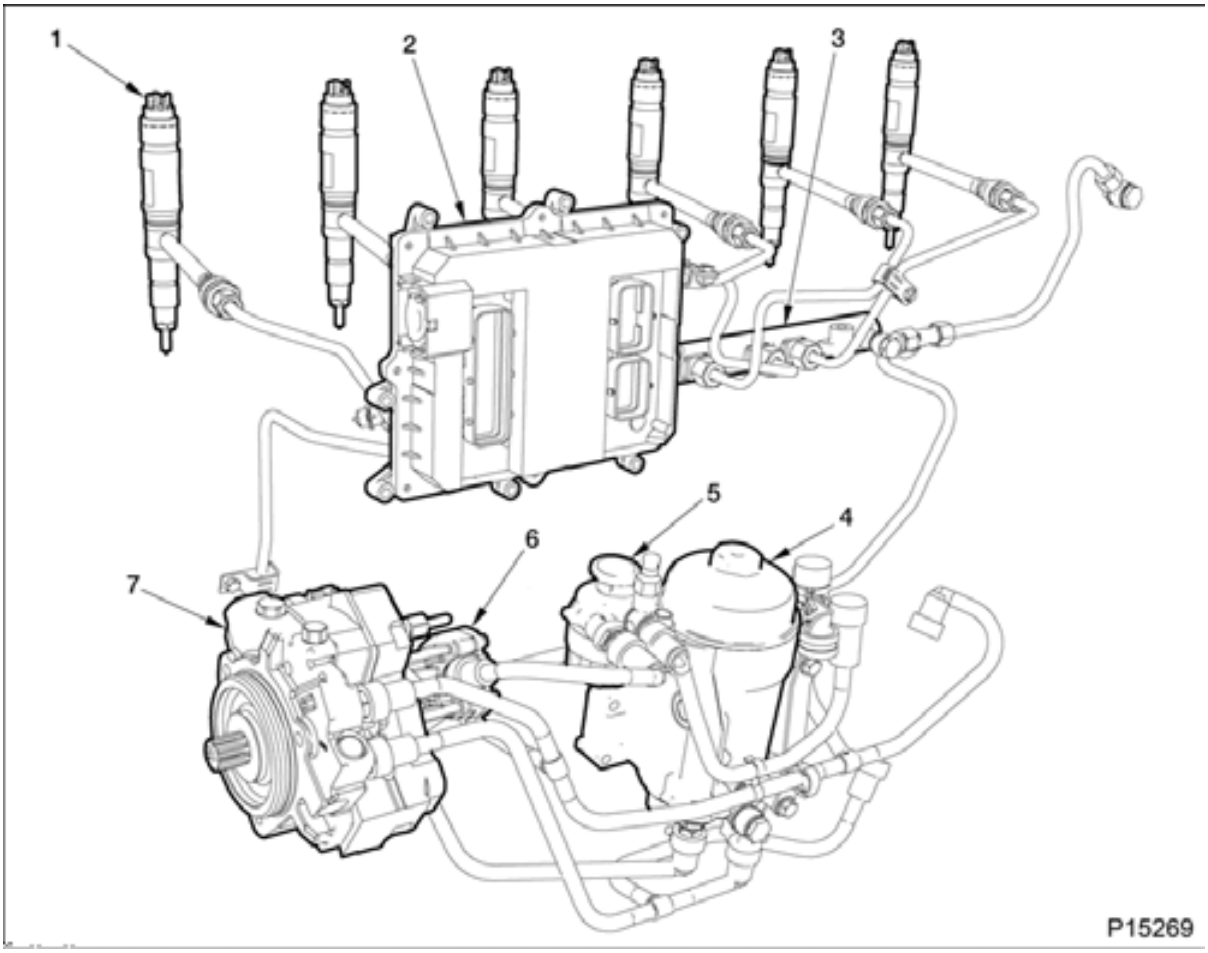

Figure 14 Fuel system

1. Injector (6)
2. Engine Control Module (ECM)
3. Pressure pipe rail
4. Fuel filter housing assembly
5. Fuel primer pump assembly
6. Low pressure fuel pump
7. High pressure pump

The International® MaxxForce® 11 and 13 engines are equipped with a high pressure common rail injection system. The common rail fuel injection system provides fuel under constant high pressure to the fuel injectors for optimal fuel atomization in the combustion chamber.

Fuel is pumped from the tank and through a fuel strainer element by a low pressure fuel pump mounted on the left side of engine. Fuel flows from the low pressure fuel pump through a main fuel filter housing assembly before being supplied to a high pressure pump. The high pressure pump supplies high pressure fuel to a pressure pipe rail, which feeds the injectors through individual tubes. The low pressure fuel pump and the high pressure pump are assembled as one gear driven unit.

The fuel system is controlled by the ECM, various sensors, and the Fuel Pressure Control Valve (FPCV) located in the high pressure pump.

In addition to providing high pressure fuel to the injectors, the fuel system also provides low pressure filtered fuel to the aftertreatment and cold start assist systems.

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Low Pressure Fuel System

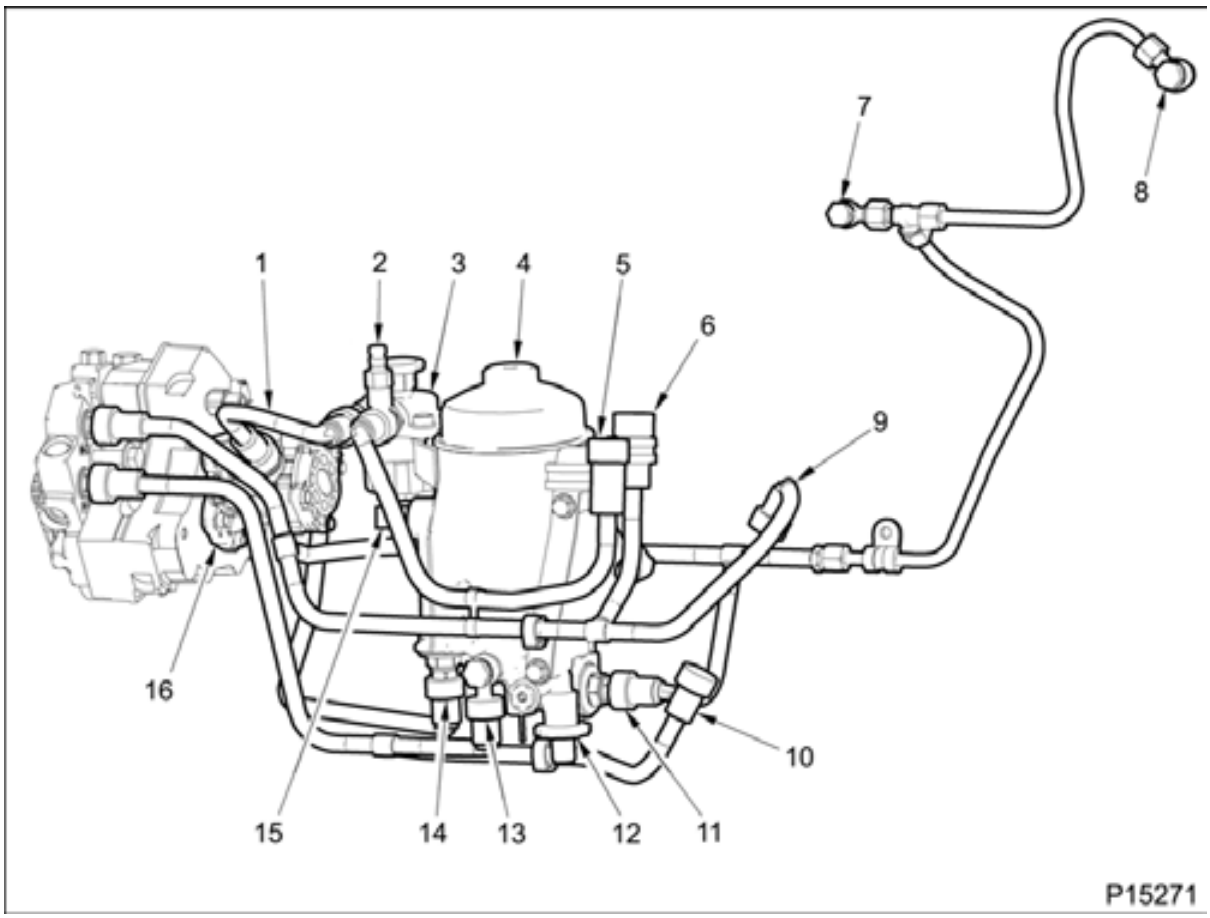

Figure 15 Low pressure fuel system

1. Preliminary filter feed fuel line
2. Quick disconnect valve
3. Fuel primer pump assembly
4. Fuel filter housing assembly
5. Fuel supply from tank connector
6. Fuel return to tank connector
7. Rail pressure relief valve return
8. Injector fuel return
9. Fuel return line
10. Filter T-connector fuel line
11. Return from fuel filter connection
12. Water drain valve
13. Fuel supply to high pressure pump connection
14. Fuel supply to fuel filter connection
15. Engine Fuel Pressure (EFP) sensor
16. Low pressure fuel pump (part of high pressure pump)

The low pressure fuel system pumps fuel from the tank through the fuel strainer element and separator filter element, then to the high pressure fuel system, cold start assist system, and aftertreatment system. The low pressure fuel system consists of fuel lines, fuel primer pump assembly, low pressure fuel pump, fuel filter housing assembly, and fuel pressure sensor.

Fuel Primer Pump Assembly

The fuel is drawn from the tank through the fuel primer pump assembly and into the low pressure fuel pump. The fuel primer pump assembly has an integrated fuel strainer element that can be washed. The fuel primer pump assembly is manually operated and is used to prime the low pressure fuel system anytime the system is emptied.

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Low Pressure Fuel Pump

Fuel is drawn from the fuel primer pump assembly into the low pressure fuel pump. The low pressure fuel pump is flanged to and is driven by the high pressure pump. The low pressure fuel pump supplies fuel to the fuel filter housing assembly at pressures varying between 496 kPa (72 psi) at idle, and 896 kPa (130 psi) at rated speed. The low pressure fuel pump is equipped with an internal pressure regulator that relieves the fuel pressure internally if the pressure exceeds 896 kPa (130 psi).

Fuel Filter Housing Assembly

The fuel filter housing assembly is located on the left side of the engine and has a disposable filter element. An Engine Fuel Pressure (EFP) sensor is installed on the front side of the fuel filter housing assembly and it measures fuel pressure between the low pressure fuel pump and the filter element. The fuel filter housing assembly also has a drain valve that allows water and dirt to be drained periodically and during filter element replacement. An additional function of the fuel filter housing assembly is fuel system self-deaeration. The air separated from fuel is pushed back into the fuel tanks through the return line.

The fuel filter housing assembly is equipped with two additional ports to provide filtered fuel to the aftertreatment system and to the cold start assist system. An orifice regulator is integrated into the fuel filter housing assembly and regulates the fuel pressure for the cold start assist system to 55 kPa (8 psi).

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High Pressure Fuel System

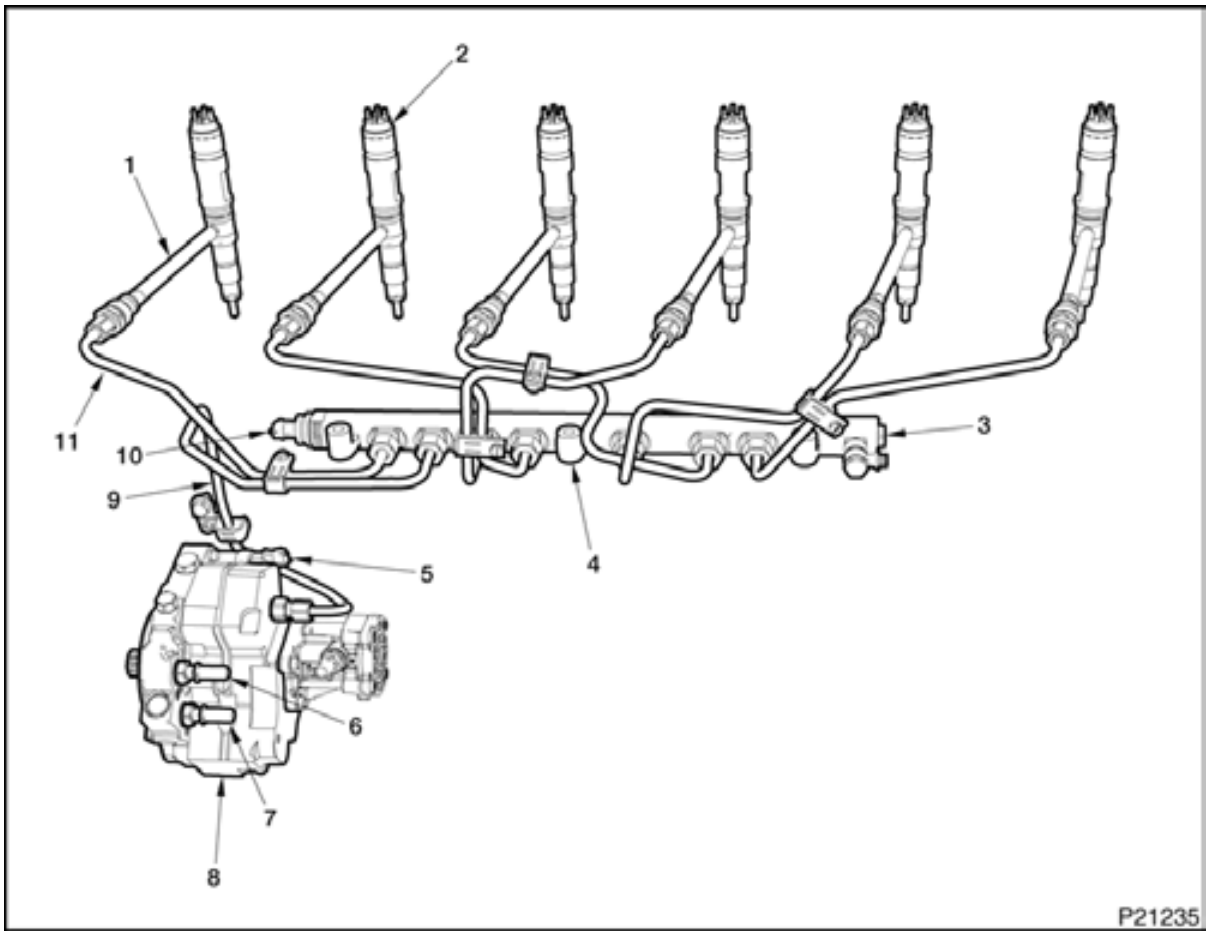

Figure 16 High pressure fuel system

1. Pressure pipe (6)
2. Injector (6)
3. Rail pressure relief valve
4. Pressure pipe rail
5. Fuel Pressure Control Valve (FPCV) (part of high pressure pump)
6. Fuel return from high pressure pump threaded union
7. Fuel supply to high pressure pump threaded union
8. High pressure pump
9. Pressure line
10. Fuel Rail Pressure (FRP) sensor
11. Injection line (6)

Pressurization and injection are separate in the common rail injection system. The optimal injection pressure is generated by the high pressure pump at any engine speed. High pressure fuel quantity from high pressure pump is controlled by a proportional valve. The injection timing and quantity are calculated in the Engine Control Module (ECM) and implemented by solenoid valve controlled injectors. The use of solenoid valve controlled injectors allows three injections per cycle.

The first injection is used to reduce combustion noise and emissions by introducing a small amount of fuel into the cylinder, preventing a rapid rise in cylinder pressure when combustion begins. The first injection occurs only during idling and in partial load mode. The second injection is the main injection. This injection allows high temperatures to be maintained during combustion, but not long enough to allow generation of large soot amounts. The third injection is done during the power stroke to maximize cylinder temperature and reduce engine soot generation.

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The high pressure fuel system consists of high pressure pump with integrated Fuel Pressure Control Valve (FPCV), pressure pipe rail, fuel high pressure fuel lines, injectors, FRP sensor, and pressure relief valve.

High Pressure Pump

The high pressure pump supplies the necessary quantity of high pressure fuel for all operating engine modes. The high pressure pump is gear driven and is fuel lubricated. Fuel from the low pressure fuel pump is forced through the fuel filter housing assembly and into the high pressure pump. The flow of fuel to the suction chamber of the high pressure pump is controlled by the FPCV in order to control the high pressure fuel output.

Fuel Pressure Control Valve (FPCV)

The FPCV is a variable position actuator installed on the suction side of the high pressure pump and controls the output fuel pressure. The ECM sends a Pulse Width Modulated (PWM) signal to control the FPCV. A 100% duty cycle PWM signal corresponds to zero fuel pressure delivery, while a 0% duty cycle PWM corresponds to maximum fuel pressure delivery.

Pressure Pipe Rail

The pressure pipe rail is a high pressure fuel storage unit. The storage volume of the pressure pipe rail is designed to reduce pressure pulses caused by the high pressure pump and injectors, and to maintain constant fuel pressure even when large fuel quantities are injected into the cylinders. Connection between the pressure pipe rail and injectors are made through individual injection lines.

Fuel Rail Pressure (FRP) Sensor

The FRP sensor is a variable resistance sensor that monitors the fuel pressure in the high pressure fuel rail.

The FRP sensor is mounted in the front of the high pressure pipe rail on the left side of the engine.

Pressure Relief Valve

The pressure relief valve maintains the fuel pressure inside the pressure pipe rail below 179,000 kPa (26,000 psi). If the high pressure pump fuel output exceeds 179,000 kPa (26,000 psi), the pressure relief valve opens and allows fuel to flow into the fuel return line. With the pressure relief valve open, the fuel pressure in the pressure pipe rail drops to approximately 80,000 kPa (11,600 psi).

Injector

The International® MaxxForce® 11 and 13 engines are equipped with electronically controlled injectors. During engine operation, injectors are supplied at all times with high pressure fuel, and the injector solenoid valves open up to three times per cycle. The injectors are positioned vertically in the center of the cylinder head and are held in place by brackets. The seal between the injectors and the combustion chamber consists of a copper washer on the tip of each injector.

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Engine Lubrication System

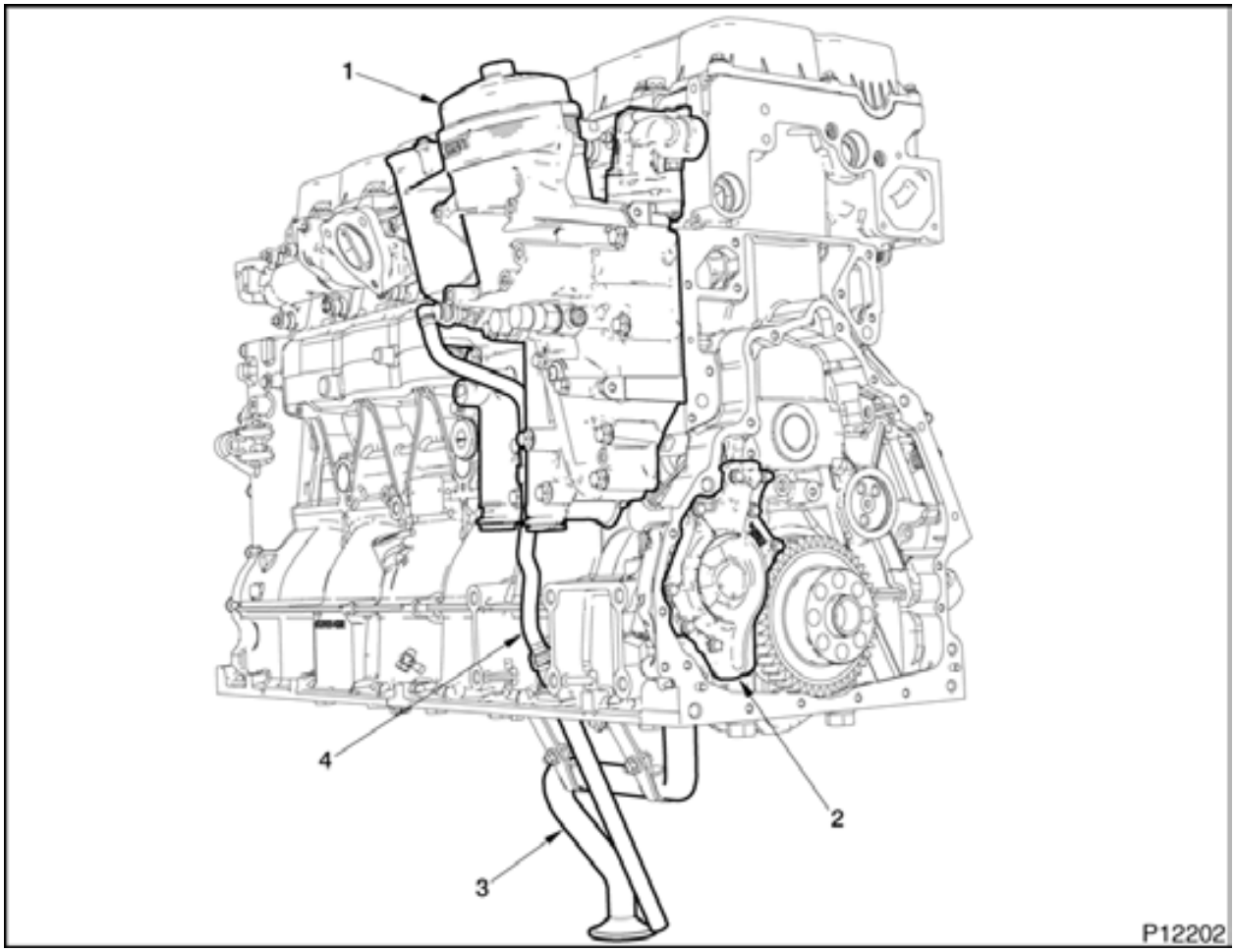

Figure 17 Oil system overview (typical)

1. Oil module
2. Oil pump
3. Oil suction line
4. Oil return tube

Engine oil pressure is generated by a gerotor oil pump located inside the front cover and is driven off of the crankshaft gear. The oil module is located on the right side of the engine and houses the oil filter element, the oil cooler assembly, and the oil pressure regulator. Pressurized filtered oil passes between the oil filter element and cylinder head through an external flange elbow. Oil drains back into the oil module through a separate passage in the external flange elbow, and into the crankcase from an opening at the rear of the cylinder head.

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Oil Flow and Components

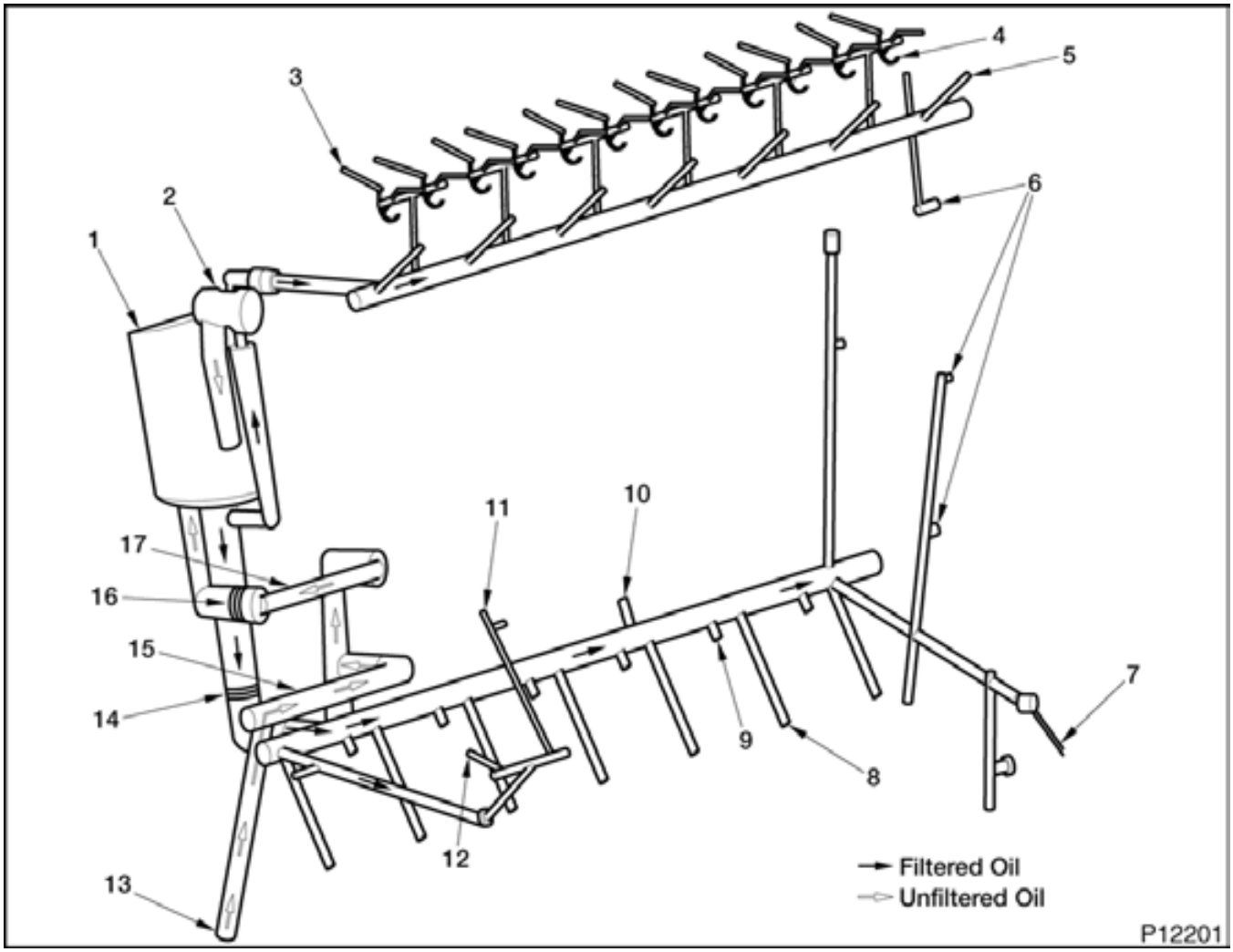

Figure 18 Oil flow

1. Oil filter element
2. Oil return from cylinder head
3. Oil supply to exhaust valve bridge
4. Oil supply to rocker gear
5. Oil supply to camshaft bearings
6. Oil supply to intermediate gears
7. Oil supply to air compressor
8. Oil supply to crankshaft main bearings
9. Oil supply to piston oil sprayer nozzles
10. Oil supply to turbochargers
11. Oil supply to drive housing
12. Oil supply to front cover
13. Oil pump output
14. Oil pressure relief valve
15. Oil supply to oil module
16. Oil return shutoff valve
17. Oil cooler

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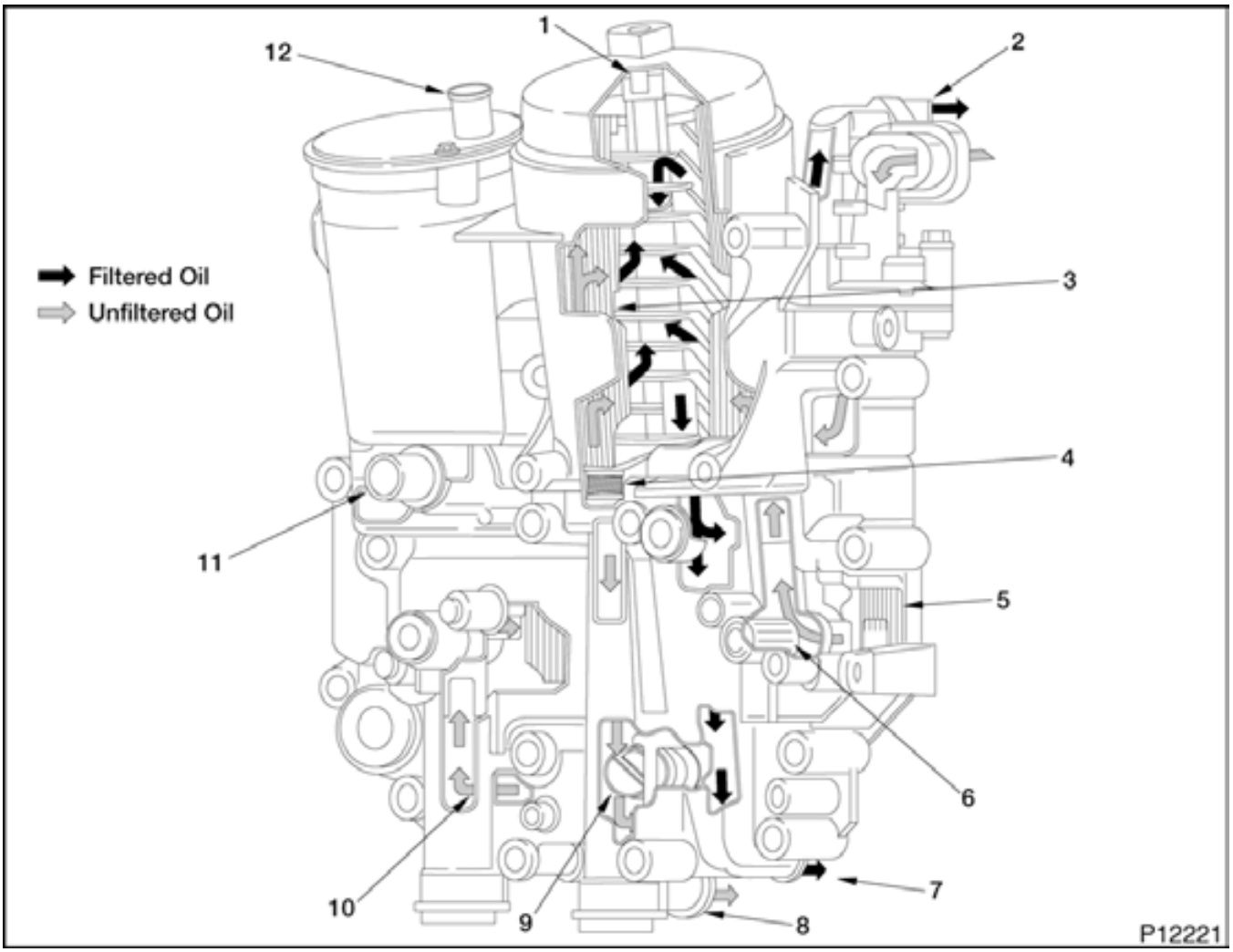

Figure 19 Oil module flow

1. Oil filter bypass valve (part of oil module)
2. Oil supply to cylinder head
3. Oil filter element
4. Service oil drain valve
5. Oil cooler
6. Oil return shutoff valve
7. Oil supply to crankcase
8. Oil return to crankcase
9. Oil pressure relief valve
10. Oil supply from oil pump
11. Crankcase breather oil return connection
12. Oil module to crankcase breather connection

Unfiltered oil is drawn from the oil pan through the pickup tube and front cover passage by the crankshaft driven gerotor pump. The pressurized oil is moved through a vertical crankcase passage and into the oil module.

Inside the oil module, unfiltered oil flows through plates in the oil cooler heat exchanger. Engine coolant flows around the plates to cool the surrounding oil. An oil return shutoff valve installed at the exit from the oil cooler prevents the oil from draining through the oil pump and back into the oil pan when the engine is stopped. If the oil pressure coming out of the oil pump is too high, a pressure relief valve allows the excess oil to return through the crankcase and into the oil pan before entering the oil cooler.

Oil that exits the oil cooler flows through a return shutoff valve that prevents the oil from draining back into the oil pan. From the return shutoff valve, oil enters the oil filter element and flows from the outside to the inside of the filter element to remove debris.

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When the filter is restricted, an oil filter bypass valve opens and allows oil to bypass the filter so engine lubrication is maintained. If the oil pressure inside the oil filter element is too high, an oil pressure relief valve, located at the bottom of the oil filter element housing, allows the excess oil to return to the oil pan.

After passing through the oil filter element, the oil flow is directed to the cylinder head and the crankcase.

Clean oil enters cylinder head through an external flange elbow connected directly to the oil module. Inside the cylinder head, oil flows through passages to lubricate the camshaft bearings, rocker arms, exhaust valve bridges, and cylinder intermediate gear.

Clean oil enters the crankcase directly from the oil module to lubricate the crankshaft, high pressure pump, air compressor, intermediate gears, and turbochargers. The crankshaft has cross-drillings that direct oil to the connecting rods.

Oil sprayer nozzles continuously direct cooled oil to the bottom of the piston crowns.

The turbochargers are lubricated with filtered oil from an external supply tube that connects the main oil gallery from the crankcase to the center housing of each turbocharger. Oil drains back to the oil pan through the low and high pressure turbocharger oil return pipes connected to the crankcase.

A service oil drain valve, located at the bottom of the filter element cavity, opens automatically when the filter element is lifted for replacement, and allows the oil from the oil filter element cavity to drain into the oil pan.

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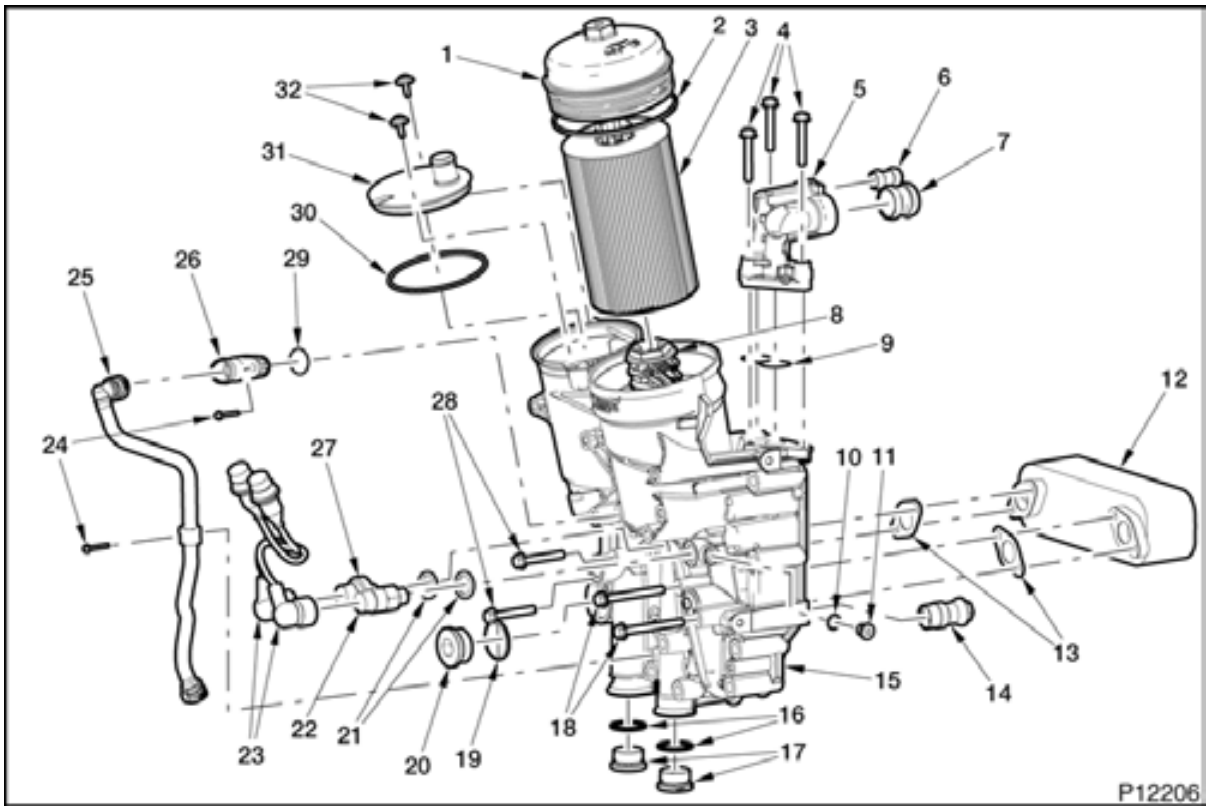

Figure 20 Oil module

1. Oil filter cover
2. O-ring seal
3. Oil filter element
4. M8 x 50 hex bolt (3)
5. Flange elbow
6. DMR20/DN14 extension tube
7. DMR37/DN29 extension tube
8. Oil filter bypass valve (part of oil module)
9. Gasket for flange elbow
10. Seal
11. M10 x 1.0 plug
12. Oil cooler
13. Oil cooler gaskets
14. Oil pressure relief valve
15. Oil module
16. Plug seal (2)
17. M33 x 2 plug (2)
18. M8 x 80 hex bolt (2)
19. Plug seal
20. M38 x 1.5 plug
21. BS-16.7 x 24.0 O-ring seal
22. Engine Oil Pressure (EOP) sensor
23. Adapter lines (electrical connections)
24. M6 x 18 hex bolt (2)
25. Oil return tube
26. Straight fitting
27. Engine Oil Temperature (EOT) sensor
28. M8 x 55 hex bolt (2)
29. O-ring seal
30. O-ring seal
31. Breather cup
32. M6 bolt with washer (2)

The oil module contains a canister style filter, the oil cooler, the EOP and EOT sensors, a pressure relief valve, an oil filter bypass valve, and an oil return shutoff valve. The oil module housing also collects, and then directs crankcase emissions to the breather system through the breather cup at the top of the oil module housing. The oil that separates from the crankcase emissions before it reaches the breather system is drained back into the oil pan through the oil return tube.

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Engine Cooling System

Cooling System Components

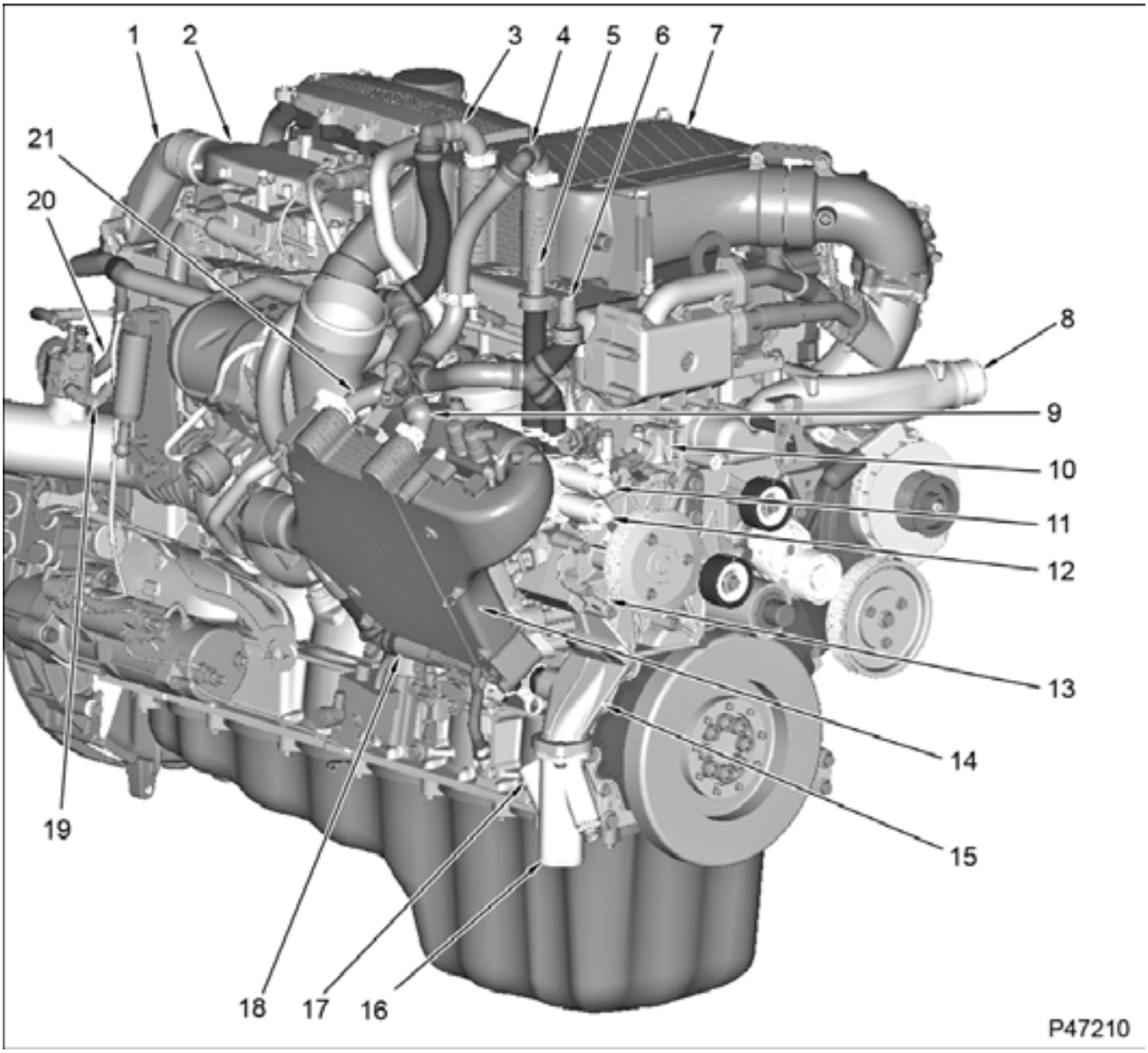

Figure 21 Cooling system components

1. Coolant elbow (middle)
2. Coolant elbow (upper)
3. High-pressure Charge Air Cooler (HPCAC) return coolant pipe
4. HPCAC supply coolant pipe
5. Low Temperature Radiator (LTR) coolant supply pipe
6. Coolant return from LTR
7. HPCAC
8. Coolant elbow (supply to radiator)
9. LPCAC return coolant pipe
10. Thermostat housing assembly
11. Coolant Mixer Valve (CMV)
12. Coolant Flow Valve (CFV)
13. Water pump
14. LPCAC
15. Distributor case
16. Coolant elbow (return from radiator)
17. Surge tank line connector
18. Charge Air Cooler (CAC) return coolant pipe
19. AFI coolant return line
20. Aftertreatment Fuel Injector (AFI) coolant supply line
21. Low Pressure Charge Air Cooler (LPCAC) supply coolant pipe

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Cooling System Flow

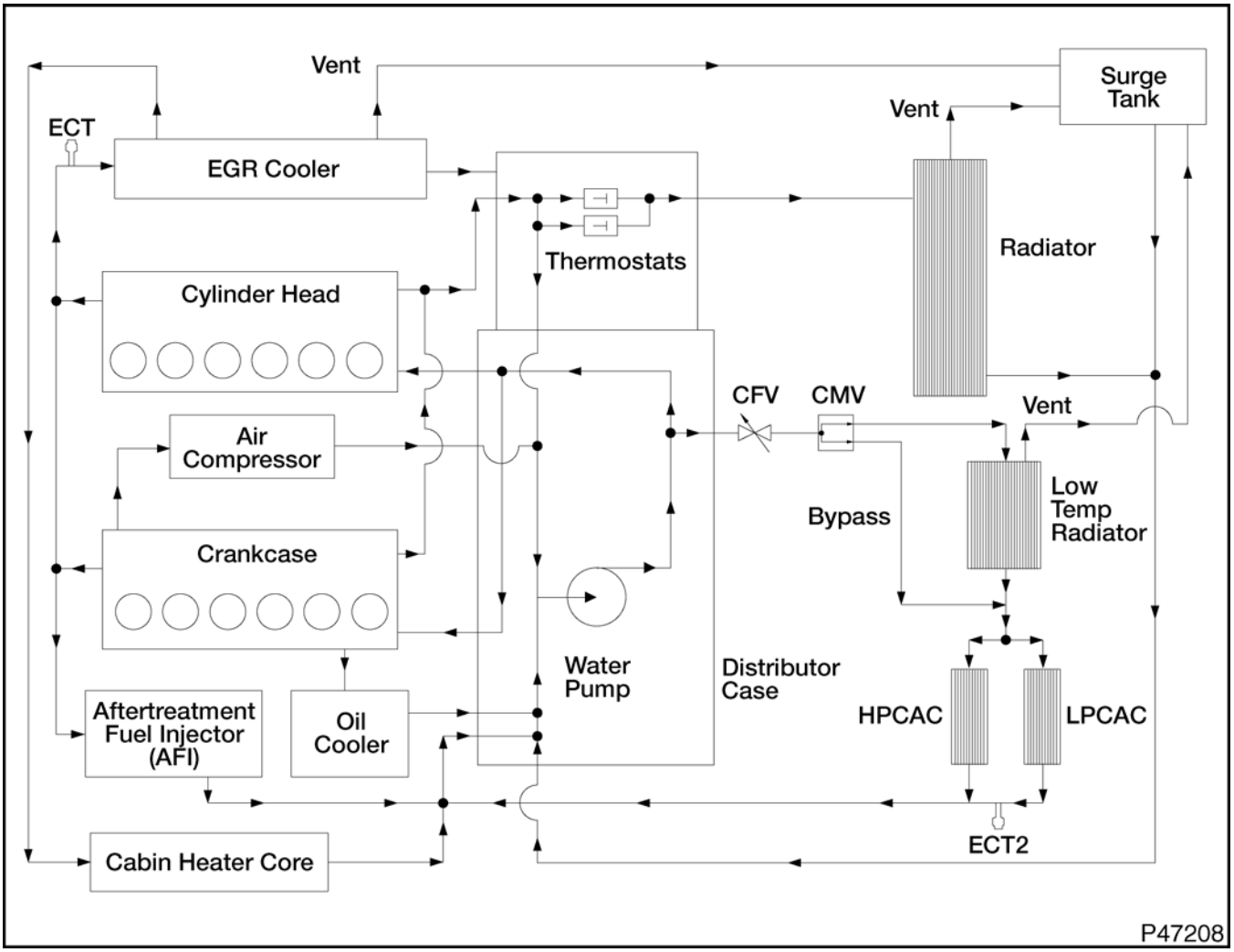

Figure 22 Cooling system flow

The water pump is located on the distributor case and draws coolant from the radiator through the coolant inlet at the lower right side of the distributor case.

The International® MaxxForce® 11 and 13 engines have no coolant passages between the crankcase and cylinder head through the cylinder head gasket. This design eliminates the possibility of coolant leaks at the cylinder head gasket. Coolant in and out of the crankcase and cylinder head is directed through external passages. Coolant flows through the crankcase and cylinder head from front to rear. This coolant flows around the cylinder liners and combustion chambers to absorb heat from combustion.

Coolant exiting the crankcase and cylinder head at the rear of the engine is directed through an external coolant elbow to the Exhaust Gas Recirculation (EGR) module. Coolant passes between the EGR cooler plates, travels parallel to the exhaust flow, and exits into the distributor case. A deaeration port on the top of the EGR module directs coolant and trapped air towards the coolant surge tank.

Coolant from the pump also flows through the HPCAC and the LPCAC to regulate the charge air temperature. Flow through the charge air coolers

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is controlled by the Coolant Mixer Valve (CMV) and Coolant Flow Valve (CFV). Depending on the coolant temperature, CMV sends coolant through the Charge Air Coolers (CACs), or indirectly to the CACs, after going through the Low Temperature Radiator (LTR) located in front of the main coolant radiator. When the charge air temperature is too low, CMV bypasses the LTR and directs all the coolant through the CACs. When the charge air temperature increases, CMV directs a percentage of the coolant to the LTR before it enters the CACs to cool the charge air. If the engine coolant temperature is too high, CMV sends all of the coolant flow through the LTR and through the CACs to help cool the engine faster.

Both coolant valves are controlled by the Engine Control Module (ECM) based on signals from the Engine Coolant Temperature (ECT) sensor, ECT2 sensor, and the Manifold Air Pressure/Intake Air Temperature 2 (MAP/IAT2) sensors.

Coolant flow to the radiator is controlled by two thermostats. When the thermostats are closed, coolant flowing out of the EGR cooler is directed through a bypass port inside the front cover into the water pump. When the thermostats are open the bypass port is blocked, and coolant is directed from the engine into the radiator.

Coolant passes through the radiator and is cooled by air flowing through the radiator from ram air and operation of the coolant fan. The coolant returns to the engine through the inlet elbow.

The air compressor is cooled with coolant supplied by a hose from the left side of the crankcase. Coolant passes through the air compressor cylinder head and returns through a passage inside the crankcase to the distributor case.

The oil module receives coolant from a passage in the crankcase. Coolant passes between the oil cooler plates and returns back to the water pump suction passage located in the front cover.

Thermostat Operation

The International® MaxxForce® 11 and 13 engines are fitted with two thermostats in a common housing to ensure sufficient coolant flow in all operating conditions. The thermostats are located at the top of the distributor case.

The thermostat housing assembly has two outlets. One directs coolant to the radiator when the engine is at operating temperature. The second outlet directs coolant to the water pump until the engine reaches operating temperature. The thermostats begin to open at 83°C (181°F) and are fully open at 91°C (196°F).

When engine coolant is below the 83°C (181°F) the thermostats are closed, blocking coolant flow to the radiator. Coolant is forced to flow through a bypass port back to the water pump.

When coolant temperature reaches the opening temperature of 83°C (181°F) the thermostats open allowing some coolant to flow to the radiator. When coolant temperature exceeds 91°C (196°F), the lower seat blocks the bypass port directing full coolant flow to the radiator.

Coolant Control Valve (CCV) operation

The CCV is installed on the upper right side of the distributor housing and controls the coolant flow to the CACs.

The CCV has two separate solenoid actuated valves; CMV, and CFV. The CMV and the CFV are part of the CCV assembly and cannot be serviced separately. The CMV and CFV solenoids are controlled by two separate Pulse Width Modulated (PWM) signals from the ECM. The PWM signal duty cycles vary between 0% and 100% depending on the coolant and charge air temperature.

CFV

The CFV is installed on the lower side of CCV and controls the amount of coolant flow through the LPCAC and HPCAC. If the engine coolant temperature is too low, the CFV closes to reduce the coolant flow through the CACs.

CMV

The CMV is installed on the upper side of CCV and controls the coolant flow through the LTR. When the temperature of the charge air and coolant coming out of the CACs is low, the CMV directs the coolant through a LTR bypass directly into the CACs. This helps the engine reach its normal operating temperature faster. If the temperature of the charge air and coolant coming out of the CACs is high, the CMV directs the coolant flow through the LTR. This

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prevents an overheating of the charge air cooler which can result in failure of the CACs.

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Engine Retarder System

The engine retarder system is optional equipment for all engine displacements. The engine retarder system uses exhaust back pressure and engine oil pressure to improve the engine braking power by holding the exhaust valves slightly open during the cylinder compression and power strokes.

During engine retarder operation, both the compression and expansion strokes of the power cylinders are used to absorb road speed energy through the powertrain.

The operator can enable or disable the engine retarder by pressing a dash mounted ON/OFF switch.

Engine Retarder Control System Components

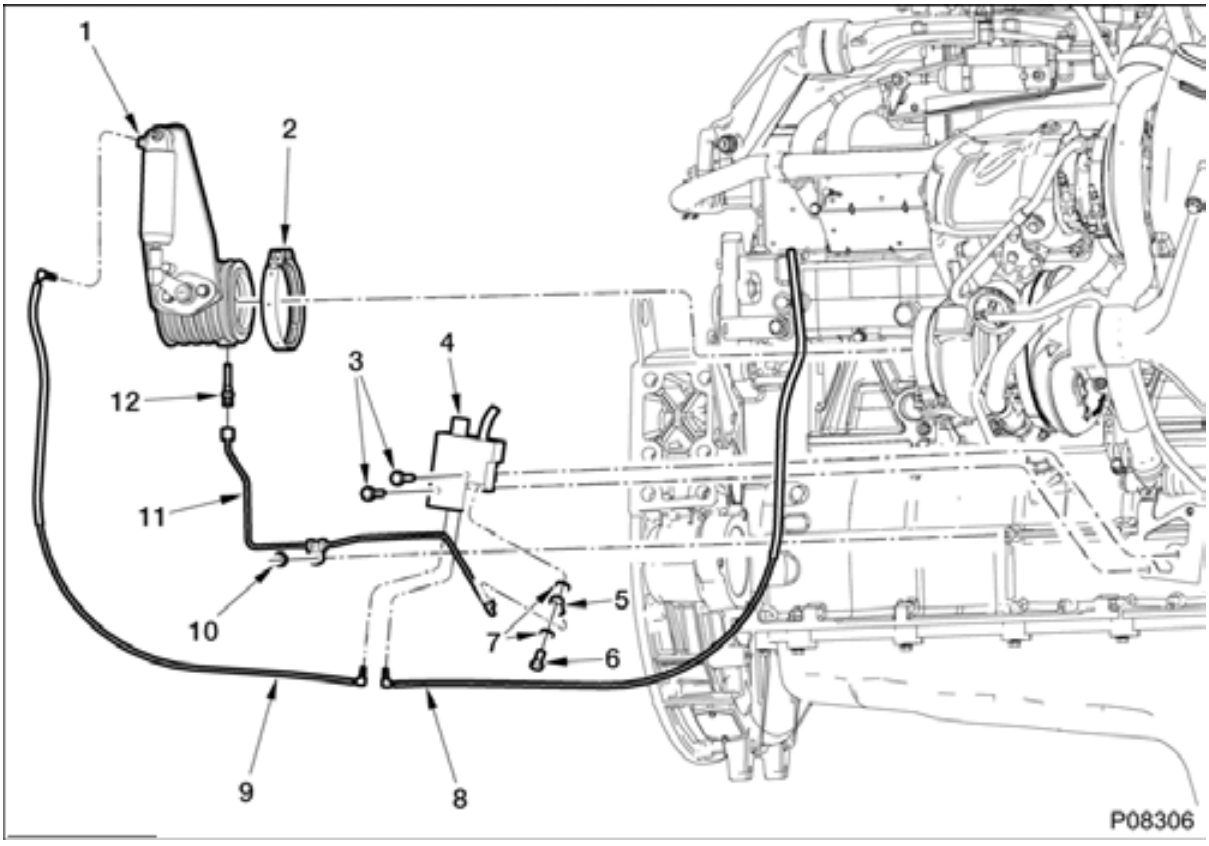

Figure 23 Engine retarder control system – external components

1. Exhaust manifold with butterfly
2. DMR 114 profiled clamp
3. M8 x 55 hex bolt (2)
4. Retarder control
5. Ring union
6. Size 6 hollow screw
7. 10 x 1.35 seal (2)
8. Air supply line assembly
9. Pressure air line
10. M8 x 16 x 20 stud bolt
11. Pressure line
12. Straight union

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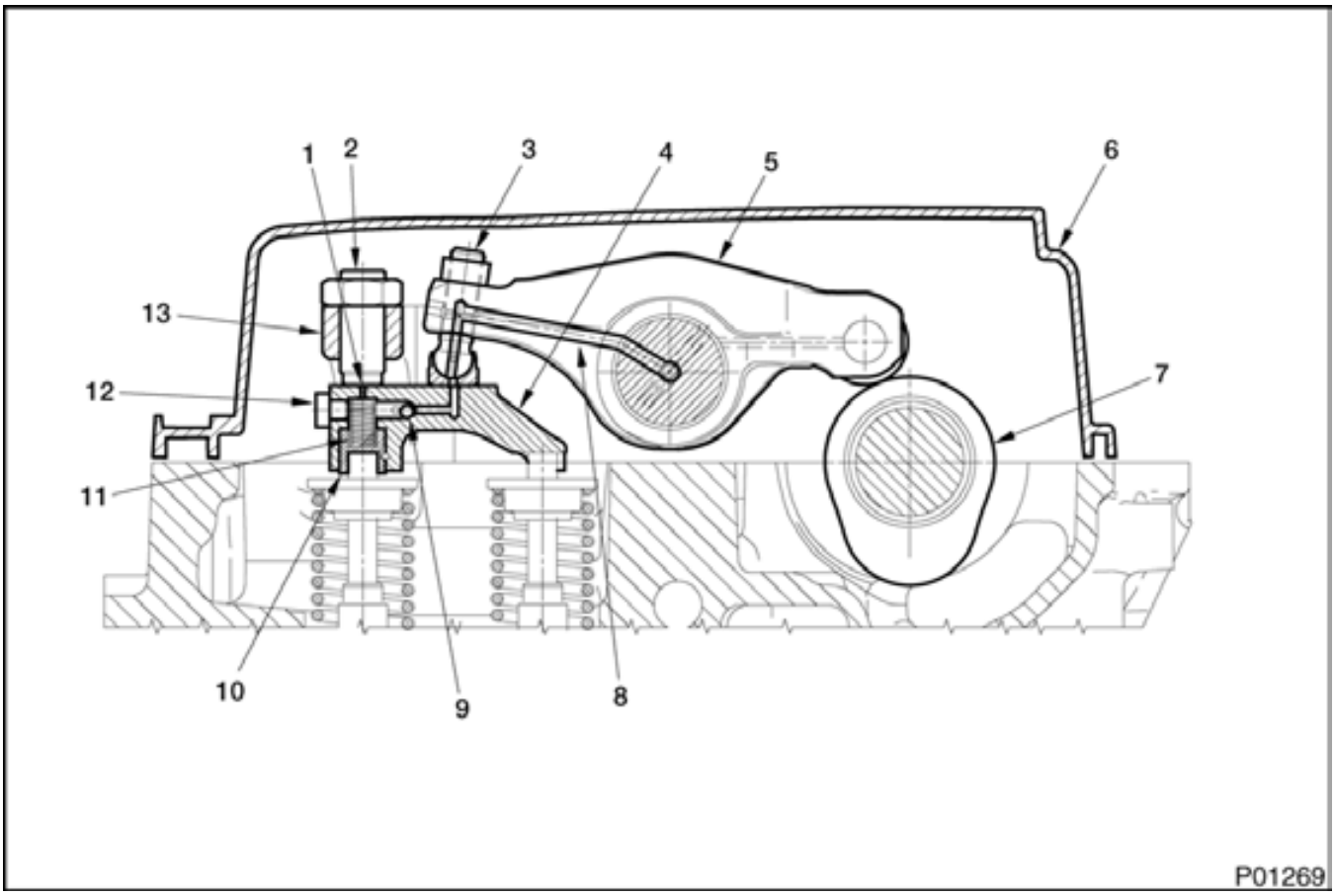

Figure 24 Engine retarder control system – internal components

1. Valve bridge orifice
2. Engine retarder adjusting screw
3. Exhaust valve lash adjusting screw
4. Exhaust valve bridge
5. Rocker arm
6. Valve cover
7. Camshaft
8. Oil passage
9. Check valve
10. Engine retarder piston
11. Spring
12. Plug
13. Counterpiece

Retarder Control

The retarder control is a proportional valve that controls the compressed air supply to the butterfly valve actuator located in the exhaust manifold. Compressed air is supplied to the retarder control from the truck air system.

The retarder control has an integrated exhaust back pressure sensor that is connected to the retarder exhaust manifold through a pressure line. The retarder control monitors the exhaust back pressure and automatically adjusts the butterfly valve position to achieve optimum exhaust back pressure for maximum engine retarder efficiency.

The retarder control is installed on the lower right side of the engine.

Engine Retarder Exhaust Manifold

The engine retarder exhaust manifold is located in the exhaust system on the right side of the engine, immediately after the low pressure turbocharger. A butterfly valve inside the engine retarder exhaust manifold is open and closed by an external air controlled actuator. Compressed air to the actuator is provided through the retarder control.

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Engine Retarder Counterpiece and Exhaust Valve Bridge

The engine retarder control system uses engine oil pressure to hold the exhaust valves slightly open during engine retarding. Pressurized engine oil is supplied through the rocker arms to the engine retarder piston located inside the exhaust valve bridge. A spring located inside the valve bridge ensures that the valve bridge and the exhaust rocker arm are in contact at all times during engine operation, to ensure continuous oil supply to the engine retarder piston. The spring height is taken into consideration when the valve lash is adjusted, and requires the technician to fully compress the spring before setting the exhaust valves lash. The spring also pushes the engine retarder piston onto the exhaust valve stem. The counterpiece has a retarder lash adjusting screw that blocks the orifice located on the valve bridge. When the rocker arm pushes the valve bridge to open the exhaust valves, the orifice allows the release of oil pressure inside the valve bridge.

Engine Retarder System Operation

When the engine retarder is operated, the engine retarder butterfly valve in the exhaust system is closed and exhaust back pressure builds up in the cylinder head exhaust ports. The increased exhaust back pressure forces the exhaust valves to open slightly during retarder operation. As the exhaust valve opens slightly, a spring pushes the engine retarder piston inside the exhaust valve bridge forcing it to follow the exhaust valve stem. As the engine retarder piston is pushed down, the engine oil supplied through the rocker arm passage fills the space behind the engine retarder piston. A check valve inside the exhaust valve bridge and an orifice blocked by the engine retarder adjusting screw prevent the oil from backing up, causing a hydraulic lock behind the engine retarder piston. The locked engine retarder piston holds the exhaust valve slightly open until the next exhaust stroke. At the beginning of the exhaust stroke, the camshaft lobe pushes the rocker arm onto the exhaust valve bridge opening the exhaust valves completely. As the valve bridge is pushed down by the rocker arm, the orifice located in the valve bridge above the engine retarder piston opens and bleeds off the oil that caused the hydraulic lock inside the valve bridge. At the end of the exhaust stroke, the exhaust valve closes completely and, if the engine retarder is still activated, the cycle repeats on all power cylinders.

When the engine retarder is deactivated, the butterfly valve opens, releases the exhaust back pressure, and the exhaust valves return to normal operation at the next exhaust stroke.

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Open Crankcase Breather System

Open Crankcase Breather System Components

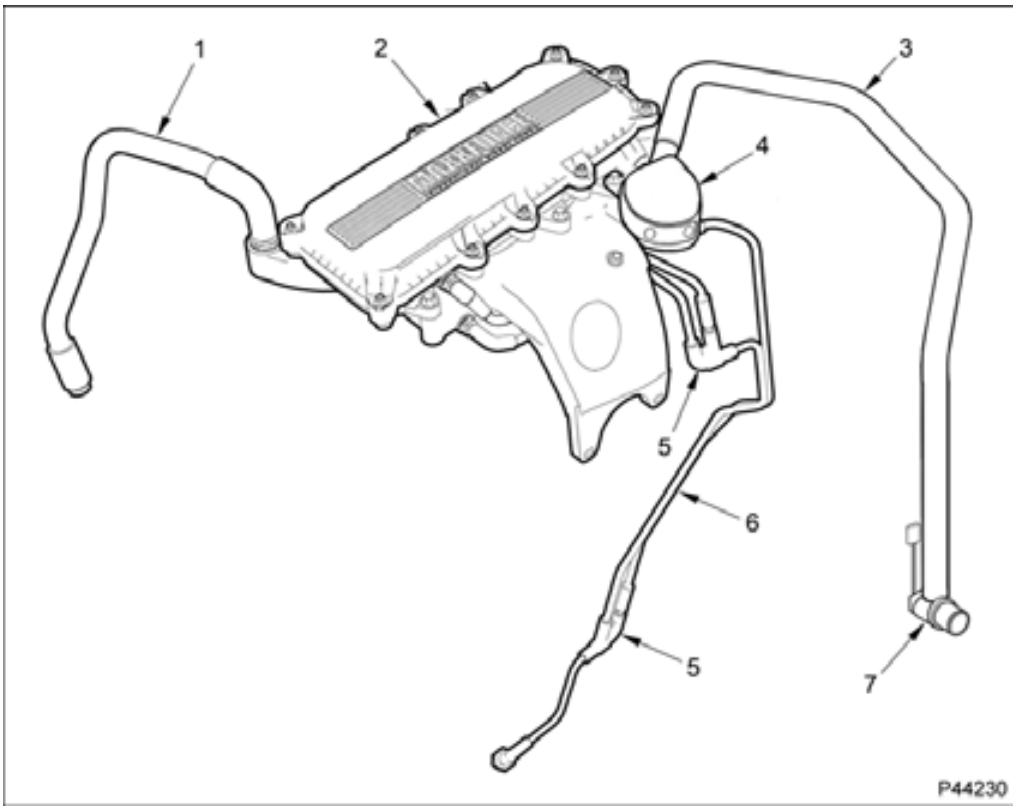

Figure 25 Open crankcase breather system

1. Breather inlet tube assembly
2. Service breather assembly
3. Breather outlet tube and heater assembly
4. Cyclone breather (with housing insulation)
5. Check valve assembly (2)
6. Oil return tube assembly
7. Breather outlet heater assembly

Open Crankcase Breather System Operation

The open crankcase breather system uses an engine mounted oil separator to return oil to the crankcase and vent blow-by gases to the atmosphere. The primary component of the system is the breather filter, in the service breather assembly. The breather filter separates oil mist from blow-by gases.

The blow-by gases exit the crankcase on the upper side of the oil module and enter the breather system through the breather inlet tube. From the breather inlet tube, blow-by gases enter the service breather assembly, where heavy oil particles are separated and drain into the oil pan through check valves in oil return tubes.

From the service breather assembly, blow-by gases pass through a cyclone breather that passively spins the blow-by gases to remove finer oil mist. Oil captured by the cyclone breather tube also returns to the oil pan through the oil return tubes. The cleaned blow-by gases exit to the atmosphere through the breather outlet tube and heater assembly. The breather outlet heater assembly prevents the end of breather outlet tube from plugging with ice, during cold climate conditions.

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Cold Start Assist System

Cold Start Assist System Components

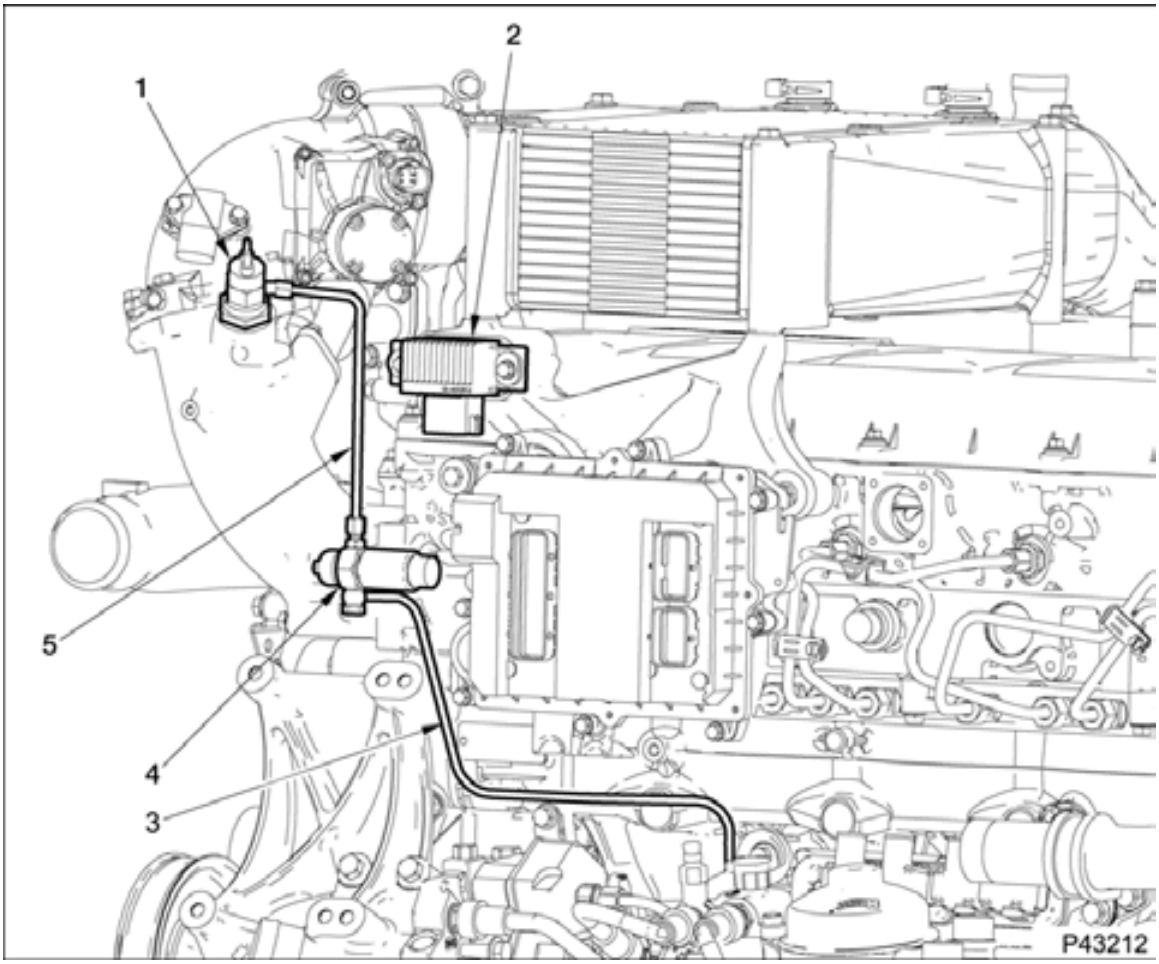

Figure 26 Cold start assist system

1. Glow plug
2. Cold Start Relay (CSR)
3. Cold start supply tube
4. Cold Start Solenoid (CSS) valve
5. MV-glow plug fuel line

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Glow Plug

The glow plug is connected to the MV-glow plug fuel line. The function of the glow plug is to heat the intake air by vaporizing and igniting fuel in the air inlet duct.

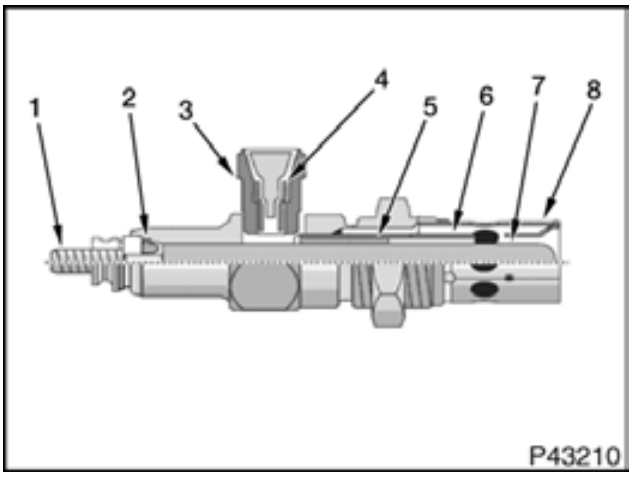

Figure 27 Glow plug

1. Electrical connection
2. Insulation
3. MV-glow plug fuel line connection
4. Metering device
5. Vaporizer filter
6. Vaporizer tube
7. Heater element
8. Protective sleeve

The glow plug has an internal fuel metering device, a vaporizer filter, a vaporizer tube, a heater element, and a protective sleeve. The protective sleeve has holes that allow enough air to pass through the glow plug to enable the fuel vaporization and combustion.

The glow plug is installed on the left front side of the engine in the air inlet duct.

Cold Start Relay (CSR)

The CSR is located on the left side of the engine above the Engine Control Module (ECM). The CSR provides voltage to the glow plug and is controlled by the Engine Interface Module (EIM).

Cold Start Solenoid (CSS) Valve

The CSS valve is located on the left side of the engine and is controlled by the EIM. The CSS valve is supplied with low fuel pressure regulated fuel from the fuel filter housing assembly through the cold start supply tube.

When the EIM provides battery voltage to the CSS valve, the solenoid opens and allows fuel to flow to the glow plug through the MV-glow plug fuel line.

Cold Start Assist System Operation

The cold start assist system operates only in temperatures lower than 11°C (52°F).

When the truck operator turns the ignition switch to ON, the wait-to-start lamp in the instrument cluster illuminates. Based on the temperature readings from the Engine Coolant Temperature (ECT), Engine Oil Temperature (EOT), and the Intake Air Temperature (IAT) sensors, the EIM activates the Cold Start Relay (CSR). The CSR then energizes the glow plug for approximately 45 seconds.

Once the glow plug is heated to approximately 1000°C (1832°F), the wait-to-start lamp starts to flash and the operator needs to crank the engine. When the engine starts rotating, the CSS valve opens and allows fuel to enter the glow plug through the MV-glow plug fuel line. Inside the glow plug, the fuel passes through the vaporizer tube. The vaporized fuel then mixes with the intake air and ignites in contact with the heater element.

Once the engine starts, the glow plug remains energized and fuel continues to be injected to the glow plug, and the wait-to-start lamp continues to flash for a maximum of 4 minutes. When the wait-to-start lamp stops flashing, the glow plug and the CSS valve are deactivated. If the operator accelerates while the wait-to-start lamp flashes, the cold start assist system will shutdown.

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Electronic Control System

Electronic Control System Components

The International® MaxxForce® 11 and 13 engines are equipped with three control modules; Engine Control Module (ECM), Engine Interface Module (EIM) and Aftertreatment Control Module (ACM).

Operation and Function

The control modules monitor and control engine performance to ensure maximum performance and adherence to emissions standards. The ECM, EIM, and ACM perform the following functions:

- Provide reference voltage (VREF)
- Condition input signals
- Process and store control strategies
- Control actuators

Reference Voltage (VREF)

The control modules supply 5 volt VREF signals to input sensors in the electronic control system. By comparing the 5 volt VREF signal sent to the sensors with their respective returned signals, the control modules determine pressures, positions, and other variables important to engine and vehicle functions.

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 control modules microprocessors can process.

Microprocessor

The control modules microprocessors store operating instructions (control strategies) and value tables (calibration parameters). The control modules compare stored instructions and values with conditioned input values to determine the correct strategy for all engine operations.

Continuous calculations in the control modules occur in the foreground and background.

- Foreground calculations are 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 slower rates. Engine temperature is an example.

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

Diagnostic strategies are also programmed into the control modules. Some strategies monitor inputs continuously and command the necessary outputs for 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 when the ignition switch is turned to OFF or when power to the control modules 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 switch is turned to OFF or power to control module is interrupted. RAM information includes the following:

- Engine temperature
- Engine rpm
- Accelerator pedal position

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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 one of the following ways, depending upon type of actuator:

- Duty cycle (percent time on/off)
- Controlled pulse width
- Switched on or off
- CAN messages

Actuators

Control modules control engine operation with the following:

- Coolant Mixer Valve (CMV)
- Coolant Flow Valve (CFV)
- Retarder control
- Exhaust Gas Recirculation (EGR) control valve
- Exhaust Gas Recirculation Position (EGRP) sensor
- Boost Control Solenoid (BCS) valve
- Cold Start Relay (CSR)
- Cold Start Solenoid (CSS) valve
- Intake Throttle Valve (ITV)
- Fuel Pressure Control Valve (FPCV)

Coolant Mixer Valve (CMV) and Coolant Flow Valve (CFV)

The CMV and CFV are a combined solenoid assembly that regulate coolant flow and temperature through the Charge Air Coolers (CACs).

CFV controls the rate of coolant flow through the CACs and CMV regulates the temperature of the coolant, by directing the coolant either through the low temperature radiator or through an internal bypass. Both valves are controlled by the ECM.

The CMV and CFV are mounted on the Coolant Control Valve (CCV), which is located on the right side of the front cover.

Retarder Control

The retarder control is a proportional valve with integrated exhaust back pressure sensor that controls the butterfly valve in the retarder exhaust manifold.

The retarder control regulates the amount of air pressure applied to the pneumatic cylinder. The pneumatic cylinder actuates the engine retarder butterfly valve in the exhaust system in response to commands by the ECM.

The retarder control is mounted on a bracket on the lower right side of the engine, near the front.

Exhaust Gas Recirculation (EGR) Control Valve

The EGR control valve controls the EGR throttle valve.

The EGR control valve receives the desired EGR position from the ECM to activate the EGR throttle valve for exhaust gas recirculation. The EGR control valve then regulates the amount of air pressure applied to the pneumatic actuator that controls the flow of exhaust gases through the EGR system.

The EGR control valve is mounted to the EGR module on top of the engine.

Exhaust Gas Recirculation Position (EGRP) Sensor

The EGRP sensor monitors the position of the EGR throttle valve.

The closed loop control system uses the EGR position signal. The ECM monitors the EGRP signal and determines the amount of air pressure the EGR control valve should then provide to the EGR throttle valve actuator.

The EGRP sensor is contained within the EGR throttle valve actuator on the right side of the EGR module at the top right side of the engine. The EGRP sensor is not serviced individually.

Boost Control Solenoid (BCS) Valve

The BCS valve controls the boost control actuator on the high pressure turbocharger.

The BCS valve either applies air pressure to the boost control actuator, or vents system pressure to the atmosphere, in response to commands from the ECM.

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The BCS valve is mounted on a bracket on the lower right side of the engine, near the front.

Cold Start Relay (CSR)

The cold start assist system aids cold engine starting by warming the incoming air supply prior to, and during, cranking.

The EIM is programmed to energize the glow plug elements through the CSR while monitoring certain programmed conditions for engine coolant temperature, intake air temperature, engine oil temperature, and atmospheric pressure.

The EIM activates the CSR. The relay delivers battery voltage (VBAT) to the heater element for a set time, depending on engine coolant temperature and altitude. The ground circuit is supplied directly from the battery ground at all times. The relay is controlled by switching on a voltage source from the EIM.

Cold Start Solenoid (CSS) Valve

The CSS valve controls the fuel flow to the glow plug during cold start assist operation.

When the cold start assist is required, the EIM provides voltage to open the CSS valve during cranking.

The CSS valve is mounted on the air inlet duct on the top left side of the engine.

Intake Throttle Valve (ITV)

The ITV is a variable position actuator that restricts intake air flow by way of an internal butterfly valve to help heat the exhaust aftertreatment during regeneration, and to assist when heavy EGR is requested.

The ITV changes butterfly valve position in response to ECM signals. The ITV contains an internal position sensor that monitors butterfly valve position and transmits a position signal to the ECM.

The ITV is mounted on the air inlet duct on the top front of the engine.

Fuel Pressure Control Valve (FPCV)

The FPCV is a variable position actuator that regulates fuel pressure in the pressure pipe rail.

The FPCV changes valve position through pulse width modulated signals from the ECM. It controls the flow of fuel to the suction side of the high pressure pump.

The FPCV is mounted on the upper side of the high pressure pump. They are serviced as an assembly.

Engine and Vehicle Sensors

Thermistor Sensor

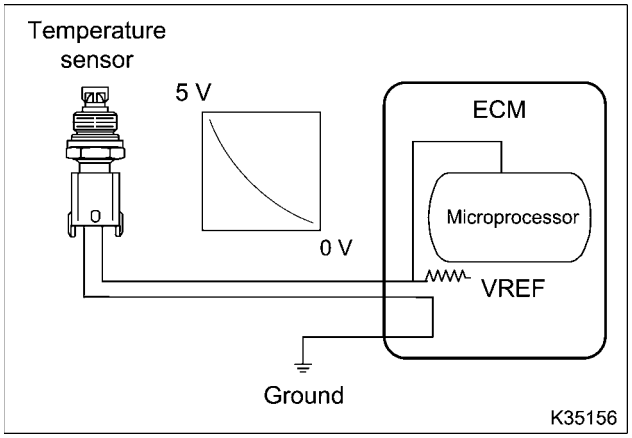

Figure 28 Thermistor

A thermistor sensor changes 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 control module to a voltage signal matched with a temperature value.

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

Thermistor type sensors include the following:

- Aftertreatment temperature sensors
- Engine Coolant Temperature (ECT) sensors
- Engine Oil Temperature (EOT) sensor
- Intake Air Temperature (IAT) sensor
- Manifold Absolute Pressure/ Intake Air Temperature 2 (MAP/IAT2) Sensor
- Manifold Air Temperature (MAT) sensor

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Aftertreatment Temperature Sensors

Three sensors used in the Aftertreatment System include the following:

- Exhaust Gas Temperature 1 (EGT1) sensor
- EGT2 sensor
- EGT3 sensor

The EGT1 sensor provides a feedback signal to the Aftertreatment Control Module (ACM) indicating Diesel Oxidation Catalyst (DOC) inlet temperature. The EGT1 sensor is the first temperature sensor installed past the turbocharger and just before the DOC.

The EGT2 sensor provides a feedback signal to the ACM indicating Diesel Particulate Filter (DPF) inlet temperature. The EGT2 sensor is the second temperature sensor installed past the turbocharger and just after the DOC.

The EGT3 sensor provides a feedback signal to the ACM indicating DPF outlet temperature. The EGT3 sensor is the third temperature sensor installed past the turbocharger and just after the DPF.

During a catalyst regeneration, the ACM and the ECM monitor all three sensors along with the EGR system and ITV.

Engine Coolant Temperature (ECT) Sensor

The ECT sensor is a thermistor sensor that detects engine coolant temperature.

This engine has two ECT sensors. The ECT sensor is installed in the underside of the EGR coolant elbow at the back of the engine. The ECT2 sensor is installed in the Charge Air Cooler (CAC) coolant return pipe on the upper right side of the engine.

The ECT and ECT2 signals are monitored by the ECM for operation of the instrument panel temperature gauge, coolant temperature compensation, charge air temperature control, optional Engine Warning Protection System (EWPS), and the wait to start lamp. The ECM uses ECT sensor input as a backup, if EOT sensor values are out of range.

Engine Oil Temperature (EOT) Sensor

The EOT sensor is a thermistor sensor that detects engine oil temperature.

The EOT signal is monitored by the ECM for cold start assist, EGR valve control, and engine fueling calculations.

The EOT sensor is installed in the side of the oil module, on the right side of the engine.

Intake Air Temperature (IAT) Sensor

The Engine Interface Module (EIM) monitors the IAT signal to control injector timing and fuel rate during cold starts. The IAT signal is also used to control EGR position and intake throttle control. The IAT sensor is installed in the intake tube next to the air cleaner, on top of the engine.

Manifold Absolute Pressure/Intake Air Temperature 2 (MAP/IAT2) Sensor

The MAP/IAT2 sensor is used to measure the absolute charge-air pressure and intake air temperature.

The MAP/IAT2 sensor is installed in the ITV on top of the engine.

Manifold Air Temperature (MAT) Sensor

The MAT sensor is a thermistor sensor that monitors the temperature of recirculated exhaust gas.

EGR operation is shut down under certain temperature conditions, to prevent sulphurous acids from condensing under cold charge-air temperatures and to protect the engine from excessively hot intake air in the event of an EGR fault.

The MAT sensor is installed in the intake channel of the cylinder head, on the left side of the engine.

Variable Resistance Sensor

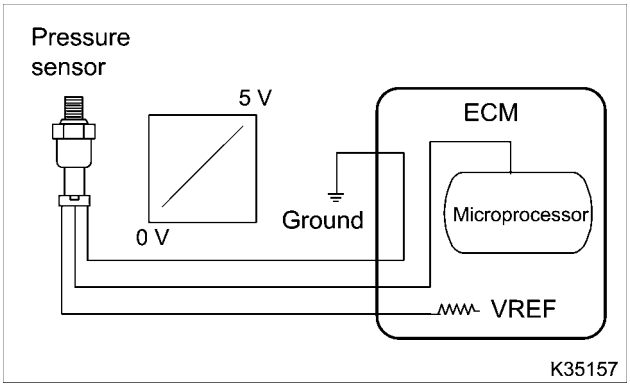

Figure 29 Variable resistance sensor

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Variable resistance 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 resistance of the sensor.

The sensor is connected to the control module through the VREF, signal, and signal ground wires.

The sensor receives the VREF and returns an analog signal voltage to the control module. The control module compares the voltage with pre-programmed values to determine pressure.

Variable resistance sensors include the following:

- Exhaust Gas Differential Pressure (EGDP) sensor
- Engine Fuel Pressure (EFP) sensor
- Engine Oil Pressure (EOP) sensor
- Fuel Rail Pressure (FRP) sensor

Exhaust Gas Differential Pressure (EGDP) Sensor

The EGDP sensor provides a feedback signal to the Aftertreatment Control Module (ACM) indicating the pressure difference between the inlet and outlet of the particulate filter. During a catalyst regeneration, the ACM and the ECM monitor this sensor along with three aftertreatment system thermistor sensors, the EGR system, and the ITV.

The EGDP sensor is a differential pressure sensor with two tap-offs installed past the turbocharger. A tap-off is located before and after the DPF.

Engine Fuel Pressure (EFP) Sensor

The EFP sensor is a variable resistance sensor that measures fuel supply pressure.

The EFP sensor provides feedback to the ECM for the low pressure fuel system.

The EFP sensor is installed in the front of the fuel filter housing assembly on the left side of the engine.

Engine Oil Pressure (EOP) Sensor

The EOP sensor is a variable resistance sensor that detects engine oil pressure.

The EOP signal is monitored by the ECM for operation of the instrument panel pressure gauge and optional EWPS.

The EOP sensor is installed in the side of the oil module, on the right side of the engine.

Fuel Rail Pressure (FRP) Sensor

The FRP sensor is a variable resistance sensor that monitors the fuel pressure in the pressure pipe rail.

The FRP sensor measures the fuel pressure just prior to injection.

The FRP sensor is mounted in the front of the pressure pipe rail on the left side of the engine.

Magnetic Pickup Sensor

A magnetic pickup sensor contains a permanent magnet core that is surrounded by a coil of wire. The sensor generates a voltage signal through the collapse of a magnetic field that is created by a moving metal trigger. The movement of the trigger then creates an AC voltage in the sensor coil.

Magnetic pickup sensors used include the following:

- Crankshaft Position (CKP) sensor
- Camshaft Position (CMP) sensor
- Vehicle Speed Sensor (VSS)

Crankshaft Position (CKP) Sensor

The CKP sensor is a magnetic pickup sensor that indicates crankshaft speed and position.

The CKP sensor sends a pulsed signal to the Engine Control Module (ECM) as the crankshaft turns. The CKP sensor reacts to a 60 tooth timing disk machined into the flywheel. For crankshaft position reference, 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 sensor is installed in the top left of the flywheel housing.

Camshaft Position (CMP) Sensor

The CMP sensor is a magnetic pickup sensor that indicates camshaft speed and position.

The CMP sensor sends a pulsed signal to the ECM as a toothed wheel on the camshaft rotates past the CMP sensor. The ECM calculates camshaft speed and position from CMP signal frequency.

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The CMP sensor is installed in the left rear of the cylinder head.

Vehicle Speed Sensor (VSS)

The VSS provides the EIM 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 EIM, is used with tire size and axle ratio to calculate vehicle speed. The VSS is located on the left side of the transmission housing for automatic transmissions, or at rear of the transmission housing for manual transmissions.

Potentiometer

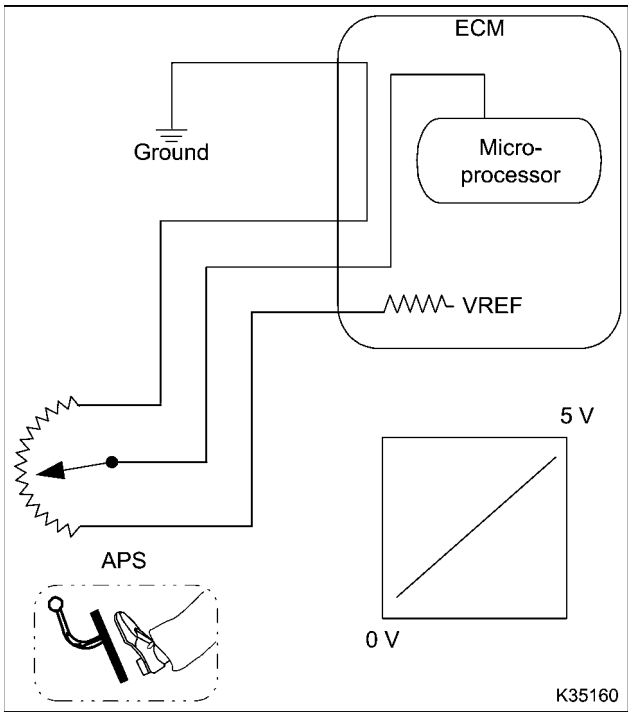

Figure 30 Potentiometer

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.

The engine has one potentiometer, the Accelerator Position Sensor (APS).

Accelerator Position Sensor (APS)

The APS provides the EIM with a feedback signal (linear analog voltage) that indicates the operator's demand for power. The APS is installed in the cab on the accelerator pedal.

Switches

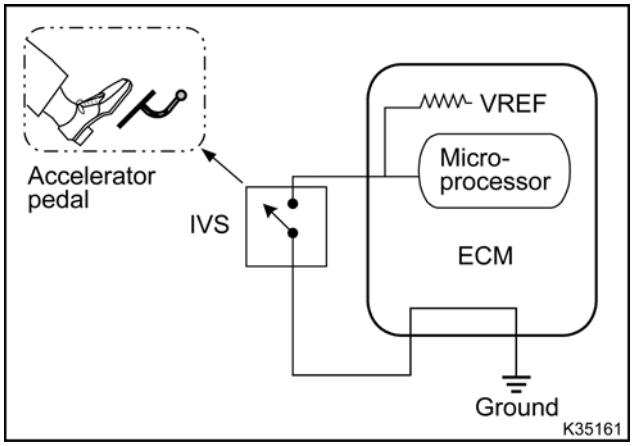

Figure 31 Switch

Switch sensors indicate position, level, or status. They operate open or closed, regulating the flow of current. A switch sensor can be a voltage input switch or a grounding switch. A voltage input switch supplies the control module 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.

Switches include the following:

- Driveline Disengagement Switch (DDS)
- Engine Coolant Level (ECL)
- Idle Validation Switch (IVS)

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 or datalink communication functions as the DDS.

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Engine Coolant Level (ECL) Switch

The ECL switch is part of the Engine Warning Protection System (EWPS). The ECL switch is located on the deaeration tank. When the magnetic switch is open, the tank is considered full of coolant.

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

Idle Validation Switch (IVS)

The IVS is a redundant switch that provides the Engine Interface Module (EIM) with a signal that verifies when the APS is in the idle position. The IVS is located on the APS.

Exhaust Lambda Sensor (ELS)

The ELS monitors oxygen levels in exhaust gases.

The ELS is used to tune the engine operation to a specified air-to-fuel ratio in the exhaust.

The ELS compares oxygen levels in the exhaust stream with oxygen levels in the outside air. It then generates a voltage that is transmitted to the ECM. The level of voltage generated by the ELS corresponds to the oxygen levels in the exhaust stream.

The ELS is installed in the turbo exhaust pipe, directly after the exhaust valve with butterfly.

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Mounting 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, make sure 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.

Engine Cleaning

1. Using Disposable Air and Fuel Caps (page 58), cover all engine openings to prevent water and degreasing agents from entering engine.
2. Cover exposed electrical connectors and the Electronic Control Module (ECM) using plastic and duct tape.
3. Use an appropriate detergent mixed in the correct ratio as described on the detergent directions and apply to engine using a hot pressure washer or similar cleaning equipment.

Mounting Engine on Stand

NOTE: Before mounting engine on engine stand, complete steps 1 through 6.

1. Drain coolant by disconnecting lowest cooler line from air compressor.

WARNING: To prevent personal injury or death, dispose of oil or discard components, according to applicable regulations.

2. Remove oil pan drain plug and drain oil into a suitable container.
3. Inspect oil pan drain plug O-ring. Discard and replace if damaged.
4. After oil is drained, lubricate oil pan drain plug O-ring with clean engine oil and install oil pan drain plug.
5. Tighten oil pan drain plug to special torque (page 58).
6. Remove Retarder Control (page 126).
7. Remove Pressure Line (page 124).
8. Remove Boost Control Solenoid (BCS) valve (page 142).

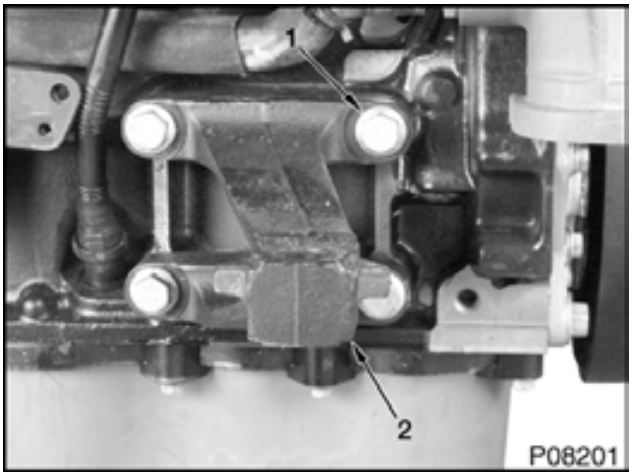

Figure 32 Engine support

1. M14 x 50 hex bolt (4)
2. Engine support

NOTE: For reinstallation of engine support, tighten M14 x 50 hex bolts to special torque (page 58).

9. Remove four M14 x 50 hex bolts and right engine support.

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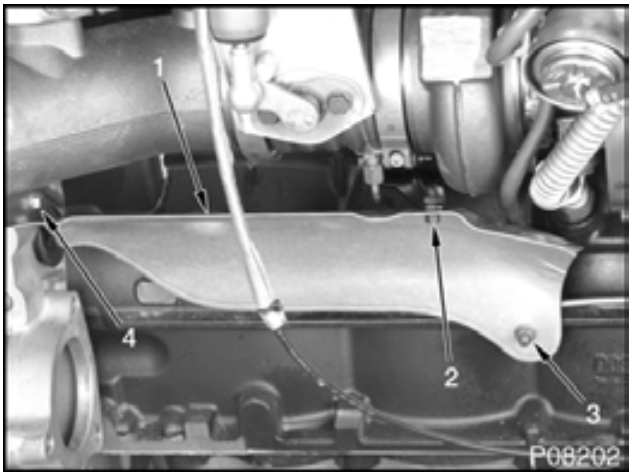

Figure 33 Heat starter shield

1. Heat starter shield
2. M8 x 16 bolt
3. M8 hex nut
4. M8 x 16 bolt

NOTE: For reinstallation of heat starter shield, tighten two M8 x 16 bolts and one M8 hex nut to standard torque (page 457).

10. Remove two M8 x 16 bolts, one M8 hex nut and heat starter shield.

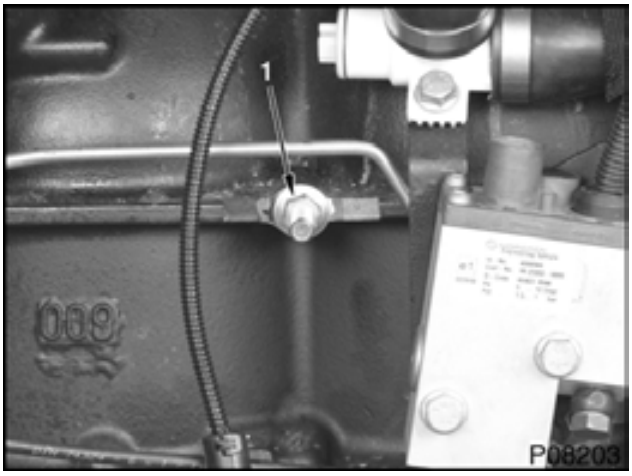

Figure 34 Stud bolt

1. Stud bolt

NOTE: For reinstallation of stud bolt, tighten stud bolt to standard torque (page 457).

11. Remove stud bolt from crankcase.

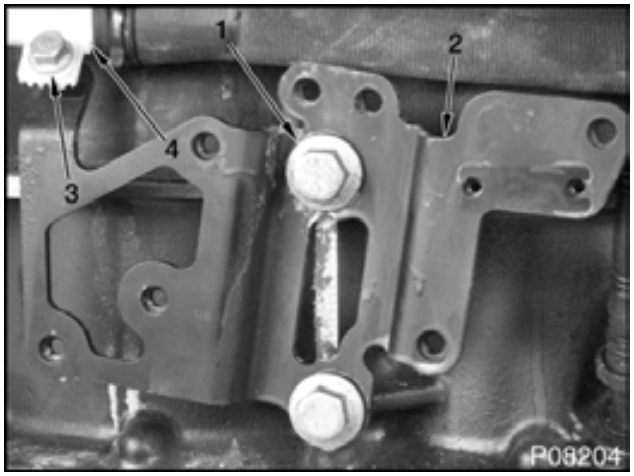

Figure 35 Bracket

1. M14 x 25 hex bolt (2)
2. Bracket
3. M8 x 16 hex bolt
4. Coolant pipe CAC-return

NOTE: For reinstallation of coolant pipe CAC-return, tighten M8 x 16 to standard torque (page 457).

12. Remove M8 x 16 hex bolt and position coolant pipe CAC-return aside.

NOTE: For reinstallation of bracket, tighten two M14 x 25 hex bolts to standard torque (page 457).

13. Remove two M14 x 25 hex bolts and bracket.

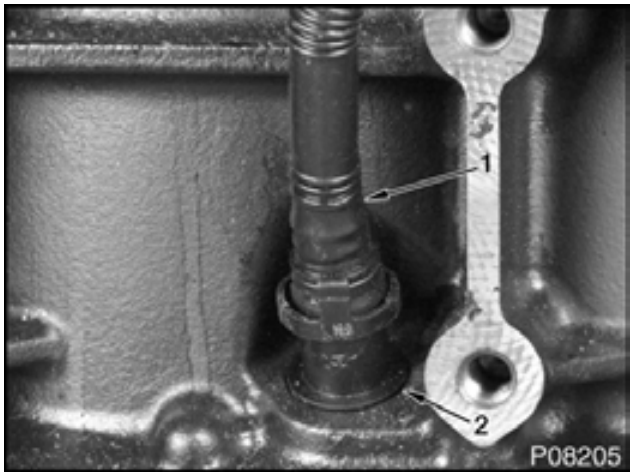

Figure 36 Oil return tube

1. Oil return tube
2. Crankcase oil drain tube

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14. Squeeze tabs on oil return tube to disconnect from crankcase oil drain tube and position aside.

⚠ 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.

15. Attach hoist hook lifting bracket to engine lifting eyes. Use safety catches on hoist hooks when lifting engine.

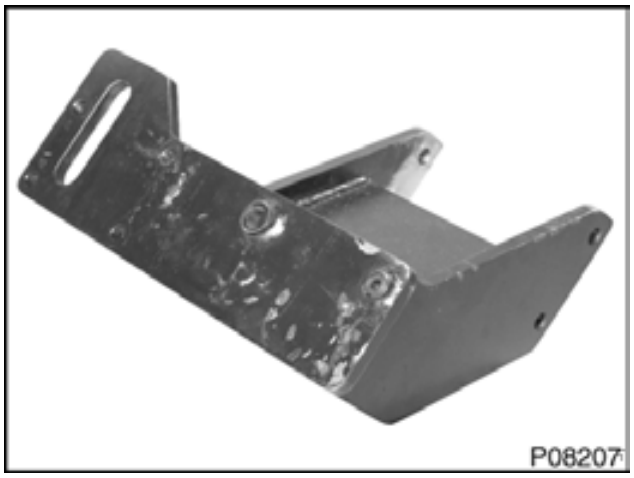

Figure 37 Engine Stand Mounting Bracket

⚠ WARNING: To prevent personal injury or death, use only grade 8 or class 10.9 bolts to secure Engine Stand Mounting Bracket to engine and engine lift stand.

NOTE: See manufacturer's safety instructions (included with engine lift stand and Engine Stand Mounting Bracket).

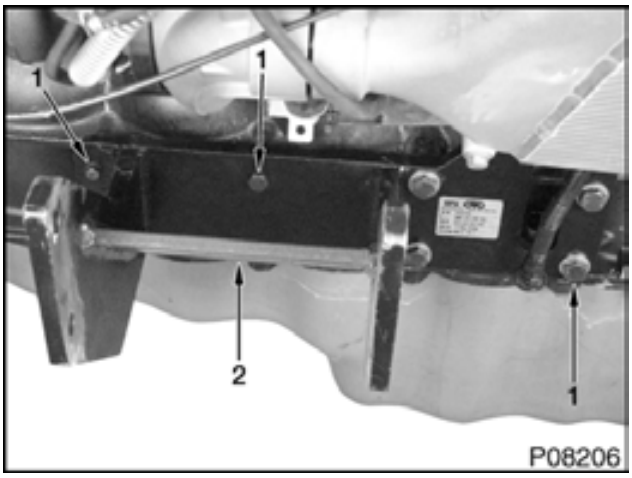

Figure 38 Engine Stand Mounting Bracket

1. Hex bolt (part of ZTSE4789)
2. Engine Stand Mounting Bracket

16. Position Engine Stand Adapter Plate (page 58) on right side of engine. Secure bracket plate with six mounting bolts and washers (part of Engine Stand Mounting Bracket). Tighten bolts to standard torque (page 457).
17. Mount engine on engine lift stand using four grade 8 5/8 x 1.5 inch mounting bolts. Tighten bolts to standard torque (page 457).

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Special Torque

Table 1 Mounting Engine on Stand

Oil pan drain plug	75 N·m (55 lbf·ft)
Engine support hex bolts	230 N·m (170 lbf·ft)

Special Service Tools

Table 2 Mounting Engine on Stand

Description	Tool Number
Engine Stand Adapter Plate	ZTSE4789
Disposable Air and Fuel Caps	ZTSE4891

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Engine Electronic Components

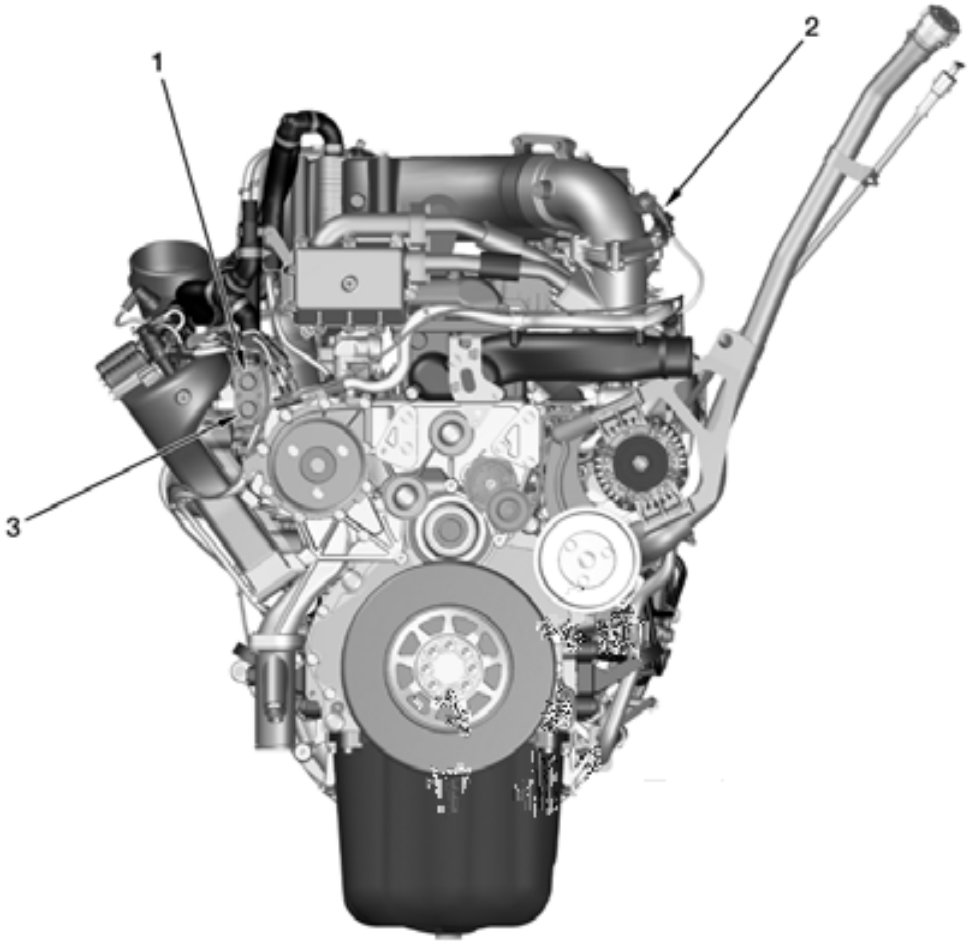

Figure 39 Electronic components – front

1. Coolant Mixer Valve (CMV)
2. Manifold Absolute Pressure/Intake Air Temperature 2 (MAP/IAT2) sensor
3. Coolant Flow Valve (CFV)

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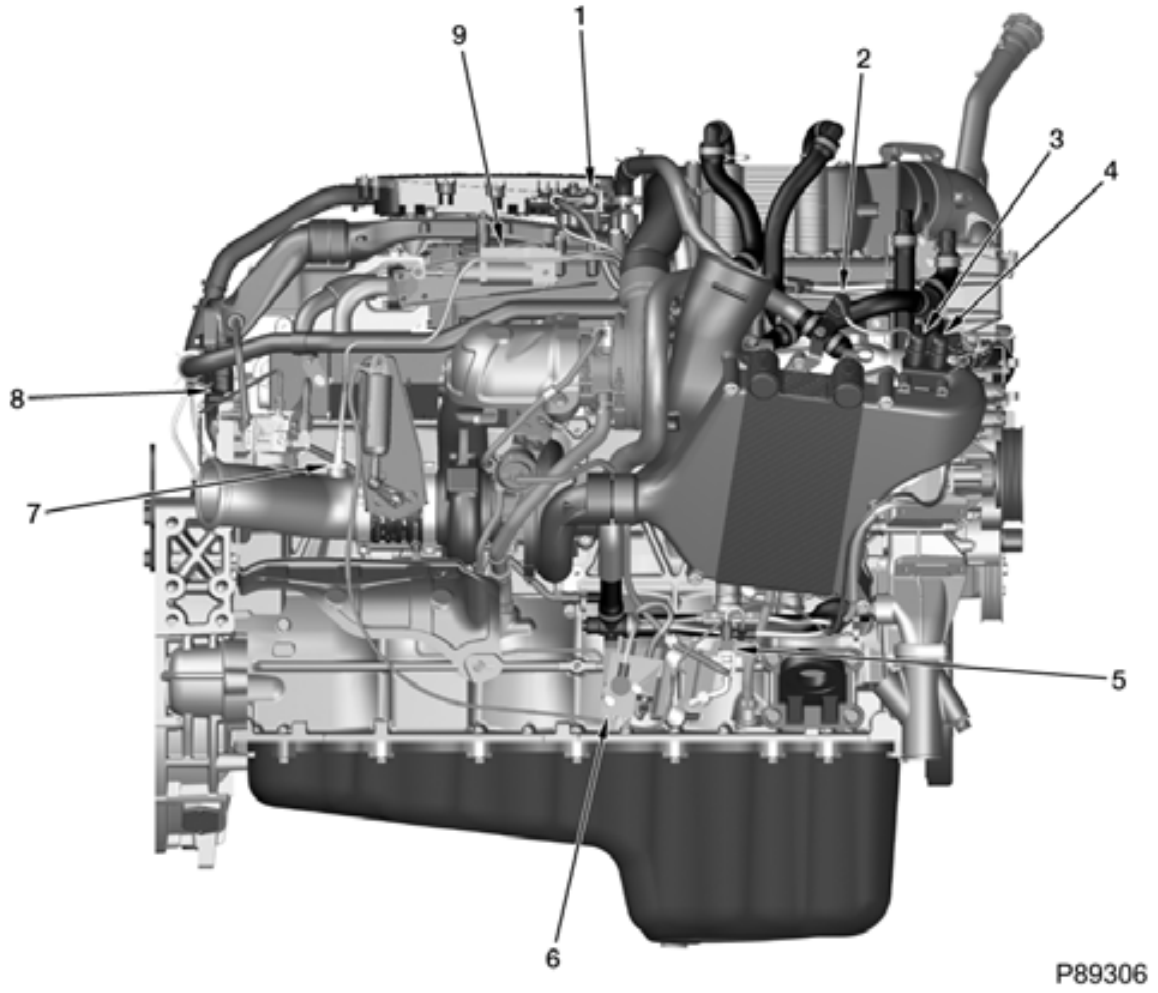

Figure 40 Electronic components – right

1. Exhaust Gas Recirculation (EGR) valve
2. Engine Coolant Temperature 2 (ECT2) sensor
3. Engine Oil Pressure (EOP) sensor adapter line
4. Engine Oil Temperature (EOT) sensor adapter line
5. Boost Control Solenoid (BCS) valve
6. Retarder Control
7. Exhaust Lambda Sensor (ELS)
8. Engine Coolant Temperature (ECT) sensor
9. Exhaust Gas Recirculation Position (EGRP) sensor

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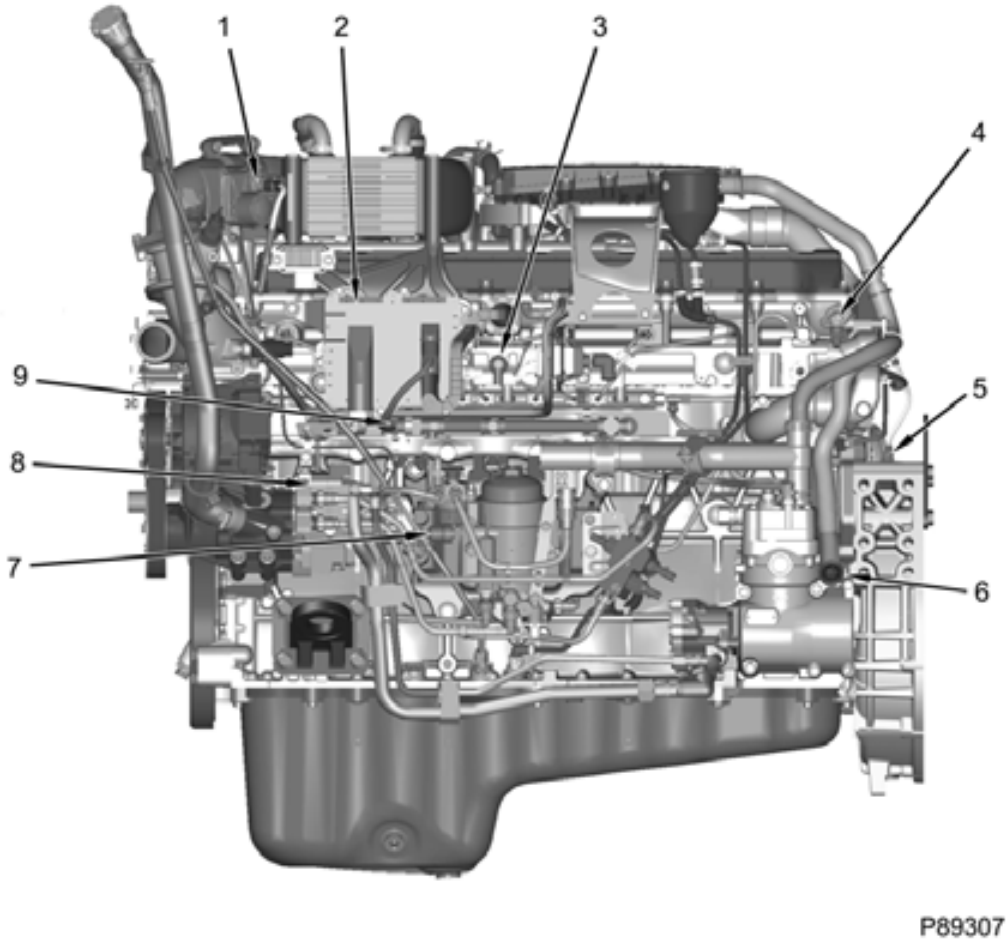

Figure 41 Electronic components – left

1. Intake Throttle Valve (ITV)
2. Engine Control Module (ECM)
3. Manifold Air Temperature (MAT) sensor
4. Camshaft Position (CMP) sensor
5. Crankshaft Position (CKP) sensor
6. Breather outlet heater assembly
7. Engine Fuel Pressure (EFP) sensor
8. Fuel Pressure Control Valve (FPCV)
9. Fuel Rail Pressure (FRP) sensor

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Main Engine Wiring Harness Attachment Points

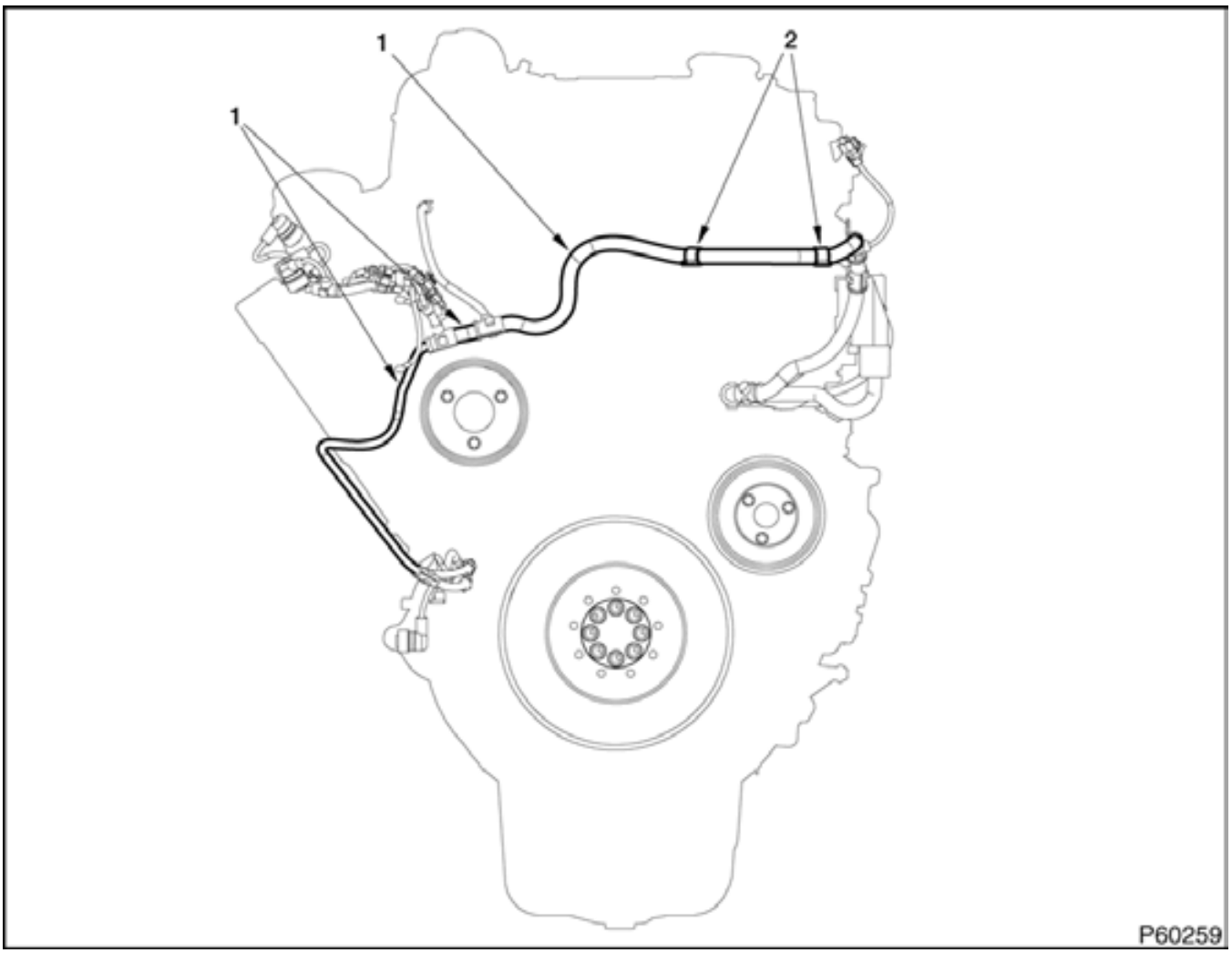

Figure 42 Wiring harness attachment points– front

1. Tie strap (3)
2. M4 x 16 hex bolt (2)

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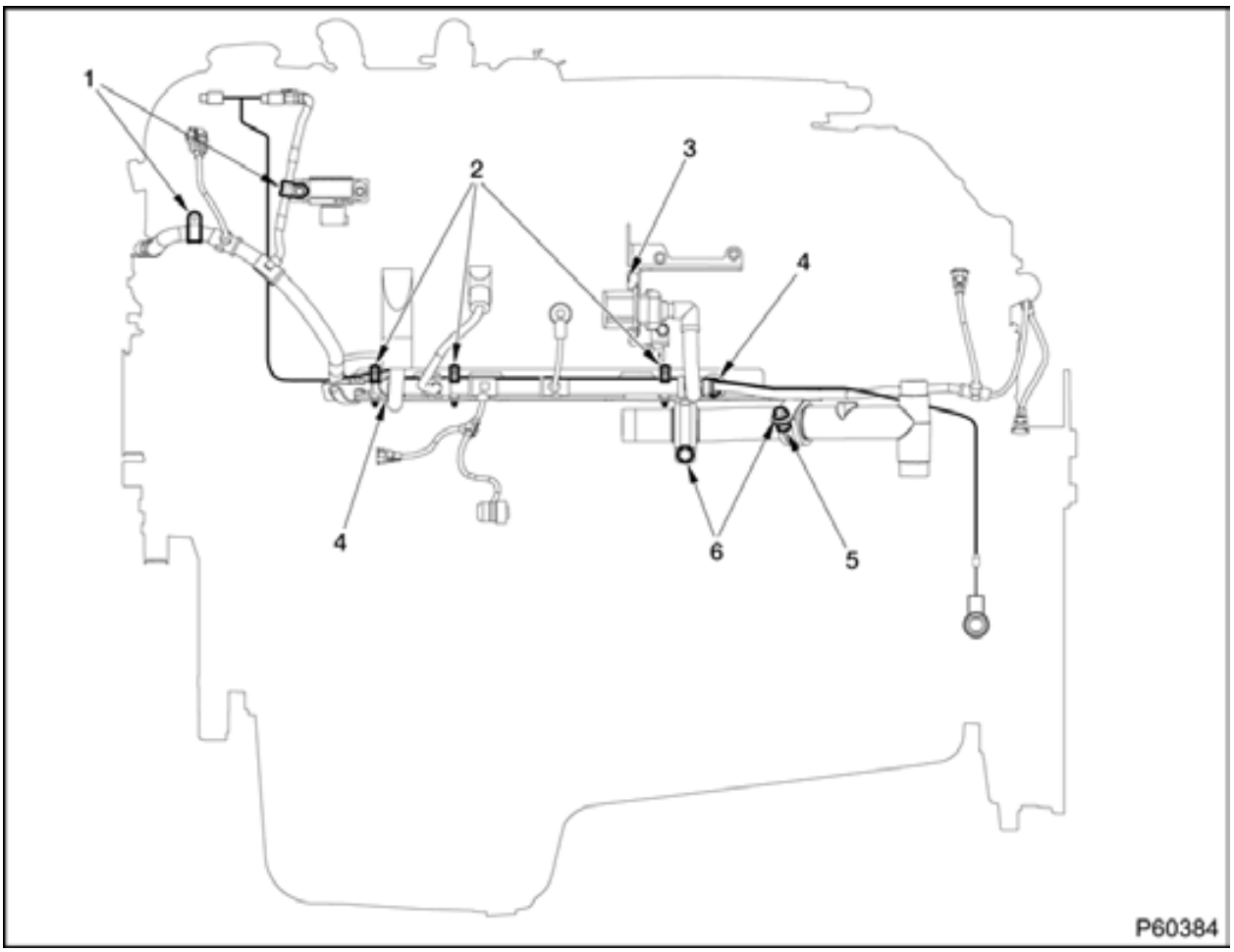

Figure 43 Wiring harness attachment points– left

1. M4 x 16 hex bolt (2)
2. Bracket for corrugated pipe (3)
3. ST4.8x13 tapping screw (4)
4. M8 x 16 hex bolt (2)
5. M10 hex nut
6. M10 x 25 hex bolt (2)

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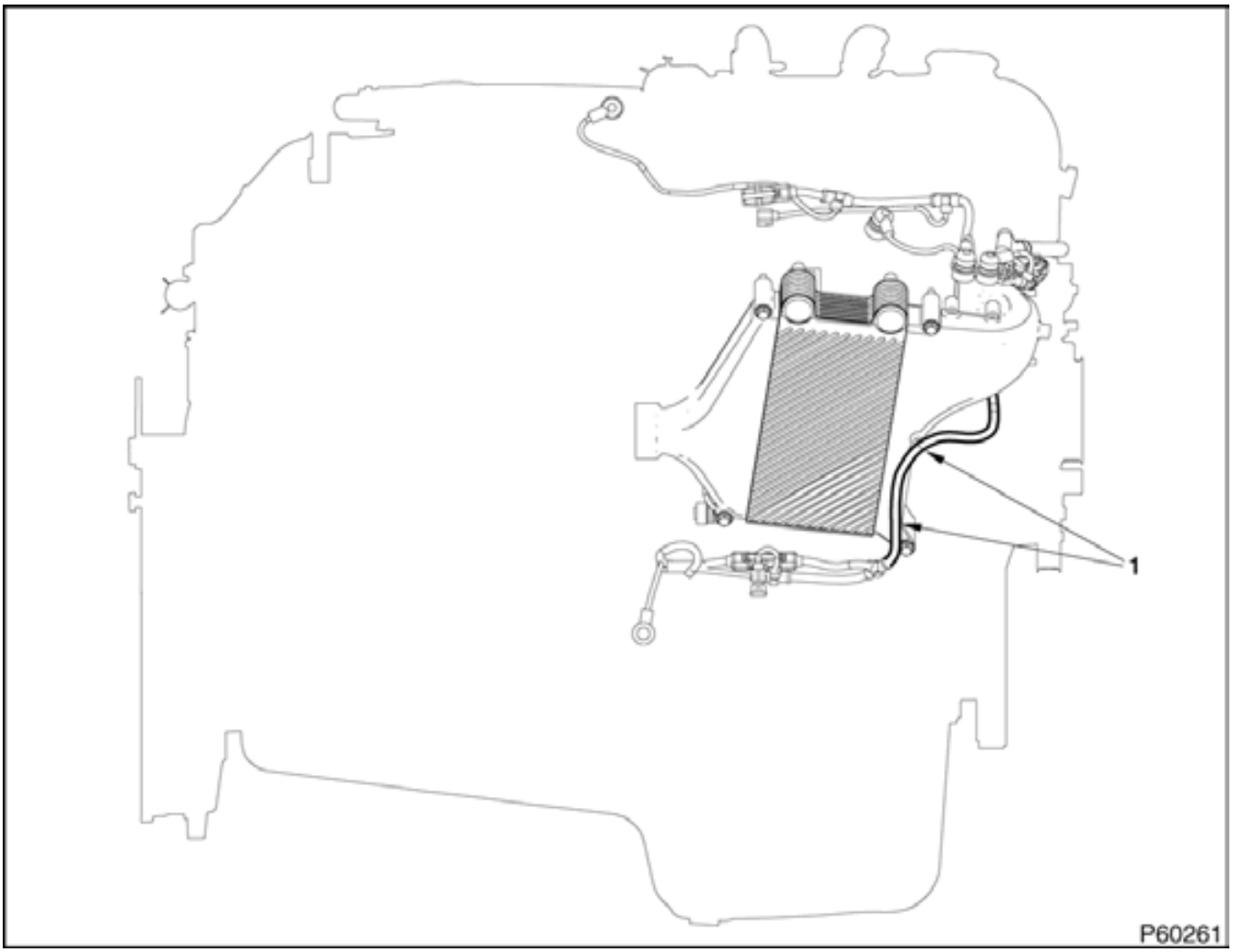

Figure 44 Wiring harness attachment points– right

1. Tie strap (2)

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Description of Engine Sensors, Valves, and Actuators

NOTE: Refer to the following publications for information on diagnostics and troubleshooting:

- EGES-420 International® MaxxForce® 11 and 13 *Diagnostic Manual*
- EGED-425 International® MaxxForce® 11 and 13 *Engine Performance Form*
- EGED-430 International® MaxxForce® 11 and 13 *Engine Wiring Diagram*
- EGED-435 International® MaxxForce® 11 and 13 *Signal Values* (available on ISIS® only)

Crankshaft Position (CKP) Sensor

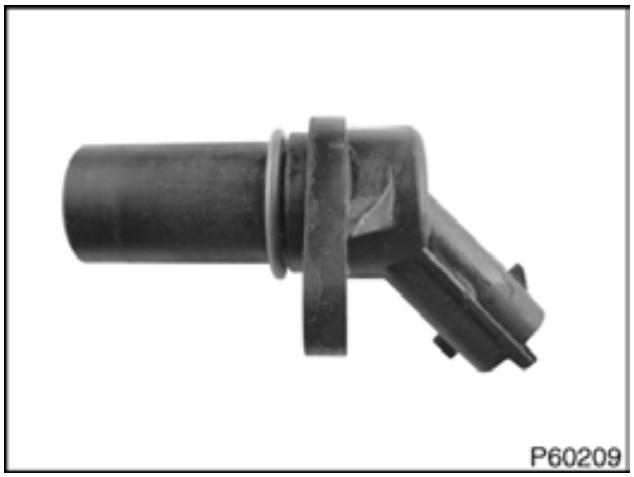

Figure 45 CKP sensor

The CKP sensor is a magnetic pickup sensor that indicates crankshaft speed and position.

The CKP sensor sends a pulsed signal to the Engine Control Module (ECM) as the crankshaft turns. The CKP sensor reacts to a 60 tooth timing disk machined into the flywheel. For crankshaft position reference, 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 sensor is installed in the top left of the flywheel housing.

Camshaft Position (CMP) Sensor

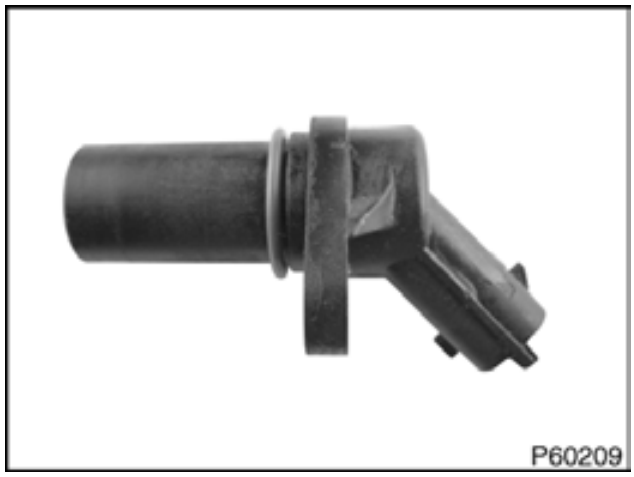

Figure 46 CMP sensor

The CMP sensor is a magnetic pickup sensor that indicates camshaft speed and position.

The CMP sensor sends a pulsed signal to the Engine Control Module (ECM) as a toothed wheel on the camshaft rotates past the CMP sensor. The ECM calculates camshaft speed and position from CMP signal frequency.

The CMP sensor is installed in the left rear of the cylinder head.

Engine Coolant Temperature (ECT) Sensor

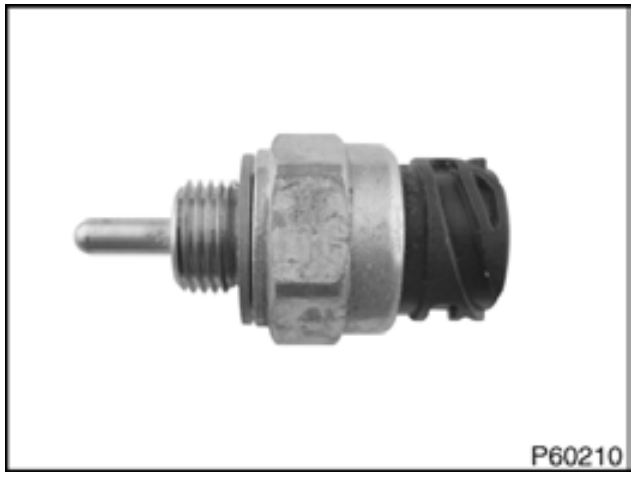

Figure 47 ECT sensor

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The ECT sensor is a thermistor sensor that detects engine coolant temperature.

The ECT and ECT2 signals are monitored by the ECM for operation of the instrument panel temperature gauge, coolant temperature compensation, charge air temperature control, optional Engine Warning Protection System (EWPS), and the wait to start lamp. The ECM uses ECT sensor input as a backup, if EOT sensor values are out of range.

This engine has two ECT sensors. The ECT sensor is installed in the underside of the EGR coolant elbow at the back of the engine. The ECT2 sensor is installed in the Charge Air Cooler (CAC) coolant return pipe on the upper right side of the engine.

Engine Oil Temperature (EOT) Sensor

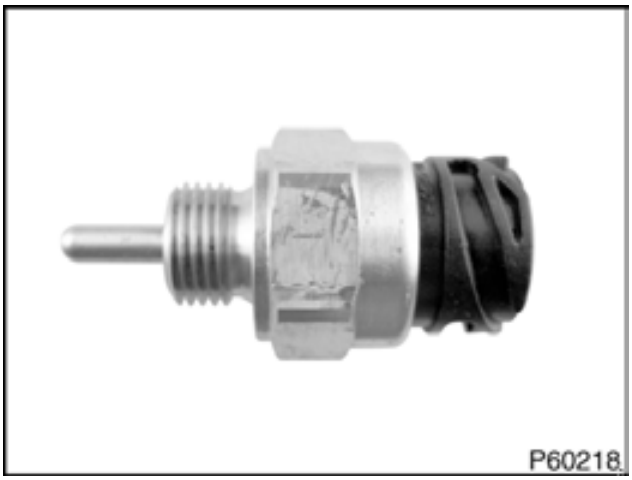

Figure 48 EOT sensor

The EOT sensor is a thermistor sensor that detects engine oil temperature.

The EOT signal is monitored by the ECM for cold start assist, EGR valve control, and engine fueling calculations.

The EOT sensor is installed in the side of the oil module, on the right side of the engine.

Engine Oil Pressure (EOP) Sensor

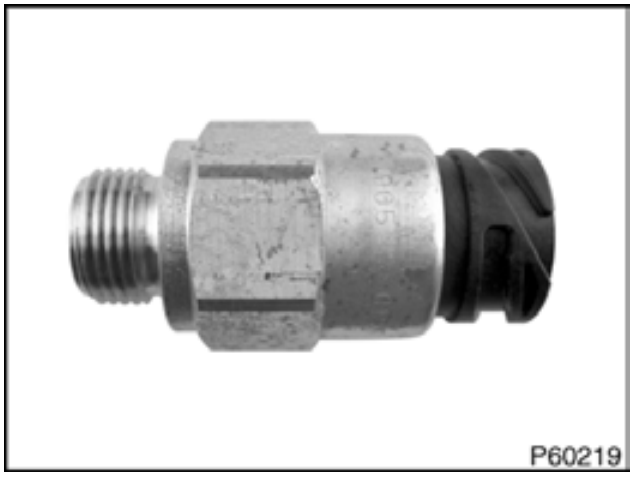

Figure 49 EOP sensor

The EOP sensor is a variable resistance sensor that detects engine oil pressure.

The EOP signal is monitored by the Engine Control Module (ECM) for operation of the instrument panel pressure gauge and optional Engine Warning Protection System (EWPS).

The EOP sensor is installed in the side of the oil module, on the right side of the engine.

Engine Fuel Pressure (EFP) Sensor

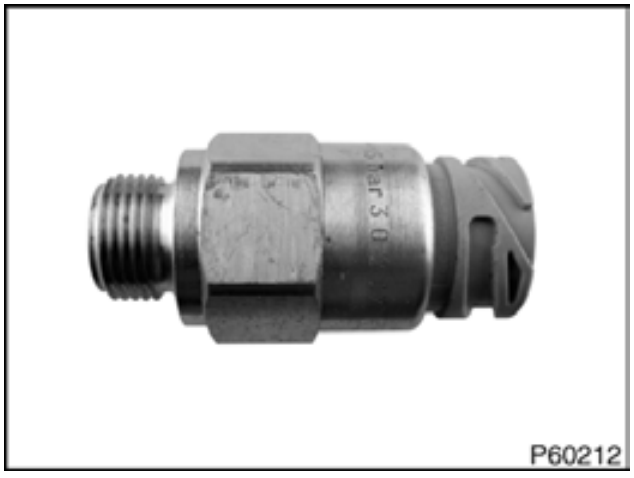

Figure 50 EFP sensor

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The EFP sensor is a variable resistance sensor that measures fuel supply pressure.

The EFP sensor provides feedback to the Engine Control Module (ECM) for the low pressure fuel system.

The EFP sensor is installed in the front of the fuel filter housing assembly on the left side of the engine.

Fuel Rail Pressure (FRP) Sensor

Figure 51 FRP sensor

The FRP sensor is a variable resistance sensor that monitors the fuel pressure in the pressure pipe rail. The FRP sensor measures the fuel pressure just prior to injection.

The FRP sensor is mounted in the front of the pressure pipe rail on the left side of the engine.

Manifold Absolute Pressure/Intake Air Temperature 2 (MAP/IAT2) Sensor

Figure 52 MAP/IAT2 sensor

The MAP/IAT2 sensor is used to measure the absolute charge-air pressure and intake air temperature.

The MAP/IAT2 sensor is installed in the Intake Throttle Valve (ITV) on top of the engine.

Manifold Air Temperature (MAT) Sensor

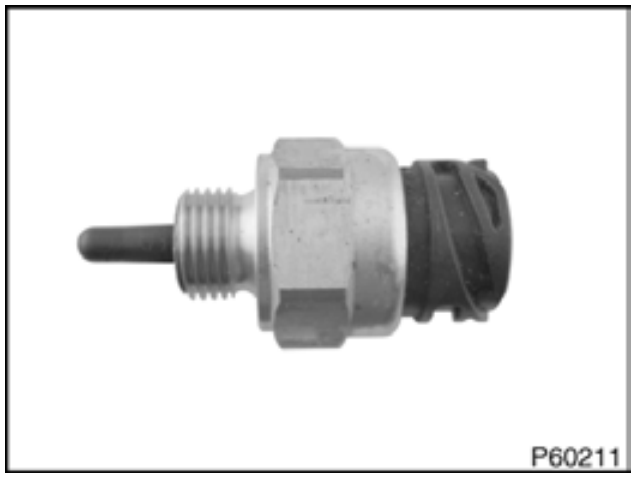

Figure 53 MAT sensor

The MAT sensor is a thermistor sensor that monitors the temperature of recirculation of exhaust gas.

Exhaust Gas Recirculation (EGR) system operation is shut down under certain temperature conditions,

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to prevent sulphurous acids from condensing under cold charge-air temperatures and to protect the engine from excessively hot intake air in the event of an EGR fault.

The MAT sensor is installed in the intake channel of the cylinder head, on the left side of the engine.

Exhaust Lambda Sensor (ELS)

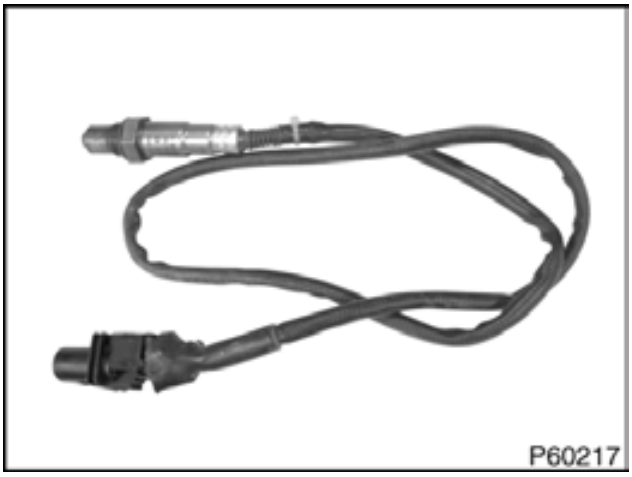

Figure 54 ELS

The ELS monitors oxygen levels in exhaust gases.

The ELS is used to tune the engine operation to a specified air to fuel ratio in the exhaust.

The ELS compares oxygen levels in the exhaust stream with oxygen levels in the outside air. It then generates a voltage that is transmitted to the Engine Control Module (ECM). The level of voltage generated by the ELS corresponds to the oxygen levels in the exhaust stream.

The ELS is installed in the turbo exhaust pipe, directly after the exhaust valve with butterfly.

Intake Throttle Valve (ITV)

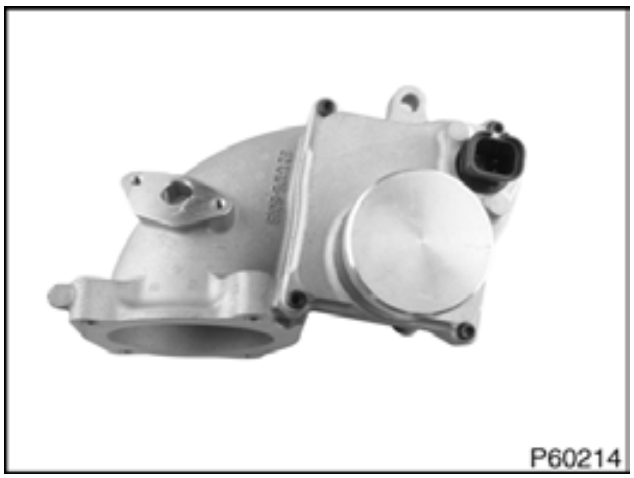

Figure 55 ITV

The ITV is a variable position actuator that restricts intake air flow by way of an internal butterfly valve to help heat the exhaust after treatment during regeneration and to assist when heavy EGR is requested.

The ITV changes butterfly valve position in response to Engine Control Module (ECM) signals. The ITV contains an internal position sensor that monitors butterfly valve position and transmits a position signal to the ECM. This sensor is part of the ITV and cannot be serviced separately.

The ITV is mounted on the air inlet duct on the top left front of the engine.

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Fuel Pressure Control Valve (FPCV)

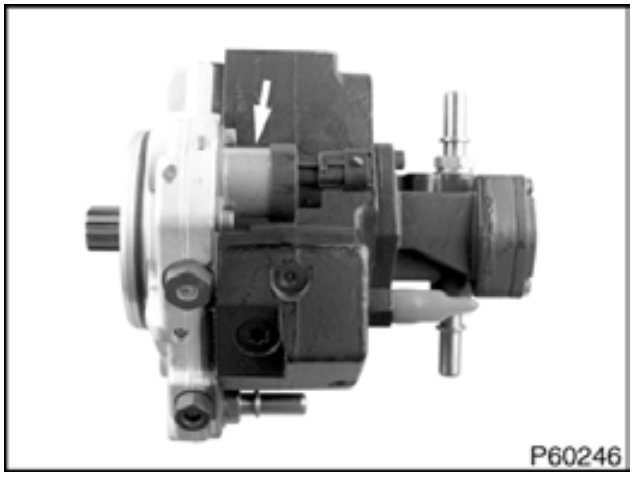

Figure 56 FPCV (part of high pressure pump)

The FPCV is a variable position actuator that regulates fuel pressure in the pressure pipe rail.

The FPCV changes valve position through pulse width modulated signals from the Engine Control Module (ECM). It controls the flow of fuel to the suction side of the high pressure pump.

The FPCV is mounted on the upper right side of the high pressure pump. They are serviced as an assembly.

Coolant Control Valve (CCV)

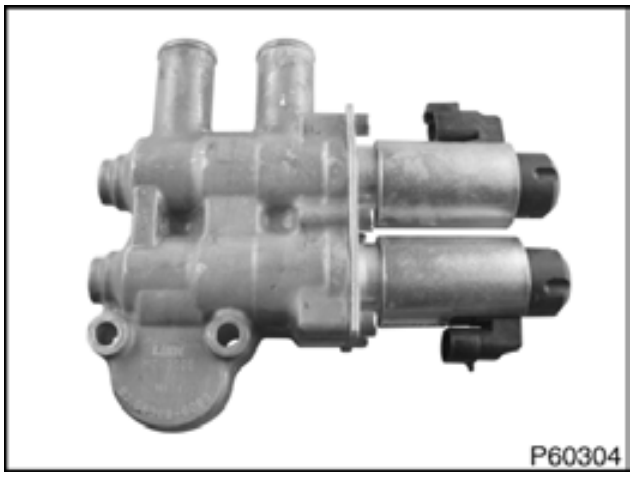

Figure 57 CCV

The CCV is a combined solenoid assembly that regulates coolant flow and temperature through the Low Pressure Charge Air Cooler (LPCAC) and High Pressure Charge Air Cooler (HPCAC).

The Coolant Flow Valve (CFV) controls the rate of coolant flow through the LPCAC and HPCAC. The Coolant Mixer Valve (CMV) regulates the temperature of the coolant, by directing the coolant either through the low temperature radiator or through an internal bypass. Both are controlled by the Engine Control Module (ECM).

The CCV is mounted on the right side of the front cover.

Retarder Control

Figure 58 Retarder control

The retarder control is a proportional valve with integrated exhaust back pressure sensor that measures exhaust back pressure and controls the engine retarder.

The retarder control monitors exhaust back pressure and relays this information to the Engine Control Module (ECM). It then controls the amount of air pressure applied to the pneumatic cylinder that actuates the butterfly valve located in the exhaust manifold in response to commands by the ECM.

The retarder control is mounted on a bracket on the lower right side of the engine, near the front.

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Exhaust Gas Recirculation (EGR) Control Valve

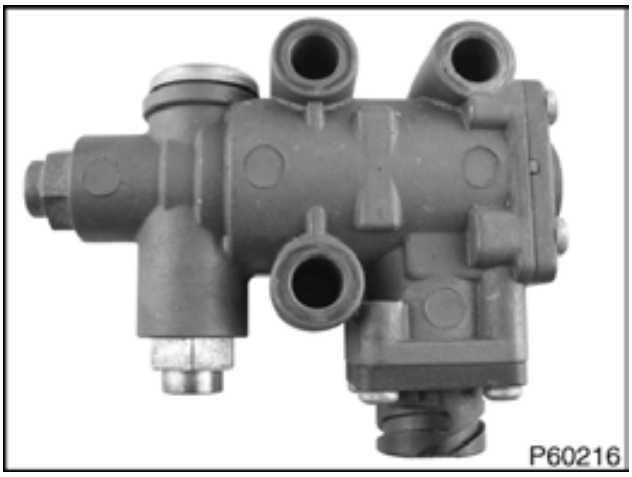

Figure 59 EGR control valve

The EGR control valve controls the EGR actuator.

The EGR control valve receives the desired EGR position from the Engine Control Module (ECM) to activate the EGR throttle valve for exhaust gas recirculation. The EGR control valve then regulates the amount of air pressure applied to the pneumatic actuator that controls the flow of exhaust gases through the EGR system.

The EGR control valve is mounted to the EGR module on top of the engine.

Exhaust Gas Recirculation Position (EGRP) Sensor

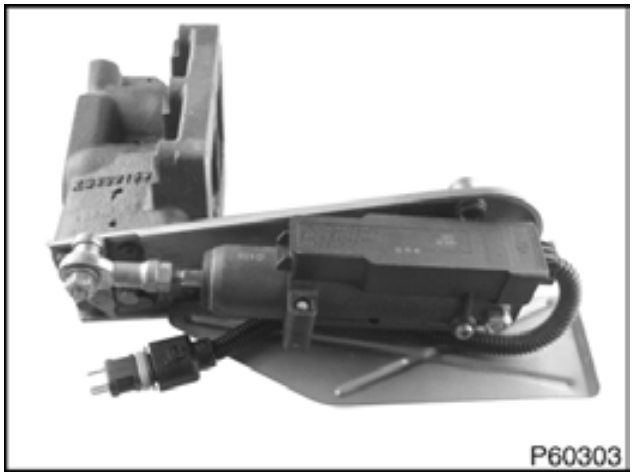

Figure 60 EGRP sensor (part of EGR throttle valve)

The EGRP sensor monitors the position of the EGR throttle valve.

The closed loop control system uses the EGR position signal. The Engine Control Module (ECM) monitors the EGRP signal and determines the amount of air pressure the EGR control valve should provide to the pneumatic EGR throttle valve actuator.

The EGRP sensor is contained within the pneumatic EGR throttle valve actuator installed as part of the EGR throttle valve on the top right side of the engine.

The sensor is not serviced separately. It is serviced as part of the EGR throttle valve.

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Boost Control Solenoid (BCS) Valve

Figure 61 BCS valve

The BCS valve controls the wastegate on the high pressure turbocharger.

The BCS valve either applies air pressure to the wastegate's pneumatic actuator or vents system pressure to the atmosphere, in response to commands from the Engine Control Module (ECM).

The BCS valve is mounted on a bracket on the lower right side of the engine, near the front.

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Removal

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, remove ground cable from negative terminal of main battery before disconnecting or connecting electrical components. Always connect ground cable last.

Crankshaft Position (CKP) Sensor

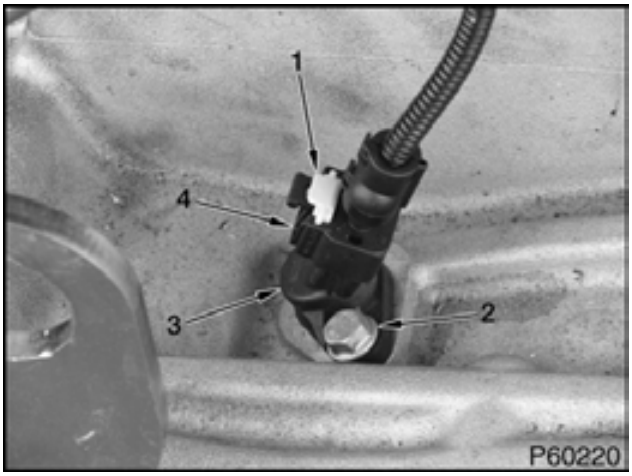

Figure 62 CKP sensor

1. Locking tab
2. M4 x 14 bolt
3. CKP sensor
4. CKP electrical connector

1. Pull out yellow locking tab on CKP sensor electrical connector.
2. Press release lever and disconnect electrical connector from CKP sensor installed in top left of flywheel housing.
3. Remove M4 x 14 bolt from CKP sensor.
4. Remove CKP sensor and discard O-ring.

Camshaft Position (CMP) Sensor

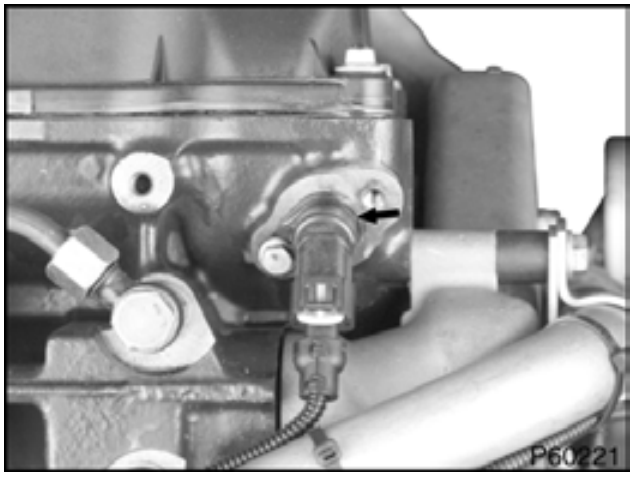

Figure 63 CMP sensor

1. Pull out yellow locking tab on CMP sensor electrical connector.
2. Press release lever and disconnect electrical connector from CMP sensor installed in rear left of cylinder head.
3. Remove M4 x 14 bolt from CMP sensor.
4. Remove CMP sensor and discard O-ring.

Engine Coolant Temperature (ECT) Sensor

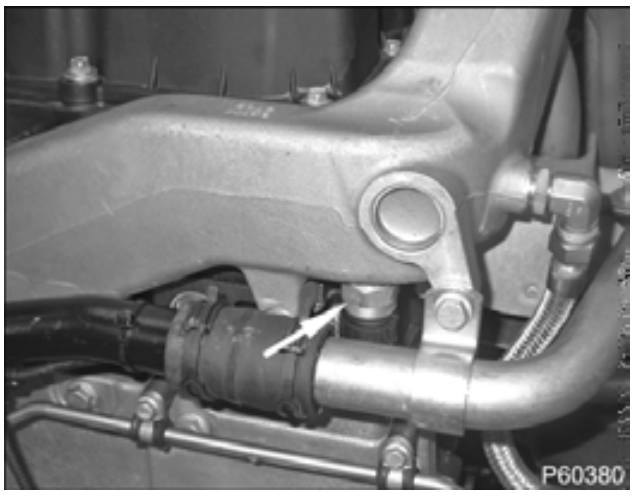

Figure 64 ECT sensor

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1. Turn ECT sensor electrical connector locking ring 90° counterclockwise.
2. Disconnect electrical connector from ECT sensor installed in underside of Exhaust Gas Recirculation (EGR) coolant elbow.
3. Remove ECT sensor and discard gasket.

Engine Coolant Temperature 2 (ECT2) Sensor

Figure 65 ECT2 sensor connector

1. Turn ECT2 sensor electrical connector locking ring 90° counterclockwise.
2. Disconnect electrical connector from ECT2 sensor installed in Charge Air Cooler (CAC) return coolant pipe on upper right side of engine.
3. Remove ECT2 sensor and discard gasket.

Engine Oil Pressure (EOP) Sensor and Engine Oil Temperature (EOT) Sensor Adapter Lines

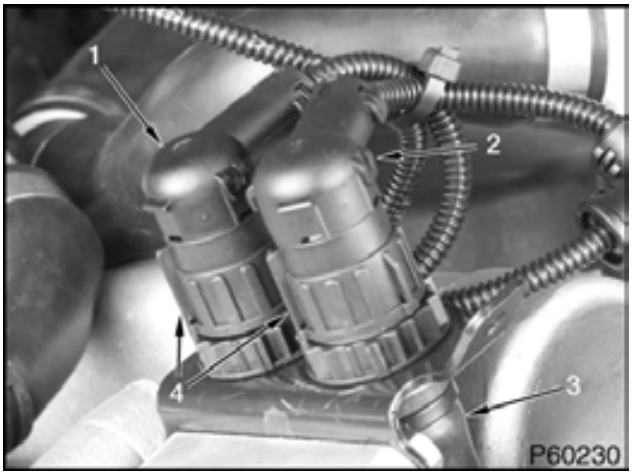

Figure 66 EOP sensor and EOT sensor adapter lines

1. EOP sensor electrical connector
2. EOT sensor electrical connector
3. EOP and EOT sensor lines under bracket
4. Electrical connector locking rings

1. Turn EOT and EOP adapter line electrical connector locking rings 90° counterclockwise.
2. Disconnect electrical connectors from EOP sensor and EOT sensor adapter lines installed in Low Pressure Charge Air Cooler (LP-CAC) bracket.
3. See (Engine Oil Temperature (EOT)/Engine Oil Pressure (EOP) Sensors, page 228) for removal of EOT and EOP sensors.

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Engine Fuel Pressure (EFP) Sensor

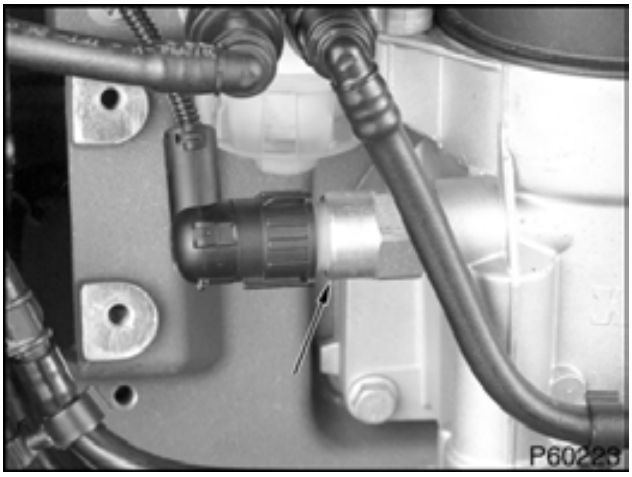

Figure 67 EFP sensor

1. Turn EFP sensor electrical connector locking ring 90° counterclockwise.
2. Disconnect electrical connector from EFP sensor installed in fuel filter.
3. Remove EFP sensor and discard gasket.

Fuel Rail Pressure (FRP) Sensor

Figure 68 FRP sensor

1. Pull out yellow locking tab on FRP sensor electrical connector.
2. Press release lever and disconnect electrical connector from FRP sensor installed in front of pressure pipe rail on left side of engine.
3. Remove FRP sensor.
4. Cover exposed pressure pipe rail opening using Disposable Air and Fuel Caps (page 91).

Manifold Absolute Pressure/Intake Air Temperature 2 (MAP/IAT2) Sensor

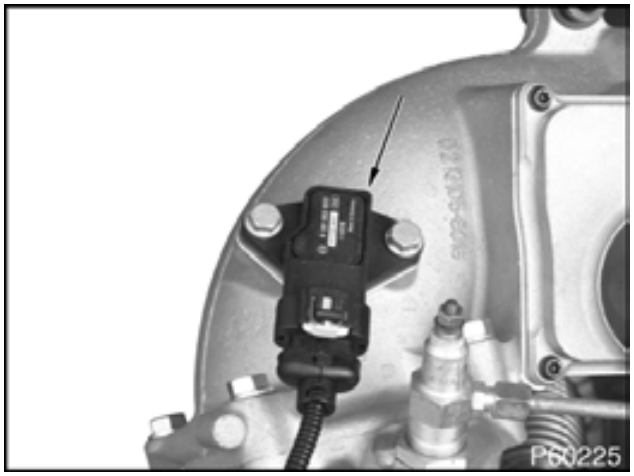

Figure 69 MAP/IAT2 sensor

1. Pull out yellow locking tab on MAP/IAT2 sensor electrical connector.
2. Press release lever and disconnect electrical connector from MAP/IAT2 sensor.
3. Remove two M4 x 16 hex bolts from MAP/IAT2 sensor.
4. Remove MAP/IAT2 sensor and discard O-ring.

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Manifold Air Temperature (MAT) Sensor

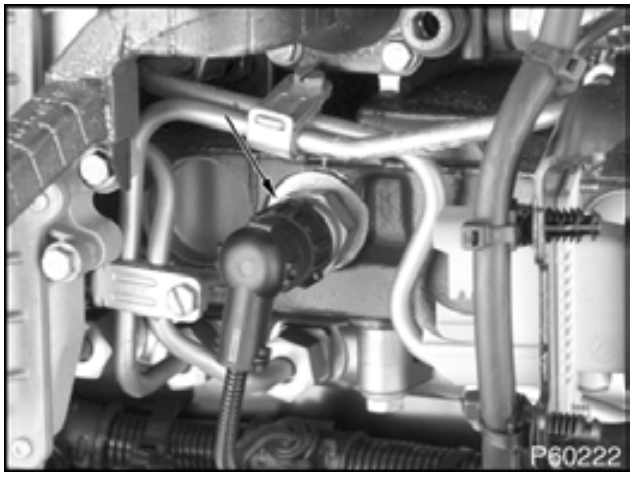

Figure 70 MAT sensor

1. Turn MAT sensor electrical connector locking ring 90° counterclockwise.
2. Disconnect electrical connector from MAT sensor.
3. Remove MAT sensor and discard gasket.

Exhaust Lambda Sensor (ELS)

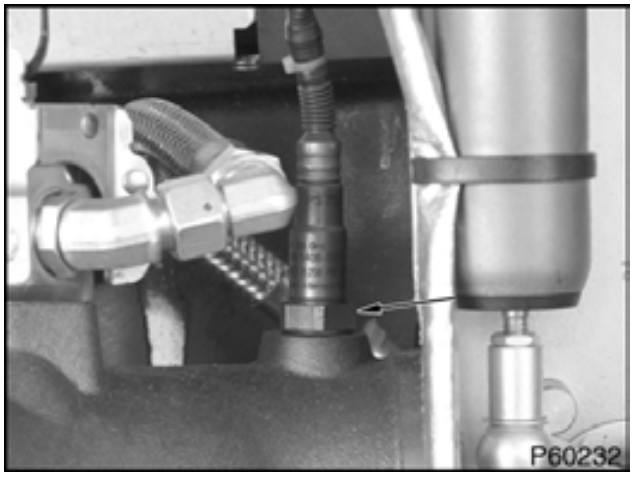

Figure 71 ELS

1. Press release lever and disconnect electrical connector from ELS.
2. Remove ELS and discard gasket.

Intake Throttle Valve (ITV)

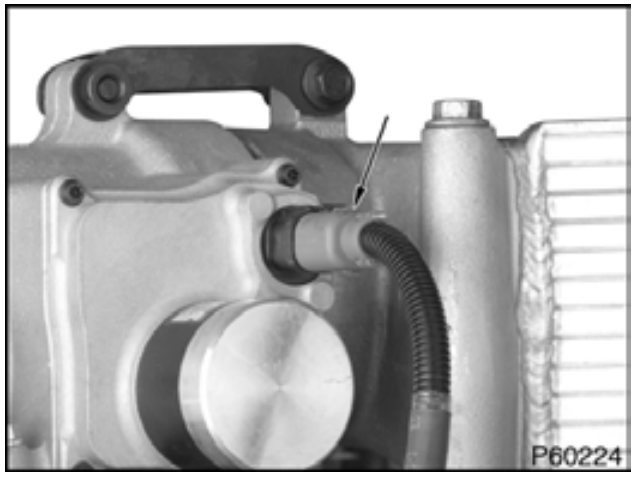

Figure 72 ITV electrical connector

1. Press release lever and disconnect electrical connector from ITV, located on top front of engine.
2. See Intake Throttle Valve (ITV) (page 146) for removal of ITV.

Fuel Pressure Control Valve (FPCV)

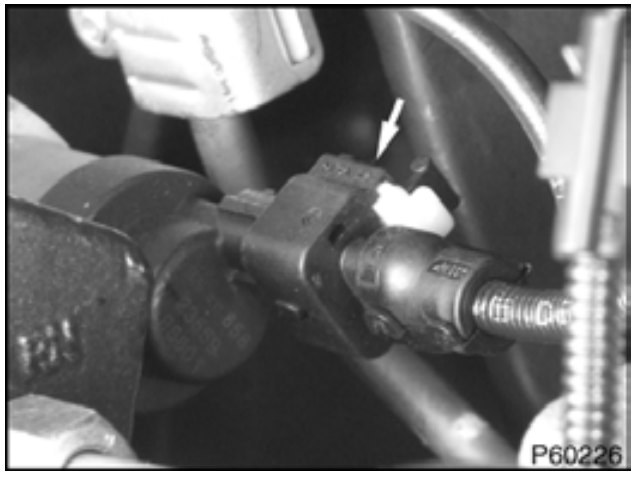

Figure 73 FPCV electrical connector

1. Pull out yellow locking tab on FPCV electrical connector.

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2. Press release lever and disconnect electrical connector from FPCV, mounted on upper side of high pressure pump.
3. See High Pressure Pump (page 208) for removal of high pressure pump with integral FPCV if the FPCV requires replacement.

Coolant Control Valve (CCV)

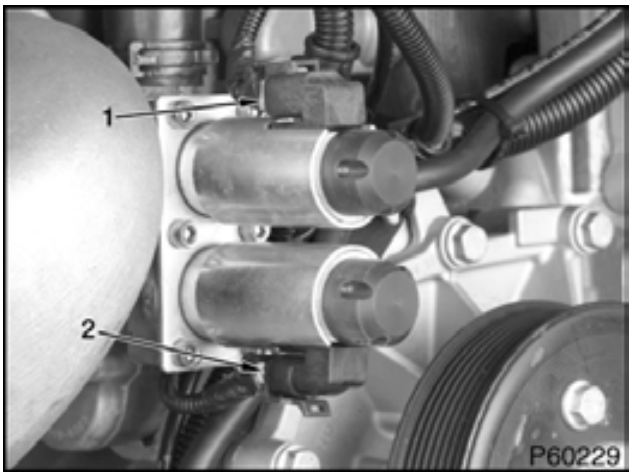

Figure 74 CCV

1. Coolant Mixer Valve (CMV) electrical connector
2. Coolant Flow Valve (CFV) electrical connector

1. Press release lever and disconnect electrical connector from CMV, mounted with CFV as an assembly on right side of front cover.
2. Lift release lever and disconnect electrical connector from CFV, mounted with CMV as an assembly on right side of front cover.
3. See (Coolant Control Valve (CCV), page 299) for removal.

Retarder Control and Boost Control Solenoid (BCS) Valve

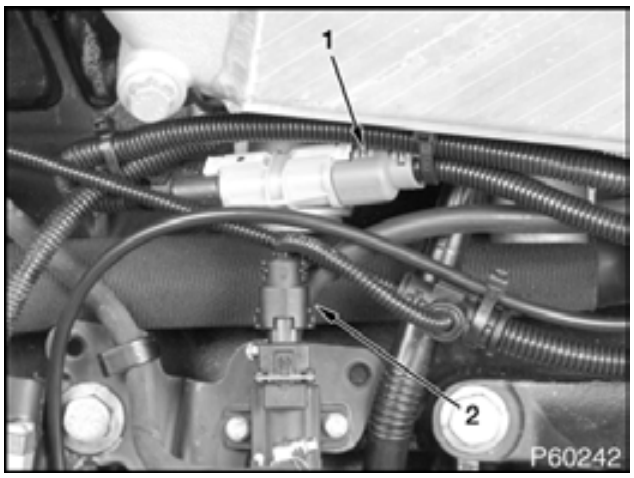

Figure 75 Retarder control and BCS valve electrical connectors

1. Retarder control electrical connector
2. BCS valve electrical connector

1. Press release lever and disconnect electrical connector from retarder control, mounted on bracket on lower right side of engine.
2. Lift release lever and disconnect electrical connector from BCS valve, mounted on bracket on lower right side of engine.
3. See Retarder Control (page 126) for removal of retarder control.
4. See Boost Control Solenoid (BCS) Valve (page 142) for removal of BCS valve.

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Exhaust Gas Recirculation (EGR) Control Valve

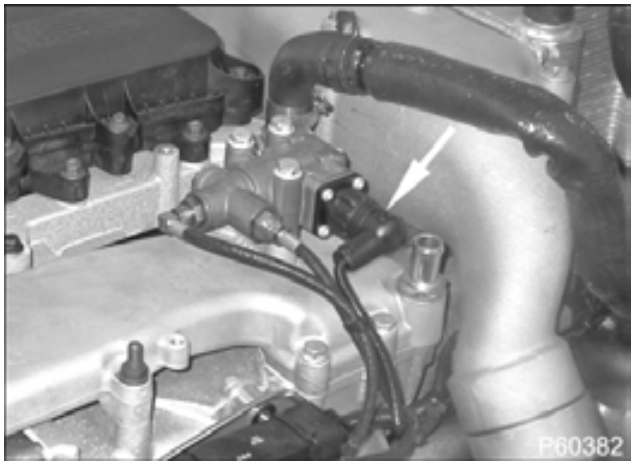

Figure 76 EGR control valve electrical connector

1. Turn EGR control valve electrical connector locking ring 90° counterclockwise.
2. Disconnect electrical connector from EGR control valve.
3. See Exhaust Gas Recirculation (EGR) Control Valve (page 259) for removal of EGR control valve.

Exhaust Gas Recirculation Position (EGRP) Sensor

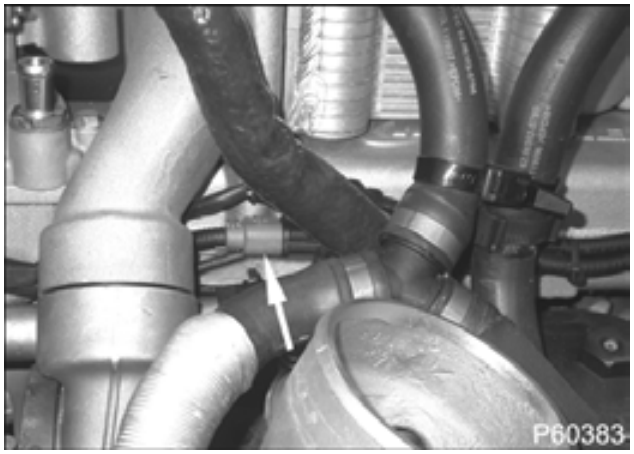

Figure 77 EGRP sensor electrical connector

1. Press release lever and disconnect electrical connector from EGRP sensor (part of EGR throttle valve).
2. See Exhaust Gas Recirculation (EGR) Throttle Valve (page 261) for removal.

