ENGINE SERVICE MANUAL

Navistar® N13 with SCR

Navistar, Inc.

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Summary of Changes

Section Updated	Description
Engine Systems	Inserted updated Engine Systems section taken from 0000002161R9
Inlet Air Heater System	• Installation procedure updated to reflect correct installation of the IAHFI in the air intake throttle duct.
Engine Electrical	Added following new sections: • NOx IN sensor module • AFTPAV • AFTFI • AFTFP1 • AFTFSV Remove MAF sensor procedures.
Aftertreatment System	New or updated procedures: • Aftertreatment (AFT) Fuel Doser Module • Aftertreatment Purge Air Valve (AFTPAV) Assembly • Aftertreatment Fuel Injector (AFTFI) Assembly • AFTI Coolant Return Tube Assembly • AFTI Coolant Supply Tube Assembly • AFTI Fuel Tube Assembly Remove PDOC sections Change naming of “metering unit” to “AFT fuel doser module”
Fuel System	New or updated procedures: • Fuel Supply and Drain (Return) Lines • Fuel Filter Housing Assembly
Appendix D	Inserted Appendix D: Component Locator — copied from 0000002161R9

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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.

Navistar® N13 with SCR *Engine Operation and Maintenance Manual*

Navistar® N13 with SCR *Engine Service Manual* (EPA 10)

Navistar® N13 with SCR *Engine Diagnostic Manual* (EPA 10)

Navistar® N13 with SCR *Hard Start and No Start Diagnostics Form* (EPA 10)

N13 with SCR *Performance Diagnostics Form* (EPA 10)

Navistar® N13 with SCR *Electronic Control System Diagnostics Form* (EPA 10)

Technical Service Literature is revised periodically. 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, diagnostic test equipment, and diagnostic software.
- Availability of current information for engine application and engine systems.
- Knowledge of the principles of operation for engine application and engine systems.
- Knowledge to understand and do procedures in diagnostic and service publications.

Technical Service Literature required for Effective Diagnosis

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

Safety Information

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

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

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

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

Batteries

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

- Protect your eyes.
- Do not expose batteries to flames or sparks.
- Do not smoke in workplace.

Compressed Air

- Use an OSHA approved blow gun rated at 207 kPa (30 psi).
- Limit 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 or damaged 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

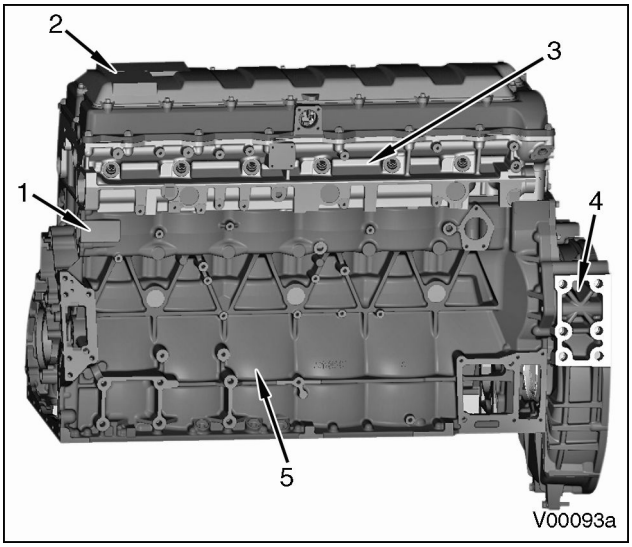

Figure 1 Engine serial number

1. Engine Serial Number (ESN) location
2. Engine emission label
3. Cylinder head
4. Flywheel housing
5. Crankcase

The Engine Serial Number (ESN) is located on the front of the crankcase (left side), below the cylinder head.

Engine Serial Number Examples

Navistar® N13: 126HM2YXXXXXXX

Engine Serial Number Codes

126 – N13 with SCR engines
H – Diesel, turbocharged, Charge Air Cooler (CAC), and electronically controlled
M2 – Motor truck
Y – Huntsville, Alabama
7 digit suffix – Engine serial number sequence

Engine Emission Label

0000054345

Figure 2 2010 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 (ESN)
- EPA, Onboard Diagnostics (OBD), 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:

- Aftertreatment Control Module (ACM)
- Aftertreatment Purge Air Valve (AFTPAV)
- Air compressor
- Air conditioning compressor
- Alternator
- Cooling fan clutch
- Diesel Oxidation Catalyst (DOC)
- Diesel Particulate Filter (DPF)
- Engine Control Module (ECM)
- High Pressure (HP) fuel pump
- Power steering pump
- Selective Catalyst Reduction (SCR) catalyst
- Starter motor
- Turbochargers

Engine Specifications

Navistar® N13 Diesel Engine	
Engine Configuration	4 stroke, inline six cylinder diesel
Advertised brake horsepower @ rpm	
• Navistar® N13	See EPA exhaust emission label
Peak torque @ rpm	
• Navistar® N13	See EPA exhaust emission label
Displacement	
• Navistar® N13	12.4 L (758 in³)
Compression ratio	
• Navistar® N13	17.0:1
Stroke	
• Navistar® N13	166 mm (6.54 in)
Bore (sleeve diameter)	
• Navistar® N13	126 mm (4.96 in)
Total engine weight (dry weight without trim or accessories)	

• Navistar® N13	1087 kgs (2392 lbs)
Firing order	1-5-3-6-2-4
Engine rotation direction (facing flywheel)	Counterclockwise
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)
• Navistar® N13	
Lube system capacity (overhaul only, with filter)	44 L (46 qts)
• Navistar® N13	
Engine oil pressure at operating temperature with SAE 15W-40 oil	
• Low idle	69 kPa (10 psi) min.
• High idle	276 - 483 kPa (40 - 70 psi)
Idle speed (no load)	600 rpm, nominal
Thermostat operating temperature	
• Primary	83°C - 95°C (181°F - 203°F)
• Secondary	87°C - 102°C (189°F - 216°F)

Heavy Duty On Board Diagnostics (HD-OBD)

The EPA has added new regulations for 2010 to reduce heavy duty vehicle emissions. The HD-OBD system is designed specifically for electronically controlled heavy duty engines. The goal for HD-OBD regulation is to keep engine emissions in specification for as long as a given vehicle is in use.

HD-OBD is legislated to be implemented in three phases:

- 2010: First engine for each Original Equipment Manufacture (OEM) becomes fully certified.
    - The lead engine is determined by a legislated equation based on projected sales volume & useful life of the engine.
    - For Navistar®, this is the EPA 2010® N13 engine.
- 2013: One engine in each engine family becomes fully certified.
    - This will be the largest step of the three phases.
- 2016: All engines must be fully HD-OBD certified.

The HD-OBD system continuously monitors for proper engine operation, and will alert the vehicle operator to emission-related faults using the Malfunction Indicator Lamp (MIL).

The MIL is installed in the Electronic Instrument Cluster. When a detected emissions fault occurs, the MIL will be illuminated. Diagnostic information is also stored in the Engine Control Module (ECM), and may be accessed by the technician for diagnosis and repair of the malfunction. Diagnostic information is accessed by connecting the Electronic Service Tool (EST) to the in-cab Diagnostic Connector.

Engine Description

The Navistar® N13 diesel engine is designed for increased durability, reliability, and ease of maintenance.

The cylinder head has four valves per cylinder for increased airflow. The overhead valve train includes rocker arms and valve bridges to operate the four valves. The fuel injector is centrally located between the four valves, directing fuel over the piston for improved performance and reduced 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.

Navistar® N13 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 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 retaining rings secure the piston pin in the piston. The rear oil seal carrier is part of the flywheel housing.

A gerotor lube oil pump is mounted behind the front cover and is driven by the crankshaft. Pressurized oil is supplied to various engine components. All Navistar® N13 engines also use an engine oil cooler and a cartridge-style engine oil filter, which are installed in the engine lube oil module.

The low-pressure fuel pump draws fuel from the fuel tank(s) through a chassis mounted filter/water separator. The low-pressure fuel pump provides fuel for the engine mounted fuel module. Conditioned low-pressure fuel is supplied from the engine mounted fuel module to the high-pressure fuel pump, Inlet Air Heater fuel solenoid, and the AFT fuel doser module.

The high-pressure fuel system is a direct fuel injected common-rail system. The common-rail includes a high-pressure fuel pump, two fuel rail supply lines, fuel rail, six fuel injectors, and pressure relief valve.

The fuel injectors are installed in the cylinder head under the valve cover and are electronically actuated by the ECM.

Navistar® N13 engines use a dual stage, fixed geometry turbocharger assembly. Each stage includes a Charge Air Cooler (CAC). The High Pressure (HP) turbocharger includes a pneumatically operated wastegate. The Low Pressure Charge Air Cooler (LPCAC) is mounted on the lower right side of the engine, and uses the engine cooling system to regulate charge air temperatures. The High Pressure Charge Air Cooler (HPCAC) is mounted in front

of the engine cooling package. The HPCAC is an air-to-air type cooler, and requires no connections to the engine's cooling system.

The Exhaust Gas Recirculation (EGR) system circulates cooled exhaust into the air inlet duct. The dual stage EGR cooler provides regulated cooling of the EGR gases before entering the air inlet duct. This cools the combustion process, and reduces Nitrogen Oxides (NO_X) emissions.

The open crankcase breather system uses a centrifugal Crankcase Oil Separator (CCOS) to return oil mist to the crankcase, and vent the cleaned crankcase gasses to the atmosphere. The CCOS is part of the oil module. The breather system has been redesigned, and uses no crankcase breather filter or external piping. Blowby gases enter the CCOS through the side of the crankcase.

The Inlet Air Heater system warms the incoming air supply during engine cranking and several minutes after cold engine start up to help reduce emissions.

The Navistar® Engine Brake by Jacobs® is optional for Navistar® N13 engine displacements. The engine brake is a compression release system that provides additional vehicle braking performance. The operator can control the engine brake for different operating conditions.

Optional Equipment

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.

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.

Chassis Mounted Equipment

- The chassis mounted fuel filter/water separator removes a majority of the water and foreign particles that may enter the fuel system from the supply tank(s). This filter works with the engine mounted fuel module to eliminate foreign matter and moisture from the fuel before entering the fuel injection system.
- The Low Temperature Radiator (LTR) regulates the temperature of the LPCAC and the low-temperature stage of the EGR cooler. The LTR is mounted in front of the radiator cooling package, and requires connections to the engine cooling system.
- The HPCAC lowers temperature after the air is compressed by the turbochargers, and has no connections to the engine cooling system. The HPCAC is an air-to-air cooler. The HPCAC is mounted in front of the radiator cooling package.
- The Diesel Oxidation Catalyst (DOC) oxidizes hydrocarbons and carbon monoxide, provides heat for exhaust system warm-up, aids in temperature management for the Diesel Particulate Filter (DPF), and oxidizes NO into NO_2 for passive DPF regeneration. The DOC is monitored by the Aftertreatment Control Module (ACM) using one Diesel Oxidation Catalyst Inlet Temperature (DOCIT) sensor positioned at the DOC inlet, and one Diesel Particulate Filter Inlet Temperature (DPFIT) sensor positioned at the DPF inlet.
- The DPF temporarily stores carbon-based particulates, oxidizes stored particulates, stores non-combustible ash, and provides required exhaust back pressure for proper engine performance. The DPF is monitored by the ACM using the DOC / DPF temperature sensor module installed on the DPF, and the Diesel Particulate Filter Differential Pressure (DPFDP) / outlet pressure sensor installed on or near the DPF.
- The Selective Catalyst Reduction (SCR) catalyst oxidizes Nitrogen Oxides (NOx) into Nitrogen gas and water. The SCR catalyst is monitored by the ACM using a NOx IN sensor module installed after the HP turbocharger outlet pipe, and a NOx OUT sensor module installed after the outlet of the SCR catalyst. An ammonia (NH_3) sensor provides feedback to the ACM related to Diesel Exhaust Fluid (DEF) injection into the SCR catalyst.

Air Management System

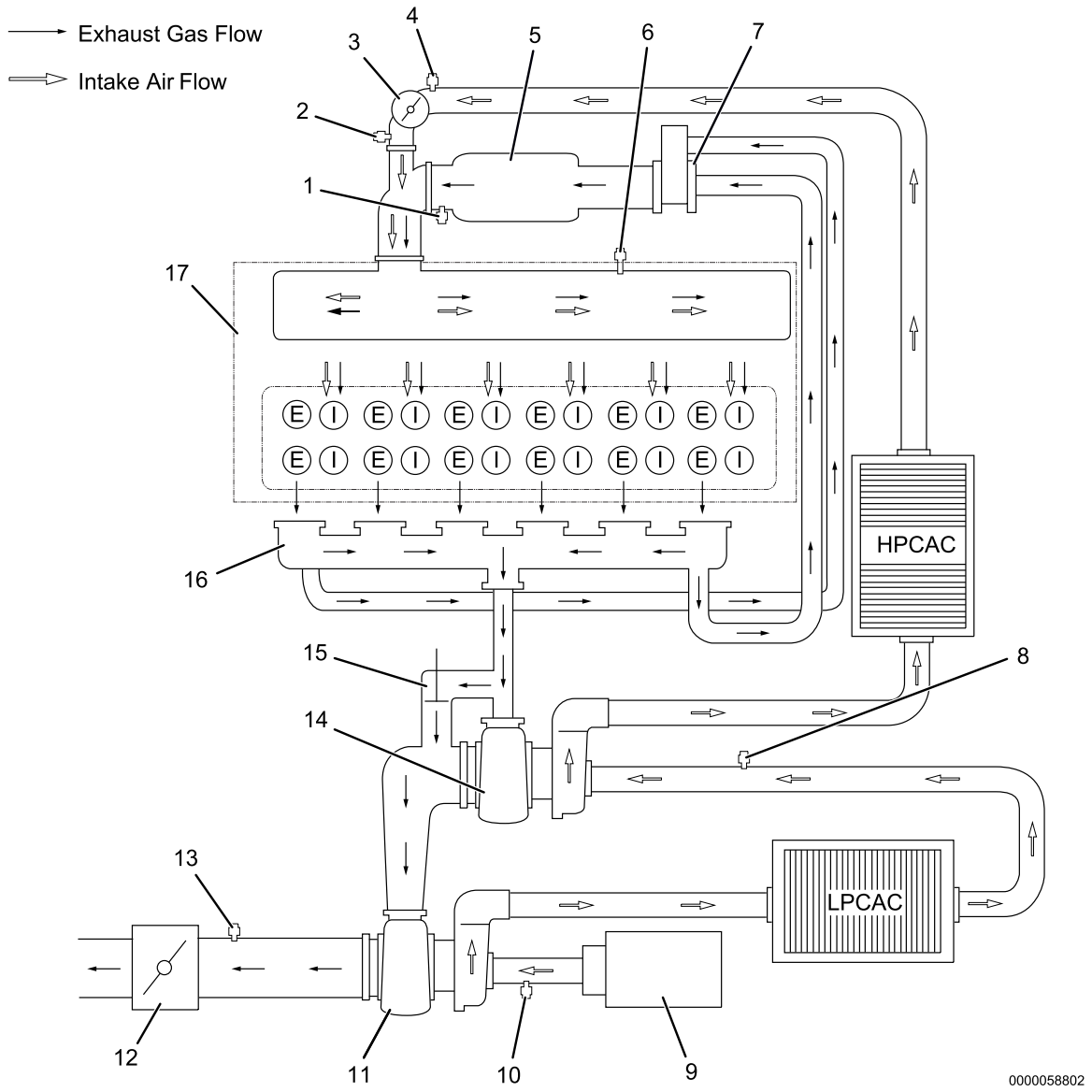

Figure 3 Air Management System

1. Exhaust Gas Recirculation Temperature (EGRT) sensor
2. Intake Manifold Pressure (IMP) sensor
3. Engine Throttle Valve (ETV)
4. Charge Air Cooler Outlet Temperature (CACOT) Sensor
5. EGR cooler
6. Intake Manifold Temperature (IMT) sensor
7. EGR valve
8. Turbocharger 2 Compressor Inlet Sensor (TC2IS)
9. Air filter housing
10. Humidity Sensor (HS) / Inlet Air Temperature (IAT) sensor
11. Low Pressure (LP) turbocharger
12. Exhaust Back Pressure Valve (EBPV)
13. Oxygen Sensor (O_2S)
14. High Pressure (HP) turbocharger
15. HP turbocharger wastegate
16. Exhaust manifold
17. Cylinder head

Airflow

Air flows through the air filter assembly and enters the Low-Pressure (LP) turbocharger. The LP turbocharger increases air pressure and temperature before entering the Low Pressure Charge Air Cooler (LPCAC). Cooled and compressed air then flows from the LPCAC into the High Pressure (HP) turbocharger (compressor inlet). Hot and highly compressed air flows from the HP turbocharger (compressor outlet) into the High Pressure Charge Air Cooler (HPCAC) where it is cooled, and into the intake throttle duct, and continues through the Engine Throttle Valve (ETV). The HP and LP turbochargers can increase pressures up to 345 kPa (50 psi).

If the Exhaust Gas Recirculation Valve (EGRV) is open, exhaust gases pass through the EGR cooler and into the intake throttle duct where it is mixed with filtered air. This mixture flows into the intake manifold, and then the cylinder head. The intake manifold is an integral part of the cylinder head casting.

During cold weather, the Inlet Air Heater system activates the heater element, vaporizing and igniting small quantities of fuel into the air inlet duct.

After combustion, exhaust gases exit through the cylinder head exhaust valves and ports. The exhaust gas is forced through the exhaust manifold where, depending on EGRV position, it is split between the EGR system and the exit path through the HP turbocharger, LP turbocharger, and Exhaust Back Pressure Valve (EBPV).

The EBPV is operated by the Air Control Valve (ACV), a pneumatic actuator. When the ACV is applied, the EBPV restricts flow and increases exhaust back pressure. Operation of the EBPV is controlled by the ECM using the ACV and the Turbocharger 1 Turbine Outlet Pressure (TC1TOP) sensor. When the EBPV is opened, exhaust back pressure is released.

Exhaust gases exiting the engine flow through the EBPV, then through the vehicle Aftertreatment (AFT) system, and out the exhaust tail pipe.

Turbochargers

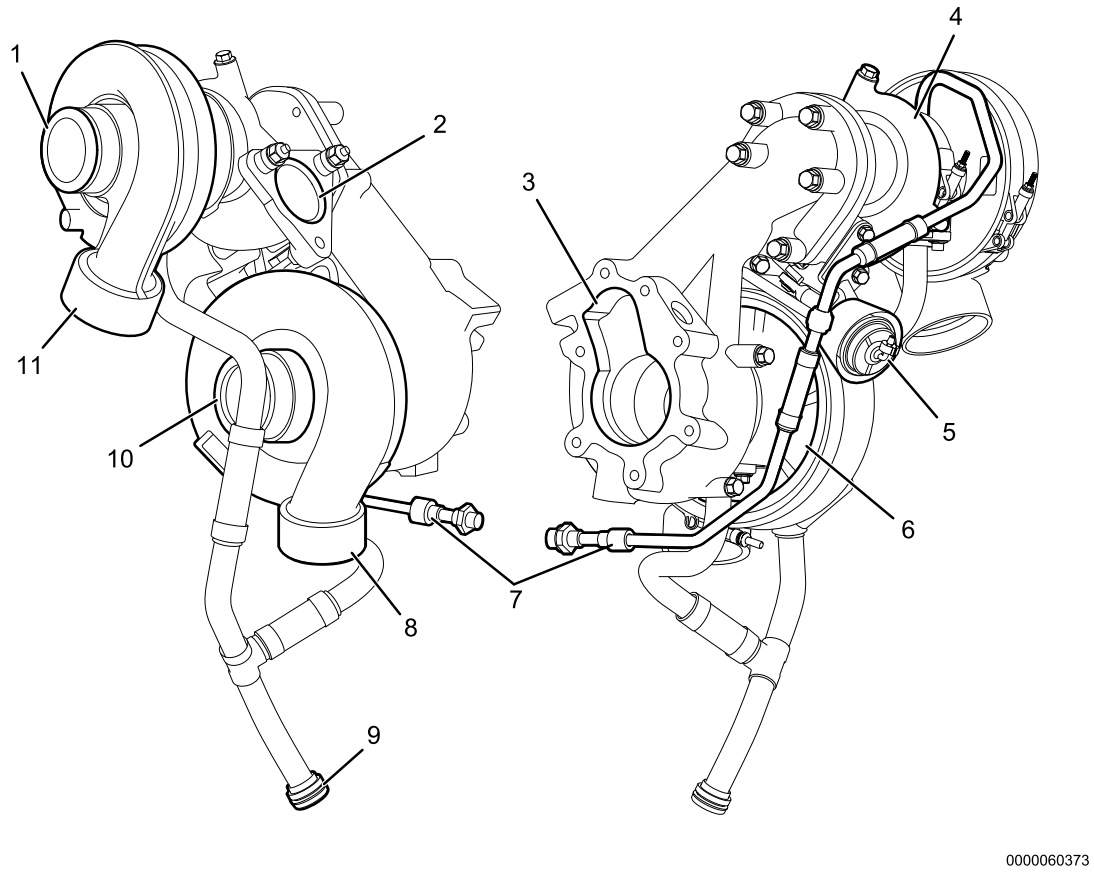

Figure 4 High and Low Pressure Turbocharger Components – Inner and Outer views

1. High Pressure (HP) turbocharger compressor inlet
2. HP turbocharger turbine inlet
3. LP turbocharger turbine outlet
4. HP turbocharger
5. HP turbocharger wastegate actuator
6. Low Pressure (LP) turbocharger
7. Turbocharger oil supply tube
8. LP turbocharger compressor outlet
9. Oil return tube
10. LP turbocharger compressor inlet
11. HP turbocharger compressor outlet

Navistar® N13 engines are equipped with a pneumatically regulated two-stage turbocharger system. The High Pressure (HP) and Low Pressure (LP) turbochargers are installed in parallel on the right side of the engine.

Intake air flow: Filtered air enters the LP compressor, where it is compressed and directed to the Low Pressure Charge Air Cooler (LPCAC). Cooled compressed air then enters the HP compressor, where it is further compressed and directed into the High Pressure Charge Air Cooler (HPCAC). Compressed air then goes through the Engine Throttle Valve (ETV) and the intake throttle duct. This system provides high charge air pressure to improve engine performance and to help reduce emissions.

Exhaust gas flow: The HP turbocharger is connected to the exhaust manifold through the HP turbine inlet. Exhaust gases exit the HP turbine outlet and are directed to the LP turbine inlet. The HP turbocharger is equipped with a wastegate, which is controlled by a pneumatic actuator. The HP turbocharger wastegate is used to regulate boost by controlling the amount of exhaust gas that bypasses the turbine of the turbocharger. When boost demand

is low, the wastegate is opened, allowing part of the exhaust gas flow to bypass the HP turbine.

Control system signals associated with the HP and LP turbochargers have been renamed for 2010.

All signals related to the LP turbocharger are designated as Turbocharger 1 (TC1) signals, and are identified below:

- Turbocharger 1 Turbine Outlet Pressure (TC1TOP)

All signals associated with the HP turbocharger are designated as Turbocharger 2 (TC2), and are identified below:

- Turbocharger 2 Wastegate Control (TC2WC)
- Turbocharger 2 Compressor Inlet Sensor (TC2CIS)

Air Control Valve (ACV)

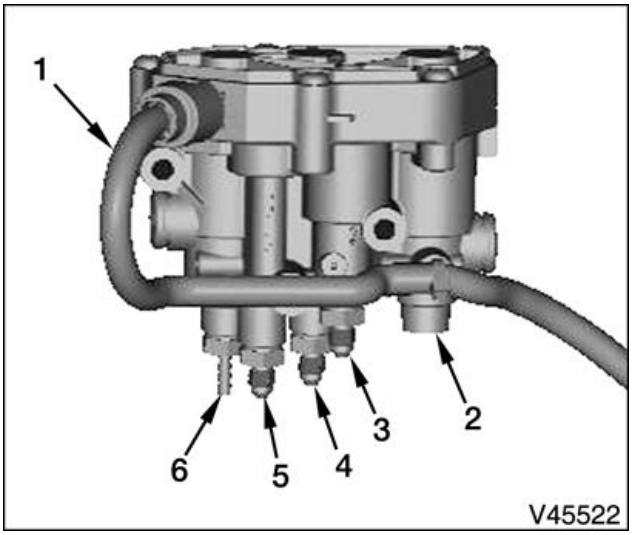

Figure 5 Air Control Valve (ACV) Connections

1. Pigtail harness (to engine sensor harness connector)
2. Plug
3. Vehicle air supply port
4. Exhaust Back Pressure Valve (EBPV) control port
5. Turbocharger 1 Turbine Outlet Pressure (TC1TOP) sensor port
6. High Pressure (HP) turbocharger wastegate control port

The ACV assembly contains the High Pressure (HP) turbocharger wastegate control port, the Exhaust Back Pressure Valve (EBPV) control port, and the Turbocharger 1 Turbine Outlet Pressure (TC1TOP) port. Although these components are integral to the ACV, each circuit is controlled by the Engine Control Module (ECM). The ACV controls compressed air for each control valve. The air supply port is connected to the vehicle's air system.

The ECM provides a Pulse Width Modulated (PWM) signal for operation of the wastegate control valve. With no PWM signal, the control valve is closed, and vehicle no air is supplied to the wastegate actuator.

When an increase in the boost is required, the ECM supplies PWM voltage to close the control valve. This reduces air pressure to the wastegate actuator causing the wastegate to close and vent air pressure, results in increased boost. The limit values of the PWM signals are between approximately 9%, corresponding to a fully opened air control valve, and 100% corresponding to a closed air control valve.

The TC1TOP sensor and EBPV control valve are in the ACV. The EBPV control valve is also operated by the ECM using PWM, and the TC1TOP sensor is monitored by the ECM. The EBPV control valve operates the EBPV actuator.

Boost Control

The wastegate control valve, in the ACV, provides for operation of a pneumatic wastegate actuator for the HP turbocharger. Boost is controlled for HP turbocharger, by signals sent from the ECM to the ACV. In normal operation the wastegate is actuated by the ACV using vehicle compressed air, regulated to 43 psi (296 kPa). Positioning of the wastegate by the ACV is based on boost pressure and temperature signals monitored by the ECM.

Because of the ability to generate very high charge air pressure levels and to avoid Charge Air Cooler (CAC) overloading, the wastegate actuator for the HP turbocharger is also spring loaded. When boost levels increase above specification, boost pressure alone will open the wastegate, and the exhaust gases will bypass the HP turbocharger. Exhaust back pressure is constantly monitored by the ECM using TC1TOP. The TC1TOP sensor is part of the ACV, and is connected to the exhaust system by a steel line.

Low Pressure Charge Air Cooler (LPCAC)

The LPCAC is installed between the High Pressure (HP) and Low Pressure (LP) turbochargers, and is mounted to the lower right side of the engine. The LPCAC air inlet is connected to the LP turbocharger compressor outlet, and uses engine coolant to regulate the LP charge air temperature. The LPCAC air outlet is connected to the compressor inlet of the HP turbocharger.

High Pressure Charge Air Cooler (HPCAC)

The HPCAC is installed between the HP turbocharger and the intake throttle duct. The HPCAC air inlet is connected to the HP compressor outlet, and uses ambient airflow entering the front of the vehicle to reduce the charge air temperature. The HPCAC air outlet is connected to the intake throttle duct.

Intake Manifold Pressure (IMP) Sensor

Monitors charge air pressure entering the intake throttle duct and provides information used for boost and EGR control.

The IMP provides an analog voltage output to the Engine Control Module (ECM) which is proportional to pressure applied to an internal diaphragm in the sensor. The IMP sensor is connected to the ECM by the Reference Voltage (VREF), signal, and ground wires. A transfer function in the ECM software converts the analog voltage to a pressure value which is then used by software strategies.

Intake Manifold Temperature (IMT) Sensor

This sensor monitors charge air temperature entering the intake throttle duct. The temperature measured is an input to the engine coolant control strategy. It also is used for evaluation of on-board diagnostics to ensure proper functionality of the charge air cooling system.

This temperature sensor is a thermistor and has two connections to the Engine Control Module (ECM). A thermistor varies resistance as temperature changes. When interfaced to the ECM circuitry, a change in sensor resistance results in a voltage change internal to the ECM. A transfer function contained in the ECM software translates the measured voltage to a temperature value.

The ECM continuously monitors the voltage resulting from the thermistor's changing resistance. High and low diagnostic voltage thresholds are evaluated to ensure that the output voltage is within a valid range.

Turbocharger 2 Compressor Inlet Sensor (TC2IS)

This sensor is a dual function sensor that detects pressure and temperature of the charge air entering the High Pressure (HP) compressor. It is installed in the piping between the Low Pressure (LP) compressor outlet and the HP compressor inlet. This sensor is used for evaluation by on-board diagnostics to ensure proper functionality of the charge air cooling system.

This sensor consists of a thermistor which varies resistance as temperature changes. When interfaced to the Engine Control Module (ECM) circuitry, a change in sensor resistance results in a voltage change internal to the ECM. An internal diaphragm which deflects due to pressure changes results in an analog voltage output to the ECM which is proportional to the pressure. Transfer functions contained in the ECM software translate the measured voltages into a temperature and a pressure value.

The ECM continuously monitors the voltages resulting from changes in both the temperature and pressure. High and low diagnostic voltage thresholds are evaluated to ensure output voltage is within a valid range.

Exhaust Gas Recirculation (EGR) System

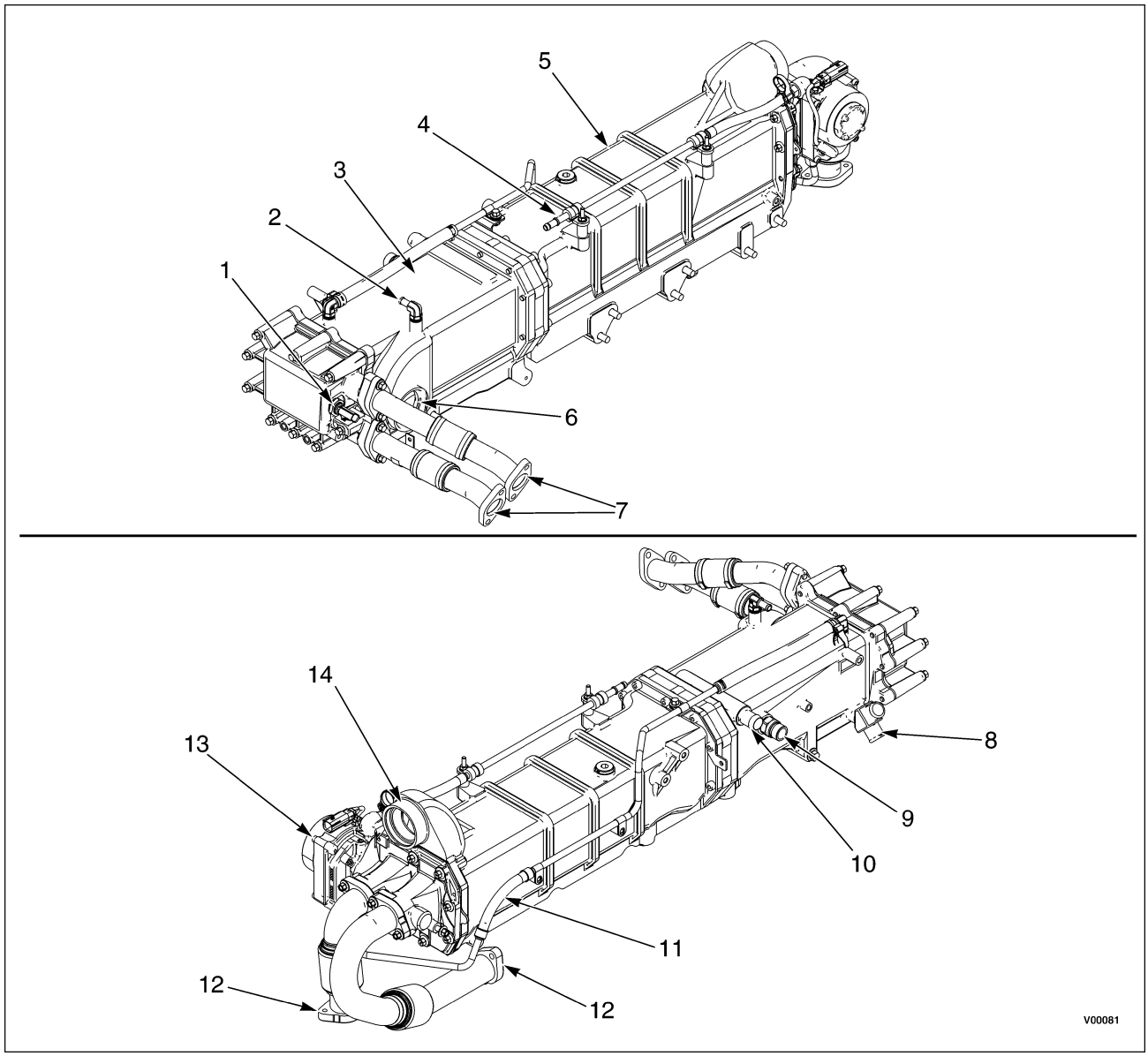

Figure 6 EGR system components

1. EGRT sensor
2. EGR cooler air bleed (to deaeration tank)
3. EGR cooler (low-temperature stage)
4. EGRV coolant return line (to deaeration tank)
5. High temperature EGR cooler
6. Intake Manifold Temperature (IMT)
7. EGR cooler outlet tube (2) (gases)
8. Low temperature EGR cooler inlet (coolant)
9. Engine Coolant Temperature 2 (ECT2) sensor
10. Low temperature EGR cooler outlet (coolant)
11. EGRV coolant supply line
12. EGR cooler inlet tubes (gases)
13. EGRV
14. EGR cooler inlet (coolant)

EGR System Overview

The EGR system reduces NO_X engine emissions by introducing inert cooled exhaust gas into the air inlet duct. NO_X forms during a reaction between nitrogen and oxygen at high-temperatures during combustion.

The Engine Control Module (ECM) monitors signals from the Charge Air Cooler Outlet Temperature (CACOT) sensor, Oxygen sensor (O_2S), Engine Coolant Temperature 1 (ECT1) sensor, EGRT sensor to control the EGR system.

EGR is switched Off (EGRV closed) if any of the following conditions are present:

- Engine coolant temperature less than 10°C (50°F) will close the EGR valve
- Intake manifold temperatures less than 7°C (45°F) will close the EGR valve
- During engine brake operation

EGR Flow

Hot exhaust gas from the exhaust manifold flows through the EGR inlet tubes to the Exhaust Gas Recirculation Valve (EGRV). When EGR is commanded, the EGRV opens and allows exhaust gas to enter the EGR cooler. Exhaust gas flows through the EGR cooler, is cooled and then flows through the EGR outlet tubes, and into the intake throttle duct where it is mixed with filtered air.

EGR System Control

The EGR system consists of the EGRV, Engine Throttle Valve (ETV), and Oxygen Sensor (O_2S). The EGRV contains a Pulse Width Modulated (PWM) controlled valve and Exhaust Gas Recirculation Position (EGRP) sensor.

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

The ECM commands the EGRV to move and hold position. The EGRP sensor, installed inside the EGRV, monitors and provides an EGRV position signal to the ECM.

The O_2S is installed in the exhaust, in front of the aftertreatment fuel injector. The O_2S has a heater element that heats the sensor to its normal operating temperature of 780°C (1436°F). During initial engine warm-up, the O_2S heater element is activated only after engine coolant reaches 40°C (104°F) and the exhaust gas temperature DOCIT sensor exceeds 100°C (212°F) for more than 30 seconds.

EGRV Control

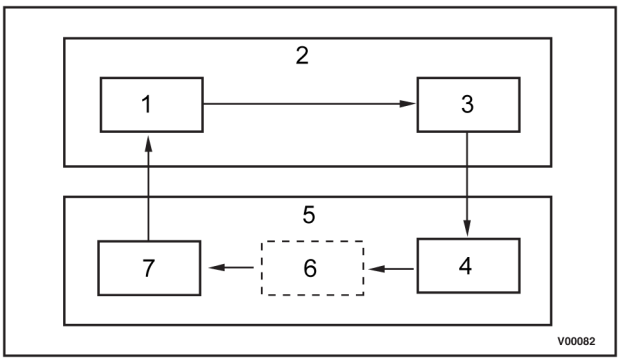

Figure 7 EGRV position control

1. EGR position monitored by ECM
2. Engine Control Module (ECM)
3. ECM commands EGR to desired position
4. EGRV to desired position
5. EGRV
6. EGRV position matches ECM command
7. EGR position sent to ECM

The EGRV has an integrated position sensor, and provides feedback to the ECM indicating EGRV position.

EGR – Open Loop

During engine warm-up and before the Oxygen Sensor (O_2S) reaches normal operating temperature, the Exhaust Gas Recirculation (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.

EGR – Closed Loop

After the O_2S reaches operating temperature, the EGR system switches to closed loop operation. In closed loop, the EGR system is controlled by the ECM based on coolant temperature and O2S readings.

EGR Flow Cooling

The EGR system includes a two-stage EGR cooler, and Coolant Control Valve (CCV) to allow the Engine Control Module (ECM) to regulate EGR cooler temperatures. The ECM monitors intake manifold temperature through the Exhaust Gas Recirculation Temperature 1 (EGRT1) sensor and the CCV regulates coolant flow through the Low Temperature Radiator (LTR). Refer to Engine Cooling System (page 38) in this section for more information.

Aftertreatment (AFT) System

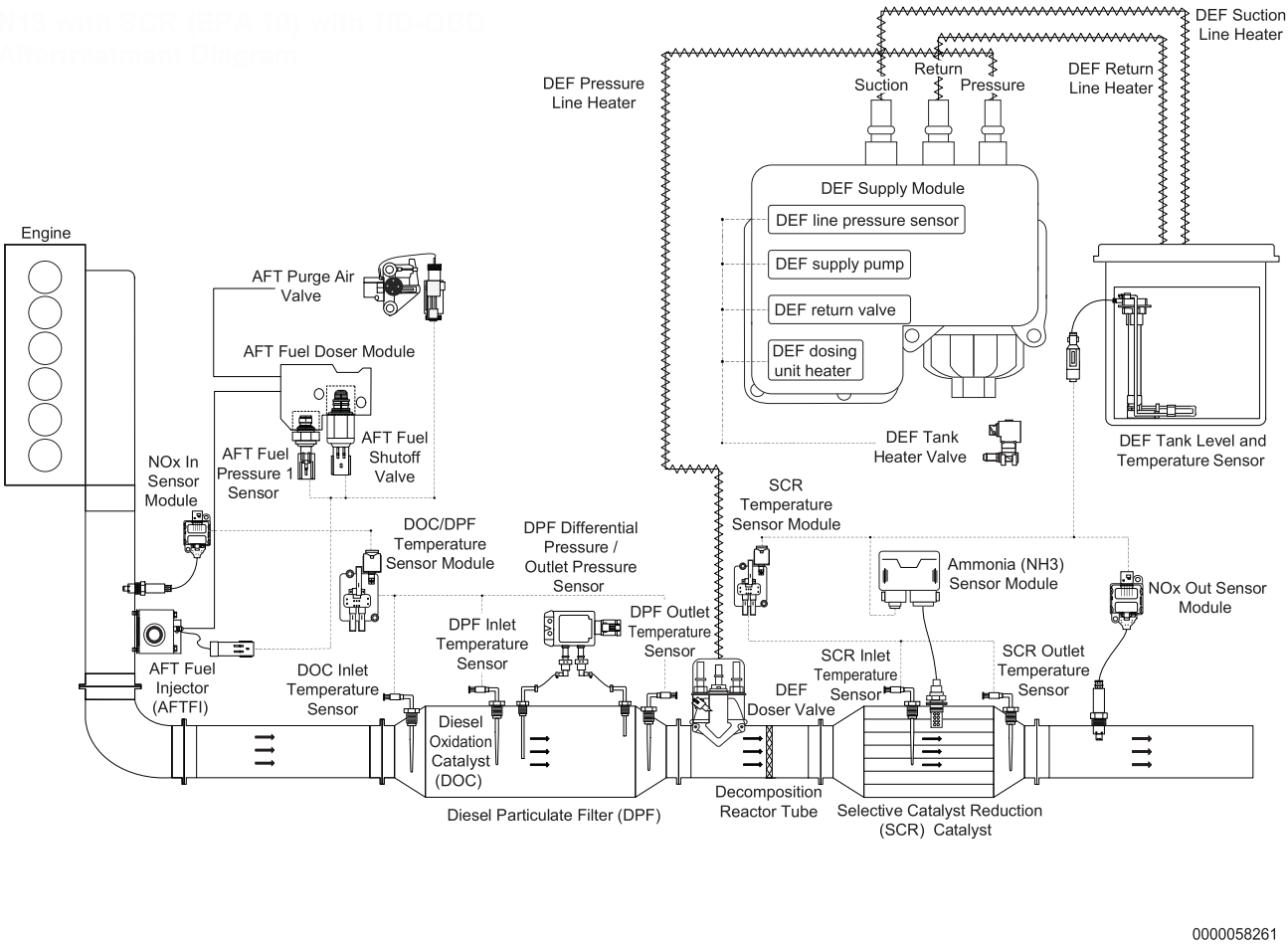

Figure 8 Functional Diagram of AFT system

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

The AFT system performs the following functions:

- Monitors exhaust gas temperatures DOC In, DPF In, DPF Out, SCRIT, SCROT temperature, and Diesel Particulate Filter (DPF) delta pressure. It controls engine operating parameters for emission control and failure recognition.
- May cancel regeneration in the event of catalyst or sensor failure
- Monitors the level of soot accumulation in the DPF
- Initiates regeneration automatically when DPF is full with soot and controls engine operating parameters to increase temperature to have successful regeneration
- Maintains vehicle and engine performance during regeneration
- Monitors NOx levels in the exhaust
- Initiates Diesel Exhaust Fluid (DEF) dosing automatically when NOx levels are above a pre-calibrated threshold
- Monitors and adjusts DEF dosing per Ammonia (NH_3) sensor feedback

Decomposition Reactor Tube

The decomposition reactor tube does the following:

- Converts DEF to ammonia and CO2
- Uses an internal mixer to ensure even evaporation of DEF into the exhaust stream

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 (restriction)
- 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

Selective Catalyst Reduction (SCR) Catalyst

The SCR catalyst does the following:

- Completes the breakdown of DEF into ammonia and CO2
- Converts ammonia and NOx to Nitrogen gas and water

Aftertreatment (AFT) 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.

Diesel Exhaust Fluid (DEF) Injection

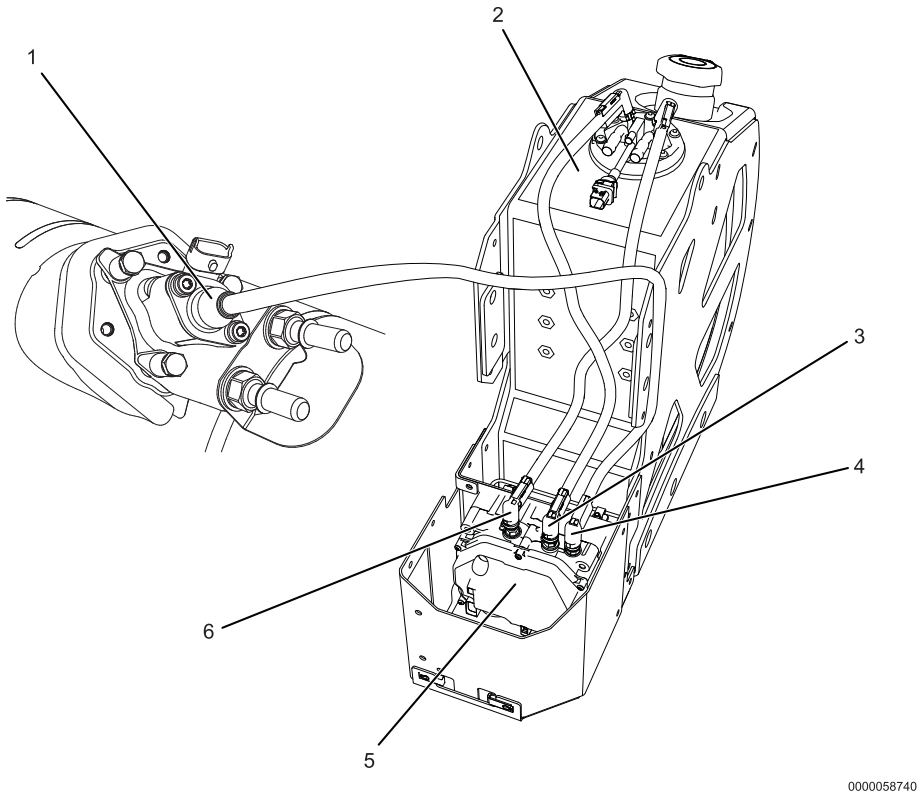

Figure 9 Diesel Exhaust Fluid (DEF) Injection Components

1. Diesel Exhaust Fluid Doser Valve (DEFDV)
2. DEF tank
3. DEF supply module return line
4. DEF supply module pressure line
5. DEF supply module
6. DEF suction line

Diesel Exhaust Fluid (DEF) injection is required when Nitrogen Oxides (NOx) levels exceed acceptable limits.