Engine Control Module (ECM) and Electronic Control Unit Bracket

1. Disconnect ground (-) cable from battery.

NOTE: The ECM can be removed without removing electronic control unit bracket.

Figure 78 ECM electrical connector wire ties

2. Note location of wire ties for reinstallation. Cut wire ties retaining ECM injector electrical connector and vehicle electrical connector release levers.

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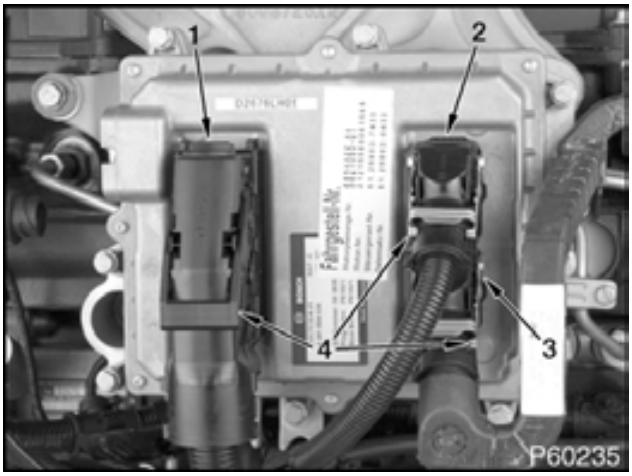

Figure 79 ECM electrical connectors

1. Engine electrical connector - 89 pin
2. Vehicle electrical connector - 36 pin
3. Injector electrical connector - 16 pin
4. Connector release levers

3. Lift release levers and disconnect ECM electrical connectors by pulling straight out.

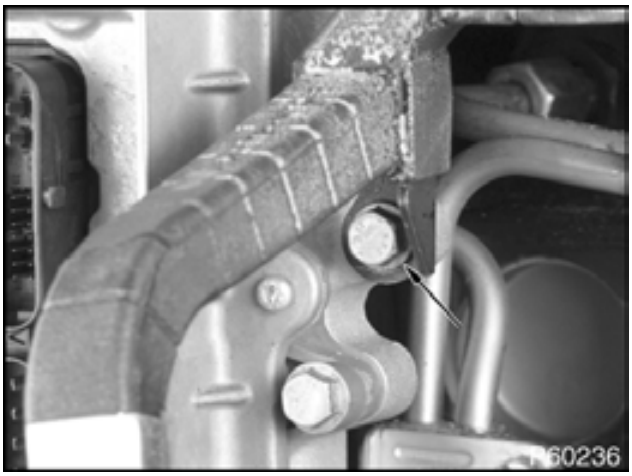

Figure 80 M4 x 16 bolt

4. Remove M4 x 16 bolt retaining injector harness to electronic control unit bracket.

Figure 81 ECM

1. M4 x 30 bolt (8)
2. ECM

5. Remove eight M4 x 30 bolts and ECM.

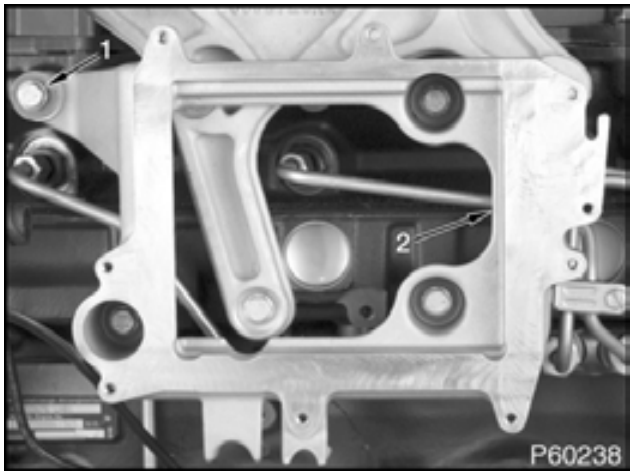

Figure 82 Electronic control unit bracket

1. M6 x 40 bolt (4)
2. Electronic control unit bracket

6. Remove four M6 x 40 bolts, eight rubber grommets and electronic control unit bracket.

Engine Interface Module (EIM)

1. See Engine Interface Module (EIM) (page 206) for removal of EIM.

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Main Engine Wiring Harness

WARNING: To prevent personal injury or death, remove ground cable from negative terminal of main battery before disconnecting or connecting electrical components. Always connect ground cable last.

CAUTION: To prevent engine damage, do not tug on wiring harnesses; if resistance is felt, find the problem and free connectors or clips.

1. Disconnect ground (-) cable from battery.
2. Remove breather heater nut from breather outlet heater assembly and remove heater assembly from breather heater bracket.
3. Disconnect heater connector on overlay harness from breather outlet heater assembly.
4. Disconnect overlay harness from main engine wiring harness and Intake Throttle Valve (ITV) connector.

NOTE: Mark or label wire tie attachment points, for later installation of overlay harness

5. Remove wire ties and overlay harness.
6. Disconnect main engine wiring harness from sensors, valves, and actuators.

NOTE: Note routing and attachment points of main engine wiring harness for reinstallation.

7. Remove all clamps, clips, and ties that secure main engine wiring harness to engine.
8. Carefully lift main engine wiring harness from engine.

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Cleaning and Inspection

Main Engine Wiring Harness

1. Carefully inspect main engine wiring harness for worn conduit, frayed insulation or heat damage to wires. Repair or replace if necessary.
2. Inspect sensor, actuator and valve connectors for cracked connector bodies, bent or loose pins, chafing, and damaged or missing O-rings. Replace connectors if necessary.
3. Inspect each connector for the following conditions and replace, if necessary:
   - Corroded connectors and green, gray, or white deposits on metal terminals.
   - Terminals incorrectly latched in connector body or pushed back relative to other terminals in same connector.
   - Make sure that each connector has its seals in place. During disassembly, a seal may pull off its connector and remain in mating socket of a sensor or actuator. A connector assembled without the correct seals can be contaminated with moisture and have corroded terminals, causing a poor electrical connection.

Sensors and Valves

1. Check all connector pins on sensors or valves. If bent or corroded, replace damaged sensor.
2. Remove scale or carbon build up.
3. Check for body cracks and leakage
4. If orifices or valves are plugged, replace sensors or valves.

Engine Control Module (ECM)

1. Inspect rubber seal on harness connector and in ECM pin recesses.
2. Check for bent pins in ECM connections.

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Installation

Main Engine Wiring Harness

1. Position main engine wiring harness on engine.

NOTE: Be sure to route and secure main engine wiring harness assembly in its correct configuration.

2. Install wiring harness clamps, clips, and ties that secure main engine wiring harness to engine. Refer to Main Engine Wiring Harness Attachment Points (page 64).
3. Connect main engine wiring harness to sensors, valves, and actuators.
   a. Refer to Engine Electronic Component Locations (page 61).
   b. Refer to individual sensor and valve installation procedures within this section for specific instructions.
4. Connect overlay harness to Intake Throttle Valve (ITV), main engine wiring harness, and route overlay harness along resonator tube to breather outlet heater assembly.
5. Connect overlay harness to connector on breather outlet heater assembly.
6. Slide breather outlet heater assembly onto breather heater bracket.
7. Install breather heater nut onto breather heater bracket.
8. Install wire ties at marked locations.
9. Connect ground (-) cable to battery if all electrical repairs and connector connections are complete.

Engine Interface Module (EIM)

1. See Engine Interface Module (EIM) (page 211) for installation of EIM.

Engine Control Module (ECM) and Electronic Control Unit Bracket

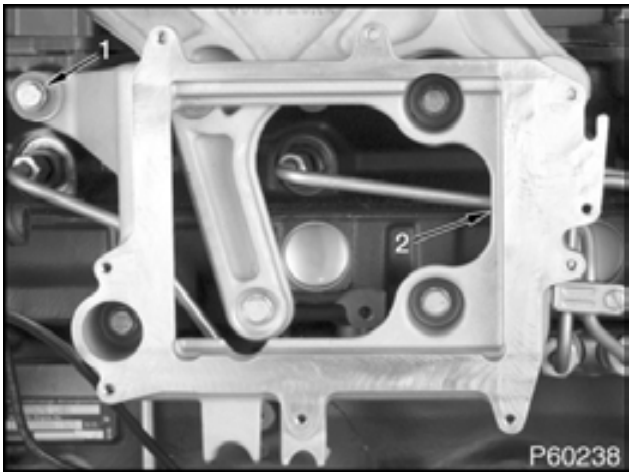

Figure 83 Electronic control unit bracket

1. M6 x 40 bolt (4)
2. Electronic control unit bracket

1. Install electronic control unit bracket, eight rubber grommets, and four M6 x 40 bolts. Tighten bolts to standard torque (page 457).

Figure 84 ECM

1. M4 x 30 bolt (8)
2. ECM

2. Install ECM and eight M4 x 30 bolts. Tighten bolts to standard torque (page 457).

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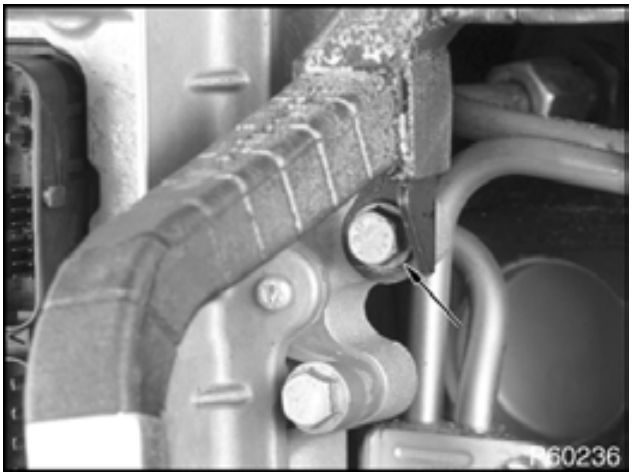

Figure 85 M4 x 16 bolt

3. Install M4 x 16 bolt retaining injector harness to electronic control unit bracket. Tighten M4 x 16 bolt to standard torque (page 457).

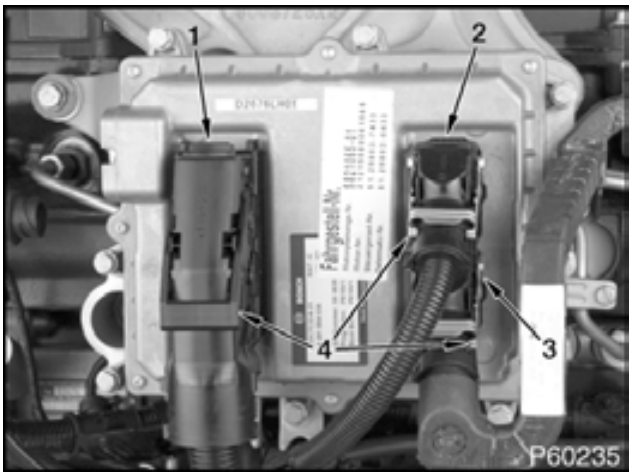

Figure 86 ECM electrical connectors

1. Engine electrical connector - 89 pin
2. Vehicle electrical connector - 36 pin
3. Injector electrical connector - 16 pin
4. Connector release levers

4. Connect ECM electrical connectors by pushing straight in, then pushing down connector release levers until they lock into place.

Figure 87 ECM electrical connector wire ties

5. Install new wire ties retaining ECM injector electrical connector and vehicle electrical connector release levers.
6. Connect ground (-) cable to battery if all electrical repairs and connector connections are complete.

Exhaust Gas Recirculation Position (EGRP) Sensor

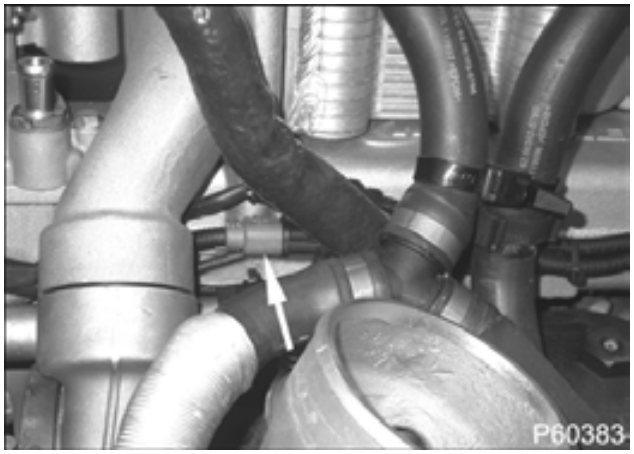

Figure 88 EGRP sensor electrical connector

1. See Exhaust Gas Recirculation (EGR) Throttle Valve (page 266) for installation.
2. Connect electrical connector to EGRP sensor (part of EGR throttle valve) by pushing in until an audible click is heard.

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Exhaust Gas Recirculation (EGR) Control Valve

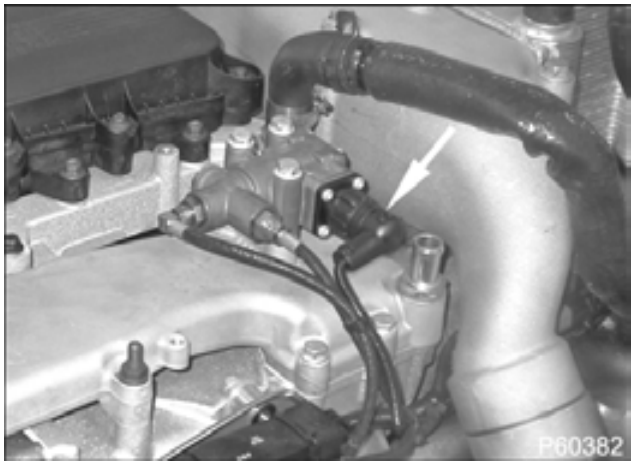

Figure 89 EGR control valve electrical connector

1. See Exhaust Gas Recirculation (EGR) Control Valve (page 269) for installation of EGR control valve.

NOTE: It may be necessary to rotate the harness connector to ensure the alignment tabs engage properly.

2. Connect electrical connector to EGR control valve.
3. Turn EGR control valve electrical connector locking ring 90° clockwise.

Retarder Control and Boost Control Solenoid (BCS) Valve

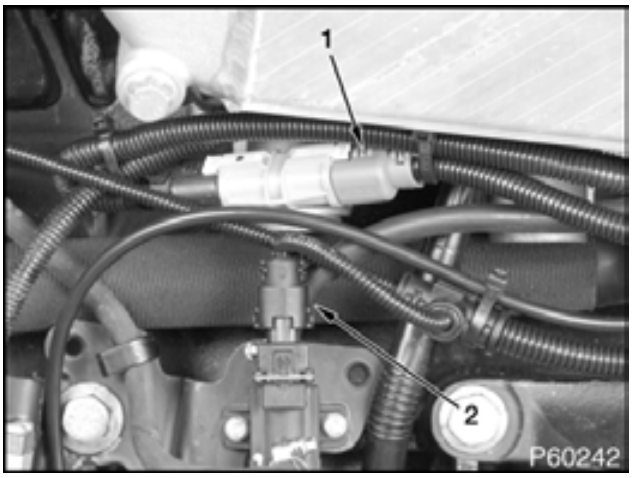

Figure 90 Retarder control and BCS valve electrical connectors

1. Retarder control electrical connector
2. BCS valve electrical connector

1. See Boost Control Solenoid (BCS) Valve (page 167) for installation of BCS valve.
2. See Retarder Control (page 127) for installation of retarder control.
3. Connect electrical connectors to retarder control and BCS valve by pushing in until an audible click is heard.

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Coolant Control Valve (CCV)

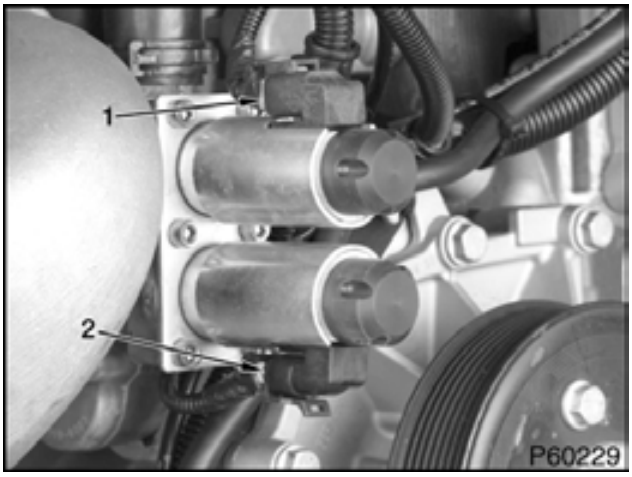

Figure 91 CCV

1. Coolant Mixer Valve (CMV) electrical connector
2. Coolant Flow Valve (CFV) electrical connector

1. See Coolant Control Valve (CCV) (page 306) for installation.
2. Connect electrical connectors to CMV and CFV by pushing in until an audible click is heard.

Fuel Pressure Control Valve (FPCV)

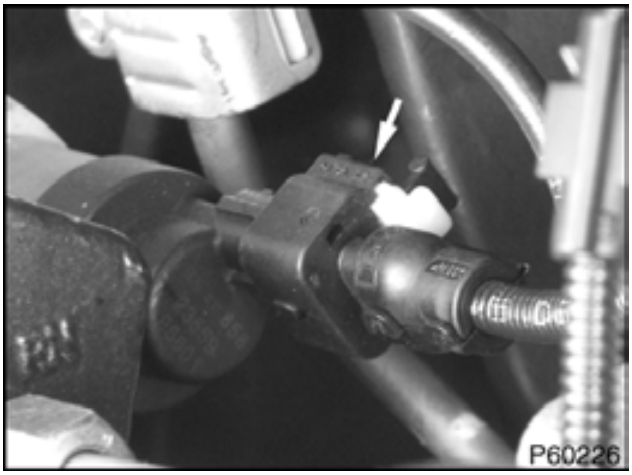

Figure 92 FPCV electrical connector

1. See High Pressure Pump (page 210) for installation of high pressure pump.
2. Connect electrical connector to FPCV by pushing in until an audible click is heard.
3. Push in yellow locking tab on FPCV electrical connector.

Intake Throttle Valve (ITV)

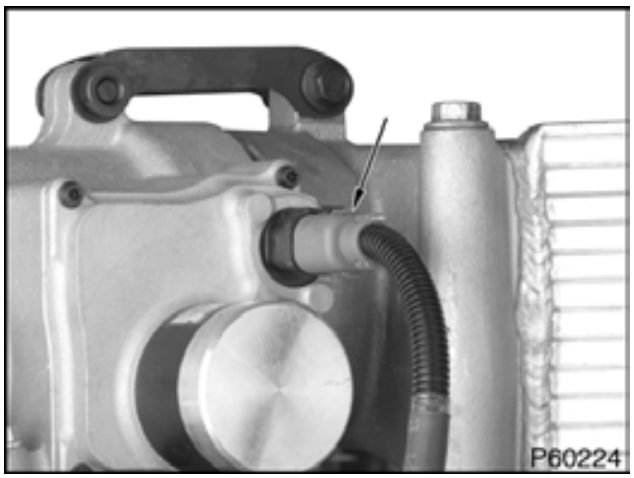

Figure 93 ITV electrical connector

1. See Intake Throttle Valve (ITV) (page 163) for installation of ITV.
2. Connect electrical connector to ITV by pushing in until an audible click is heard.

Exhaust Lambda Sensor (ELS)

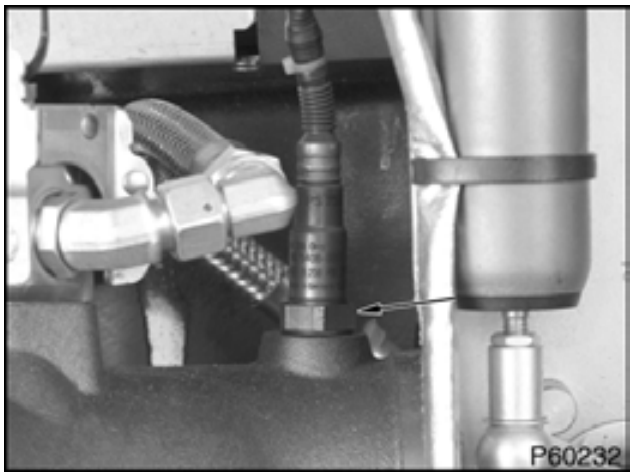

Figure 94 ELS

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1. Install ELS with new gasket. Tighten ELS to special torque (page 91).
2. Connect electrical connector to ELS by pushing in until an audible click is heard.

Manifold Air Temperature (MAT) Sensor

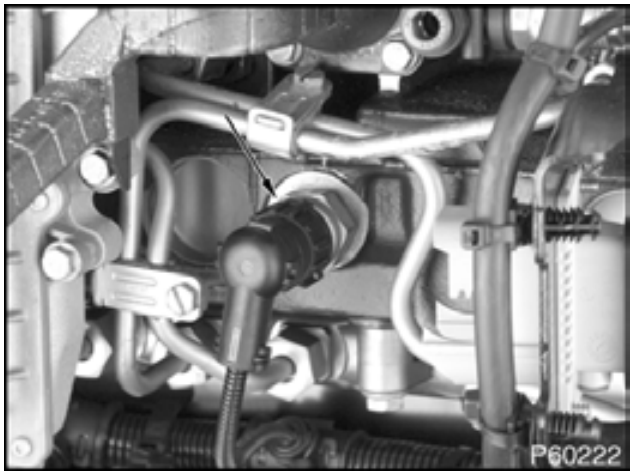

Figure 95 MAT sensor

1. Install MAT sensor with new gasket. Tighten MAT sensor to special torque (page 91).

NOTE: It may be necessary to rotate the harness connector to ensure the alignment tabs engage properly.

2. Connect electrical connector to MAT sensor.
3. Turn MAT sensor electrical connector locking ring 90° clockwise.

Manifold Absolute Pressure/Intake Air Temperature 2 (MAP/IAT2) Sensor

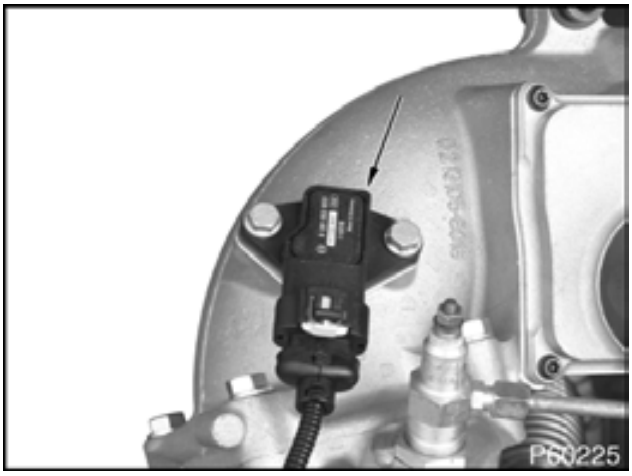

Figure 96 MAP/IAT2 sensor

1. Install MAP/IAT2 sensor with new O-ring.
2. Install two M4 x 16 hex bolts to MAP/IAT2 sensor. Tighten bolts to special torque (page 91).
3. Connect electrical connector to MAP/IAT2 sensor by pushing in until an audible click is heard.
4. Push in yellow locking tab on MAP/IAT2 sensor electrical connector.

Fuel Rail Pressure (FRP) Sensor

Figure 97 FRP sensor

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1. Install FRP sensor. Tighten FRP sensor to special torque (page 91).
2. Connect electrical connector to FRP sensor by pushing in until an audible click is heard.
3. Push in yellow locking tab on FRP sensor electrical connector.

Engine Fuel Pressure (EFP) Sensor

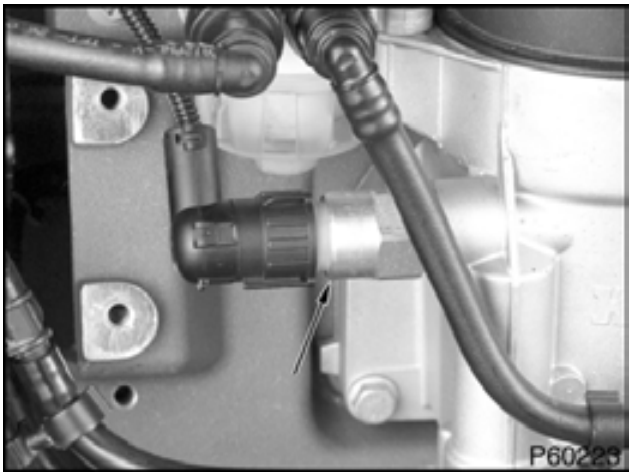

Figure 98 EFP sensor

1. Install EFP sensor with new gasket. Tighten EFP sensor to special torque (page 91).

NOTE: It may be necessary to rotate the harness connector to ensure the alignment tabs engage properly.

2. Connect electrical connector to EFP sensor.
3. Turn EFP sensor electrical connector locking ring 90° clockwise.

Engine Oil Pressure (EOP) Sensor and Engine Oil Temperature (EOT) Sensor Adapter Lines

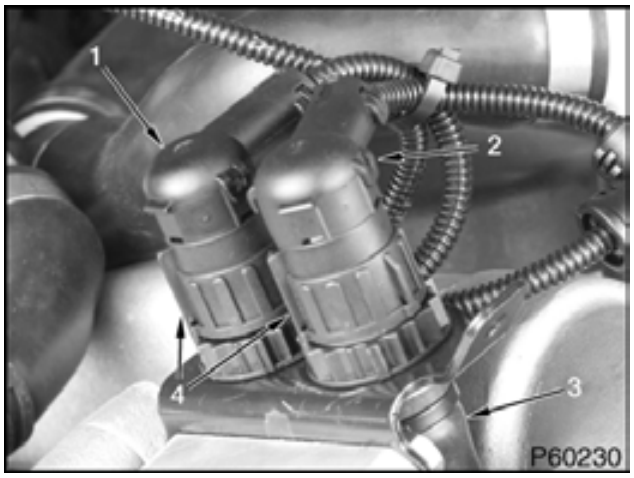

Figure 99 EOP sensor and EOT sensor adapter lines

1. EOP sensor electrical connector
2. EOT sensor electrical connector
3. EOP and EOT sensor lines under bracket
4. Electrical connector locking rings

1. See Engine Oil Temperature (EOT)/Engine Oil Pressure (EOP) Sensors (page 246) for installation of EOT and EOP sensors.

NOTE: It may be necessary to rotate the harness connector to ensure the alignment tabs engage properly.

2. Connect electrical connectors to EOP sensor and EOT sensor adapter lines.
3. Turn EOT and EOP adapter line electrical connector locking rings 90° clockwise.

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Engine Coolant Temperature 2 (ECT2) Sensor

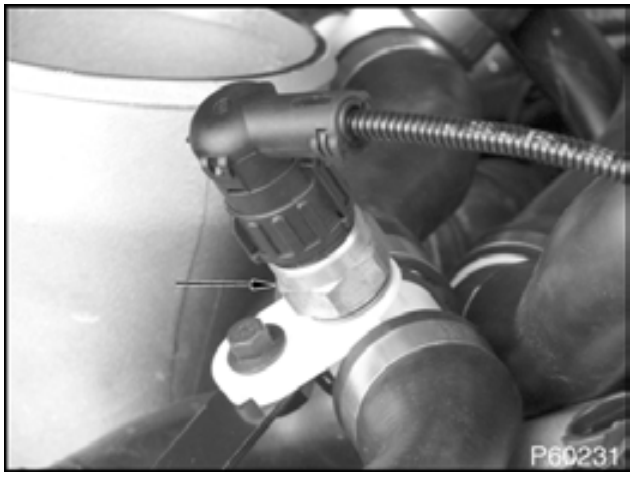

Figure 100 ECT2 sensor

1. Install ECT2 sensor with new gasket. Tighten ECT2 sensor to special torque (page 91).

NOTE: It may be necessary to rotate the harness connector to ensure the alignment tabs engage properly.

2. Connect electrical connector to ECT2 sensor.
3. Turn ECT2 sensor electrical connector locking ring 90° clockwise.

Engine Coolant Temperature (ECT) Sensor

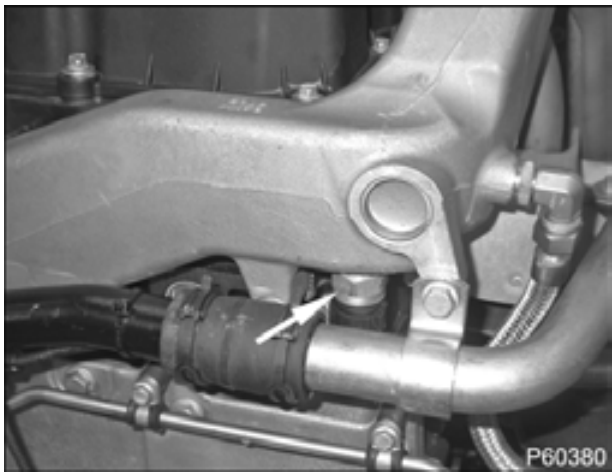

Figure 101 ECT sensor

1. Install ECT sensor with new gasket. Tighten ECT sensor to special torque (page 91).

NOTE: It may be necessary to rotate the harness connector to ensure the alignment tabs engage properly.

2. Connect electrical connector to ECT sensor.
3. Turn ECT sensor electrical connector locking ring 90° clockwise.

Camshaft Position (CMP) Sensor

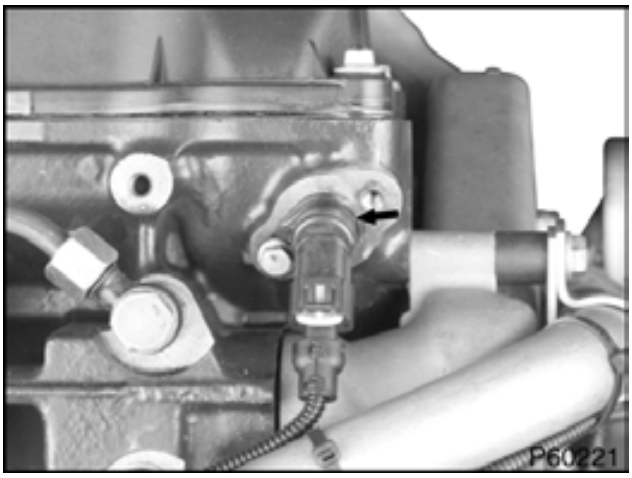

Figure 102 CMP sensor

1. Lubricate new O-ring with oil-based grease and install on CMP sensor.
2. Install CMP sensor.
3. Install M4 x 14 bolt to CMP sensor. Tighten bolt to special torque (page 91).
4. Connect electrical connector to CMP sensor by pushing in until an audible click is heard.
5. Push in yellow locking tab on CMP sensor electrical connector.

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Crankshaft Position (CKP) Sensor

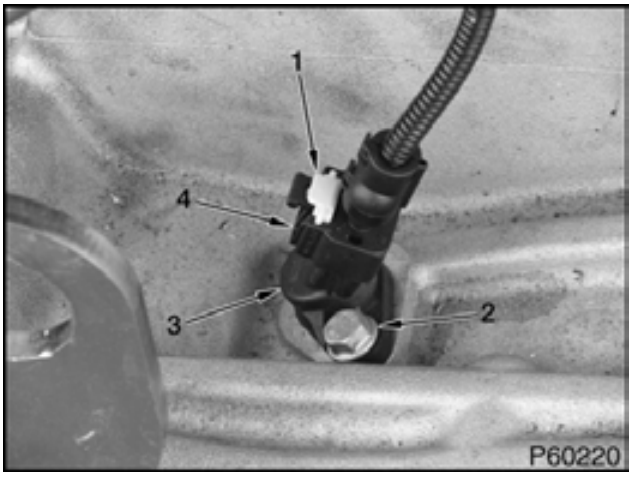

Figure 103 CKP sensor

1. Locking tab
2. M4 x 14 bolt
3. CKP sensor
4. CKP electrical connector

1. Lubricate new O-ring with oil-based grease and install on CKP sensor.
2. Install CKP sensor.
3. Install M4 x 14 bolt to CKP sensor. Tighten bolt to special torque (page 91).
4. Connect electrical connector to CKP sensor by pushing in until an audible click is heard.
5. Push in yellow locking tab on CKP sensor electrical connector.

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Special Torque

Table 3 Engine Electrical

Camshaft Position (CMP) sensor bolt	8 N·m (71 lbf·in)
Crankshaft Position (CKP) sensor bolt	8 N·m (71 lbf·in)
Engine Coolant Temperature (ECT) sensor	45 N·m (33 lbf·ft)
Engine Coolant Temperature 2 (ECT2) sensor	45 N·m (33 lbf·ft)
Engine Fuel Pressure (EFP) sensor	45 N·m (33 lbf·ft)
Exhaust Lambda Sensor (ELS)	50 N·m (37 lbf·ft)
Fuel Rail Pressure (FRP) sensor	140 N·m (103 lbf·ft)
Manifold Absolute Pressure/Intake Air Temperature 2 (MAP/IAT2) sensor bolts	9 N·m (80 lbf·in)
Manifold Air Temperature (MAT) sensor	45 N·m (33 lbf·ft)

Special Service Tools

Table 4 Engine Electrical

Description	Tool Number
Disposable Air and Fuel Caps	ZTSE4891

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Exploded View

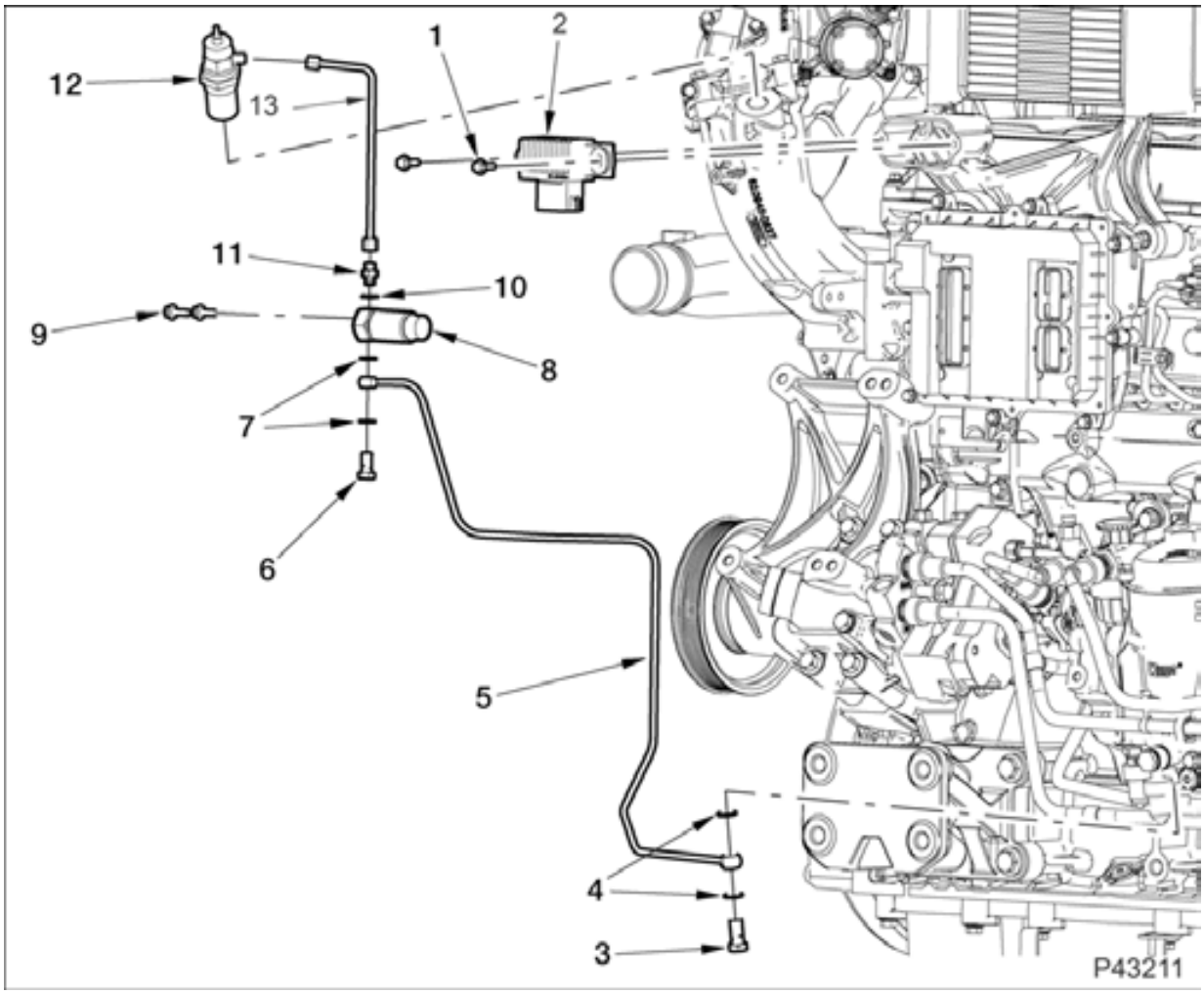

Figure 104 Cold start assist components

1. M6 x 20 hex bolt (2)
2. Cold Start Relay (CSR)
3. Size 8 hollow screw
4. 12.7 x 18 seal (2)
5. Cold start supply tube
6. Size 6 hollow screw
7. 10.7 x 16 seal (2)
8. Cold Start Solenoid (CSS) valve
9. M6 x 20 hex bolt (2)
10. 8.7 x 14 seal
11. Adapter
12. Glow plug
13. MV-glow plug fuel line

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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, 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.

Cold Start Relay (CSR)

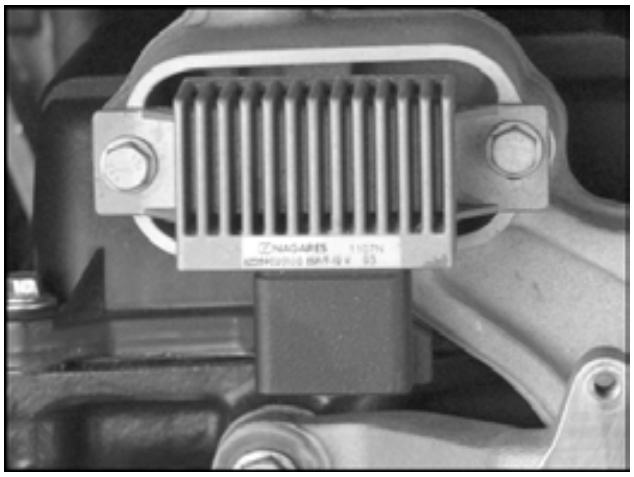

Figure 105 CSR

1. CSR
2. M6 x 20 hex bolt (2)

1. Remove two M6 x 20 hex bolts and remove CSR.

MV-Glow Plug Fuel Line

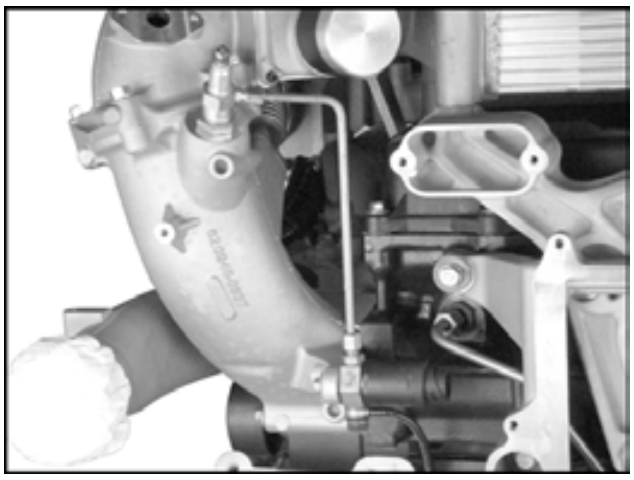

Figure 106 MV-glow plug fuel line

1. Glow plug
2. MV-glow plug fuel line
3. Cold Start Solenoid (CSS) valve

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WARNING: To prevent personal injury or death, dispose of fuel in a container marked DIESEL FUEL, according to applicable regulations.

1. Place suitable container clearly marked DIESEL FUEL under MV-glow plug fuel line.
2. Loosen MV-glow plug fuel line fitting nuts that attach to CSS valve adapter and glow plug fitting. Drain fuel into container and remove MV-glow plug fuel line.

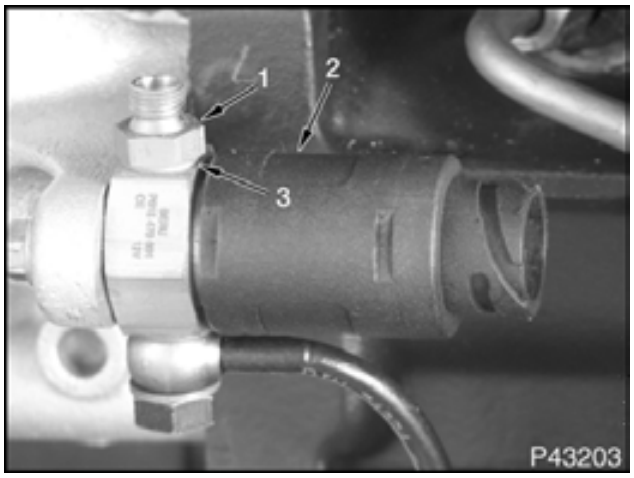

Figure 107 Adapter

1. Adapter
2. CSS valve
3. 8.7 x 14 seal

3. Remove adapter and discard 8.7 x 14 seal from CSS valve.

Cold Start Supply Tube

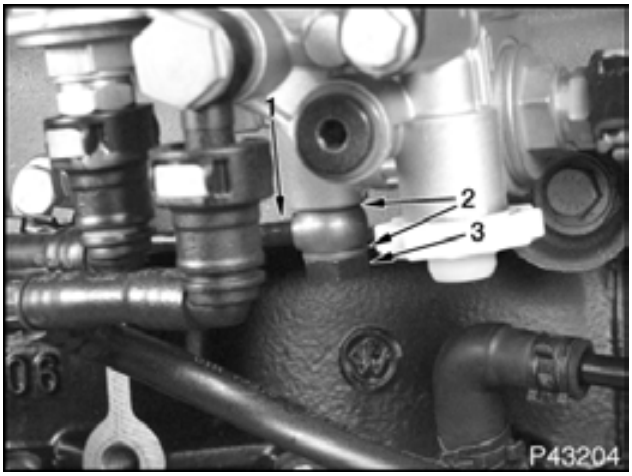

Figure 108 Cold start supply tube (at fuel service center)

1. Cold start supply tube
2. 12.7 x 18 seal (2)
3. Size 8 hollow screw

WARNING: To prevent personal injury or death, dispose of fuel in a container marked DIESEL FUEL, according to applicable regulations.

1. Place suitable container clearly marked DIESEL FUEL under lower end of cold start supply tube.
2. Remove size 8 hollow screw from fuel service center and drain fuel into container.
3. Remove and discard two 12.7 x 18 seals.

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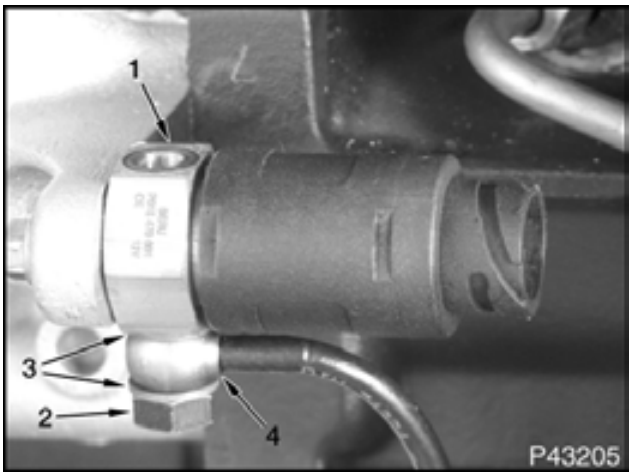

Figure 109 Cold start supply tube (at cold start solenoid (CSS) valve)

1. CSS valve
2. Size 6 hollow screw
3. 10.7 x 16 seal (2)
4. Cold start supply tube

4. Remove size 6 hollow screw from CSS valve.
5. Remove and discard two 10.7 X 16 seals.
6. Remove cold start supply tube.

Cold Start Solenoid (CSS) Valve

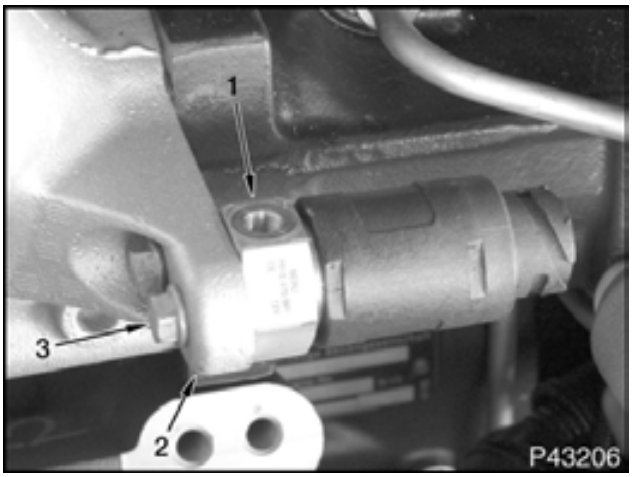

Figure 110 CSS valve

1. CSS valve
2. Air inlet duct
3. M6 x 20 hex bolt (2)

1. Remove two M6 x 20 hex bolts and CSS valve.

Glow Plug

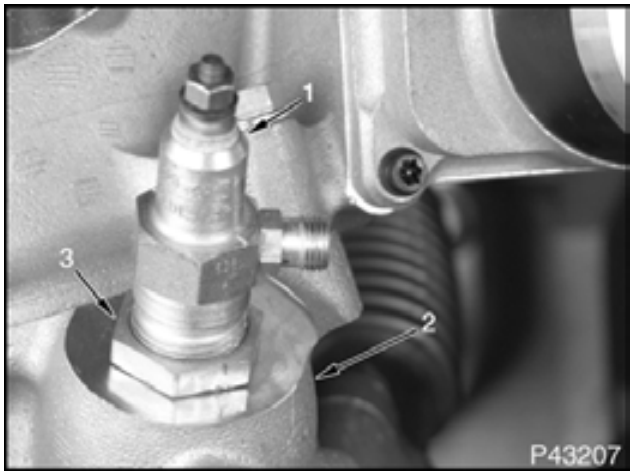

Figure 111 Glow plug

1. Glow plug
2. Air inlet duct
3. Glow plug locking nut (part of glow plug)

1. Loosen glow plug locking nut.
2. Remove glow plug by rotating counterclockwise.

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Installation

Glow Plug

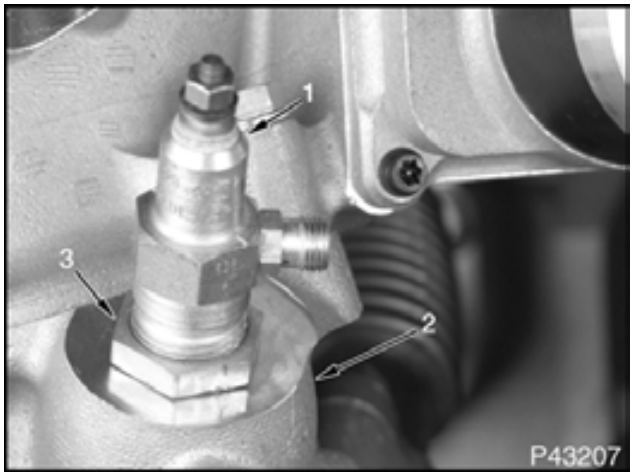

Figure 112 Glow plug

1. Glow plug
2. Air inlet duct
3. Glow plug locking nut (part of glow plug)

1. Install glow plug.
   a. If the MV-glow plug fuel line was removed, make sure glow plug is loose to ensure correct glow plug orientation when the fuel line is installed.
   b. If MV-glow plug fuel line was not removed, connect the fuel line. Tighten MV-glow plug fuel fitting nut to special torque (page 102). Tighten glow plug locking nut to special torque (page 102).

Cold Start Solenoid (CSS) Valve

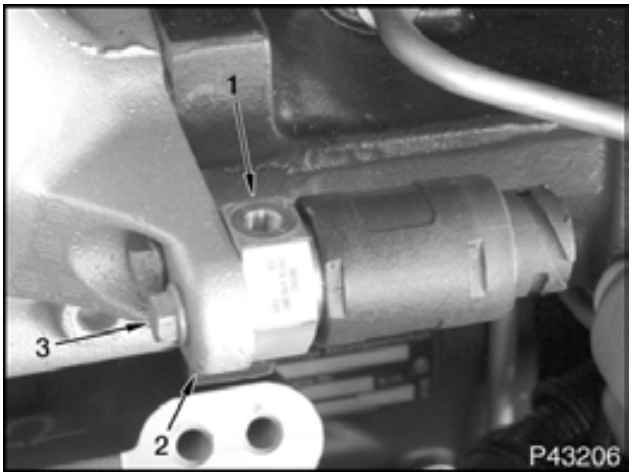

Figure 113 CSS valve

1. CSS valve
2. Air inlet duct
3. M6 x 20 hex bolt (2)

1. Install two M6 x 20 hex bolts and CSS valve. Tighten bolts to special torque (page 102).

Cold Start Supply Tube

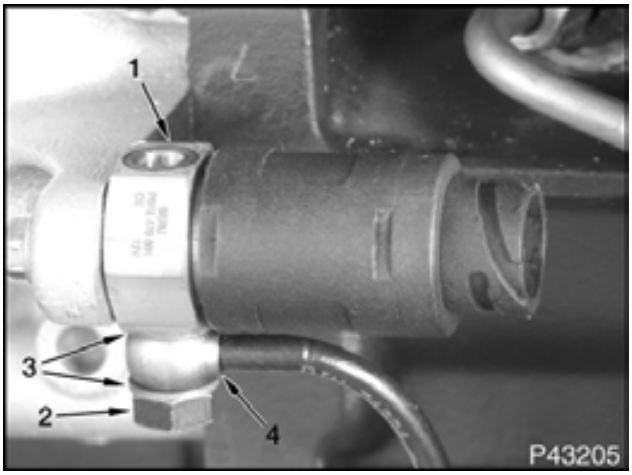

Figure 114 Cold start supply tube (at cold start solenoid (CSS) valve)

1. CSS valve
2. Size 6 hollow screw
3. 10.7 X 16 seals (2)
4. Cold start supply tube

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1. Position cold start supply tube onto CSS valve. Install two new 10.7 X 16 seals and size 6 hollow screw into CSS valve.

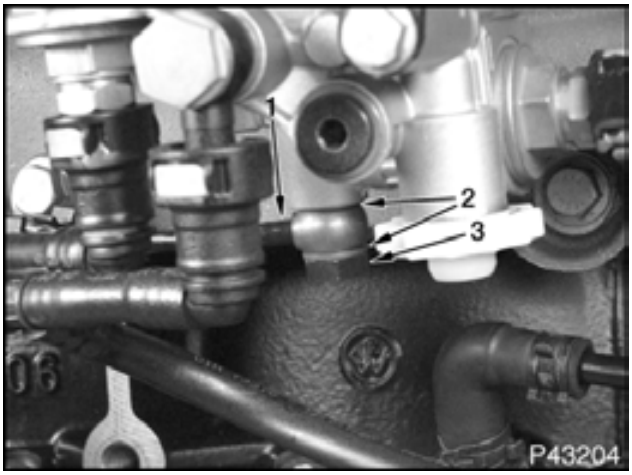

Figure 115 Cold start supply tube (at fuel service center)

1. Cold start supply tube
2. 12.7 x 18 seal (2)
3. Size 8 hollow screw

2. Position cold start supply tube onto fuel service center. Install two new 12.7 x 18 seals and size 8 hollow screw into fuel service center.
3. Tighten size 6 and size 8 hollow screws to special torque (page 102).

MV-Glow Plug Fuel Line

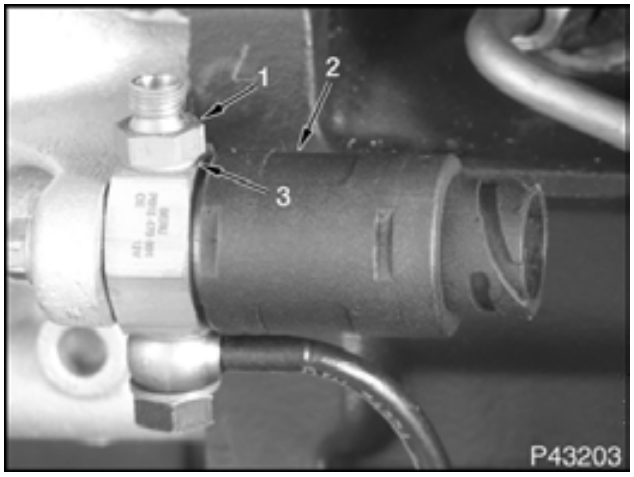

Figure 116 Adapter

1. Adapter
2. Cold start solenoid (CSS) valve
3. 8.7 x 14 seal

1. Install a new 8.7 X 14 seal and adapter onto CSS valve. Tighten adapter to special torque (page 102).

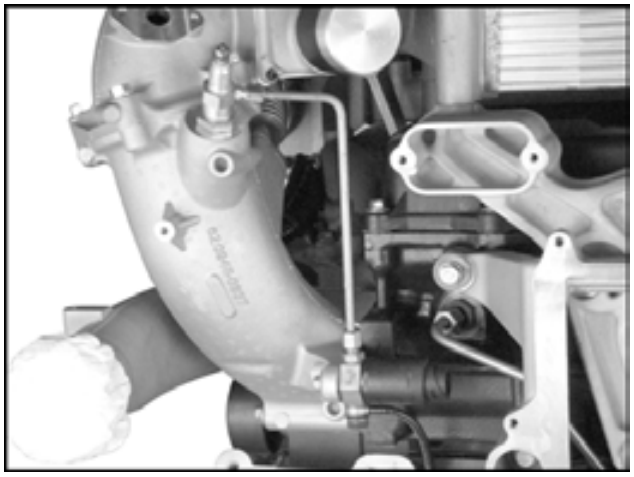

Figure 117 MV-glow plug fuel line

1. Glow plug
2. MV-glow plug fuel line
3. CSS valve

2. Install MV-glow plug fuel line into glow plug and CSS valve. Tighten fitting nuts to special torque (page 102).

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3. If the glow plug was removed, tighten glow plug locking nut to special torque (page 102).

1. Install CSR and two M6 x 20 hex bolts. Tighten bolts to special torque (page 102).

Cold Start Relay (CSR)

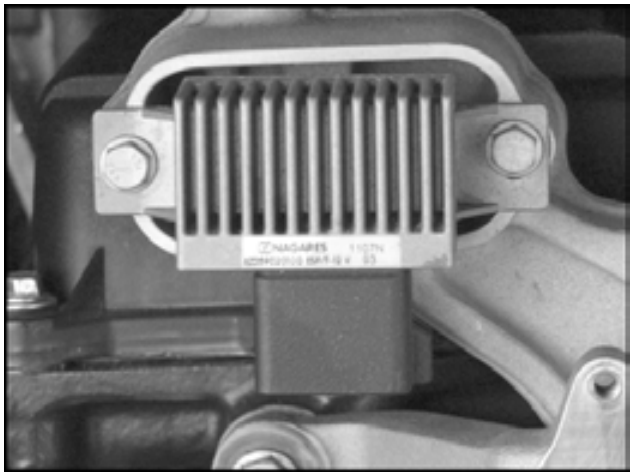

Figure 118 CSR

1. CSR
2. M6 x 20 hex bolt (2)

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Special Torque

Table 5 Cold Start Assist

Adapter	15 N·m (11 lbf·ft)
Cold start relay (CSR) hex bolts	8 N·m (71 lbf·in)
Size 6 hollow screw	15 N·m (11 lbf·ft)
Size 8 hollow screw	15 N·m (11 lbf·ft)
MV-glow plug fuel line fitting nuts	10 N·m (11 lbf·ft)
Cold start solenoid (CSS) valve hex bolts	6 N·m (53 lbf·in)
Glow plug locking nut	25 N·m (18 lbf·ft)

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Exploded Views

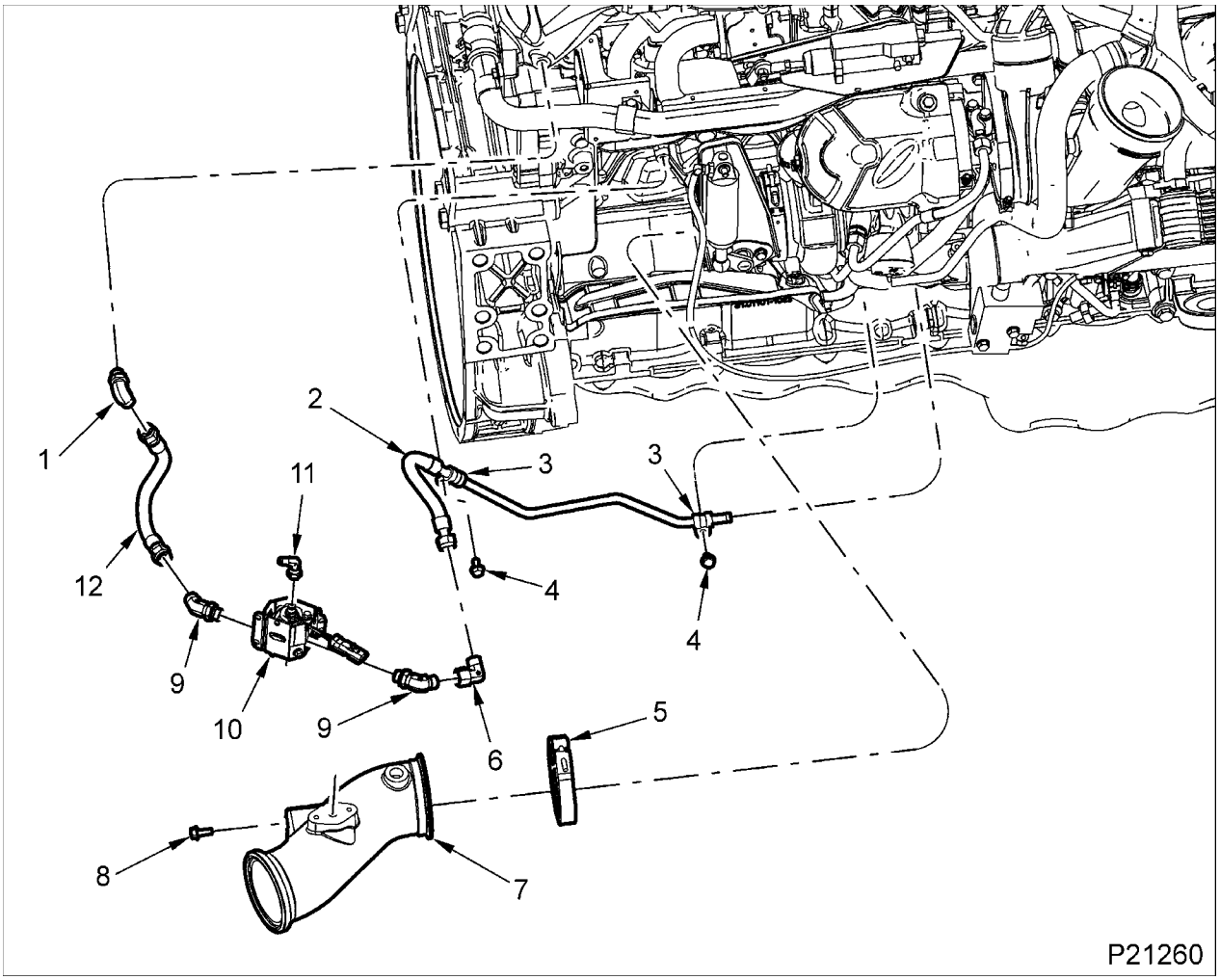

Figure 119 Aftertreatment system components

1. Parker® wee 12
2. Coolant return assembly
3. P-clamp (2)
4. M8 x 16 hex bolt (2)
5. Profiled clamp (119)
6. Parker® ew12
7. Turbo exhaust pipe
8. M8 x 20 hex bolt
9. Parker® vee 12 (2)
10. Aftertreatment Fuel Injector (AFI)
11. Parker® 4C6MXSS
12. Coolant supply line

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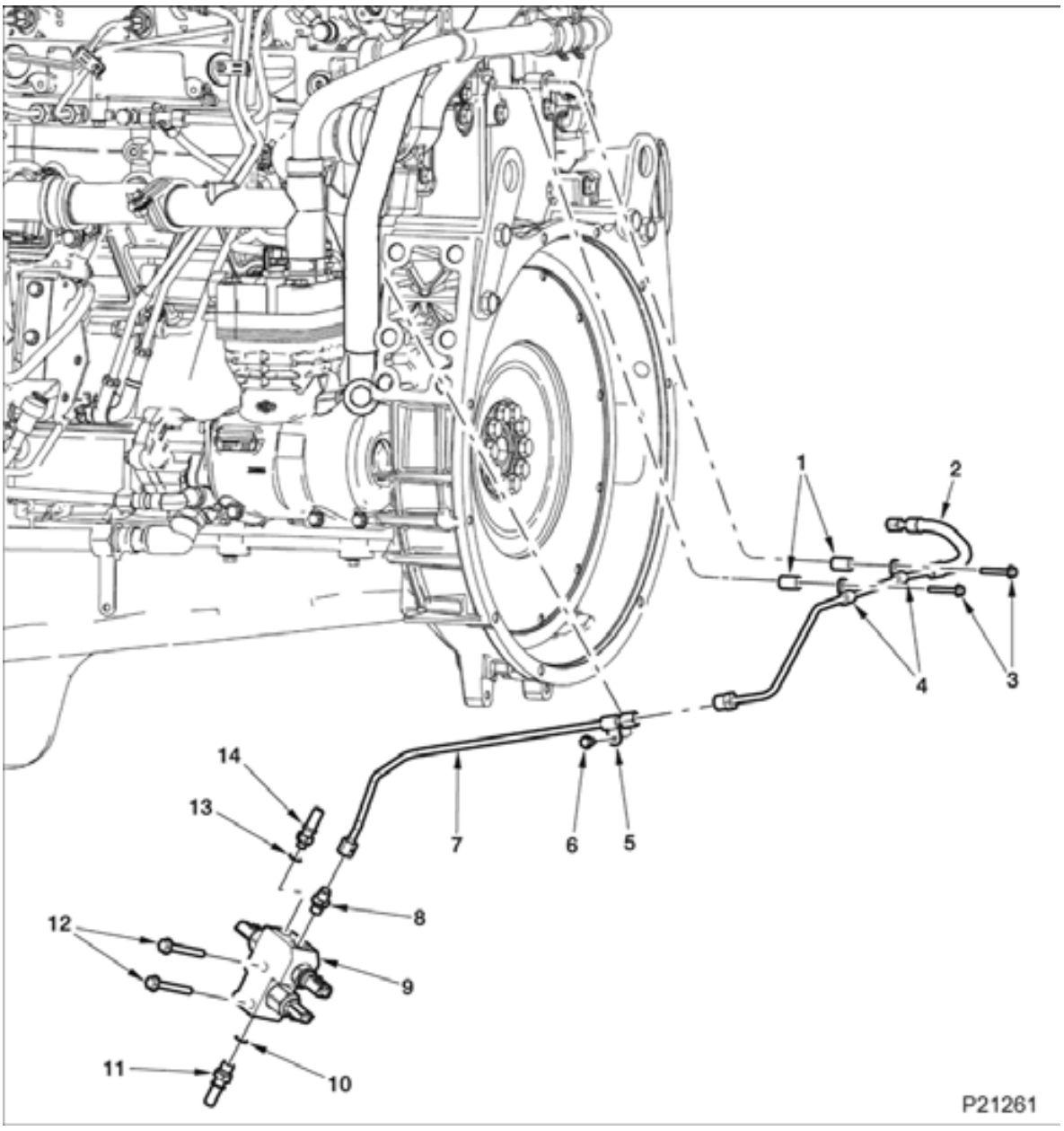

Figure 120 Aftertreatment system fuel supply

1. 6 x 15 x 23 bushing (2)
2. Fuel supply assembly (upper line)
3. M6 x 40 hex bolt (2)
4. P-clamp (2)
5. P-clamp
6. M8 x 16 hex bolt
7. Fuel supply assembly (lower line)
8. Straight fitting
9. Hydrocarbon (HC) cut-off valve
10. A14 x 18 seal ring
11. M14 x 1.5 threaded union
12. M8 x 55 hex bolt (2)
13. 9 x 2 O-ring
14. M10 x 1 threaded union

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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, 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.

Fuel Supply Assembly

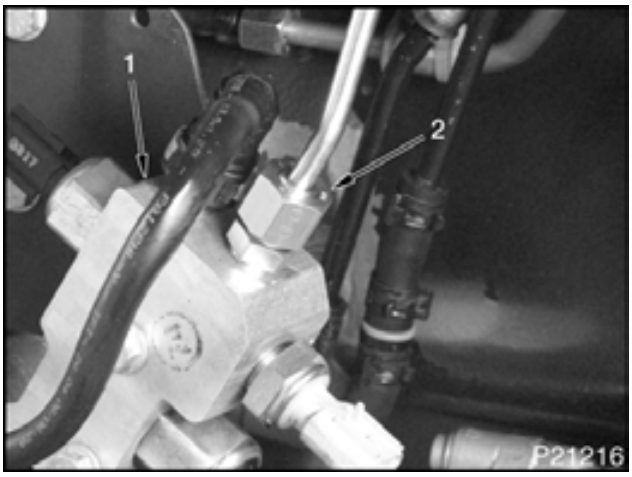

Figure 121 Fuel supply assembly (lower line)

1. Hydrocarbon (HC) cut-off valve
2. Fuel supply assembly (lower line) fitting nut

WARNING: To prevent personal injury or death, dispose of fuel in a container marked DIESEL FUEL, according to applicable regulations.

1. Place suitable container clearly marked DIESEL FUEL under HC cut-off valve.
2. Loosen fuel supply assembly (lower line) fitting nut and disconnect assembly from straight fitting at HC cut-off valve.

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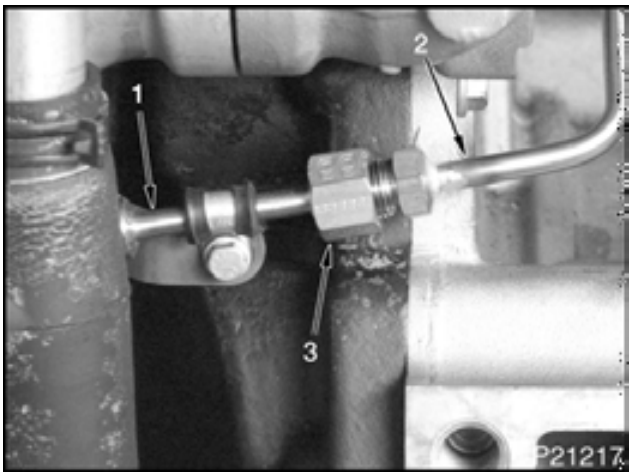

Figure 122 Fuel supply assembly (connection)

1. Fuel supply assembly (lower line)
2. Fuel supply assembly (upper line)
3. Fuel supply assembly fitting nut

3. Loosen fuel supply assembly (lower line) fitting nut and disconnect fuel supply assembly (lower line) from fuel supply assembly (upper line).

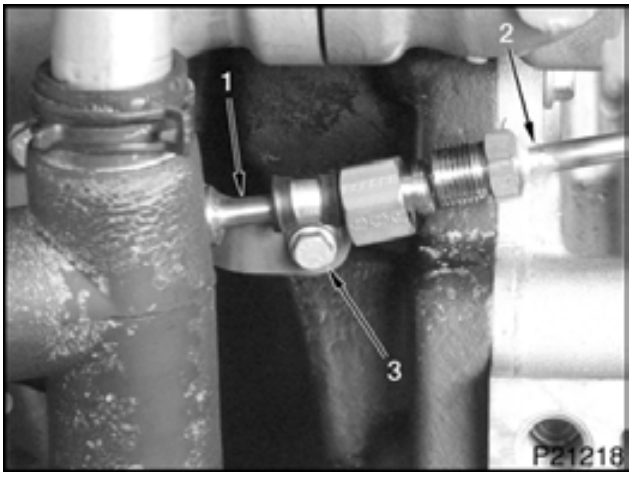

Figure 123 Fuel supply assembly (lower line)

1. Fuel supply assembly (lower line)
2. Fuel supply assembly (upper line)
3. M8 x 16 hex bolt

4. Remove M8 x 16 hex bolt and fuel supply assembly (lower line).

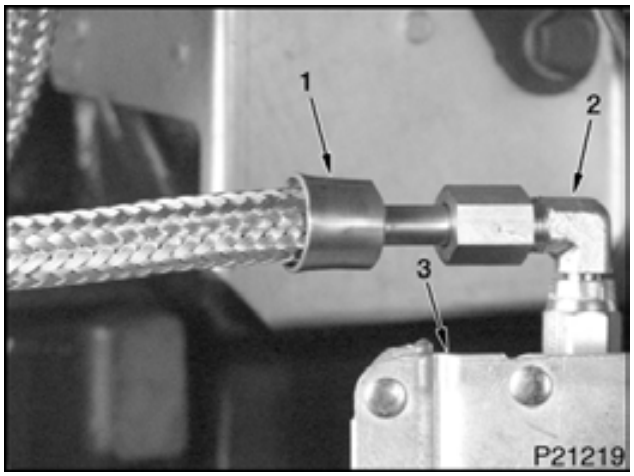

Figure 124 Fuel supply assembly (upper line connection)

1. Fuel supply assembly (upper line)
2. Parker® 4C6MXSS
3. Aftertreatment Fuel Injector (AFI)

5. Loosen fuel supply assembly (upper line) fitting nut and disconnect assembly from Parker® 4C6MXSS at AFI.

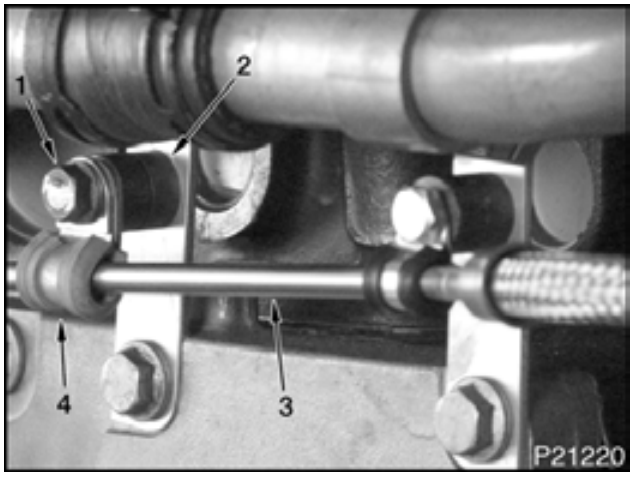

Figure 125 Fuel supply assembly (upper line)

1. M6 x 40 hex bolt (2)
2. 6 x 15 x 23 bushing (2)
3. Fuel supply assembly (upper line)
4. P-clamp (2)

6. Remove two M6 x 40 hex bolts, two 6 x 15 x 23 bushings and fuel supply assembly (upper line).

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Hydrocarbon (HC) Cut-Off Valve

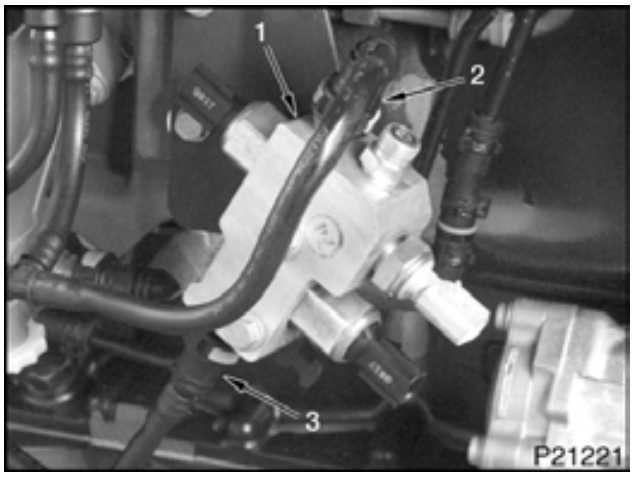

Figure 126 HC cut-off valve connections

1. HC cut-off valve
2. Fuel line assembly
3. Fuel line assembly

WARNING: To prevent personal injury or death, dispose of fuel in a container marked DIESEL FUEL, according to applicable regulations.

1. Place suitable container clearly marked DIESEL FUEL under HC cut-off valve.

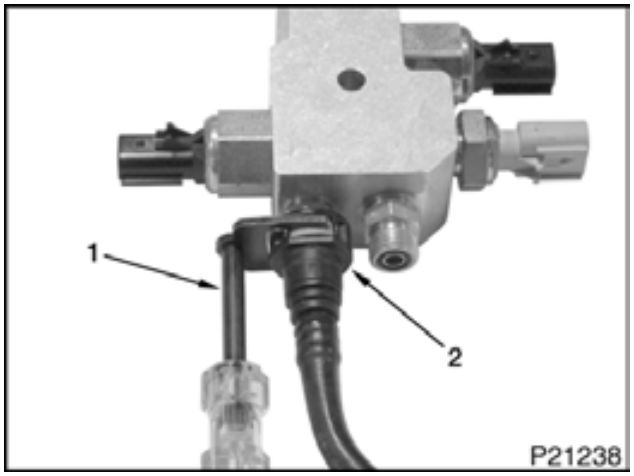

Figure 127 Fuel line disconnect tool on fuel line assembly

1. Fuel line disconnect tool 11.8 mm
2. Fuel line assembly (2)

2. Using Fuel Line Disconnect Tool 11.8 mm (page 120) disconnect two fuel line assemblies from HC cut-off valve.

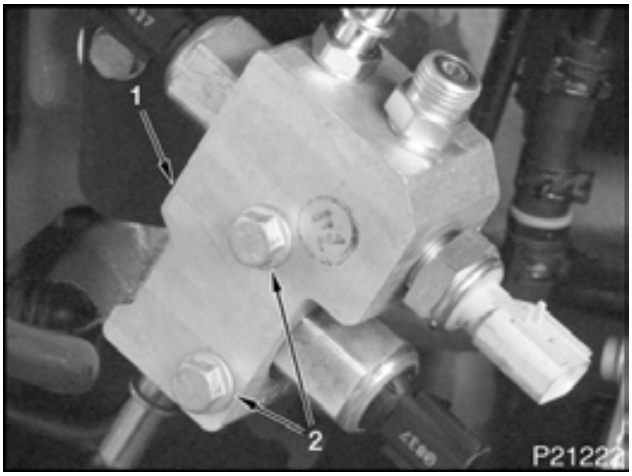

Figure 128 HC cut-off valve

1. HC cut-off valve
2. M8 x 55 hex bolt (2)

3. Remove two M8 x 55 hex bolts and HC cut-off valve.

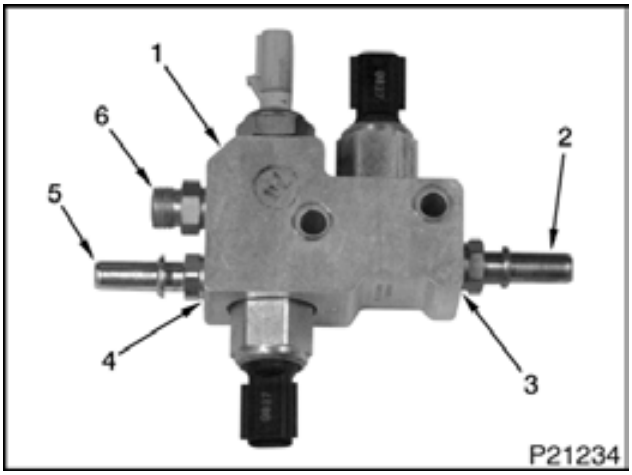

Figure 129 HC cut-off valve (fitting/unions)

1. HC cut-off valve
2. M14 x 1.5 threaded union
3. A14 x 18 seal ring
4. 9 x 2 O-ring
5. M10 x 1 threaded union
6. Straight fitting

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NOTE: Proceed with steps 4, 5, and 6 only if HC cut-off valve fittings are found to be leaking or if HC cut-off valve is being replaced.

4. Remove M14 x 1.5 threaded union from HC cut-off valve. Remove and discard A14 x 18 seal ring.
5. Remove M10 x 1 threaded union from HC cut-off valve. Remove and discard 9 x 2 O-ring.
6. Remove and discard straight fitting from HC cut-off valve.

Coolant Supply Line

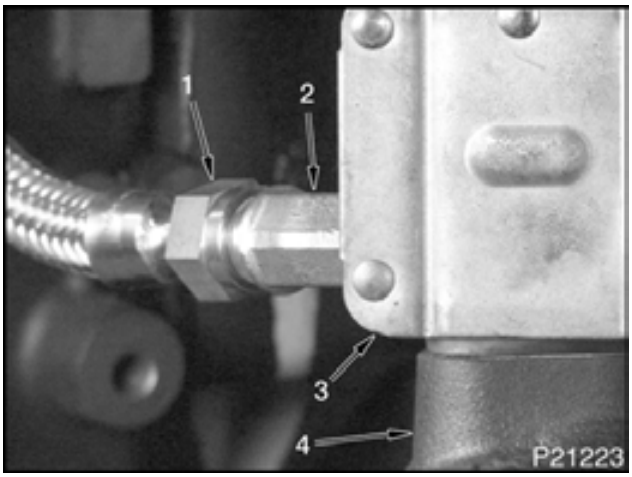

Figure 130 Coolant supply line

1. Coolant supply line fitting nut
2. Parker® vee 12
3. Aftertreatment Fuel Injector (AFI)
4. Turbo exhaust pipe

1. Loosen the coolant supply line fitting nut and disconnect line from Parker® vee 12 at AFI.

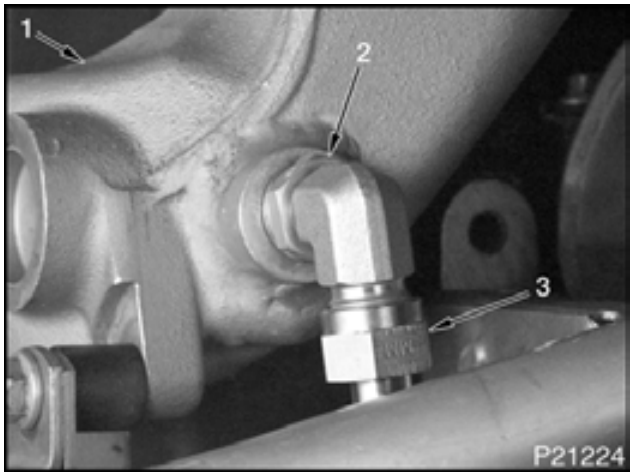

Figure 131 Coolant supply line

1. Coolant elbow
2. Parker® wee 12
3. Coolant supply line

2. Loosen coolant supply line fitting nut and disconnect line from Parker® wee 12 at coolant elbow. Remove coolant supply line.

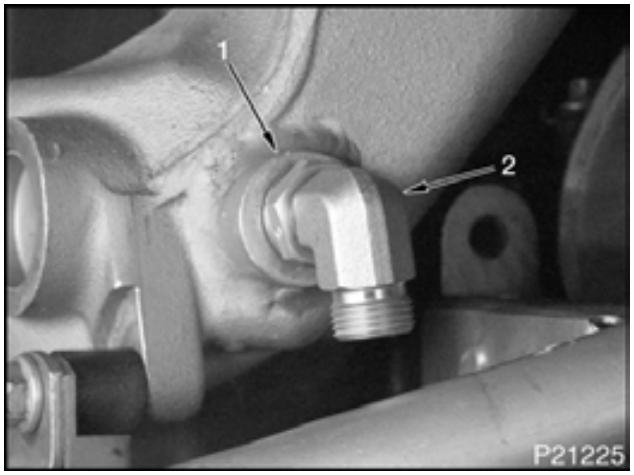

Figure 132 Coolant elbow connection

1. Coolant elbow
2. Parker® wee 12

NOTE: Proceed with step 3 only if Parker® wee 12 is found to be leaking or if coolant elbow is being replaced.

3. Remove Parker® wee 12 from coolant elbow.

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Coolant Return Assembly

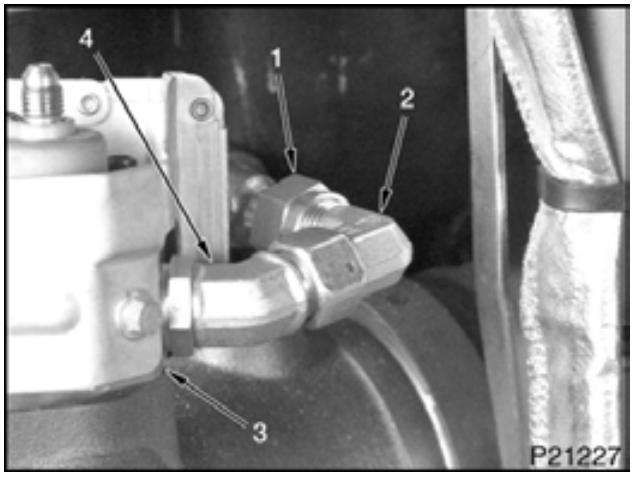

Figure 133 Coolant return assembly (upper connection)

1. Coolant return assembly fitting nut
2. Parker® ew12
3. Aftertreatment Fuel Injector (AFI)
4. Parker® vee 12

1. Loosen coolant return assembly fitting nut and disconnect assembly from Parker® ew12.

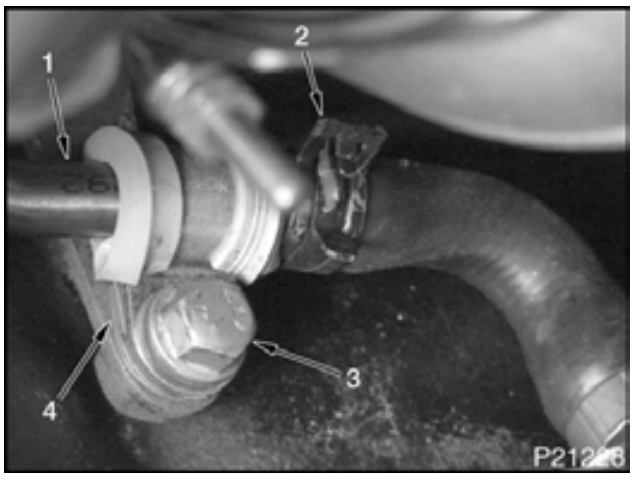

Figure 134 Coolant return assembly (lower connection)

1. Coolant return assembly
2. Clamp
3. M8 x 16 hex bolt
4. P-clamp

2. Release clamp and disconnect coolant return assembly from Charge Air Cooler (CAC) return coolant pipe.
3. Remove M8 x 16 hex bolt from P-clamp.

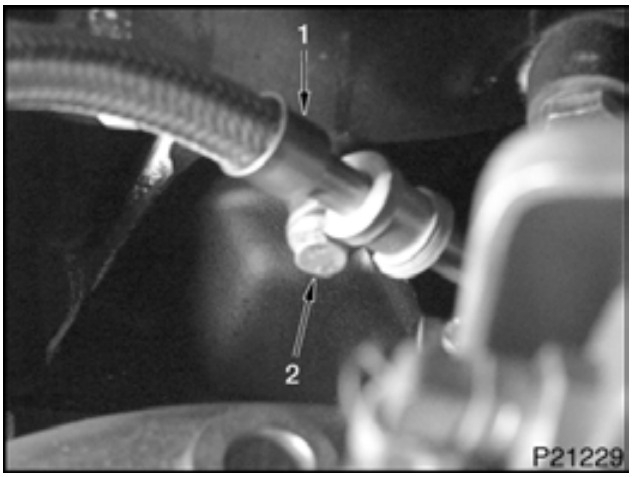

Figure 135 Coolant return assembly

1. Coolant return assembly
2. M8 x 16 hex bolt

4. Remove M8 x 16 hex bolt and remove the coolant return assembly.

Aftertreatment Fuel Injector (AFI)

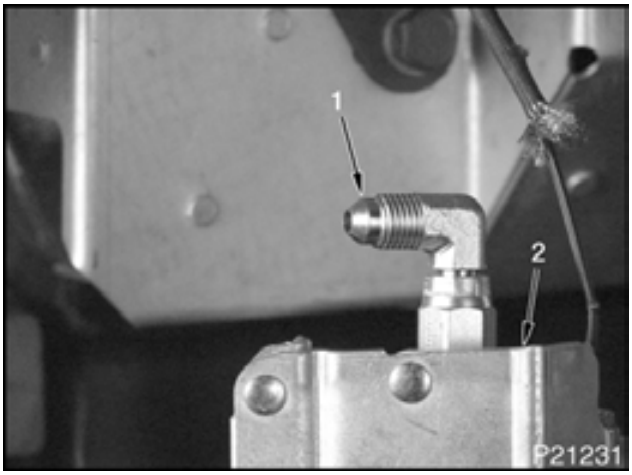

Figure 136 Parker® 4C6MXSS connection at Aftertreatment Fuel Injector (AFI)

1. Parker® 4C6MXSS
2. AFI

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NOTE: Proceed with steps 1 through 4 only if fittings are found to be leaking or if AFI is being replaced.

1. Remove Parker® 4C6MXSS from AFI.

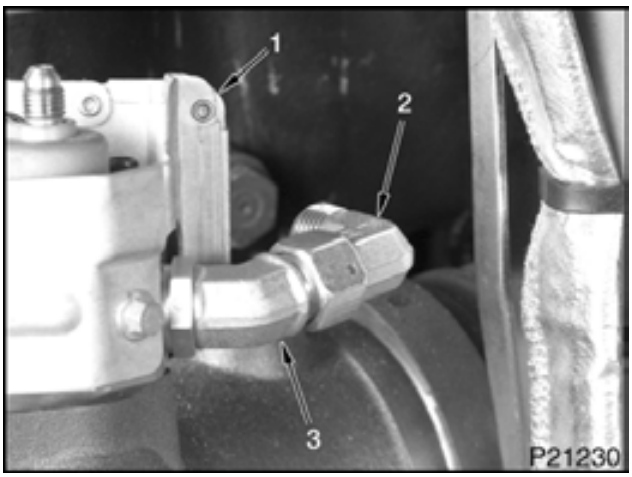

Figure 137 Aftertreatment Fuel Injector (AFI) connection

1. AFI
2. Parker® ew12
3. Parker® vee 12

2. Remove Parker® ew12 from Parker® vee 12.
3. Remove Parker® vee 12 from AFI.

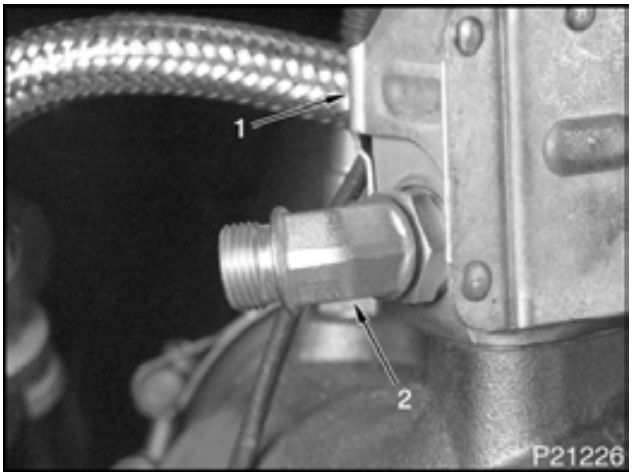

Figure 138 Parker® vee 12 connection at Aftertreatment Fuel Injector (AFI)

1. AFI
2. Parker® vee 12

4. Remove Parker® vee 12 from AFI.

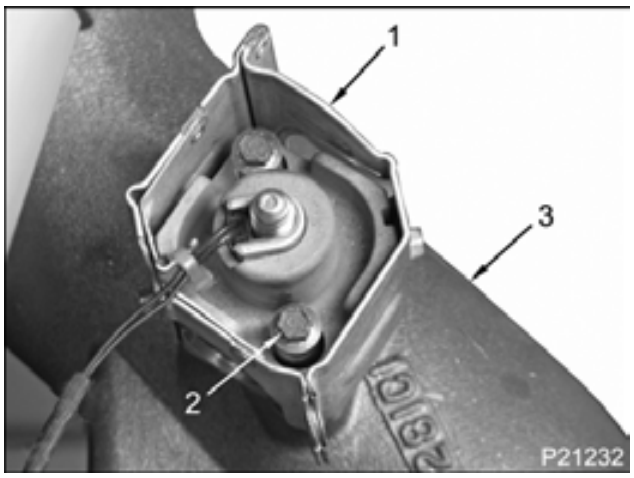

Figure 139 Aftertreatment Fuel Injector (AFI)

1. AFI
2. AFI hex bolt (2)
3. Turbo exhaust pipe

NOTE: Do not lose spacer between AFI and gasket.

5. Remove two hex bolts, two spacers, and AFI from turbo exhaust pipe.
6. Discard gasket.

Turbo Exhaust Pipe

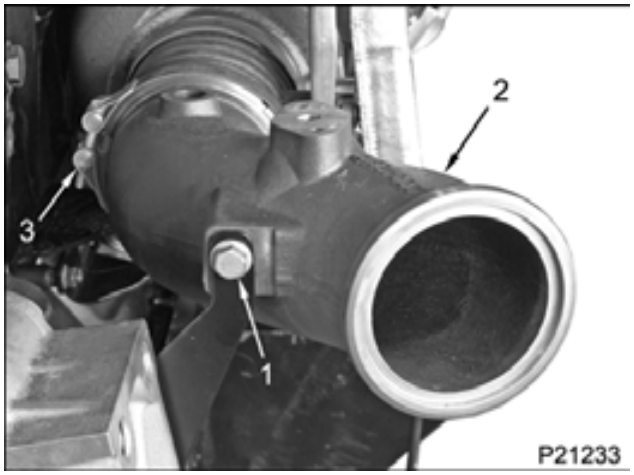

Figure 140 Turbo exhaust pipe

1. M10 x 20 hex bolt
2. Turbo exhaust pipe
3. Profiled clamp (119)

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1. Remove M10 x 20 hex bolt from turbo exhaust pipe.
2. Loosen profiled clamp and remove turbo exhaust pipe. Discard profile clamp.

Cleaning and Inspection

Figure 141 Aftertreatment Fuel Injector (AFI)

1. AFI Cavity
2. AFI Nozzle tip

1. Spray AFI cavity and nozzle tip with carb and choke cleaner (page 120).
2. Use a white nylon detail brush (page 120) to clean the cavity and nozzle tip of the AFT.

NOTE: Use circular strokes and focus on the nozzle tip; the orifice of the nozzle tip must be open. Additional sprays of carb and choke cleaner and brushing may be necessary.

3. After brushing, flush AFI cavity and nozzle tip with carb and choke cleaner.

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

4. Dry cavity and nozzle tip with filtered compressed air.

Installation

Turbo Exhaust Pipe

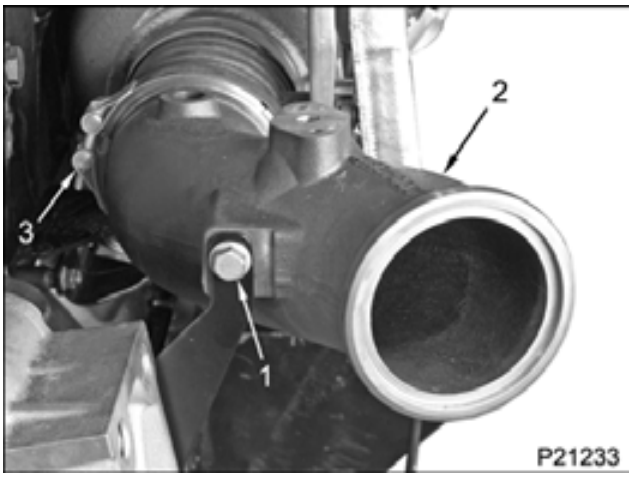

Figure 142 Turbo exhaust pipe

1. M10 x 20 hex bolt
2. Turbo exhaust pipe
3. Profiled clamp

1. Install turbo exhaust pipe and profiled clamp.
2. Install M10 x 20 hex bolt into turbo exhaust pipe and tighten to standard torque (page 457).
3. Install new 119 profile clamp. Tighten to special torque (page 120).

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Aftertreatment Fuel Injector (AFI)

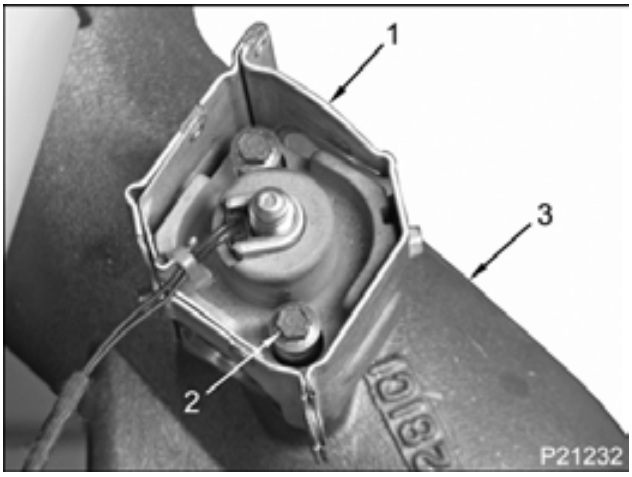

Figure 143 Aftertreatment Fuel Injector (AFI)

1. AFI
2. AFI hex bolt (2)
3. Turbo exhaust pipe

1. Apply a light coating of high-temperature nickel-graphite anti-seize compound (page 120) to AFI hex bolt threads.
2. Apply a light coating of clean engine oil to AFI hex bolt head bearing surfaces.

NOTE: Remember to install spacer between gasket and AFI.

3. Install new gasket on AFI.
4. Install AFI onto turbo exhaust pipe. Tighten hex bolts as follows.
   a. Pre-tighten hex bolts to 8 N·m (75 lbf-in)
   b. Tighten hex bolts to 14 N·m (125 lbf-in)
5. Apply Parker® ThreadMate™ (page 120) to Parker® vee 12, Parker® ew12, and Parker® 4C6MXSS threads.

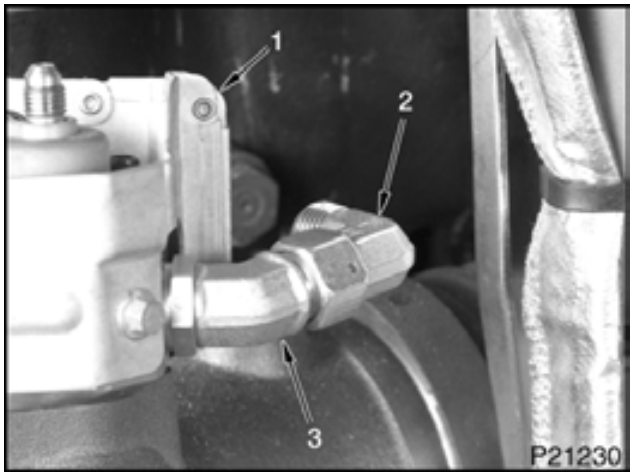

Figure 144 Aftertreatment Fuel Injector (AFI) connection

1. AFI
2. Parker® ew12
3. Parker® vee 12

NOTE: Proceed with steps 6 through 9 only if fittings were found to be leaking or if AFI was replaced.

6. Install Parker® vee12 into AFI and hand tighten.
7. Install Parker® ew12 onto Parker® vee 12 and hand tighten.

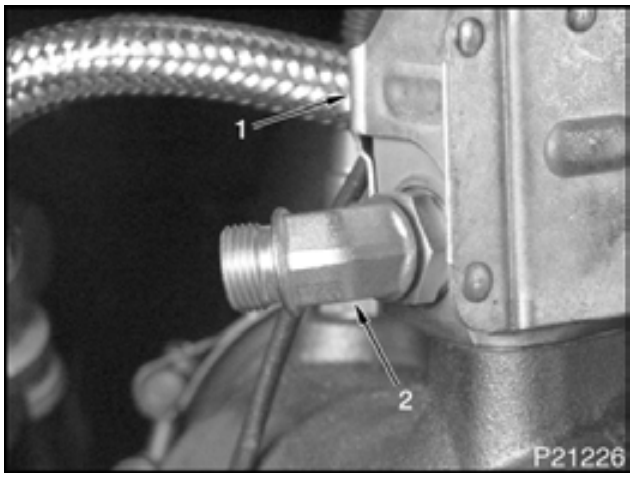

Figure 145 Parker® vee 12 connection at Aftertreatment Fuel Injector (AFI)

1. AFI
2. Parker® vee 12

8. Install Parker® vee 12 into AFI and hand tighten.

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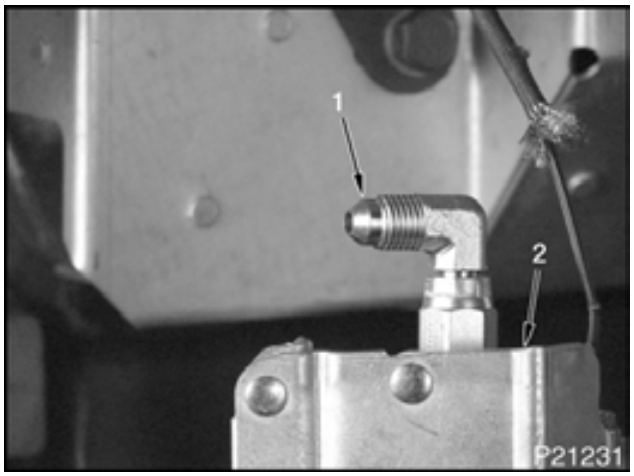

Figure 146 Parker® 4C6MXSS at Aftertreatment Fuel Injector (AFI)

1. Parker® 4C6MXSS
2. AFI

9. Install Parker® 4C6MXSS onto AFI and hand tighten.

Coolant Return Assembly

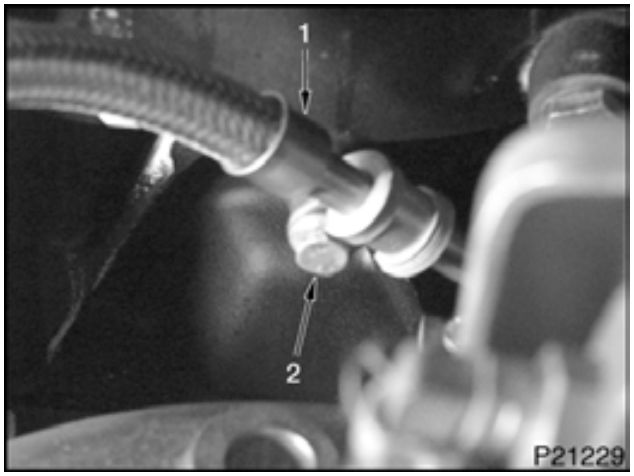

Figure 147 Coolant return assembly

1. Coolant return assembly
2. M8 x 20 hex bolt

1. Position coolant return assembly and install M8 x 20 hex bolt through P-clamp. Tighten hex bolt to special torque (page 120).

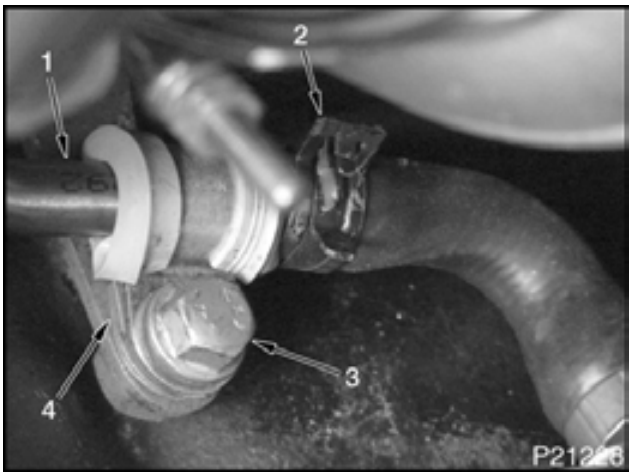

Figure 148 Coolant return assembly (lower connection)

1. Coolant return assembly
2. Clamp
3. M8 x 20 hex bolt
4. P-clamp

2. Install M8 x 20 hex bolt into P-clamp. Tighten hex bolt to special torque (page 120).
3. Connect coolant return assembly to Charge Air Cooler (CAC) return coolant pipe and install clamp.

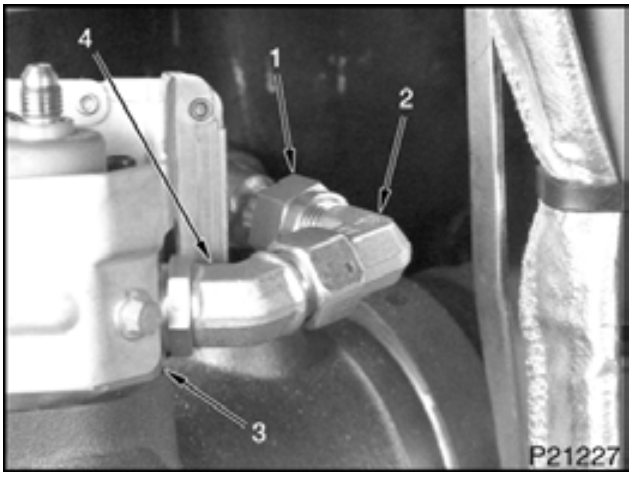

Figure 149 Coolant return assembly (upper connection)

1. Coolant return assembly fitting nut
2. Parker® ew12
3. Aftertreatment Fuel Injector (AFI)
4. Parker® vee 12

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4. Connect and hand tighten coolant return assembly fitting nut to Parker® ew12 at AFI.

NOTE: Proceed with steps 5 through 7 only if fittings were removed or if AFI was replaced.

5. Align Parker® vee 12 and Parker® ew12 to maintain coolant return assembly clearance.
6. Tighten Parker® vee 12 fitting at AFI to special torque (page 120).
7. Tighten Parker® ew12 fitting at Parker® vee 12 to special torque (page 120).
8. Tighten coolant return assembly fitting nut to Parker® ew12 as follows.
   a. Hand tighten.
   b. Turn an additional 90°.

Coolant Supply Line

1. Apply Parker® ThreadMate™ (page 120) to threads of Parker® wee 12.

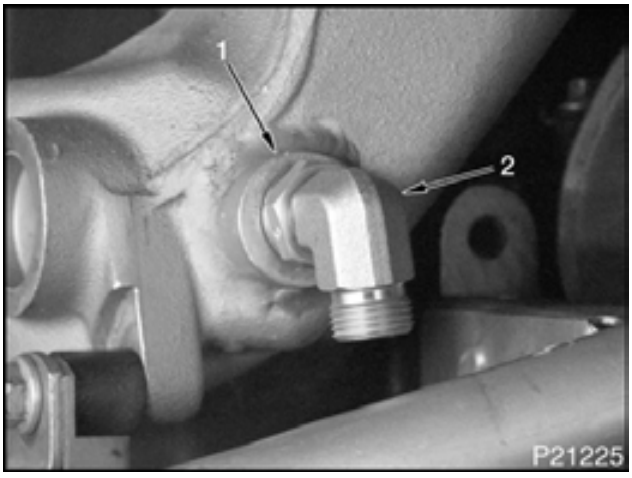

Figure 150 Coolant elbow connection

1. Coolant elbow
2. Parker® wee 12

NOTE: Proceed with step 2 only if fitting was removed or if coolant elbow was replaced.

2. Install Parker® wee 12 into coolant elbow and hand tighten.

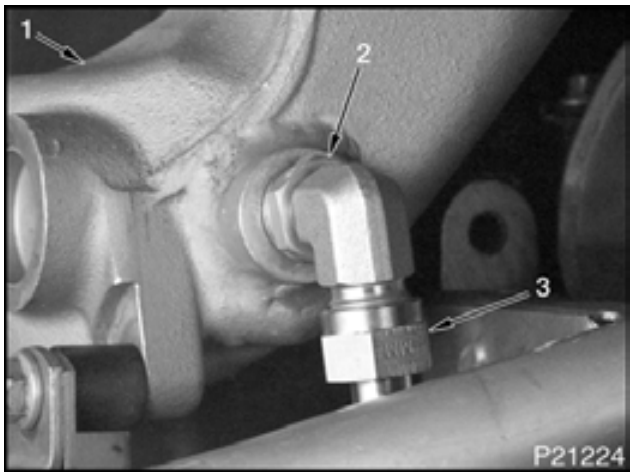

Figure 151 Coolant supply line connection at coolant elbow

1. Coolant elbow
2. Parker® wee 12
3. Coolant supply line

3. Connect and hand tighten coolant supply line fitting nut onto Parker® wee 12 at coolant elbow.

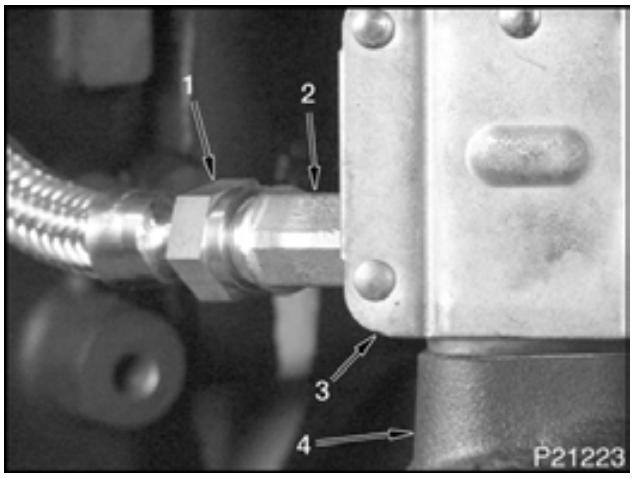

Figure 152 Coolant supply line connection at AFI

1. Coolant supply line
2. Parker® vee 12
3. AFI
4. Turbo exhaust pipe

4. Connect coolant supply line fitting nut onto Parker® vee 12 at AFI.

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NOTE: Proceed with steps 5, 6, and 7 only if fittings were removed, or if the AFI or coolant elbow was replaced.

5. Align Parker® vee 12 and Parker® wee 12 to maintain coolant supply line clearance.
6. Tighten Parker® vee 12 at AFI to special torque (page 120).
7. Tighten Parker® wee 12 at coolant elbow to special torque (page 120).
8. Tighten coolant supply line fitting nuts onto Parker® vee 12 at AFI and at Parker® wee 12 at the coolant elbow as follows:
   a. Hand tighten.
   b. Turn an additional 90°.

Hydrocarbon (HC) Cut-Off Valve

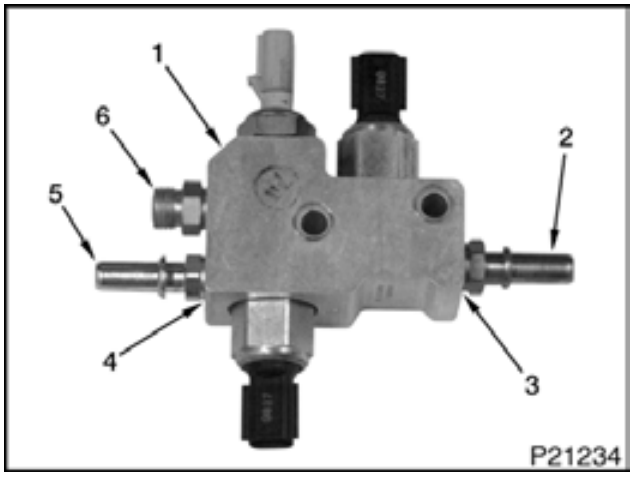

Figure 153 HC cut-off valve (fitting/unions)

1. HC cut-off valve
2. M14 x 1.5 threaded union
3. A14 x 18 seal ring
4. 9 x 2 O-ring
5. M10 x 1 threaded union
6. Straight fitting

NOTE: Proceed with steps 1, 2 and 3 only if fittings were removed or the HC cut-off valve was replaced.

1. Install new straight fitting to HC cut-off valve. Tighten to special torque (page 120).
2. Install a new 9 x 2 O-ring. Install M10 x 1 threaded union to HC cut-off valve. Tighten to special torque (page 120).
3. Install a new A14 x 18 seal ring. Install M14 x 1.5 threaded union to HC cut-off valve. Tighten to special torque (page 120).

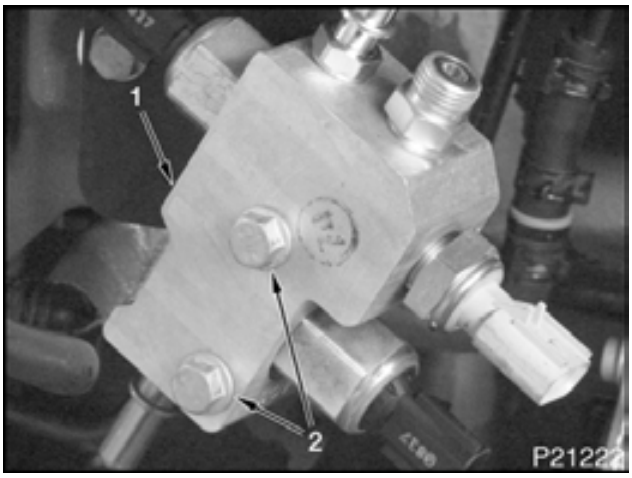

Figure 154 HC cut-off valve

1. HC cut-off valve
2. M8 x 55 hex bolts (2)

4. Install HC cut-off valve and two M8 x 55 hex bolts. Tighten two hex bolts to special torque (page 120).

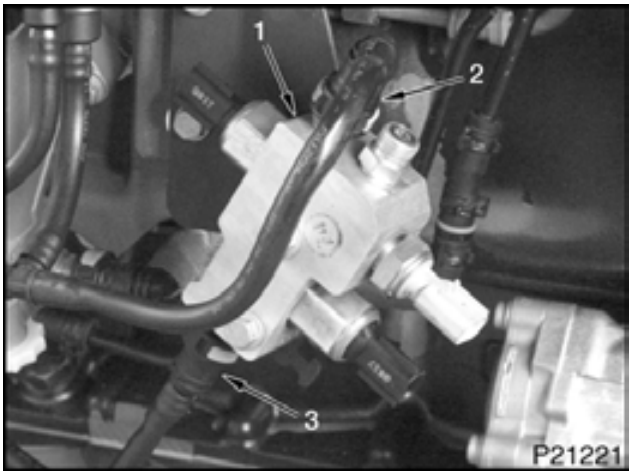

Figure 155 HC cut-off valve

1. HC cut-off valve
2. Fuel line assembly
3. Fuel line assembly

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5. Position fuel line assemblies onto unions and push on to connect to HC cut-off valve until an audible click is heard.

Fuel Supply Assembly

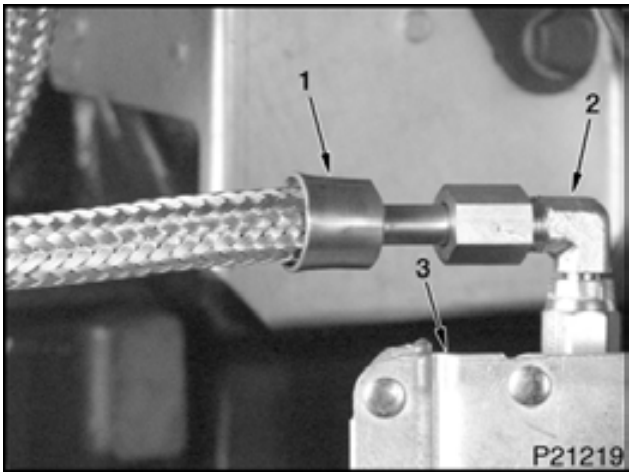

Figure 156 Fuel supply assembly (upper line connection)

1. Fuel supply assembly (upper line)
2. Parker® 4C6MXSS
3. Aftertreatment fuel injector (AFI)

1. Position fuel supply assembly (upper line) into correct location.
2. Connect and hand tighten fuel supply assembly (upper line) onto Parker® 4C6MXSS at AFI.

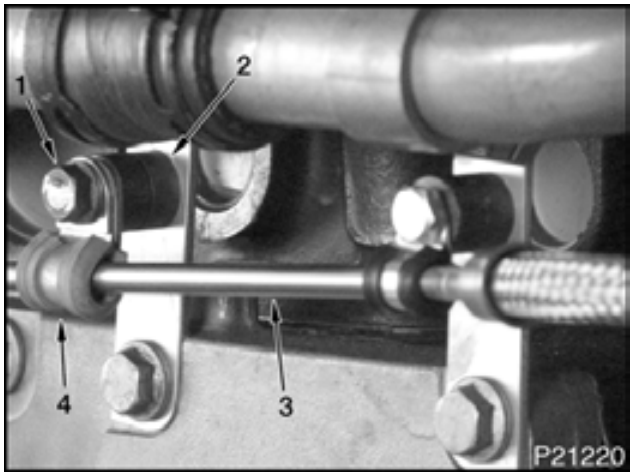

Figure 157 Fuel supply assembly (upper line)

1. M6 x 40 hex bolt (2)
2. 6 x 15 x 23 bushing (2)
3. Fuel supply assembly (upper line)
4. P-clamp (2)

3. Install two M6 x 40 hex bolts, two 6 x 15 x 23 bushings for fuel supply assembly (upper line). Tighten hex bolts to special torque (page 120).

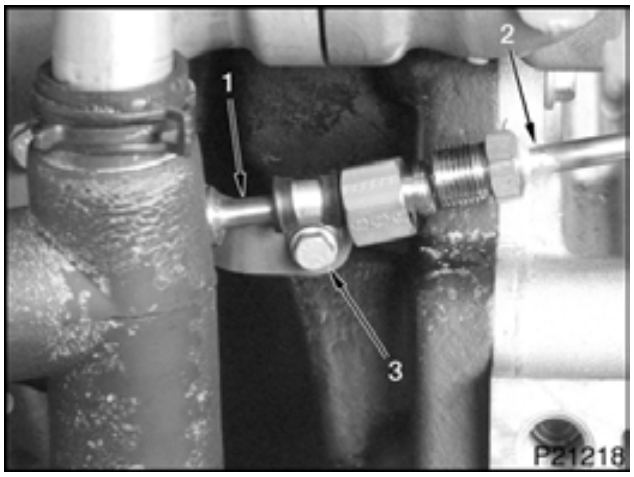

Figure 158 Fuel supply assembly (lower line)

1. Fuel supply assembly (lower line)
2. Fuel supply assembly (upper line)
3. M8 x 16 hex bolt

4. Position fuel supply assembly (lower line) and install M8 x 16 hex bolt. Tighten hex bolt to special torque (page 120).

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5. Apply Parker® ThreadMate™ (page 120) to threads of fuel supply assembly (upper line).

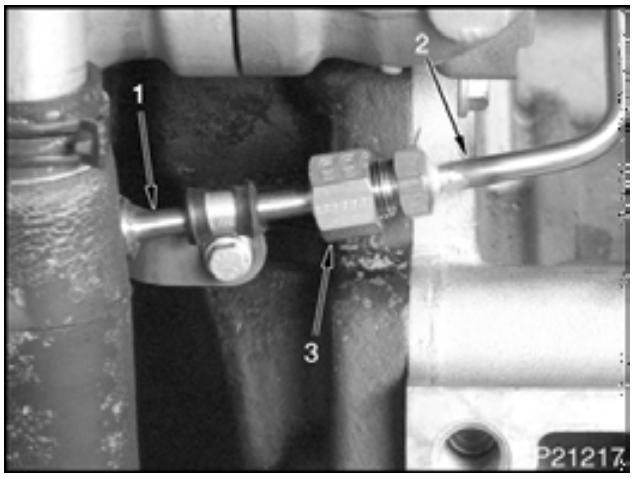

Figure 159 Fuel supply assembly (connection)

1. Fuel supply assembly (lower line)
2. Fuel supply assembly (upper line)
3. Fuel supply assembly fitting nut

6. Connect fuel supply assembly (upper line) onto fuel supply assembly (lower line). Tighten fitting nut to special torque (page 120).
7. Apply Parker® ThreadMate™ (page 120) to threads of straight fitting on HC cut-off valve.

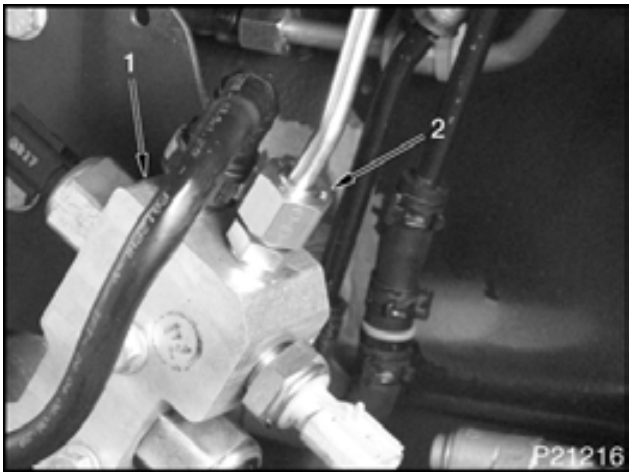

Figure 160 Fuel supply assembly (lower line)

1. Hydrocarbon (HC) cut-off valve
2. Fuel supply assembly (lower line)

8. Connect fuel supply assembly (lower line) onto HC cut-off valve. Tighten fitting nut to special torque (page 120).
9. Tighten fuel supply assembly (upper line) fitting nut to Parker® 4C6MXSS to special torque (page 120).

NOTE: Proceed with steps 10 and 11 only if fitting was removed or if AFI was replaced.

10. Align Parker® 4C6MXSS to maintain fuel supply assembly (upper line) clearance.
11. Tighten Parker® 4C6MXSS onto AFI to special torque (page 120).

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Special Torque

Table 6 Aftertreatment System (in order of installation)

Profiled clamp (119)	7 N·m (62 lbf·in)
Aftertreatment fuel injector (AFI) hex bolts	See tightening steps in procedure.
Coolant return assembly P-clamp hex bolts	31 N·m (23 lbf·ft)
Parker® vee 12 onto AFI	41 N·m (30 lbf·ft)
Parker® ew12 onto Parker® vee 12	41 N·m (30 lbf·ft)
Coolant return assembly fitting nut to Parker® ew12	See tightening steps in procedure.
Parker® wee 12 into coolant elbow	41 N·m (30 lbf·ft)
Coolant supply line fitting nuts	See tightening steps in procedure.
Straight fitting into HC cut-off valve	24 N·m (18 lbf·ft)
M10 x 1 threaded union into HC cut-off valve	23 N·m (11 lbf·ft)
M14 x 1.5 threaded union into HC cut-off valve	35 N·m (26 lbf·ft)
Hydrocarbon (HC) cut-off valve hex bolts	31 N·m (23 lbf·ft)
M6 x 40 fuel supply assembly (upper line) P-clamp hex bolts	13 N·m (11 lbf·ft)
M8 x 16 fuel supply assembly (lower line) P-clamp hex bolt	31 N·m (23 lbf·ft)
Fuel supply assembly (upper line) fitting nut at connection of upper and lower lines	40 N·m (30 lbf·ft)
Fuel supply assembly (lower line) fitting nut at HC cut-off valve	27 N·m (20 lbf·ft)
Fuel supply assembly fitting nut (upper line) at Parker® 4C6MXSS	27 N·m (20 lbf·ft)
Parker® 4C6MXSS into AFI	15 N·m (11 lbf·ft)

Special Service Tools

Table 7 Aftertreatment System

Description	Tool Number
Parker® ThreadMate™	Obtain locally
High-Temperature Nickel-Graphite Anti-Seize Compound	Obtain locally
Fuel Line Disconnect Tool 11.8 mm	ZTSE4773
White nylon detail brush	Obtain locally
Carb and choke cleaner	Obtain locally

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Exploded View

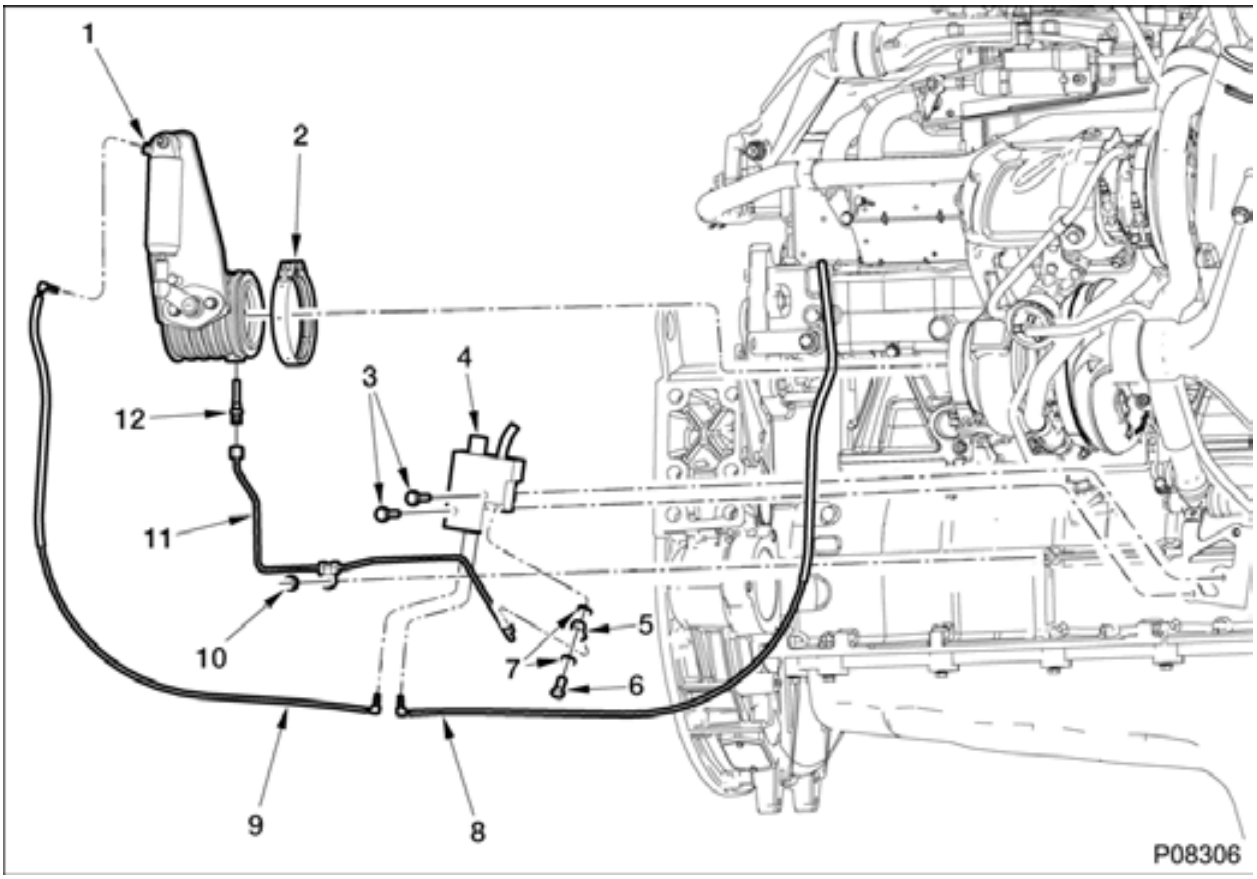

Figure 161 Retarder control system

1. Exhaust manifold with butterfly
2. DMR 114 profiled clamp
3. M8 x 55 hex bolt (2)
4. Retarder control
5. Ring union
6. Size 6 hollow screw
7. 10 x 1.35 seal (2)
8. Air supply line assembly
9. Pressure air line
10. M8 x 16 x 20 stud bolt
11. Pressure line
12. Straight union

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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, 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.

NOTE: Refer to the following service sections for information on removal of components prior to this section:

- Engine Electrical
- Aftertreatment System

Pressure Line

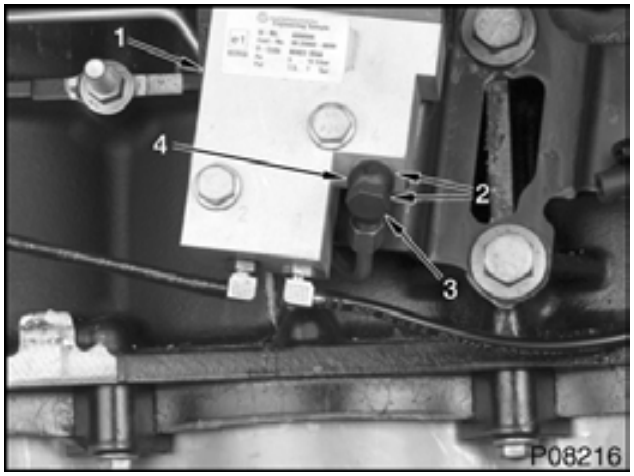

Figure 162 Pressure line connection at retarder control

1. Retarder control
2. 10 x 1.35 seal (2)
3. Size 6 hollow screw
4. Ring union

1. Remove size 6 hollow screw and disconnect ring union from retarder control. Discard two 10 x 1.35 seals.

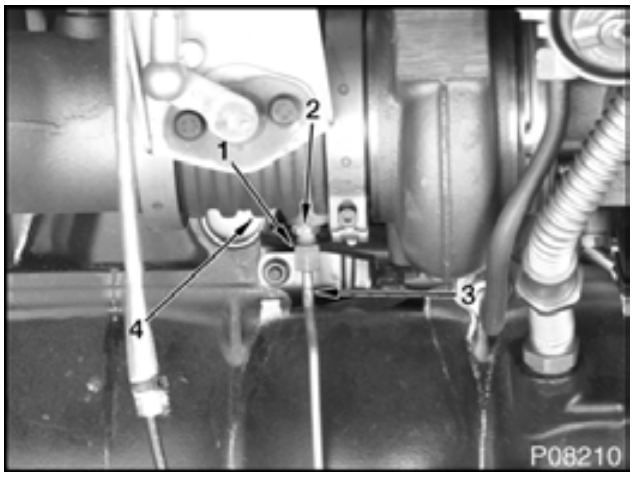

Figure 163 Pressure line connection at exhaust manifold with butterfly

1. Pressure line fitting nut
2. Straight union
3. Pressure line
4. Exhaust manifold with butterfly

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2. Loosen pressure line fitting nut from straight union.

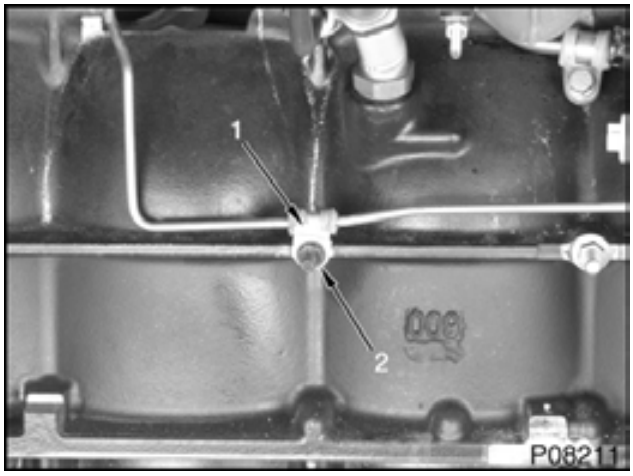

Figure 164 Pressure line P-clamp

1. Pressure line P-clamp
2. M8 x 16 x 20 stud bolt

3. Remove M8 x 16 x 20 stud bolt from pressure line P-clamp and remove pressure line.

NOTE: Do next step only if replacing ring union or pressure line due to leakage.

4. Remove ring union from pressure line.

Pressure Air Line

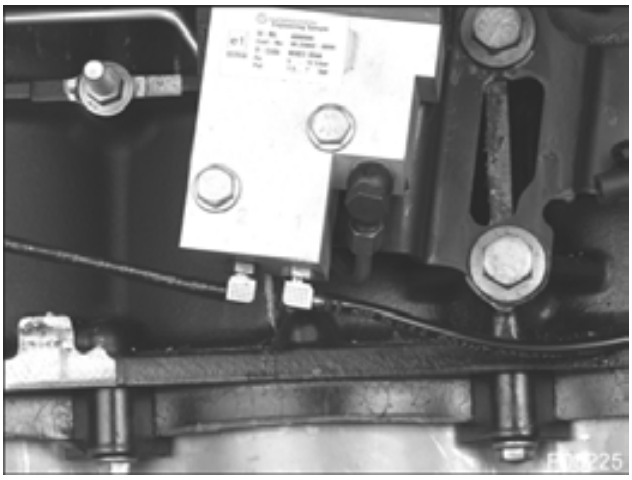

Figure 165 Pressure air line connection to retarder control

1. Retarder control
2. Pressure air line threaded fitting

1. Loosen pressure air line threaded fitting at retarder control and disconnect pressure air line.

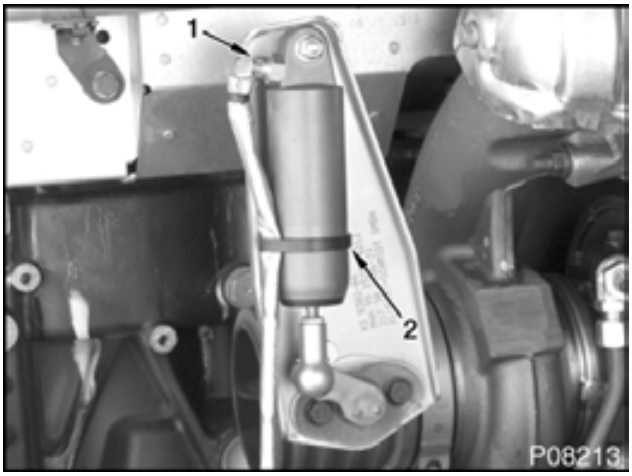

Figure 166 Pressure air line connection to exhaust manifold with butterfly

1. Pressure air line threaded fitting
2. Tie strap

2. Loosen pressure air line threaded fitting at exhaust manifold with butterfly and disconnect pressure air line.

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3. Remove tie strap and remove pressure air line.

Retarder Control

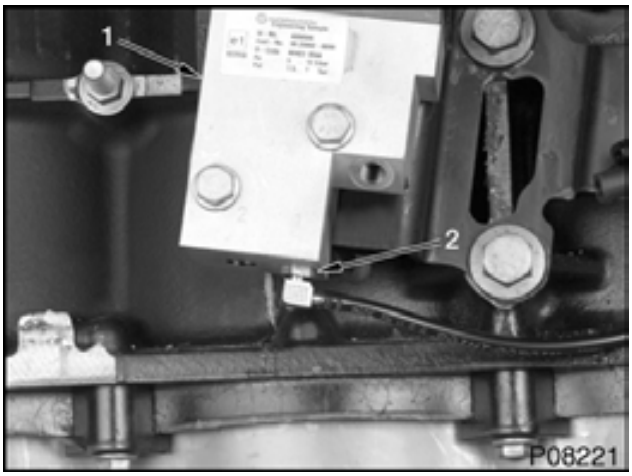

Figure 167 Air supply line assembly connection to retarder control

1. Retarder control
2. Air supply line assembly threaded fitting

1. Loosen air supply line assembly threaded fitting at retarder control and disconnect air supply line assembly.

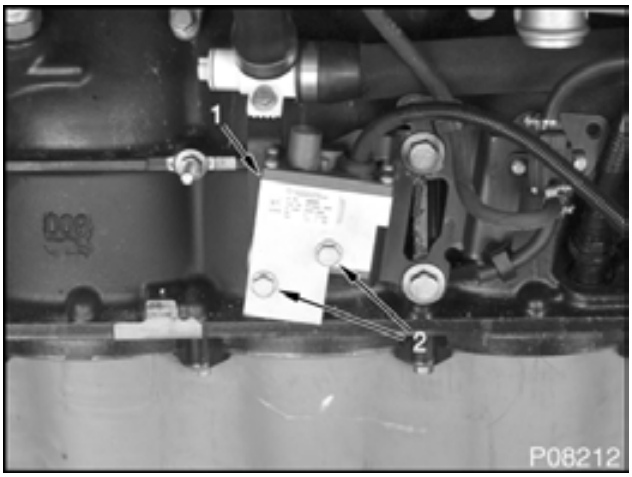

Figure 168 Retarder control

1. Retarder control
2. M8 x 55 hex bolt (2)

2. Remove two M8 x 55 hex bolts and retarder control.

Exhaust Manifold with Butterfly

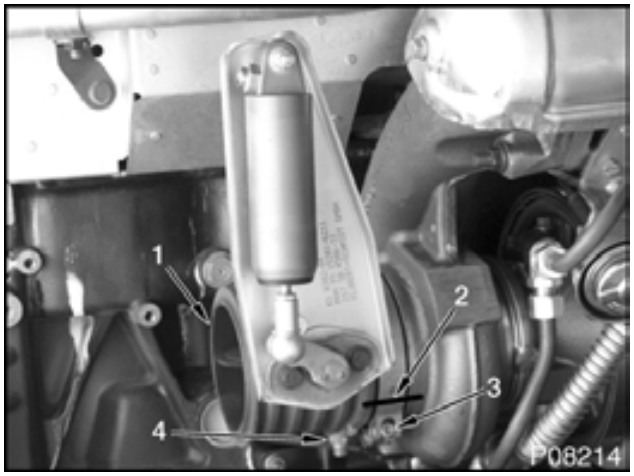

Figure 169 Exhaust manifold with butterfly

1. Exhaust manifold with butterfly
2. Orientation mark
3. DMR 114 profiled clamp
4. Straight union

1. Mark location of exhaust manifold with butterfly for correct orientation in relation to turbine housing.
2. Loosen DMR 114 profiled clamp and remove exhaust manifold with butterfly. Discard profile clamp.

NOTE: Perform next step only if replacing exhaust manifold with butterfly or if straight union is leaking.

3. Remove straight union from exhaust manifold with butterfly.

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Installation

Exhaust Manifold with Butterfly

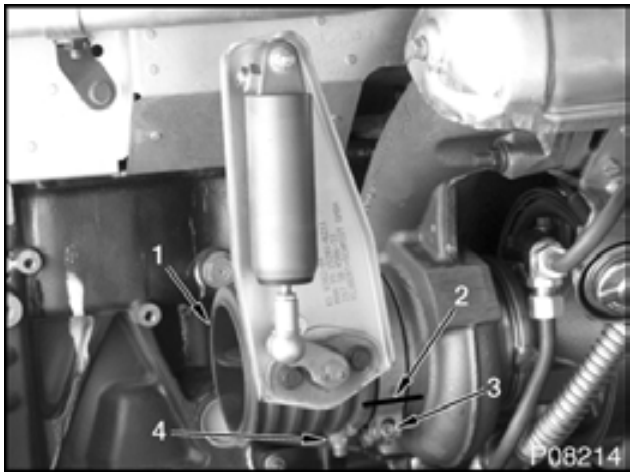

Figure 170 Exhaust manifold with butterfly

1. Exhaust manifold with butterfly
2. Orientation mark
3. DMR 114 profiled clamp
4. Straight union

NOTE: If replacing exhaust manifold with butterfly, transfer orientation mark to new exhaust manifold with butterfly for correct orientation.

1. Position new DMR 114 profiled clamp and install exhaust manifold with butterfly to correct location as marked. Tighten new profiled clamp to special torque (page 132).

NOTE: Perform next step only if exhaust manifold with butterfly was replaced or if straight union was replaced.

2. Tighten straight union as follows:
   a. Hand tighten straight union.
   b. Turn an additional 90°.

Retarder Control

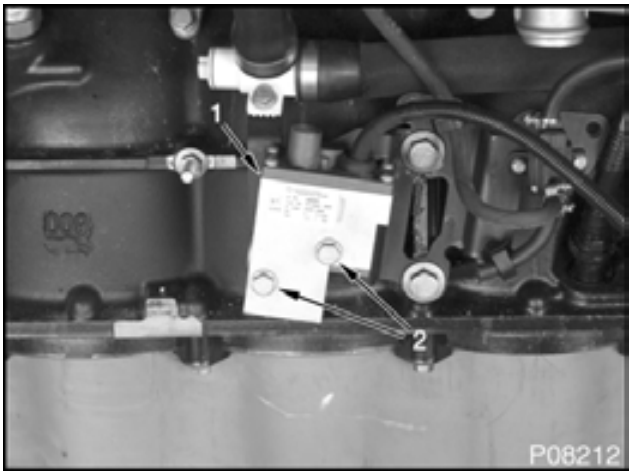

Figure 171 Retarder control

1. Retarder control
2. M8 x 55 hex bolt (2)

1. Install retarder control and two M8 x 55 hex bolts. Tighten hex bolts to special torque (page 132).

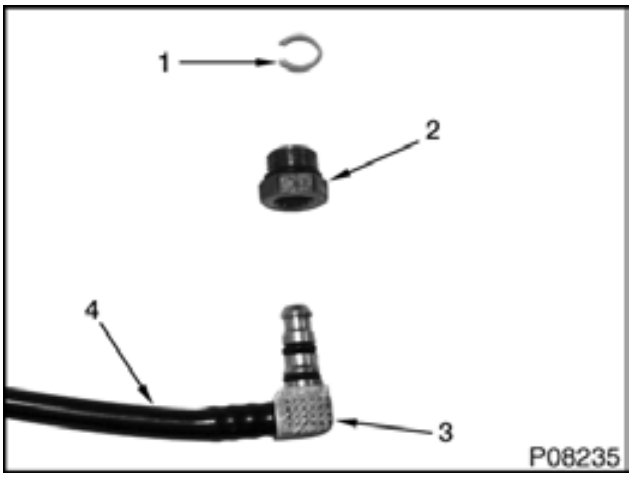

Figure 172 Air supply line assembly connections

1. Clip
2. Threaded fitting (with O-ring)
3. Male end (part of air supply line assembly)
4. Air supply line assembly

NOTE: If retarder control was replaced, perform steps 2 through 4. If retarder control was not replaced, perform steps 5 and 6.

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NOTE: If air supply line assembly was replaced or was found to be leaking, perform steps 7 and 8. If air supply line assembly was not replaced, perform steps 5 and 6.

2. Remove old clip and threaded fitting from existing air supply line assembly.

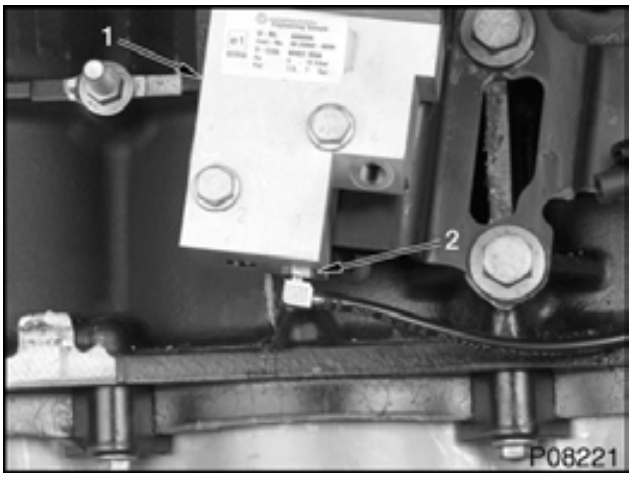

Figure 173 Air supply line assembly connection to retarder control

1. Retarder control
2. Threaded fitting

3. Lubricate existing air supply line assembly O-rings with P-80® Rubber Lubricant or equivalent(page 132).
4. Install and push air supply line assembly into new threaded fitting (mounted on new retarder control) until a click is heard. This ensures the air supply line assembly has locked into the clip and is properly installed.
5. Lubricate existing air supply line assembly threaded fitting O-ring with P-80® Rubber Lubricant or equivalent (page 132).
6. Position existing air supply line assembly and install threaded fitting into retarder control. Tighten threaded fitting to special torque (page 132).
7. Lubricate new air supply line assembly threaded fitting O-ring with P-80® Rubber Lubricant or equivalent (page 132). Install new clip and new threaded fitting into retarder control. Tighten threaded fitting to special torque (page 132).
8. Install and push new air supply line assembly into threaded fitting until a click is heard. This ensures the air supply line assembly has locked into the clip and is properly installed.

Pressure Air Line

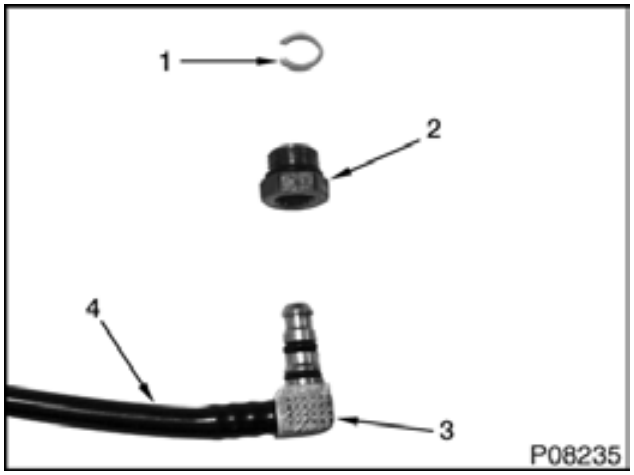

Figure 174 Pressure air line connections

1. Clip
2. Threaded fitting (with O-ring)
3. Male end (part of pressure air line)
4. Pressure air line

NOTE: If retarder control was replaced, perform steps 1 through 3. If retarder control was not replaced, perform steps 4 and 5.

NOTE: If pressure air line was replaced or was found to be leaking, perform steps 6 and 7. If pressure air line was not replaced, perform steps 4 and 5.

1. Remove old clip and threaded fitting from pressure air line.

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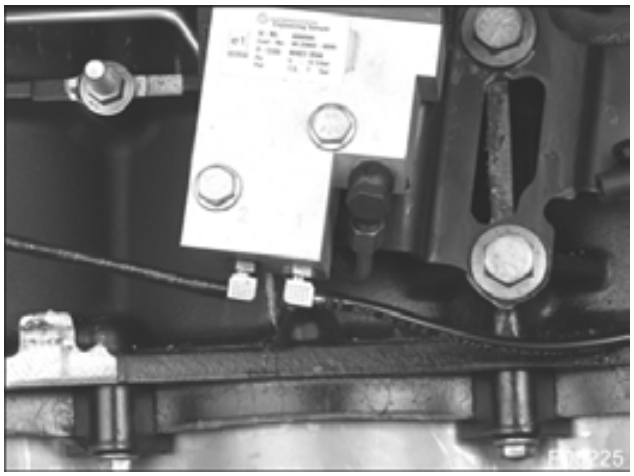

Figure 175 Pressure air line connection to retarder control

1. Retarder control
2. Pressure air line threaded fitting

2. Lubricate existing pressure air line O-rings with P-80® Rubber Lubricant or equivalent (page 132).
3. Install and push pressure air line into new threaded fitting (mounted on new retarder control) until a click is heard. This ensures the pressure air line has locked into place and is properly installed.
4. Lubricate existing pressure air line threaded fitting O-ring with P-80® Rubber Lubricant or equivalent (page 132).
5. Position existing pressure air line and install threaded fitting into retarder control. Tighten threaded fitting to special torque (page 132).
6. Lubricate new pressure air line threaded fitting O-ring with P-80® Rubber Lubricant or equivalent(page 132). Install new clip and new threaded fitting into retarder control. Tighten threaded fitting to special torque (page 132).
7. Install and push new pressure air line into threaded fitting until a click is heard. This ensures the pressure air line has locked into place and is properly installed.

NOTE: If exhaust manifold with butterfly was replaced, perform steps 8 through 10. If exhaust manifold with butterfly was not replaced, perform steps 11 and 12.

NOTE: If pressure air line was replaced or was found to be leaking, perform steps 13 and 14. If pressure air line was not replaced, perform steps 11 and 12.

8. Remove old clip and threaded fitting from pressure air line.
9. Lubricate existing pressure air line O-rings with P-80® Rubber Lubricant or equivalent (page 132).
10. Install and push existing pressure air line into new threaded fitting (mounted on new exhaust manifold with butterfly) until a click is heard. This ensures the pressure air line has locked into place and is properly installed.
11. Lubricate existing pressure air line threaded fitting O-ring with P-80® Rubber Lubricant or equivalent (page 132).
12. Position existing pressure air line and install fitting nut into exhaust manifold with butterfly. Tighten fitting nut to special torque (page 132).
13. Lubricate new pressure air line O-rings with P-80® Rubber Lubricant or equivalent (page 132). Install new clip and new threaded fitting into exhaust manifold with butterfly. Tighten threaded fitting to special torque (page 132).
14. Install and push new pressure air line into threaded fitting until a click is heard. This ensures the pressure air line had locked into place and is properly installed.

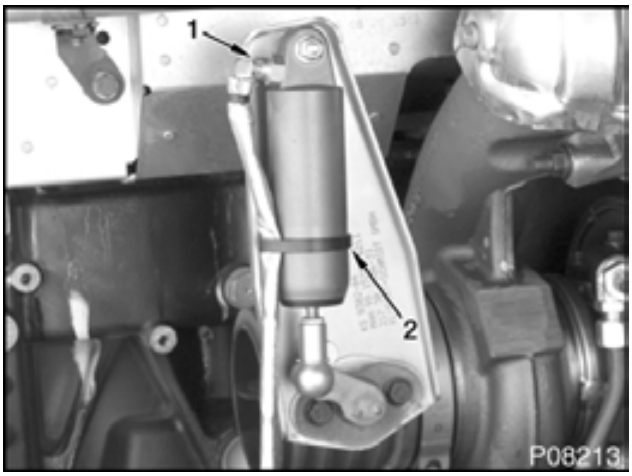

Figure 176 Exhaust manifold with butterfly connection

1. Pressure air line fitting nut
2. Tie strap

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NOTE: Make sure installing tie strap does not kink air line.

15. Install new tie strap as shown in figure above.

Pressure Line

NOTE: Do step 1 only if ring union was previously removed from pressure line, otherwise begin with step 2.

1. Install ring union onto pressure line. Do not tighten at this time.

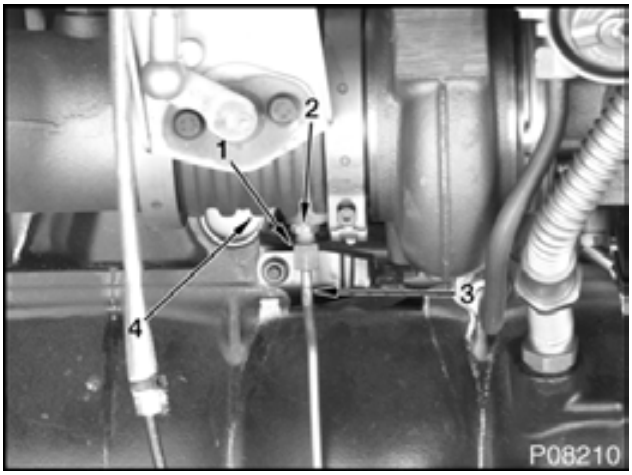

Figure 177 Pressure line connection at exhaust manifold with butterfly

1. Pressure line fitting nut
2. Straight union
3. Pressure line
4. Exhaust manifold with butterfly

2. Position pressure line and fitting nut and install into straight union. Hand tighten fitting nut.

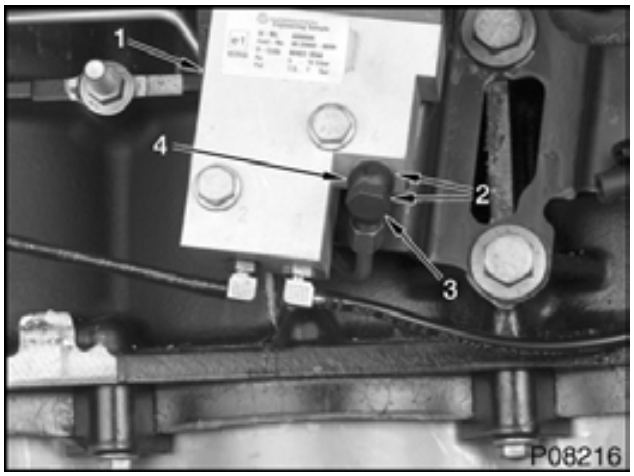

Figure 178 Pressure line connection at retarder control

1. Retarder control
2. 10 x 1.35 seal (2)
3. Size 6 hollow screw
4. Ring union

3. Position ring union and two new 10 x 1.35 seals into retarder control. Install size 6 hollow screw. Hand tighten size 6 hollow screw.

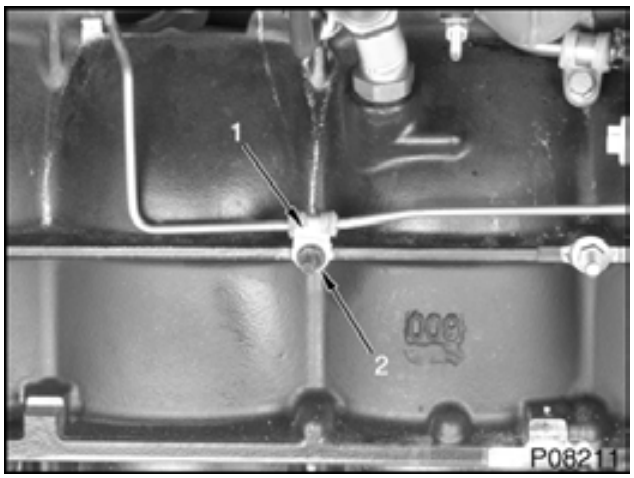

Figure 179 Pressure line P-clamp

1. Pressure line P-clamp
2. M8 x 16 x 20 stud bolt

4. Install M8 x 16 x 20 stud bolt through pressure line P-clamp and into crankcase. Tighten stud bolt to special torque (page 132).

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5. Tighten size 6 hollow screw at retarder control to special torque (page 132).
6. If loosened in step 1, tighten pressure line fitting nut at ring union to special torque (page 132).
7. Tighten pressure line fitting nut at straight union to special torque (page 132).

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Special Torque

Table 8 Retarder Control System Components

DMR 114 profiled clamp	6 N·m (53 lbf·in)
Pressure line P-clamp stud bolt	35 N·m (26 lbf·ft)
Retarder control hex bolts	35 N·m (26 lbf·ft)
Size 6 hollow screw	20 N·m (15 lbf-ft)
Pressure line fitting nut to straight union	30 N·m (22 lbf·ft)
Pressure line fitting nut to ring union	30 N·m (22 lbf·ft)
Straight union	See tightening steps in procedure.
Pressure air line fitting nut to retarder control	12 N·m (106 lbf·in)
Pressure air line fitting nut to exhaust manifold with butterfly	12 N·m (106 lbf·in)
Air supply line assembly fitting nut to retarder control	12 N·m (106 lbf·in)

Special Service Tools

Table 9 Engine Retarder Control

Description	Tool Number
P-80®Rubber Lubricant or equivalent	Obtain locally

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Exploded Views

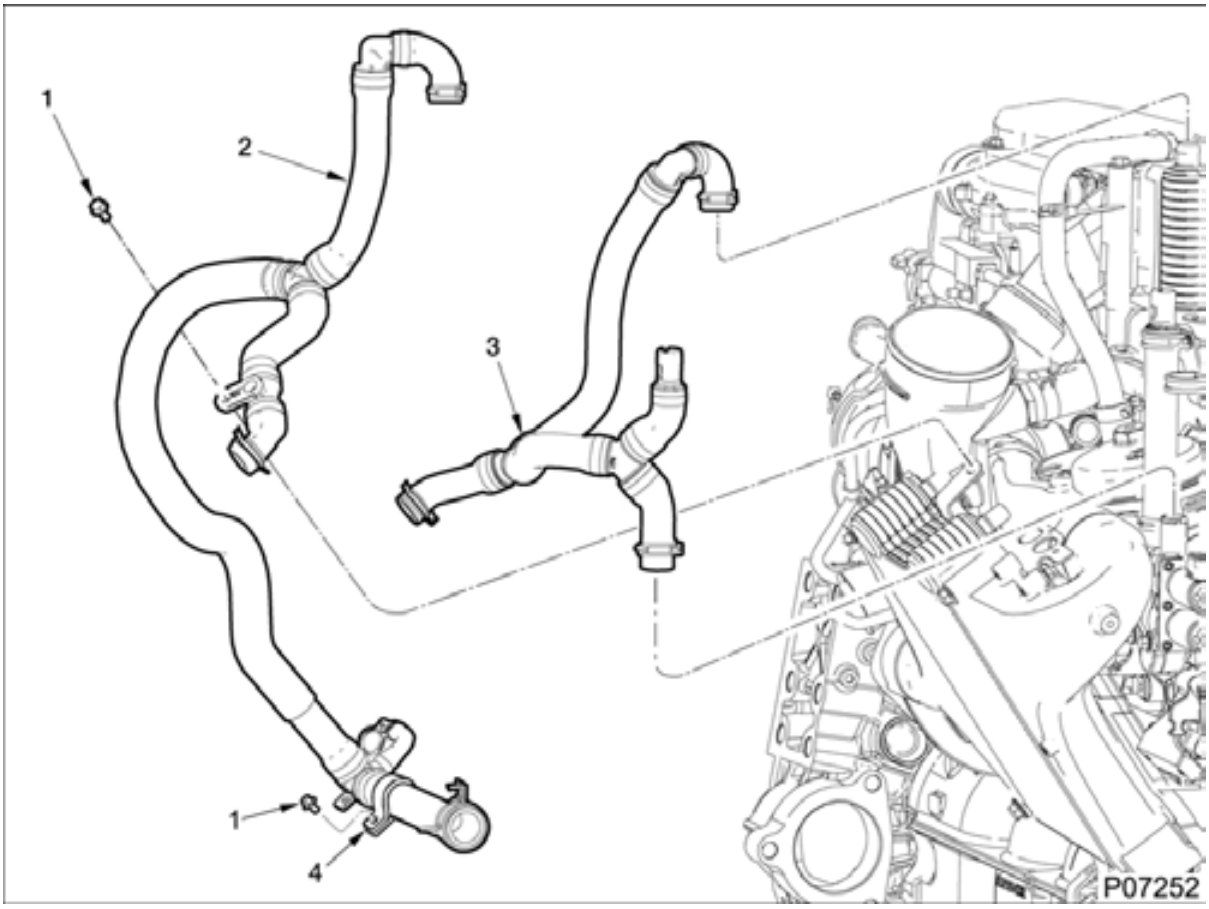

Figure 180 Coolant pipes

1. M8 x 16 hex bolt (2)
2. Charge Air Cooler (CAC) return coolant pipe
3. CAC supply coolant pipe
4. P-clip

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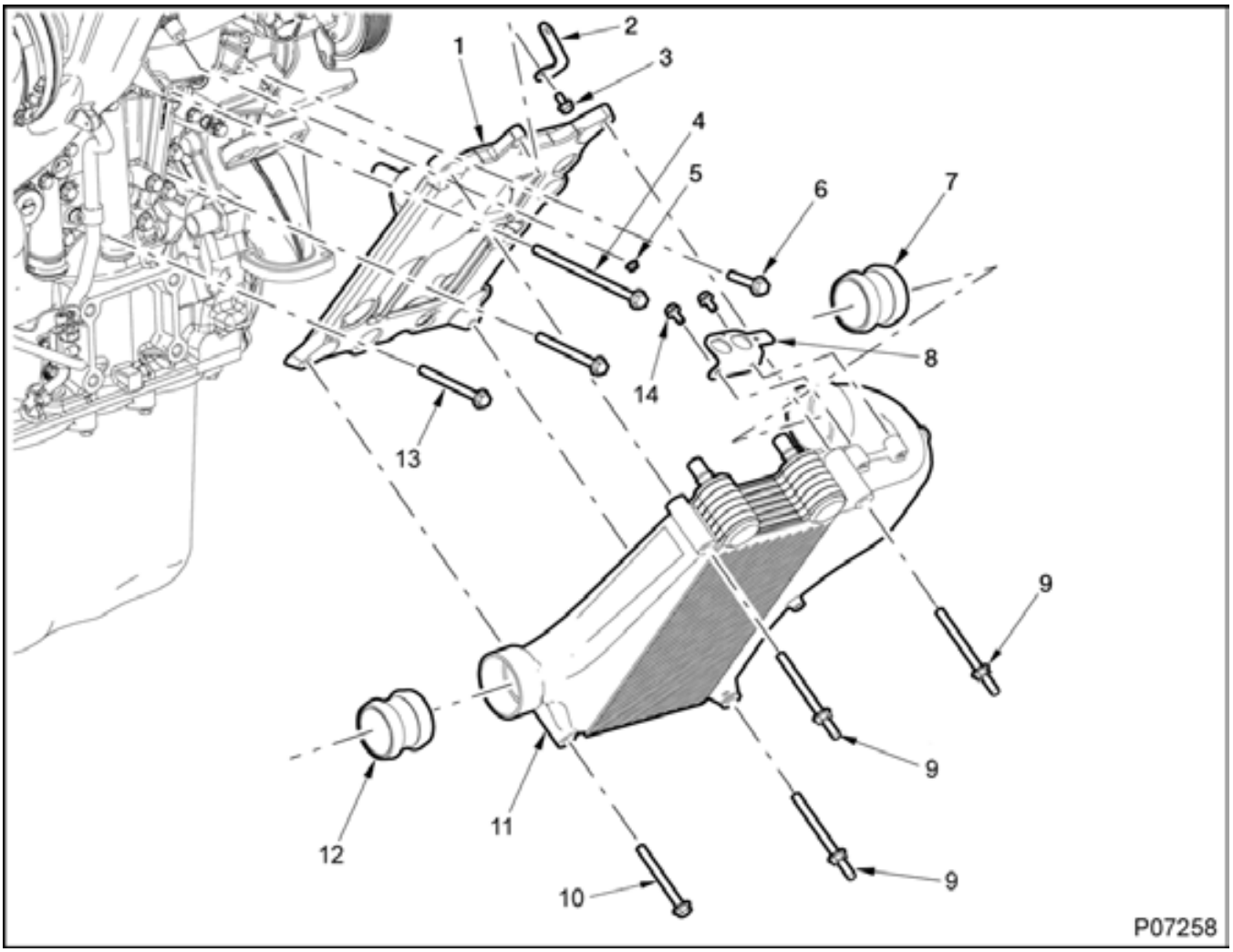

Figure 181 Low Pressure Charge Air Cooler (LPCAC)

1. LPCAC bracket
2. Temperature sensor bracket
3. M8 x 16 hex bolt
4. M10 x 190 hex bolt
5. M6 hexagon nut
6. M10 x 50 hex bolt
7. DMR70 extension tube
8. Adapter line bracket
9. M10 x 90 stud bolt (3)
10. M10 x 90 hex bolt
11. LPCAC
12. DMR70 extension tube
13. M10 x 110 hex bolt (2)
14. M8 x 16 hex bolt (2)

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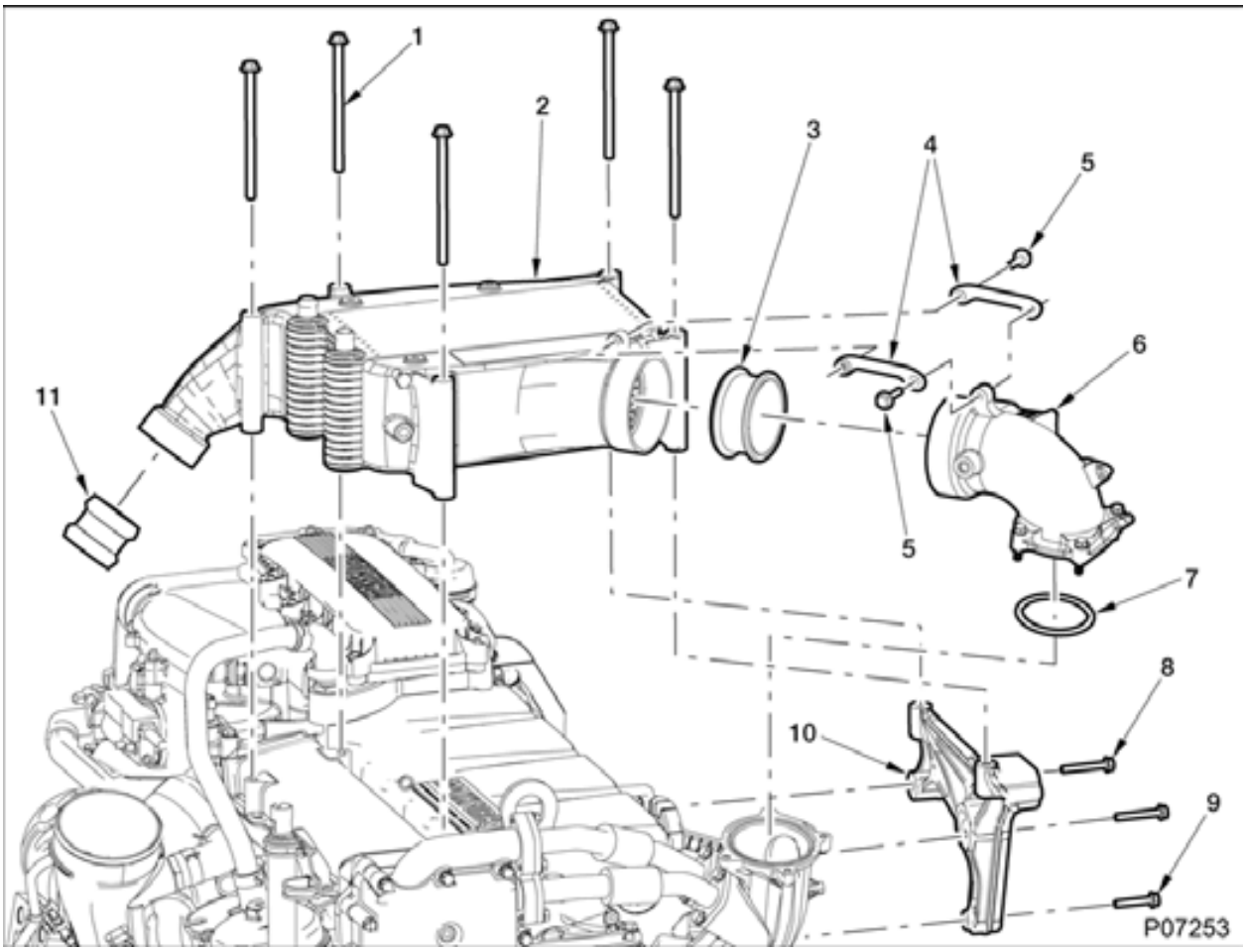

Figure 182 High Pressure Charge Air Cooler (HPCAC)

1. M10 x 160 hex bolt (5)
2. HPCAC
3. DMR110/92 extension tube
4. Latch arm (2)
5. M10 x 30 hex bolt (2)
6. Intake Throttle Valve (ITV)
7. O-ring
8. M8 x 55 hex bolt (2)
9. M8 x 45 hex bolt
10. HPCAC bracket
11. DMR70 extension tube

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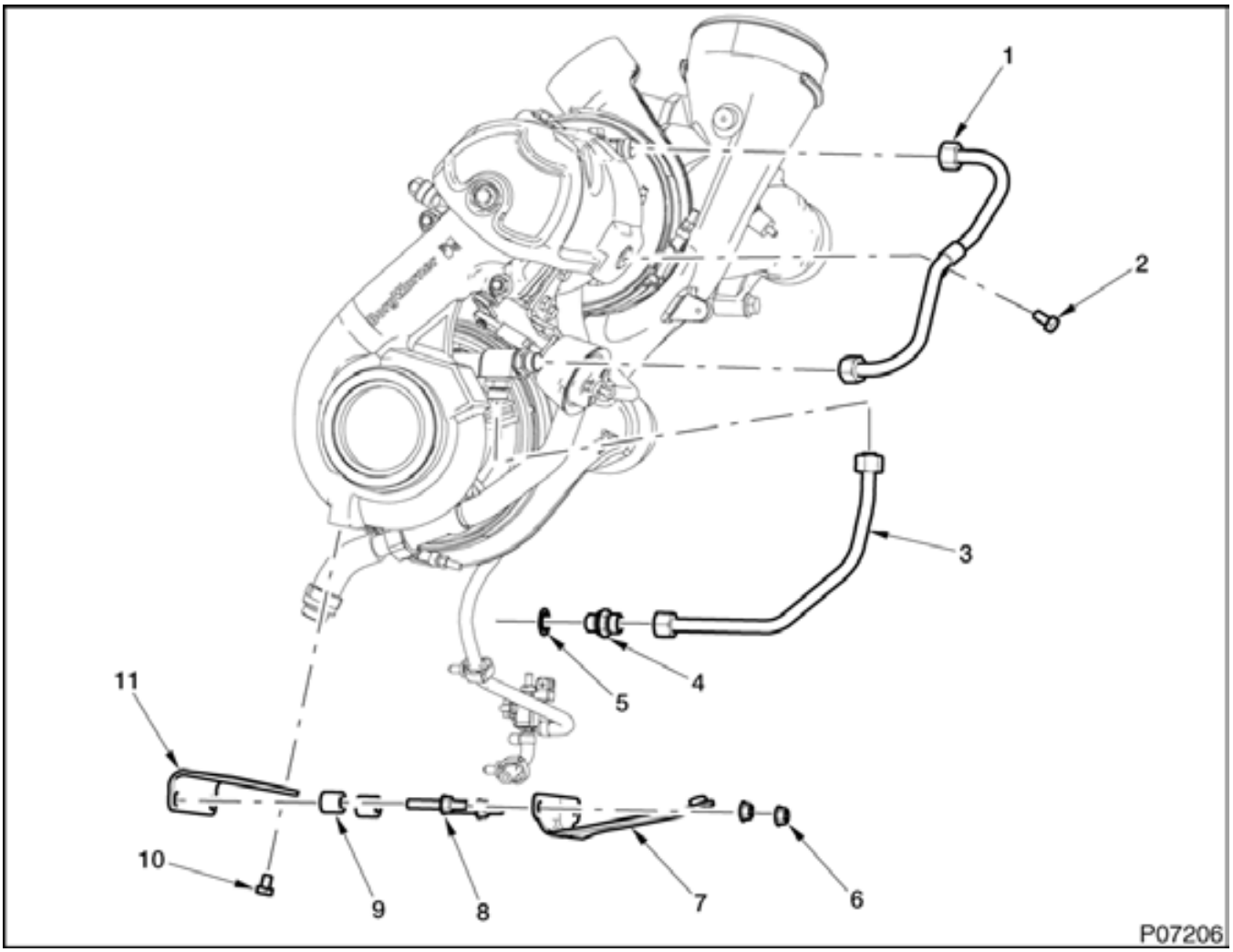

Figure 183 Oil pressure pipes and bracket

1. High pressure turbocharger oil pressure pipe
2. M8 x 16 hex bolt
3. Low pressure turbocharger oil pressure pipe
4. L12A straight union
5. BS-24.7 x 32 seal
6. M8 hex nut (2)
7. Starter heat shield bracket
8. M8 x 35 stud bolt (2)
9. Bushing (2)
10. M8 x 12 hex bolt
11. Bracket (turbocharger support)

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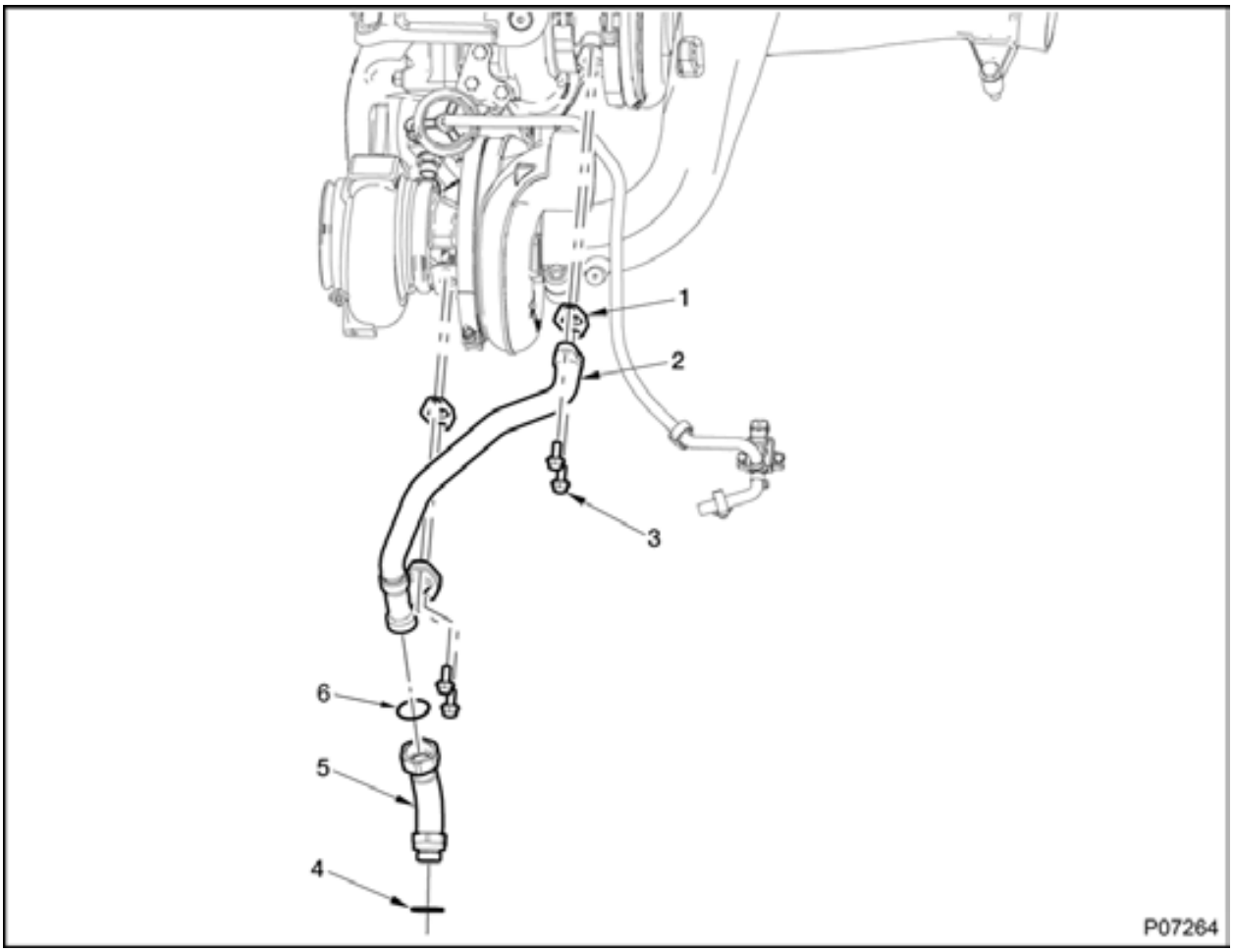

Figure 184 Oil return pipe

1. Gasket (2)
2. High pressure turbocharger oil return pipe
3. M8 x 20 hex bolt (4)
4. BS-16.7 x 24 seal
5. Low pressure turbocharger oil return pipe
6. Seal ring

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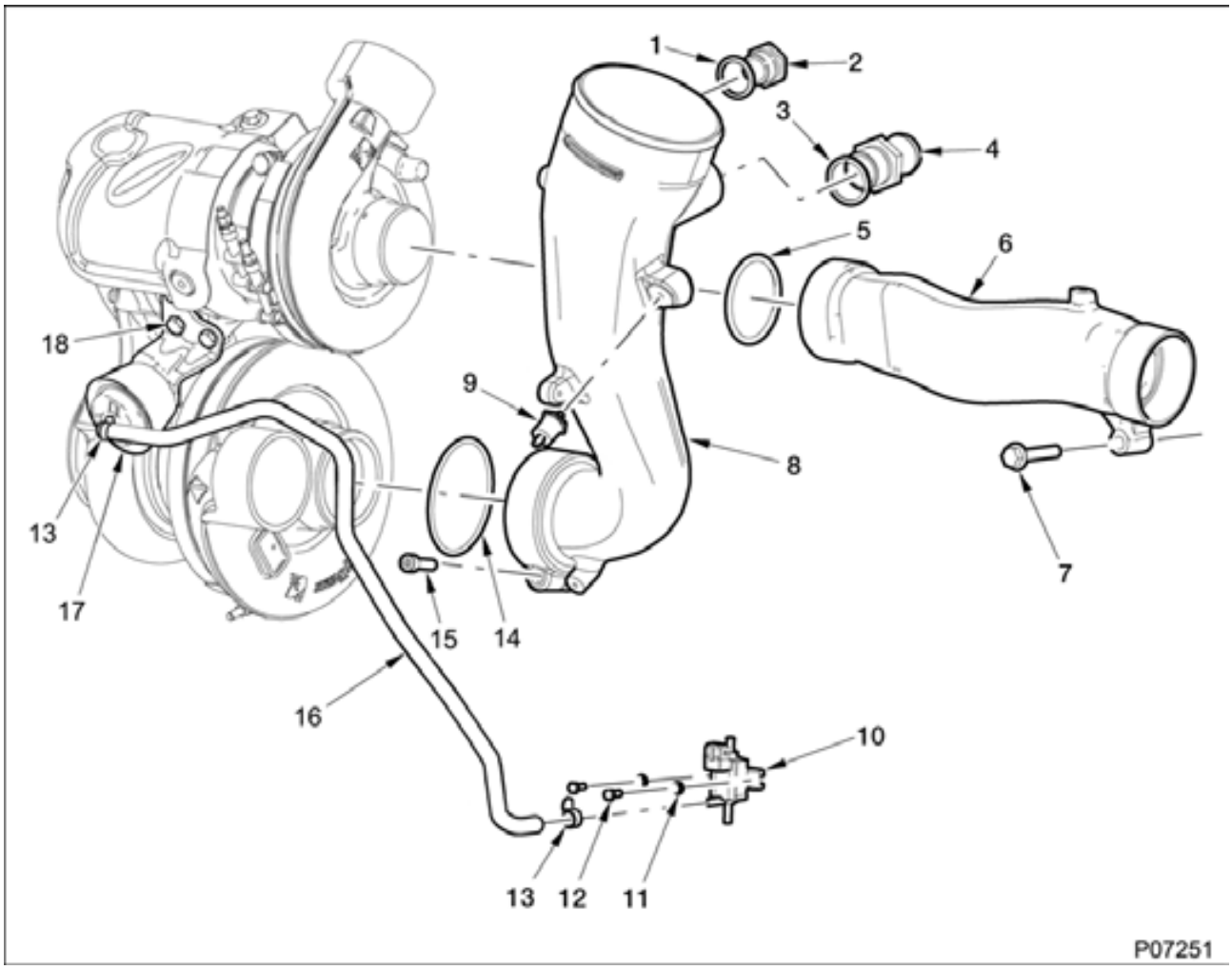

Figure 185 Air intake and boost control

1. BS-26.7 x 34 seal
2. M26 Plug
3. BS-32.7 x 40 seal
4. M32 x 1.5 threaded union
5. 62.87 x 5.33 O-ring
6. Intercooler elbow
7. M10 x 50 hex bolt
8. Air intake manifold
9. Rubber pad
10. Boost Control Solenoid (BCS) valve
11. M5 washer (2)
12. M5 x 12 hex bolt (2)
13. Crimp clamp (2)
14. BS-32.7 x 40 seal
15. M8 x 30 cylinder screw
16. BCS valve output line
17. Boost control actuator
18. M8 x 14 hex bolt (3)

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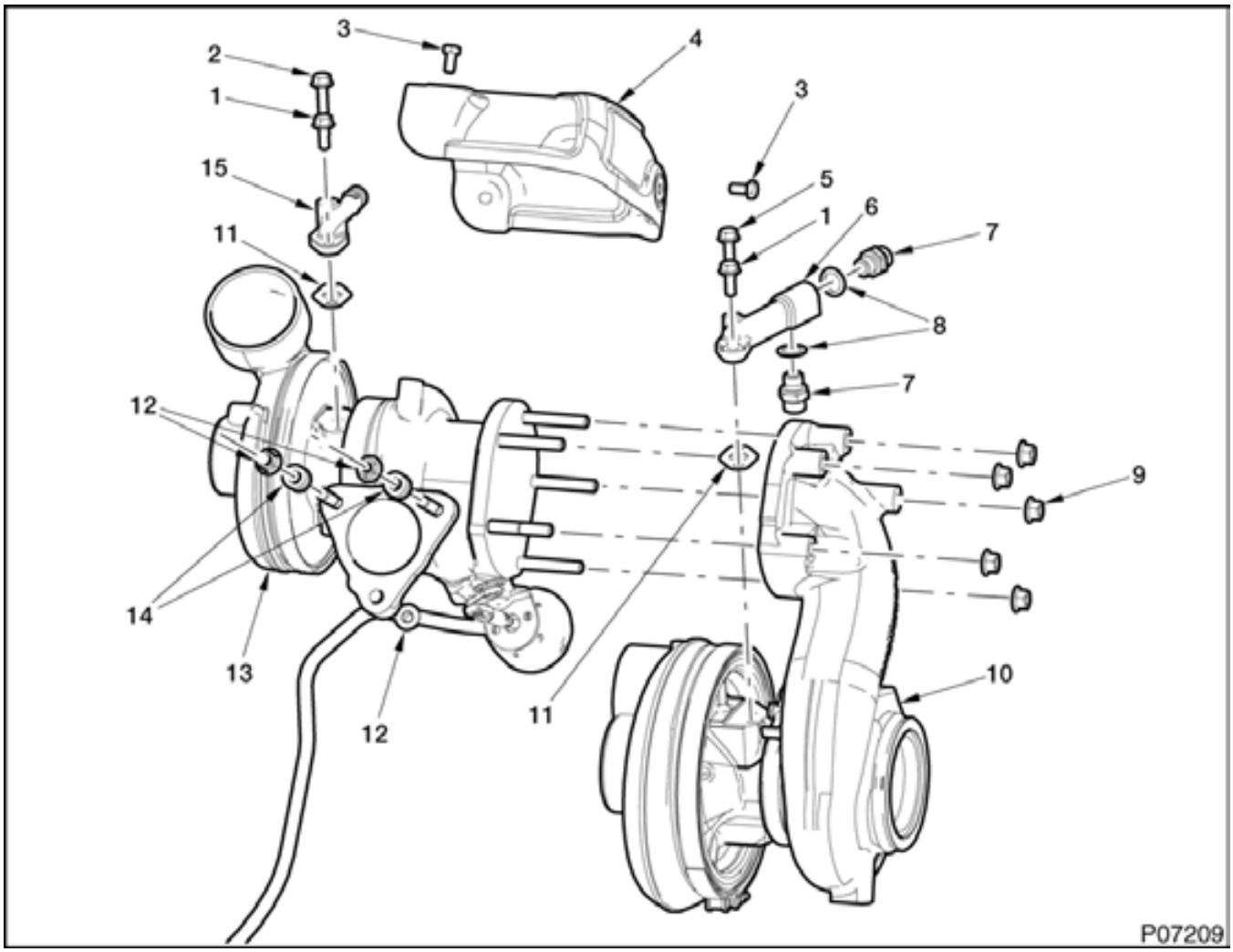

Figure 186 Turbochargers

1. M8 x 20 hex bolt (2)
2. M8 x 45 hex bolt
3. M8 x 16 hex bolt (2)
4. Heat shield
5. M8 x 35 hex bolt
6. Low pressure turbocharger oil pressure connection flange
7. Straight union (2)
8. Seal (2)
9. M10 hexagon nut (5)
10. Low pressure turbocharger
11. Gasket (2)
12. M10 hexagon nut (3)
13. High pressure turbocharger
14. High temperature spacing bushing (2)
15. High pressure turbocharger oil pressure connection flange

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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 the transmission to park or neutral, set the parking brake, and block the wheels before doing diagnostic or service procedures.

WARNING: To prevent personal injury or death, make sure the engine and turbocharger have cooled before removing the turbocharger.

WARNING: To prevent personal injury or death, remove the ground cable from the negative terminal of the main battery before disconnecting or connecting electrical components. Always connect the ground cable last.

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: Refer to the following service sections for information on removal of components prior to this section.

- Engine Electrical
- Aftertreatment System
- Engine Retarder Control

Boost Control Solenoid (BCS) Valve

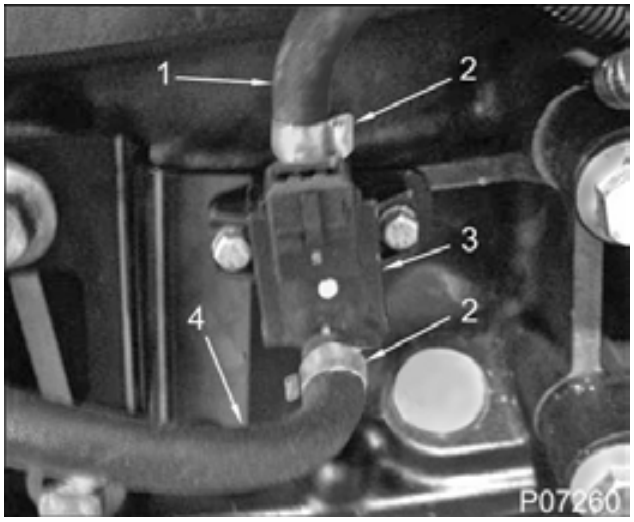

Figure 187 BCS valve lines

1. BCS valve supply line
2. Crimp clamp
3. BCS valve
4. BCS valve output line

1. Cut and remove crimp clamps and disconnect two hoses from BCS valve.

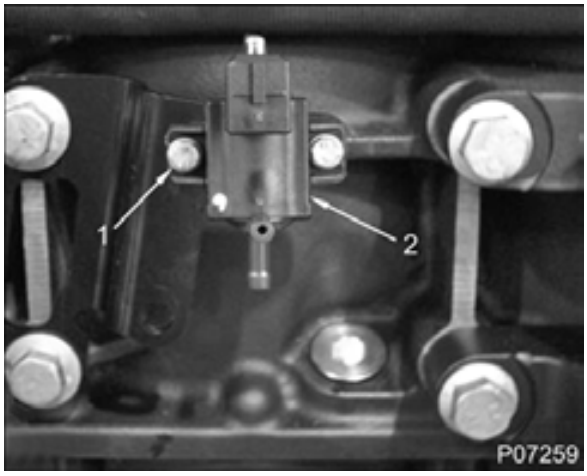

Figure 188 BCS valve

1. M5 x 12 hex bolt (2)
2. BCS valve

2. Remove two M5 x 12 hex bolts and two M5 washers.

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3. Remove BCS valve.

Boost Control Solenoid (BCS) Valve Supply Line

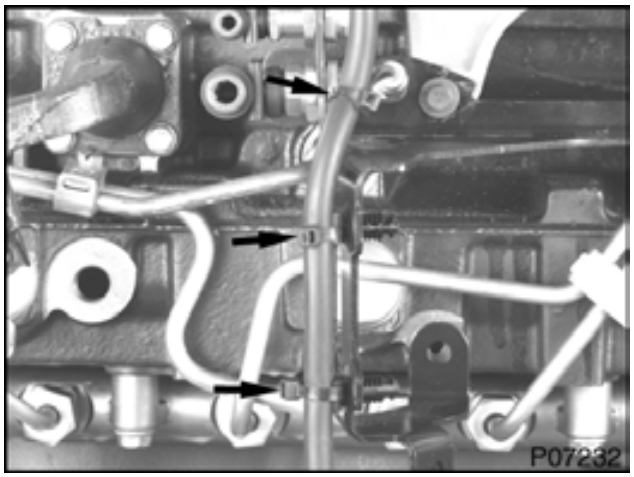

Figure 189 Tie straps

1. Remove three tie straps retaining BCS valve supply line to bracket.

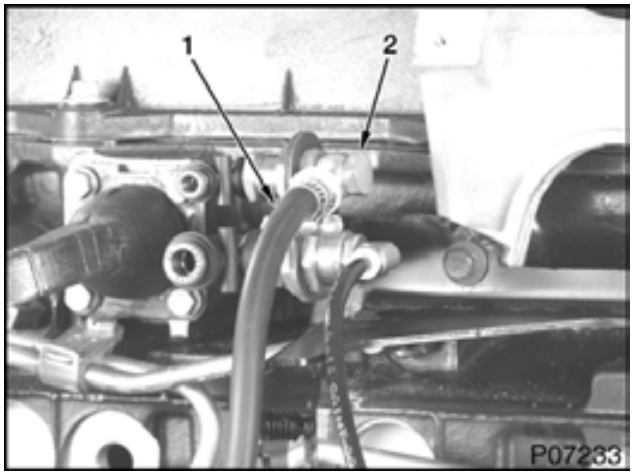

Figure 190 BCS valve supply line

1. BCS valve supply line
2. Banjo bolt

2. Remove banjo bolt and disconnect BCS valve supply line from air fitting. Discard washers.
3. Note routing of BCS valve supply line for later reassembly. Remove line.

Low Pressure Charge Air Cooler (LPCAC)

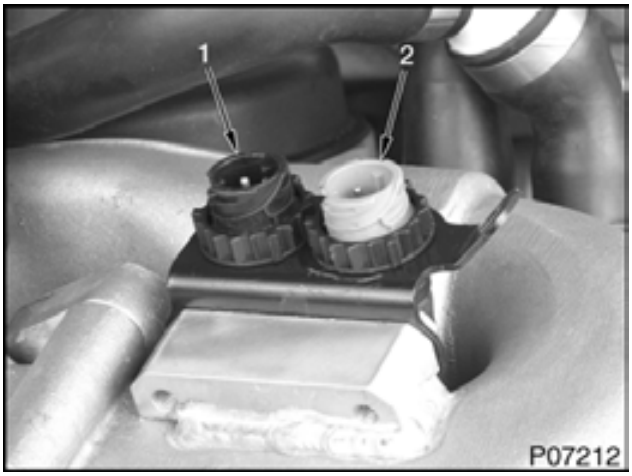

Figure 191 Adapter lines (electrical connections)

1. Engine Oil Pressure (EOP) sensor adapter line
2. Engine Oil Temperature (EOT) sensor adapter line

1. Remove retaining ring by turning counterclockwise and release EOP sensor adapter line from adapter line bracket on LPCAC.
2. Remove retaining ring by turning counterclockwise and release EOT sensor adapter line from adapter line bracket on LPCAC.

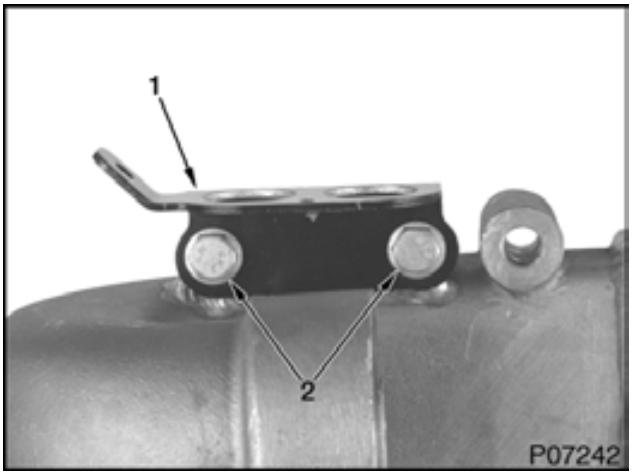

Figure 192 Adapter line bracket

1. Adapter line bracket
2. M8 x 16 hex bolt (2)

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3. Remove two M8 x 16 hex bolts and adapter line bracket.

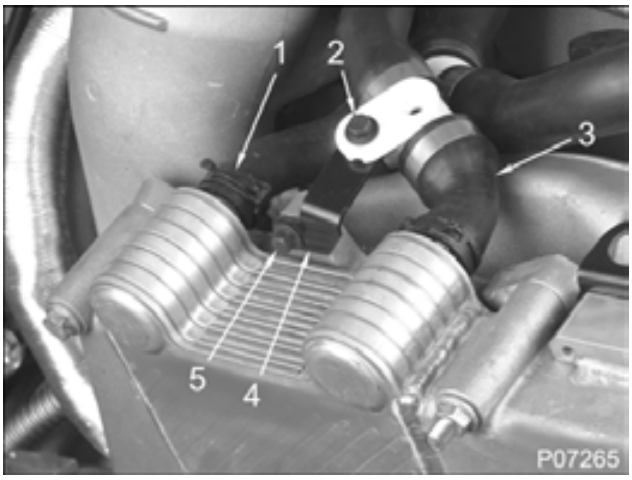

Figure 193 Low Pressure Charge Air Cooler (LPCAC) coolant pipe connections

1. CAC supply coolant pipe
2. M8 x 16 hex bolt
3. CAC return coolant pipe
4. Temperature sensor bracket
5. M8 x 16 hex bolt

4. Release hose clamp and disconnect CAC supply coolant pipe from LPCAC.
5. Remove M8 x 16 hex bolt from bracket on LPCAC.
6. Release hose clamp and disconnect CAC return coolant pipe from LPCAC.
7. Remove M8 x 16 hex bolt and temperature sensor bracket.

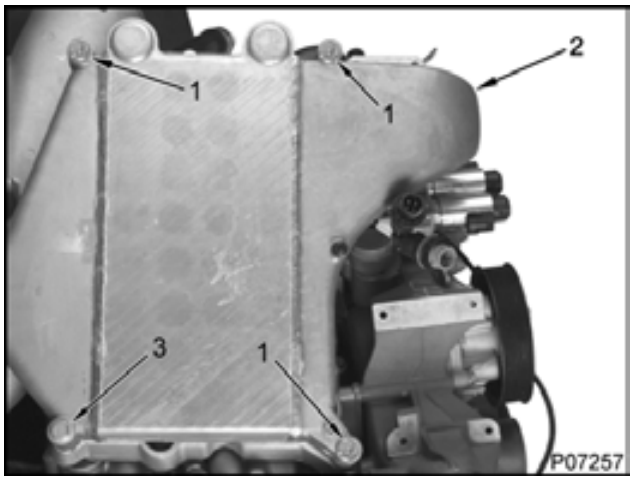

Figure 194 Low Pressure Charge Air Cooler (LPCAC)

1. M10 x 90 stud bolt (3)
2. LPCAC
3. M10 x 90 hex bolt

8. Remove one M10 x 90 hex bolt.
9. Remove three M10 x 90 stud bolts.
10. Remove LPCAC from engine.

CAUTION: To prevent engine damage, do not remove extension tubes by grabbing sealing surface.

11. Remove two DMR70 extension tubes from LPCAC. Inspect sealing surfaces of DMR70 extension tubes. Discard if damaged.

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Low Pressure Charge Air Cooler (LPCAC) Bracket

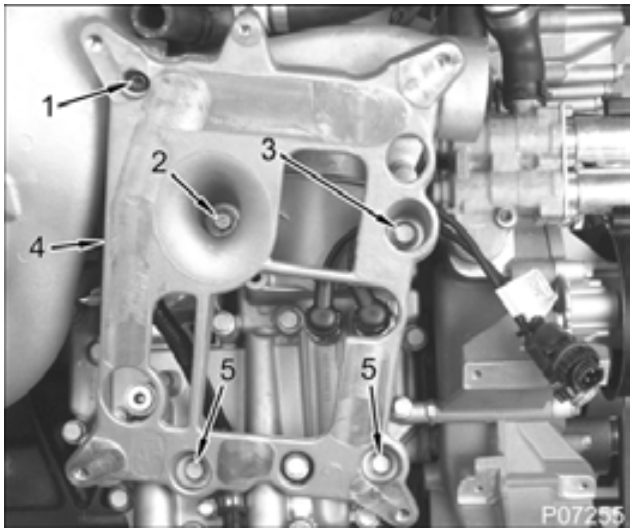

Figure 195 Low Pressure Charge Air Cooler (LPCAC) bracket

1. M6 hexagon nut
2. M10 x 190 hex bolt
3. M10 x 50 hex bolt
4. LPCAC bracket
5. M10 x 110 hex bolt (2)

1. Remove M10 x 190 hex bolt, M6 hexagon nut, M10 x 50 hex bolt, and two M10 x 110 hex bolts from LPCAC bracket.
2. Remove LPCAC bracket.

High Pressure Charge Air Cooler (HPCAC)

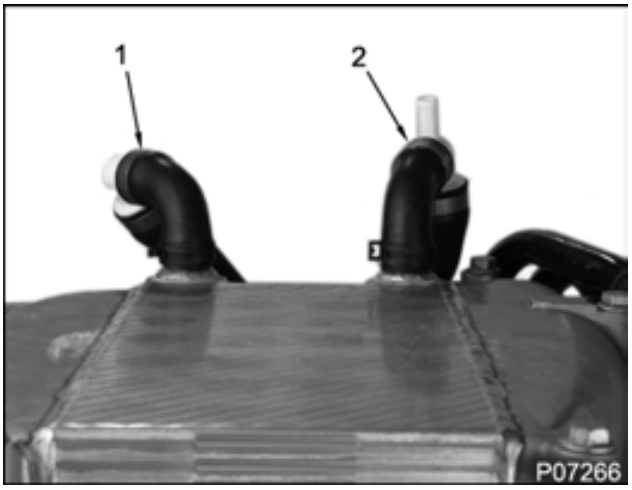

Figure 196 High Pressure Charge Air Cooler (HPCAC) coolant pipe connections

1. CAC supply coolant pipe
2. CAC return coolant pipe

1. Release hose clamp and disconnect CAC supply coolant pipe from HPCAC.
2. Release hose clamp and disconnect CAC return coolant pipe from HPCAC.

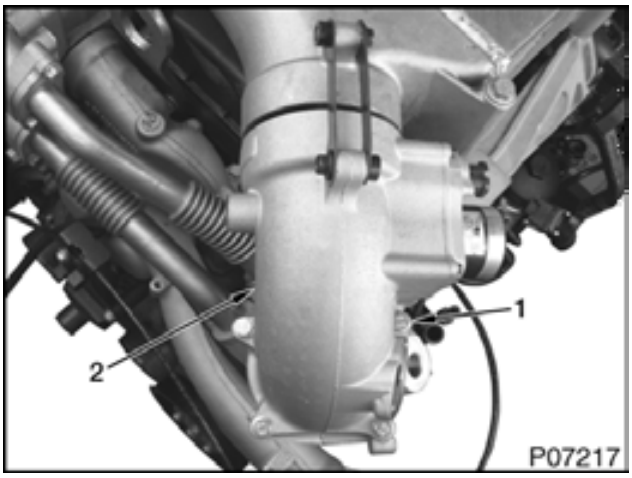

Figure 197 Intake Throttle Valve (ITV)

1. ITV bolt (4)
2. ITV

NOTE: The captive ITV bolts can be locked in a raised position by pulling up and turning counterclockwise.

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3. Unscrew four captive ITV bolts.

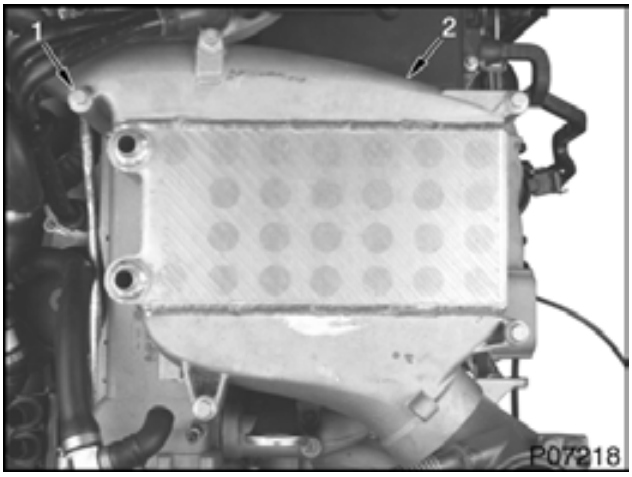

Figure 198 High Pressure Charge Air Cooler (HPCAC)

1. M10 x 160 hex bolt (5)
2. HPCAC

4. Remove five M10 x 160 hex bolts.
5. Remove HPCAC and ITV as an assembly.

CAUTION: To prevent engine damage, do not remove extension tube by grabbing sealing surface.

6. Remove DMR70 extension tube from HPCAC. Inspect sealing surfaces of DMR70 extension tube. Discard if damaged.
7. Remove and discard ITV O-ring.

NOTE: If the HPCAC pressure test is to be performed, it must be done now before proceeding to ITV removal. See High Pressure Charge Air Cooler (HPCAC) Pressure Test (page 155).

Intake Throttle Valve (ITV)

NOTE: It is not necessary to remove the ITV from the High Pressure Charge Air Cooler (HPCAC) unless the HPCAC is to be replaced due to damage or a failed pressure test.

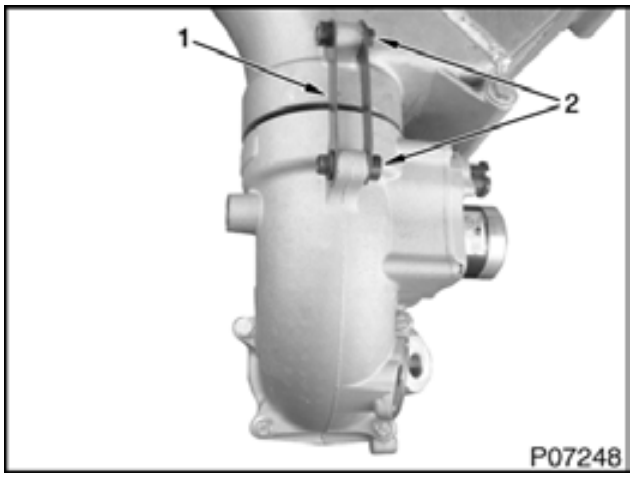

Figure 199 Intake Throttle Valve (ITV)

1. Latch arm (2)
2. M10 x 30 hex bolt (2)

1. Remove two M10 x 30 hex bolts and two latch arms from ITV and HPCAC.
2. Remove ITV from HPCAC.

CAUTION: To prevent engine damage, do not remove extension tube by grabbing sealing surface.

3. Remove DMR110/92 extension tube from ITV. Inspect sealing surfaces of DMR110/92 extension tube for damage. Discard if damaged.

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High Pressure Charge Air Cooler (HPCAC) Bracket

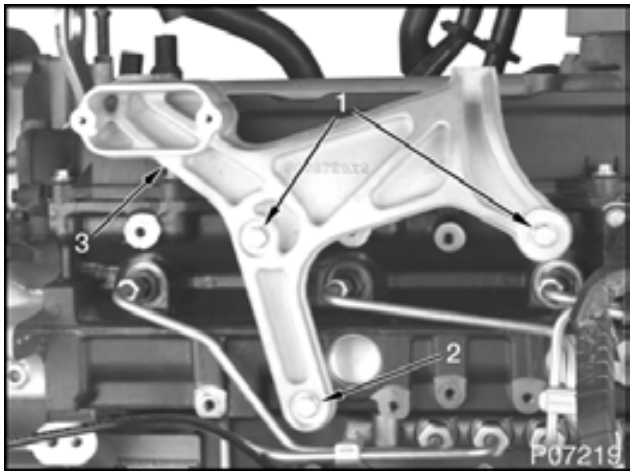

Figure 200 High Pressure Charge Air Cooler (HPCAC) bracket

1. M8 x 55 hex bolt (2)
2. M8 x 45 hex bolt
3. HPCAC bracket

1. Remove two M8 x 55 hex bolts and M8 x 45 hex bolt.
2. Remove HPCAC bracket.

Coolant Pipes

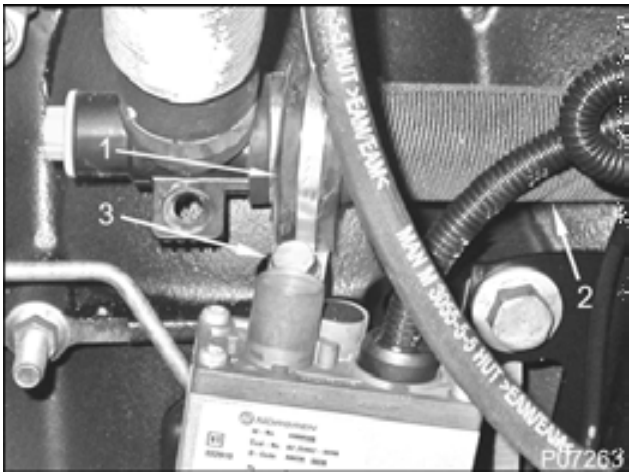

Figure 201 P-clamp for CAC return coolant pipe

1. P-clamp
2. CAC return coolant pipe
3. M8 x 16 hex bolt

1. Remove M8 x 16 hex bolt.

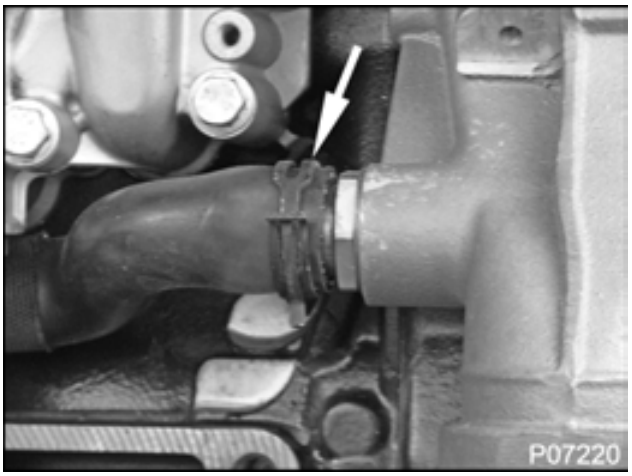

Figure 202 Charge Air Cooler (CAC) return coolant pipe

2. Release hose clamp and disconnect CAC return coolant pipe from front cover and remove from engine.

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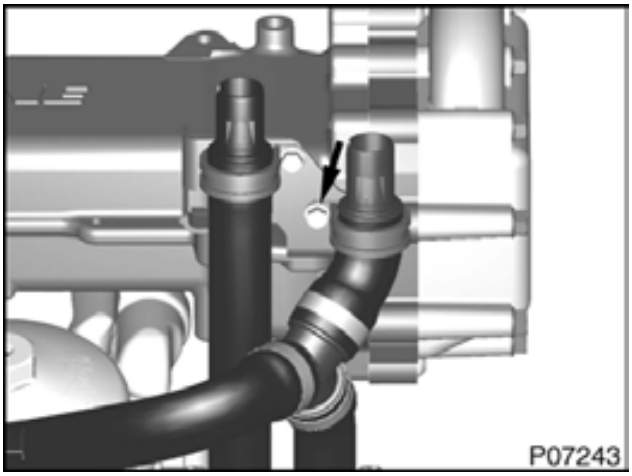

Figure 203 Charge Air Cooler (CAC) supply coolant pipe to bracket connection

3. Remove M6 x 16 hex bolt and remove CAC supply coolant pipe from bracket.

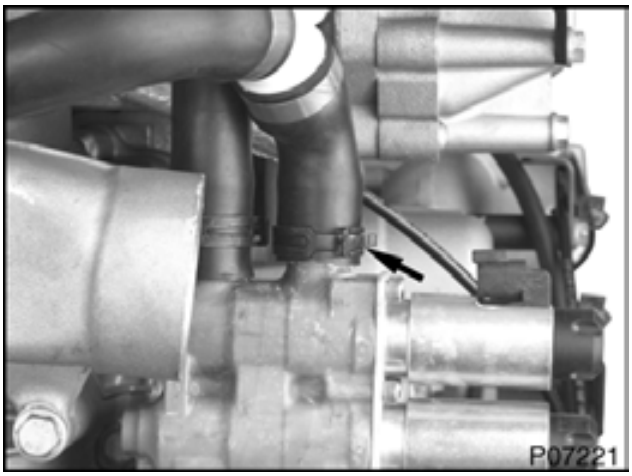

Figure 204 Charge Air Cooler (CAC) supply coolant pipe

4. Release hose clamp and disconnect CAC supply coolant pipe from Coolant Control Valve (CCV) and remove from engine.

Air Intake Manifold

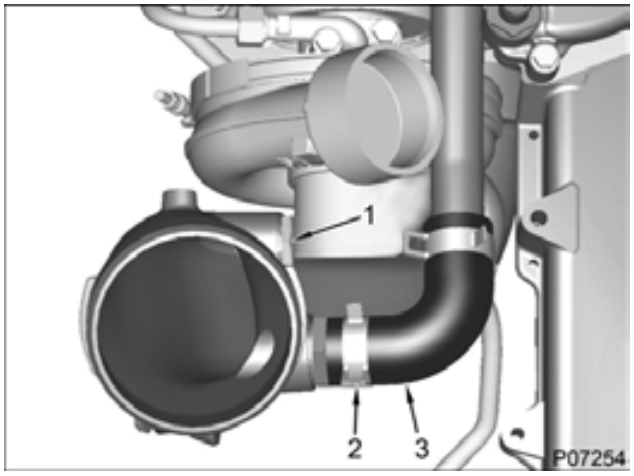

Figure 205 Breather connection

1. M26 Plug
2. 44/15 spring clip
3. DMR32 shaped hose

1. Release 44/15 spring clip and disconnect DMR32 shaped hose from M32 x 1.5 threaded union in air intake manifold.

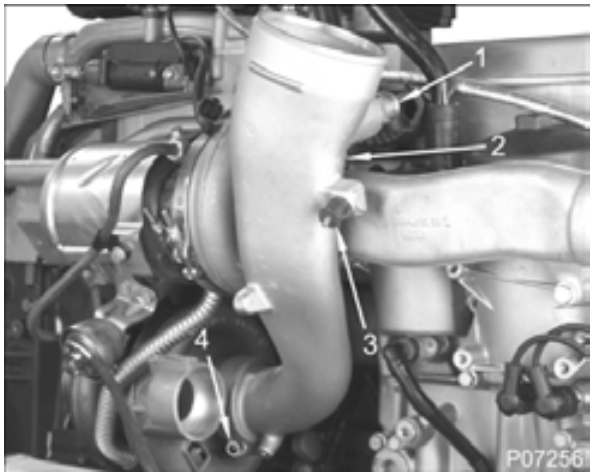

Figure 206 Air intake manifold

1. M32 x 1.5 threaded union
2. Air intake manifold
3. Rubber pad
4. M8 x 30 cylinder screw

2. Remove M8 x 30 cylinder screw and remove air intake manifold from low pressure turbocharger.

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NOTE: Complete steps 4 through 7, if air intake manifold is being replaced or the union or plug is leaking.

3. Unscrew rubber pad from air intake manifold.
4. Remove M32 x 1.5 threaded union.
5. Remove BS-32.7 x 40 seal and inspect seal surfaces. Discard seal if damaged.
6. Remove M26 plug.
7. Remove BS-26.7 x 34 seal and inspect seal surfaces. Discard seal if damaged.

Intercooler Elbow

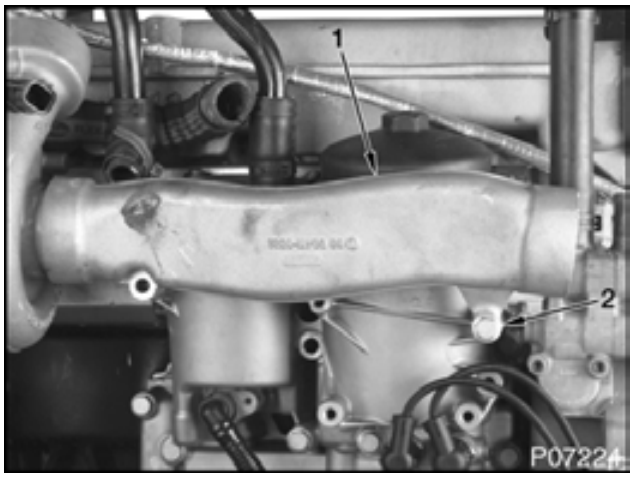

Figure 207 Intercooler elbow

1. Intercooler elbow
2. M10 x 50 hex bolt

1. Remove M10 x 50 hex bolt and intercooler elbow from high pressure turbocharger. Inspect 62.87 x 5.33 O-ring. Discard if damaged.

Turbochargers

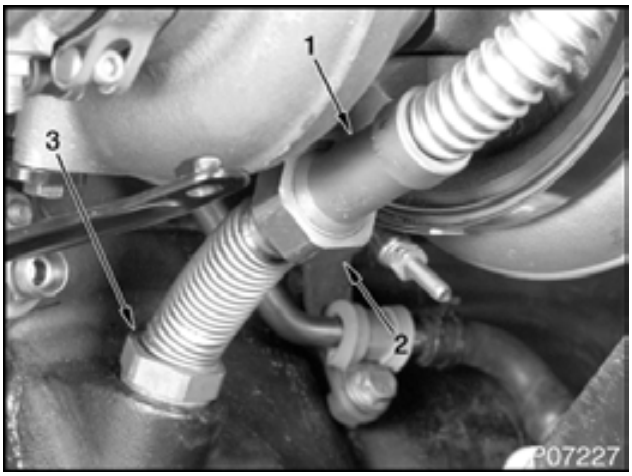

Figure 208 Low pressure turbocharger oil return pipe

1. High pressure turbocharger oil return pipe
2. Low pressure turbocharger oil return pipe fitting nut
3. Low pressure turbocharger oil return pipe

1. Loosen low pressure turbocharger oil return pipe fitting nut from high pressure turbocharger oil return pipe fitting nut and disconnect pipe from low pressure turbocharger oil return pipe.
2. Remove low pressure turbocharger oil return pipe from crankcase and discard BS-16.7 x 24 seal.

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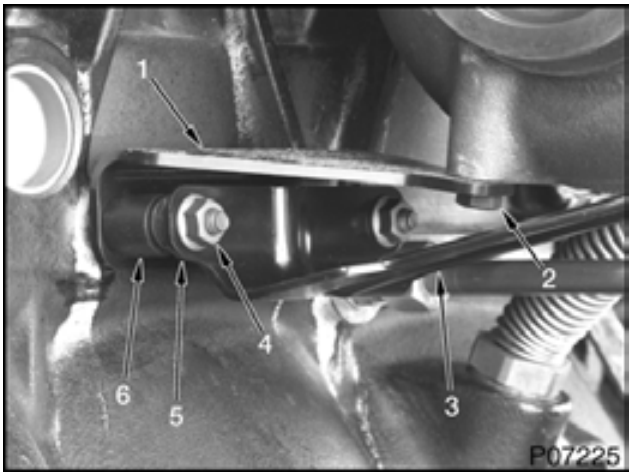

Figure 209 Starter heat shield bracket and bracket

1. Bracket (turbocharger support)
2. M8 x 12 hex bolt
3. Starter heat shield bracket
4. M8 hex nut (2)
5. M8 x 35 stud bolt (2)
6. Bushing (2)

3. Remove two M8 hex nuts and starter heat shield bracket.
4. Remove M8 x 12 hex bolt.
5. Remove two M8 x 35 stud bolts, two bushings, and bracket supporting the turbocharger.

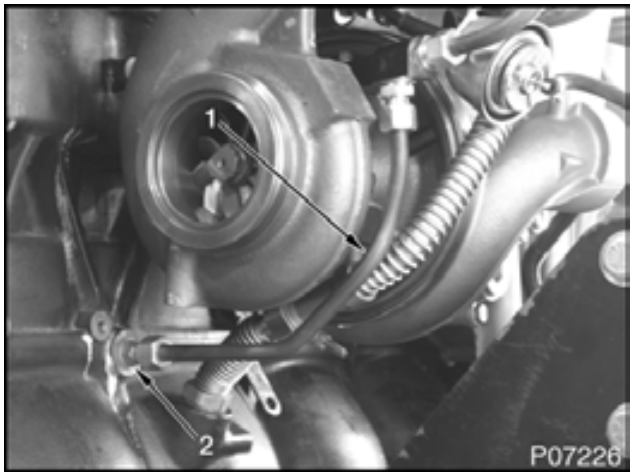

Figure 210 Low pressure turbocharger oil pressure pipe

1. Low pressure turbocharger oil pressure pipe
2. L12A straight union

6. Loosen low pressure turbocharger oil pressure pipe fitting nuts and remove pipe.
7. Remove L12A straight union from right side of crankcase and discard BS-24.7 x 32 seal.

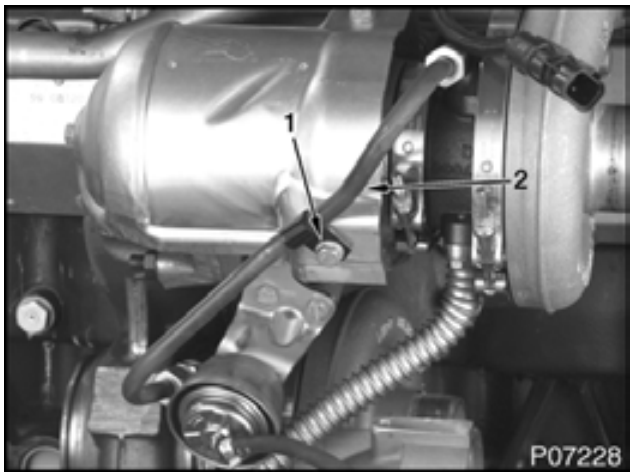

Figure 211 High-pressure turbocharger oil pressure pipe

1. M8 x 16 hex bolt
2. High-pressure turbocharger oil pressure pipe

8. Remove M8 x 16 hex bolt.
9. Loosen two high-pressure turbocharger oil pressure pipe fitting nuts and remove pipe.

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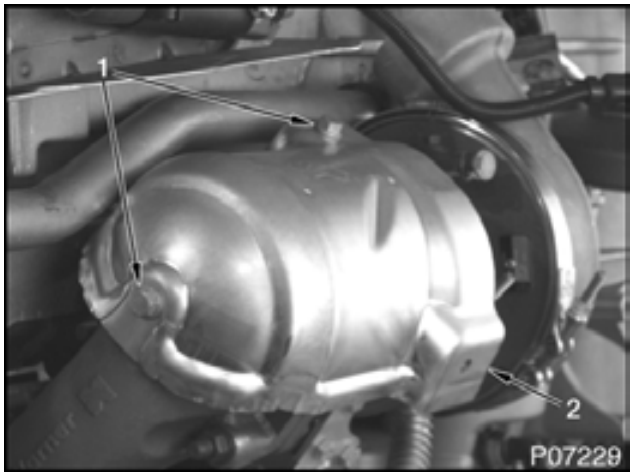

Figure 212 Heat shield

1. M8 x 16 hex bolt (2)
2. Heat shield

10. Remove two M8 x 16 hex bolts and heat shield.

NOTE: If replacing boost control actuator, do steps 11 through 16. If installing a new complete turbocharger assembly, skip steps 11 through 16.

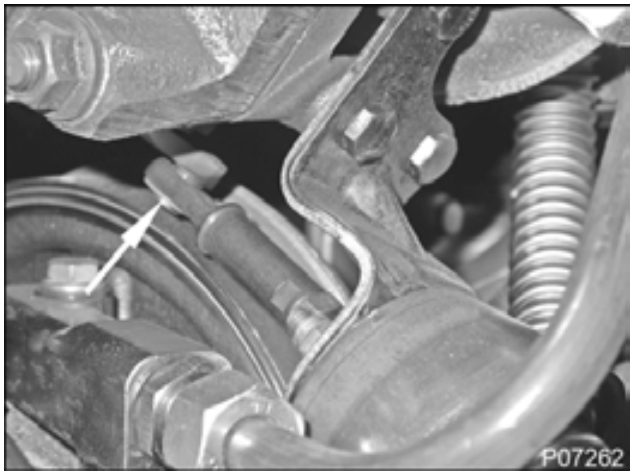

Figure 213 C-clip

11. Remove C-clip from turbocharger linkage.

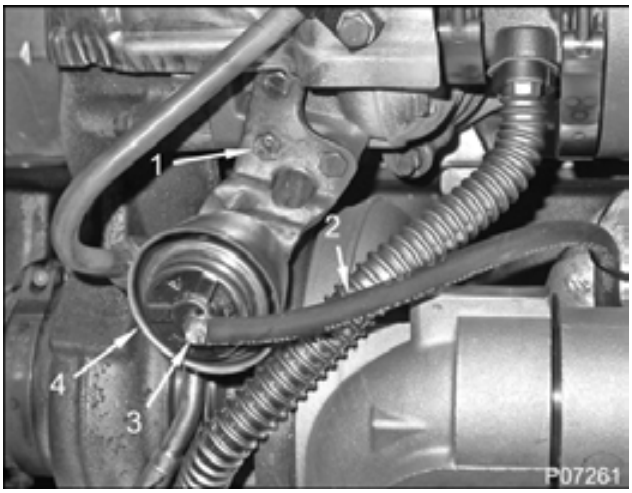

Figure 214 Boost control actuator

1. M8 x 14 hex bolt (3)
2. BCS valve output line
3. Crimp clamp
4. Boost control actuator

12. Cut and remove crimp clamp from BCS valve output line.
13. Disconnect BCS valve output line from boost control actuator.
14. Remove three M8 x 14 hex bolts
15. Remove boost control actuator.

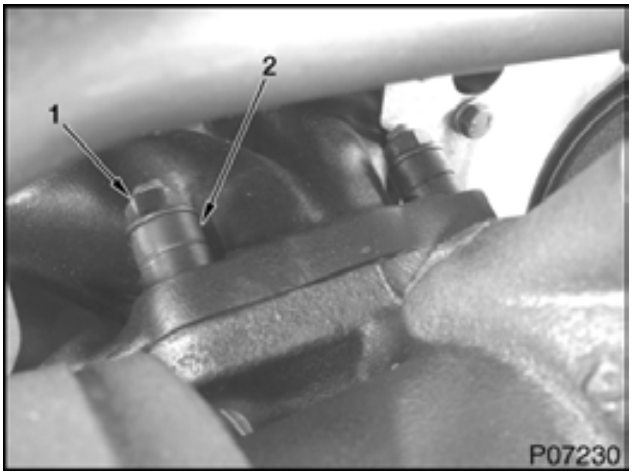

Figure 215 High pressure turbocharger connection (upper nuts)

1. M10 hexagon nut (2)
2. High temperature spacing bushing (2)

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16. Remove two M10 hexagon nuts and high temperature spacing bushings.

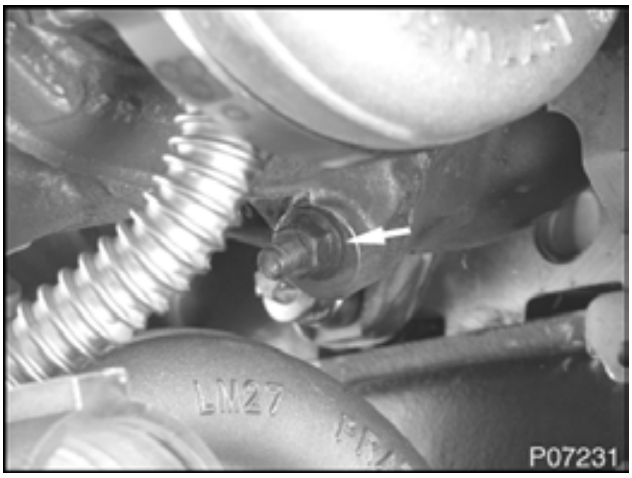

Figure 216 High pressure turbocharger connection (lower nut)

WARNING: To prevent personal injury or death, get help to remove or install the turbochargers.

17. Remove one M10 hexagon nut and turbochargers. Use an assistant to support turbochargers during removal.

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Disassembly

Turbochargers

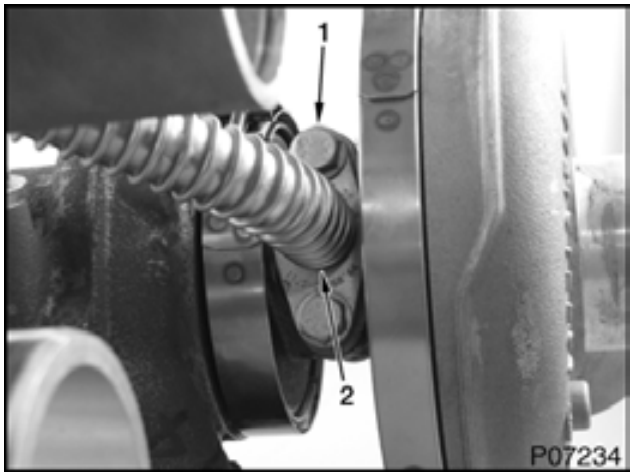

Figure 217 High pressure turbocharger oil return pipe (upper connection)

1. M8 x 20 hex bolt (2)
2. High pressure turbocharger oil return pipe

1. Remove two M8 x 20 hex bolts.
2. Disconnect high pressure turbocharger oil return pipe from high pressure turbocharger and discard gasket.

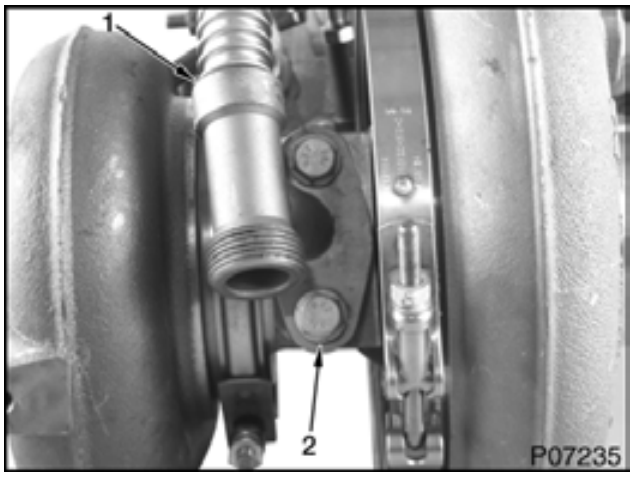

Figure 218 High pressure turbocharger oil return pipe (lower connection)

1. High pressure turbocharger oil return pipe
2. M8 x 20 hex bolt (2)

3. Remove two M8 x 20 hex bolts.
4. Disconnect and remove high pressure turbocharger oil return pipe from low pressure turbocharger. Discard gasket.

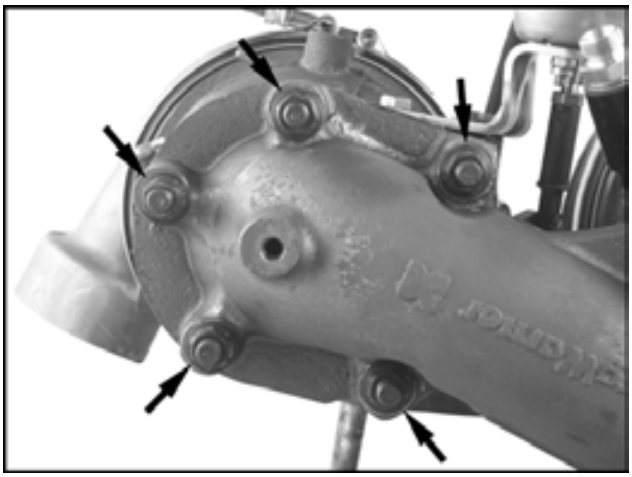

Figure 219 Turbocharger connection

5. Remove five M10 hexagon nuts and separate high pressure turbocharger from low pressure turbocharger.

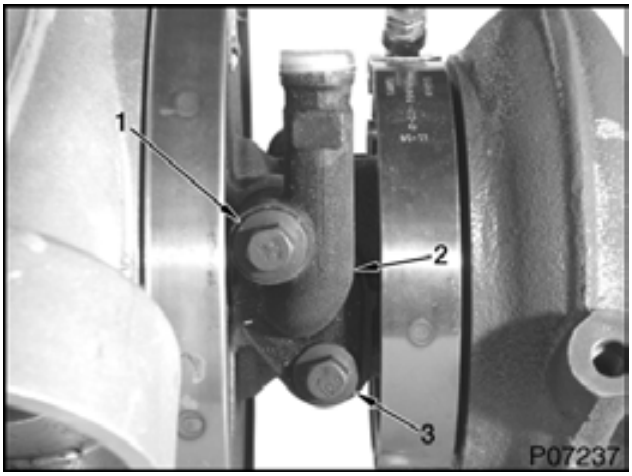

Figure 220 High pressure turbocharger oil pressure connection flange

1. M8 x 45 hex bolt
2. High pressure turbocharger oil pressure connection flange
3. M8 x 20 hex bolt

6. Remove M8 x 20 and M8 x 45 hex bolts.

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7. Remove high pressure turbocharger oil pressure connection flange and discard gasket.

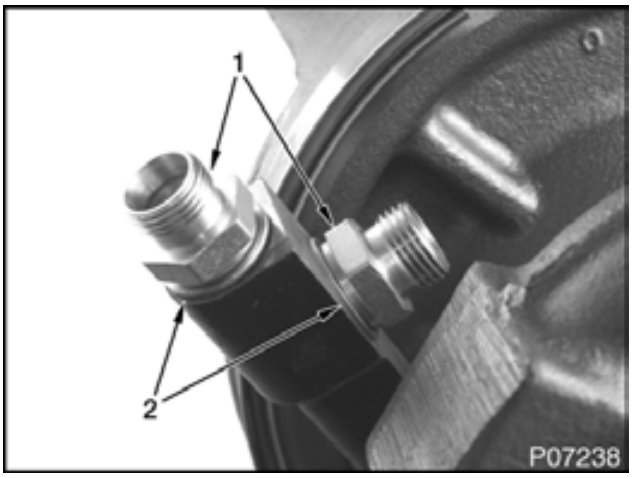

Figure 221 Straight unions

1. Straight union (2)
2. Seal (2)

NOTE: Complete next step only if straight unions are found to be leaking.

8. Remove two straight unions and discard seals.

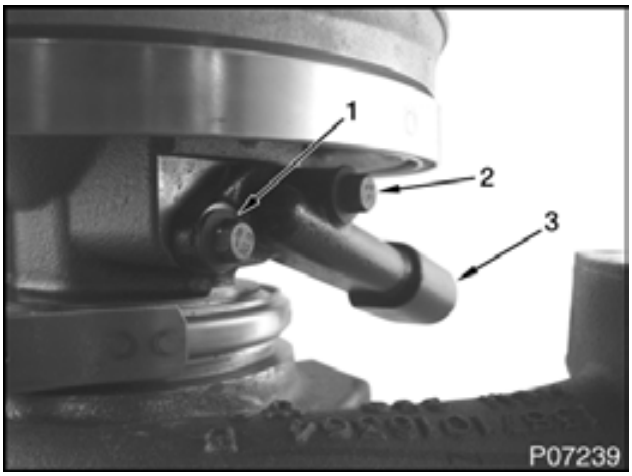

Figure 222 Low pressure turbocharger oil pressure connection flange

1. M8 x 20 hex bolt
2. M8 x 35 hex bolt
3. Low pressure turbocharger oil pressure connection flange

9. Remove M8 x 20 and M8 x 35 hex bolts.
10. Remove low pressure turbocharger oil pressure connection flange and discard gasket.

Cleaning and Inspection

Turbochargers and Related Parts Cleaning

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

NOTE: Do not use a caustic solution on turbochargers and related components.

1. Clean piping between air intake manifold and air cleaner assembly with soap and steam clean. Dry all piping with filtered compressed air.
2. Clean High Pressure Charge Air Cooler (HPCAC), Low Pressure Charge Air Cooler (LPCAC), air intake manifold, and intercooler elbow with filtered compressed air.
3. Clean oil pressure pipes and oil return pipes with suitable solvent and a nylon brush. Dry pipes with filtered compressed air. Replace any damaged pipes.
4. Clean all gasket surfaces.

Turbochargers Inspection

1. Inspect turbochargers for cracks and leaks. Replace if necessary.
2. Inspect compressor impellers and turbine wheels for blade erosion, bending, breakage or deposits. Replace turbochargers if damaged.

NOTE: Replace turbochargers if blades are bent. Do not attempt to straighten bent wheel blades.

3. Place turbochargers on a bench with the shafts in a horizontal position.

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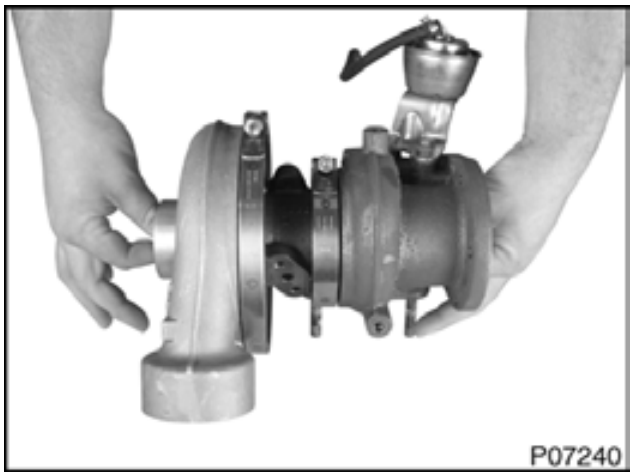

Figure 223 Free rotation of turbocharger assembly shaft (typical)

4. Turn turbine shafts by hand and check for wheel rub in each housing.

   The wheels must rotate freely. If there is any rubbing or interference, replace turbocharger.

Low Pressure Charge Air Cooler (LPCAC) Pressure Test

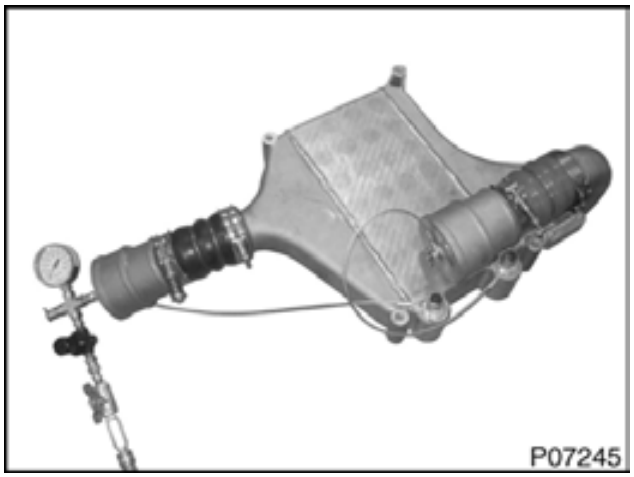

Figure 224 LPCAC pressure test

1. Attach Charge Air Cooler Tester Kit (page 169) to LPCAC using instructions supplied with tool and three inch couplers and clamps (obtain locally).

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

2. Pressurize LPCAC to 30 psi (205 kPa).
3. Spray a soapy water solution on LPCAC and tester components. Verify there are no leaks from hose connections or tester components.
4. If a leak is visually detected on LPCAC or tester gauge pressure drops, replace LPCAC.
5. Remove Charge Air Cooler Tester from LPCAC.

High Pressure Charge Air Cooler (HPCAC) Pressure Test

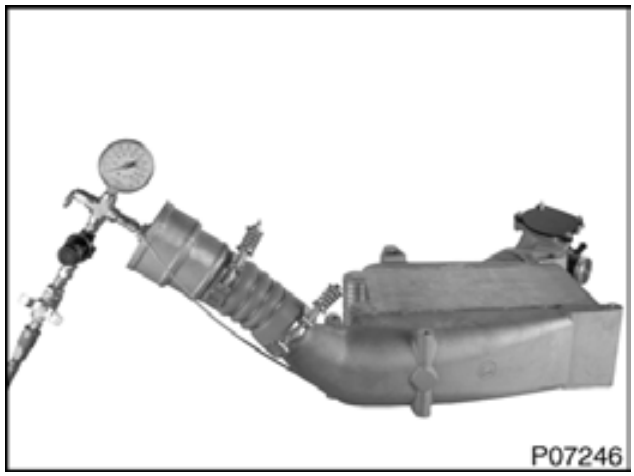

Figure 225 HPCAC pressure test

1. Install Manifold Absolute Pressure/Intake Air Temperature 2 (MAP/IAT2) sensor.
2. Attach High Pressure CAC Test Plate (page 169) and Charge Air Cooler Tester Kit (page 169) to HPCAC using instructions supplied with tool and three inch couplers and clamps (obtain locally).
3. Pressurize HPCAC to 30 psi (205 kPa).
4. Spray a soapy water solution on HPCAC and tester components. Verify there are no leaks from hose connections or tester components.
5. If a leak is visually detected on HPCAC or tester gauge pressure drops, replace HPCAC.
6. Remove MAP/IAT2 sensor.

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Assembly

Turbochargers

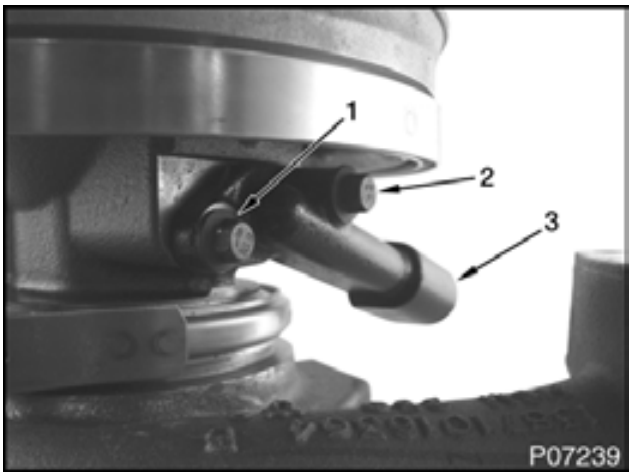

Figure 226 Low pressure turbocharger oil pressure connection flange

1. M8 x 20 hex bolt
2. M8 x 35 hex bolt
3. Low pressure turbocharger oil pressure connection flange

1. Install low pressure turbocharger oil pressure connection flange with new gasket.
2. Install M8 x 20 and M8 x 35 hex bolts. Tighten hex bolts to standard torque (page 457).

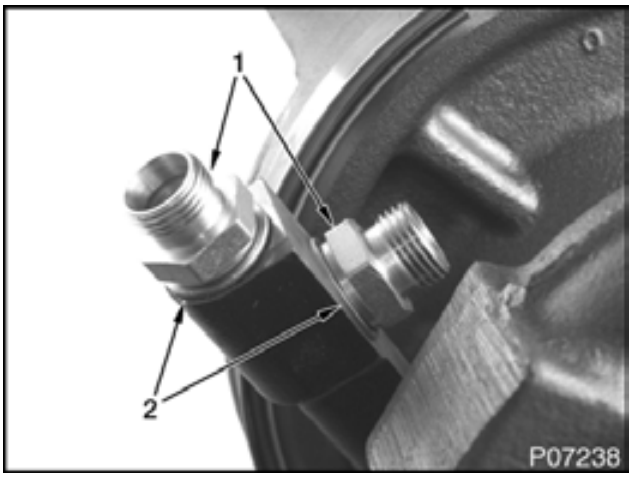

Figure 227 Straight unions

1. Straight union (2)
2. Seal (2)

NOTE: Complete steps 3 and 4 if straight unions were removed.

3. Install two straight unions with new seals.
4. Tighten straight unions as follows:
   a. Hand tighten straight unions.
   b. Turn an additional 90°.

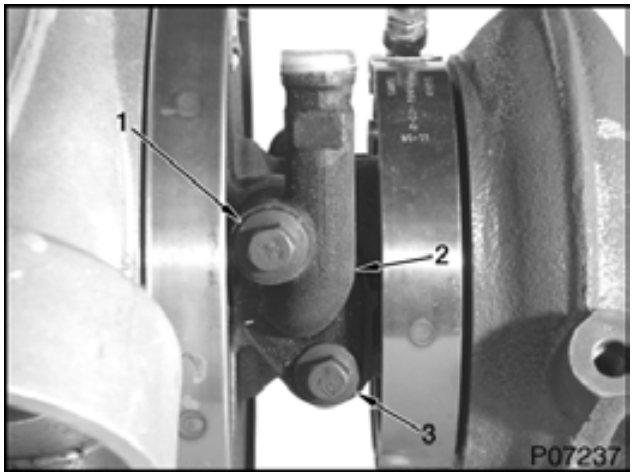

Figure 228 High pressure turbocharger oil pressure connection flange

1. M8 x 45 hex bolt
2. High pressure turbocharger oil pressure connection flange
3. M8 x 20 hex bolt

5. Install high pressure turbocharger oil pressure connection flange with new gasket.
6. Install M8 x 20 and M8 x 45 hex bolts. Tighten hex bolts to standard torque (page 457).

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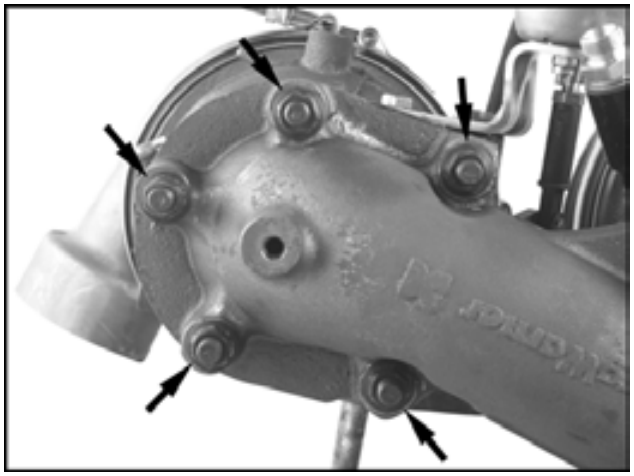

Figure 229 Turbocharger connection

7. Connect high pressure turbocharger to low pressure turbocharger. Install five M10 hexagon nuts and tighten as follows:
   a. Tighten nuts to 10 N·m (89 lbf·in).
   b. Turn nuts an additional 90°.

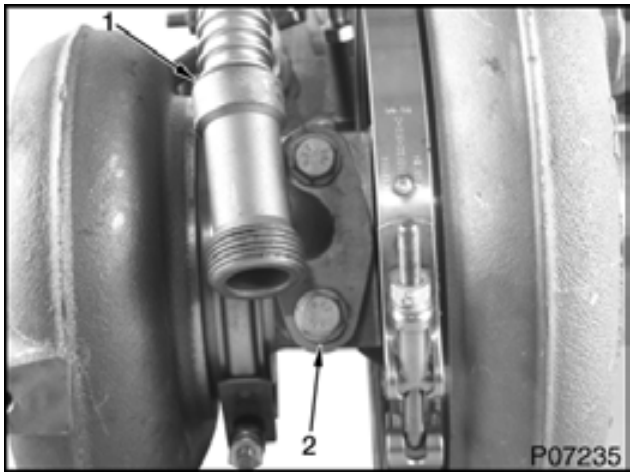

Figure 230 High pressure turbocharger oil return pipe (lower connection)

1. High pressure turbocharger oil return pipe
2. M8 x 20 hex bolt (2)

8. Position high pressure turbocharger oil return pipe to low pressure turbocharger with new gasket.
9. Install two M8 x 20 hex bolts. Tighten hex bolts to standard torque (page 457).

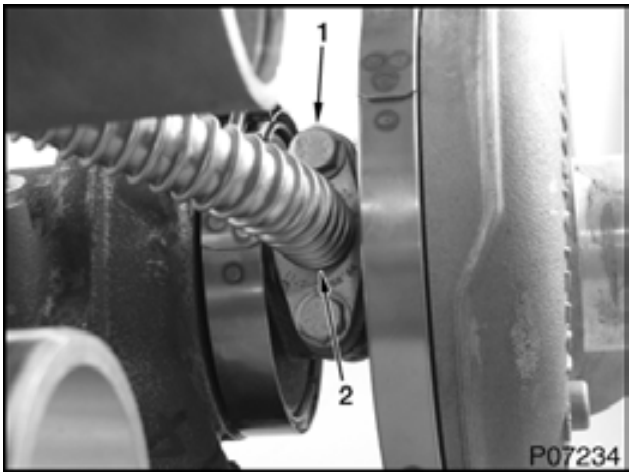

Figure 231 High pressure turbocharger oil return pipe (upper connection)

1. M8 x 20 hex bolt (2)
2. High pressure turbocharger oil return pipe

10. Position high pressure turbocharger oil return pipe to high pressure turbocharger with new gasket.
11. Install two M8 x 20 hex bolts. Tighten hex bolts to standard torque (page 457).

Installation

Turbochargers

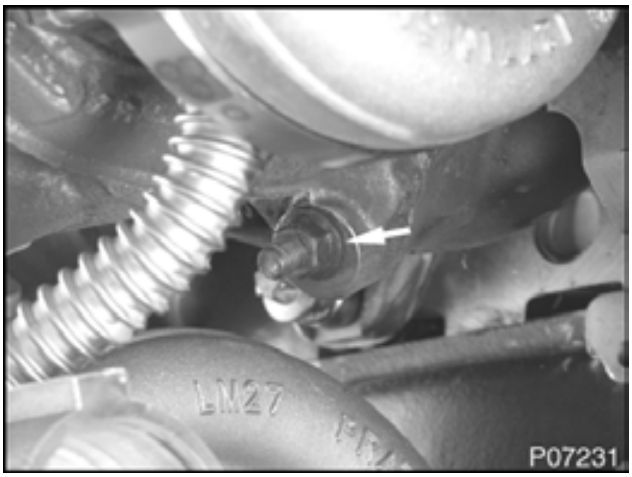

Figure 232 High pressure turbocharger connection (lower nut)

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WARNING: To prevent personal injury or death, get help to remove or install the turbochargers.

1. Install turbochargers and one M10 hexagon nut with help from an assistant to support turbochargers. Tighten hexagon nut to standard torque (page 457).

NOTE: If replacing boost control actuator, do steps 2 through 6. If installing a new complete turbocharger assembly, skip steps 2 through 6.

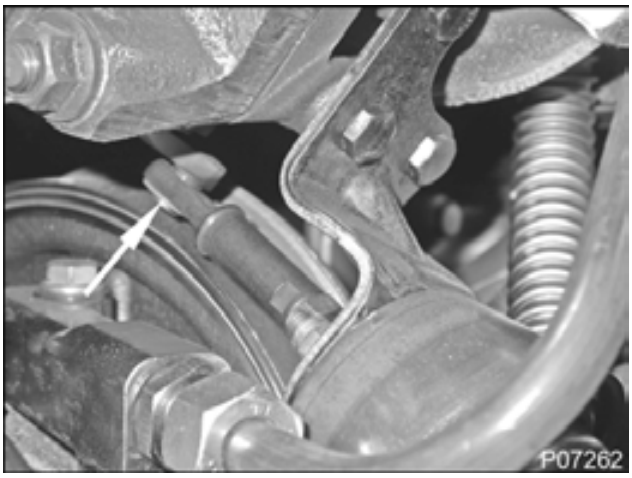

Figure 233 C-clip

2. Position boost control actuator and install C-clip on turbocharger linkage.

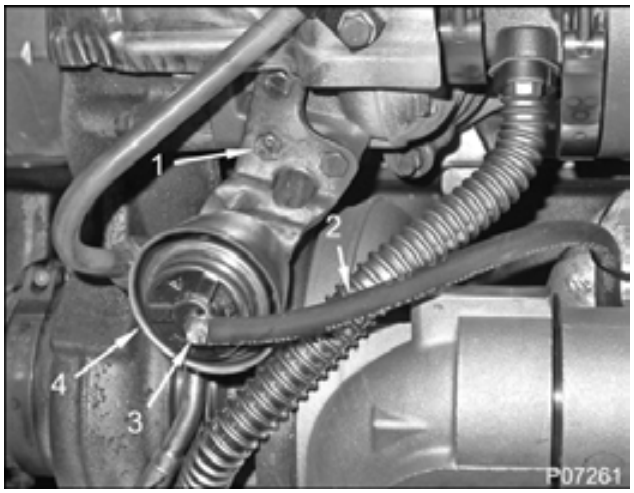

Figure 234 Boost control actuator

1. M8 x 14 hex bolt (3)
2. BCS valve output line
3. Crimp clamp
4. Boost control actuator

3. Position boost control actuator and install three M8 x 14 hex bolts.
4. Tighten each M8 x 14 hex bolt to standard torque (page 457).
5. Put crimp clamp onto BCS valve output line
6. Connect BCS valve output line to boost control actuator and crimp the crimp clamp.

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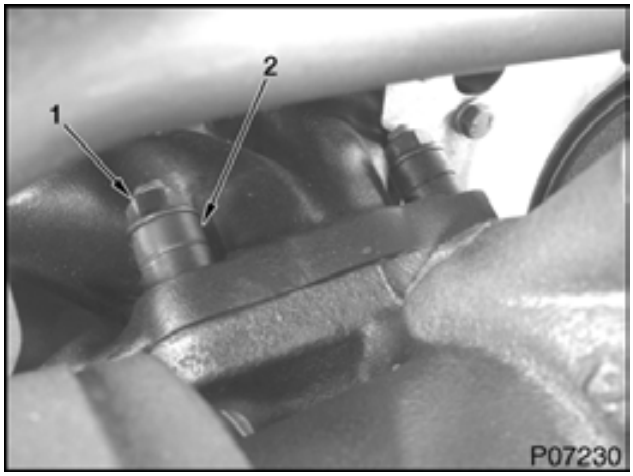

Figure 235 High pressure turbocharger connection (upper nuts)

1. M10 hexagon nut (2)
2. High temperature spacing bushing (2)

7. Install two M10 hexagon nuts and high temperature spacing bushings. Tighten hexagon nuts to standard torque (page 457).

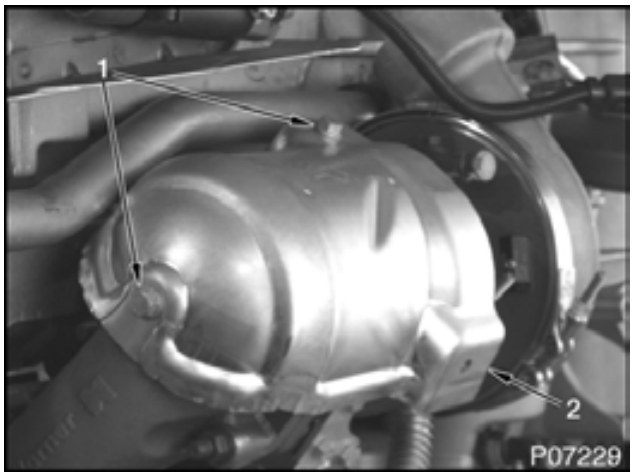

Figure 236 Heat shield

1. M8 x 16 hex bolt (2)
2. Heat shield

8. Install heat shield and two M8 x 16 hex bolts. Tighten hex bolts to standard torque (page 457).

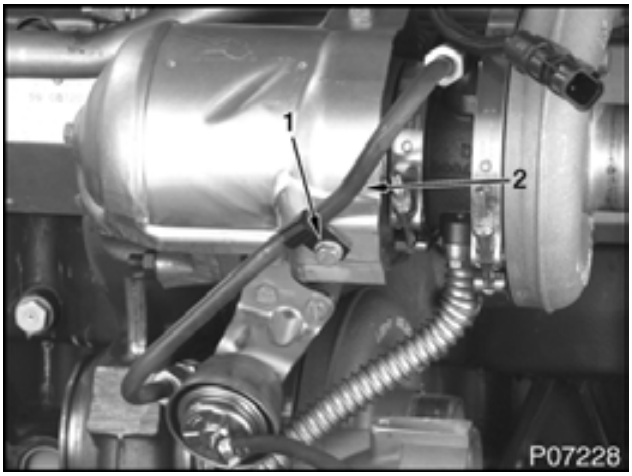

Figure 237 High pressure turbocharger oil pressure pipe

1. M8 x 16 hex bolt
2. High pressure turbocharger oil pressure pipe

9. Position high pressure turbocharger oil pressure pipe and tighten fitting nuts as follows:
   a. Tighten fitting nuts to 10 N·m (89 lbf·in).
   b. Turn nuts an additional 90°.
10. Install M8 x 16 hex bolt. Tighten hex bolt to standard torque (page 457).

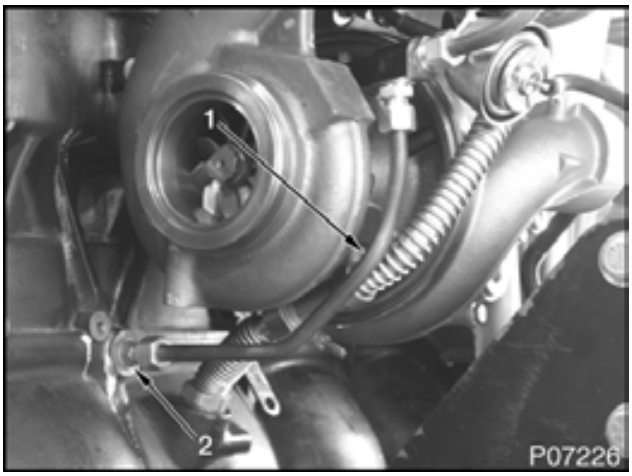

Figure 238 Low pressure turbocharger oil pressure pipe

1. Low pressure turbocharger oil pressure pipe
2. L12A straight union

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11. Install L12A straight union and new BS-24.7 x 32 seal into right side of crankcase. Tighten straight union as follows:
    a. Hand tighten straight union.
    b. Turn an additional 90°.
12. Install low pressure turbocharger oil pressure pipe. Tighten fitting nuts as follows:
    a. Tighten fitting nuts to 10 N·m (89 lbf·in).
    b. Turn nuts an additional 90°.

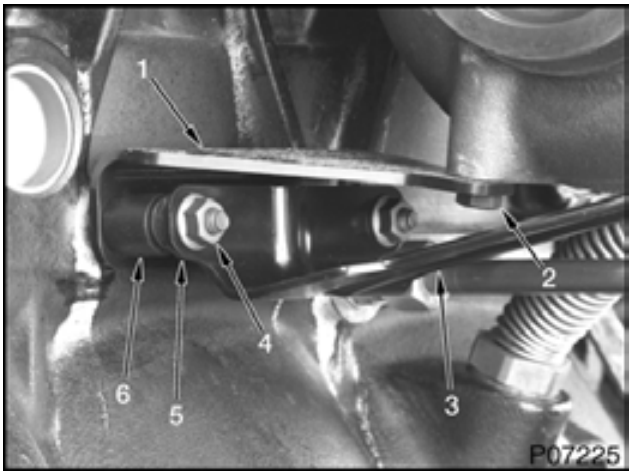

Figure 239 Starter heat shield bracket and bracket

1. Bracket (turbocharger support)
2. M8 x 12 hex bolt
3. Starter heat shield bracket
4. M8 hex nut (2)
5. M8 x 35 stud bolt (2)
6. Bushing (2)

13. Install bracket supporting turbocharger, two bushings, and two M8 x 35 stud bolts. Tighten stud bolts to standard torque (page 457).
14. Install M8 x 12 hex bolt. Tighten hex bolt to standard torque (page 457).
15. Install starter heat shield bracket and two M8 hex nuts. Tighten hex nuts to standard torque (page 457).

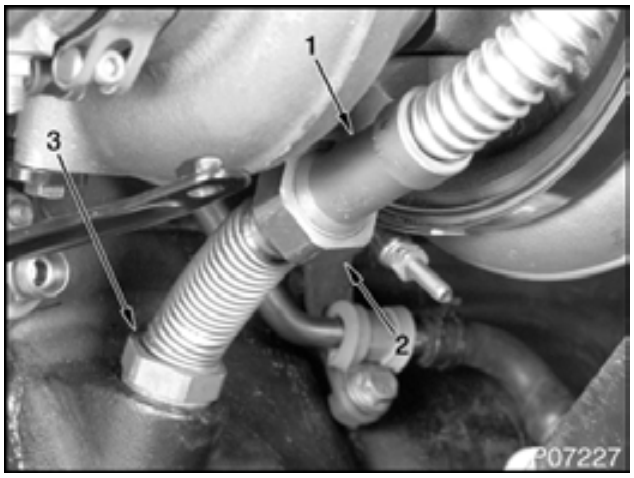

Figure 240 Low pressure turbocharger oil return pipe

1. High pressure turbocharger oil return pipe
2. Low pressure turbocharger oil return pipe fitting nut
3. Low pressure turbocharger oil return pipe

16. Install low pressure turbocharger oil return pipe with new seal into crankcase. Tighten fitting nut as follows:
    a. Tighten nut to 10 N·m (89 lbf·in).
    b. Turn nut an additional 90°.
17. Connect low pressure turbocharger oil return pipe to high pressure turbocharger oil return pipe. Tighten fitting nut as follows:
    a. Tighten nut to 10 N·m (89 lbf·in).
    b. Turn nut an additional 90°.

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Intercooler Elbow

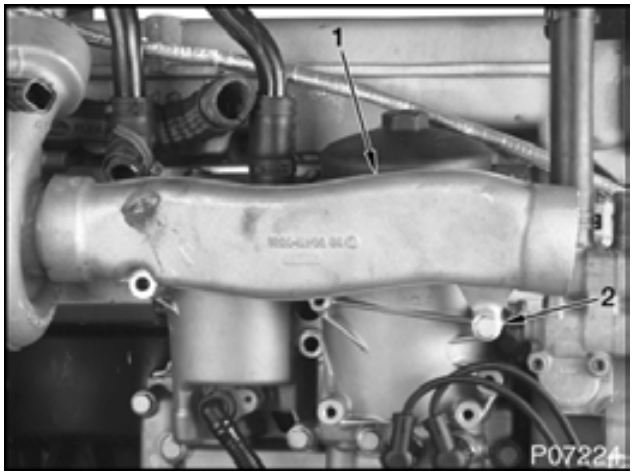

Figure 241 Intercooler elbow

1. Intercooler elbow
2. M10 x 50 hex bolt

NOTE: Install new 62.87 x 5.33 O-ring if old O-ring was found to be defective.

1. Lubricate 62.87 x 5.33 O-ring with P-80® Rubber Lubricant or equivalent (page 169) and install into intercooler elbow.
2. Install intercooler elbow to high pressure turbocharger with M10 x 50 hex bolt. Tighten hex bolt to standard torque (page 457).

Air Intake Manifold

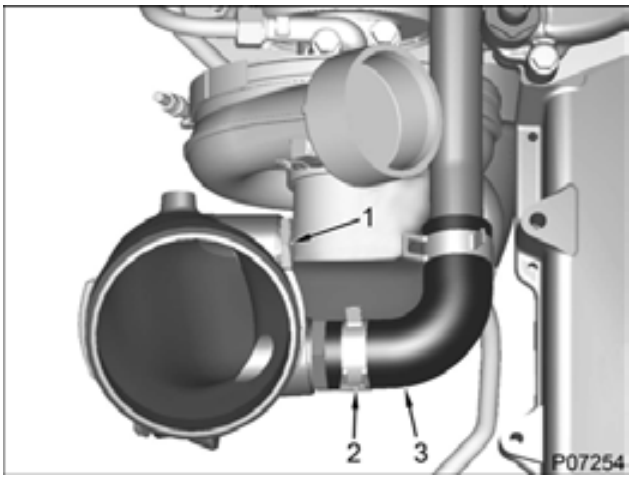

Figure 242 Breather connection

1. M26 Plug
2. 44/15 spring clip
3. DMR32 shaped hose

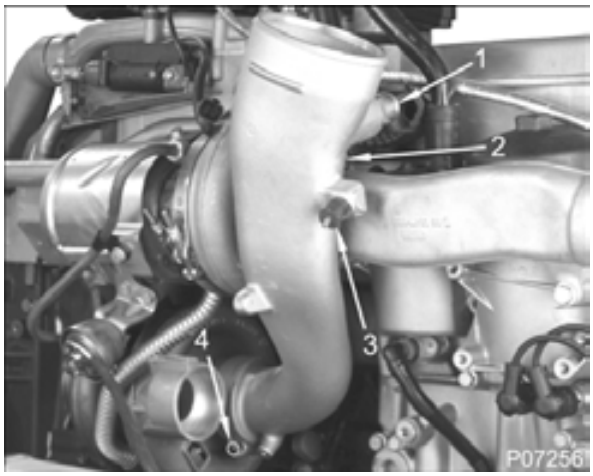

Figure 243 Air intake manifold

1. M32 x 1.5 threaded union
2. Air intake manifold
3. Rubber pad
4. M8 x 30 cylinder screw

NOTE: Complete steps 1 through 5, if air intake manifold was replaced or union and plug were removed.

1. Install a new BS-26.7 x 34 onto M26 plug.
   a. Hand tighten plug

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b. Turn an additional 90°.

2. If the old BS-32.7 x 40 seal was defective, lubricate a new BS-32.7 x 40 seal with P-80® Rubber Lubricant or equivalent (page 169) and install seal and onto M32 x 1.5 threaded union.
3. Install M32 x 1.5 threaded union into air intake manifold.
   a. Hand tighten threaded union.
   b. Turn an additional 90°.
4. Connect DMR32 shaped hose to M32 x 1.5 threaded union and install 44/15 spring clip.
5. Install rubber pad into air intake manifold. Tighten rubber pad to special torque (page 169).
6. Install air intake manifold to low pressure turbocharger. Install M8 x 30 cylinder screw. Do not tighten at this time.

Coolant Pipes

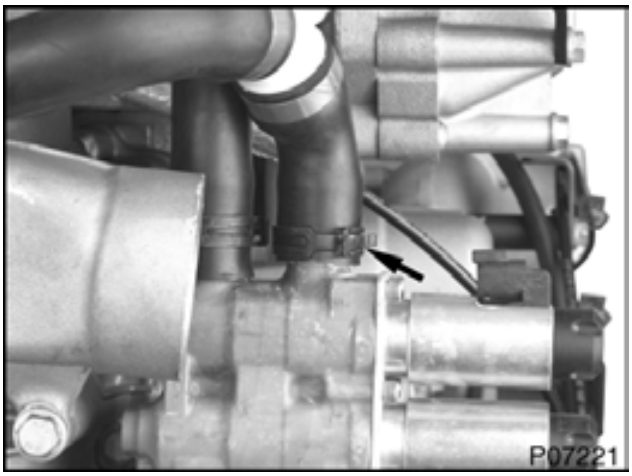

Figure 244 Charge Air Cooler (CAC) supply coolant pipe

1. Install CAC supply coolant pipe to engine and connect to Coolant Control Valve (CCV). Install hose clamp.

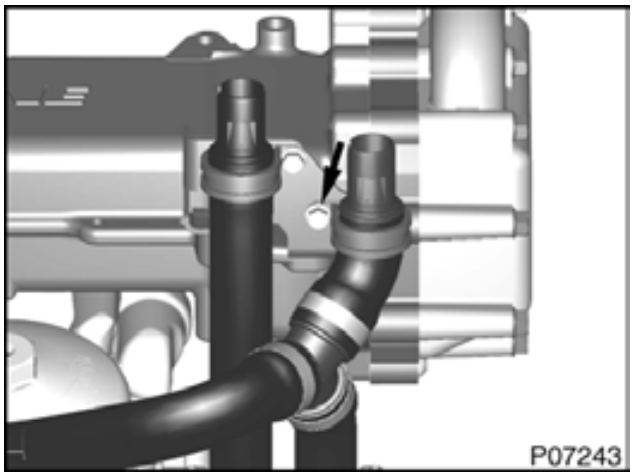

Figure 245 Charge Air Cooler (CAC) supply coolant pipe to bracket connection

2. Install CAC supply coolant pipe to bracket and install M6 x 16 hex bolt. Tighten hex bolt to standard torque (page 457).

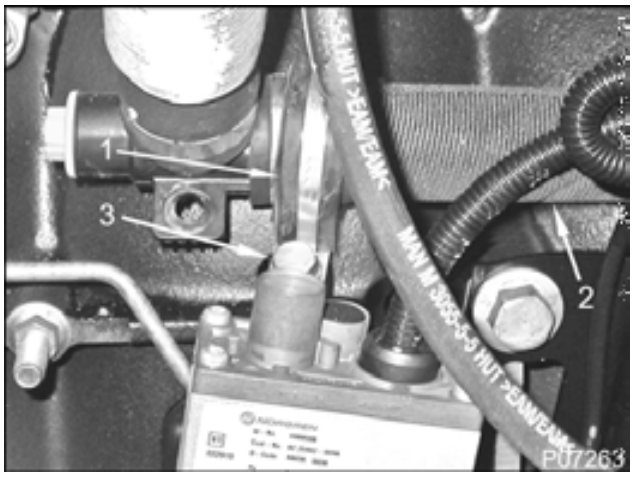

Figure 246 P-clamp for CAC return coolant pipe

1. P-clamp
2. CAC return coolant pipe
3. M8 x hex bolt

3. Position P-clamp for CAC return coolant pipe.
4. Install M8 x hex bolt and tighten to standard torque (page 457).

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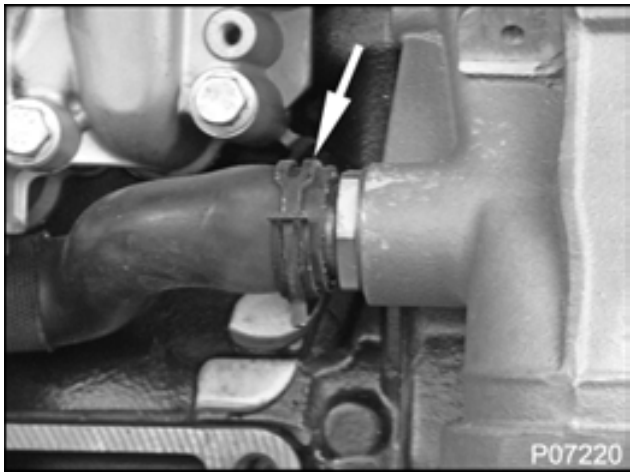

Figure 247 CAC return coolant pipe

5. Install CAC return coolant pipe to engine and connect to front cover. Install hose clamp.

High Pressure Charge Air Cooler (HPCAC) Bracket

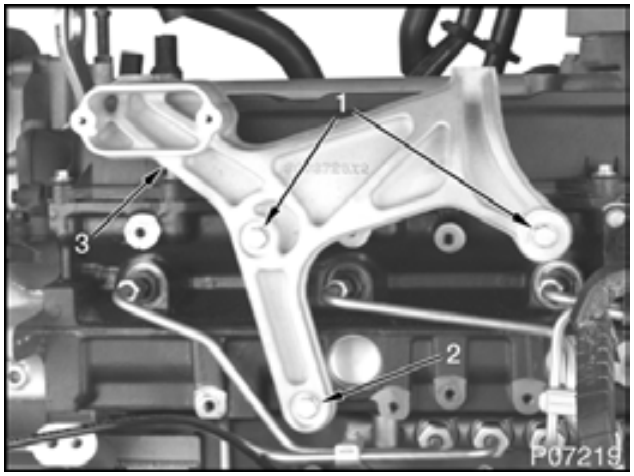

Figure 248 High Pressure Charge Air Cooler (HPCAC) bracket

1. M8 x 55 hex bolt (2)
2. M8 x 45 hex bolt
3. HPCAC bracket

1. Install HPCAC bracket.
2. Install two M8 x 55 and M8 x 45 hex bolts. Tighten hex bolts to standard torque (page 457).

Intake Throttle Valve (ITV)

NOTE: Complete this procedure if ITV was previously removed from High Pressure Charge Air Cooler (HPCAC).

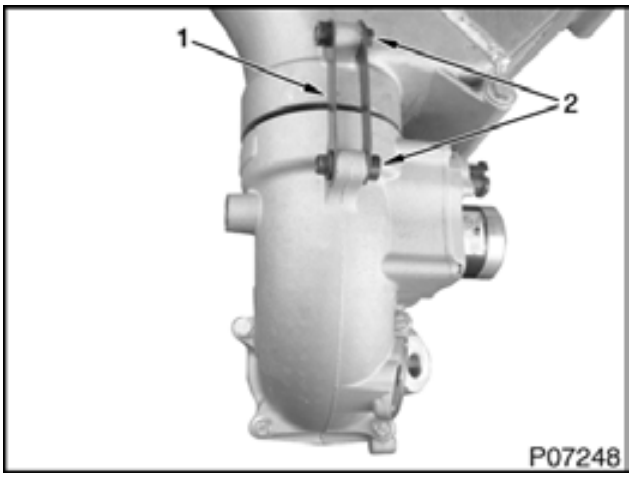

Figure 249 Intake Throttle Valve (ITV)

1. Latch arm (2)
2. M10 x 30 hex bolt (2)

1. Lubricate both ends of DMR110/92 extension tube sealing surfaces with P-80® Rubber Lubricant or equivalent (page 169) and install one end into HPCAC. Install ITV to HPCAC.
2. Install two latch arms and two M10 x 30 hex bolts to ITV and HPCAC. Do not tighten at this time.

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High Pressure Charge Air Cooler (HPCAC)

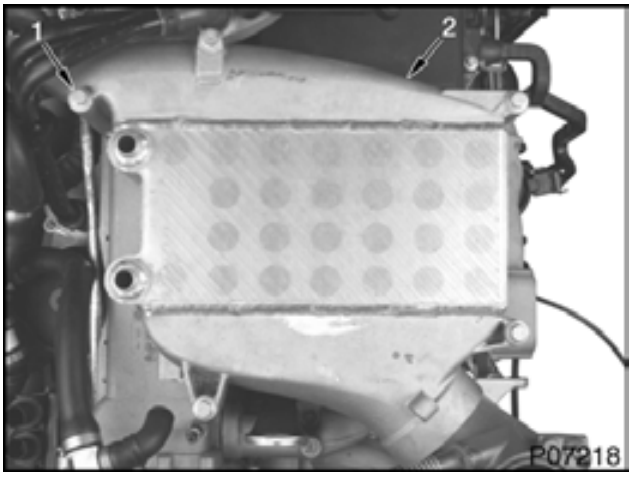

Figure 250 High Pressure Charge Air Cooler (HPCAC)

1. M10 x 160 hex bolt (5)
2. HPCAC

1. Lubricate both ends of DMR70 extension tube sealing surfaces with P-80® Rubber Lubricant or equivalent (page 169) and install one end into HPCAC.
2. Install new ITV O-ring.
3. Install HPCAC.
4. Install five M10 x 160 hex bolts. Tighten hex bolts to standard torque (page 457).

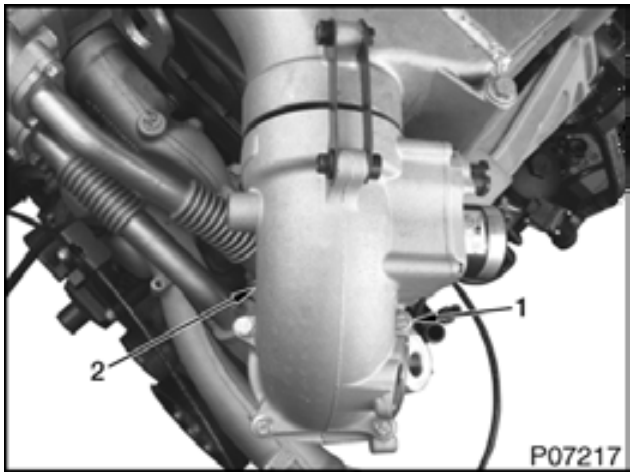

Figure 251 Intake Throttle Valve (ITV)

1. ITV bolt (4)
2. ITV

NOTE: The captive ITV bolts can be locked in a raised position by pulling up and turning counterclockwise.

5. Screw in four captive ITV bolts. Tighten bolts to standard torque (page 457).
6. Tighten two latch arm M10 x 30 hex bolts to standard torque (page 457).

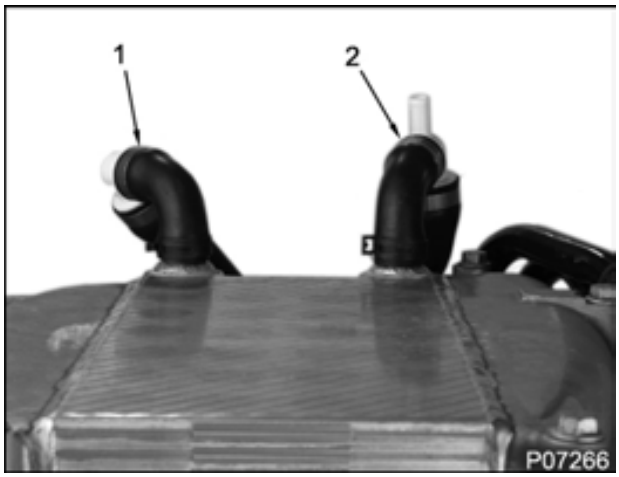

Figure 252 High Pressure Charge Air Coolant (HPCAC) coolant pipe connections

1. CAC supply coolant pipe
2. CAC return coolant pipe

7. Connect CAC return coolant pipe to HPCAC and install hose clamp.

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8. Connect CAC supply coolant pipe to HPCAC and install hose clamp.

Low Pressure Charge Air Cooler (LPCAC) Bracket

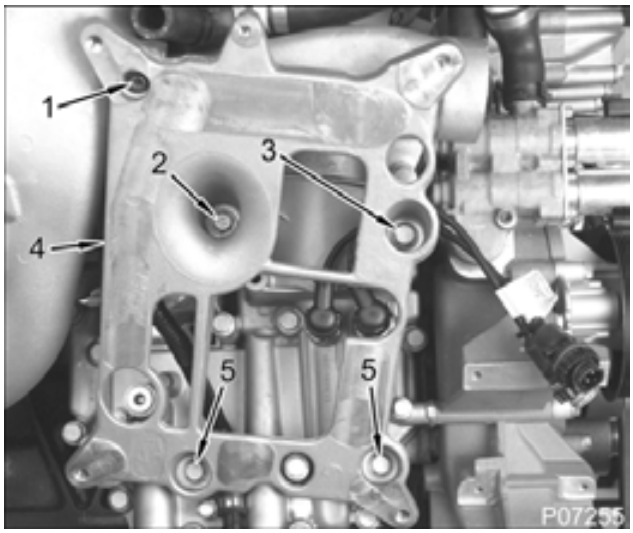

Figure 253 Low Pressure Charge Air Cooler (LPCAC) bracket

1. M6 hexagon nut
2. M10 x 190 hex bolt
3. M10 x 50 hex bolt
4. LPCAC bracket
5. M10 x 110 hex bolt (2)

1. Install LPCAC bracket.
2. Install M10 x 190 hex bolt, M6 hexagon nut, M10 x 50 hex bolt, and two M10 x 110 hex bolts to LPCAC bracket. Tighten hexagon nut and hex bolts to standard torque (page 457).
3. Tighten air intake manifold M8 x 30 cylinder screw to special torque (page 169).

Low Pressure Charge Air Cooler (LPCAC)

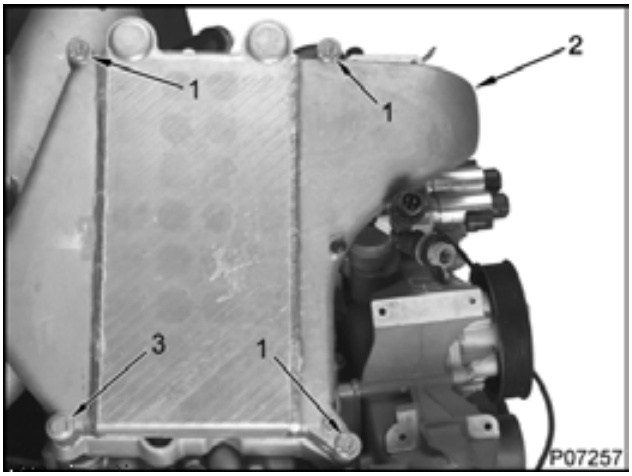

Figure 254 Low Pressure Charge Air Cooler (LPCAC)

1. M10 x 90 stud bolt (3)
2. LPCAC
3. M10 x 90 hex bolt

1. Lubricate both DMR70 extension tube sealing surfaces with P-80® Rubber Lubricant or equivalent (page 169) and install into LPCAC.
2. Install LPCAC to engine until both DMR70 extension tubes seat in intercooler elbow and low pressure turbocharger.
3. Install three M10 x 90 stud bolts. Tighten hex bolts to standard torque (page 457).
4. Install one M10 x 90 hex bolt. Tighten hex bolts to standard torque (page 457).

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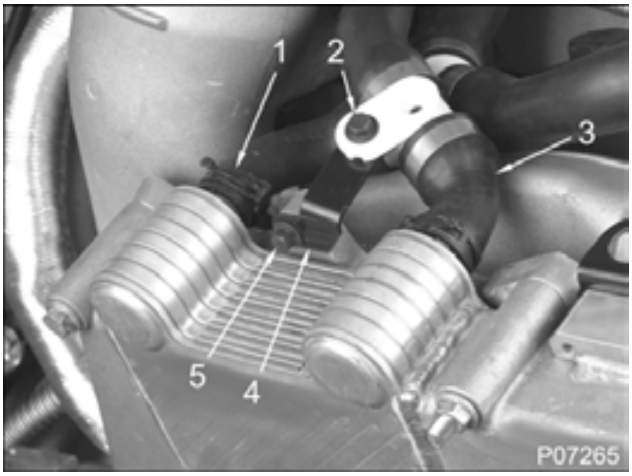

Figure 255 Low Pressure Charge Air Cooler (LPCAC) coolant pipe connections

1. CAC supply coolant pipe
2. M8 x 16 hex bolt
3. CAC return coolant pipe
4. Temperature sensor bracket
5. M8 x 16 hex bolt.

5. Connect CAC return coolant pipe to LPCAC and install hose clamp.
6. Install M8 x 16 hex bolt to bracket on LPCAC. Tighten hex bolt to standard torque (page 457).
7. Connect CAC supply coolant pipe to LPCAC and install hose clamp.
8. Install temperature sensor bracket and M8 x 16 bolt. Tighten bolt to standard torque (page 457).

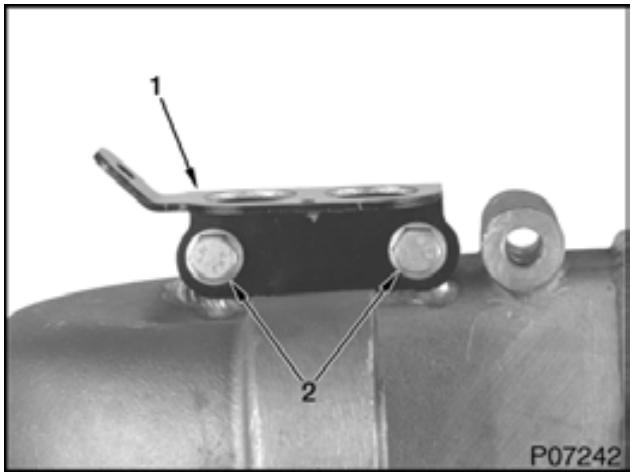

Figure 256 Adapter line bracket

1. Adapter line bracket
2. M8 x 16 hex bolt (2)

9. Install adapter line bracket and two M8 x 16 hex bolts. Tighten hex bolts to standard torque (page 457).

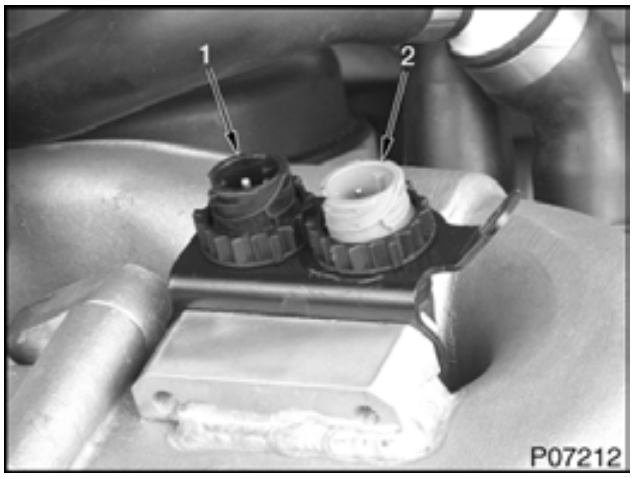

Figure 257 Adapter lines (electrical connections)

1. Engine Oil Pressure (EOP) sensor adapter line
2. Engine Oil Temperature (EOT) sensor adapter line

NOTE: Be sure to align flat spots on adapter line connectors with flat spots in adapter line bracket holes.

10. Install EOT sensor adapter line and retaining ring to adapter line bracket on LPCAC and turn adapter line retaining ring clockwise until tight.

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11. Install EOP sensor adapter line and retaining ring to adapter line bracket on LPCAC and turn adapter line retaining ring clockwise until tight.

Boost Control Solenoid (BCS) Valve Supply Line

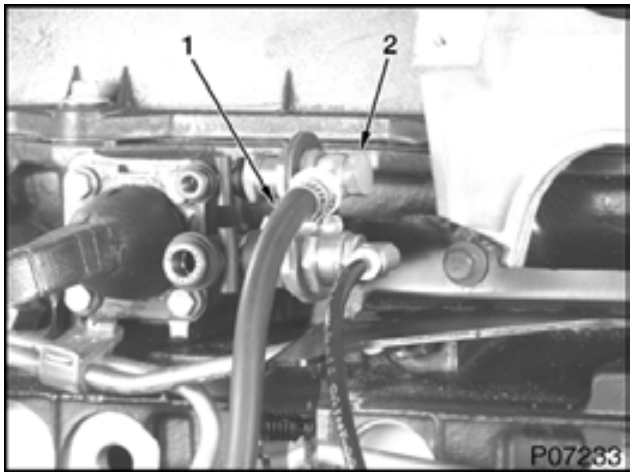

Figure 258 BCS valve supply line

1. BCS valve supply line
2. Banjo bolt

1. Connect BCS valve supply line to air fitting and install banjo bolt with new washers. Tighten banjo bolt to special torque (page 169).

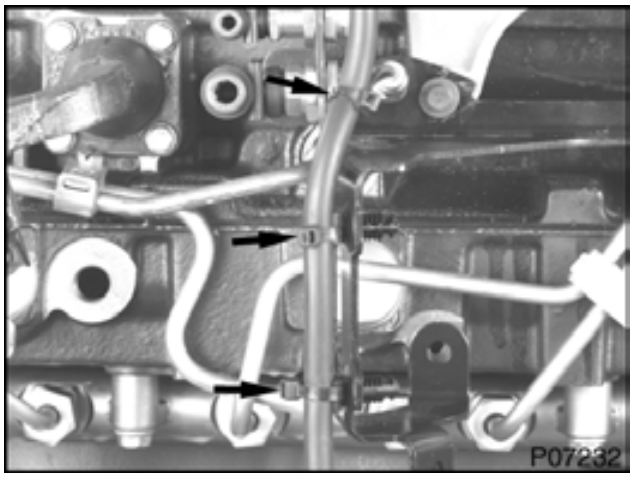

Figure 259 Tie straps

2. Install three new tie straps retaining BCS valve supply line to bracket.

Boost Control Solenoid (BCS) Valve

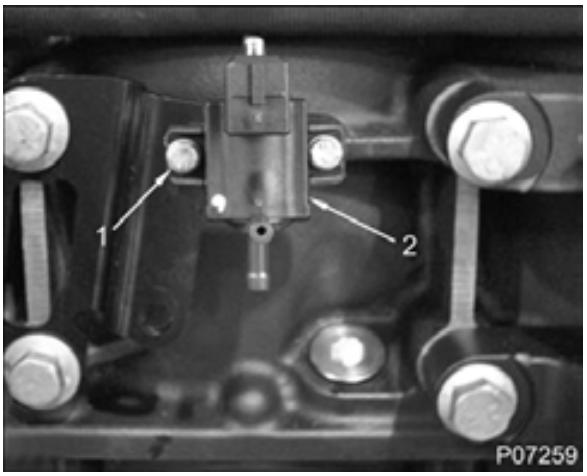

Figure 260 BCS valve

1. M5 x 12 hex bolt (2)
2. BCS valve

1. Install BCS valve.
2. Install two M5 x 12 hex bolts and two M5 washers. Tighten hex bolts to standard torque (page 457).

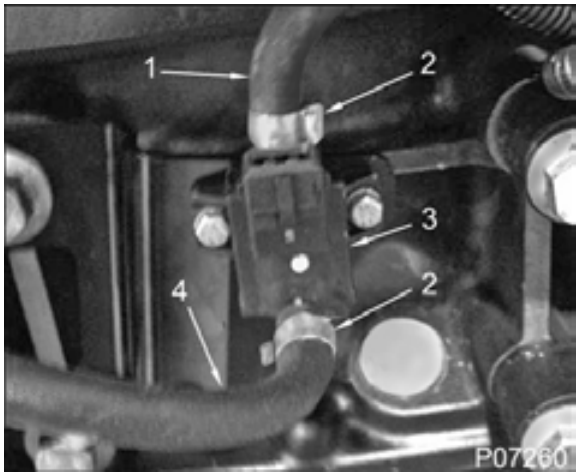

Figure 261 BCS valve lines

1. BCS valve supply line
2. Crimp clamp
3. BCS valve
4. BCS valve output line

3. Put a crimp clamp on each hose.

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4. Connect hoses to BCS valve and crimp each crimp clamp.

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Special Torque

Table 10 Turbochargers

High pressure turbocharger to low pressure turbocharger hexagon nuts	See tightening steps in procedure.
Banjo bolt	10 N·m (89 lbf·in)
Air intake manifold cylinder screw	10 N·m (89 lbf·in)
M32 x 1.5 threaded union (air intake duct)	See tightening steps in procedure.
M26 plug	See tightening steps in procedure.
Rubber pad	10 N·m (89 lbf·in)
Straight union (for low pressure turbocharger oil pressure connection flange)	See tightening steps in procedure.
L12A straight union	See tightening steps in procedure.
Low pressure turbocharger oil pressure pipe fitting nuts	See tightening steps in procedure.
High pressure turbocharger oil pressure pipe fitting nuts	See tightening steps in procedure.
Low pressure turbocharger oil return pipe fitting nut	See tightening steps in procedure.
Low pressure turbocharger oil return pipe (to crankcase)	See tightening steps in procedure.

Special Service Tools

Table 11 Turbochargers

Description	Tool Number
Charge Air Cooler Tester Kit	ZTSE4341
High Pressure CAC Test Plate	ZTSE4909
P-80® Rubber Lubricant or equivalent	Obtain locally

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Exploded Views

Power Steering

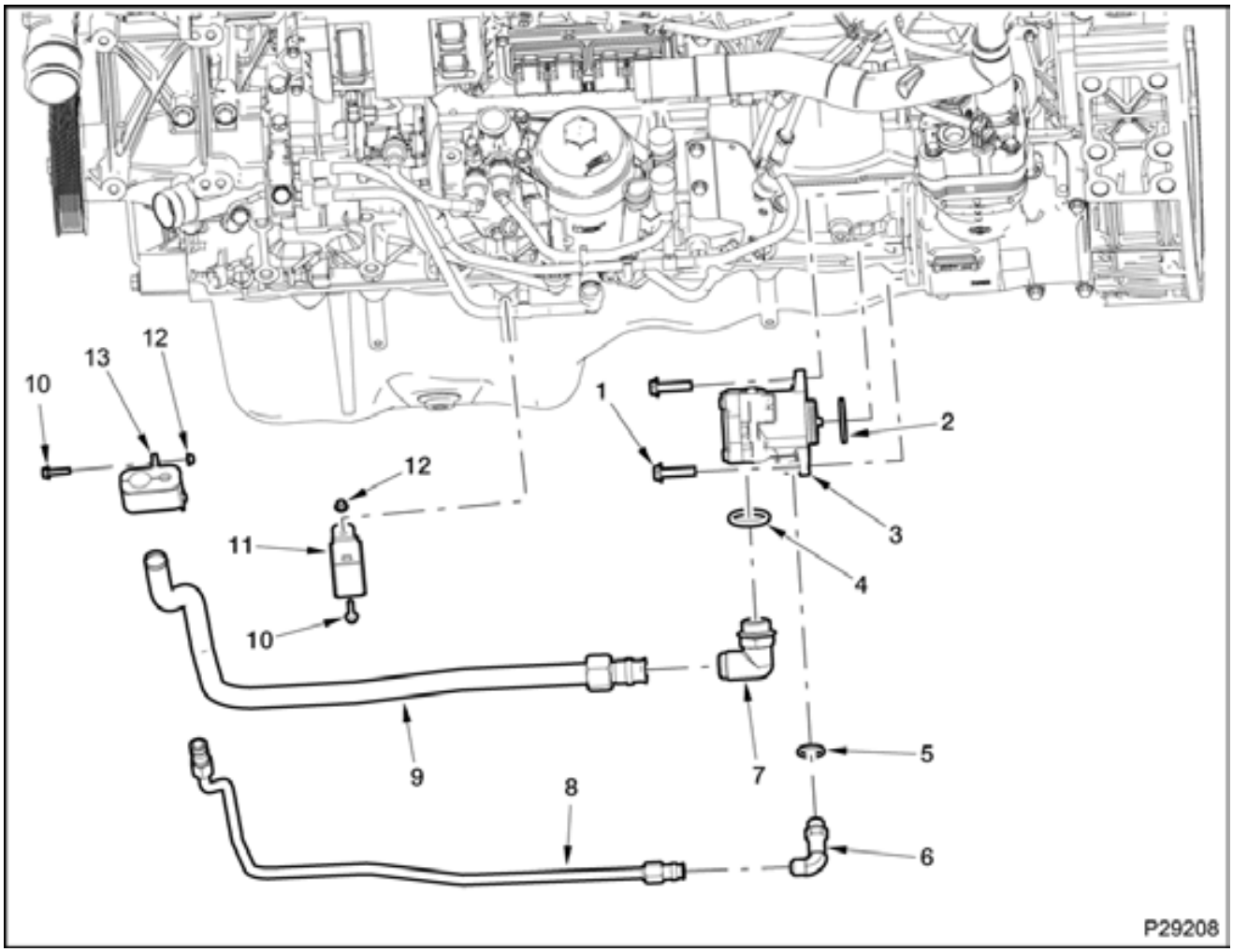

Figure 262 Power steering system (typical)

1. M10 x 40 heavy bolt (2)
2. Power steering pump adapter
3. Power steering pump
4. 0.087 x 0.644 O-ring
5. 1 1/16-12 STD O-ring
6. 1/2” 90 degree tube elbow
7. 1-1/16” 90 degree elbow
8. High pressure tube
9. Low pressure tube
10. M6 x 25 bolt (2)
11. T-bracket
12. M6 nut (2)
13. Support bracket

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Air Compressor

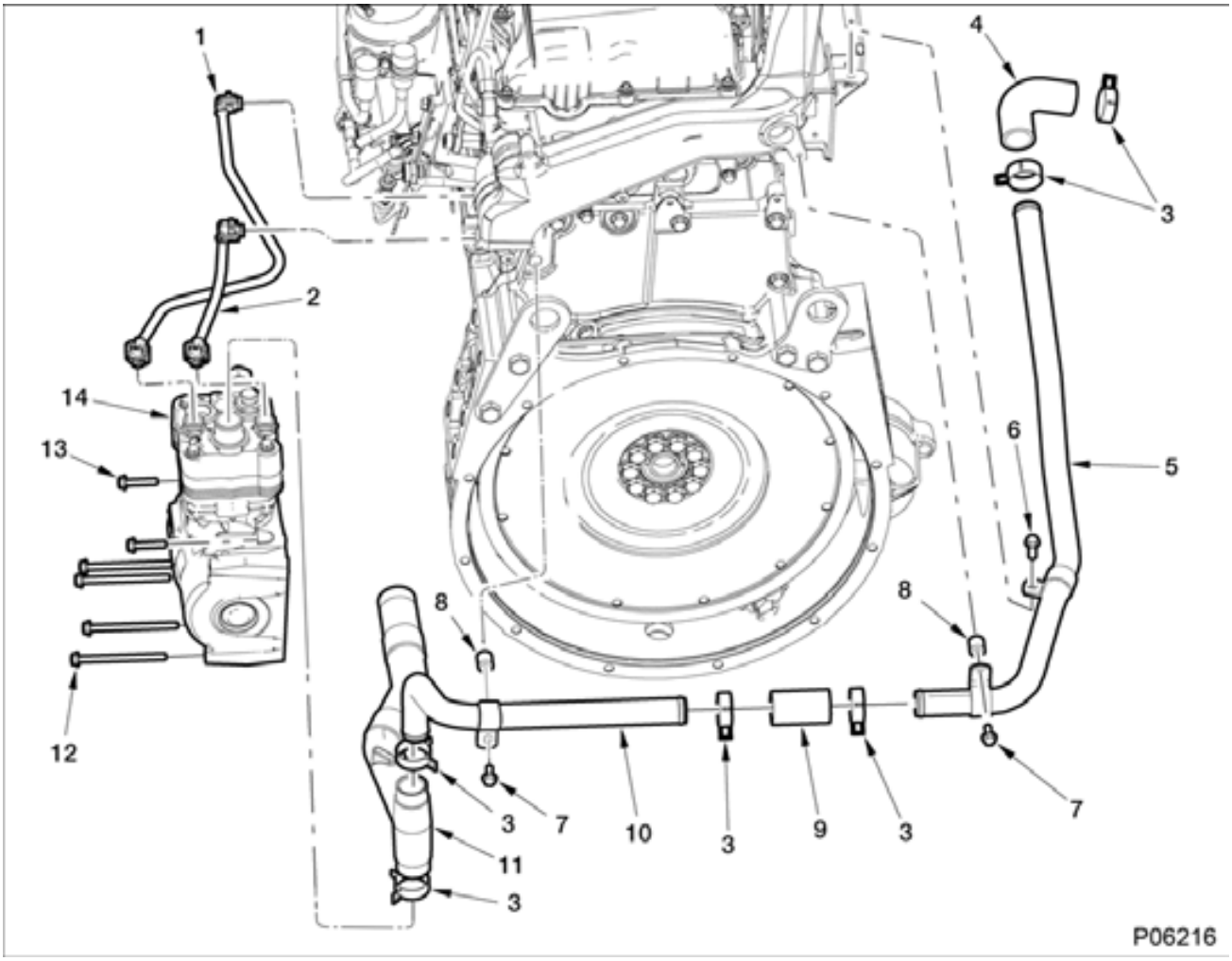

Figure 263 Air compressor system (typical)

1. Air compressor coolant pipe (supply)
2. Air compressor coolant pipe (return)
3. 44/15 spring clip (6)
4. DMR32 shaped hose
5. Air compressor suction pipe
6. M8 x 25 hex bolt
7. M8 x 65 hex bolt (2)
8. Bushing (2)
9. Hose
10. Air compressor suction pipe
11. Air compressor shaped hose
12. M8 x 110 hex bolt (4)
13. M8 x 40 hex bolt (2)
14. Air compressor

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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, make sure 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.

Power Steering Pressure Tubes

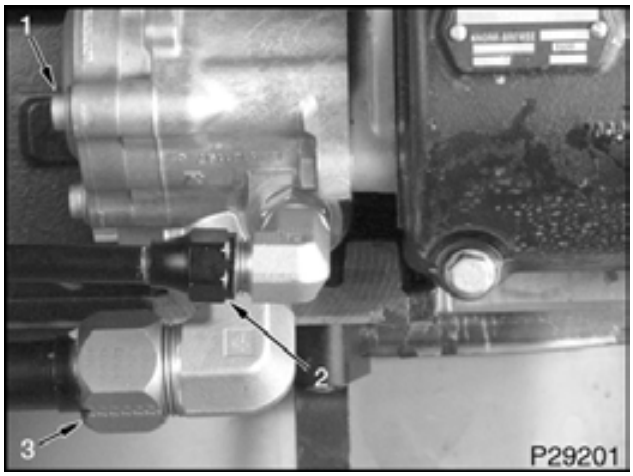

Figure 264 Pressure tubes

1. Power steering pump
2. High pressure tube fitting nut
3. Low pressure tube fitting nut

1. Loosen high pressure tube fitting nut and disconnect tube from 1/2" 90 degree tube elbow.
2. Loosen low pressure tube fitting nut and disconnect tube from 1-1/16" 90 degree elbow.

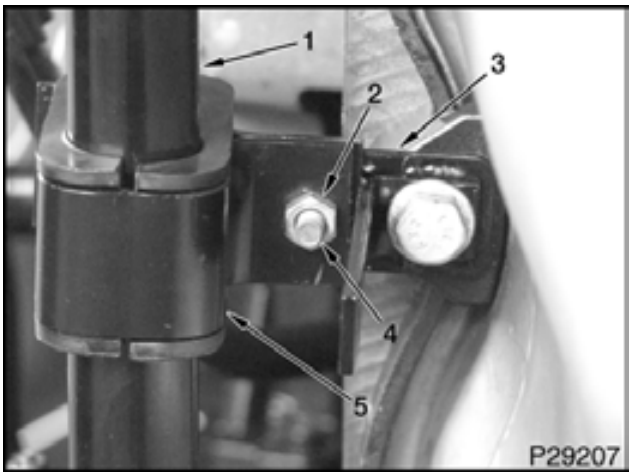

Figure 265 Pressure tubes support bracket

1. High and low pressure tube assembly
2. M6 nut
3. T-bracket
4. M6 x 25 hex bolt
5. Support bracket

3. Remove rear support bracket M6 nut and M6 x 25 hex bolt from T-bracket at the oil pan.
4. If equipped, remove front support bracket M6 nut and M6 x 25 hex bolt from T-bracket on front engine support.
5. Remove high and low pressure tube as an assembly.

NOTE: If replacing high or low pressure tubes, do steps 6 and 7.

6. Remove the rear support brackets and rubber isolator from the high and low pressure tubes.
7. Remove M6 nut, M6 x 25 hex bolt, front support brackets and rubber isolator from the high and low pressure tubes.

Power Steering Elbows

NOTE: This procedure should be completed only if replacing power steering pump, or if one or both of the elbows are leaking.

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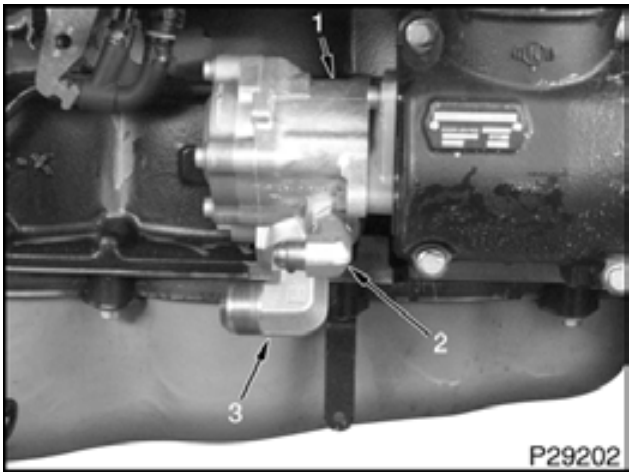

Figure 266 Power steering elbows

1. Power steering pump
2. 1/2” 90 degree tube elbow
3. 1-1/16” 90 degree elbow

1. Loosen the lock nut and rotate the 1/2” 90 degree tube elbow counterclockwise to remove from power steering pump.
2. Loosen the lock nut and rotate the 1-1/16” 90 degree elbow counterclockwise to remove from power steering pump.

Power Steering Pump

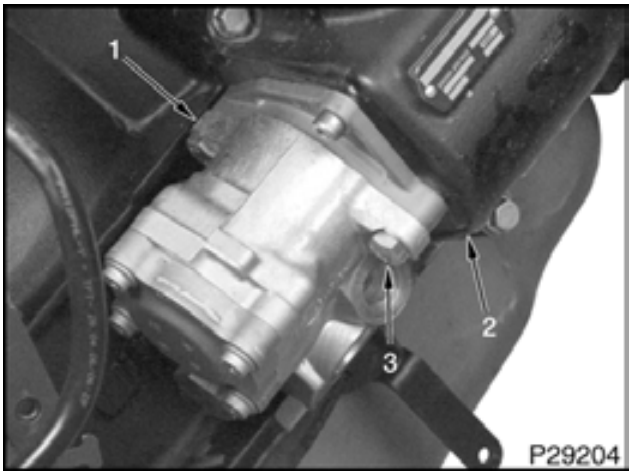

Figure 267 Power steering pump

1. Power steering pump
2. Air compressor
3. M10 x 40 heavy bolt (2)

1. Remove two M10 x 40 heavy bolts and power steering pump.
2. Check O-ring for damage and replace as necessary.

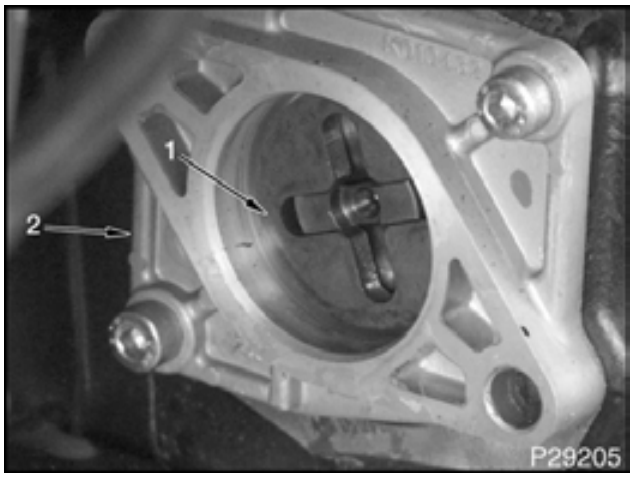

Figure 268 Power steering pump adapter

1. Power steering pump adapter
2. Air compressor

3. Remove power steering pump adapter from air compressor bore.

Air Compressor Suction Pipes

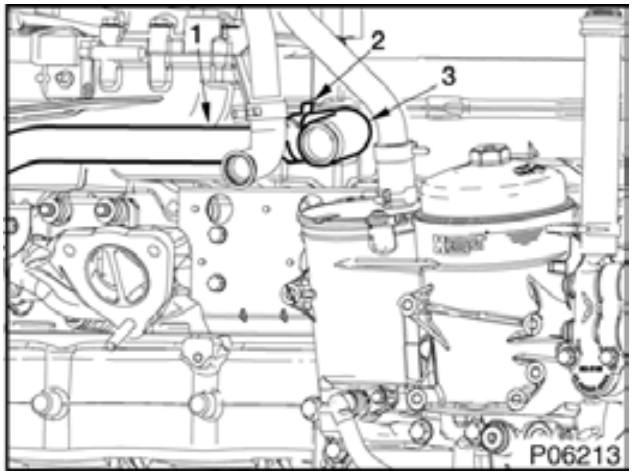

Figure 269 Air compressor suction pipe

1. Air compressor suction pipe
2. 44/15 spring clip
3. DMR32 shaped hose

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1. Loosen 44/15 spring clips and remove DMR32 shaped hose from air compressor suction pipe.

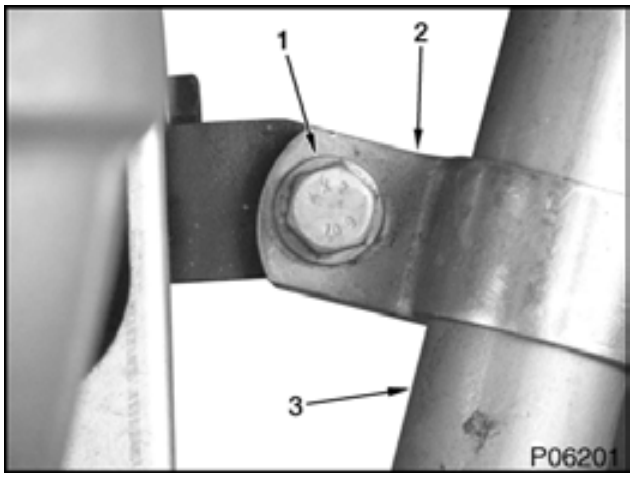

Figure 270 Air compressor suction pipe

1. M8 x 25 hex bolt
2. Bracket
3. Air compressor suction pipe

2. Remove M8 x 25 hex bolt from bracket.

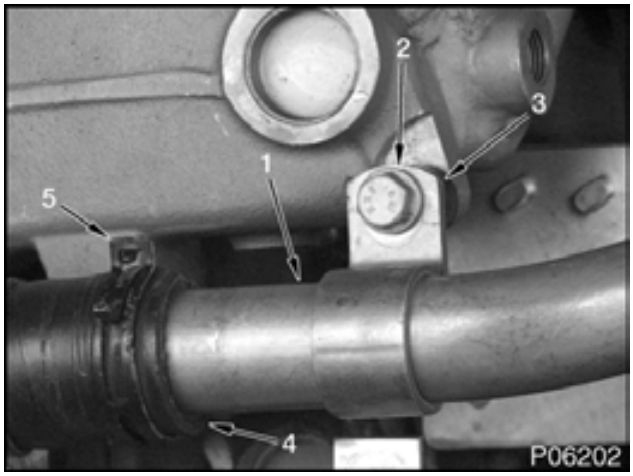

Figure 271 Air compressor suction pipe bolt

1. Air compressor suction pipe
2. M8 x 65 hex bolt
3. Bushing
4. Hose
5. 44/15 spring clip

3. Remove M8 x 65 hex bolt from coolant elbow.

4. Loosen 44/15 spring clip at hose and remove air compressor suction pipe.

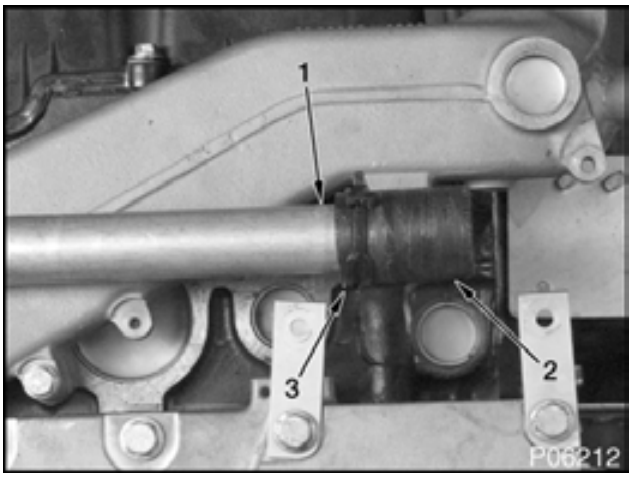

Figure 272 Hose

1. Air compressor suction pipe
2. Hose
3. 44/15 spring clip

5. Loosen 44/15 spring clip and remove hose from air compressor suction pipe.

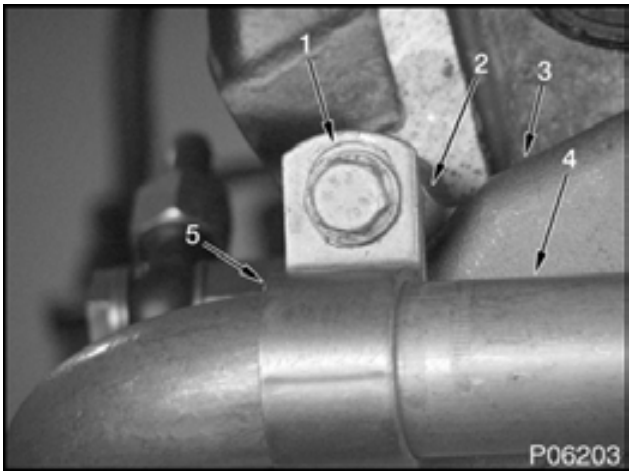

Figure 273 Air compressor suction pipe

1. M8 x 65 hex bolt
2. Bushing
3. Coolant elbow
4. Air compressor suction pipe
5. Bracket

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6. Remove M8 x 65 hex bolt and bushing from cylinder head.

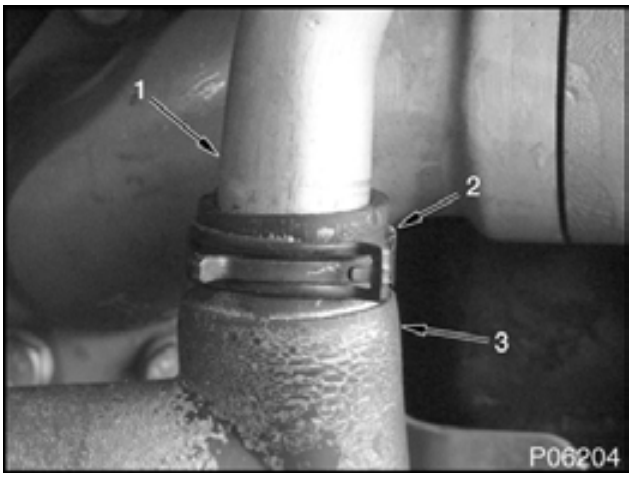

Figure 274 Air compressor suction pipe

1. Air compressor suction pipe
2. 44/15 spring clip
3. Air compressor shaped hose

7. Loosen 44/15 spring clip at air compressor shaped hose and remove air compressor suction pipe.

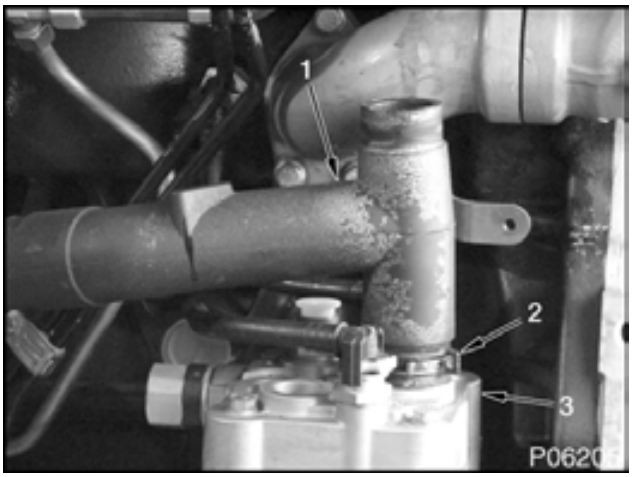

Figure 275 Air compressor shaped hose

1. Air compressor shaped hose
2. 44/15 spring clip
3. Air compressor

8. Loosen 44/15 spring clip and remove air compressor shaped hose from air compressor.

Air Compressor Coolant Pipe (Supply)

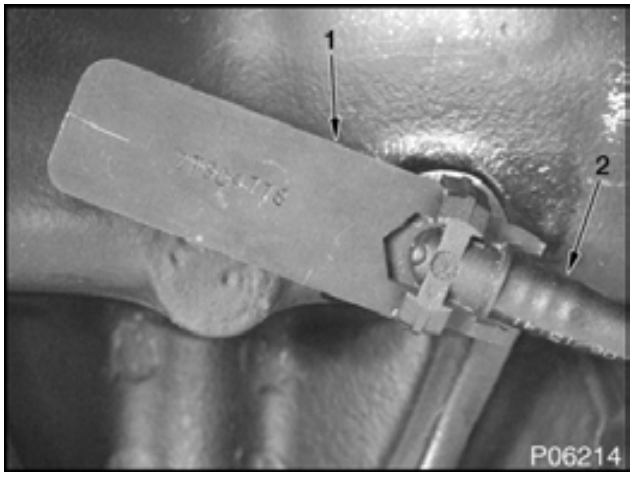

Figure 276 Air compressor coolant pipe (supply)

1. Coolant Line Release Tool
2. Air compressor coolant pipe (supply)

1. Place suitable container under air compressor to collect any residual coolant.
2. Insert Coolant Line Release Tool (page 187), into retaining clips of air compressor coolant pipe (supply) and remove from crankcase.

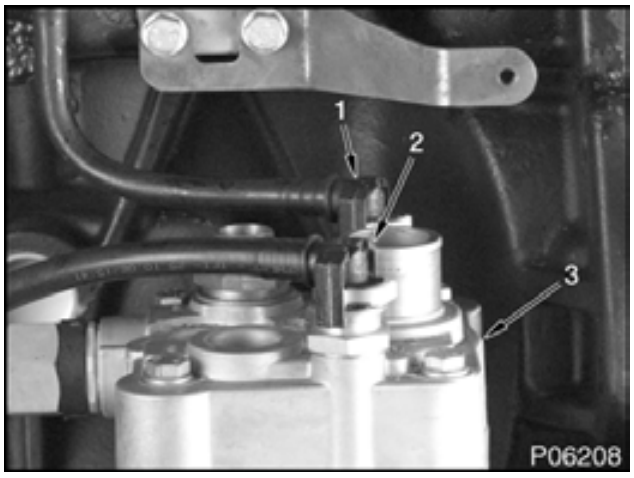

Figure 277 Air compressor coolant pipe (supply)

1. Air compressor coolant pipe (return)
2. Air compressor coolant pipe (supply)
3. Air compressor

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3. Using Coolant Line Release Tool (page 187), release and remove air compressor coolant pipe (supply) from air compressor.

Air Compressor Coolant Pipe (Return)

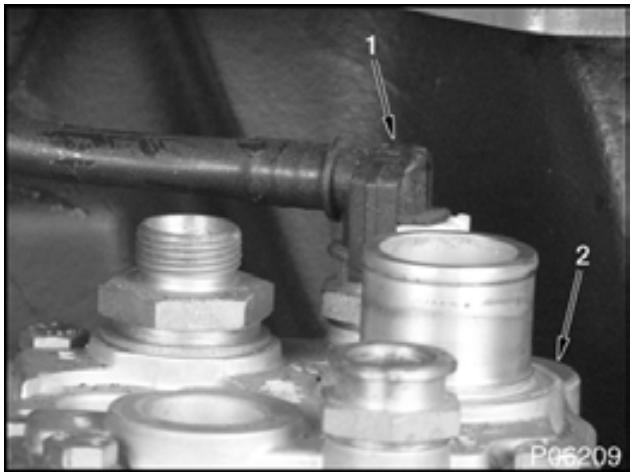

Figure 278 Air compressor coolant pipe (return)

1. Air compressor coolant pipe (return)
2. Air compressor

1. Place suitable container under air compressor to collect any residual coolant.
2. Using Coolant Line Release Tool (page 187), release air compressor coolant pipe (return) from air compressor.

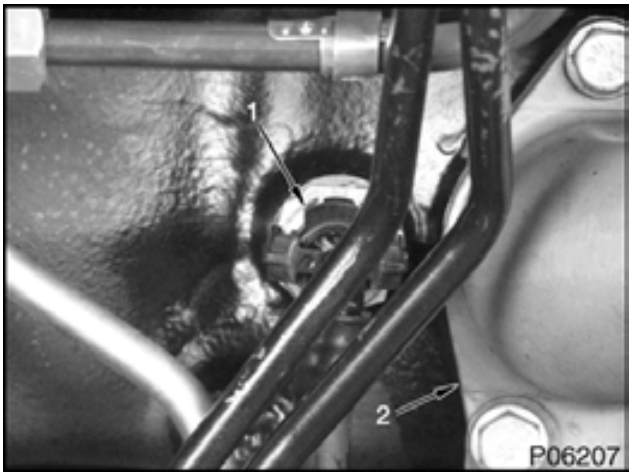

Figure 279 Air compressor coolant pipe (return)

1. Air compressor coolant pipe (return)
2. Coolant elbow

3. Using Coolant Line Release Tool (page 187), release and remove air compressor coolant pipe (return) from crankcase.

Air Compressor

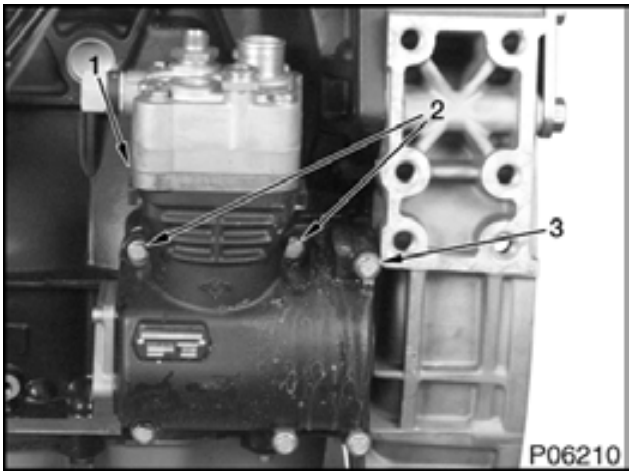

Figure 280 Air compressor (typical)

1. Air compressor
2. M8 x 40 hex bolt (2)
3. M8 x 110 hex bolt (4)

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WARNING: To prevent personal injury or death, get help when removing or installing the air compressor.

1. Remove two M8 x 40 hex bolts and four M8 x 110 hex bolts.
2. Remove air compressor from alignment dowels.

Cleaning

All Components

1. Cover coolant, fluid and air openings to ensure dirt does not enter air compressor and power steering pump.
2. Clean foreign material from gasket surfaces of air compressor. Use a scraper to remove gasket from gasket surfaces.
3. Use only hot water to clean all hoses and tubes.

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Installation

Air Compressor

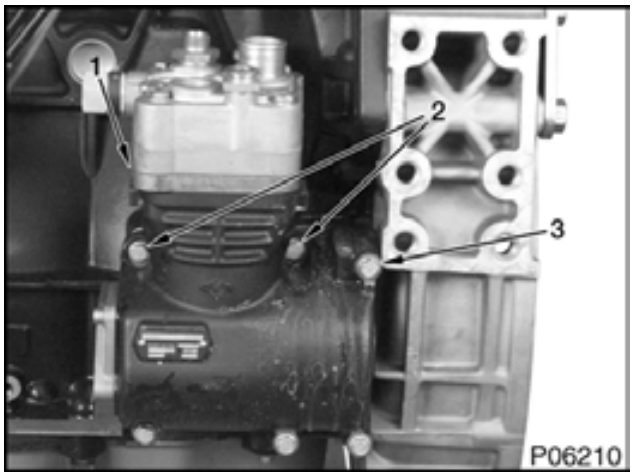

Figure 281 Air compressor (typical)

1. Air compressor
2. M8 x 40 hex bolt (2)
3. M8 x 110 hex bolt (4)

WARNING: To prevent personal injury or death, get help when removing or installing the air compressor.

CAUTION: To prevent engine damage, apply Liquid Gasket and component within 5 minutes of application to inhibit the formation of a skin and ensure a leak proof joint.

1. Apply Loctite® 5900 sealant or equivalent (page 187) to crankcase and air compressor mating surface.
2. Position air compressor and install two M8 x 40 hex bolts and four M8 x 110 hex bolts. Tighten hex bolts to special torque (page 187).

Air Compressor Coolant Pipe (Return)

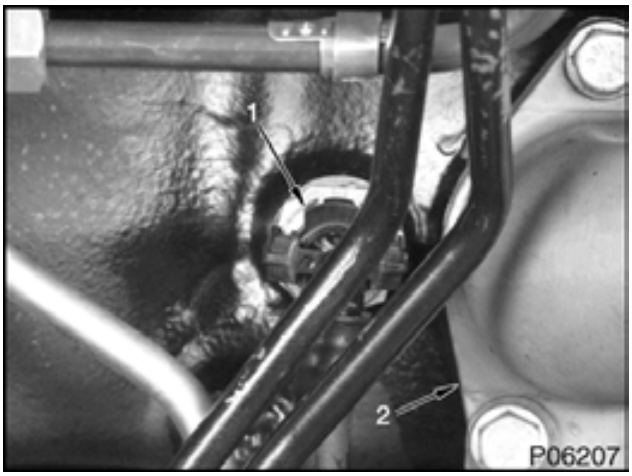

Figure 282 Air compressor coolant pipe (return)

1. Air compressor coolant pipe (return)
2. Coolant elbow

1. Check coolant pipe O-ring before reassembly. Replace O-ring as needed.
2. Position air compressor coolant pipe (return) and press against crankcase until a click is heard.

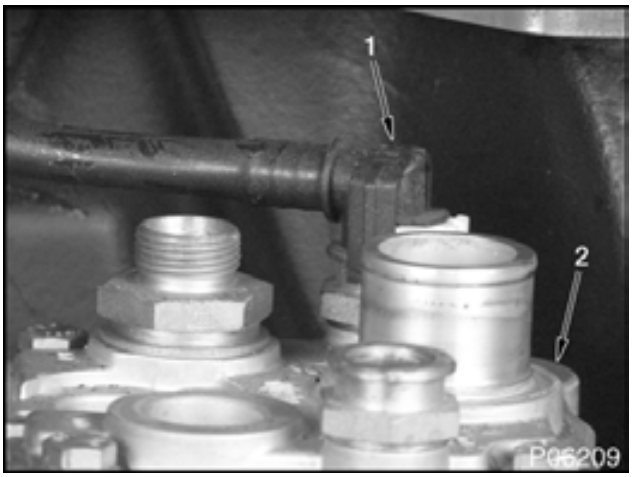

Figure 283 Air compressor coolant pipe (return)

1. Air compressor coolant pipe (return)
2. Air compressor

3. Press on air compressor coolant pipe (return) to air compressor until a click is heard.

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Air Compressor Coolant Pipe (Supply)

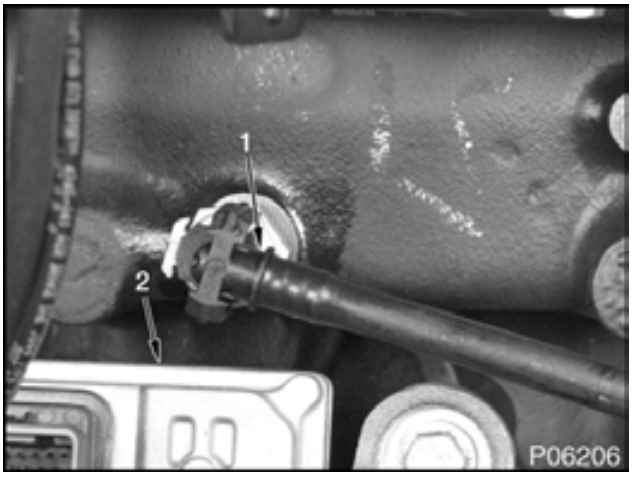

Figure 284 Air compressor coolant pipe (supply)

1. Air compressor coolant pipe (supply)
2. Engine Interface Module (EIM)

1. Check coolant pipe O-ring before reassembly. Replace O-ring as needed.
2. Position air compressor coolant pipe (supply) and press against crankcase until a click is heard.

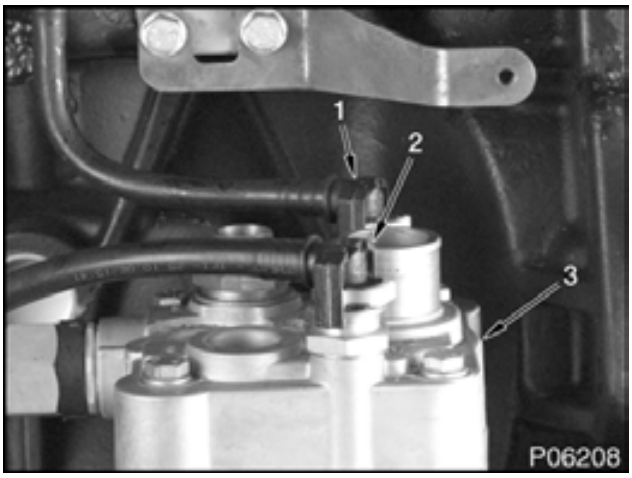

Figure 285 Air compressor coolant pipe (supply)

1. Air compressor coolant pipe (return)
2. Air compressor coolant pipe (supply)
3. Air compressor

3. Press on air compressor coolant pipe (supply) to air compressor until a click is heard.

Air Compressor Suction Pipes

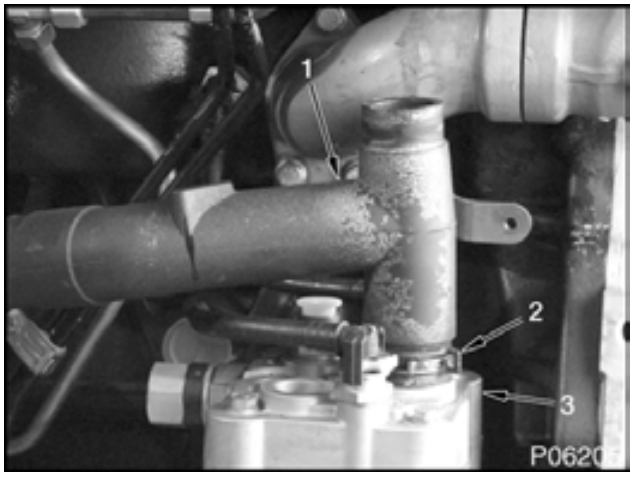

Figure 286 Air compressor shaped hose

1. Air compressor shaped hose
2. 44/15 spring clip
3. Air compressor

1. Install air compressor shaped hose to air compressor and release 44/15 spring clip.

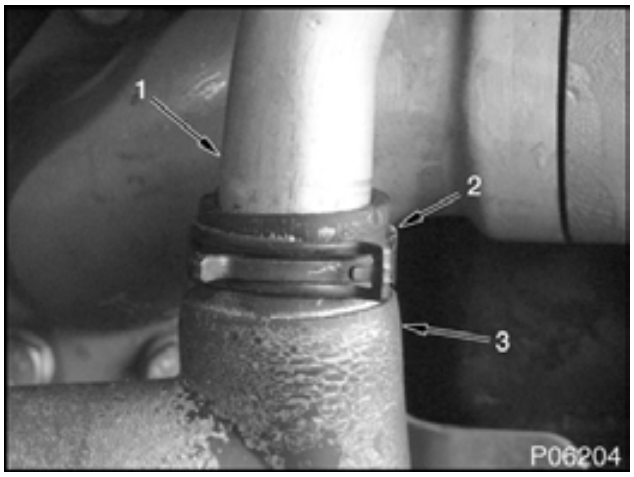

Figure 287 Air compressor suction pipe

1. Air compressor suction pipe
2. 44/15 spring clip
3. Air compressor shaped hose

2. Install air compressor suction pipe and release 44/15 spring clip at air compressor shaped hose.

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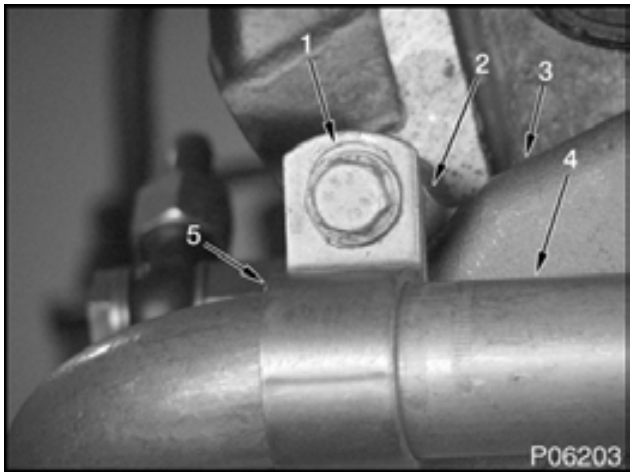

Figure 288 Air compressor suction pipe

1. M8 x 65 hex bolt
2. Bushing
3. Coolant elbow
4. Air compressor suction pipe
5. Bracket

3. Position air compressor suction pipe and install M8 x 65 hex bolt though pipe bracket and bushing to cylinder head. Tighten hex bolt to special torque (page 187).

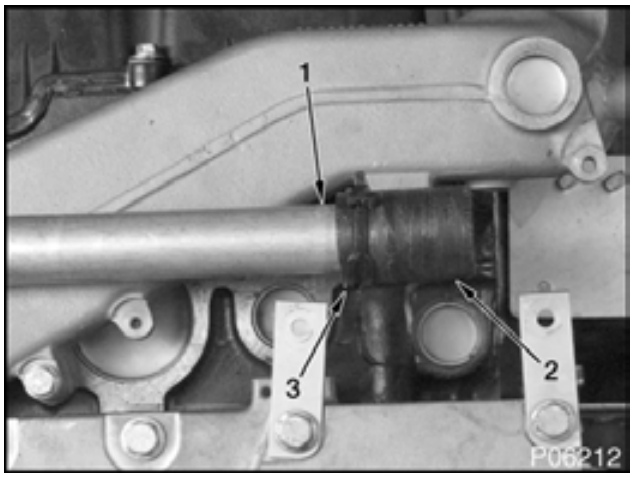

Figure 289 Hose

1. Air compressor suction pipe
2. Hose
3. 44/15 spring clip

4. Install hose to air compressor suction pipe and release 44/15 spring clip.

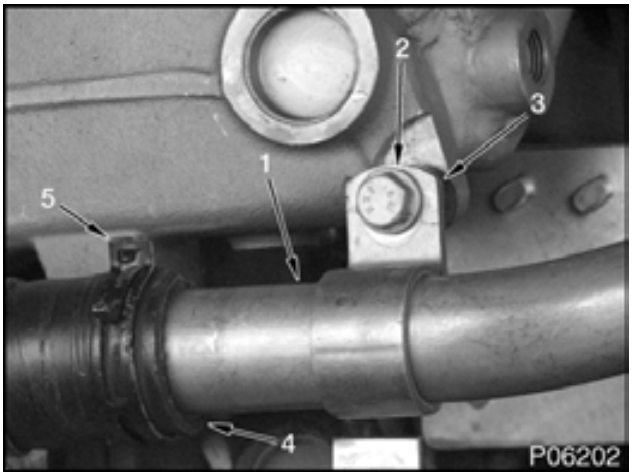

Figure 290 Air compressor suction pipe

1. Air compressor suction pipe
2. M8 x 65 hex bolt
3. Bushing
4. Hose
5. 44/15 spring clip

5. Install air compressor suction pipe to hose and release 44/15 spring clip.

6. Position air compressor suction pipe and install M8 x 65 hex bolt though pipe bracket and bushing to coolant elbow. Tighten hex bolt to special torque (page 187).

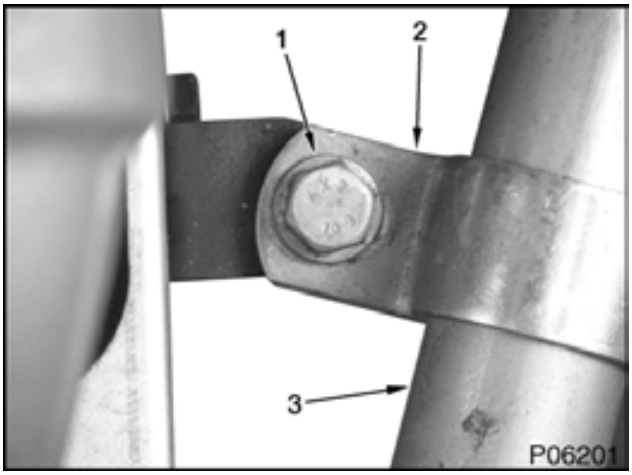

Figure 291 Air compressor suction pipe

1. M8 x 25 hex bolt
2. Bracket
3. Air compressor suction pipe

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7. Install M8 x 25 hex bolt to bracket. Tighten hex bolt to standard torque (page 457).