The Aftertreatment Control Module (ACM) determines when DEF injection is required by monitoring signals from the Nitrogen Oxides (NOx) IN sensor module, NOx OUT sensor module, and Ammonia (NH_3) sensor.

When NOx levels are too high, the ACM commands the DEF supply pump ON, allowing DEF to be drawn from DEF tank, through the suction line, and to the DEF supply module. DEF then exits the supply module and travels to the Diesel Exhaust Fluid Doser Valve (DEFDV) through the pressure line. The ACM then commands the DEFDV ON allowing DEF to be sprayed into the aftertreatment system.

Aftertreatment Fuel Injection

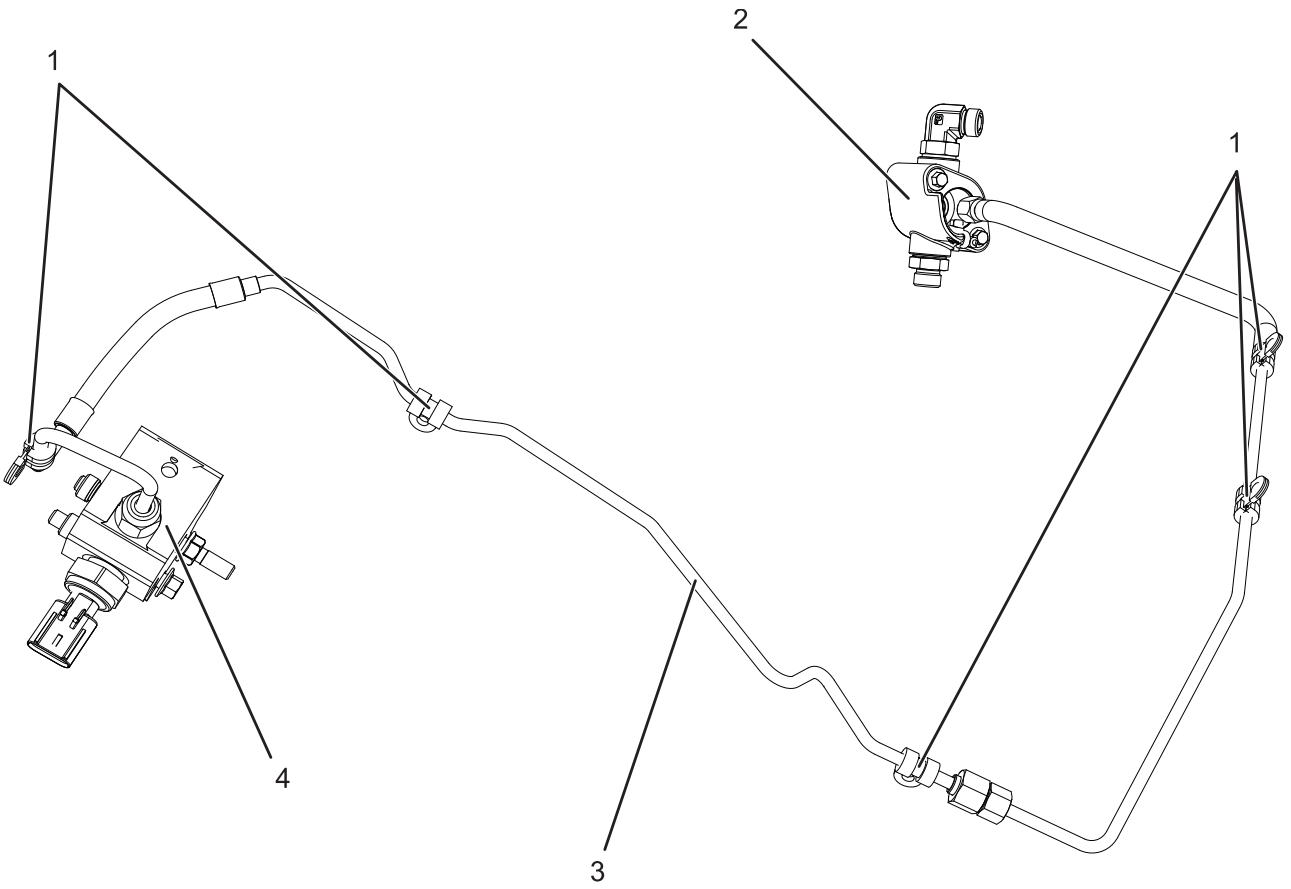

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Figure 10 Aftertreatment Fuel Injection Components (Top View)

1. Fuel line retainers (rear and left side of engine block)
2. Aftertreatment Fuel Injector (AFTFI)
3. AFTFI fuel pressure line
4. AFT fuel doser module

The AFT fuel doser module injects fuel into the exhaust system to increase temperature of the Diesel Oxidation Catalyst (DOC), and is necessary for Diesel Particulate Filter (DPF) regeneration. AFT fuel doser module is controlled by the Aftertreatment Control Module (ACM). The ACM receives signals from the Aftertreatment Fuel Pressure 1 (AFTFP1) sensor (installed in the AFT fuel doser module), and control operation when aftertreatment fuel injection (regeneration) is required. The ACM also controls the Aftertreatment Fuel Shutoff Valve (AFTFSV) (installed in the AFT fuel doser module) which controls the volume of fuel sent to the AFTFI.

AFT Fuel Doser Module Injection

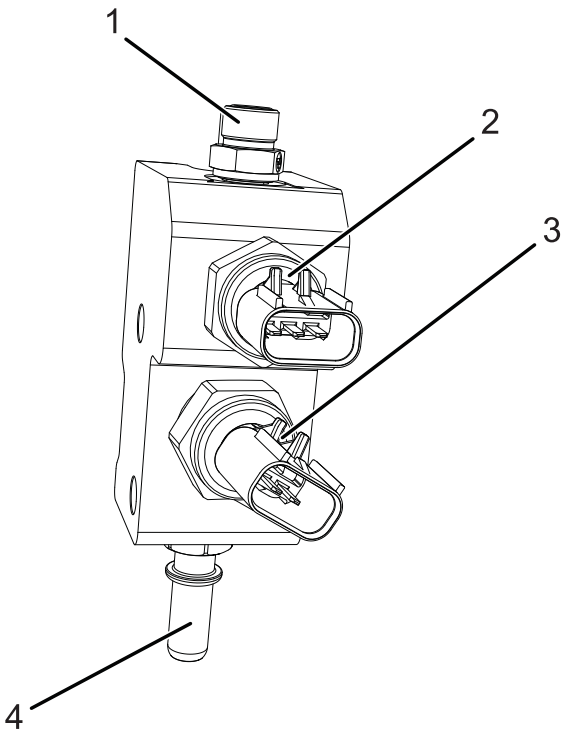

Figure 11 AFT Fuel Doser Module (Left Side View)

1. Fuel outlet port to Aftertreatment Fuel Injector (AFTFI)
2. Aftertreatment Fuel Pressure 1 (AFTFP1) sensor
3. Aftertreatment Fuel Shutoff Valve (AFTFSV)
4. Fuel supply from fuel filter assembly

The AFT fuel doser module is connected to the clean side of the low-pressure fuel system, and provides a metered amount of fuel to the Aftertreatment Fuel Injector (AFTFI). The AFT fuel doser module provides pressurized fuel injection pulses to the AFTFI. The AFTFI is a solenoid type injector, and will only inject fuel when commanded ON by the Aftertreatment Control Module (ACM). The AFT fuel doser module is installed on the left side of the engine, to the rear of the fuel module.

The AFTFP1 sensor monitors fuel pressure in the AFT fuel doser module, and provides constant feedback to the ACM.

Aftertreatment Fuel Injector (AFTFI)

The AFTFI is installed on the right side of the engine, in the exhaust pipe after the exhaust Oxygen Sensor (O_2S).

Pressurized fuel is supplied to the AFTFI thru the AFT fuel doser module using the Aftertreatment Fuel Shutoff Valve (AFTFSV). When conditions required for regeneration are met, the ACM commands the AFTFSV ON, allowing pressurized fuel to reach the AFTFI.

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

Crankcase Oil Separator

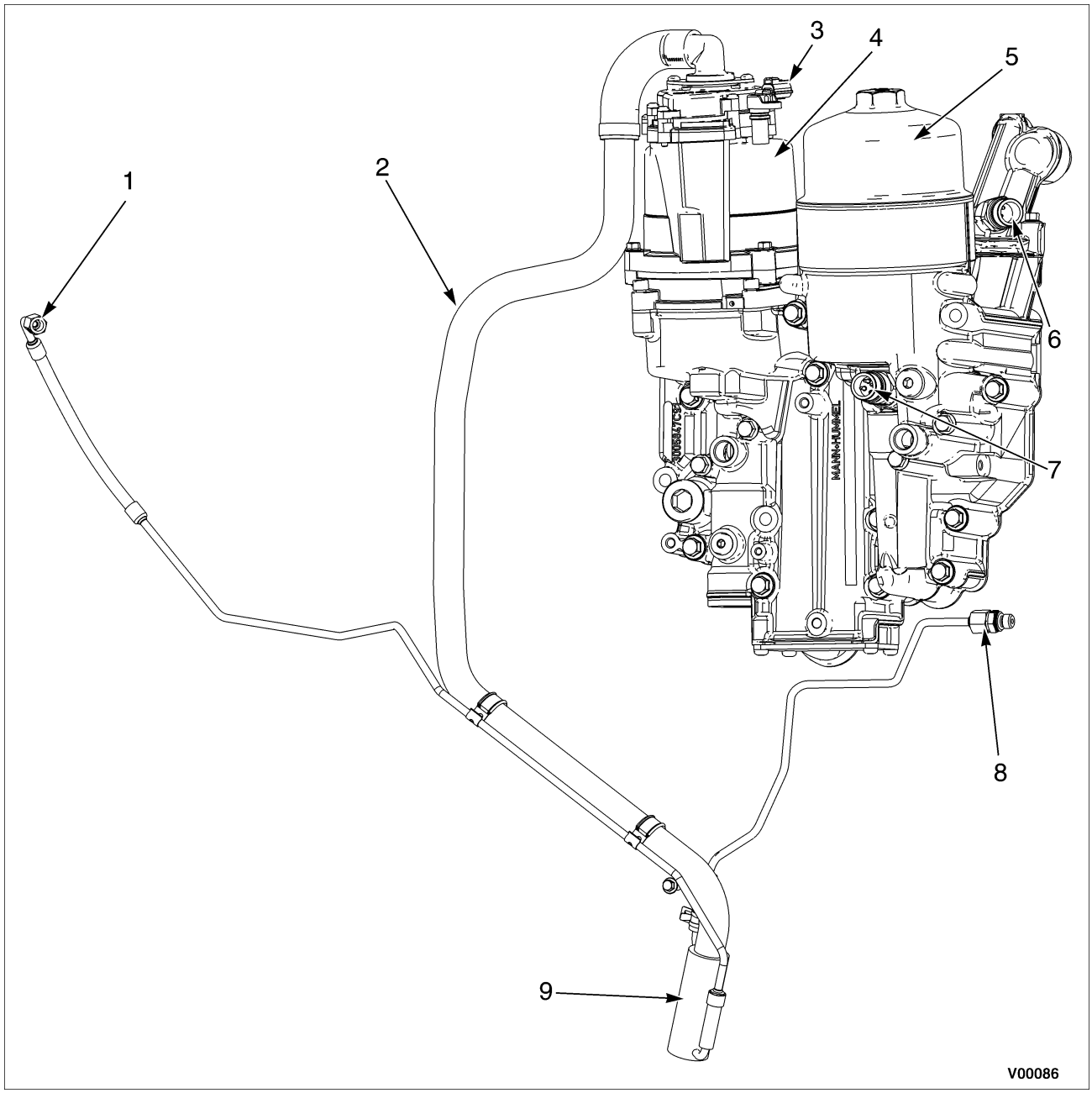

Figure 12 Oil Module with Crankcase Oil Separator

1. Coolant supply line
2. CCOS vent tube
3. Crankcase Oil Separator Speed (CCOSS) sensor
4. Crankcase Centrifuge Oil Separator (CCOS)
5. Oil filter access cap
6. Engine Oil Temperature (EOT) sensor
7. Engine Oil Pressure (EOP) sensor
8. Coolant return line
9. CCOS ventilation tube heater

Crankcase ventilation is provided using the CCOS. Excess crankcase vapors are filtered by the CCOS, and are then vented to the atmosphere.

A centrifugal oil separator, driven by engine oil pressure, separates and directs oil mist to the side of the CCOS housing. The separated oil drains from the oil separator, through the crankcase, and into the oil pan. The oil separator is an integral part of the oil module.

Fuel Management System

Fuel System Components

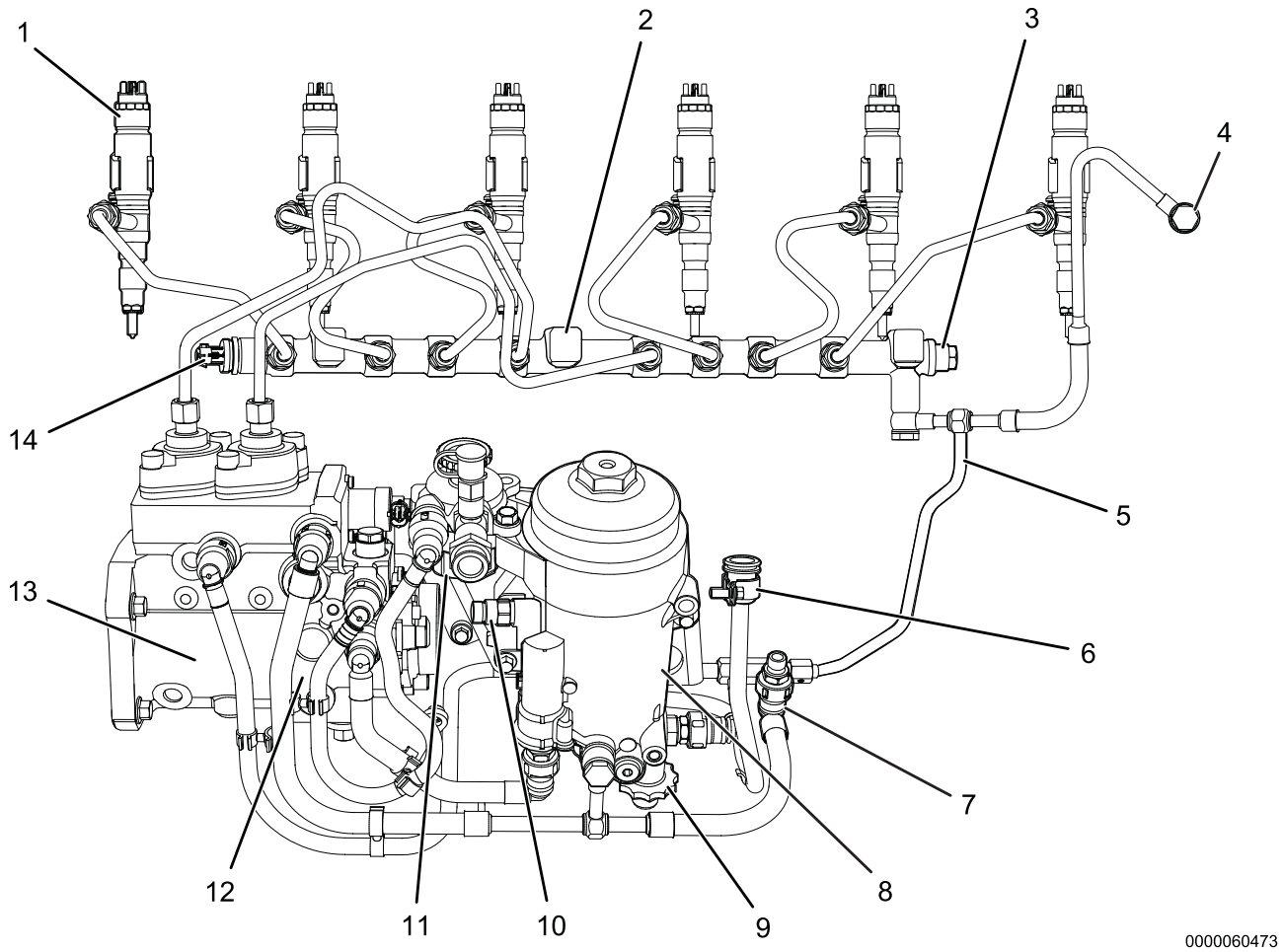

Figure 13 Fuel system

1. (Fuel) Injector (6)
2. Fuel Rail
3. Fuel rail pressure limiting valve
4. Fuel return from cylinder head
5. Fuel return line
6. Engine fuel return connection (to chassis filter)
7. Fuel supply to AFT fuel doser module
8. Fuel filter housing assembly
9. Fuel filter drain screw
10. Fuel Delivery Pressure (FDP) sensor
11. Fuel primer pump assembly
12. Low Pressure (LP) fuel pump
13. High Pressure (HP) fuel pump
14. Fuel Rail Pressure (FRP) sensor

Navistar® N13 engines are equipped with a high-pressure common rail fuel injection system which provides pressurized fuel to the fuel injectors for optimal fuel atomization in the combustion chamber.

Excess fuel is returned to the chassis mounted filter separator, before returning to the fuel tank.

The fuel system is controlled by the Engine Control Module (ECM), various sensors, and the Fuel Pressure Control Valve (FPCV) installed in the HP fuel pump.

Fuel Flow

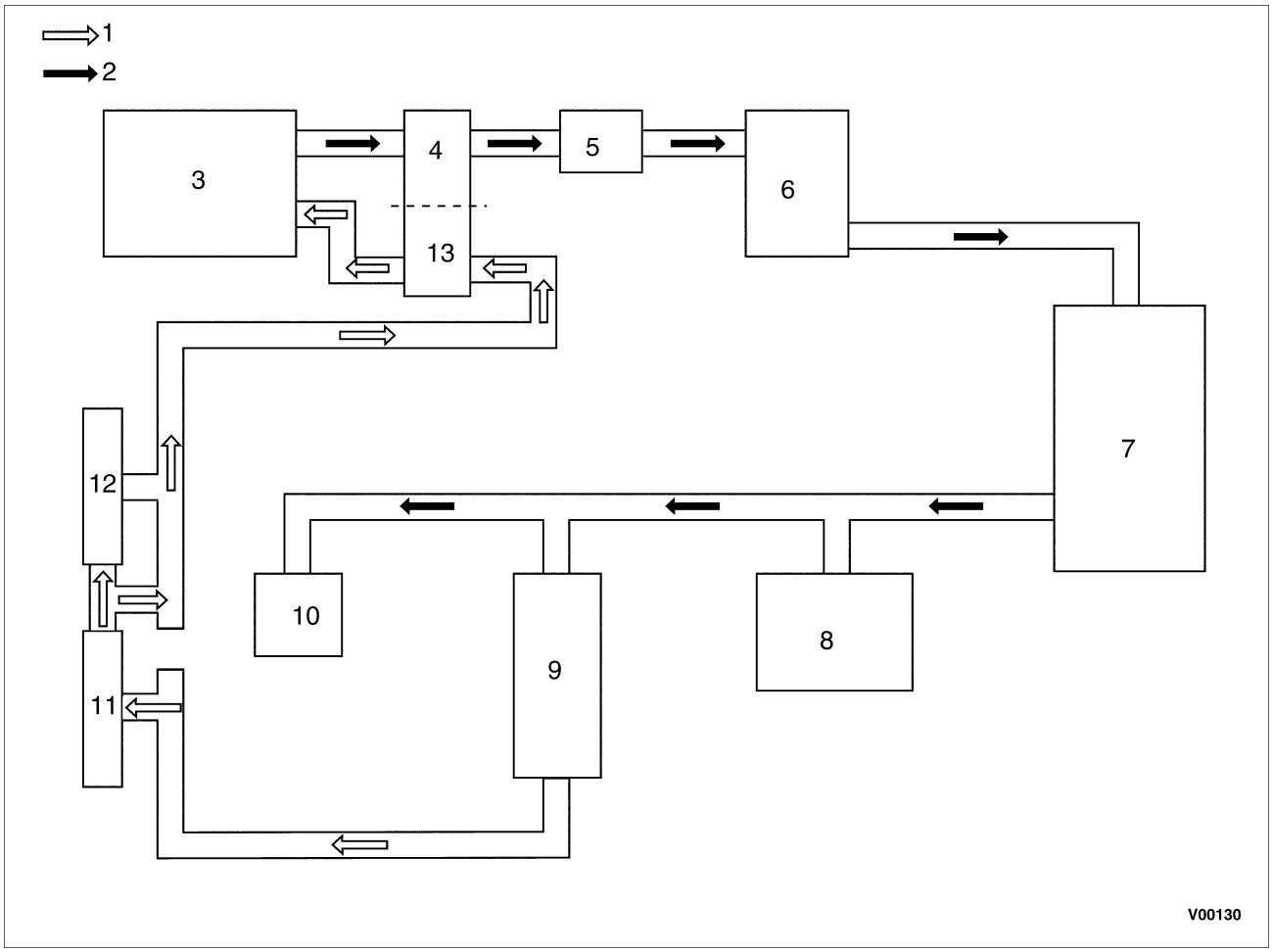

Figure 14 Fuel supply flow diagram

1. Fuel Return
2. Fuel supply
3. Fuel tank
4. Chassis mounted fuel filter/water separator (Top portion)
5. Fuel primer pump assembly with fuel strainer element
6. Low Pressure (LP) fuel pump
7. Fuel filter housing assembly (engine mounted)
8. AFT fuel doser module
9. High Pressure (HP) fuel pump
10. Inlet Air Heater Fuel Solenoid (IAHFS)
11. Fuel rail
12. Fuel injectors
13. Chassis mounted fuel filter/water separator (bottom portion)

Fuel is pumped from the tank, through the chassis mounted fuel filter/water separator using the Low Pressure (LP) fuel pump. Fuel is pumped from the LP fuel pump to the engine mounted fuel filter assembly, before being supplied to the High Pressure (HP) fuel pump. The HP fuel pump supplies high-pressure fuel to the fuel rail, which feeds the fuel injectors through individual tubes. The LP fuel pump and HP fuel pump are assembled as one gear driven unit, and are serviced as an assembly.

Low Pressure Fuel System

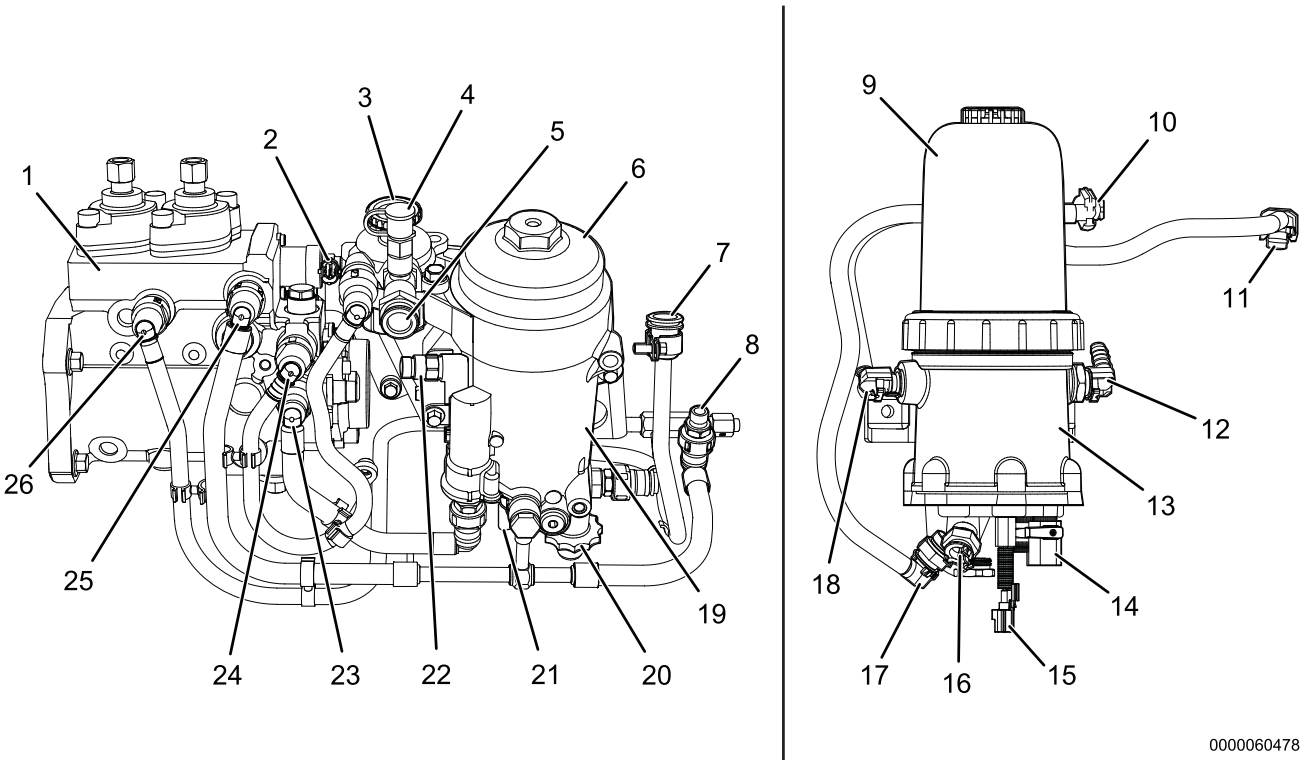

Figure 15 Low Pressure (LP) fuel system

1. High Pressure (HP) fuel pump
2. Fuel Pressure Control Valve (FPCV)
3. Fuel primer pump assembly w/ fuel strainer element
4. Fuel pressure test port
5. Engine fuel supply connection
6. Engine mounted secondary fuel filter access
7. Engine fuel return connection
8. Fuel supply to AFT fuel doser module
9. Chassis mounted primary fuel filter access
10. Fuel supply to engine
11. Fuel return from engine
12. Fuel supply from tank
13. Chassis mounted fuel filter/water separator
14. Fuel Heater
15. Water In Fuel (WIF) sensor
16. Fuel return to tank
17. Fuel return from engine
18. Fuel supply to engine
19. Fuel filter housing assembly (engine mounted)
20. Fuel filter drain screw
21. Inlet air heater port
22. Fuel Delivery Pressure (FDP) sensor
23. LP fuel pump outlet
24. LP fuel pump inlet
25. HP fuel pump inlet
26. HP fuel pump return

The LP fuel pump pumps fuel from the tank through the chassis mounted fuel filter/water separator, fuel strainer element, and engine filter element, then to the high-pressure fuel system, inlet air heater system, and AFT fuel doser module.

In addition to providing high-pressure fuel to the injectors, the fuel system provides filtered low-pressure fuel to the downstream injection and Inlet air heater systems.

Chassis Mounted Filter/Water Separator

The chassis mounted filter/water separator removes debris and water from the fuel before it enters the fuel primer pump and low-pressure fuel pump. The chassis mounted filter/water separator includes a Water In Fuel (WIF) sensor and optional fuel heater.

Fuel Primer Pump Assembly

During fuel system priming, fuel is drawn from the tank through the chassis mounted filter/water separator by the fuel primer pump assembly. The fuel primer pump assembly has an integrated fuel strainer element that can be cleaned. The fuel primer pump assembly is manually operated, and is used to prime the low-pressure fuel system anytime the fuel system has been emptied. The primer pump provides unrestricted fuel flow to the low-pressure pump during normal engine operation.

Low Pressure (LP) Fuel Pump

The LP fuel pump and the High Pressure (HP) fuel pump are one assembly. Fuel is drawn through the fuel primer pump assembly and into the LP fuel pump. The LP pump supplies fuel to the fuel filter housing assembly at pressures varying between approximately 85 psi (586 kPa) at idle, and 120 psi (827 kPa) at rated speed. The LP fuel pump has an internal pressure regulator that relieves the fuel pressure internally if the pressure exceeds 189 psi (1300 kPa).

Fuel Filter Assembly

The fuel filter assembly is installed on the left side of the engine and has a disposable filter element. A Fuel Delivery Pressure (FDP) sensor is installed on the front side of the fuel filter assembly, which measures fuel pressure between the LP fuel pump and the filter element. The fuel filter assembly also has a drain screw that allows water and dirt to be drained periodically. Because water may accumulate inside the fuel filter assembly, use the drain screw to drain water per maintenance schedule in the *Engine Operation and Maintenance Manual*. An additional function of the fuel filter 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 assembly also provides filtered fuel to the AFT fuel doser module and inlet air heater system. An orifice regulator is integrated into the fuel filter assembly, and regulates the fuel pressure for the inlet air heater system to approximately 10 psi (70 kPa).

High Pressure Fuel System

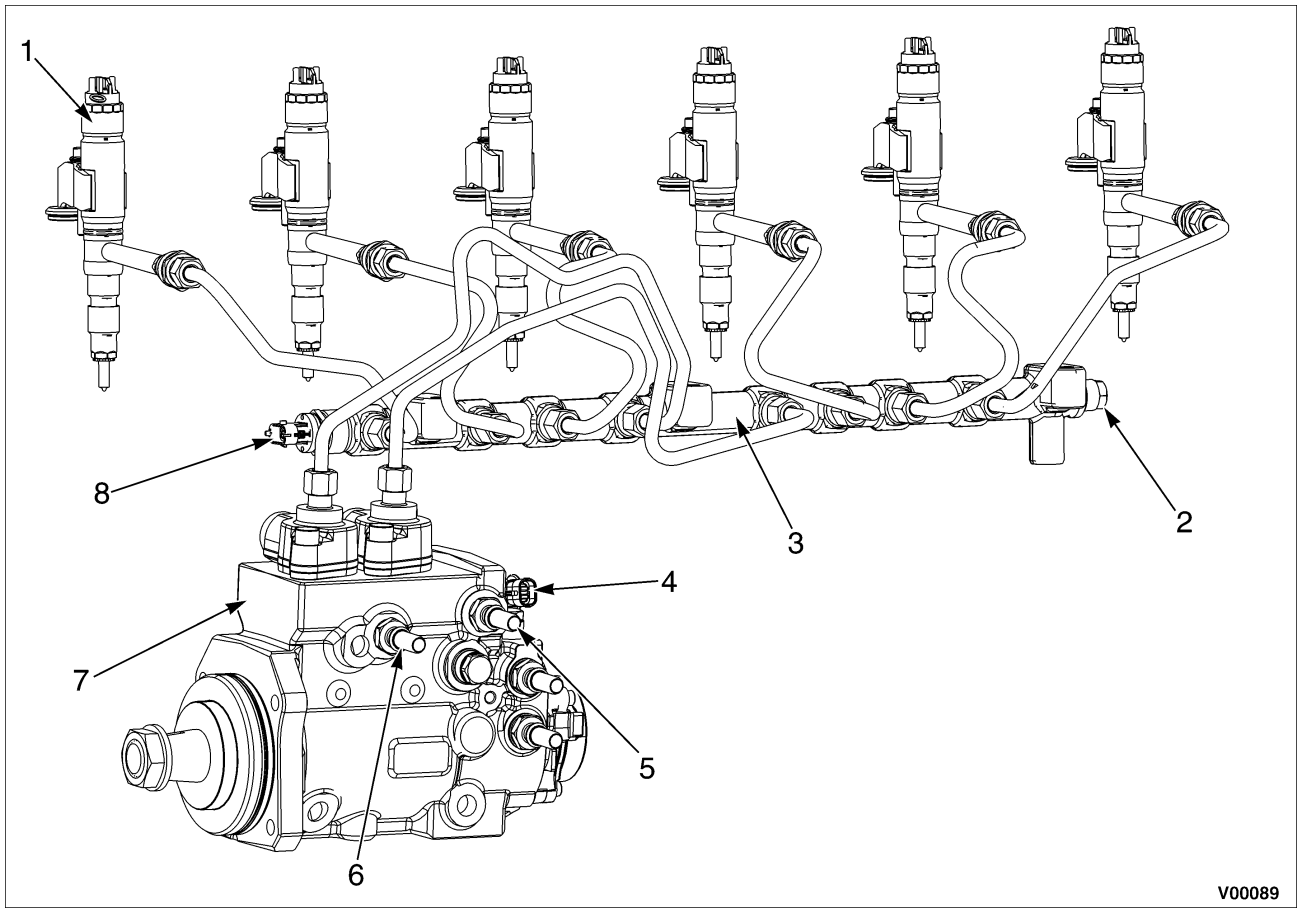

Figure 16 High Pressure (HP) fuel system

1. (Fuel) Injector (6)
2. Rail pressure limiting valve
3. Fuel rail
4. Fuel Pressure Control Valve (FPCV)
5. Fuel inlet - HP fuel pump
6. Fuel return - HP fuel pump
7. HP fuel pump
8. Fuel Rail Pressure (FRP) sensor

Pressurization and injection are separate in the common rail injection system. Optimal fuel injection pressure is generated by the high-pressure pump at any engine speed. High-pressure fuel quantity from the high-pressure pump is controlled by the FPCV. 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 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.

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

High Pressure (HP) Pump

The HP pump supplies the necessary quantity of HP fuel for all operating engine modes. The HP pump is gear driven and is fuel lubricated. Fuel from the LP fuel pump is forced through the fuel module assembly, and into the HP pump. The flow of fuel to the suction chamber of the HP pump is controlled by the FPCV, in order to control HP 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 Engine Control Module (ECM) sends a Pulse Width Modulated (PWM) signal to control the FPCV. A 100% duty cycle PWM signal corresponds to minimum fuel pressure delivery, while a 0% duty cycle PWM corresponds to maximum fuel pressure delivery.

Fuel Rail

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

Fuel Rail Pressure (FRP) Sensor

The FRP sensor is a variable resistance sensor that monitors fuel pressure in the High Pressure (HP) fuel rail. The FRP sensor is mounted in the front of the fuel rail, on the left side of the engine.

Rail Pressure Limiting Valve

The rail pressure limiting valve maintains fuel pressure inside the fuel rail below approximately 37,700 psi (260,000 kPa). If HP fuel pump output exceeds specification the rail pressure limiting valve opens and fuel flows into the fuel return line. With the pressure limiting valve open, fuel pressure in the high-pressure fuel rail drops to approximately 15,950 psi (110,000 kPa).

Fuel Injectors

Navistar® N13 engines are equipped with electronically controlled fuel injectors. During engine operation, injectors are supplied with high-pressure fuel, and the injector solenoid valves open up to three times per combustion cycle. The injectors are positioned vertically in the center of the cylinder head and are held in place by clamps. The seal between the injectors and the combustion chamber consists of a copper washer on the tip of each injector.

Inlet Air Heater System

Inlet Air Heater System Components

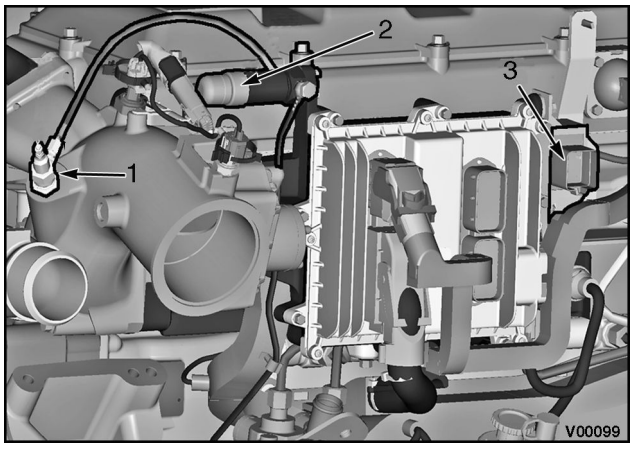

Figure 17 Inlet Air Heater System

1. Inlet Air Heater Fuel Igniter (IAHFI)
2. Inlet Air Heater Fuel Solenoid (IAHFS) valve
3. Inlet Air Heater Relay (IAHR)

Inlet Air Heater Fuel Igniter (IAHFI)

The Inlet Air Heater system rapidly activates the heater element, vaporizing and igniting small quantities of fuel into the air inlet duct.

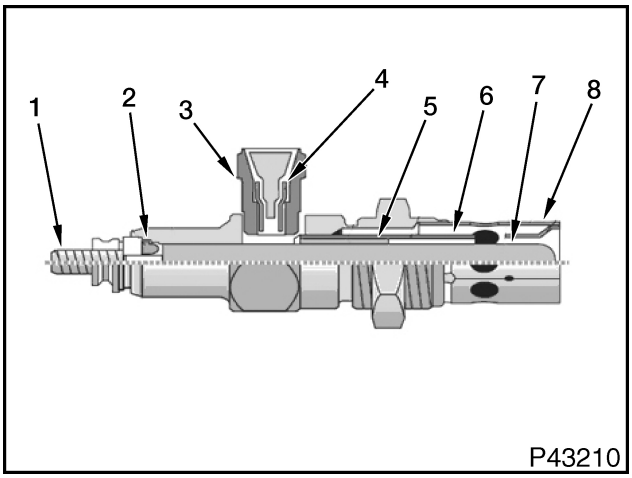

Figure 18 Inlet Air Heater Fuel Igniter (partial cut away view)

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

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

The IAHFI is installed on the left front side of the engine, in the intake throttle duct.

Inlet Air Heater Relay (IAHR)

The IAHR is installed on the left side of the engine at the rear of the Engine Control Module (ECM). The IAHR provides voltage to the IAHFI, and is controlled by the ECM.

Inlet Air Heater Fuel Solenoid (IAHFS) Valve

The IAHFS valve is installed on the left side of the engine and is controlled by the ECM. The IAHFS valve is supplied with low-pressure fuel regulated from the fuel filter assembly.

When the ECM provides battery voltage to the IAHFS valve, the solenoid opens and allows fuel to flow to the IAHFI through the IAHFI fuel line.

Inlet Air Heater System Operation

The Inlet Air Heater system operates only in temperatures lower than 10°C (50°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) sensors, the ECM activates the IAHR heater element. The IAHR then energizes the IAHFI for approximately 35 seconds.

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

With the engine running, the IAHFI remains energized and fuel continues to be injected, and the wait-to-start lamp continues to flash for a maximum of four minutes. When the wait-to-start lamp stops flashing, the IAHFI and the IAHFS valve are deactivated. If the operator accelerates while the wait-to-start lamp is flashing, the Inlet Air Heater system will shutdown.

Oil Flow and Components

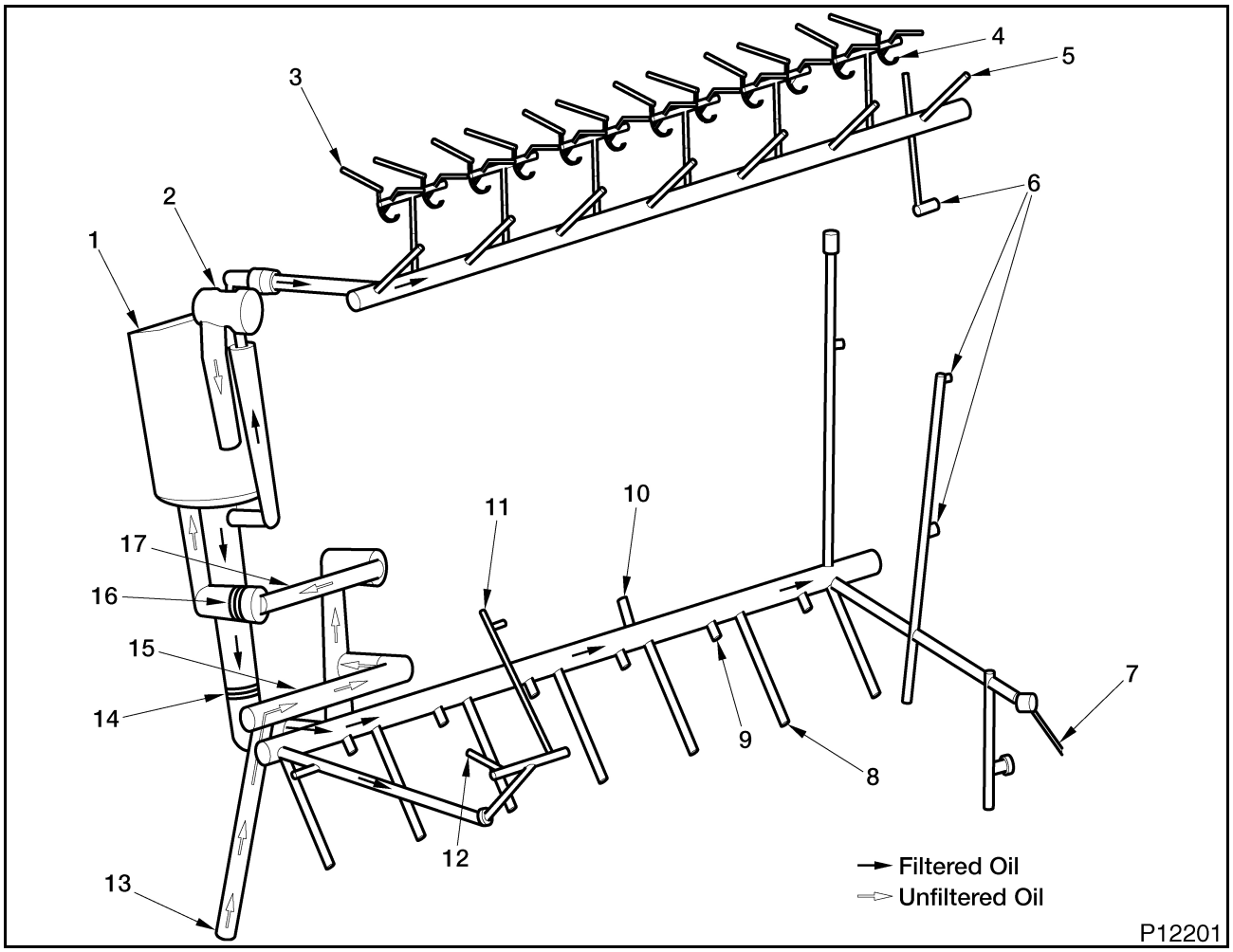

Figure 19 Oil flow

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

Unfiltered oil is drawn from the oil pan through the pickup tube and front cover passage by the crankshaft driven gerotor pump. 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 oil from draining through the oil pump and back into the oil pan when the engine is stopped. If oil pressure coming out of the oil pump is too high, a pressure relief valve allows excess oil to return through the crankcase 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. When the filter is restricted, an oil filter bypass valve opens and allows oil to bypass the filter so engine lubrication is maintained. If oil pressure inside the oil filter element is too high, an oil pressure relief valve, installed 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, oil flow is directed to the cylinder head and crankcase.

Clean oil enters the cylinder head through an external flange elbow connected 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 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 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, installed 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.

Oil is also supplied to the Navistar® Engine Brake housings (under valve cover) through specially designed rocker mounting bolts.

Crankcase Oil Separator

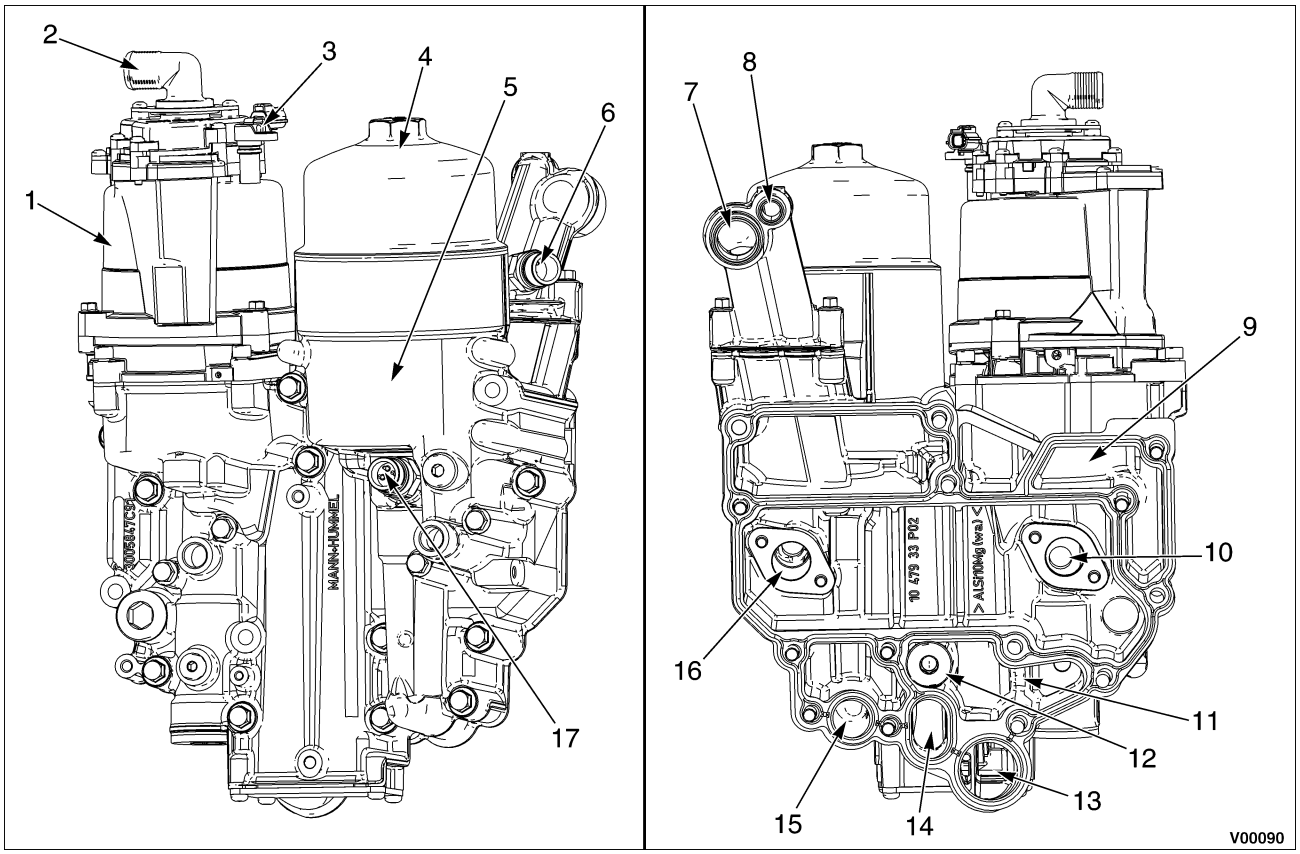

Figure 20 Oil module with crankcase oil separator assembly (inner and outer views)

1. Crankcase Oil Separator (CCOS)
2. CCOS vent outlet
3. Crankcase Oil Separator Speed (CCOSS) sensor
4. Filter cover
5. Oil filter assembly
6. Engine Oil Temperature (EOT) sensor
7. Oil return from cylinder head
8. Oil supply to cylinder head
9. Crankcase gas inlet
10. Oil cooler inlet
11. Oil supply from oil pump
12. Regulator
13. CCOS oil return
14. Oil module pressure relief port
15. Oil out to crankcase
16. Oil cooler outlet to crankcase
17. Engine Oil Pressure (EOP) sensor

The oil module contains a canister style filter, oil cooler, EOP and EOT sensors, a pressure relief valve, an oil filter bypass valve, and an oil return shutoff valve. The oil module also collects, and directs crankcase emissions to the CCOS. The oil that separates from the crankcase emissions, before it reaches the CCOS, is drained back into the oil pan through the oil return port.

Remote Mounted Centrifugal Oil Filter (Optional)

The remote mounted centrifugal oil filter is used to remove particulates from engine oil, reducing wear and extending engine oil change intervals. During operation, dirty oil enters the oil supply port to a regulator valve. When engine oil pressure exceeds approximately 248 kPa (36 psi), the regulator valve opens, and oil enters the centrifugal element through the center hollow spindle. Inside the element, centrifugal acceleration separates contaminants from oil. Contaminants accumulate on the serviceable rotor surface as a solid cake. Clean oil exits through opposing twin nozzles that power the centrifuge and returns to the crankcase from the oil level control base. Oil level is managed by the oil float. When the oil float raises, compressed air enters the system to force oil back to the crankcase. When the oil float drops, the air supply port is closed.

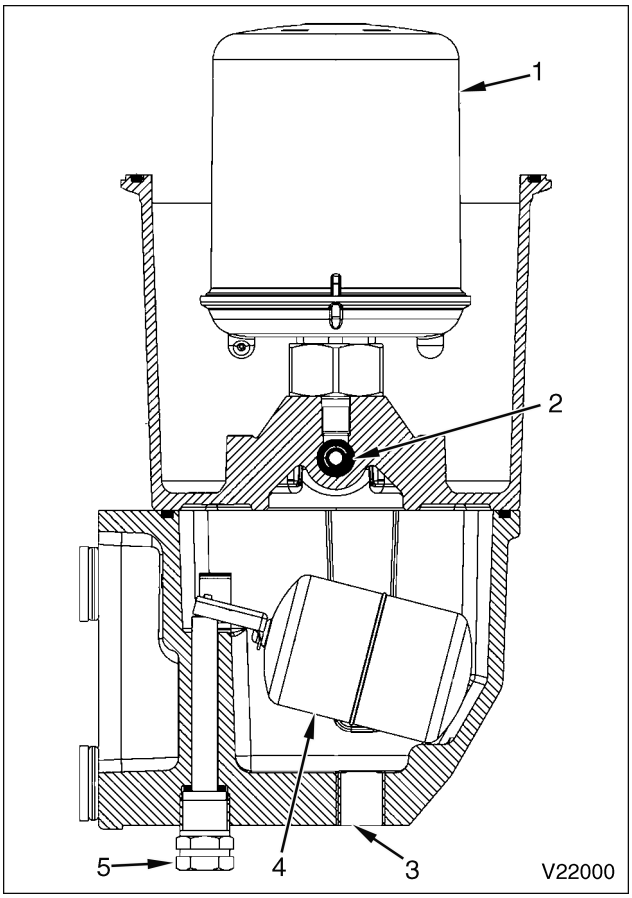

Figure 21 Remote Mounted Centrifugal Oil Filter

1. Serviceable rotor
2. Oil supply port (regulator valve)
3. Oil return port
4. Oil float
5. Air supply port (regulator valve)

Engine Cooling System

Cooling System Flow

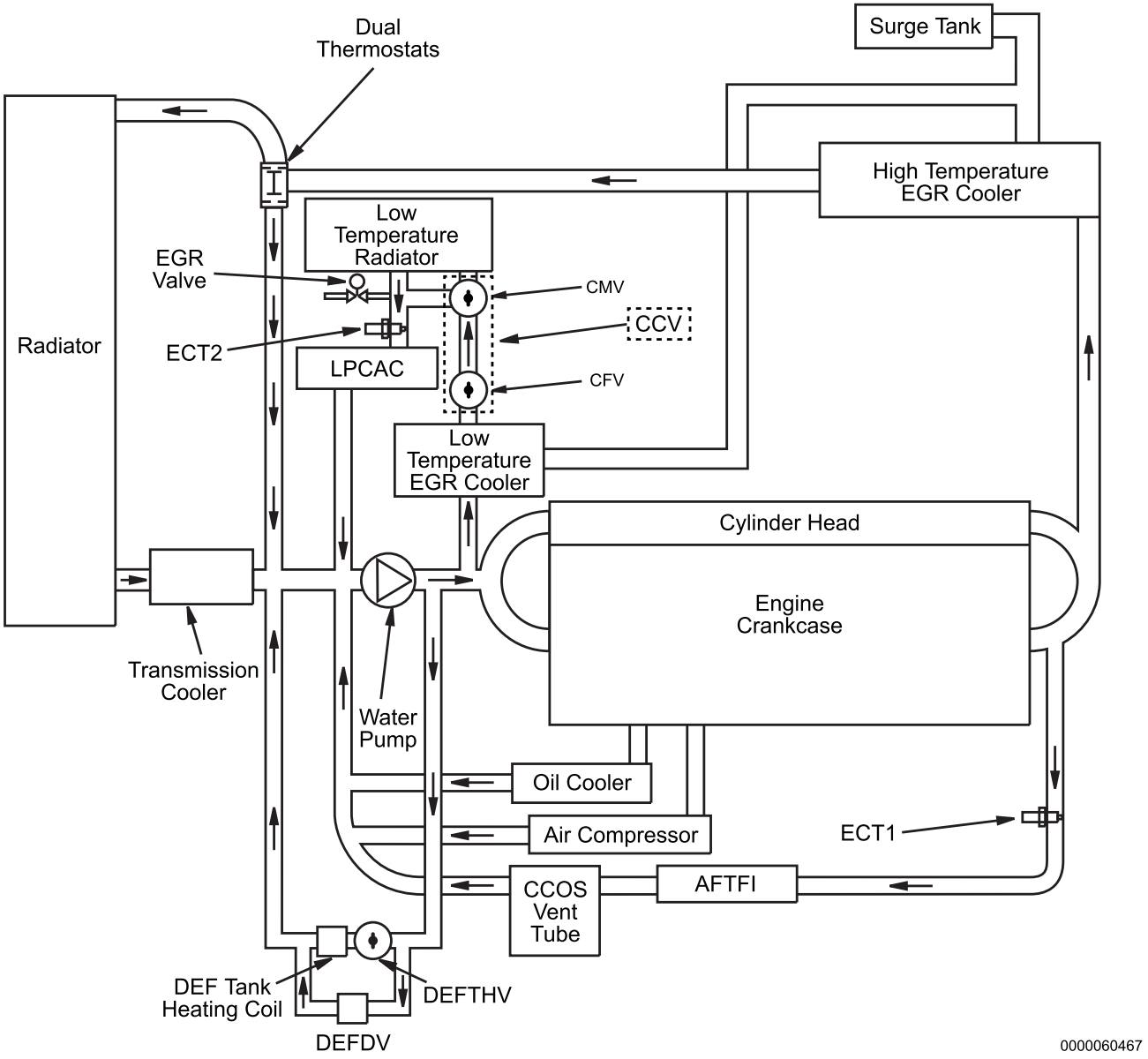

Figure 22 Cooling system flow

The water pump is installed on the water distribution housing and draws coolant from the radiator through the coolant inlet.

Navistar® N13 engines have no coolant passages between the crankcase and cylinder head through the cylinder head gasket. This 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 pipe to the high-temperature stage of the Exhaust Gas Recirculation (EGR) cooler. Coolant passes between the EGR cooler plates, travels parallel to the exhaust flow, through a transfer passage in the left side of the low-temperature EGR cooler, into the EGR cooler return manifold, and into the thermostat housing. A deaeration port on top of the high-temperature EGR cooler directs coolant and trapped air to the coolant deareation tank.

Coolant from the water pump also flows through the low-temperature EGR Cooler and then through the Low Pressure Charge Air Cooler (LPCAC) to regulate charge air temperature. Flow through the low-temperature EGR cooler/charge air cooler is controlled by the Coolant Mixer Valve (CMV) and Coolant Flow Valve (CFV). Depending on the coolant flow, CMV sends coolant through the low-temperature EGR Cooler, or bypass indirectly to the LPCAC, after going through the Low Temperature Radiator (LTR) installed in front of the main coolant radiator. When charge air temperature is too low, CMV bypasses the LTR and directs all the coolant through the Charge Air Cooler (CAC). When charge air temperature increases, the CMV directs a percentage of coolant to the LTR before it enters the CAC 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 LPCAC to help cool the engine faster.

Both CMV and CFV are controlled by the Engine Control Module (ECM) based on signals from the Engine Coolant Temperature 1 (ECT1) sensor, ECT2 sensor, Intake Manifold Pressure (IMP), and Inlet Air Temperature (IAT) 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 first through the transmission cooler, then through the engine coolant 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 coolant return line to the engine crankcase.

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.

The Diesel Exhaust Doser Valve (DEFDV) and DEF Tank Heater Valve (DEFTHV) receive coolant from a supply line running from the lower radiator hose. When DEF tank temperature is too low, the Aftertreatment Control Module (ACM) commands the DEFTHV ON allowing coolant to pass through the DEF tank heating coil. Coolant from the DEF tank heating coil and DEFDV then returns to the water pump inlet through a coolant return line.

Thermostat Operation

Navistar® N13 engines are fitted with two thermostats in a common housing to ensure sufficient coolant flow in all operating conditions. The thermostat housing is installed on top of the water distribution housing.

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 approximately 83°C (181°F) and are fully open at 91°C (196°F).

When engine coolant is below approximately 83°C (181°F), the thermostats are closed, blocking coolant flow to the radiator.

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

Coolant Control Valve (CCV) assembly operation

The CCV is installed on the upper right side of the water distribution housing and controls coolant flow to the Charge Air Coolers (CAC)s.

The CCV has two separate solenoid actuated valves. The Coolant Mixer Valve (CMV) and the Coolant Flow Valve (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 Engine Control Module (ECM). The PWM signal duty cycles vary between 0% and 100% depending on coolant and charge air temperature.

Coolant Flow Valve (CFV)

The CFV is installed on the lower side of the CCV and controls coolant flow through the Low Pressure Charge Air Cooler (LPCAC). The CFV will close to reduce coolant flow through the LPCAC when the engine is operating at high speeds.

Coolant Mixer Valve (CMV)

The CMV is installed on the upper side of the CCV and controls coolant flow through the Low Temperature Radiator (LTR). When charge air and coolant temperature coming out of the LPCAC is low, the CMV directs coolant through a LTR bypass into the LPCAC. This helps the engine reach normal operating temperature faster. If charge air and coolant temperature coming out of the LPCAC is high, the CMV directs coolant flow through the LTR. This prevents overheating the LPCAC, which can result in LPCAC failure.

Engine Brake System

Engine Brake Control System Components

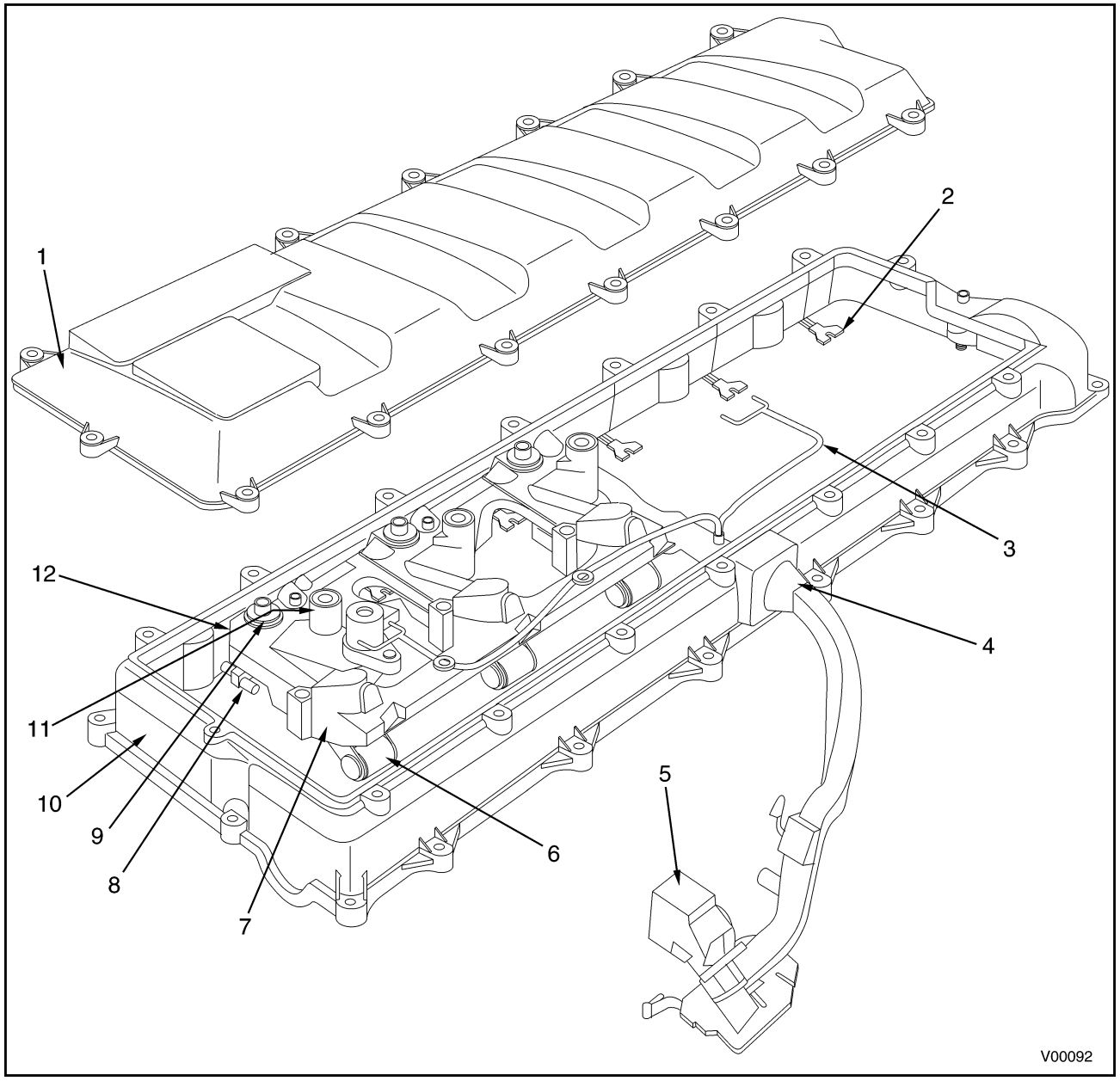

Figure 23 Engine brake control system components

1. Upper valve cover
2. Injector harness connector
3. Engine brake solenoid harness connector lead (2)
4. Pass through harness
5. ECM E1 connector
6. Master piston roller assembly (3 each housing)
7. Engine brake master piston (within housing)
8. Exhaust valve bridge
9. Engine brake slave piston
10. Valve cover base
11. Engine brake solenoid (1 each housing)
12. Engine brake housing assembly (2)

Engine Brake System Description

The Navistar® Engine Brake by Jacobs® braking system is standard equipment on the ProStar® and optional equipment on the TranStar® and WorkStar® for Navistar®N13 engines. The braking system is a hydro-mechanical device that mounts under the engine's valve cover. It turns your power-producing diesel engine into a power-absorbing air compressor.

Here's how: when the driver releases the accelerator pedal, the forward momentum of the truck continues to turn the drivetrain and engine. The pistons continue to move up and down. Once activated, the engine brake opens the exhaust valves near the peak of the compression stroke, releasing the highly compressed air through the exhaust systems. Little energy is returned to the piston, and as the cycle repeats, the energy of the truck's forward motion is now directed toward motoring the diesel engine, thus reducing the forward motion causing the truck to slow down.

Engine Brake System Operation

The engine brake system consists of two hydraulic braking housings, activated using two Engine Control Module (ECM) actuated brake solenoids, and an exhaust bridge (pin). The engine brake depends on engine oil for operation; minimum oil temperature for retarder activation is approximately 40°C (104°F).

Engine brake operation is automatic after the operator turns it On using the On / Off switch. When the clutch is engaged and the throttle is not depressed, the engine brake is automatically activated.

NOTE: The operator can select various engine brake retarding levels by pressing a HIGH/MEDIUM/LOW switch.

Activation occurs through the following steps:

1. Engine oil pressure fills the housing passages up to the solenoid.
2. Activation of the engine brake is communicated by the ECM using the J1939 Controller Area Network (CAN) data link. When activated, the energized solenoid valve permits engine lube oil to flow under pressure through the control valve to both the master piston and slave piston circuits.
3. Oil pressure causes the master piston roller assembly to move down, picking up the motion of the cam (dedicated braking lobe) pushing the piston back into the housing creating high-pressure oil.
4. High-pressure oil flows back through the master piston, slave piston and control valve circuits.
5. The check ball in the control valve seats, trapping oil in the circuit creating a high-pressure link between the slave piston and master piston.
6. Once the high-pressure link is created, the master piston follows the cam profile causing the slave piston to move down, momentarily opening exhaust valve (single valve opening), while the engine piston is near its top dead center position, releasing compressed cylinder air to the exhaust manifold.
7. Compressed air escapes to atmosphere completing compression braking cycle.

NOTE:

1. **The Navistar® Engine Brake by Jacobs® will disengage during Anti-lock Brake System (ABS) braking.**
2. **Will interact with the vehicle cruise control for smooth operation during engine braking**
3. **Will interact with the Eaton UltraShift® Transmission for smooth up-shifts under fueling conditions**

Electronic Control System

Electronic Control System Components

Navistar®N13 engines are equipped with two control modules, the Engine Control Module (ECM), and the Aftertreatment Control Module (ACM).

Operation and Function

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

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

Reference Voltage (VREF)

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

Signal Conditioner

Signal conditioning circuitry in the ECM and ACM convert analog signals to digital signals, squares up sine wave signals, and amplifies low intensity signals.

Microprocessor

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

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

Diagnostic Trouble Codes

Diagnostic Trouble Codes (DTCs) are stored by the ECM if inputs or conditions do not comply with expected values. Diagnostic fault codes are communicated using the Suspect Parameter Number (SPN) and Failure Mode Indicator (FMI) identifiers, and are accessed using an electronic service tool with ServiceMaxx™ diagnostic software or other J1939 and J1708 RP1210B compliant interface device.

Microprocessor Memory

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

Read Only Memory (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

Random Access Memory (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

Actuator Control

The Engine Control Module (ECM) and Aftertreatment Control Module (ACM) control 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)
- Pulse Width Modulated (PWM)
- Switched On or Off

Actuators

The ECM controls engine operation with the following:

- Coolant Control Valve (CCV)
- Exhaust Back Pressure Valve (EBPV)
- Exhaust Gas Recirculation Valve (EGRV)
- Air Control Valve (ACV)
- Inlet Air Heater Relay (IAHR)
- Inlet Air Heater Fuel Solenoid (IAHFS) valve
- Engine Throttle Valve (ETV)
- Fuel Pressure Control Valve (FPCV)
- Intake Air Heater Fuel Ignitor (IAHFI) relay

The ACM controls aftertreatment system operation with the following:

- Aftertreatment Fuel Shutoff Valve (AFTFSV)
- Aftertreatment Purge Air Valve (AFTPAV)
- Diesel Exhaust Fluid Dosing Unit Heater (DEFDUH)
- Diesel Exhaust Fluid Doser Valve (DEFDV)
- Diesel Exhaust Fluid Line Heater Relay (DEFLHR)
- Diesel Exhaust Fluid Pressure Line Heater (DEFPLH)
- Diesel Exhaust Fluid Return Line Heater (DEFRLH)
- Diesel Exhaust Fluid Return Valve (DEFRV)
- Diesel Exhaust Fluid Suction Line Heater (DEFSLH)
- Diesel Exhaust Fluid Supply Pump (DEFSP) and Temperature Sensor
- Diesel Exhaust Fluid Tank Heater Valve (DEFTHV)
- Diesel Exhaust Fluid Unit Heater Relay (DEFUHR)

Coolant Control Valve (CCV)

The Coolant Mixer Valve (CMV) and Coolant Flow Valve (CFV) are a combined solenoid assembly that regulates coolant flow and temperature through the Low Pressure Charge Air Cooler (LPCAC) and the low-temp EGR cooler. The CMV and CFV are housed in the CCV assembly.

The CFV controls the rate of coolant flow through the CAC, and the CMV regulates the temperature of the coolant, by directing coolant either through the Low Temperature Radiator (LTR) or through an internal bypass. Both valves are controlled by the Engine Control Module (ECM).

The CCV is installed on the water distribution housing.

Exhaust Back Pressure Valve (EBPV) Control

The EBPV is controlled using the Air Control Valve (ACV) assembly. The ACV assembly contains the EBPV control valve, and the Turbocharger 1 Turbine Outlet Pressure (TC1TOP) sensor. Both are used by the ECM to control EBPV operation.

The EBPV regulates air pressure applied to the EBPV pneumatic actuator. The pneumatic cylinder actuates the valve (in the exhaust system) in response to commands by the ECM.

The EBPV actuator is mounted on the right side of the engine, after the turbocharger exhaust connection.

Exhaust Gas Recirculation (EGR) Valve

The EGRV is mounted on the rear of the EGR cooler, on top of the engine. The EGRV assembly receives the desired valve position from the ECM. The EGRV regulates the flow of exhaust gases through the EGR system.

Air Control Valve (ACV)

The ACV contains solenoids used for control of the High Pressure (HP) turbocharger wastegate and EBPV. It also contains the TC1TOP sensor.

ACV solenoids are controlled through pulse width modulated signals sent by the ECM.

The ACV is installed on the right side of the engine, near the center of the EGR cooler.

Inlet Air Heater Relay (IAHR)

The Inlet Air Heater system warms incoming air supply up to four minutes for cold engine emissions reduction.

The Engine Control Module (ECM) is programmed to energize the Inlet Air Heater Fuel Igniter (IAHFI) heater element through the Inlet Air Heater Relay (IAHR) while monitoring engine coolant temperature, air inlet temperature, engine oil temperature, and atmospheric pressure.

The IAHR delivers battery voltage to the heater element for a set time, depending on engine coolant temperature and altitude. The ground circuit is supplied from the battery ground. The relay is controlled by switching on a voltage source from the ECM, and is installed to the rear of the ECM.

Inlet Air Heater Fuel Solenoid (IAHFS) Valve

The IAHFS valve controls fuel flow to the IAHFI during Inlet Air Heater operation.

When Inlet Air Heater is required, the ECM provides voltage to open the IAHFS valve.

The IAHFS valve is mounted on the intake throttle duct, on the top left side of the engine.

Engine Throttle Valve (ETV)

The ETV controls the flow of fresh air (boosted and cooled) into the engine's air intake path through the Charge Air Cooler (CAC) to help heat the exhaust aftertreatment during regeneration, and to when heavy Exhaust Gas Recirculation (EGR) is requested. The electronic portion of the ETV contains a microprocessor that monitors valve position, electronic chamber temperature, controls the electric motor, and reports diagnostic faults to the ECM. The ETV changes position in response to ECM signals.

The ETV is integrated into the intake throttle duct, on the top left side of the engine.

Fuel Pressure Control Valve (FPCV)

The FPCV is a variable position actuator that controls fuel flow to the suction side of the high-pressure fuel pump.

The FPCV changes valve position through pulse width modulated signals from the ECM.

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

Aftertreatment Fuel Shutoff Valve (AFTFSV)

The AFTFSV is used to control fuel flow to the Aftertreatment Fuel Injector (AFTFI). The AFTFSV is controlled through an On-Off signal sent by the Aftertreatment Control Module (ACM). The AFTFSV is installed in the AFT fuel doser module, located to the rear of the fuel filter assembly, on the left side of the engine.

Aftertreatment Purge Air Valve (AFTPAV)

The AFTPAV is used to purge the AFTFI of fuel after active regeneration of the aftertreatment system. When purging is needed, the Aftertreatment Control Module (ACM) commands the AFTPAV ON, and AFTFI open. This allows pressurized air from the vehicle air tanks, to flow through the AFTPAV, AFT fuel doser module, and out the AFTFI.

The AFTPAV is mounted on the left side of the engine, behind the AFT fuel doser module.

Diesel Exhaust Fluid Dosing Unit Heater (DEFDUH)

The DEFDUH is used to maintain proper DEF temperature in the DEF supply module.

The ACM is programmed to energize the DEFDUH through the Diesel Exhaust Fluid Unit Heater Relay (DEFUHR) when DEF supply module temperature is too low.

Diesel Exhaust Fluid Doser Valve (DEFDV)

The DEFDV is a solenoid assembly controlled by the Aftertreatment Control Module (ACM). When the ACM commands DEF dosing, it opens the doser valve and allows DEF to be sprayed into the exhaust stream.

Diesel Exhaust Fluid Line Heater Relay (DEFLHR)

The DEF line heaters are used to maintain proper DEF temperature to avoid DEF freezing. When DEF temperature is too low. The ACM commands the DEFLHR ON, sending power to the DEF line heaters.

The DEFLHR is installed in the Power Distribution Module (PDM), behind the DEF tank.

Diesel Exhaust Fluid Pressure Line Heater (DEFPLH)

The DEFPLH is used to maintain proper DEF temperature in the DEF supply module pressure line.

The DEFPLH is wrapped around the pressure line between the DEF supply module and DEFDV.

Diesel Exhaust Fluid Return Line Heater (DEFRLH)

The DEFRLH is used to maintain proper DEF temperature in the DEF supply module return line.

The DEFRLH is wrapped around the return line between the DEF supply module and DEF tank.

Diesel Exhaust Fluid Return Valve (DEFRV)

The DEFRV is switched On or Off by the ACM.

The DEFRV regulates the flow of DEF exiting the DEF supply module. When purging is needed, the ACM will turn the DEFRV ON, and returns DEF in the lines to the tank.

The DEFRV is part of the DEF supply module, and is not serviceable individually.

Diesel Exhaust Fluid Suction Line Heater (DEFSLH)

The DEFSLH is used to maintain proper DEF temperature in the DEF supply module suction line.

The DEFSLH is wrapped around the suction line between the DEF supply module and DEF tank.

Diesel Exhaust Fluid Supply Pump (DEFSP) and Temperature Sensor

The DEFSP is controlled using a Pulse Width Modulated (PWM) signal from the ACM.

The DEF supply module has an internal temperature sensor used to monitor DEFSP temperature.

The DEFSP is part of the DEF supply module, and is not serviceable individually.

Diesel Exhaust Fluid Tank Heater Valve (DEFTHV)

The DEFTHV controls coolant flow to the DEF tank. When DEF temperature is low, the ACM commands the DEFTHV open, allowing coolant flow to warm the DEF tank.

The DEFTHV is typically mounted to the vehicle frame.

Diesel Exhaust Fluid Unit Heater Relay (DEFUHR)

The DEFUHR aids in defrosting the DEF supply module. When DEF temperature is too low, the ACM energizes the heater element inside the DEF supply module through the DEFUHR.

Engine and Vehicle Sensors

Thermistor Sensors

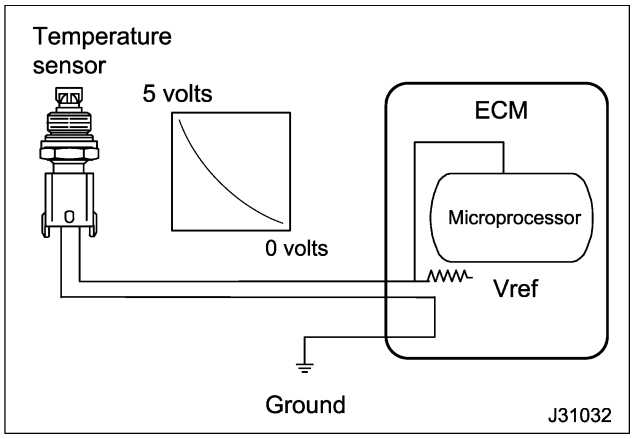

Figure 24 Thermistor

A thermistor sensor changes electrical resistance with changes in temperature. As temperature changes at the thermistor, voltage at the ECM or ACM will change accordingly. Thermistors work with the control

module to produce a voltage signal proportional to temperature values.

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 temp sensors
- Engine Oil Temperature (EOT) sensor
- Turbocharger 2 Compressor Inlet Sensor (TC2CIS)
- Charge Air Cooler Outlet Temperature (CACOT) sensor
- Intake Manifold Temperature (IMT) sensor
- EGR (cooler) Temperature (EGRT) sensor
- Ambient Air Temperature (AAT) sensor

Aftertreatment Temperature Sensors

Temperature sensors used in the Aftertreatment System include the following:

- Diesel Exhaust Fluid Tank Level and Temperature (DEFTLT) sensor
- DOC / DPF temperature sensor module
    - Diesel Oxidation Catalyst Inlet Temperature (DOCIT) sensor
    - Diesel Particulate Filter Inlet Temperature (DPFIT) sensor
    - Diesel Particulate Filter Outlet Temperature (DPFOT) sensor
- SCR temperature sensor module
    - Selective Catalyst Reduction Inlet Temperature (SCRIT) sensor
    - Selective Catalyst Reduction Outlet Temperature (SCROT) sensor

Diesel Exhaust Fluid Tank Level and Temperature (DEFTLT) Sensor Module

The DEFTLT sensor module is a combination sensor that monitors DEF tank level and temperature, and communicates to the Aftertreatment Control Module (ACM) through J1939 Controller Area Network (CAN) communication.

The DEFTLT sensor module is installed inside the DEF tank.

Diesel Oxidation Catalyst (DOC) / Diesel Particulate Filter (DPF) Temperature Sensor Module

The DOC / DPF temperature sensor module monitors aftertreatment DPF and DOC temperature. The DOC / DPF temperature sensor module monitors signals from the DOC Inlet Temperature (DOCIT), DPF Inlet Temperature (DPFIT), and DPF Outlet Temperature (DPFOT) sensors, and communicates these signals to the Aftertreatment Control Module (ACM) through J1939 Controller Area Network (CAN) communication.

The DOCIT, DPFIT, and DPFOT sensors are not serviceable individually, and are part of the DOC / DPF temperature sensor module.

Selective Catalyst Reduction (SCR) Temperature Sensor Module

The SCR temperature sensor module monitors aftertreatment SCR catalyst temperature. The SCR temperature sensor module monitors signals from the SCR Inlet Temperature (SCRIT) sensor, and SCR Outlet Temperature (SCROT) sensor, and communicates these signals to the ACM through J1939 Controller Area Network (CAN) communication.

The SCRIT sensor and SCROT sensor are not serviceable individually, and are part of the SCR temperature sensor module.

Engine Coolant Temperature (ECT) Sensors

The ECT1 and ECT2 sensors are thermistor-type sensors that detect engine coolant temperature.

The ECT1 signal is monitored by the ECM for operation of the instrument panel temperature gauge, coolant temperature compensation, charge air temperature control, EGR system control, optional Engine Warning Protection System (EWPS), and the wait to start lamp. The ECM uses ECT1 sensor input as a backup, if EOT sensor values are out of range.

The ECT1 sensor is installed in the underside of the EGR coolant crossover manifold, at the back

of the engine. The ECT2 sensor is installed in the low-temperature stage of the EGR cooler, on the right side of the engine.

Engine Oil Temperature (EOT) Sensor

The EOT sensor is a thermistor sensor that detects engine oil temperature. The EOT sensor is installed in the side oil module flange, behind the oil filter cover, on the right side of the engine.

Turbocharger 2 Compressor Inlet Sensor (TC2CIS)

The TC2CIS sensor includes a thermistor sensor that monitors the temperature of charge air entering the High Pressure (HP) turbocharger. This sensor also monitors boost pressure for the Low Pressure (LP) turbocharger.

The TC2CIS sensor is monitored by the Engine Control Module (ECM), and is used for calculating fuel delivery and controlling turbocharger wastegate operation.

The TC2CIS is installed in the piping between the LP compressor outlet and the HP compressor inlet.

Charge Air Cooler Outlet Temp (CACOT) Sensor

The CACOT sensor is a thermistor sensor that monitors the temperature of charge air entering the intake air duct.

The CACOT signal is monitored by the ECM.

The CACOT sensor is installed on the intake air duct, before the Engine Throttle Valve (ETV).

Intake Manifold Temperature (IMT) Sensor

The IMT sensor is a thermistor sensor that monitors temperature.

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

Exhaust Gas Recirculation Temperature (EGRT) Sensor

The EGRT sensor is a thermistor sensor that detects the exhaust gas temperature entering the EGR cooler.

The EGRT signal is monitored by the ECM.

The EGRT sensor is installed in the front of the low temp EGR cooler on the left side.

Ambient Air Temperature (AAT) Sensor

The AAT sensor is a thermistor sensor that detects the temperature of ambient air.

The AAT signal is monitored by the ECM.

The AAT sensor is installed in various places depending on the vehicle.

Variable Capacitance Sensors

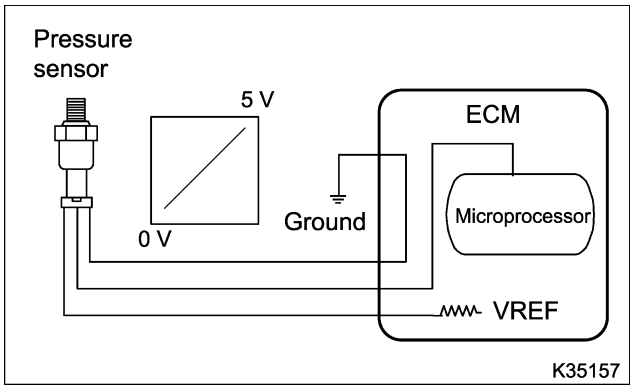

Figure 25 Variable capacitance sensor example

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

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

The sensor receives the VREF and returns an analog signal voltage to the Engine Control Module (ECM) or Aftertreatment Control Module (ACM). The ECM or ACM compares the voltage with pre-programmed values to determine pressure.

Variable capacitance sensors include the following:

- Aftertreatment Fuel Pressure 1 (AFTFP1)
- Diesel Exhaust Fluid Line Pressure (DEFLP) sensor
- Diesel Particulate Filter Differential Pressure (DPFDP) / outlet pressure sensor
- Fuel Delivery Pressure (FDP) sensor
- Engine Oil Pressure (EOP) sensor
- Fuel Rail Pressure (FRP) sensor

- Intake Manifold Pressure (IMP) sensor
- Turbocharger 1 Turbine Outlet Pressure (TC1TOP) sensor

Aftertreatment Fuel Pressure 1 (AFTFP1) Sensor

The AFTFP1 sensor is a variable capacitance sensor that the ACM uses to monitor fuel pressure into the aftertreatment system.

The AFTFP1 sensor is installed in the AFT fuel doser module, to the rear of the fuel filter assembly.

Diesel Exhaust Fluid Line Pressure (DEFLP) Sensor

The DEFLP sensor is a variable capacitance sensor that measures DEF pressure from the DEF Supply Pump (DEFSP).

The DEFLP sensor provides feedback to the ACM for the DEF dosing system.

The DEFLP sensor is not serviceable individually and is part of the DEF supply module.

Diesel Particulate Filter Differential Pressure (DPFDP) / Outlet Pressure Sensor

The DPFDP / outlet pressure sensor provides a feedback signal to the ACM indicating the pressure difference between the inlet and outlet of the DPF.

The DPFDP / outlet pressure sensor is a differential pressure sensor with two tap-offs installed at the DPF. A tap-off is installed before and after the DPF.

Fuel Delivery Pressure (FDP) Sensor

The FDP sensor is a variable capacitance sensor that measures fuel supply pressure.

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

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

Engine Oil Pressure (EOP) Sensor

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

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

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

Fuel Rail Pressure (FRP) Sensor

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

The FRP sensor measures fuel pressure just before injection.

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

Intake Manifold Pressure (IMP) Sensor

The IMP sensor is a variable capacitance sensor that monitors the pressure of charge air entering the intake air duct.

The IMP signal is monitored by the ECM for control of the EGR system and turbocharger wastegates.

The IMP sensor is installed in the intake air duct, after the Engine Throttle Valve (ETV).

Turbocharger 1 Turbine Outlet Pressure (TC1TOP)

The TC1TOP sensor is a variable capacitance sensor that monitors exhaust back pressure.

The sensor measures back pressure in the exhaust system. A tap for the TC1TOP is installed in the exhaust, between the low-pressure turbocharger and Exhaust Back Pressure Valve (EBPV).

The TC1TOP sensor is installed in the Air Control Valve (ACV), on the right side of the engine.

Magnetic Pickup Sensors

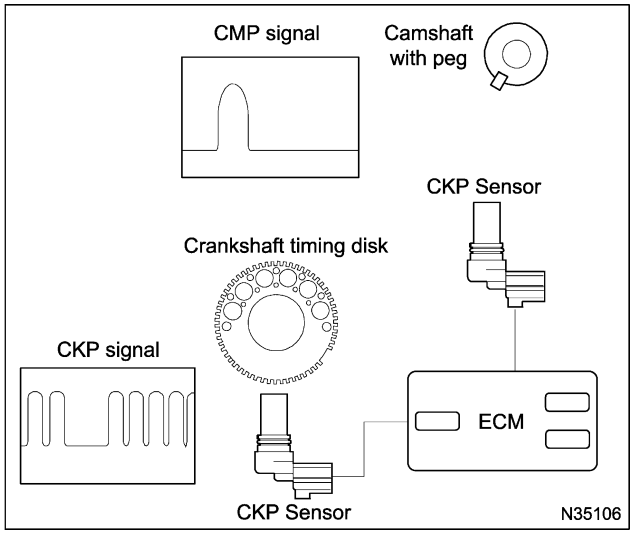

Figure 26 Magnetic pickup sensor examples

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 created by a moving metal trigger. The movement of the trigger then creates Alternate Current (AC) voltage in the sensor coil.

Magnetic pickup sensors used include the following:

- CKP sensor
- CMP sensor
- VSS
- CCOSS sensor

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 holes drilled into the flywheel adjacent to the ring gear. 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.

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

Vehicle Speed Sensor (VSS)

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

Crankcase Oil Separator Speed (CCOSS) sensor

The CCOSS sensor sends the ECM information about the speed of the crankcase oil separator internal components. The detected sine wave signal (AC) received by the ECM is used to monitor operation of the cyclonic oil separator, installed inside the breather assembly on the engine oil filter assembly.

Potentiometer Sensors

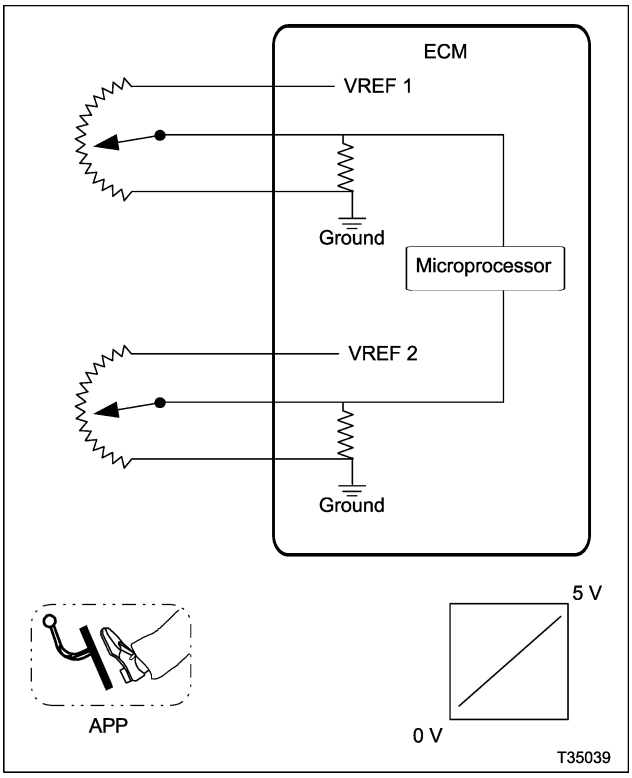

Figure 27 Potentiometer example

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 two potentiometers, both contained in the Accelerator Pedal Position (APP) Sensor.

Accelerator Pedal Position (APP)

The APP provides the ECM with a dual feedback signal (dual linear analog voltages) that indicate the operator's demand for power. The APP contains two potentiometers, and provides two individual signals (APP1 and APP2) to the ECM. The APP is installed in the cab on the accelerator pedal assembly.

Switches

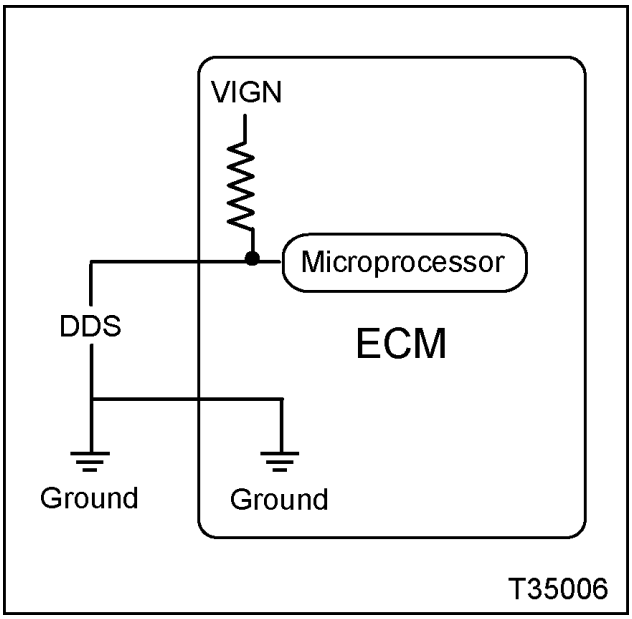

Figure 28 Switch example

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)
- Oil Level Sensor (OLS)

Driveline Disengagement Switch (DDS)

The DDS determines if a vehicle is in gear. For manual transmissions, the clutch switch serves as the DDS. For automatic transmissions, the neutral indicator switch functions as the DDS. The DDS signal is sent to the Body Controller (BC) and transmitted on the J1939 Controller Area Network (CAN) datalink to the engine ECM.

Engine Coolant Level (ECL) Switch

The ECL switch is part of the Engine Warning and Protection System (EWPS). The ECL switch is installed 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.

Oil Level Sensor (OLS)

The OLS is part of the EWPS. The OLS is installed in the engine oil pan. The OLS measures the volume of oil in the oil pan and broadcast the percentage volume over J1939 Controller Area Network (CAN).

If the level of engine lube oil is low, the red ENGINE lamp on the instrument panel is illuminated.

Additional Sensors

Ammonia (NH_3) Sensor Module

The NH_3 sensor module is used to control DEF dosing by monitoring ammonia levels at the Selective Catalyst Reduction (SCR) catalyst.

The NH_3 sensor module monitors the NH_3 sensor signal, and communicates this signal to the Aftertreatment Control Module (ACM).

The NH_3 sensor is not serviceable individually, and is part of the NH_3 sensor module.

Humidity Sensor (HS)

The HS measures the moisture content of filtered air entering the intake system.

Using HS input, the Engine Control Module (ECM) will make adjustments to prevent condensation of airborne water particles (moisture). The HS also houses the IAT sensor, which is used by the ECM for calculating fuel delivery.

Nitrogen Oxides (NOx) IN Sensor Module

The Nitrogen Oxides (NOx) IN sensor module is a smart device used to measure the NOx emissions at the intake of the aftertreatment system. The NOx IN sensor module performs internal diagnostics and reports malfunctions back to the ACM using the J1939 CAN data link.

The NOx IN sensor is not serviceable individually, and is part of the NOx IN sensor module.

Nitrogen Oxides (NOx) OUT Sensor Module

The Nitrogen Oxides (NOx) OUT sensor module is a smart device used to measure NOx emissions at the outlet of the SCR catalyst. The NOx OUT sensor module performs internal diagnostics and reports malfunctions back to the ACM using the J1939 CAN data link.

The NOx OUT sensor is permanently attached to the NOx control module. They are not serviceable independently and it is a single component.