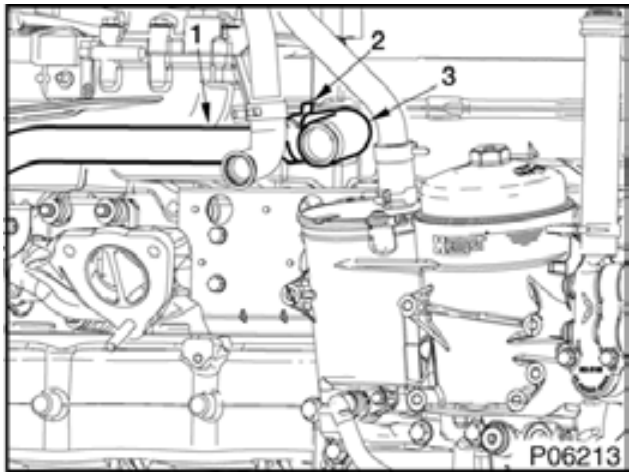

Figure 292 Air compressor suction pipe

1. Air compressor suction pipe
2. 44/15 spring clip
3. DMR32 shaped hose

8. Install DMR32 shaped hose to air compressor suction pipe and release 44/15 spring clip.

Power Steering Pump

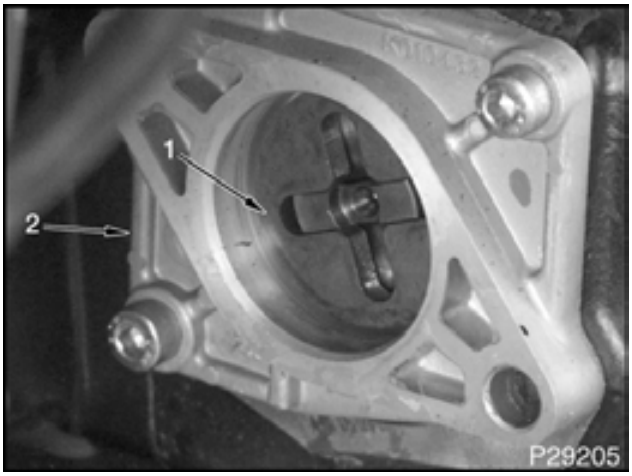

Figure 293 Power steering pump adapter

1. Power steering pump adapter
2. Air compressor

1. Install power steering pump adapter to air compressor bore.

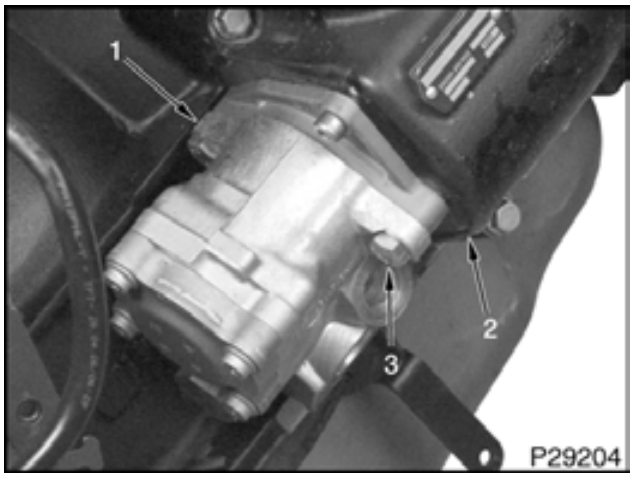

Figure 294 Power steering pump (typical)

1. Power steering pump
2. Air compressor
3. M10 x 40 heavy bolt (2)

2. If O-ring was removed or is damaged, install a new O-ring.
3. Install power steering pump and two M10 x 40 heavy bolts. Tighten bolts to special torque (page 187).

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Power Steering Elbow

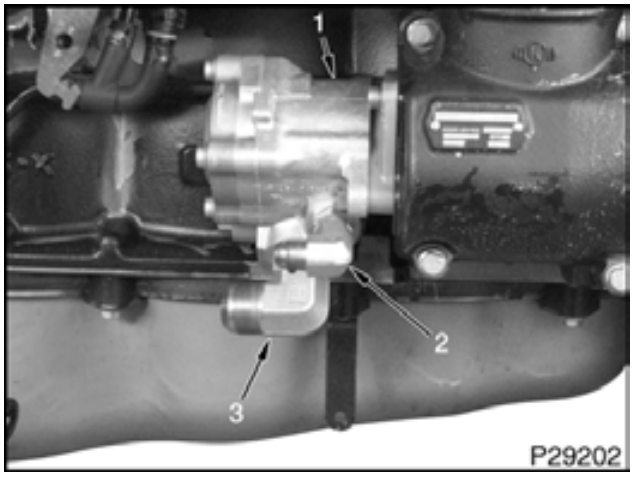

Figure 295 Power steering elbow

1. Power steering pump
2. 1/2” 90 degree tube elbow
3. 1-1/16” 90 degree elbow

NOTE: This procedure should be completed only if replacing power steering pump, or if one or both of the elbows were removed.

1. Check seals on elbow for damage. Replace as necessary.
2. Install 1/2” 90 degree tube elbow to power steering pump. Lock nuts should not be tightened until power steering lines are installed for proper orientation.
3. Install 1-1/16” 90 degree elbow to power steering pump. Lock nuts should not be tightened until power steering lines are installed for proper orientation.

Power Steering Pressure Tubes

NOTE: If high or low pressure tubes were replaced, do steps 1 and 2.

1. Install front support brackets, isolator, M6 x25 hex bolt and M6 nut onto the high and low pressure tubes.
2. Install the rear support brackets and rubber isolator onto the high and low pressure tubes.

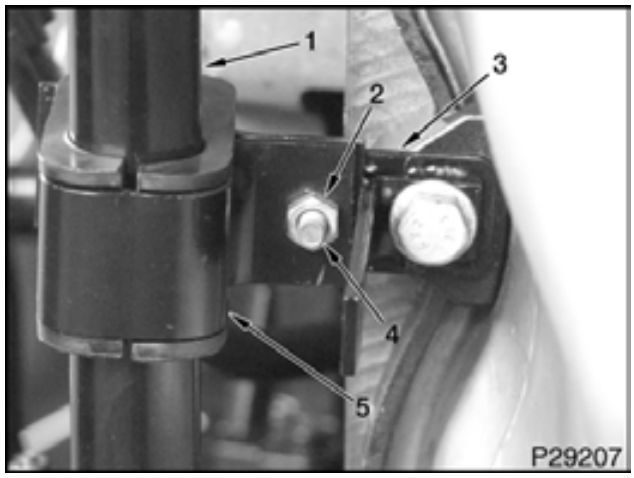

Figure 296 Pressure tubes support bracket

1. High and low pressure tube assembly
2. M6 nut
3. T-bracket
4. M6 x 25 hex bolt
5. Support bracket

3. Position high and low pressure tube as an assembly. Install M6 x 25 hex bolt and M6 nut onto rear support brackets and t-bracket at the oil pan. Tighten nut to standard torque (page 457).
4. If equipped, install front support bracket to T-bracket on front engine support and secure with M6 nut. Tighten nut to standard torque (page 457).

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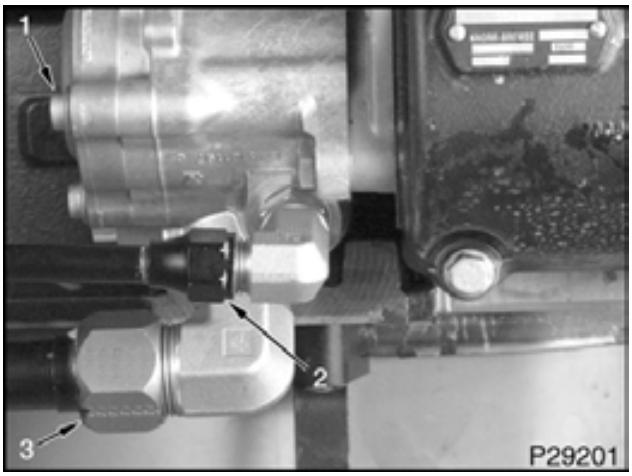

Figure 297 Pressure tube(s)

1. Power steering pump
2. High pressure tube
3. Low pressure tube

5. Install high and low pressure tubes to elbows. Tighten pressure tube fitting nuts to special torque (page 187).

NOTE: Proceed with steps 5 and 6 only if fitting was removed or if power steering pump was replaced.

6. Using a appropriate size wrench to hold the elbow. Tighten 1/2" 90 degree tube elbow lock nut to special torque (page 187).
7. Using a appropriate size wrench to hold the elbow. Tighten 1-1/16" 90 degree elbow lock nut to special torque (page 187).

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Special Torque

Table 12 Air Compressor and Power Steering/Fuel Pump

1-1/16" 90 degree elbow lock nut	55 N·m (40 lbf·ft)
1/2" 90 degree tube elbow lock nut	45 N·m (33 lbf·ft)
Air compressor hex bolts	35 N·m (26 lbf·ft)
Air compressor suction pipe M8 x 65 hex bolts	35 N·m (26 lbf·ft)
High pressure tube fitting nut	62 N·m (45 lbf·ft)
Low pressure tube fitting nut	164 N·m (120 lbf·ft)
Power steering pump heavy bolts	67 N·m (49 lbf·ft)

Special Service Tools

Table 13 Air Compressor

Description	Tool Number
Coolant Line Release Tool	ZTSE4778
Loctite® 5900 Sealant or equivalent	Obtain locally

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Exploded Views

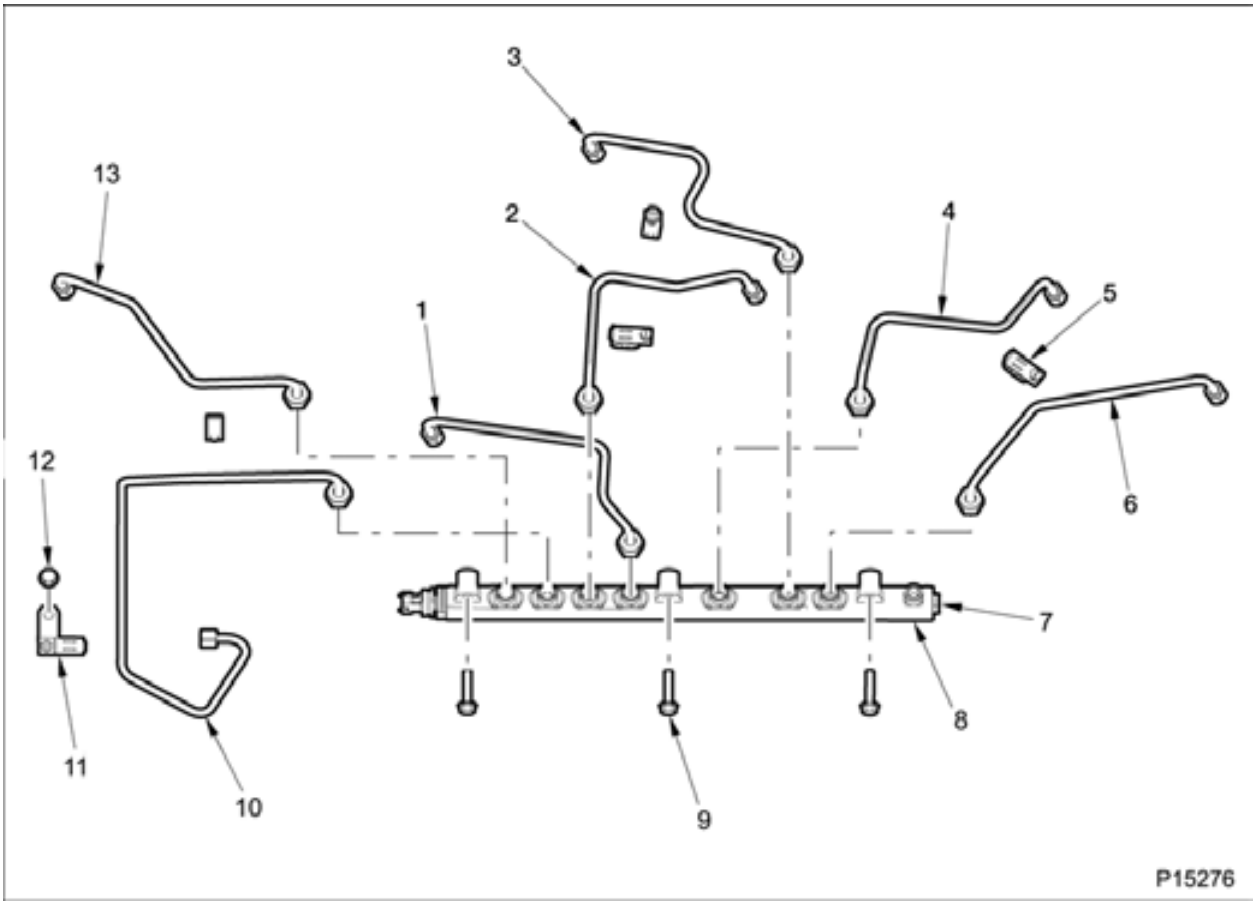

Figure 298 High-pressure fuel piping

1. Cylinder 2 injection line
2. Cylinder 4 injection line
3. Cylinder 3 injection line
4. Cylinder 5 injection line
5. Clamp (4)
6. Cylinder 6 injection line
7. Rail pressure relief valve
8. Pressure pipe rail
9. M8 x 35 hex bolt (3)
10. Pressure line
11. Pressure line clamp
12. Pressure line clamp bolt
13. Cylinder 1 injection line

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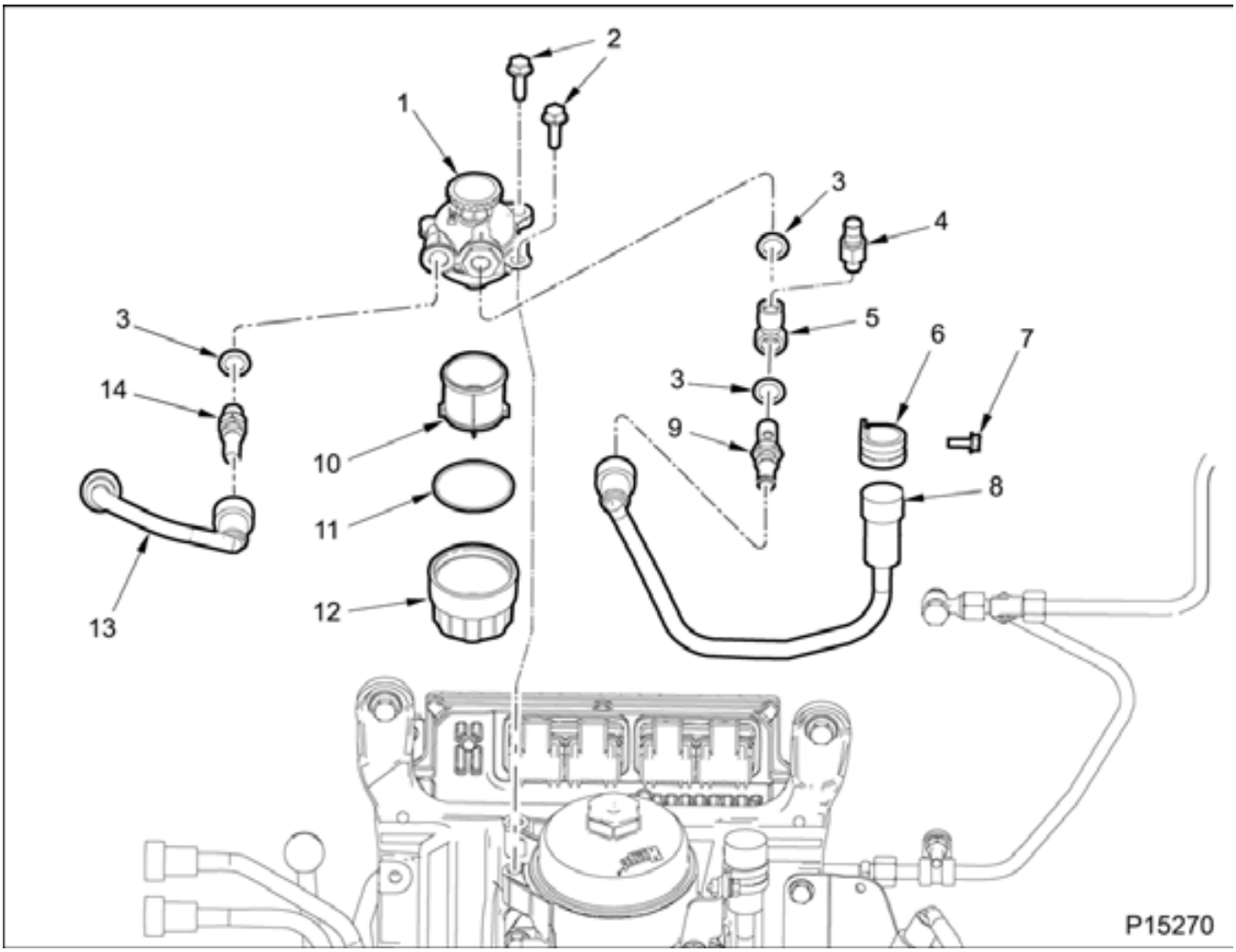

Figure 299 Fuel primer pump assembly

1. Fuel primer pump assembly
2. M6 x 25 hex bolt (2)
3. 14.7 x 22 seal (3)
4. Quick disconnect valve
5. Banjo fitting
6. P-clamp (2)t
7. M6 x 16 hex bolt
8. Pre-filter supply fuel line
9. M14 x 1.5 threaded union (long)
10. Fuel strainer element
11. O-ring seal
12. Fuel strainer cover
13. Preliminary filter feed fuel line
14. M14 x 1.5 threaded union

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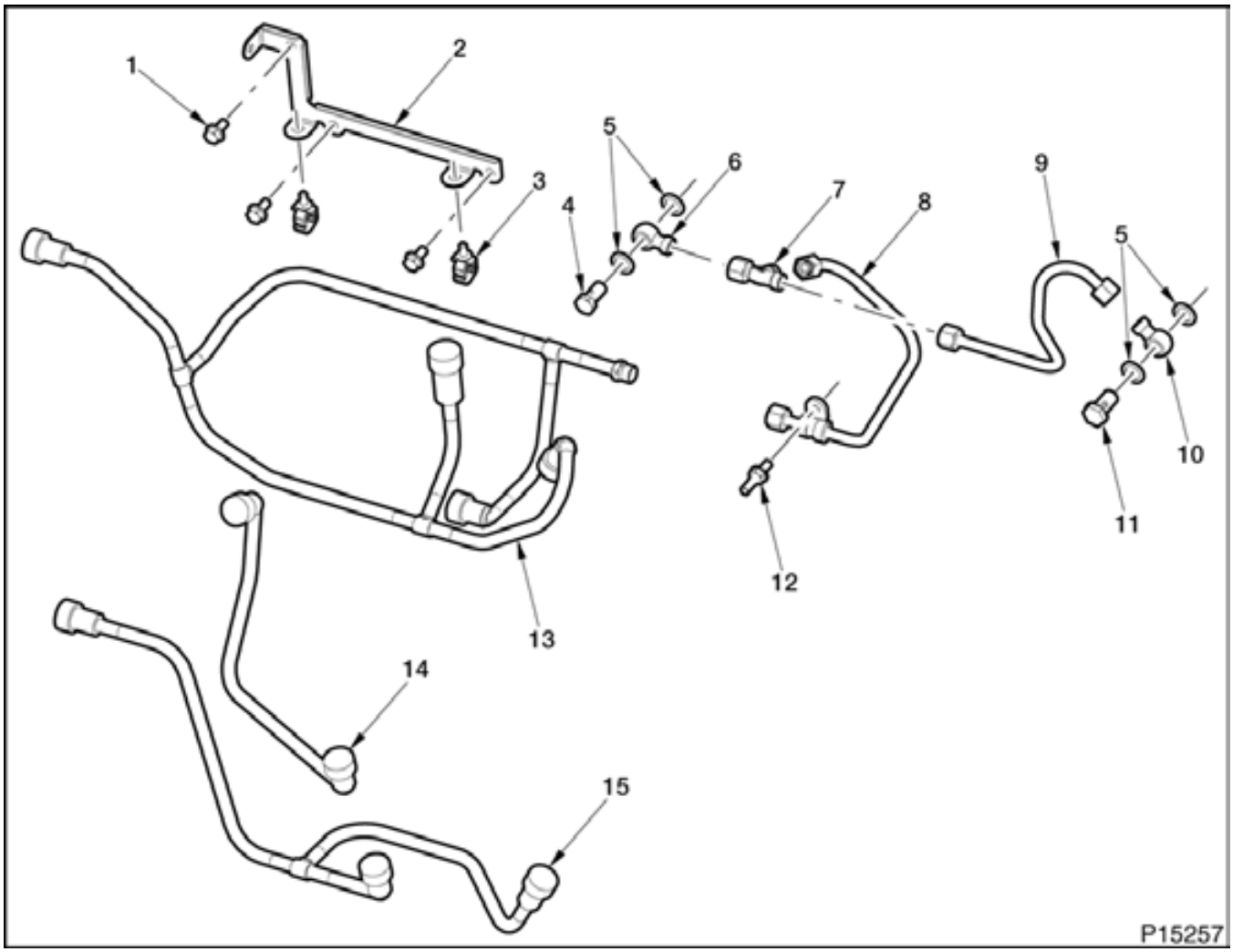

Figure 300 Fuel supply and return lines

1. M8 x 16 hex bolt (3)
2. Fuel line bracket
3. Fuel line clip (2)
4. Size 8 hollow screw
5. 14.7 x 22 seal (4)
6. Ring union
7. L10-A4C adapter
8. Fuel drip line (pressure pipe rail)
9. Fuel drip line (injector)
10. Ring union
11. Hollow screw
12. M8 x 16 stud bolt
13. Fuel return line
14. Filter-feedpump fuel line
15. Filter T-connector fuel line

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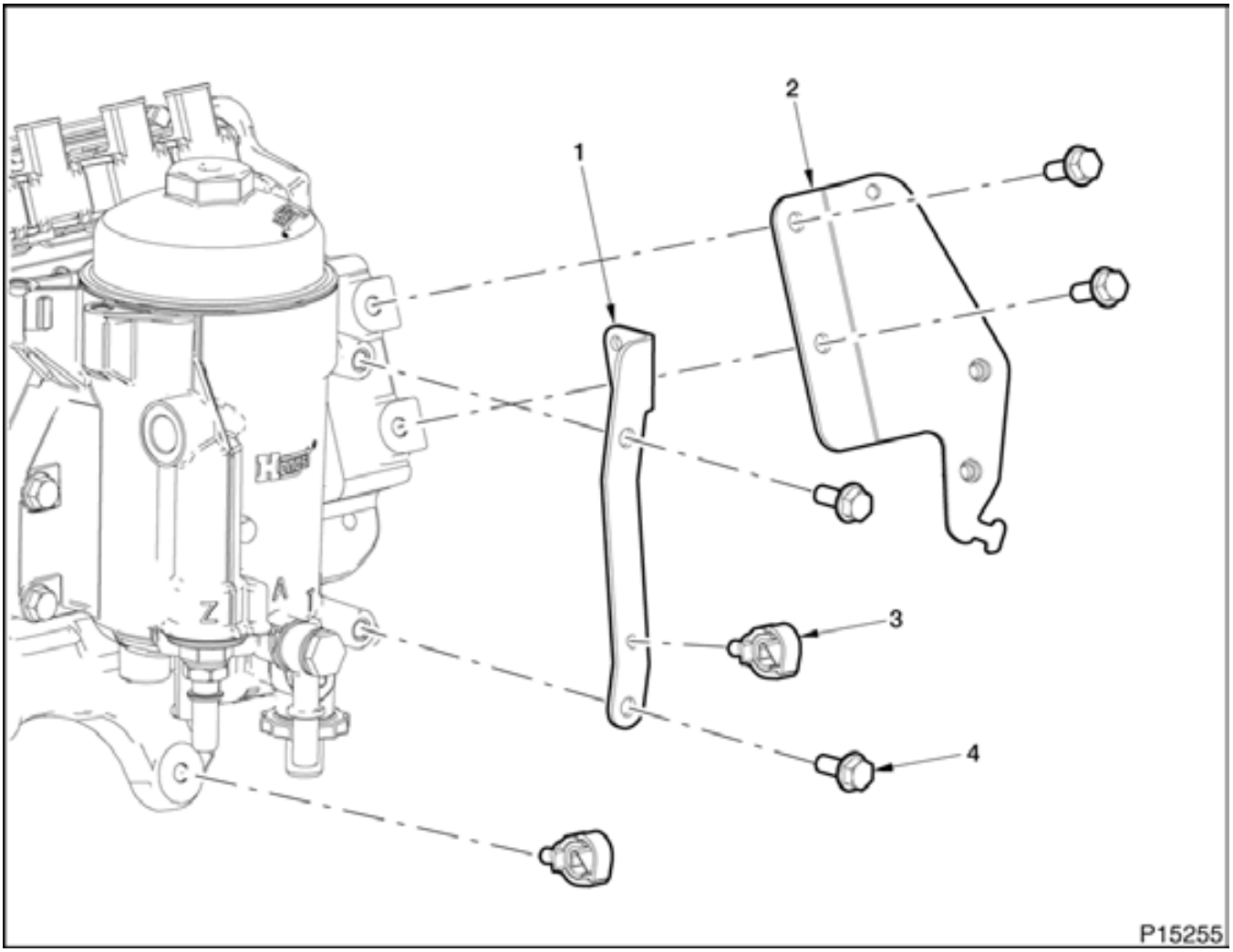

Figure 301 Check valve bracket and Hydrocarbon (HC) cut-off valve bracket

1. Check valve bracket
2. HC cut-off valve bracket
3. Fuel line clip (2)
4. M8 x 20 hex bolt (4)

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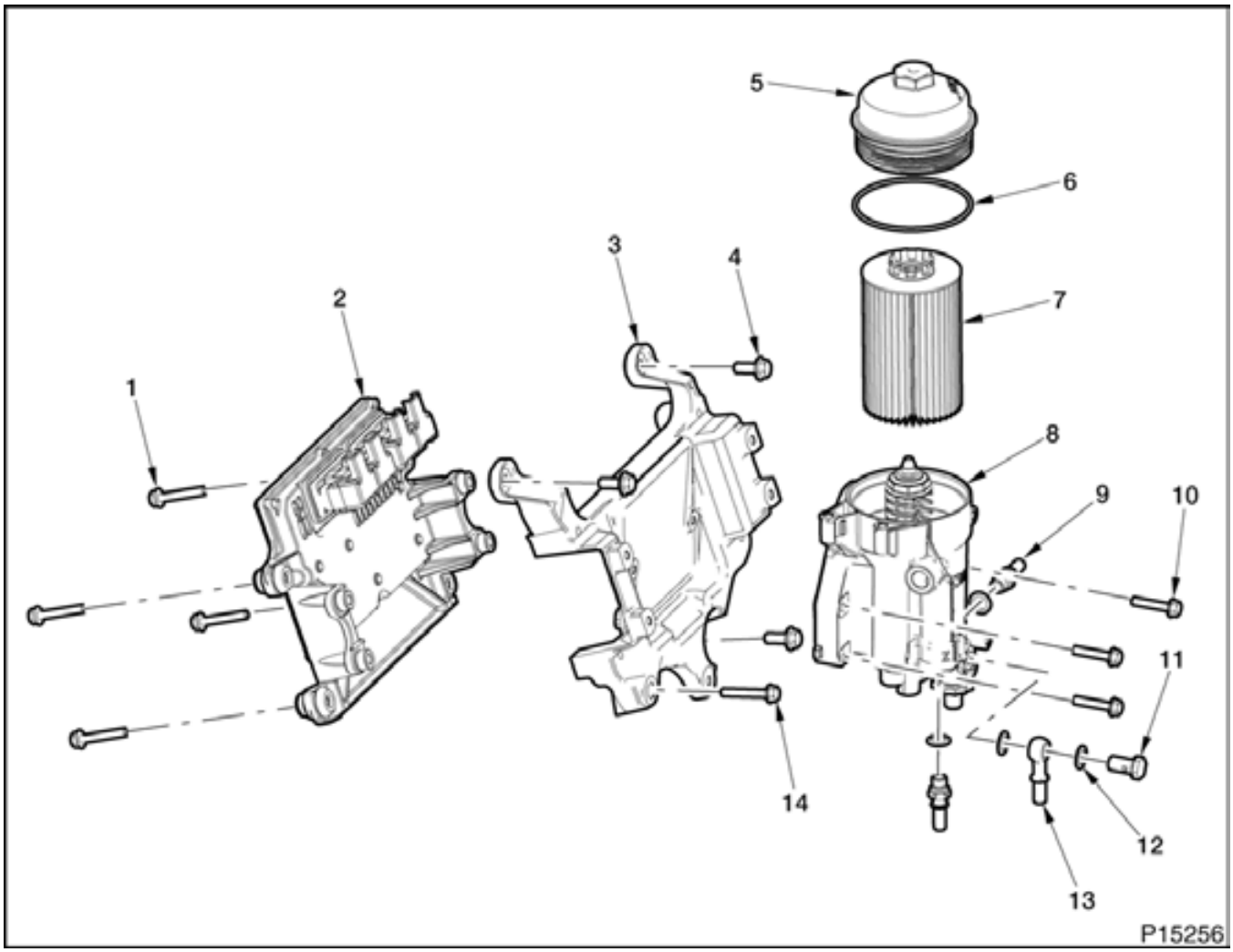

Figure 302 Fuel filter housing assembly and Engine Interface Module (EIM)

1. M8 x 50 hex bolt (4)
2. EIM
3. Fuel filter bracket
4. M10 x 25 hex bolt (3)
5. Screw cap
6. Screw cap O-ring
7. Filter element
8. Fuel filter housing assembly
9. M14 x 1.5 threaded union (2)
10. M8 x 40 hex bolt (3)
11. Hollow screw
12. 14.7 x 22 seal (4)
13. Ring union
14. M10 x 50 hex bolt

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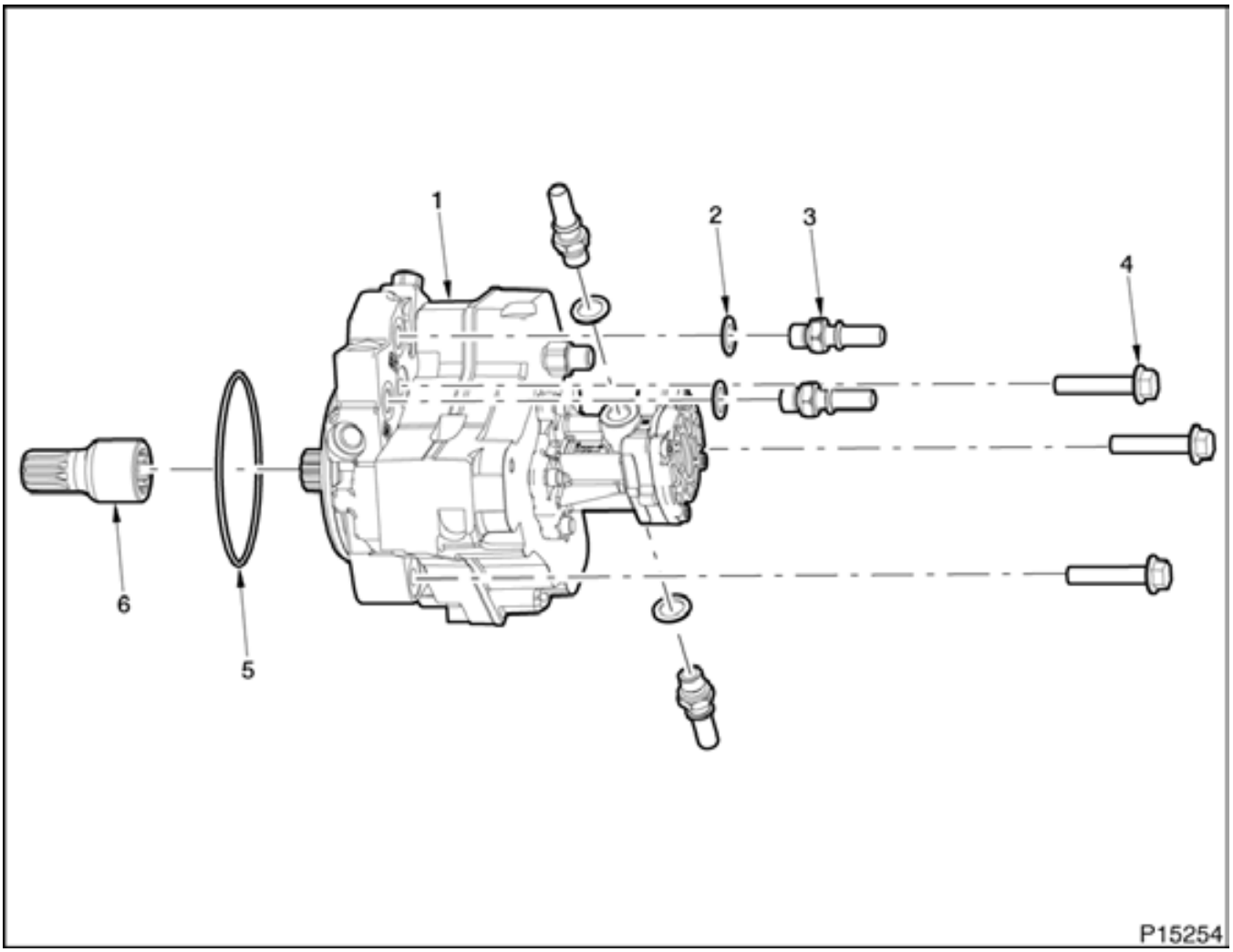

Figure 303 High pressure pump

1. High pressure pump
2. 14.7 x 22 seal (4)
3. M14 x 1.5 threaded union (4)
4. M10 x 50 hex bolt (3)
5. O-ring
6. Driving sleeve

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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 the transmission to park or neutral, set the parking brake, and block the wheels before doing diagnostic or service procedures.

WARNING: To prevent personal injury or death, engine must be stationary for at least 5 minutes before doing any work on high pressure fuel system to allow for system depressurization.

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

WARNING: To prevent personal injury or death, remove the ground cable from the negative terminal of the main battery before disconnecting or connecting electrical components. Always connect the ground cable last.

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

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, do not turn ignition key to ON during disassembly. This would pump fuel from the high pressure pump through disconnected tubing, causing a fuel spill and possible fire.

NOTE: Refer to the following service sections for information on removal of components prior to this section.

- Engine Electrical
- Cold Start Assist
- Aftertreatment System
- Turbochargers

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High Pressure Fuel Lines

WARNING: To prevent personal injury or death, engine must be stationary for at least 5 minutes before doing any work on high pressure fuel system to allow for system depressurization.

CAUTION: To prevent damage to engine, plug component connections immediately after each fuel line is removed using clean fuel system caps.

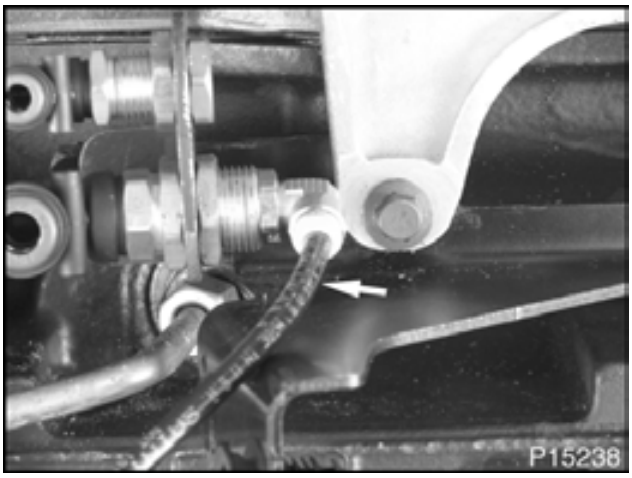

Figure 304 Air supply line

1. Disconnect air supply line from Parker® 90° elbow fitting by pushing in release ring and pulling line straight out.

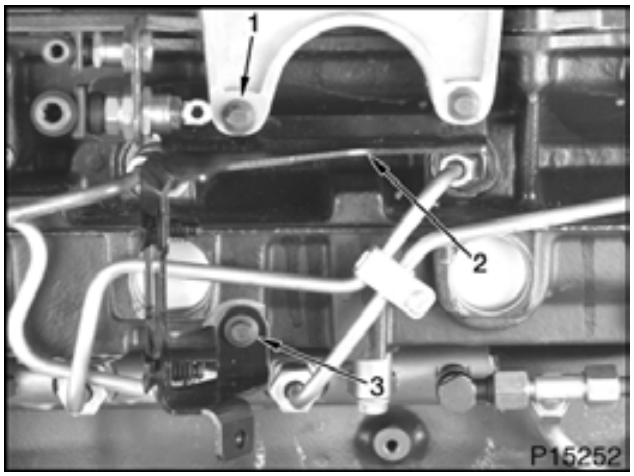

Figure 305 Wire loom bracket

1. M8 x 30 hex bolt (2)
2. Wire loom bracket
3. M8 x 16 hex bolt

2. Remove two M8 x 30 hex bolts, M8 x 16 hex bolt, and wire loom bracket.

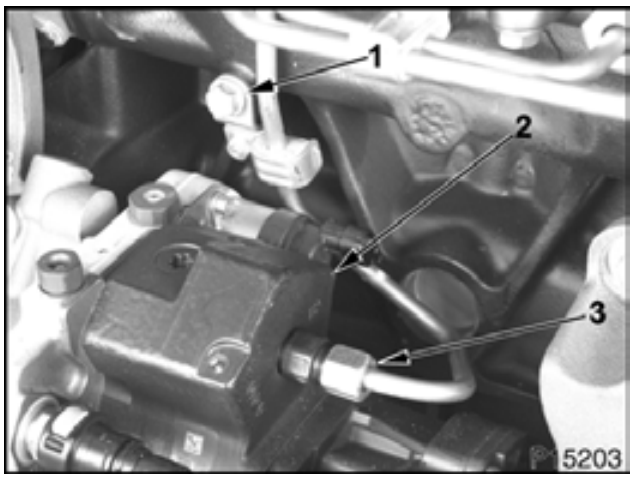

Figure 306 Pressure line

1. Pressure line clamp bolt
2. High pressure pump
3. Pressure line

3. Remove pressure line clamp bolt from crankcase.
4. Remove pressure line clamp from pressure line.

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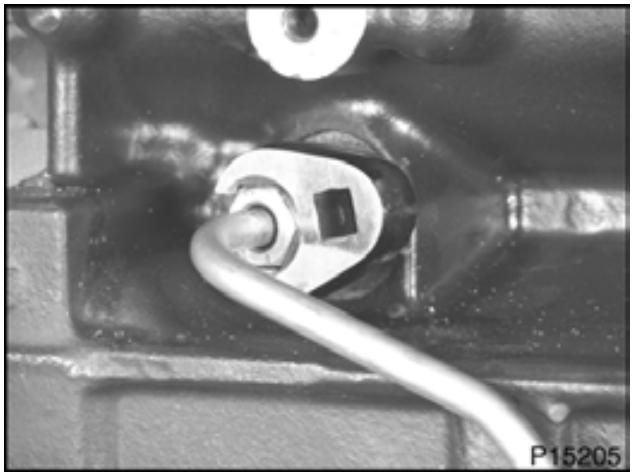

Figure 307 Crowfoot wrench (typical)

5. Obtain a crowfoot wrench (page 220) for removal of all high pressure fuel lines.
6. Loosen pressure line fitting nut and disconnect pressure line from high pressure pump.

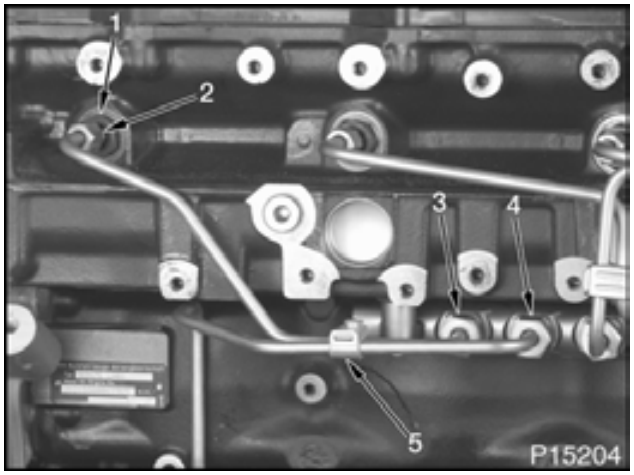

Figure 308 Pressure line and cylinder 1 injection line

1. Pressure pipe neck
2. Cylinder 1 injection line fitting nut at pressure pipe neck
3. Cylinder 1 injection line fitting nut at pressure pipe rail
4. Pressure line fitting nut at pressure pipe rail
5. Clamp

7. Remove clamp from cylinder 1 injection line and pressure line.
8. Loosen cylinder 1 injection line fitting nut and disconnect line at pressure pipe neck.
9. Loosen cylinder 1 injection line fitting nut and disconnect line at pressure pipe rail.
10. Loosen pressure line fitting nut and disconnect line at pressure pipe rail.

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

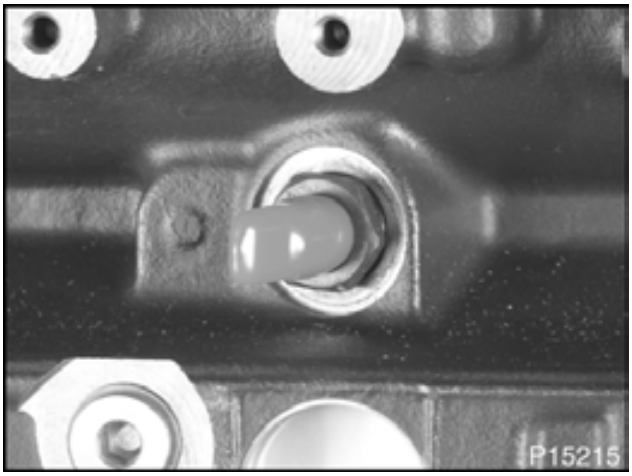

Figure 309 Fuel cap at pressure pipe neck (typical)

11. Remove and discard pressure line and cylinder 1 injection line. Immediately cap open pressure pipe neck, pressure pipe rail and high pressure pump connections with clean Disposable Air and Fuel Caps (page 220).

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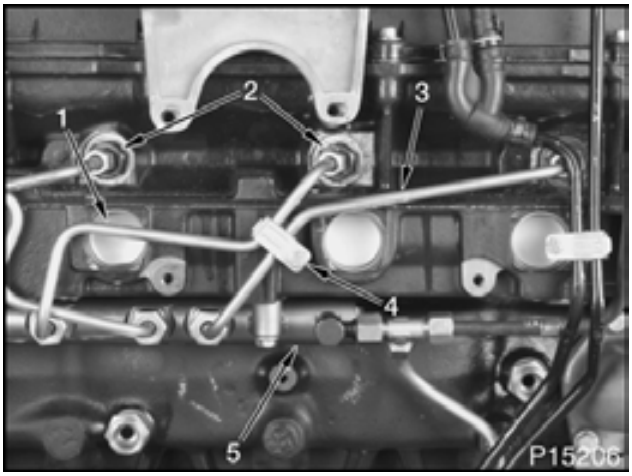

Figure 310 Cylinders 5 and 6 injection lines

1. Cylinder 5 injection line
2. Pressure pipe necks
3. Cylinder 6 injection line
4. Clamp
5. Pressure pipe rail

12. Remove clamp from cylinders 5 and 6 injection lines.
13. Loosen cylinders 5 and 6 injection line fitting nuts and disconnect lines at pressure pipe necks.
14. Loosen cylinders 5 and 6 injection line fitting nuts and disconnect lines at pressure pipe rail.

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

15. Remove and discard cylinders 5 and 6 injection lines. Immediately cap open pressure pipe neck and pressure pipe rail connections with clean Disposable Air and Fuel Caps (page 220).

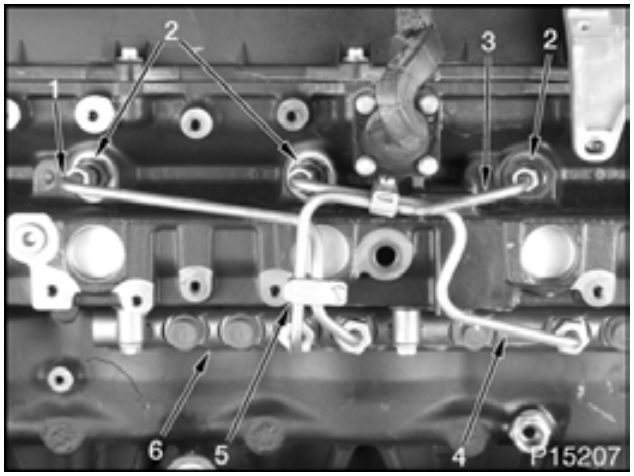

Figure 311 Cylinders 2, 3 and 4 injection lines

1. Cylinder 2 injection line
2. Pressure pipe necks
3. Cylinder 4 injection line
4. Cylinder 3 injection line
5. Clamp (2)
6. Pressure pipe rail

16. Remove two clamps from cylinders 2, 3, and 4 injection lines.
17. Loosen cylinders 2, 3, and 4 injection line fitting nuts and disconnect lines at pressure pipe necks.
18. Loosen cylinders 2, 3, and 4 injection line fitting nuts and disconnect lines at pressure pipe rail.

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

19. Remove and discard cylinders 2 , 3 , and 4 injection lines. Immediately cap open pressure pipe neck and pressure pipe rail connections with clean Disposable Air and Fuel Caps (page 220).

Fuel Drip Lines

NOTE: It is not necessary to disassemble the fuel drip lines unless individual components are leaking or damaged.

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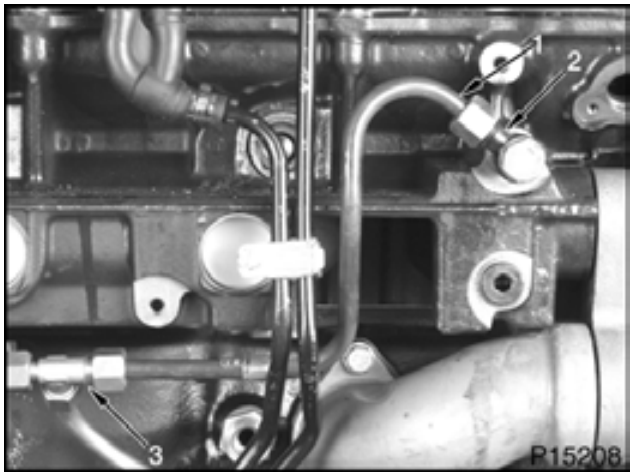

Figure 312 Fuel drip line (injector)

1. Fuel drip line (injector)
2. Ring union
3. L10-A4C adapter

1. Loosen fuel drip line (injector) fitting nuts. Disconnect and remove line from ring union and L10-A4C adapter.

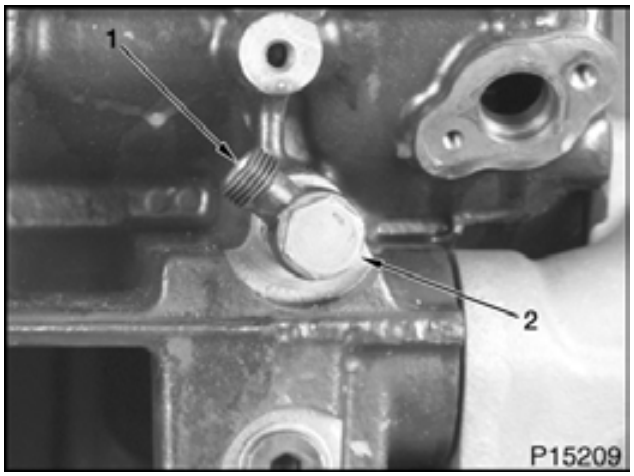

Figure 313 Ring union

1. Ring union
2. Hollow screw

2. Remove hollow screw and ring union from cylinder head and discard two 14.7 x 22 seals.

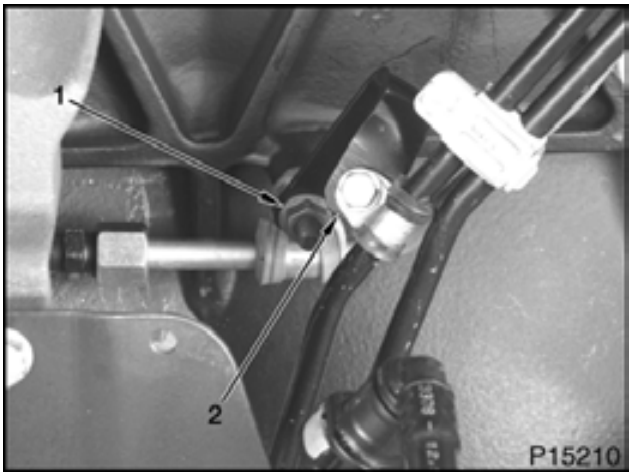

Figure 314 Support tube assembly

1. M6 hex nut
2. Support tube assembly

3. Remove M6 hex nut and position support tube assembly aside.

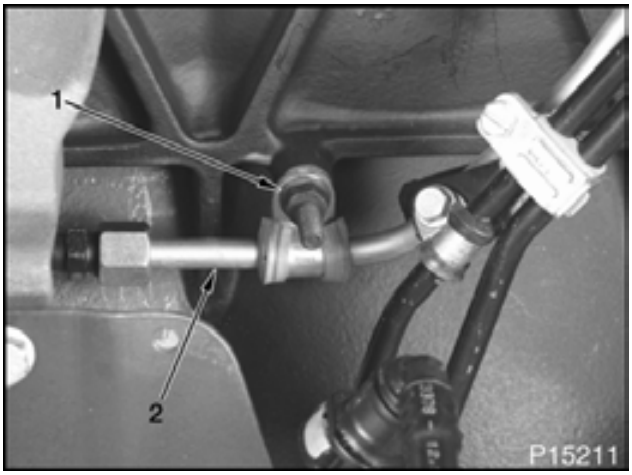

Figure 315 Fuel drip line (pressure pipe rail) stud bolt

1. M8 x 16 stud bolt
2. Fuel drip line (pressure pipe rail)

4. Remove M8 x 16 stud bolt.

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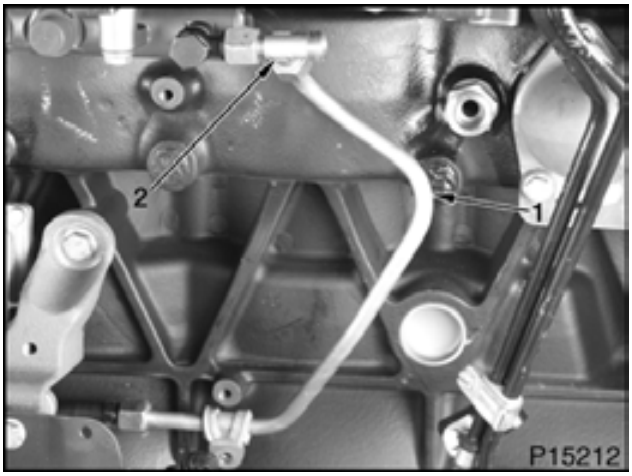

Figure 316 Fuel drip line (pressure pipe rail) and L10-A4C adapter

1. Fuel drip line (pressure pipe rail)
2. L10-A4C adapter

5. Loosen fuel drip line (pressure pipe rail) fitting nuts. Disconnect and remove line from fuel return line and L10-A4C adapter.
6. Loosen L10-A4C adapter fitting nut and remove adapter from ring union.

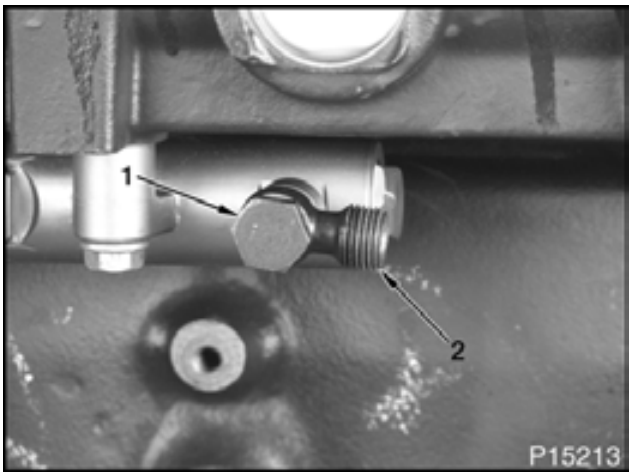

Figure 317 Ring union

1. Size 8 hollow screw
2. Ring union

7. Remove size 8 hollow screw and ring union from pressure pipe rail and discard two 14.7 x 22 seals. Cap opening in pressure pipe rail with clean Disposable Air and Fuel Caps (page 220).

Pressure Pipe Rail

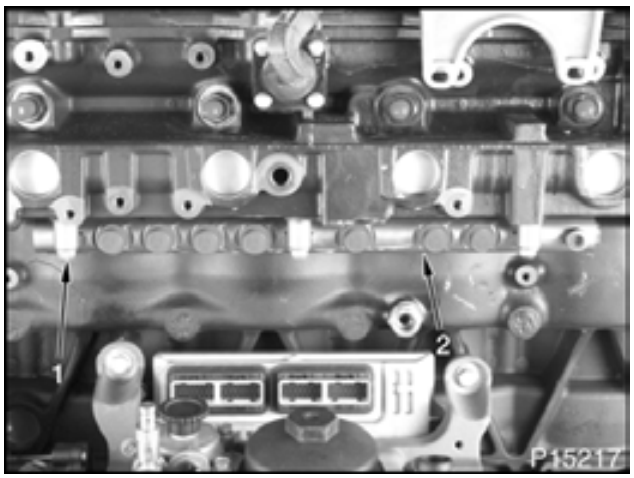

Figure 318 Pressure pipe rail

1. M8 x 35 hex bolt (3)
2. Pressure pipe rail

1. Remove three M8 x 35 hex bolts and pressure pipe rail.

Fuel Primer Pump Assembly

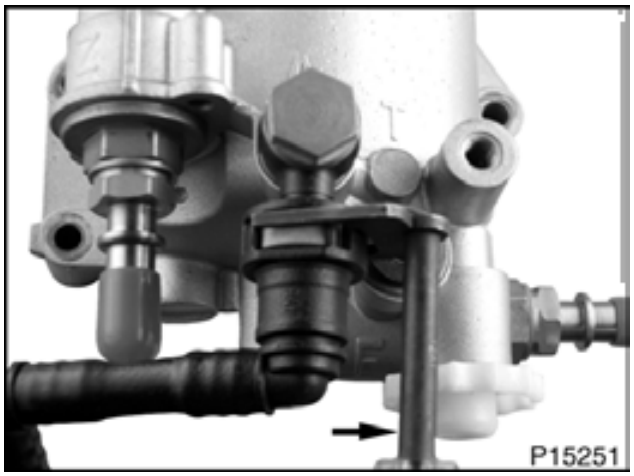

Figure 319 Usage of Fuel Line Disconnect Tool 11.8 mm (typical)

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1. Use Fuel Line Disconnect Tool 11.8 mm (page 220) to disconnect all low pressure fuel line quick-connect fittings.
   a. Slide tines of tool over release buttons on quick-connect fitting.
   b. Pull quick-connect fitting to disconnect.

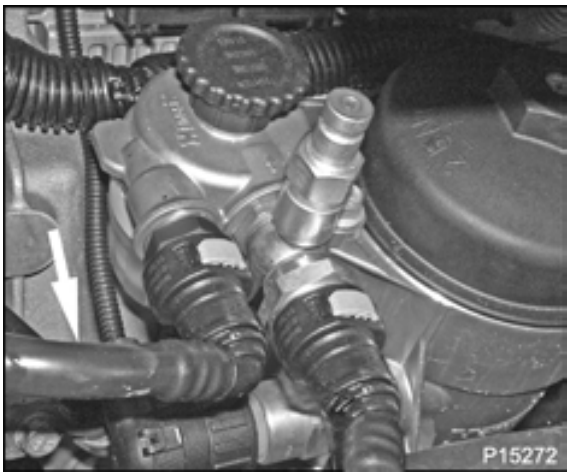

Figure 320 Preliminary filter feed fuel line

2. Disconnect and remove preliminary filter feed fuel line from fuel primer pump assembly and high pressure pump. Immediately cap openings using clean Disposable Air and Fuel Caps (page 220).

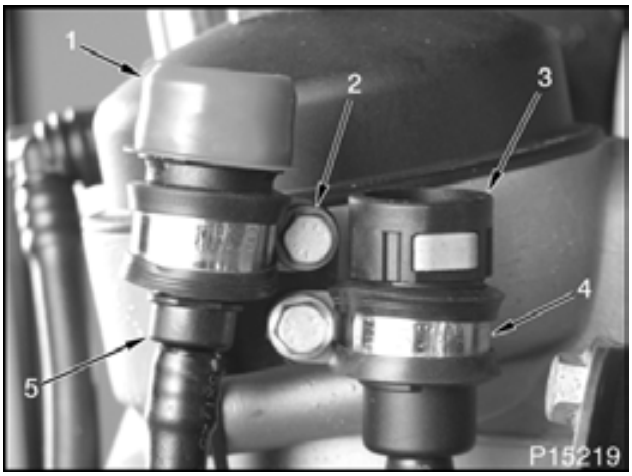

Figure 321 P-clamps at fuel filter housing assembly

1. Fuel cap
2. M6 x 16 hex bolt (2)
3. Fuel return line
4. P-clamp (2)
5. Pre-filter supply fuel line

3. Remove two M6 x 16 hex bolts and two P-clamps from pre-filter supply fuel line and fuel return line.

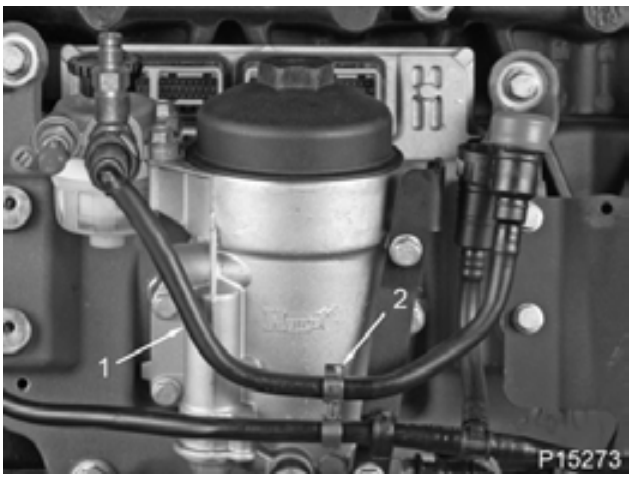

Figure 322 Pre-filter supply fuel line

1. Pre-filter supply fuel line
2. Fuel line clip

4. Remove fuel line clip from pre-filter supply fuel line and fuel return line.

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5. Disconnect and remove pre-filter supply fuel line from fuel primer pump assembly. Immediately cap openings using clean Disposable Air and Fuel Caps (page 220).

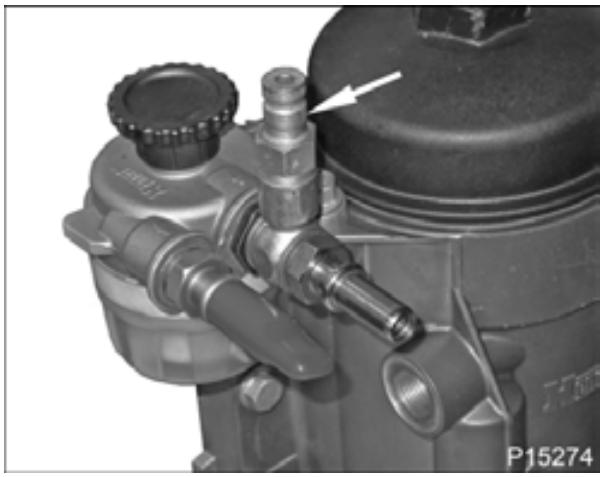

Figure 323 Quick disconnect valve

6. Remove quick disconnect valve from banjo fitting on fuel primer pump assembly. Immediately cap opening using clean Disposable Air and Fuel Caps (page 220).

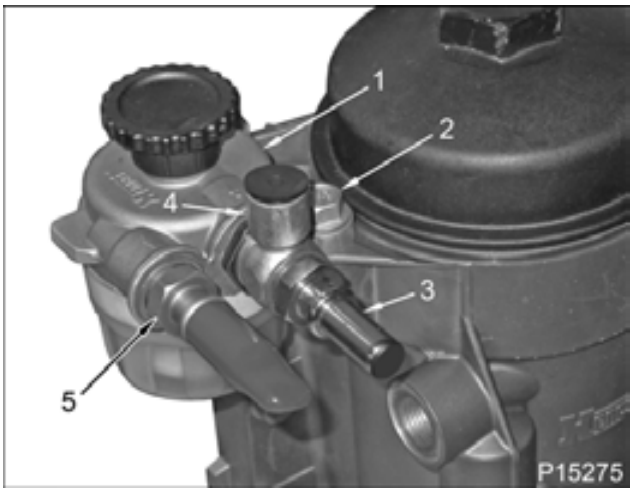

Figure 324 Fuel primer pump assembly

1. Fuel primer pump assembly
2. M6 x 25 hex bolt (2)
3. M14 x 1.5 threaded union (long)
4. Banjo fitting
5. M14 x 1.5 threaded union

7. Remove two M6 x 25 hex bolts and fuel primer pump assembly from fuel filter housing assembly.

NOTE: If fuel primer pump assembly is to be replaced or fittings are found to be leaking, continue with step 8 as required.

8. Remove M14 x 1.5 threaded union, M14 x 1.5 threaded union (long), and banjo fitting from fuel primer pump assembly. Discard three 14.7 x 22 seals.

Fuel Filter Housing Assembly

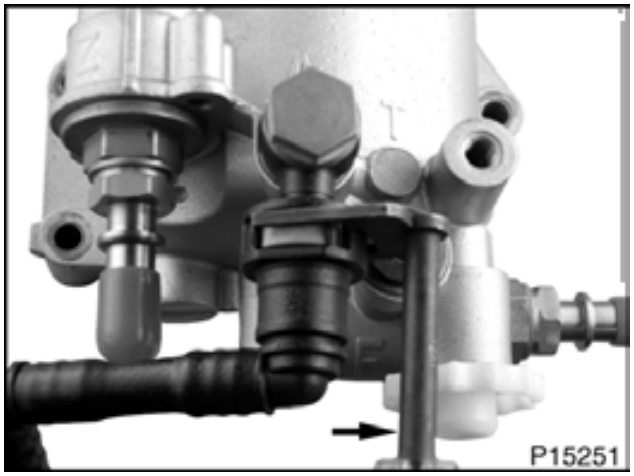

Figure 325 Usage of Fuel Line Disconnect Tool 11.8 mm (typical)

1. Use Fuel Line Disconnect Tool 11.8 mm (page 220) to disconnect all low pressure fuel line quick-connect fittings.
   a. Slide tines of tool over release buttons on quick-connect fitting.
   b. Pull quick-connect fitting to disconnect.

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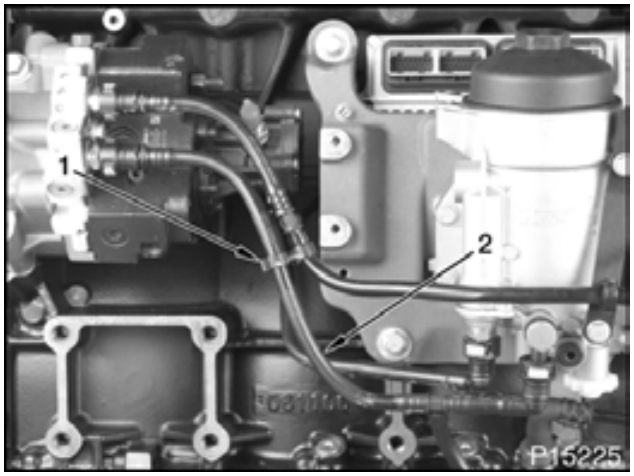

Figure 326 Filter T-connector fuel line

1. Fuel line clip
2. Filter T-connector fuel line

2. Remove fuel line clip.
3. Disconnect and remove filter T-connector fuel line from high pressure pump and fuel filter housing assembly. Immediately cap openings using clean Disposable Air and Fuel Caps (page 220).

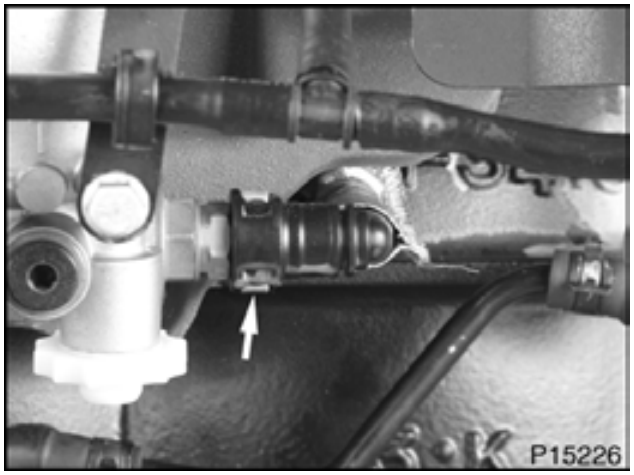

Figure 327 Fuel return line at fuel filter housing assembly

4. Disconnect fuel return line from fuel filter housing assembly. Immediately cap opening on fuel filter housing assembly using clean Disposable Air and Fuel Caps (page 220).

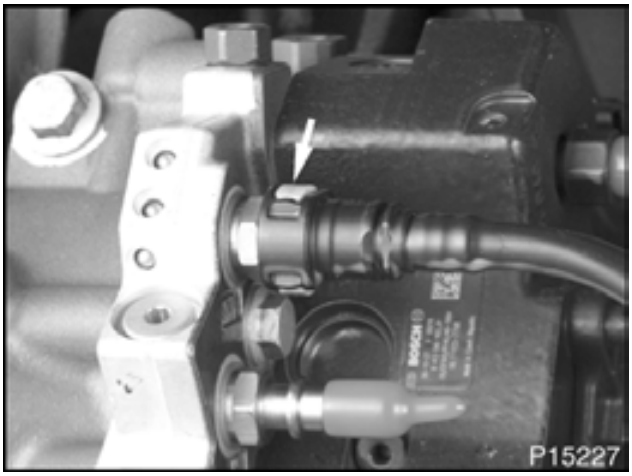

Figure 328 Fuel return line at high pressure pump

5. Disconnect fuel return line from high pressure pump. Immediately cap opening on high pressure pump using clean Disposable Air and Fuel Caps (page 220).

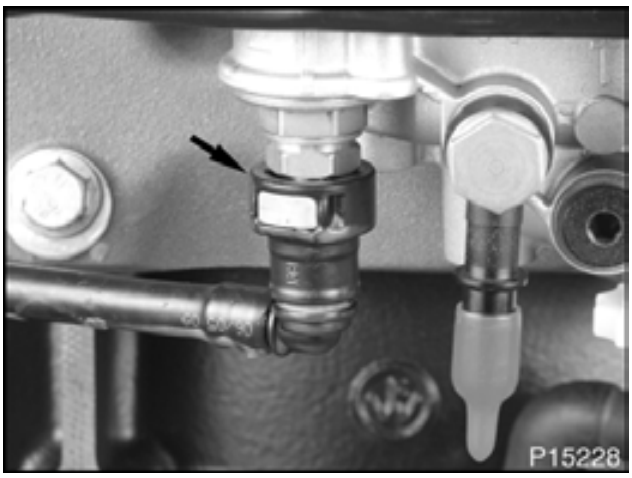

Figure 329 Filter-feedpump fuel line

6. Disconnect and remove filter-feedpump fuel line from fuel filter housing assembly and high pressure pump. Immediately cap openings using clean Disposable Air and Fuel Caps (page 220).

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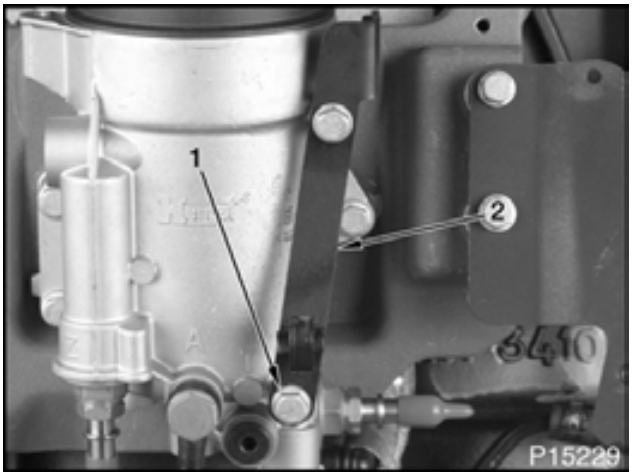

Figure 330 Check valve bracket

1. M8 x 20 hex bolt (2)
2. Check valve bracket

NOTE: Complete steps 7 and 8 only if fuel filter housing assembly is to be replaced.

7. Remove two M8 x 20 hex bolts and check valve bracket.

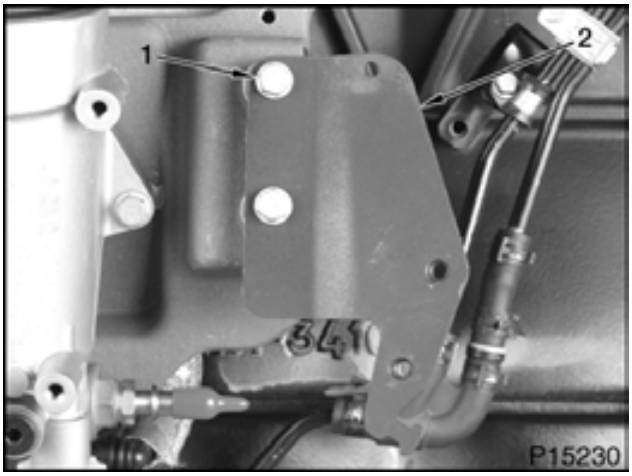

Figure 331 Hydrocarbon (HC) cut-off valve bracket

1. M8 x 20 hex bolt (2)
2. HC cut-off valve bracket

8. Remove two M8 x 20 hex bolts and HC cut-off valve bracket.

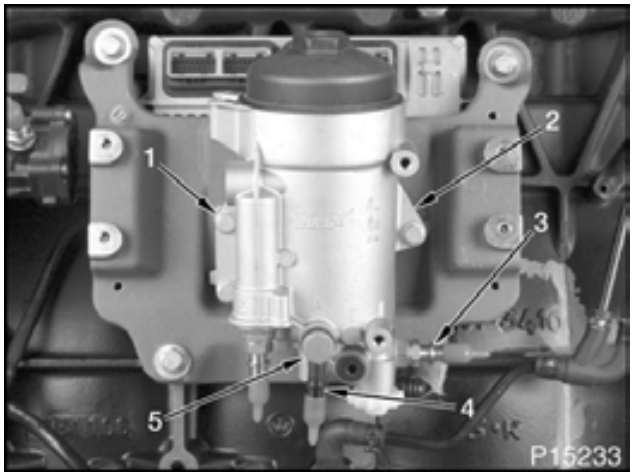

Figure 332 Fuel filter housing assembly

1. M8 x 40 hex bolt (3)
2. Fuel filter housing assembly
3. M14 x 1.5 threaded union (2)
4. Ring union
5. Hollow screw

9. Remove three M8 x 40 hex bolts and fuel filter housing assembly.

NOTE: If fuel filter housing assembly is to be replaced or fittings are found to be leaking, continue with steps 10 and 11.

10. Remove hollow screw and ring union from fuel filter housing assembly. Discard two 14.7 x 22 seals.

11. Remove two M14 x 1.5 threaded unions from fuel filter housing assembly. Discard two 14.7 x 22 seals.

Engine Interface Module (EIM)

NOTE: If the engine is out of chassis, it is not necessary to detach the fuel primer pump assembly or fuel filter housing assembly from the fuel filter bracket to service the EIM. If the engine is in chassis, the fuel primer pump assembly and fuel filter housing assembly must be removed.

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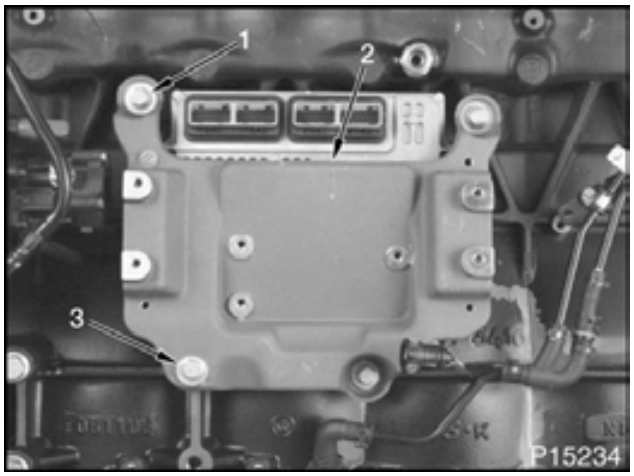

Figure 333 Fuel filter bracket

1. M10 x 25 hex bolt (3)
2. Fuel filter bracket
3. M10 x 50 hex bolt

1. Remove three M10 x 25 hex bolts, M10 x 50 hex bolt, and fuel filter bracket.

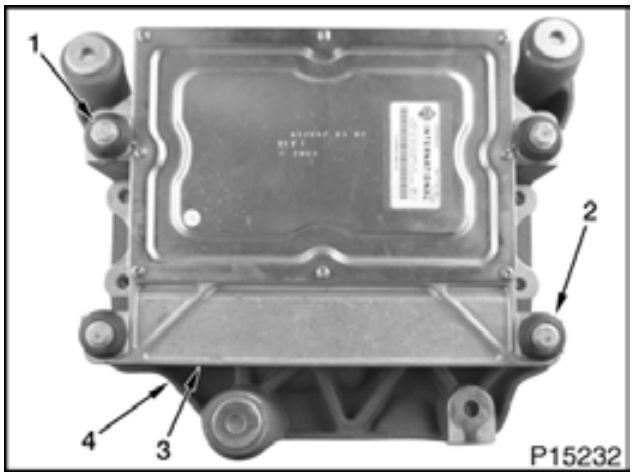

Figure 334 EIM

1. M8 x 50 hex bolt (4)
2. Rubber bearing (8)
3. EIM
4. Fuel filter bracket

2. Remove four M8 x 50 hex bolts, eight rubber bearings, and EIM from fuel filter bracket.

Fuel Return Line

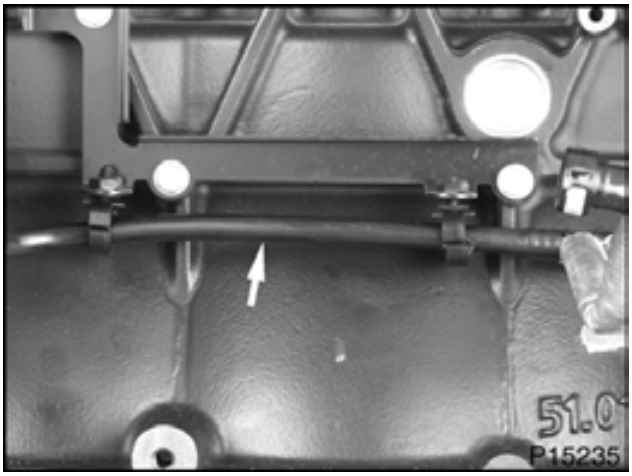

Figure 335 Fuel return line

1. Remove fuel return line from fuel line clips.

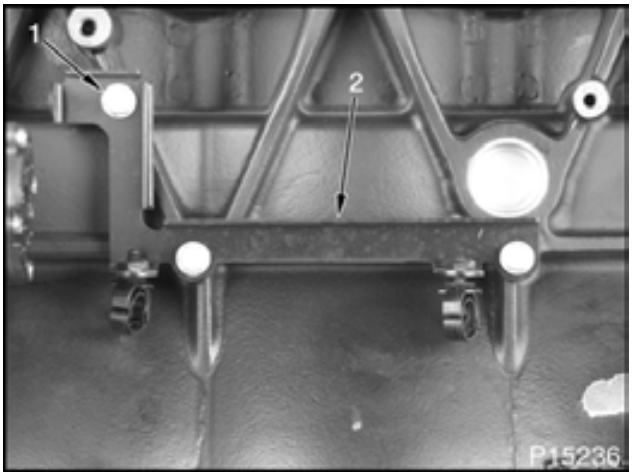

Figure 336 Fuel line bracket

1. M8 x 16 hex bolt (3)
2. Fuel line bracket

2. Remove three M8 x 16 hex bolts and fuel line bracket.

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High Pressure Pump

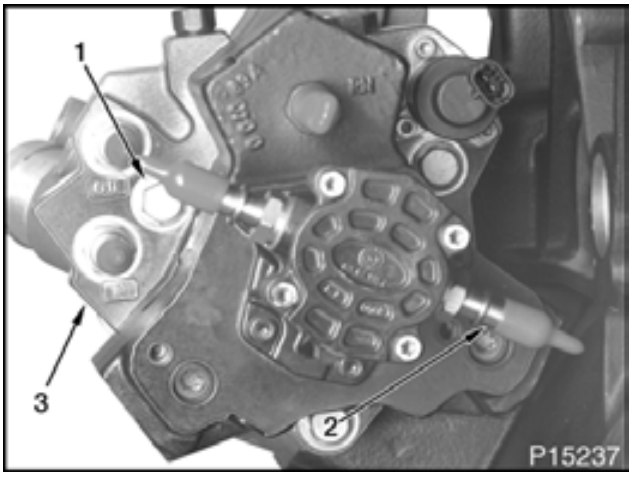

Figure 337 High pressure pump

1. M10 x 50 hex bolt (3)
2. M14 x 1.5 threaded union (4)
3. High pressure pump

1. Remove three M10 x 50 hex bolts and high pressure pump and discard O-ring.
2. Remove driving sleeve from high pressure pump input shaft.

NOTE: If high pressure pump is to be replaced or fittings are found to be leaking, continue with step 3.

3. Remove four M14 x 1.5 threaded unions from high pressure pump. Discard four 14.7 x 22 seals.

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Cleaning and Inspection

1. Inspect low pressure fuel lines for kinks, obstructions or other damage. Replace if necessary.
2. Inspect low pressure fuel line quick-connect fitting O-ring seals for damage. Replace low pressure fuel lines if necessary.
3. Inspect fuel filter housing assembly and fuel primer pump assembly for damage. Replace if necessary.
4. Inspect high pressure pump input shaft and driving sleeve splines for wear or damage. Replace if necessary.

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

5. Clean outside surfaces of low pressure fuel lines, fuel filter housing assembly, and fuel primer pump assembly with a suitable non-caustic solvent. Dry with filtered compressed air.
6. Inspect EIM rubber bearings. Replace if worn or damaged.

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Installation

High Pressure Pump

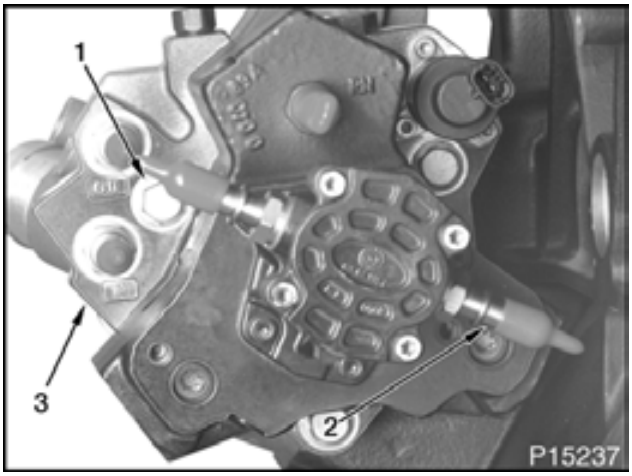

Figure 338 High pressure pump

1. M10 x 50 hex bolt (3)
2. M14 x 1.5 threaded union (4)
3. High pressure pump

1. Lubricate new O-ring with clean engine oil and install on high pressure pump.
2. Install driving sleeve onto high pressure pump input shaft.
3. Install high pressure pump and three M10 x 50 hex bolts. Tighten hex bolts to special torque (page 220).

NOTE: If high pressure pump was replaced or fittings were previously removed, continue with step 4.

4. Install four M14 x 1.5 threaded unions with four new 14.7 x 22 seals to high pressure pump. Tighten threaded unions to special torque (page 220).

Fuel Return Line

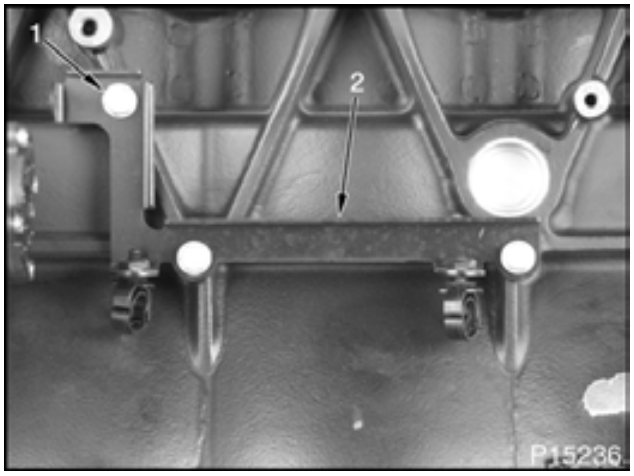

Figure 339 Fuel line bracket

1. M8 x 16 hex bolt (3)
2. Fuel line bracket

1. Install fuel line bracket and three M8 x 16 hex bolts. Tighten hex bolts to standard torque (page 457).

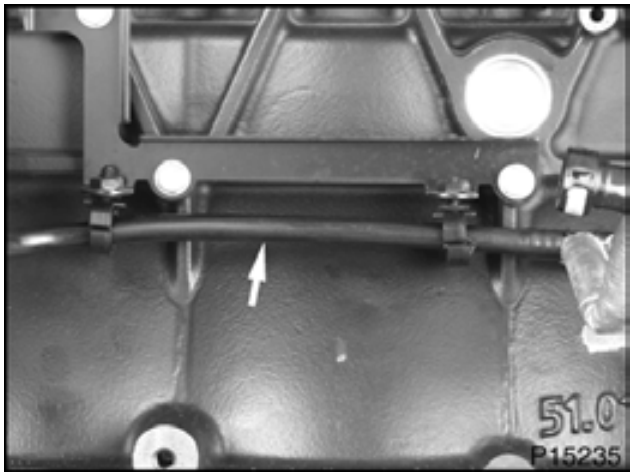

Figure 340 Fuel return line

2. Install fuel return line into fuel line clips.

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Engine Interface Module (EIM)

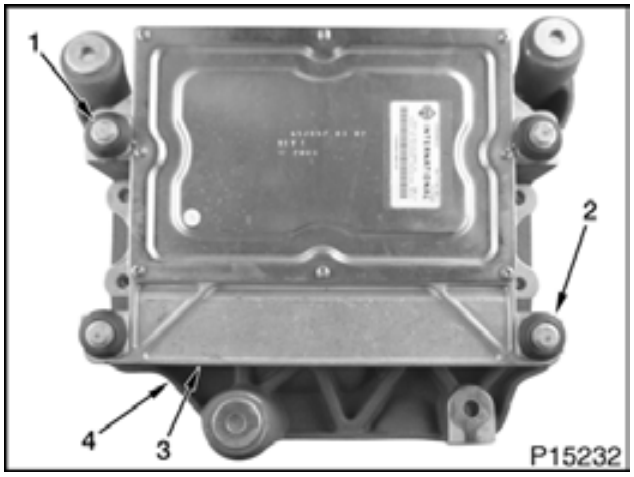

Figure 341 EIM

1. M8 x 50 hex bolt (4)
2. Rubber bearing (8)
3. EIM

1. Install EIM, eight rubber bearings, and four M8 x 50 hex bolts to fuel filter bracket. Tighten hex bolts to standard torque (page 457).

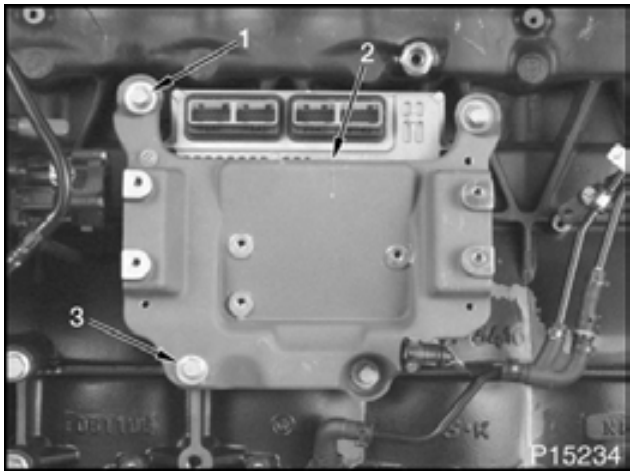

Figure 342 Fuel filter bracket

1. M10 x 25 hex bolt (3)
2. Fuel filter bracket
3. M10 x 50 hex bolt

2. Install fuel filter bracket, M10 x 50 hex bolt, and three M10 x 25 hex bolts. Tighten hex bolts to special torque (page 220).

Fuel Filter Housing Assembly

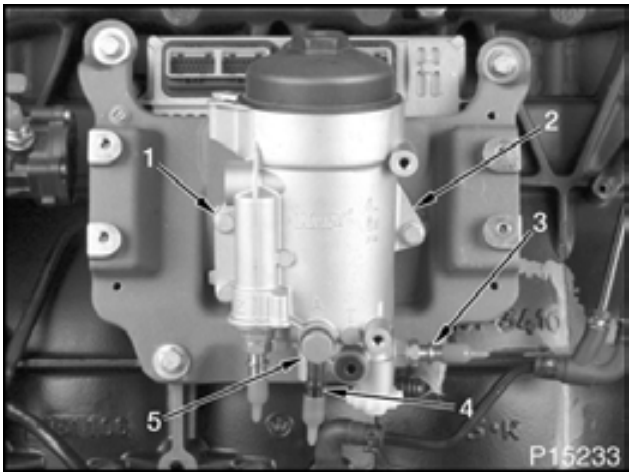

Figure 343 Fuel filter housing assembly

1. M8 x 40 hex bolt (3)
2. Fuel filter housing assembly
3. M14 x 1.5 threaded union (2)
4. Ring union
5. Hollow screw

1. Install fuel filter housing assembly and three M8 x 40 hex bolts. Tighten hex bolts to special torque (page 220).

NOTE: If fuel filter housing assembly was replaced or fittings were previously removed, continue with steps 2 and 3.

2. Install two M14 x 1.5 threaded unions with two new 14.7 x 22 seals into fuel filter housing assembly. Tighten threaded unions to special torque (page 220).
3. Install hollow screw and ring union with two new 14.7 x 22 seals into fuel filter housing assembly. Align ring union at six o'clock position and tighten hollow screw to special torque (page 220).

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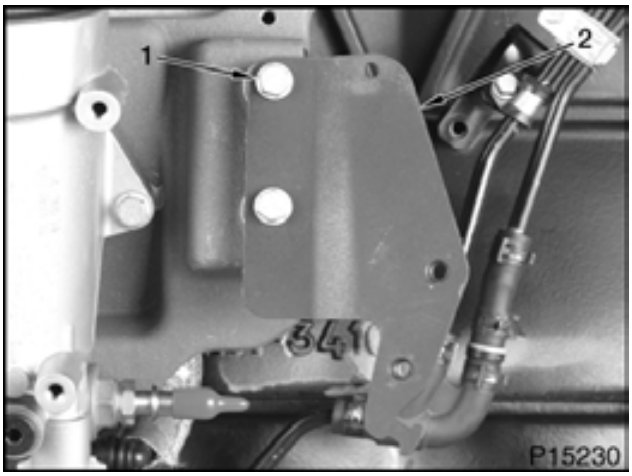

Figure 344 Hydrocarbon (HC) cut-off valve bracket

1. M8 x 20 hex bolt (2)
2. HC cut-off valve bracket

4. Install HC cut-off valve bracket and two M8 x 20 hex bolts. Tighten hex bolts to standard torque (page 457).

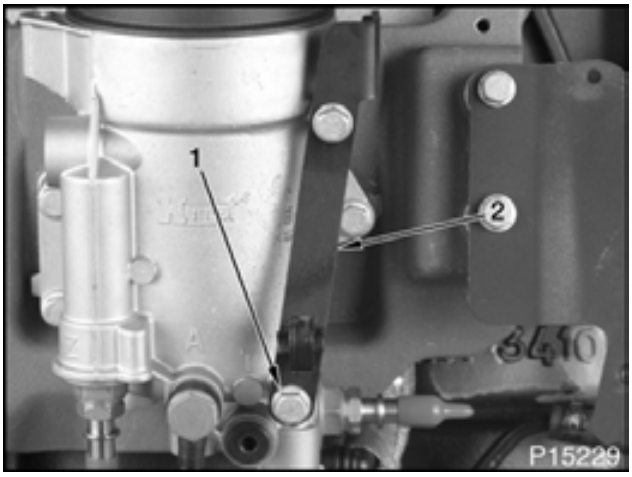

Figure 345 Check valve bracket

1. M8 x 20 hex bolt (2)
2. Check valve bracket

5. Install check valve bracket and two M8 x 20 hex bolts. Tighten hex bolts to standard torque (page 457).

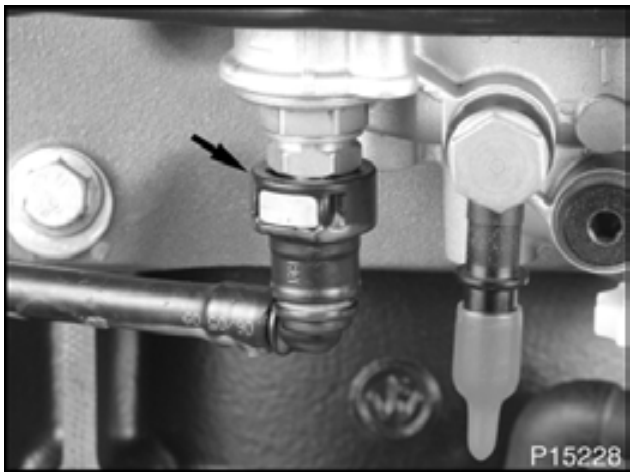

Figure 346 Filter-feedpump fuel line

6. Install and connect filter-feedpump fuel line to fuel filter housing assembly and high pressure pump by pushing on quick-connect fitting until an audible click is heard. Pull quick-connect fitting to make sure it is seated.

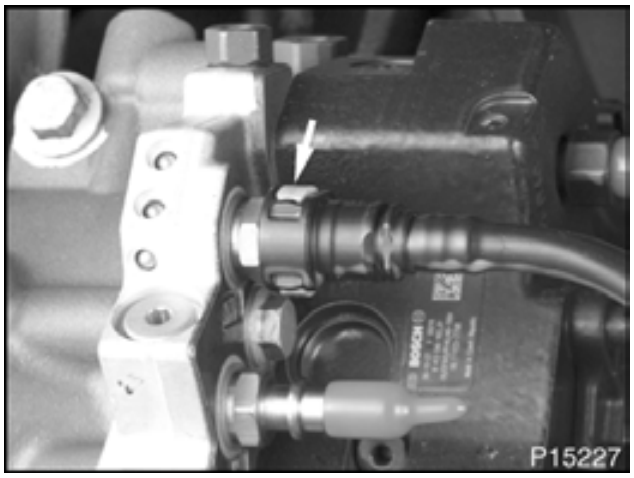

Figure 347 Fuel return line at high pressure pump

7. Connect fuel return line to high pressure pump by pushing on quick-connect fitting until an audible click is heard. Pull quick-connect fitting to make sure it is seated.

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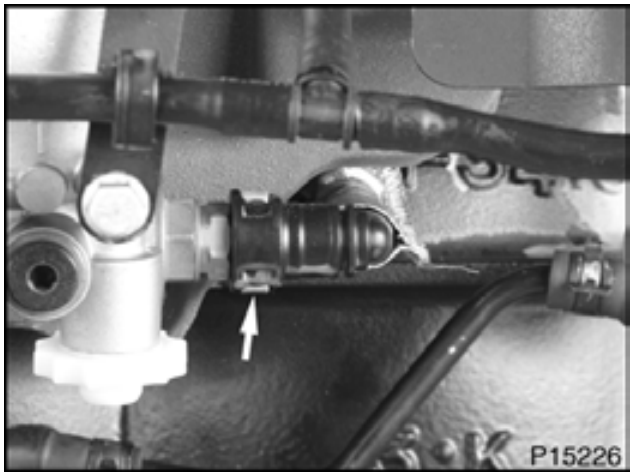

Figure 348 Fuel return line at fuel filter housing assembly

8. Connect fuel return line to fuel filter housing assembly by pushing on quick-connect fitting until an audible click is heard. Pull quick-connect fitting to make sure it is seated.

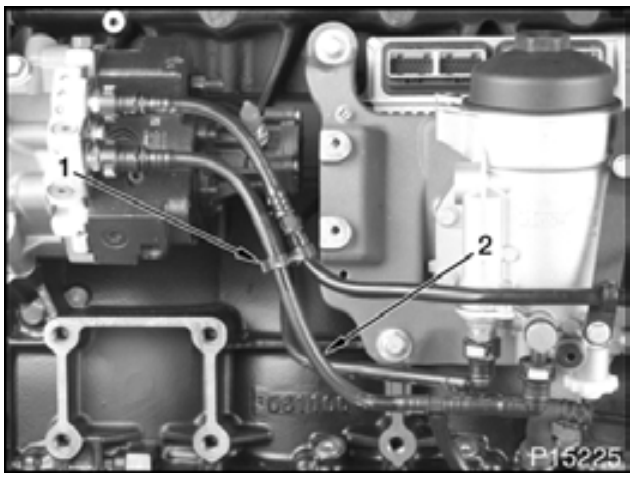

Figure 349 Filter T-connector fuel line

1. Fuel line clip
2. Filter T-connector fuel line

9. Install and connect filter T-connector fuel line to high pressure pump and fuel filter housing assembly by pushing on quick-connect fitting until an audible click is heard. Pull quick-connect fitting to make sure it is seated.
10. Install fuel line clip.

Fuel Primer Pump Assembly

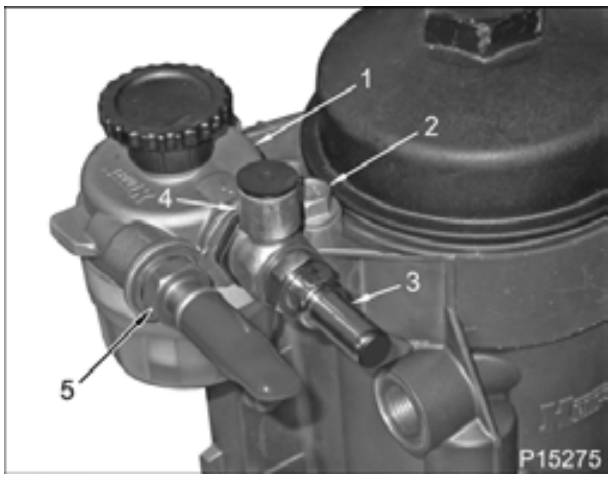

Figure 350 Fuel primer pump assembly

1. Fuel primer pump assembly
2. M6 x 25 hex bolt (2)
3. M14 x 1.5 threaded union (long)
4. Banjo fitting
5. M14 x 1.5 threaded union

1. Install fuel primer pump assembly and two M6 x 25 hex bolts to fuel filter housing assembly. Tighten hex bolts to special torque (page 220).

NOTE: If fuel primer pump assembly was replaced or fittings were previously removed, continue with step 2.

2. Install M14 x 1.5 threaded union, M14 x 1.5 threaded union (long), and banjo fitting with three new 14.7 x 22 seals into fuel primer pump assembly. Align ring union at twelve o'clock position. Tighten threaded unions to special torque (page 220).

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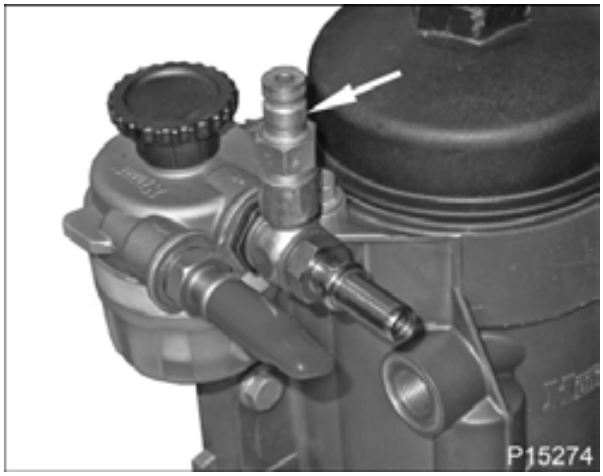

Figure 351 Quick disconnect valve

3. Install quick disconnect to banjo fitting on fuel primer pump assembly. Tighten quick disconnect to special torque (page 220).

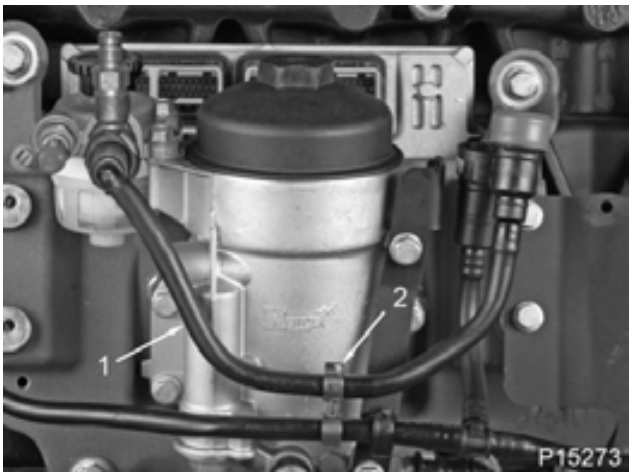

Figure 352 Pre-filter supply fuel line

1. Pre-filter supply fuel line
2. Fuel line clip

4. Install and connect pre-filter supply fuel line to fuel primer pump assembly by pushing on quick-connect fitting until an audible click is heard. Pull quick-connect fitting to make sure it is seated.
5. Install fuel line clip on pre-filter supply fuel line and fuel return line.

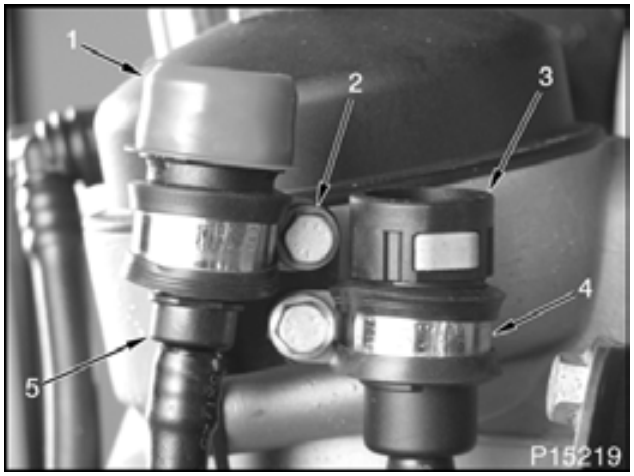

Figure 353 P-clamps at fuel filter housing assembly

1. Fuel cap
2. M6 x 16 hex bolt (2)
3. Fuel return line
4. P-clamp (2)
5. Pre-filter supply fuel line

6. Install two P-clamps and two M6 x 16 hex bolts to pre-filter supply fuel line and fuel return line. Tighten hex bolts to standard torque (page 457).

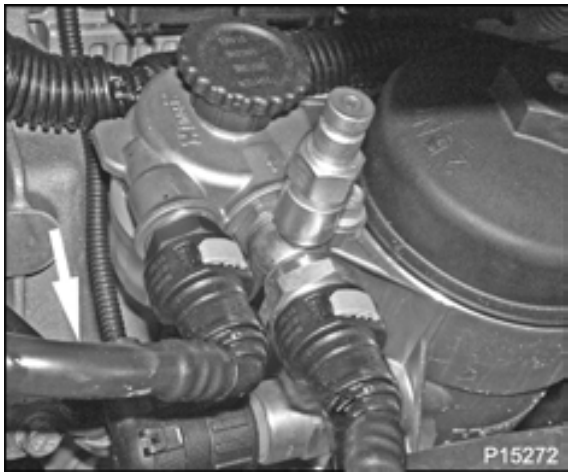

Figure 354 Preliminary filter feed fuel line

7. Install and connect preliminary filter feed fuel line to fuel primer pump assembly and high pressure pump by pushing on quick-connect fittings until an audible click is heard. Pull quick-connect fitting to make sure it is seated.

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Pressure Pipe Rail

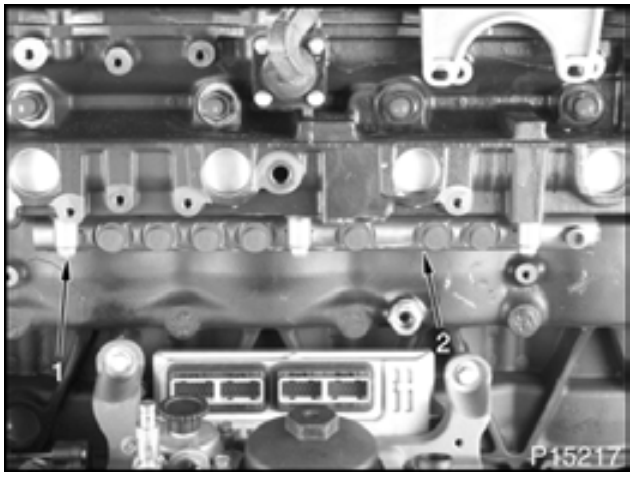

Figure 355 Pressure pipe rail

1. M8 x 35 hex bolt (3)
2. Pressure pipe rail

1. Install pressure pipe rail and three M8 x 35 hex bolts. Tighten hex bolts to special torque (page 220).

Fuel Drip Lines

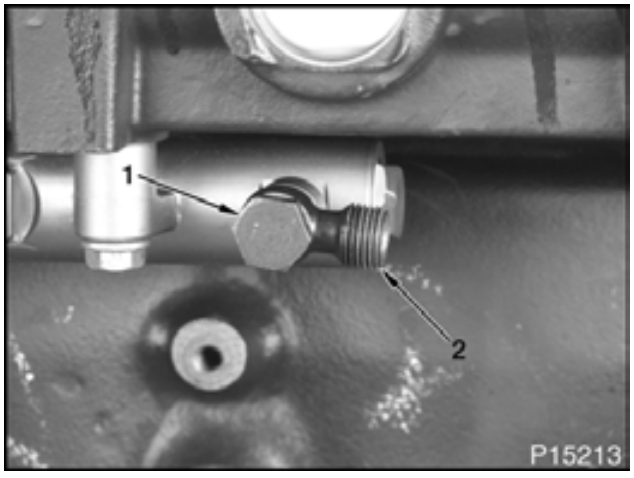

Figure 356 Ring union

1. Size 8 hollow screw
2. Ring union

1. Install size 8 hollow screw and ring union into pressure pipe rail with two new 14.7 x 22 seals. Do not tighten at this time.

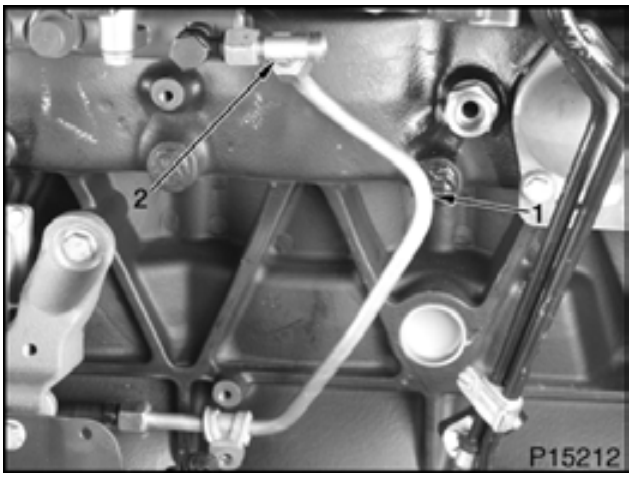

Figure 357 Fuel drip line (pressure pipe rail)

1. Fuel drip line (pressure pipe rail)
2. L10-A4C adapter

2. Install L10-A4C adapter onto ring union. Do not tighten at this time.

NOTE: Use a backup wrench when tightening fitting nuts onto L10–A4C adapter.

3. Install and connect fuel drip line (pressure pipe rail) to fuel return line and L10-A4C adapter. Tighten fuel drip line fitting nuts to special torque (page 220).
4. Tighten size 8 hollow screw to special torque (page 220).
5. Tighten L10-A4C adapter to special torque (page 220).

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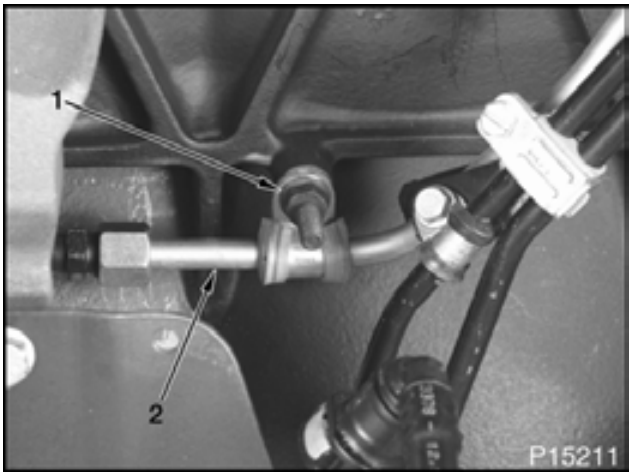

Figure 358 Fuel drip line (pressure pipe rail) stud bolt

1. M8 x 16 stud bolt
2. Fuel drip line (pressure pipe rail)

6. Install M8 x 16 stud bolt and tighten to standard torque (page 457).

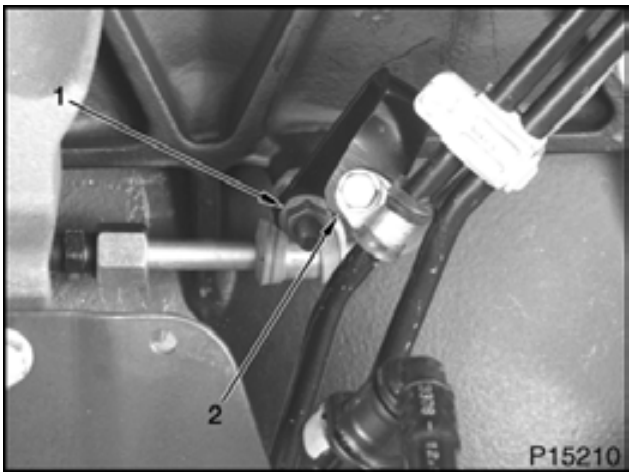

Figure 359 Support tube assembly

1. M6 hex nut
2. Support tube assembly

7. Reposition support tube assembly and install M6 hex nut. Tighten hex nut to standard torque (page 457).

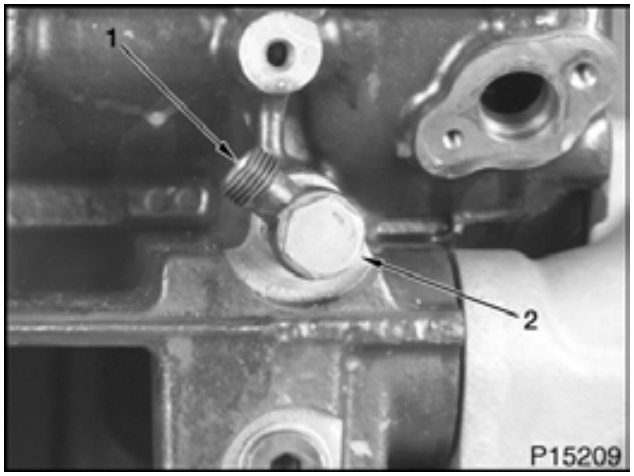

Figure 360 Ring union

1. Ring union
2. Hollow screw

8. Install hollow screw and ring union into cylinder head with two new 14.7 x 22 seals. Do not tighten at this time.

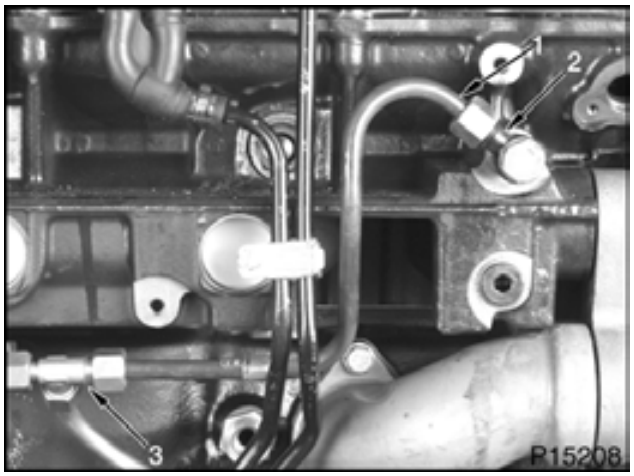

Figure 361 Fuel drip line (injector)

1. Fuel drip line (injector)
2. Ring union
3. L10–A4C adapter

NOTE: Use a backup wrench when tightening fitting nuts onto L10–A4C adapter.

9. Install and connect fuel drip line (injector) to ring union and L10-A4C adapter. Tighten fuel drip line fitting nuts to special torque (page 220).

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10. Tighten hollow screw to special torque (page 220).

High Pressure Fuel Lines

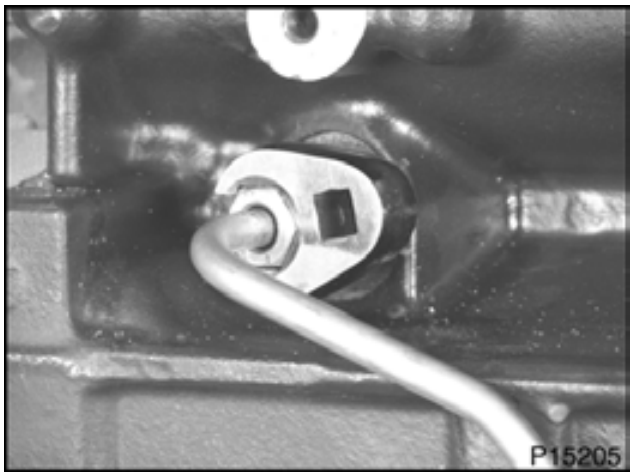

Figure 362 Crowfoot wrench (typical)

1. Obtain a crowfoot wrench (page 220) to connect all high pressure fuel line fittings. When using a crowfoot wrench to tighten fittings, calculate the torque compensation (page 458) to match specific wrench configuration.

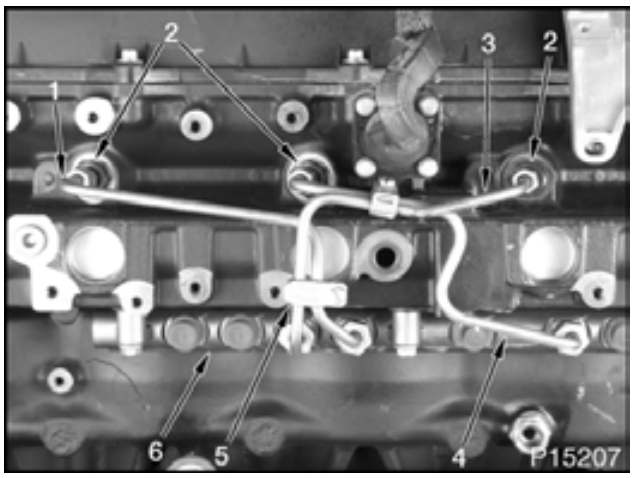

Figure 363 Cylinders 2, 3 and 4 injection lines

1. Cylinder 2 injection line
2. Pressure pipe necks
3. Cylinder 4 injection line
4. Cylinder 3 injection line
5. Clamp (2)
6. Pressure pipe rail

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

2. Install new cylinders 2, 3, and 4 injection lines.
3. Connect cylinders 2, 3, and 4 injection lines to pressure pipe rail. Do not tighten at this time.
4. Connect cylinders 2, 3, and 4 injection lines to pressure pipe necks. Tighten injection line fitting nuts to special torque (page 220).
5. Install two clamps on cylinders 2, 3, and 4 injection lines and tighten clamp bolts to standard torque (page 457).

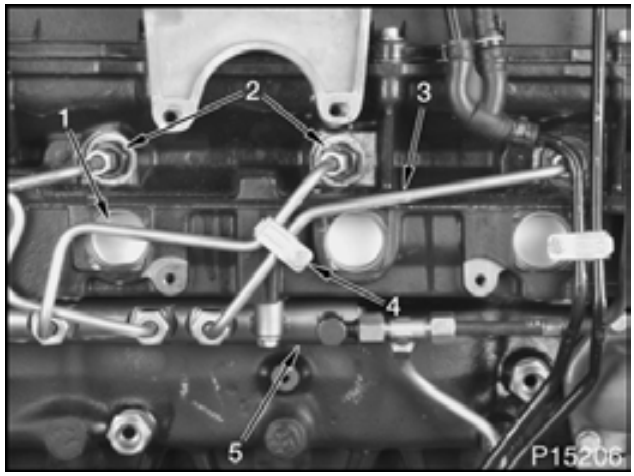

Figure 364 Cylinders 5 and 6 injection lines

1. Cylinder 5 injection line
2. Pressure pipe necks
3. Cylinder 6 injection line
4. Clamp
5. Pressure pipe rail

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

6. Install new cylinders 5 and 6 injection lines.
7. Connect cylinders 5 and 6 injection lines to pressure pipe rail. Do not tighten at this time.

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8. Connect cylinders 5 and 6 injection lines to pressure pipe necks. Tighten injection line fitting nuts to special torque (page 220).
9. Install clamp on cylinders 5 and 6 injection lines and tighten clamp bolts to standard torque (page 457).

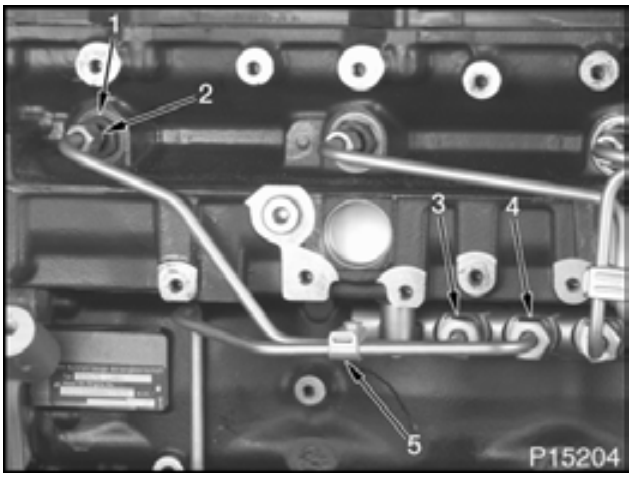

Figure 365 Pressure line and cylinder 1 injection line

1. Pressure pipe neck
2. Cylinder 1 injection line fitting nut at pressure pipe neck
3. Cylinder 1 injection line fitting nut at pressure pipe rail
4. Pressure line fitting nut at pressure pipe rail
5. Clamp

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

10. Install new pressure line and cylinder 1 injection line.
11. Connect pressure line at pressure pipe rail. Do not tighten at this time.
12. Connect cylinder 1 injection line at pressure pipe rail. Do not tighten at this time.
13. Connect cylinder 1 injection line at pressure pipe neck. Tighten pressure line and injection line fitting nuts to special torque (page 220).

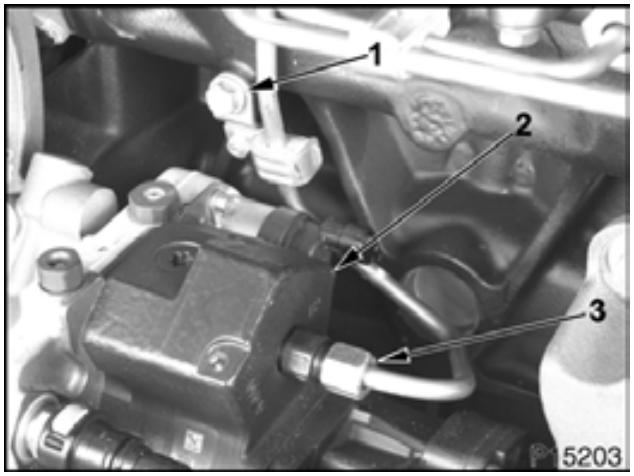

Figure 366 Pressure line

1. Pressure line clamp bolt
2. High pressure pump
3. Pressure line

14. Connect pressure line to high pressure pump. Tighten pressure line fitting nut to special torque (page 220).
15. Install pressure line clamp on pressure line. Tighten clamp bolt to standard torque (page 457).
16. Install pressure line clamp bolt to crankcase. Tighten bolt to standard torque (page 457).

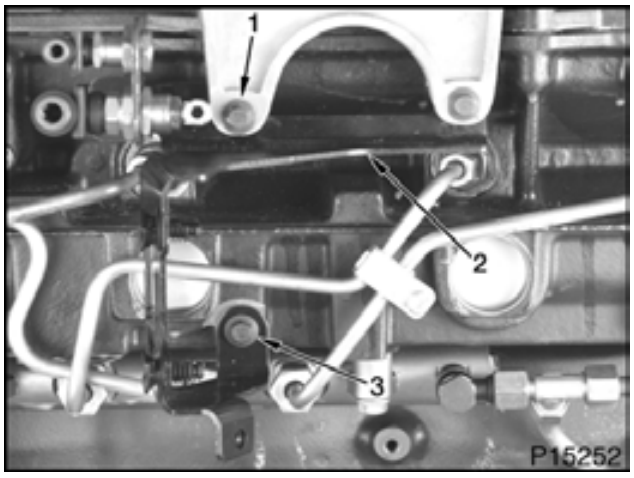

Figure 367 Wire loom bracket

1. M8 x 30 hex bolt (2)
2. Wire loom bracket
3. M8 x 16 hex bolt

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17. Install wire loom bracket, M8 x 16 hex bolt, and two M8 x 30 hex bolts. Tighten hex bolts to standard torque (page 457).

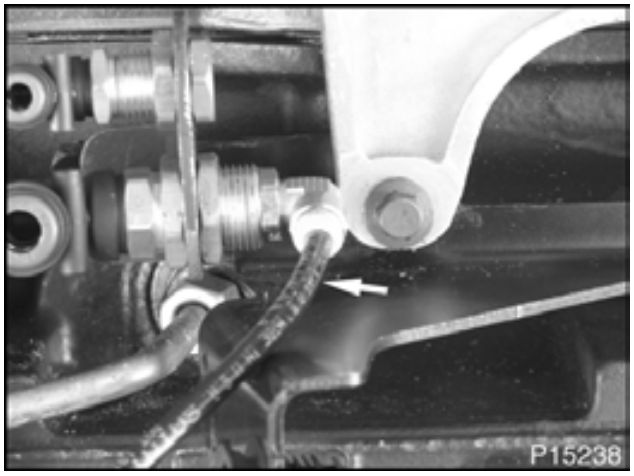

Figure 368 Air supply line

18. Connect air supply line to Parker® 90° elbow fitting by pushing air line into fitting until fully seated.

Filter Element and Fuel Strainer Element

Refer to International® MaxxForce® 11 and 13 *Engine Operation and Maintenance Manual* for filter element and fuel strainer element service procedures.

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Specifications

Table 14 Fuel System

Fuel strainer filtration	300 microns
Fuel filter element filtration	3-5 microns

Special Torque

Table 15 Fuel System

Quick disconnect valve	35 N·m (26 lbf·ft)
Fuel filter housing assembly hex bolts	35 N·m (26 lbf·ft)
Fuel filter bracket hex bolts	35 N·m (26 lbf·ft)
High pressure pump hex bolts	60 N·m (44 lbf·ft)
Hollow screws (all sizes in this section)	30 N·m (21 lbf·ft)
Fuel drip line fitting nuts	40 N·m (30 lbf·ft)
Fuel filter screw cap	20-25 N·m (15-18 lbf·ft)
Fuel primer pump assembly hex bolts	45 N·m (33 lbf·ft)
Fuel strainer cover	10 N·m (89 lbf·in)
Injection line fitting nuts	10 N·m (89 lbf·in) + 60°
L10-A4C adapter	40 N·m (30 lbf·ft)
Pressure line fitting nuts	10 N·m (89 lbf·in) + 60°
Pressure pipe rail hex bolts	30 N·m (21 lbf·ft)
M14 x 1.5 threaded unions	30 N·m (21 lbf·ft)

Special Service Tools

Table 16 Fuel System

Description	Tool Number
Crowfoot Wrench	Obtain locally
Disposable Air and Fuel Caps	ZTSE4891
Fuel Line Disconnect Tool 11.8 mm	ZTSE4773

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Exploded Views

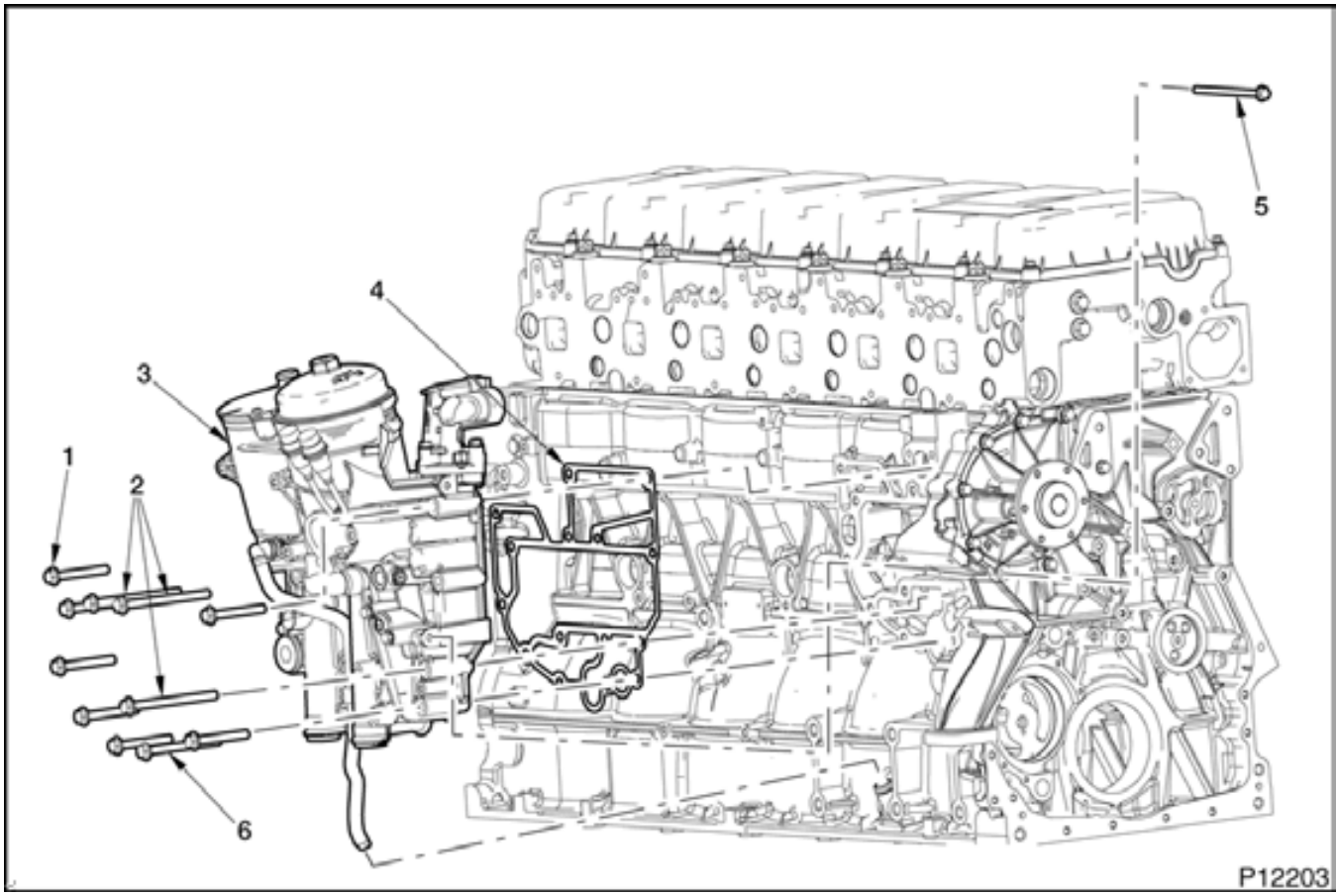

Figure 369 Oil module to engine

1. M10 x 80 hex bolt (8)
2. M10 x 130 hex bolt (3)
3. Oil module
4. 26 x 48 x 1.0 gasket
5. M8 x 130 hex bolt
6. M10 x 110 hex bolt

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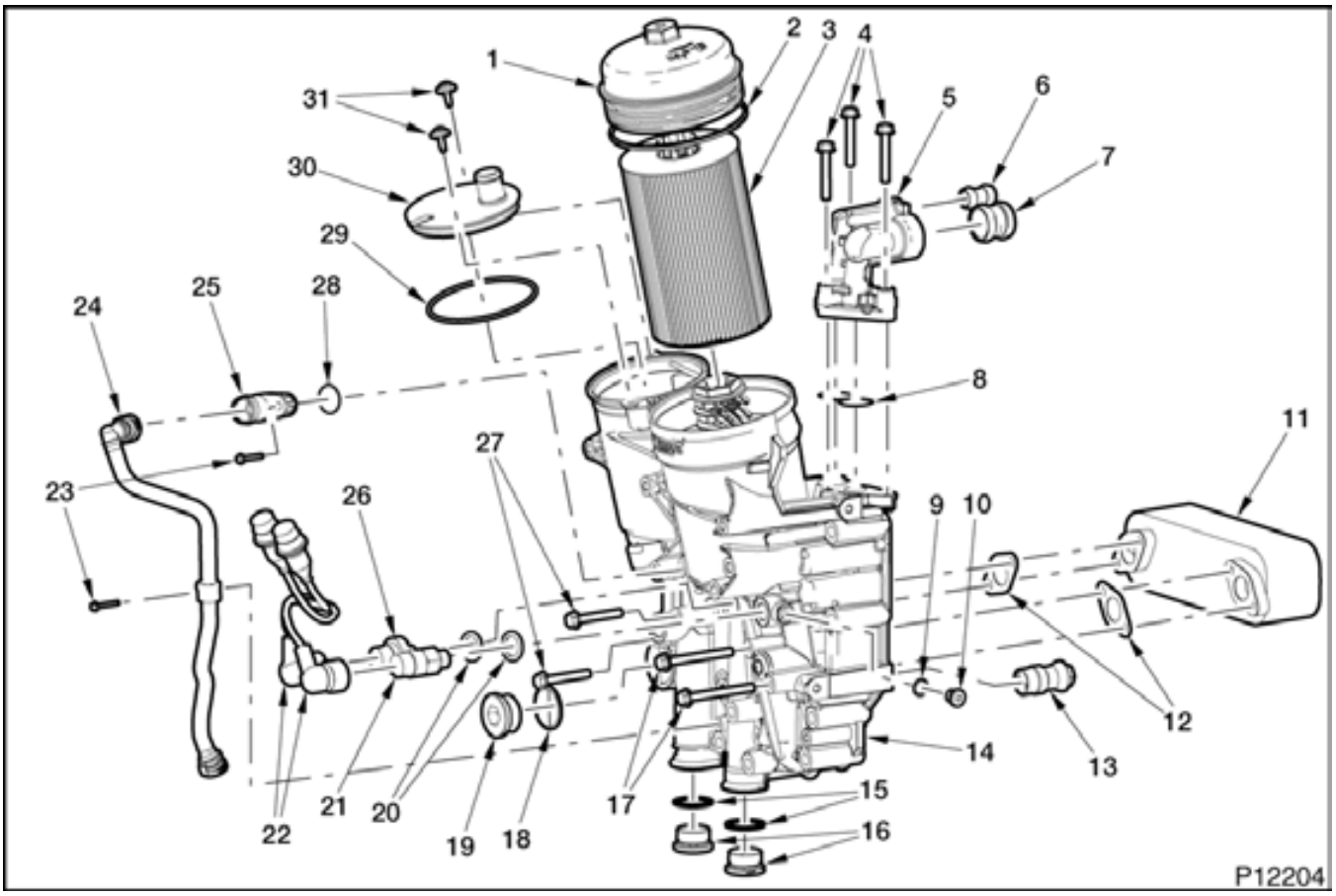

Figure 370 Oil module

1. Oil filter cover
2. O-ring seal
3. Oil filter element
4. M8 x 50 hex bolt (3)
5. Flange elbow
6. DMR20/DN14 extension tube
7. DMR37/DN29 extension tube
8. Gasket for flange elbow
9. Seal
10. M10 x 1.0 plug
11. Oil cooler
12. Oil cooler gaskets
13. Oil pressure relief valve
14. Oil module
15. Plug seal (2)
16. M33 x 2 plug (2)
17. M8 x 80 hex bolt (2)
18. Plug seal
19. M38 x 1.5 plug
20. BS-16.7 x 24.0 O-ring seal
21. Engine Oil Pressure (EOP) sensor
22. Adapter lines (electrical connections)
23. M6 x 18 hex bolt (2)
24. Oil return tube
25. Straight fitting
26. Engine Oil Temperature (EOT) sensor
27. M8 x 55 hex bolt (2)
28. O-ring seal
29. O-ring seal
30. Breather cup
31. M6 bolt with washer (2)

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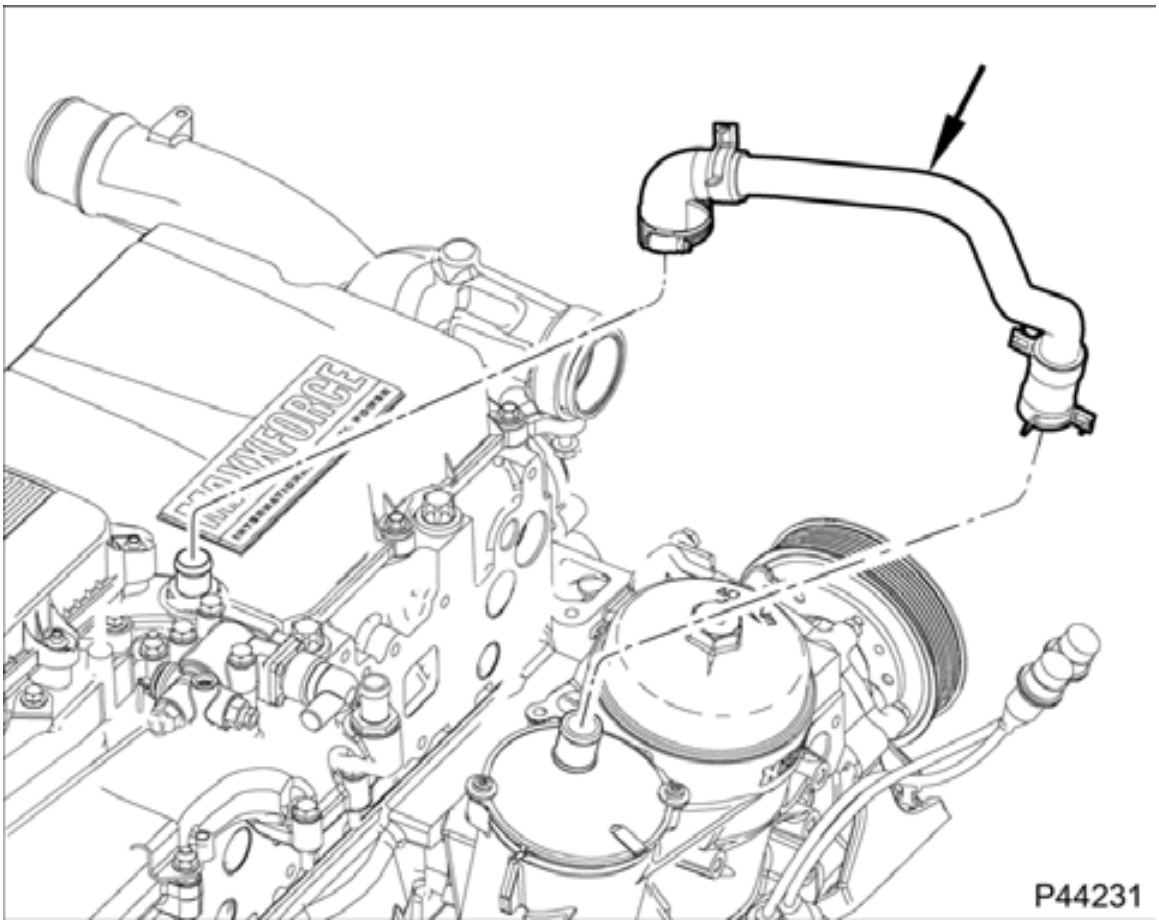

Figure 371 Breather inlet tube assembly

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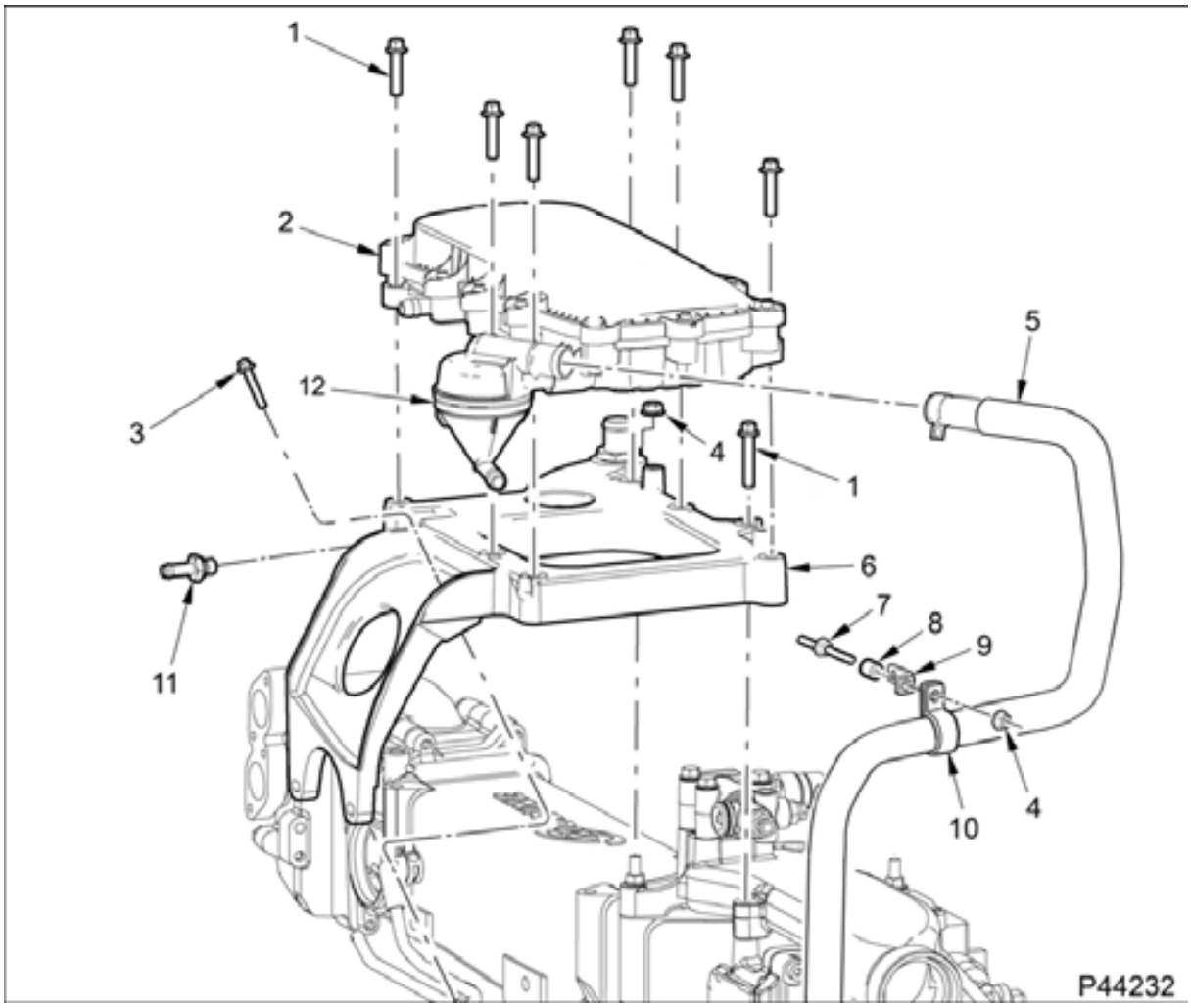

Figure 372 Crankcase ventilation breather base assembly components

1. M8 x 35 hex bolt (6)
2. Service breather assembly
3. M6 x 35 hex bolt
4. M8 hex nut
5. Breather outlet tube and heater assembly
6. Service breather assembly bracket
7. M8 x 45 x 30 stud bolt
8. 10 mm spacer
9. HPCAC hose bracket
10. P-clamp
11. M12 straight fitting
12. Cyclone breather

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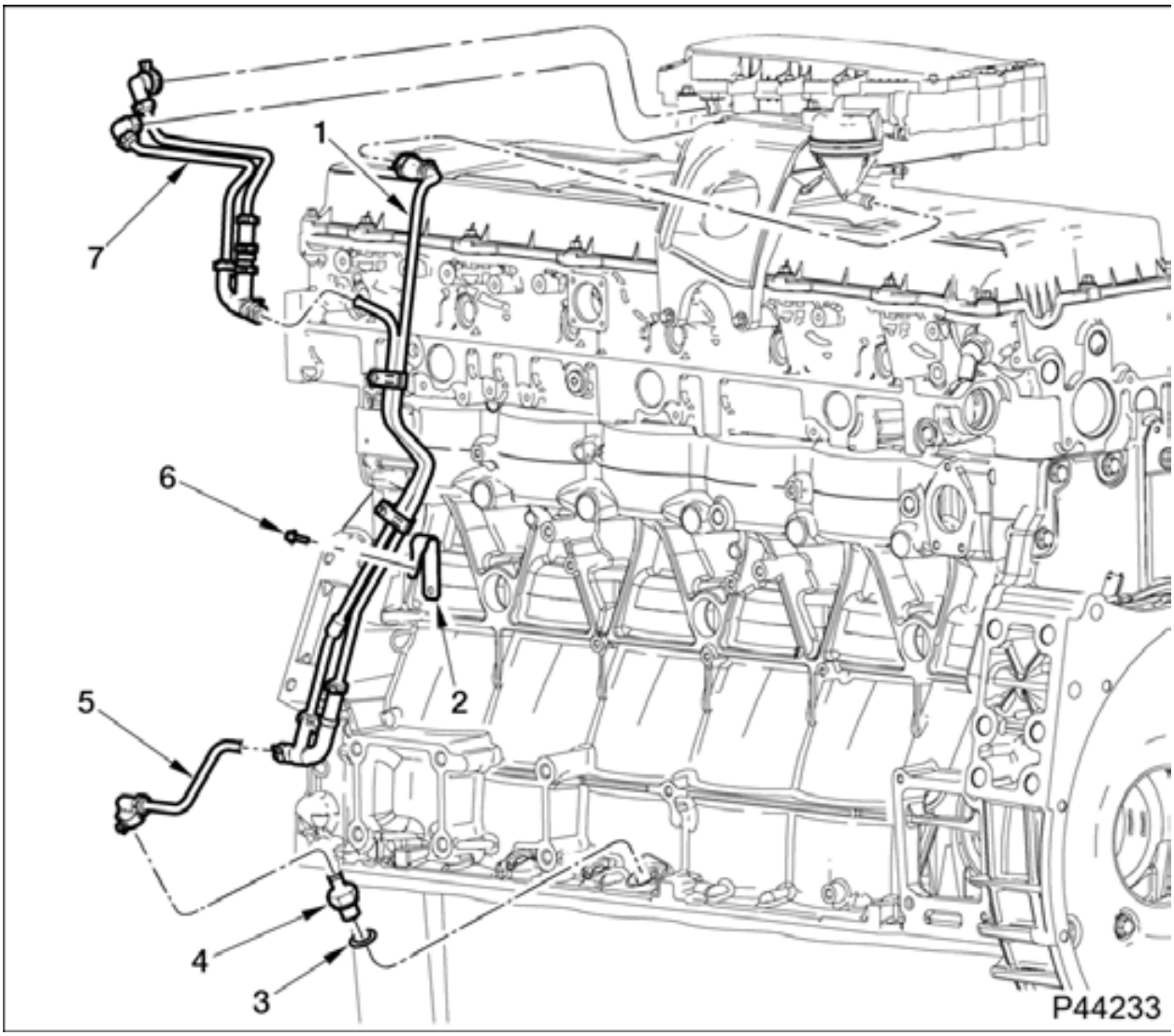

Figure 373 Crankcase ventilation return breather tubes

1. Middle tube assembly
2. Support tube assembly
3. BS-26.7 x 34.9 seal
4. M26 x 1.5 threaded union
5. Lower tube assembly
6. M6 x 16 hex bolt
7. Upper tube assembly

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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 the transmission to park or neutral, set the parking brake, and block the wheels before doing diagnostic or service procedures.

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

WARNING: To prevent personal injury or death, remove the ground cable from the negative terminal of the main battery before disconnecting or connecting electrical components. Always connect the ground cable last.

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: Refer to the following service sections for information on removal of components prior to this section.

- Engine Electrical
- Turbochargers
- Fuel System

Oil Filter Element

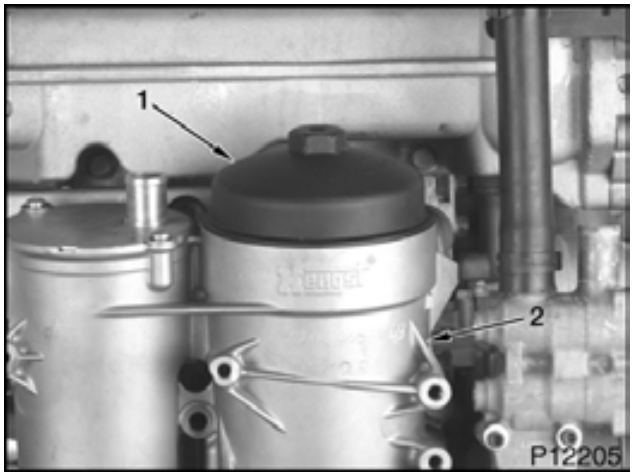

Figure 374 Oil filter cover

1. Oil filter cover
2. Oil module

1. Unscrew oil filter cover from oil module.
2. Pull oil filter element off oil filter cover.
3. Remove and discard O-ring seal.

Engine Oil Temperature (EOT)/Engine Oil Pressure (EOP) Sensors

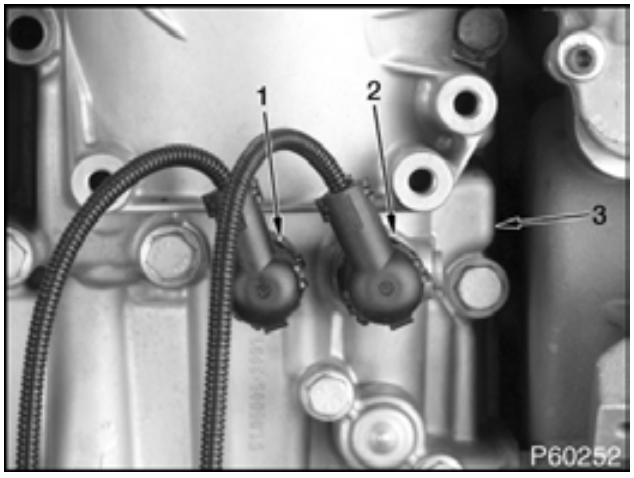

Figure 375 EOT/EOP sensor adapter lines (electrical connections)

1. EOT sensor adapter line
2. EOP sensor adapter line
3. Oil module

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NOTE: If replacing just the EOT sensor, disconnect only the EOT sensor adapter line. If replacing just the EOP sensor, disconnect only the EOP sensor adapter line.

1. Rotate connector locking nuts 1/4 turn counterclockwise, disconnect and remove EOT and EOP sensor adapter lines.

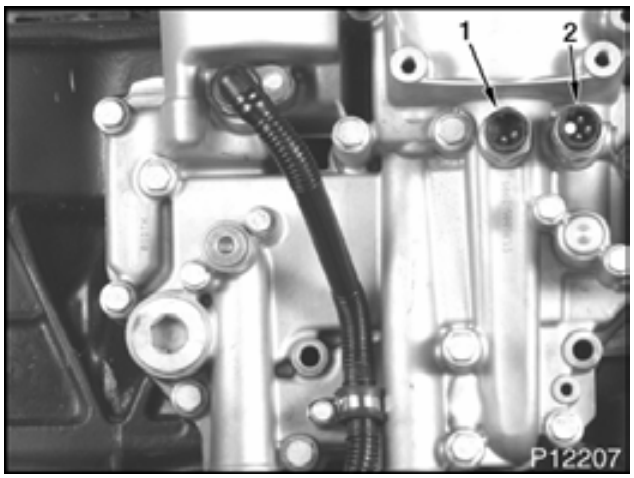

Figure 376 EOP and EOT sensors

1. EOT sensor
2. EOP sensor

NOTE: If replacing just the EOT sensor, remove only the EOT sensor. If replacing just the EOP sensor, remove only the EOP sensor.

2. Remove EOT and EOP sensors and BS-16.7 x 24.0 O-ring seal. Replace O-ring seal if damaged or leaking.

Oil Module Breather Cup

NOTE: Perform this procedure only if breather cup shows signs of leakage.

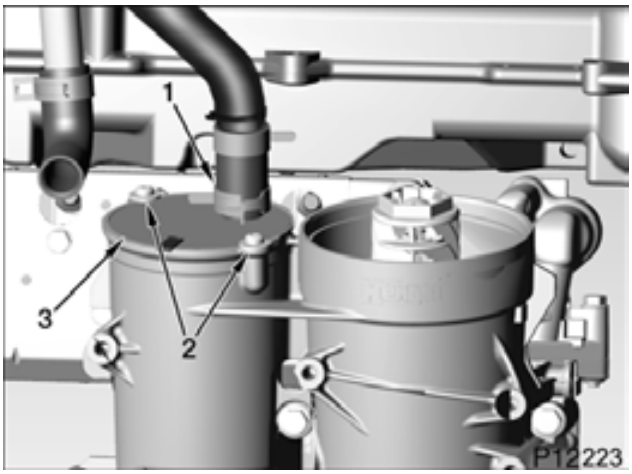

Figure 377 Breather cup

1. Clamp
2. M6 bolt with washer (2)
3. Breather cup

1. Release clamp and disconnect breather inlet tube assembly from breather cup.
2. Remove two M6 bolts with washers.
3. Remove breather cup and O-ring seal. Discard O-ring seal if damaged or leaking.

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Oil Module

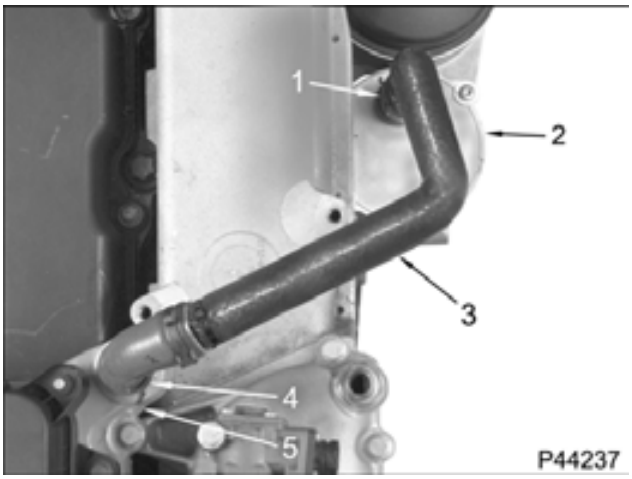

Figure 378 Breather inlet tube assembly

1. Clamp
2. Breather cup
3. Breather inlet tube assembly
4. Clamp
5. Service breather assembly bracket

NOTE: Perform next step if breather cup was not previously removed.

1. Release clamp and disconnect breather inlet tube assembly from oil module.
2. Release clamp, disconnect breather inlet tube assembly from service breather assembly bracket, and remove breather inlet tube assembly.

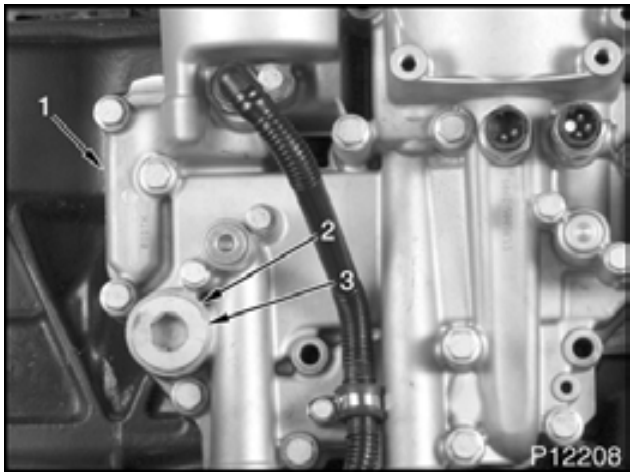

Figure 379 Draining coolant from oil module

1. Oil module
2. Plug seal
3. M38 x 1.5 plug

CAUTION: To prevent engine damage, drain all coolant from oil module before removing oil module. If coolant enters the oil sump, oil contamination will occur and the oil pan will have to be drained.

3. Remove M38 x 1.5 plug from oil module and drain coolant. Discard old plug seal.
4. Install M38 x 1.5 plug and new plug seal. Tighten to special torque (page 247).

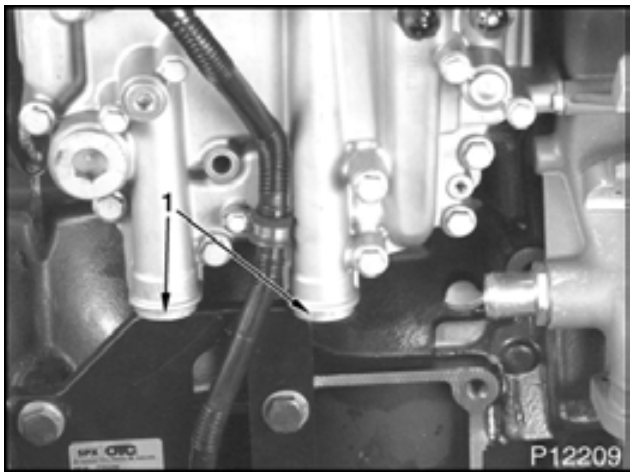

Figure 380 Draining residual oil from oil module

1. M33 x 2 plug (2)

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WARNING: To prevent personal injury or death, dispose of oil or discard components, according to applicable regulations.

5. Remove two M33 x 2 plugs from oil module and drain residual oil. Discard two plug seals.
6. Install two M33 x 2 plugs with two new plug seals. Tighten to special torque (page 247).

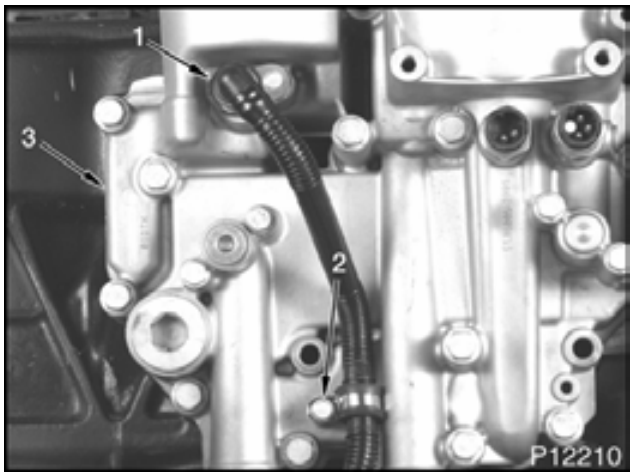

Figure 381 Oil return tube to oil module

1. Oil return tube
2. M6 x 18 hex bolt
3. Oil module

7. Squeeze tabs on oil return tube and disconnect from straight fitting on oil module.
8. Remove M6 x 18 hex bolt and oil return tube.

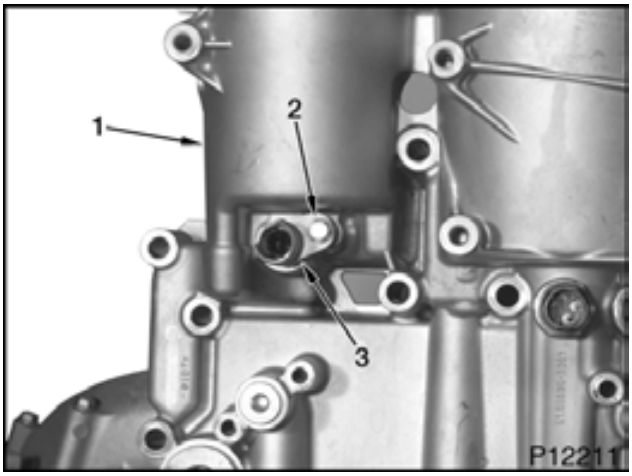

Figure 382 Straight fitting

1. Oil module
2. M6 x 18 hex bolt
3. Straight fitting

9. Remove M6 x 18 hex bolt.
10. Remove straight fitting from oil module. Inspect O-ring seal. Discard if damaged.

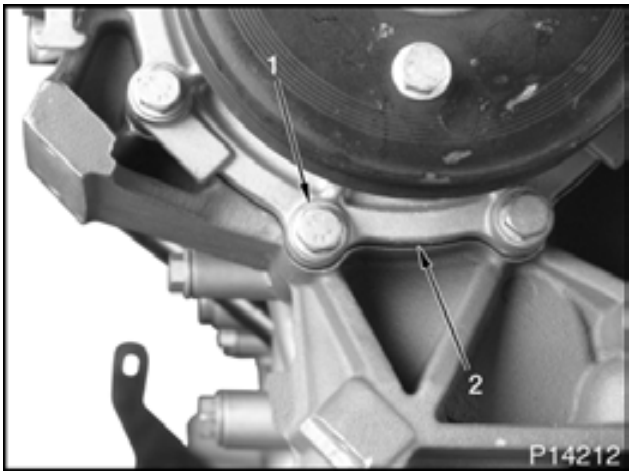

Figure 383 Water pump bolt

1. M8 x 130 hex bolt
2. Water pump

11. Remove M8 x 130 hex bolt from water pump.

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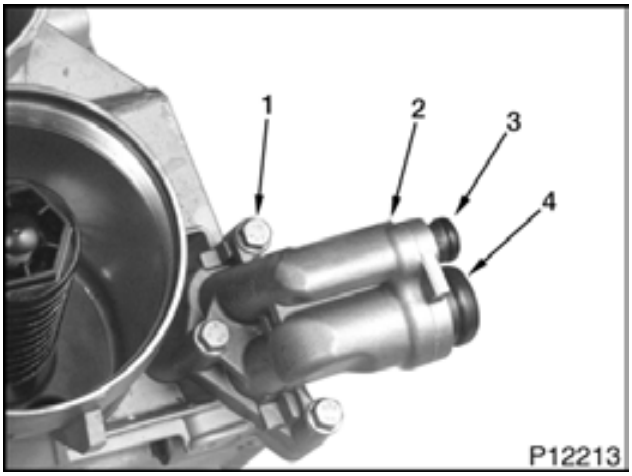

Figure 384 Flange elbow and DMR20/DN14 and DMR37/DN29 extension tubes

1. M8 x 50 hex bolt (3)
2. Flange elbow
3. DMR20/DN14 extension tube
4. DMR37/DN29 extension tube

12. Remove three M8 x 50 hex bolts and flange elbow. Discard gasket for flange elbow.
13. Without removing the DMR20/DN14 and DMR37/DN29 extension tubes, inspect tubes for damage or signs of oil leakage.
    - If tubes are not damaged or have no signs of oil leakage, cover tubes and set aside.
    - If tubes are damaged or show signs of oil leakage, remove and discard tubes.

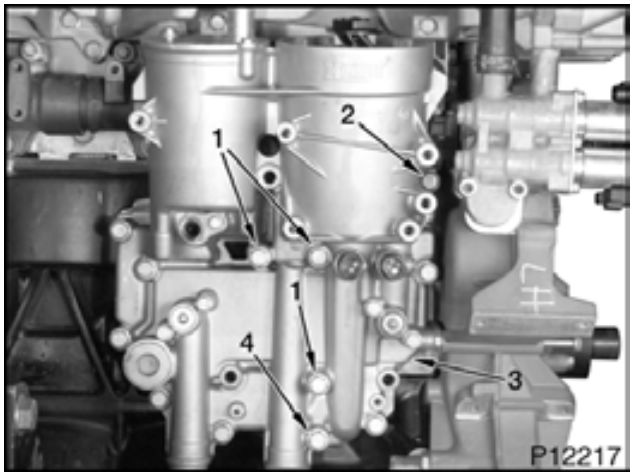

Figure 385 Oil module

1. M10 x 130 hex bolt (3)
2. M10 x 80 hex bolt (8)
3. Oil module
4. M10 x 110 hex bolt

14. Remove eight M10 x 80 hex bolts, three M10 x 130 hex bolts and one M10 x 110 hex bolt.
15. Remove oil module and 26 x 48 x 1.0 gasket from engine.

Oil Pressure Relief Valve

NOTE: Perform this procedure if replacing oil pressure relief valve or if engine has oil pressure related issues.

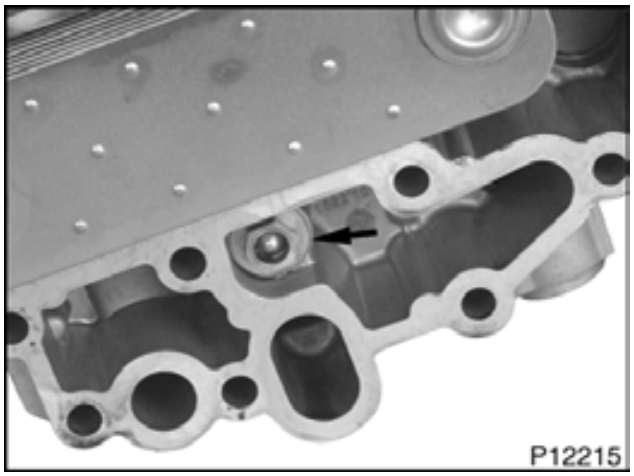

Figure 386 Oil pressure relief valve

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1. Remove oil pressure relief valve. Clean and inspect oil pressure relief valve.

Oil Cooler

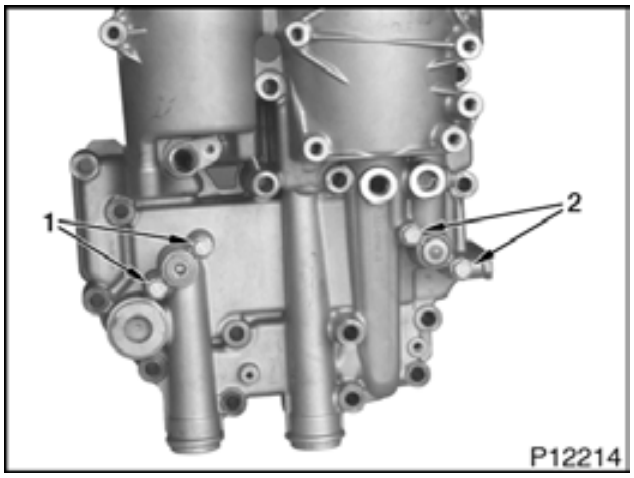

Figure 387 Oil cooler

1. M8 x 55 hex bolt (2)
2. M8 x 80 hex bolt (2)

1. Remove two M8 x 55 and two M8 x 80 hex bolts.
2. Remove oil cooler and gaskets from oil module. Discard gaskets.

Oil Module M10 x 1.0 Plug

NOTE: Remove M10 x 1.0 plug only if the plug shows signs of leakage.

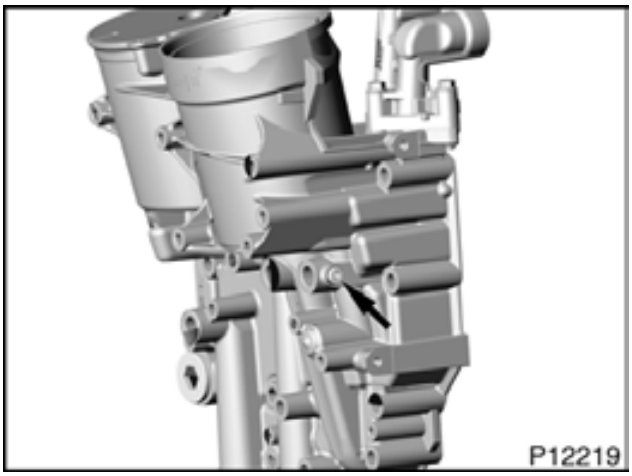

Figure 388 M10 x 1.0 Plug

1. Remove M10 x 1.0 plug and seal. Inspect seal and discard if damaged.

Service Breather Assembly

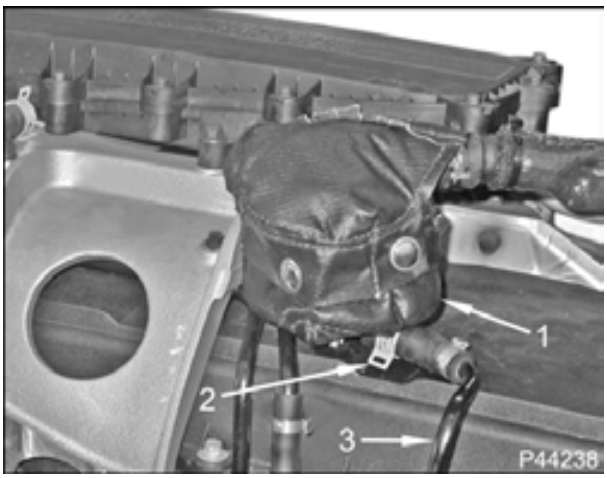

Figure 389 Middle tube assembly connection to cyclone breather

1. Cyclone breather (with housing insulation)
2. Clamp
3. Middle tube assembly

1. Release clamp and disconnect middle tube assembly from cyclone breather.

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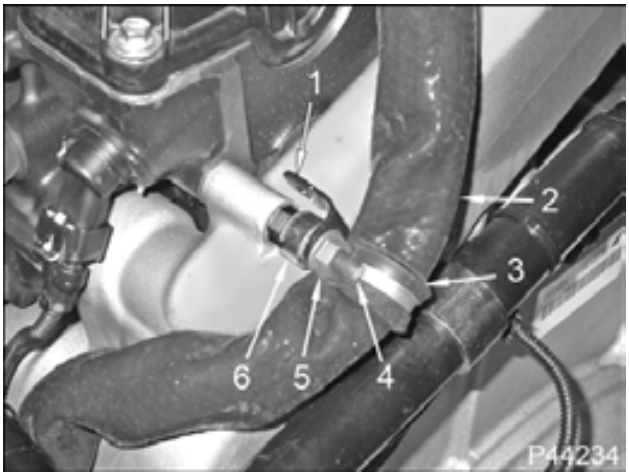

Figure 390 P-clamp and mounting hardware for breather outlet tube and heater assembly

1. HPCAC hose bracket
2. Breather outlet tube and heater assembly
3. P-clamp
4. M8 x 45 x 30 stud bolt
5. M8 hex nut
6. 10 mm spacer

2. Remove M8 hex nut from M8 x 45 x 30 stud bolt.
3. Remove Breather outlet tube and heater assembly, secured with P-clamp, from M8 x 45 x 30 stud bolt.
4. Remove HPCAC hose bracket and 10 mm spacer.