Oxygen Sensor (O_2S)

The O_2S monitors oxygen levels in the exhaust.

O_2S input is used by the ECM to control EGR flow to a specified ratio by monitoring the level of unused oxygen in the exhaust stream.

The O_2S compares oxygen levels in the exhaust stream with oxygen levels in the outside air. The sensor generates an analog voltage and is monitored by the ECM. The level of voltage generated by the O2S corresponds to the oxygen levels in the exhaust stream.

The O2S is installed in the turbocharger exhaust pipe, after the Exhaust Back Pressure Valve (EBPV).

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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.

WARNING: To prevent personal injury or death, make sure the engine is supported before removing mounting hardware.

Engine Cleaning

1. Using Disposable Air and Fuel Caps (page 60), cover all engine openings to prevent water, degreasing agents or detergents from entering engine.
2. Cover exposed electrical connectors and the Engine 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, do the following.

1. Drain any remaining coolant from individual components as necessary into a suitable container.
2. Remove oil drain plug and drain oil into a suitable container.
3. Inspect oil drain plug O-ring. Discard and replace if damaged.
4. After oil is drained, lubricate oil drain plug O-ring with clean engine oil and install oil drain plug.
5. Tighten oil drain plug to special torque (page 60).

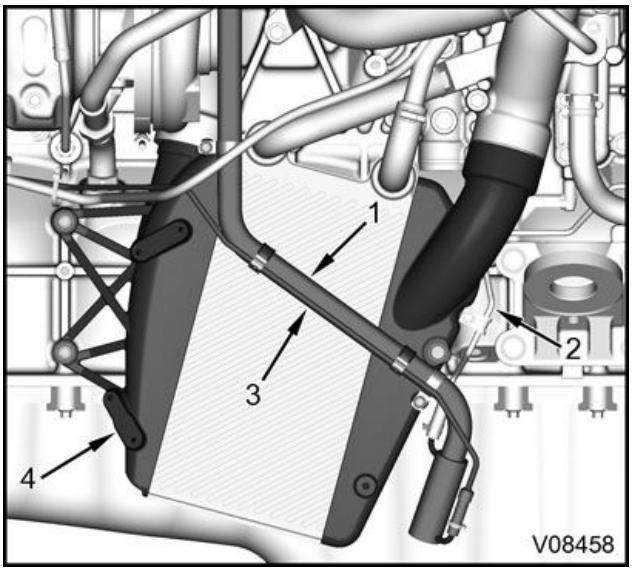

Figure 29 Low-pressure Charge Air Cooler (LPCAC) and tubes

1. Open breather tube assembly
2. Heater hose return tube
3. HCI coolant return tube assembly
4. LPCAC

6. Remove HCI coolant return tube assembly. See HCI Coolant Return Tube Assembly (page 127).
7. Disconnect heater hose return tube from water distribution housing, tube clamp and open breather tube assembly. See Oil Module Assembly (page 283).

8. Remove open breather tube assembly. See Oil Centrifuge (page 282).
9. Remove oil module assembly. See Oil Module Assembly (page 283).
10. Remove Low-Pressure Charge Air Cooler (LPCAC). See Low-Pressure Charge Air Cooler (LPCAC) (page 172).
11. Remove starter motor assembly.

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.

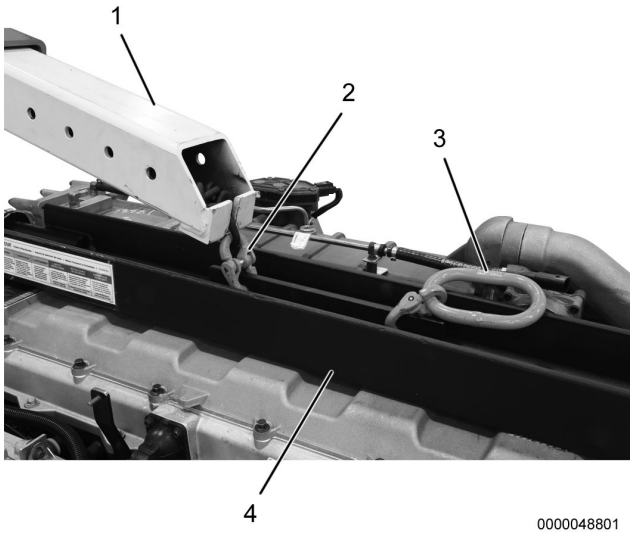

Figure 30 Lifting Chain Assembly Connected to Main Engine Lift Bracket

1. Engine lift
2. Lifting Chain Assembly 12-000-01-07
3. Rear Lifting Ring 12-000-01-05
4. Main Engine Lift Bracket 12-000-01-01

12. Connect Lifting Chain Assembly (Figure 30) (Item 2) on Main Engine Lift Bracket (Figure 30) (Item 4) to engine lift (Figure 30) (Item 1) using chain link closest to lifting ring. Connect at Rear Lifting Ring (Figure 30) (Item 3) if lifting engine and transmission as single assembly.

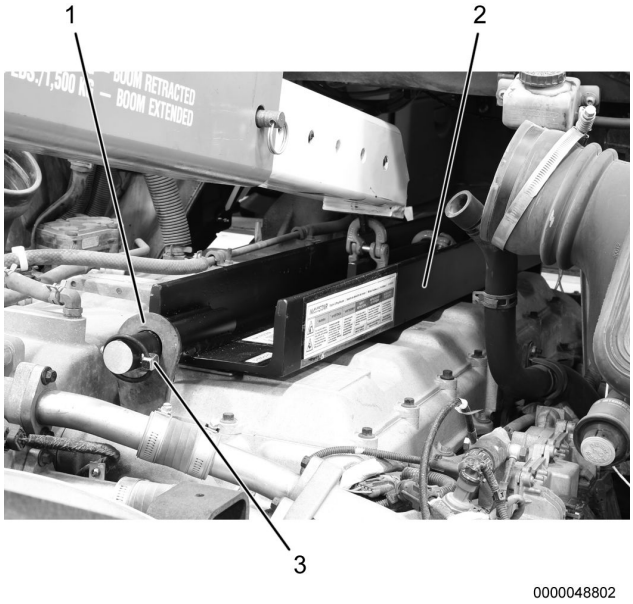

Figure 31 Main Engine Lift Bracket Secured to Front Engine Lifting Eyelet

1. Front engine lifting eyelet
2. Main Engine Lift Bracket 12-000-01-01
3. Lynch Pin 12-000-01-03

13. Slide Main Engine Lift Bracket (Figure 31) (Item 2) into front engine lifting eyelet. Secure lift bracket with Lynch Pin (Figure 31) (Item 3).

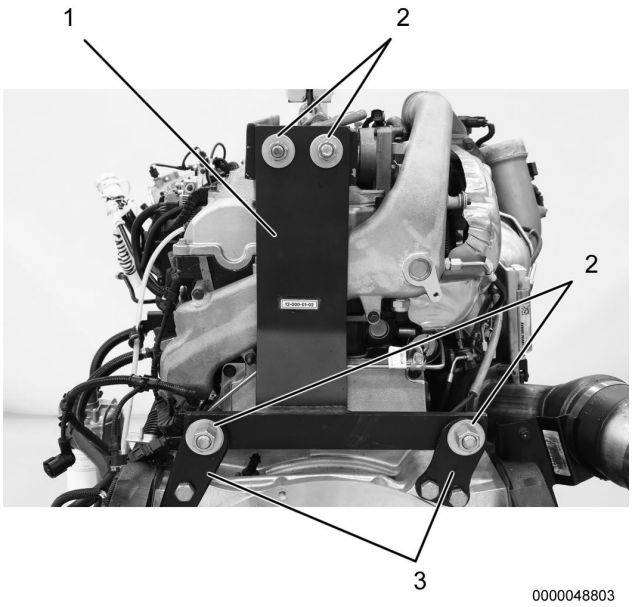

Figure 32 Adapter Bracket Installed

1. Adapter Bracket 12-000-01-02
2. Bolt and nut (4)
3. Rear lifting eyelet (2)

14. Remove engine cover (dog house).
15. Install Adapter Bracket (Figure 32) (Item 1) to front side of rear lifting eyelets (Figure 32) (Item 3) on flywheel housing and Main Engine Lift Bracket. Secure with four bolts and nuts (Figure 32) (Item 2). Install all bolts loosely to allow for bracket movement.

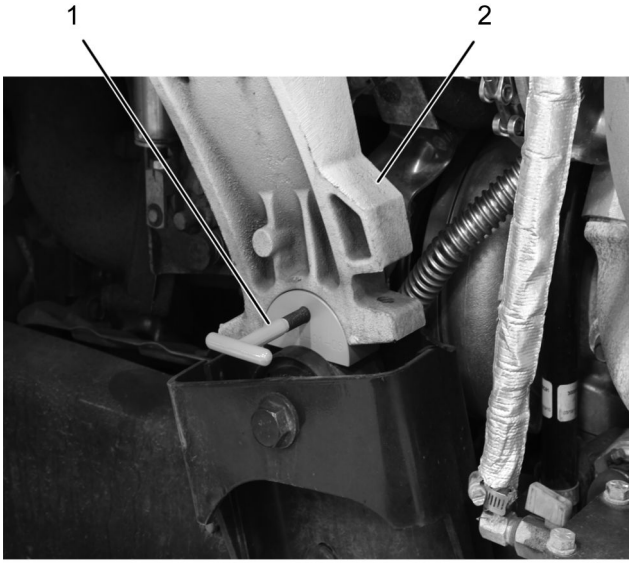

Figure 33 Cab Shim Assembly Installed

1. Cab Shim Assembly 12-000-01-06
2. Cab mount

NOTE: Installation of Cab Shim Assembly 12-000-01-06 is not required for all models, although it may provide additional access for some models.

16. To install Cab Shim Assembly:
    a. Remove steel strap securing cab mount (Figure 33) (Item 2) to cab bushing.
    b. Safely raise passenger side of cab.
    c. Install Cab Shim Assembly (Figure 33) (Item 1).
    d. Lower cab mount (Figure 33) (Item 2) down on Cab Shim Assembly.
17. Raise and remove engine from vehicle using engine lift.

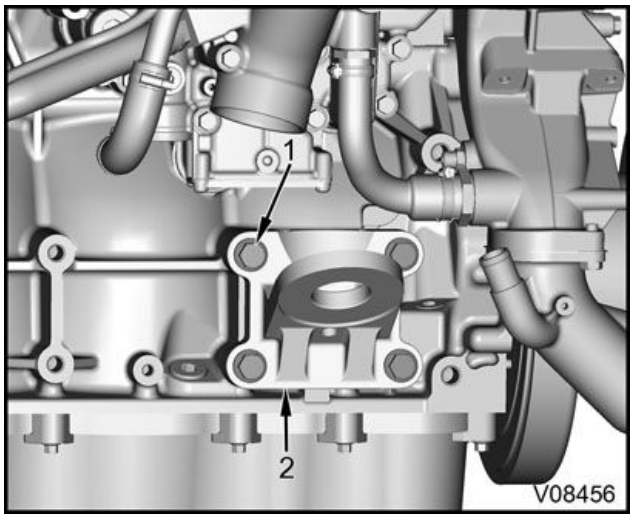

Figure 34 Engine front mount support (right side)

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

NOTE: For reinstallation of engine front mount support, tighten M14 x 50 bolts to special torque (page 60).

18. Remove four M14 x 50 bolts (Figure 34) (Item 1) and engine front mount support (right).

Figure 35 Engine Stand Adapter Plate (mounting bracket) 12-051-01

⚠ WARNING: To prevent personal injury or death, use metric class 10.9 or SAE grade 8 bolts when mounting Engine Stand Adapter Plate to engine and engine stand. See instructions included with engine stand and Engine Stand Adapter Plate.

NOTE: See manufacturer's safety instructions included with engine stand and Engine Stand Adapter Plate.

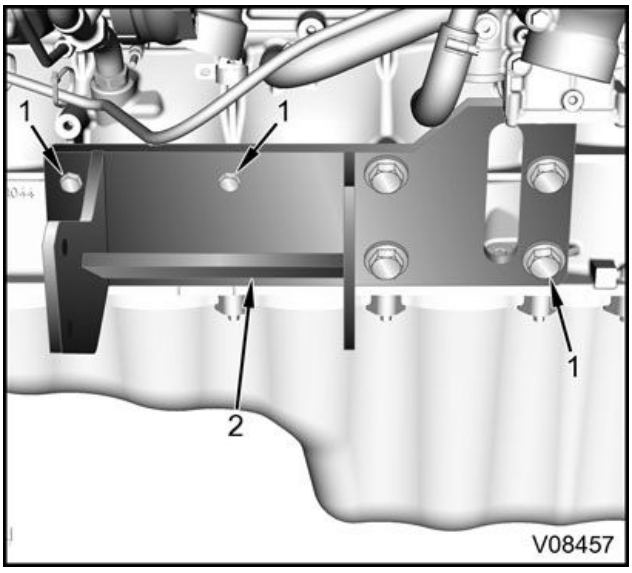

Figure 36 Engine Stand Adapter Plate (mounting bracket) Mounted to Engine

1. Mounting bolts (6) 12-051–01-02
2. Engine Stand Adapter Plate (mounting bracket) 12-051-01

19. Position Engine Stand Adapter Plate (Figure 36) (Item 2) on right side of engine. Secure adapter plate with six mounting bolts (Figure 36) (Item 1). Tighten bolts to standard torque (page 547).

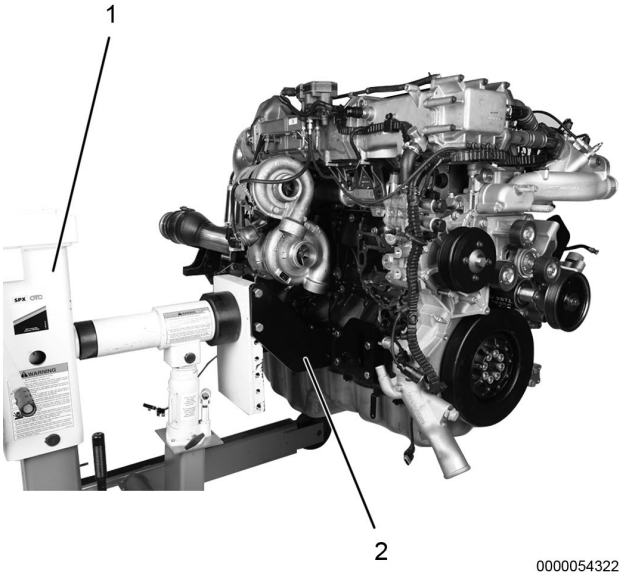

Figure 37 Engine Stand Adapter Plate Attached to Engine Roll-Over Stand

1. Engine Roll-Over Stand OTC1750A
2. Engine Stand Adapter Plate 12-051-01

20. Attach Engine Stand Adapter Plate to Engine Roll-Over Stand (Figure 37) (item 1) using four 5/8 x 1.5 inch grade 8 mounting bolts. Tighten bolts to standard torque (page 547).

Special Torque

M14 x 50 engine front mount support bolts	225 N·m (166 lb·ft)
Oil drain plug	75 N·m (55 lb·ft)

Special Service Tools

Description	Tool Number
Disposable Air and Fuel Caps	ZTSE4891
Engine Lifting Bracket	12-000-01
Engine Roll-Over Stand	OTC1750A
Engine Stand Adapter Plate	12-051-01

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Description of Engine Sensors, Valves and Actuators

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

- **Navistar® N13 Engine Diagnostic Form**
- **Navistar® N13 Engine Diagnostic Form**
- **Navistar® N13 Electronic Control System Diagnostic Form**

Crankshaft Position (CKP) Sensor

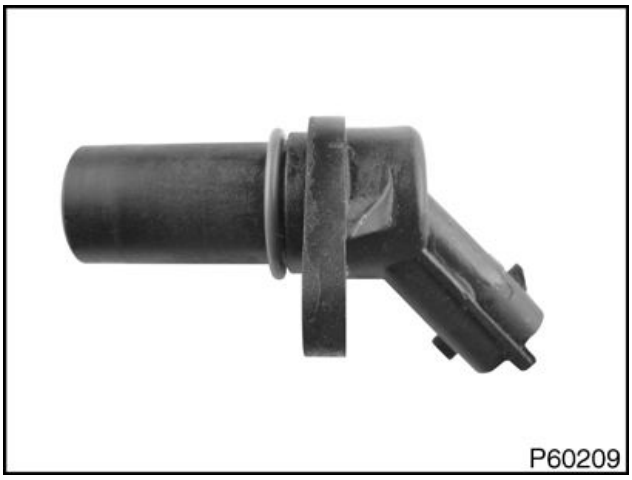

Figure 38 CKP sensor

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 holes drilled into the flywheel adjacent to the ring gear. For crankshaft position reference, teeth 59 and 60 are missing. By comparing the CKP signal with the Camshaft Position (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

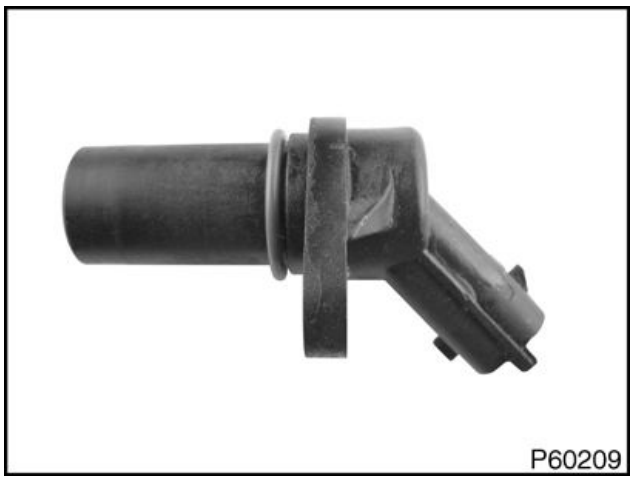

Figure 39 CMP sensor

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.

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

Engine Coolant Temperature (ECT) Sensors

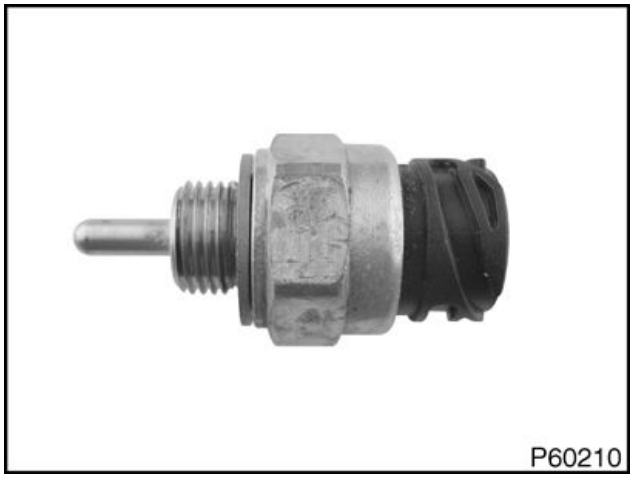

Figure 40 ECT sensor

The ECT1 and ECT2 sensors are thermistor sensors that detect engine coolant temperature.

The ECT1 and ECT2 signals are monitored by the ECM for operation of the instrument panel temperature gauge, coolant temperature compensation, charge air temperature control, Exhaust Gas Recirculation (EGR) system control, optional Engine Warning Protection System (EWPS) and the wait to start lamp. The ECM uses ECT1 sensor input as a backup, if Engine Oil Temperature (EOT) sensor values are out of range.

The ECT1 sensor is installed in the underside of the EGR coolant crossover manifold at the back of the engine. The ECT2 sensor is installed in the low-temperature stage of the EGR cooler on the right side of the engine.

Engine Oil Temperature (EOT) Sensor

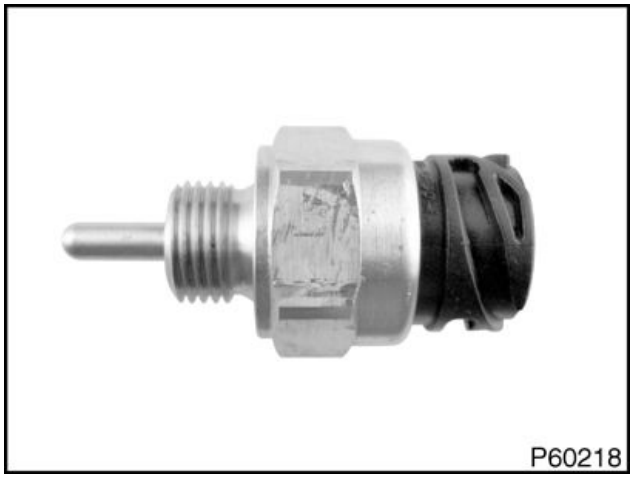

Figure 41 EOT sensor

The EOT sensor is a thermistor sensor that detects engine oil temperature, and is monitored by the ECM for inlet air heater assist. The EOT sensor is installed in the oil module flange, behind the CCV on the right side of the engine.

Engine Oil Pressure (EOP) Sensor

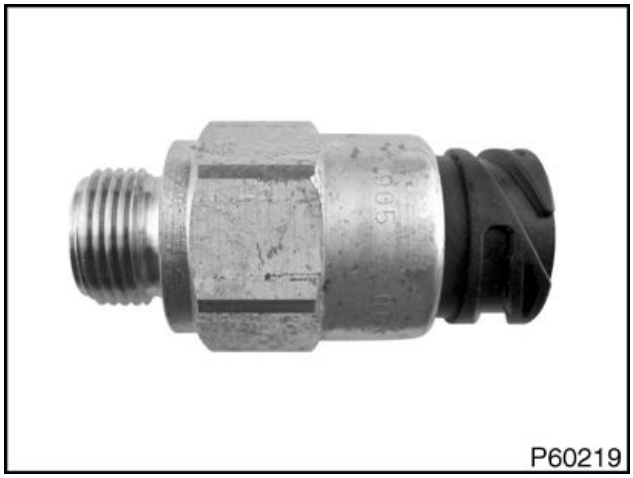

Figure 42 EOP sensor

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 oil module, on the right side of the engine.

Crankcase Oil Separator Speed (CCOSS) Sensor

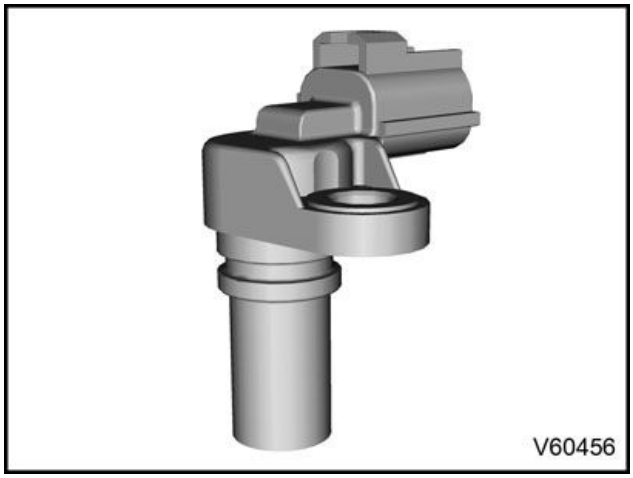

Figure 43 CCOSS sensor

The CCOSS sensor sends the ECM information about the speed of the crankcase oil separator internal components. The detected sine wave signal (AC) is used to monitor proper operation of the cyclonic

oil separator, located on the oil centrifuge on the oil module assembly.

Fuel Delivery Pressure (FDP) Sensor

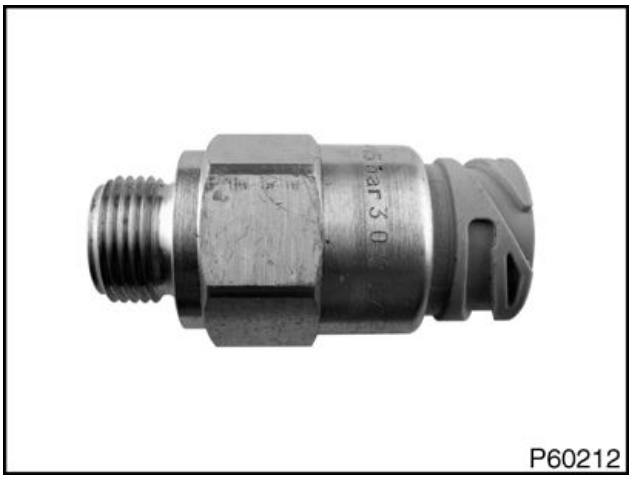

Figure 44 FDP sensor

The FDP sensor is a variable resistance sensor that measures fuel supply pressure, and provides feedback to the ECM for the low-pressure fuel system. The FDP sensor is installed in the front of the fuel filter housing assembly on the left side of the engine.

Fuel Pressure Control Valve (FPCV)

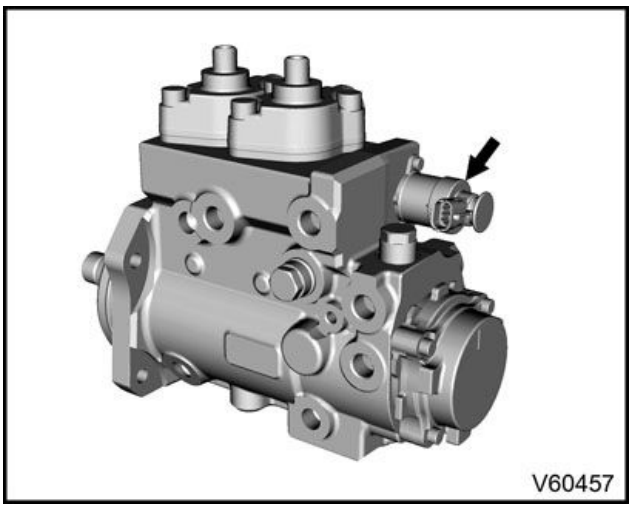

Figure 45 FPCV

The FPCV is a variable-position actuator that controls the flow of fuel to the suction side of the high-pressure fuel pump.

The FPCV changes valve position through pulse-width modulated signals from the ECM.

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

Nitrogen Oxides (NOx) IN Sensor Module

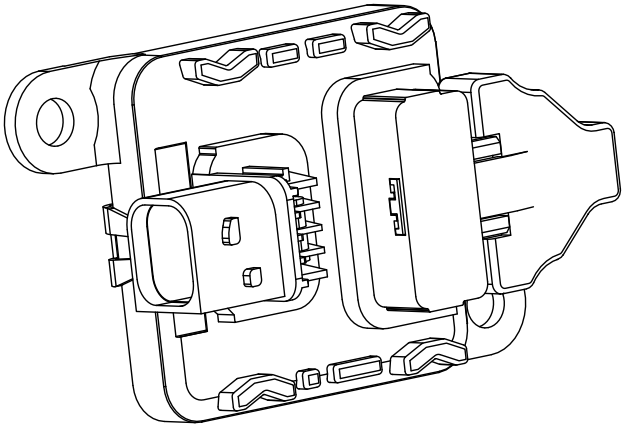

Figure 46 NOx In Sensor Module

The Nitrogen Oxides Inlet Sensor (NOx IN) monitors the amount of Oxides of nitrogen in the exhaust before entering the Aftertreatment system. The Aftertreatment Control Module (ACM) uses this information, along with the NOxOut sensor, to monitor NOx emissions, control the Aftertreatment system, and warn the operator should the system fail. The NOx IN Sensor is located in the Low Pressure Turbocharger Outlet Pipe on the right side of the engine.

Aftertreatment Fuel Pressure Sensor 1 (AFTFP1)

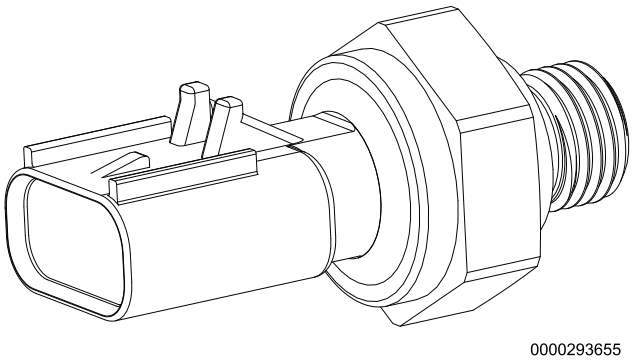

Figure 47 AFTFP1 Sensor

The Aftertreatment Fuel Pressure Sensor 1 (AFTFP1) is a variable resistance sensor that measures fuel pressure available to the Aftertreatment Fuel Injector (AFTFI) and provides constant feedback to the Aftertreatment Control Module (ACM) for proper operation of the Aftertreatment System. The AFTFP1 is the top connector located on the Aftertreatment (AFT) Fuel Doser Module on the left side of the engine.

Aftertreatment Fuel Shutoff Valve (AFTFSV)

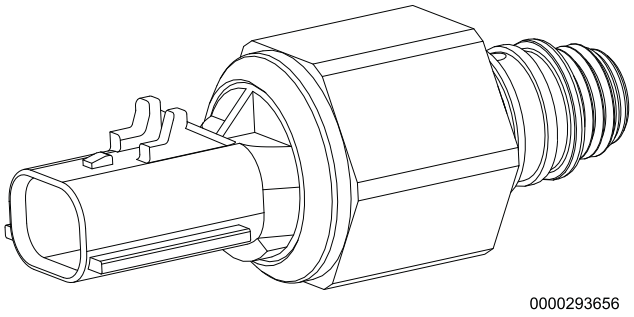

Figure 48 AFTFSV

The Aftertreatment Fuel Shutoff Valve (AFTFSV) is controlled by the Aftertreatment Control Module (ACM). When conditions for a regeneration are met, the ACM commands the AFTFSV to open allowing clean, pressurized fuel to flow through the Aftertreatment (AFT) fuel doser module to the Aftertreatment Fuel Injector (AFTFI). The AFTFSV is the bottom connector installed in the lower port of the AFT Fuel Doser Module on the left side of the engine.

Humidity / Inlet Air Temperature (IAT) Sensor

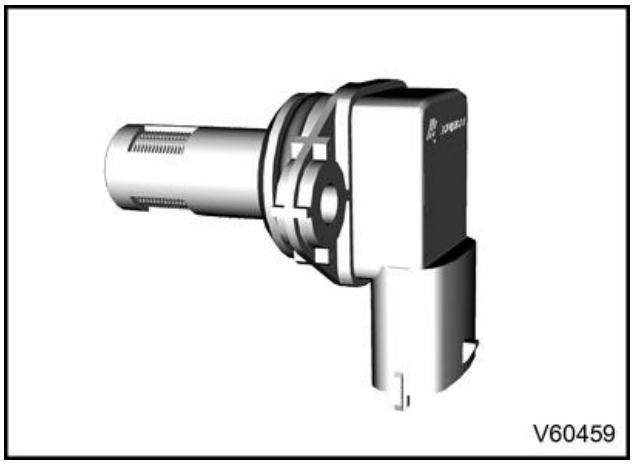

Figure 49 HS / IAT sensor

The HS / IAT sensor measures the moisture content of filtered air entering the intake system.

The HS / IAT sensor is used by the ECM to prevent EGR system component degradation due to moisture contamination. Using the sensor, the ECM will adjust EGR system flow to prevent condensation of airborne water particles. The sensor also measures intake air temperature, which is used by the ECM for calculating fuel delivery.

The HS / IAT sensor is mounted in the air inlet duct at the upper right side of the engine.

Charge Air Cooler Outlet Temperature (CACOT) Sensor

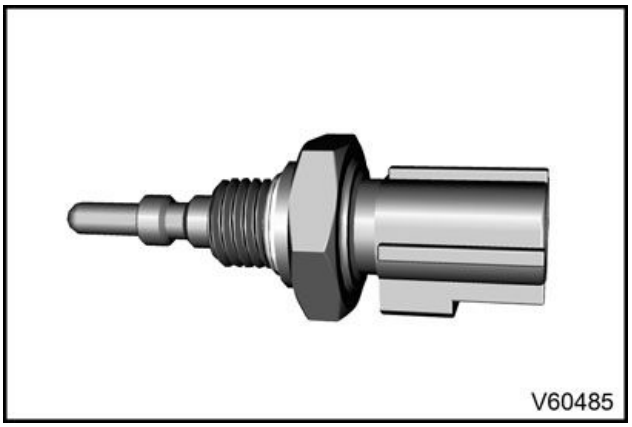

Figure 50 CACOT sensor

The CACOT sensor is a thermistor sensor that monitors the temperature of charge air entering the intake air duct.

The CACOT signal is monitored by the ECM for control of the EGR system.

The CACOT sensor is installed on the air intake throttle duct, before the Engine Throttle Valve (ETV).

Intake Manifold Pressure (IMP) Sensor

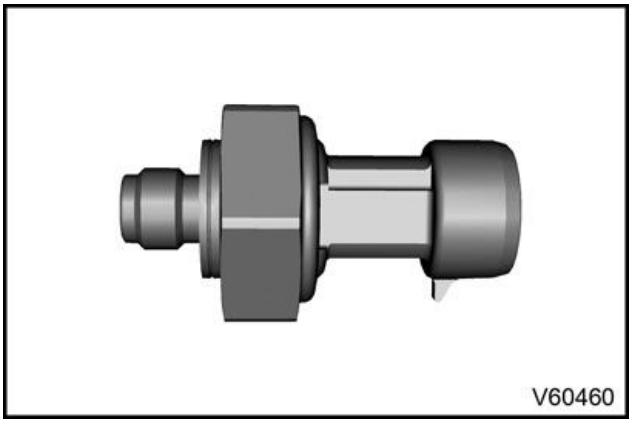

Figure 51 IMP sensor

The IMP sensor is a variable capacitance sensor that monitors the pressure of charge air entering the air intake throttle duct. The IMP signal is monitored by the ECM for control of the EGR system and turbocharger wastegates.

The IMP sensor is installed on the air intake throttle duct after the ETV.

Fuel Rail Pressure (FRP) Sensor

Figure 52 FRP sensor

The FRP sensor is a variable capacitance sensor that monitors the fuel pressure in the high-pressure fuel rail. The sensor measures the fuel pressure just before injection.

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

Intake Manifold Temperature (IMT) Sensor

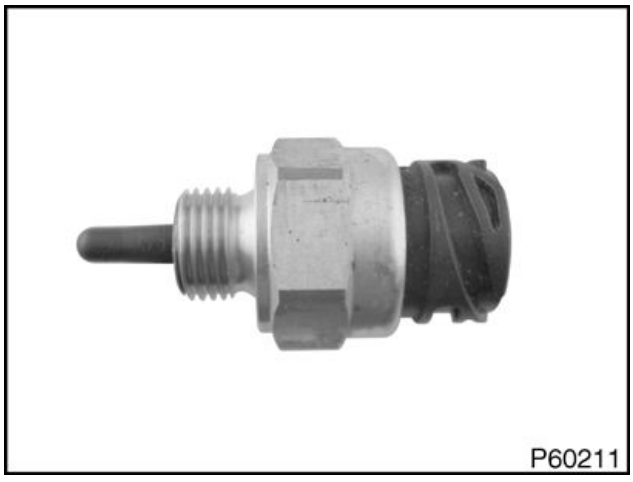

Figure 53 IMT sensor

The IMT sensor is a thermistor sensor that monitors the temperature of the mixture of recirculated exhaust gas and fresh intake air.

EGR system operation is shut down under certain temperature conditions, to prevent 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 IMT sensor is installed in the intake channel of the cylinder head, on the left side of the engine.

Oxygen Sensor (O2S)

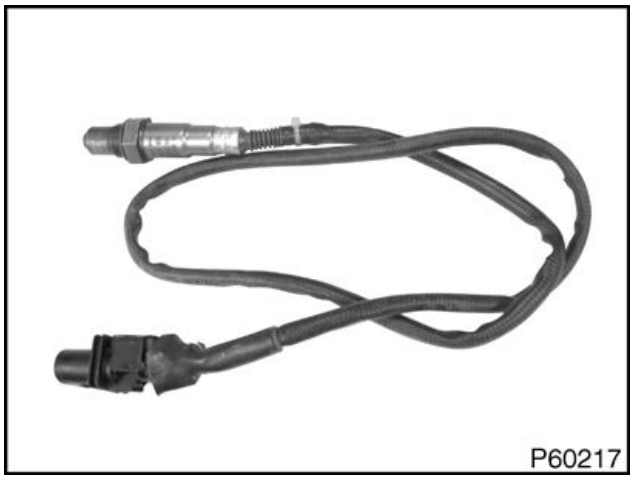

Figure 54 O2S

The O2S monitors oxygen levels in exhaust gases. It is used to tune engine operation by monitoring the level of unused oxygen in the exhaust stream.

The O2S compares oxygen levels in the exhaust stream with oxygen levels in the outside air. The sensor generates an analog voltage and is monitored by the ECM. The level of voltage generated by the O2S corresponds to the oxygen levels in the exhaust stream.

The O2S is installed in the exhaust back pressure valve housing.

NOTE: The Oxygen sensor should only be replaced after a coolant and/or oil loss into the exhaust system has been verified based on the Engine Symptoms Diagnostics in the Engine Diagnostic Manual.

Engine Throttle Valve (ETV)

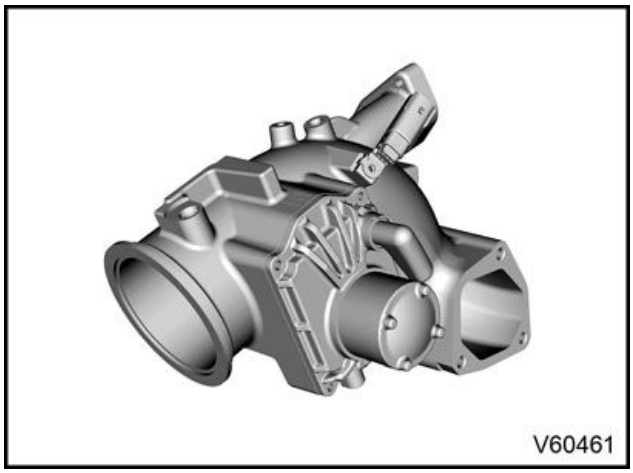

Figure 55 ETV

The ETV controls the flow of filtered air (boosted and cooled) into the engine's air intake through the Charge Air Cooler (CAC) to help heat the exhaust aftertreatment during regeneration, and to assist when heavy EGR is requested. The electronic portion of the ETV contains a microprocessor that monitors valve position, electronic chamber temperature, controls the electric motor and reports diagnostic faults to the ECM. The ETV changes position in response to ECM signals.

The ETV is integrated into the air intake throttle duct at the front top left side of the engine.

Coolant Control Valve (CCV)

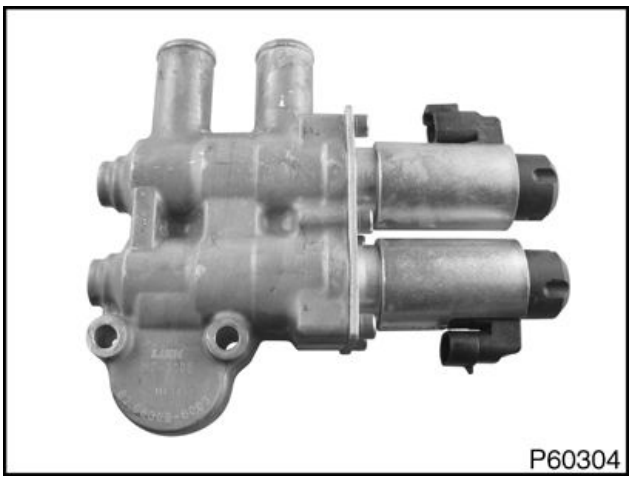

Figure 56 CCV

The Coolant Mixer Valve (CMV) and Coolant Flow Valve (CFV) are a combined solenoid assembly that regulates coolant flow and temperature through the Low-pressure Charge Air Cooler (LPCAC) and the low temperature EGR cooler. The CMV and CFV are housed in the CCV assembly.

The CFV controls the rate of coolant flow through the CAC and the 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 CCV is mounted on the right side of the water distribution housing.

Air Control Valve (ACV) Assembly

NOTE: Various air control valves have been used on this engine. Early production air control valves use two mounting bolts and later production valves use three mounting bolts. Late production valves may also utilize a remote electrical connector attached to a pigtail harness.

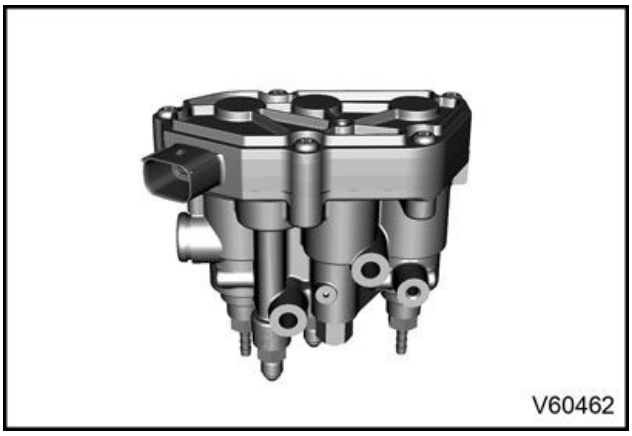

Figure 57 Early production ACV with two mounting bolts

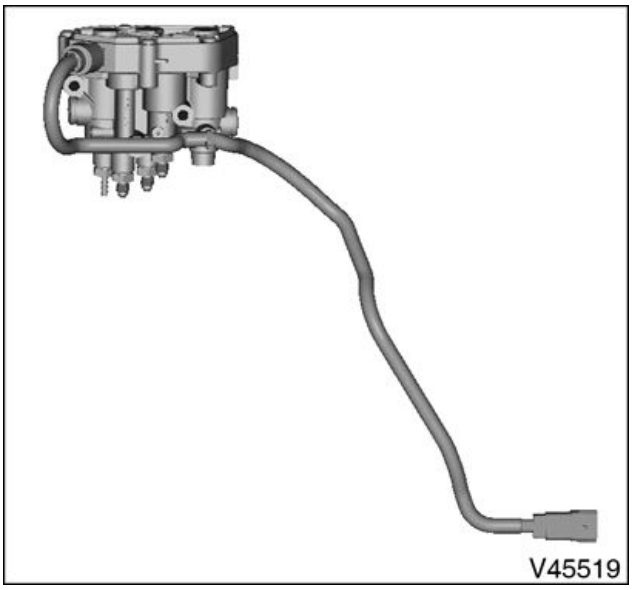

Figure 58 Late production ACV with pigtail

The ACV contains solenoids for the control of the high-pressure turbocharger wastegate and Exhaust Back Pressure Valve (EBPV). It also contains the Turbocharger 1 Turbine Outlet Pressure (TC1TOP) sensor. ACV solenoids are controlled through pulse-width modulated signals sent by the ECM.

The ACV assembly is installed on the right side of the engine, mounted near the center of the EGR cooler.

Exhaust Gas Recirculation (EGR) Valve

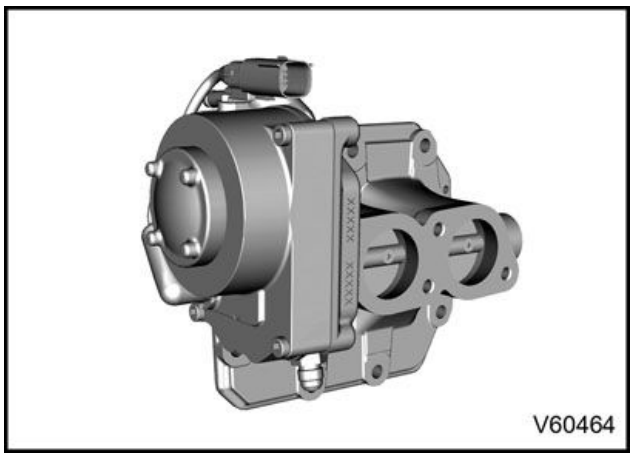

Figure 59 EGR valve

The EGR valve regulates the flow of exhaust gases through the EGR system. The desired valve position is controlled by commands from the ECM.

The EGR valve is mounted on the rear of the EGR cooler on top of the engine.

Exhaust Gas Recirculation Temperature (EGRT) Sensor

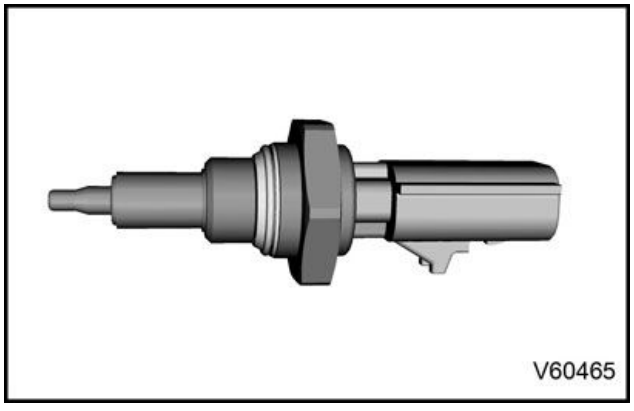

Figure 60 EGRT sensor

The EGRT sensor is a thermistor sensor that detects the exhaust gas temperature exiting the EGR cooler. The sensor signal is monitored by the ECM to control the Coolant Flow Valve (CFV) and Coolant Mixer Valve (CMV), and check for proper EGR cooling.

The EGRT sensor is installed in the front of the low-temperature EGR cooler on the left side.