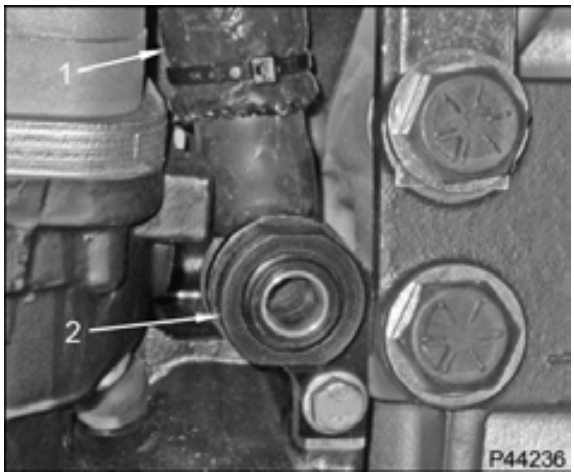

Figure 391

1. Breather outlet tube and heater assembly
2. Breather heater nut

5. Remove breather heater nut from breather outlet heater assembly.
6. Disconnect heater connector.
7. Remove breather outlet tube and heater assembly.

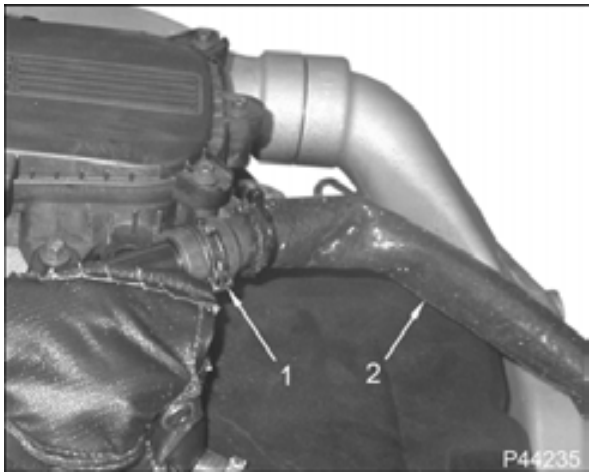

Figure 392 Breather outlet tube and heater assembly

1. Clamp
2. Breather outlet tube and heater assembly

8. Disconnect Breather outlet tube and heater assembly from cyclone breather.

Figure 393 Cyclone breather

1. M6 x 35 hex bolt
2. Cyclone breather (with housing insulation)

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9. Remove M6 x 35 hex bolt.
10. Remove cyclone breather (with housing insulation)
11. Unsnap and remove housing insulation from cyclone breather.

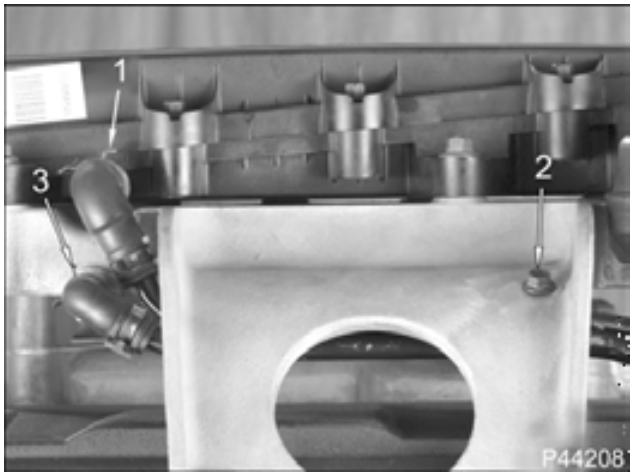

Figure 394 Upper tube assembly connections to service breather assembly

1. Clamp
2. M6 x 35 hex bolt
3. Clamp

12. Remove M6 x 35 hex bolt from service breather assembly bracket.
13. Release clamp and disconnect upper tube assembly from service breather assembly.
14. Release clamp and disconnect upper tube assembly from M12 straight fitting on service breather assembly bracket.

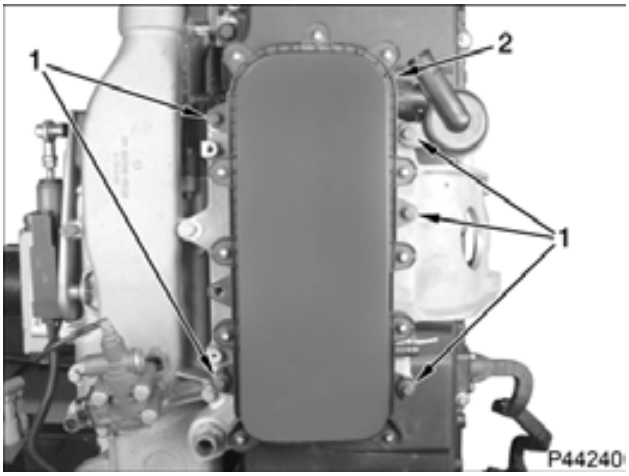

Figure 395 Service breather assembly

1. M8 x 35 hex bolt (5)
2. Service breather assembly

15. Remove five M8 x 35 hex bolts and service breather assembly.

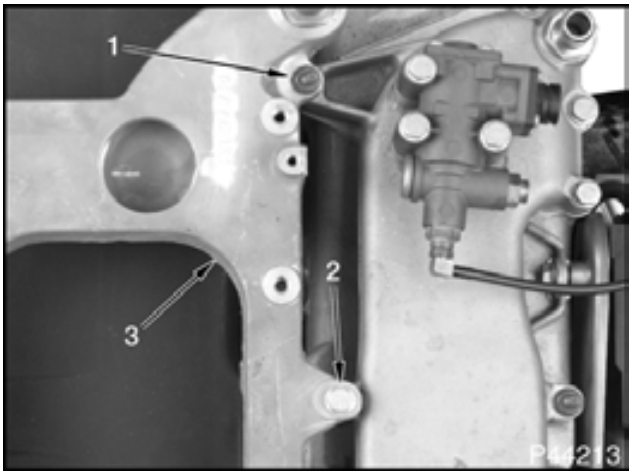

Figure 396 Service breather assembly bracket

1. M8 hex nut
2. M8 x 35 hex bolt
3. Service breather assembly bracket

16. Remove M8 hex nut, M8 x 35 hex bolt and remove service breather assembly bracket.

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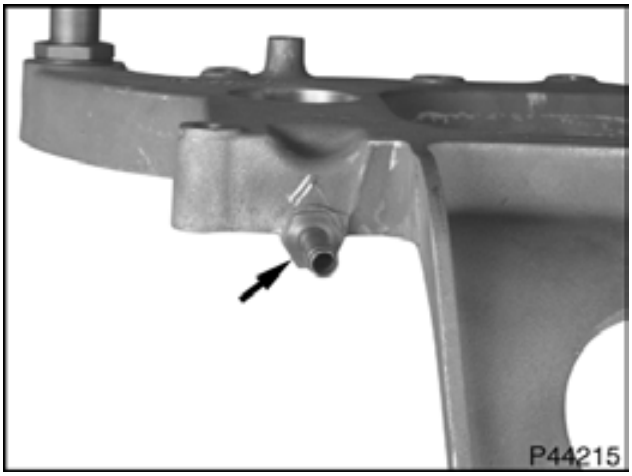

Figure 397 Service breather assembly bracket M12 straight fitting

17. If M12 straight fitting is leaking or if service breather assembly bracket is being replaced, remove M12 straight fitting.

Upper Tube Assembly

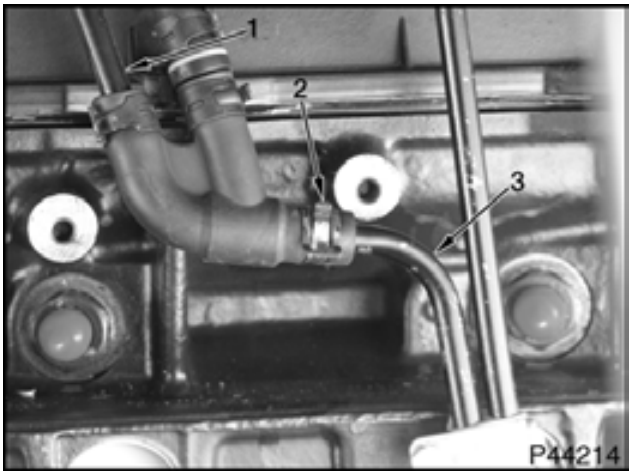

Figure 398 Upper tube assembly

1. Upper tube assembly
2. Clamp
3. Middle tube assembly

1. Release clamp, disconnect and remove upper tube assembly from middle tube assembly.

Middle Tube Assembly

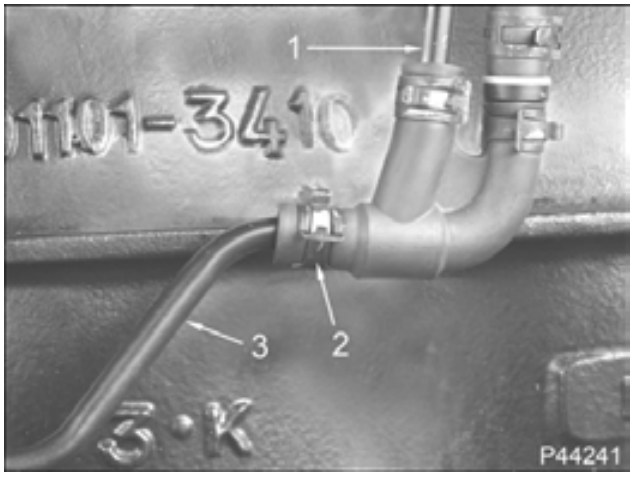

Figure 399 Middle tube assembly

1. Middle tube assembly
2. Clamp
3. Lower tube assembly

1. Release clamp, disconnect and remove middle tube assembly from lower tube assembly.

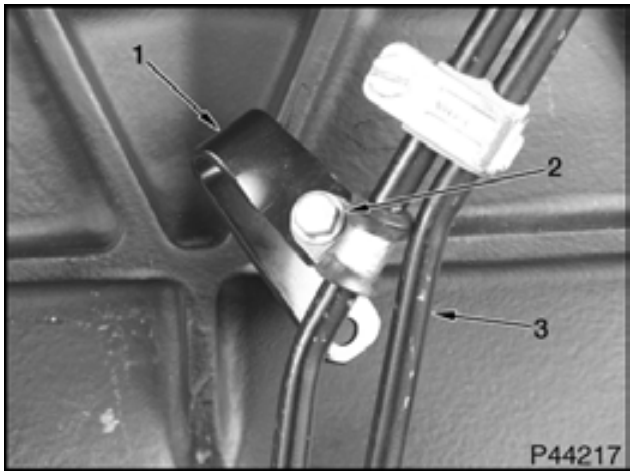

Figure 400 Support tube assembly

1. Support tube assembly
2. M6 x 16 hex bolt
3. Middle tube assembly

NOTE: Mark location of support bracket for correct orientation in relation to middle tube assembly.

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2. If middle tube assembly is being replaced, remove M6 x 16 hex bolt and support tube assembly.

Lower Tube Assembly

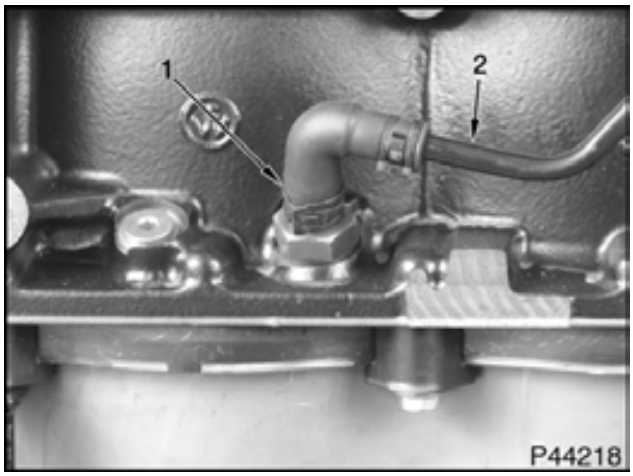

Figure 401 Lower tube assembly

1. Clamp
2. Lower tube assembly

1. Release clamp and disconnect lower tube assembly from M26 x 1.5 threaded union.

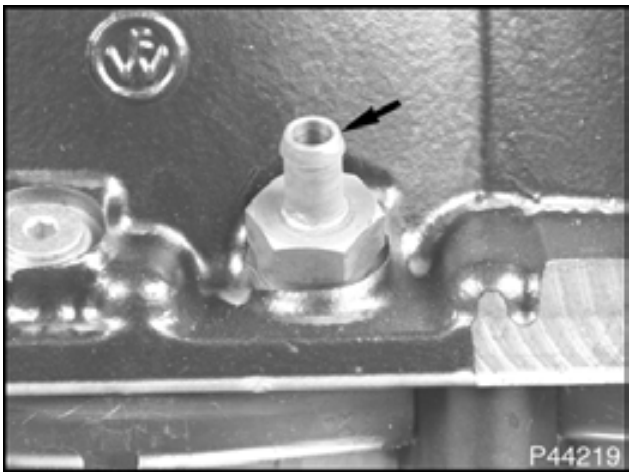

Figure 402 M26 x 1.5 threaded union

1. M26 x 1.5 threaded union

NOTE: Perform next step only if M26 x 1.5 threaded union or BS-26.7 x 34.9 seal is found to be leaking.

2. Remove M26 x 1.5 threaded union from crankcase. Discard BS-26.7 x 34.9 seal.

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Cleaning, Inspection, and Testing

Oil Cooler

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

CAUTION: To prevent engine damage, replace the oil cooler if an engine bearing fails. Bearing debris can not be removed from the oil cooler.

1. The oil cooler can be cleaned in solvent and dried with filtered compressed air.
   - Clean the oil cooler in a suitable solvent.
   - Flush and drain oil cooler to remove any residue. Dry components with filtered compressed air.

Oil Cooler Leak Test

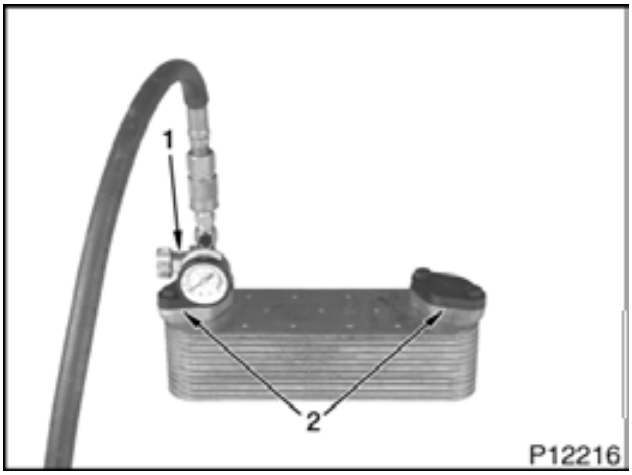

Figure 403 Oil cooler pressure test

1. Air pressure regulator
2. Oil Cooler Pressure Test Plates

1. Install Oil Cooler Pressure Test Plates (page 247) on oil cooler.
2. Attach an air pressure regulator (page 247) to oil cooler pressure test plate. Connect to compressed air supply and adjust air pressure to approximately 172 to 207 kPa (25 to 30 psi).
3. Immerse oil cooler in a large container of clean water.
4. Inspect oil cooler and test plates for leaks. If test plate fittings leak, tighten fittings and continue looking for leaks. Air bubbles at any location on the oil cooler indicate a leak. Replace oil cooler if leaking.

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

5. Dry oil cooler using filtered compressed air.

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Installation

Lower Tube Assembly

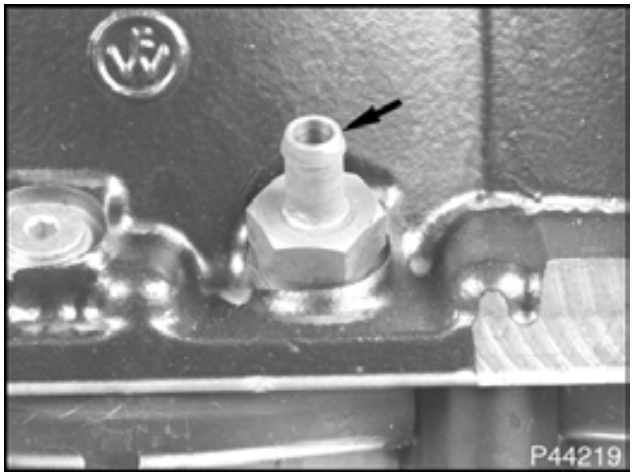

Figure 404 M26 x 1.5 threaded union

NOTE: Perform next step only if M26 x 1.5 threaded union or BS-26.7 x 34.9 seal were removed.

1. Install M26 x 1.5 threaded union and BS-26.7 x 34.9 seal into crankcase. Tighten union to special torque (page 247).

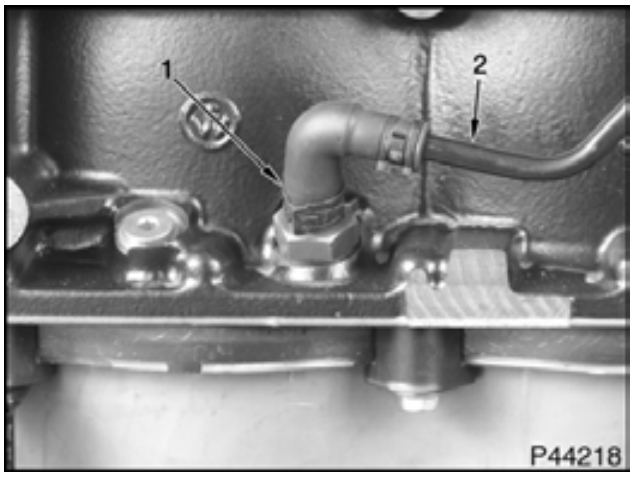

Figure 405 Lower tube assembly

1. Clamp
2. Lower tube assembly

2. Position lower tube assembly and connect to M26 x 1.5 threaded union and install clamp.

Middle Tube Assembly

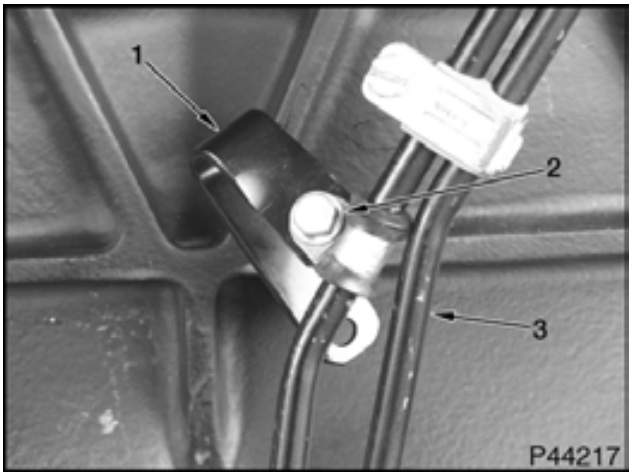

Figure 406 Support tube assembly

1. Support tube assembly
2. M6 x 16 hex bolt
3. Middle tube assembly

1. If middle tube assembly was replaced, transfer orientation mark from support bracket to new middle tube assembly for correct orientation. Install M6 x 16 hex bolt. Tighten hex bolt to standard torque (page 457).

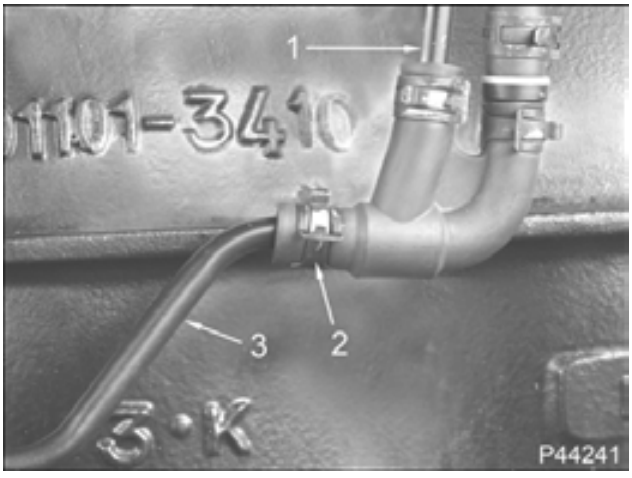

Figure 407 Middle tube assembly

1. Middle tube assembly
2. Clamp
3. Lower tube assembly

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2. Position middle tube assembly and connect to lower tube assembly and install clamp.

Upper Tube Assembly

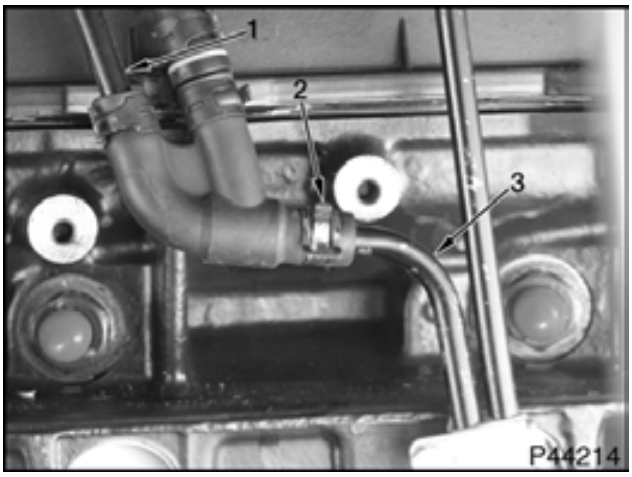

Figure 408 Upper tube assembly

1. Upper tube assembly
2. Clamp
3. Middle tube assembly

1. Position upper tube assembly and connect to middle tube assembly and install clamp.

Service Breather Assembly

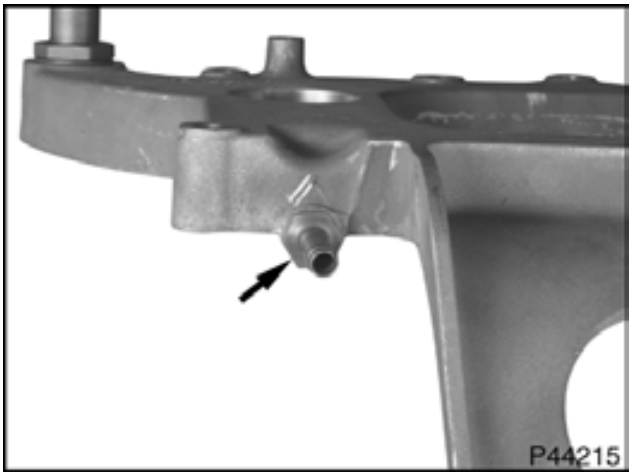

Figure 409 Service breather assembly bracket M12 straight fitting

1. If service breather assembly bracket was replaced or the M12 straight fitting was leaking, install M12 straight fitting. Tighten straight fitting to special torque (page 247).

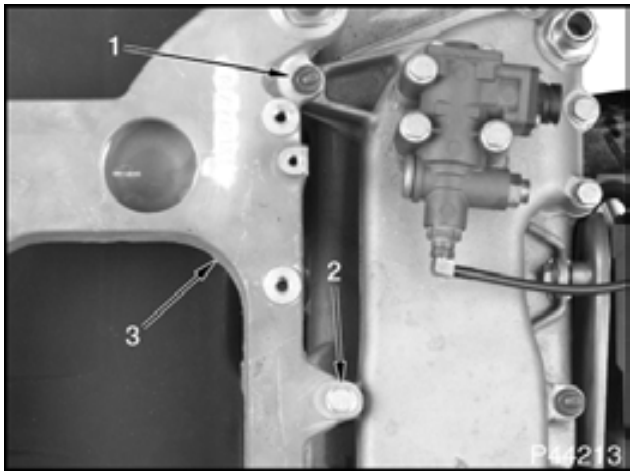

Figure 410 Service breather assembly bracket

1. M8 hex nut
2. M8 x 35 hex bolt
3. Service breather assembly bracket

2. Install service breather assembly bracket, M8 x 35 hex bolt, and M8 hex nut. Tighten hex bolt and hex nut to standard torque (page 457).

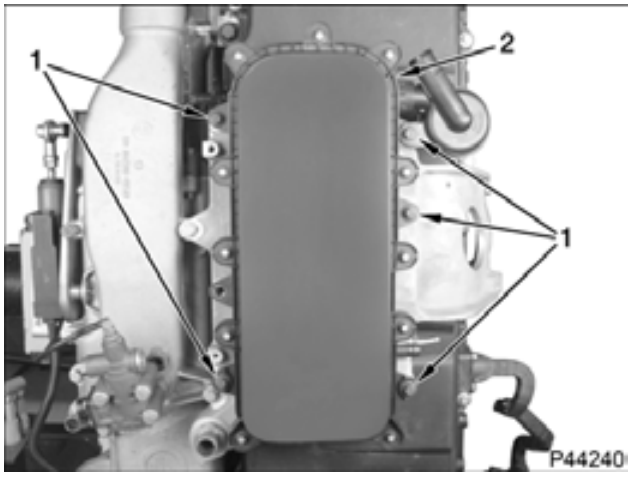

Figure 411 Service breather assembly

1. M8 x 35 hex bolt (5)
2. Service breather assembly

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3. Install service breather assembly and five M8 x 35 hex bolts. Tighten hex bolts to standard torque (page 457).

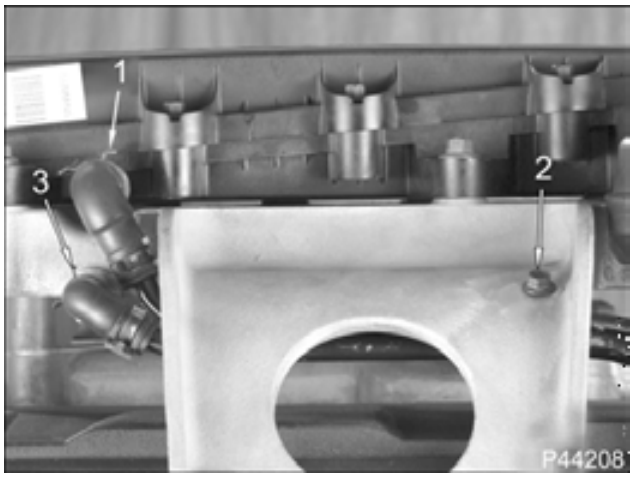

Figure 412 Upper tube assembly connection to service breather assembly

1. Clamp
2. M6 hex bolt
3. Clamp

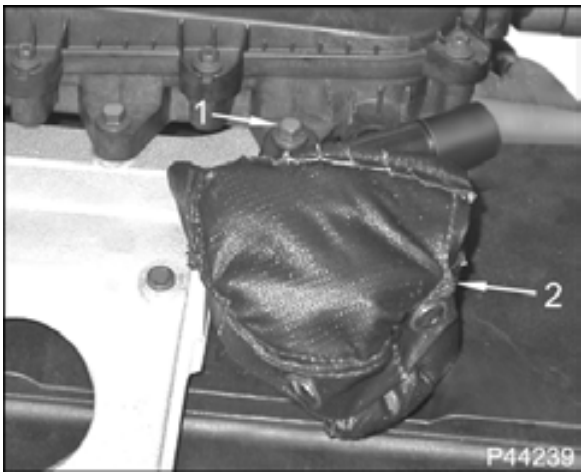

Figure 413 Cyclone breather

1. M6 x 35 hex bolt
2. Cyclone breather (with housing insulation)

4. Install cyclone breather insulation.
5. Insert cyclone breather and install M6 x 35 hex bolt.
6. Tighten M6 x 35 hex bolt to standard torque (page 457).

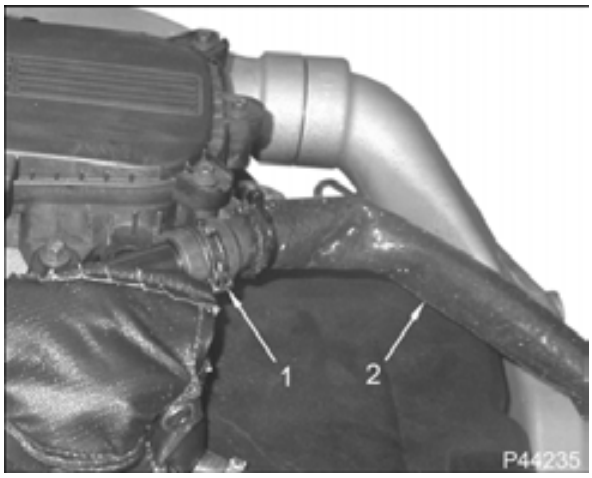

Figure 414 Breather outlet tube and heater assembly

1. Clamp
2. Breather outlet tube and heater assembly

7. Connect breather outlet tube and heater assembly to cyclone breather.

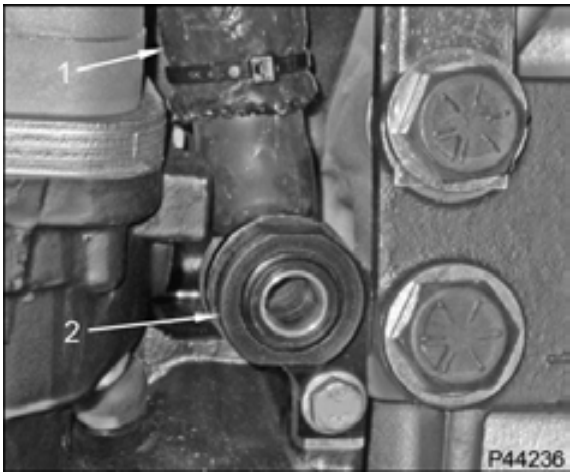

Figure 415

1. Breather outlet tube and heater assembly
2. Breather heater nut

8. Connect heater connector.
9. Install breather heater nut from breather outlet heater assembly.

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10. Tighten breather heater nut to special torque (page 247).

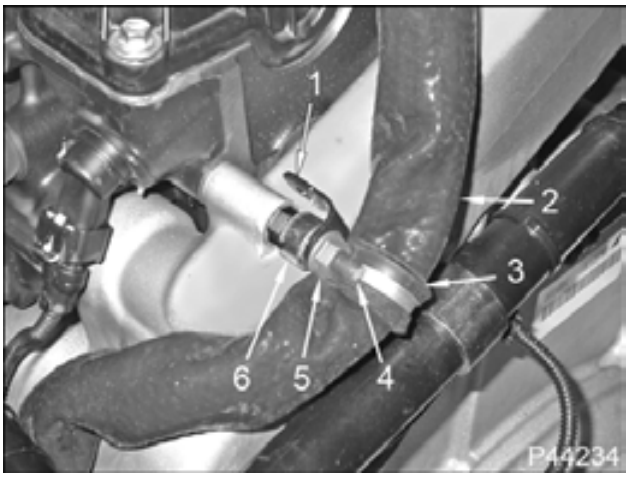

Figure 416 P-clamp and mounting hardware for breather outlet tube and heater assembly

1. HPCAC hose bracket
2. Breather outlet tube and heater assembly
3. P-clamp
4. M8 x 45 x 30 stud bolt
5. M8 hex nut
6. 10 mm spacer

11. Install 10 mm spacer and HPCAC hose bracket and onto M8 x 45 x 30 stud bolt.
12. Install P-clamp onto M8 x 45 x 30 stud bolt.
13. Install M8 hex nut and tighten to standard torque (page 457).
14. Connect upper tube assembly to service breather assembly and install clamp.
15. Connect upper tube assembly to M12 straight fitting on service breather assembly bracket and install clamp.
16. Install M6 x 35 hex bolt through service breather assembly bracket and into upper tube assembly bracket. Tighten hex bolt to standard torque (page 457).

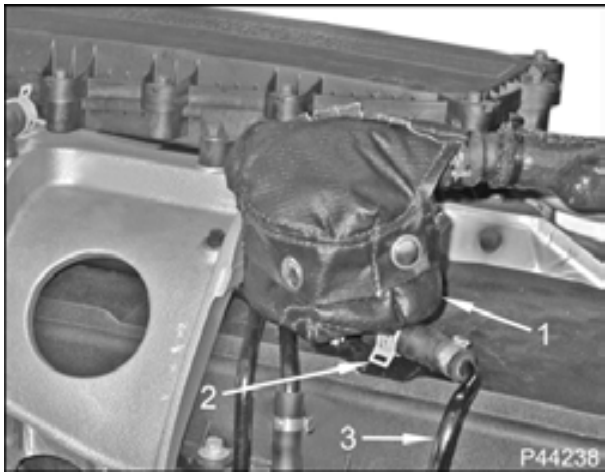

Figure 417 Middle tube assembly connection to cyclone filter

1. Cyclone breather (with housing insulation)
2. Clamp
3. Middle tube assembly

17. Connect middle tube assembly to cyclone breather and install clamp.

Oil Cooler

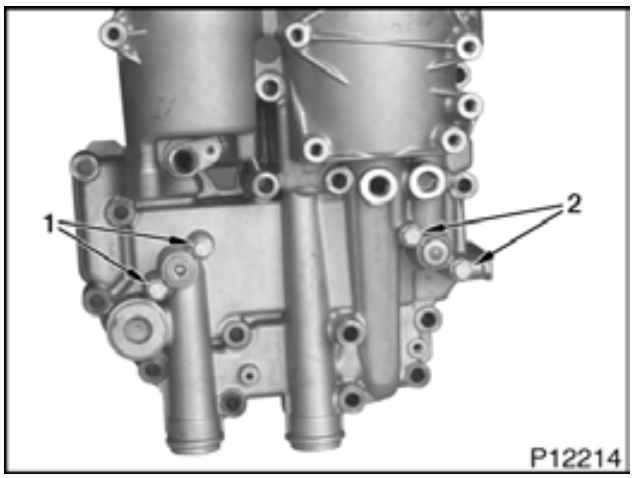

Figure 418 Oil cooler

1. M8 x 55 hex bolt (2)
2. M8 x 80 hex bolt (2)

1. Install oil cooler and new gaskets into oil module.
2. Install two M8 x 55 and two M8 x 80 hex bolts . Tighten hex bolts to special torque (page 247).

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Oil Module M10 x 1.0 Plug

NOTE: Perform this procedure if M10 x 1.0 plug was removed.

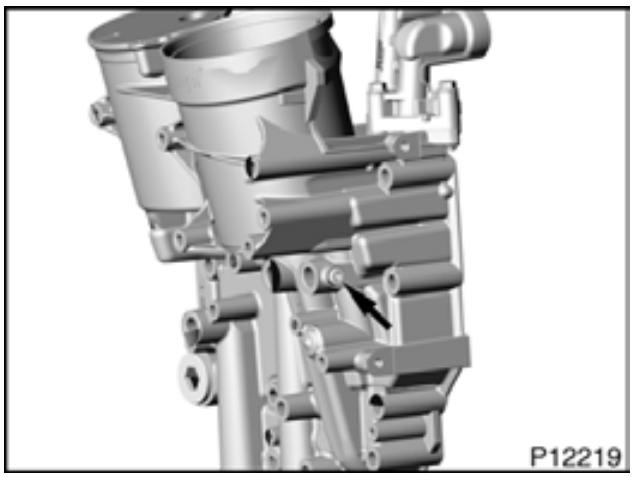

Figure 419 M10 x 1.0 Plug

1. Install new seal onto M10 x 1.0 plug. Lube new seal with clean engine oil. Tighten plug to special torque (page 247).

Oil Pressure Relief Valve

NOTE: Perform this procedure if oil pressure relief valve was replaced or removed.

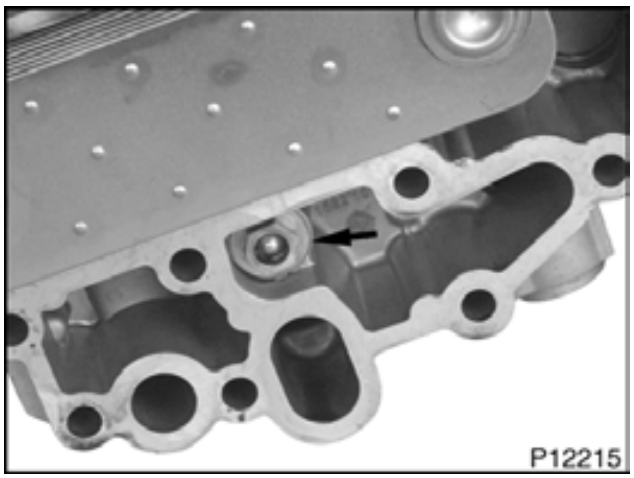

Figure 420 Oil pressure relief valve

1. Install oil pressure relief valve. Tighten valve to special torque (page 247).

Oil Module

1. Position new 26 x 48 x 1.0 gasket onto oil module.

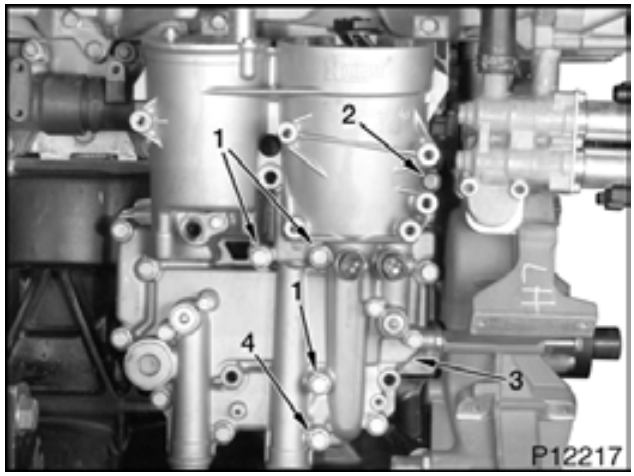

Figure 421 Oil module

1. M10 x 130 hex bolt (3)
2. M10 x 80 hex bolt (8)
3. Oil module
4. M10 x 110 hex bolt

2. Position oil module and loosely install eight M10 x 80 hex bolts, three M10 x 130 hex bolts and one M10 x 110 hex bolt. Do not tighten bolts at this time.

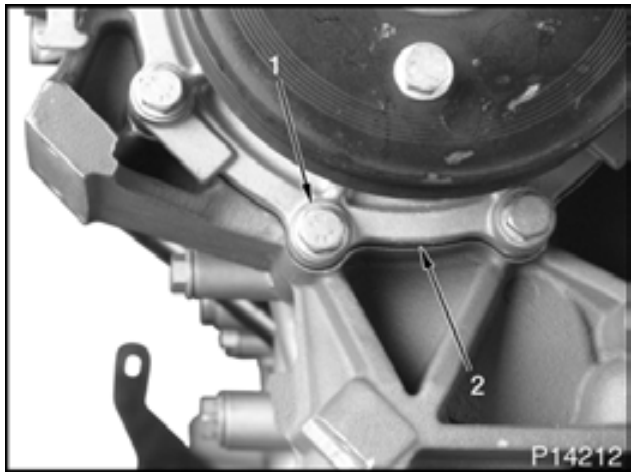

Figure 422 Water pump bolt

1. M8 x 130 hex bolt
2. Water pump

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CAUTION: To prevent engine damage, tighten water pump hex bolt before the other oil module hex bolts. Damage to oil module housing may occur if the water pump hex bolt is not tightened first.

3. Install M8 x 130 hex bolt to water pump. Tighten hex bolt to special torque (page 247).

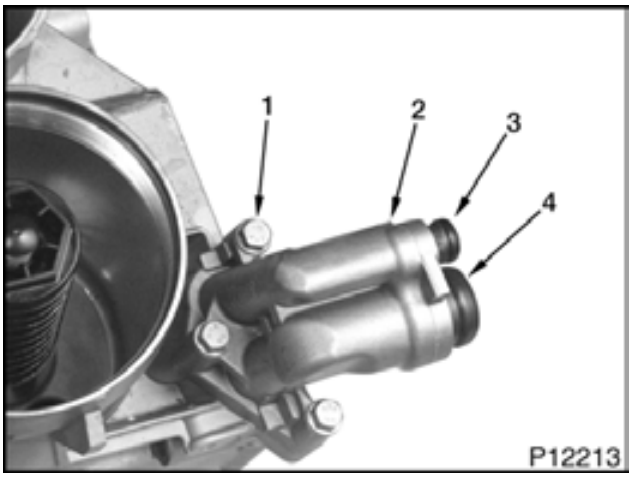

Figure 423 Flange elbow and DMR20/DN14 and DMR37/DN29 extension tubes

1. M8 x 50 hex bolt (3)
2. Flange elbow
3. DMR20/DN14 extension tube
4. DMR37/DN29 extension tube

4. If DMR20/DN14 and DMR37/DN29 extension tubes were removed, lubricate sealing surfaces of new DMR20/DN14 and DMR37/DN29 extension tubes that fit into the flange elbow.
5. Install new DMR20/DN14 and DMR37/DN29 extension tubes into flange elbow.
6. Lubricate the ends of DMR20/DN14 and DMR37/DN29 extension tubes that fit into the crankcase, with P-80® Rubber Lubricant or equivalent (page 247).
7. Position extension tube in flange elbow with holes in the crankcase and push flange elbow into holes in the crankcase to engage extension tubes.
8. Put a new gasket between the flange elbow and the oil module gasket surface and install three M8 x 50 hex bolts.
9. Tighten three M8 x 50 hex bolts to special torque (page 247) to secure flange elbow.
10. Tighten eight M10 x 80 hex bolts, three M10 x 130 hex bolts and one M10 x 110 hex bolt to special torque (page 247) to secure oil module.

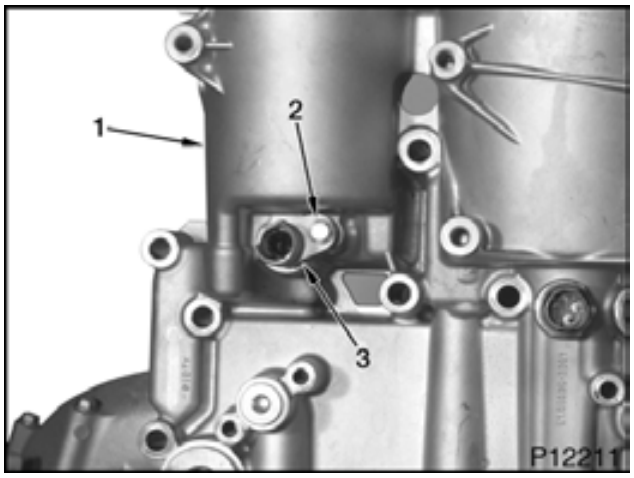

Figure 424 Straight fitting

1. Oil module
2. M6 x 18 hex bolt
3. Straight fitting

11. Install new O-ring seal onto straight fitting. Lube O-ring seal with clean engine oil. Install straight fitting into oil module.
12. Install M6 x 18 hex bolt. Tighten hex bolt to standard torque (page 457).

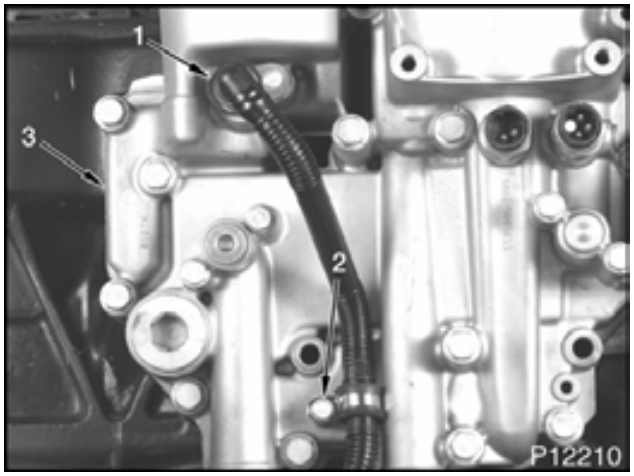

Figure 425 Oil return tube to oil module

1. Oil return tube connection
2. M6 x 18 hex bolt
3. Oil module

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13. Connect oil return tube onto straight fitting until an audible click is heard. Install M6 x 18 hex bolt. Tighten hex bolt to standard torque (page 457).

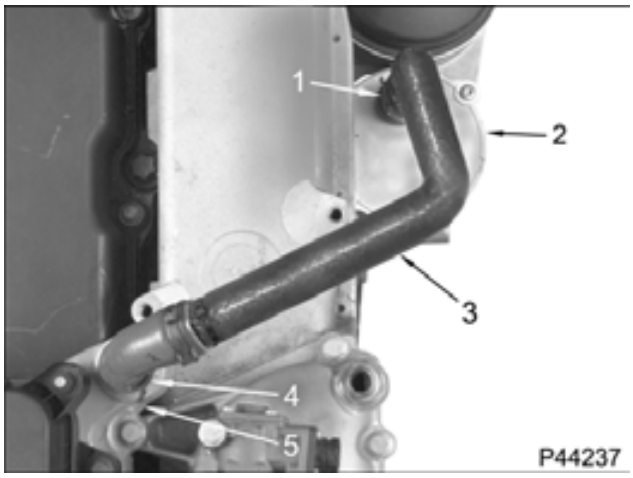

Figure 426 Breather inlet tube assembly

1. Clamp
2. Breather cup
3. Breather inlet tube assembly
4. Clamp
5. Service breather assembly bracket

NOTE: Perform next step if breather cup was not removed.

14. Connect breather inlet tube assembly to breather cup and install clamp.
15. Connect breather inlet tube assembly to service breather assembly bracket and install clamp.

Oil Module Breather Cup

NOTE: Perform this procedure only if breather cup was serviced due to signs of leakage.

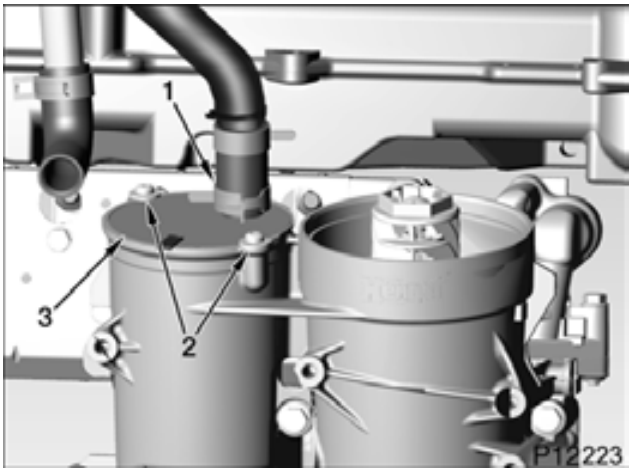

Figure 427 Oil module breather cup

1. Clamp
2. M6 bolt with washer (2)
3. Breather cup

1. Install breather cup and new O-ring seal. Lube new O-ring with clean engine oil.
2. Install two M6 bolts with washers. Tighten bolts with washers to standard torque (page 457).
3. Connect breather inlet tube assembly to oil module and install clamp.

Engine Oil Temperature (EOT)/Engine Oil Pressure (EOP) Sensors

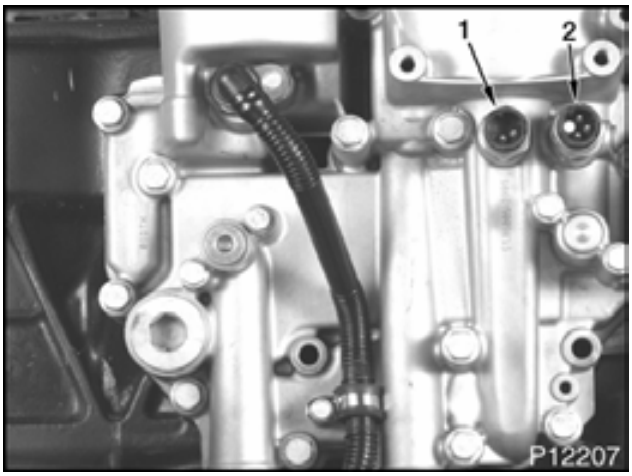

Figure 428 EOP and EOT sensors

1. EOT sensor
2. EOP sensor

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NOTE: If replacing just the EOT sensor, install only EOT sensor. If replacing just the EOP sensor, install only EOP sensor.

1. Install EOT and EOP sensors and new BS-16.7 x 24.0 O-ring seal. Lube O-ring seal with clean engine oil. Tighten sensors to special torque (page 247).

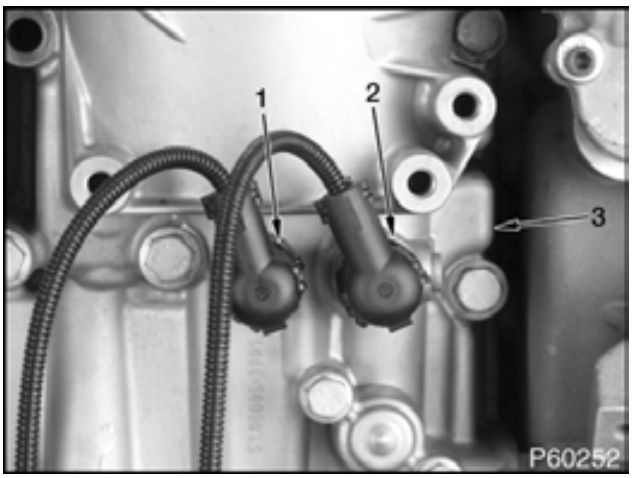

Figure 429 EOT/EOP sensor adapter lines (electrical connections)

1. EOT sensor adapter line
2. EOP sensor adapter line
3. Oil module

NOTE: If replacing just the EOT sensor, connect only EOT sensor adapter line. If replacing just the EOP sensor, connect only EOP sensor adapter line.

2. Connect EOT and EOP sensor adapter lines. Rotate the connector locking nuts 1/4 turn clockwise to secure adapter lines to EOT and EOP sensors.

Oil Filter Element

1. Install O-ring seal onto oil filter cover. Lube O-ring with clean engine oil.
2. Install oil filter element onto oil filter cover.

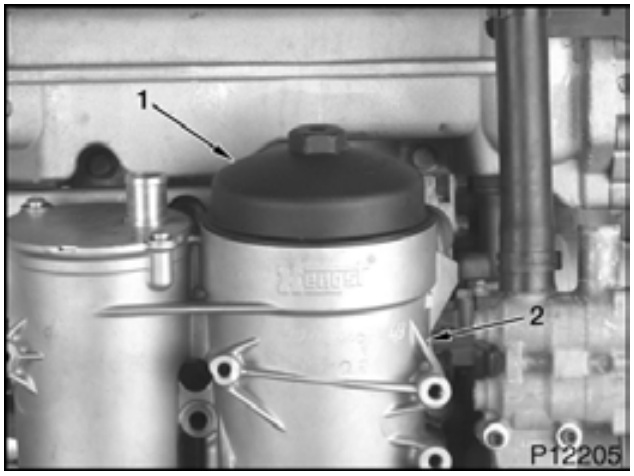

Figure 430 Oil filter cover

1. Oil filter cover
2. Oil module

3. Install oil filter element, O-ring seal and oil filter cover as an assembly into oil module. Tighten cover to special torque (page 247).

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Special Torque

Table 17 Oil Module and Breather System

Breather hex nut	2.8 N·m (25 lbf·in)
Engine Oil Pressure (EOP) sensor	47 N·m (35 lbf·ft)
Engine Oil Temperature (EOT) sensor	47 N·m (35 lbf·ft)
Oil cooler hex bolts	25 N·m (18 lbf·ft)
Oil filter cover	40 N·m (30 lbf·ft)
Oil module hex bolts	75 N·m (55 lbf·ft)
Oil pressure relief valve	40 N·m (30 lbf·ft)
M10 x 1.0 plug	75 N·m (55 lbf·ft)
M38 x 1.5 plug	80 N·m (59 lbf·ft)
M33 x 2 plugs	80 N·m (59 lbf·ft)
Flange elbow hex bolts	25 N·m (18 lbf·ft)
Water pump hex bolt	35 N·m (26 lbf·ft)
M26 x 1.5 threaded union	25 N·m (18 lbf·ft)
M12 straight fitting	25 N·m (18 lbf·ft)

Special Service Tools

Table 18 Oil Cooler

Description	Tool Number
Air Pressure Regulator	Obtain locally
Oil Cooler Pressure Test Plates	ZTSE4879
P-80®Rubber Lubricant or equivalent	Obtain locally

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Exploded Views

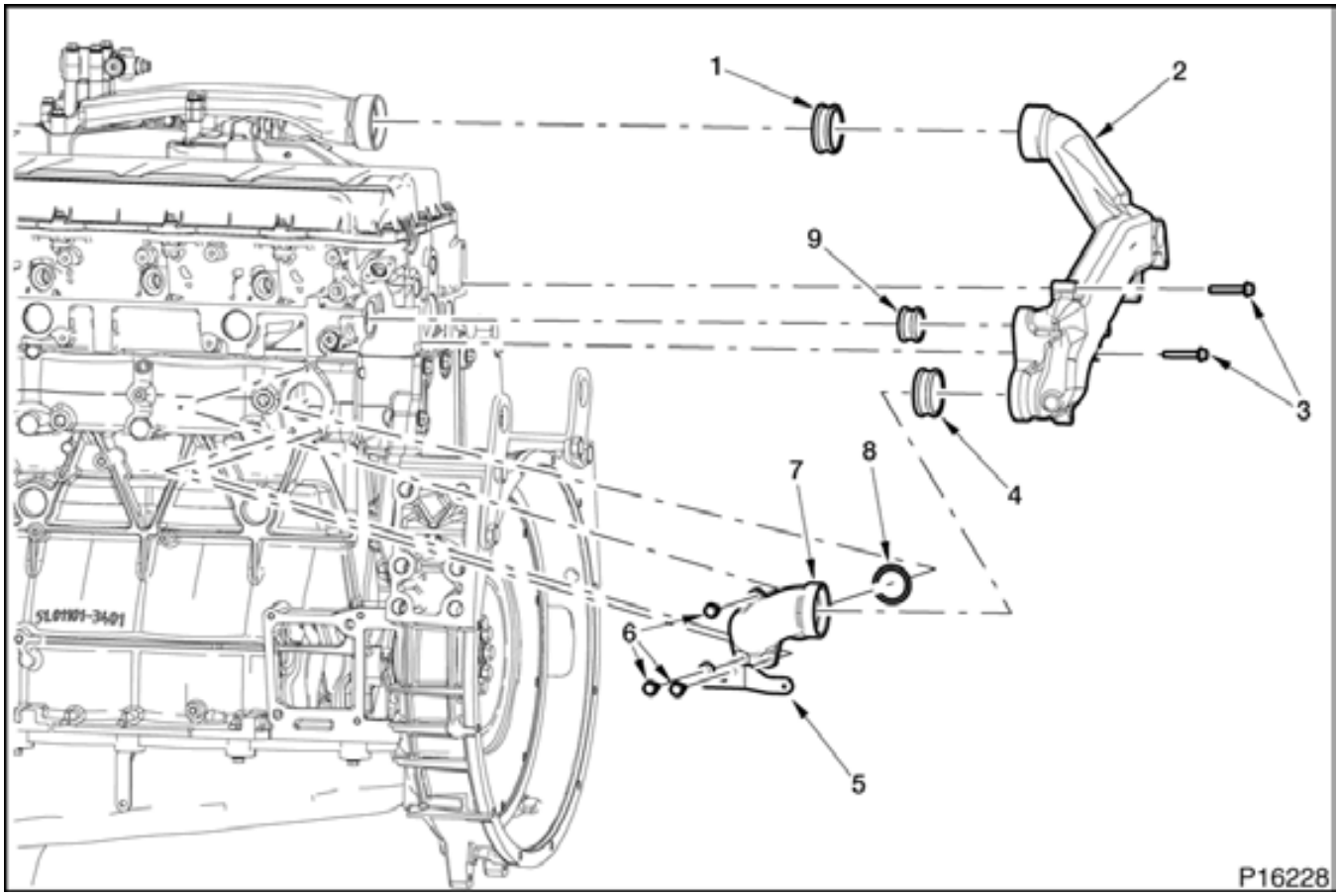

Figure 431 EGR system coolant elbows

1. DMR62/51 extension tube
2. Coolant elbow (middle)
3. M8 x 50 hex bolt (2)
4. DMR62/51 extension tube
5. Hydrocarbon Injection (HCI) supply bracket
6. M8 x 25 hex bolt (3)
7. Coolant elbow (lower)
8. 60 x 3 O-ring
9. DMR44/35 extension tube

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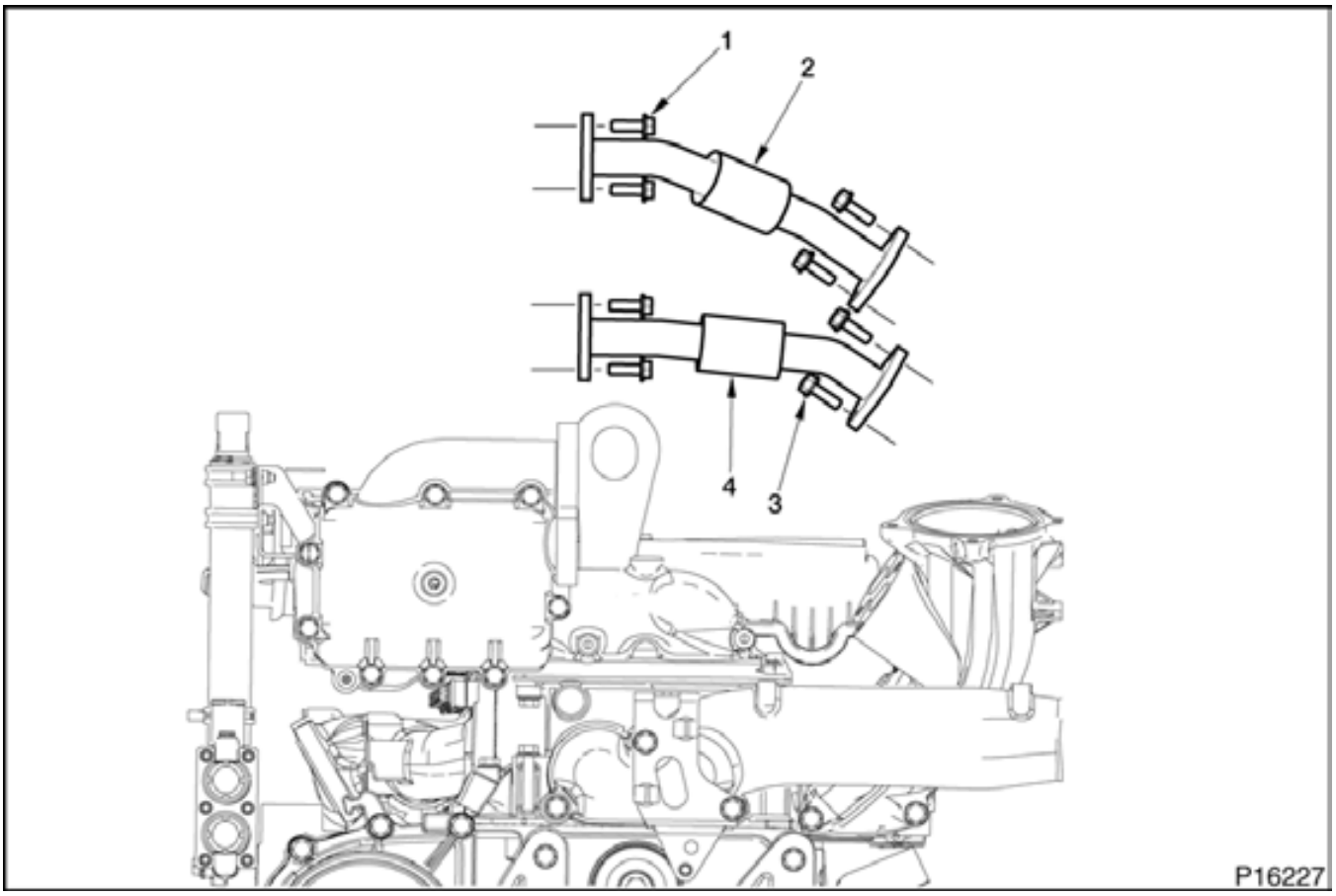

Figure 432 EGR tubes (front)

1. M8 x 25 hex bolt (4)
2. Front inner tube
3. M8 x 25 hex bolt (4)
4. Front outer tube

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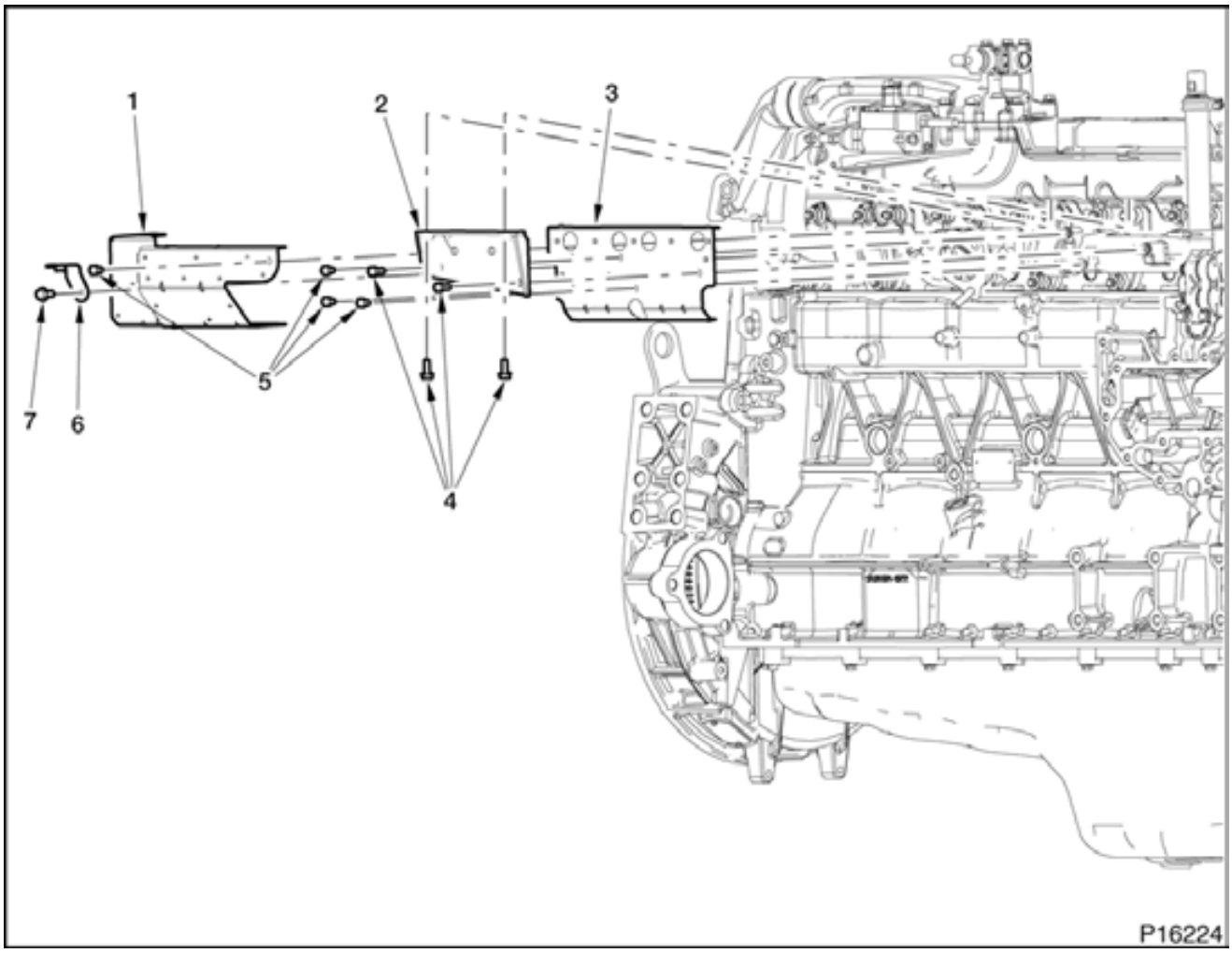

Figure 433 EGR system heat protection plates and bracket

1. Heat protection plate (rear)
2. Bracket
3. Heat protection plate (front)
4. M8 x 20 hex bolt (4)
5. M8 x 12 hex bolt (4)
6. Bracket for suction pipe
7. M8 x 20 hex bolt

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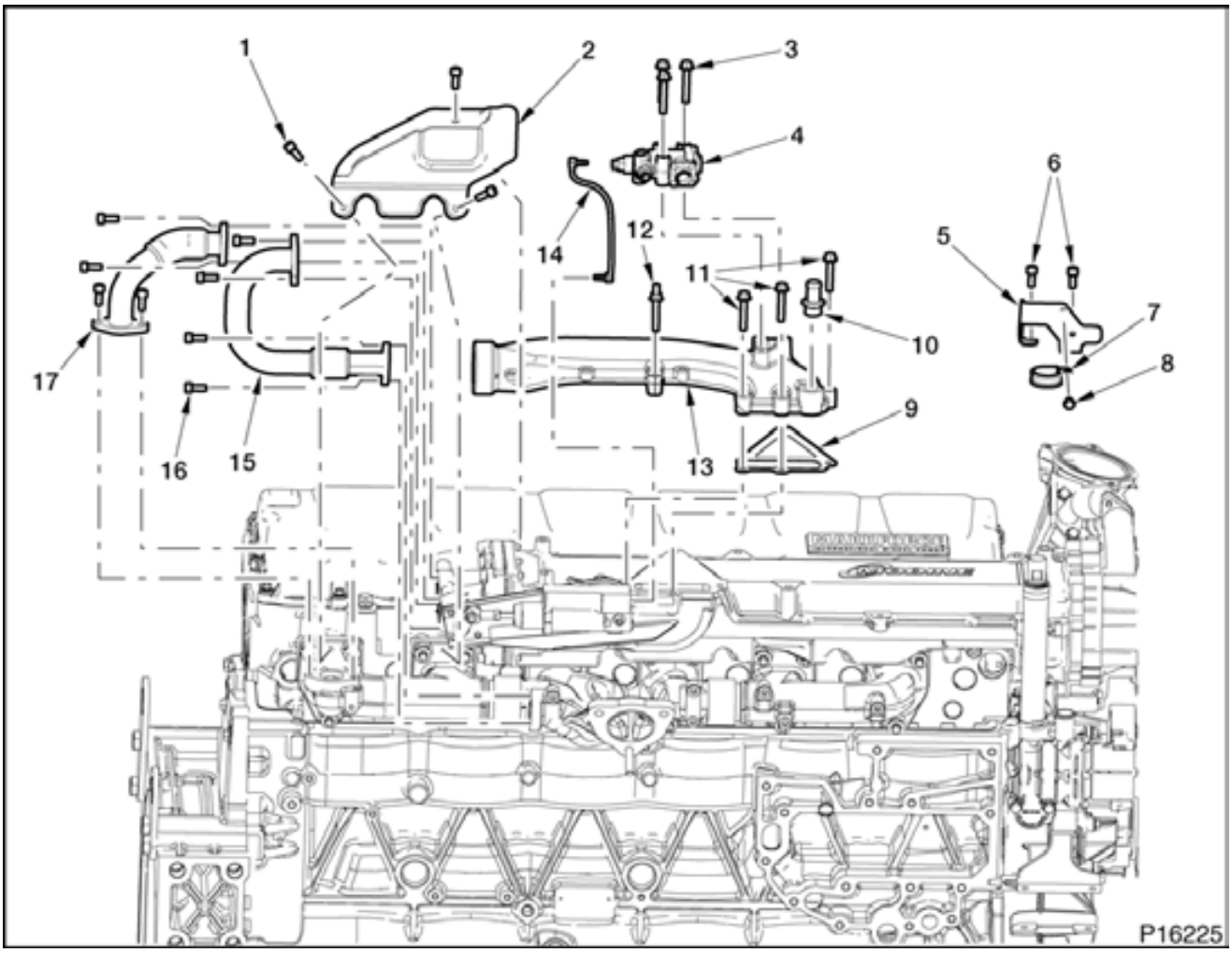

Figure 434 EGR system components

1. M8 x 12 hex bolt (3)
2. Heat protection plate (inner)
3. M8 x 50 hex bolt (3)
4. EGR control valve
5. Bracket for coolant line
6. M8 x 20 hex bolt
7. Clamp pipe
8. M6 x 16 hex bolt
9. Gasket
10. Hose coupling
11. M8 x 45 hex bolt (3)
12. M8 x 45 x 15 stud bolt
13. Coolant elbow (upper)
14. EGR control valve - EGR cooler module air line assembly
15. Rear outer tube
16. M8 x 20 cylinder screw (8)
17. Rear inner tube

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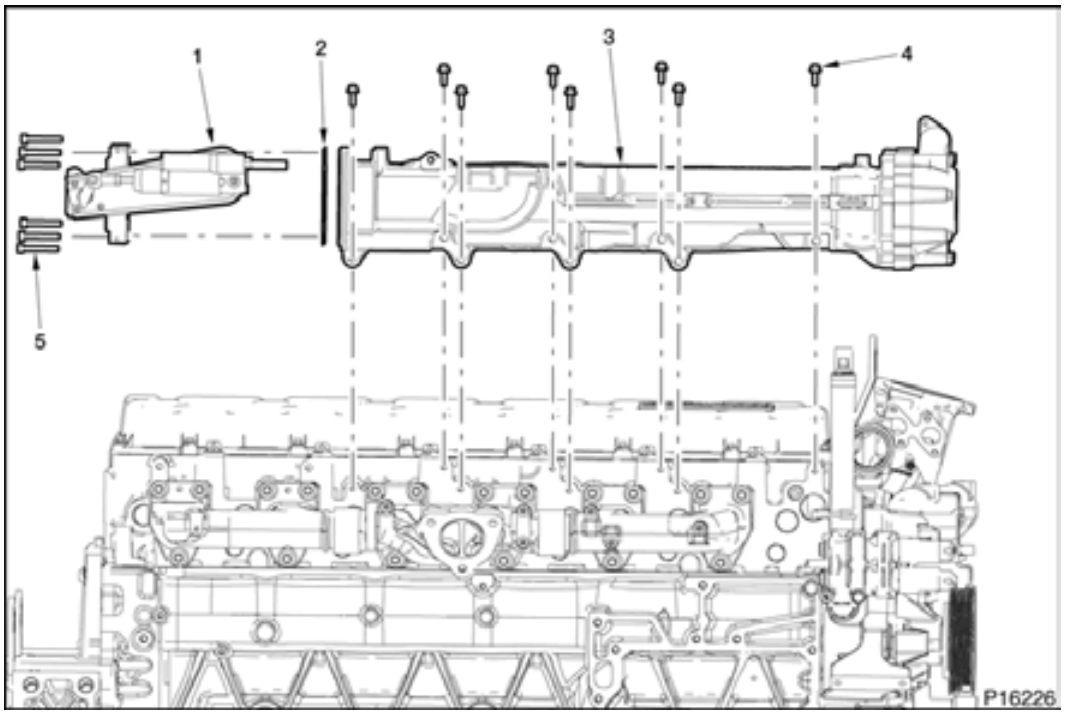

Figure 435 EGR module and components

1. EGR throttle valve
2. Gasket
3. EGR module
4. M8 x 35 hex bolt (8)
5. Cylinder screw (6)

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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, 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.

NOTE: Refer to the following service sections for information on removal of components prior to this section.

- Engine Electrical
- Turbochargers
- Air Compressor and Power Steering Pump
- Oil Cooler, Filter Housing and Crankcase Ventilation

Coolant Elbow (Middle)

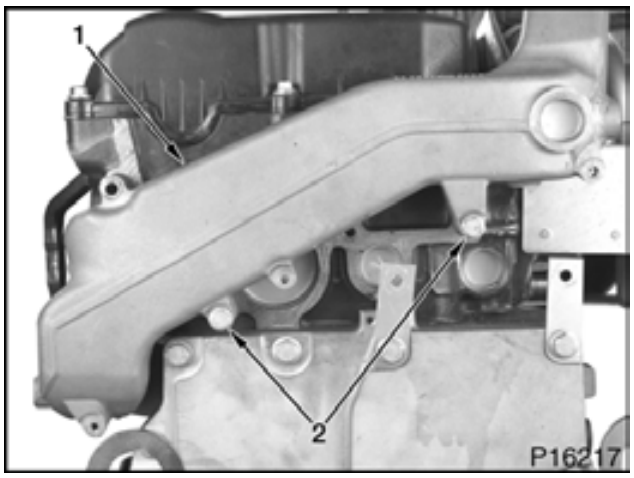

Figure 436 Coolant elbow (middle)

1. Coolant elbow (middle)
2. M8 x 50 hex bolt (2)

1. Remove the two M8 x 50 hex bolts and coolant elbow (middle).

CAUTION: To prevent engine damage, do not remove extension tubes by grabbing sealing surface.

2. Remove DMR62/51 and DMR44/35 extension tubes. Inspect extension tube sealing surfaces for damage. Replace as needed.

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Coolant Elbow (Lower)

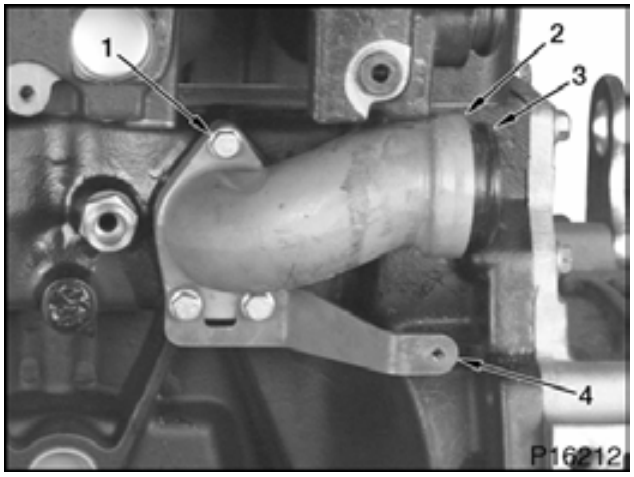

Figure 437 Coolant elbow (lower)

1. M8 x 25 hex bolt (3)
2. Coolant elbow (lower)
3. DMR62/51 extension tube
4. Hydrocarbon Injection (HCI) supply bracket

CAUTION: To prevent engine damage, do not remove extension tubes by grabbing sealing surface.

1. Remove DMR62/51 extension tube from coolant elbow (lower). Inspect extension tube sealing surface for damage. Replace as needed.
2. Remove two lower M8 x 25 hex bolts and HCI supply bracket.
3. Remove one M8 x 25 hex bolt and coolant elbow (lower). Remove and discard 60 x 3 O-ring.

Bracket

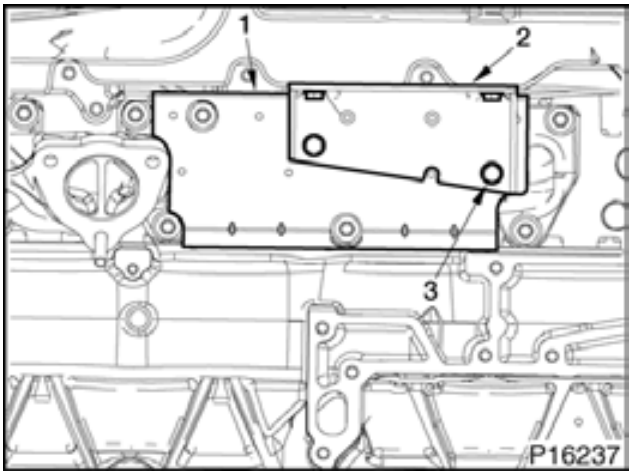

Figure 438 Bracket

1. Heat protection plate (front)
2. Bracket
3. M8 x 20 hex bolt (4)

1. Remove four M8 x 20 hex bolts and bracket.

Heat Protection Plate (Front)

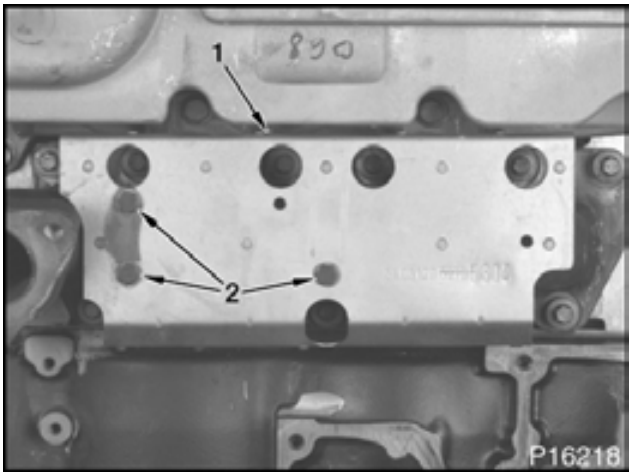

Figure 439 Heat protection plate (front)

1. Heat protection plate (front)
2. M8 x 12 hex bolt (3)

1. Remove three M8 x 12 hex bolts and heat protection plate (front).

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Heat Protection Plate (Rear)

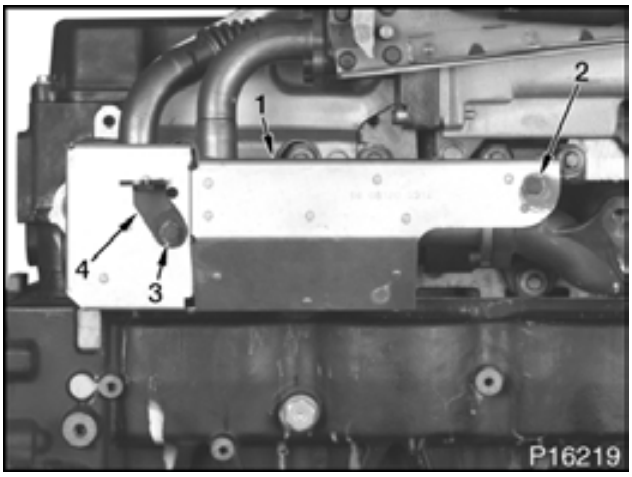

Figure 440 Heat protection plate (rear)

1. Heat protection plate (rear)
2. M8 x 12 hex bolt
3. M8 x 20 hex bolt
4. Bracket for suction pipe

1. Mark location of bracket for suction pipe for proper orientation during installation.
2. Remove M8 x 20 hex bolt and bracket for suction pipe.
3. Remove M8 x 12 hex bolt and heat protection plate (rear).

Air Supply Line Assembly

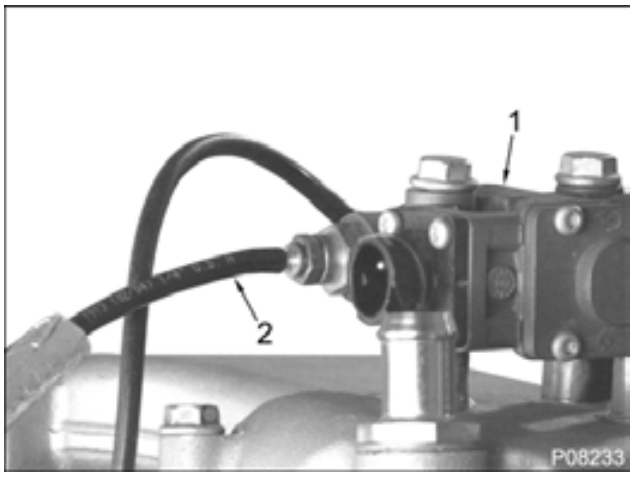

Figure 441 Air supply line assembly

1. Exhaust Gas Recirculation (EGR) control valve
2. Air supply line assembly

1. Loosen air supply line assembly fitting nut and disconnect air supply line assembly from EGR control valve.
2. Note routing of air supply line assembly and remove air supply line assembly from the engine.

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Air Line Assembly

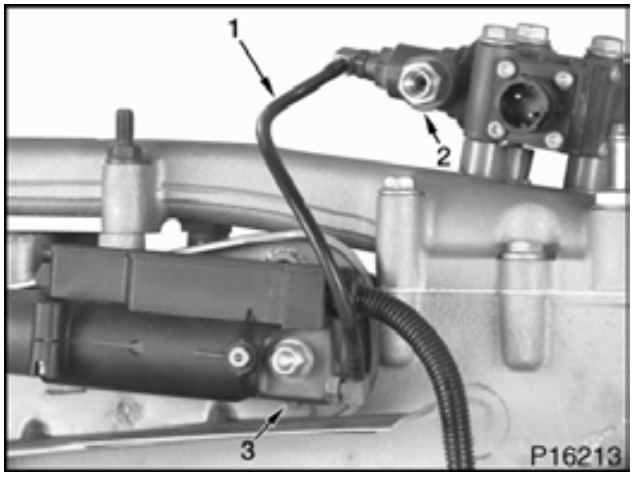

Figure 442 Exhaust Gas Recirculation (EGR) control valve - EGR module air line assembly

1. EGR control valve - EGR module air line assembly
2. EGR control valve
3. EGR throttle valve actuator (part of EGR Throttle Valve)

1. Loosen air line assembly fitting nut and disconnect air line assembly from EGR control valve.
2. Loosen air line assembly fitting nut and disconnect line assembly from EGR throttle valve actuator. Remove air line assembly.

Exhaust Gas Recirculation (EGR) Control Valve

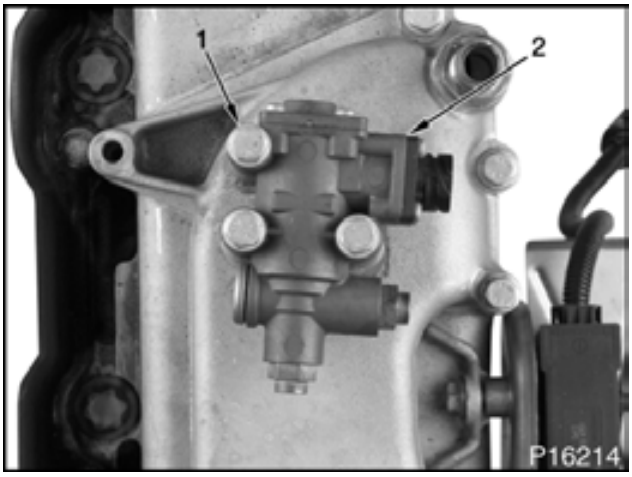

Figure 443 EGR control valve

1. M8 x 50 hex bolt (3)
2. EGR control valve

1. Remove three M8 x 50 hex bolts and EGR control valve.

Bracket for Low Temperature Radiator (LTR) Supply

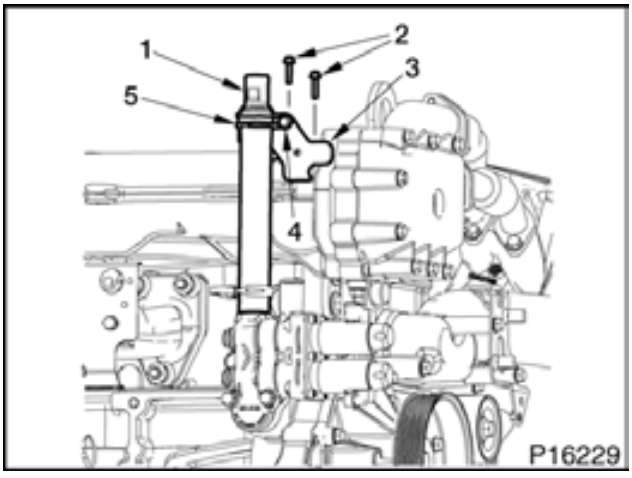

Figure 444 Bracket for LTR supply

1. Coolant pipe LTR supply
2. M8 x 20 hex bolt (2)
3. Bracket for coolant line
4. M6 x 16 hex bolt
5. Pipe clamp

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1. Remove M6 x 16 hex bolt and pipe clamp from coolant pipe LTR supply.
2. Remove two M8 x 20 hex bolts and bracket for coolant line.

Front Tubes

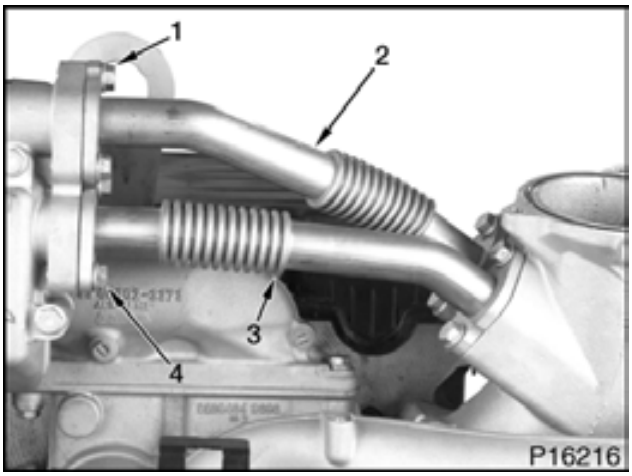

Figure 445 Front tubes

1. M8 x 25 hex bolt (4)
2. Front inner tube
3. Front outer tube
4. M8 x 25 hex bolt (4)

1. Remove four M8 x 25 hex bolts.
2. Remove and discard front outer tube.
3. Remove four M8 x 25 hex bolts.
4. Remove and discard front inner tube.

Rear Tubes

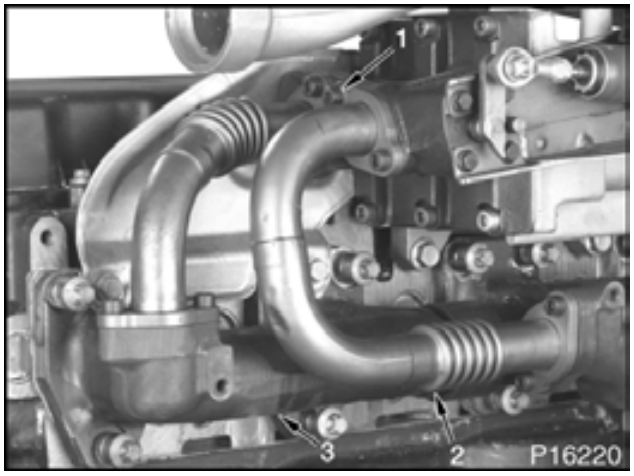

Figure 446 Rear outer tube

1. M8 x 20 cylinder screw (4)
2. Rear outer tube
3. Exhaust manifold

1. Remove four M8 x 20 cylinder screws.
2. Remove and discard rear outer tube.

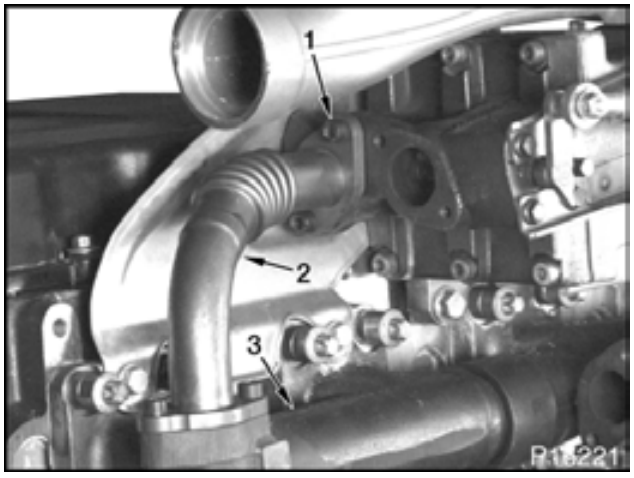

Figure 447 Rear inner tube

1. M8 x 20 cylinder screw (4)
2. Rear inner tube
3. Exhaust manifold

3. Remove four M8 x 20 cylinder screws.
4. Remove and discard rear inner tube.

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Heat Protection Plate (Inner)

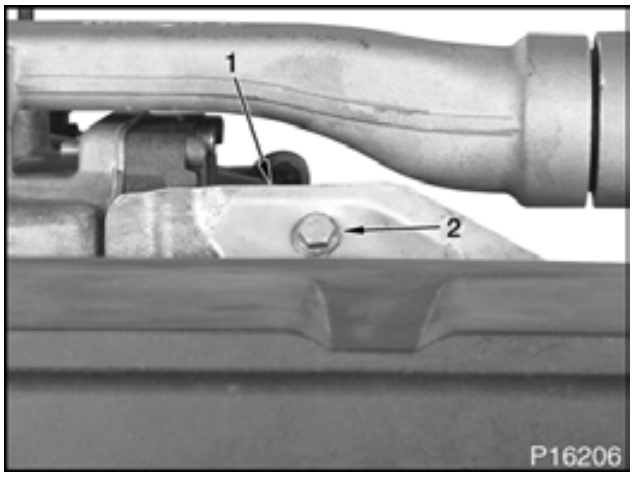

Figure 448 Heat protection plate (inner)

1. Heat protection plate (inner)
2. M8 x 12 hex bolt

1. Remove M8 x 12 hex bolt at top of engine next to valve cover.

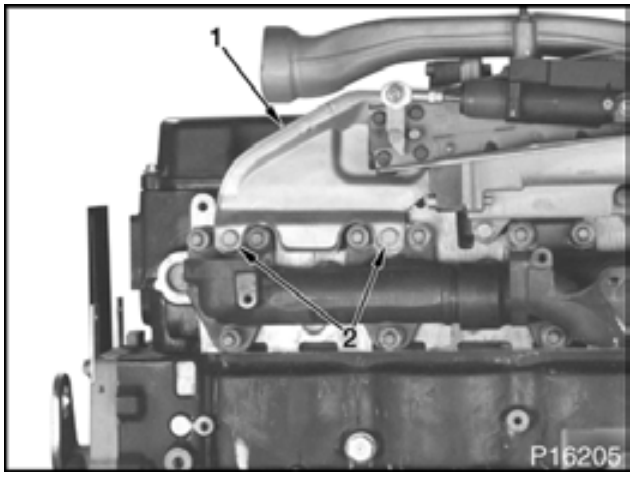

Figure 449 Heat protection plate (inner)

1. Heat protection plate (inner)
2. M8 x 12 hex bolt (2)

2. Remove two M8 x 12 hex bolts adjacent to exhaust manifold and heat protection plate (inner).

Coolant Elbow (Upper)

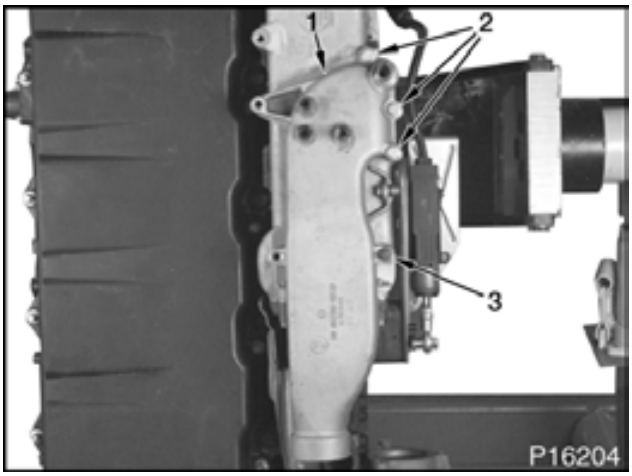

Figure 450 Coolant elbow (upper)

1. Coolant elbow (upper)
2. M8 x 45 hex bolt (3)
3. M8 x 45 x 15 stud bolt

1. Remove three M8 x 45 hex bolts, M8 x 45 x 15 stud bolt.
2. Remove coolant elbow (upper).
3. Remove and discard gasket.

Exhaust Gas Recirculation (EGR) Throttle Valve

NOTE: If removing complete EGR module for disassembly of engine, do not remove EGR throttle valve.

NOTE: EGR throttle valve can also be removed in vehicle.

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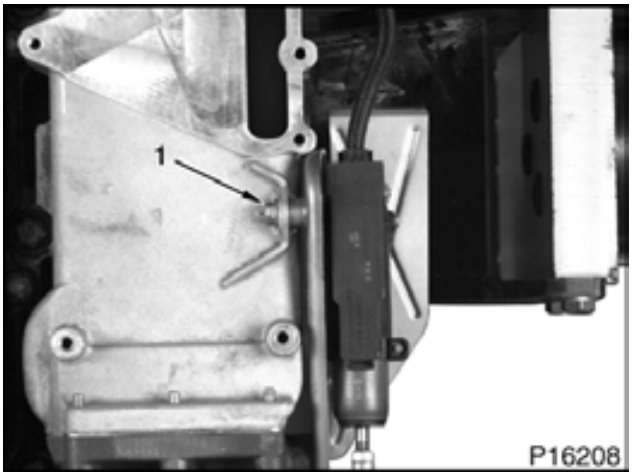

Figure 451 EGR throttle valve bracket hex bolt

1. M8 x 30 hex bolt

1. Remove M8 x 30 hex bolt from EGR throttle valve bracket.

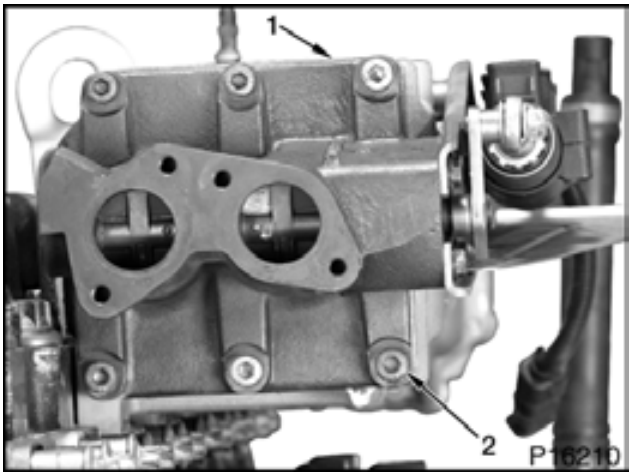

Figure 452 EGR throttle valve

1. EGR throttle valve
2. Cylinder screw (6)

2. Remove six cylinder screws and EGR throttle valve.
3. Remove and discard gasket.

Exhaust Gas Recirculation (EGR) Module

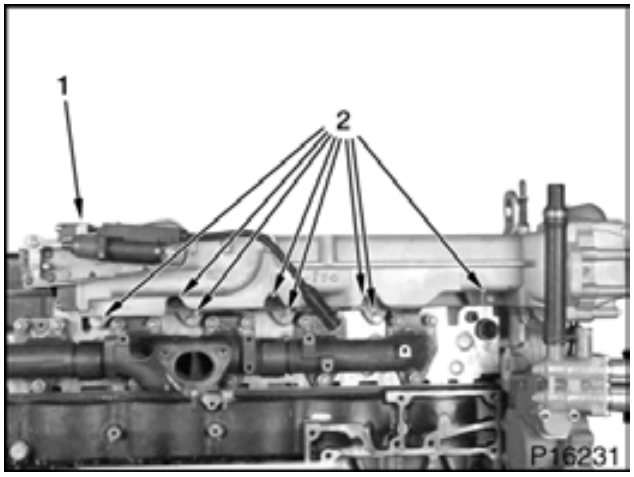

Figure 453 EGR module

1. EGR module
2. M10 x 35 hex bolt (8)

1. Remove eight M10 x 35 hex bolts and EGR module.

Cleaning, Inspection, and Testing

Exhaust Gas Recirculation (EGR) System Components

1. Using steam, clean all carbon from ends of EGR control valve and coolant elbows.
2. Using steam, clean EGR coolant supply and EGR coolant return ports in front of front crankcase cover assembly.
3. Inspect EGR system components for cracks and damage. Replace worn or damaged parts.

Exhaust Gas Recirculation (EGR) Module Pressure Test

In vehicle

1. Remove EGR Throttle Valve (page 261) from EGR module.
2. Remove Front Tubes (page 260) from EGR module.

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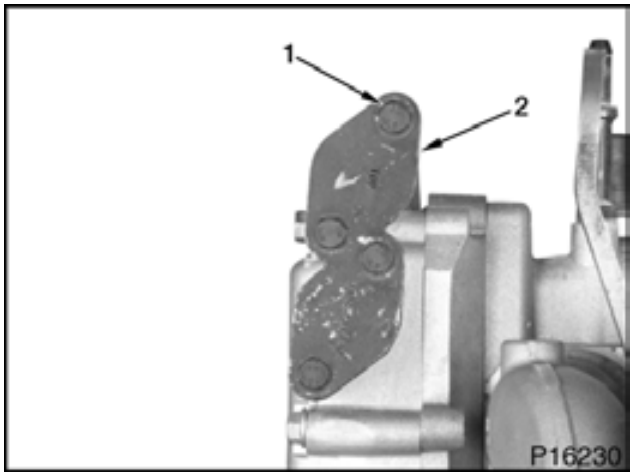

Figure 454 EGR module with EGR Cooler Pressure Test Plates installed

1. Hex bolt (4) (part of ZTSE4877)
2. EGR Cooler Pressure Test Plate number 2

3. Install EGR Cooler Pressure Test Plate number 2 (page 273) to front of EGR module.

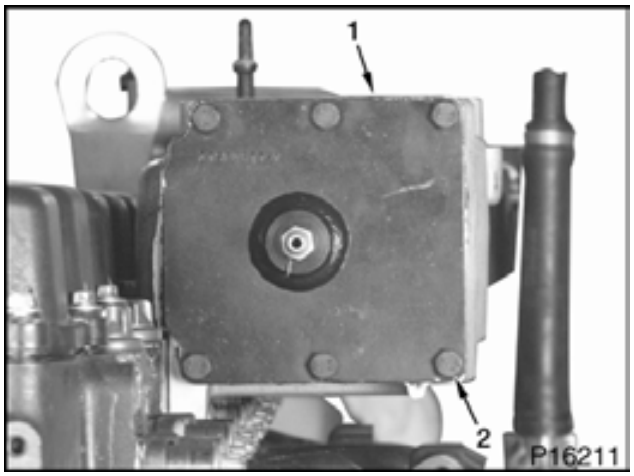

Figure 455 EGR module with EGR cooler pressure test plates installed

1. EGR Cooler Pressure Test Plate number 1
2. Hex bolt (6) (part of ZTSE4877)

4. Install EGR Cooler Pressure Test Plate number 1 (page 273) to rear of EGR module.

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

5. Attach an air pressure regulator (page 273) to EGR Cooler Pressure Test Plate. Connect to compressed air supply.
6. Pressurize EGR module to 207 kPa (30 psi) at ambient temperature. Shut off the air supply and hold for 60 seconds. If detectable pressure loss is observed, replace EGR module (page 262). If no detectable pressure loss is observed, EGR module is good.

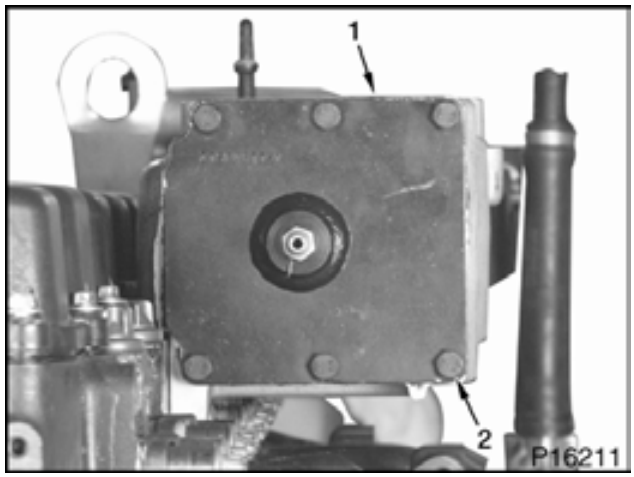

Figure 456 EGR module with EGR Cooler Pressure Test Plates installed

1. EGR Cooler Pressure Test Plate number 1
2. Hex bolt (6) (part of ZTSE4877)

7. Remove EGR Cooler Pressure Test Plate number 1 (page 273) from rear of EGR module.

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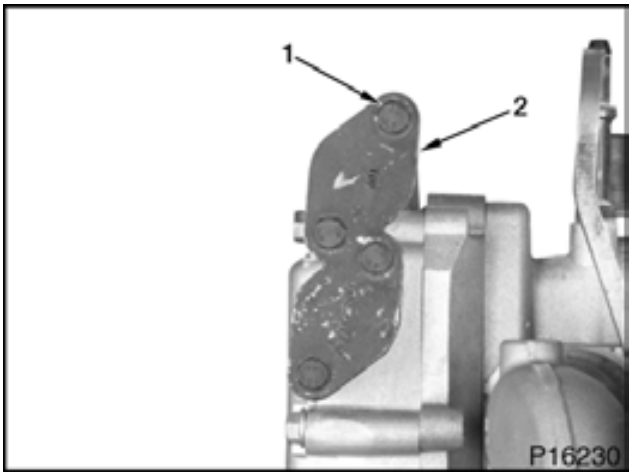

Figure 457 EGR module with EGR Cooler Pressure Test Plates installed

1. Hex bolt (4) (part of ZTSE4877)
2. EGR Cooler Pressure Test Plate number 2

8. Remove EGR Cooler Pressure Test Plate number 2 (page 273) from front of EGR module.

CAUTION: To prevent engine damage, do not reuse front or rear EGR tubes.

9. Install new Front Tubes (page 268) to EGR module.
10. Install EGR Throttle Valve (page 266) to EGR module.

On bench

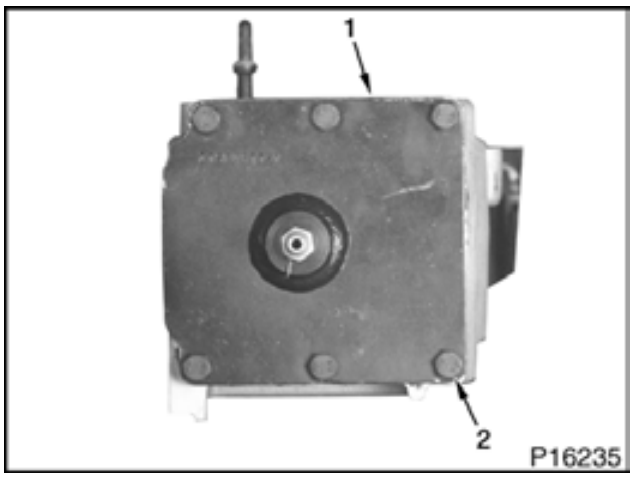

Figure 458 EGR module with EGR Cooler Pressure Test Plates installed

1. EGR Cooler Pressure Test Plate number 1
2. Hex bolt (6) (part of ZTSE4877)

1. Install EGR Cooler Pressure Test Plate number 1 (page 273) to rear of EGR module.

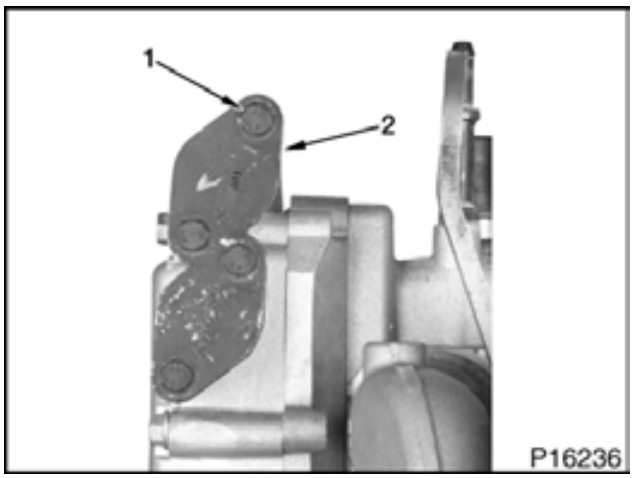

Figure 459 EGR module with EGR Cooler Pressure Test Plates installed

1. Hex bolt (4) (part of ZTSE4877)
2. EGR Cooler Pressure Test Plate number 2

2. Install EGR Cooler Pressure Test Plate number 2 (page 273) to front of EGR module.

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

3. Attach an air pressure regulator (page 273) to EGR Cooler Pressure Test Plate number 1. Connect to shop air supply and adjust air pressure to a maximum pressure of 207 kPa (30 psi).
4. Completely submerge EGR module in a large container of water. Inspect for air bubbles coming from coolant passages.
5. If bubbles are found, replace EGR module. If no leaks are found, reassemble EGR module.

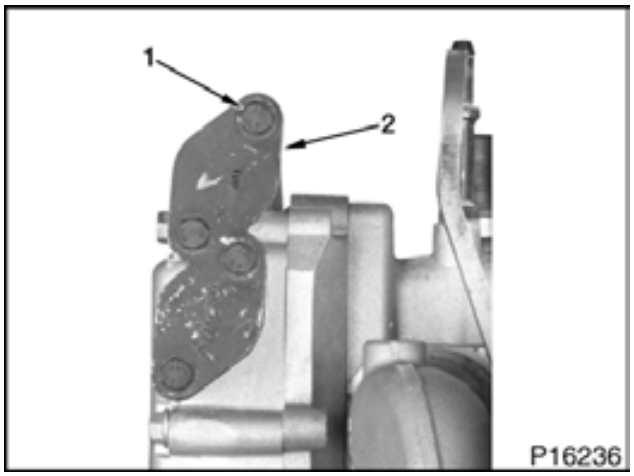

Figure 460 EGR module with EGR Cooler Pressure Test Plates installed

1. Hex bolt (4) (part of ZTSE4877)
2. EGR Cooler Pressure Test Plate number 2

6. Remove EGR Cooler Pressure Test Plate number 2 (page 273) from front of EGR module.

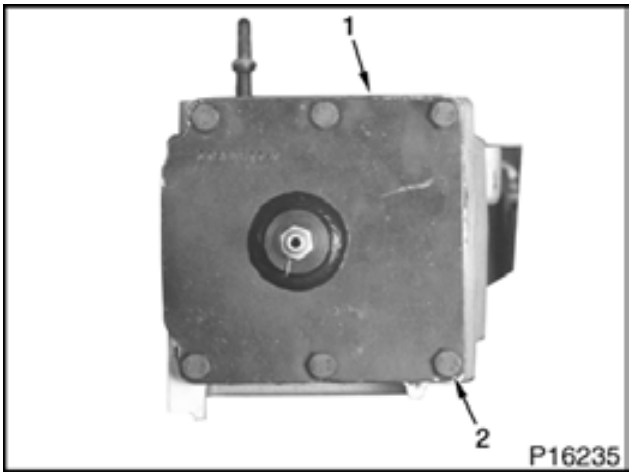

Figure 461 EGR module with EGR Cooler Pressure Test Plates installed

1. EGR Cooler Pressure Test Plate number 1
2. Hex bolt (6) (part of ZTSE4877)

7. Remove EGR Cooler Pressure Test Plate number 1 (page 273) from rear of EGR module.

Installation

Exhaust Gas Recirculation (EGR) Module

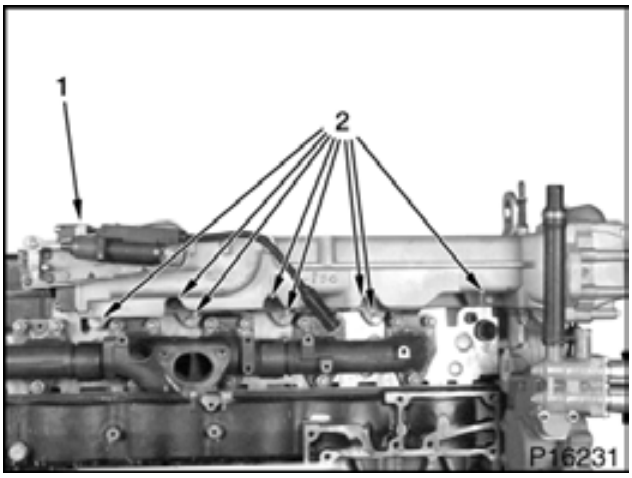

Figure 462 EGR module

1. EGR module
2. M10 x 35 hex bolt (8)

1. Install EGR module and eight M10 x 35 hex bolts. Tighten bolts to special torque (page 273).

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Exhaust Gas Recirculation (EGR) Throttle Valve

NOTE: Complete this procedure only if the EGR throttle valve was removed.

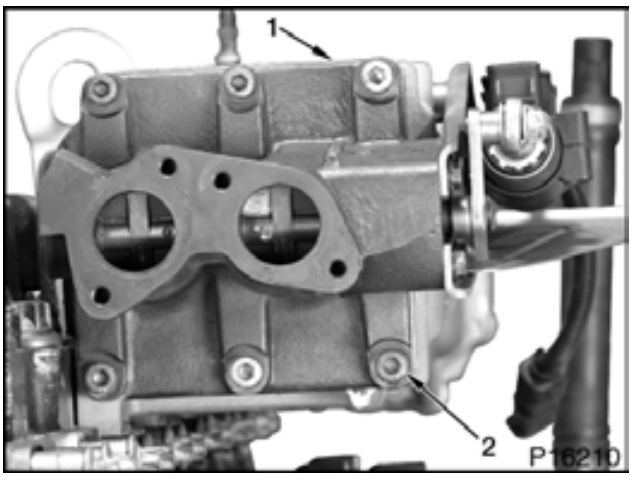

Figure 463 EGR throttle valve

1. EGR throttle valve
2. Cylinder screw (6)

1. Install a new gasket.
2. Install EGR throttle valve and six cylinder screws. Tighten screws to special torque (page 273).

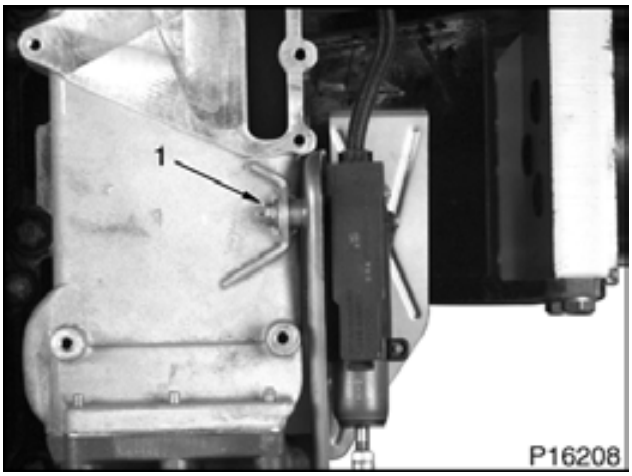

Figure 464 Exhaust Gas Recirculation (EGR) throttle valve bracket hex bolt

1. M8 x 30 hex bolt

3. Install M8 x 30 hex bolt to EGR throttle valve bracket and tighten to standard torque (page 457).

Coolant Elbow (Upper)

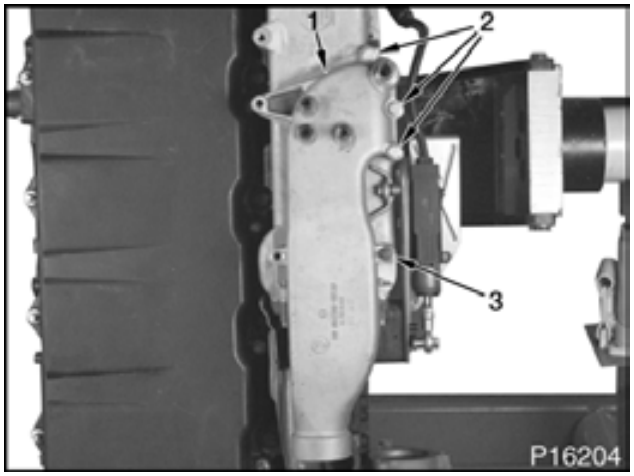

Figure 465 Coolant elbow (upper)

1. Coolant elbow (upper)
2. M8 x 45 hex bolt (3)
3. M8 x 45 x 15 stud bolt

1. Install a new gasket.
2. Install coolant elbow (upper), three M8 x 45 hex bolts and M8 x 45 x 15 stud bolt. Tighten hex bolts and stud bolt to special torque (page 273).

Heat Protection Plate (Inner)

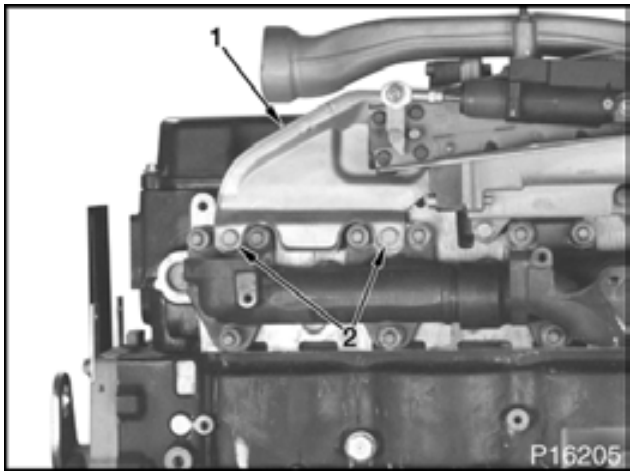

Figure 466 Heat protection plate (inner)

1. Heat protection plate (inner)
2. M8 x 12 hex bolt (2)

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1. Install heat protection plate (inner) and two M8 x 12 hex bolts adjacent to exhaust manifold. Tighten hex bolts to standard torque (page 457).

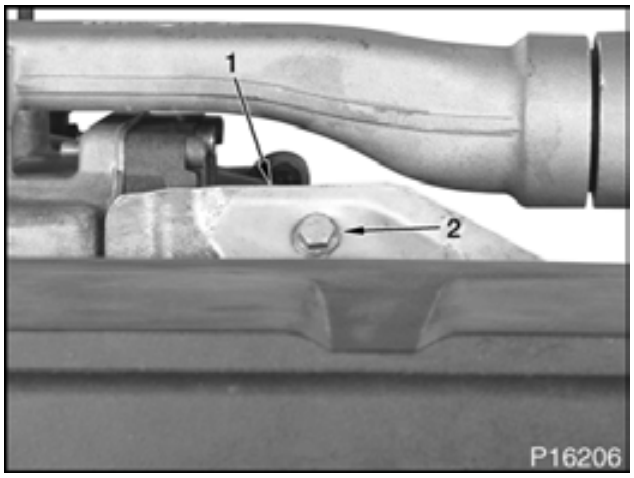

Figure 467 Heat protection plate (inner)

1. Heat protection plate (inner)
2. M8 x 12 hex bolt

2. Install M8 x 12 hex bolt at top of engine next to valve cover. Tighten hex bolt to standard torque (page 457).

Rear Tubes

CAUTION: To prevent engine damage, do not reuse front or rear EGR tubes.

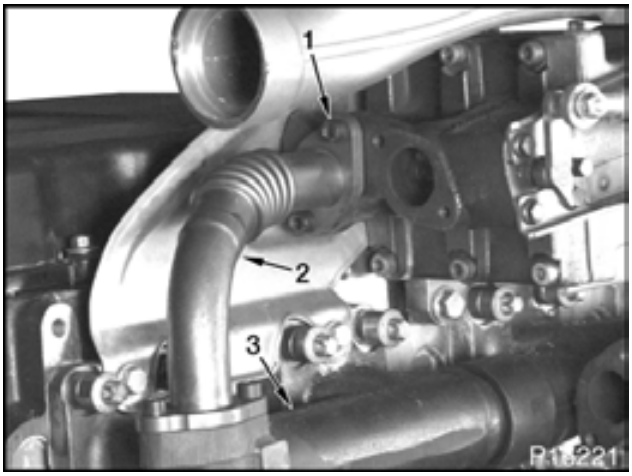

Figure 468 Rear inner tube

1. M8 x 20 cylinder screw (4)
2. Rear inner tube
3. Exhaust manifold

1. Install new rear inner tube and four M8 x 20 cylinder screws. Tighten cylinder screws to special torque (page 273).

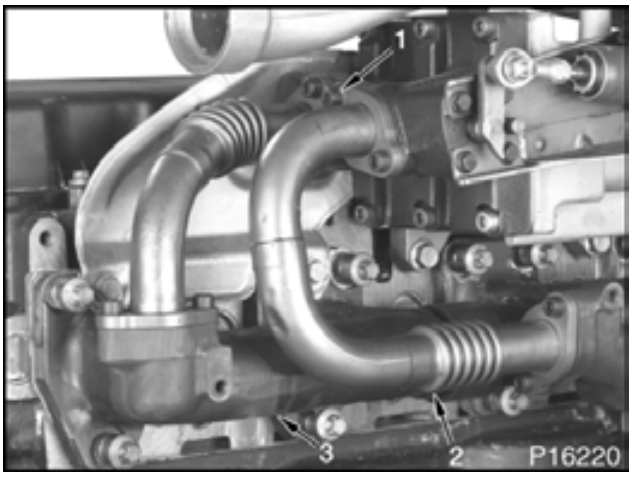

Figure 469 Rear outer tube

1. M8 x 20 cylinder screw (4)
2. Rear outer tube
3. Exhaust manifold

2. Install new rear outer tube and four M8 x 20 cylinder screws. Tighten cylinder screws to special torque (page 273).

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Front Tubes

CAUTION: To prevent engine damage, do not reuse front or rear EGR tubes.

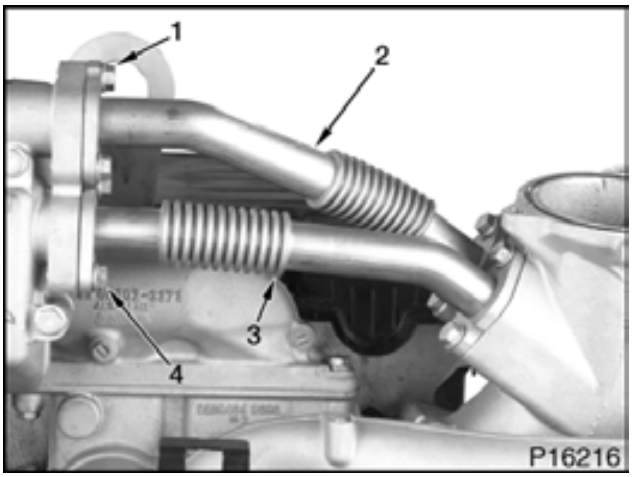

Figure 470 Front tubes

1. M8 x 25 hex bolt (4)
2. Front inner tube
3. Front outer tube
4. M8 x 25 hex bolt (4)

1. Install new front inner tube and four M8 x 25 hex bolts. Tighten hex bolts to special torque (page 273).
2. Install new front outer tube and four M8 x 25 hex bolts. Tighten hex bolts to special torque (page 273).

Bracket for Low Temperature Radiator (LTR) Supply

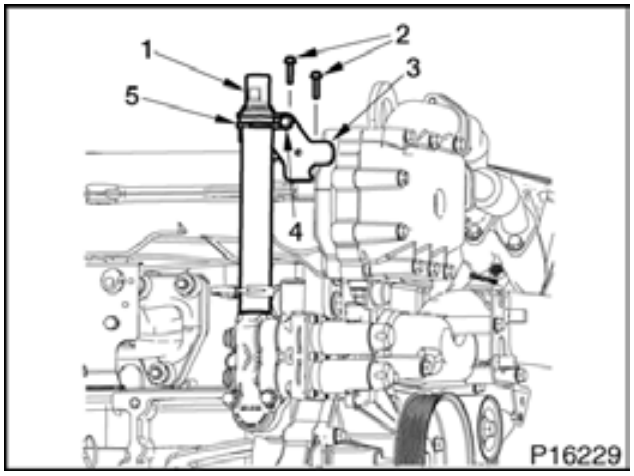

Figure 471 Bracket for LTR supply

1. Coolant pipe LTR supply
2. M8 x 20 hex bolt (2)
3. Bracket for coolant line
4. M6 x 16 hex bolt
5. Pipe clamp

1. Install bracket for coolant line and two M8 x 20 hex bolts. Tighten hex bolts to standard torque (page 457).
2. Install pipe clamp onto coolant pipe LTR supply and M6 x 16 hex bolt. Tighten pipe clamp to special torque (page 273).

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Exhaust Gas Recirculation (EGR) Control Valve

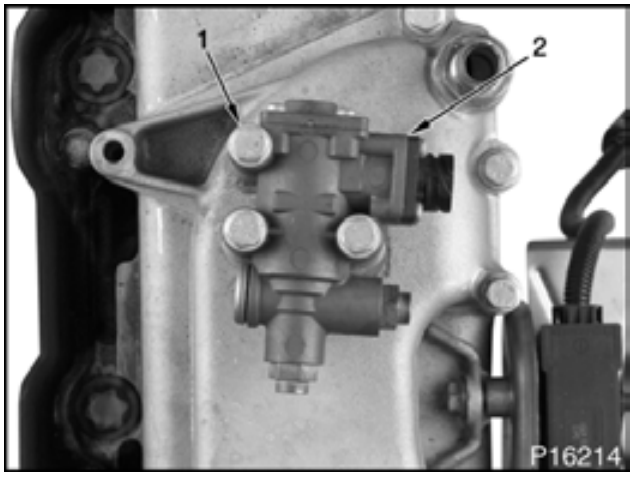

Figure 472 EGR control valve

1. M8 x 50 hex bolt (3)
2. EGR control valve

1. Install EGR control valve and three M8 x 50 hex bolts. Tighten hex bolts to standard torque (page 457).

Air Line Assembly

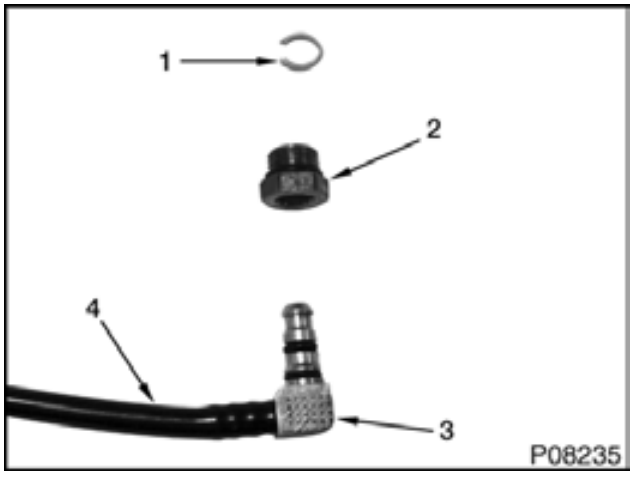

Figure 473 Air line assembly connections

1. Clip
2. Threaded fitting (with O-ring)
3. Male end (part of air line assembly)
4. Air line assembly

NOTE: If installing a new exhaust gas recirculation (EGR) control valve and/or EGR throttle valve was replaced do steps 1 though 3. If EGR control valve and/or EGR throttle valve was not replaced do steps 4 and 5.

NOTE: If air line assembly was replaced or was found to be leaking, do steps 6 and 7. If air line assembly was not replaced, do steps 4 and 5.

1. Remove old clip and threaded fitting from air line assembly fitting.
2. Lubricate air line assembly O-rings with P-80® Rubber Lubricant or equivalent (page 273).
3. Install and push air line assembly into new threaded fitting (mounted on new EGR control valve and/or EGR throttle valve actuator) until a click is heard. This ensures air line assembly has locked into the clip and is properly installed.
4. Lubricate air line assembly threaded fitting O-ring with P-80® Rubber Lubricant or equivalent (page 273).

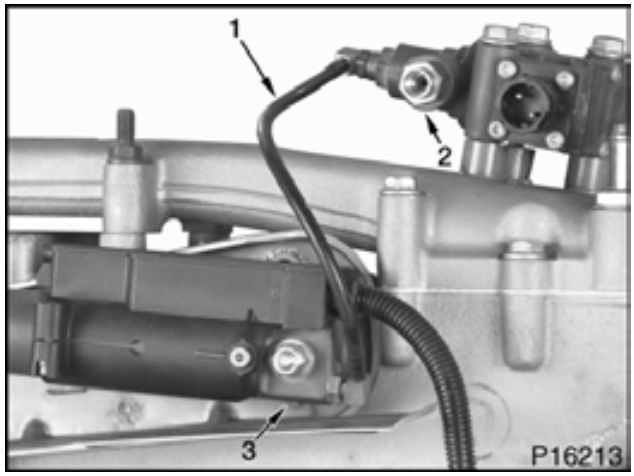

Figure 474 EGR control valve - EGR cooler module air line assembly

1. EGR control valve - EGR cooler module air line assembly
2. EGR control valve
3. EGR throttle valve actuator (part of EGR Throttle Valve)

5. Position air line assembly and install threaded fitting into EGR control valve and/or EGR throttle valve actuator. Tighten threaded fittings to special torque (page 273).

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6. Lubricate new air line assembly threaded fitting O-ring with P-80® Rubber Lubricant or equivalent (page 273). Install new threaded fitting and new clip into EGR control valve and/or EGR throttle valve actuator. Tighten threaded fitting to special torque (page 273).
7. Install and push new air line assembly into threaded fitting until a click is heard. This ensures air line assembly has locked into the clip and is properly installed.

Air Supply Line Assembly

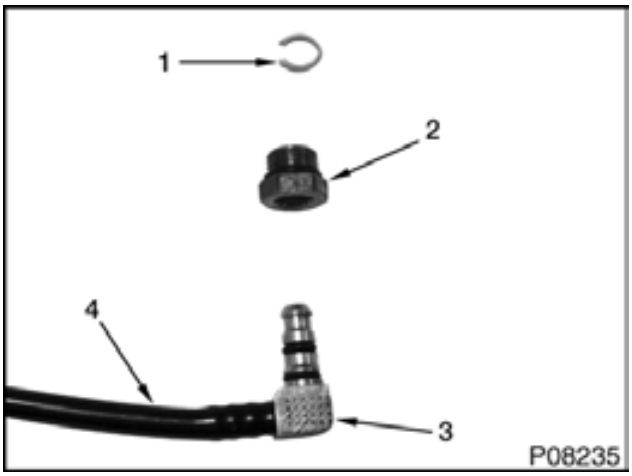

Figure 475 Air supply line assembly connections

1. Clip
2. Threaded fitting (with O-ring)
3. Male end (part of air line assembly)
4. Air supply line assembly

NOTE: If installing a new exhaust gas recirculation (EGR) control valve was replaced do steps 1 though 3. If EGR control valve was not replaced do steps 4 and 5.

NOTE: If air supply line assembly was replaced or was found to be leaking, perform steps 6 and 7. If air supply line assembly was not replaced, perform steps 4 and 5.

1. Remove old clip and threaded fitting from air supply line fitting.
2. Lubricate air supply line assembly O-rings with P-80® Rubber Lubricant or equivalent (page 273).
3. Install and push air supply line assembly into new threaded fitting (mounted on new EGR control valve) until a click is heard. This ensures air supply line assembly has locked into the clip and is properly installed.
4. Lubricate air supply line assembly threaded fitting O-ring with P-80® Rubber Lubricant or equivalent (page 273).

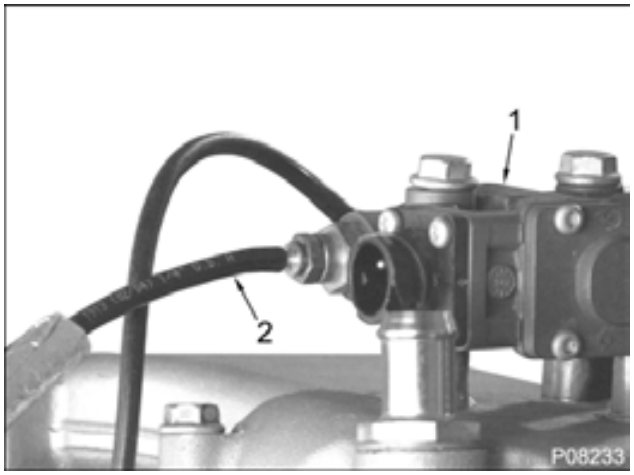

Figure 476 Air supply line assembly

1. EGR control valve - EGR module air line assembly
2. EGR control valve
3. Air supply line assembly

5. Position air supply line assembly and install threaded fitting into EGR control valve. Tighten threaded fitting to special torque (page 273).
6. Lubricate new air supply line assembly threaded fitting O-ring with P-80® Rubber Lubricant or equivalent (page 273). Install new threaded fitting and new clip into EGR control valve. Tighten threaded fitting to special torque (page 273).
7. Install and push new air supply line assembly into threaded fitting until a click is heard. This ensures air supply line assembly has locked into clip and is properly installed.

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Heat Protection Plate (Rear)

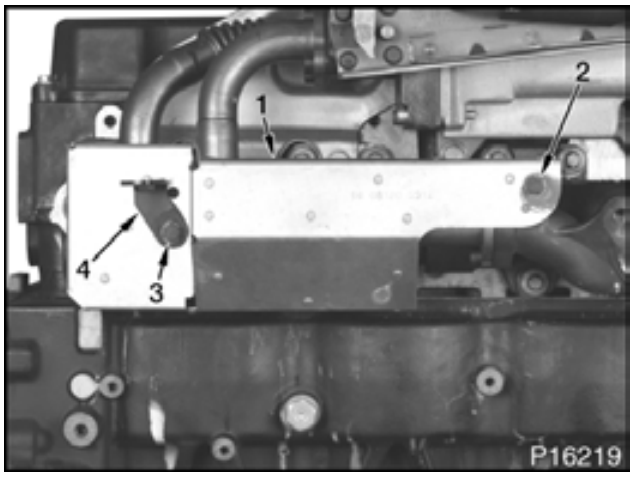

Figure 477 Heat protection plate (rear)

1. Heat protection plate (rear)
2. M8 x 12 hex bolt
3. M8 x 20 hex bolt
4. Bracket for suction pipe

1. Install heat protection plate (rear) and M8 x 12 hex bolt.
2. Position bracket for suction pipe as noted during removal procedure and install M8 x 20 hex bolt.
3. Tighten heat protection plate hex bolts to special torque (page 273).

Heat Protection Plate (Front)

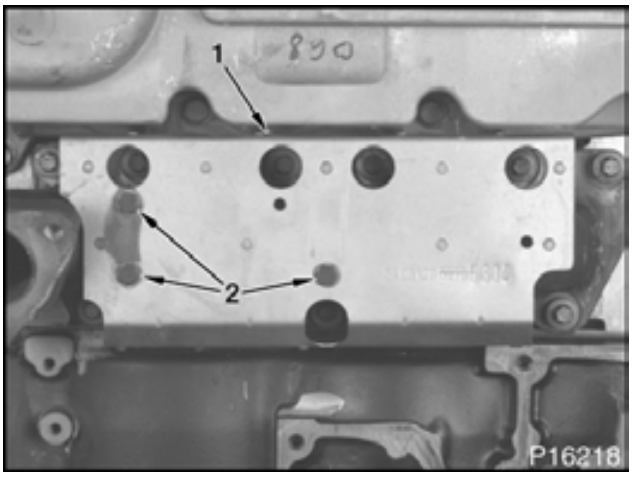

Figure 478 Heat protection plate (front)

1. Heat protection plate (front)
2. M8 x 12 hex bolt (3)

1. Install heat protection plate (front) and three M8 x 12 hex bolts. Tighten hex bolts to special torque (page 273).

Bracket

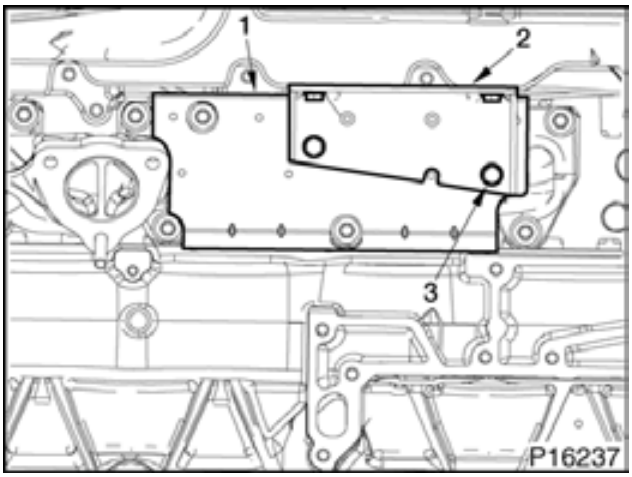

Figure 479 Bracket

1. Heat protection plate (front)
2. Bracket
3. M8 x 20 hex bolt (4)

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1. Install bracket and four M8 x 20 hex bolts. Tighten hex bolts to standard torque (page 457).

Coolant Elbow (Lower)

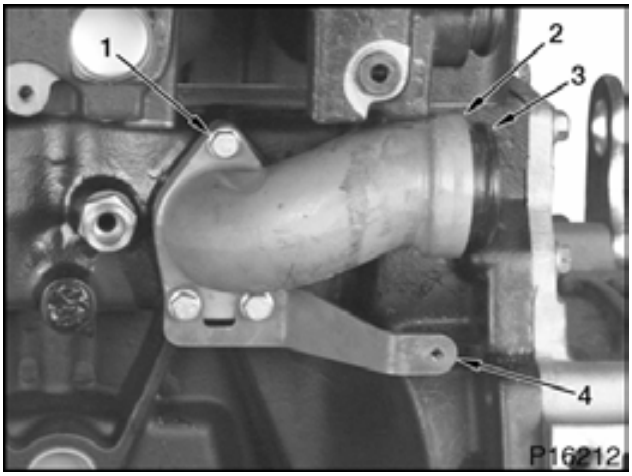

Figure 480 Coolant elbow (lower)

1. M8 x 25 hex bolt (3)
2. Coolant elbow (lower)
3. DMR62/51 extension tube
4. Hydrocarbon Injection (HCI) supply bracket

1. Install new 60 x 3 O-ring. Install coolant elbow (lower) and loosely install upper M8 x 25 hex bolt.
2. Install HCI supply bracket and loosely install two lower M8 x 25 hex bolts.
3. Tighten three coolant elbow (lower) hex bolts to special torque (page 273).
4. Lubricate sealing surfaces of DMR62/51 extension tube with P-80® Rubber Lubricant or equivalent (page 273). Install DMR62/51 extension tube to coolant elbow (lower).

Coolant Elbow (Middle)

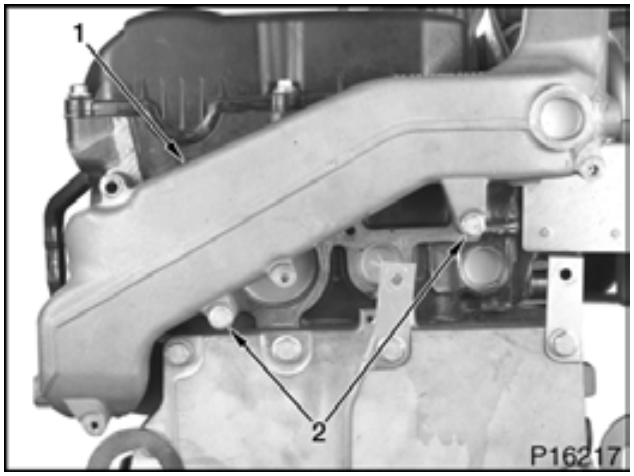

Figure 481 Coolant elbow (middle)

1. Coolant elbow (middle)
2. M8 x 50 hex bolt (2)

1. Lubricate DMR62/51 and DMR44/35 extension tubes sealing surfaces with P-80® Rubber Lubricant or equivalent (page 273). Install DMR62/51 extension tube and DMR44/35 extension tube into coolant elbow (middle).
2. Install coolant elbow (middle) and two M8 x 50 hex bolts. Tighten hex bolts to special torque (page 273).

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Special Torque

Table 19 Exhaust Gas Recirculation (EGR) System

Air line assembly threaded fitting	12 N·m (106 lbf·in)
Air supply line assembly threaded fitting	12 N·m (106 lbf·in)
Coolant elbow (middle) hex bolt	35 N·m (28 lbf·ft)
Coolant elbow (upper) hex bolts and stud bolt	35 N·m (28 lbf·ft)
Coolant elbow (lower) hex bolts	35 N·m (28 lbf·ft)
Coolant pipe low temperature radiator (LTR) supply pipe clamp	4 N·m (35 lbf·in)
EGR throttle valve cylinder screws	35 N·m (26 lbf·ft)
EGR module hex bolts	75 N·m (55 lbf·ft)
Front inner and outer tubes hex bolts	35 N·m (28 lbf·ft)
Rear inner and outer tubes cylinder screws	35 N·m (28 lbf·ft)
Heat protection plates (front and rear) hex bolts	22 N·m (16 lbf·ft)

Special Service Tools

Table 20 Exhaust Gas Recirculation (EGR) System

Description	Tool Number
Air Pressure Regulator	Obtain locally
EGR Cooler Pressure Test Plates	ZTSE4877
P-80® Rubber Lubricant or equivalent	Obtain locally

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Exploded Views

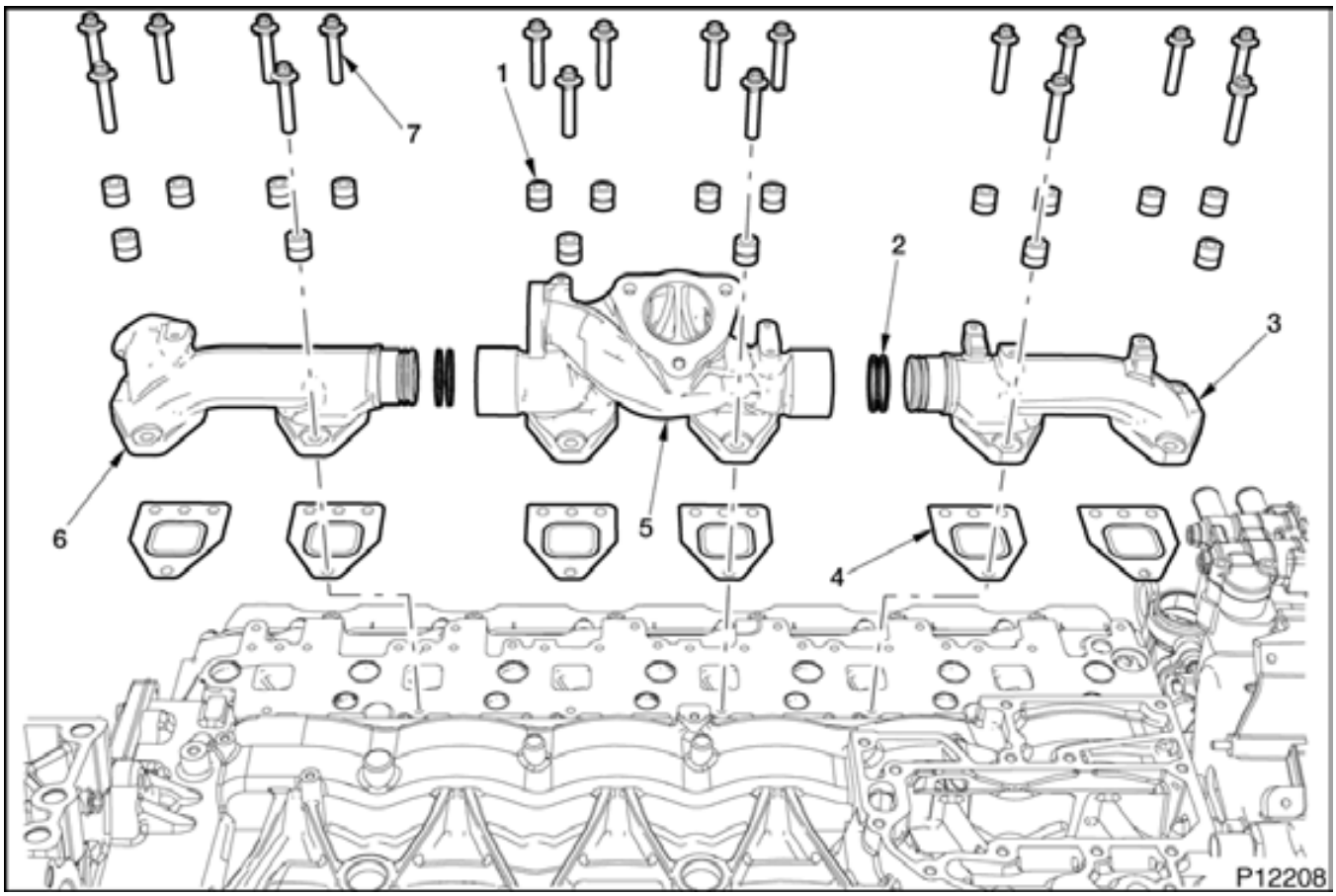

Figure 482 Exhaust manifold

1. High temperature spacing sleeve (18)
2. Multipiece oil ring (4)
3. Front exhaust manifold
4. Exhaust manifold gasket (6)
5. Middle exhaust manifold
6. Rear exhaust manifold
7. M10 x 48 screw (18)

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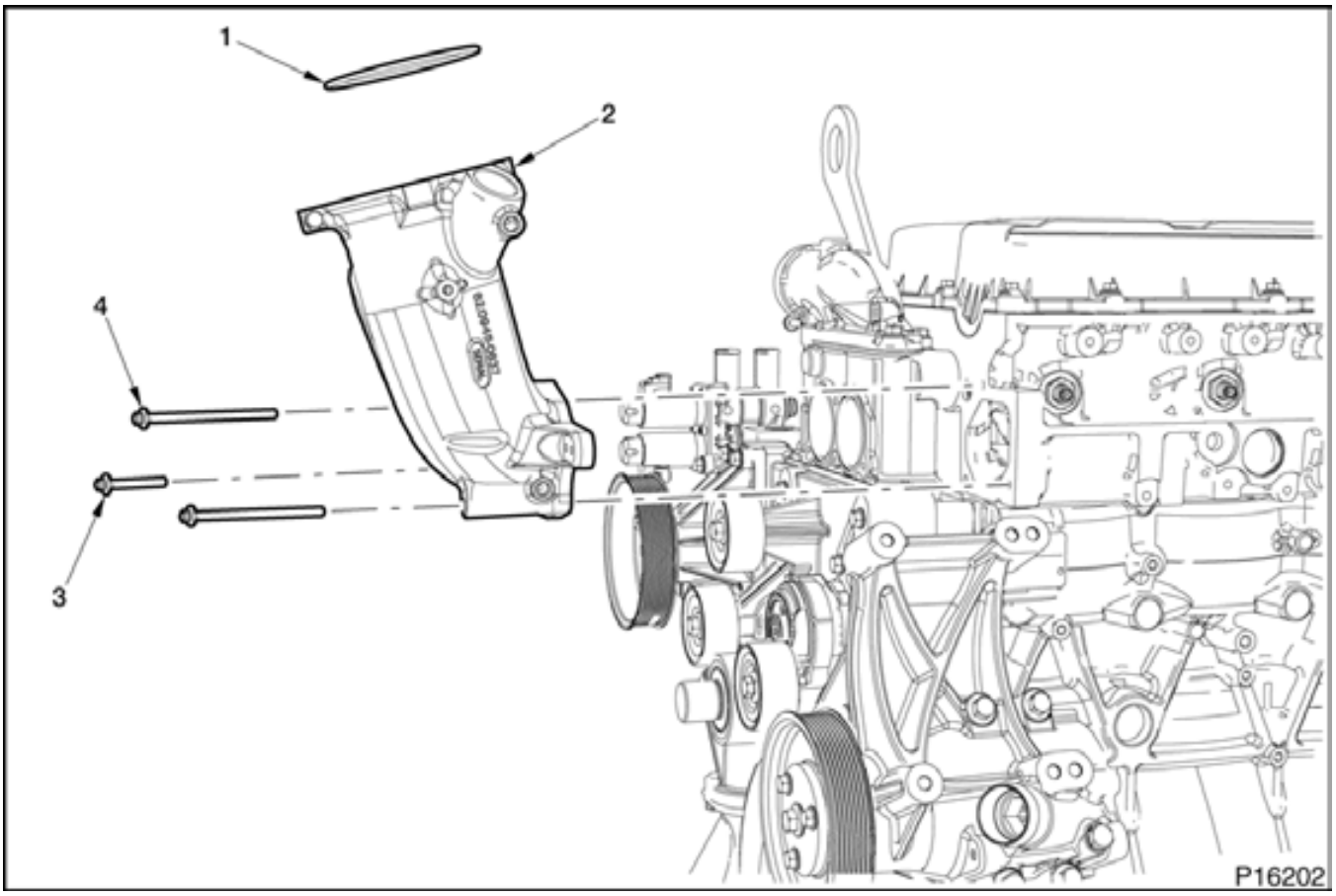

Figure 483 Air Inlet Duct

1. O-ring
2. Air inlet duct
3. M8 x 50 hex bolt
4. M8 x 90 hex bolt (2)

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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, make sure 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.

NOTE: Refer to the following service sections for information on removal of components prior to this section.

- Engine Electrical
- Cold Start Assist
- Aftertreatment System
- Engine Retarder Control
- Turbocharger
- Oil Cooler and Filter Housing and Crankcase Ventilation
- Exhaust Gas Recirculating (EGR) System

Exhaust Manifold

CAUTION: To prevent engine damage, do not reuse high-temperature spacing sleeves and exhaust manifold screws.

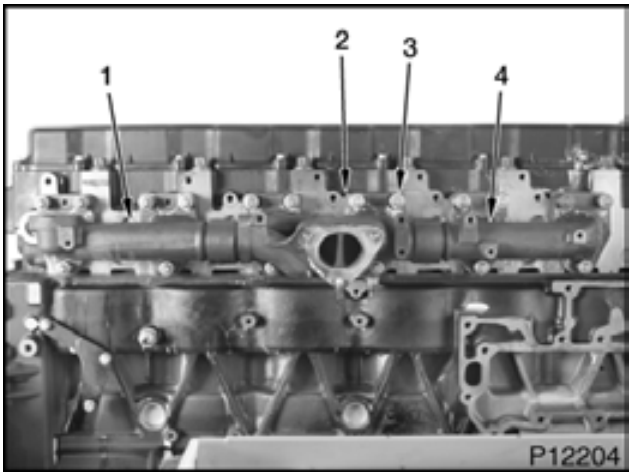

Figure 484 Exhaust manifold

1. Rear exhaust manifold
2. Middle exhaust manifold
3. M10 x 48 screw (18) and high temperature spacing sleeve (18)
4. Front exhaust manifold

1. Remove 18 M10 x 48 screws and 18 high temperature spacing sleeves. Discard screws and sleeves after removal.
2. Remove exhaust manifold assembly and discard six exhaust manifold gaskets.

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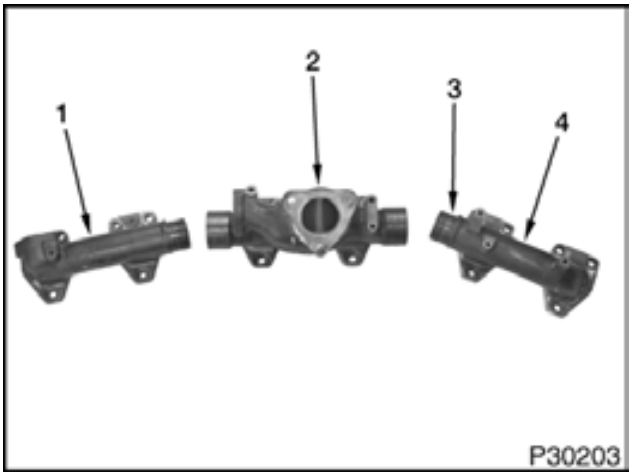

Figure 485 Exhaust manifolds

1. Rear exhaust manifold
2. Middle exhaust manifold
3. Multipiece oil ring (4)
4. Front exhaust manifold

3. Separate front and rear exhaust manifold sections from middle exhaust manifold.
4. Remove and discard four multipiece oil rings from front and rear exhaust manifolds.

Air Inlet Duct

CAUTION: To prevent engine damage, make sure that gasket debris and dirt does not enter cylinder head opening.

1. If equipped, remove High Mount Fan Drive (page 296).
2. Remove Coolant Elbow (page 296).

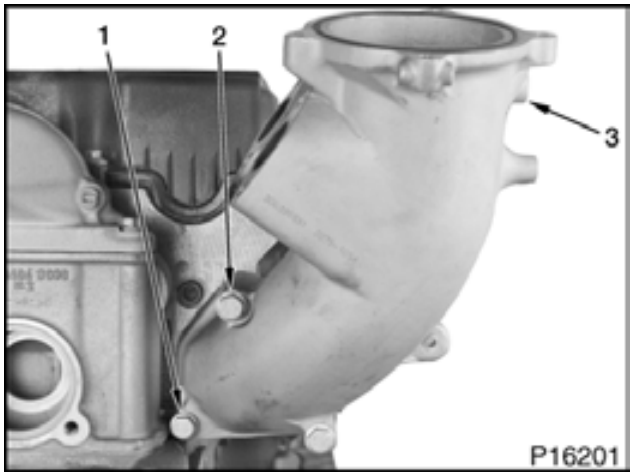

Figure 486 Air inlet duct

1. M8 x 50 hex bolt
2. M8 x 90 hex bolt (2)
3. Air inlet duct

3. Remove M8 x 50 hex bolt and two M8 x 90 hex bolts.
4. Remove air inlet duct.

Cleaning, Inspection, and Testing

Air Inlet Duct and Exhaust Manifolds

NOTE: Do not use air tools or abrasive pads to clean aluminum parts.

Air inlet duct and three exhaust manifold sections are castings and may be cleaned with steam or suitable non-caustic solvents.

1. Clean cylinder head to air inlet duct and exhaust manifold gasket surfaces.

Manifold Warp Test for Exhaust Manifolds

1. Use a straightedge and feeler gauge (page 283) to check seating surface flatness of three exhaust manifold sections.
2. Check for flatness – across left and right and diagonally. See specifications (page 283).
3. If specification is not met, replace individual exhaust manifold section. Do not resurface.

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Installation

Air Inlet Duct

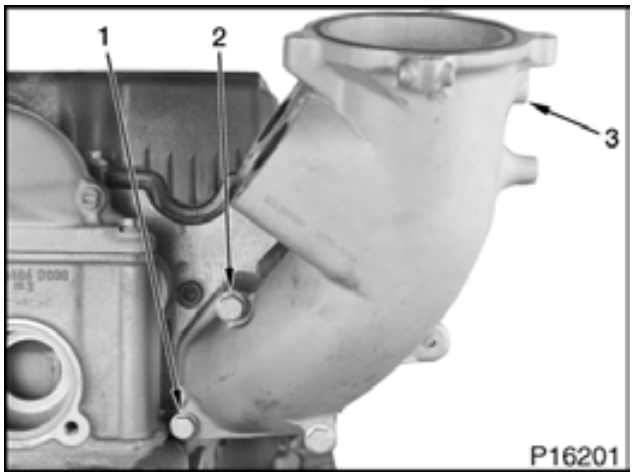

Figure 487 Air inlet duct

1. M8 x 50 hex bolt
2. M8 x 90 hex bolt (2)
3. Air inlet duct

1. Apply Loctite® 5900 sealant or equivalent (page 283) to joining surfaces of air inlet duct and cylinder head.
2. Install air inlet duct.
3. Install M8 x 50 hex bolt and two M8 x 90 hex bolts. Tighten bolts to special torque (page 283).
4. Install Coolant Elbow (page 309).
5. If equipped, install High Mount Fan Drive (page 310).

Exhaust Manifold

CAUTION: To prevent engine damage, hand torque all fasteners of the exhaust manifolds. The exhaust manifold hardware has a special high-temperature coating which will be damaged by air tools.

CAUTION: To prevent engine damage, do not reuse high-temperature spacing sleeves and exhaust manifold screws.

NOTE: Do not apply anti-seize compound to threads.

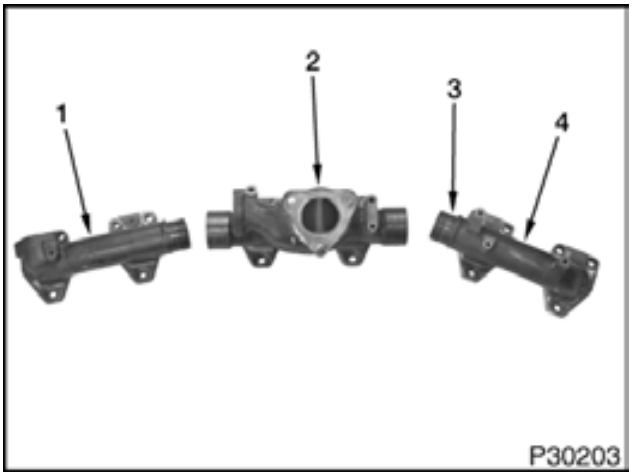

Figure 488 Exhaust manifold

1. Rear exhaust manifold
2. Middle exhaust manifold
3. Multipiece oil ring (4)
4. Front exhaust manifold

1. Install four new multpiece oil rings. Two to the front and two to the rear exhaust manifolds.
2. Install the front and rear exhaust manifold into middle exhaust manifold.

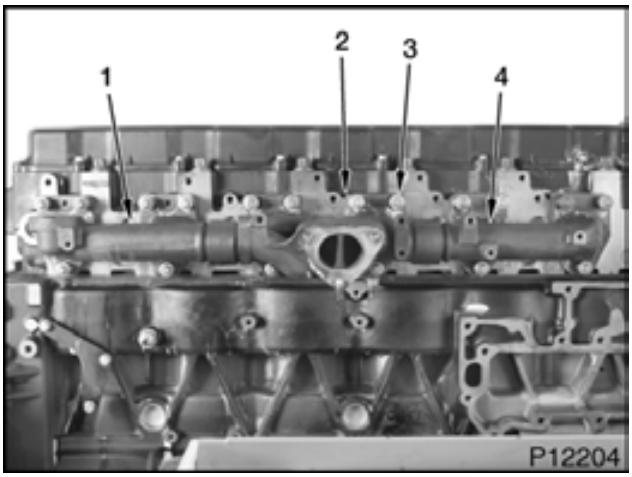

Figure 489 Exhaust manifold

1. Rear exhaust manifold
2. Middle exhaust manifold
3. M10 x 48 screw (18) and high temperature spacing sleeve (18)
4. Front exhaust manifold

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NOTE: Ensure that raised part of exhaust manifold gasket is facing out towards exhaust manifold.

3. Position six new exhaust manifold gaskets and install exhaust manifold assembly.

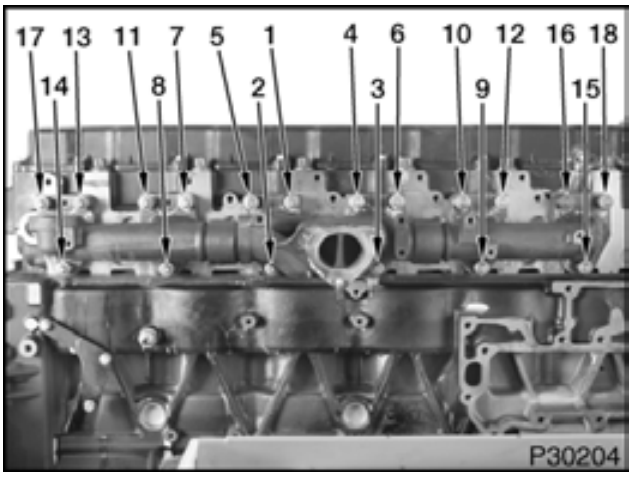

Figure 490 Exhaust manifold tightening sequence

4. Install 18 new M10 x 48 screws and 18 new high temperature spacing sleeves. Use tightening sequence indicated in figure 9.
   a. Tighten screws to 20 N·m (15 lbf·ft).
   b. Turn screws an additional 90°.