Turbocharger 2 Compressor Inlet Sensor (TC2CIS)

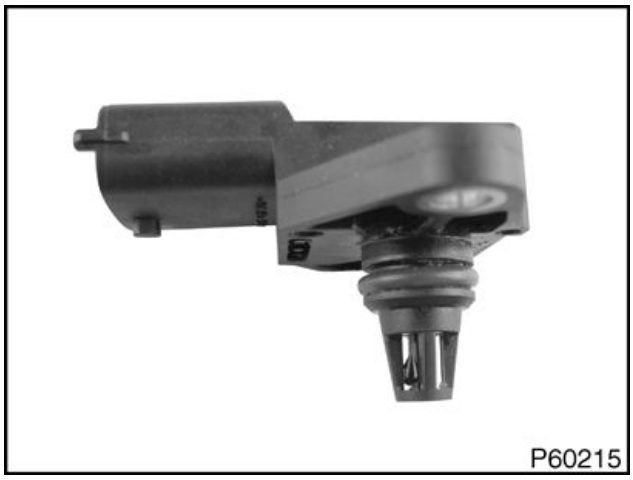

Figure 61 TC2CIS

The TC2CIS sensor includes a thermistor sensor that monitors the temperature of charge air entering the high-pressure turbocharger. This sensor also monitors boost pressure for the low-pressure turbocharger.

The TC2CIS sensor is monitored by the ECM, and is used to check for proper thermostat operation and charge air cooling.

The TC2CIS is installed in the piping between the low-pressure compressor outlet and the high-pressure compressor inlet.

Removal

Warnings and Cautions

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

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

Disconnect ground cable (–) from the negative terminal of the battery.

Crankshaft Position (CKP) Sensor

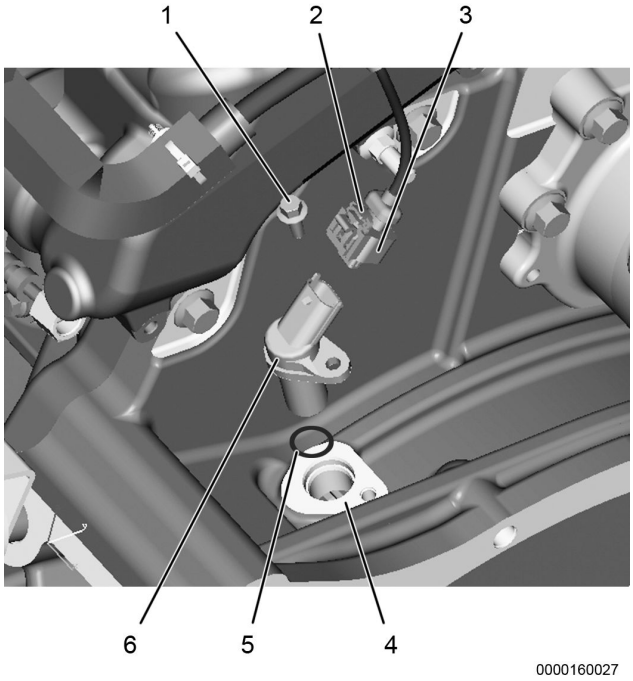

Figure 62 CKP sensor

1. M6 x 16 bolt
2. Locking tab
3. CKP sensor harness connector
4. Flywheel housing
5. O-ring
6. CKP sensor

1. Pull out locking tab (Figure 62) (Item 2) on CKP sensor harness connector (Figure 62) (Item 3).
2. Press release lever and disconnect harness connector from CKP sensor (Figure 62) (Item 6) installed in top left of flywheel housing (Figure 62) (Item 4).
3. Remove M6 x 16 bolt (Figure 62) (Item 1) from CKP sensor.
4. Remove CKP sensor and discard O-ring (Figure 62) (Item 5).

Camshaft Position (CMP) Sensor

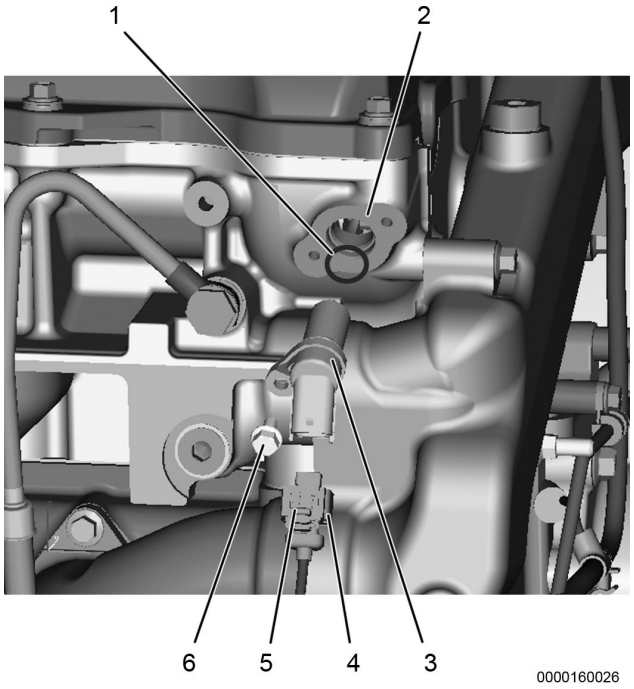

Figure 63 CMP sensor

1. O-ring
2. Cylinder head
3. CMP sensor
4. CMP sensor harness connector
5. Locking tab
6. M6 x 12 bolt

1. Pull out locking tab (Figure 63) (Item 5) on CMP sensor harness connector (Figure 63) (Item 4).
2. Press release lever and disconnect harness connector from CMP sensor (Figure 63) (Item 3) installed in rear left of cylinder head (Figure 63) (Item 2).
3. Remove M6 x 12 bolt (Figure 63) (Item 6) from CMP sensor.
4. Remove CMP sensor and discard O-ring (Figure 63) (Item 1).

Engine Coolant Temperature 1 (ECT1) Sensor

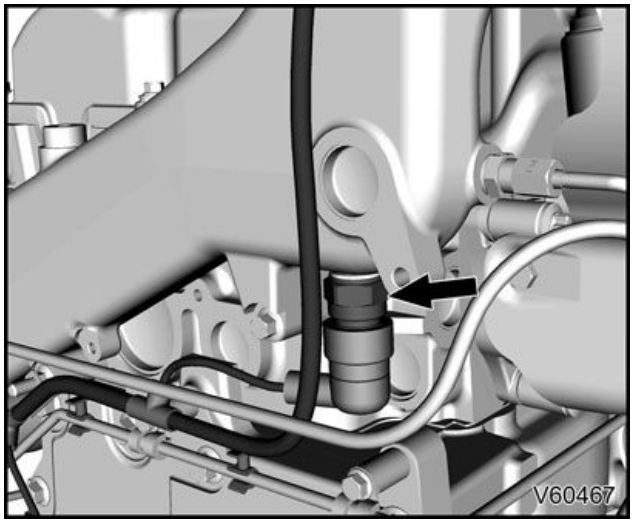

Figure 64 ECT1 sensor

1. Turn ECT1 sensor harness connector locking ring 90° counterclockwise.
2. Disconnect harness connector from ECT1 sensor installed in underside of Exhaust Gas Recirculation (EGR) coolant manifold at rear of engine.
3. Remove ECT1 sensor and discard seal ring.

Engine Coolant Temperature 2 (ECT2) Sensor

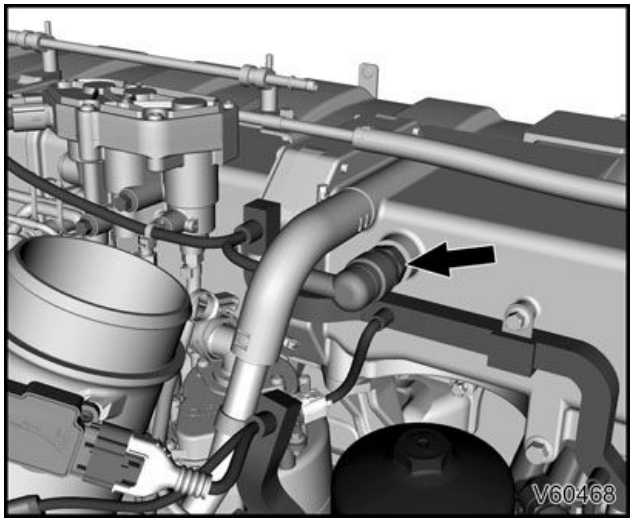

Figure 65 ECT2 sensor connector

1. Turn ECT2 sensor harness connector locking ring 90°counterclockwise.
2. Disconnect harness connector from ECT2 sensor installed in EGR module low-temperature housing on upper right side of engine.
3. Remove ECT2 sensor and discard seal ring.

Engine Oil Temperature (EOT) Sensor

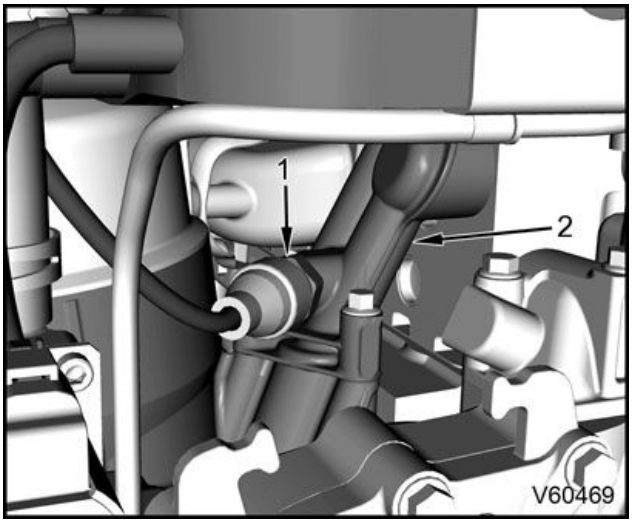

Figure 66 EOT sensor

1. EOT sensor
2. Oil module flange

1. Turn EOT harness connector locking ring 90° counterclockwise.
2. Disconnect harness connector from EOT sensor and remove sensor from oil module flange. Discard seal ring.

Engine Oil Pressure (EOP) Sensor

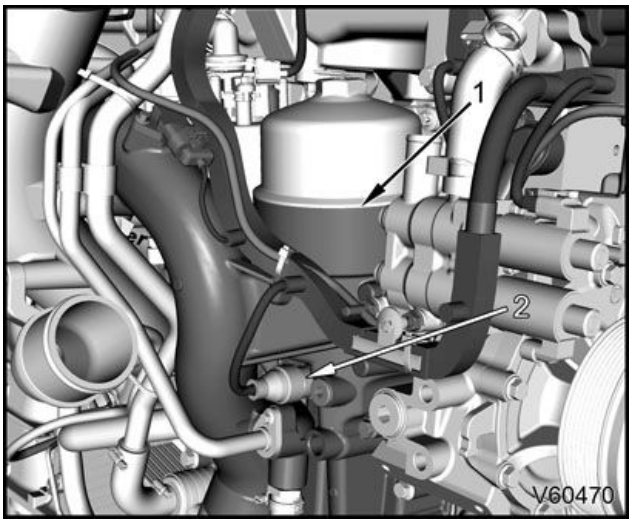

Figure 67 EOP sensor

1. Oil module assembly
2. EOP sensor

1. Turn EOP harness connector locking ring 90° counterclockwise.
2. Disconnect harness connector from EOP sensor and remove sensor from oil module assembly. Discard seal ring.

Crankcase Oil Separator Speed (CCOSS) Sensor

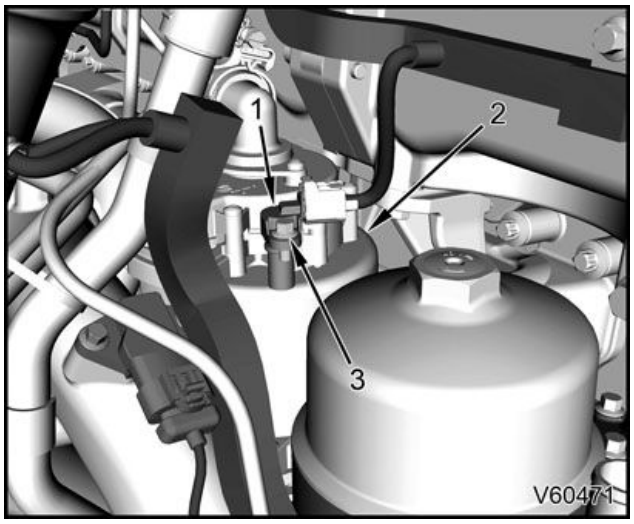

Figure 68 CCOSS sensor

1. CCOSS sensor
2. Oil centrifuge (part of oil module assembly)
3. M6 x 14 bolt and nut

1. Press release tab to disconnect wiring harness connector from CCOSS sensor.
2. Remove M6 x 14 bolt and nut and remove sensor from bracket on oil centrifuge.

Fuel Delivery Pressure (FDP) Sensor

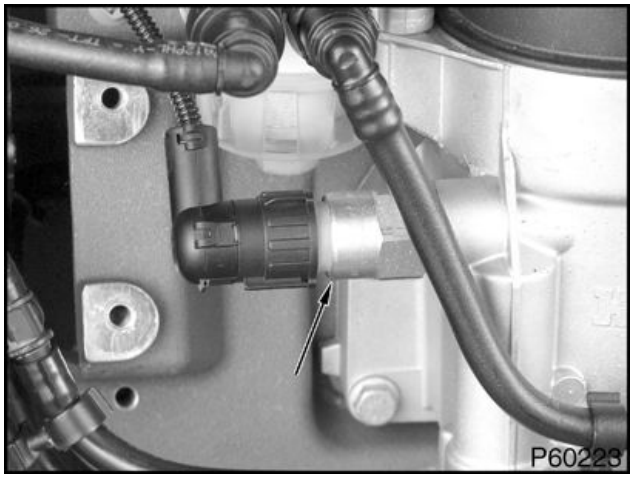

Figure 69 FDP sensor

1. Turn FDP sensor harness connector locking ring 90° counterclockwise.
2. Disconnect harness connector from FDP sensor installed in fuel filter assembly.
3. Remove FDP sensor and discard seal ring.

Fuel Pressure Control Valve (FPCV)

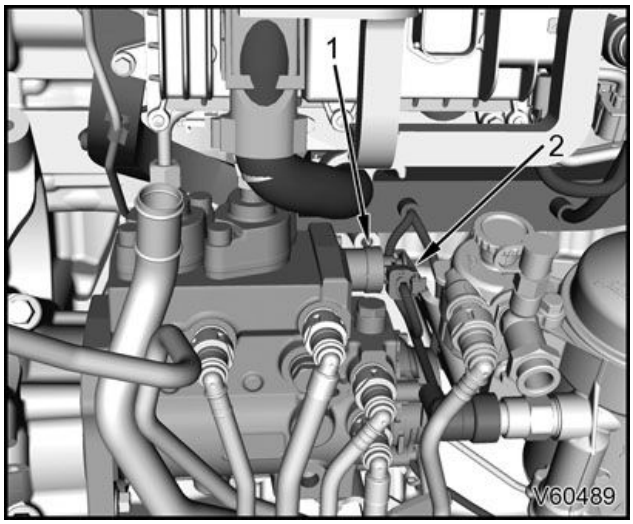

Figure 70 FPCV (on high-pressure fuel pump)

1. FPCV
2. Harness connector

1. Pull out yellow locking tab on FPCV harness connector.
2. Press release tab and disconnect harness connector from FPCV mounted at upper rear of high-pressure fuel pump.
3. See High-pressure Fuel Pump (HPFP) and Drive Housing (page 239) for removal of high-pressure pump with integral FPCV if the FPCV requires replacement.

Humidity / Intake Air Temperature (IAT) Sensor

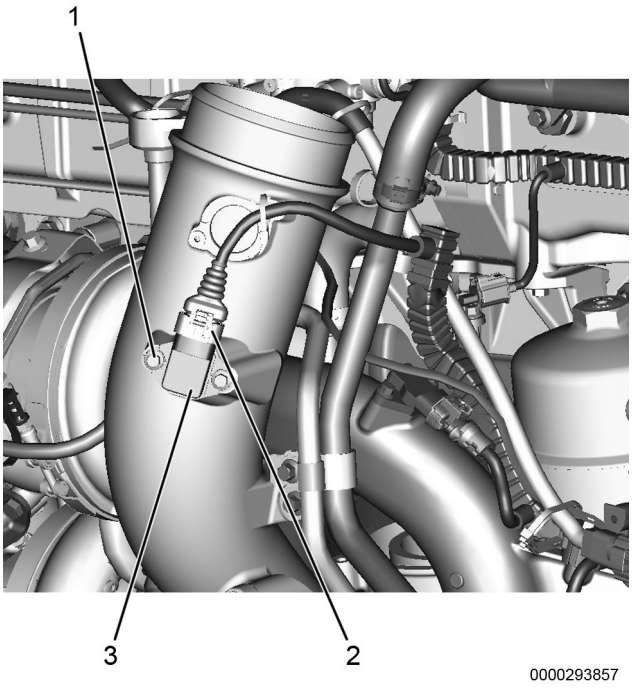

Figure 71 HS / IAT sensor

1. M6 x 16 bolt (2)
2. Harness connector
3. IAT sensor

1. Pull out yellow locking tab on IAT harness connector (Figure 71) (Item 2).
2. Press release tab to disconnect harness connector from IAT sensor (Figure 71) (Item 3).
3. Remove two M6 x 16 bolts (Figure 71) (Item 1) and remove sensor from air inlet duct. Discard O-ring.

Charger Air Cooler Outlet Temperature (CACOT) Sensor

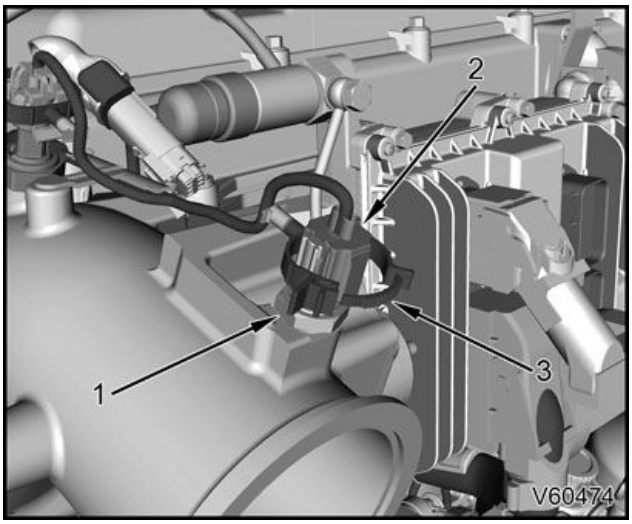

Figure 72 CACOT sensor

1. CACOT sensor
2. Harness connector
3. Standoff tie strap

1. Press release tab to loosen tie strap and remove standoff bracket securing connector harness lead to CACOT sensor.
2. Press release tab to disconnect harness from CACOT sensor.
3. Remove CACOT sensor from throttle valve housing. Discard O-ring.

Intake Manifold Pressure (IMP) Sensor

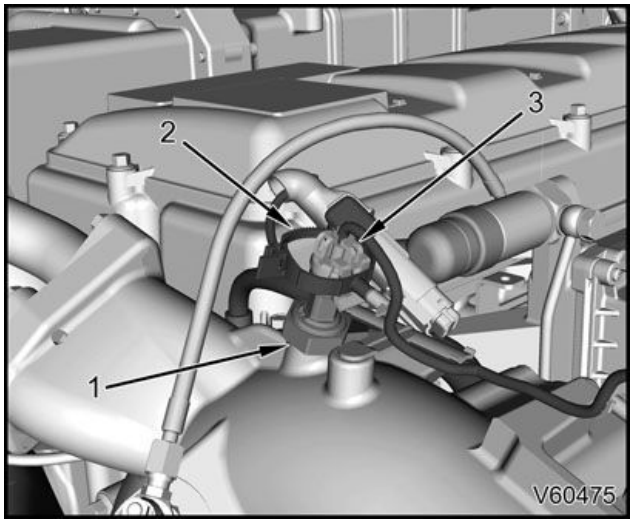

Figure 73 IMP sensor

1. IMP sensor
2. Standoff tie strap
3. Harness connector

1. Press release tab to loosen tie strap and remove standoff bracket securing harness connector lead to IMP sensor.
2. Press release tab to disconnect harness from IMP sensor.
3. Remove IMP sensor from Engine Throttle Valve (ETV) housing. Discard O-ring.

Fuel Rail Pressure (FRP) Sensor

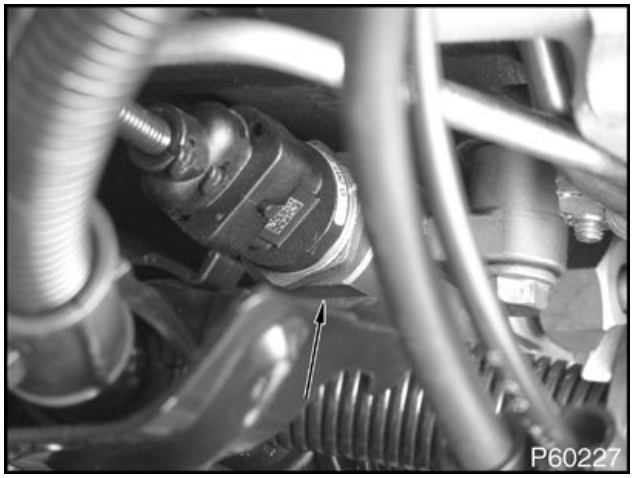

Figure 74 FRP sensor (typical)

1. Pull out yellow locking tab on FRP sensor harness connector.
2. Press release lever and disconnect harness connector from FRP sensor installed in front of fuel rail on left side of engine.
3. Remove FRP sensor from fuel rail.
4. Install plastic protective cap from Disposable Air and Fuel Caps (page 276), to prevent dirt from entering fuel system

Intake Manifold Temperature (IMT) Sensor

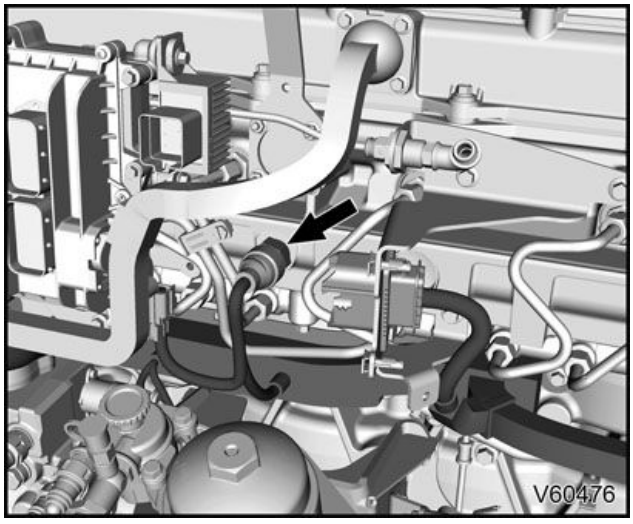

Figure 75 IMT sensor

1. Turn IMT sensor harness connector locking ring 90° counterclockwise.
2. Disconnect harness connector from IMT sensor.
3. Remove IMT sensor from cylinder head and discard seal ring.

Oxygen Sensor (O2S)

NOTE: The Oxygen sensor should only be replaced after a coolant and/or oil loss into the exhaust system has been verified based on the Engine Symptoms Diagnostics in the Engine Diagnostic Manual.

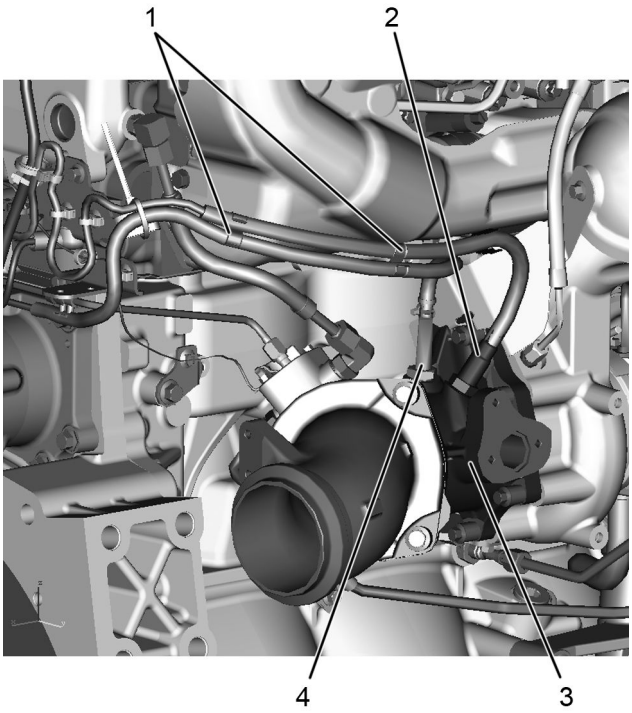

Figure 76 O2S (valve actuator removed for clarity)

1. Clip (2)
2. O2S (with harness lead)
3. Exhaust back pressure valve housing
4. NOx IN Sensor (with harness lead)

1. Press release lever and disconnect O2S harness lead (Figure 76) (Item 2) from engine electrical harness at left rear of engine.
2. Disconnect clips (Figure 76) (Item 1) securing O2S harness lead at right rear of engine to coolant tube and to valve actuator bracket.
3. Only if required, remove O2S from exhaust back pressure valve housing (Figure 76) (Item 2).

Nitrogen Oxides (NOx) IN Sensor Module

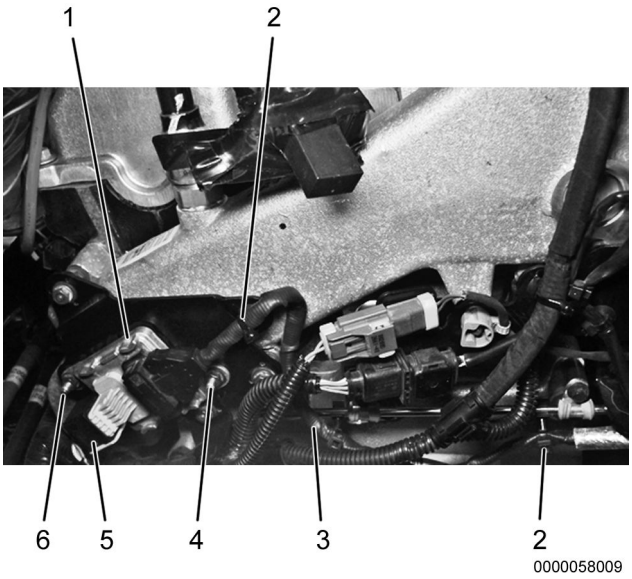

Figure 77 NOx IN Sensor Module Connector

1. NOx IN sensor module
2. Tiedown strap
3. NOx IN sensor harness
4. NOx IN sensor module nut (2)
5. NOx IN sensor module connector

1. Disconnect NOx IN sensor module connector (Figure 77) (Item 5) from NOx IN sensor module (Figure 77) (Item 1).
2. Cut tiedown straps (Figure 77) (Item 2).
3. Remove two NOx IN sensor module nuts (Figure 77) (Item 4) from NOx IN sensor module.

Nitrogen Oxides (NOx) In Sensor

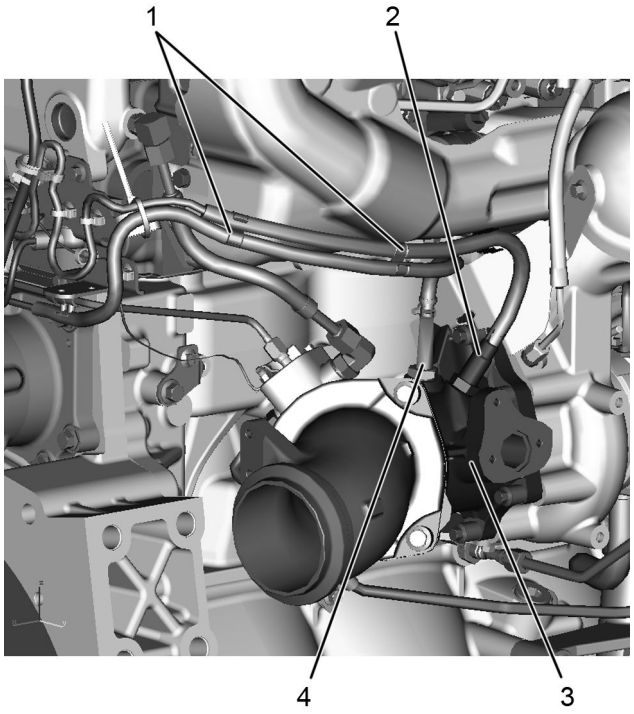

Figure 78 NOx In Sensor (valve actuator removed for clarity)

1. Clip (2)
2. O2S (with harness lead)
3. Exhaust back pressure valve housing
4. NOx IN sensor (with harness lead)

1. Press release lever and disconnect NOx IN sensor (Figure 78) (Item 4) harness lead from engine electrical harness at left rear of engine.
2. Disconnect clips (Figure 78) (Item 1) securing NOx IN sensor harness lead at right rear of engine to coolant tube and to valve actuator bracket.
3. Only if required, remove NOx IN sensor from exhaust back pressure valve housing (Figure 78) (Item 3).

Engine Throttle Valve (ETV)

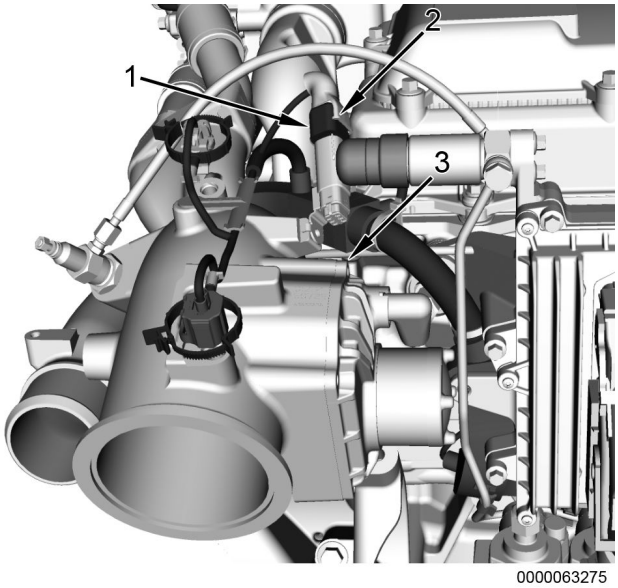

Figure 79 ETV

1. Harness connector
2. CPA tab
3. ETV

1. Push RED Connector Position Assurance (CPA) tab (Figure 79) (Item 2) away from Engine Throttle Valve (ETV) (Figure 79) (Item 3), and press release tab to disconnect harness connector (Figure 79) (Item 1) from ETV.
2. See Inlet Air Heater Fuel Igniter (IAHFI) and Fuel Supply Inlet Air Heater Hose (page 111) for removal procedure of the fuel supply inlet air heater hose.
3. See Air Intake Throttle Duct (page 341) for removal procedure of duct.

Coolant Control Valve (CCV)

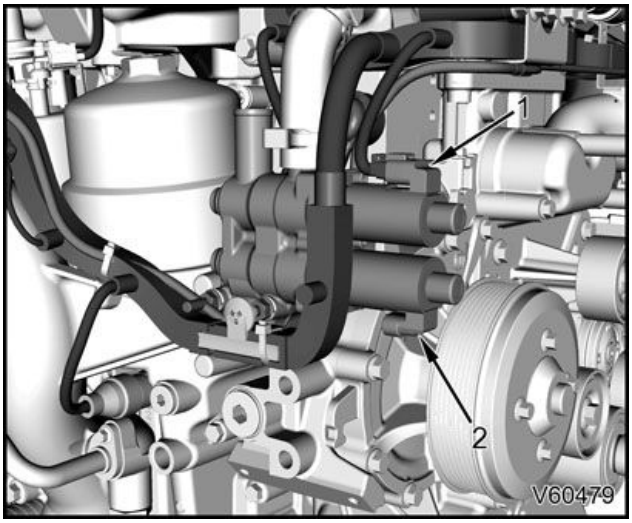

Figure 80 CCV

1. Coolant Mixer Valve (CMV) terminal
2. Coolant Flow Valve (CFV) terminal

NOTE: The coolant mixer and coolant flow valves are not serviced separately. Both valves are an integral part of the CCV assembly which is available as a unit.

1. Press release tab and disconnect harness connector from CMV, installed in the CCV assembly on the right side of the water distribution housing.
2. Lift release tab and disconnect harness connector from CFV, also in the CCV assembly.
3. See Coolant Control Valve (CCV) Assembly (page 368) for removal procedure.

Exhaust Gas Recirculation (EGR) Valve

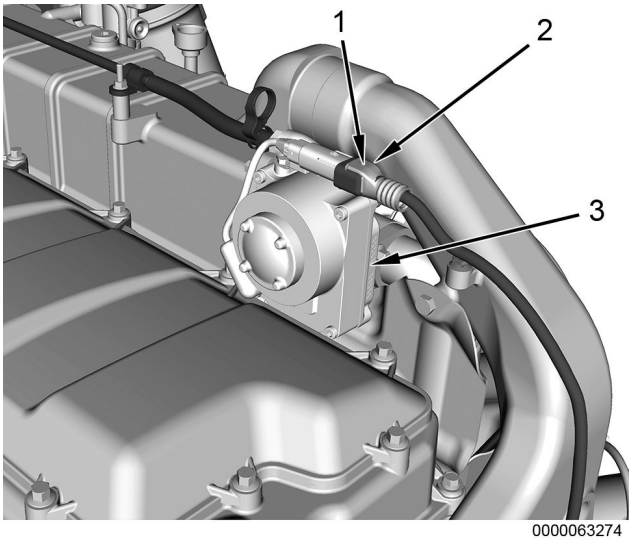

Figure 81 EGR valve harness connector

1. CPA tab
2. Harness connector
3. EGR valve

1. Push RED Connector Position Assurance (CPA) tab (Figure 81) (Item 1) away from Exhaust Gas Recirculation (EGR) valve (Figure 81) (Item 3), and press release tab to disconnect harness connector (Figure 81) (Item 2) from EGR valve.
2. Remove dual flap EGR valve. See EGR Dual Flap Valve (page 307).

Exhaust Gas Recirculation Temperature (EGRT) Sensor

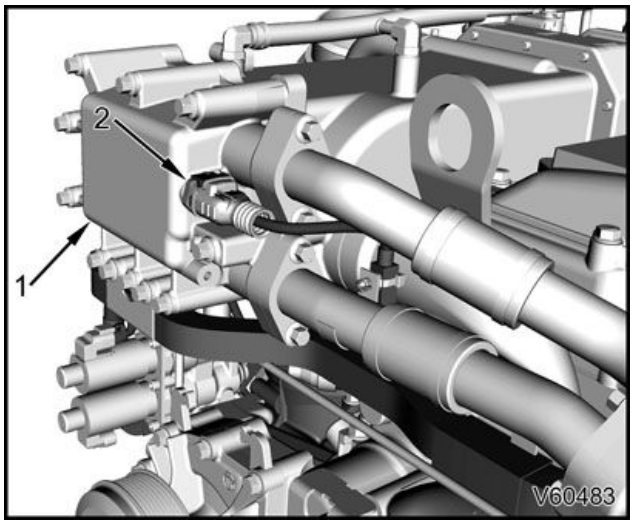

Figure 82 EGRT sensor harness connector

1. EGR module cover
2. EGRT sensor

1. Pull out red locking tab on EGRT sensor connector.
2. Press release tab to disconnect harness connector from EGRT sensor.

NOTE: The EGRT has a non-serviceable crush washer for sealing. If sensor is removed, the complete sensor must be replaced.

3. Only if required, remove EGRT sensor from EGR module cover and discard.

Turbocharger 2 Compressor Inlet Sensor (TC2CIS)

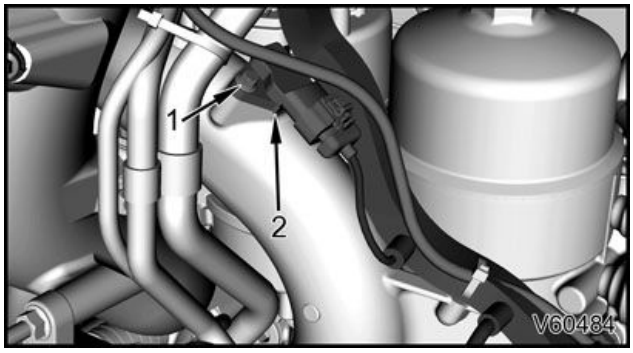

Figure 83 TC2CIS

1. M6 x 16 bolt (2)
2. TC2CIS

1. Pull out yellow lock tab on TC2CIS harness connector.
2. Press release tab and disconnect harness lead from TC2CIS.
3. Remove two M6 x 16 bolts and sensor from high-pressure turbocharger air supply duct. Discard O-ring seal.

Wiring Harness ECM Connections

⚠ 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. If not done, disconnect ground (–) cable from the negative terminal of the battery.
2. Note location of wire ties for reinstallation. Cut wire ties securing engine injector, engine sensor and chassis harness connector lock levers at ECM.

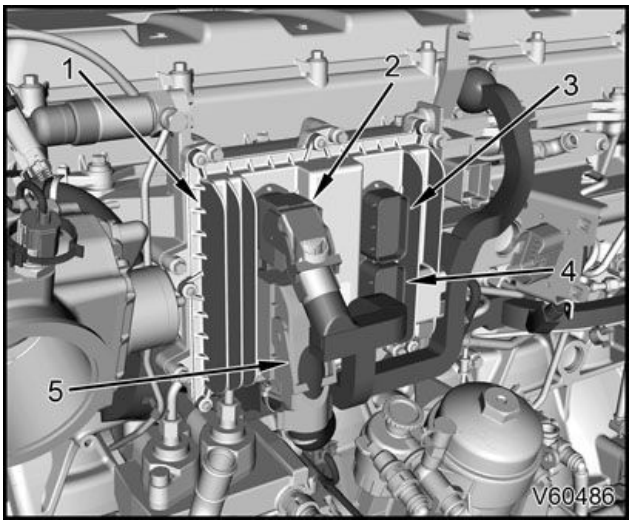

Figure 84 ECM harness connectors

1. ECM
2. Engine injector harness connector (to ECM 16-pin E2 terminal)
3. ECM 58-pin C2 chassis terminal
4. ECM 58-pin C1 chassis terminal
5. Engine sensor harness connector (to ECM 96-pin E1 terminal)

3. If not already done, disconnect chassis wiring harness connectors from ECM 58-pin C1 and C2 terminals.
4. Remove connector clip and lift lock lever to release engine injector harness connector. Pull straight out to remove connector from ECM terminal E2.
5. Lift lock lever to release engine sensor harness connector. Pull straight out to remove connector from ECM terminal E1.

Engine Injector (Wiring) Harness

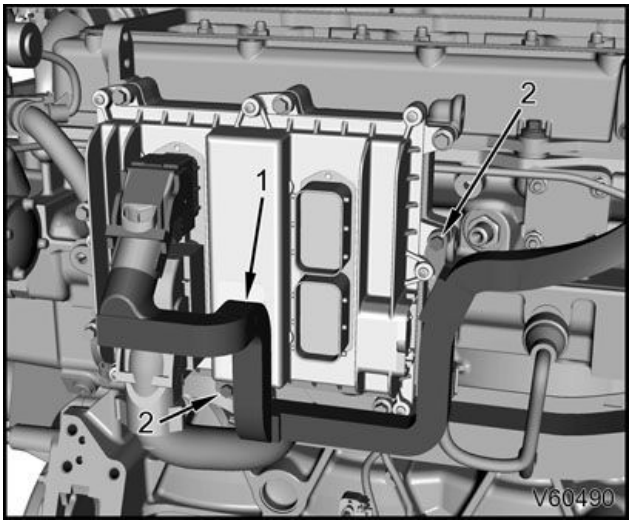

Figure 85 Injector harness attachment points at ECM

1. Injector harness
2. M6 x 30 bolt (2)

1. Remove two M6 x 30 bolts and remove injector harness retainer clips from ECM.
2. Remove upper valve cover from valve cover base. See Upper Valve Cover and Base(page 409) .

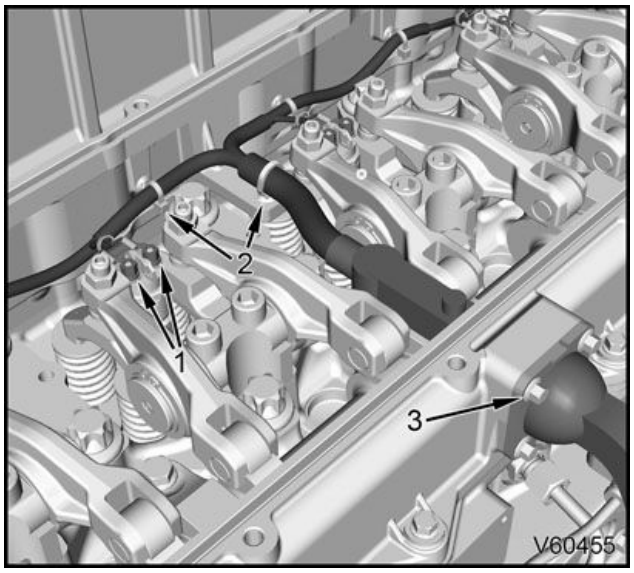

Figure 86 Injector harness attachment points at cylinder head

1. Injector harness nut (12)
2. Tie strap (7)
3. M6 x 16 bolt (4)

3. Loosen 12 harness nuts (two at each injector) and disconnect harness leads from injector terminals.
4. Cut tie straps at six locations securing injector harness to valve cover base.
5. Cut tie strap securing harness at center of cylinder head.
6. Remove four M6 x 16 bolts from injector harness mounting flange.
7. Carefully pull harness through valve cover base opening and remove harness from engine.

Engine Sensor (Wiring) Harness

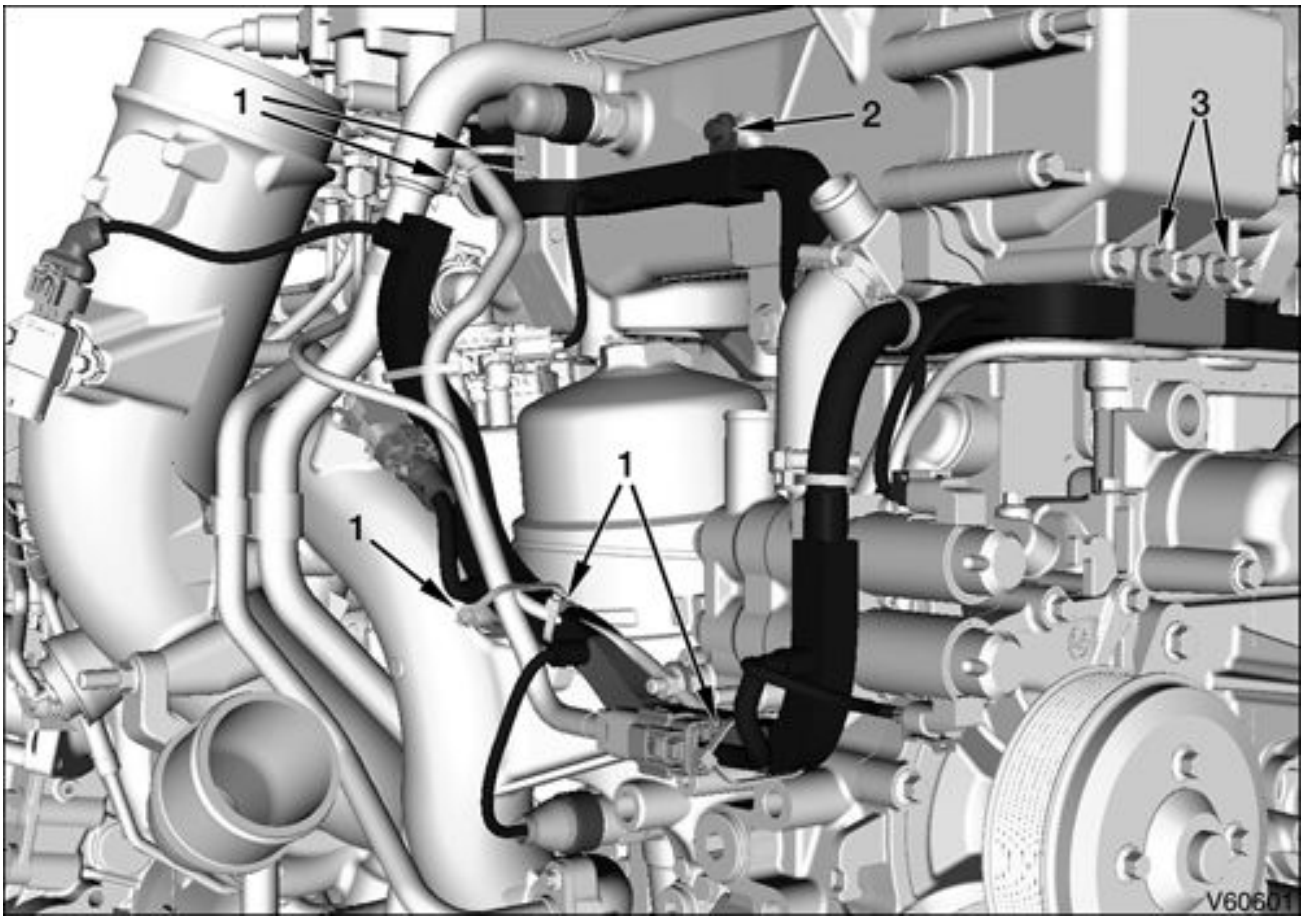

Figure 87 Sensor harness attachment points at right front

1. Tie strap (5)
2. M8 x 12 bolt
3. M8 x 16 bolt (2)

1. Disconnect harness connectors at IAT, MAF (if equipped), TC2CIS, EOP, ACV, ECT2, CCOSS, CCV and EOT terminals.
2. Starting on right side at front, cut tie straps securing sensor harness at ACV, CCV and to air supply tube.
3. Remove M8 x 12 bolt attaching harness clip to EGR cooler low-temperature housing.
4. Remove two M8 x 16 bolts attaching harness clip to EGR module cover.
5. At left front, disconnect harness connectors at EGRT, CACOT, IMP, FRP, FDP and EOL sensors.