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Specifications

Table 21 Exhaust Manifolds

Exhaust manifold maximum allowable warpage	0.1 mm (0.003 in)

Special Torque

Table 22 Air Inlet Duct and Exhaust Manifolds

Exhaust manifold screws	See tightening procedure and sequence
Air inlet duct hex bolts	15 N·m (11 lbf·ft)

Special Service Tools

Table 23 Air Inlet Duct and Exhaust Manifolds

Description	Tool Number
Feeler Gauge	Obtain locally
Straightedge	Obtain locally
Loctite® 5900 Sealant or equivalent	Obtain locally

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Exploded Views

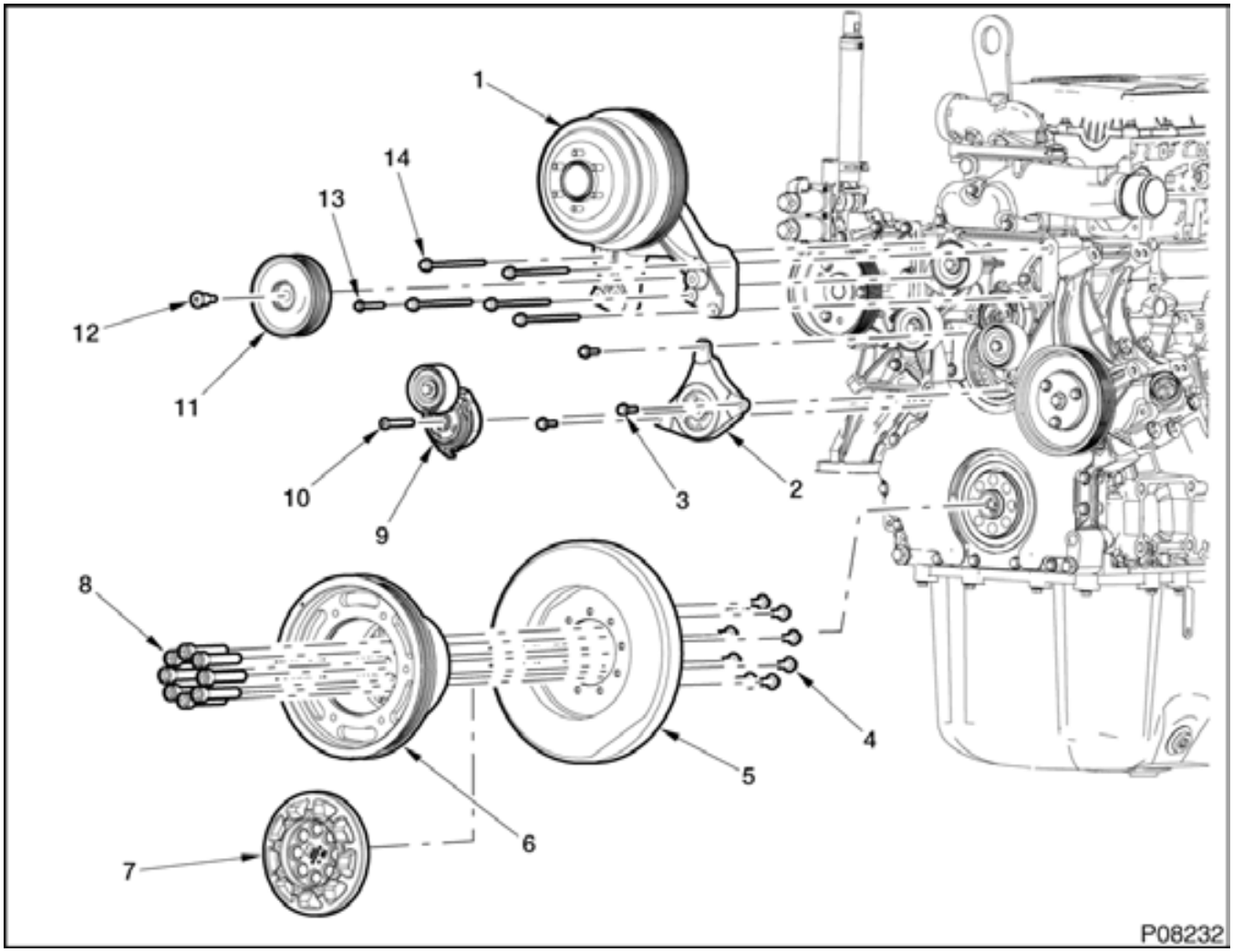

Figure 491 High mount fan drive system and vibration damper

1. Air clutch fan drive
2. Tensioner bracket
3. M8 x 30 hex bolt (3)
4. M10 x 35 hex bolt (9)
5. Vibration damper
6. Fan drive pulley (in place of hub for high mount fan application)
7. Hub for vibration damper (in place of pulley for low mount fan application)
8. M16 x 85 cylinder screw (8)
9. Tensioner
10. M10 x 70 countersunk screw
11. Pulley assembly
12. Shoulder bolt
13. M10 x 65 hex bolt
14. M10 x 150 hex bolt (5)

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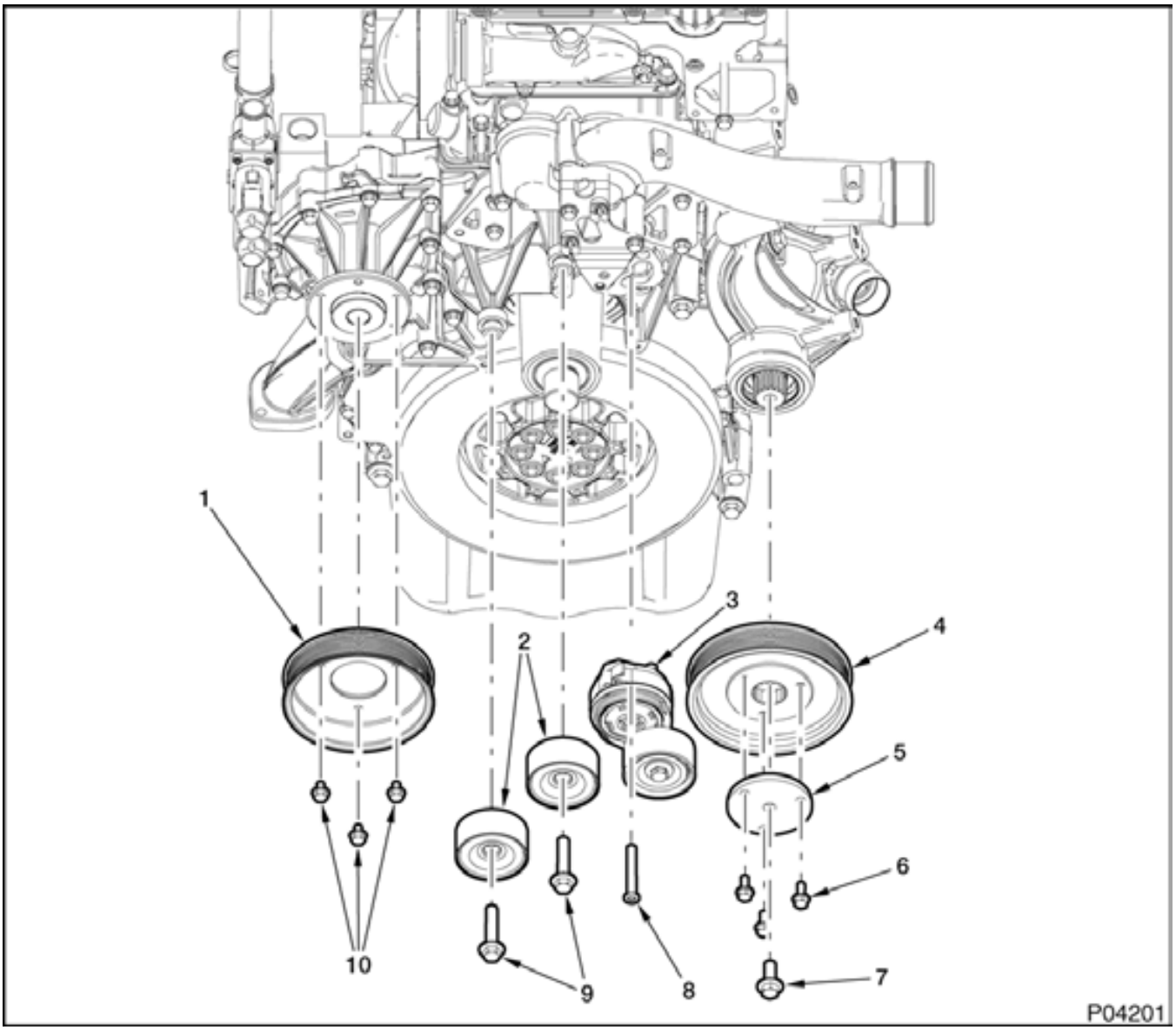

Figure 492 Accessory drive system (typical)

1. Pulley (water pump)
2. Cable roller (2)
3. Automatic belt tensioner
4. Pulley (drive housing)
5. Washer
6. M8 x 20 hex bolt (3)
7. M12 x 30 hex bolt
8. M10 x 70 countersunk screw
9. M12 x 55 hex bolt (2)
10. M8 x 12 hex bolt (3)

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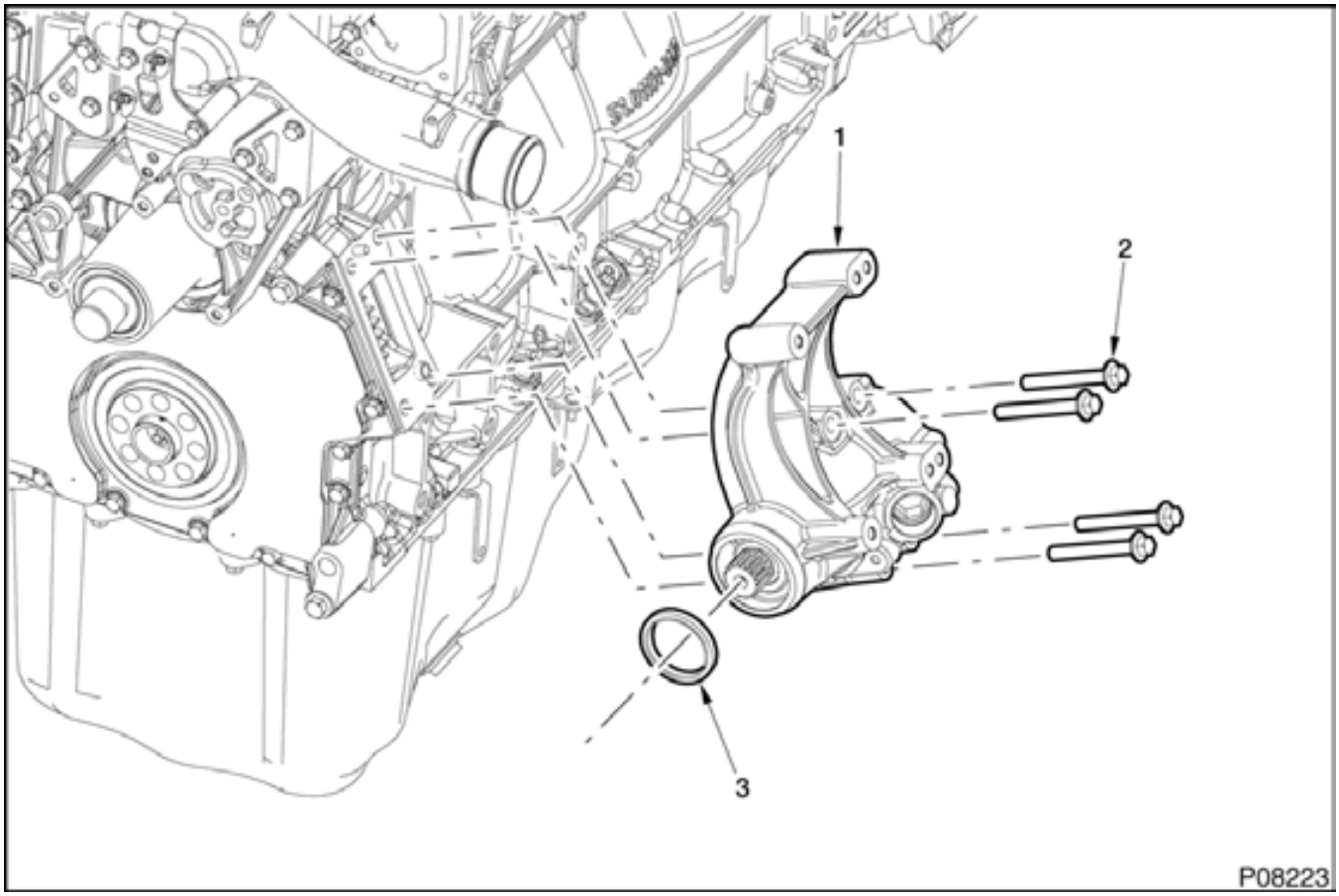

Figure 493 Drive housing

1. Drive housing
2. M12 x 90 hex bolt (4)
3. Radial shaft seal

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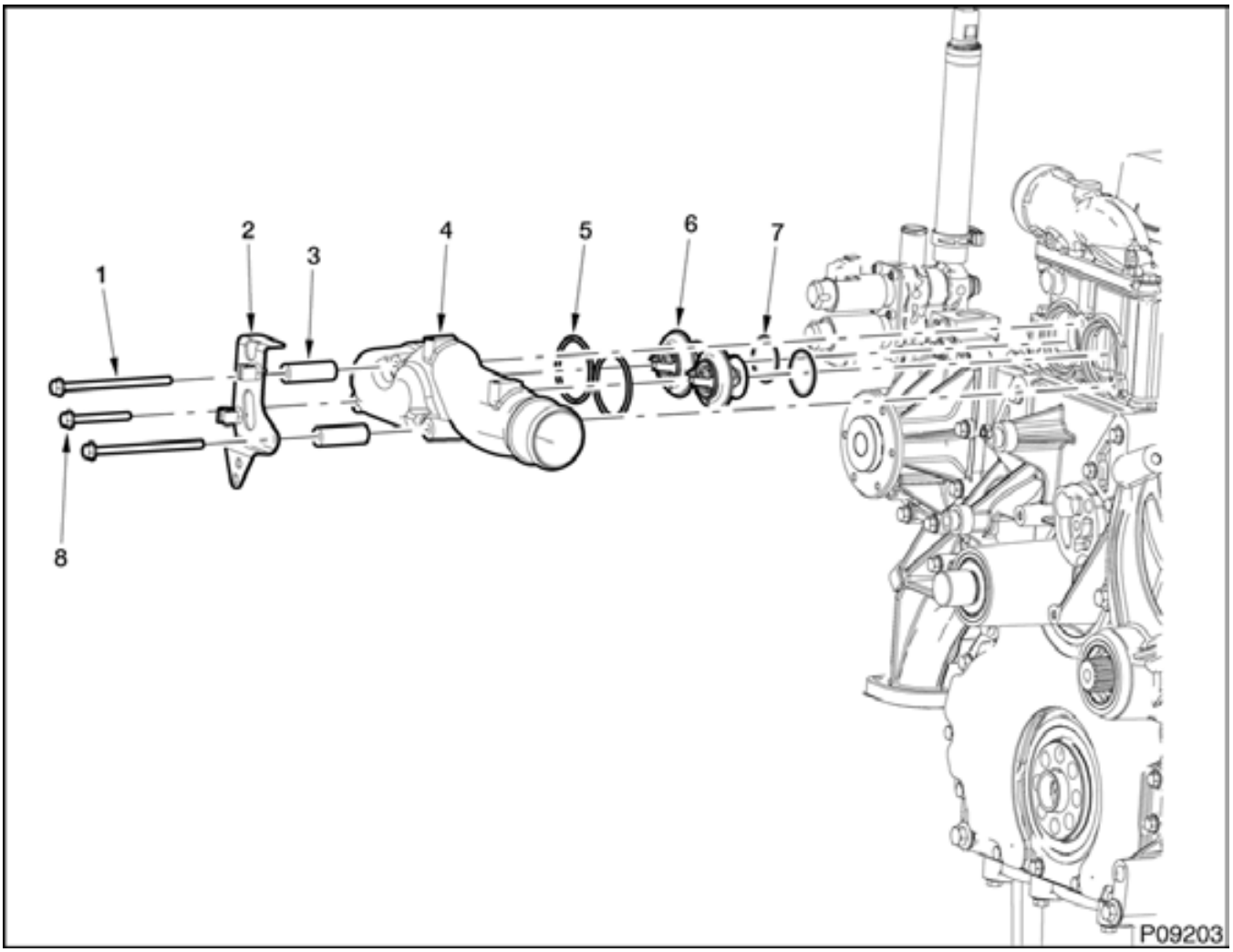

Figure 494 Thermostat elements and coolant elbow

1. M8 x 130 hex bolt (2) (M8 x 70 with high mount fan only)
2. Bracket (with low mount fan only)
3. Bushing (2) (with low mount fan only)
4. Coolant elbow (to radiator)
5. 60 x 4 O-ring (2)
6. Thermostat element (2)
7. Gasket (2)
8. M8 x 70 hex bolt

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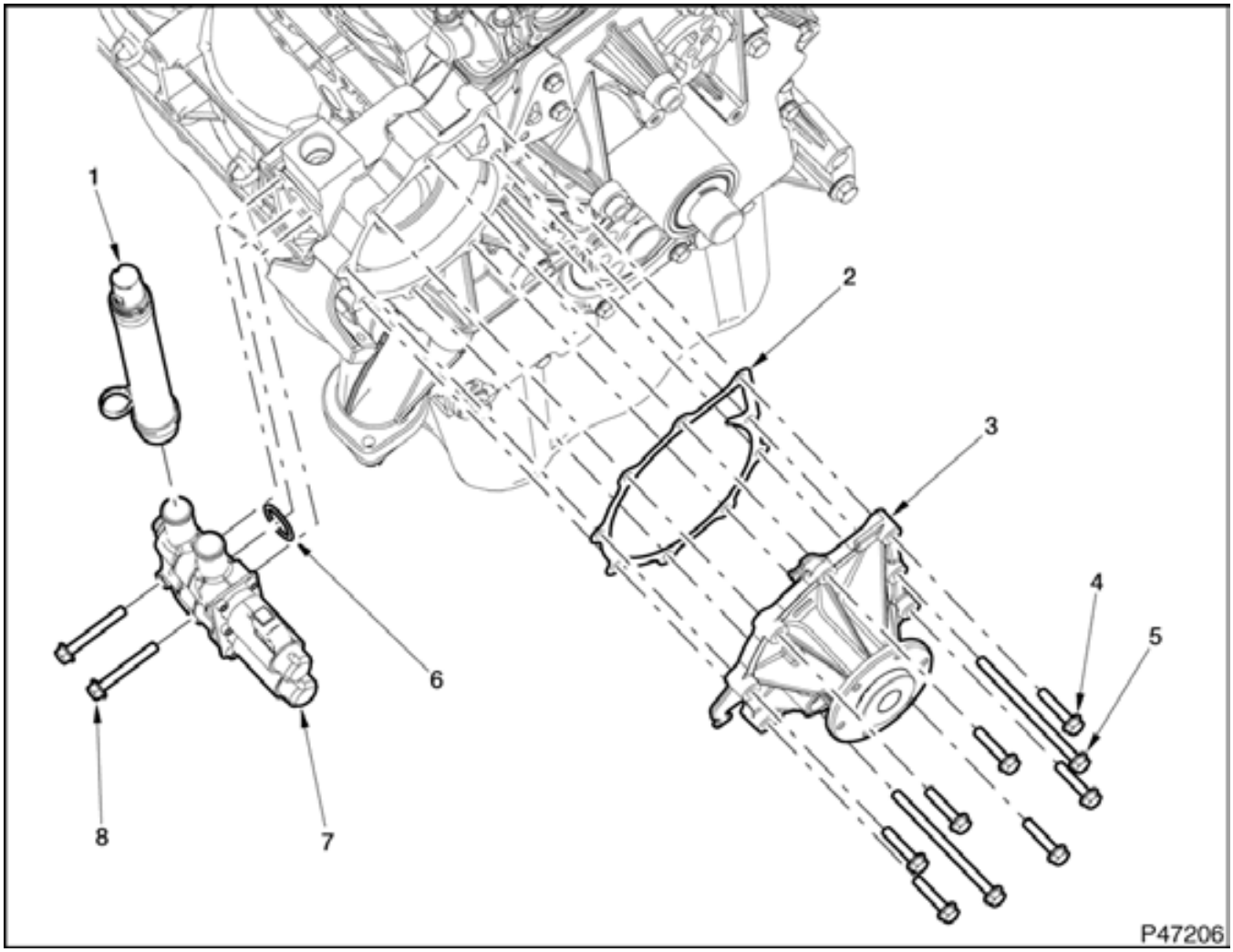

Figure 495 Water pump and Coolant Control Valve (CCV)

1. Coolant pipe low temperature radiator (LTR) supply
2. Water pump gasket
3. Water pump
4. M8 x 40 hex bolt (7)
5. M8 x 130 hex bolt (2)
6. O-ring
7. CCV
8. M8 x 60 hex bolt (2)

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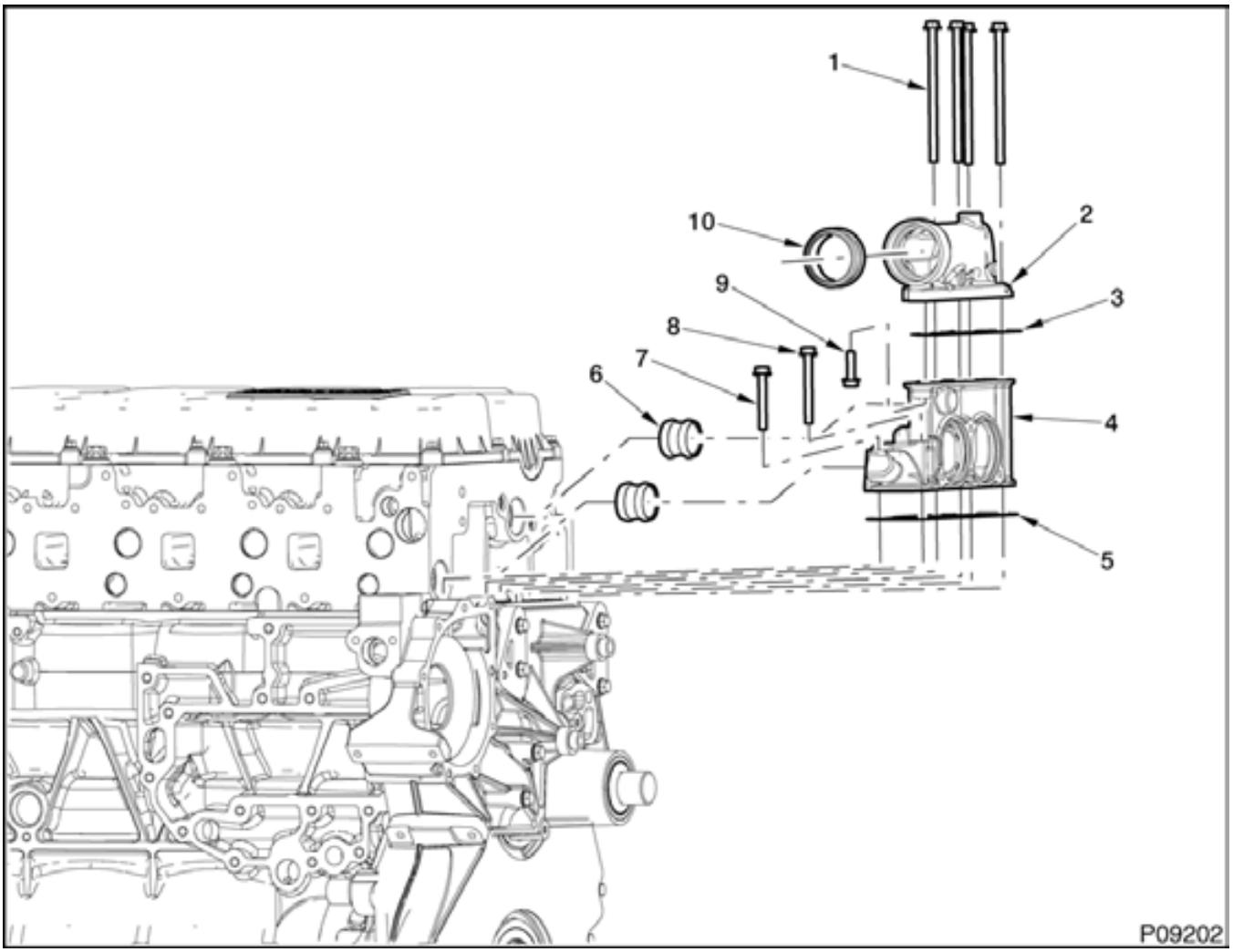

Figure 496 Thermostat housing assembly

1. M8 x 145 hex bolt (4)
2. Coolant elbow (to EGR module)
3. Gasket
4. Thermostat housing assembly
5. Gasket
6. DMR40/DMR32 extension tube (2)
7. M8 x 60 hex bolt
8. M8 x 75 hex bolt
9. M8 x 30 hex bolt
10. DMR62 extension tube

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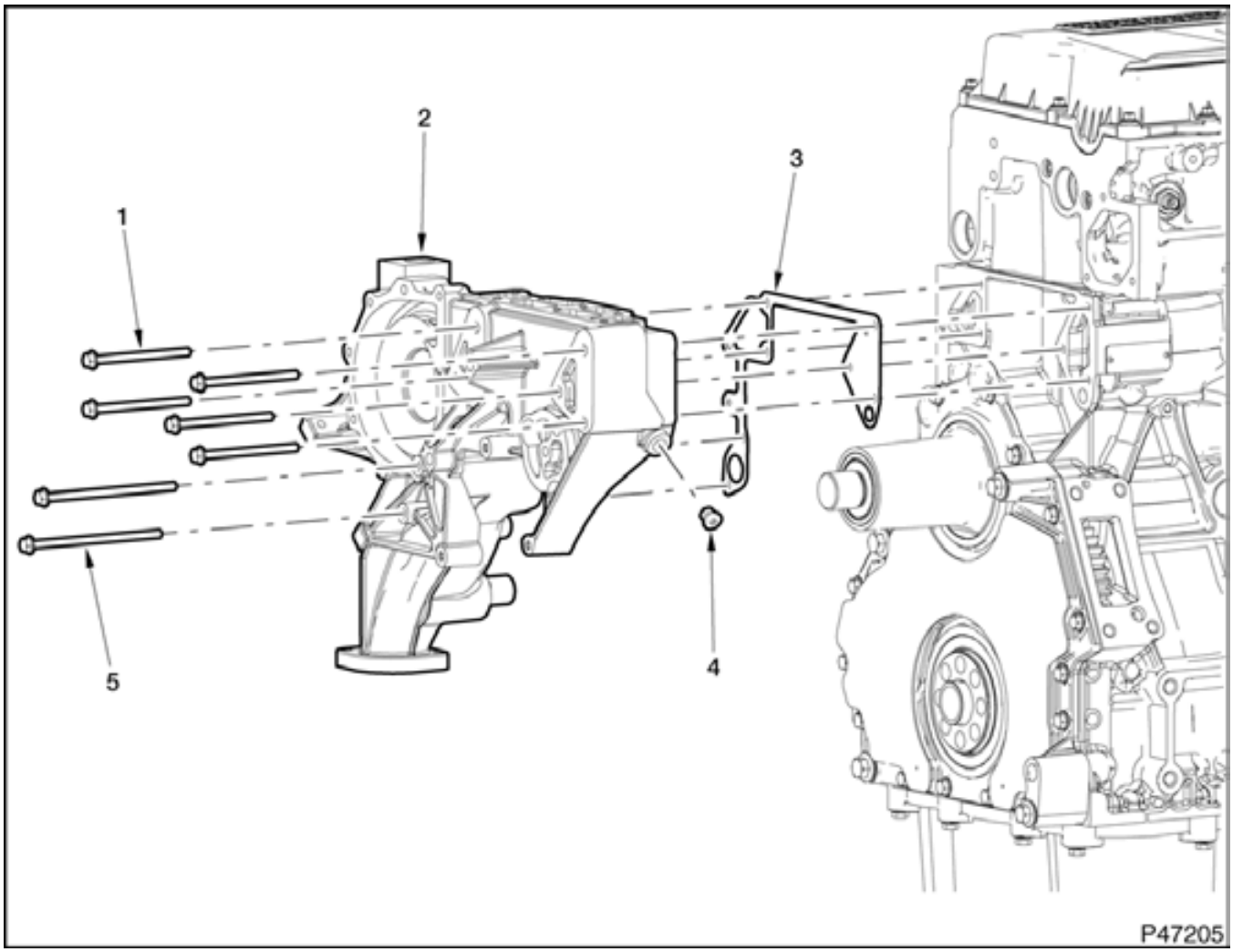

Figure 497 Distributor case (typical)

1. M8 x 110 bolt (5)
2. Distributor case
3. Gasket
4. M14 x 1.5 drain plug
5. M8 x 150 bolt (2)

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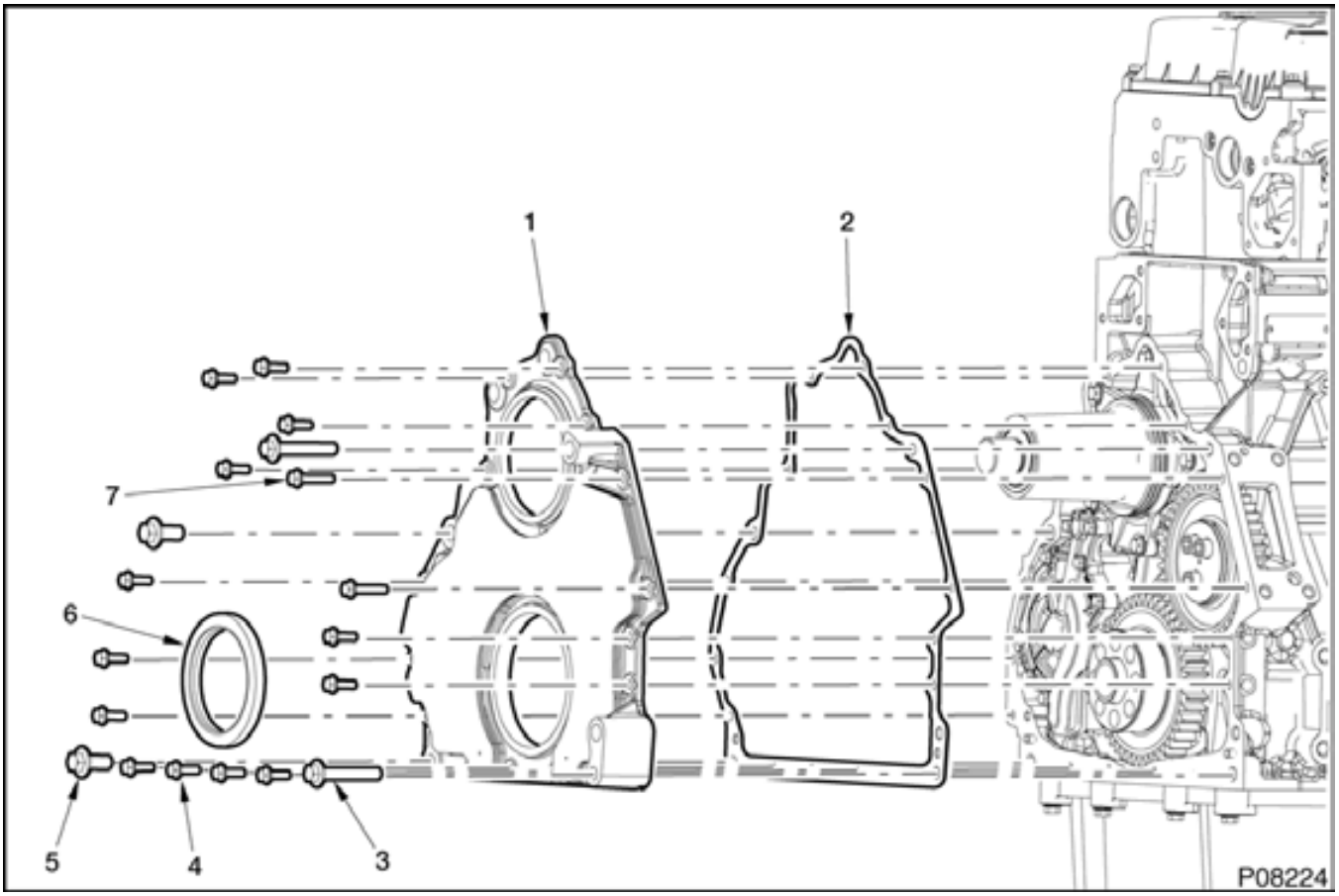

Figure 498 Front crankcase cover (typical)

1. Cover
2. Front cover gasket
3. M12 x 70 hex bolt (2)
4. M8 x 25 hex bolt (13)
5. M14 x 30 hex bolt (2)
6. Radial shaft seal
7. M8 x 40 hex bolt (2)

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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, make sure 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.

NOTE: Refer to the following service sections for information on removal of components prior to this section.

- Engine Electrical
- Fuel System
- Exhaust Gas Recirculation (EGR) System

Pulley (High Mount Fan)

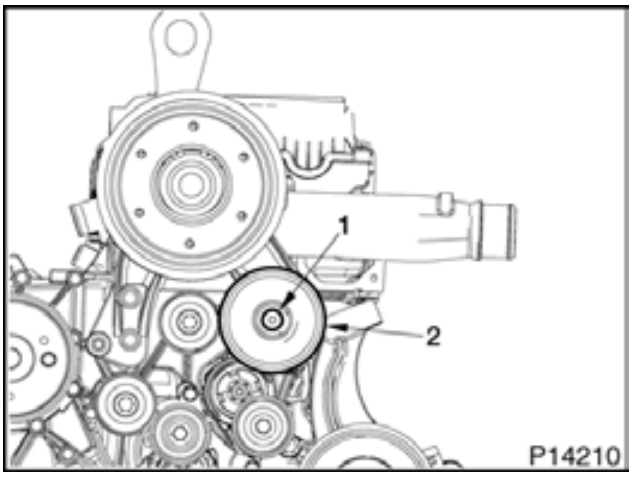

Figure 499 Pulley assembly

1. Shoulder bolt
2. Pulley assembly

1. Remove shoulder bolt and pulley assembly.

Tensioner Bracket (High Mount Fan)

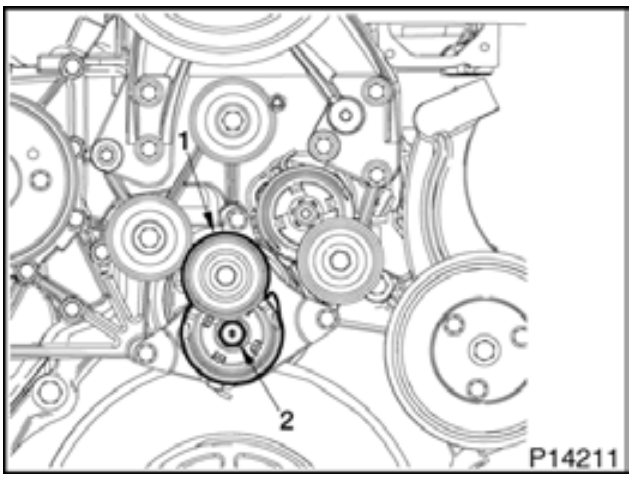

Figure 500 Tensioner

1. Tensioner
2. M10 x 70 countersunk screw

1. Remove M10 x 70 countersunk screw and tensioner.

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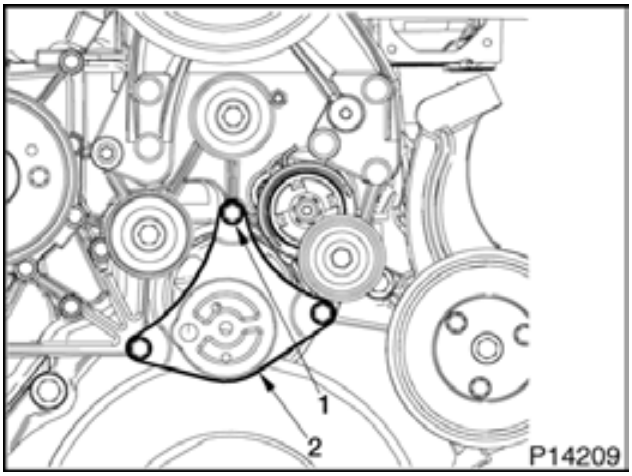

Figure 501 Tensioner bracket

1. M8 x 30 hex bolt (3)
2. Tensioner bracket

2. Remove three M8 x 30 hex bolts and tensioner bracket.

High Mount Fan Drive

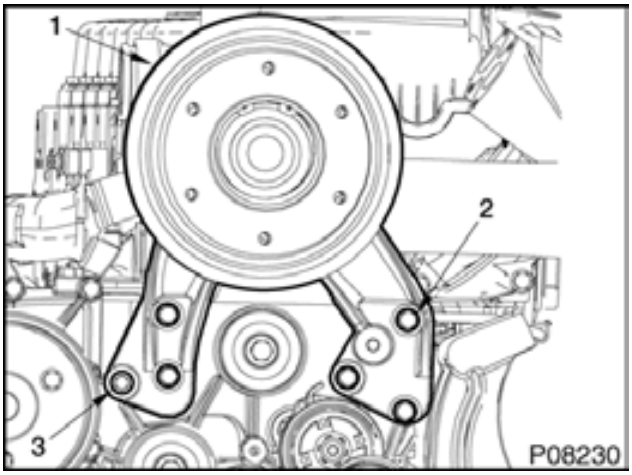

Figure 502 Air clutch fan drive

1. Air clutch fan drive
2. M10 x 150 hex bolt (5)
3. M10 x 65 hex bolt

1. Disconnect air line from back of air clutch fan drive.
2. Remove five M10 x 150 and M10 x 65 hex bolts and air clutch fan drive.
3. Discard all hex bolts.

Coolant Elbow and Thermostat Elements

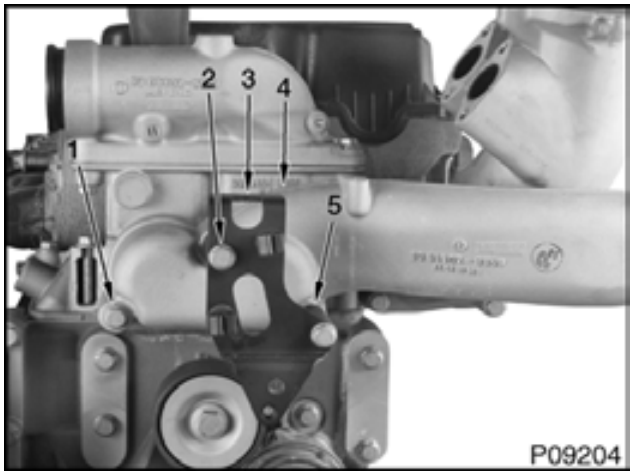

Figure 503 Coolant elbow (to radiator)

1. M8 x 70 hex bolt
2. M8 x 130 hex bolt (2) (M8 x 70 with high mount fan only)
3. Bracket (with low mount fan only)
4. Coolant elbow
5. Bushing (2) (with low mount fan only)

1. Remove coolant elbow hex bolts as follows:
   a. If equipped with low mount fan, remove M8 x 70 and two M8 x 130 hex bolts, bracket and two bushings.
   b. If equipped with high mount fan, remove three M8 x 70 hex bolts.
2. Remove coolant elbow.

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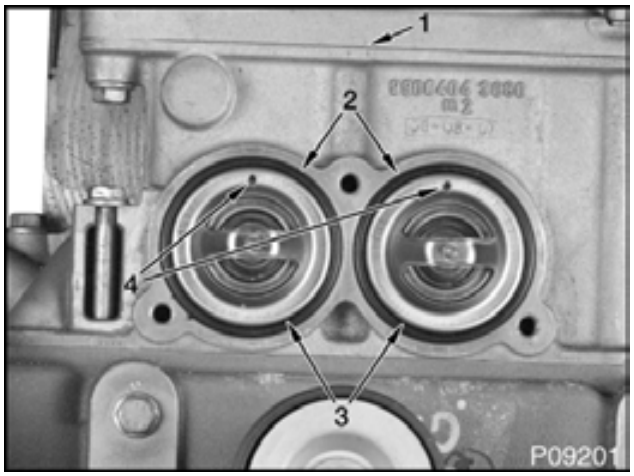

Figure 504 Thermostat elements

1. Thermostat housing assembly
2. 60 x 4 O-ring (2)
3. Thermostat element (2)
4. Ball valves (part of thermostat elements)

3. Remove and discard two 60 x 4 O-rings.
4. Remove two thermostat elements and gaskets from thermostat housing assembly. Discard gaskets.

Automatic Belt Tensioner and Cable Roller (Typical)

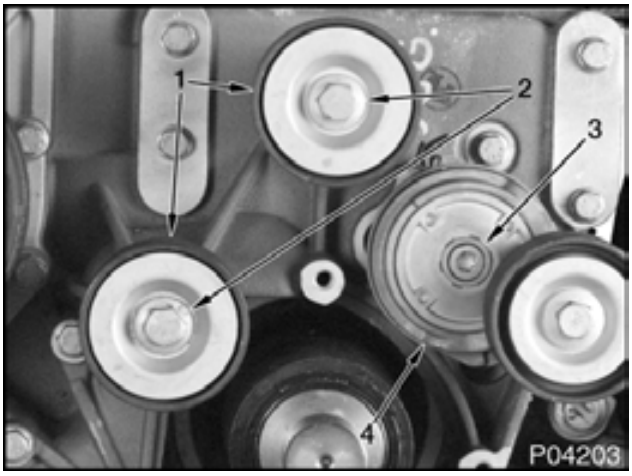

Figure 505 Automatic belt tensioner and cable roller

1. Cable roller (2)
2. M12 x 55 hex bolt (2)
3. M10 x 70 countersunk screw
4. Automatic belt tensioner

1. Remove two M12 x 55 hex bolts and cable rollers.

CAUTION: To prevent engine damage, do not twist the belt tensioner; damage to the locating pin may occur, resulting in improper alignment of the belt tensioner.

2. Remove M10 x 70 countersunk screw and automatic belt tensioner.

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Water Pump Pulley

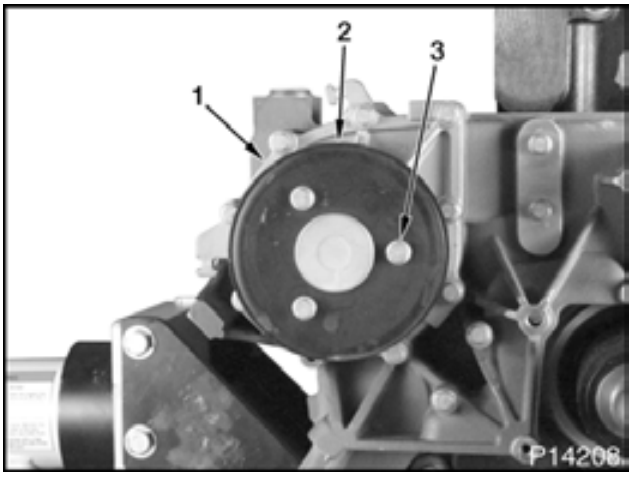

Figure 506 Water pump pulley

1. Water pump
2. Pulley
3. M8 x 12 hex bolt (3)

1. Remove three M8 x 12 hex bolts and water pump pulley.

Drive Housing Pulley

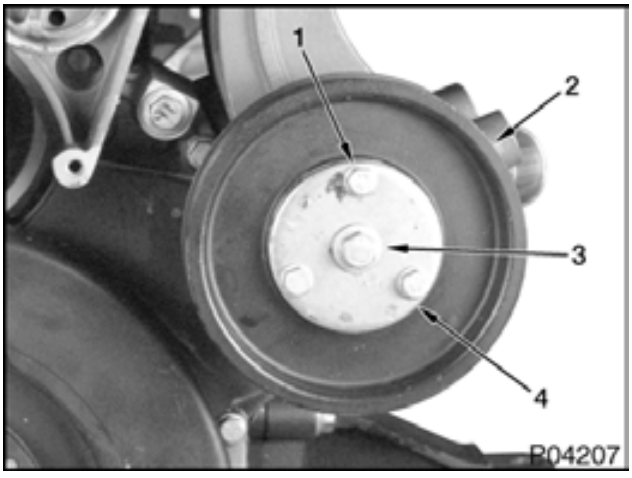

Figure 507 Drive housing pulley

1. M8 x 20 hex bolt (3)
2. Pulley
3. M12 x 30 hex bolt
4. Washer

1. Remove M12 x 30 and three M8 x 20 hex bolts. Clean any sealer off of bolt threads.
2. Remove washer from drive housing pulley and clean sealer off of washer.

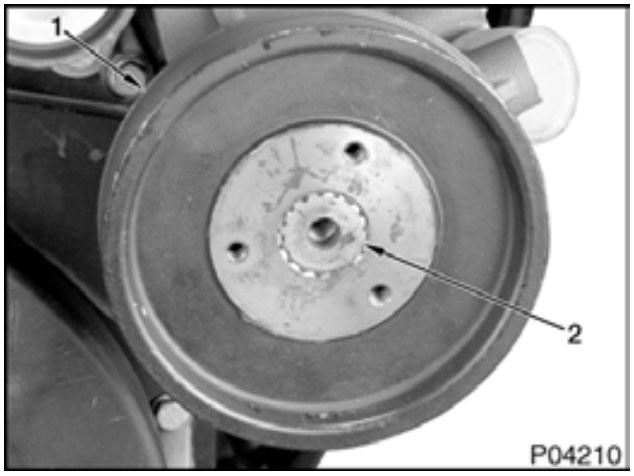

Figure 508 Drive housing pulley

1. Pulley
2. Drive housing shaft

3. Remove pulley from drive housing shaft. Clean any sealer from drive housing shaft and pulley.

Vibration Damper (Typical)

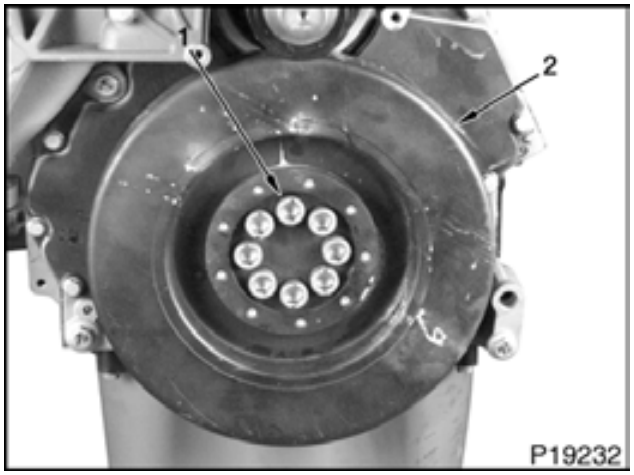

Figure 509 Vibration damper (without fan drive pulley)

1. M16 x 85 cylinder screw (8)
2. Vibration damper

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WARNING: To prevent personal injury or death, support the vibration damper when removing bolts. The damper can easily slide off the end of the crankshaft.

NOTE: If equipped with high mount fan, remove pulley and vibration damper together. If equipped with vibration damper hub, remove hub and vibration damper together.

1. Remove eight M16 x 85 cylinder screws.
2. Remove vibration damper with hub or pulley as an assembly.
3. For vibration damper replacement only, remove hub or fan drive pulley by removing nine M10 x 35 hex bolts.

Drive Housing Radial Shaft Seal

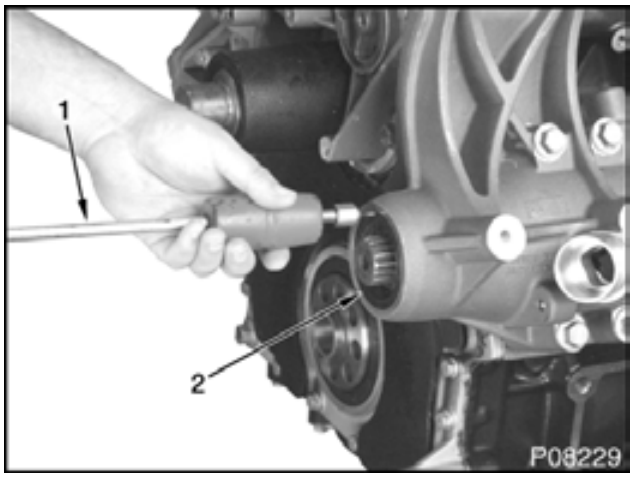

Figure 510 Drive housing radial shaft seal

1. Slide hammer
2. Radial shaft seal

1. With an awl and hammer, punch two holes 180° apart in radial shaft seal.
2. Thread a slide hammer (page 312) with correct size screw into one of the two holes.
3. Slide hammer until one side of seal begins to pull out of drive housing. Move slide hammer to other hole and repeat until radial shaft seal is completely removed.

Drive Housing

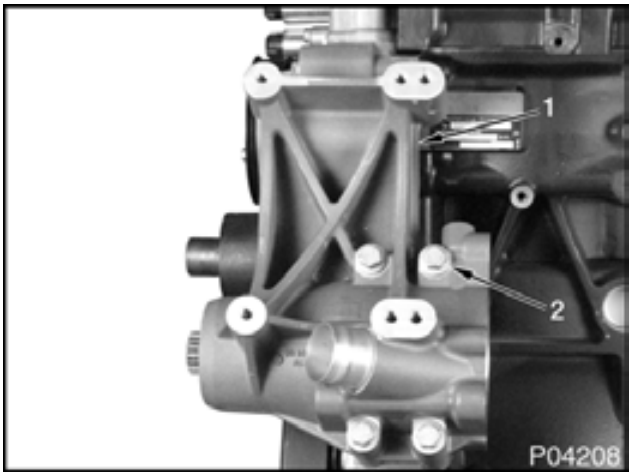

Figure 511 Drive housing

1. Drive housing
2. M12 x 90 hex bolt (4)

1. Remove four M12 x 90 drive housing hex bolts.
2. Remove drive housing off crankcase dowels.
3. Clean all RTV from sealing surfaces.

Coolant Control Valve (CCV)

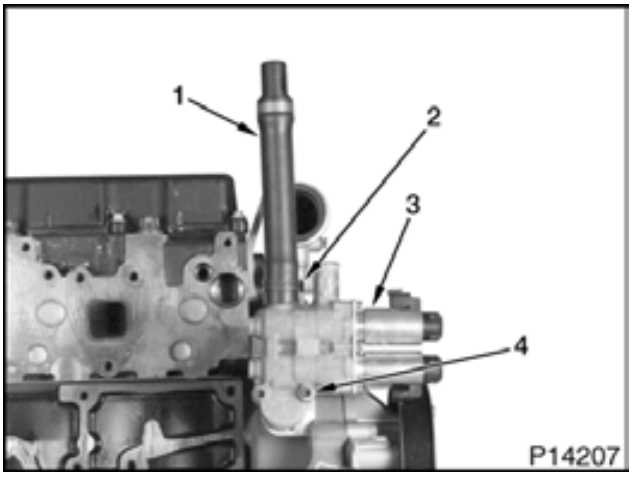

Figure 512 Coolant Control Valve (CCV)

1. Coolant pipe low temperature radiator (LTR) supply
2. Clamp
3. CCV
4. M8 x 60 hex bolt (2)

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1. Release clamp and remove coolant pipe LTR supply.
2. Remove two M8 x 60 hex bolts and CCV with O-ring.

Thermostat Housing Assembly

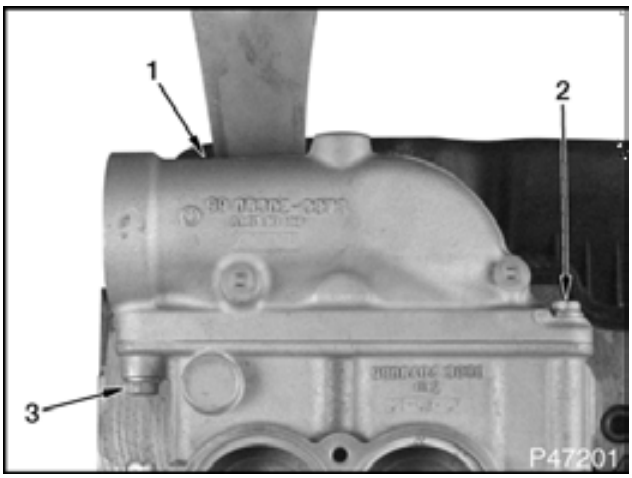

Figure 513 Coolant elbow (to Exhaust Gas Recirculation (EGR) module)

1. Coolant elbow
2. M8 x 145 hex bolt (4)
3. M8 x 30 hex bolt

CAUTION: To prevent engine damage, do not remove extension tubes by grabbing sealing surface.

1. Remove DMR62 extension tube from coolant elbow. Inspect extension tube for damage, replace as needed.
2. Remove four M8 x 145 hex bolts and M8 x 30 hex bolt.
3. Remove coolant elbow (EGR module) and discard gasket.

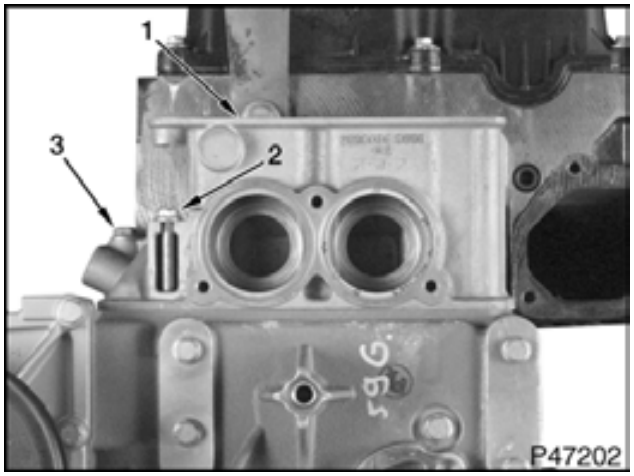

Figure 514 Thermostat housing assembly

1. Thermostat housing assembly
2. M8 x 75 hex bolt
3. M8 x 60 hex bolt

4. Remove M8 x 75 and M8 x 60 hex bolts.
5. Remove thermostat housing assembly and discard gasket.

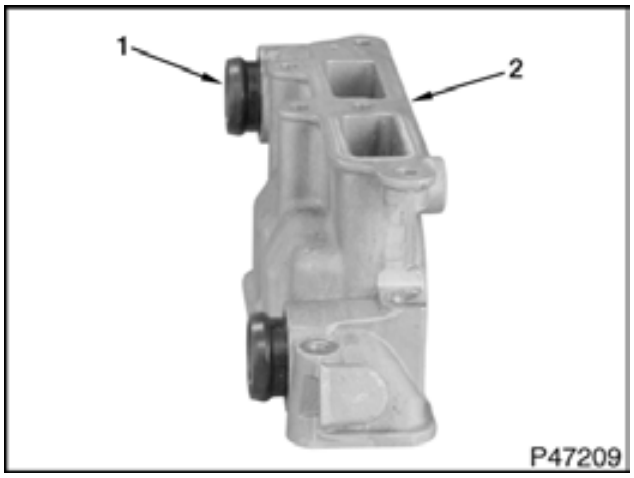

Figure 515 Thermostat housing assembly

1. DMR40/DMR32 extension tube
2. Thermostat housing assembly

CAUTION: To prevent engine damage, do not remove extension tubes by grabbing sealing surface.

6. Remove two DMR40/DMR32 extension tubes from thermostat housing assembly. Inspect extension tubes for damage, replace as needed.

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Water Pump

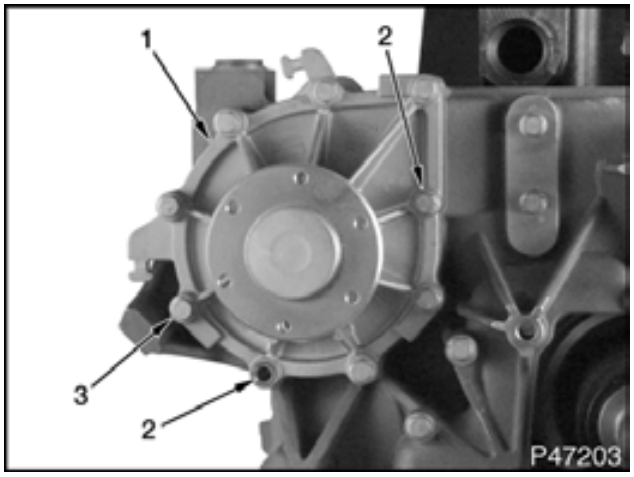

Figure 516 Water pump

1. Water pump
2. M8 x 130 hex bolt (2)
3. M8 x 40 hex bolt (7)

NOTE: If the oil module was removed previously, the second M8 x 130 bolt will already have been removed.

1. Remove one or two M8 x 130 hex bolts and seven M8 x 40 hex bolts.

CAUTION: To prevent engine damage, do not drop water pump impeller or hit impeller with hard objects.

2. Remove water pump and discard water pump gasket.

Distributor Case

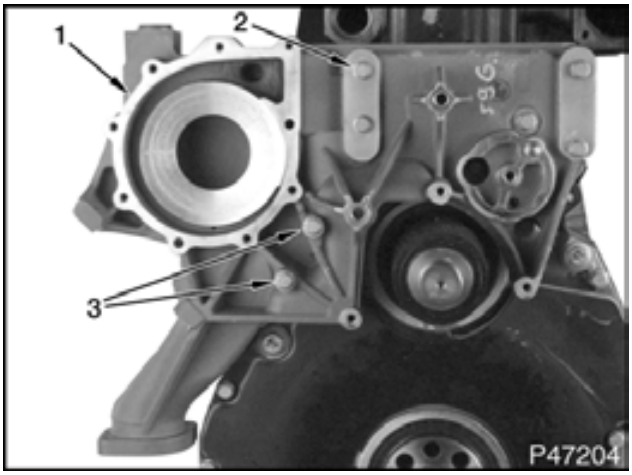

Figure 517 Distributor case

1. Distributor case
2. M8 x 110 hex bolt (5)
3. M8 x 150 hex bolt (2)

1. Remove two M8 x 150 and five M8 x 110 hex bolts.
2. Remove distributor case and discard gasket.

Front Crankcase Cover Radial Shaft Seal

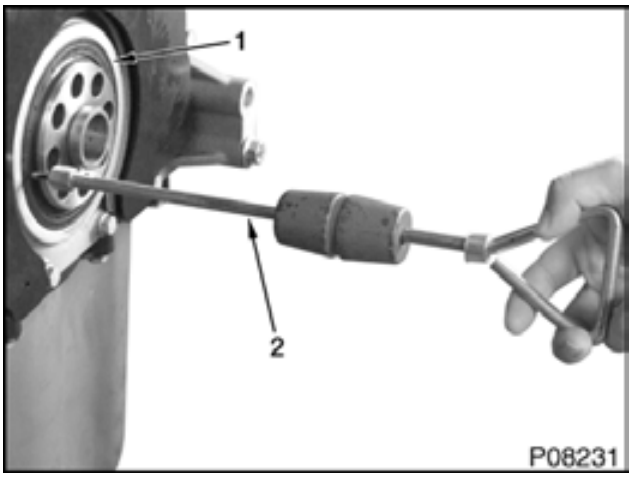

Figure 518 Radial shaft seal

1. Radial shaft seal
2. Slide hammer

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WARNING: To prevent personal injury or death, wear safety glasses with side shields when doing the following procedure.

1. With an awl and hammer, punch two holes 180° apart in front oil seal.
2. Thread a slide hammer (page 312) with correct size screw in one of the two holes.
3. Slide hammer until one side of seal begins to pull out of cover. Move slide hammer to other hole and repeat until front oil seal is removed completely.

Front Crankcase Cover

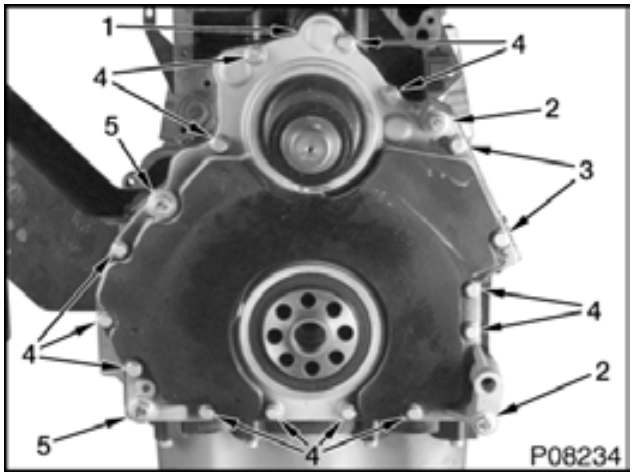

Figure 519 Front crankcase cover bolts (typical)

1. Cover
2. M12 x 70 hex bolt (2)
3. M8 x 40 hex bolt (2)
4. M8 x 25 hex bolt (13)
5. M14 x 30 hex bolt (2)

1. Remove two M8 x 40 hex bolts, two M14 x 30 hex bolts, two M12 x 70 hex bolts and 13 M8 x 25 hex bolts.
2. Remove cover and front cover gasket from crankcase dowels. Discard front cover gasket.

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Cleaning, Inspection, and Testing

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

1. Clean distributor case, water pump, coolant elbows, thermostat housing, front engine mount, and front crankcase cover with a suitable non-caustic solvent.
2. Blow parts dry using filtered compressed air.
3. Clean coolant and oil seal mating surfaces on the crankcase, cylinder head, distributor case, water pump, coolant elbow, thermostat housing, and front crankcase cover.
4. Inspect distributor case, coolant elbow, vibration damper, and front crankcase cover, for damage, contamination, or excessive wear. Replace parts if required.
5. Inspect automatic belt tensioner and pulley to make sure tensioner arm and pulley are properly in line with the fan drive belt and not coming apart. Make sure tensioner arm is not binding and pulley bearing is not loose. Replace belt tensioner if required.
6. Inspect cable rollers to make sure pulleys are properly in line with the fan drive belt and not coming apart. Replace cable rollers if required.
7. Inspect thermostat elements. If thermostat elements are stuck open, damaged, cracked, or not opening properly replace thermostat elements.
8. Inspect water pump. Wiggle water pump hub and shaft. If water pump bearing has excess play, replace water pump. Inspect water pump housing for coolant leaks. Replace water pump if leaking.

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Installation

Front Crankcase Cover

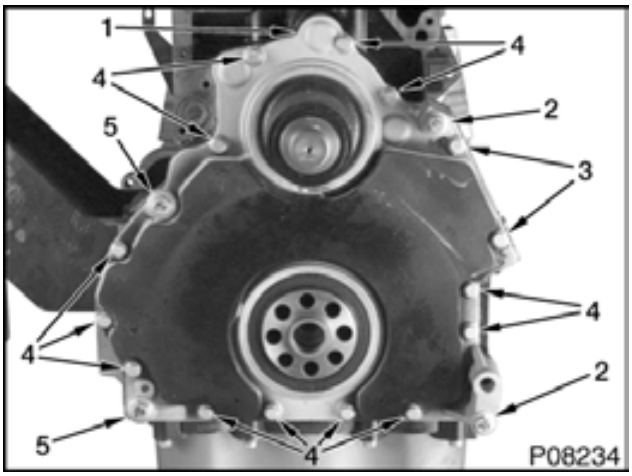

Figure 520 Front crankcase cover bolts (typical)

1. Cover
2. M12 x 70 hex bolt (2)
3. M8 x 40 hex bolt (2)
4. M8 x 25 hex bolt (13)
5. M14 x 30 hex bolt (2)

1. Position a new front cover gasket on crankcase dowels.
2. Install cover on crankcase dowels.
3. Install two M8 x 40 hex bolts, two M14 x 30 hex bolts, two M12 x 70 hex bolts and 13 M8 x 25 hex bolts. Tighten hex bolts to special torque (page 312).

Front Crankcase Cover Radial Shaft Seal

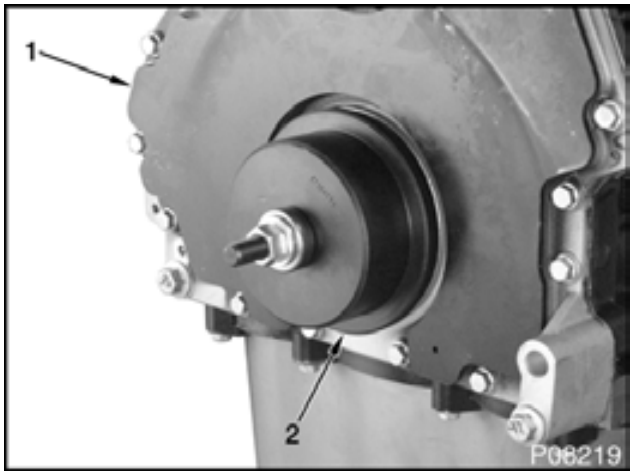

Figure 521 Radial shaft seal

1. Cover
2. Front Crankshaft Seal Installer

CAUTION: To avoid damage to the radial shaft seal, do not touch inner seal lip, allow oil or grease on any part of the seal during installation.

1. Using Front Crankshaft Seal Installer (page 312), install new radial shaft seal into cover.
   a. Install inner hub of tool to crankshaft flange. Use two bolts provided with tool.
   b. Install radial shaft seal to inner hub of tool.
   c. Install pressing hub and nut and tighten to install radial shaft seal. When tool bottoms out, seal is fully installed.

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Distributor Case

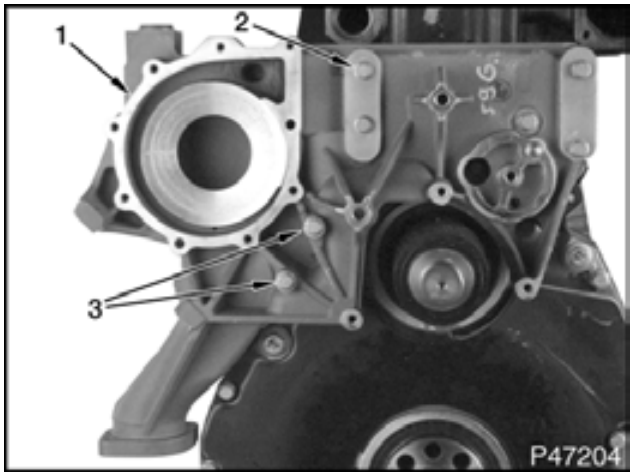

Figure 522 Distributor case

1. Distributor case
2. M8 x 110 hex bolt (5)
3. M8 x 150 hex bolt (2)

1. Install new gasket and distributor case.
2. Install two M8 x 150 hex bolts and five M8 x 110 hex bolts. Tighten hex bolts to special torque (page 312).

Water Pump

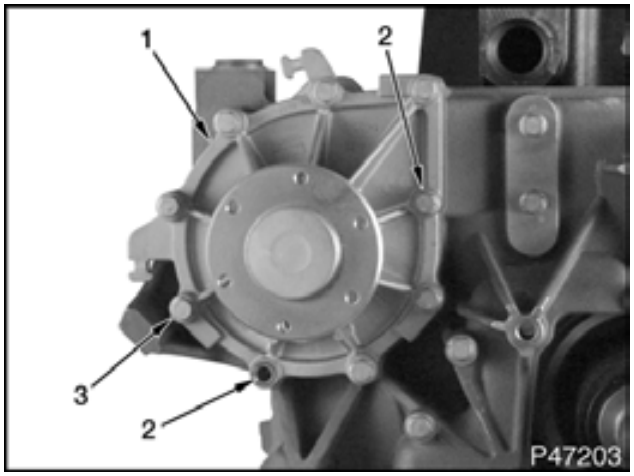

Figure 523 Water pump

1. Water pump
2. M8 x 130 hex bolt (2)
3. M8 x 40 bolt (7)

NOTE: If the oil module was removed previously, the second M8 x 130 bolt will not be installed at this time.

1. Install new water pump gasket and water pump.
2. Install one or two M8 x 130 bolts and seven M8 x 40 hex bolts. Tighten hex bolts to special torque (page 312).

Thermostat Housing Assembly

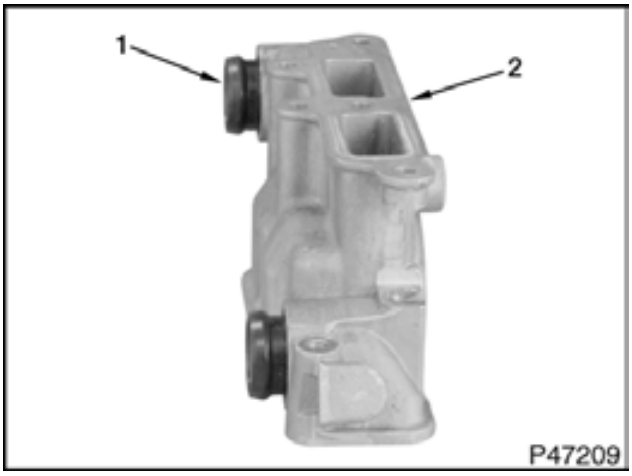

Figure 524 Thermostat housing assembly

1. DMR40/DMR32 extension tube
2. Thermostat housing assembly

1. Lubricate sealing surfaces of two DMR40/DMR32 extension tubes with P-80® Rubber Lubricant or equivalent (page 312) and install into thermostat housing assembly.

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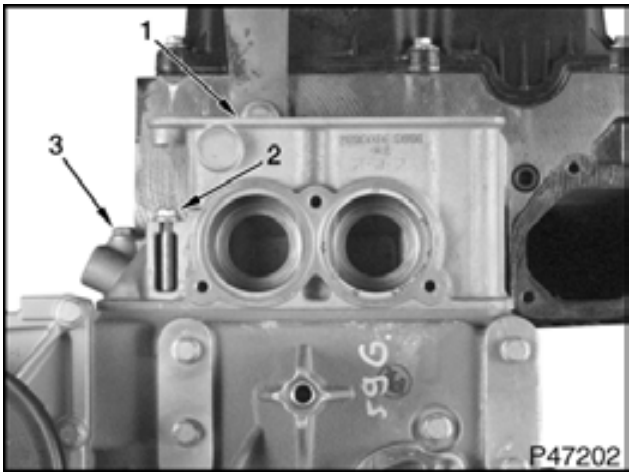

Figure 525 Thermostat housing assembly

1. Thermostat housing assembly
2. M8 x 75 hex bolt
3. M8 x 60 hex bolt

2. Install new gasket and thermostat housing assembly.
3. Install M8 x 75 and M8 x 60 hex bolts. Do not tighten hex bolts until coolant elbow is installed.

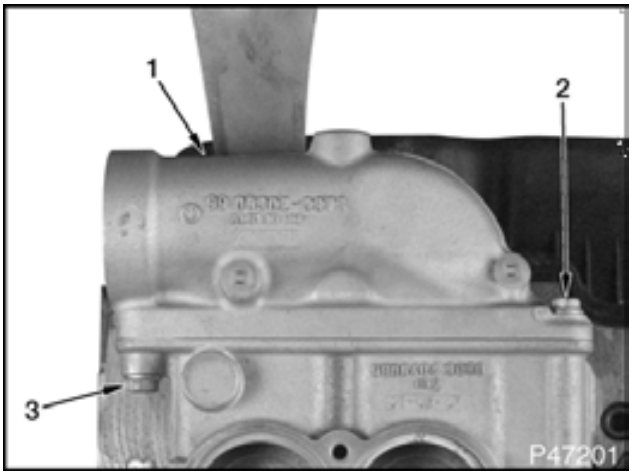

Figure 526 Coolant elbow (to Exhaust Gas Recirculation (EGR) module)

1. Coolant elbow
2. M8 x 145 hex bolt (4)
3. M8 x 30 hex bolt

4. Install new gasket and coolant elbow.
5. Install four M8 x 145 hex bolts and M8 x 30 hex bolt. Tighten hex bolts to special torque (page 312).
6. Tighten M8 x 75 and M8 x 60 thermostat housing assembly hex bolts to special torque (page 312).
7. Lubricate sealing surfaces of DMR62 extension tube with P-80® Rubber Lubricant or equivalent (page 312) and install into coolant elbow.

Coolant Control Valve (CCV)

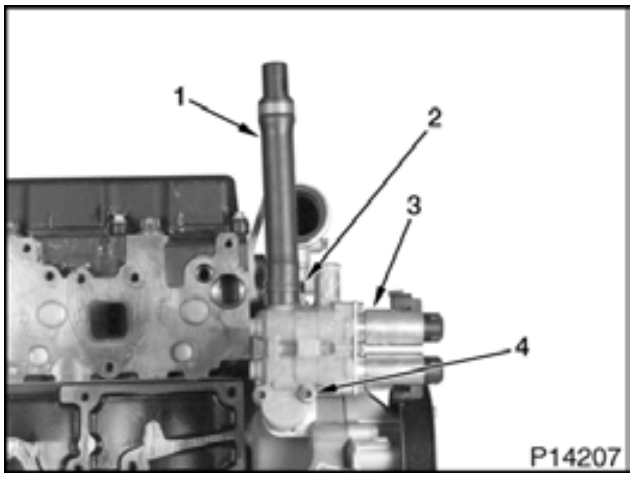

Figure 527 Coolant control valve (CCV)

1. Coolant pipe low temperature radiator (LTR) supply
2. Clamp
3. CCV
4. M8 x 60 hex bolt (2)

1. Inspect O-ring for damage and replace as needed.
2. Install CCV and two M8 x 60 hex bolts. Tighten hex bolts to special torque (page 312).
3. Install coolant pipe LTR supply and release clamp.

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Drive Housing

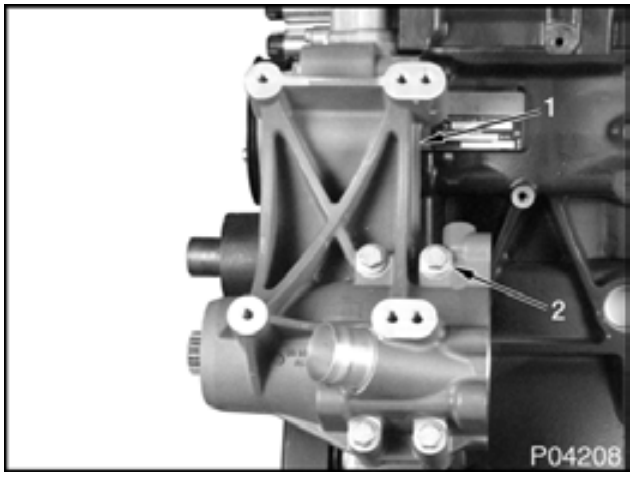

Figure 528 Drive housing

1. Drive housing
2. M12 x 90 hex bolt (4)

CAUTION: To prevent engine damage, apply Liquid Gasket and component within 5 minutes of application to inhibit the formation of a skin and ensure a leak proof joint.

1. Apply Loctite® 5900 or Wacker 442T (page 312) to joining surfaces of drive housing and crankcase.
2. Install drive housing on crankcase dowels.
3. Install four M12 x 90 drive housing hex bolts. Tighten hex bolts to special torque (page 312).

Drive Housing Radial Shaft Seal

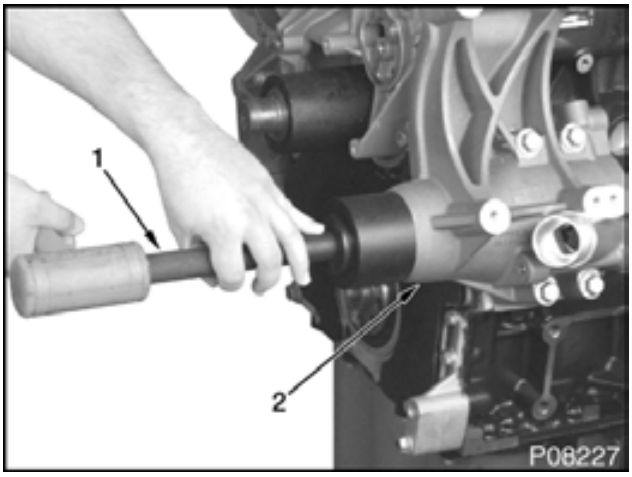

Figure 529 Drive housing radial shaft seal

1. Fan Hub/High Pressure Drive Seal Installer
2. Drive housing

1. Using Fan Hub/High Pressure Drive Seal Installer (page 312), drive new radial shaft seal into drive housing. Seal is fully installed when tool bottoms out on housing.

Vibration Damper (Typical)

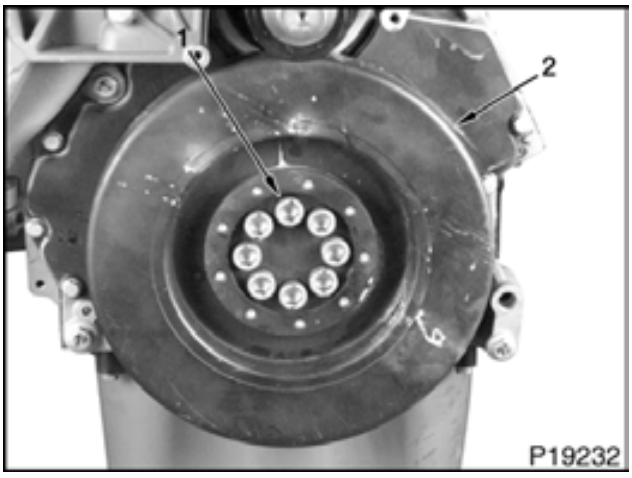

Figure 530 Vibration damper (without fan drive pulley)

1. M16 x 85 cylinder screw (8)
2. Vibration damper

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NOTE: Install hub or pulley and vibration damper together as an assembly.

1. If previously disassembled, assemble vibration damper hub or fan drive pulley to vibration damper with nine M10 x 35 hex bolts. Tighten hex bolts to special torque (page 312).
2. Install vibration damper with hub or pulley as an assembly.
3. Install eight M16 x 85 cylinder screws. Using a crisscross pattern, tighten cylinder screws as follows.
   a. Tighten cylinder screws to 150 N·m (111 lbf·ft).
   b. Turn cylinder screws an additional 90°.

Drive Housing Pulley

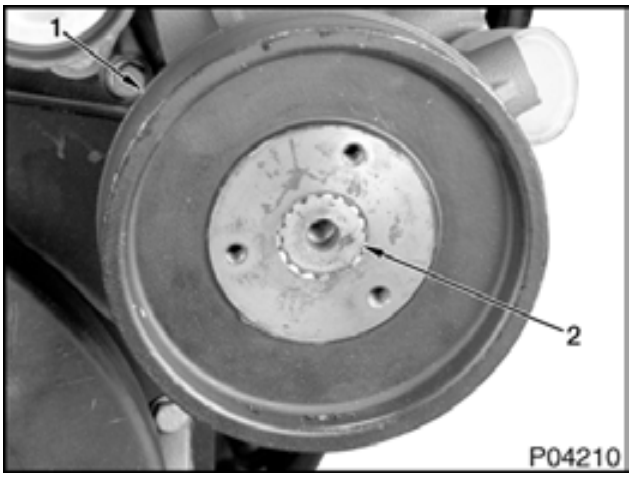

Figure 531 Drive housing pulley

1. Pulley
2. Drive housing shaft

1. Apply Loctite® 5900 sealant or equivalent (page 312) to drive housing shaft.
2. Install pulley onto drive housing shaft.

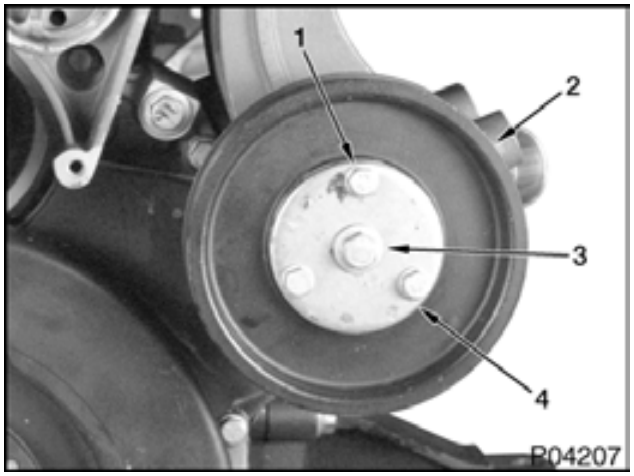

Figure 532 Drive housing pulley

1. M8 x 20 hex bolt (3)
2. Pulley
3. M12 x 30 hex bolt
4. Washer

3. Apply Loctite® 5900 sealant or equivalent (page 312) to washer. Install washer to pulley.
4. Install M12 x 30 and three M8 x 20 hex bolts. Tighten hex bolts to special torque (page 312).

Water Pump Pulley

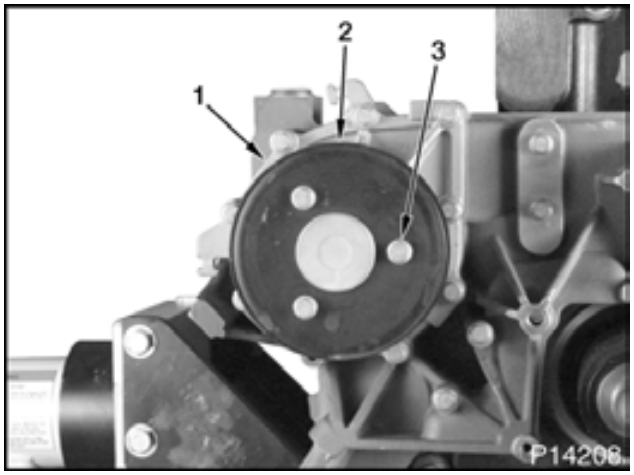

Figure 533 Water pump pulley

1. Water pump
2. Pulley
3. M8 x 12 hex bolt (3)

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1. Install water pump pulley and three M8 x 12 hex bolts. Tighten hex bolts to special torque (page 312).

Automatic Belt Tensioner and Cable Roller (Typical)

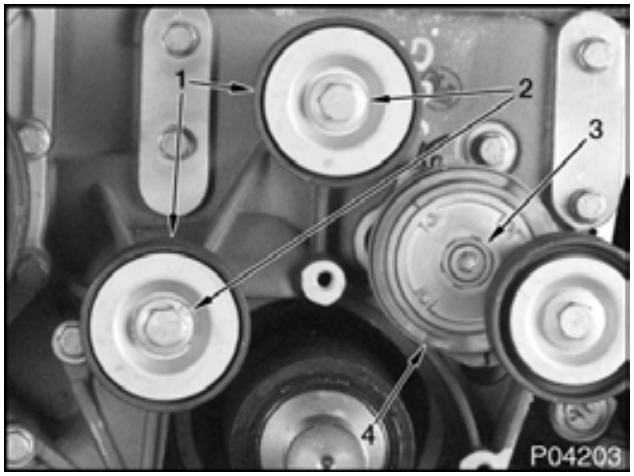

Figure 534 Automatic belt tensioner and cable roller (typical)

1. Cable roller (2)
2. M12 x 55 hex bolt (2)
3. M10 x 70 countersunk screw
4. Automatic belt tensioner

CAUTION: To prevent engine damage, do not twist the belt tensioner; damage to the locating pin may occur, resulting in improper alignment of the belt tensioner.

1. Install automatic belt tensioner and M10 x 70 countersunk screw. Make sure locating pin is placed into locating hole. Tighten countersunk screw to special torque (page 312).
2. Install two cable rollers and two M12 x 55 hex bolts. Tighten hex bolts to special torque (page 312).

Coolant Elbow and Thermostat Element

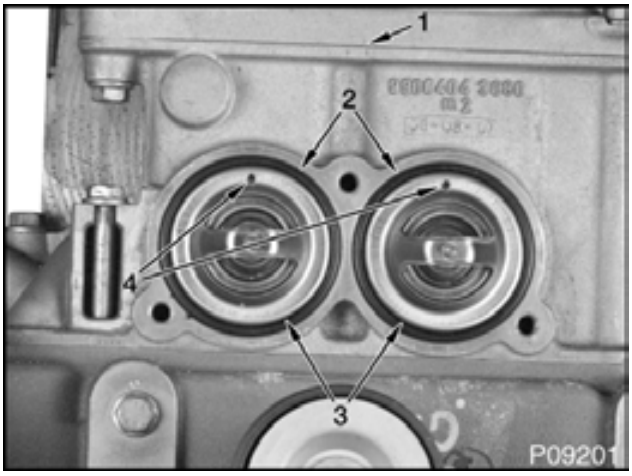

Figure 535 Thermostat elements

1. Thermostat housing assembly
2. 60 x 4 O-ring (2)
3. Thermostat element (2)
4. Ball valves (part of thermostat elements)

1. Install two new gaskets and two thermostat elements into thermostat housing assembly with ball valves at 12 o'clock position.
2. Install two new 60 x 4 O-rings.

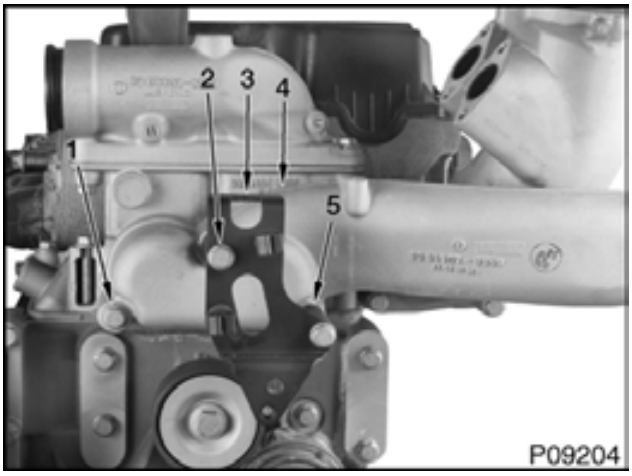

Figure 536 Coolant elbow (to radiator)

1. M8 x 70 hex bolt
2. M8 x 130 hex bolt (2)
3. Bracket (with low mount fan only)
4. Coolant elbow
5. Bushing (2) (with low mount fan only)

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3. Install coolant elbow.
4. If equipped with low mount fan, install bracket and two bushings.
5. Install coolant elbow hex bolts as follows:
   a. If equipped with low mount fan, install one M8 x 70 hex bolt and two M8 x 130 hex bolts. Tighten coolant elbow hex bolts to special torque (page 312).
   b. If equipped with high mount fan, install three M8 x 70 bolts. Tighten coolant elbow hex bolts to special torque (page 312).

High Mount Fan Drive

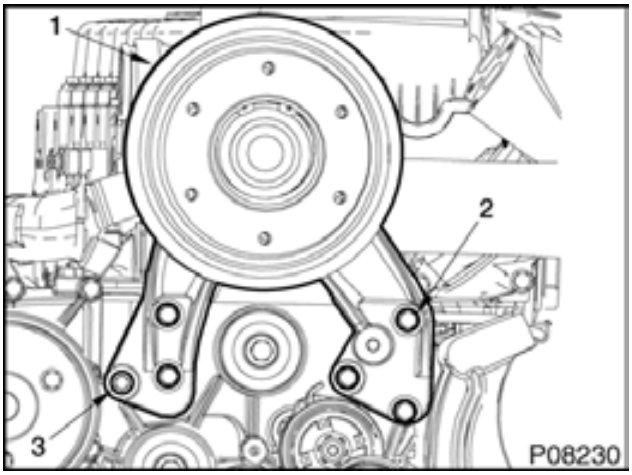

Figure 537 Air clutch fan drive

1. Air clutch fan drive
2. M10 x 150 hex bolt (5)
3. M10 x 65 hex bolt

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 chemicals other than engine oil.

1. Clean thread holes of air clutch fan drive.

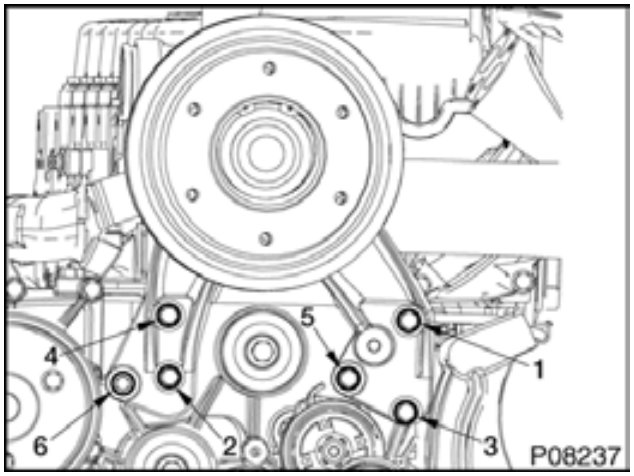

Figure 538 Tensioner bracket tightening sequence

2. Install air clutch fan drive and five new M10 x 150 and one new M10 x 65 hex bolt with engine oil applied to threads.
3. Tighten hex bolts using sequence indicated above as follows.
   a. Tighten six hex bolts to 37 N·m (27 lbf·ft).
   b. Re-tighten six hex bolts to 37 N·m (27 lbf·ft).
   c. Turn five M10 x 150 hex bolts an additional 90° in sequence.
   d. Tighten M10 x 65 hex bolt to 61 N·m (45 lbf·ft).
4. Connect air line to back of air clutch fan drive.

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Tensioner Bracket (High Mount Fan)

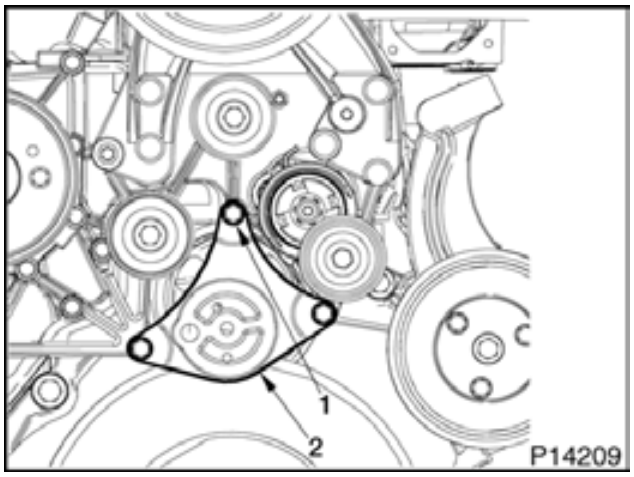

Figure 539 Tensioner bracket

1. Tensioner bracket
2. M8 x 30 hex bolt (3)

1. Install tensioner bracket and three M8 x 30 hex bolt. Tighten hex bolts to standard torque (page 457).

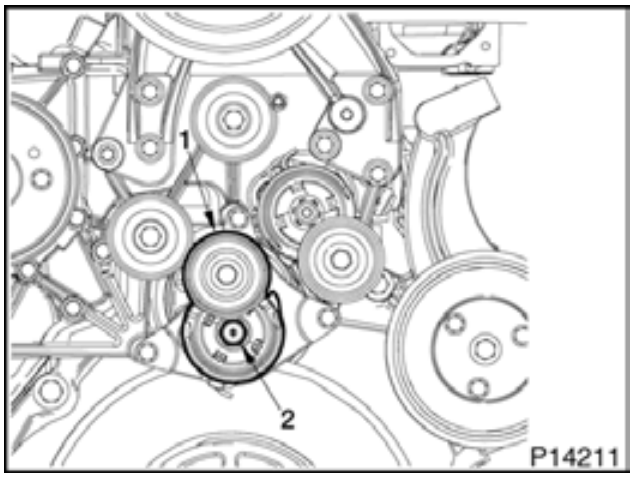

Figure 540 High mount fan tensioner

1. Tensioner
2. M10 x 70 countersunk screw

2. Install tensioner and M10 x 70 countersunk screw. Make sure locating pin is placed into locating hole. Tighten countersunk screw to special torque (page 312).

Pulley (High Mount Fan)

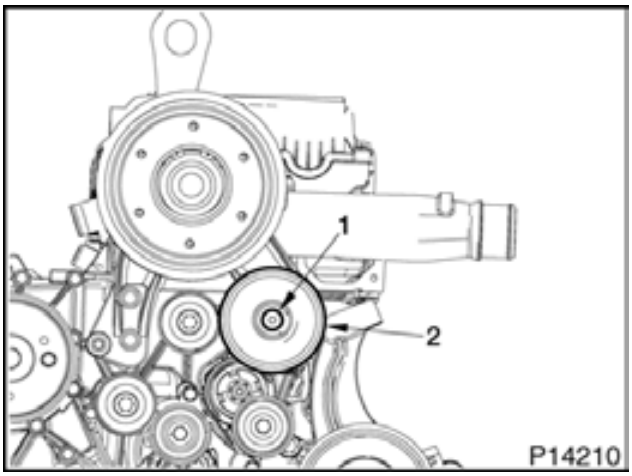

Figure 541 Pulley assembly

1. Shoulder bolt
2. Pulley assembly

1. Install pulley assembly and shoulder bolt. Tighten shoulder bolt to special torque (page 312).

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Special Torque

Table 24 Front Cover, High Mount Fan Drive, Cooling System, Related Components

Air clutch fan drive hex bolts	See tightening steps in procedure
Automatic belt tensioner countersunk screw	47 N·m (35 lbf·ft)
Cable roller hex bolts	60 N·m (44 lbf·ft)
Coolant Control Valve (CCV) hex bolts	31 N·m (23 lbf·ft)
Coolant elbow (to Exhaust Gas Recirculation (EGR) module) hex bolts	35 N·m (26 lbf·ft)
Coolant elbow (to radiator) hex bolts	35 N·m (26 lbf·ft)
Distributor case hex bolts	35 N·m (26 lbf·ft)
Drive housing hex bolts	115 N·m (85 lbf·ft)
High mount fan bracket	See tightening steps in procedure
High mount fan tensioner countersunk screw	47 N·m (35 lbf·ft)
Hub and pulley hex bolts to vibration damper	45 N·m (33 lbf·ft)
High mount fan pulley assembly shoulder bolt	62 N·m (45 lbf·ft)
M8 x 20 drive housing pulley hex bolts	35 N·m (26 lbf·ft)
M8 x 25 front crankcase cover hex bolts	35 N·m (26 lbf·ft)
M8 x 40 front crankcase cover hex bolts	35 N·m (26 lbf·ft)
M12 x 30 drive housing pulley hex bolt	115 N·m (85 lbf·ft)
M12 x 70 front crankcase cover hex bolts	115 N·m (85 lbf·ft)
M14 x 30 front crankcase cover hex bolts	115 N·m (85 lbf·ft)
Thermostat housing assembly hex bolts	35 N·m (26 lbf·ft)
Water pump hex bolts	35 N·m (26 lbf·ft)
Water pump pulley hex bolts	35 N·m (26 lbf·ft)
Vibration damper cylinder screws	See tightening steps in procedure

Special Service Tools

Table 25 Front Cover, High Mount Fan Drive, Cooling System, Related Components

Description	Tool Number
Fan Hub High Pressure Drive Seal Installer	ZTSE4776
Front Crankshaft Seal Installer	ZTSE4873
Loctite® 5900 Sealant or Wacker 442T	Obtain locally
P-80® Rubber Lubricant or equivalent	Obtain locally
Slide Hammer	Obtain locally

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Exploded Views

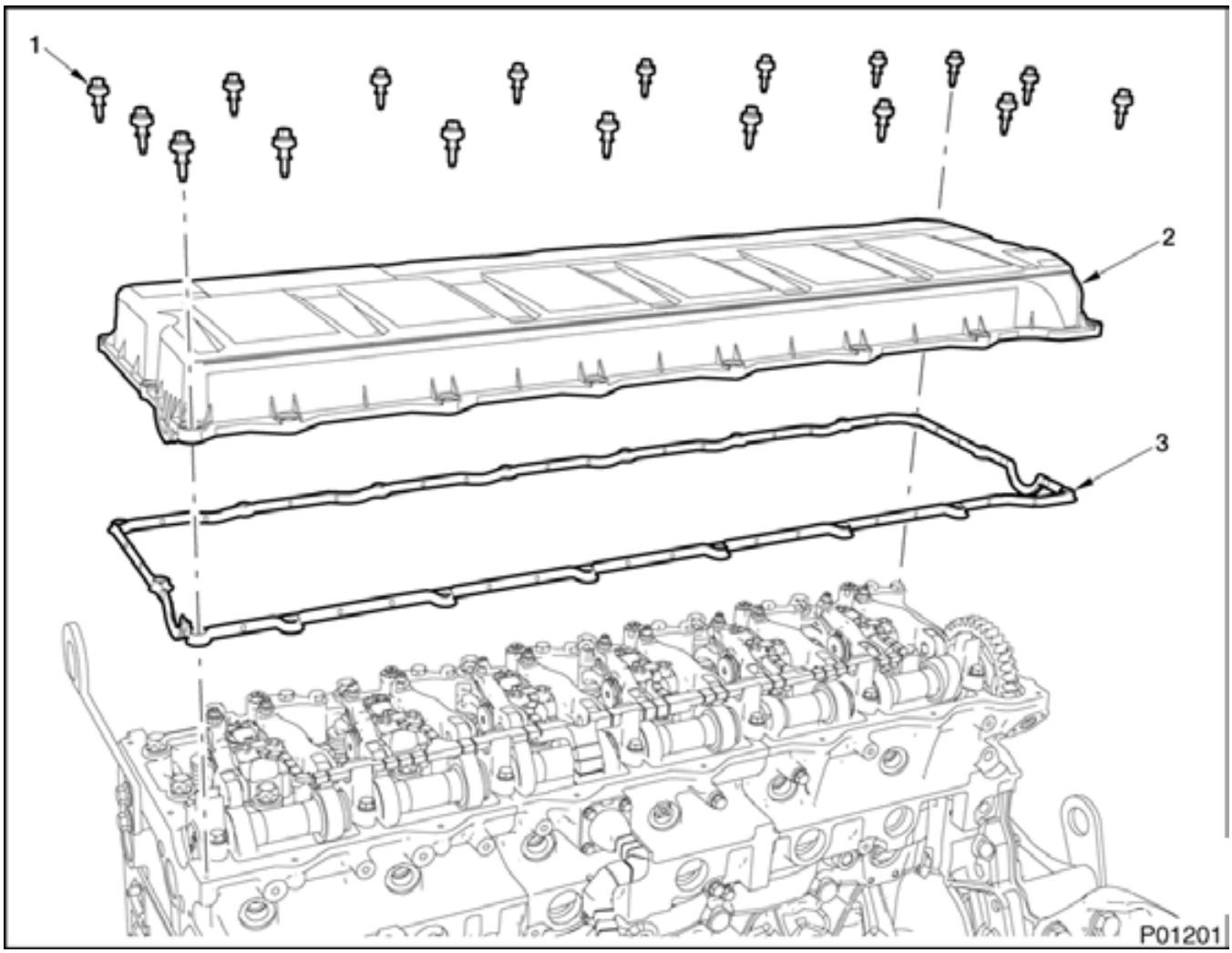

Figure 542 Valve cover

1. Screw with damper element (18)
2. Valve cover
3. Valve cover gasket

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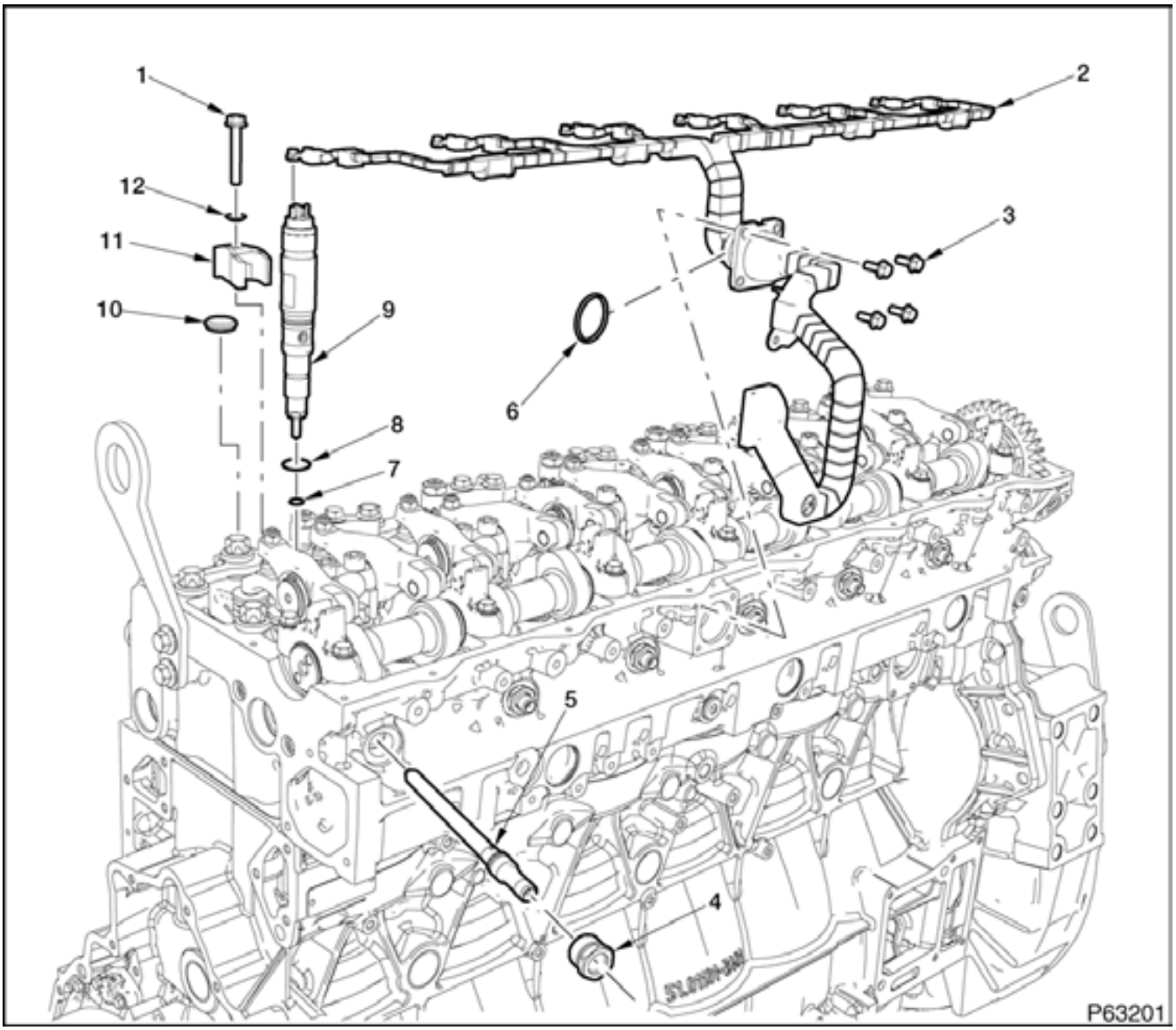

Figure 543 Injector harness and fuel injectors

1. M8 x 50 hex bolt (6)
2. Injector harness
3. M6 x 16 hex bolt (4)
4. Pressure pipe nut (6)
5. Pressure pipe neck (6)
6. O-ring
7. Sealing washer (6)
8. O-ring (6)
9. Injector (6)
10. Thrust washer (6)
11. Pressure flange (6)
12. Retaining washer (6)

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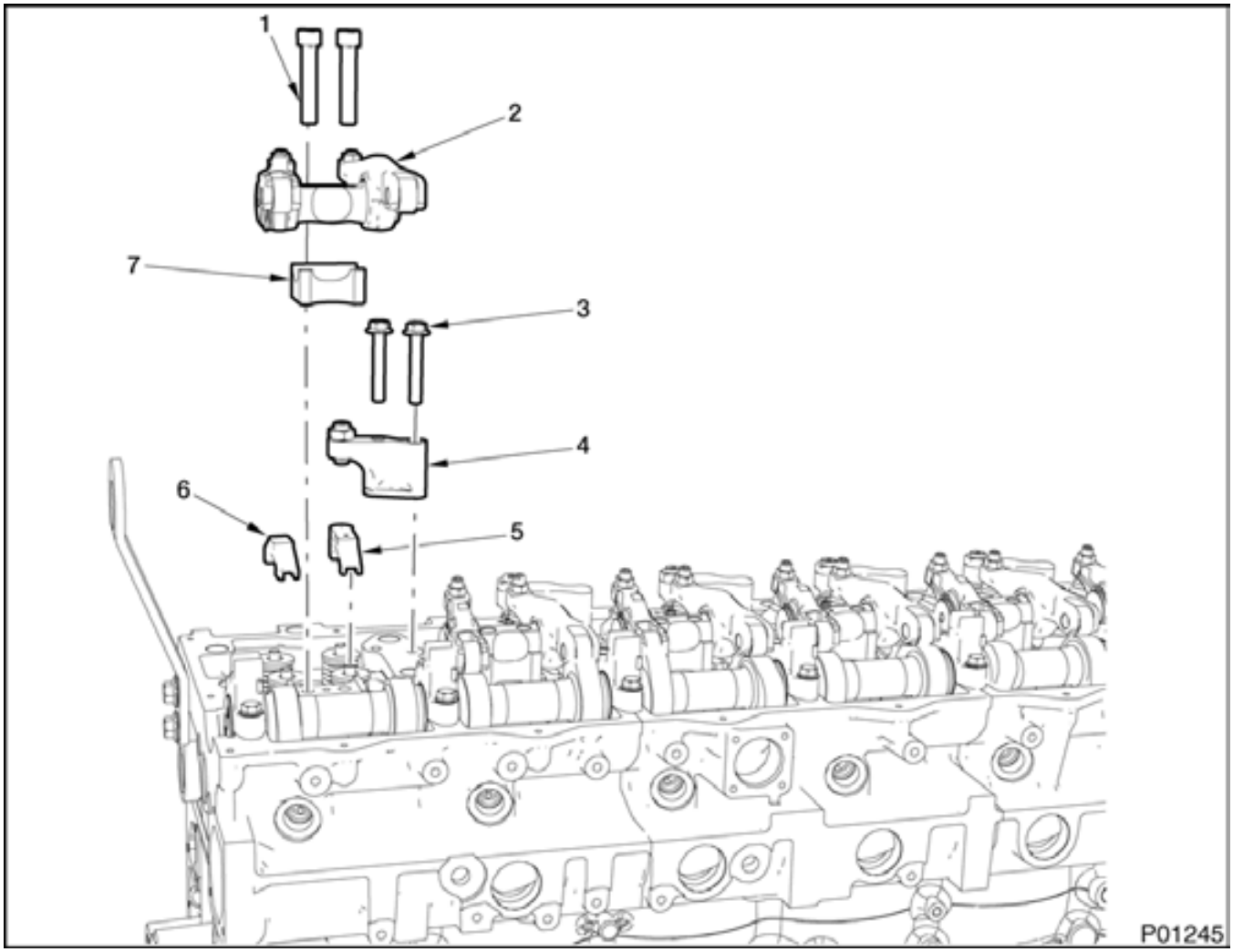

Figure 544 Rocker gears and valve bridges

1. M12 x 60 cylinder screw (12)
2. Rocker gear (6)
3. M10 x 60 hex bolt (12)
4. Counterpiece (6)
5. Valve bridge (exhaust) (6)
6. Valve bridge (intake) (6)
7. Rocker bearing block (6)

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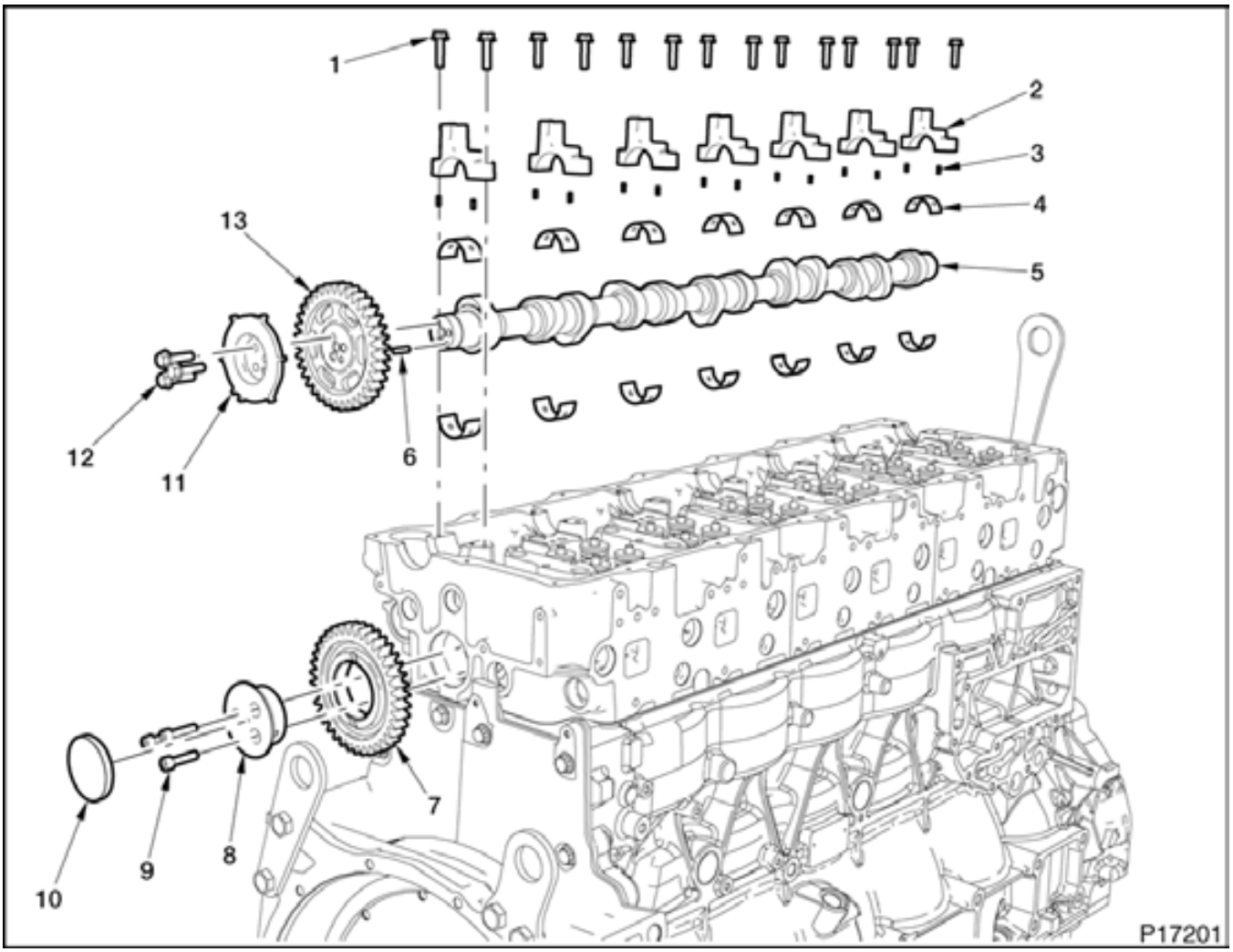

Figure 545 Camshaft and intermediate gear

1. M8 x 35 hex bolt (14)
2. Cylinder head bearing cap (7)
3. 4 mm dowel pin (14)
4. Bearing shell (14)
5. Camshaft
6. 6 mm dowel pin
7. Cylinder intermediate gear
8. Small gear stud
9. M8 x 30 cylinder screw (3)
10. Cover
11. Camshaft pulse wheel
12. M8 x 30 hex bolt (3)
13. Camshaft gear

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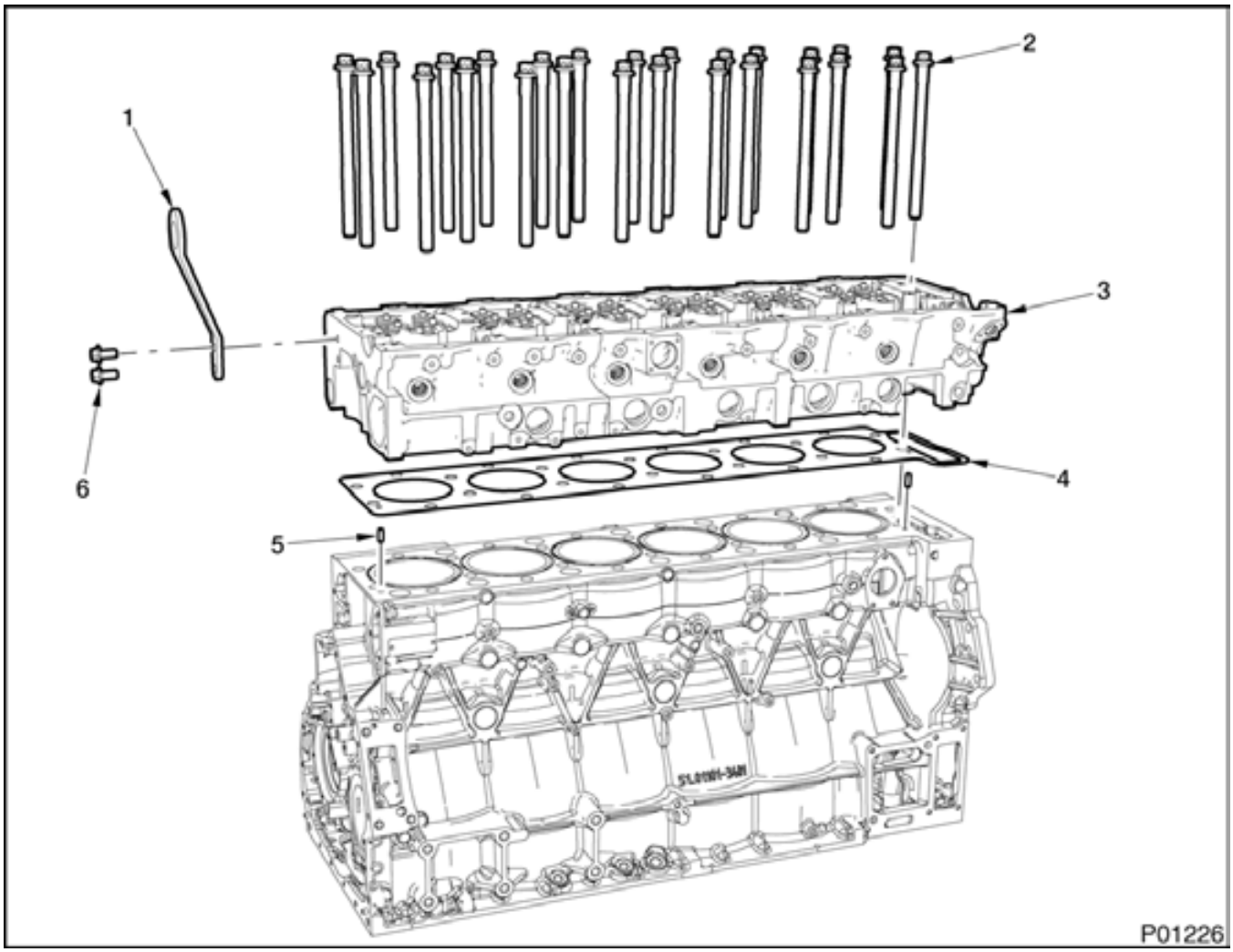

Figure 546 Cylinder head

1. Lifting eye
2. M18 x 246 collar bolt (26)
3. Cylinder head
4. Cylinder head gasket
5. 8 mm dowel pin (2)
6. M12 x 25 hex bolt (2)

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Periodic Service

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 the transmission to park or neutral, set the parking brake, and block the wheels before doing diagnostic or service procedures.

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

WARNING: To prevent personal injury or death, remove the ground cable from the negative terminal of the main battery before disconnecting or connecting electrical components. Always connect the ground cable last.

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.

Valve Lash Adjustment

NOTE: Valve lash must be set with engine cold and cylinder head assembled to crankcase.

1. Remove valve cover (page 325).
2. If previously removed, install Drive Housing (page 307).

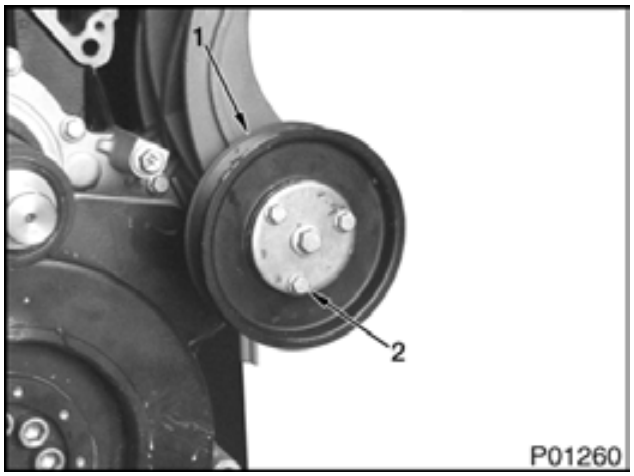

Figure 547 Pulley bolts (drive housing)

1. Pulley (drive housing)
2. M8 x 20 hex bolt (3)

NOTE: Do not remove center bolt and pulley.

3. Remove three M8 x 20 hex bolts from drive housing pulley.

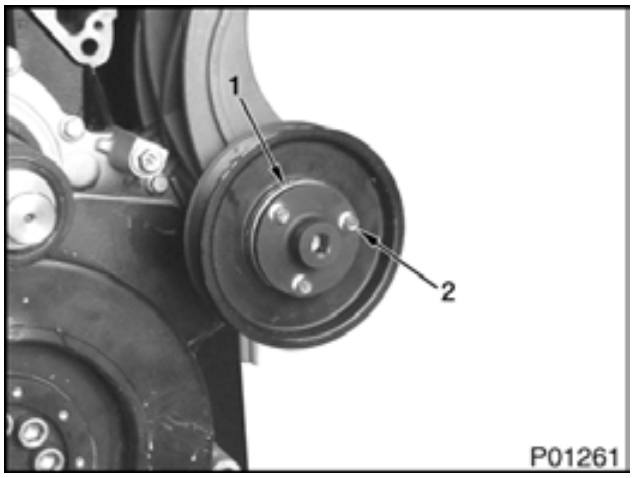

Figure 548 Engine Rotating Tool

1. Engine Rotating Tool
2. M8 x 25 hex bolt (3) (part of Engine Rotating Tool)

CAUTION: To prevent engine damage, install the Engine Rotating Tool using only the M8 x 25 bolts included with the tool.

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Figure 549 Engine Rotating Tool

4. Install Engine Rotating Tool (page 355) and three M8 x 25 hex bolts. Tighten hex bolts to standard torque (page 457).

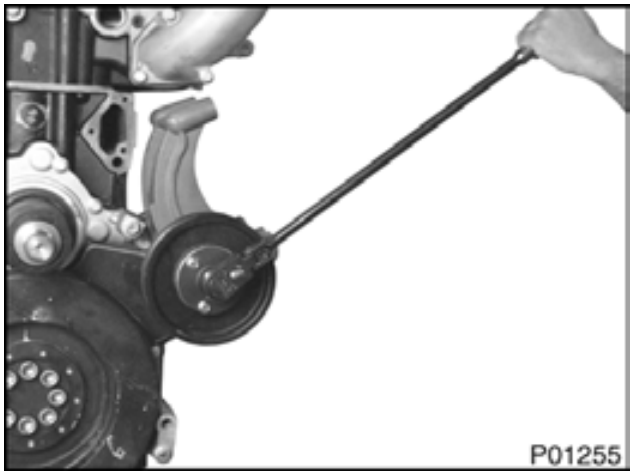

Figure 550 Rotating the engine

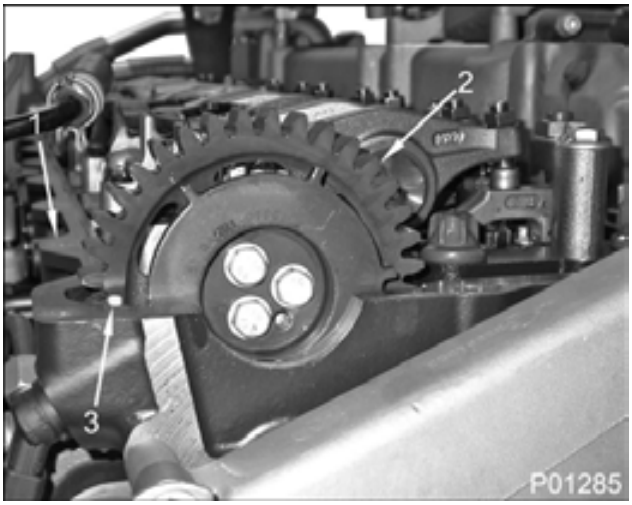

Figure 551 Camshaft gear timing mark

1. Valve cover surface
2. Camshaft gear
3. Timing mark (aligned with valve cover surface)

5. Using the Engine Rotating Tool, turn crankshaft in direction of engine rotation until the camshaft timing gear mark aligns with the valve cover surface on the intake side of the engine.

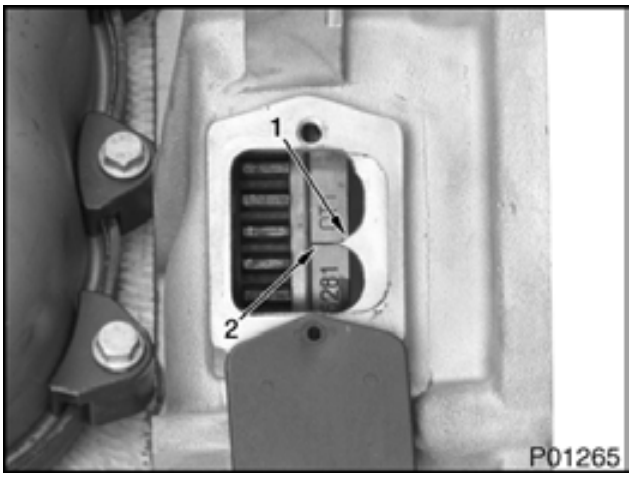

Figure 552 Flywheel housing timing index

1. Flywheel housing timing index
2. Flywheel timing mark

6. Remove timing hole cover from lower side of flywheel housing.

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7. Use a pry bar to rotate crankshaft in direction needed to align the flywheel timing mark with flywheel housing timing index.

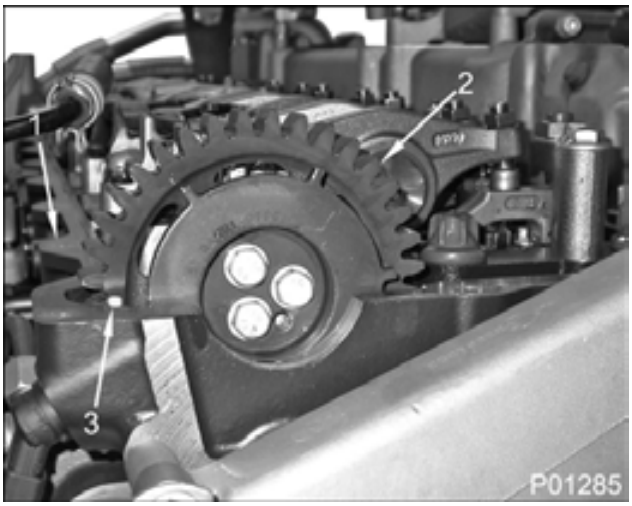

Figure 553 Camshaft gear timing mark

1. Valve cover surface
2. Camshaft gear
3. Timing mark (aligned with valve cover surface)

8. Recheck that the timing mark on camshaft gear is aligned with the valve cover gasket surface (on intake side of cylinder head). If flywheel and camshaft gear marks are in agreement, the engine is at TDC for cylinder 1. Skip step 6 and proceed to Valve Overlap Procedure below.

CAUTION: To prevent engine damage, a new large idler gear must be installed, if the large idler gear has slipped.

9. If flywheel and camshaft gear marks are not in agreement, the large idler gear has slipped. See Oil Pump, Low Mount Fan Drive and Timing Gears section (page 396) for procedure to install a new big intermediate gear.

Valve Overlap Procedure

NOTE: Valve lash adjustments are done in firing order sequence (1, 5, 3, 6, 2, 4), using the valve overlap method. Valve overlap happens on the companion cylinder near the end of the exhaust stroke and the beginning of the intake stroke, when both valves are open for a short period of time.

1. Starting with cylinder 1 at TDC compression, set valve lash for cylinder 1, according to Valve Lash Adjustment Procedure below.
2. After valves for cylinder 1 have been adjusted, rotate crankshaft slowly and watch valves for cylinder 2; watch the exhaust valve as it closes, and watch for intake valve to start opening. When cylinder 2 intake and exhaust valves are open equally, adjust valves on cylinder 5 according to the Valve Lash Adjustment Procedure below.
3. Repeat Valve Overlap Procedure, in order for remaining cylinders 3,6,2, and 4. See Table 26 (page 323).

Valve Lash Adjustment

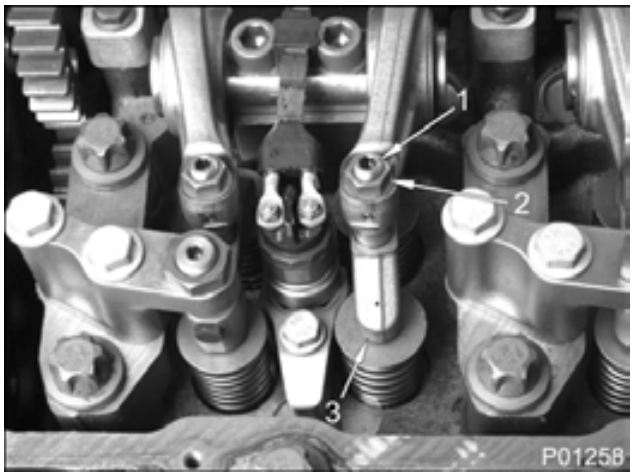

Figure 554 Intake valve lash adjustment (typical)

1. Adjusting screw
2. M10 hexagon nut
3. Valve bridge (intake)

1. Adjust intake valve lash for the cylinder with piston at TDC as follows:
   a. Loosen intake valve lash adjustment M10 hexagon nut.
   b. Insert a 0.5 mm (0.019 in) feeler gauge (page 355) between intake valve bridge and adjusting screw, and tighten adjusting screw until a slight drag on feeler gauge is felt.
   c. Hold adjusting screw in position and tighten intake valve lash adjustment M10 hexagon nut to special torque (page 354).

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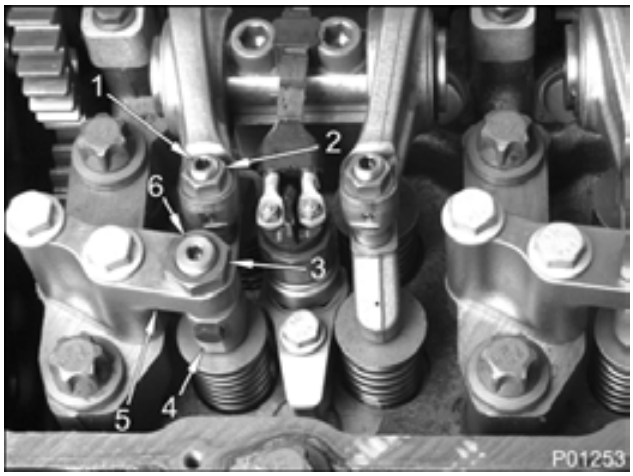

Figure 555 Exhaust valve and retarder lash adjustment (typical)

1. Adjusting screw (exhaust valve)
2. M10 hexagon nut
3. M14 hexagon nut
4. Valve bridge (exhaust)
5. Counterpiece
6. Adjusting screw (counterpiece)

2. Adjust counterpiece and exhaust valve lash for the cylinder with piston at TDC as follows:
   a. Loosen counterpiece adjustment M14 hexagon nut and back out counterpiece adjusting screw until it no longer contacts valve bridge.
   b. Push valve bridge down onto exhaust valves several times to push oil out from piston inside exhaust valve bridge.
   c. Loosen exhaust valve lash adjustment M10 hexagon nut. Back out exhaust valve lash adjusting screw until a 0.8 mm (0.0314 in) feeler gauge (page 355) can be inserted between exhaust valve bridge and exhaust valve lash adjusting screw.
   d. Tighten exhaust valve lash adjusting screw until it grips the feeler gauge. Turning resistance increases while adjusting screw is tightened due to retarder piston spring inside exhaust valve bridge being compressed.
   e. Tighten exhaust valve lash adjustment M10 hexagon nut to special torque (page 354).
   f. Insert a 0.6 mm (0.0236 in) feeler gauge between counterpiece adjusting screw and valve bridge. Tighten counterpiece adjusting screw until it grips the feeler gauge.
   g. Tighten counterpiece adjustment M14 hexagon nut to special torque (page 354).
3. Turn crankshaft in direction of engine rotation to position next cylinder in firing order at TDC compression (one at a time) and adjust lash for the respective cylinder. For each cylinder positioned at TDC compression, the companion cylinder will be in valve overlap as shown in following table.

Table 26

Cylinder at TDC compression	Companion cylinder in valve overlap
1	6
5	2
3	4
6	1
2	5
4	3

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Removal

NOTE: Refer to the following service sections for information on removal of components prior to this section.

- Engine Electrical
- Turbochargers
- Air Compressor and Power Steering Pump
- Fuel System
- Oil Cooler, Filter Housing, and Crankcase Ventilation
- Exhaust Gas Recirculation (EGR) System
- Air Inlet Duct and Exhaust Manifolds
- Front Cover, High Mount Fan Drive, Cooling System, and Related Components

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Valve Cover

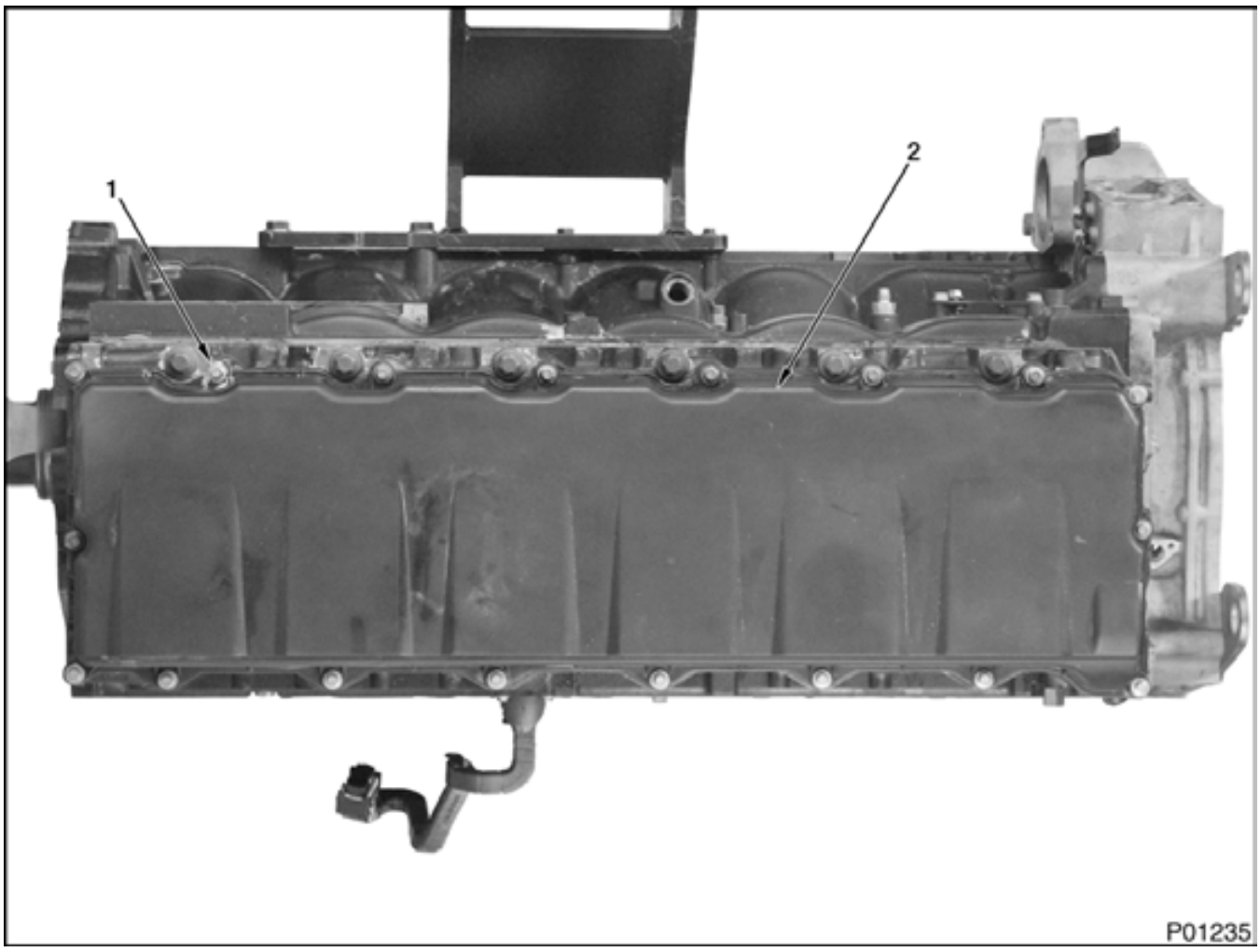

Figure 556 Valve Cover

1. Screw with damper element (18) 2. Valve cover

CAUTION: To prevent engine damage, do not use air tools to remove or install valve cover.

NOTE: The valve cover screws can only be removed from valve cover as assemblies with the damper elements. The screws and damper elements should only be completely removed from cover if replacing the valve cover gasket.

1. Release 18 screws with damper elements from cylinder head. Do not completely remove screws from valve cover at this time.
2. Remove valve cover.

NOTE: Valve cover gasket can be reused and does not require removal from valve cover unless damaged.

3. Inspect valve cover gasket for damage. If damaged, continue with steps 4 and 5.

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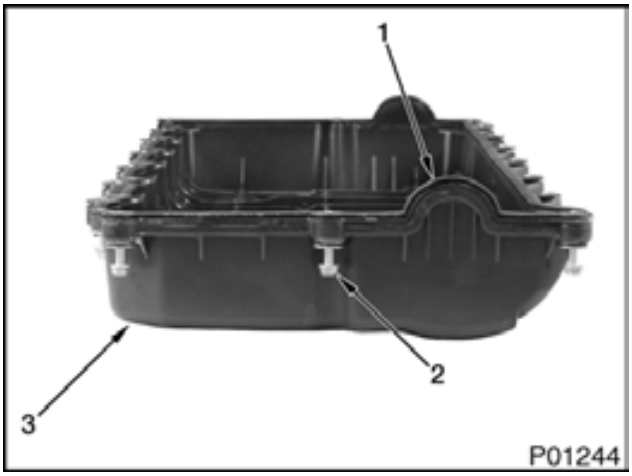

Figure 557 Valve cover gasket

1. Valve cover gasket
2. Screw with damper element (18)
3. Valve cover

4. Completely remove 18 screws with damper elements from valve cover to release valve cover gasket.
5. Discard valve cover gasket.

Fuel Injectors

CAUTION: To prevent engine damage, remove injectors before removing cylinder head.

CAUTION: To prevent engine damage, do not use power tools.

CAUTION: To prevent engine damage, install new injector O-ring and sealing washer before installing injector.

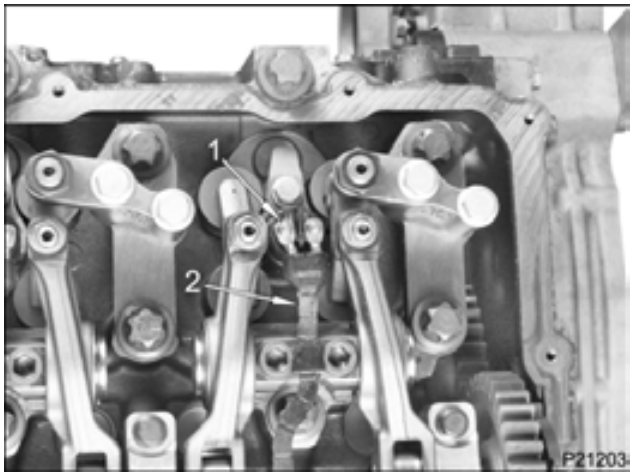

Figure 558 Fuel injector connections (typical)

1. Injector harness nuts (12)
2. Injector harness

NOTE: The injector harness nuts are part of the injector harness and cannot be separated.

1. Loosen 12 injector harness nuts and position injector harness aside.

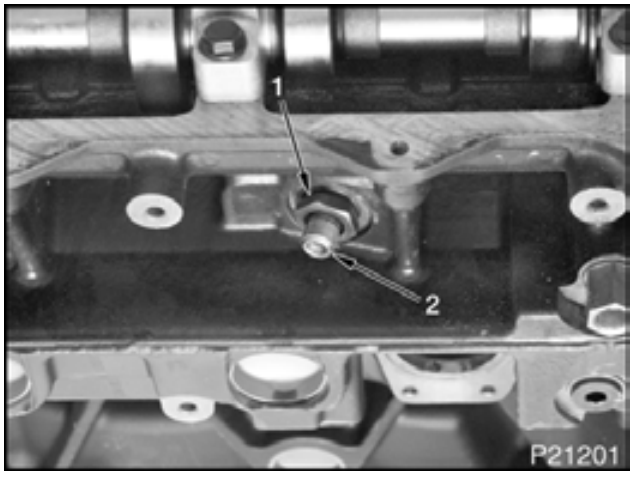

Figure 559 Pressure pipe neck (typical)

1. Pressure pipe nut (6)
2. Pressure pipe neck (6)

2. Remove six pressure pipe nuts.
3. Remove and discard six pressure pipe necks.

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4. Cover cylinder head pressure pipe neck bores with appropriate size plugs from Disposable Air and Fuel Caps (page 355).

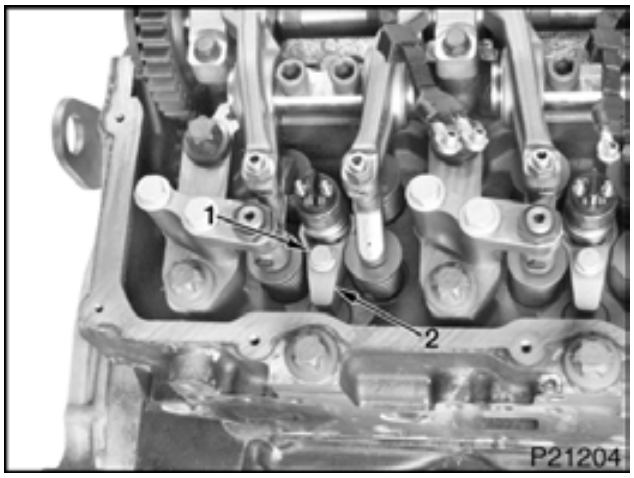

Figure 560 Pressure flange hex bolt (typical)

1. M8 x 50 hex bolt (6) and retaining washer (6)
2. Pressure flange (6)

5. Remove six M8 x 50 pressure flange hex bolts and six retaining washers.

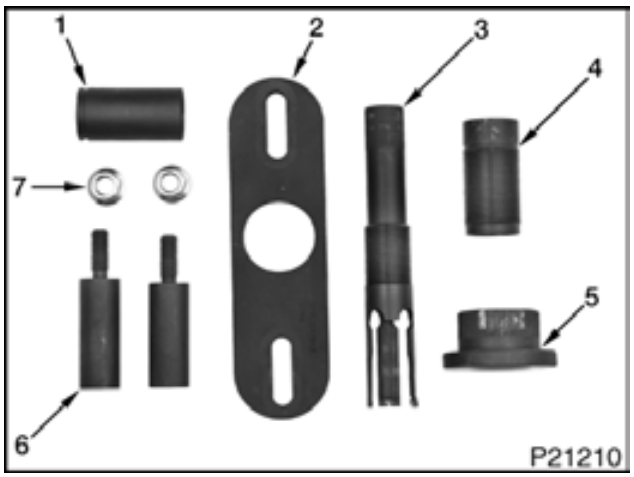

Figure 561 Injector puller

1. Clamping sleeve
2. Extractor plate
3. Extractor
4. Knurled nut
5. Extractor nut
6. Plate column (2)
7. Plate column nuts (2)

6. Use Injector Puller (page 355) to remove injectors.

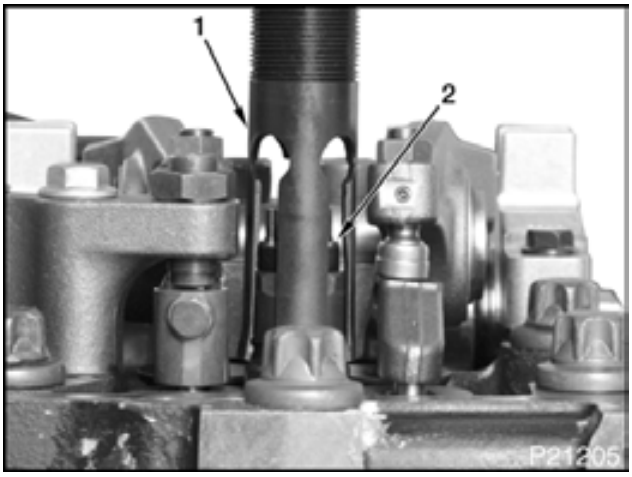

Figure 562 Injector extractor (typical)

1. Extractor (part of Injector Puller)
2. Injector

7. Install extractor on injector.

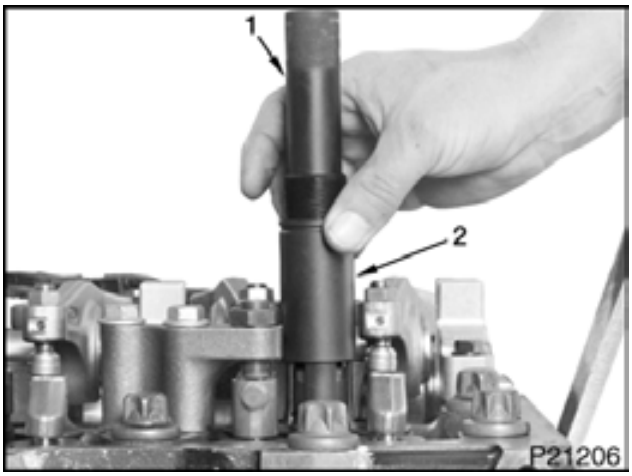

Figure 563 Clamping sleeve (typical)

1. Extractor (part of Injector Puller)
2. Clamping sleeve (part of Injector Puller)

8. Slide clamping sleeve over extractor.

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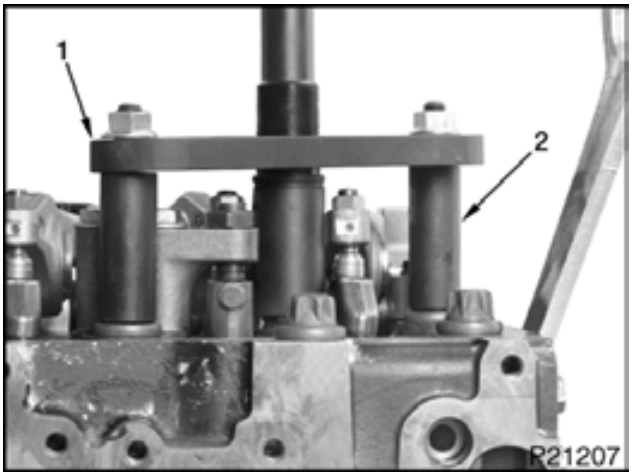

Figure 564 Extractor plate and plate columns (typical)

1. Extractor plate (part of Injector Puller)
2. Plate column (2) (part of Injector Puller)

9. Position two plate columns on two opposite cylinder head bolts, and slide extractor plate over extractor and plate columns.
10. Install and finger tighten plate column nuts on plate columns.

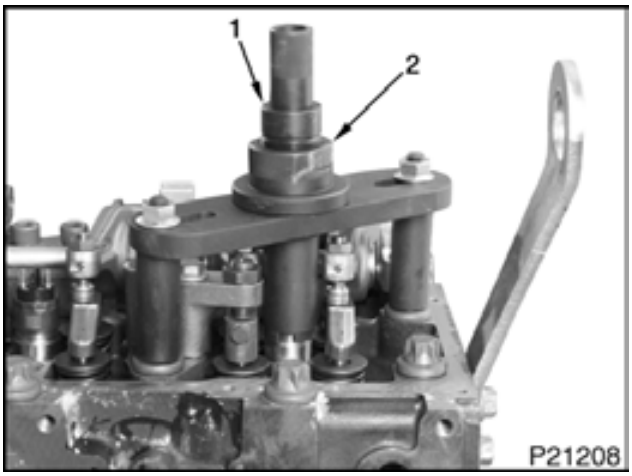

Figure 565 Extractor nut (typical)

1. Knurled nut (part of Injector Puller)
2. Extractor nut (part of Injector Puller)

11. Install knurled nut and extractor nut on injector with the extractor nut backed out.
12. Hold knurled nut and tighten extractor nut to remove injector with sealing washer and pressure flange.

NOTE: Make sure that no sealing washer remains in the injector bore after the injector is removed.

13. Cover cylinder head injector bore with appropriate size plugs from Disposable Air and Fuel Caps (page 355).

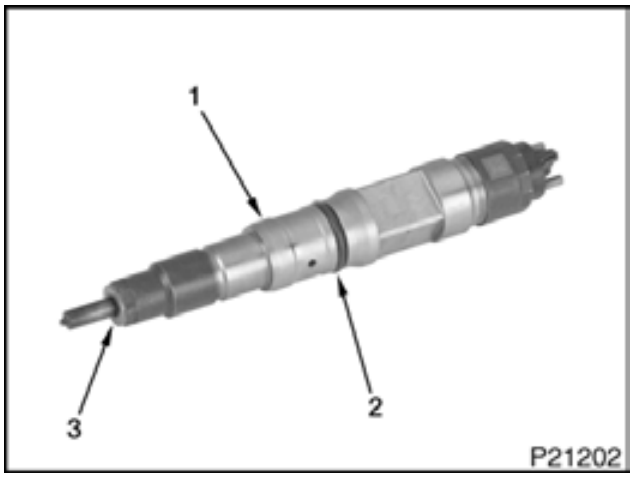

Figure 566 Injector seals (typical)

1. Injector
2. O-ring
3. Sealing washer

14. Using a small hand tool, remove and discard sealing washer. Wipe injector nozzle with a lint free cloth. Do not remove O-ring at this time.

CAUTION: To prevent engine damage, do not clean fuel injectors with solvents or brake cleaner.

15. Clean injector tip with Fuel Injector Tip Cleaning Brush (page 355).
16. Insert injector into Fuel Injector Cup (page 355), and place in Fuel Injector Rack Holder (page 355).

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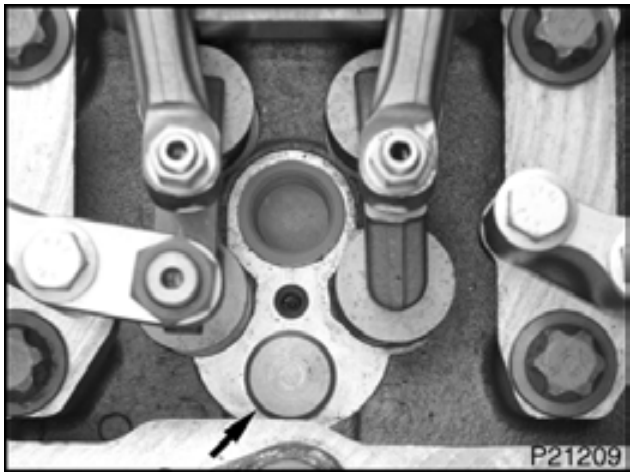

Figure 567 Thrust washer (typical)

17. Remove six thrust washers from cylinder head.

Counterpiece

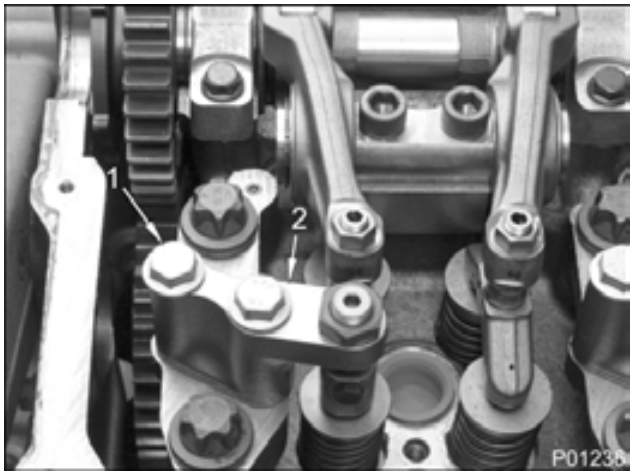

Figure 568 Counterpiece bolts (typical)

1. M10 x 60 hex bolt (12)
2. Counterpiece (6)

1. Remove 12 M10 x 60 hex bolts.
2. Remove six counterpieces from cylinder head.

Rocker Gear

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

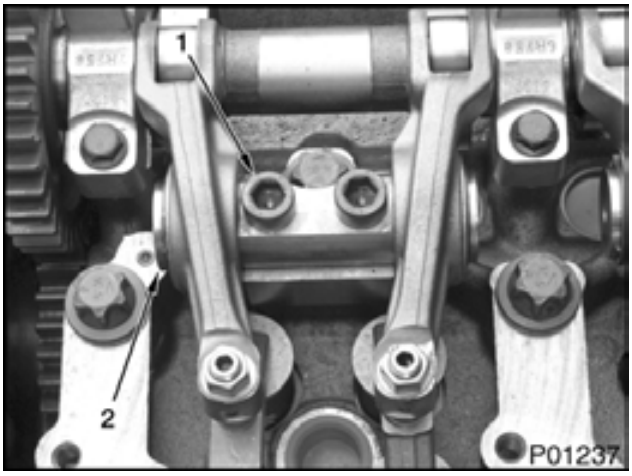

Figure 569 Rocker gear (typical)

1. M12 x 60 cylinder screw (12)
2. Rocker gear (6)

1. Mark rocker gears 1 through 6 so they can be installed in their original cylinder location.
2. Remove 12 M12 x 60 cylinder screws.
3. Remove six rocker gears.

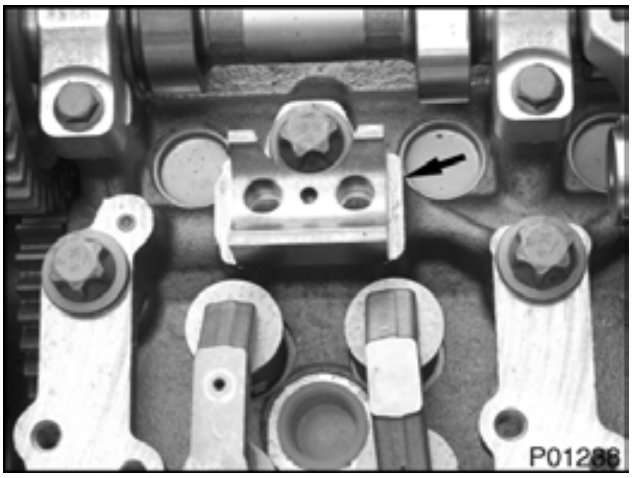

Figure 570 Rocker bearing block (typical)

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4. Mark rocker bearing blocks 1 through 6 so they can be installed in their original cylinder location.
5. Remove six rocker bearing blocks.

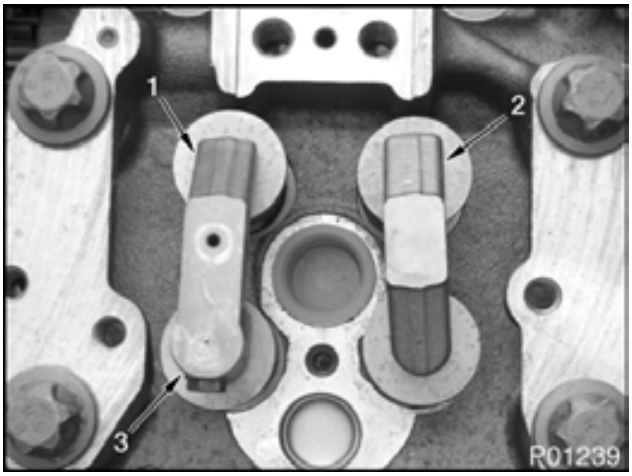

Figure 571 Valve bridges (typical)

1. Valve bridge (exhaust) (6)
2. Valve bridge (intake) (6)
3. Counterpiece end

6. Mark valve bridges so they can be installed in their original location and orientation.
7. Remove 12 valve bridges.

Camshaft

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

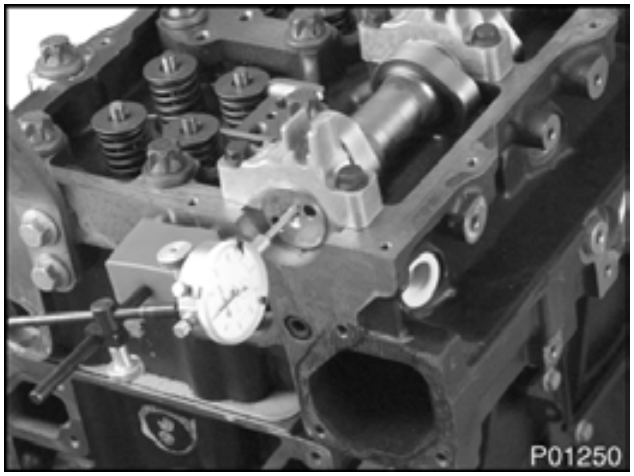

Figure 572 Camshaft end play check

1. Check camshaft end play as follows:
   a. Mount dial indicator with magnetic base (page 355) on cylinder head with indicator tip on end of camshaft as shown.
   b. Move camshaft toward rear of engine and zero the dial indicator.
   c. Move camshaft back and forth while reading dial indicator. Compare dial indicator reading with specifications (page 354).
   d. If end play exceeds specified limits, install a new camshaft.

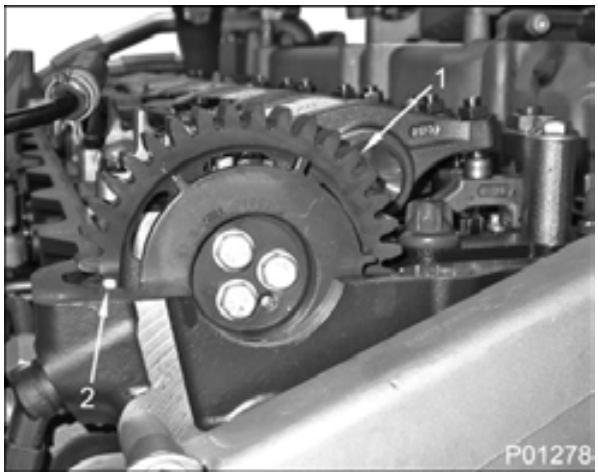

Figure 573 Camshaft timing mark

1. Camshaft gear
2. Timing mark

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2. Rotate engine until timing mark on camshaft gear is aligned with cylinder head surface.

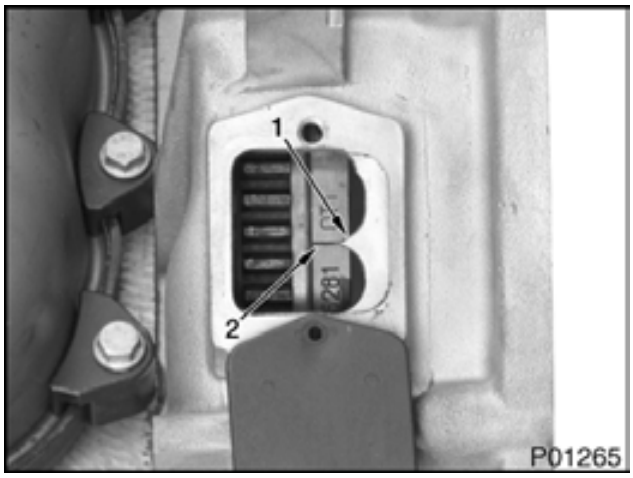

Figure 574 Flywheel housing timing index

1. Flywheel housing timing index
2. Flywheel timing mark

3. Remove sealing cap from lower side of flywheel housing and verify timing mark on flywheel is aligned with flywheel housing timing index.
   - If timing mark on flywheel is out of alignment, then the timing has slipped due to big intermediate gear slippage. Install a new big intermediate gear. See Oil Pump, Low Mount Fan Drive and Timing Gears section (page 393) for procedures to replace big intermediate gear.
   - If timing mark on flywheel is aligned with flywheel housing timing index, continue to next step.

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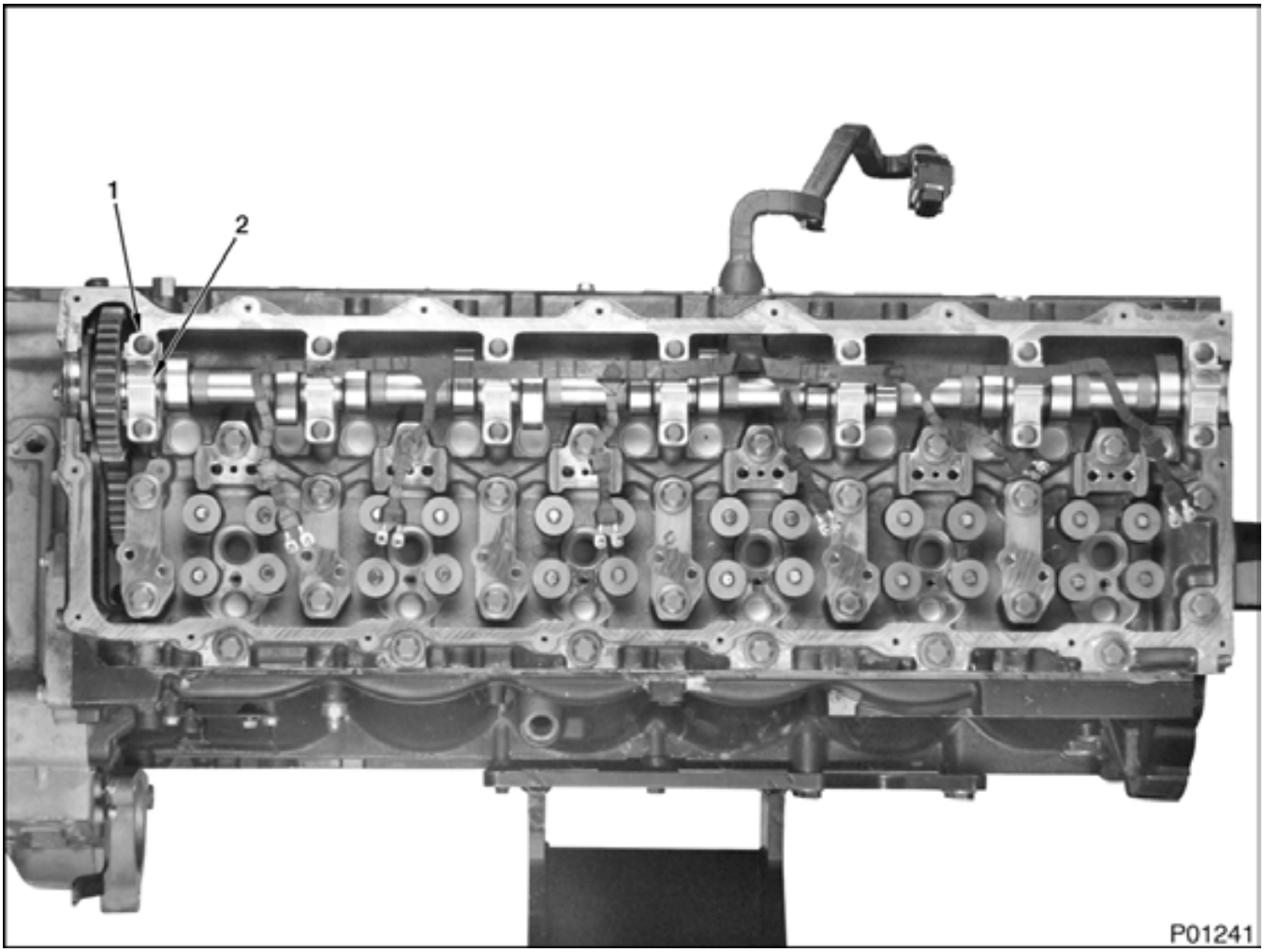

Figure 575 Camshaft bearing bolts

1. M8 x 35 hex bolt (14)
2. Cylinder head bearing cap (7)

4. Remove 14 M8 x 35 hex bolts.
5. Remove seven cylinder head bearing caps. Mark each cylinder head bearing cap number and orientation.

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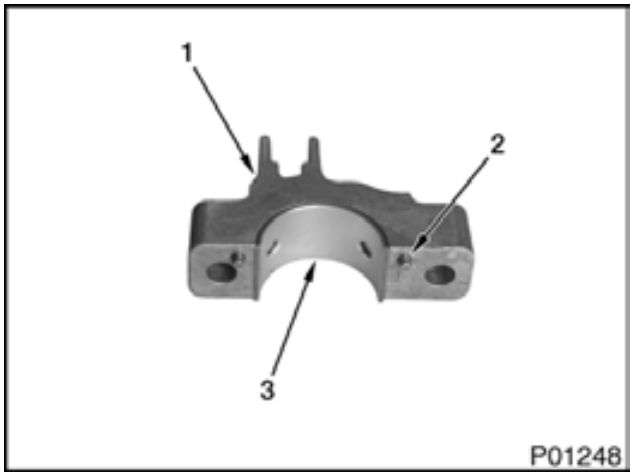

Figure 576 Cylinder head bearing cap and bearing (typical)

1. Cylinder head bearing cap
2. 4 mm dowel pin (2)
3. Bearing shell

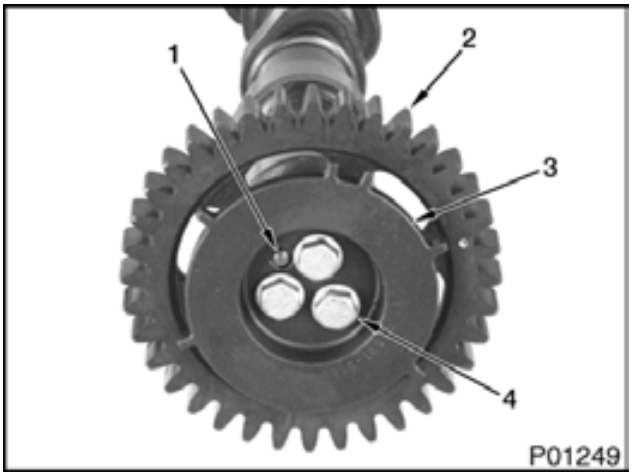

Figure 577 Camshaft gear and camshaft pulse wheel

1. 6 mm dowel pin
2. Camshaft gear
3. Camshaft pulse wheel
4. M8 x 30 hex bolt (3)

6. Remove seven bearing shells from cylinder head bearing caps. Mark each bearing shell with cylinder head bearing cap number and orientation.
7. If damaged, remove 14 – 4 mm dowel pins from seven cylinder head bearing caps.
8. Remove camshaft.
9. Remove seven lower bearing shells from cylinder head. Mark each bearing shell with cylinder head bearing cap number and orientation.
10. Remove three M8 x 30 hex bolts.
11. Remove camshaft pulse wheel and camshaft gear.
12. If damaged, remove 6 mm dowel pin from camshaft.

Fuel Injector Harness

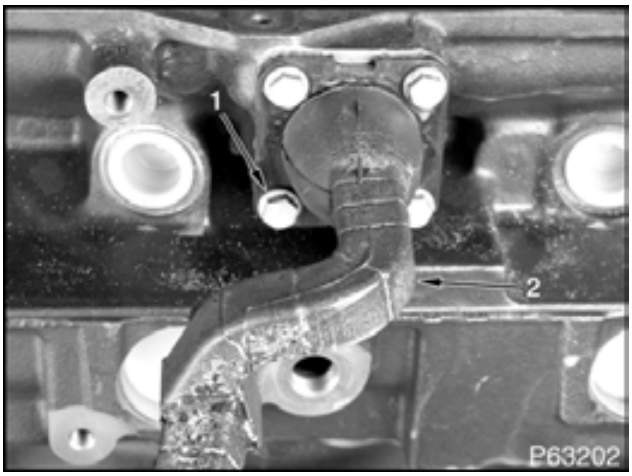

Figure 578 Injector harness bolts

1. M6 x 16 hex bolt (4)
2. Injector harness

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1. Remove four M6 x 16 hex bolts.
2. Remove injector harness.
3. If damaged, remove and discard O-ring from injector harness flange.

Cylinder Head

CAUTION: To prevent engine damage, remove injectors before removing cylinder head.

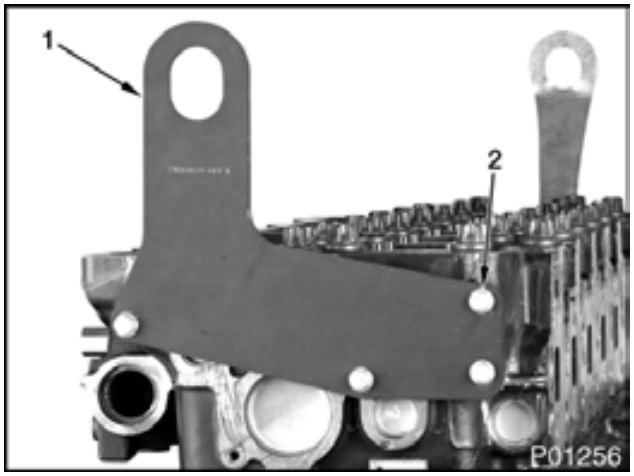

Figure 579 Cylinder Head Lifting Bracket

1. Cylinder head lifting bracket
2. M8 x 20 class 10.9 bolt (4)

1. Position Cylinder Head Lifting Bracket (page 355) on rear end of cylinder head.
2. Install four M8 x 20 class 10.9 bolts (page 355). Tighten bolts to standard torque (page 457).

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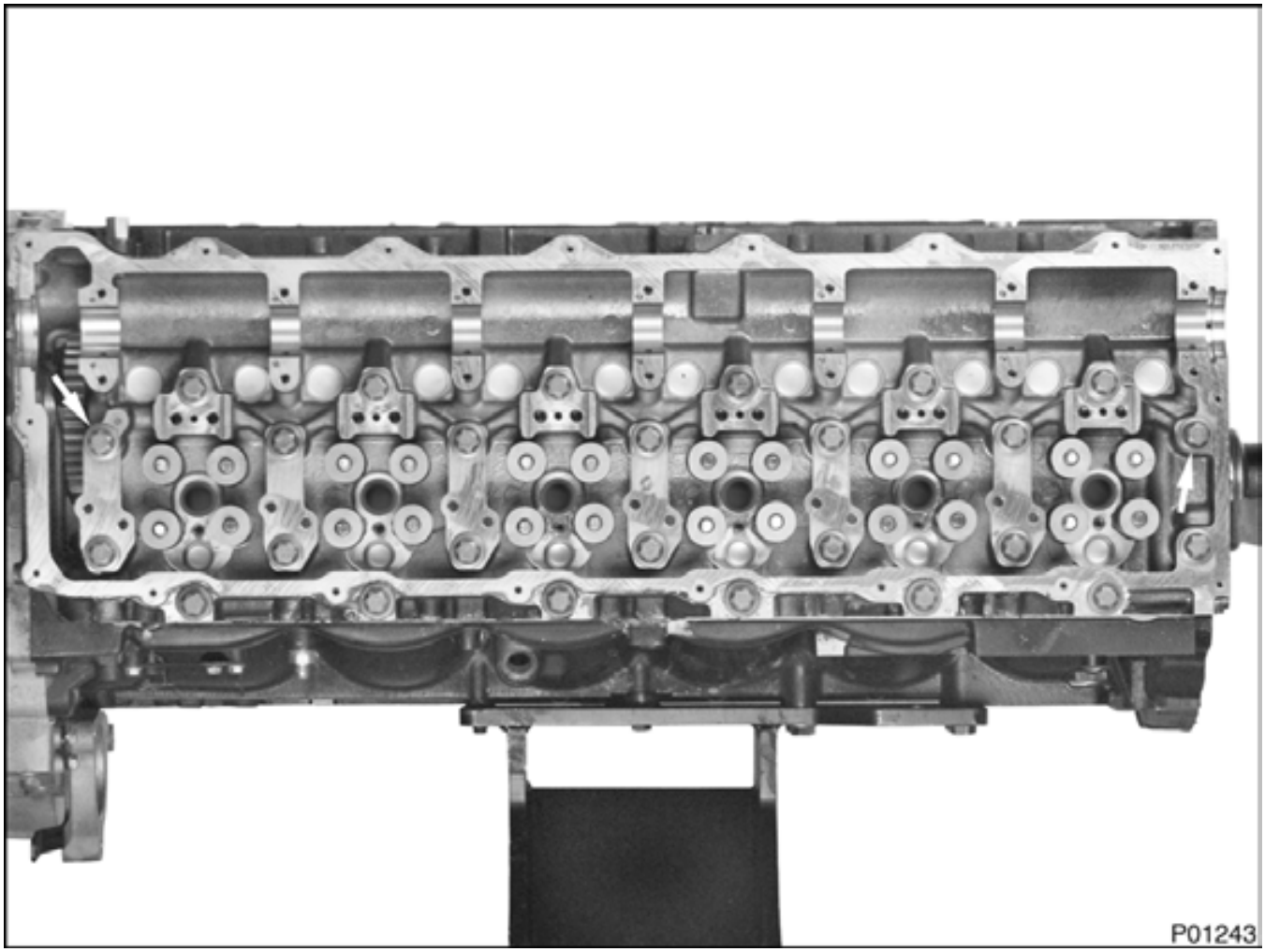

Figure 580 Cylinder head bolts

3. Use Head Bolt Torx Socket (page 355), and working in a circular pattern, loosen, remove, and discard 26 M18 x 246 collar bolts. Begin with the outer bolts and move inward.

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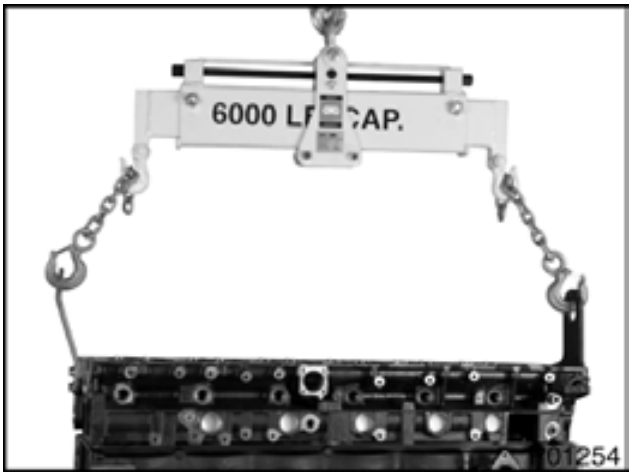

Figure 581 Cylinder head removal

4. Lift cylinder head using a suitable lifting device.

CAUTION: To prevent engine damage, do not scratch gasket surface of cylinder head.

CAUTION: To prevent engine damage, carefully set cylinder head on blocks to protect the cylinder intermediate gear.

5. Place cylinder head on a clean non-metallic surface.
6. Remove four M8 x 20 class 10.9 bolts and Cylinder Head Lifting Bracket (page 355).
7. Remove and discard cylinder head gasket.

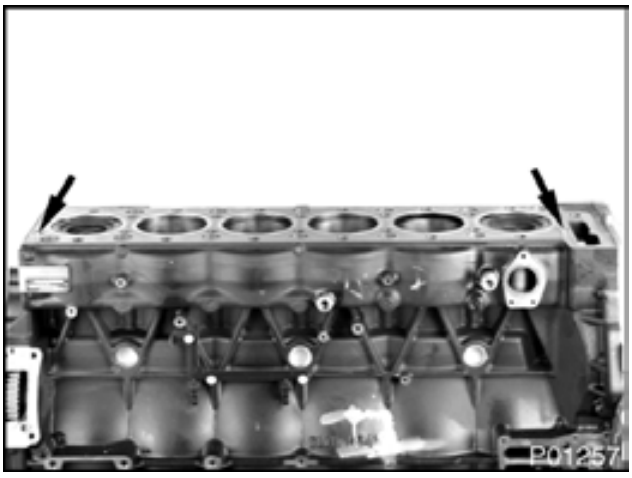

Figure 582 8 mm dowel pin (2)

8. If damaged, remove two 8 mm dowel pins.

Cylinder Intermediate Gear

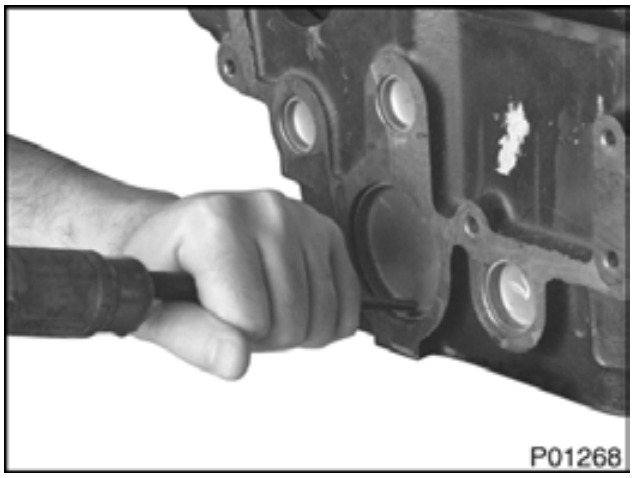

Figure 583 Cover removal

1. Use a punch to knock in bottom of cover. Remove and discard cover.

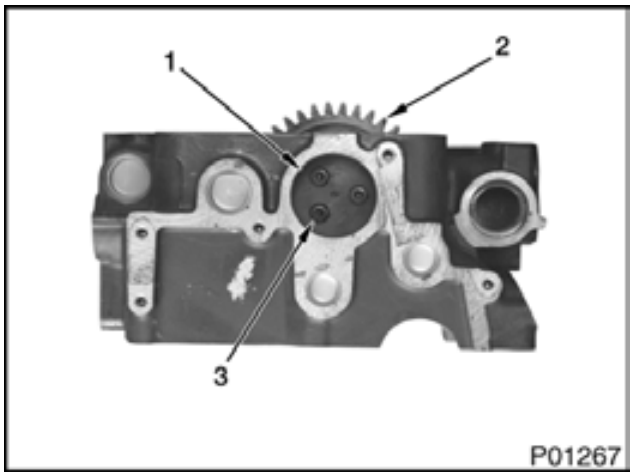

Figure 584 Cylinder intermediate gear

1. Small gear stud
2. Cylinder intermediate gear
3. M8 x 30 cylinder screw (3)

2. Remove three M8 x 30 cylinder screws, small gear stud, and cylinder intermediate gear.

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Cleaning, Inspection, and Testing

Cylinder Head and Crankcase Components

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

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 chemicals other than engine oil.

CAUTION: To prevent engine damage, do not scratch gasket surface of cylinder head.

1. Use a scraper and wire brush to remove deposits and gasket material from valve heads and gasket surface.
2. Use a suitable solvent to remove dirt, grease, and deposits from removed parts.
3. Clean all bolt holes. Make sure gasket surfaces, and oil return passages are clean. Clean all surfaces and ports with steam, and then dry with filtered compressed air.
4. Clean all bolts (except head bolts) with a suitable solvent and dry thoroughly. New head bolts must be installed.

CAUTION: To prevent engine damage, clean and dry threads in crankcase bolt holes with filtered compressed air. Dirt or oil in holes may cause binding and incorrect torque readings.

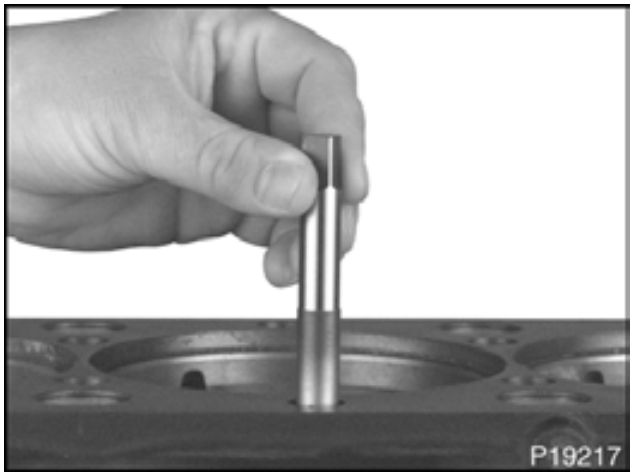

Figure 585 Head bolt bottoming tap

5. Clean cylinder head bolt holes in crankcase with Head Bolt Bottoming Tap (page 355).
6. Clean out debris with filtered compressed air.

Camshaft Bearings

1. With camshaft removed, install previously marked bearing shells and cylinder head bearing caps. Tighten M8 x 35 hex bolts to special torque (page 354).

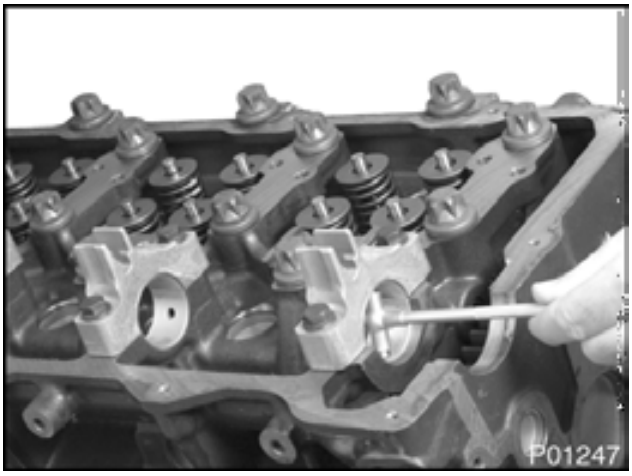

Figure 586 Camshaft bearing check

2. Use a telescoping gauge set (page 355) and a 1-2 inch micrometer (page 355) to measure camshaft bearing inside diameter. If inside diameter does not meet specifications (page 354), install new camshaft bearings.

Fuel Injector Bore

1. Use Injector Sleeve Brushes (page 355) in injector bore to remove deposits.

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

2. Use filtered compressed air to clean out debris from injector bores.

Fuel Injector Harness

Inspect injector wire harness for kinked wires or terminals. Replace harness if kinks are found. Kinked

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wires can result in oil leak between the harness protective foam covering and the wires.

Valves Leak Test

NOTE: Position wooden blocks so the view of all the valves seats is not restricted.

1. Position cylinder head on wooden blocks with cylinder head gasket surface facing down.

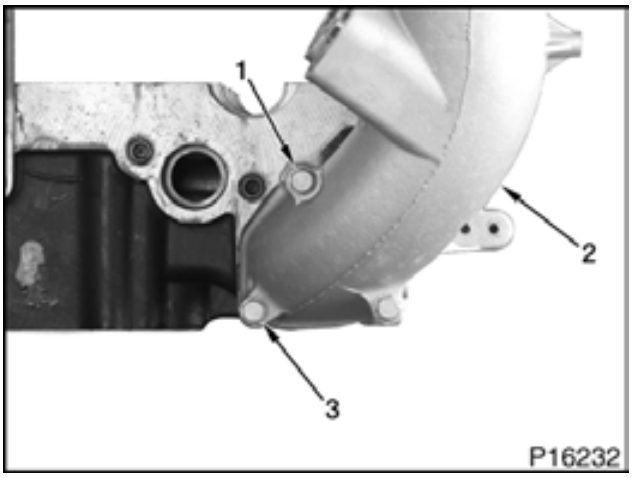

Figure 587 Air inlet duct

1. M8 x 90 hex bolt (2)
2. Air inlet duct
3. M8 x 50 hex bolt

2. Apply Loctite® 5900 sealant or equivalent (page 355) to joining surfaces of air inlet duct and cylinder head.
3. Install air inlet duct.
4. Install M8 x 50 hex bolt and two M8 x 90 hex bolts. Tighten hex bolts to special torque (page 354).
5. Spray mineral spirits into exhaust ports.
6. Pour mineral spirits into air inlet duct until intake manifold inside cylinder head is filled.

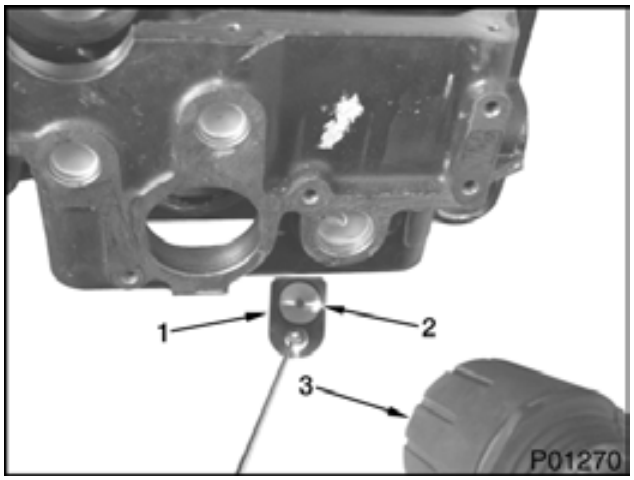

Figure 588 Leak inspection

1. Inspection mirror
2. Reflection of valve
3. Flashlight

NOTE: Valve seats must not leak. If valve seats leak, install a new cylinder head. Cylinder head replacement is not required if the cylinder head passes the mineral spirits test.

7. Wait five minutes. Use an inspection mirror to inspect valve seat area for leakage of mineral spirits. If there is no leakage of mineral spirits through the intake or exhaust valves, the cylinder head is acceptable for reinstallation.

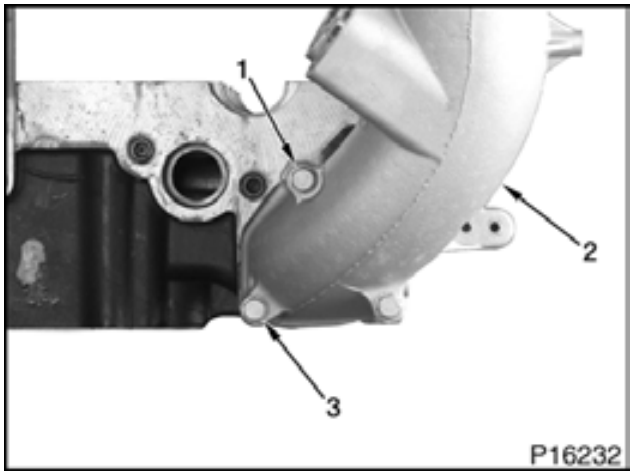

Figure 589 Air inlet duct

1. M8 x 90 hex bolt (2)
2. Air inlet duct
3. M8 x 50 hex bolt

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8. Position a suitable container under air inlet duct to catch mineral spirits and loosen M8 x 50 hex bolt and two M8 x 90 hex bolts.
9. Remove air inlet duct.
10. Lift rear end of cylinder head to drain all remaining mineral spirits out of the intake manifold.

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Installation

Cylinder Intermediate Gear

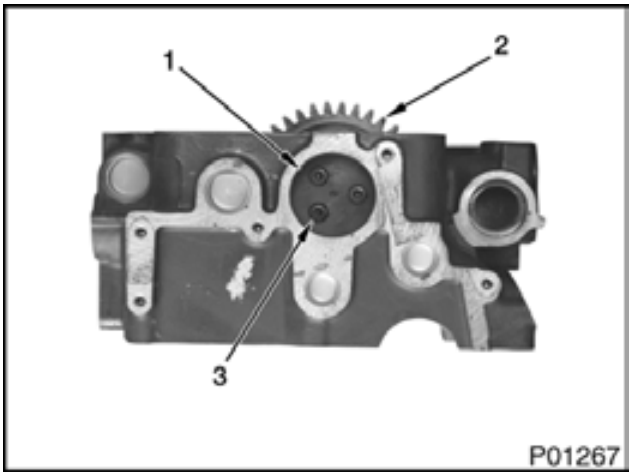

Figure 590 Cylinder intermediate gear

1. Small gear stud
2. Cylinder intermediate gear
3. M8 x 30 cylinder screw (3)

1. Install small gear stud and cylinder intermediate gear.
2. Install three M8 x 30 cylinder screws. Tighten cylinder screws to special torque (page 354).
3. Clean cylinder head mating surfaces for cylinder intermediate gear access cover.
4. Apply Loctite® 262™ Threadlocker (page 355) to the outside edge of new cylinder intermediate gear access cover.

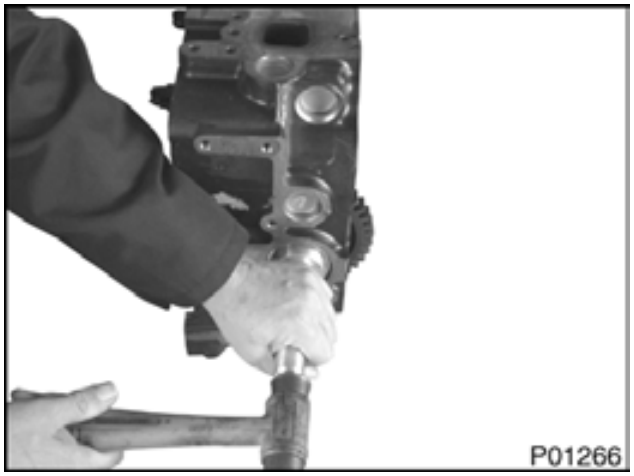

Figure 591 Cover installation

5. Drive new cover into the hole using a bearing installer (page 355) approximately 6mm (0.25 in) smaller in diameter than the cover.
6. Recess cover 2.3 mm (0.9 in) below the machined surface.

Cylinder Head

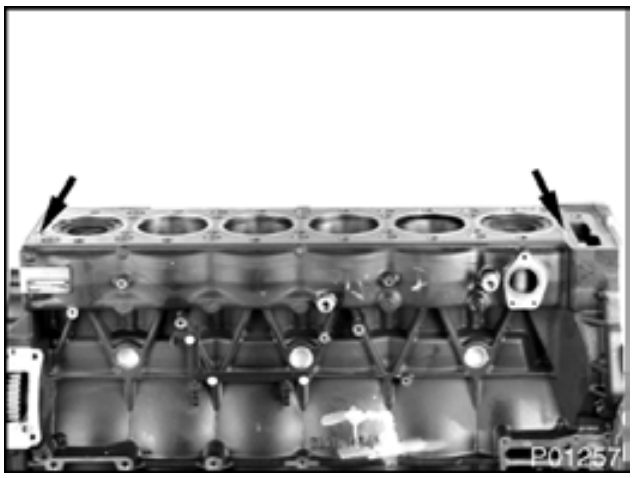

Figure 592 8 mm dowel pin (2)

1. If previously removed, install two 8 mm dowel pins on crankcase.

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

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 chemicals other than engine oil.

CAUTION: To prevent engine damage, clean and blow dry threads in the crankcase bolt holes with filtered compressed air. Dirt or oil in holes may cause binding or an incorrect torque reading.

CAUTION: To prevent engine damage, remove debris from cylinder head. If debris is not removed, a faulty seal between the cylinder head and gasket will cause oil, coolant, and compression leaks. Do not apply sealant to head gasket surfaces.

CAUTION: To prevent engine damage, install a new cylinder head gasket with part number facing up.

2. Install a new cylinder head gasket on crankcase, over dowel pins.

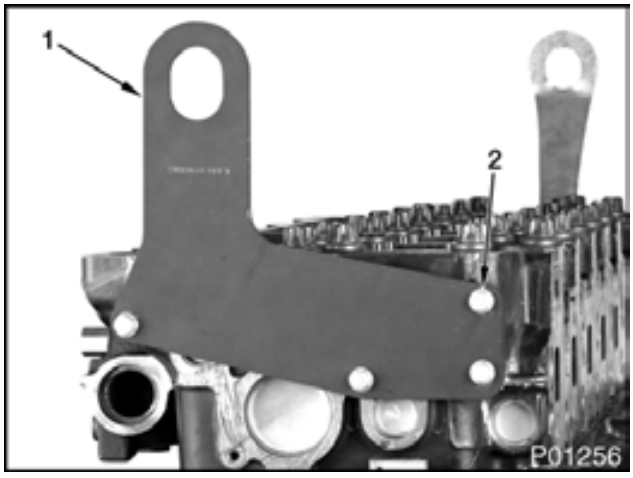

Figure 593 Cylinder Head Lifting Bracket

1. Cylinder Head Lifting Bracket
2. M8 x 20 class 10.9 bolt (4)

3. Position Cylinder Head Lifting Bracket (page 355) on rear end of cylinder head.
4. Install four M8 x 20 class 10.9 bolts (page 355). Tighten bolts to standard torque (page 457).

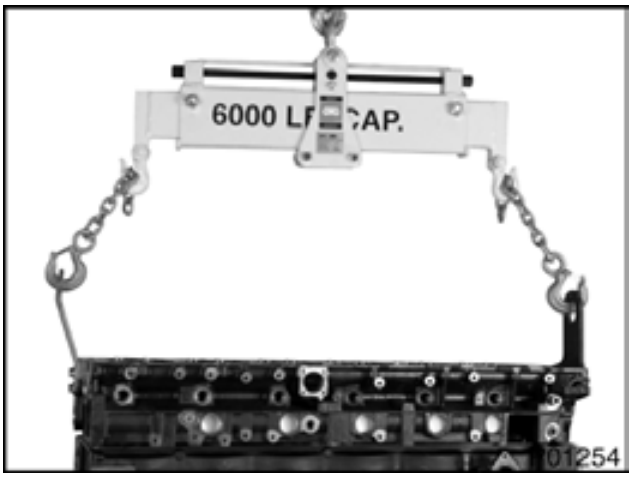

Figure 594 Cylinder head installation

CAUTION: To prevent engine damage, do not drop or slide cylinder head on cylinder head gasket. This will damage the cylinder head gasket, dowel pins, and the cylinder intermediate gear.

5. Lower cylinder head on crankcase.

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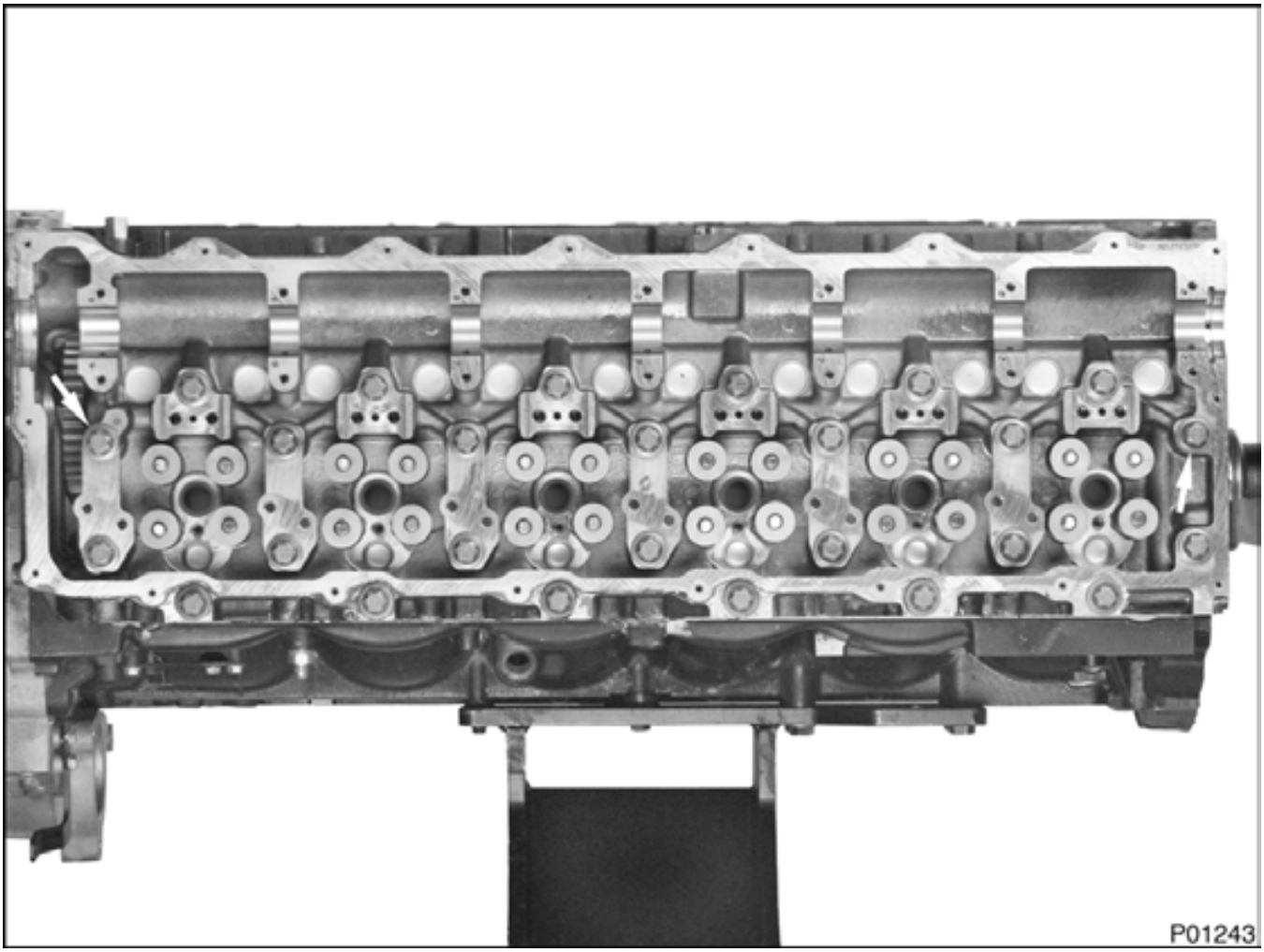

Figure 595 Cylinder head bolts

CAUTION: To prevent engine damage, install new head bolts. Lightly lubricate new bolt threads and mating surfaces of bolt flanges with clean engine oil. Too much oil will cause hydrostatic lock and give incorrect torque reading.

6. Install 26 new lightly lubricated M18 x 246 collar bolts. Do not tighten bolts at this time.
7. Remove four M8 x 20 class 10.9 bolts and Cylinder Head Lifting Bracket (page 355).

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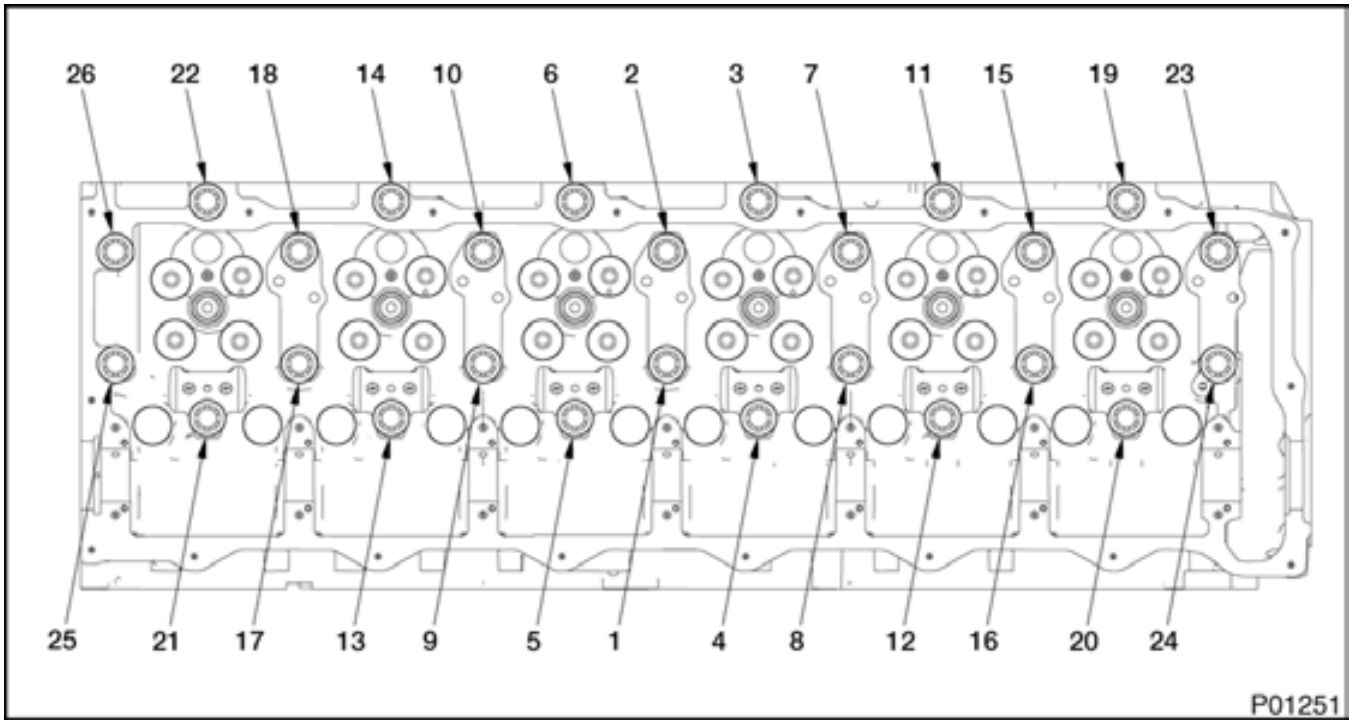

Figure 596 Cylinder head bolts tightening sequence

CAUTION: To prevent engine damage, use only permanent ink markers to identify bolt torque orientation.

CAUTION: To prevent engine damage, use a torque wrench to tighten cylinder head bolts; do not use an impact wrench.

NOTE: For proper cylinder head surface seating and sealing, follow the correct tightening sequence.

8. Use Head Bolt Torx Socket (page 355) to tighten the M18 x 246 collar bolts in sequence indicated above as follows:
    1. Hand tighten collar bolts.
    2. Tighten collar bolts numbered 1 through 26 to 10 N·m (89 lbf·in) in numerical sequence.
    3. Tighten collar bolts numbered 1 through 26 to 150 N·m (111 lbf·ft) in numerical sequence.
    4. Tighten collar bolts numbered 1 through 26 to 300 N·m (221 lbf·ft) in numerical sequence.
    5. Rotate collar bolts numbered 1 through 26 an additional 90° (1/4 turn) clockwise in numerical sequence.
    6. Rotate collar bolts numbered 1 through 26 an additional 90° (1/4 turn) clockwise in numerical sequence for second time.
    7. Rotate collar bolts numbered 1 through 26 an additional 90° (1/4 turn) clockwise in numerical sequence for third time.

Fuel Injector Harness

1. If necessary, install a new O-ring on injector harness flange.

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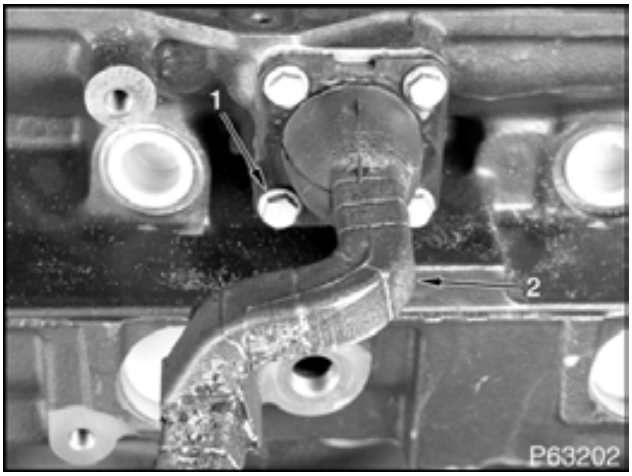

Figure 597 Injector harness bolts

1. M6 x 16 hex bolt (4)
2. Injector harness

2. Lightly lubricate O-ring on injector harness flange with clean engine oil.
3. Install injector harness and four M6 x 16 hex bolts.
4. Tighten hex bolts to standard torque (page 457).

Camshaft

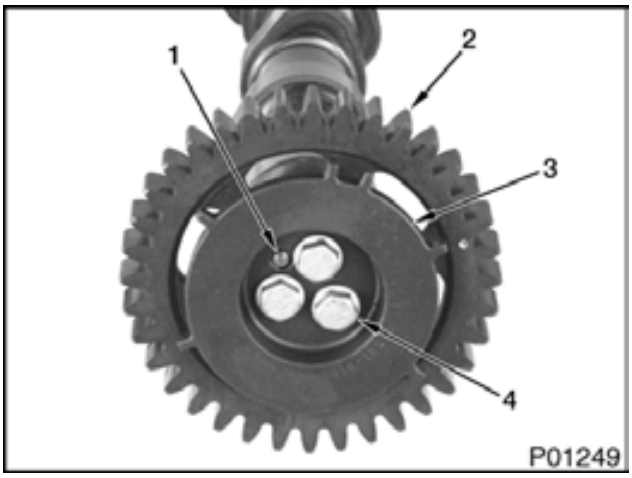

Figure 598 Camshaft gear and camshaft pulse wheel

1. 6 mm dowel pin
2. Camshaft gear
3. Camshaft pulse wheel
4. M8 x 30 hex bolt (3)

1. If previously removed, install 6 mm dowel pin into camshaft.
2. Align camshaft gear with dowel pin and install on camshaft.
3. Align camshaft pulse wheel with dowel pin and install on camshaft.
4. Install and finger tighten three M8 x 30 hex bolts.

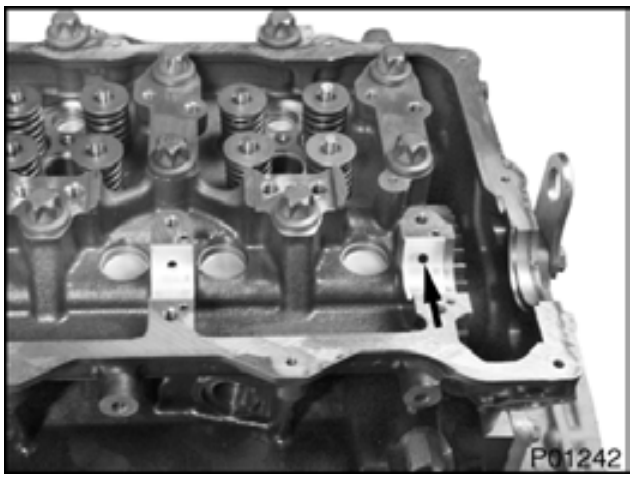

Figure 599 Camshaft lower bearing shell (typical)

NOTE: If original camshaft bearing shells are installed, make sure to place them as previously marked in their original location and orientation.

5. Install seven new or previously marked camshaft lower bearing shells on cylinder head. Make sure oil holes in bearings are aligned with oil holes in cylinder head bearing support.
6. Rotate crankshaft so that cylinder number 1 is positioned at Top Dead Center (TDC).

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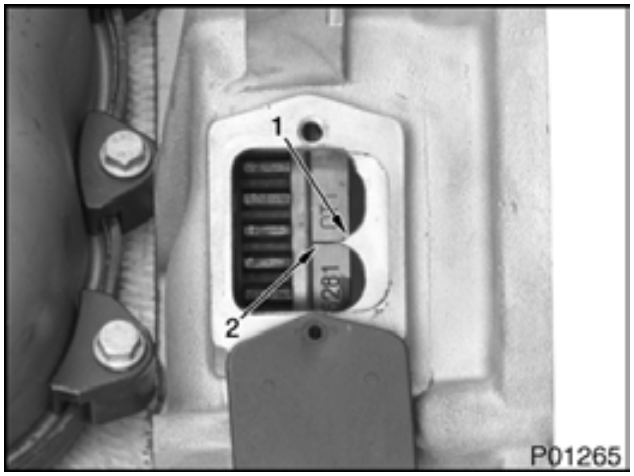

Figure 600 Flywheel housing timing index

1. Flywheel housing timing index
2. Flywheel timing mark

7. Verify timing mark on flywheel is aligned with flywheel housing timing index at bottom of flywheel housing.

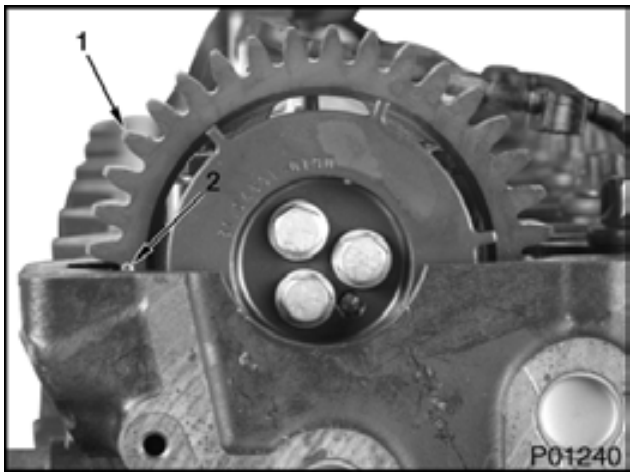

Figure 601 Camshaft timing mark

1. Camshaft gear
2. Timing mark

8. Lower camshaft on cylinder head and make sure timing mark on camshaft gear is aligned with cylinder head surface.

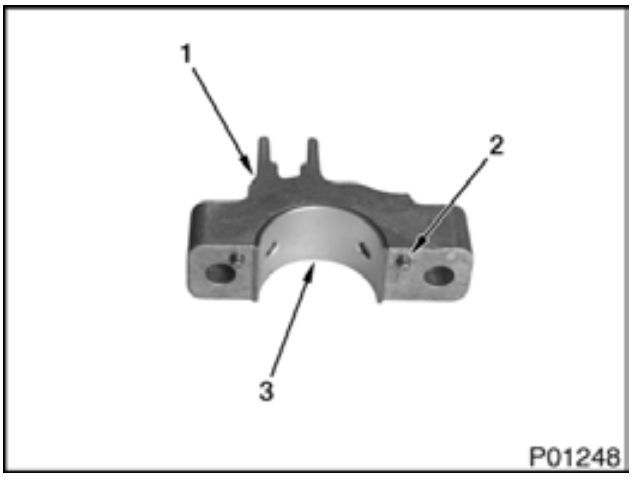

Figure 602 Cylinder head bearing cap and bearing (typical)

1. Cylinder head bearing cap
2. 4 mm dowel pin (2)
3. Bearing shell

NOTE: Make sure that each bearing cap has the two dowel pins installed.

9. If previously removed, install 14 – 4 mm dowel pins into seven bearing caps.

NOTE: If original bearing shells are installed, make sure they are placed as previously marked in their original location and orientation.

10. Install seven new or previously marked bearing shells on cylinder head bearing caps.

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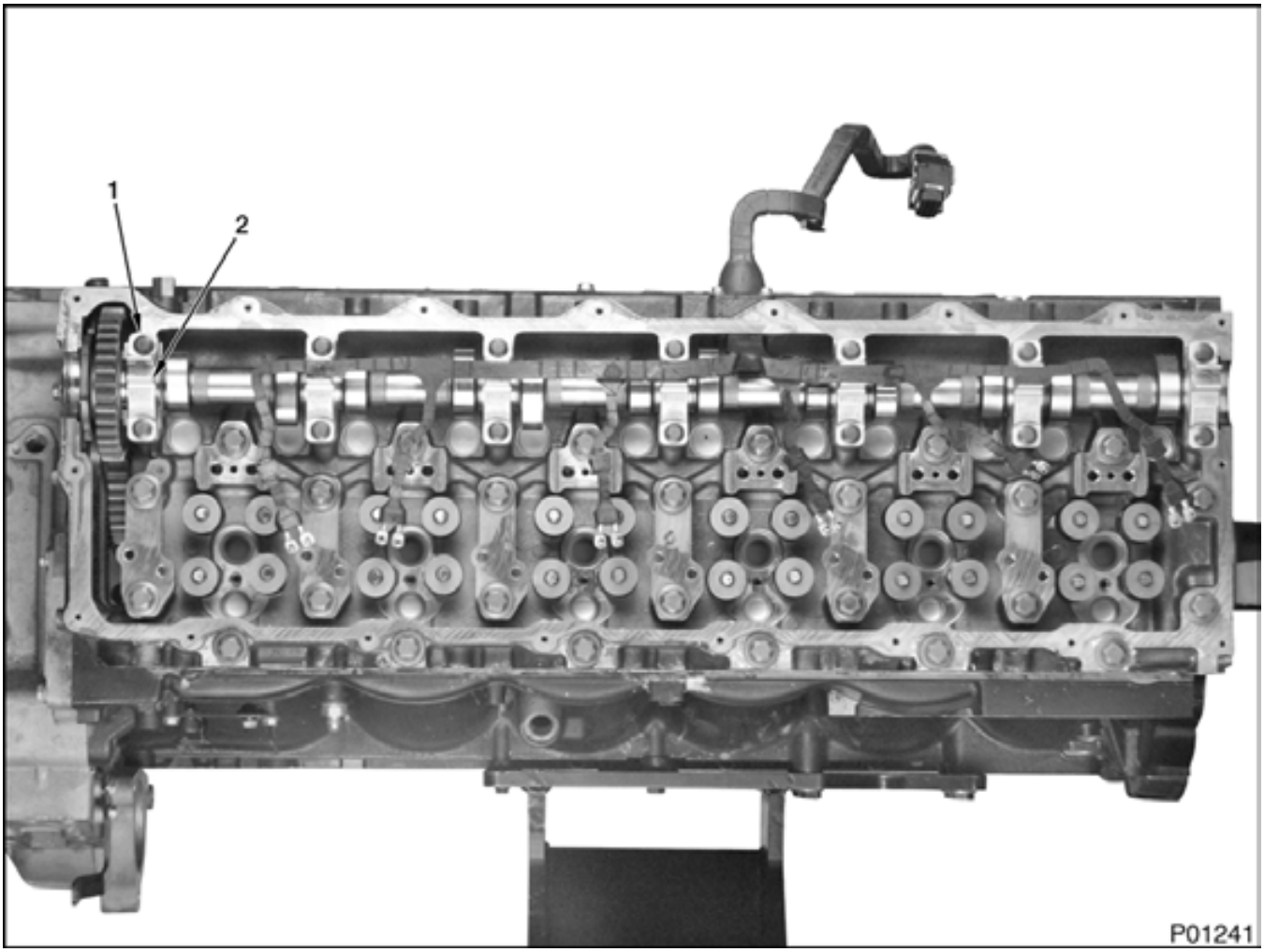

Figure 603 Camshaft bearing bolts

1. M8 x 35 hex bolt (14)
2. Cylinder head bearing cap (7)

11. Install seven previously marked cylinder head bearing caps with bearing shells in their original location and orientation.
12. Install 14 M8 x 35 hex bolts. Tighten hex bolts to special torque (page 354).

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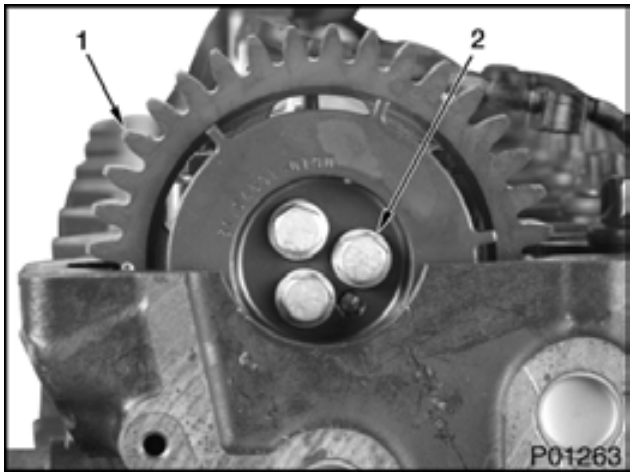

Figure 604 Camshaft gear bolts tightening

1. Camshaft gear
2. M8 x 30 hex bolt (3)

13. Tighten three M8 x 30 hex bolts to 15 N·m (133 lbf·in).
14. Tighten three M8 x 30 hex bolts an additional 90° (1/4 turn).

Rocker Gear

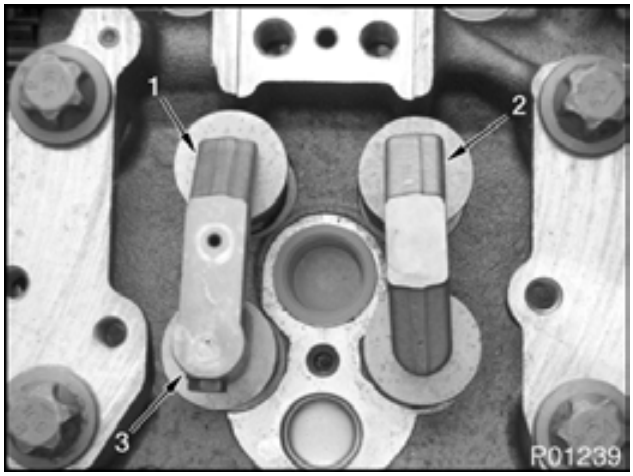

Figure 605 Valve bridges (typical)

1. Valve bridge (exhaust) (6)
2. Valve bridge (intake) (6)
3. Counterpiece end

NOTE: If original valve bridges are installed, make sure they are placed as previously marked in their original location.

1. Place six exhaust valve bridges on exhaust valves with counterpiece end oriented toward exhaust manifold and milled end toward camshaft.

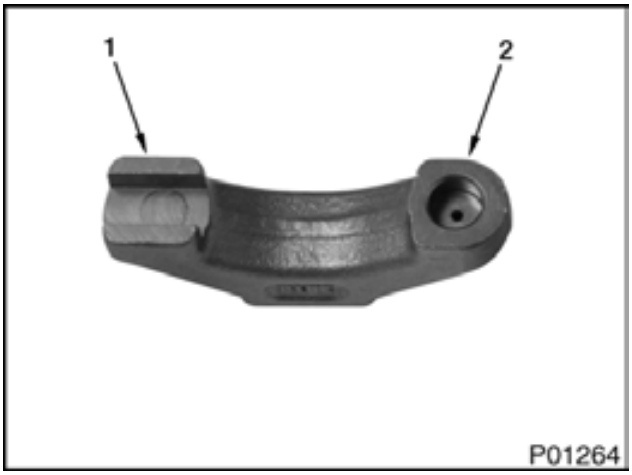

Figure 606 Intake valve bridge orientation (typical)

1. Camshaft side
2. Exhaust manifold side

2. Place six intake valve bridges on intake valves with milled end oriented toward camshaft.

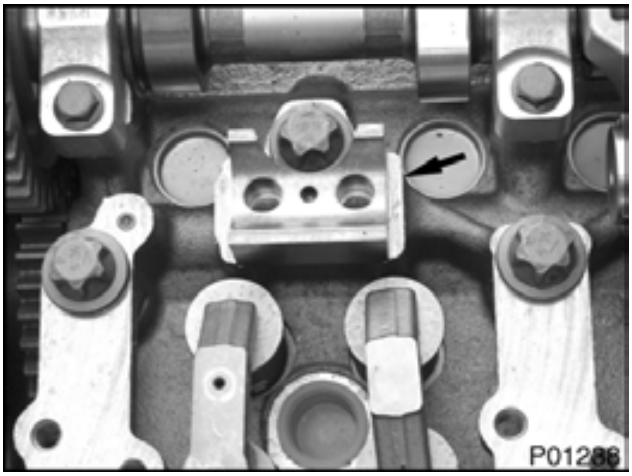

Figure 607 Rocker bearing block (typical)

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NOTE: If original rocker bearing blocks are installed, make sure they are placed as previously marked in their original location.

3. Install six rocker bearing blocks.

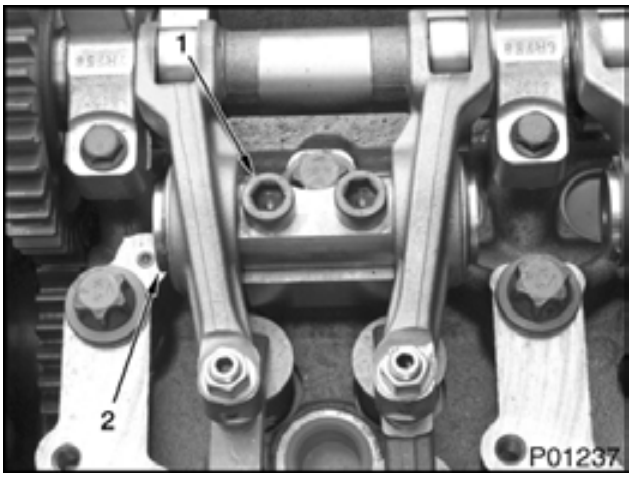

Figure 608 Rocker gear (typical)

1. M12 x 60 cylinder screw (12)
2. Rocker gear (6)

NOTE: If original rocker gears are installed, make sure they are placed as previously marked in their original location.

4. Install six rocker gears.
5. Install 12 M12 x 60 cylinder screws. Tighten cylinder screws to special torque (page 354).

Counterpiece

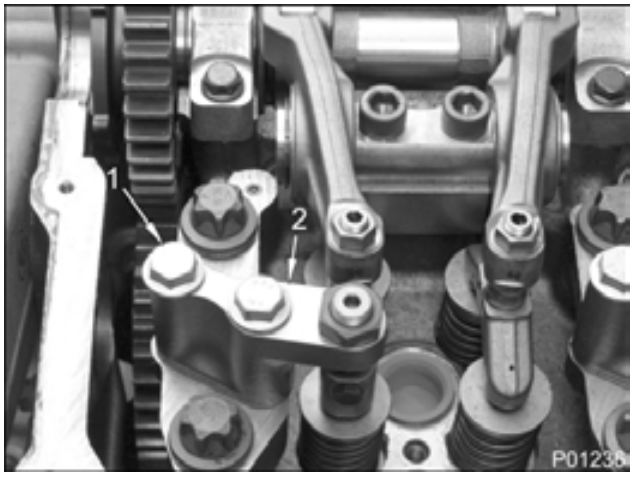

Figure 609 Counterpiece bolts (typical)

1. M10 x 60 hex bolt (12)
2. Counterpiece (6)

1. Place six counterpieces on cylinder head.
2. Install 12 M10 x 60 hex bolts. Tighten hex bolts to special torque (page 354).
3. Adjust counterpiece, exhaust, and intake valves lash. See Valve Lash Adjustment (page 320).

Fuel Injectors

CAUTION: To prevent engine damage, remove protective plugs and cups only before immediate installation of components.

CAUTION: To prevent engine damage, do not use power tools.

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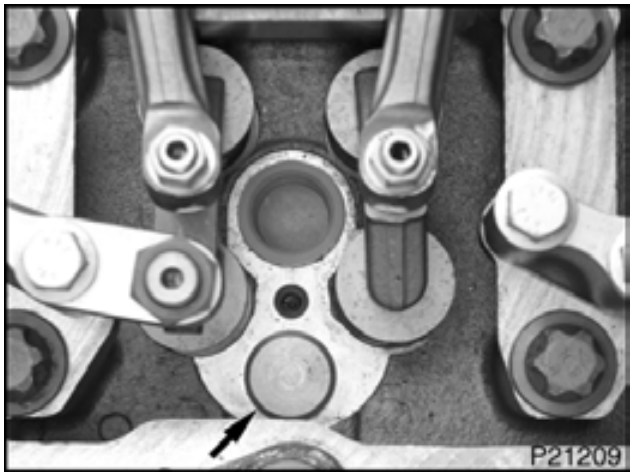

Figure 610 Thrust washer (typical)

1. Install six thrust washers on cylinder head.

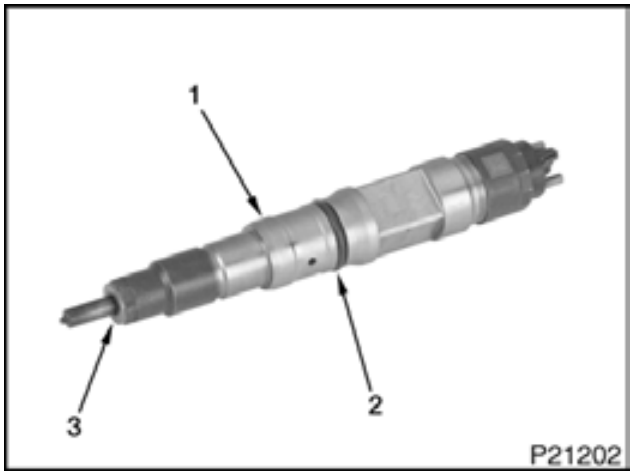

Figure 611 Injector seals (typical)

1. Injector
2. O-ring
3. Sealing washer

CAUTION: To prevent engine damage, install new injector O-ring and sealing washer before installing injector.

2. Install a new sealing washer onto injector tip.
3. Install a new O-ring. Lubricate O-ring with clean engine oil.

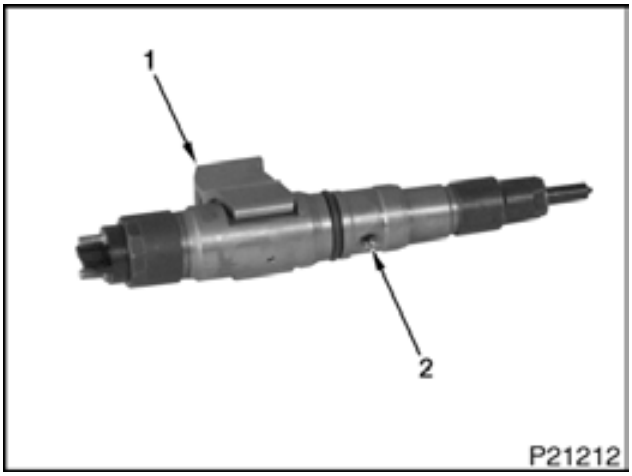

Figure 612 Injector and pressure flange orientation (typical)

1. Pressure flange
2. Injector inlet opening

4. Slide injector into pressure flange with injector inlet opening on opposite side of pressure flange.

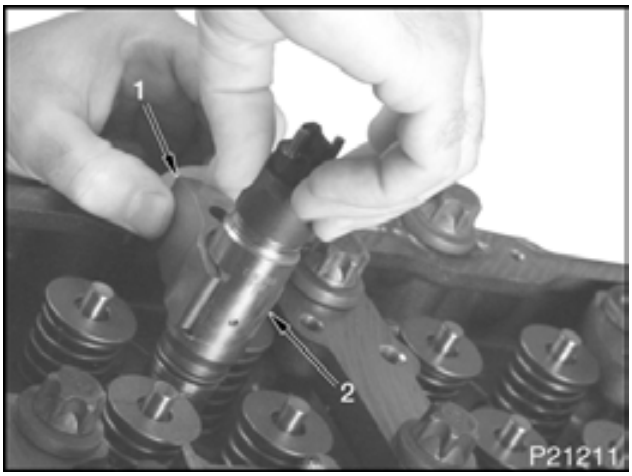

Figure 613 Injector and pressure flange installation (typical)

1. Pressure flange
2. Injector

CAUTION: To prevent engine damage, align injector and pressure flange correctly with cylinder head; do not twist injector when inserting injector into cylinder head.

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NOTE: Make sure that injector bore in cylinder head is clean and no old sealing washer remains inside the bore.

5. Install injector by lowering injector and pressure flange as one unit into injector bore.
6. Using Injector Installer (page 355), firmly press injector and pressure flange and make sure injector is fully seated into cylinder head.

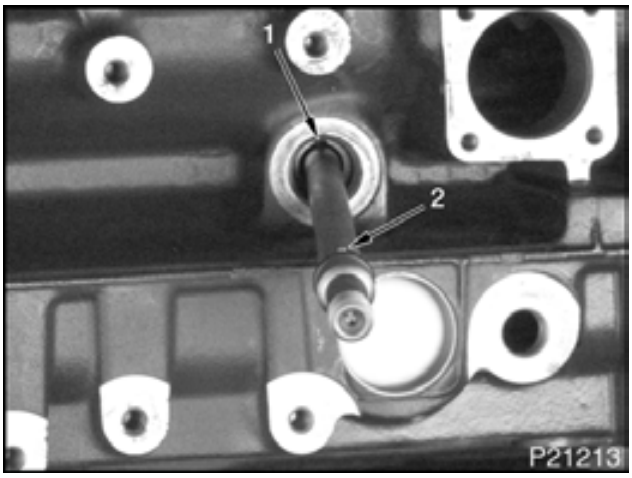

Figure 614 Pressure pipe neck alignment (typical)

1. Cylinder head notch
2. Locating ball

CAUTION: To prevent engine damage, install new pressure pipe.

7. Align locating ball on pressure pipe neck with notch in cylinder head, and install six new pressure pipe necks.

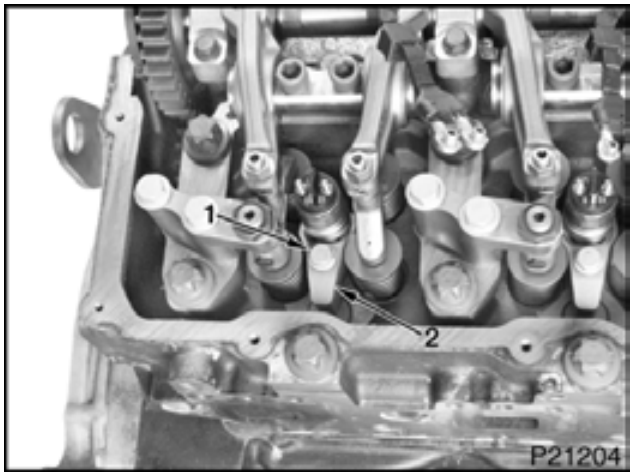

Figure 615 Pressure flange hex bolt (typical)

1. M8 x 50 hex bolt (6) and retaining washer (6)
2. Pressure flange

8. Install six M8 x 50 pressure flange hex bolts and six retaining washers.
9. Pre-tighten M8 x 50 hex bolts to 2 N·m (18 lbf·in).

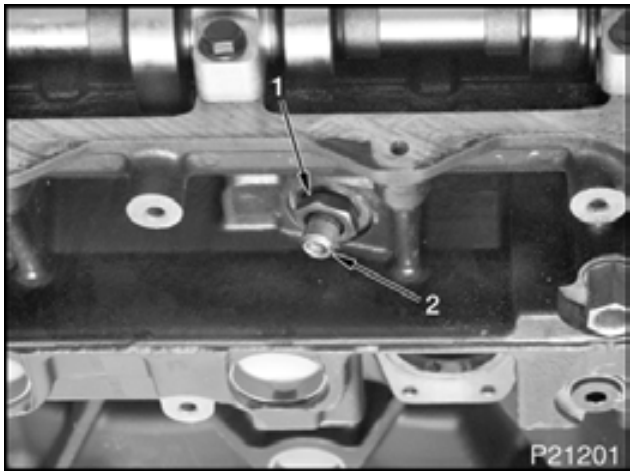

Figure 616 Pressure pipe neck (typical)

1. Pressure pipe nut (6)
2. Pressure pipe neck (6)

10. Install six pressure pipe nuts. Tighten pressure pipe nuts to initial torque of 10 N·m (89 lbf·in).
11. Tighten six M8 x 50 pressure flange hex bolts to 25 N·m (18 lbf·ft).

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12. Tighten six M8 x 50 pressure flange hex bolts an additional 90° (1/4 turn).
13. Tighten six pressure pipe nuts to special torque (page 354).

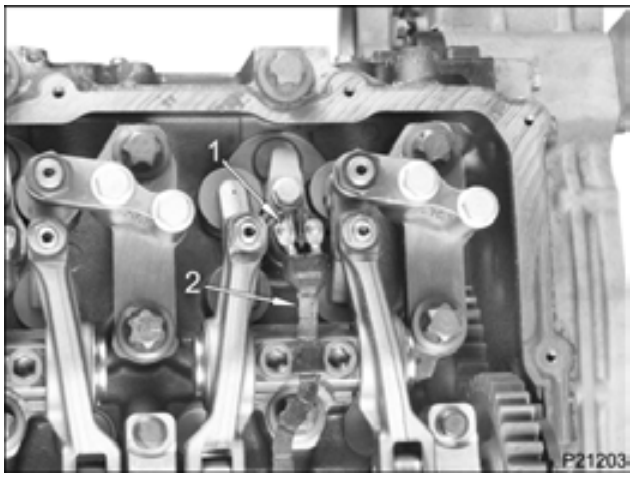

Figure 617 Injector connections (typical)

1. Injector harness nuts (12)
2. Injector harness

CAUTION: To prevent engine damage, hold injector harness terminals to prevent twisting or turning while tightening the injector harness nuts. Kinked harness terminals can result in an oil leak path between the protective cover and the wire.

CAUTION: To prevent engine damage, use a torque wrench to tighten injector harness nuts to 1.5 Nm (13 lbf in).

14. Connect injector harness to injectors. Make sure harness terminals are in straight alignment with harness. Hold terminals stationary to avoid twisting, and tighten nuts to special torque (page 354).

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Valve Cover

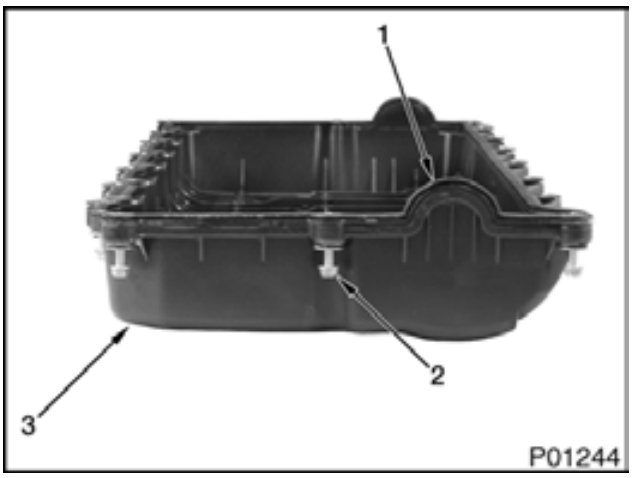

Figure 618 Valve cover gasket

1. Valve cover gasket
2. Screw with damper element (18)
3. Valve cover

1. If necessary, install a new valve cover gasket.
2. If previously removed, install 18 screws with damper element on valve cover and through valve cover gasket.

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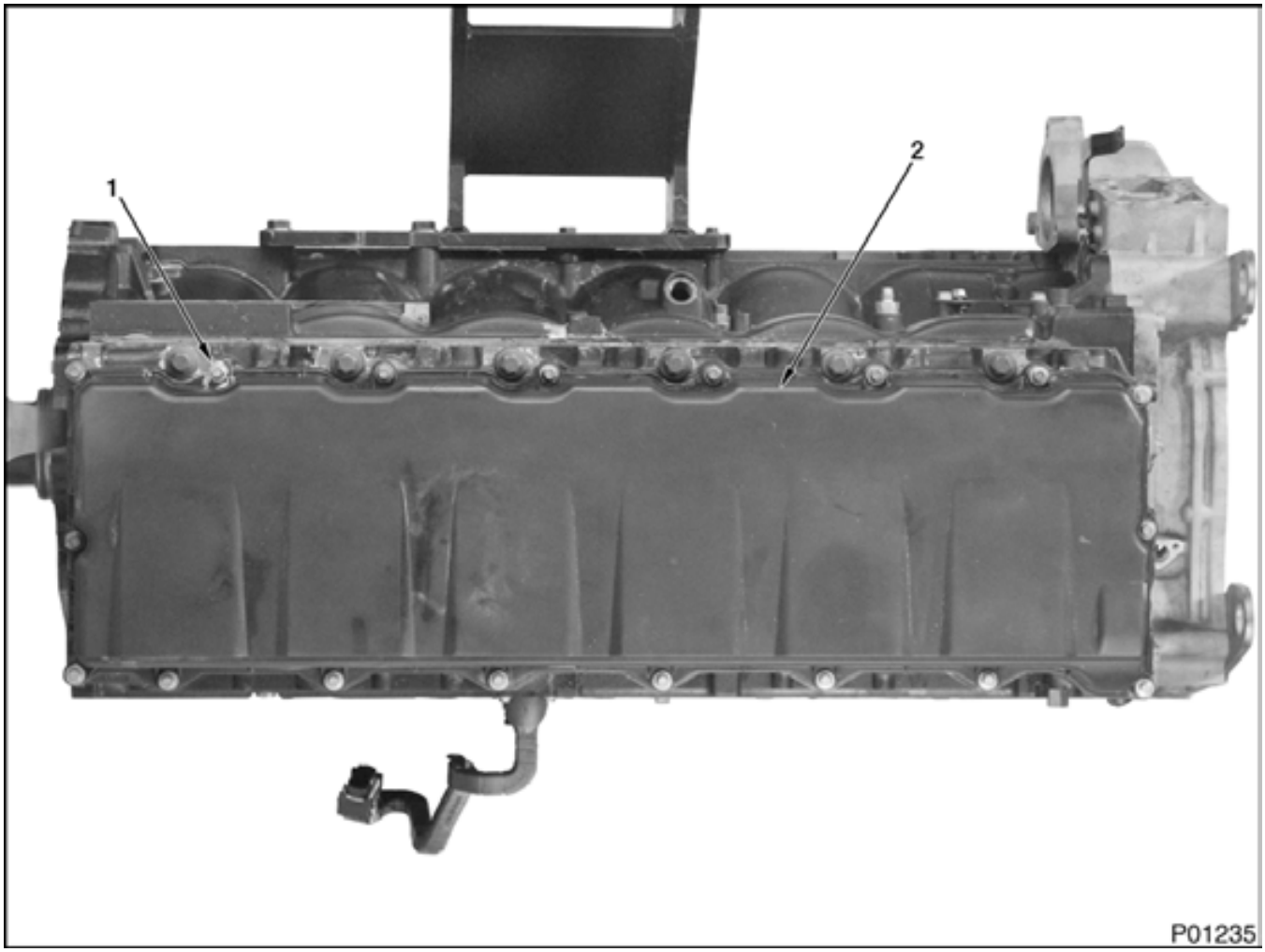

Figure 619 Valve Cover

1. Screw with damper element (18)
2. Valve cover

CAUTION: To prevent engine damage, do not use air tools to remove or install valve cover.

3. Place valve cover on cylinder head.
4. Tighten 18 screws with damper elements to special torque (page 354).

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Specifications

Table 27 Cylinder Head, Camshaft and Valve Train

Camshaft	
Camshaft end play	0.25 – 0.85 mm (0.0098 – 0.0334 in)
Camshaft bearing inside diameter	39.925 – 39.950 mm (1.57185 – 1.57283 in)
Valve Lash Adjustment	
Intake valve clearance	0.5 mm (0.0196 in)
Exhaust valve clearance	0.8 mm (0.0314 in)
Counterpiece clearance	0.6 mm (0.0236 in)
Cylinder Intermediate Gear Access Cover	
Cover recess	2.3 mm (0.9 in)

Special Torque

Table 28 Cylinder Head, Camshaft and Valve Train

Air inlet duct hex bolts	15 N·m (11 lbf·ft)
Cylinder head bearing cap hex bolt	35 N·m (26 lbf·ft)
Camshaft gear hex bolts	See tightening steps in procedure
Cylinder head collar bolts	See tightening steps in procedure
Cylinder intermediate gear cylinder screws	30 N·m (22 lbf·ft)
Counterpiece adjustment M14 hexagon nuts	45 N·m (33 lbf·ft)
Counterpiece hex bolts	75 N·m (55 lbf·ft)
Exhaust valve lash adjustment M10 hexagon nuts	45 N·m (33 lbf·ft)
Injector harness nuts	1.5 N·m (13 lbf·in)
Injector pressure flange hex bolts	See tightening steps in procedure
Intake valve lash adjustment M10 hexagon nuts	45 N·m (33 lbf·ft)
Pressure pipe nuts	55 N·m (40 lbf·ft)
Rocker gear cylinder screws	105 N·m (77 lbf·ft)
Valve cover screw with damper elements	11 N·m (97 lbf·in)

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Special Service Tools

Table 29 Cylinder Head, Camshaft and Valve Train

Description	Tool Number
1–2 inch Micrometer	Obtain locally
Bearing Installer	Obtain locally
Cylinder Head Lifting Bracket	ZTSE4869
Dial Indicator with Magnetic Base	Obtain locally
Disposable Air and Fuel Caps	ZTSE4891
Engine Rotating Tool	ZTSE4786
Feeler Gauge	Obtain locally
Fuel Injector Tip Cleaning Brush	ZTSE4301
Fuel Injector Rack Holder	ZTSE4299B
Fuel Injector Cups	ZTSE4892
Head Bolt Bottoming Tap	ZTSE4855
Head Bolt Torx Socket	ZTSE4835
Injector Installer	ZTSE4777
Injector Puller	ZTSE4770
Injector Sleeve Brushes	ZTSE4751
Loctite® 262™ Threadlocker	Obtain locally
Loctite® 5900 sealant or equivalent	Obtain locally
M8 x 20 class 10.9 bolts	Obtain locally
Telescoping Gauge Set	Obtain locally

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Exploded View

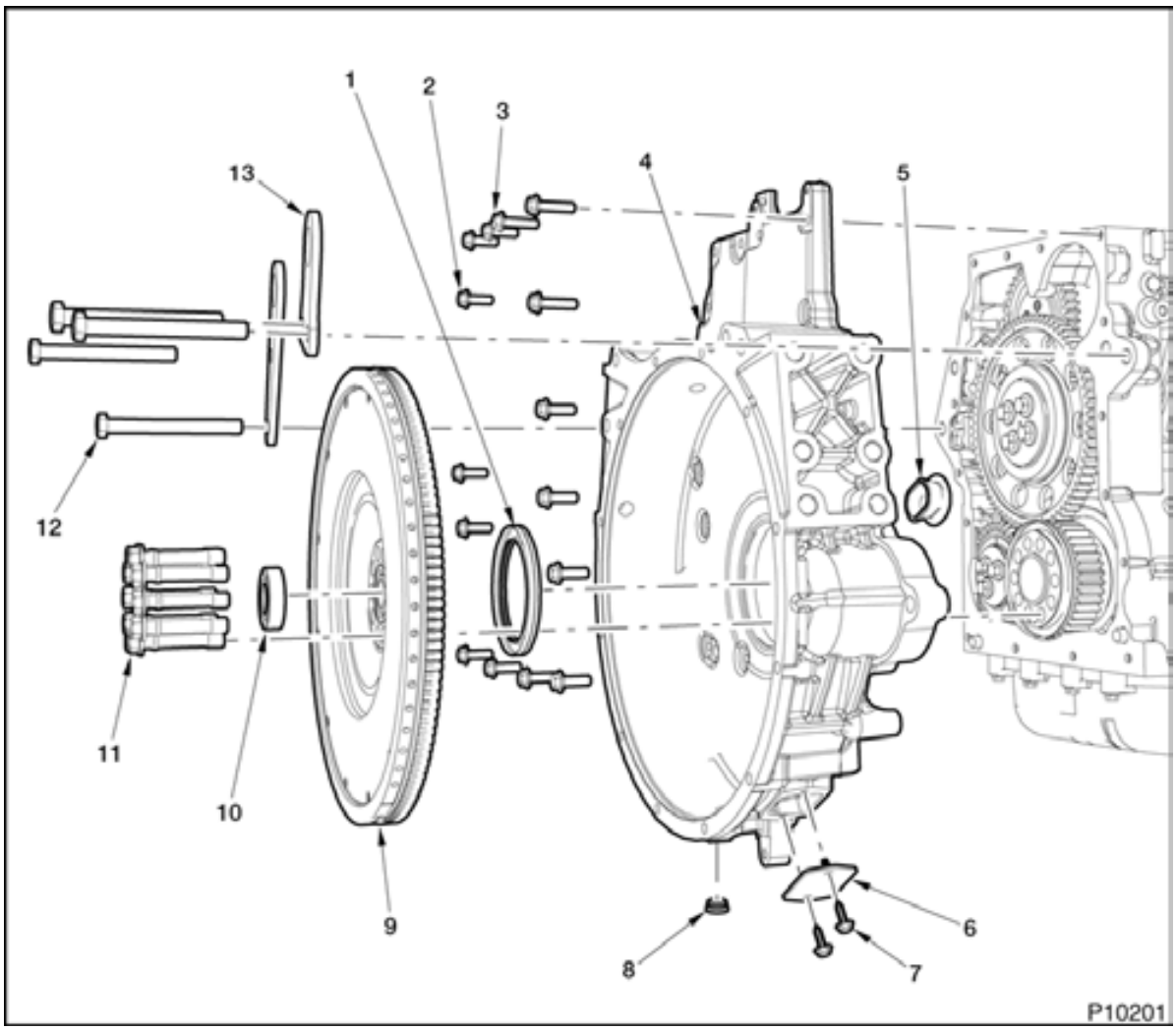

Figure 620 Flywheel housing and flywheel

1. Radial shaft seal
2. M10 x 30 hex bolt (12)
3. M10 x 40 hex bolt (3)
4. Flywheel housing
5. Plug
6. Sealing cap
7. Tapping screw (2)
8. Plug
9. Flywheel
10. Pilot bearing
11. 12KT flywheel bolt (10)
12. M16 x 150 hex bolt (4)
13. Lifting eye (2)

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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, make sure 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.

NOTE: Refer to the following service sections for information on removal of components prior to this section.

- Aftertreatment System

Preliminary Checks

Flywheel Assembly (Manual Transmission)

1. Inspect flywheel for cracks around webbing and bolt holes.
2. Inspect flywheel for heat cracks and extensive scoring.
3. Inspect all ring gear teeth for starter pinion damage.
4. Replace flywheel if necessary.

Flywheel Surface Runout

CAUTION: To prevent engine damage, check runout of flywheel surface for correct alignment of engine to transmission. Failure to ensure correct bore concentricity and face runout may reduce life of clutch or transmission.

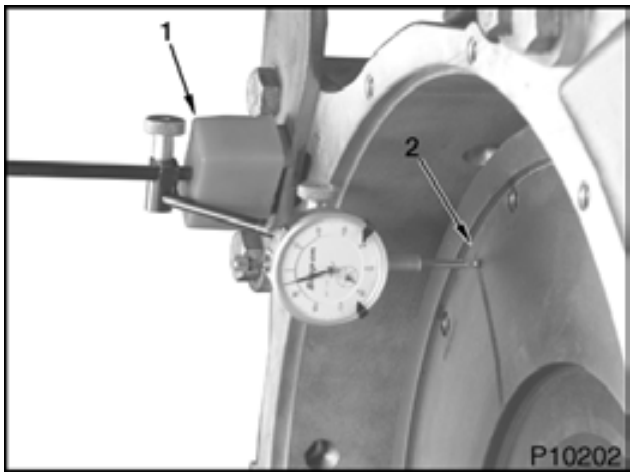

Figure 621 Flywheel surface runout

1. Dial indicator with magnetic base
2. Flywheel

1. Attach dial indicator with magnetic base (page 368) to surface of lifting eye. Place indicator tip against flywheel.

NOTE: Keep crankshaft end play at zero and rotate in same direction for all measurements.

2. Push the flywheel inward to eliminate crankshaft end play, set dial indicator zero.
3. While pushing inward on the flywheel to eliminate crankshaft end play effects, slowly rotate crankshaft one complete revolution. Verify reading is within specification (page 368).

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Pilot Bearing

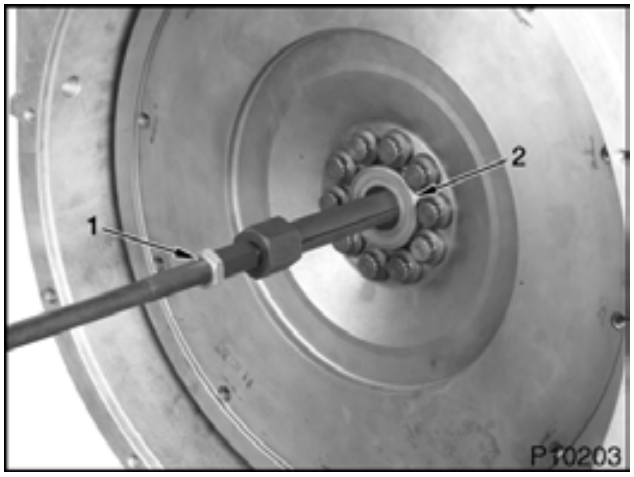

Figure 622 Pilot bearing removal

1. Slide hammer
2. Blind hole puller

1. Using a slide hammer (page 368), install blind hole puller (page 368), into pilot bearing.
2. Remove pilot bearing.

Flywheel (Manual Transmission)

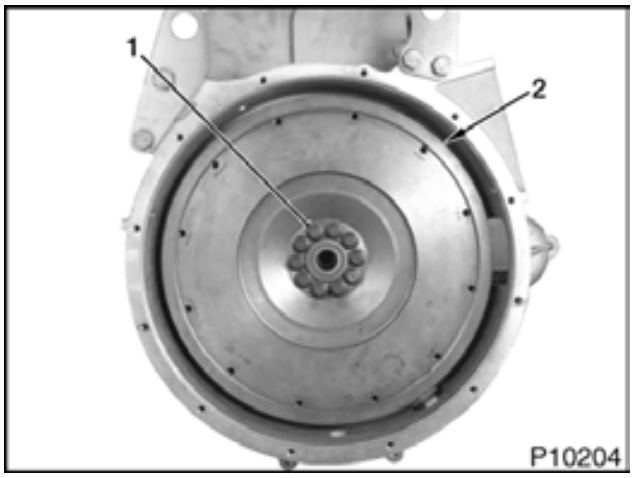

Figure 623 Flywheel removal

1. 12KT flywheel bolt (10)
2. Flywheel

1. Remove and discard two 12KT flywheel bolts at approximately 3 o'clock and 9 o'clock position.
2. Install two guide pins (make locally) into crankshaft flange.
3. Remove and discard remaining eight flywheel bolts.
4. Slide flywheel off guide pins and out of flywheel housing.
5. Remove guide pins from crankshaft timing gear.

Radial Shaft Seal

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields when doing the following procedure.

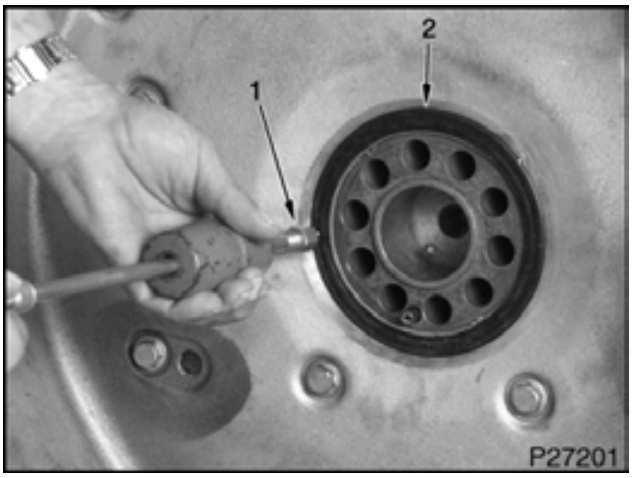

Figure 624 Radial shaft seal removal

1. Slide hammer
2. Radial shaft seal

1. With an awl and hammer, punch two holes 180° apart in radial shaft seal.
2. Thread a slide hammer (page 368) with correct size screw into one of the two holes.
3. Slide hammer until one side of seal begins to pull out of flywheel housing. Move slide hammer to other hole and repeat until radial shaft seal is completely removed.

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Lifting Eyes

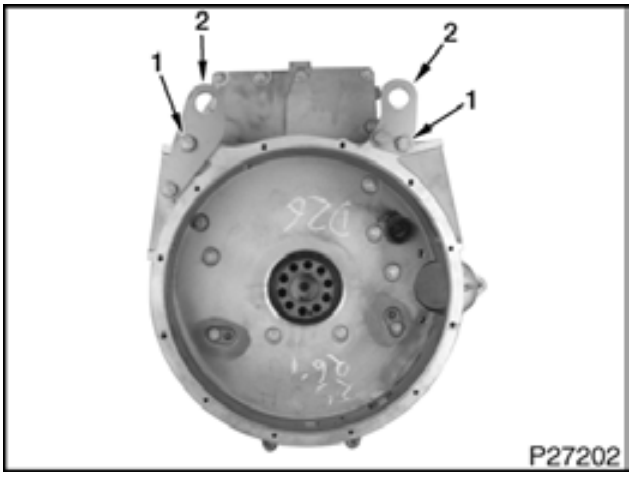

Figure 625 Lifting eye

1. M16 x 150 hex bolt (4)
2. Lifting eye (2)

1. Remove four M16 x 150 hex bolts.
2. Remove two lifting eyes.

Flywheel housing

WARNING: To prevent personal injury or death, get help when removing or installing the flywheel housing

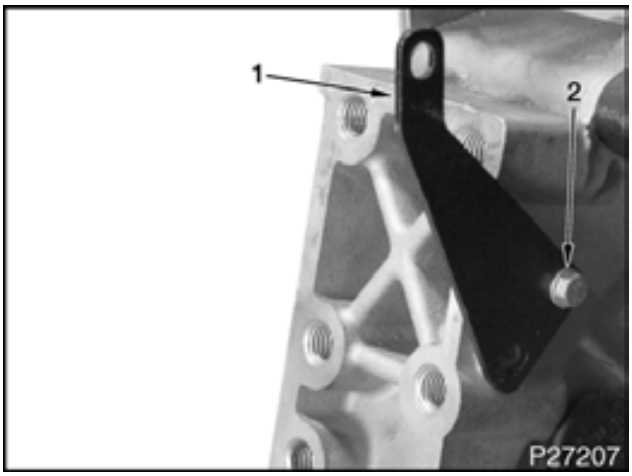

Figure 626 Bracket for turbo exhaust pipe

1. Bracket for turbo exhaust pipe
2. M8 x 16 bolt

1. Remove M8 x 16 bolt and bracket for turbo exhaust pipe from flywheel housing.

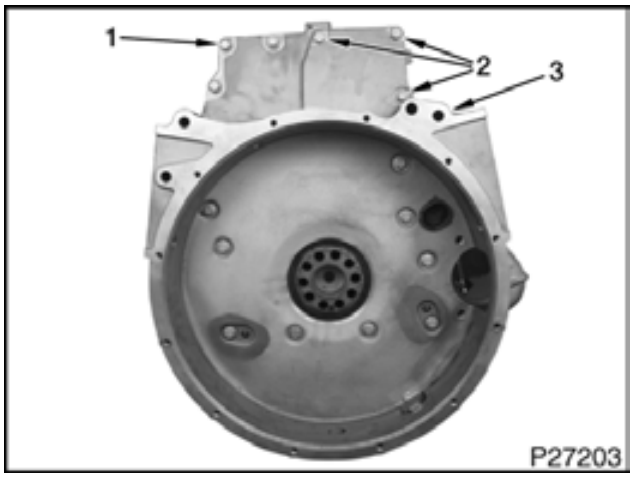

Figure 627 Flywheel housing

1. M10 x 30 hex bolt (12)
2. M10 x 40 hex bolt (3)
3. Flywheel housing

2. Remove 12 M10 x 30 and three M10 x 40 hex bolts from flywheel housing.
3. Use a thin gasket scraper to separate sealant between flywheel housing and crankcase.

WARNING: To prevent personal injury or death, get help when removing or installing the flywheel housing.

4. Remove flywheel housing with aid of an assistant.

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Cleaning

All Components

1. Clean foreign material from gasket surfaces of crankcase and flywheel housing. Use a scraper or wire brush to remove sealant from gasket surfaces.
2. Gasket surfaces must be oil-free for good adhesion of liquid gasket during assembly. Use a commercially available, non-caustic brake cleaner to clean gasket surfaces of crankcase and flywheel housing.

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

3. Wash flywheel and flywheel housing. Dry all with filtered compressed air.
4. Wash crankshaft timing gear, with a stiff brush and suitable solvent. Dry all with filtered compressed air.

Preliminary Checks

Flywheel Assembly (Manual Transmission)

1. Inspect flywheel for cracks around webbing and bolt holes.
2. Inspect flywheel for heat cracks and extensive scoring.
3. Inspect all ring gear teeth for starter pinion damage.
4. Replace flywheel if necessary.

Recondition

Flywheel

NOTE: Flywheels used with manual transmissions may be resurfaced to correct minor wear and scoring. If flywheel meets the following requirements it can be resurfaced.

WARNING: To prevent personal injury or death, do not machine flywheel beyond minimum thickness specified for flywheel resurfacing.

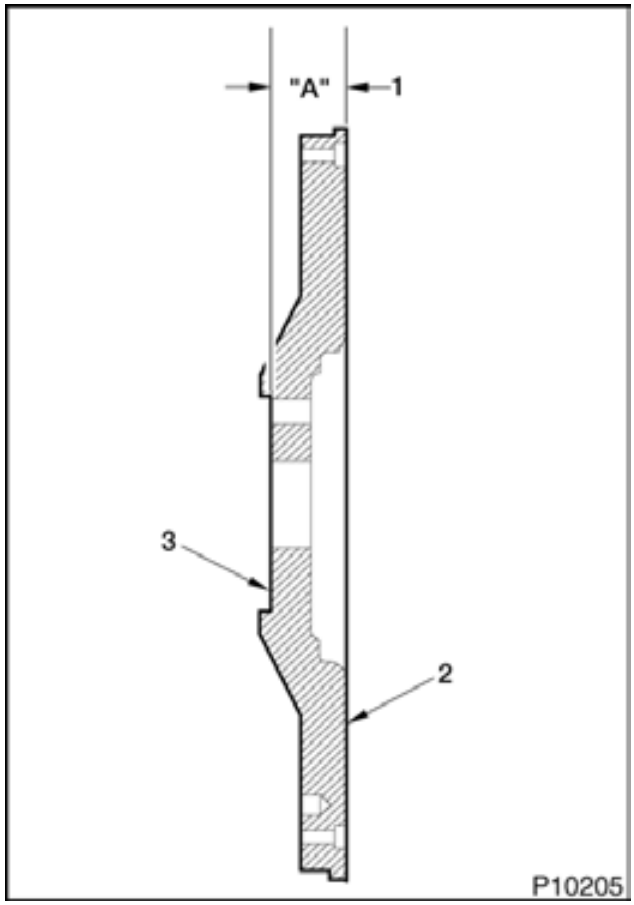

Figure 628 Flywheel surface dimension (typical)

1. Flywheel thickness (dimension “A”)
2. Clutch disc mounting face
3. Crankshaft timing gear face

NOTE: Flywheel resurfacing information is provided for guidance only. International Truck and Engine Corporation assumes no responsibility either for the results of any work performed in accordance with this information or for the ability of service personnel to detect cracks.

WARNING: To prevent personal injury or death, carefully examine flywheel for any cracks or heat checks before and after resurfacing. Cracks in the flywheel can cause it to separate. If there are any questions, do not reuse the flywheel.

1. Check flywheel for cracks and damage. Replace flywheel if required.

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2. Using 1–2 inch micrometer (page 368), measure flywheel thickness and compare to minimum required thickness specification (dimension “A”) (page 368). Discard flywheel if below minimum thickness specification or if flywheel will be below minimum thickness after resurfacing.
3. Resurface flywheel. See Flywheel Resurfacing Machine operators manual for instructions on flywheel resurfacing procedure.
4. Check flywheel for cracks and damage after resurfacing. Replace flywheel if required.
5. Measure flywheel thickness after resurfacing and compare to minimum required thickness specification. Discard flywheel if below minimum thickness specification.

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Installation

Flywheel Housing

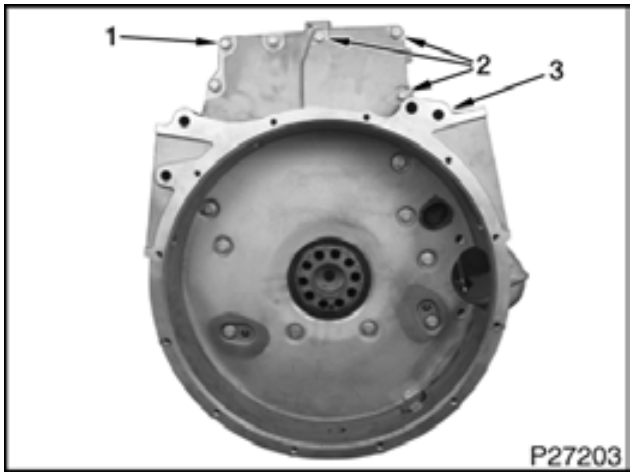

Figure 629 Flywheel housing

1. M10 x 30 hex bolt (12)
2. M10 x 40 hex bolt (3)
3. Flywheel housing

CAUTION: To prevent engine damage, apply Liquid Gasket and component within 5 minutes of application to inhibit the formation of a skin and ensure a leak proof joint.

1. Verify flywheel housing alignment dowels are installed into the crankcase and are not damaged. Replace as necessary.
2. Apply Loctite 5900 or equivalent (page 368) to joining surfaces of flywheel housing and crankcase.

WARNING: To prevent personal injury or death, get help when removing or installing the crankcase rear cover.

3. Install flywheel housing to crankcase with aid of an assistant.
4. Install 12 M10 x 30 and three M10 x 40 flywheel housing hex bolts. Tighten bolts to special torque (page 368).

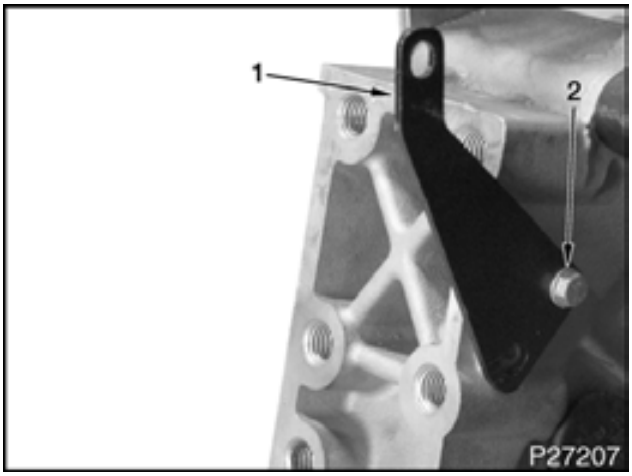

Figure 630 Bracket for turbo exhaust pipe

1. Bracket for turbo exhaust pipe
2. M8 x 16 bolt

5. Install M8 x 16 bolt and bracket for turbo exhaust pipe to flywheel housing. Tighten bolt to standard torque (page 457).

Lifting Eyes

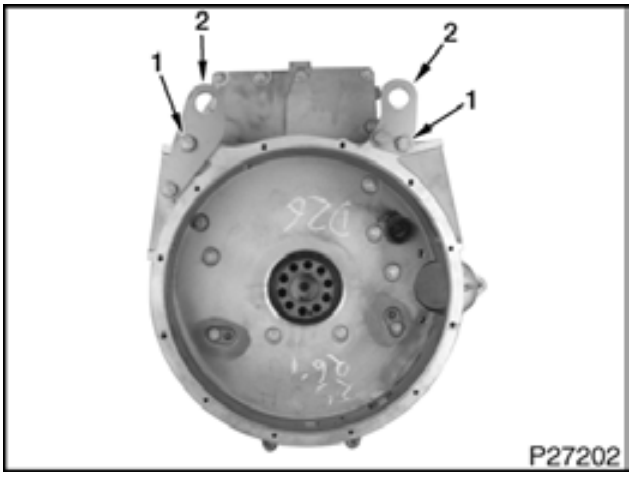

Figure 631 Lifting eyes

1. M16 x 150 hex bolt (4)
2. Lifting eye (2)

1. Install two lifting eyes.
2. Install four M16 x 150 lifting eyes hex bolts. Tighten hex bolts to special torque (page 368).

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Radial Shaft Seal

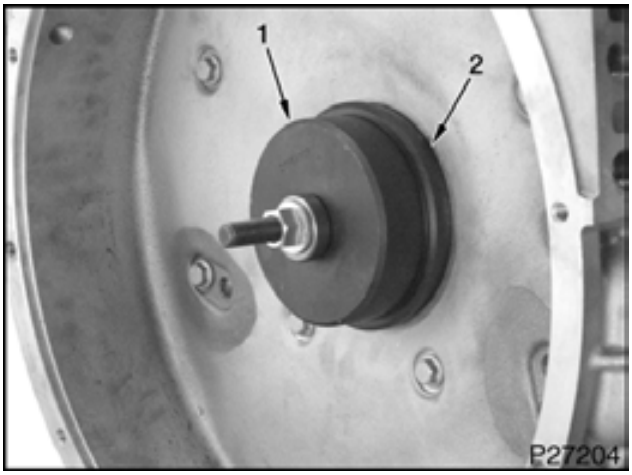

Figure 632 Radial shaft seal installation

1. Rear Oil Seal Installer
2. Radial shaft seal

CAUTION: To avoid damage to the radial shaft seal, do not touch inner seal lip, allow oil or grease on any part of the seal during installation.

1. Using Rear Oil Seal Installer (page 368), install radial shaft seal into flywheel housing.
   a. Install inner hub of tool to crankshaft flange. Use two bolts provided with tool.
   b. Install radial shaft seal to inner hub of tool.
   c. Install pressing hub and nut and tighten to install radial shaft seal. When tool bottoms out, seal is fully installed.

Flywheel Assembly (Manual Transmission)

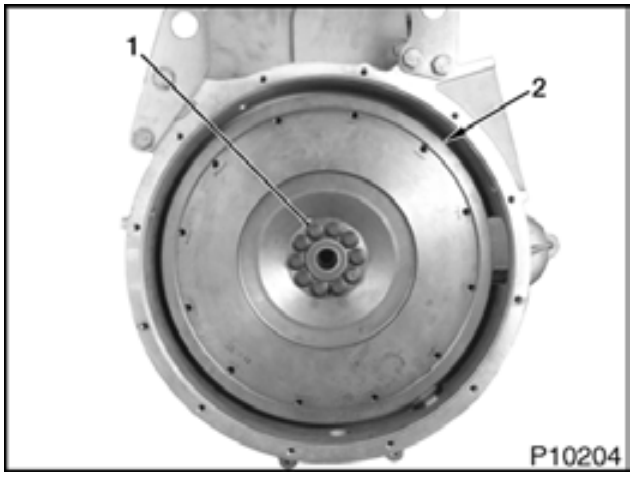

Figure 633 Flywheel installation

1. 12KT flywheel bolt (10)
2. Flywheel

WARNING: To prevent personal injury or death, inspect flywheel for cracks or heat checks after resurfacing. Do not install flywheel if damaged or questionable. Flywheel resurfacing information is provided for guidance only. INTERNATIONAL does not assume responsibility for work done by service personnel.

1. Install two guide pins (made locally) into crankshaft flange at approximately 3 o'clock and 9 o'clock position.
2. Align crankshaft timing gear pin hole in flywheel assembly with crankshaft timing gear pin and slide flywheel onto guide pins.

CAUTION: To prevent engine damage, always install new flywheel mounting bolts.

CAUTION: To prevent engine damage, do not use anti-seize compounds or grease on new flywheel or flexplate mounting bolts.

3. Loosely install eight new 12KT flywheel bolts to secure flywheel assembly to crankshaft flange.
4. Remove both guide pins and loosely install two remaining new 12KT flywheel bolts.

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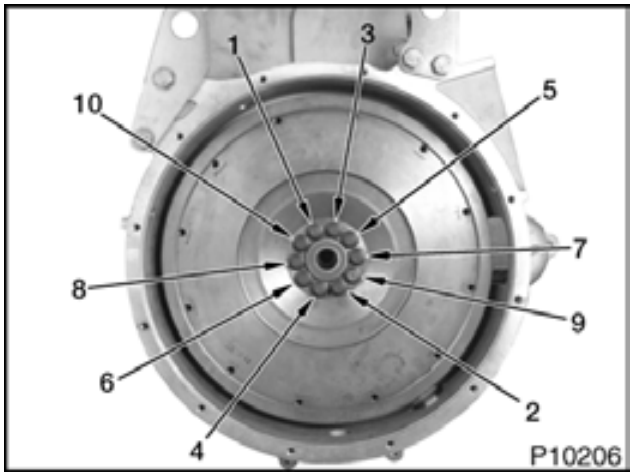

Figure 634 Flywheel tightening sequence

NOTE: For proper flywheel installation, follow the correct tightening sequence while keeping the crankshaft from turning.

5. Tighten 12KT flywheel bolts using sequence indicated above as follows:
   a. Tighten 12KT flywheel bolts to 110 N·m (81 lbf·ft).
   b. Turn 12KT flywheel bolts 90°.
   c. Turn 12KT flywheel bolts an additional 90°.

Pilot Bearing (Flywheel)

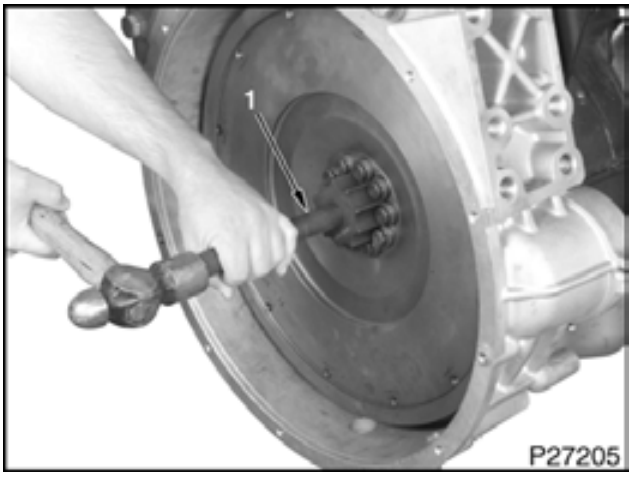

Figure 635 Pilot bearing installation

1. Pilot bearing
2. Dial caliper

1. Place pilot bearing in flywheel bore.
2. Using Pilot Bearing Installation Tool (page 368), install pilot bearing into flywheel. When tool bottoms out, pilot bearing is fully installed.

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Specifications

Table 30 Flywheel and Flywheel Housing

Flywheel minimum thickness (dimension “A”)	46 mm (1.811 in)
Flywheel maximum surface runout	0.20 mm (0.0079 in)

Special Torque

Table 31 Flywheel and Flywheel Housing

12KT flywheel bolts	See tightening steps in procedure.
Flywheel housing hex bolts	75 N·m (55 lbf·ft)
Lifting eye hex bolts	180 N·m (133 lbf·ft)

Special Service Tools

Table 32 Flywheel and Flywheel Housing

Description	Tool Number
1–2 Inch Micrometer	Obtain locally
Blind Hole Puller	Obtain locally
Pilot Bearing Installation Tool	ZTSE4898
Brake Cleaner (non-caustic)	Obtain locally
Dial Indicator with Magnetic Base	Obtain locally
Loctite 5900 or Equivalent	Obtain locally
Rear Oil Seal Installer	ZTSE4875
Slide Hammer	Obtain locally

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Exploded Views

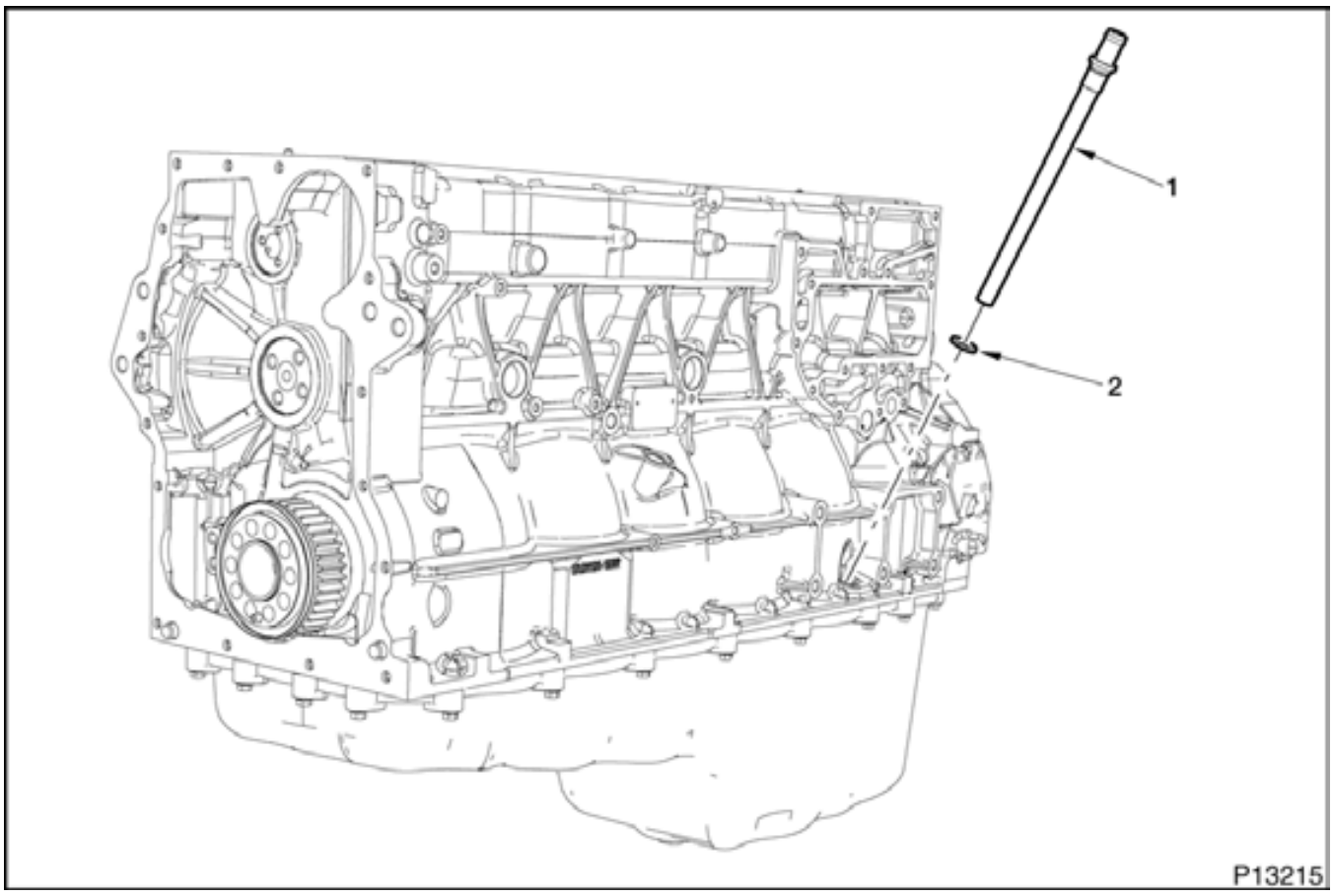

Figure 636 Oil return pipe (front sump)

1. Oil return pipe
2. Copper washer

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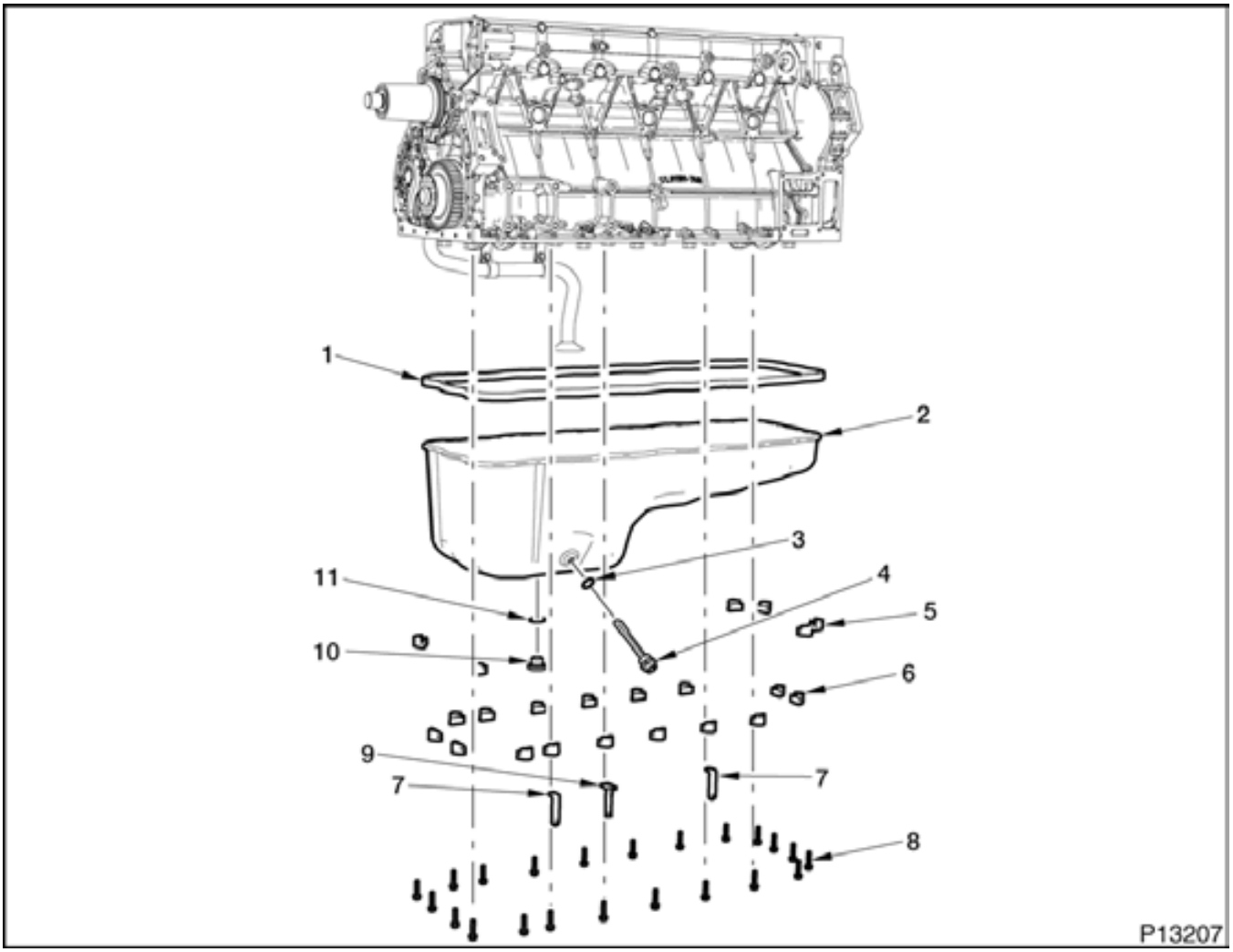

Figure 637 Oil sump (front sump shown, rear sump similar)

1. Oil sump gasket
2. Oil sump (front sump)
3. Preheater gasket (optional equipment)
4. Preheater (optional equipment)
5. Oil sump retainer (concave groove) (6)
6. Oil sump retainer (convex groove) (16)
7. Bracket (2) (right angle bracket)
8. M8 x 40 hex bolt (22)
9. Bracket (T-bracket)
10. M27 x 2 drain plug
11. Drain plug gasket

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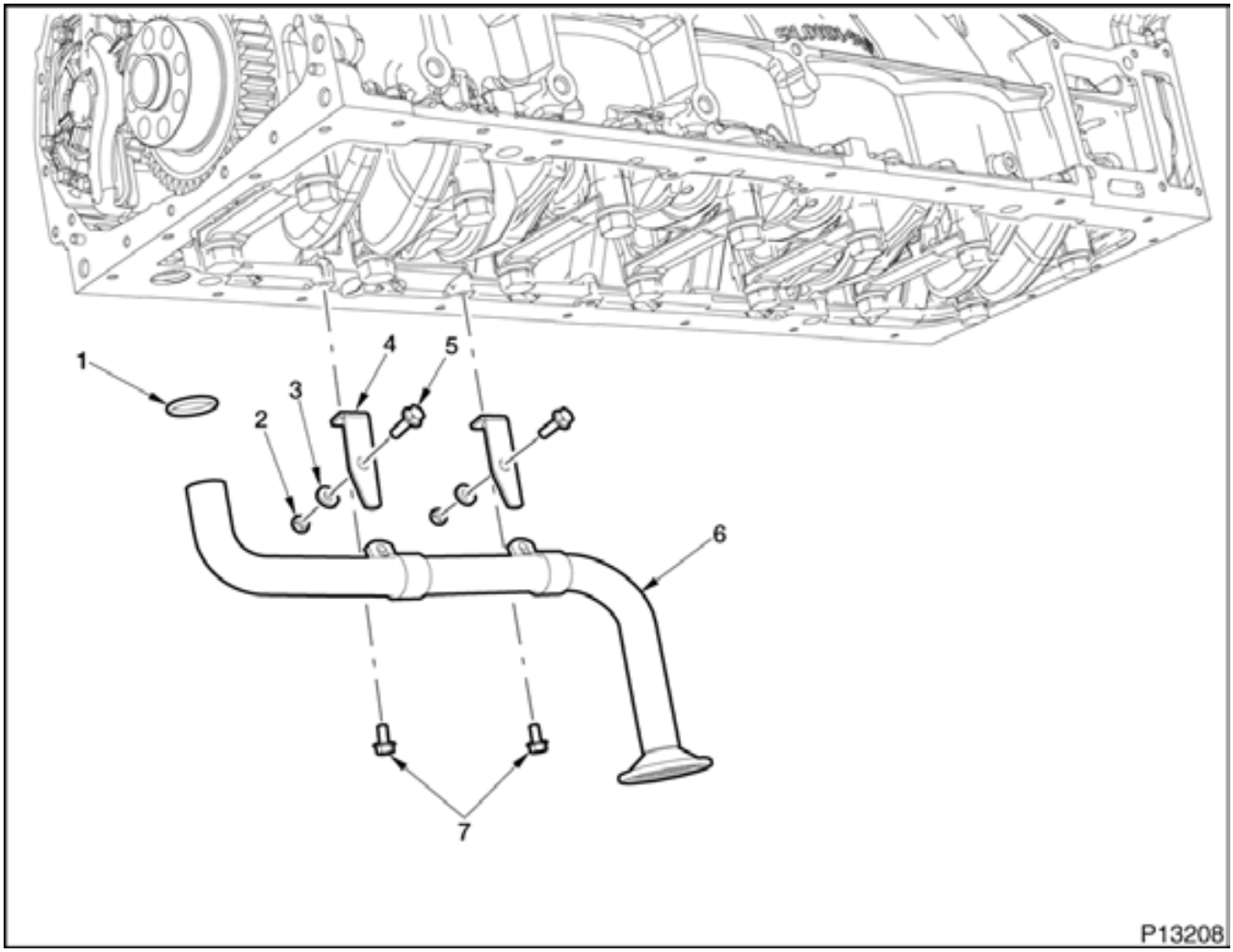

Figure 638 Oil suction line — Front sump

1. O-ring
2. BM8-8 hexagon nut (2)
3. D9/19/4 washer (2)
4. Oil suction line bracket (2)
5. M8 x 25 hex bolt (2)
6. Oil suction line
7. M8 x 16 hex bolt (2)

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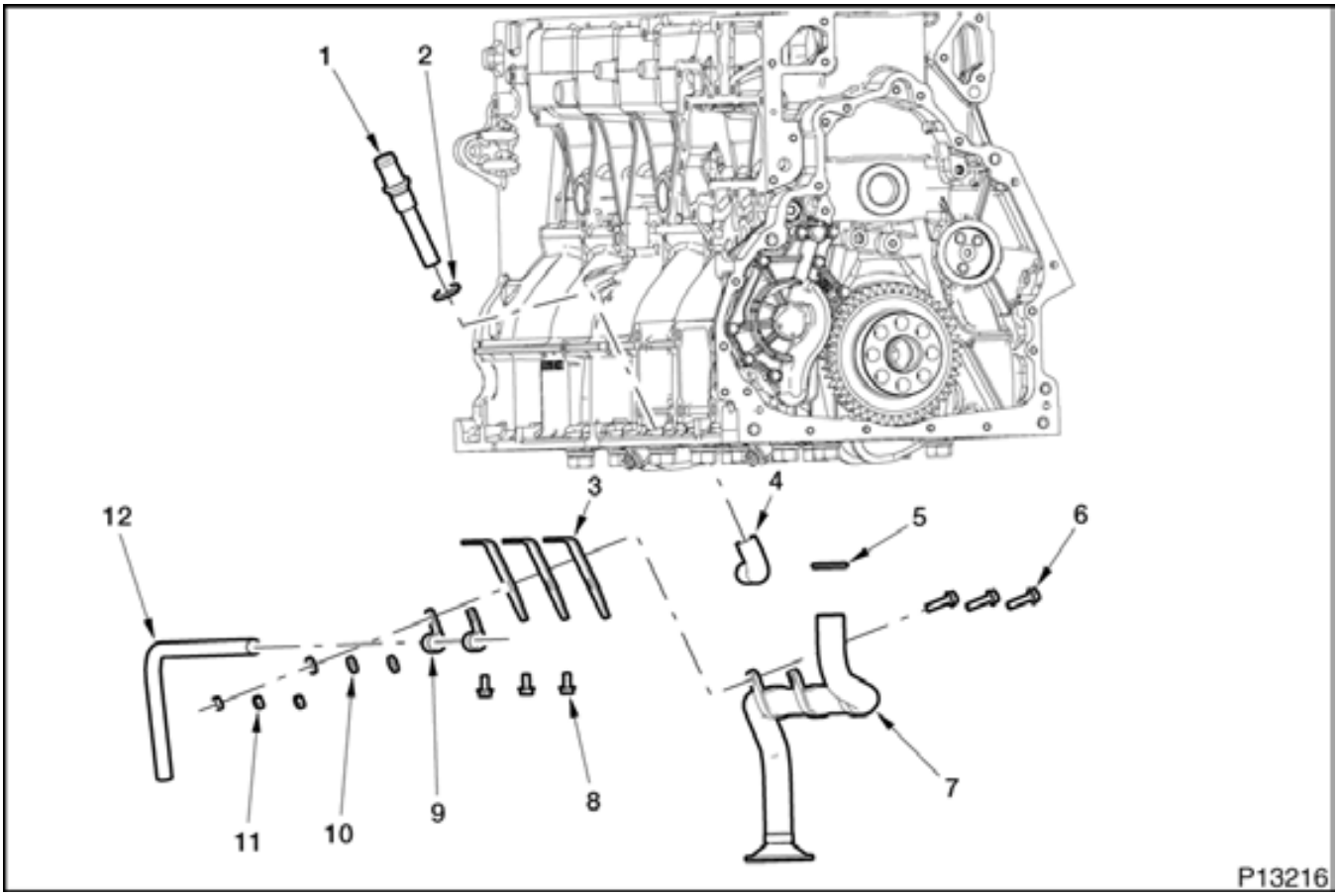

Figure 639 Oil suction line — Rear sump

1. Oil return pipe (Rear sump)
2. Copper washer
3. Oil suction line bracket (3)
4. Rubber elbow
5. O-ring
6. M8 x 25 hex bolt (3)
7. Oil suction line
8. M8 x 16 hex bolt (3)
9. Clamp (2)
10. D9/19/4 washer (3)
11. BM8-8 hexagon nut (3)
12. Oil return line

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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 the transmission to park or neutral, set the parking brake, and block the wheels before doing diagnostic or service procedures.

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

WARNING: To prevent personal injury or death, remove the ground cable from the negative terminal of the main battery before disconnecting or connecting electrical components. Always connect the ground cable last.

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: Refer to the following service sections for information on removal of components prior to this section.

- Engine Electrical — required for preheater removal.

Oil Sump

WARNING: To prevent personal injury or death, dispose of oil or discard components, according to applicable regulations.

1. On front sump engines, remove oil return pipe and discard copper washer.
2. Remove M27 x 2 drain plug and gasket and drain oil into a suitable container.
3. If equipped, remove preheater. On vehicles not equipped with preheater, remove drain plug and gasket.
4. Remove and discard preheater gasket.

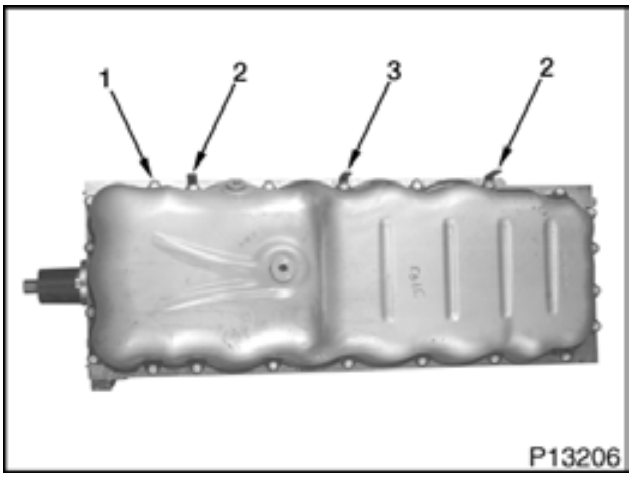

Figure 640 Oil sump (front sump)

1. M8 x 40 hex bolt (22)
2. Bracket (right angle) (2)
3. Bracket (T-bracket)

NOTE: Record style and location of brackets for correct placement during installation.

5. Remove 22 M8 x 40 hex bolts and three brackets.

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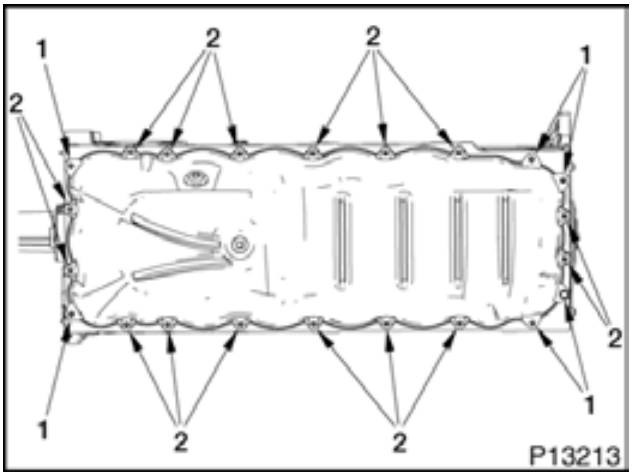

Figure 641 Oil sump retainers

1. Oil sump retainer (concave groove) (6)
2. Oil sump retainer (convex groove) (16)

6. Remove six oil sump retainers (concave groove).
7. Remove 16 oil sump retainers (convex groove).
8. Remove oil sump and oil sump gasket as an assembly.
9. Clean and inspect the oil sump gasket. Discard oil sump gasket if damaged.

Oil Suction Line — Front Sump

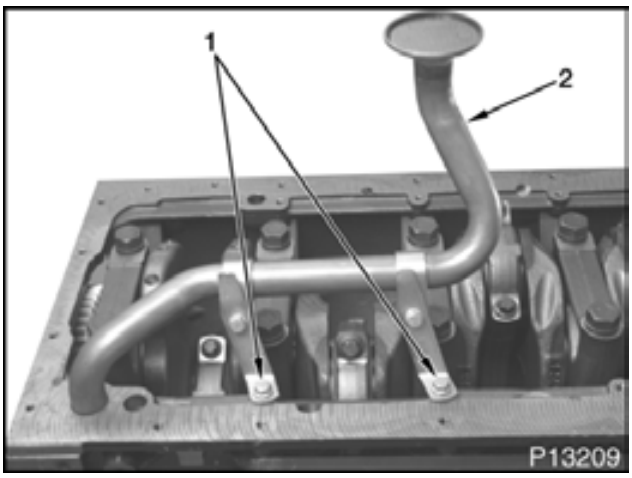

Figure 642 Oil suction line

1. M8 x 16 hex bolt (2)
2. Oil suction line

1. Remove two M8 x 16 hex bolts and oil suction line.
2. If required, remove the two M8 x 25 hex bolts, BM8–8 hexagon nuts, D9/19/4 washers and oil suction line brackets.

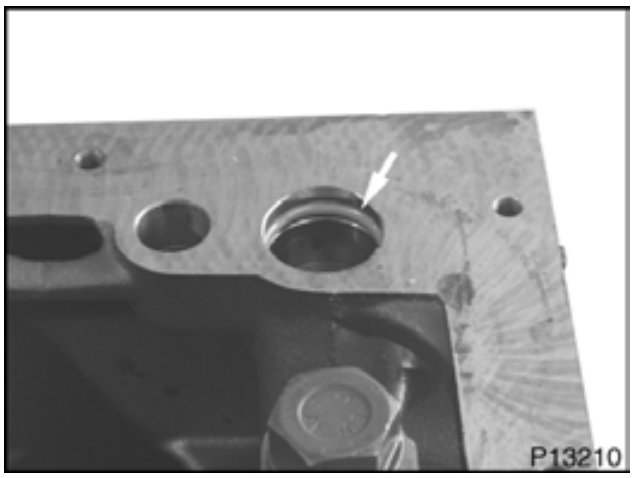

Figure 643 Oil suction line O-ring

3. Remove and discard oil suction line O-ring.

Oil Suction Line — Rear Sump

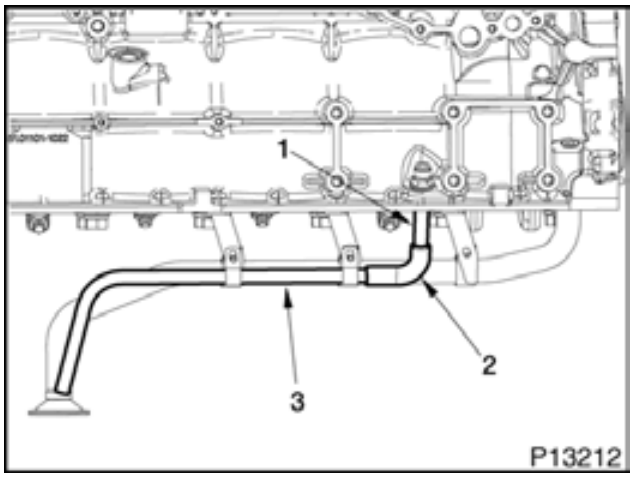

Figure 644 Oil return pipe

1. Oil return pipe
2. Rubber elbow
3. Oil return line

1. Remove three M8 x 16 hex bolts holding oil suction line brackets to crankcase.

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2. Disconnect rubber elbow from oil return pipe.
3. Remove oil suction line and oil return line as an assembly.
4. If required, remove three M8 x 25 hex bolts, BM8–8 hexagon nuts and D9/19/4 washers and remove oil return line, clamps and rubber elbow.
5. Unscrew the oil return pipe and discard copper washer.

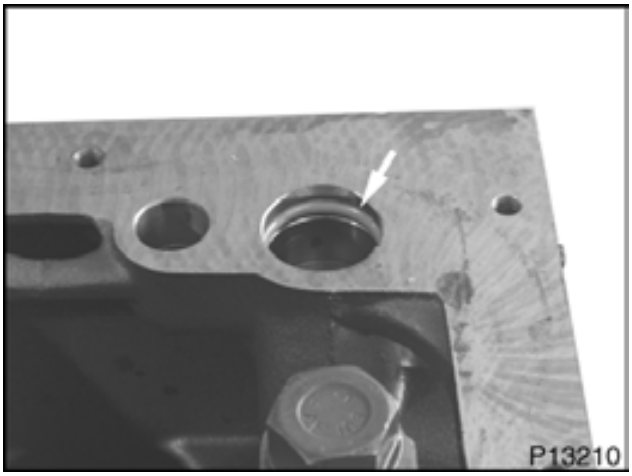

Figure 645 Oil suction line O-ring

6. Remove and discard oil suction line O-ring.

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Cleaning and Inspection

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

Oil Sump

1. Inspect bottom of oil sump for metallic debris or other evidence of engine damage. Investigate any abnormalities as required.
2. Clean oil sump with a suitable solvent.
3. Dry with filtered compressed air.
4. Look for warping, dents, and cracking. Replace the oil sump if necessary.

Oil Suction Line

1. Clean oil suction line and bracket with a suitable solvent.
2. Dry with filtered compressed air.
3. Inspect oil suction line and bracket for cracking. Replace if necessary.

Oil Return Line

1. Clean oil return line and clamps in suitable solvent.
2. Dry with filtered compressed air.
3. Inspect oil return line and clamps for cracking. Replace if necessary.

Oil Return Pipe

1. Clean oil return pipe in suitable solvent.
2. Clean mating crankcase threads of oil residue.

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Installation

Oil Suction Line — Front sump

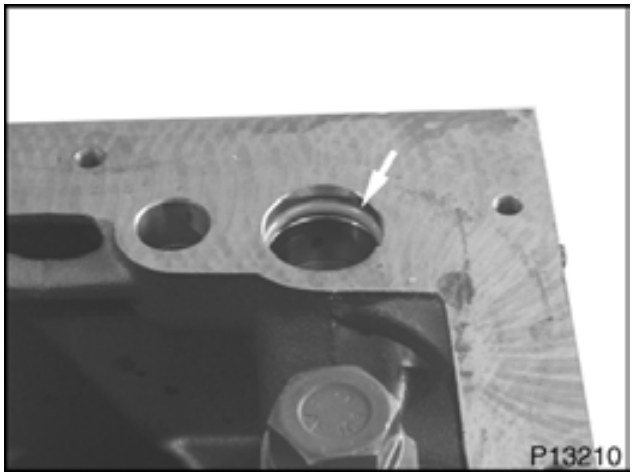

Figure 646 Oil suction line o-ring

1. Install a new oil suction line O-ring. Lubricate O-ring with clean engine oil.
2. If required, position two oil suction line brackets and loosely install two M8 x 25 hex bolts, BM8–8 hexagon nuts, D9/19/4 washers.

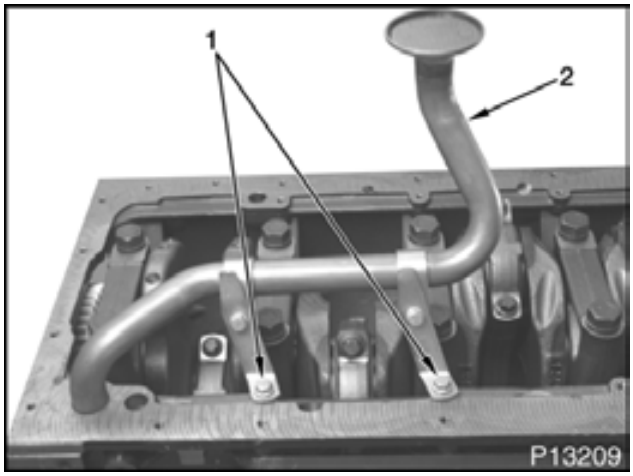

Figure 647 Oil suction line

1. M8 x 16 hex bolt (2)
2. Oil suction line

3. Install oil suction line and two M8 x 16 hex bolts.
4. Tighten two M8 x 16 hex bolts to standard torque (page 457).
5. Tighten two BM8–8 hexagon nuts to standard torque (page 457).

Oil Suction Line — Rear Sump

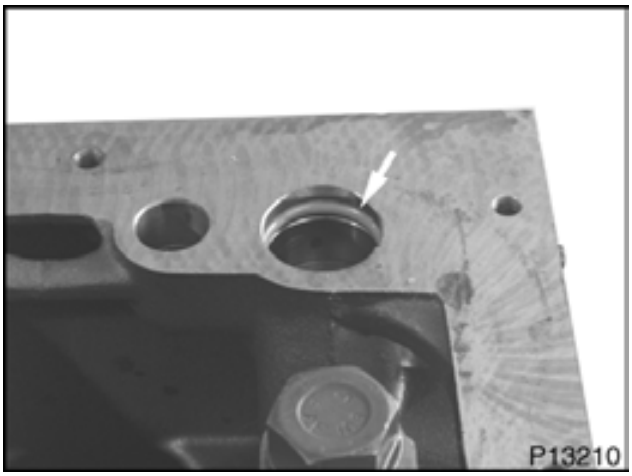

Figure 648 Oil suction line O-ring

1. Install a new oil suction line O-ring. Lubricate O-ring with clean engine oil.

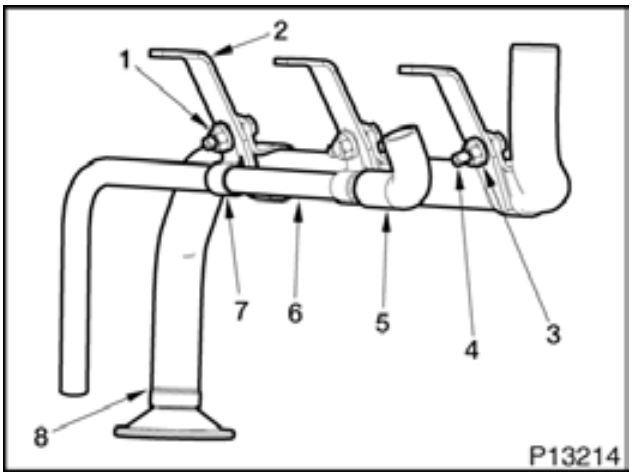

Figure 649 Rear sump oil line assembly

1. BM8-8 hexagon nut (3)
2. Oil suction line bracket (3)
3. D9/19/4 washer (3)
4. M8 x 25 hex bolt (3)
5. Rubber elbow
6. Oil return line
7. Clamp (2)
8. Oil suction line

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2. Apply Loctite® 242 (page 382) or equivalent to oil return pipe threads.
3. Install a new copper washer and screw in the oil return pipe. Tighten oil return pipe to special torque (page 382).
4. If required, position oil return line, rubber elbow, clamps and brackets as an assembly onto oil suction line.
5. If removed, loosely install three M8 x 25 hex bolts, D9/19/4 washers and BM8–8 hexagon nuts.
6. Install oil suction line and oil return line as an assembly.

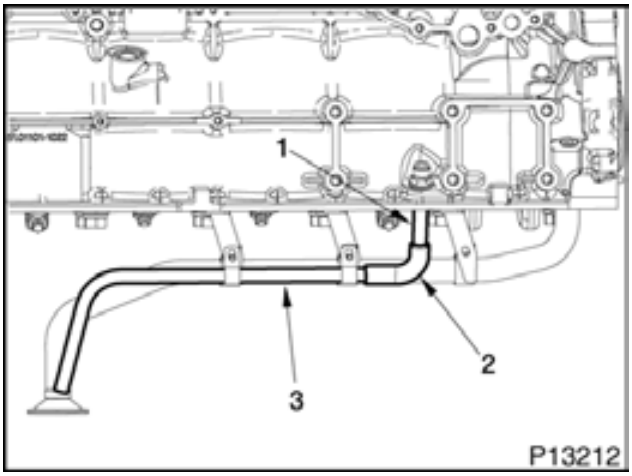

Figure 650 Oil return pipe

1. Oil return pipe
2. Rubber elbow
3. Oil return line

7. Connect rubber elbow to oil return pipe.
8. Install three M8 x 16 hex bolts through oil suction line brackets.
9. Tighten three M8 x 16 hex bolts to standard torque (page 457).
10. Tighten three M8 x 25 bolts to standard torque (page 457).

Oil Sump

1. Install oil sump gasket on oil sump.
2. Position oil sump and oil sump gasket as an assembly on crankcase.

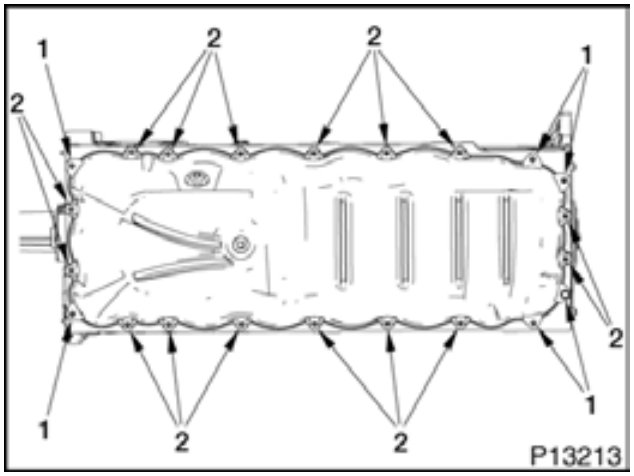

Figure 651 Oil sump retainers

1. Oil sump retainer (concave groove) (6)
2. Oil sump retainer (convex groove) (16)

3. Install an oil sump retainer (concave groove) and a 22 M8 x 40 hex bolt in each corner or the oil sump. Finger tighten each bolt

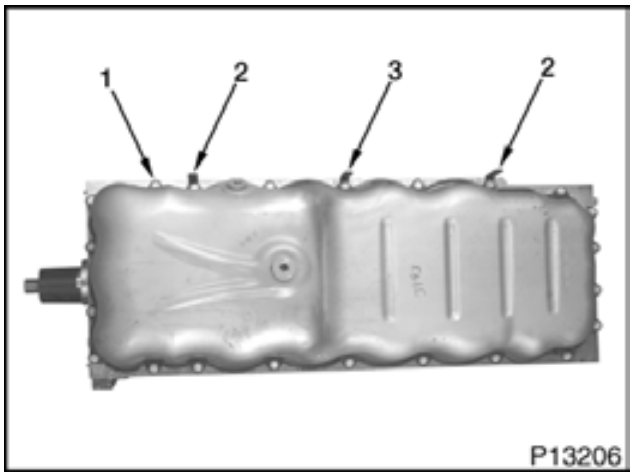

Figure 652 Oil sump (front sump)

1. M8 x 40 hex bolt (22)
2. Bracket (right angle bracket) (2)
3. Bracket (T-bracket)

4. Position three brackets on oil sump retainers in original locations.
5. Install the remaining retainers and M8 x 40 hex bolts. Finger tighten each bolt

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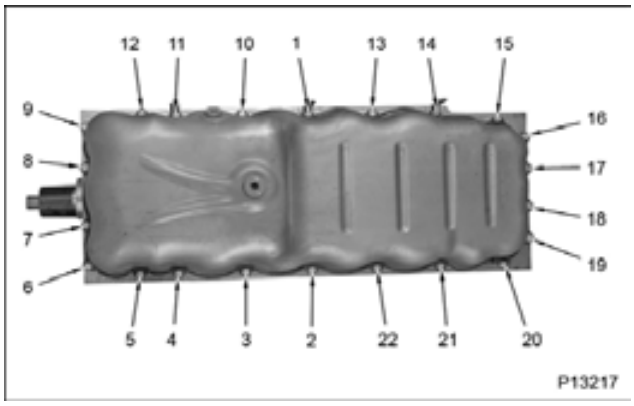

Figure 653 Torque sequence

6. Follow the torque sequence and tighten 22 M8 x 40 hex bolts to special torque (page 382).
7. Re-torque 22 M8 x 40 hex bolts to special torque (page 382).
8. If equipped with preheater, inspect the preheater O-ring to determine reuseability. If it is free of defects, it can be reused. If defective, a new O-ring is required.
9. If equipped with preheater, lubricate the preheater O-ring, then install preheater and lubricated O-ring into the oil pan. Tighten to special torque (page 382).

   On vehicles not equipped with preheater, install drain plug with a lubricated and inspected drain plug O-ring. Tighten to special torque (page 382).
10. Inspect the oil pan drain plug O-ring. If it is free of defects, it can be reused. If defective, new O-ring is required.
11. Lubricate the oil pan drain plug O-ring with clean engine oil and put O-ring on the M27 x 2 drain plug.
12. Install M27 x 2 drain plug and tighten to special torque (page 382).
13. On front sump engines, apply Loctite® 242 (page 382) or equivalent to oil return pipe threads.
14. Install a new copper washer and screw in the oil return pipe. Tighten oil return pipe to special torque (page 382).

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Special Torque

Table 33 Oil Sump Components

Drain plug	75 N·m (55 lbf·ft)
Oil return pipe	4 N·m (35 lbf·in)
Oil sump bolts	35 N·m (26 lbf·ft)
Preheater or replacement drain plug	75 N·m (55 lbf·ft)

Special Service Tools

Table 34 Oil Sump System

Description	Tool Number
Loctite ® 242	Obtain locally

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Exploded Views

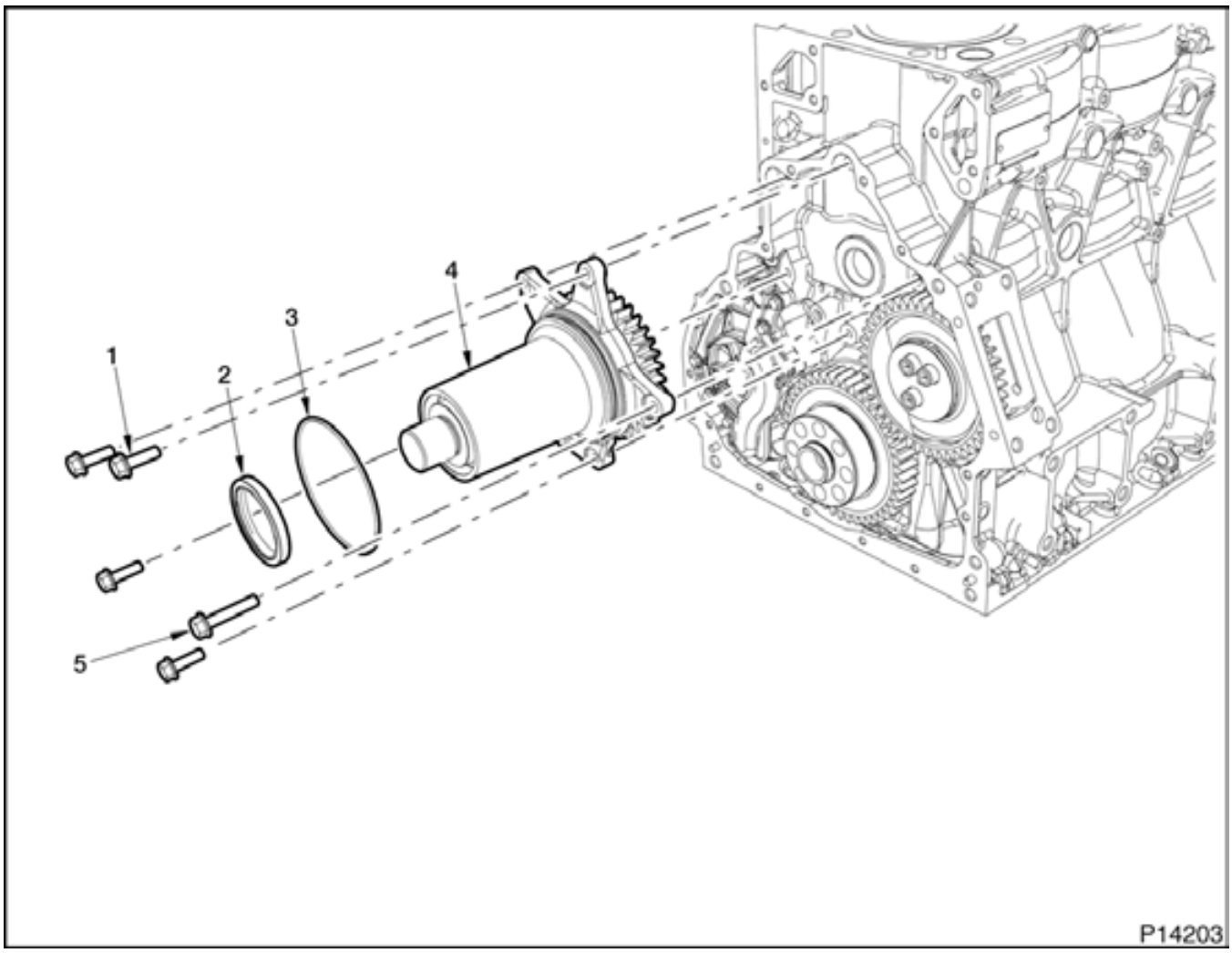

Figure 654 Fan drive

1. M8 x 25 hex bolts (4)
2. Radial shaft seal
3. O-ring
4. Fan drive
5. M8 x 40 hex bolt

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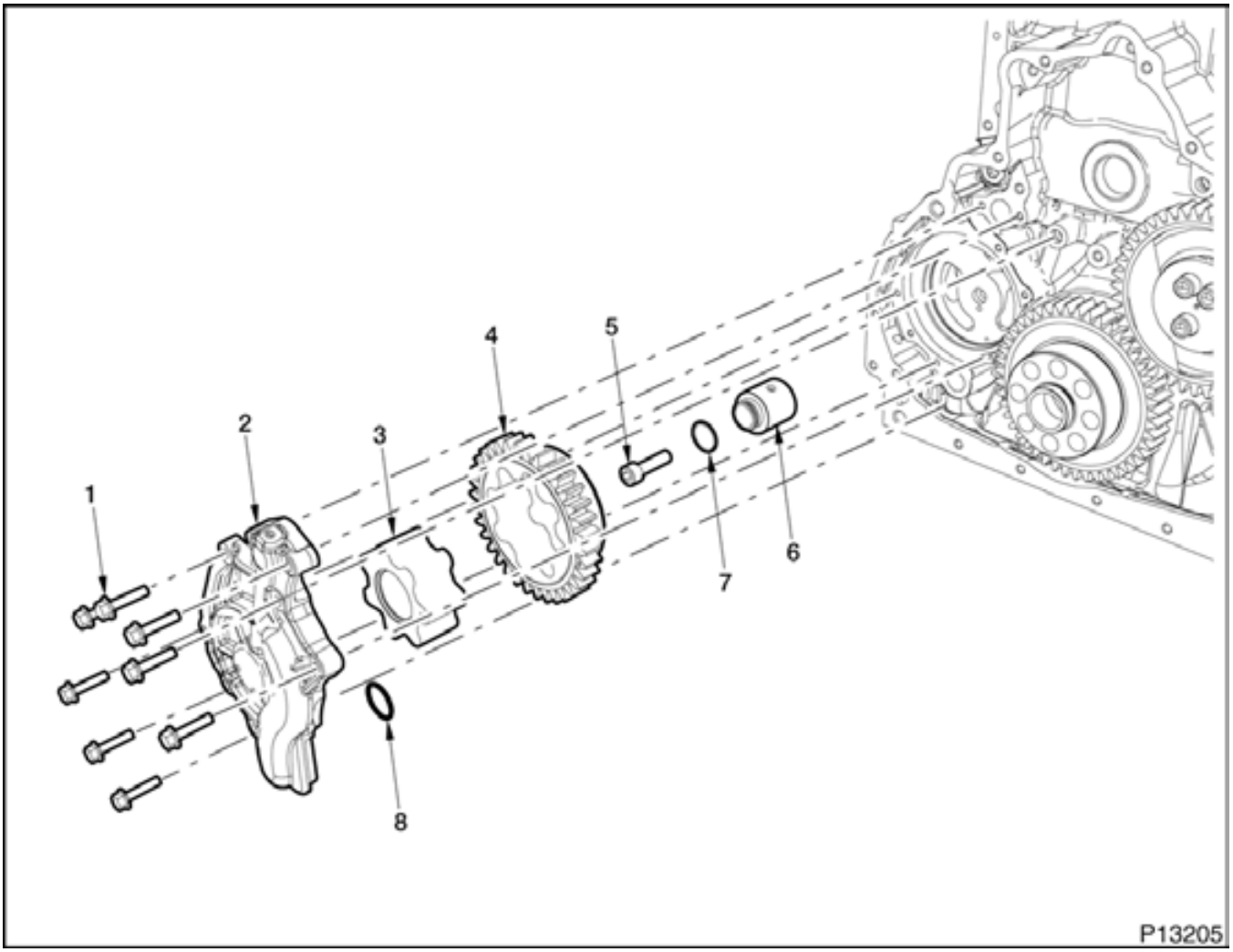

Figure 655 Oil pump

1. M6 x 25 hex bolts (8)
2. Oil pump cover
3. Oil pump pinion
4. Oil pump ring gear
5. M10 x 35 cylinder screw
6. Axle
7. O-ring
8. O-ring

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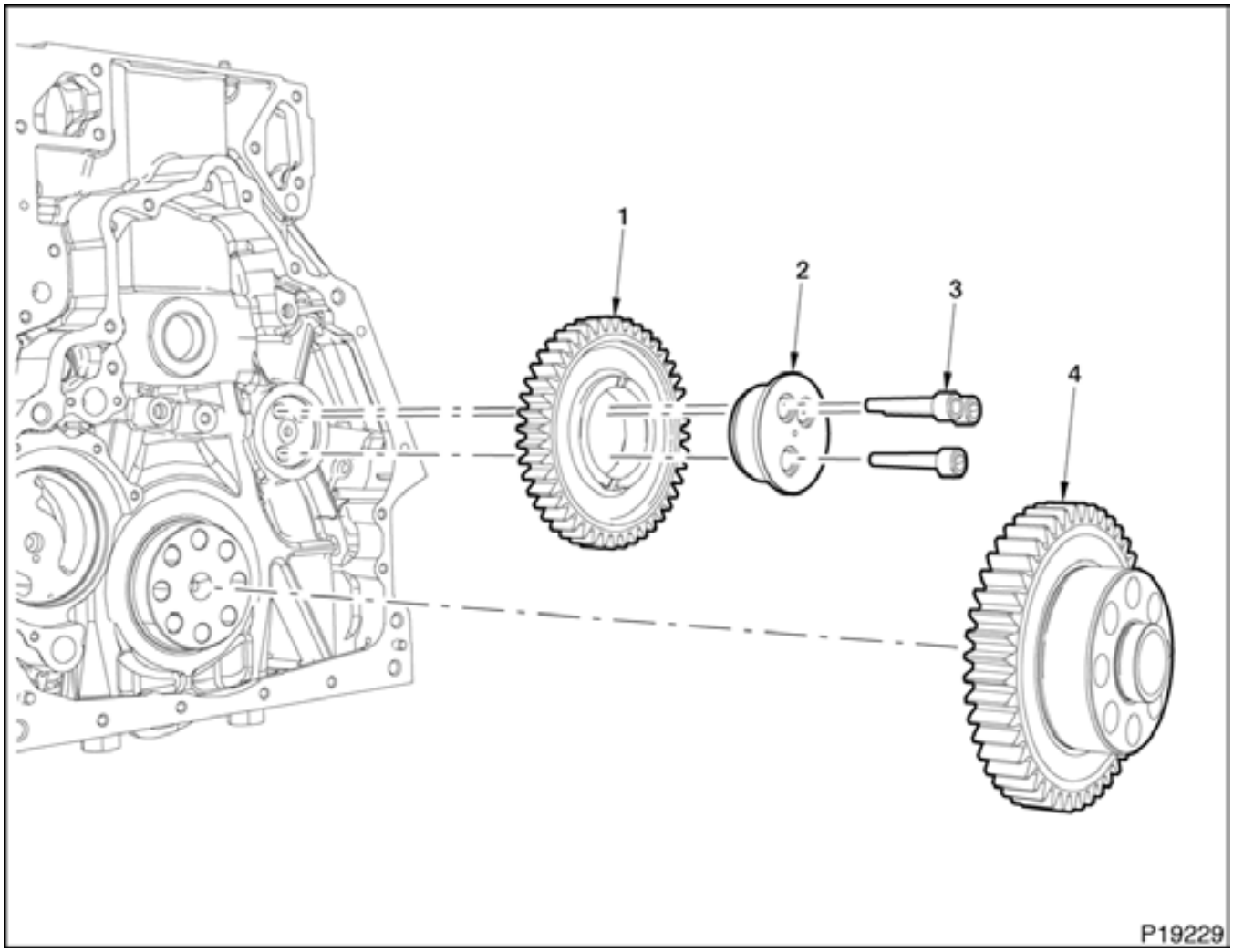

Figure 656 Front timing gears

1. Front intermediate gear
2. Front gear stud
3. M12 x 50 cylinder screws (3)
4. Crankshaft timing gear

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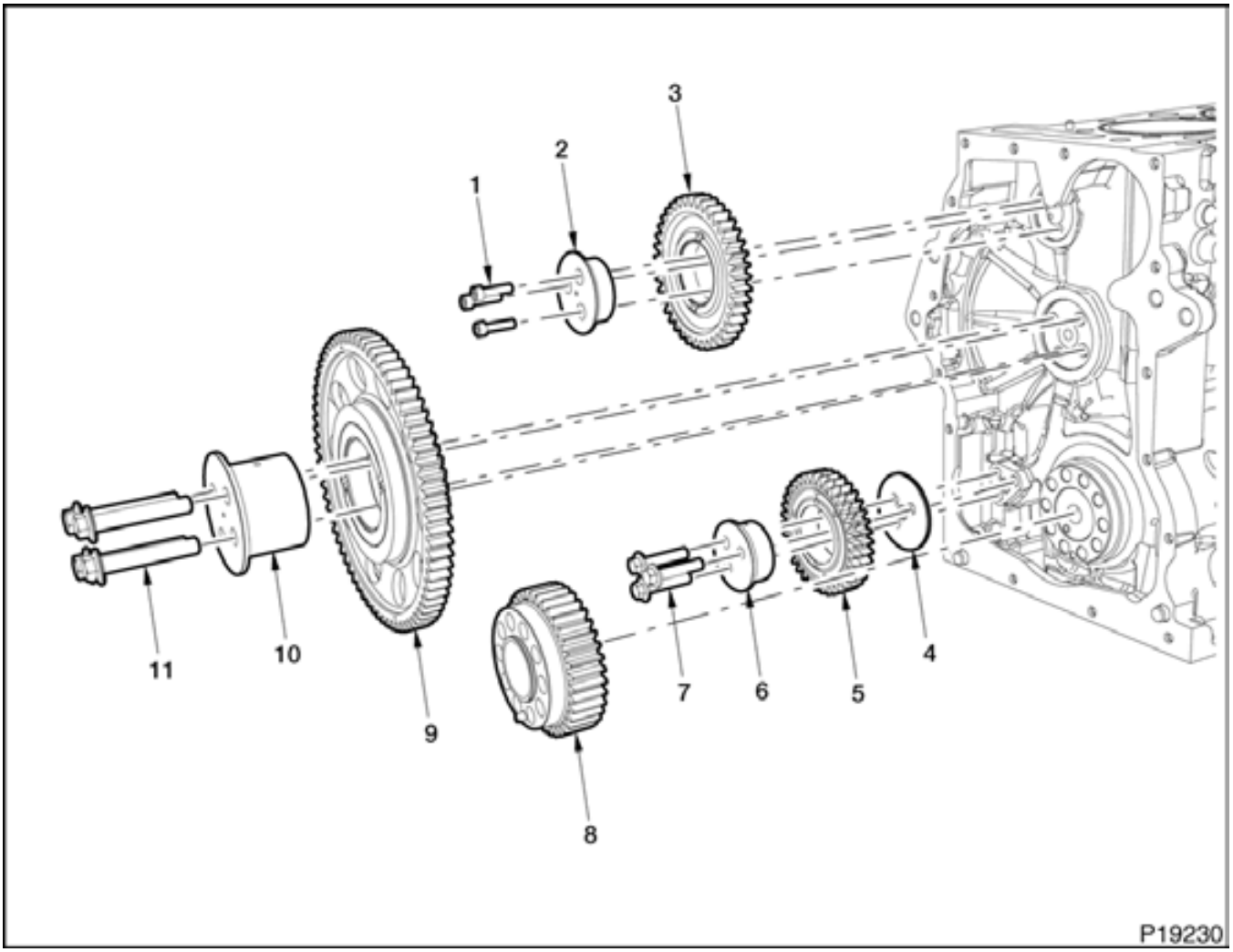

Figure 657 Rear timing gears

1. M8 x 30 cylinder screws (3)
2. Small gear stud
3. Crankcase intermediate gear
4. Air compressor thrust washer
5. Air compressor intermediate gear
6. Air compressor gear stud
7. M12 x 55 hex bolts (3)
8. Crankshaft timing gear
9. Big intermediate gear
10. Big gear stud
11. M14 x 80 hex bolts (4)

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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 the transmission to park or neutral, set the parking brake, and block the wheels before doing diagnostic or service procedures.

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

WARNING: To prevent personal injury or death, remove the ground cable from the negative terminal of the main battery before disconnecting or connecting electrical components. Always connect the ground cable last.

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: Refer to the following service sections for information on removal of components prior to this section.

- Front Cover, High Mount Fan Drive, Cooling System, and Related Components
- Cylinder Head, Camshaft and Valve Train
- Flywheel and Flywheel Housing

Preliminary Checks

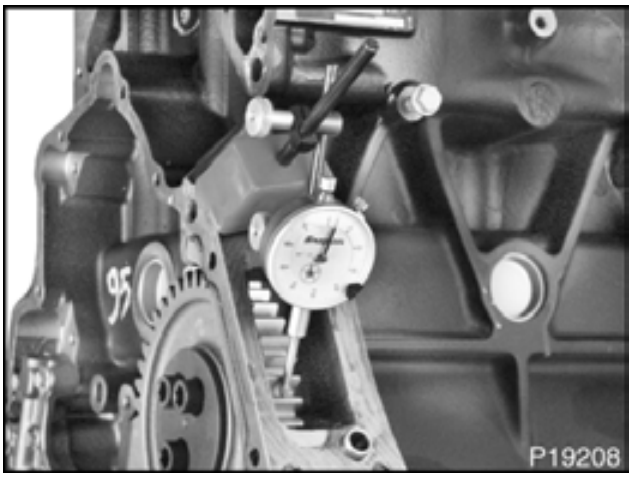

Figure 658 Front intermediate gear backlash measurement

1. Rotate engine and look for any damaged gear teeth. Replace damaged gears as necessary.
2. Place dial indicator with magnetic base (page 400) on front of crankcase with indicator tip on front intermediate gear.
3. Turn front intermediate gear clockwise and zero dial indicator.
4. Turn front intermediate gear back and forth while reading dial indicator. Compare dial indicator reading with specifications (page 400).
5. If backlash exceeds specified limits, replace front intermediate gear.

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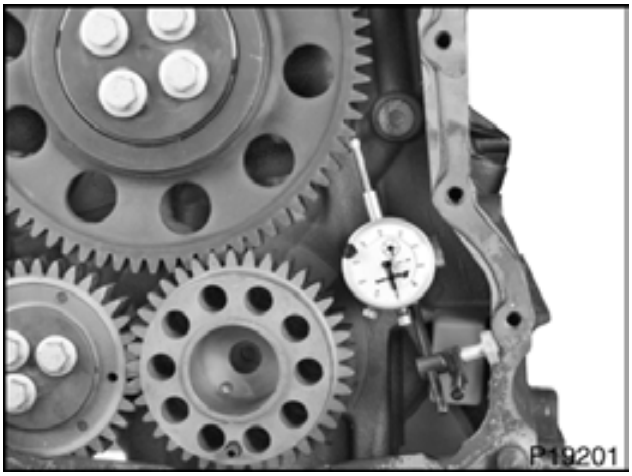

Figure 659 Big intermediate gear backlash measurement

6. Place dial indicator with magnetic base (page 400) on rear of crankcase with indicator tip on big intermediate gear.
7. Turn big intermediate gear clockwise and zero dial indicator.
8. Turn big intermediate gear back and forth while reading dial indicator. Compare dial indicator reading with specifications (page 400).
9. If backlash exceeds specified limits, replace big intermediate gear.

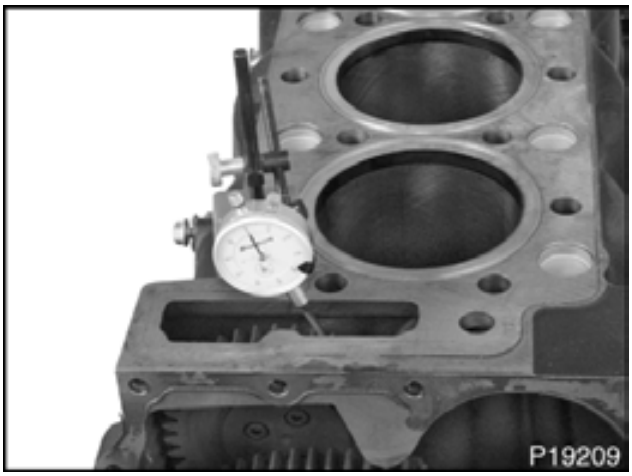

Figure 660 Crankcase intermediate gear backlash measurement

10. Place dial indicator with magnetic base (page 400) on top rear of crankcase with indicator tip on crankcase intermediate gear.
11. Turn crankcase intermediate gear clockwise and zero dial indicator.
12. Turn crankcase intermediate gear back and forth while reading dial indicator. Compare dial indicator reading with specifications (page 400).
13. If backlash exceeds specified limits, replace crankcase intermediate gear.

Radial Shaft Seal

WARNING: To prevent personal injury or death, wear safety glasses with side shields when doing the following procedure.

1. With an awl and hammer, punch two holes 180° apart in radial shaft seal.

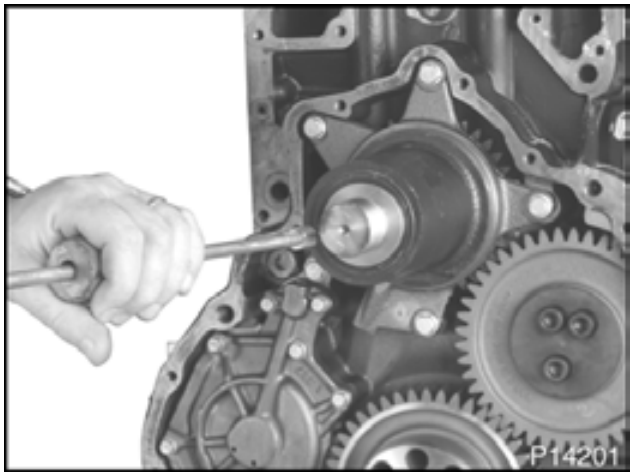

Figure 661 Radial shaft seal removal

2. Thread a slide hammer (page 400) with correct size screw in one of the two holes.
3. Slide hammer until one side of seal begins to pull out of fan drive. Move slide hammer to other hole and repeat until radial shaft seal is removed. Discard radial shaft seal.

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Fan Drive

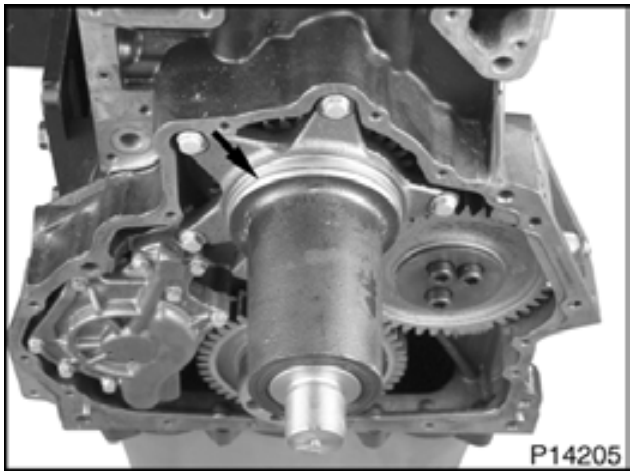

Figure 662 O-ring

1. Remove and discard O-ring.

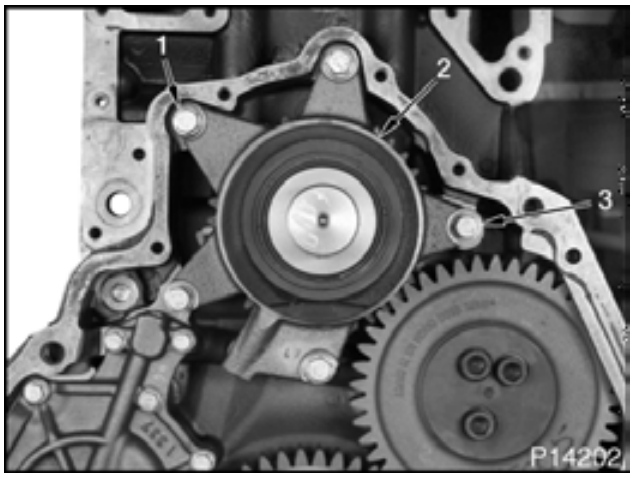

Figure 663 Fan drive

1. M8 x 25 hex bolts (4)
2. Fan drive
3. M8 x 40 hex bolt

2. Remove four M8 x 25 hex bolts, one M8 x 40 hex bolt and fan drive.

Oil Pump

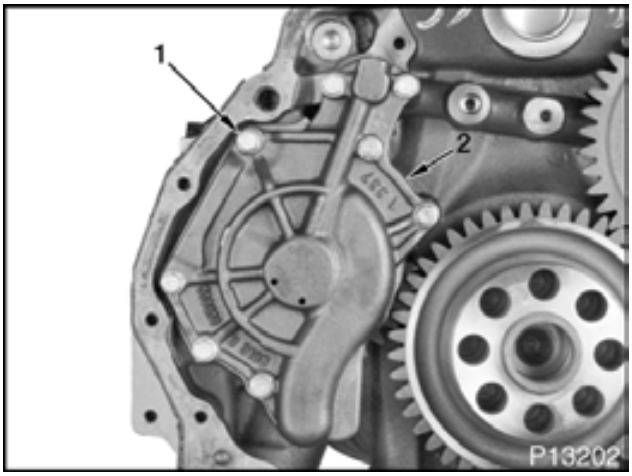

Figure 664 Oil pump cover

1. M6 x 25 hex bolts (8)
2. Oil pump cover

1. Remove eight M6 x 25 hex bolts.
2. Remove oil pump cover.
3. Remove and discard O-ring.

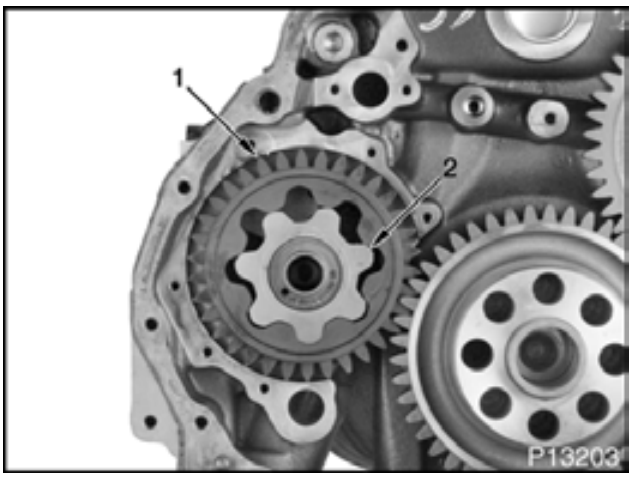

Figure 665 Oil pump pinion and oil pump ring gear

1. Oil pump ring gear
2. Oil pump pinion

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

4. Use a permanent marker to mark the front of oil pump pinion and oil pump ring gear for correct assembly orientation.
5. Remove oil pump pinion and oil pump ring gear.

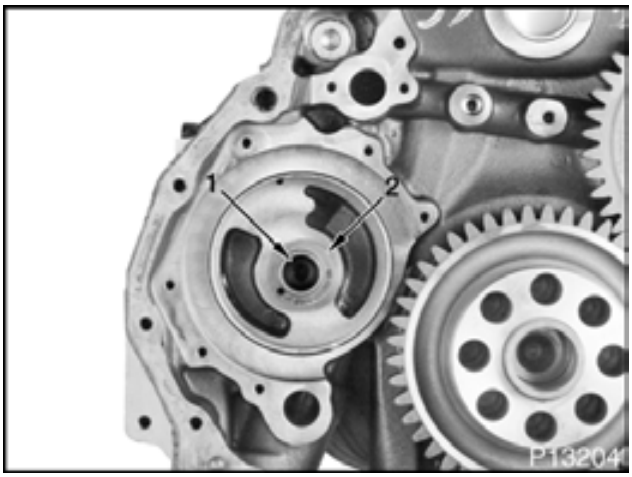

Figure 666 Axle

1. M10 x 35 cylinder screw
2. Axle

6. Remove M10 x 35 cylinder screw and axle.
7. Remove and discard O-ring.

Front Timing Gears

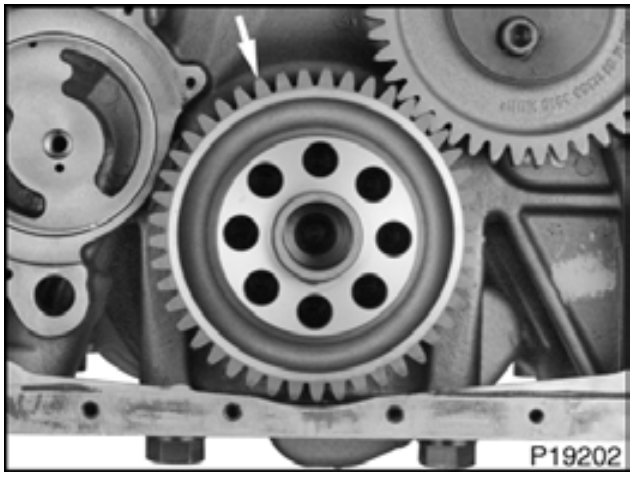

Figure 667 Crankshaft timing gear

1. Using a gear puller (page 400), remove crankshaft timing gear.

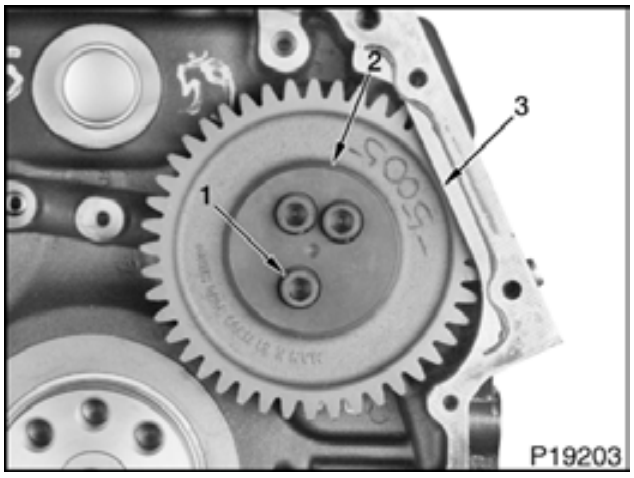

Figure 668 Front intermediate gear

1. M12 x 50 cylinder screws (3)
2. Front gear stud
3. Front intermediate gear

2. Remove three M12 x 50 cylinder screws, front gear stud, and front intermediate gear.

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Rear Timing Gears

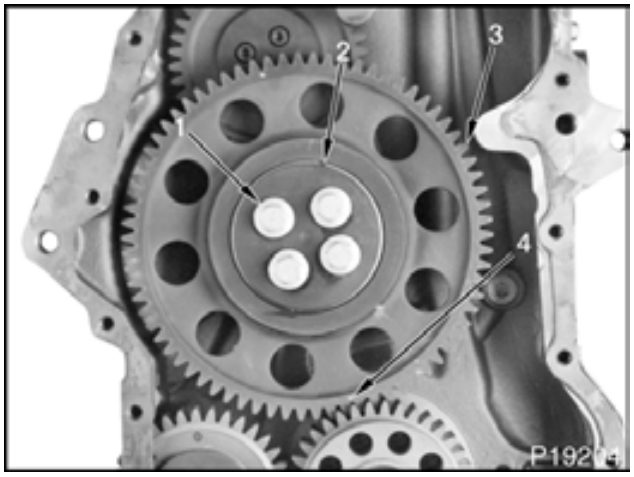

Figure 669 Big intermediate gear

1. M14 x 80 hex bolts (4)
2. Big gear stud
3. Big intermediate gear
4. Timing mark

1. Remove four M14 x 80 hex bolts, big gear stud, and big intermediate gear.

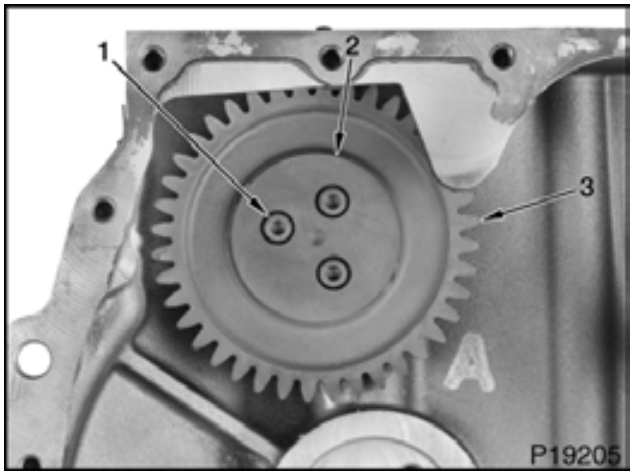

Figure 670 Crankcase intermediate gear

1. M8 x 30 cylinder screws (3)
2. Small gear stud
3. Crankcase intermediate gear

2. Remove three M8 x 30 cylinder screws, small gear stud, and crankcase intermediate gear.

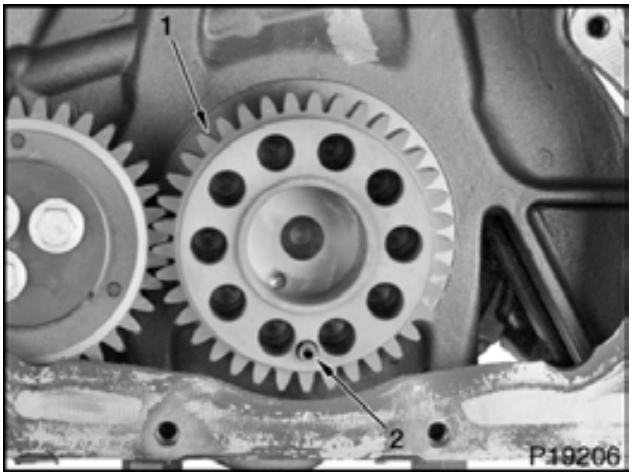

Figure 671 Crankshaft timing gear

1. Crankshaft timing gear
2. Pin, 8 x 60

3. Using a gear puller (page 400), remove crankshaft timing gear.

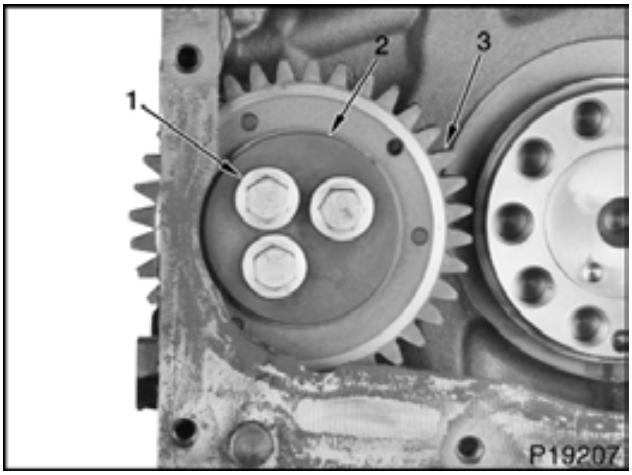

Figure 672 Air compressor intermediate gear

1. M12 x 55 hex bolts (3)
2. Air compressor gear stud
3. Air compressor intermediate gear
4. Air compressor thrust washer (not shown, behind gear)

4. Remove three M12 x 55 hex bolts and air compressor gear stud, air compressor intermediate gear, and air compressor thrust washer.