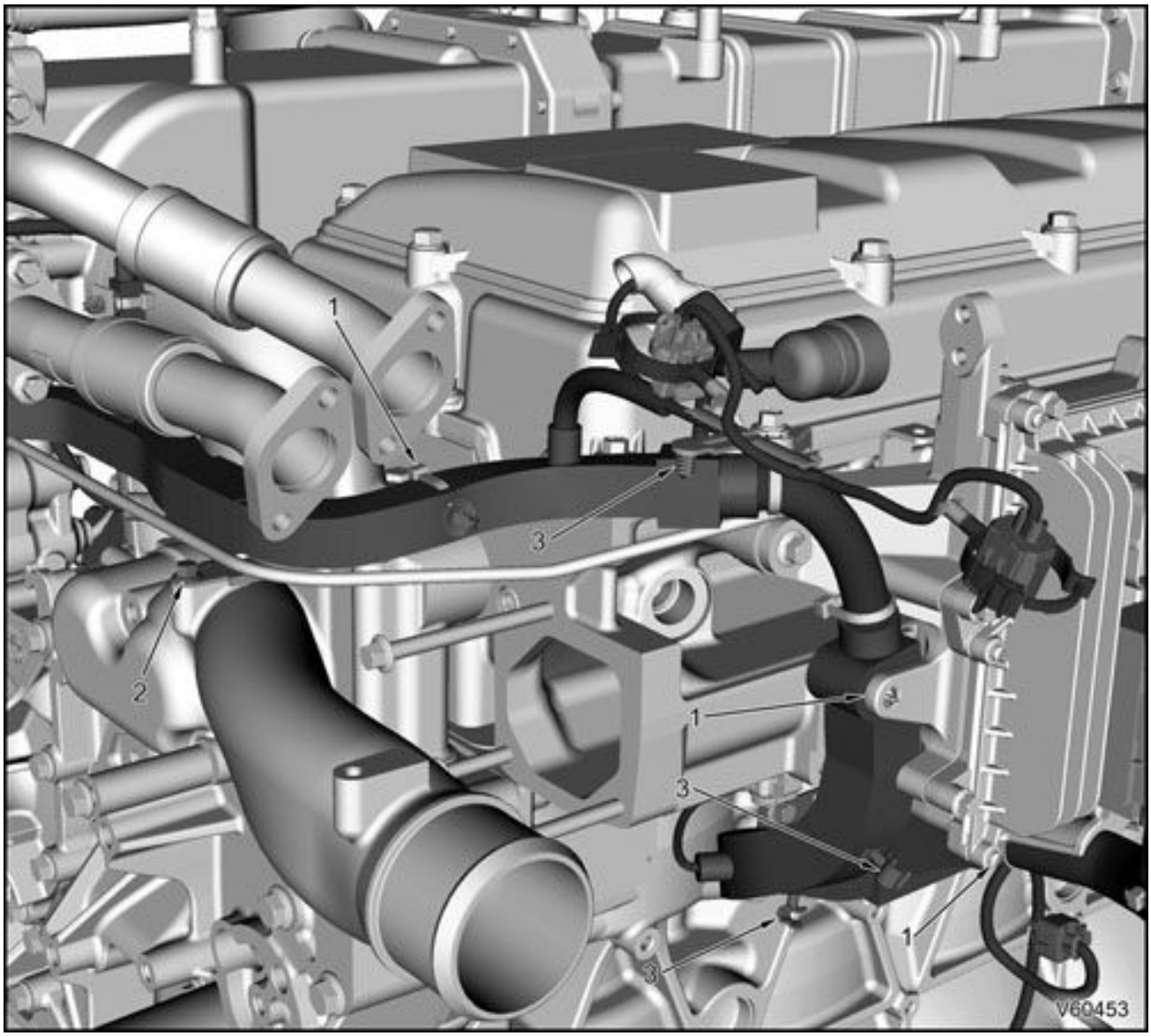

Figure 88 Sensor harness attachment points at left front (air intake throttle duct removed for clarity)

1. Tie strap (3)
2. M6 x 16 bolt
3. Other attachments

6. Cut tie straps securing sensor harness to back of air intake throttle duct and at back and bottom of ECM support.
7. Remove M6 x 16 bolt attaching harness clip to coolant outlet manifold.
8. Remove other attachments as necessary.
9. At left rear, disconnect harness connectors at CMP, CKP, ECT1 sensors and EGR valve.

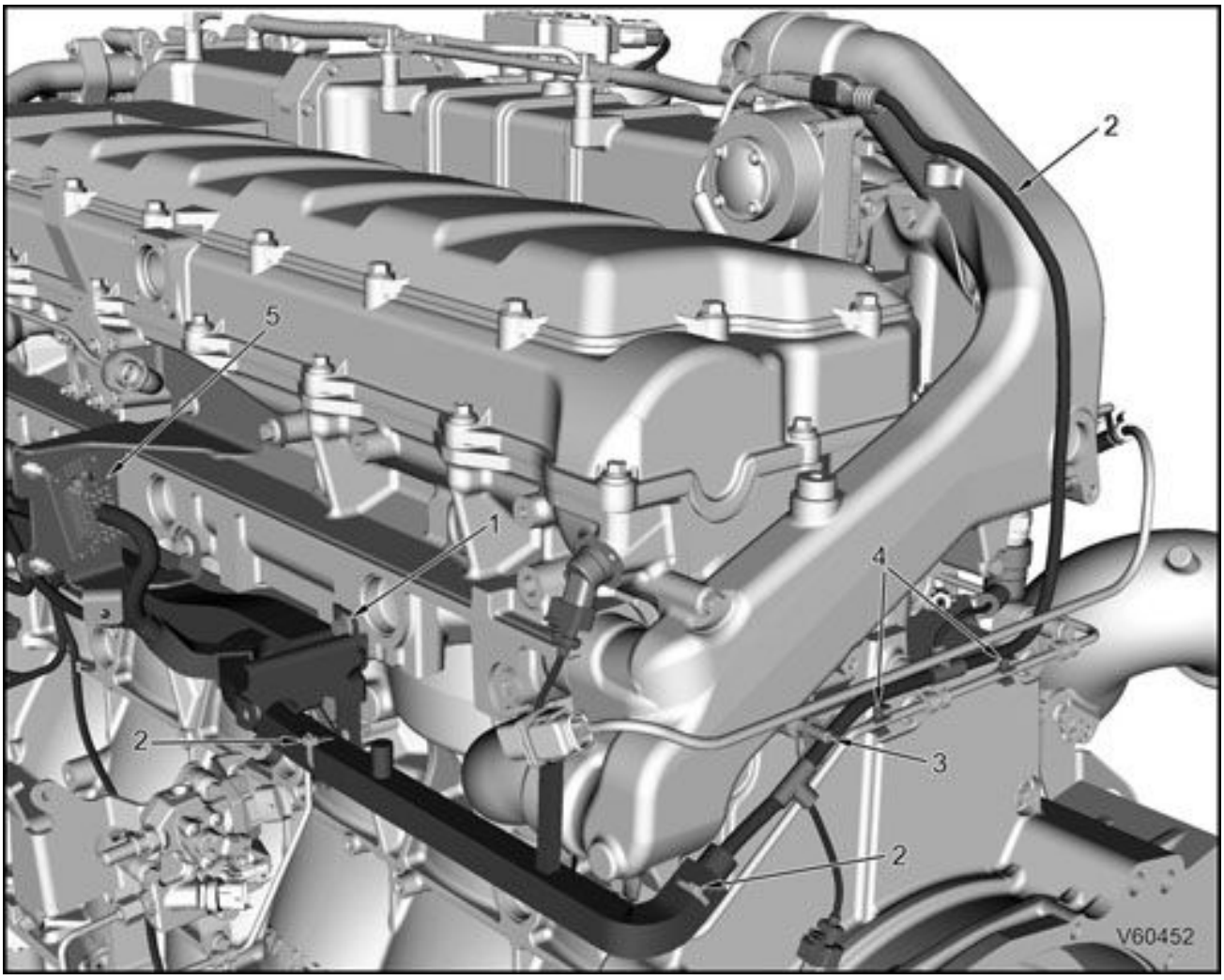

Figure 89 Sensor harness attachment points at left rear

1. M8 x 16 bolt (2)
2. Tie strap (3)
3. M8 stud
4. Harness clips
5. 21-way connector

10. At left side and rear of engine, cut tie straps securing sensor harness to harness support and coolant manifold.
11. Disconnect harness from M8 stud at coolant manifold.
12. At left center of engine, remove two M8 x 16 bolts attaching harness bracket to crankcase.
13. Remove sensor harness from engine using care to avoid damage to harness as it is removed from around components.
14. Remove 21-way connector from harness bracket.

Engine Control Module (ECM) and Support

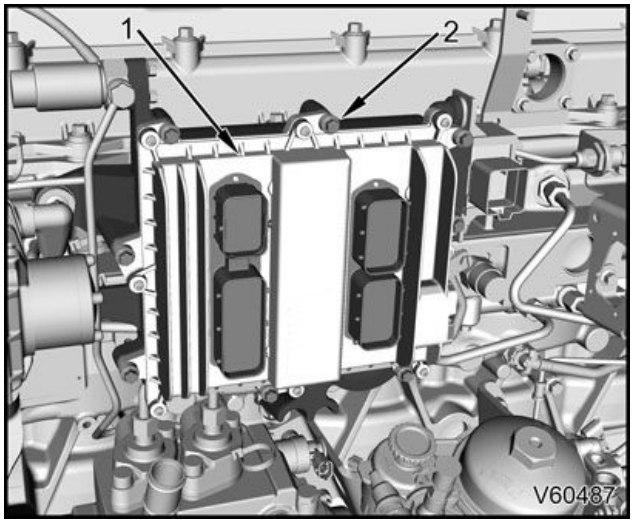

Figure 90 ECM mounting bolts

1. ECM
2. M6 x 30 bolt (8)

1. Remove eight M6 x 30 bolts and remove ECM from support.

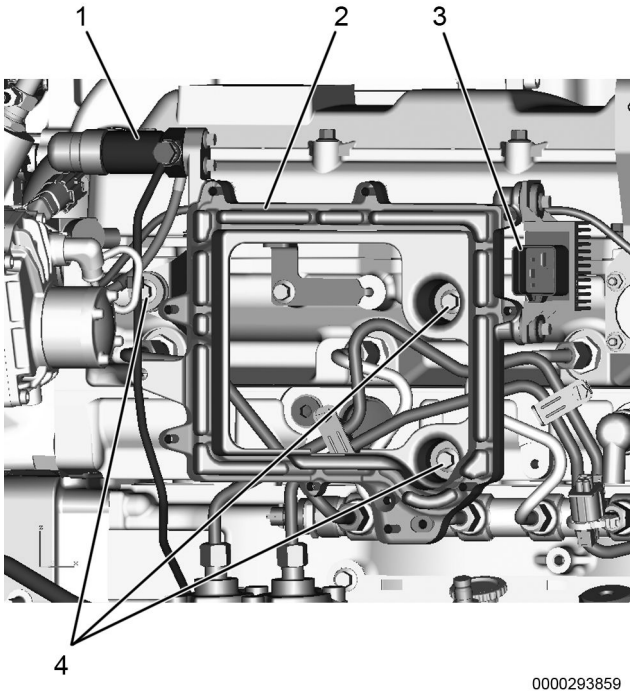

Figure 91 ECM support

1. Inlet Air Heater Fuel Solenoid (IAHFS)
2. ECM support
3. Inlet Air Heater Relay (IAHR)
4. M8 x 40 bolt (3) with EDC bracket insulators (6)

2. Remove IAHR from ECM support. See Relay Assembly (page 110).
3. Remove IAHFS (Figure 91) (Item 1) from ECM support (Figure 91) (Item 2). See Fuel Supply Solenoid Hose (page 112).
4. Remove three M8 x 40 bolts, six EDC bracket insulators (Figure 91) (Item 4) (three on each side of support) and ECM support from cylinder head.

Cleaning and Inspection

Engine Injection and Engine Sensor Wiring Harnesses

1. Carefully inspect engine injection wiring harnesses for worn conduit, frayed insulation or heat damage to wires. Repair or replace if necessary.
2. Inspect injector terminal ends and ECM terminal connector for cracked connector body, bent or loose pins, chafing and damaged or missing terminal nuts. Replace connector or terminal ends 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.
4. Carefully inspect main engine sensors wiring harness for worn conduit, frayed insulation or heat damage to wires. Repair or replace if necessary.
5. 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.
6. 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 and valves. If bent or corroded, replace damaged component.
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.

Installation

Engine Control Module (ECM) and Support

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

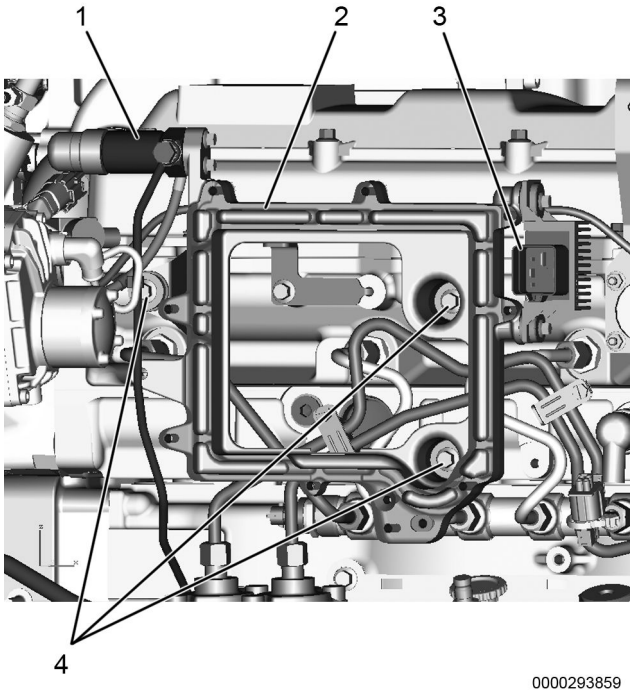

Figure 92 ECM support

1. Inlet Air Heater Fuel Solenoid (IAHFS)
2. ECM support
3. Inlet Air Heater Relay (IAHR)
4. M8 x 40 bolt (3) with EDC bracket insulator (6)

1. Place ECM support in position on engine and install six EDC bracket insulators and three M8 x 40 bolts. Tighten bolts to special torque (page 106).
2. Install IAHFS on ECM support. See Fuel Supply Solenoid Hose (page 114).
3. Install IAHR on ECM support. See Relay Assembly (page 117).

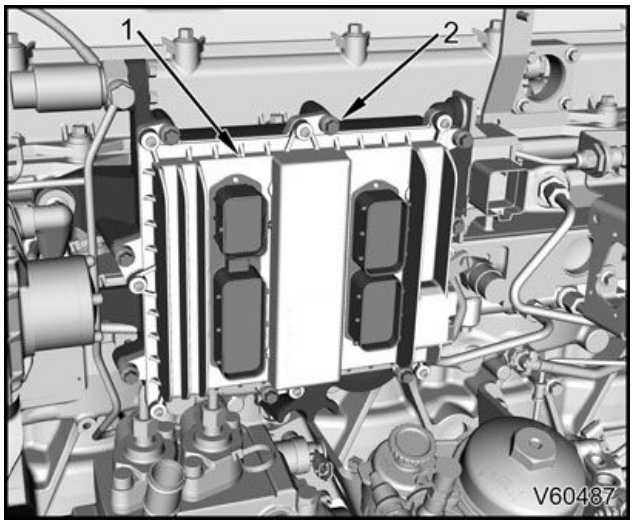

Figure 93 ECM mounting bolts

1. ECM
2. M6 x 30 bolt (8)

4. Place ECM in position on support and install eight M6 x 30 bolts hand tight.

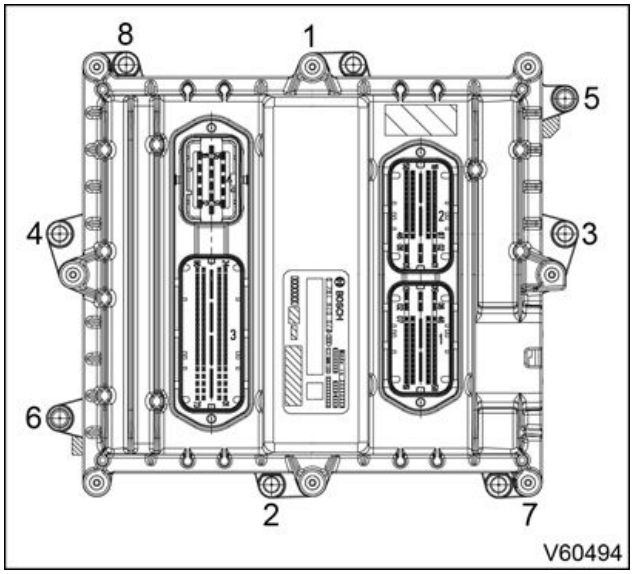

Figure 94 ECM bolt tightening sequence

5. Tighten M6 x 30 bolts in sequence shown to special torque (page 106).

Engine Sensor (Wiring) Harness

1. Place sensor harness in position on engine using care to properly route it around and between components.

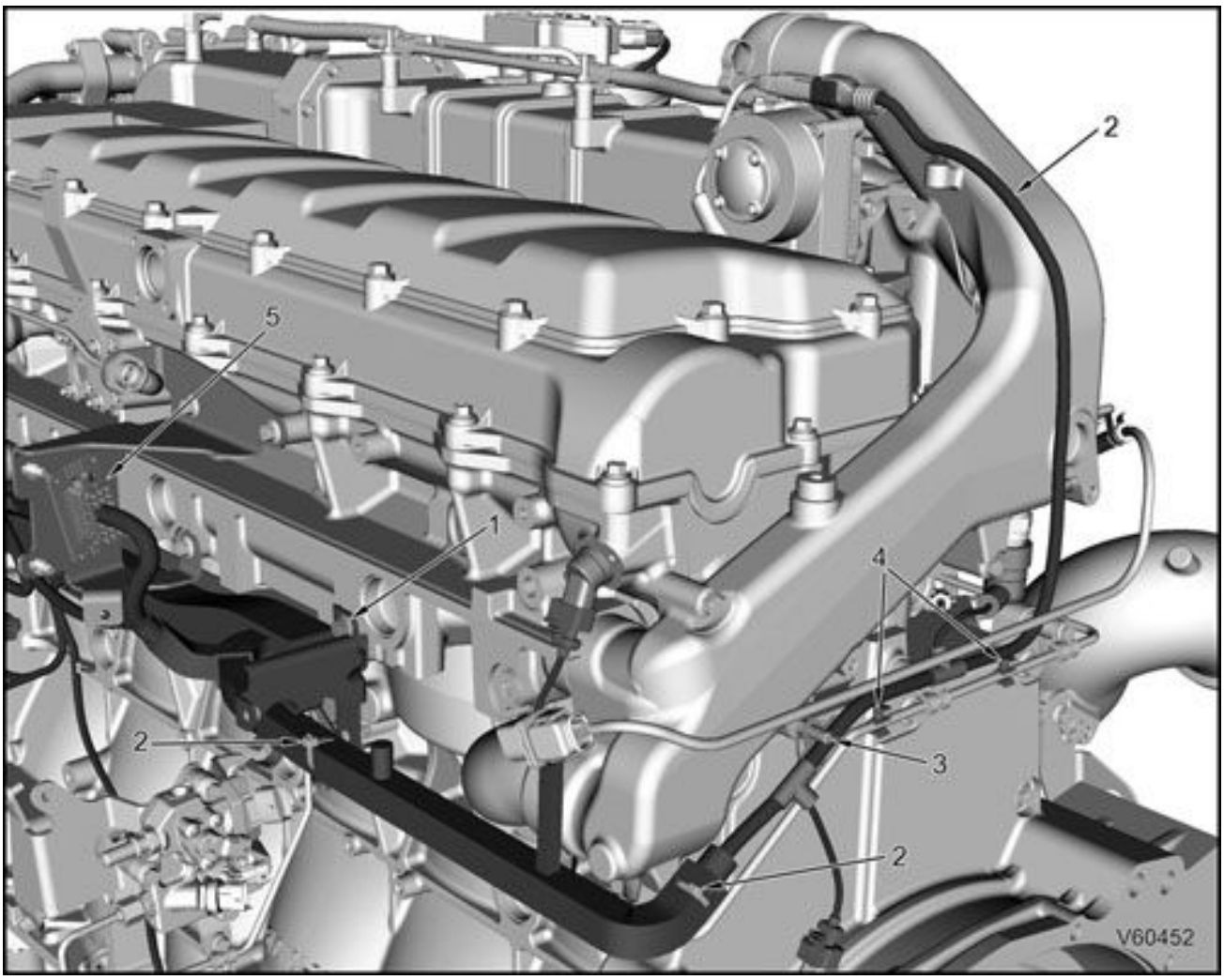

Figure 95 Sensor harness attachment points at left rear

1. M8 x 16 bolt (2)
2. Tie strap (3)
3. M8 stud
4. Harness clips
5. 21-way connector

2. Install two M8 x 16 bolts to attach harness bracket to crankcase. Tighten bolts to special torque (page 106).
3. Attach harness clip to M8 stud at coolant manifold.
4. Install three tie straps to secure sensor harness to harness support and coolant manifold.
5. Attach 21-way connector to harness bracket.
6. At left rear, connect harness connectors at CMP, CKP, ECT1 sensors and EGR valve.

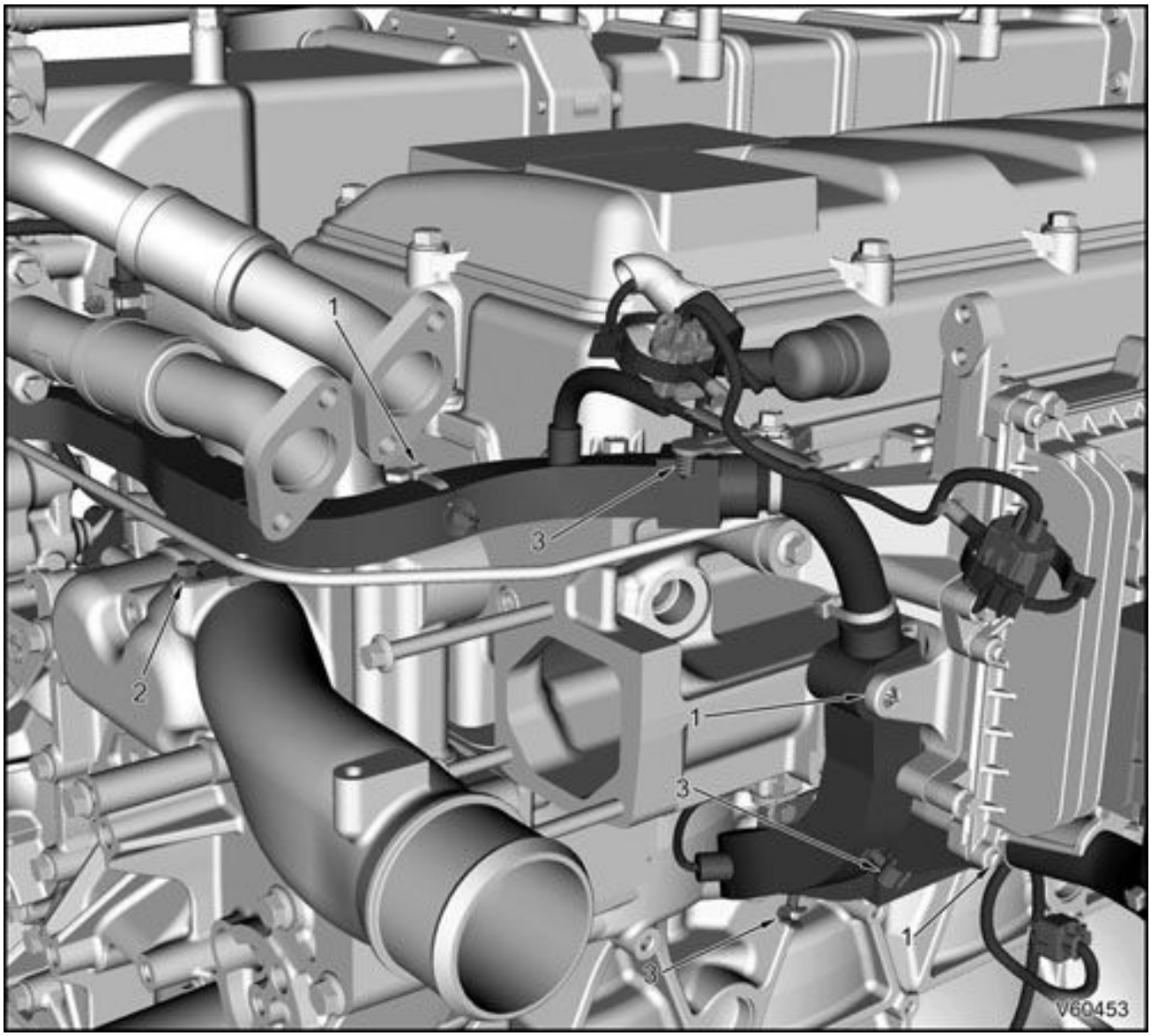

Figure 96 Sensor harness attachment points at left front (air intake throttle duct removed for clarity)

1. Tie strap (3)
2. M6 x 16 bolt
3. Other attachments

7. Install M6 x 16 bolt to attach harness clip to coolant outlet manifold. Tighten bolt to standard torque (page 547).
8. Install three tie straps to secure sensor harness to back of air intake throttle duct and back and bottom of ECM support.
9. Install other attachments as necessary.
10. Connect harness connectors at EGRT, CACOT, IMP, FRP, FDP and EOL sensors.

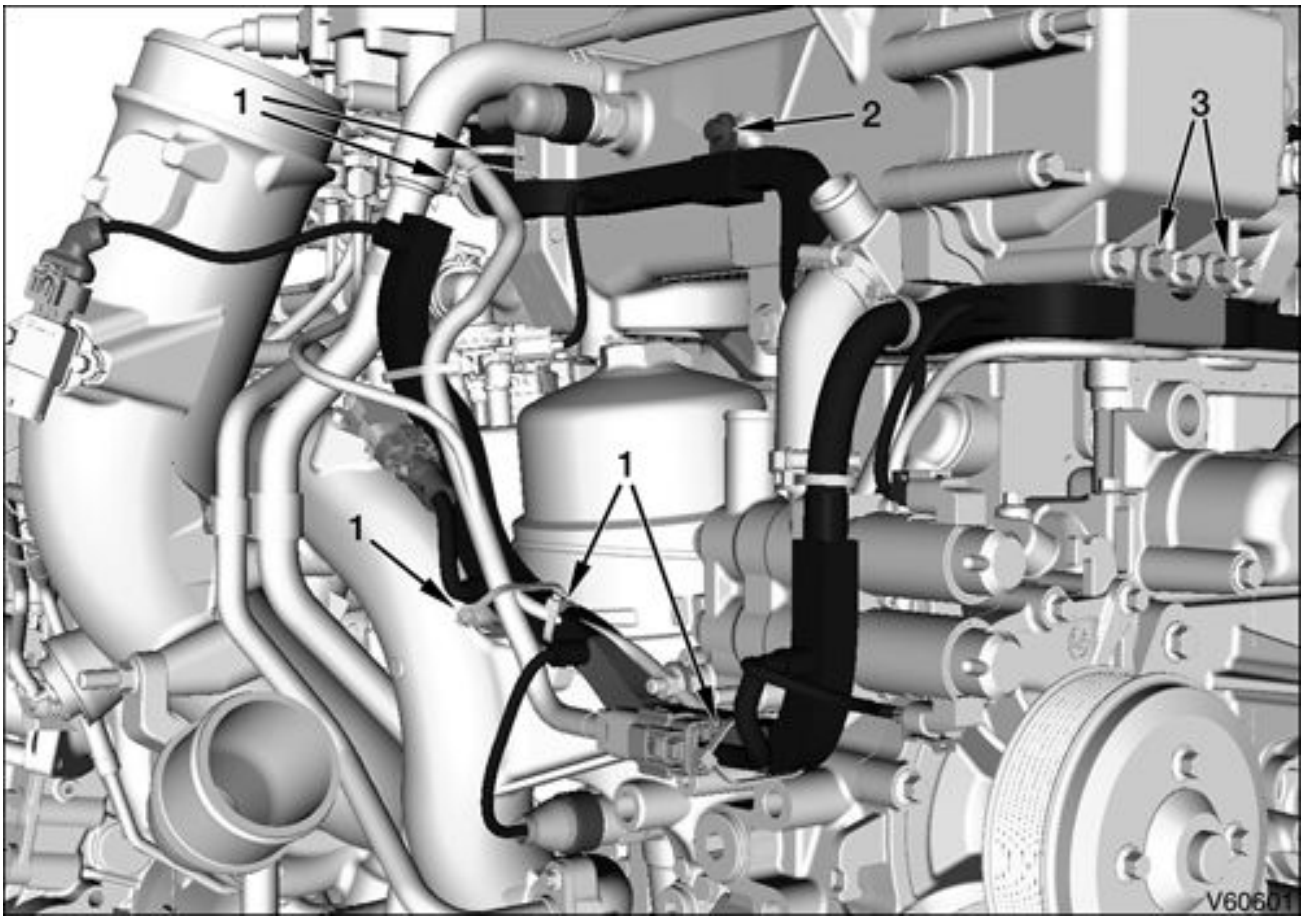

Figure 97 Sensor harness attachment points at right front

1. Tie strap (5)
2. M8 x 12 bolt
3. M8 x 16 bolt (2)

11. Install two M8 x 16 bolts to attach harness clip to EGR module cover. Tighten bolts to special torque (page 106).
12. Install M8 x 12 bolt to attach harness clip to EGR cooler low-temperature housing. Tighten bolt to standard torque (page 547).
13. Install tie straps to secure sensor harness at ACV, EGR cooler, CCV and to air supply tube.
14. Connect harness connectors at IAT, MAF (if equipped), TC2CIS, EOP, ACV, ECT2, CCOSS, CCV and EOT terminals.

Engine Injector (Wiring) Harness

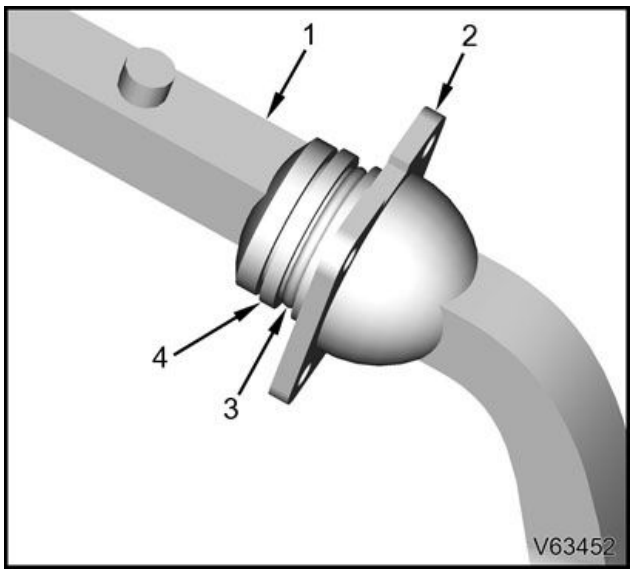

Figure 98 Engine injector (wiring) harness O-ring location

1. Engine injector (wiring) harness
2. Harness mounting flange
3. 32.92 x 3.53 O-ring
4. Harness flange collar

1. Check that 32.92 x 3.53 O-ring is in position on collar of harness mounting flange and in good condition. Replace as necessary.

CAUTION: To prevent engine damage, verify injector harness wires are not pinched or rubbing against the engine brake housing or rocker arm assembly.

2. Carefully route injector harness through valve cover base opening and along valve cover base to injectors.

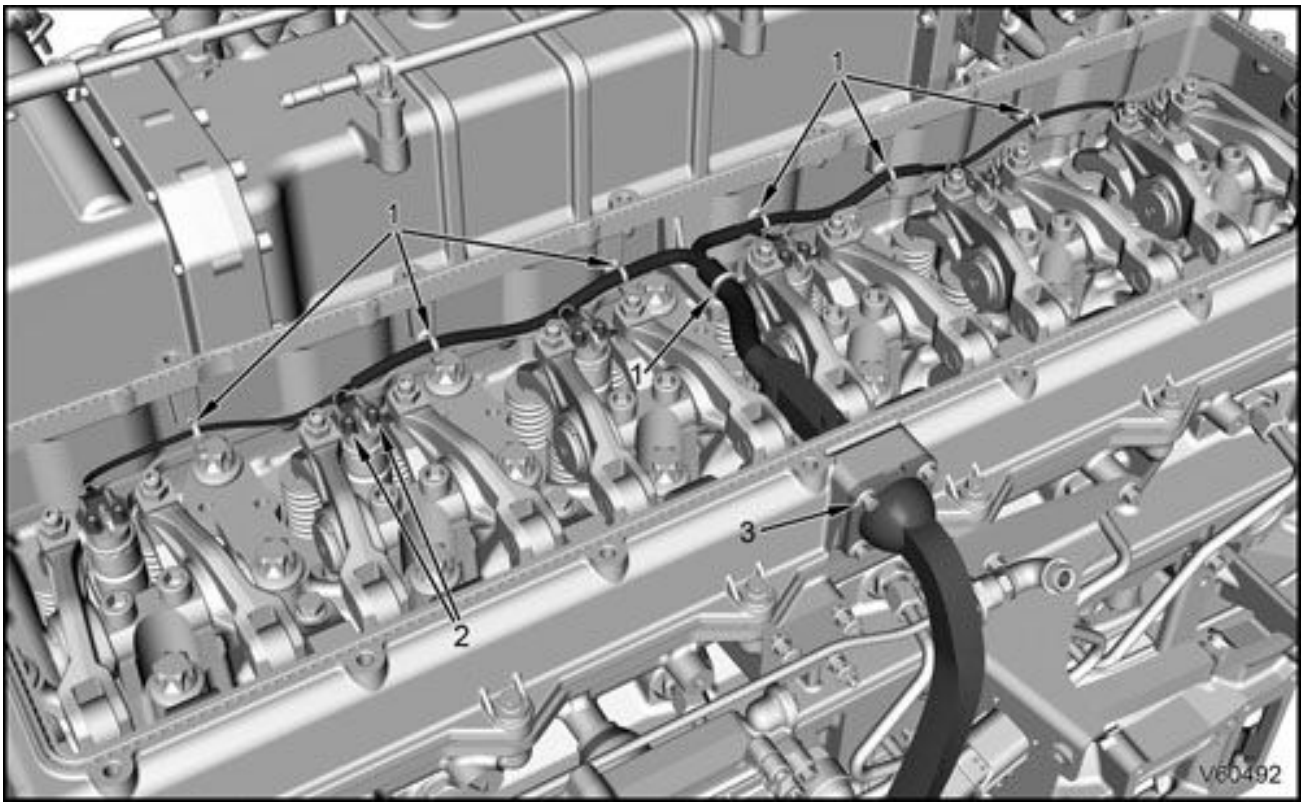

Figure 99 Injector harness attachment points at cylinder head

1. Tie strap (7)
2. Injector harness nut (12)
3. M6 x 16 bolt (4)

3. Install four M6 x 16 bolts to attach injector harness mounting flange to valve cover base. Tighten bolts to standard torque (page 547).
4. Install tie strap to secure injector at center of cylinder head.
5. Install tie straps at six locations to secure injector harness to valve cover base.
6. Install 12 harness nuts to connect harness leads to injector terminals.

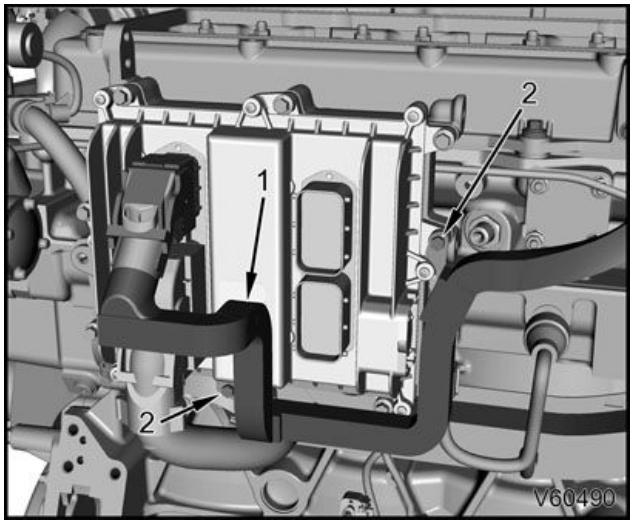

Figure 100 Injector harness attachment points at ECM

1. Injector harness
2. M6 x 30 bolt (2)

7. Install two M6 x 30 bolts to attach engine injector harness retainer clips to ECM. Tighten bolts to special torque (page 106).

Wiring Harness ECM Connections

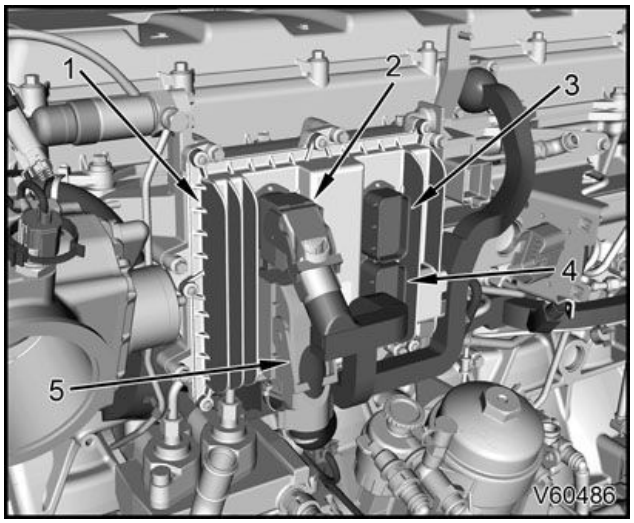

Figure 101 ECM harness connectors

1. ECM
2. Engine injector harness connector (to ECM 16-pin E2 terminal)
3. ECM 58-pin C2 chassis terminal
4. ECM 58-pin C1 chassis terminal
5. Engine sensor harness connector (to ECM 96-pin E1 terminal)

1. Check that ECM E1 and E2 terminal pins are straight and undamaged.
2. Align engine sensor harness connector with ECM E1 terminal and push connector straight in to engage pins. Push down on lock lever to draw in and secure connector.

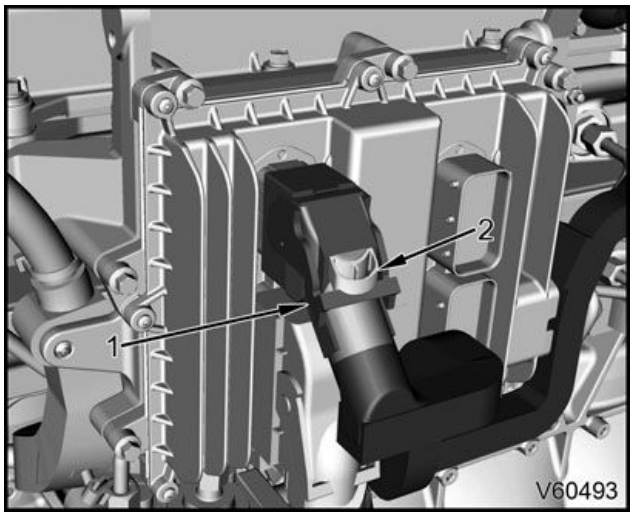

Figure 102 Injector harness connector

1. Lock lever
2. Connector clip

3. Align engine injector harness connector with ECM E2 terminal and push connector straight in to engage pins. Push down on lock lever to draw in and secure connector. Install connector clip.
4. Connect chassis harness connectors to ECM 58–pin C1 and C2 terminals. Lock connectors in place.

Turbocharger 2 Compressor Inlet Sensor (TC2CIS)

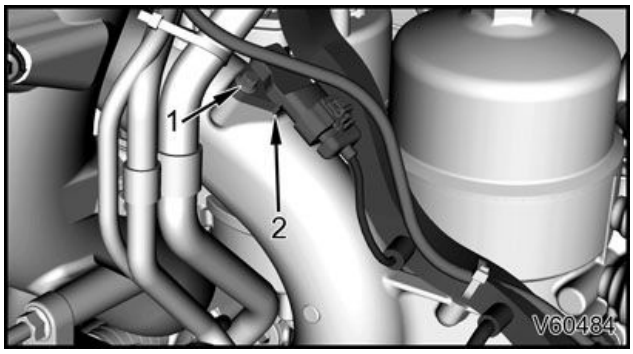

Figure 103 TC2CIS

1. M6 x 16 bolt (2)
2. TC2CIS

1. Place TC2CIS sensor in position on air supply duct and install two M6 x 16 bolts. Tighten bolts to special torque (page 106).
2. Connect harness to TC2CIS terminal by pushing in on connector until a click is heard.
3. Push in yellow tab to lock connector.

Exhaust Gas Recirculation Temperature (EGRT) Sensor

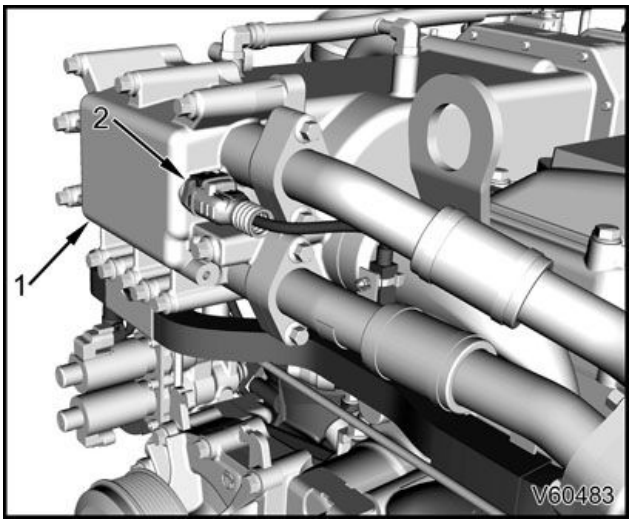

Figure 104 EGRT sensor

1. EGR module cover
2. EGRT sensor

1. Install EGRT sensor in module cover. Tighten sensor to special torque (page 106).
2. Connect harness to EGRT sensor terminal by pushing in on connector until a click is heard.
3. Push in red tab to lock connector.

Exhaust Gas Recirculation (EGR) Valve

1. Install Exhaust Gas Recirculation (EGR) dual flap valve. See EGR Dual Flap Valve (page 323).

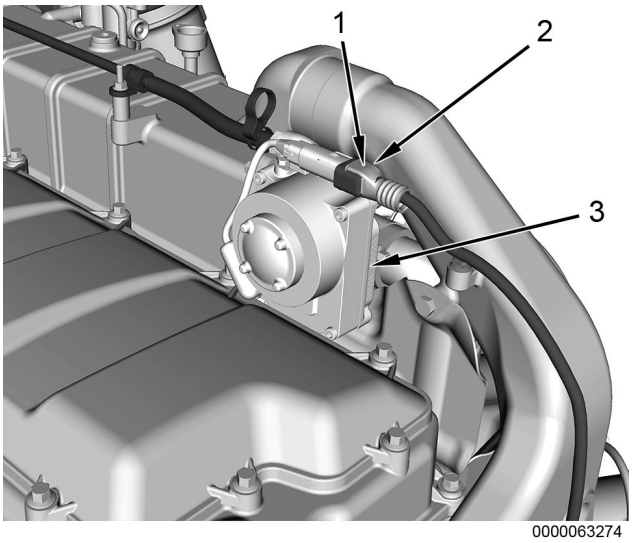

Figure 105 EGR valve harness connector

1. CPA tab
2. Harness connector
3. EGR valve

2. Connect harness connector (Figure 105) (Item 2) to EGR valve (Figure 105) (Item 3) by pushing in on harness connector until a click is heard.
3. Engage Connector Position Assurance (CPA) tab (Figure 105) (Item 1).