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Cleaning and Inspection

Timing Gears

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

1. Wash timing gears and gear pins with a stiff brush and suitable solvent. Dry all with filtered compressed air.
2. Inspect timing gears for irregular wear pattern and worn or damaged teeth. Replace as necessary.
3. Inspect timing gear studs for worn or damaged bearing surfaces. Replace as necessary.

Oil Pump

1. Wash all parts thoroughly in a suitable solvent.

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

2. Dry with filtered compressed air.
3. Inspect oil pump pinion, oil pump ring gear, and oil pump cover for nicks, burrs or scoring.
4. Replace any damaged components.
5. Temporarily install oil pump components (page 397) in crankcase without O-ring and tighten M6 x 25 bolts to special torque (page 400).

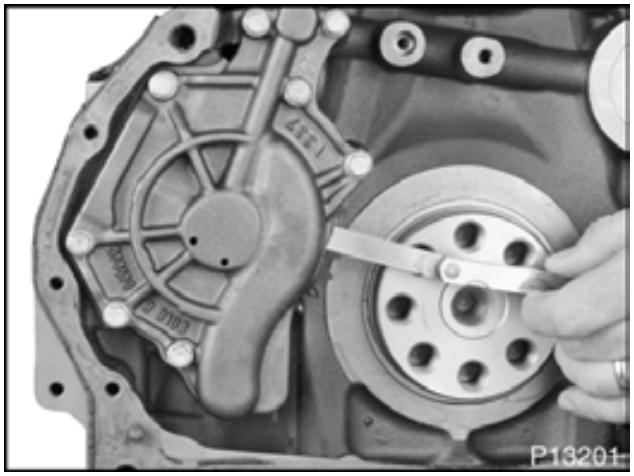

Figure 673 End play measurement

6. Using a feeler gauge (page 400), measure end play between oil pump cover and oil pump gears.

NOTE: There are two oil pump assemblies. When replacing oil pump parts, be sure you are ordering the correct set.

7. If end play exceeds specification (page 400), replace oil pump cover, oil pump pinion, and oil pump ring gear as a set.
8. Remove oil pump components for final assembly.

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Installation

Rear Timing Gears

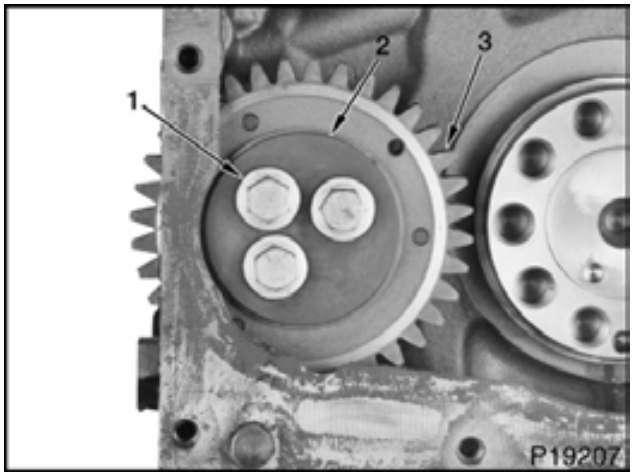

Figure 674 Air compressor intermediate gear

1. M12 x 55 hex bolts (3)
2. Air compressor gear stud
3. Air compressor intermediate gear
4. Air compressor thrust washer (not shown, behind gear)

CAUTION: To prevent engine damage, install air compressor thrust washer with larger chamfer side facing crankcase.

1. Install air compressor thrust washer (with larger chamfer side facing crankcase), air compressor gear stud, and air compressor intermediate gear.
2. Install three air compressor intermediate gear M12 x 55 hex bolts. Tighten bolts to special torque (page 400).

Figure 675 Crankshaft alignment pin hole

3. Rotate crankshaft so that alignment pin hole is at 6 o'clock position. This positions cylinder No. 1 at Top Dead Center (TDC).

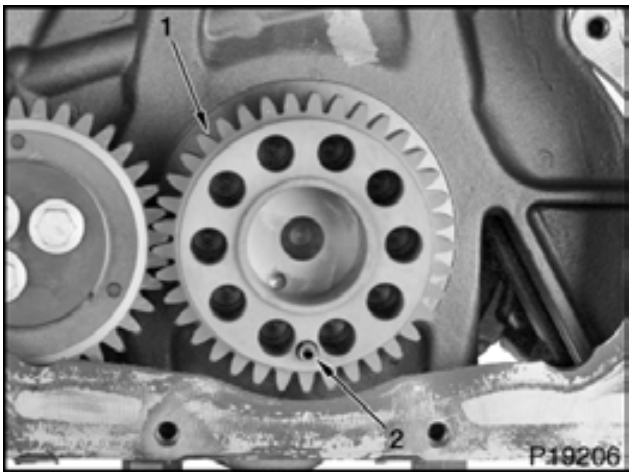

Figure 676 Crankshaft timing gear

1. Crankshaft timing gear
2. Pin, 8 x 60

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields when doing the following procedure.

4. Using a hammer and brass drift, install crankshaft timing gear so pin in gear engages crankshaft alignment pin hole.

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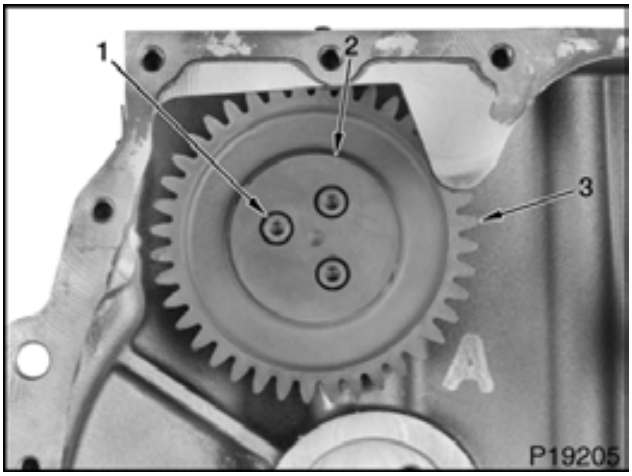

Figure 677 Crankcase intermediate gear

1. M8 x 30 cylinder screw (3)
2. Small gear stud
3. Crankcase intermediate gear

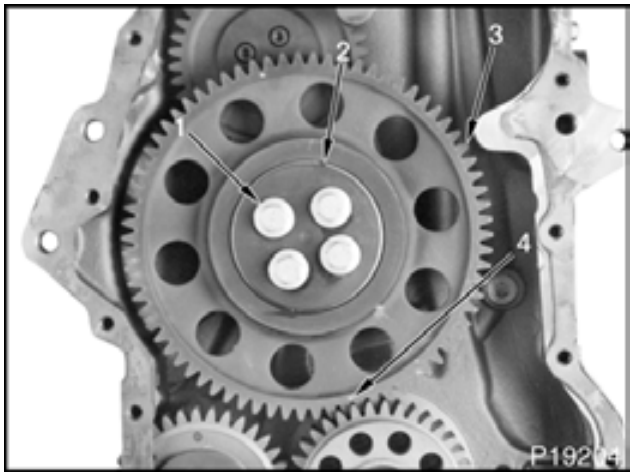

Figure 678 Big intermediate gear

1. M14 x 80 hex bolt (4)
2. Big gear stud
3. Big intermediate gear
4. Timing mark

CAUTION: To prevent engine damage, insert the crankcase intermediate gear into the crankcase with the flatter contact surface facing outwards.

5. Install crankcase intermediate gear and small gear stud.
6. Install three crankcase intermediate gear M8 x 30 cylinder screws. Tighten screws to special torque (page 400).

NOTE: This gear has two timing marks 180° apart; either may be used.

7. Install big gear stud and big intermediate gear, aligning timing mark with mark on crankshaft timing gear (flywheel side).
8. Install four big intermediate gear M14 x 80 hex bolts. Tighten bolts to special torque (page 400).

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Front Timing Gears

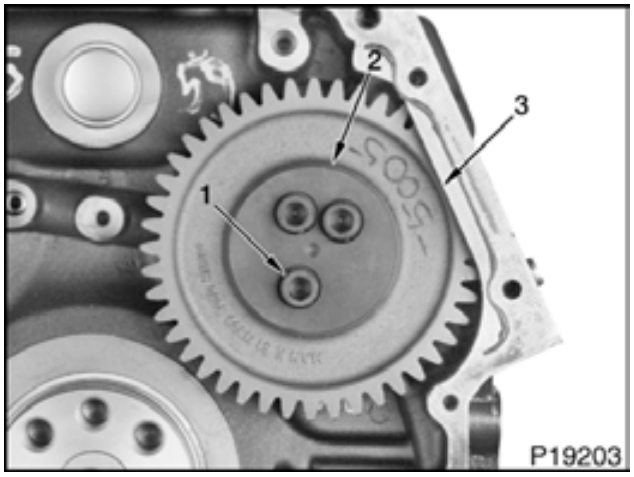

Figure 679 Front intermediate gear

1. M12 x 50 cylinder screw (3)
2. Front gear stud
3. Front intermediate gear

1. Install front intermediate gear and front gear stud.
2. Install three front intermediate gear M12 x 50 cylinder screws. Tighten screws to special torque (page 400).

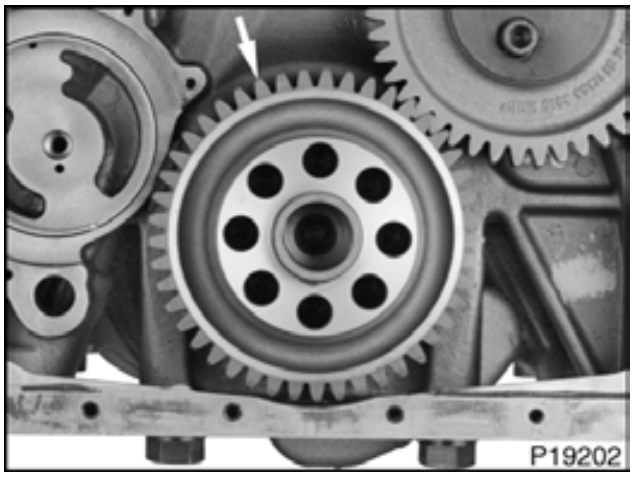

Figure 680 Crankshaft timing gear

3. Install two suitable bolts 180° apart through crankshaft timing gear into front of crankshaft.

WARNING: To prevent personal injury or death, wear safety glasses with side shields when doing the following procedure.

4. Using a hammer and brass drift, install crankshaft timing gear.
5. Remove two bolts.

Oil Pump

1. Lubricate new axle O-ring with clean engine oil and install on axle.

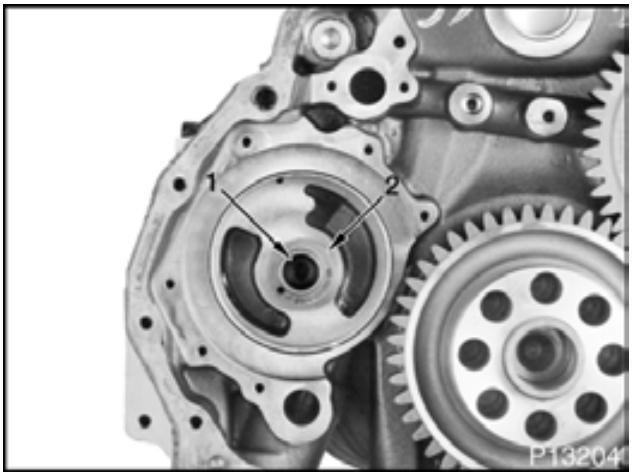

Figure 681 Axle

1. M10 x 35 cylinder screw
2. Axle

2. Install axle and M10 x 35 cylinder screw. Tighten screw to special torque (page 400).

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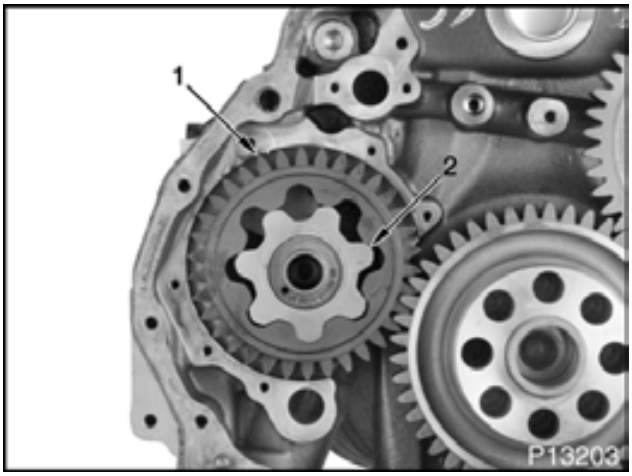

Figure 682 Oil pump pinion and oil pump ring gear

1. Oil pump ring gear
2. Oil pump pinion

3. Lubricate oil pump pinion and oil pump ring gear with clean engine oil.
4. Install oil pump pinion and oil pump ring gear, with previously made index marks facing towards front.
5. Lubricate new oil pump cover O-ring with clean engine oil and install on cover.

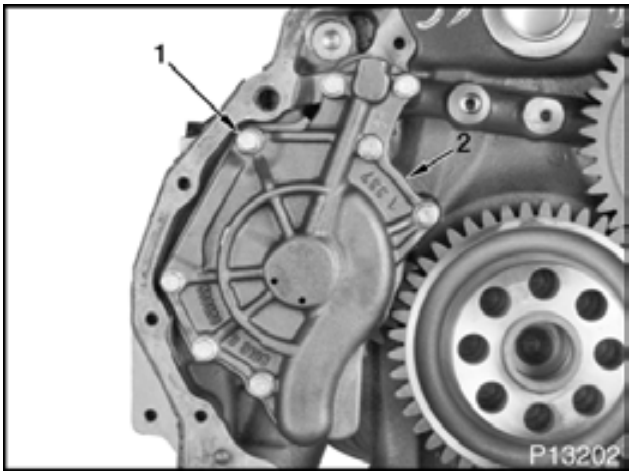

Figure 683 Oil pump cover

1. M6 x 25 hex bolt (8)
2. Oil pump cover

6. Install oil pump cover.
7. Install eight M6 x 25 hex bolts. Tighten bolts to special torque (page 400).

Fan Drive

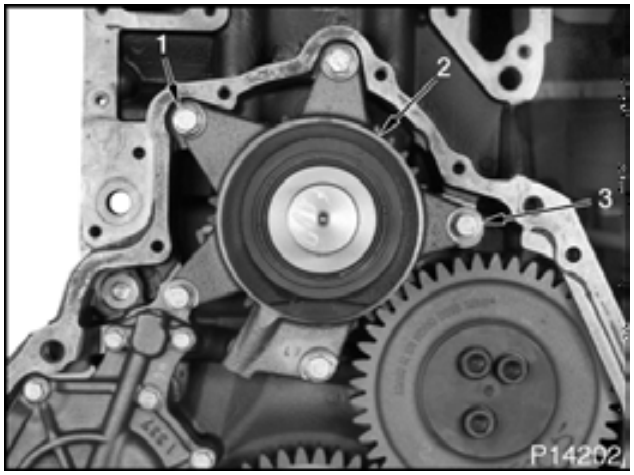

Figure 684 Fan drive

1. M8 x 25 hex bolt (4)
2. Fan drive
3. M8 x 40 hex bolt

1. Install fan drive, M8 x 40 hex bolt and four M8 x 25 hex bolts. Tighten bolts to special torque (page 400).

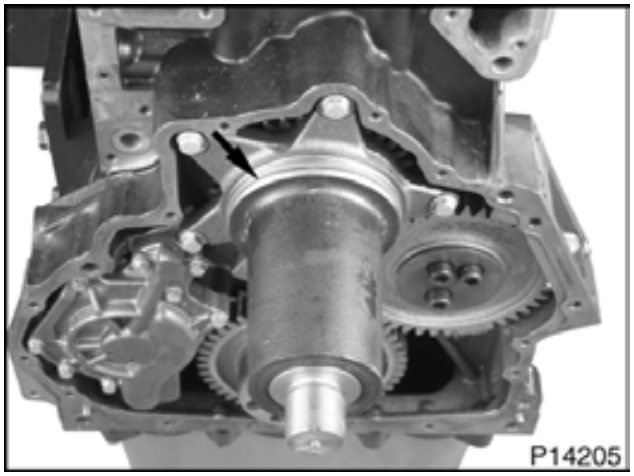

Figure 685 O-ring

2. Lubricate new O-ring with clean engine oil and install on fan drive.

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Radial Shaft Seal

1. Lubricate radial shaft seal with clean engine oil.

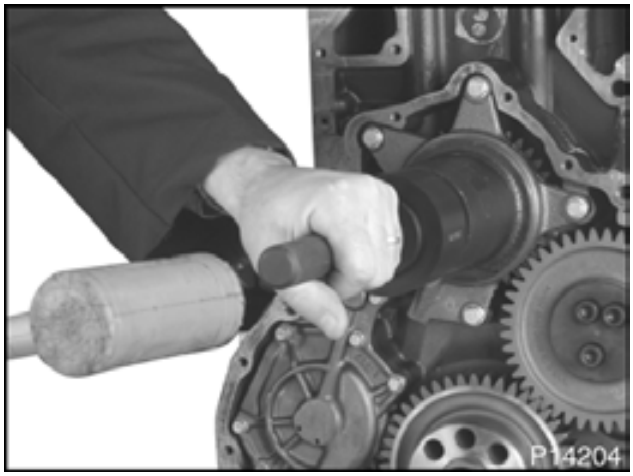

Figure 686 Radial shaft seal installation

2. Using Fan Hub High Pressure Drive Seal Installer (page 400), install new radial shaft seal until it seats within bore.

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Specifications

Table 35 Oil Pump, Low Mount Fan Drive, and Timing Gears

Front Timing Gears	
Front intermediate gear backlash	0.057 - 0.183 mm (0.0022 - 0.0072 in)
Oil Pump	
Oil pump pinion and oil pump ring gear end play	0.030 - 0.120 mm (0.0012 - 0.0047 in)
Rear Timing Gears	
Big intermediate gear backlash	0.052 - 0.176 mm (0.0020 - 0.0069 in)
Crankcase intermediate gear backlash	0.052 - 0.176 mm (0.0020 - 0.0069 in)

Special Torque

Table 36 Oil Pump, Low Mount Fan Drive, and Timing Gears

Front intermediate gear cylinder screws	105 N·m (77 lbf·ft)
Air compressor intermediate gear hex bolts	115 N·m (85 lbf·ft)
Crankcase intermediate gear cylinder screws	30 N·m (22 lbf·ft)
Big intermediate gear hex bolts	175 N·m (129 lbf·ft)
Fan drive hex bolts	35 N·m (26 lbf·ft)
Oil pump cover hex bolts	15 N·m (133 lbf·in)
Axle cylinder screw	65 N·m (48 lbf·ft)

Special Service Tools

Table 37 Oil Pump, Low Mount Fan Drive, and Timing Gears

Description	Tool Number
Dial Indicator with Magnetic Base	Obtain locally
Fan Hub High Pressure Drive Seal Installer	ZTSE4776
Feeler Gauge	Obtain locally
Gear Puller	Obtain locally
Slide Hammer	Obtain locally

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Exploded Views

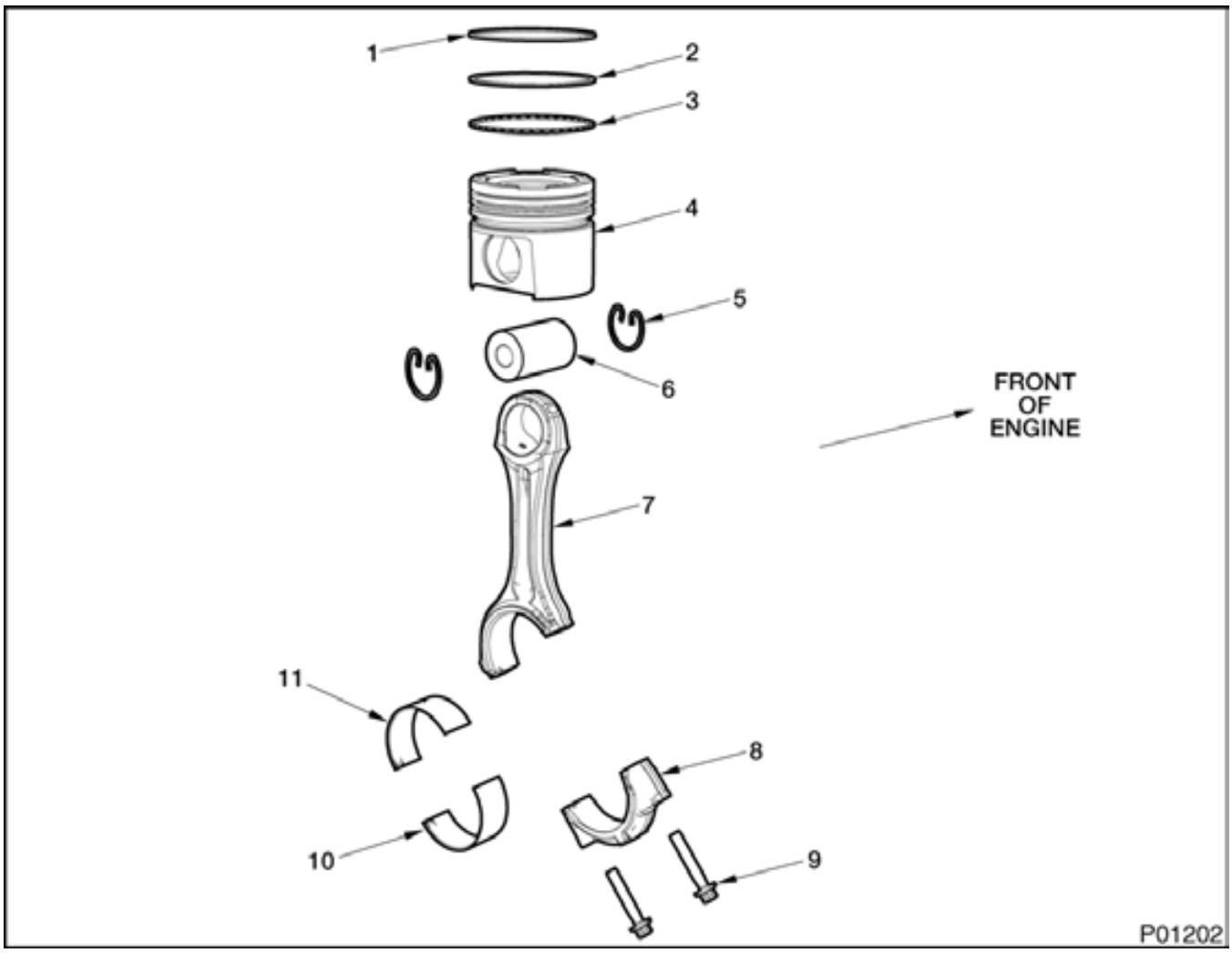

Figure 687 Piston and connecting rod

1. Keystone ring (6)
2. Taper face compression ring (6)
3. Bevelled oil scraper ring (6)
4. Piston (6)
5. Circlip (12)
6. Piston pin (6)
7. Connecting rod (6)
8. Connecting rod cap (6)
9. M12 x 64 screw (12)
10. Lower bearing shell (6)
11. Upper bearing shell (6)

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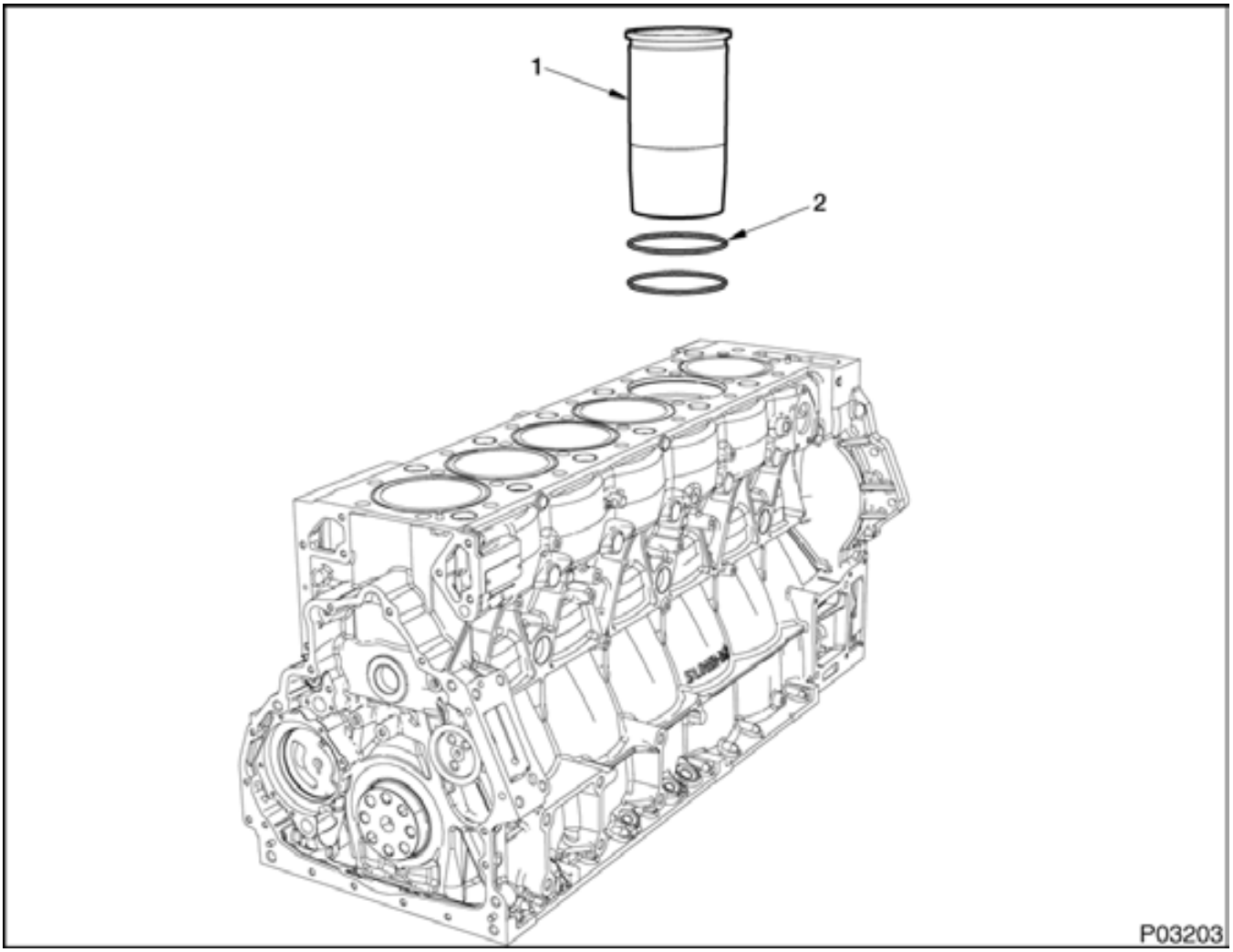

Figure 688 Cylinder liner

1. Cylinder liner (6)
2. 139 seal (12)

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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, make sure 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.

NOTE: Refer to the following service sections for information on removal of components prior to this section.

- Engine Electrical
- Cold Start Assist
- Aftertreatment System
- Engine Braking System
- Turbochargers
- Fuel System
- Oil Cooler, Filter Housing, and Crankcase Ventilation
- Exhaust Gas Recirculating (EGR) System
- Air Inlet Duct and Exhaust Manifold
- Cylinder Head, Camshaft, and Valve Train
- Flywheel and Flywheel Housing (as needed)
- Oil Pan and Oil Suction Tube

Preliminary Checks

NOTE: Evaluate piston protrusion before removing any piston and connecting rod assemblies. This helps identify bent or twisted connecting rods.

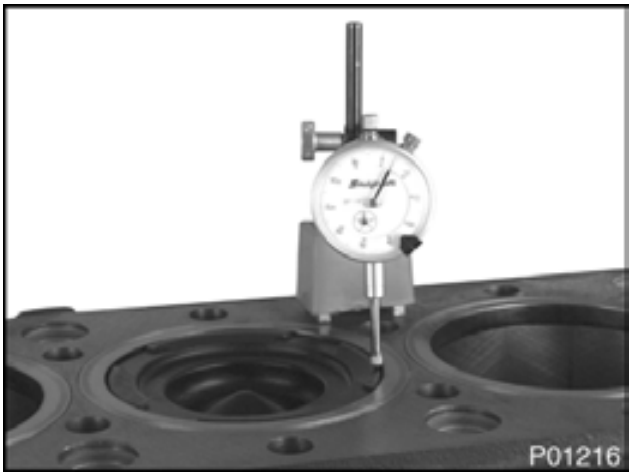

Figure 689 Checking piston protrusion

NOTE: Piston protrusion readings are done in line with piston pin, eliminating rocking movement of piston at any other position of measurement.

1. Check piston protrusion as follows:
   a. Make sure crankcase deck surface is clean.

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b. Zero dial indicator with magnetic base (page 418) on crankcase deck surface.

c. Position dial indicator tip over piston head at 3 o'clock position.

d. Rotate crankshaft in direction of normal rotation to raise piston to its maximum outward protrusion at cylinder Top Dead Center (TDC). Read this maximum protrusion on dial indicator.

e. Reposition dial indicator tip on piston head at 9 o'clock position.

f. Rotate crankshaft to raise piston to its maximum protrusion. Read maximum protrusion on dial indicator.

g. Average the two readings. Replace piston and connecting rod if protrusion is not within specifications (page 416).

Piston and Connecting Rod

CAUTION: To prevent engine damage, check for a carbon ridge on top of cylinder liners. If found, remove carbon ridge with a razor knife before removing rod and piston assemblies.

1. Scrape carbon ridge from top of cylinder bore, if necessary. Use care not to damage liner bore surface.

CAUTION: To prevent engine damage, stamp, mark, or tag each connecting rod and cap with the correct cylinder number.

This engine has fractured connecting rods. Do not alter or damage fractured mating surfaces of the rod and cap. A cap from one connecting rod is not interchangeable with another connecting rod. The matching connecting rod and cap numbers or symbols indicate a matched set.

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

2. Rotate crankshaft to position journals for removal of connecting rod assemblies. Mark connecting rod locations.

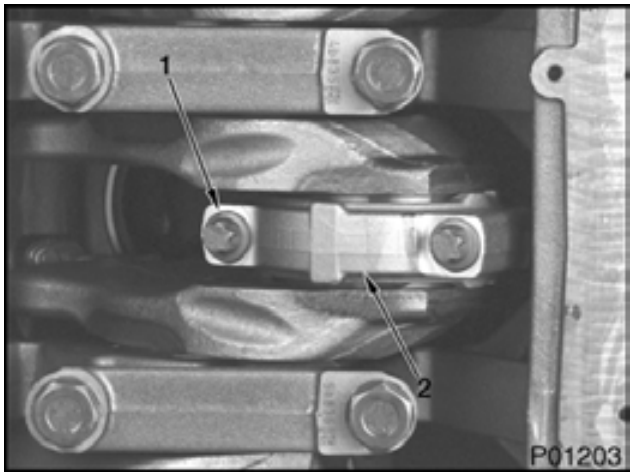

Figure 690 Connecting rod cap

1. M12 x 64 screw (2)
2. Connecting rod cap

CAUTION: To prevent engine damage, keep the fractured mating surfaces of the connecting rod and cap clean and free of lint and debris. Do not allow the mating surfaces to rest on other surfaces. Do not bump the mating surfaces or drop the connecting rod or cap. This could chip or mar the mating surfaces, causing incorrect mating of rod and cap.

CAUTION: To prevent engine damage, assemble connecting rod cap and connecting rod with their fractured mating surfaces in the original orientation. Matching numbers must be next to each other.

NOTE: When removed, make sure matching connecting rod and connecting rod cap numbers stay together as a set. A cap from one connecting rod is not interchangeable with any other connecting rod.

3. Using Connecting Rod Bolt Torx Socket (page 418) remove two M12 x 64 screws and connecting rod cap. Save screws for reuse during connecting rod bore check procedure.

CAUTION: To prevent engine damage, do not push on fractured surface of connecting rod.

CAUTION: To prevent engine damage, do not damage oil sprayer nozzle when removing connecting rod and piston assembly. If nozzle is bent during piston assembly removal, replace nozzle.

4. Remove piston and connecting rod assemblies from cylinder liners as follows:

   a. Rotate engine to a vertical position.

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b. Use a wooden or plastic handle and push piston and connecting rod assembly from cylinder liner.

c. Once piston rings are free of cylinder bore, remove piston and connecting rod assembly from cylinder liner.

d. Mark each piston and rod assembly with cylinder number from which each was removed, using a permanent marker.

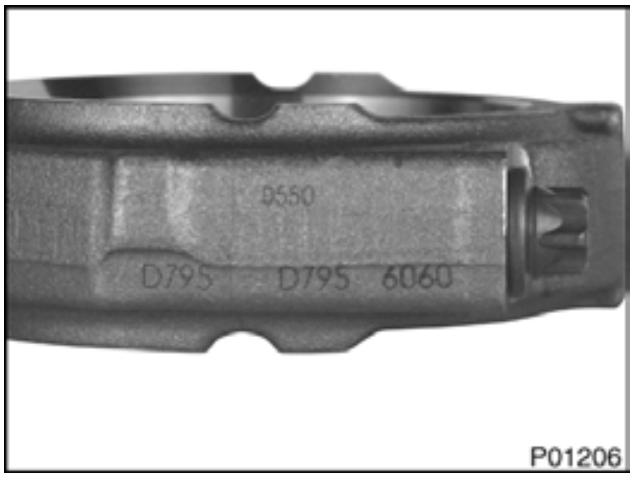

Figure 691 Correct connecting rod and cap joint fit

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

NOTE: The upper connecting rod bearing has an oil hole, the lower connecting rod bearing does not.

5. Remove connecting rod upper and lower bearing shells by pushing out. Mark connecting rod bearing shells for position and orientation and set aside for inspection.

Piston Disassembly

WARNING: To prevent personal injury or death, wear safety glasses with side shields when removing piston pin retaining rings.

Figure 692 Circlip

1. Using a pair of pliers, remove two circlips.

CAUTION: To prevent engine damage, do not mark piston pin for cylinder and location on outer diameter; place mark only on flat end or tapered inside surface.

2. Remove piston pin from its bore by hand, and separate connecting rod from piston.

Figure 693 Piston ring removal (typical)

NOTE: Only expand piston rings enough to fit over top of piston.

NOTE: Keep piston rings organized for each cylinder.

3. Using piston ring expansion pliers (page 418) , remove keystone ring, taper face compression ring, and bevelled oil scraper ring.

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Cylinder Liners

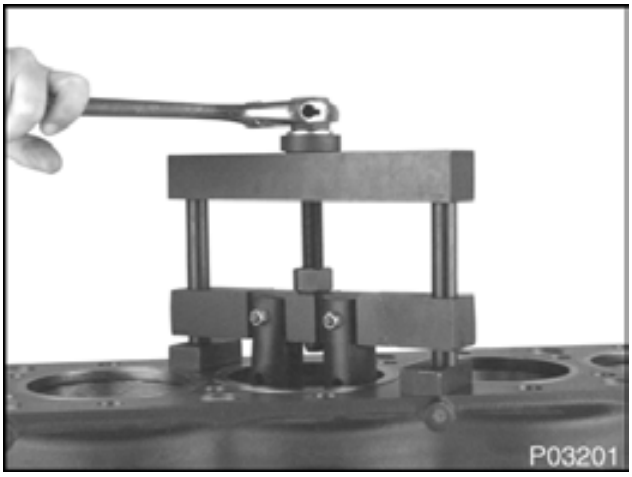

Figure 694 Cylinder liner removal

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

NOTE: Care must be taken not to damage oil sprayer nozzles during cylinder liner removal.

1. Remove six cylinder liners from crankcase as follows:
   a. Insert Cylinder Liner Puller (page 418) into cylinder liner.
   b. Engage removal tool hooks under bottom edge of cylinder liner.
   c. Position removal tool feet diagonally on crankcase deck surface.
   d. Turn threaded shaft clockwise to extract cylinder liner.
   e. Mark cylinder liners for position and set aside for inspection.
2. Remove and discard two 139 seals from each crankcase cylinder liner bore.

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Cleaning and Inspection

Cleaning

CAUTION: To prevent engine damage, do not use caustic solvents, wire brushes or bead blasting media to clean aluminum pistons.

CAUTION: To prevent engine damage, do not use solvents or a wire brush to clean the fractured mating surface of connecting rods.

1. Use a soap and water solution to clean pistons. Soak piston first, and then clean with a non-metallic brush.
2. Clean piston ring grooves thoroughly.
3. The following disassembled components may be cleaned using a suitable solvent:
   - Piston pins
   - Circlips
4. Thoroughly clean connecting rod bolt holes and threads.

Piston Inspection

1. Inspect pistons for scuffed or scored skirts, cracked or worn ring lands, and cracked or scuffed pin bores. Replace damaged pistons.

Figure 695 Second and third ring groove clearance check (typical)

NOTE: It is not possible to measure side clearance of keystone ring groove.

2. Check side clearance of taper face compression ring groove as follows:
   a. Place edge of a new taper face compression ring in its respective ring groove. Roll taper face compression ring all around ring groove to ensure ring is free in its groove.
   b. With edge of taper face compression ring in taper face compression ring groove, use a feeler gauge (page 418) to measure side clearance between ring and groove.
   c. Compare taper face compression ring side clearance to specifications (page 416). Excessive side clearance indicates ring groove wear and requires piston replacement.
3. Check side clearance of bevelled oil scraper ring groove as follows:
   a. Place edge of a new bevelled oil scraper ring in its respective ring groove. Roll bevelled oil scraper ring all around ring groove to ensure ring is free in its groove.
   b. With edge of bevelled oil scraper ring in the bevelled oil scraper ring groove, use a feeler gauge (page 418) to measure side clearance between ring and groove.
   c. Compare bevelled oil scraper ring side clearance to specifications (page 416). Excessive side clearance indicates ring groove wear and requires piston replacement.

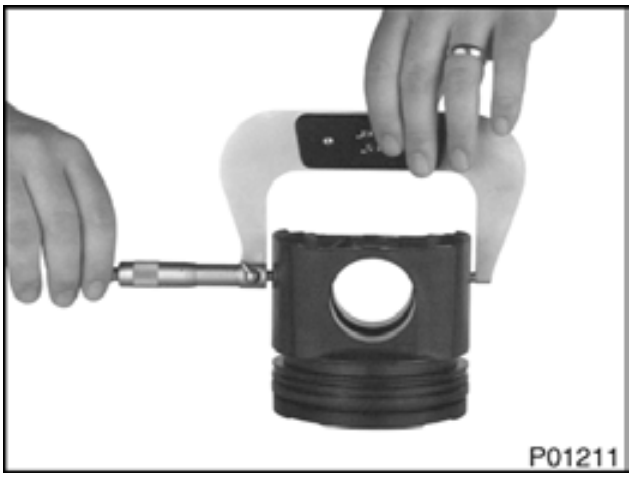

Figure 696 Piston skirt diameter

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4. Using a 4–5 inch micrometer (page 418), measure diameter of piston at intervals given in Specifications (page 416). If measurements do not meet specification, replace piston.

Piston Ring Inspection

CAUTION: To prevent engine damage, install new piston rings if a piston is removed. Faulty piston rings cannot always be detected visually.

1. Inspect new piston rings for cleanliness.

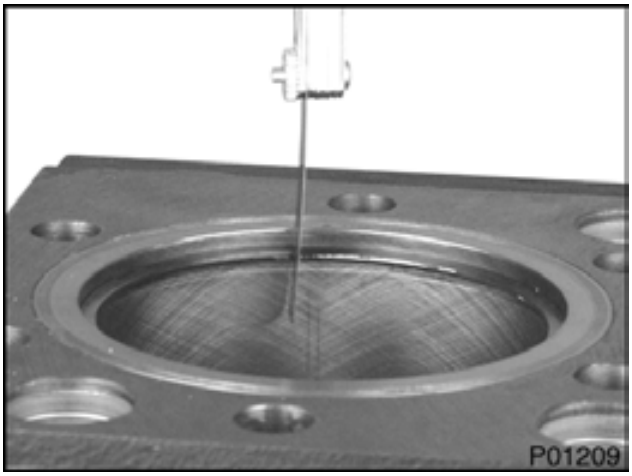

Figure 697 Piston ring end gap clearance in cylinder bore

2. Before installing new piston rings, check ring gap for each ring as follows:
   a. Push piston ring down into cylinder bore. Make sure the piston ring is square with cylinder wall. An inverted piston head can be used to push piston ring to desired location of measurement (usually at top of piston stroke).
   b. Use a feeler gauge (page 418) to measure gap between ends of each piston ring.
   c. If gap does not meet specifications (page 416), select another ring or recheck cylinder liner wear.

Connecting Rod Inspection

CAUTION: To prevent engine damage, keep the fractured mating surfaces of the connecting rod and cap clean and free of lint and debris. Do not allow the mating surfaces to rest on other surfaces. Do not bump the mating surfaces or drop the connecting rod or cap. This could chip or mar the mating surfaces, causing incorrect mating of rod and cap.

CAUTION: To prevent engine damage, do not use solvents or a wire brush to clean the fractured mating surface of connecting rods.

1. Inspect connecting rod screw threads for nicks or damage. Replace as required.
2. Inspect connecting rod and cap mating surfaces and bearing bore for any indication of damage. Bore must be smooth and free of scoring or nicks. Replace connecting rod if necessary.

Figure 698 Inside diameter of piston pin bore

3. Inspect connecting rod piston pin bore for wear as follows:
   a. Using a telescoping gauge (page 418) and a micrometer (page 418), measure piston pin bore at two locations 90° apart.
   b. If inside diameter of piston pin bore exceeds specification (page 416), replace connecting rod.

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Connecting Rod Bore Check

CAUTION: To prevent engine damage, do not use air powered tools to install connecting rod bolts; this can seize rod bolts.

1. Lubricate used connecting rod M12 x 64 screws with clean engine oil. Assemble cap to connecting rod without bearing shell. Tighten screws to initial and final torque values (page 417).

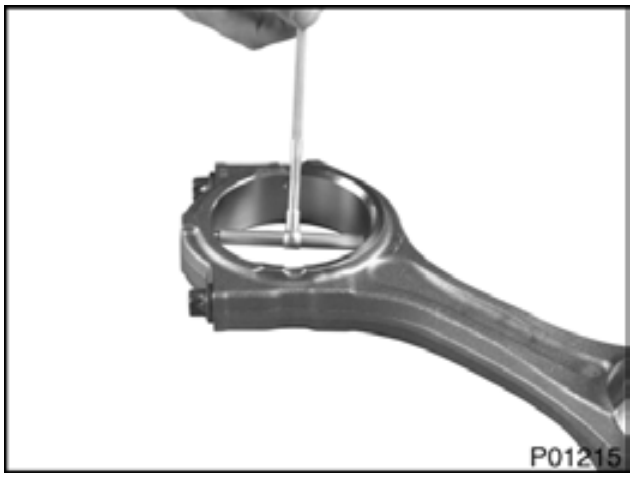

Figure 699 Measurement of connecting rod bore

2. Using a telescoping gauge (page 418) and a 3–4 inch micrometer (page 418), measure connecting rod bearing bore diameter in three locations. If connecting rod bore diameter does not meet specifications (page 416), replace connecting rod.
3. After all connecting rod bores are inspected, disassemble connecting rods and discard used M12 x 64 screws.
4. With connecting rod cap removed, inspect surface finish of connecting rod bearing bore. Bore must be smooth and free of scoring, nicks or burrs. Replace connecting rod as necessary.

Piston Pin Inspection

1. Inspect piston pins for scoring or wear. Replace as necessary.

Figure 700 Piston pin wear

2. Using a 2–3 inch micrometer (page 418), measure piston pin outside diameter at two locations 90° apart.
3. Measure each end of pin. If outside diameter of any piston pin is less than minimum specifications (page 416), replace piston pin.

Figure 701 Inside diameter measurement of piston pin bore

4. Using a telescoping gauge (page 418) and 2–3 inch micrometer (page 418), measure each piston pin bore inside diameter, at two locations 90° apart. If piston pin bore inside diameter is not within specifications (page 416), replace piston.
5. To check piston pin running clearance, subtract outside diameter of piston pin from inside

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diameter of piston pin bore. If clearance exceeds specifications (page 416), replace piston pin and check piston pin clearance using new piston pin.

Cylinder Liner Inspection

1. Install six cylinder liners (without seals) into crankcase.

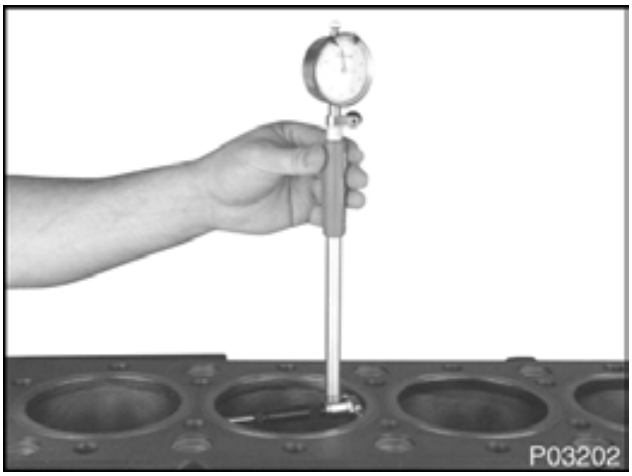

Figure 702 Cylinder liner bore measurement

2. Using a dial bore gauge (page 418), measure the cylinder liner inside diameter at 120° intervals, at four different depths of cylinder liner. If cylinder liner inside diameter is not within specification (page 416), replace cylinder liner.

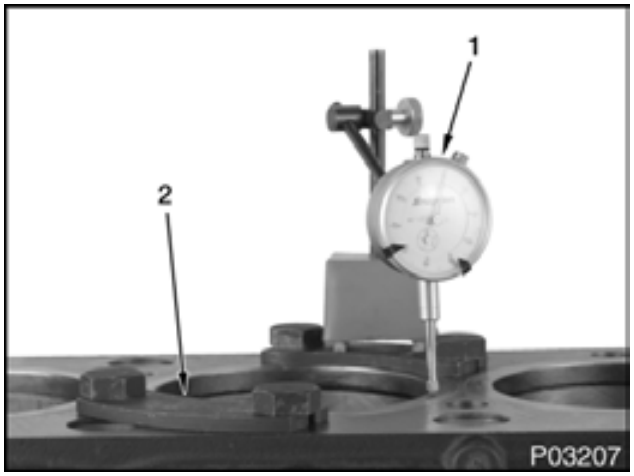

Figure 703 Cylinder liner protrusion measurement

1. Dial indicator with magnetic base
2. Cylinder Liner Protrusion Tool

3. Check cylinder liner protrusion above crankcase deck as follows:
   a. Install Sleeve Protrusion Hold Down Clamps (page 418) using four included bolts. Torque bolts to special torque (page 417).
   b. Place dial indicator with magnetic base (page 418) on crankcase deck surface.
   c. Position dial indicator tip on crankcase deck adjacent to cylinder liner flange. Zero dial indicator.
   d. Carefully pivot dial indicator until tip is resting on cylinder liner flange. Record reading.
   e. Measure cylinder liner protrusion at three locations evenly spaced around the cylinder liner. Average the three readings to determine cylinder liner protrusion.
   f. If cylinder liner protrusion is not within specification (page 416), fit new cylinder liner and repeat steps a through e.
   g. If after trying all available new piston liners and specification still cannot be met, contact Tech Central at 1-800-336-4500.
   h. Remove six cylinder liners and continue with installation.

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Installation

Cylinder Liners

1. Lubricate two new 139 seals for cylinder liner with clean engine oil and install in crankcase cylinder liner bore.
2. Using a soft-faced hammer, install cylinder liner by striking evenly until seated.

Piston Assembly

WARNING: To prevent personal injury or death, wear safety glasses with side shields when doing the following procedure.

Figure 704 Piston ring installation (typical)

CAUTION: To prevent engine damage, install piston rings correctly. Both intermediate and compression rings have the same identification markings. The marking must face up for the ring to be installed correctly. The intermediate ring has a rectangular cross section and goes in the middle groove. The top compression ring has a keystone cross section and goes in the top groove.

NOTE: Only expand piston rings enough to fit over top of piston.

1. Using piston ring expansion pliers (page 418) , install piston rings.
   a. Install expansion spring component of bevelled oil scraper ring into bottom piston groove.
   b. Install oil scraper component of bevelled oil scraper ring over expansion spring with the gap 180° from the spring wire latch.
   c. Install taper face compression ring into middle piston groove. Make sure ring is installed with identification mark facing up.
   d. Install keystone ring into top piston groove. Make sure ring is installed with identification mark facing up.
2. Space ring gaps approximately 120° apart after ring installation.
3. Connect piston to connecting rod as follows:
   a. Lubricate connecting rod piston pin bore, piston pin bore, and piston pin with clean engine oil.
   b. Set piston face down, so arrow mark stamped on piston crown is at 6 o'clock position.
   c. Hold connecting rod so open end faces 3 o'clock position of piston when installed.
   d. Place connecting rod into piston.

Figure 705 Circlip

   e. Using a pair of pliers, install first circlip at one end of piston pin bore.
   f. Slide piston pin through bored holes, stopping at installed circlip.
   g. Using a pair of pliers, install second circlip.

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Piston and Connecting Rod

1. Turn crankshaft so crank pin on the cylinder to receive piston installation is at bottom of its stroke.
2. Lightly coat piston and piston rings with clean engine oil.
3. Coat cylinder liner walls, crankshaft journals, and piston ring compressor (page 418) with clean engine oil.
4. Place piston in piston ring compressor (page 418).
5. Install connecting rod bearing shells in connecting rod and cap. Coat bearing shells with clean engine oil. Connecting rod bearing shells with the oil hole are inserted in the upper positions.

Figure 706 Arrow mark on piston

CAUTION: To prevent engine damage, the arrow stamped on top of piston must face front of engine.

CAUTION: To prevent engine damage, do not damage oil sprayer nozzle when installing connecting rod and piston assembly. If nozzle is bent during piston assembly installation, replace nozzle.

NOTE: Before installing piston and connecting rod assembly, make sure all oil sprayer nozzles are installed.

6. Carefully put piston and piston ring compressor combination and connecting rod assembly in cylinder liner with arrow mark facing towards front of engine.

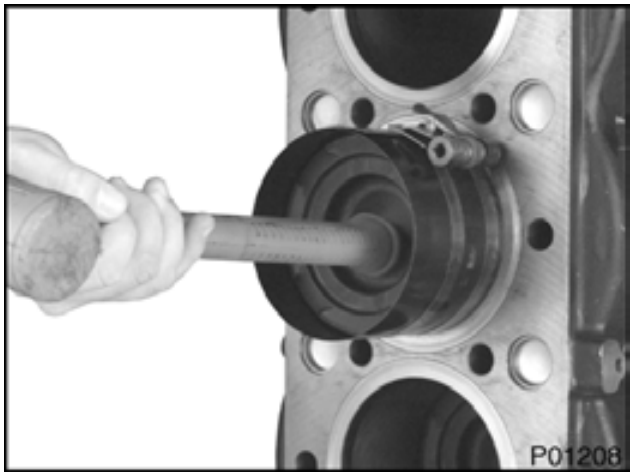

Figure 707 Installation of piston in cylinder bore

7. Once piston and connecting rod assembly have been inserted in cylinder liner, use a handle (wood or plastic) of a hammer to tap piston into cylinder liner. Guide connecting rod in place on crankshaft.

CAUTION: To prevent engine damage, lightly lubricate bolt threads and mating surfaces of bolt flanges with clean engine oil. Too much oil will cause hydrostatic lock and give incorrect torque reading.

8. Apply clean engine oil to bolt threads for connecting rod and upper and lower bearing shell in cap before installing screws.

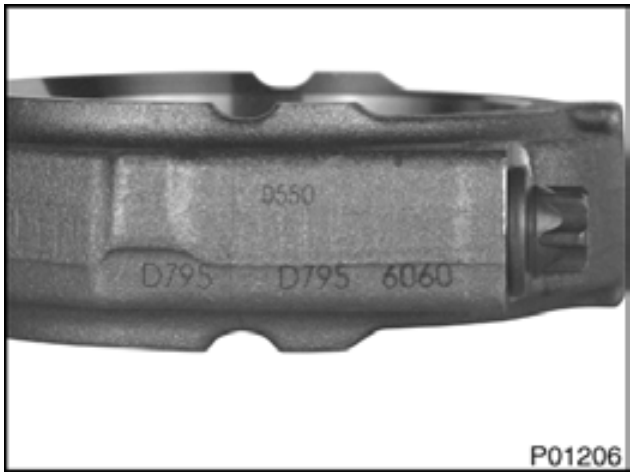

Figure 708 Correct connecting rod and cap joint fit

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CAUTION: To prevent engine damage, install connecting rods with correct caps in the correct direction. If a rod cap is reversed, an offset will be seen at the mating surfaces. If a reverse assembly is installed on the crankshaft, the connecting rod must be replaced. Also, check crank pin fillets for damage that would require replacement of the crankshaft.

9. Assemble cap to connecting rod with matching identification code on same crankshaft journal from which it was removed. Be certain that longer leg of connecting rod is positioned towards left side of crankcase.

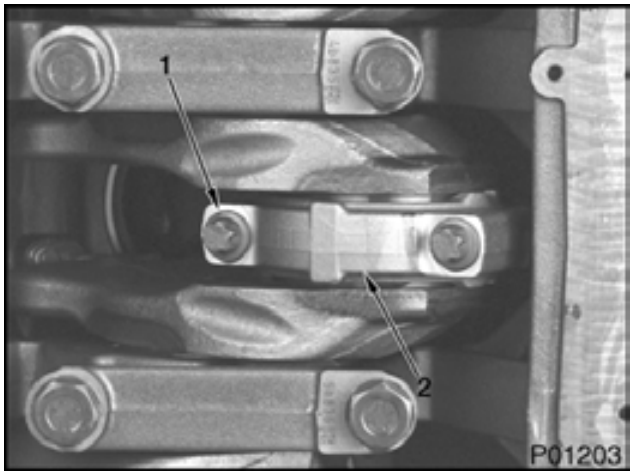

Figure 709 Connecting rod cap

1. M12 x 64 screw (2)
2. Connecting rod cap

CAUTION: To prevent engine damage, install new M12 x 64 screws.

CAUTION: To prevent engine damage, do not use air powered tools to install connecting rod bolts; this can seize rod bolts.

CAUTION: To prevent engine damage, do not rotate crankshaft until M12 x 64 screws are fully tightened, as this may cause bearing shells to rotate in place.

10. Install two new M12 x 64 screws.
11. Using Connecting Rod Bolt Torx Socket (page 418) tighten screws evenly to initial and final torque values (page 417).
12. Repeat installation procedure for remaining connecting rod and piston assemblies.

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Specifications

Table 38 Power Cylinders

Connecting Rods	
Piston pin bore inside diameter	52.06 ± 0.005 mm (2.0496 ± 0.0001 in)
Connecting rod bearing bore diameter (crankshaft end)	95.000 to 95.022 mm (3.7402 to 3.7402 in)
Pistons — 11L	
Skirt diameter measured 16 mm from piston bottom edge	119.88 ± 0.009 mm (4.7197 ± 0.0004 in)
Piston protrusion measured from crankcase deck to piston	0.3 ± 0.22 mm (0.0118 ± 0.009 in)
Piston pin bore inside diameter	52.010 - 52.016 mm (2.0476 - 2.0479 in)
Piston pin running clearance	0.010 - 0.024 mm (0.0004 - 0.0009 in)
Pistons — 13L	
Skirt diameter measured 26.9 mm from piston bottom edge	125.950 ± 0.013 mm (4.9587 ± 0.0005 in)
Piston protrusion measured from crankcase deck to piston	0.3 ± 0.22 mm (0.0118 ± 0.009 in)
Piston pin bore inside diameter	52.04 - 52.05 mm (2.0490 - 2.0492 in)
Piston pin running clearance	0.040 - 0.058 mm (0.0016 - 0.0023 in)
Piston Pins	
Outside diameter	51.992 - 52.000 mm (2.0469 - 2.0472 in)
Piston Rings — 11L	
Keystone ring	
Ring gap	0.4 - 0.55 mm (0.0157 - 0.0217 in)
Taper face compression ring	
Ring gap	0.90 - 1.00 mm (0.0354 - 0.0393 in)
Side clearance	0.07 - 0.13 mm (0.0028 - 0.0051 in)
Bevelled oil scraper ring	
Ring gap	0.25 - 0.55 mm (0.0098 - 0.0217 in)

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Table 38 Power Cylinders (cont.)

Side clearance	0.03 - 0.07 mm (0.0012 - 0.0028 in)
Piston Rings — 13L	
Keystone ring	
Ring gap	0.4 - 0.55 mm (0.0157 - 0.0217 in)
Taper face compression ring	
Ring gap	1.00 - 1.02 mm (0.0394 - 0.0402 in)
Side clearance	0.02 - 0.11 mm (0.0008 - 0.0043 in)
Bevelled oil scraper ring	
Ring gap	0.25 - 0.50 mm (0.0098 - 0.0197 in)
Side clearance	0.05 - 0.09 mm (0.0020 - 0.0035 in)
Liner dimensions — 11L	
Liner protrusion	0.050 - 0.085 mm (0.0019 - 0.0033 in)
Liner inside diameter	120 ± 0.01 mm (4.7244 ± 0.0004 in)
Liner dimensions — 13L	
Liner protrusion	0.050 - 0.085 mm (0.0019 - 0.0033 in)
Liner inside diameter	126 ± 0.01 mm (4.9606 ± 0.0004 in)

Special Torque

Table 39 Power Cylinders

Connecting rod screws	Initial	100 N·m (74 lbf·ft)
	Final	90°
Cylinder Liner Protrusion Tool bolts		80 N·m (59 lbf·ft)

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Special Service Tools

Table 40 Power Cylinders

Description	Tool Number
2–3 inch Micrometer	Obtain locally
3–4 inch Micrometer	Obtain locally
4–5 inch Micrometer	Obtain locally
Connecting Rod Bolt Torx Socket	ZTSE4843
Cylinder Liner Puller	ZTSE2536
Dial Bore Gauge	Obtain locally
Dial Indicator with Magnetic Base	Obtain locally
Feeler Gauge	Obtain locally
Piston Ring Compressor	Obtain locally
Piston Ring Expansion Pliers	Obtain locally
Sleeve Protrusion Hold Down Clamps	ZTSE4825
Telescoping Gauge Set	Obtain locally

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Exploded View

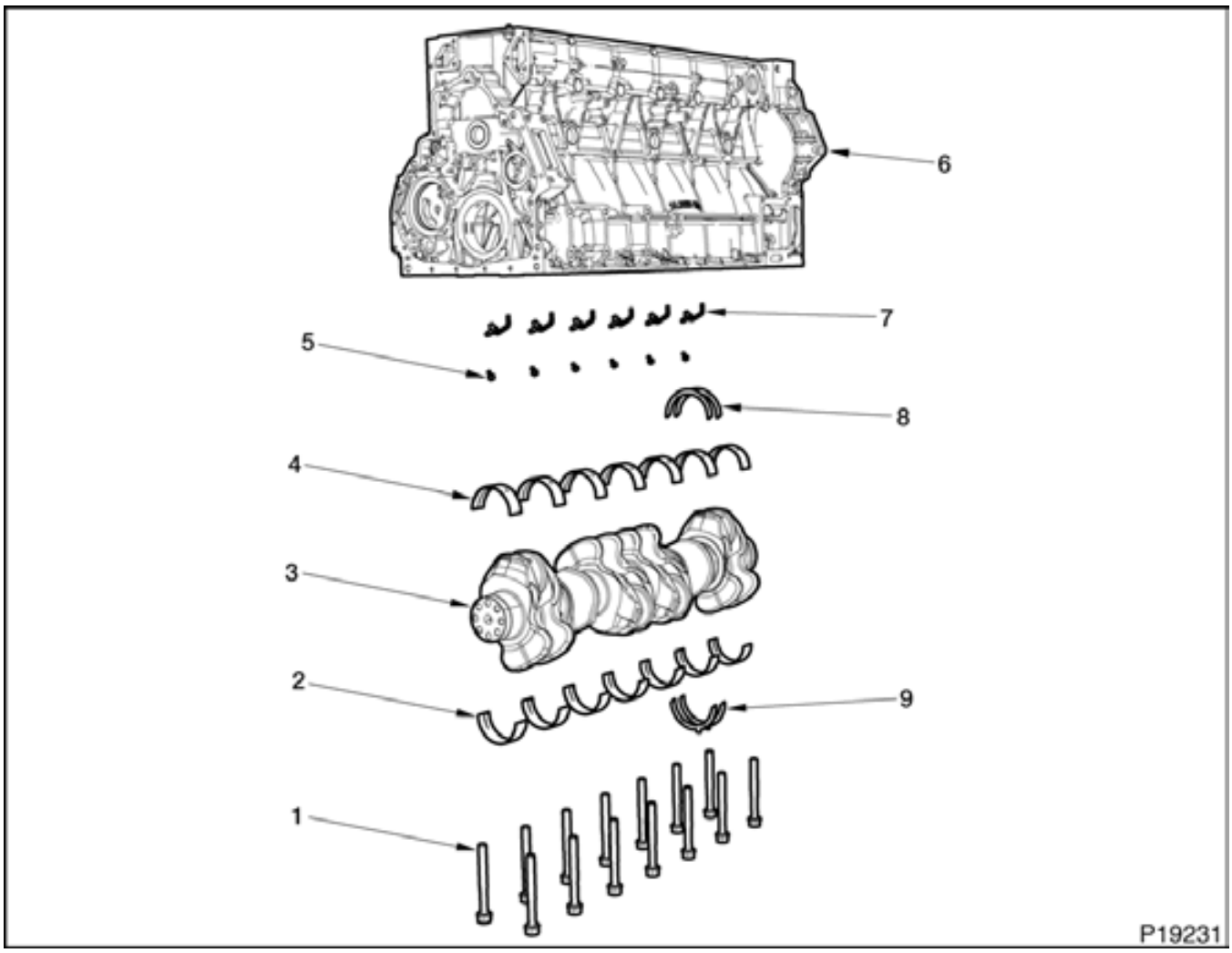

Figure 710 Crankcase and crankshaft

1. Hex collar bolt (14)
2. Lower main bearing (7)
3. Crankshaft
4. Upper main bearing (with oil hole) (7)
5. M6 x 12 hex bolt (6)
6. Crankcase
7. Oil sprayer nozzle (6)
8. Upper main bearing thrust washer (2)
9. Lower main bearing thrust washer (2)

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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, make sure 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.

NOTE: Refer to the following service sections for information on removal of components prior to this section.

- Engine Electrical
- Cold Start Assist
- Aftertreatment System
- Engine Braking System
- Turbochargers
- Air Compressor and Power Steering Pump
- Fuel System
- Oil Cooler and Filter Housing
- Exhaust Gas Recirculating (EGR) System
- Intercooler Elbow and Exhaust Manifolds
- Front Cover, High Mount Fan Drive, Cooling System, and Related Components
- Cylinder Head, Camshaft, and Valve Train
- Flywheel and Flywheel Housing
- Oil Pan and Oil Suction Tube
- Oil Pump, Low Mount Fan Drive, and Timing Gears
- Power Cylinders

Preliminary Checks

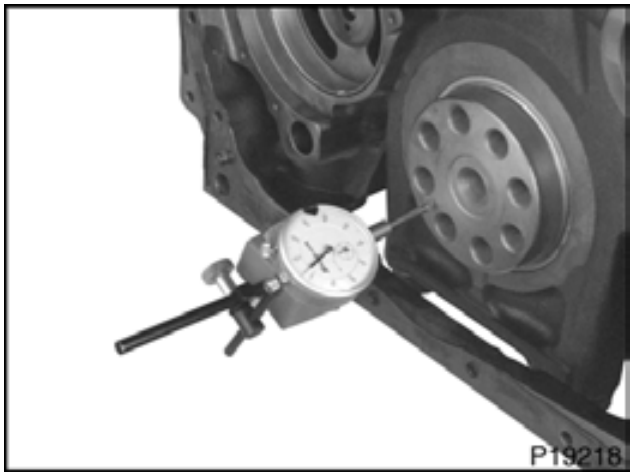

Figure 711 Crankshaft end play

1. Check crankshaft end play as follows:

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a. Mount dial indicator with magnetic base (page 431) on crankcase with indicator tip on end of crankshaft as shown.

b. Move crankshaft forward with pry bar and zero the dial indicator.

c. Move crankshaft back and forth while reading dial indicator. Compare dial indicator reading with specifications (page 431).

d. If end play exceeds specified limits, replace main bearing thrust washers.

Crankshaft

1. Position engine so that bottom of main bearing caps are facing upwards.

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

2. Mark main bearing caps for location and orientation.

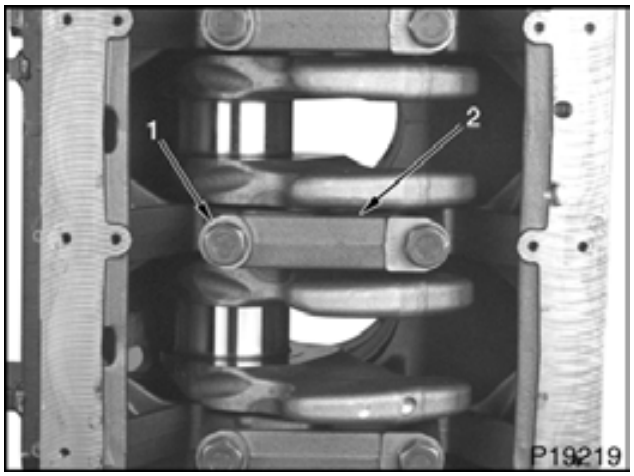

Figure 712 Main bearing caps

1. Hex collar bolt (14)
2. Main bearing cap (7)

CAUTION: To prevent engine damage, do not drop main bearing caps. Damage to the fractured mating surface of a main bearing cap will require replacement of the crankcase and mated main bearing caps.

3. Remove 14 hex collar bolts and seven main bearing caps. Save bolts for Main Bearing Inspection Procedure (page 426).

4. Remove lower main bearings and lower main bearing thrust washers from main bearing caps by pushing out.

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

5. Number removed lower main bearings and lower main bearing thrust washers and set aside for inspection.

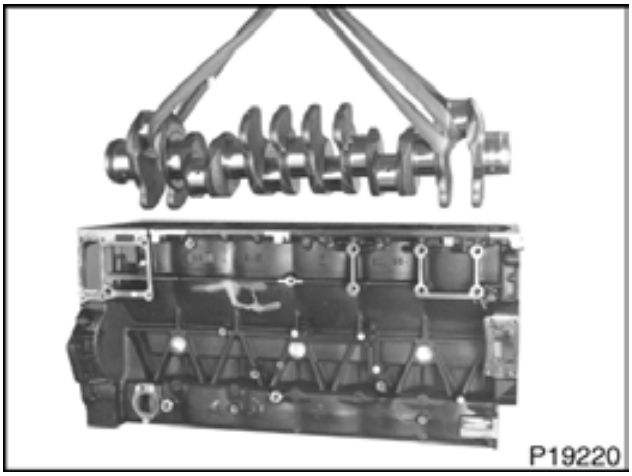

Figure 713 Crankshaft removal

WARNING: To prevent personal injury or death, use a correct size lifting sling and hoist with a safety latch on hook.

CAUTION: To prevent engine damage, do not bend, drop or mar crankshaft.

NOTE: Use only a soft-sided lifting sling. Do not use chains or steel cables.

6. Attach lifting sling (page 431) to crankshaft. Lift crankshaft up and out of crankcase and set aside for inspection.

7. Remove upper main bearings and upper main bearing thrust washers from crankcase by pushing out.

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

8. Number removed upper main bearings and upper main bearing thrust washers to match the previously removed lower main bearings and lower main bearing thrust washers and set aside for inspection.

Oil Sprayer Nozzles

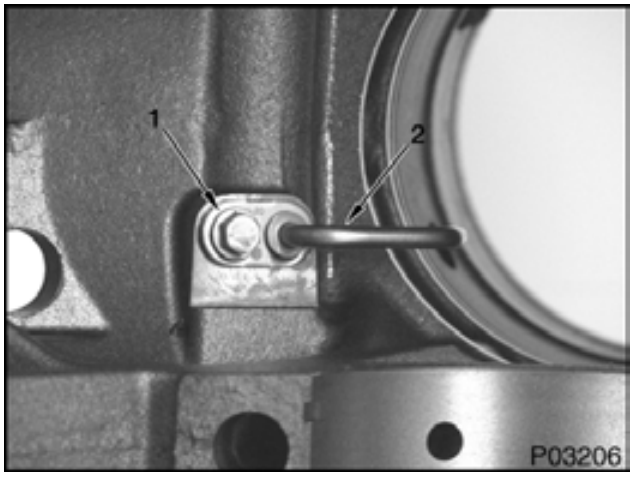

Figure 714 Oil sprayer nozzle

1. M6 x 12 hex bolt (6)
2. Oil sprayer nozzle (6)

Remove six M6 x 12 hex bolts and six oil sprayer nozzles.

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Cleaning, Inspection, and Testing

Crankcase

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 chemicals other than engine oil.

NOTE: Thoroughly clean and inspect crankcase before and after reconditioning.

1. Clean crankcase in a chemical bath or hot tank. This removes all carbonized material and mineral deposits in coolant passages.

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

CAUTION: To prevent engine damage, do not use solvents or a wire brush to clean the fractured mating surface of crankcase and main bearing caps.

2. If a hot tank is not available, do the following steps:
   a. Use non-metallic stiff bristle brushes and scrapers to clean gasket material from machined surfaces of crankcase.
   b. Clean crankcase in solvent.
   c. Dry with filtered compressed air.

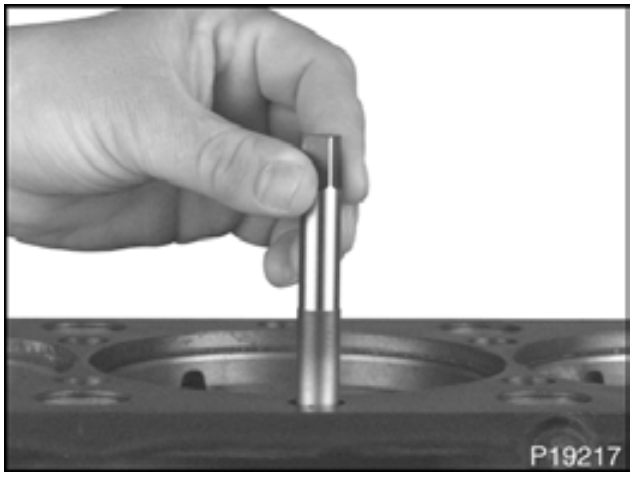

Figure 715 Cylinder head bolt holes

CAUTION: To prevent engine damage, clean and dry threads in the crankcase bolt holes with filtered compressed air. Dirt or oil in holes may cause binding and incorrect torque readings.

3. Clean cylinder head bolt holes with Head Bolt Bottoming Tap ZTSE4855 (page 431).
4. Clean hex collar bolt holes with Main Bolt Bottoming Tap ZTSE4854 (page 431).

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

5. Clean out debris with filtered compressed air.

Crankshaft

1. Clean and inspect crankshaft and main bearings.
2. Clean crankshaft with a suitable solvent.

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

3. Dry with filtered compressed air.
4. Use a stiff nylon brush to clean oil passages in crankshaft. Loosen accumulated dirt, sludge, and deposits.
5. Flush oil passages with a suitable solvent.
6. Inspect crankshaft journals (main and connecting rod) for scratches, grooves, and scoring.
7. Inspect main bearings for scratches, grooves, scoring, pitting, and inconsistent coloring.

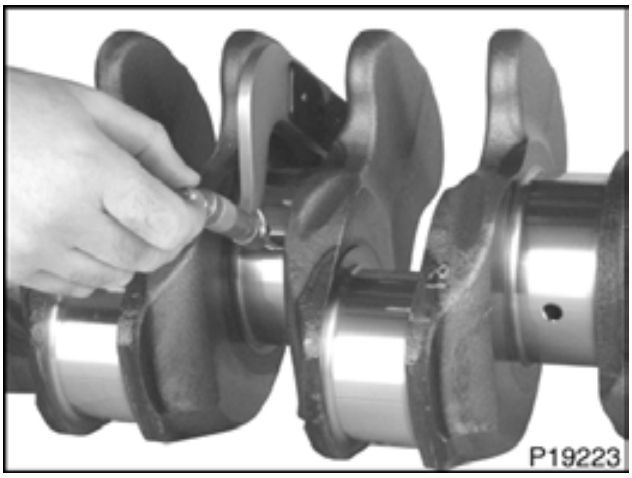

Figure 716 Measurement of crankshaft main bearing journal

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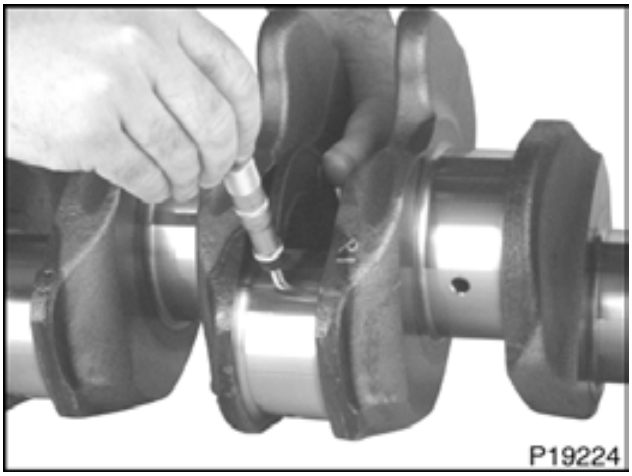

Figure 717 Measurement of crankshaft connecting rod bearing journal

CAUTION: To prevent engine damage, do not rework bearings or bearing caps to reduce journal-to-bearing running clearances. Grind or install new crankshaft.

8. Use a 3–4 inch micrometer (page 431) to measure diameter of each connecting rod journal, and a 4–5 inch micrometer (page 431) to measure diameter of each main journal. Measure each journal at both sides next to fillet radius at two directions 90° apart. Move micrometer over entire width of journal. If journal wear exceeds specification (page 431), have crankshaft machined or replace crankshaft.

Main Bearings

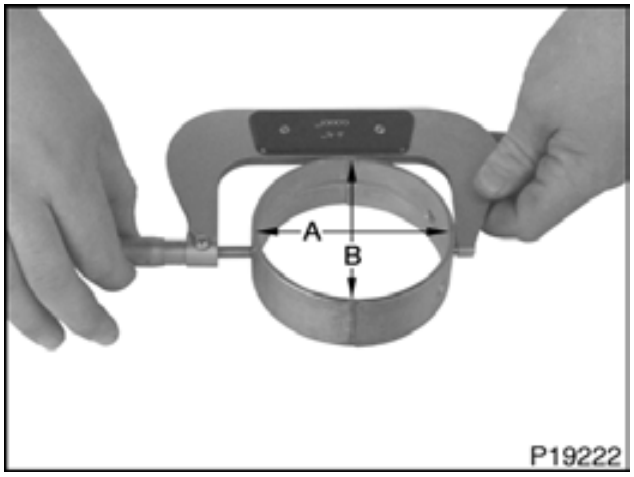

Figure 718 Main bearing free spread measurement

1. Inspect each main bearing. Replace scored, chipped or worn bearings.
2. Using a flat surface, place matching upper and lower main bearings together as shown.
3. Using a 4–5 inch micrometer (page 431), measure and note dimensions A and B as shown.
4. Calculate difference between dimensions A and B. If difference exceeds free spread specification (page 431), replace main bearings.
5. Install upper main bearings into crankcase and lower main bearings into main bearing caps in their original positions and orientation.

CAUTION: To prevent engine damage, install main bearing caps with their fractured mating surfaces in the original orientation.

6. With crankshaft still removed, install seven main bearing caps and 14 previously removed hex collar bolts. Do not use new bolts for this inspection procedure.
7. Tighten hex collar bolts as follows:
   a. Tighten No. 6 (thrust bearing) main bearing cap bolts to 10 N·m (88 lbf·in).
   b. Tighten remaining main bearing cap bolts to 10 N·m (88 lbf·in).
   c. Tighten No. 6 (thrust bearing) main bearing cap bolts to 100 N·m (74 lbf·ft).

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d. Tighten remaining main bearing cap bolts to 100 N·m (74 lbf·ft).

e. Tighten No. 6 (thrust bearing) main bearing cap bolts to 300 N·m (221 lbf·ft).

f. Tighten remaining main bearing cap bolts to 300 N·m (221 lbf·ft).

g. Turn No. 6 (thrust bearing) main bearing cap bolts an additional 90°.

h. Turn remaining main bearing cap bolts an additional 90°.

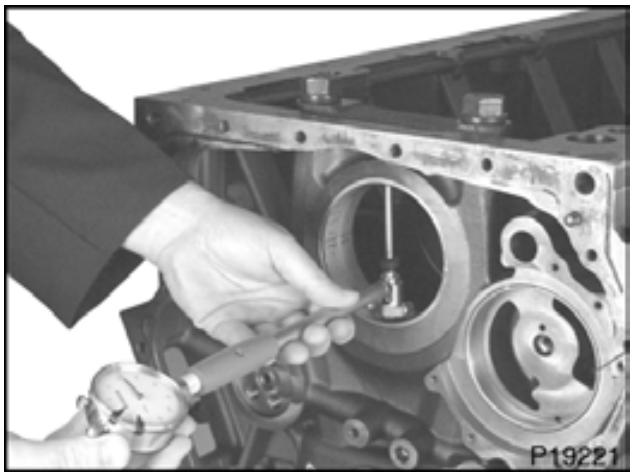

Figure 719 Main bearing installed diameter measurement

8. Using a dial bore gauge (page 431), measure main bearing installed inside diameter. If measurement does not meet specification (page 431), replace main bearings.

9. Remove 14 hex collar bolts, seven main bearing caps, upper main bearings, and lower main bearings. Discard used hex collar bolts.

Oil Sprayer Nozzles

1. Hold each oil sprayer nozzle under running water. Water should stream from nozzle end.

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

2. Clear blocked oil sprayer nozzles using filtered compressed air. Replace oil sprayer nozzle if blockage cannot be cleared.

3. Replace any cracked or bent nozzles.

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Installation

Oil Sprayer Nozzles

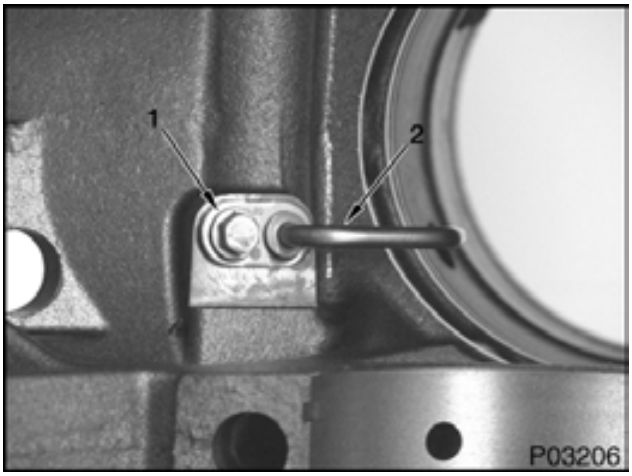

Figure 720 Oil sprayer nozzle

1. M6 x 12 hex bolt (6)
2. Oil sprayer nozzle (6)

1. Install six oil sprayer nozzles and six M6 x 12 hex bolts.
2. Tighten hex bolts to special torque (page 431).

Crankshaft

NOTE: Make sure crankshaft and bearings have been inspected per instructions in this section before proceeding.

1. Use a lint-free cloth to wipe crankcase bearing saddles free of oil.

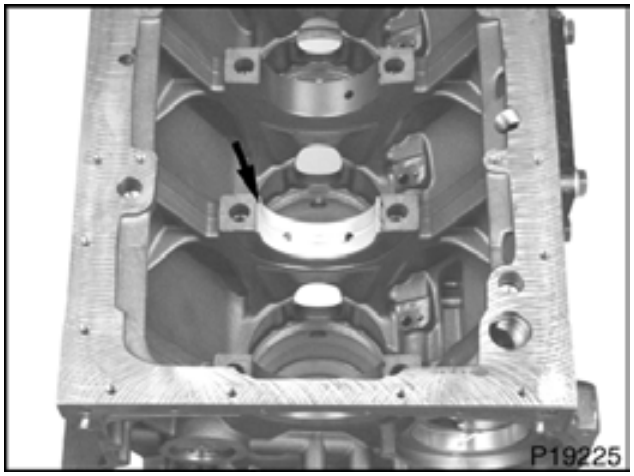

Figure 721 Main bearing (above) installation

NOTE: When inserting main bearings, make sure oil is not between back side of bearing and crankcase bearing saddles.

2. Place upper main bearings in crankcase. Make sure locking tabs on bearings are snapped into saddle, and oil holes in bearings line up with oil holes in crankcase.
3. Lubricate bearings with clean engine oil.

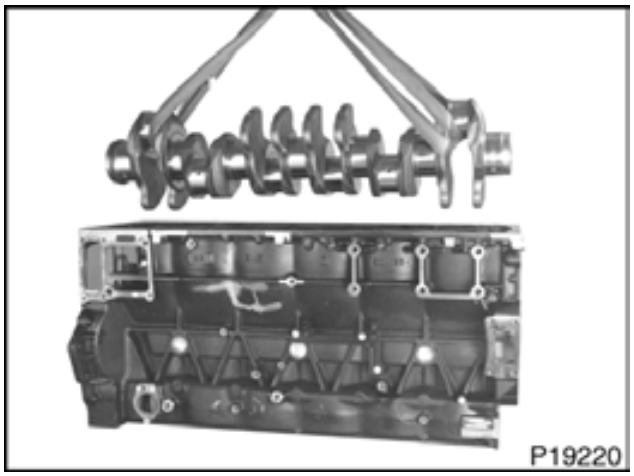

Figure 722 Crankshaft installation

WARNING: To prevent personal injury or death, use a correct size lifting sling and hoist with a safety latch on hook.

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CAUTION: To prevent engine damage, do not bend, drop or mar crankshaft.

NOTE: Use only a soft-sided lifting sling. Do not use chains or steel cables.

4. Attach lifting sling (page 431) to crankshaft. Lower crankshaft down into crankcase.

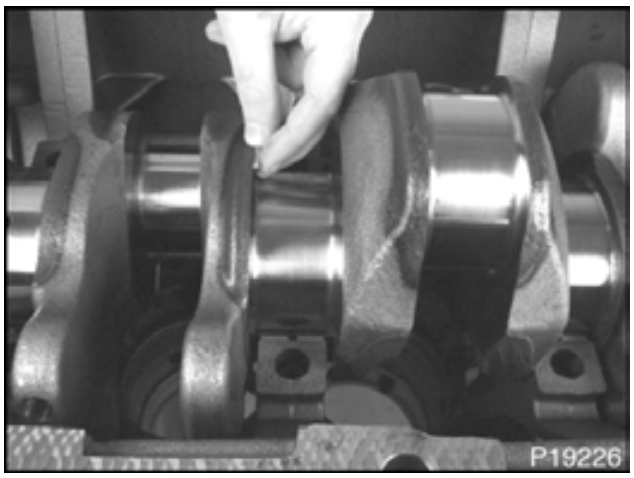

Figure 723 Thrust washer installation

NOTE: Make sure oil grooves on thrust washers face outward towards crankshaft thrust surface.

5. Install two upper main bearing thrust washers into crankcase at No. 6 main location as follows:
   a. Set upper main bearing thrust washer on top of crankshaft at No. 6 main journal.
   b. Allow upper main bearing thrust washer to pivot around crankshaft and down into position.
6. Install two lower main bearing thrust washers onto #6 main bearing cap. Make sure washer locking tabs align with notches in main bearing cap.
7. Place lower main bearings in main bearing caps. Make sure locking tabs on bearings are snapped into main bearing caps.
8. Lubricate bearings with clean engine oil.

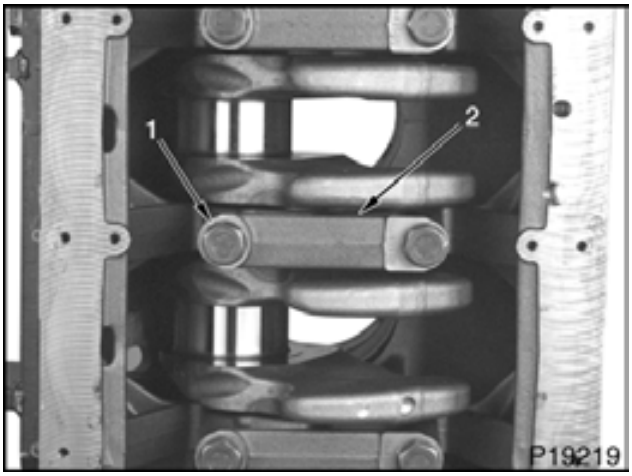

Figure 724 Main bearing caps

1. Hex collar bolt (14)
2. Main bearing cap (7)

CAUTION: To prevent engine damage, install main bearing caps with their fractured mating surfaces in the original orientation.

CAUTION: To prevent engine damage, do not drop main bearing caps. Damage to the fractured mating surface of a main bearing cap will require replacement of the crankcase and mated main bearing caps.

9. Install seven main bearing caps and 14 new hex collar bolts.

NOTE: Rotate crankshaft after completion of each main bearing cap torque procedure to verify crankshaft does not bind. Correct as required.

10. Tighten hex collar bolts as follows:
    a. Tighten No. 6 (thrust bearing) main bearing cap bolts to 10 N·m (88 lbf·in).
    b. Tighten remaining main bearing cap bolts to 10 N·m (88 lbf·in).
    c. Tighten No. 6 (thrust bearing) main bearing cap bolts to 100 N·m (74 lbf·ft).
    d. Tighten remaining main bearing cap bolts to 100 N·m (74 lbf·ft).
    e. Tighten No. 6 (thrust bearing) main bearing cap bolts to 300 N·m (221 lbf·ft).
    f. Tighten remaining main bearing cap bolts to 300 N·m (221 lbf·ft).

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g. Turn No. 6 (thrust bearing) main bearing cap bolts an additional 90°.

h. Turn remaining main bearing cap bolts an additional 90°.

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Specifications

Table 41 Crankcase and Crankshaft

Crankshaft	
Main Bearing:	
Journal diameter	103.98 - 104.00 mm (4.0937 - 4.0945 in)
Installed inside diameter	104.06 - 104.106 mm (4.0969 - 4.0987 in)
Free spread	0.20 - 1.40 mm (0.0079 - 0.0551 in)
Connecting Rod Bearing:	
Journal diameter	89.98 - 90.00 mm (3.5425 - 3.5433 in)
Crankshaft end play:	
Maximum service	0.200 - 0.401 mm (0.0079 - 0.0158 in)

Special Torque

Table 42 Crankcase and Crankshaft

Main bearing cap hex collar bolts	See tightening procedure and sequence (page 429)
Oil sprayer nozzle hex bolts	13 N·m (115 lbf·in)

Special Service Tools

Table 43 Crankcase and Crankshaft

Description	Tool Number
3–4 inch Micrometer	Obtain locally
4–5 inch Micrometer	Obtain locally
Dial Bore Gauge	Obtain locally
Dial Indicator with Magnetic Base	Obtain locally
Head Bolt Bottoming Tap	ZTSE4855
Lifting Sling	Obtain locally
Main Bolt Bottoming Tap	ZTSE4854

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Abbreviations and Acronyms

Abbreviations and Acronyms

A or amp – Ampere
ABDC – After Bottom Dead Center
ABS – Antilock Brake System
AC – Alternating Current
A/C – Air Conditioner
ACC – Air Conditioner Control
ACCEL – Accelerator
ACD – Air Conditioner Demand
ACM – Aftertreatment Control Module
ACT PWR GND – Actuator Power Ground
A/F – Air to Fuel ratio
AFD – Aftertreatment Fuel Drain
AFI – Aftertreatment Fuel Injector
AFP – Aftertreatment Fuel Pressure
AFS – Aftertreatment Fuel Supply
AFT – Aftertreatment
AIT – Air Intake Temperature
Amb – Ambient
amp or A – Ampere
AMS – Air Management System
API – American Petroleum Institute
APS – Accelerator Position Sensor
APS/IVS – Accelerator Position Sensor / Idle Validation Switch
ASTM – American Society for Testing and Materials
ATA – American Trucking Association
ATDC – After Top Dead Center
AWG – American Wire Gauge

B+ or VBAT – Battery Voltage
BAP or BARO – Barometric Absolute Pressure
BARO or BAP – Barometric Absolute Pressure
BBDC – Before Bottom Dead Center
BCP – Brake Control Pressure
BCS – Boost Control Solenoid
BDC – Bottom Dead Center
bhp – Brake Horsepower
BNO – Brake Normally Open
BOO – Brake On / Off
BPS – Brake Pressure Switch
BSV – Brake Shut-off Valve
BTDC – Before Top Dead Center
BTU – British Thermal Unit

C – Celsius
CAC – Charge Air Cooler
CAN – Controller Area Network
CAP – Cold Ambient Protection
CARB – California Air Resources Board
cc – Cubic centimeter
CCA – Cold Cranking Ampere
CCV – Coolant Control Valve
CDR – Crankcase Depression Regulator
CID – Cubic Inch Displacement
cfm – Cubic feet per minute
cfs – Cubic feet per second
CFV – Coolant Flow Valve
CKP – Crankshaft Position
CKPO – Crankshaft Position Out
cm – Centimeter
CMP – Camshaft Position
CMPO – Camshaft Position Out
CMV – Coolant Mixer Valve
CO – Carbon Monoxide
COO – Cruise On / Off switch
CPU – Central Processing Unit
CSS – Cold Start Solenoid
CSR – Cold Start Relay
CTC – Coolant Temperature Compensation
Cyl – Cylinder

DB – Decibel
DCA – Diesel Coolant Additive
DDI – Digital Direct Fuel Injection
DDS – Driveline Disengagement Switch
DLC – Data Link Connector
DME – Dimethyl Ether
DMM – Digital Multimeter
DOC – Diesel Oxidation Catalyst
DPF – Diesel Particulate Filter
DT – Diesel Turbocharged
DTC – Diagnostic Trouble Code
DTRM – Diesel Thermo Recirculation Module

EBC – Exhaust Brake Controller
EBP – Exhaust Back Pressure
EBPD – Exhaust Back Pressure Desired
ECI – Engine Crank inhibit
ECL – Engine Coolant Level
ECM – Engine Control Module
ECM PWR – Engine Control Module Power
ECT – Engine Coolant Temperature
ECT2 – Engine Coolant Temperature 2
EFAN – Electronic Engine Fan
EFANS – Electronic Engine Fan Speed
EFP – Engine Fuel Pressure
EFRC – Engine Family Rating Code
EFT – Engine Fuel Temperature
EG – Ethylene Glycol
EGC – Electronic Gauge Cluster
EGDP – Exhaust Gas Differential Pressure

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EGR – Exhaust Gas Recirculation
EGRH – Exhaust Gas Recirculation High control
EGRL – Exhaust Gas Recirculation Low control
EGRP – Exhaust Gas Recirculation Position
EGT1 – Exhaust Gas Temperature 1
EGT2 – Exhaust Gas Temperature 2
EGT3 – Exhaust Gas Temperature 3
EIM – Engine Interface Module
ELS – Exhaust Lambda Sensor
EMI – Electromagnetic Interference
EOP – Engine Oil Pressure
EOT – Engine Oil Temperature
EPA – Environmental Protection Agency
EPR – Engine Pressure Regulator
ESC – Electronic System Controller
ESN – Engine Serial Number
EST – Electronic Service Tool
EVB – Exhaust Valve Brake
EWPS – Engine Warning Protection System

F – Fahrenheit
FCV – Fuel Coolant Valve
FEL – Family Emissions Limit
fhp – Friction horsepower
FMI – Failure Mode Indicator
FPC – Fuel Pump Control
FPCV – Fuel Pressure Control Valve
fpm – Feet per minute
fps – Feet per second
FRP – Fuel Rail Pressure
ft – Foot
FVCV – Fuel Volume Control Valve

GND – Ground (electrical)
gal – Gallon
gal/h – U.S. Gallons per hour
gal/min – U. S. Gallons per minute
GCW – Gross Combined Weight
GCWR – Gross Combined Weight Rating
GPC – Glow Plug Control
GPD – Glow Plug Diagnostic
GPR – Glow Plug Relay
GVW – Gross Vehicle Weight

H_2O – Water
HC – Hydrocarbon
HCI – Hydrocarbon Injection
HFCM – Horizontal Fuel Conditioning Module
Hg – Mercury
hp – Horsepower
HPCAC – High Pressure Charge Air Cooler
hr – Hour
Hyd – Hydraulic

IAT – Intake Air Temperature
IAHC – Inlet Air Heater Control
IAHD – Inlet Air Heater Diagnostic
IAHR – Inlet Air heater Relay
IC – Integrated Circuit
ICP – Injector Control Pressure
ID – Inside Diameter
IDM – Injector Drive Module
IGN – Ignition
ILO – Injector Leak Off
in – Inch
inHg – Inch of mercury
inH_2O – Inch of water
INJ – Injector
IPR – Injection Pressure Regulator
ISIS® – International® Service Information System
IST – Idle Shutdown Timer
ITP – Internal Transfer Pump
ITV – Intake Throttle Valve
ITVH – Intake Throttle Valve High control
ITVL – Intake Throttle Valve Low control
ITVP – Intake Throttle Valve Position
IVS – Idle Validation Switch

JCT – Junction (electrical)

kg – Kilogram
km – Kilometer
km/h – Kilometers per hour
km/l – Kilometers per liter
KOEO – Key-On Engine-Off
KOER – Key-On Engine-Running
kPa – Kilopascal

L – Liter
L/h – Liters per hour
L/m – Liters per minute
L/s – Liters per second
lb – Pound
lbf – Pound-force
lb/s – Pounds per second
lbf·ft – Pound-force foot
lbf·in – Pound-force inch
lbm – Pounds of mass
LPCAC – Low Pressure Charge Air Cooler
LSD – Low Sulfur Diesel

m – Meter
m/s – Meters per second
MAF – Mass Air Flow
MAG – Magnetic
MAP – Manifold Absolute Pressure

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MAP/IAT – Manifold Absolute Pressure/Intake Air Temperature Sensor
MAT – Manifold Air Temperature
mep – Mean effective pressure
mi – Mile
mm – Millimeter
mpg – Miles per gallon
mph – Miles per hour
MPR – Main Power Relay
MSDS – Material Safety Data Sheet
MSG – Micro Strain Gauge
MSM – Multiplex System Module
MY – Model Year

NC – Normally closed (electrical)
NETS – Navistar Electronics Technical Support
Nm – Newton meter
NO – Normally Open (electrical)
NO_x – Nitrogen Oxides

OAT – Organic Acid Technology
OCC – Output Circuit Check
OCP – Overcrank Protection
OD – Outside Diameter
OL – Over Limit
ORH – Out-of-Range High
ORL – Out-of-Range Low
OSHA – Occupational Safety and Health Administration
OWL – Oil/Water Lamp

PID – Parameter Identifier
PN – Part Number
ppm – Parts per million
PROM – Programmable Read Only Memory
psi – Pounds per square inch
psia – Pounds per square inch absolute
psig – Pounds per square inch gauge
pt – Pint
PTO – Power Take-off
PWM – Pulse Width Modulate
PWR – Power (voltage)

qt – Quart

RAM – Random Access Memory
RAS – Resume / Accel Switch (speed control)
REPTO – Rear Engine Power Takeoff
RFI – Radio Frequency Interference
rev – Revolution
rpm – Revolutions per minute
RPRE – Remote Preset
RSE – Radiator Shutter Enable
RVAR – Remote Variable

SAE – Society of Automotive Engineers®
SCA – Supplemental Coolant Additive
SCCS – Speed Control Command Switches
SCS – Speed Control Switch
SHD – Shield (electrical)
SID – Subsystem Identifier
SIG GRD – Signal Ground
S/N – Serial Number
SW – Switch (electrical)
SYNC – Synchronizer

TACH – Tachometer output signal
TBD – To Be Determined
TCAPE – Truck Computer Analysis of Performance and Economy
TDC – Top Dead Center
TCM – Transmission Control Module
TTS – Transmission Tailshaft Speed

ULSD – Ultra Low Sulfur Diesel
UVC – Under Valve Cover

V – Volt
VBAT or B+ – Battery Voltage
VC – Volume Control
VEPS – Vehicle Electronics Programming System
VGT – Variable Geometry Turbocharger
VIGN – Ignition Voltage
VIN – Vehicle Identification Number
VOP – Valve Opening Pressure
VRE – Vehicle Retarder Enable
VREF – Reference Voltage
VSO or VSS_CAL – Vehicle Speed Output
VSS – Vehicle Speed Sensor
VSS_CAL or VSO – Vehicle Speed Output

WEL – Warn Engine Lamp
WIF – Water In Fuel
WTEC – World Transmission Electronically Controlled automatic transmissions (Allison)

XMNS – Transmission

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Terminology

Terms

Accessory work – The work per cycle required to drive engine accessories (normally, only those essential to engine operation).

Actuator – A device that performs work in response to an input signal.

Aeration – The entrainment of air or combustion gas in coolant, lubricant, or fuel.

Aftercooler (Charge Air Cooler) – A heat exchanger mounted in the charge air path between the turbocharger and engine intake manifold. The aftercooler reduces the charge air temperature by transferring heat from the charge air to a cooling medium (usually air).

Ambient temperature – The environmental air temperature in which a unit is operating. In general, the temperature is measured in the shade (no solar radiation) and represents the air temperature for other engine cooling performance measurement purposes. Air entering the radiator may or may not be the same ambient due to possible heating from other sources or recirculation. (SAE J1004 SEP81)

Ampere (amp) – The standard unit for measuring the strength of an electrical current. The flow rate of a charge in a conductor or conducting medium of one coulomb per second. (SAE J1213 NOV82)

Analog – A continuously variable voltage.

Analog to digital converter (A/D) – A circuit in the ECM processing section that converts an analog signal (DC or AC) to a usable digital signal for the microprocessor.

American Trucking Association (ATA) Datalink – A serial datalink specified by the American Trucking Association and the SAE.

Boost pressure – 1. The pressure of the charge air leaving the turbocharger.

2. Inlet manifold pressure that is greater than atmospheric pressure. Obtained by turbocharging.

Bottom Dead Center (BDC) – The lowest position of the piston during the stroke.

Brake Horsepower (bhp) – The power output from an engine, not the indicated horsepower. The power output of an engine, sometimes-called flywheel horsepower is less than the indicated horsepower by the amount of friction horsepower consumed in the engine.

Brake Horsepower (bhp) net – Net brake horsepower is measured with all engine components. The power of an engine when configured as a fully equipped engine. (SAE J1349 JUN90)

Calibration – The data values used by the strategy to solve equations and make decisions. Calibration values are stored in ROM and put into the processor during programming to allow the engine to operate within certain parameters.

Catalyst – A substance that produces a chemical reaction without undergoing a chemical change itself.

Catalytic converter – An antipollution device in the exhaust system that contains a catalyst for chemically converting some pollutants in the exhaust gases (carbon monoxide, unburned hydrocarbons, and oxides of nitrogen) into harmless compounds.

Cavitation – A dynamic condition in a fluid system that forms gas-filled bubbles (cavities) in the fluid.

Cetane number – 1. The auto-ignition quality of diesel fuel.

2. A rating applied to diesel fuel similar to octane rating for gasoline.

3. A measure of how readily diesel fuel starts to burn (self-ignites) at high compression temperature.

Diesel fuel with a high cetane number self-ignites shortly after injection into the combustion chamber. Therefore, it has a short ignition delay time. Diesel fuel with a low cetane number resists self-ignition. Therefore, it has a longer ignition delay time.

Charge air – Dense, pressurized, heated air discharged from the turbocharger.

Charge Air Cooler (CAC) – See **Aftercooler**.

Closed crankcase – A crankcase ventilation that recycles crankcase gases through a breather, then back to the clean air intake.

Closed loop operation – A system that uses a sensor to provide feedback to the ECM. The ECM uses the sensor to continuously monitor variables and adjust to match engine requirements.

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Cloud point – The point when wax crystals occur in fuel, making fuel cloudy or hazy. Usually below -12 °C (10 °F).

Cold cranking ampere rating (battery rating) – The sustained constant current (in amperes) needed to produce a minimum terminal voltage under a load of 7.2 volts per battery after 30 seconds.

Continuous Monitor Test – An ECM function that continuously monitors the inputs and outputs to ensure that readings are within set limits.

Coolant – A fluid used to transport heat from one point to another.

Coolant level switch – A switch sensor used to indicate low coolant level.

Crankcase – The housing that encloses the crankshaft, connecting rods, and allied parts.

Crankcase breather – A vent for the crankcase to release excess interior air pressure.

Crankcase pressure – The force of air inside the crankcase against the crankcase housing.

Current – The flow of electrons passing through a conductor. Measured in amperes.

Damper – A device that reduces the amplitude of torsional vibration. (SAE J1479 JAN85)

Deaeration – The removal or purging of gases (air or combustion gas) entrained in coolant or lubricating oil.

Deaeration tank – A separate tank in the cooling system used for one or more of the following functions:

- Deaeration
- Coolant reservoir (fluid expansion and afterboil)
- Coolant retention
- Filling
- Fluid level indication (visible)

Diagnostic Trouble Code (DTC) – Formerly called a Fault Code or Flash Code. A DTC is a three digit numeric code used for troubleshooting.

Digital Multimeter (DMM) – An electronic meter that uses a digital display to indicate a measured value. Preferred for use on microprocessor systems because it has a very high internal impedance and will not load down the circuit being measured.

Disable – A computer decision that deactivates a system and prevents operation of the system.

Displacement – The stroke of the piston multiplied by the area of the cylinder bore multiplied by the number of cylinders in the engine.

Driver (high side) – A transistor within an electronic module that controls the power to an actuator circuit.

Driver (low side) – A transistor within an electronic module that controls the ground to an actuator circuit.

Duty cycle – A control signal that has a controlled on/off time measurement from 0 to 100%. Normally used to control solenoids.

Engine lamp – An instrument panel lamp that comes on when DTCs are set. DTCs can be read as flash codes (red and amber instrument panel lamps).

Engine OFF tests – Tests that are done with the ignition switch ON and the engine OFF.

Engine rating – Engine rating includes **Rated hp** and **Rated rpm**.

Engine RUNNING tests – Tests done with the engine running.

Exhaust brake – A brake device using engine exhaust back pressure as a retarding medium.

Exhaust manifold – Exhaust gases flow through the exhaust manifold to the turbocharger exhaust inlet and are directed to the EGR cooler.

Fault detection/management – An alternate control strategy that reduces adverse effects that can be caused by a system failure. If a sensor fails, the ECM substitutes a good sensor signal or assumed sensor value in its place. A lit amber instrument panel lamp signals that the vehicle needs service.

Filter restriction – A blockage, usually from contaminants, that prevents the flow of fluid through a filter.

Flash code – See **Diagnostic Trouble Code (DTC)**.

Fuel inlet restriction – A blockage, usually from contaminants, that prevents the flow of fluid through the fuel inlet line.

Fuel pressure – The force that the fuel exerts on the fuel system as it is pumped through the fuel system.

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Fuel strainer – A pre-filter in the fuel system that keeps larger contaminants from entering the fuel system.

Fully equipped engine – A fully equipped engine is an engine equipped with only those accessories necessary to perform its intended service. A fully equipped engine does not include components that are used to power auxiliary systems. If these components are integral with the engine or for any reason are included on the test engine, the power absorbed may be determined and added to the net brake power. (SAE J1995 JUN90)

Fusible link (fuse link) – A fusible link is a special section of low tension cable designed to open the circuit when subjected to an extreme current overload. (SAE J1156 APR86)

Gradeability – The maximum percent grade which the vehicle can transverse for a specified time at a specified speed. The gradeability limit is the grade upon which the vehicle can just move forward. (SAE J227a)

Gross Combined Weight Rating (GCWR) – Maximum combined weight of towing vehicle (including passengers and cargo) and the trailer. The GCWR indicates the maximum loaded weight that the vehicle is allowed to tow.

Gross brake horsepower – The power of a complete basic engine, with air cleaner, without fan, and alternator and air compressor not charging.

Hall effect – The development of a transverse electric potential gradient in a current-carrying conductor or semiconductor when a magnetic field is applied.

Hall effect sensor – Generates a digital on/off signal that indicates speed and timing.

High speed digital inputs – Inputs to the ECM from a sensor that generates varying frequencies (engine speed and vehicle speed sensors).

Horsepower (hp) – Horsepower is the unit of work done in a given period of time, equal to 33,000 pounds multiplied by one foot per minute. **1hp = 33,000 lb x 1 ft /1 min**.

Hydrocarbons – Unburned or partially burned fuel molecules.

Idle speed –

- Low idle is minimum rpm at no load.
- High idle is maximum rpm at no load.

Intake manifold – A collection of tubes through which the fuel-air mixture flows from the fuel injector to the intake valves of the cylinders.

International NGV Tool Utilized for Next Generation Electronics (INTUNE) – The diagnostics software for chassis related components and systems.

Low speed digital inputs – Switched sensor inputs that generate an on/off (high/low) signal to the ECM. The input to the ECM from the sensor could be from a high input source switch (usually 5 or 12 volts) or from a grounding switch that grounds the signal from a current limiting resistor in the ECM that creates a low signal (0 volts).

Lubricity – Lubricity is the ability of a substance to reduce friction between solid surfaces in relative motion under loaded conditions.

Lug (engine) – A condition when the engine is operating at or below maximum torque speed.

Manometer – A double-leg liquid-column gauge, or a single inclined gauge, used to measure the difference between two fluid pressures. Typically, a manometer records in inches of water.

MasterDiagnostics® (MD) – The diagnostics software for engine related components and systems.

Microprocessor – An integrated circuit in a microcomputer that controls information flow.

Nitrogen Oxides (NO_x) – Nitrogen oxides form by a reaction between nitrogen and oxygen at high temperatures and pressures in the combustion chamber.

Normally closed – Refers to a switch that remains closed when no control force is acting on it.

Normally open – Refers to a switch that remains open when no control force is acting on it.

Ohm (Ω) – The unit of resistance. One ohm is the value of resistance through which a potential of one volt will maintain a current of one ampere. (SAE J1213 NOV82)

On demand test – A self test that the technician initiates using the EST and is run from a program in the processor.

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Output Circuit Check (OCC) – An On demand test done during an Engine OFF self test to check the continuity of selected actuators.

pH – A measure of the acidity or alkalinity of a solution.

Particulate matter – Particulate matter includes mostly burned particles of fuel and engine oil.

Piezometer – An instrument for measuring fluid pressure.

Power – Power is a measure of the rate at which work is done. Compare with **Torque**.

Power TakeOff (PTO) – Accessory output, usually from the transmission, used to power a hydraulic pump for a special auxiliary feature (garbage packing, lift equipment, etc).

Pulse Width Modulate (PWM) – The time that an actuator, such as an injector, remains energized.

Random Access Memory (RAM) – Computer memory that stores information. Information can be written to and read from RAM. Input information (current engine speed or temperature) can be stored in RAM to be compared to values stored in Read Only Memory (ROM). All memory in RAM is lost when the ignition switch is turned off.

Rated gross horsepower – Engine gross horsepower at rated speed as declared by the manufacturer. (SAE J1995 JUN90)

Rated horsepower – Maximum brake horsepower output of an engine as certified by the engine manufacturer. The power of an engine when configured as a basic engine. (SAE J1995 JUN90)

Rated net horsepower – Engine net horsepower at rated speed as declared by the manufacturer. (SAE J1349 JUN90)

Rated speed – The speed, as determined by the manufacturer, at which the engine is rated. (SAE J1995 JUN90)

Rated torque – Maximum torque produced by an engine as certified by the manufacturer.

Ratiometric Voltage – In a Micro Strain Gauge (MSG) sensor 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.

Reference voltage (V_{REF}) – A 5 volt reference supplied by the ECM to operate the engine sensors.

Reserve capacity – Time in minutes that a fully charged battery can be discharged to 10.5 volts at 25 amperes.

Signal ground – The common ground wire to the ECM for the sensors.

Speed Control Command Switches (SCCS) – A set of switches used for cruise control, Power TakeOff (PTO), and remote hand throttle system.

Steady state condition – An engine operating at a constant speed and load and at stabilized temperatures and pressures. (SAE J215 JAN80)

Strategy – A plan or set of operating instructions that the microprocessor follows for a desired goal. Strategy is the computer program itself, including all equations and decision making logic. Strategy is always stored in ROM and cannot be changed during calibration.

Stroke – Stroke is the movement of the piston from Top Dead Center (TDC) to Bottom Dead Center (BDC).

Substrate – Material that supports the washcoating or catalytic materials.

System restriction (air) – The static pressure differential that occurs at a given air flow from air entrance through air exit in a system. Usually measured in inches (millimeters) of water. (SAE J1004 SEP81)

Tachometer output signal – Engine speed signal for remote tachometers.

Thermistor – A semiconductor device. A sensing element that changes resistance as the temperature changes.

Thrust load – A thrust load pushes or reacts through a bearing in a direction parallel to the shaft.

Top Dead Center (TDC) – The uppermost position of the piston during the stroke.

Torque – A force having a twisting or turning effect. For a single force, the cross product of a vector from some reference point to the point of application of the force within the force itself. Also known as moment of force or rotation moment. Torque is a measure of the ability of an engine to do work.

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Truck Computer Analysis of Performance and Economy (TCAPE) – Truck Computer Analysis of Performance and Economy is a computer program that simulates the performance and fuel economy of trucks.

Turbocharger – A turbine driven compressor mounted to the exhaust manifold. The turbocharger increases the pressure, temperature and density of intake air to charge air.

Variable capacitance sensor – A variable capacitance sensor measures pressure. The pressure forces a ceramic material closer to a thin metal disc in the sensor, changing the capacitance of the sensor.

Vehicle Electronic System Programming System – The computer system used to program electronically controlled vehicles.

Vehicle Retarder Enable/Engage – Output from the ECM to a vehicle retarder.

Vehicle Speed Sensor (VSS) – Normally a magnetic pickup sensor mounted in the tailshaft housing of the transmission, used to indicate ground speed.

Viscosity – The internal resistance to the flow of any fluid.

Viscous fan – A fan drive that is activated when a thermostat, sensing high air temperature, forces fluid through a special coupling. The fluid activates the fan.

Volt (v) – A unit of electromotive force that will move a current of one ampere through a resistance of one Ohm.

Voltage – Electrical potential expressed in volts.

Voltage drop – Reduction in applied voltage from the current flowing through a circuit or portion of the circuit current multiplied by resistance.

Voltage ignition – Voltage supplied by the ignition switch when the key is ON.

Washcoat – A layer of alumina applied to the substrate in a monolith-type converter.

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Fuel System

Table 44 Fuel System

Fuel strainer filtration	300 microns
Fuel filter element filtration	3-5 microns

Air Inlet Duct and Exhaust Manifolds

Table 45 Exhaust Manifolds

Exhaust manifold maximum allowable warpage	0.1 mm (0.003 in)

Cylinder Head, Camshaft and Valve Train

Table 46 Cylinder Head, Camshaft and Valve Train

Camshaft	
Camshaft end play	0.25 – 0.85 mm (0.0098 – 0.0334 in)
Camshaft bearing inside diameter	39.925 – 39.950 mm (1.57185 – 1.57283 in)
Valve Lash Adjustment	
Intake valve clearance	0.5 mm (0.0196 in)
Exhaust valve clearance	0.8 mm (0.0314 in)
Counterpiece clearance	0.6 mm (0.0236 in)
Cylinder Intermediate Gear Access Cover	
Cover recess	2.3 mm (0.9 in)

Flywheel and Flywheel Housing

Table 47 Flywheel and Flywheel Housing

Flywheel minimum thickness (dimension “A”)	46 mm (1.811 in)

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Oil Pump, Low Mount Fan Drive, and Timing Gears

Table 48 Oil Pump, Low Mount Fan Drive, and Timing Gears

Front Timing Gears	
Front intermediate gear backlash	0.057 - 0.183 mm (0.0022 - 0.0072 in)
Oil Pump	
Oil pump pinion and oil pump ring gear end play	0.0030 - 0.120 mm (0.0012 - 0.0047 in)
Rear Timing Gears	
Big intermediate gear backlash	0.052 - 0.176 mm (0.0020 - 0.0069 in)
Crankcase intermediate gear backlash	0.052 - 0.176 mm (0.0020 - 0.0069 in)

Power Cylinders

Table 49 Power Cylinders

Connecting Rods	
Piston pin bore inside diameter	52.06 ± 0.005 mm (2.0496 ± 0.0001 in)
Connecting rod bearing bore diameter (crankshaft end)	95.000 to 95.022 mm (3.7402 to 3.7402 in)
Pistons — 11L	
Diameter measured 16 mm from piston bottom edge	119.88 ± 0.009 mm (4.7197 ± 0.0004 in)
Piston protrusion measured from crankcase deck to piston	0.3 ± 0.22 mm (0.0118 ± 0.009 in)
Piston pin bore inside diameter	52.010 - 52.016 mm (2.0476 - 2.0479 in)
Piston pin running clearance	0.010 - 0.024 mm (0.0004 - 0.0009 in)
Pistons — 13L	
Diameter measured 26.9 mm from piston bottom edge	125.950 ± 0.013 mm (4.9587 ± 0.0005 in)
Piston protrusion measured from crankcase deck to piston	0.3 ± 0.22 mm (0.0118 ± 0.009 in)
Piston pin bore inside diameter	52.04 - 52.05 mm (2.0490 - 2.0492 in)
Piston pin running clearance	0.040 - 0.058 mm (0.0016 - 0.0023 in)
Piston Pins	

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Table 49 Power Cylinders (cont.)

Outside diameter	51.992 - 52.000 mm (2.0469 - 2.0472 in)
Piston Rings — 11L	
Keystone ring	
Ring gap	0.4 - 0.55 mm (0.0157 - 0.0217 in)
Taper face compression ring	
Ring gap	0.90 - 1.00 mm (0.0354 - 0.0393 in)
Side clearance	0.07 - 0.13 mm (0.0028 - 0.0051 in)
Bevelled oil scraper ring	
Ring gap	0.25 - 0.55 mm (0.0098 - 0.0217 in)
Side clearance	0.03 - 0.07 mm (0.0012 - 0.0028 in)
Piston Rings — 13L	
Keystone ring	
Ring gap	0.4 - 0.55 mm (0.0157 - 0.0217 in)
Taper face compression ring	
Ring gap	1.00 - 1.02 mm (0.0394 - 0.0402 in)
Side clearance	0.02 - 0.11 mm (0.0008 - 0.0043 in)
Bevelled oil scraper ring	
Ring gap	0.25 - 0.50 mm (0.0098 - 0.0197 in)
Side clearance	0.05 - 0.09 mm (0.0020 - 0.0035 in)
Liner dimensions — 11L	
Liner protrusion	0.050 - 0.085 mm (0.0019 - 0.0033 in)
Liner inside diameter	120 ± 0.01 mm (4.7244 ± 0.0004 in)
Liner dimensions — 13L	
Liner protrusion	0.050 - 0.085 mm (0.0019 - 0.0033 in)
Liner inside diameter	126 ± 0.01 mm (4.9606 ± 0.0004 in)

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Crankcase and Crankshaft

Table 50 Crankcase and Crankshaft

Crankshaft	
Main Bearing:	
Journal diameter	103.98 - 104.00 mm (4.0937 - 4.0945 in)
Installed inside diameter	104.06 - 104.106 mm (4.0969 - 4.0987 in)
Free spread	0.20 - 1.40 mm (0.0079 - 0.0551 in)
Connecting Rod Bearing:	
Journal diameter	89.98 - 90.00 mm (3.5425 - 3.5433 in)
Crankshaft end play:	
Maximum service	0.200 - 0.401 mm (0.0079 - 0.0158 in)

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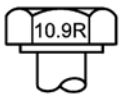
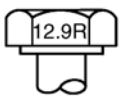
General Torque

Bolt Identification

INTERNATIONAL Class	ISO R 898 I	MATERIAL	THERMAL TREATMENT	HEAD MARKING Preferred	HEAD MARKING Optional
5.8	5.8	Low or medium Carbon steel	Non required		
8.8	8.8	Medium carbon, Medium carbon Alloy steel or low Carbon boron steel	Quench and tempered		
9.8	–	Medium carbon, Medium carbon Alloy steel or low Carbon boron steel	Quench and tempered		
10.9	10.9	Medium carbon, Medium carbon Alloy steel or low Carbon boron steel	Quench and tempered		

M03100

Figure 725 Metric fasteners – Classification and identification

INTERNATIONAL designation	MATERIAL	THERMAL TREATMENT	HEAD MARKING Preferred	HEAD MARKING Optional
CLASS		METRIC FASTENERS		
10.9R	Medium carbon, Medium carbon Alloy steel	Quench and tempered, Roll threaded after heat treatment		
12.9R	Medium carbon Alloy steel	Quench and tempered, Roll threaded after heat treatment		

M03101

Figure 726 Special fasteners – Classification and identification

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General Torque Guidelines

CAUTION: To prevent engine damage, do not substitute fasteners. All original equipment fasteners are hardened and phosphate coated.

NOTE: Inspect parts for cleanliness and defects before assembly.

Many conditions affect torque and the results of torque applications. The major purpose in tightening a fastener to a specified torque is to obtain a clamping load which exceeds any possible loading imposed on parts.

New phosphate coated fasteners do not require oil lubrication during assembly and torque application. Reused fasteners (even if originally phosphate coated) do require oil lubrication to threads and under head area for correct torque application.

Threads that are dry, excessively rough, battered, or filled with dirt require considerable effort just to rotate. Then when the clamping load is developed or the bolt tension is applied, the torque reading mounts rapidly (due to thread friction) to the specified torque value. However, the desired bolt tension and correct clamping load is not achieved. This condition can lead to failure of the fastener to maintain component integrity. The correct bolt tension and clamping effect can never be attained if the fastener is dry. Fastener threads must be new condition phosphate coated or have a film of clean lubricant (engine oil) to be considered lubricated.

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Standard Torque Charts

CAUTION: To prevent engine damage, do not use this standard torque chart with other International brand engines or engines made by other manufacturers.

Standard torque chart provides tightening values for all hardware that do not require special torque.

Standard Torque Values - Class 10.9 Metric Flange Head Bolts and Studs

Thread Diameter (mm)	Thread Pitch (mm)	Torque
6	1	13 N·m (115 lbf·in)
8	1.25	31 N·m (23 lbf·ft)
10	1.5	62 N·m (45 lbf·ft)
12	1.75	107 N·m (79 lbf·ft)
14	2	172 N·m (127 lbf·ft)
15	2	216 N·m (159 lbf·ft)
16	2	266 N·m (196 lbf·ft)
18	2.5	368 N·m (272 lbf·ft)
20	2.5	520 N·m (384 lbf·ft)

Example: Tighten four M6 x 12 pulley bolts to standard torque. What is the size and standard torque for these four bolts?

M6 x 12 refers to the bolts thread diameter and length. These bolts have a thread diameter of 6 mm and are 12 mm long.

To find the standard torque for a M6 x 12 bolt look at the torque chart above. We see the standard torque for a 6 mm thread diameter class 10.9 bolt should be 13 N·m (115 lbf·in).

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Using a Torque Wrench Extension

Occasionally an extension, crowfoot, or other adapter is necessary to use with a torque wrench to torque a bolt or line fitting. Adding adapters or extensions will alter the torque on the fastener from what the torque wrench reads. Use the following formula to calculate the correct torque wrench setting to achieve a specific torque value.

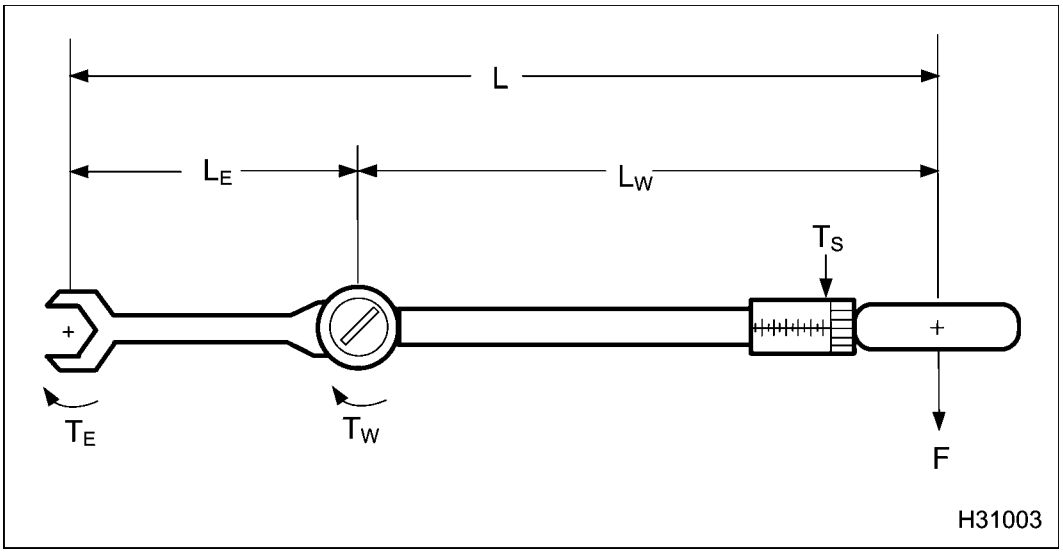

Figure 727 Torque wrench and extension

- F - Force applied by technician
- L - Total length through which force is applied to fastener
- T_W - Torque applied at end of torque wrench

$T_S = T_E (L_W / (L_W + L_E))$

- T_S - Torque wrench setting
- T_E - Torque specified at fastener
- L_W - Length of torque wrench
- L_E - Length of extension

Example: A component requires a specified torque value of 65 lbf·ft and a 6 inch extension is required to reach it. What should the torque wrench setting (T_S) be to compensate for the extension?

- Torque specified at fastener (T_E) = 65 lbf·ft
- Length of torque wrench (L_W) = 12 inches
- Length of extension (L_E) = 6 inches

$T_S = T_E (L_W / (L_W + L_E))$

T_S = 65 lbf·ft (12 inches / (12 inches + 6 inches)

T_S = 65 lbf·ft (12 inches / (18 inches)

T_S = 65 lbf·ft (0.666)

T_S = 43.33 lbf·ft

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Special Torques

Mounting Engine on Stand

Table 51 Mounting Engine on Stand

Oil pan drain plug	75 N·m (55 lbf·ft)
Engine support hex bolts	230 N·m (170 lbf·ft)

Engine Electrical

Table 52 Engine Electrical

Camshaft Position (CMP) sensor bolt	8 N·m (71 lbf·in)
Crankshaft Position (CKP) sensor bolt	8 N·m (71 lbf·in)
Engine Coolant Temperature (ECT) sensor	45 N·m (33 lbf·ft)
Engine Coolant Temperature 2 (ECT2) sensor	45 N·m (33 lbf·ft)
Engine Fuel Pressure (EFP) sensor	45 N·m (33 lbf·ft)
Exhaust Lambda Sensor (ELS)	50 N·m (37 lbf·ft)
Fuel Rail Pressure (FRP) sensor	140 N·m (103 lbf·ft)
Manifold Absolute Pressure/Intake Air Temperature 2 (MAP/IAT2) sensor bolts	9 N·m (80 lbf·in)
Manifold Air Temperature (MAT) sensor	45 N·m (33 lbf·ft)

Cold Start Assist

Table 53 Cold Start Assist

Adapter	15 N·m (11 lbf·ft)
Cold start relay (CSR) hex bolts	8 N·m (71 lbf·in)
Size 6 hollow screw	15 N·m (11 lbf·ft)
Size 8 hollow screw	15 N·m (11 lbf·ft)
MV-glow plug fuel line fitting nuts	10 N·m (11 lbf·ft)
Cold start solenoid (CSS) valve hex bolts	6 N·m (53 lbf·in)
Glow plug locking nut	25 N·m (18 lbf·ft)

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Aftertreatment System

Table 54 Aftertreatment System (in order of installation)

Profiled clamp (119)	7 N·m (62 lbf·in)
Aftertreatment fuel injector (AFI) hex bolts	See tightening steps in procedure.
Coolant return assembly P-clamp hex bolts	31 N·m (23 lbf·ft)
Parker® vee 12 onto AFI	41 N·m (30 lbf·ft)
Parker® ew12 onto Parker® vee 12	41 N·m (30 lbf·ft)
Coolant return assembly fitting nut to Parker® ew12	See tightening steps in procedure.
Parker® wee 12 into coolant elbow	41 N·m (30 lbf·ft)
Coolant supply line fitting nuts	See tightening steps in procedure.
Straight fitting into HC cut-off valve	24 N·m (18 lbf·ft)
M10 x 1 threaded union into HC cut-off valve	23 N·m (11 lbf·ft)
M14 x 1.5 threaded union into HC cut-off valve	35 N·m (26 lbf·ft)
Hydrocarbon (HC) cut-off valve hex bolts	31 N·m (23 lbf·ft)
M6 x 40 fuel supply assembly (upper line) P-clamp hex bolts	13 N·m (11 lbf·ft)
M8 x 16 fuel supply assembly (lower line) P-clamp hex bolt	31 N·m (23 lbf·ft)
Fuel supply assembly (upper line) fitting nut at connection of upper and lower lines	40 N·m (30 lbf·ft)
Fuel supply assembly (lower line) fitting nut at HC cut-off valve	27 N·m (20 lbf·ft)
Fuel supply assembly fitting nut (upper line) at Parker® 4C6MXSS	27 N·m (20 lbf·ft)
Parker® 4C6MXSS into AFI	15 N·m (11 lbf·ft)

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Engine Retarder Control

Table 55 Retarder Control System Components

DMR 114 profiled clamp	6 N·m (53 lbf·in)
Pressure line P-clamp stud bolt	35 N·m (26 lbf·ft)
Retarder control hex bolts	35 N·m (26 lbf·ft)
Size 6 hollow screw	20 N·m (15 lbf-ft)
Pressure line fitting nut to straight union	30 N·m (22 lbf·ft)
Pressure line fitting nut to ring union	30 N·m (22 lbf·ft)
Straight union	See tightening steps in procedure.
Pressure air line fitting nut to retarder control	12 N·m (106 lbf·in)
Pressure air line fitting nut to exhaust manifold with butterfly	12 N·m (106 lbf·in)
Air supply line assembly fitting nut to retarder control	12 N·m (106 lbf·in)

Turbochargers

Table 56 Turbochargers

High pressure turbocharger to low pressure turbocharger hexagon nuts	See tightening steps in procedure.
Banjo bolt	10 N·m (89 lbf·in)
Air intake manifold cylinder screw	10 N·m (89 lbf·in)
M32 x 1.5 threaded union (air intake duct)	See tightening steps in procedure.
M26 x 1.5 threaded union (air intake duct)	See tightening steps in procedure.
Rubber pad	10 N·m (89 lbf·in)
Straight union (for low pressure turbocharger oil pressure connection flange)	See tightening steps in procedure.
L12A straight union	See tightening steps in procedure.
Low pressure turbocharger oil pressure pipe fitting nuts	See tightening steps in procedure.
High pressure turbocharger oil pressure pipe fitting nuts	See tightening steps in procedure.
Low pressure turbocharger oil return pipe fitting nut	See tightening steps in procedure.
Low pressure turbocharger oil return pipe (to crankcase)	See tightening steps in procedure.

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Air Compressor and Power Steering

Table 57 Air Compressor and Power Steering

1-1/16" 90 degree elbow lock nut	55 N·m (40 lbf·ft)
1/2" 90 degree tube elbow lock nut	45 N·m (33 lbf·ft)
Air compressor hex bolts	35 N·m (26 lbf·ft)
Air compressor suction pipe M8 x 65 hex bolts	35 N·m (26 lbf·ft)
High pressure tube fitting nut	62 N·m (45 lbf·ft)
Low pressure tube fitting nut	164 N·m (120 lbf·ft)
Power steering pump heavy bolts	67 N·m (49 lbf·ft)

Fuel System

Table 58 Fuel System

Quick disconnect valve	35 N·m (26 lbf·ft)
Fuel filter housing assembly hex bolts	35 N·m (26 lbf·ft)
Fuel filter bracket hex bolts	35 N·m (26 lbf·ft)
High pressure pump hex bolts	60 N·m (44 lbf·ft)
Hollow screws (all sizes in this section)	30 N·m (21 lbf·ft)
Fuel drip line fitting nuts	40 N·m (30 lbf·ft)
Fuel filter screw cap	20-25 N·m (15-18 lbf·ft)
Fuel primer pump assembly hex bolts	45 N·m (33 lbf·ft)
Fuel strainer cover	10 N·m (89 lbf·in)
Injection line fitting nuts	10 N·m (89 lbf·in) + 60°
L10-A4C adapter	40 N·m (30 lbf·ft)
Pressure line fitting nuts	10 N·m (89 lbf·in) + 60°
Pressure pipe rail hex bolts	30 N·m (21 lbf·ft)
M14 x 1.5 threaded unions	30 N·m (21 lbf·ft)

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Oil Cooler, Filter Housing and Crankcase Ventilation

Table 59 Oil Module and Breather System

Breather hex nut	2.8 N.m (25 lbf·ft)
Engine Oil Pressure (EOP) sensor	47 N·m (35 lbf·ft)
Engine Oil Temperature (EOT) sensor	47 N·m (35 lbf·ft)
Oil cooler hex bolts	25 N·m (18 lbf·ft)
Oil filter cover	40 N·m (30 lbf·ft)
Oil module hex bolts	75 N·m (55 lbf·ft)
Oil pressure relief valve	40 N·m (30 lbf·ft)
M10 x 1.0 plug	75 N·m (55 lbf·ft)
M38 x 1.5 plug	80 N·m (59 lbf·ft)
M33 x 2 plugs	80 N·m (59 lbf·ft)
Flange elbow hex bolts	25 N·m (18 lbf·ft)
Water pump hex bolt	35 N·m (26 lbf·ft)
M26 x 1.5 threaded union	25 N·m (18 lbf·ft)
M12 straight fitting	25 N·m (18 lbf·ft)

Exhaust Gas Recirculation (EGR) System

Table 60 Exhaust Gas Recirculation (EGR) System

Air line assembly threaded fitting	12 N·m (106 lbf·in)
Air supply line assembly threaded fitting	12 N·m (106 lbf·in)
Coolant elbow (middle) hex bolt	35 N·m (28 lbf·ft)
Coolant elbow (upper) hex bolts and stud bolt	35 N·m (28 lbf·ft)
Coolant elbow (lower) hex bolts	35 N·m (28 lbf·ft)
Coolant pipe low temperature radiator (LTR) supply pipe clamp	4 N·m (35 lbf·in)
EGR throttle valve cylinder screws	35 N·m (26 lbf·ft)
EGR module hex bolts	75 N·m (55 lbf·ft)
Front inner and outer tubes hex bolts	35 N·m (28 lbf·ft)
Rear inner and outer tubes cylinder screws	35 N·m (28 lbf·ft)
Heat protection plates (front and rear) hex bolts	22 N·m (16 lbf·ft)

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Air Inlet Duct and Exhaust Manifolds

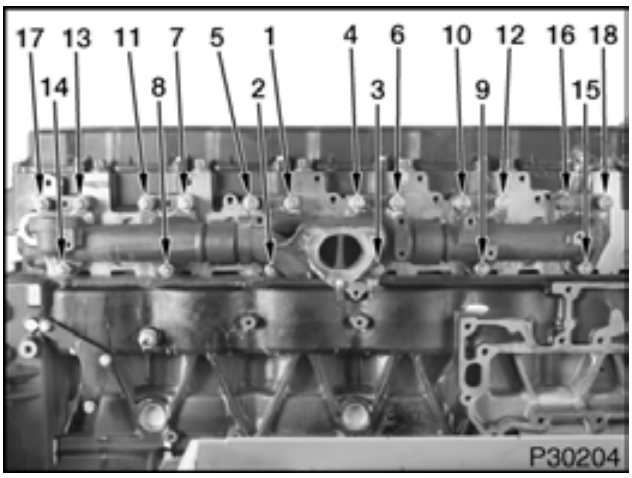

Figure 728 Exhaust manifold tightening sequence

Table 61 Air Inlet Duct and Exhaust Manifolds

Exhaust manifold screws	See tightening procedure and sequence
Air inlet duct hex bolts	15 N·m (11 lbf·ft)

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Front Cover, High Mount Fan Drive, Cooling System, Related Components

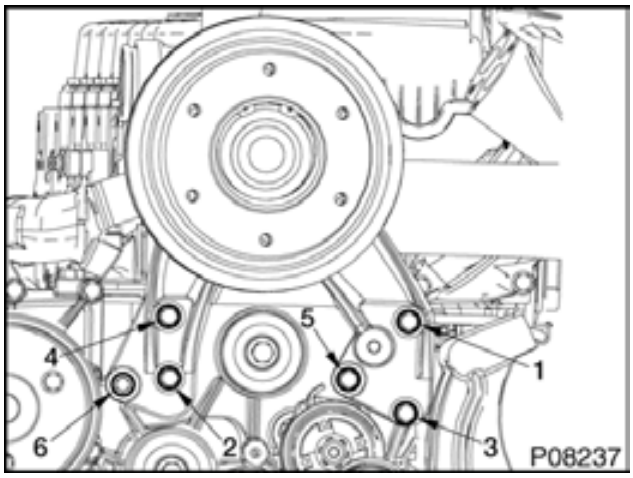

Figure 729 Tensioner bracket tightening sequence

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Table 62 Front Cover, High Mount Fan Drive, Cooling System, Related Components

Air clutch fan drive hex bolt	See tightening steps in procedure
Automatic belt tensioner countersunk screw	47 N·m (35 lbf·ft)
Cable roller hex bolts	60 N·m (44 lbf·ft)
Coolant Control Valve (CCV) hex bolts	31 N·m (23 lbf·ft)
Coolant elbow (to Exhaust Gas Recirculation (EGR) module) hex bolts	35 N·m (26 lbf·ft)
Coolant elbow (to radiator) hex bolts	35 N·m (26 lbf·ft)
Distributor case hex bolts	35 N·m (26 lbf·ft)
Drive housing hex bolts	115 N·m (85 lbf·ft)
High mount fan bracket	See tightening steps in procedure
High mount fan tensioner countersunk screw	47 N·m (35 lbf·ft)
Hub and pulley hex bolts to vibration damper	45 N·m (33 lbf·ft)
High mount fan pulley assembly shoulder bolt	62 N·m (45 lbf·ft)
M8 x 20 front crankcase cover hex bolts	35 N·m (26 lbf·ft)
M8 x 25 front crankcase cover hex bolts	35 N·m (26 lbf·ft)
M8 x 40 front crankcase cover hex bolts	35 N·m (26 lbf·ft)
M12 x 30 Drive housing pulley hex bolt	115 N·m (85 lbf·ft)
M12 x 70 front crankcase cover hex bolts	115 N·m (85 lbf·ft)
M14 x 30 front crankcase cover hex bolts	115 N·m (85 lbf·ft)
Thermostat housing assembly hex bolts	35 N·m (26 lbf·ft)
Water pump hex bolts	35 N·m (26 lbf·ft)
Water pump pulley hex bolts	35 N·m (26 lbf·ft)
Vibration damper cylinder screws	See tightening steps in procedure

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Cylinder Head, Camshaft and Valve Train

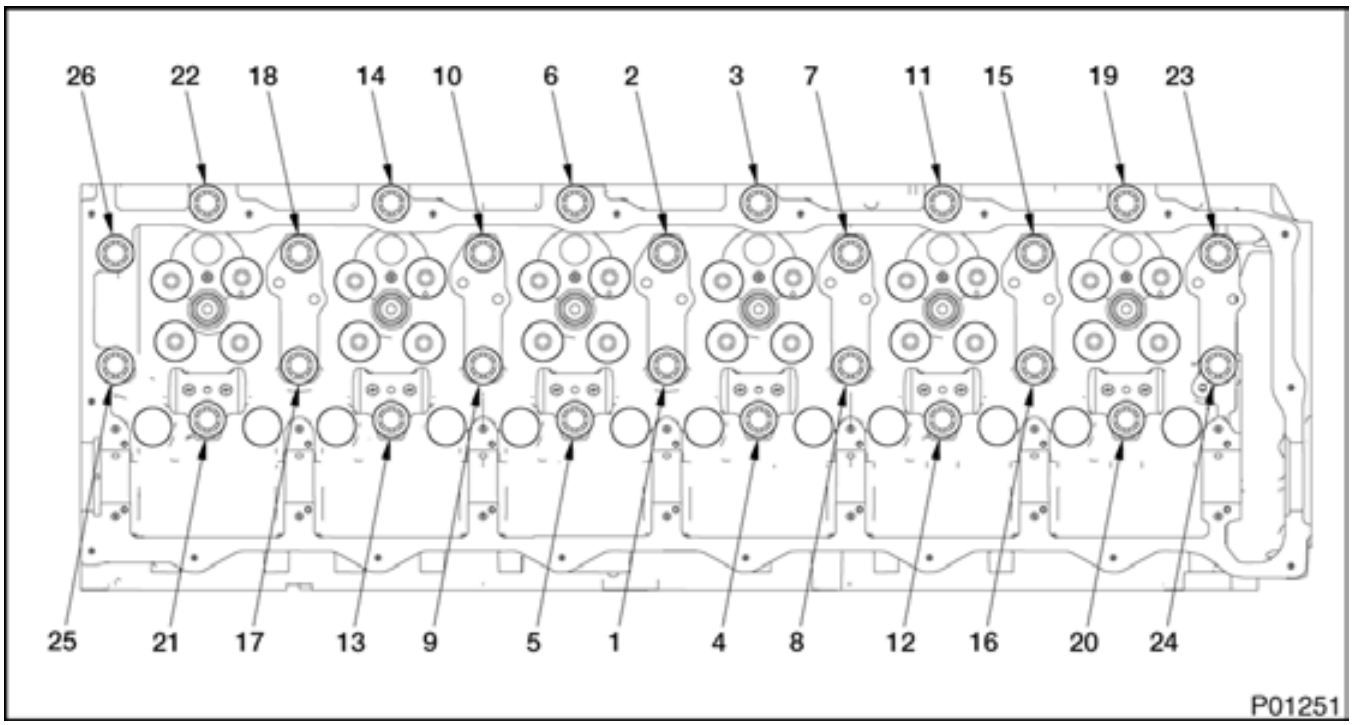

Figure 730 Cylinder head bolts tightening sequence

Table 63 Cylinder Head, Camshaft and Valve Train

Air inlet duct hex bolts	15 N·m (11 lbf·ft)
Cylinder head bearing cap hex bolt	35 N·m (26 lbf·ft)
Camshaft gear hex bolts	See tightening steps in procedure
Cylinder head collar bolts	See tightening steps in procedure
Cylinder intermediate gear cylinder screws	30 N·m (22 lbf·ft)
Counterpiece adjustment M14 hexagon nuts	45 N·m (33 lbf·ft)
Counterpiece hex bolts	75 N·m (55 lbf·ft)
Exhaust valve lash adjustment M10 hexagon nuts	45 N·m (33 lbf·ft)
Injector harness nuts	1.5 N·m (13 lbf·in)
Injector pressure flange hex bolts	See tightening steps in procedure
Intake valve lash adjustment M10 hexagon nuts	45 N·m (33 lbf·ft)
Pressure pipe nuts	55 N·m (40 lbf·ft)
Rocker gear cylinder screws	105 N·m (77 lbf·ft)
Valve cover screw with damper elements	11 N·m (97 lbf·in)

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Flywheel and Flywheel Housing

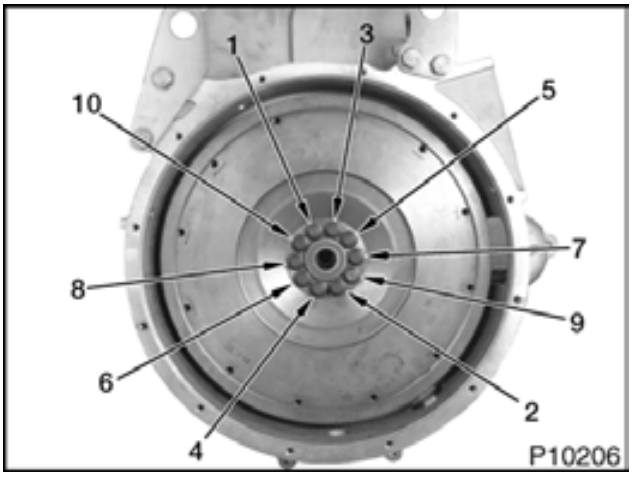

Figure 731 Flywheel tightening sequence

Table 64 Flywheel and Flywheel Housing

12KT flywheel bolts	See tightening steps in procedure.
Flywheel housing hex bolts	75 N·m (55 lbf·ft)
Lifting eye hex bolts	180 N·m (133 lbf·ft)

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Oil Pan and Oil Suction Tube

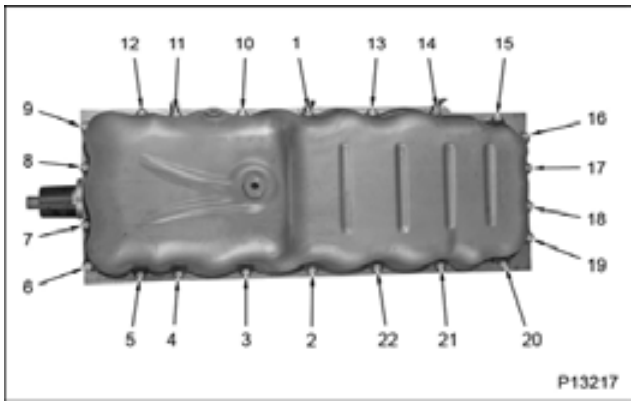

Figure 732 Torque sequence for oil sump bolts

Table 65 Oil Sump Components

Drain plug	75 N·m (55 lbf·ft)
Oil return pipe	4 N·m (35 lbf·in)
Oil sump bolts	See tightening steps procedure.
Preheater or replacement drain plug	75 N·m (55 lbf·ft)

Oil Pump, Low Mount Fan Drive, and Timing Gears

Table 66 Oil Pump, Low Mount Fan Drive, and Timing Gears

Front intermediate gear cylinder screws	105 N·m (77 lbf·ft)
Air compressor intermediate gear hex bolts	115 N·m (85 lbf·ft)
Crankcase intermediate gear cylinder screws	30 N·m (22 lbf·ft)
Big intermediate gear hex bolts	175 N·m (129 lbf·ft)
Fan drive hex bolts	35 N·m (26 lbf·ft)
Oil pump cover hex bolts	15 N·m (133 lbf·in)
Axle cylinder screw	65 N·m (48 lbf·ft)

Power Cylinders

Table 67 Power Cylinders

Connecting rod screws	Initial	100 N·m (74 lbf·ft)
	Final	90°
Cylinder Liner Protrusion Tool bolts		80 N·m (59 lbf·ft)

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Crankcase and Crankshaft

Table 68 Crankcase and Crankshaft

Main bearing cap hex collar bolts	See tightening procedure and sequence
Oil sprayer nozzle hex bolts	13 N·m (115 lbf·in)

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Special Tools

Special tools for the MaxxForce® 11 and 13 engines with ZTSE numbers can be ordered from the SPX Corporation, 1-800-520-2584.

Mounting Engine on Stand

Table 69 Mounting Engine on Stand

Description	Tool Number
Engine Stand Adapter Plate	ZTSE4789
Disposable Air and Fuel Caps	ZTSE4891

Engine Electrical

Table 70 Engine Electrical

Description	Tool Number
Disposable Air and Fuel Caps	ZTSE4891

Aftertreatment System

Table 71 Aftertreatment System

Description	Tool Number
Parker® ThreadMate™	Obtain locally
High-Temperature Nickel-Graphite Anti-Seize Compound	Obtain locally
Fuel Line Disconnect Tool 11.8 mm	ZTSE4773
White nylon detail brush	Obtain locally
Carb and choke cleaner	Obtain locally

Engine Retarder Control

Table 72 Engine Retarder Control

Description	Tool Number
P-80 ® Rubber Lubricant or equivalent	Obtain locally

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Turbochargers

Table 73 Turbochargers

Description	Tool Number
Charge Air Cooler Tester Kit	ZTSE4341
High Pressure CAC Test Plate	ZTSE4909
P-80 ® Rubber Lubricant or equivalent	Obtain locally

Air Compressor and Power Steering Pump

Table 74 Air Compressor

Description	Tool Number
Coolant Line Release Tool	ZTSE4778
Loctite® 5900 Sealant or equivalent	Obtain locally

Fuel System

Table 75 Fuel System

Description	Tool Number
Crowfoot Wrench	Obtain locally
Disposable Air and Fuel Caps	ZTSE4891
Fuel Line Disconnect Tool 11.8 mm	ZTSE4773

Oil Cooler, Filter Housing and Crankcase Ventilation

Table 76 Oil Cooler

Description	Tool Number
Air Pressure Regulator	Obtain locally
Oil Cooler Pressure Test Plates	ZTSE4879
P-80®Rubber Lubricant or equivalent	Obtain locally

Exhaust Gas Recirculation (EGR) System

Table 77 Exhaust Gas Recirculation (EGR) System

Description	Tool Number
Air Pressure Regulator	Obtain locally
EGR Cooler Pressure Test Plates	ZTSE4877
P-80® Rubber Lubricant or equivalent	Obtain locally

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Air Inlet Duct and Exhaust Manifolds

Table 78 Air Inlet Duct and Exhaust Manifolds

Description	Tool Number
Feeler Gauge	Obtain locally
Straightedge	Obtain locally
Loctite® 5900 Sealant or equivalent	Obtain locally

Front Cover, High Mount Fan Drive, Cooling System, and Related Components

Table 79 Front Cover, High Mount Fan Drive, Cooling System, and Related Components

Description	Tool Number
Fan Hub High Pressure Drive Seal Installer	ZTSE4776
Front Crankshaft Seal Installer	ZTSE4873
Liquid Gasket (RTV)	Obtain locally
Loctite® 5900 Sealant or equivalent	Obtain locally
P-80® Rubber Lubricant or equivalent	Obtain locally
Slide Hammer	Obtain locally

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Cylinder Head, Camshaft and Valve Train

Table 80 Cylinder Head, Camshaft and Valve Train

Description	Tool Number
1–2 inch Micrometer	Obtain locally
Bearing Installer	Obtain locally
Cylinder Head Lifting Bracket	ZTSE4869
Dial Indicator with Magnetic Base	Obtain locally
Disposable Air and Fuel Caps	ZTSE4891
Engine Rotating Tool	ZTSE4786
Feeler Gauge	Obtain locally
Fuel Injector Tip Cleaning Brush	ZTSE4301
Fuel Injector Rack Holder	ZTSE4299B
Fuel Injector Cups	ZTSE4892
Head Bolt Bottoming Tap	ZTSE4855
Head Bolt Torx Socket	ZTSE4835
Injector Installer	ZTSE4777
Injector Puller	ZTSE4770
Injector Sleeve Brushes	ZTSE4751
Loctite® 262™ Threadlocker	Obtain locally
Loctite® 5900 sealant or equivalent	Obtain locally
M8 x 20 class 10.9 bolts	Obtain locally
Telescoping Gauge Set	Obtain locally

Flywheel and Flywheel Housing

Table 81 Flywheel and Flywheel Housing

Description	Tool Number
1–2 Inch Micrometer	Obtain locally
Blind Hole Puller	Obtain locally
Pilot Bearing Installation Tool	ZTSE4898
Brake Cleaner (non-caustic)	Obtain locally
Dial Indicator With Magnetic Base	Obtain locally
Loctite 5900 or Equivalent	Obtain locally
Rear Oil Seal Installer	ZTSE4875
Slide Hammer	Obtain locally

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Oil Pan and Oil Suction Tube

Table 82 Oil Sump System

Description	Tool Number
Loctite ® 242	Obtain locally

Oil Pump, Low Mount Fan Drive, and Timing Gears

Table 83 Oil Pump, Low Mount Fan Drive, and Timing Gears

Description	Tool Number
Dial Indicator with Magnetic Base	Obtain locally
Fan Hub High Pressure Drive Seal Installer	ZTSE4776
Feeler Gauge	Obtain locally
Gear Puller	Obtain locally
Slide Hammer	Obtain locally

Power Cylinders

Table 84 Power Cylinders

Description	Tool Number
2–3 inch Micrometer	Obtain locally
3–4 inch Micrometer	Obtain locally
4–5 inch Micrometer	Obtain locally
Connecting Rod Bolt Torx Socket	ZTSE4843
Cylinder Liner Puller	ZTSE2536
Dial Bore Gauge	Obtain locally
Dial Indicator with Magnetic Base	Obtain locally
Feeler Gauge	Obtain locally
Piston Ring Compressor	Obtain locally
Piston Ring Expansion Pliers	Obtain locally
Sleeve Protrusion Hold Down Clamps	ZTSE4825
Telescoping Gauge Set	Obtain locally

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Crankcase and Crankshaft

Table 85 Crankcase and Crankshaft

Description	Tool Number
3–4 inch Micrometer	Obtain locally
4–5 inch Micrometer	Obtain locally
Dial Bore Gauge	Obtain locally
Dial Indicator with Magnetic Base	Obtain locally
Head Bolt Bottoming Tap	ZTSE4855
Lifting Sling	Obtain locally
Main Bolt Bottoming Tap	ZTSE4854

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Special Tools

Essential Tools

Figure 733 ZTSE4770 injector puller

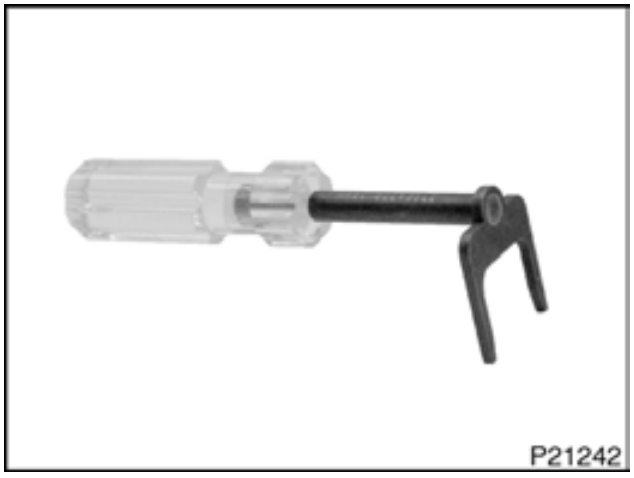

Figure 734 ZTSE4773 fuel line disconnect tool 11.8 mm

Figure 735 ZTSE4776 fan hub high pressure drive seal installer

Figure 736 ZTSE4777 injector installer

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Figure 737 ZTSE4778 coolant line release tool

Figure 738 ZTSE4786 engine rotating tool

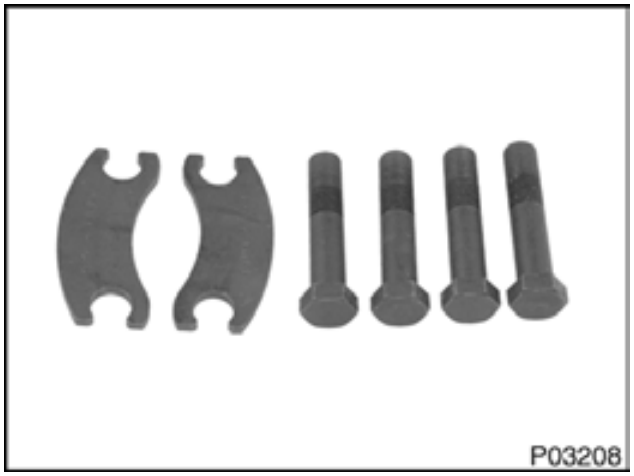

Figure 739 ZTSE4825 sleeve protrusion hold down clamps

Figure 740 ZTSE4835 head bolt torx socket

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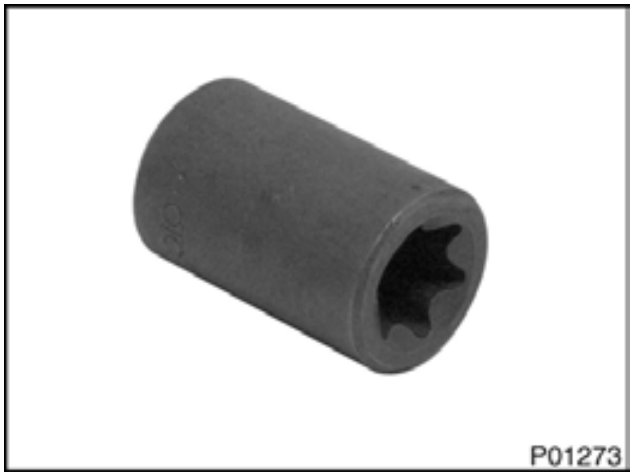

Figure 741 ZTSE4843 connecting rod bolt torx socket

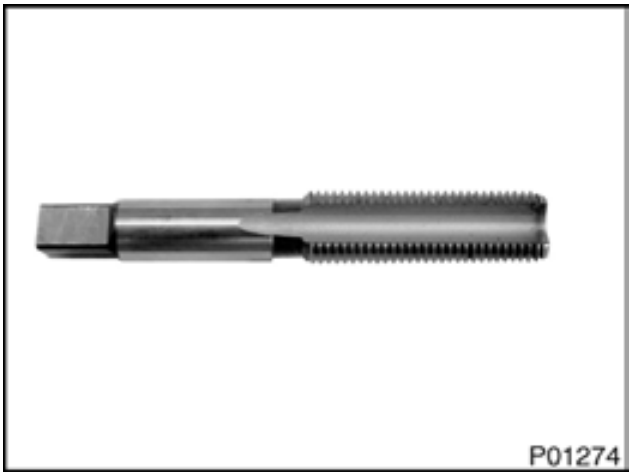

Figure 743 ZTSE4854 main bolt bottoming tap

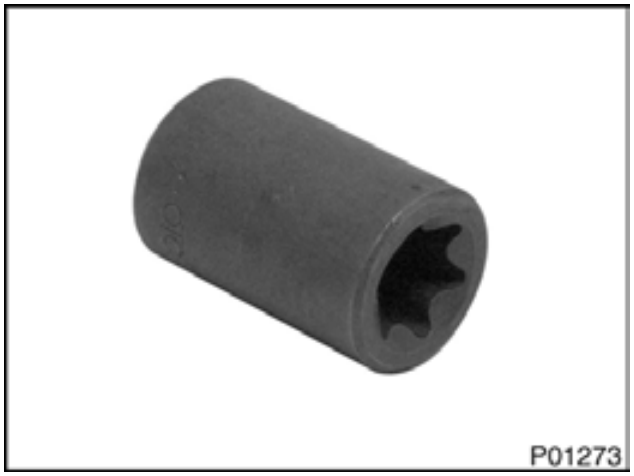

Figure 742 ZTSE4843 connecting rod bolt torx socket

Figure 744 ZTSE4855 head bolt bottoming tap

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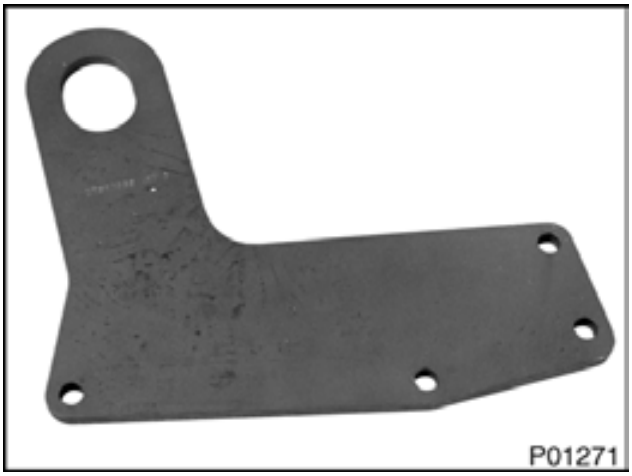

Figure 745 ZTSE4869 cylinder head lifting bracket

Figure 746 ZTSE4873 front crankshaft seal installer

Figure 747 ZTSE4875 rear oil seal installer

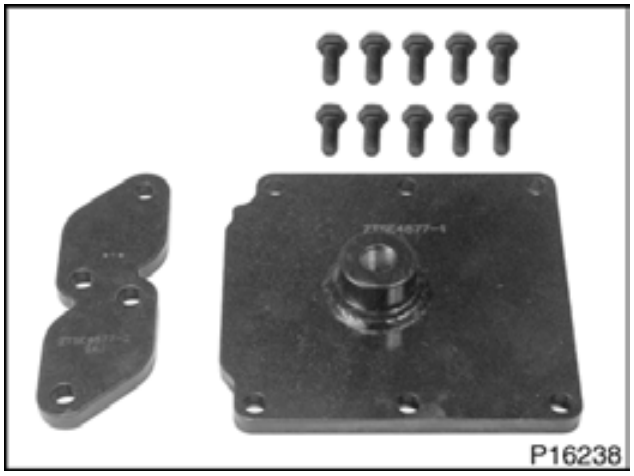

Figure 748 ZTSE4877 EGR cooler pressure test plates

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Figure 749 ZTSE4879 oil cooler pressure test plates

Figure 751 ZTSE4892 fuel injector caps (6)

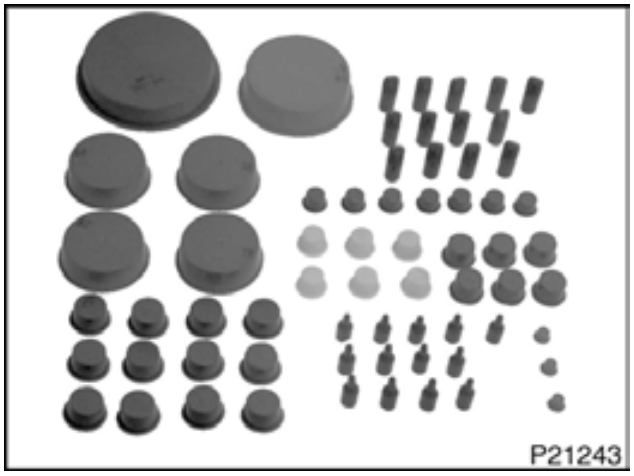

Figure 750 ZTSE4891 disposable air and fuel caps

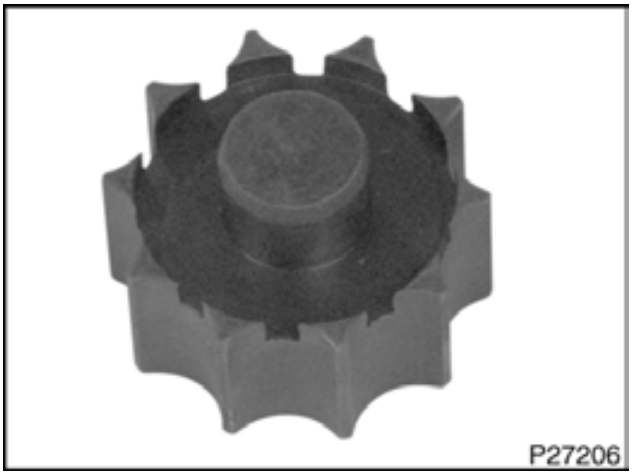

Figure 752 ZTSE4898 pilot bearing installation tool

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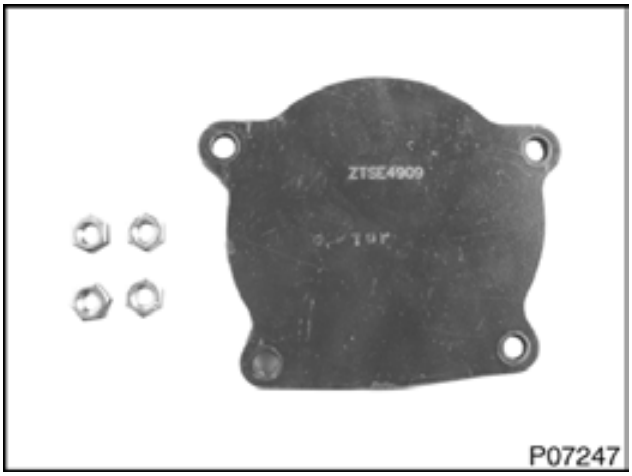

Figure 753 ZTSE4909 high pressure CAC test plate

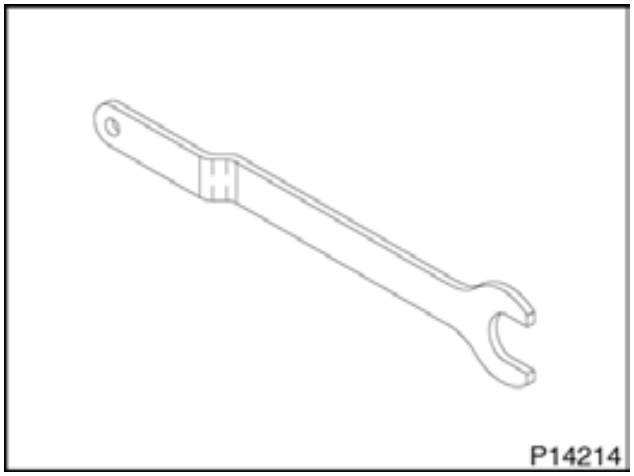

Figure 754 ZTSE4913 fan clutch nut wrench

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