Air Control Valve (ACV)

1. Install ACV. See Air Control Valve (ACV) (page 151).

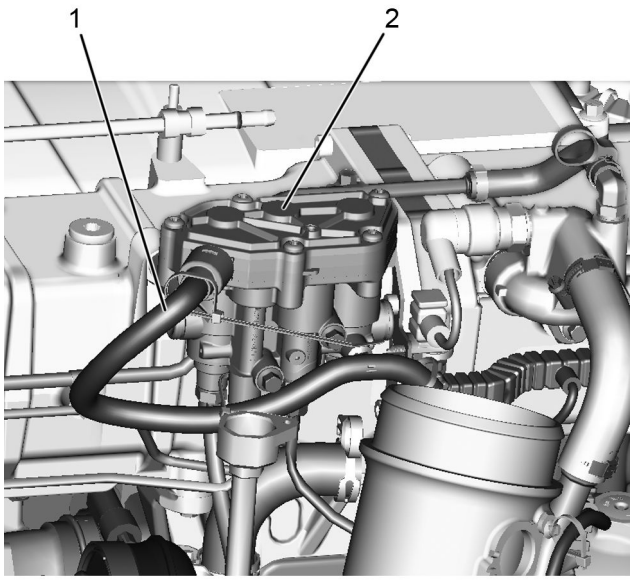

Figure 106 ACV

1. Pigtail harness
2. ACV assembly

2. Connect pigtail harness (Figure 106) (Item 1) to ACV terminal by pushing in on connector until a click is heard.

Coolant Control Valve (CCV)

NOTE: The coolant mixer and coolant flow valves are not serviced separately. Both valves are an integral part of the CCV assembly which is available as a unit.

1. See Coolant Control Valve (CCV) (page 376) for installation.

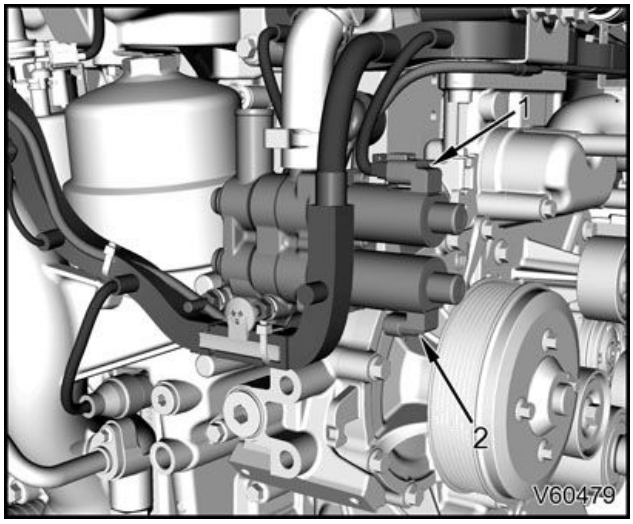

Figure 107 CCV

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

2. Connect harness CMV and CFV connectors by pushing in until a click is heard.
3. Engage release tab and secure CMV and CFV connectors to wiring harness.

Engine Throttle Valve (ETV)

1. See Air Intake Throttle Duct (page 344) for installation of air intake throttle duct and Engine Throttle Valve (ETV) as an assembly.

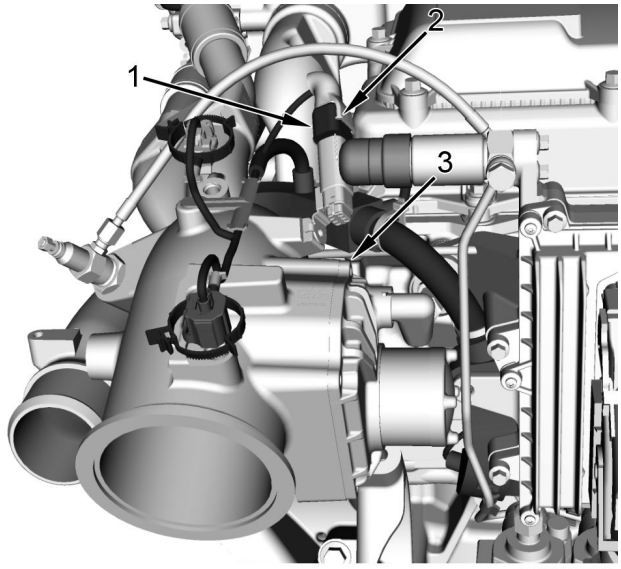

Figure 108 ETV

1. Harness connector
2. CPA tab
3. ETV

2. Connect harness connector (Figure 108) (Item 1) to ETV (Figure 108) (Item 3) by pushing in on harness connector until a click is heard.
3. Engage Connector Position Assurance (CPA) tab (Figure 108) (Item 2).
4. See Intake Manifold Pressure (IMP) Sensor (page 99) and Charge Air Cooler Outlet Temperature (CACOT) Sensor (page 100) for installation of ETV-mounted sensors.

Nitrogen Oxides (NOx) In Sensor

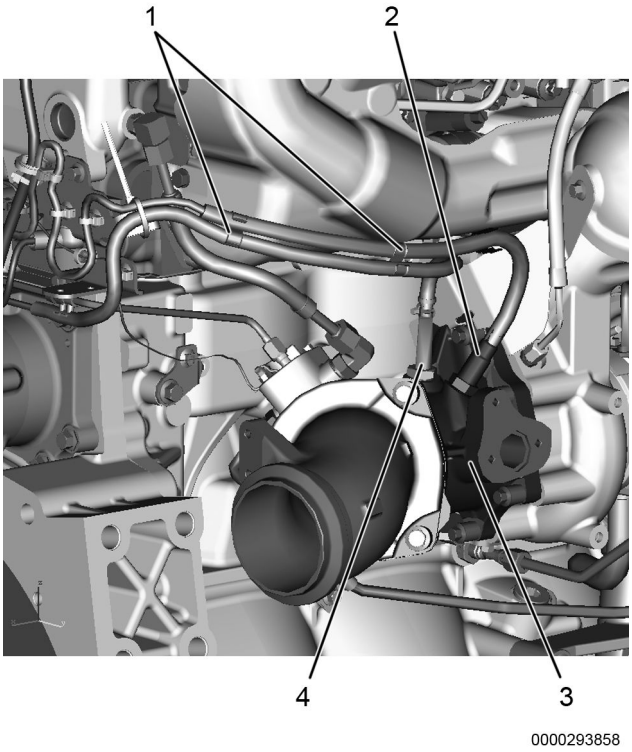

Figure 109 NOx In Sensor (valve actuator removed for clarity)

1. Clip (2)
2. O2S (with harness lead)
3. Exhaust back pressure valve housing
4. NOx IN sensor (with harness lead)

NOTE: The NOx IN sensor should be reused unless there is damage to the sealing ring and evidence of an exhaust leak.

1. Install NOx In sensor (Figure 109) (Item 4) in exhaust back pressure valve housing (Figure 109) (Item 3).
2. Tighten NOx In sensor to 37 lb-ft (50 N·m).

Nitrogen Oxides (NOx) IN Sensor Module

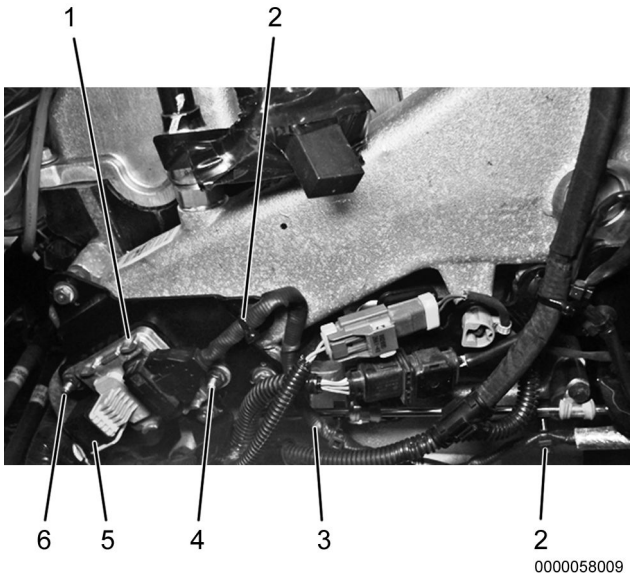

Figure 110 NOx IN Sensor Module Connector

1. NOx IN sensor module
2. Tiedown strap
3. NOx IN sensor harness
4. NOx IN sensor module nut
5. NOx IN sensor module connector
6. NOx IN sensor module nut

1. Secure NOx In sensor module (Figure 110) (Item 1) on vehicle with two NOx In sensor mo dule nuts (Figure 110) (Items 4 and 6).
2. Tighten NOx In sensor module nuts to 115 lb-in (13 N·m).
3. Secure NOx In sensor harness (Figure 110) (Item 3) with tiedown straps (Figure 110) (Item 2) as required.
4. Connect NOx In sensor module connector (Figure 110) (Item 5) to No In sensor module (Figure 110) (Item 1).

Oxygen Sensor (O2S)

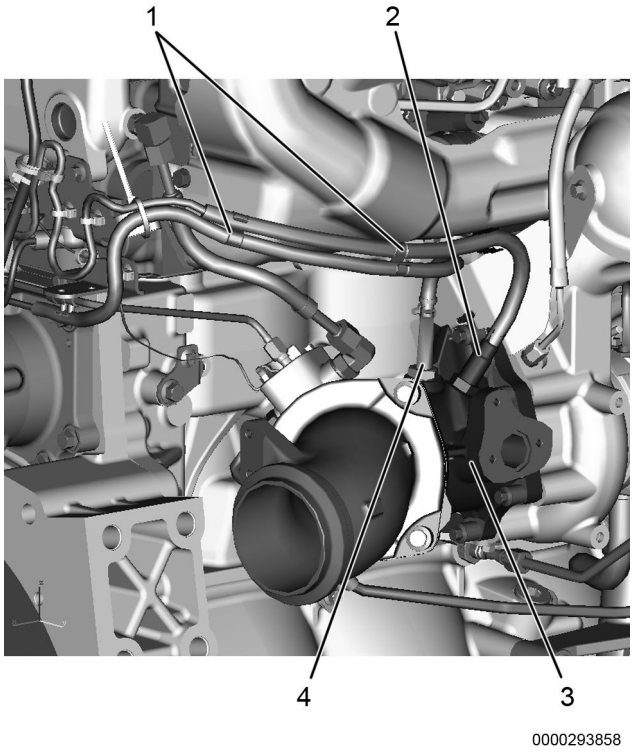

Figure 111 O2S (valve actuator removed for clarity)

1. Clip (2)
2. O2S (with harness lead)
3. Exhaust back pressure valve housing
4. NOx IN Sensor (with harness lead)

NOTE: The O2S should be reused unless there is damage to the sealing ring and evidence of an exhaust leak.

1. If removed, install O2S (Figure 111) (Item 2). Tighten O2S to 37 lbf·ft (50 N·m).
2. Attach clips (Figure 111) (Item 1) to secure harness lead to coolant tube and valve actuator bracket and at left rear of engine.
3. Connect harness to O2S terminal end by pushing in on connector until a click is heard.
4. Engage release lever.

NOTE: Any time the O2S is replaced, an Oxygen Sensor Calibration Procedure must be done. See N13 *Engine Diagnostic Manual* for details.

Intake Manifold Temperature (IMT) Sensor

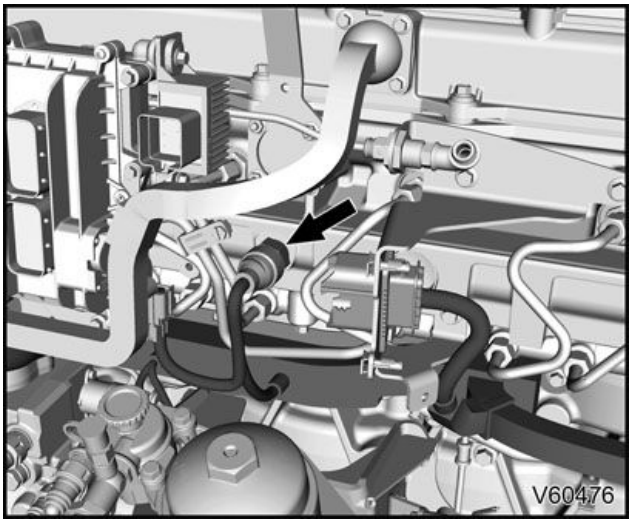

Figure 112 IMT sensor

1. Install new 16.7 x 24 seal ring and IMT sensor. Tighten sensor to special torque (page 106).

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

2. Connect harness connector to IMT sensor.
3. Turn IMT sensor harness connector locking ring 90° clockwise.

Fuel Rail Pressure (FRP) Sensor

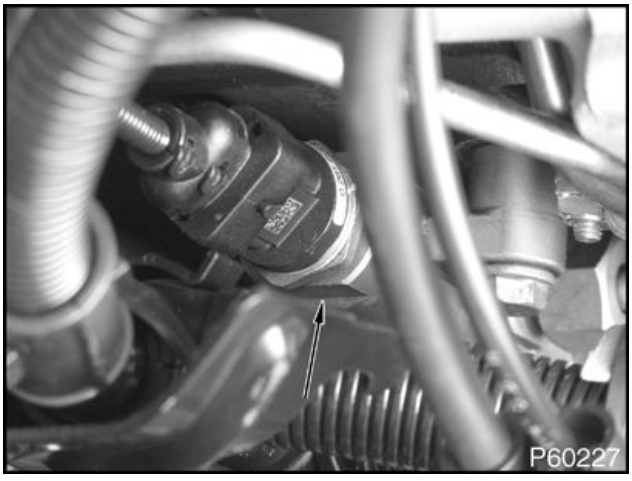

Figure 113 FRP sensor (typical)

1. Apply a thin film of Lubricant F11V27 or equivalent to the threads and seal ring of the FRP sensor.
2. Remove plastic protective cap from the FRP sensor port.
3. Install and hand tighten FRP sensor. Tighten FRP sensor to special torque (page 106).
4. Connect engine harness connector to FRP sensor terminal by pushing in on connector until a click is heard.
5. Push in yellow tab to lock engine harness connector.

Intake Manifold Pressure (IMP) Sensor

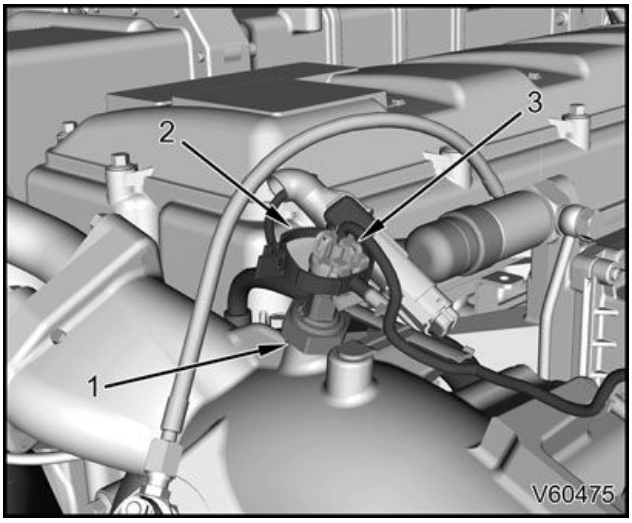

Figure 114 IMP sensor

1. IMP sensor
2. Standoff tie strap
3. Harness connector

1. Install new O-ring and install IMP sensor in Engine Throttle Valve (ETV) housing. Tighten sensor to special torque (page 106).
2. Connect harness to IMP sensor terminal by pushing in on connector until a click is heard.
3. Engage release tab.
4. Attach tie strap to secure harness standoff bracket to IMP sensor.

Charger Air Cooler Outlet Temperature (CACOT) Sensor

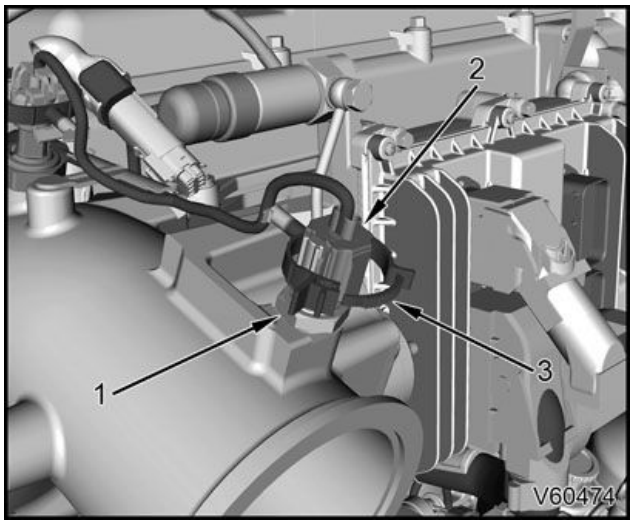

Figure 115 CACOT sensor

1. CACOT sensor
2. Harness connector
3. Standoff tie strap

1. Install new 2.2 x 9.3 ID O-ring and CACOT sensor in throttle valve housing. Tighten sensor to special torque (page 106).
2. Connect harness to CACOT sensor terminal by pushing in on connector until a click is heard.
3. Engage release tab.
4. Attach tie strap to secure harness standoff bracket to CACOT sensor.

Humidity / Inlet Air Temperature (IAT) Sensor

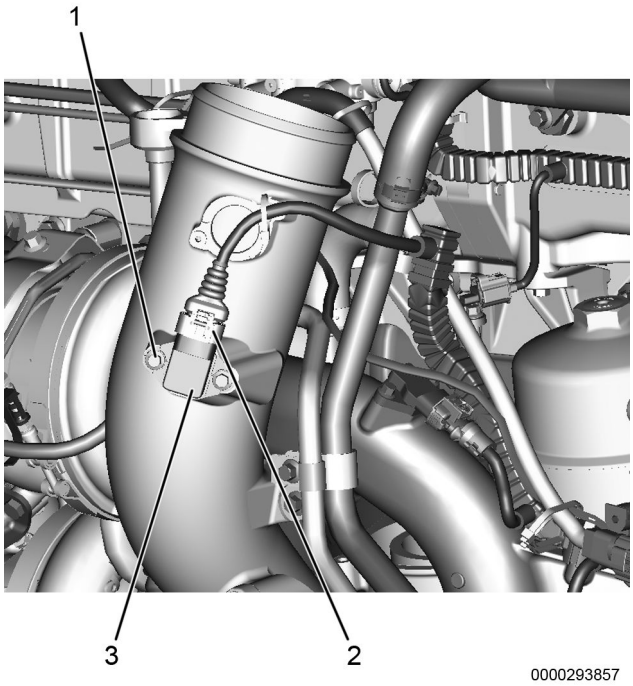

Figure 116 HS / IAT sensor

1. M6 x 16 bolt (2)
2. Harness connector
3. HS / IAT sensor

1. Insert new O-ring and placeHS / IAT sensor (Figure 116) (Item 3) in position on air inlet duct.
2. Install two M6 x 16 bolts (Figure 116) (Item 1). Tighten bolts to 80 lbf·in (9 N·m).
3. Connect harness to IAT terminal by pushing in on connector until a click is heard.
4. Push in yellow tab to lock sensor connector.

Fuel Pressure Control Valve (FPCV)

1. See High-pressure Fuel Pump (HPFP) and Drive Housing (page 253) for installation of high-pressure fuel pump.

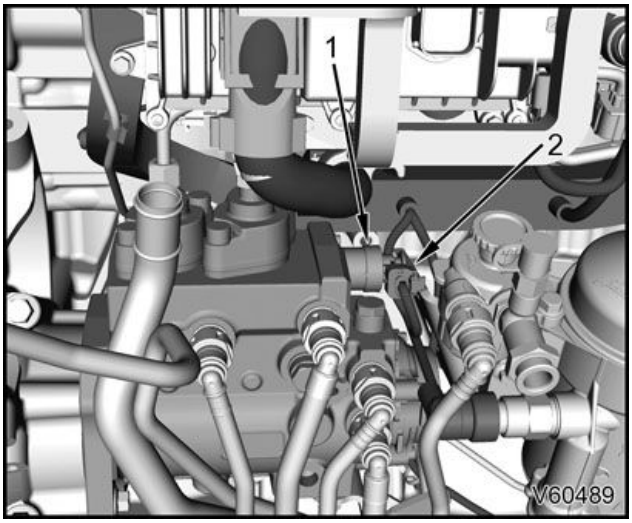

Figure 117 FPCV (on high-pressure fuel pump)

1. FPCV
2. Harness connector

2. Connect harness to FPCV terminal by pushing in on connector until a click is heard.
3. Push in yellow tab to lock sensor connector.

Fuel Delivery Pressure (FDP) Sensor

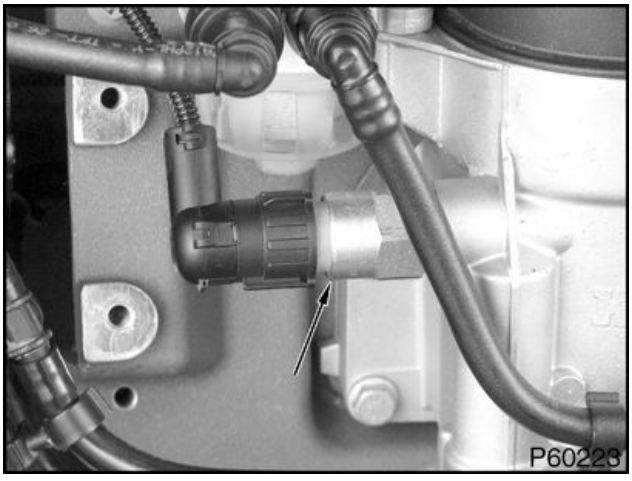

Figure 118 FDP sensor

1. Install FDP sensor and new 18.7 x 26 seal ring. Tighten sensor to special torque (page 106).

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

2. Connect harness to FDP sensor.
3. Turn sensor harness connector locking ring 90° clockwise.

Crankcase Oil Separator Speed (CCOSS) Sensor

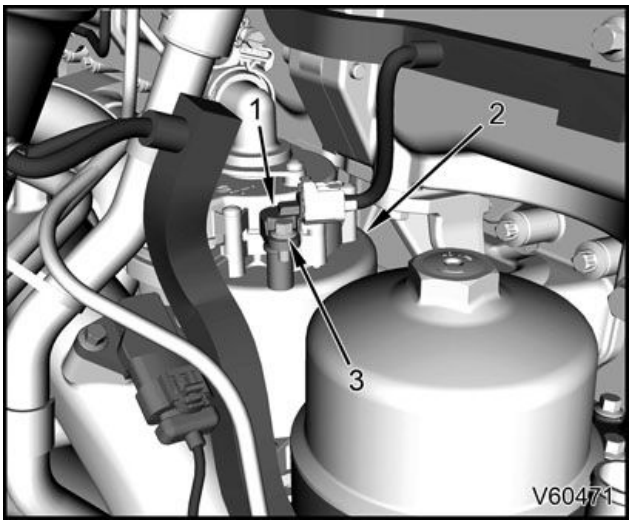

Figure 119 CCOSS sensor

1. CCOSS sensor
2. Oil centrifuge (part of oil module assembly)
3. M6 x 14 bolt and nut

1. Place CCOSS sensor in position on bracket and install M6 x 14 bolt and nut.
2. Tighten bolt to special torque (page 106).
3. Connect harness to CCOSS sensor by pushing in on connector until a click is heard.
4. Push in yellow tab to lock connector in place.

Engine Oil Pressure (EOP) Sensor

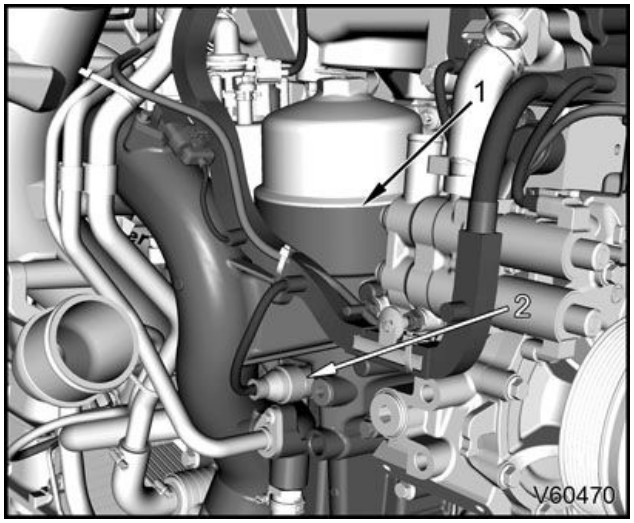

Figure 120 EOP sensor

1. Oil module assembly
2. EOP sensor

1. Install EOP sensor and new 18.7 x 26 seal ring in oil module assembly. Tighten sensor to special torque (page 106).

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

2. Connect harness to EOP sensor.
3. Turn sensor connector locking ring 90° clockwise.

Engine Oil Temperature (EOT) Sensor

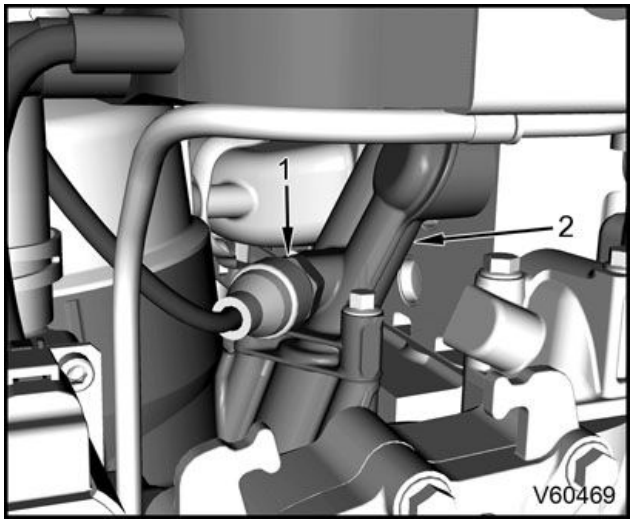

Figure 121 EOT sensor

1. EOT sensor
2. Oil module flange

1. Install EOT sensor and new 16.7 x 24 seal ring in oil module flange. Tighten sensor to special torque (page 106).

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

2. Connect harness to EOT sensor.
3. Turn sensor connector locking ring 90° clockwise.

Engine Coolant Temperature 2 (ECT2) Sensor

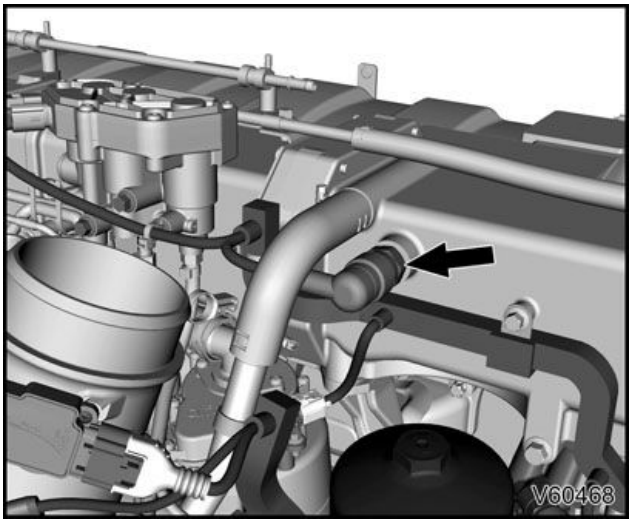

Figure 122 ECT2 sensor

1. Install ECT2 sensor and new 16.7 x 24 seal ring in EGR module low-temperature housing. Tighten sensor to special torque (page 106).

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

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

Engine Coolant Temperature 1 (ECT1) Sensor

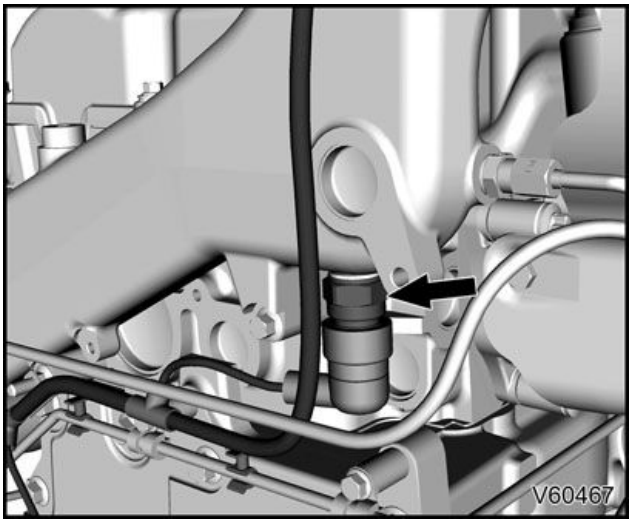

Figure 123 ECT1 sensor

1. Install ECT1 sensor with new 16.7 x 24 seal ring in EGR coolant manifold at rear of engine. Tighten sensor to special torque (page 106).

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

2. Connect harness connector to ECT1 sensor.
3. Turn sensor harness connector locking ring 90° clockwise.

Camshaft Position (CMP) Sensor

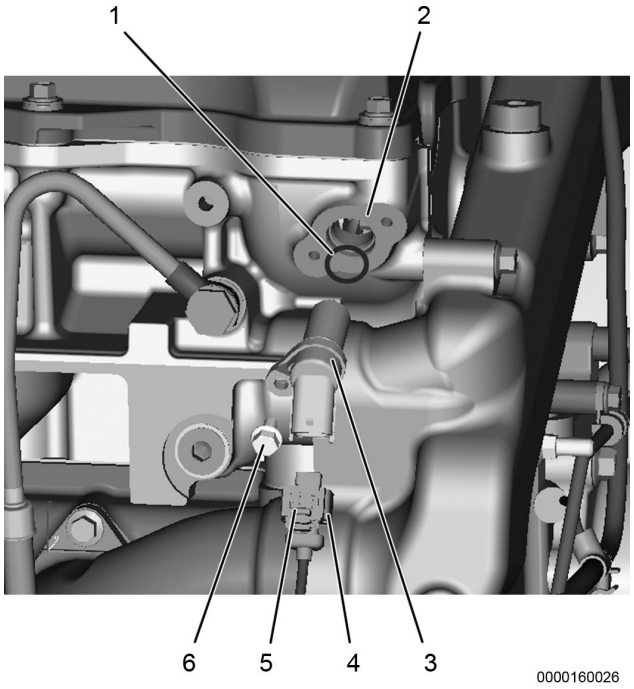

Figure 124 CMP sensor

1. O-ring
2. Cylinder head
3. CMP sensor
4. CMP sensor harness connector
5. Locking tab
6. M6 x 12 bolt

1. Clean CMP sensor bore with a shop towel.
2. Lubricate new O-ring (Figure 124) (Item 1) with oil-based grease and install on CMP sensor (Figure 124) (Item 3).

CAUTION: To prevent sensor damage, do not use chemical cleaners to clean CMP sensor.

3. Clean debris build-up on CMP sensor with a shop towel.
4. Insert CMP sensor in port at left rear of cylinder head (Figure 124) (Item 2).
5. Install M6 x 12 bolt (Figure 124) (Item 6) to attach CMP sensor to cylinder head. Tighten bolt to 71 lb·in (8 N·m).
6. Connect CMP sensor harness connector (Figure 124) (Item 4) to CMP sensor terminal by pushing in on connector until a click is heard.
7. Push in locking tab (Figure 124) (Item 5) to lock sensor connector in place.

Crankshaft Position (CKP) Sensor

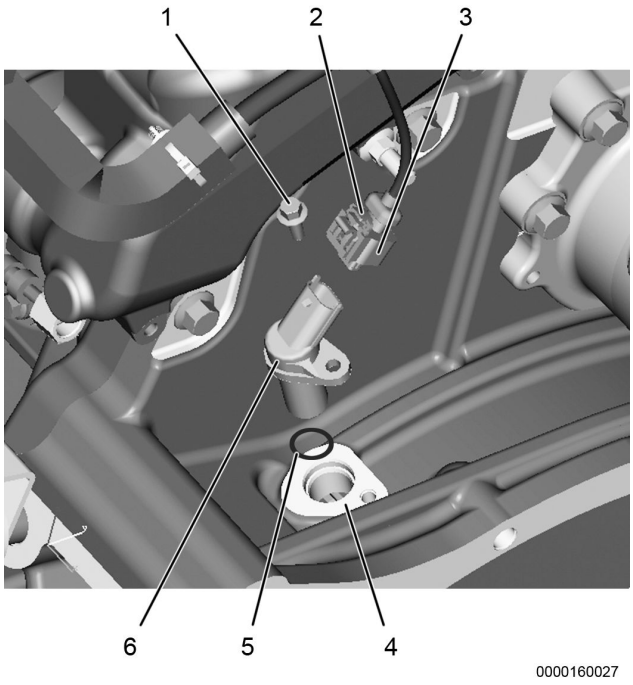

Figure 125 CKP sensor

1. M6 x 16 bolt
2. Locking tab
3. CKP sensor harness connector
4. Flywheel housing
5. O-ring
6. CKP sensor

1. Clean CKP sensor bore with a shop towel.
2. Lubricate new O-ring (Figure 125) (Item 5) with oil-based grease and install on CKP sensor (Figure 125) (Item 6).

CAUTION: To prevent sensor damage, do not use chemical cleaners to clean CKP sensor.

3. Clean debris build-up on CKP sensor with a shop towel.

4. Insert CKP sensor in port at top left of flywheel housing (Figure 125) (Item 4).
5. Install M6 x 16 bolt (Figure 125) (Item 1) to CKP sensor. Tighten bolt to 71 lb·in (8 N·m).
6. Connect CKP sensor harness connector (Figure 125) (Item 3) to CKP sensor terminal by pushing in on connector until a click is heard.
7. Push in locking tab (Figure 125) (Item 2) to lock connector in place.

Special Torque

Camshaft Position (CMP) sensor, M6 x 12 bolt	8 N·m (71 lb·in)
Charger Air Cooler Outlet Temperature (CACOT) sensor	11 N·m (97 lb·in)
Crankcase Oil Separator Speed (CCOSS) sensor, M6 x 14 bolt	10 N·m (89 lb·in)
Crankshaft Position (CKP) sensor, M6 x 16 bolt	8 N·m (71 lb·in)
Engine Control Module (ECM), M6 x 30 bolt	10 N·m (89 lb·in) See procedure for tightening sequence
Engine Control Module (ECM) support, M8 x 40 bolt	13 N·m (115 lb·in)
Engine Coolant Temperature 1 (ECT1) sensor	45 N·m (33 lb·ft)
Engine Coolant Temperature 2 (ECT2) sensor	45 N·m (33 lb·ft)
Engine injector harness retainer clip, M6 x 30 bolt	10 N·m (89 lb·in)
Engine Oil Pressure (EOP) sensor	45 N·m (33 lb·ft)
Engine Oil Temperature (EOT) sensor	45 N·m (33 lb·ft)
Engine sensor harness bracket/clip, M8 x 16 bolt	35 N·m (26 lb·ft)
Exhaust Gas Recirculation Temperature (EGRT) sensor	37 N·m (27 lb·ft)
Fuel Delivery Pressure (FDP) sensor	45 N·m (33 lb·ft)
Humidity / Inlet Air Temperature (IAT) sensor, M6 x 16 bolt	9 N·m (80 lb·in)
Intake Manifold Temperature (IMT) sensor	45 N·m (33 lb·ft)
Intake Manifold Pressure (IMP) sensor	12 N·m (106 lb·in)
Mass Air Flow (MAF) sensor, M4 x 0.7 cap screw	0.36 N·m (3 lb·in)
Oxygen Sensor (O2S)	50 N·m (37 lb·ft)
NOx IN Sensor	50 N·m (37 lb·ft)
Fuel Rail Pressure (FRP) sensor	70 N·m (52 lb·ft)
Turbocharger 2 Compressor Inlet Sensor (TC2CIS), M6 x 16 bolt	9 N·m (80 lb·in)

Special Service Tools

Description	Tool Number
Disposable Air and Fuel Caps	ZTSE4891

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Exploded View

Inlet Air Heater Components

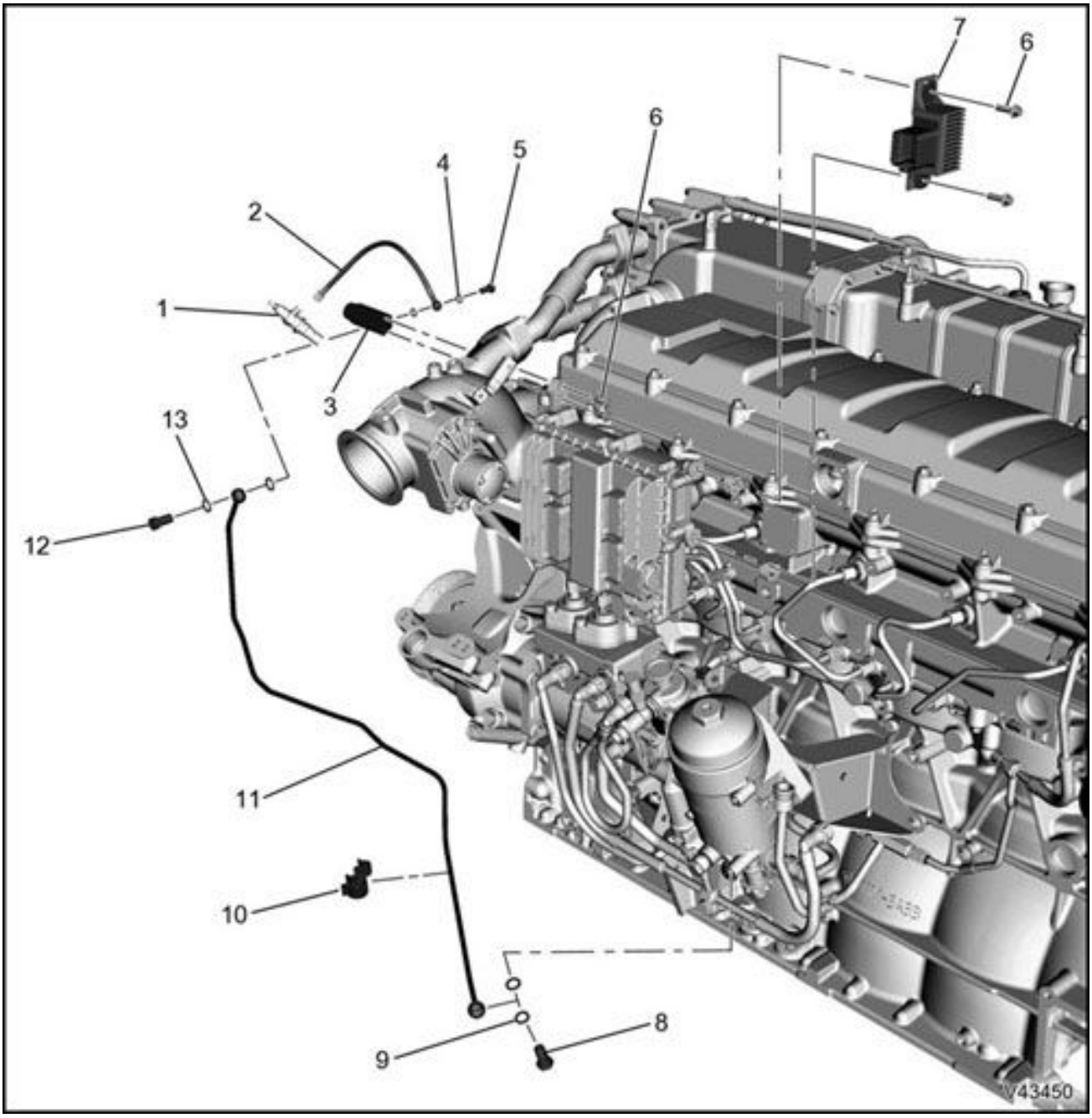

Figure 126 Inlet Air Heater Components

1. Inlet Air Heater Fuel Igniter (IAHFI)
2. Fuel supply inlet air heater hose
3. Solenoid valve
4. Washer (seal ring) (2)
5. M8 x 1 banjo bolt
6. M6 x 20 bolt (4)
7. Relay assembly
8. Banjo 8 bolt (M12 x 1.5)
9. Seal 12.7 x 18 ring (2)
10. Wiring DMR 11-13 x 6-6.5 clip
11. Fuel supply solenoid hose
12. Banjo 6 bolt (M10 x 1)
13. Seal 10.7 x 16 ring (2)

Removal

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

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

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

WARNING: To prevent personal injury or death, 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.

Relay Assembly

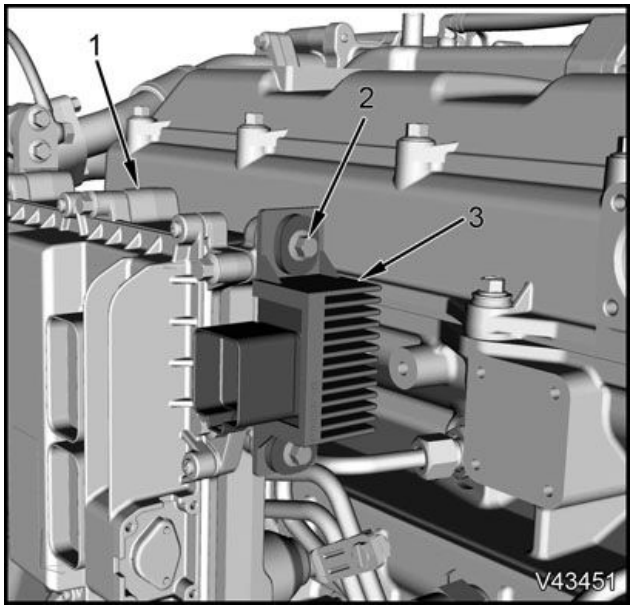

Figure 127 Relay Assembly

1. Engine Control Module (ECM) support bracket
2. M6 x 20 bolt (2)
3. Relay assembly

1. Disconnect wiring harness connector from relay assembly (Figure 127) (Item 3), if not already done.
2. Remove two M6 x 20 bolts (Figure 127) (Item 2) and remove relay assembly from ECM support bracket (Figure 127) (Item 1).

Inlet Air Heater Fuel Igniter (IAHFI) and Fuel Supply Inlet Air Heater Hose

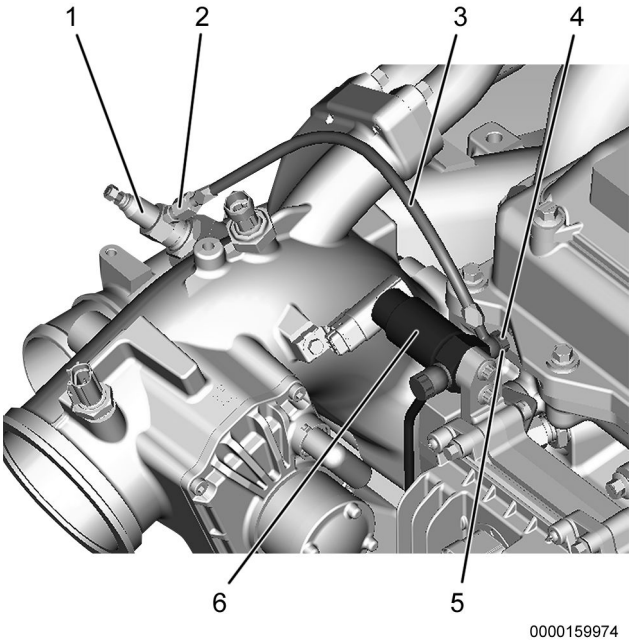

Figure 128 IAHFI and Fuel Supply Inlet Air Heater Hose

1. Inlet Air Heater Fuel Igniter (IAHFI)
2. Fuel supply inlet air heater hose fitting nut
3. Fuel supply inlet air heater hose
4. M8 x 1 banjo bolt
5. Washer (seal ring) (2)
6. Solenoid valve

WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked diesel fuel.

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

1. Place suitable container clearly marked DIESEL FUEL under fuel supply inlet air heater hose (Figure 128) (Item 3).
2. Loosen hose fitting nut (Figure 128) (Item 2) that attaches to IAHFI (Figure 128) (Item 1) fitting. Drain fuel into container.
3. Loosen and remove M8 x 1 banjo bolt (Figure 128) (Item 4) securing fuel supply inlet air heater hose to solenoid valve (Figure 128) (Item 6).
4. Remove fuel supply inlet air heater hose and discard two washers (seal rings) (Figure 128) (Item 5).

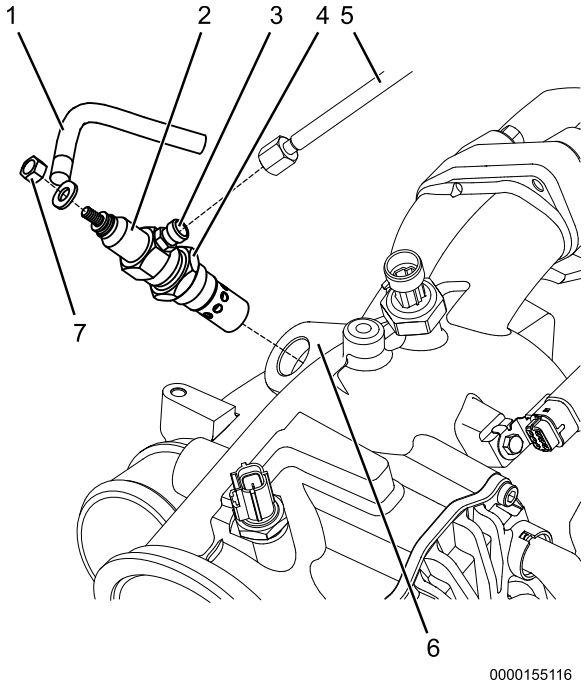

Figure 129 Inlet Air Heater Fuel Igniter (IAHFI)

1. Wiring harness
2. Inlet Air Heater Fuel Igniter (IAHFI)
3. Fuel line port
4. IAHFI locking nut
5. Fuel supply inlet air heater hose
6. Air intake throttle duct
7. IAHFI wiring harness nut

5. If not already done, remove IAHFI wiring harness nut (Figure 129) (Item 7) and remove wiring harness (Figure 129) (Item 1) from the IAHFI (Figure 129) (Item 2).
6. Loosen IAHFI locking nut (Figure 129) (Item 4).
7. Remove IAHFI from air intake throttle duct (Figure 129) (Item 6) by rotating counterclockwise.

Fuel Solenoid Valve and Fuel Supply Solenoid Hose

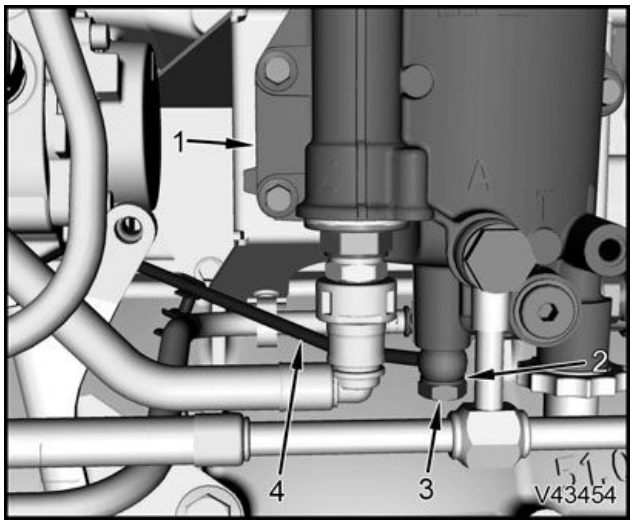

Figure 130 Fuel Supply Solenoid Hose (at Fuel Filter Housing)

1. Fuel filter housing
2. Seal 12.7 x 18 ring (2)
3. Banjo 8 bolt (M12 x 1.5)
4. Fuel supply solenoid hose

WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked diesel fuel.

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

1. Place suitable container clearly marked DIESEL FUEL under lower end of fuel supply solenoid hose (Figure 130) (Item 4).
2. Remove banjo 8 bolt (M12 x 1.5) (Figure 130) (Item 3) from fuel filter housing (Figure 130) (Item 1) and drain fuel into container.
3. Remove and discard two seal 12.7 x 18 rings (Figure 130) (Item 2).

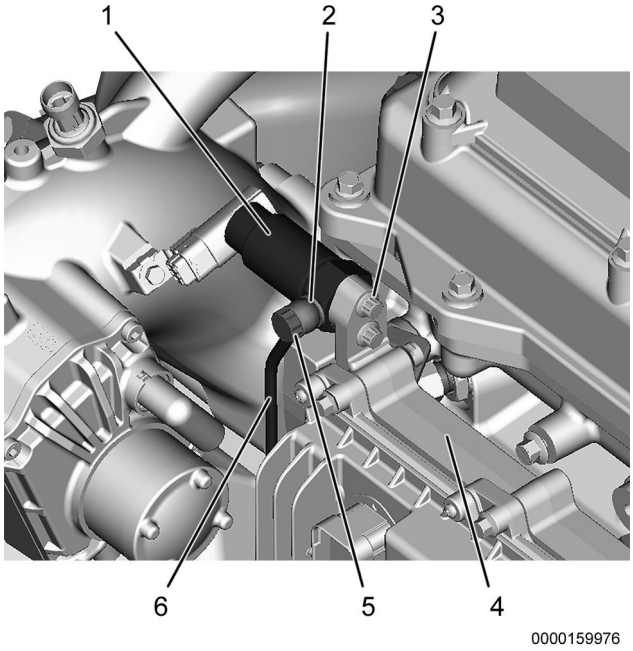

Figure 131 Fuel Supply Solenoid Hose (at Solenoid Valve)

1. Solenoid valve
2. Seal 10.7 x 16 ring (2)
3. M6 x 20 bolt (2)
4. ECM support bracket
5. Banjo 6 bolt (M10 x 1)
6. Fuel supply solenoid hose (tube)

4. Remove banjo 6 bolt (M10 x 1) (Figure 131) (Item 5) from solenoid valve (Figure 131) (Item 1).
5. Remove and discard two seal 10.7 x 16 rings (Figure 131) (Item 2).
6. Remove two M6 x 20 bolts (Figure 131) (Item 3) securing the solenoid valve to the ECM support bracket (Figure 131) (Item 4). Remove valve.

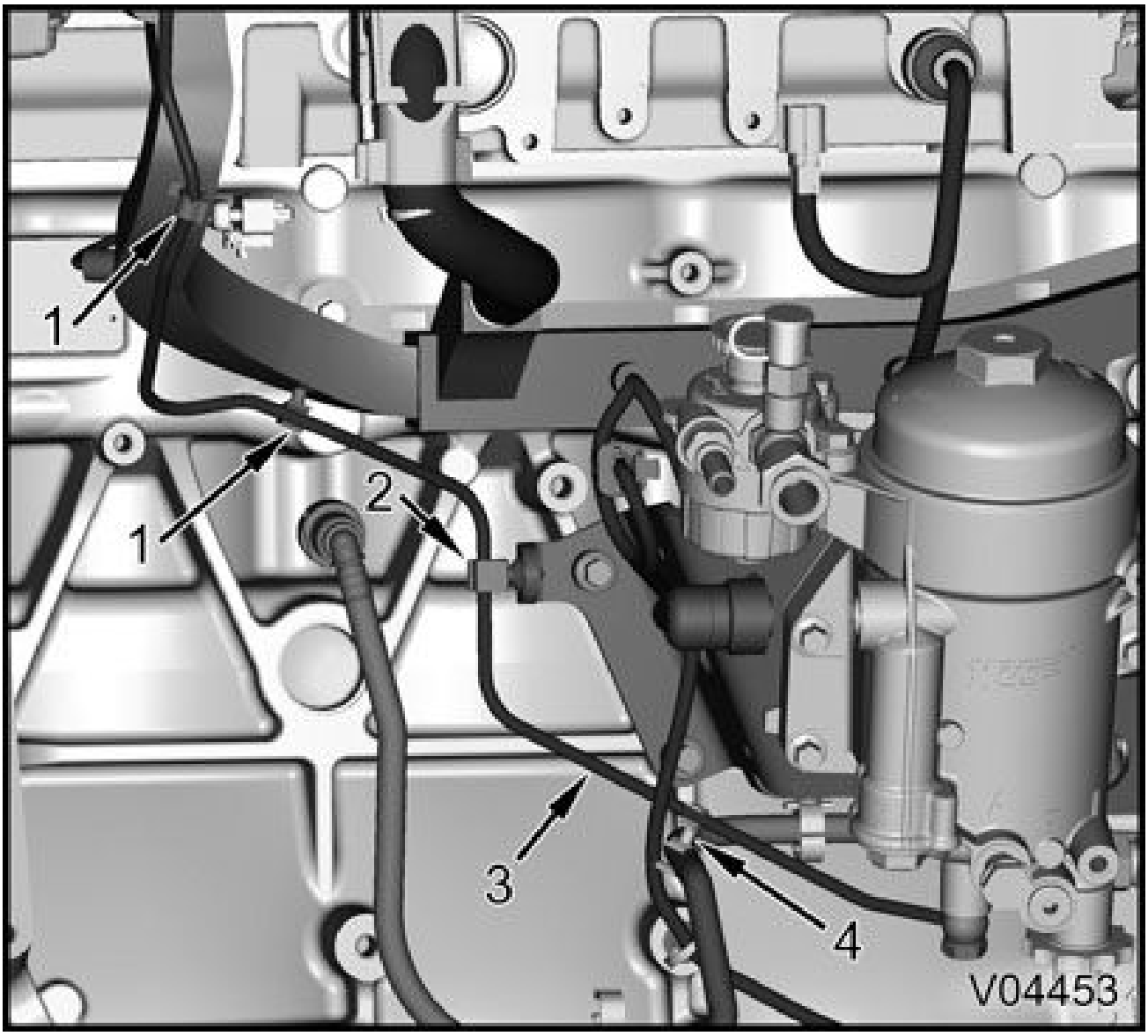

Figure 132 Fuel Supply Solenoid Hose Clips

1. Clips on electrical harness (2)
2. Clip on fuel filter bracket
3. Fuel supply solenoid hose (tube)
4. Clip on fuel drain hose

7. Remove fuel supply solenoid hose from clips on electrical harness (Figure 132) (Item 1), fuel filter bracket (Figure 132) (Item 2), and fuel drain hose (Figure 132) (Item 4) and remove hose from engine.

Installation

Fuel Solenoid Valve and Fuel Supply Solenoid Hose

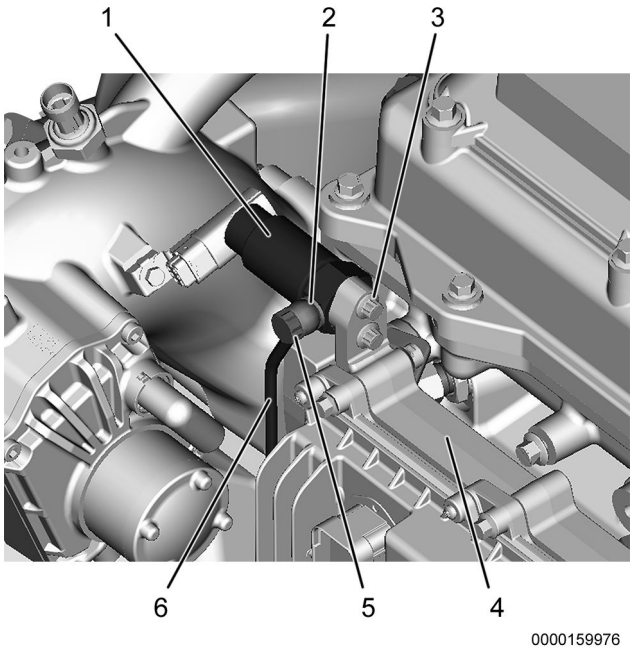

Figure 133 Fuel Supply Solenoid Hose (at Solenoid Valve)

1. Solenoid valve
2. Seal 10.7 x 16 ring (2)
3. M6 x 20 bolt (2)
4. ECM support bracket
5. Banjo 6 bolt (M10 x 1)
6. Fuel supply solenoid hose (tube)

1. Install solenoid valve (Figure 133) (Item 1) to ECM support bracket (Figure 133) (Item 4) using two M6 x 20 bolts (Figure 133) (Item 3). Finger-tighten bolts.
2. Tighten two M6 x 20 bolts to 53 lb·in (6 N·m).

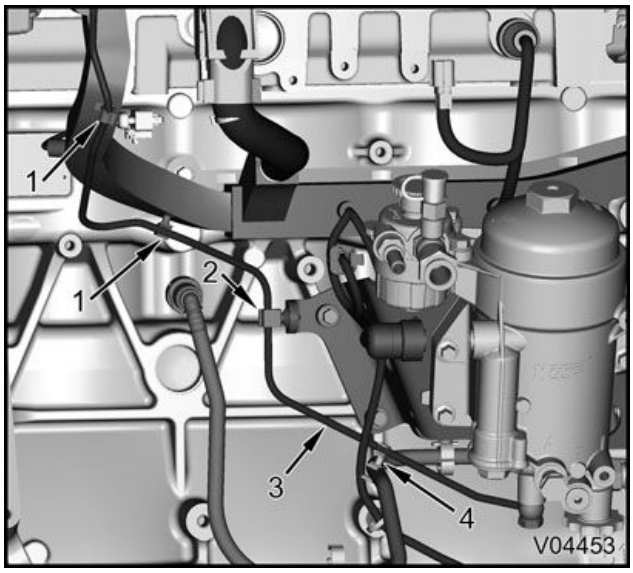

Figure 134 Fuel supply solenoid hose

1. Clips on electrical harness (2)
2. Clip on fuel filter bracket
3. Fuel supply solenoid hose (tube)
4. Clip on fuel drain hose

3. Position fuel supply solenoid hose (Figure 134) (Item 3) on engine.
4. Install two new seal 10.7 x 16 rings (Figure 133) (Item 2), and install banjo 6 bolt (M10 x 1) (Figure 133) (Item 5) into solenoid valve finger tight.

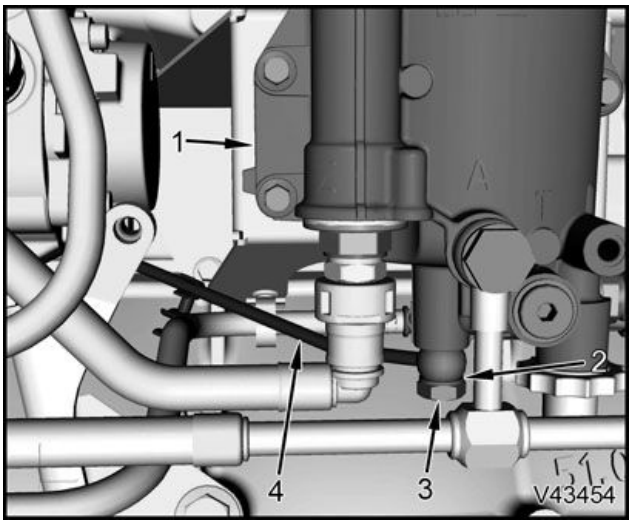

Figure 135 Fuel Supply Solenoid Hose (at Fuel Filter Housing)

1. Fuel filter housing
2. Seal 12.7 x 18 ring (2)
3. Banjo 8 bolt (M12 x 1.5)
4. Fuel supply solenoid hose (tube)

5. Install two new seal 12.7 x 18 rings (Figure 135) (Item 2) and banjo 8 bolt (Figure 135) (Item 3) into fuel filter housing finger tight.
6. Install fuel supply solenoid hose (Figure 134) (Item 3) to clips on electrical harness (Figure 134) (Item 1), fuel filter bracket (Figure 134) (Item 2), and fuel drain hose (Figure 134) (Item 4).
7. Tighten banjo 6 (M10 x 1) and 8 (M12 x 1.5) bolts to 11 lb·ft (15 N·m).

Inlet Air Heater Fuel Igniter (IAHFI) and Fuel Supply Inlet Air Heater Hose

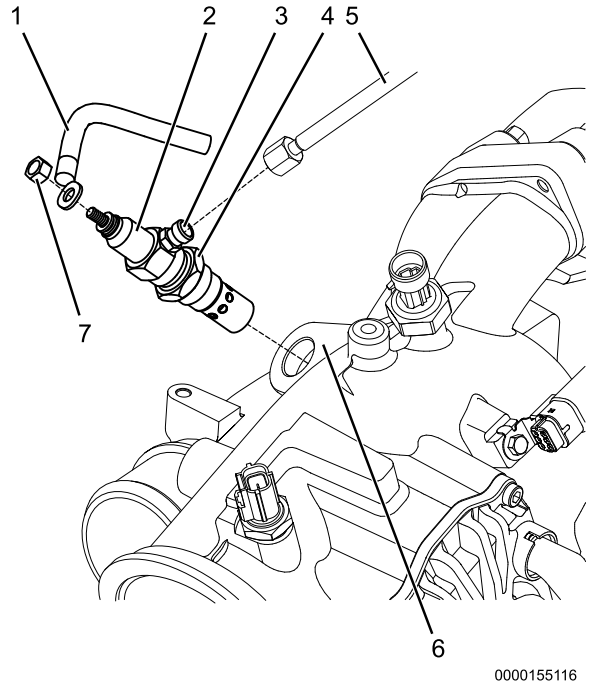

Figure 136 Inlet Air Heater Fuel Igniter (IAHFI)

1. Wiring harness
2. Inlet Air Heater Fuel Igniter (IAHFI)
3. Fuel line port
4. IAHFI locking nut
5. Fuel supply inlet air heater hose
6. Air intake throttle duct
7. IAHFI wiring harness nut

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

1. Rotate IAHFI locking nut (Figure 136) (Item 4) until nut tops out on the IAHFI body (Figure 136) (Item 2) at the top of the threads.
2. Thread IAHFI all the way into the air intake throttle duct (Figure 136) (Item 6) until nut contacts the duct housing.
3. Rotate IAHFI counterclockwise to properly orient fuel line port (Figure 136) (Item 3) with fuel supply inlet air heater hose (Figure 136) (Item 5).
4. Finger-tighten IAHFI locking nut.

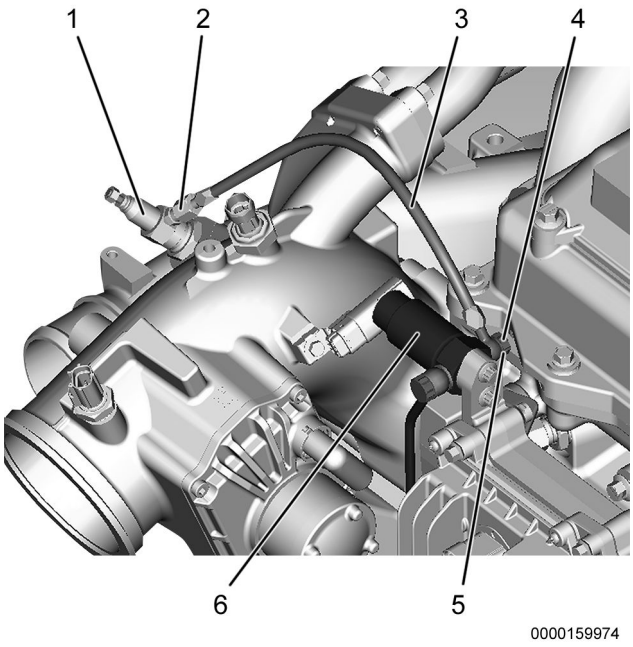

Figure 137 Inlet Air Heater Fuel Igniter (IAHFI) and Fuel Supply Inlet Air Heater Hose

1. Inlet Air Heater Fuel Igniter (IAHFI)
2. Fuel supply inlet air heater hose fitting nut
3. Fuel supply inlet air heater hose
4. M8 x 1 banjo bolt
5. Washer (seal ring) (2)
6. Solenoid valve

5. Install fuel supply inlet air heater hose (Figure 137) (Item 3), two new washers (seal rings) (Figure 137) (Item 5) and M8 x 1 banjo bolt (Figure 137) (Item 4) finger tight.
6. Install fuel supply inlet air heater hose onto IAHFI fitting finger tight.

CAUTION: To prevent engine damage, orient the fuel supply inlet air heater hose so the hose is not under any excess tension. The hose should bend in a smooth arc, is not twisted, and does not touch other engine components.

7. Tighten hose fitting nut (Figure 137) (Item 2) to 132 lb·in (10 N·m).

8. Tighten banjo bolt to 71 lb·in (8 N·m).
9. Tighten IAHFI locking nut (Figure 136) (Item 3) to 17 lb·ft (23 N·m).
10. Install wiring harness (Figure 136) (Item 1) and IAHFI wiring harness nut (Figure 136) (Item 7).
11. Tighten IAHFI wiring harness nut to 35 lb·in (4 N·m).

Relay Assembly

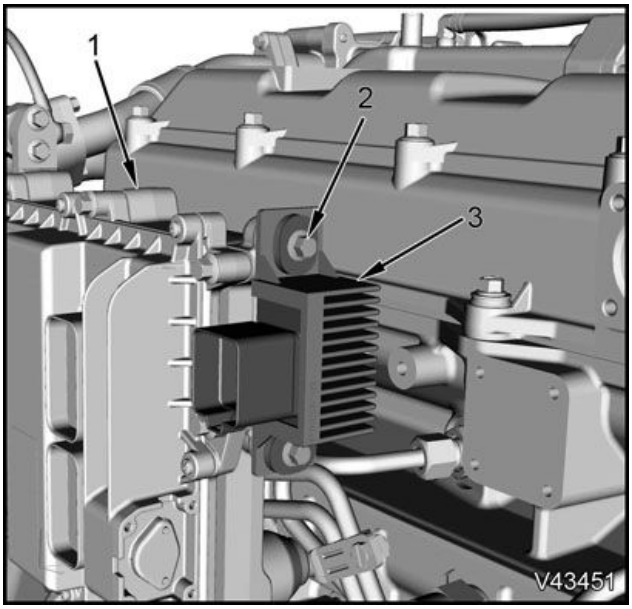

Figure 138 Relay Assembly

1. ECM support
2. Relay assembly M6 x 20 bolt (2)
3. Relay assembly

1. Position relay assembly (Figure 138) (Item 3) on mounting pad at rear of ECM support (Figure 138) (Item 1).
2. Install two relay assembly M6 x 20 bolts (Figure 138) (Item 2).
3. Tighten bolts to 89 lb·in (10 N·m).

Special Torque

Banjo 6 (M10 x 1) and 8 (M12 x 1.5) bolts	15 N·m (132 lb·in)
Banjo M8 x 1 bolt	8 N·m (71 lb·in)
Fuel supply inlet air heater hose fitting nut	10 N·m (89 lb·in)
IAHFI locking nut	23 N·m (17 lb·ft)
IAHFI wiring harness nut	4 N·m (35 lb·in)
Relay assembly M6 x 20 bolts	10 N·m (89 lb·in)
Solenoid valve M6 x 20 bolts	6 N·m (53 lb·in)

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Illustrations

Aftertreatment System Fuel Supply Components

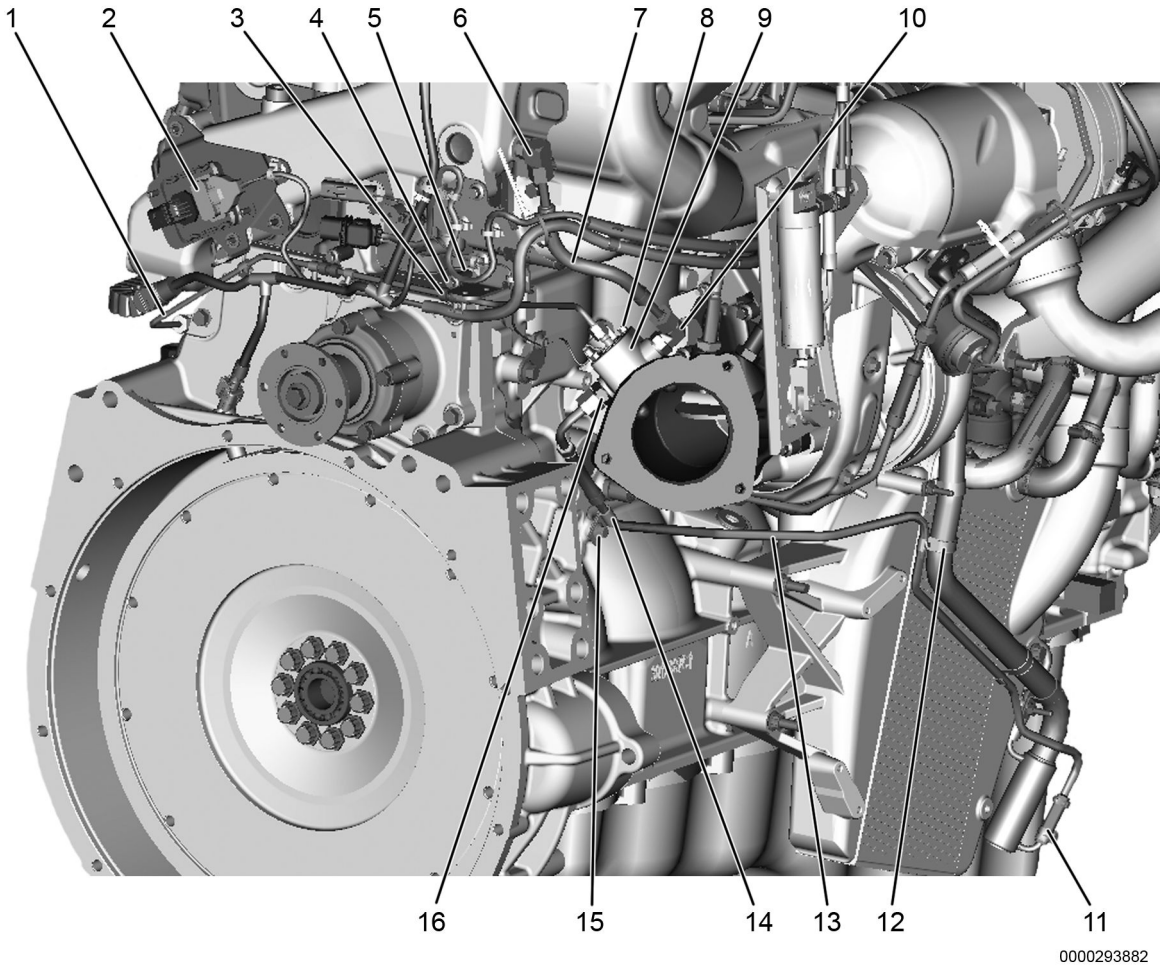

Figure 139 Aftertreatment system components

1. 1. Aftertreatment Fuel Injector (AFTI) fuel 2 tube assembly
2. NOx in sensor module assembly
3. P6 x 15 clamp (2)
4. M6 x 40 bolt (2)
5. Spacer (2)
6. 90 degree adjustable fitting
7. AFTI coolant supply tube assembly
8. Bolt (2)
9. Aftertreatment Fuel Injector (AFTI)
10. 90 degree adjustable fitting
11. Hose clamp (spring type)
12. Tube clamp (2)
13. AFTI coolant return tube
14. Pipe single cushioned clamp
15. M8 x 16 bolt
16. Straight fitting

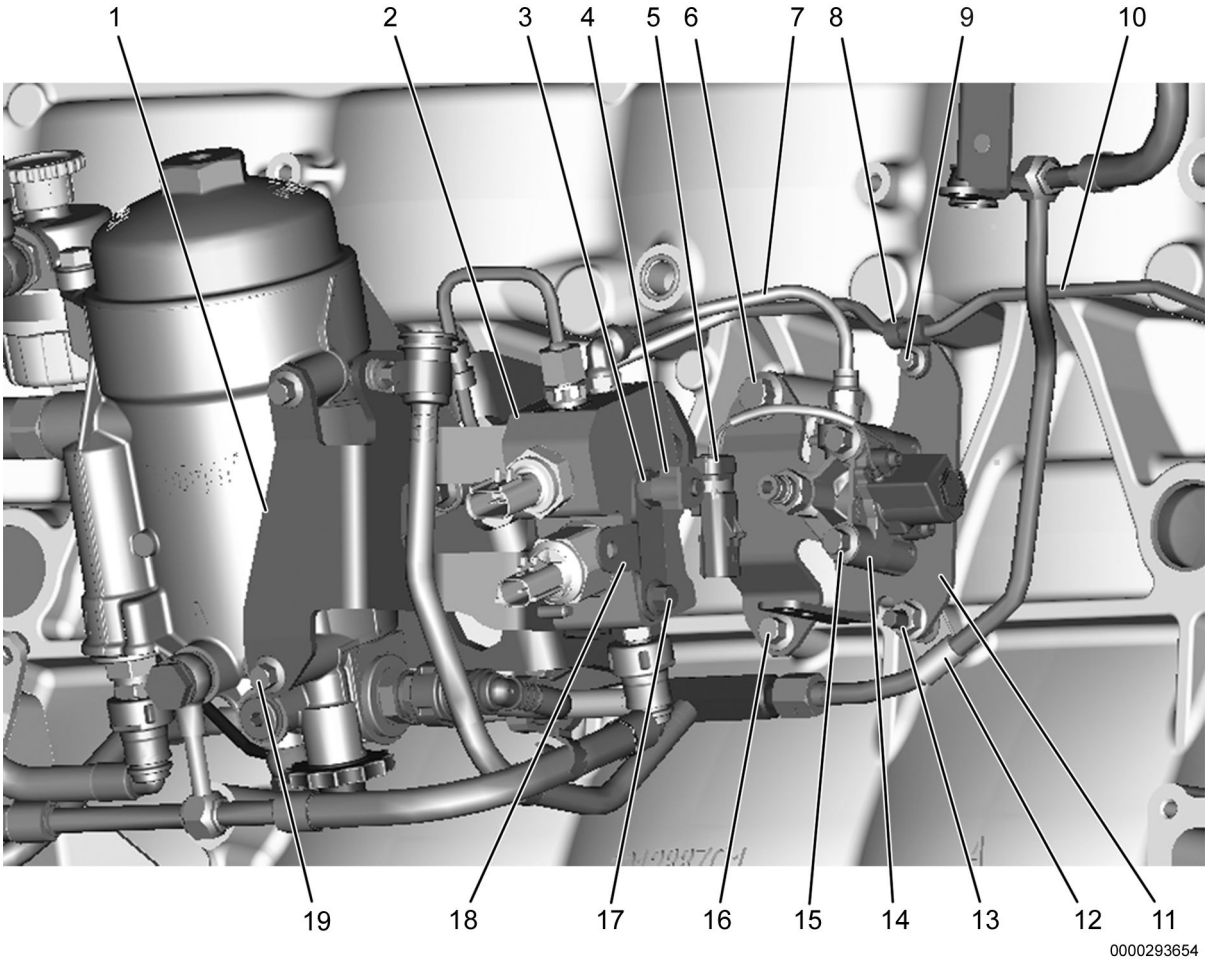

Figure 140 Aftertreatment System Fuel Supply

1. AFT fuel doser module bracket
2. Aftertreatment (AFT) fuel doser module
3. 8 x 60 stud bolt
4. Harness retainer
5. AFTPAV connector
6. M6 x 16 bolt
7. AFTPAV supply tube
8. Clamp
9. M6 x 16 bolt
10. AFTI fuel tube assembly
11. AFTPAV support bracket
12. Clamp
13. M8 nut
14. Aftertreatment Purge Air Valve (AFTPAV) assembly
15. M8 x 60 hex flange bolt (2)
16. M8 x 16 bolt
17. M8 x 65 hex flange bolt
18. Harness support
19. M6 x 16 bolt (4)

Removal

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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.

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.

Supply Fuel After Filter Hose and Tubes

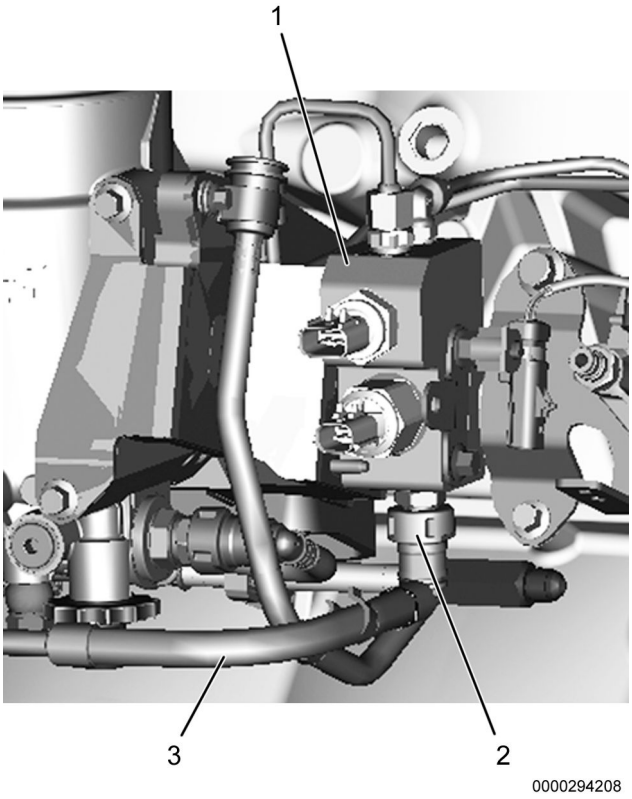

Figure 141 Supply Fuel After Filter Hose Connection

1. Aftertreatment (AFT) fuel doser module
2. Fitting (quick-connect adapter)
3. Supply fuel after-filter hose

WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked DIESEL FUEL.

CAUTION: To prevent engine damage, all fuel exposed O-rings and O-ring seals must be replaced with biodiesel compatible O-rings and O-ring seals. The specific Navistar P/N must be used for service.

1. Place suitable container clearly marked DIESEL FUEL under AFT doser module.

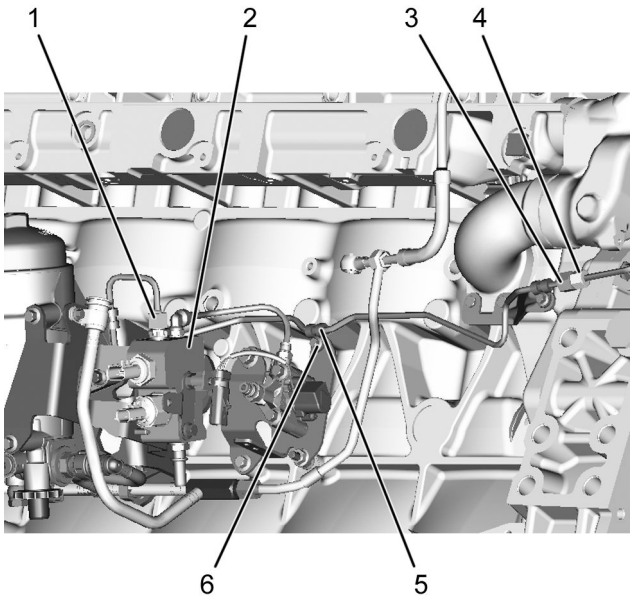

Figure 142 AFTFI Fuel 1 and 2 Tube Assemblies

1. AFTFI fuel 1 tube assembly nut
2. Aftertreatment (AFT) fuel doser module
3. AFTFI fuel 1 tube assembly nut
4. AFTFI fuel 2 tube assembly fitting (brazed to tube)
5. P-clamp (2)
6. M6 x 16 bolt (2)

2. Loosen AFTFI fuel 1 tube assembly nut (Figure 142) (Item 1) and disconnect tube from fitting assembly at AFT fuel doser module (Figure 142) (Item 2).
3. Remove two M6 x 16 bolts (Figure 142) (Item 6) and two P-clamps (Figure 142) (Item 5) from AFT fuel 1 tube assembly.

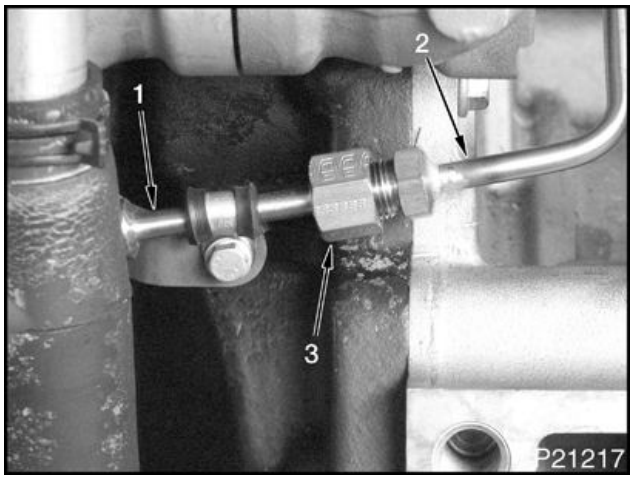

Figure 143 AFTFI Fuel 1 Tube Assembly Connection

1. AFTFI fuel 1 tube assembly
2. AFTFI fuel 2 tube assembly
3. AFTFI fuel 1 tube assembly nut
4. M6 x 16 bolt

4. Loosen AFTFI fuel 1 tube assembly nut and disconnect fuel tube from AFTFI fuel 2 tube assembly.
5. Remove M6 x 16 bolt, P-clamp and AFTFI fuel 1 tube assembly.

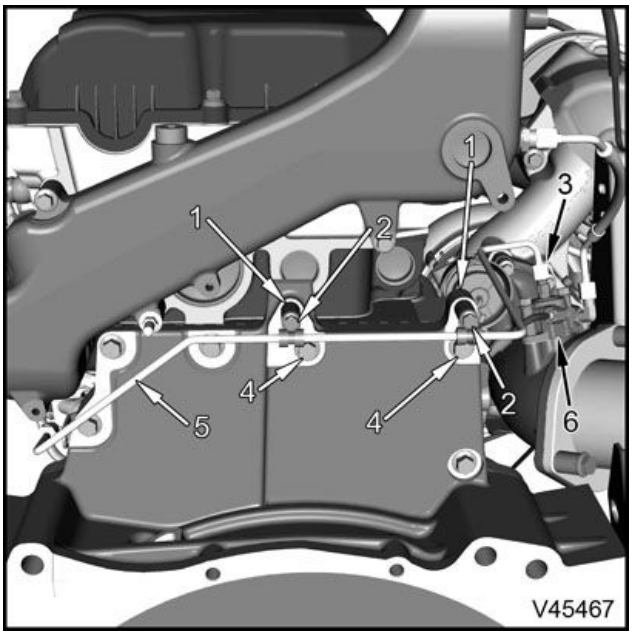

Figure 144 AFTFI Fuel 2 Tube Assembly

1. 6.6 x 15 x 23 spacer (2)
2. M6 x 40 bolt (2)
3. AFTFI fuel 2 tube assembly nut
4. P 6 x 15 clamp (2)
5. AFTFI fuel 2 tube assembly
6. Aftertreatment Fuel Injector (AFTFI) Assembly

6. Loosen AFTFI fuel 2 tube assembly nut and disconnect tube from hydrocarbon injector assembly.
7. Remove two M6 x 40 bolts, two 6.6 x 15 x 23 spacers and remove AFTFI assembly.

Aftertreatment Purge Air Valve (AFTPAV) Assembly

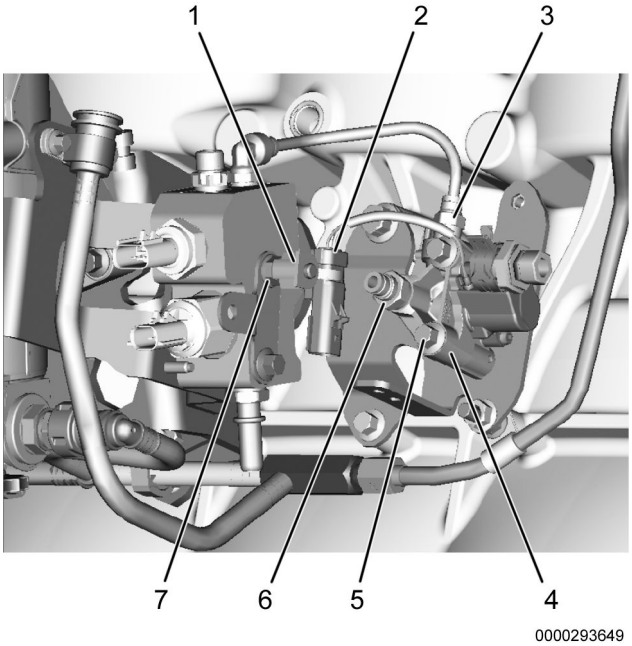

Figure 145 Aftertreatment Purge Air Valve (AFTPAV) Assembly

1. Harness retainer
2. AFTPAV connector
3. Quick connect fitting
4. Aftertreatment Purge Air Valve (AFTPAV) assembly
5. M8 x 60 hex flange bolt (2)
6. AFTPAV Air supply line quick-connect fitting
7. M8 x 60 Stud bolt

CAUTION: Ensure that air system has been drained before removing air supply line from AFTPAV quick-connect fitting.

1. Remove AFTPAV connector (Figure 145) (Item 2) together with harness retainer (Figure 145) (Item 1) from M8 x 60 Stud bolt (Figure 145) (Item 7).
2. Remove formed air tube (0.25”) from quick connect fitting (Figure 145) (Item 3).
3. Remove two M8 x 60 hex flange bolts (Figure 145) (Item 5) and AFTPAV assembly (Figure 145) (Item 4).

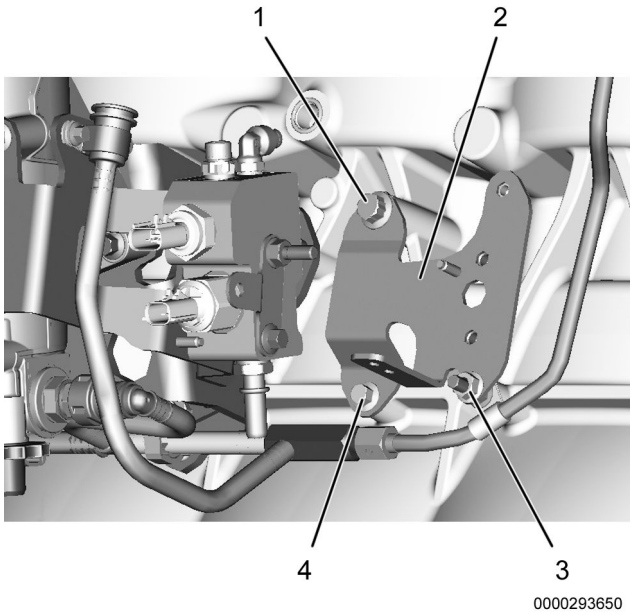

Figure 146 AFTPAV support bracket

1. M10 x 16 bolt
2. AFTPAV support bracket
3. M8 nut
4. M8 x 16 bolt

4. If necessary, remove M10 x 16 bolt (Figure 146) (Item 1), M8 x 16 bolt (Figure 146) (Item 4), and M8 nut (Figure 146) (Item 3).
5. Remove AFTPAV support bracket (Figure 146) (Item 2) from engine.

Aftertreatment (AFT) Fuel Doser Module

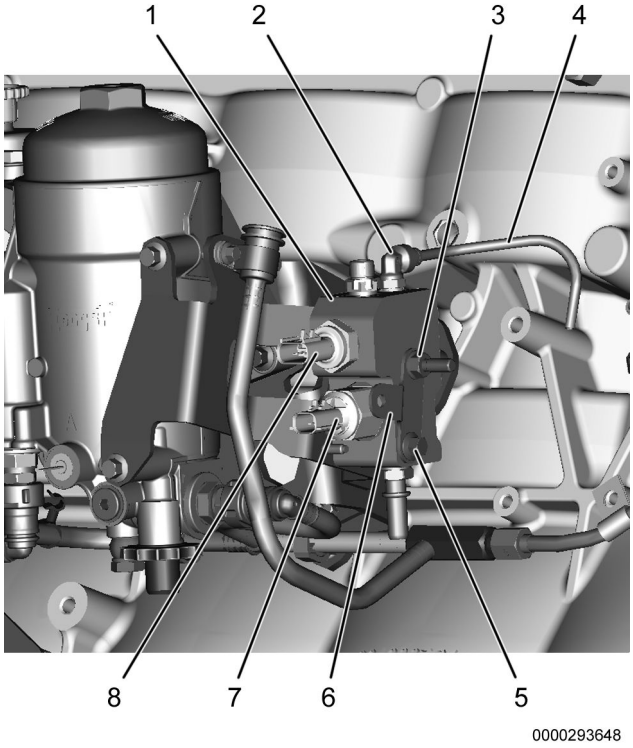

Figure 147 AFT Fuel Doser Module

1. AFT fuel doser module
2. Aftertreatment Purge Air Valve (AFTPAV) supply tube connector
3. M8 x 60 stud bolt
4. Aftertreatment Purge Air Valve (AFTPAV) supply tube
5. M8 x 65 hex flange bolt
6. Harness support bracket
7. Aftertreatment Fuel Doser Module (AFTFSV) fuel shutoff valve connector
8. Aftertreatment Fuel Pressure Sensor 1 (AFTFP1) connector

CAUTION: To prevent component damage, keep AFT fuel doser module and related components clean and protected from damage until ready to install. Do not let dirt or other debris, lubricants, or water get into fuel passages. Do not blow compressed air into fuel passages. If protection caps are used, they should be new, or ultrasonically cleaned before using.

CAUTION: To prevent component damage, do not drop AFT fuel doser module onto a hard surface. If this happens, replace the valve.

1. If not already done, remove the harness connectors from AFTFP1 (Figure 147) (Item 8) and AFTFSV (Figure 147) (Item 7).
2. Push 90 degree connector locking tab to release AFTPAV supply tube (Figure 147) (Item 4) from AFT fuel doser module (Figure 147) (Item 1) and cap off the end of tube.
3. Remove M8 x 60 stud bolt (Figure 147) (Item 3), M8 x 65 hex flange bolt (Figure 147) (Item 5), harness support bracket (Figure 147) (Item 6), and AFT fuel doser module.

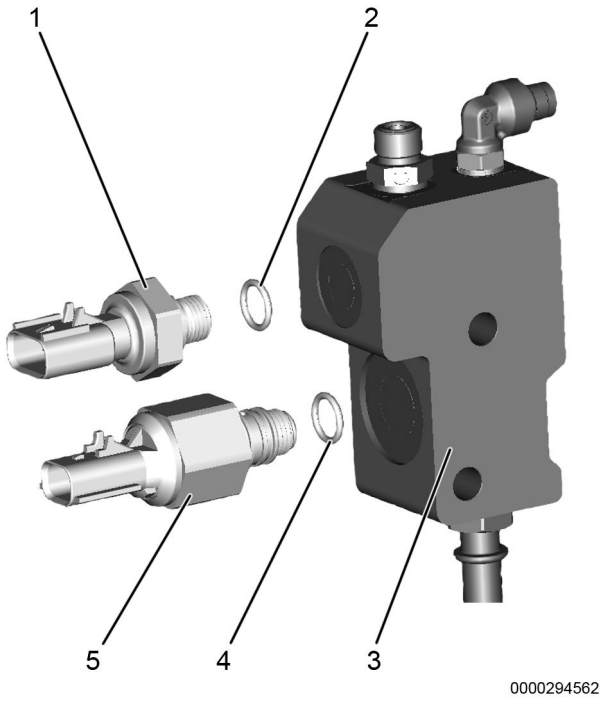

Figure 148 AFT Fuel Doser Module, AFTFP1, and AFTFSV1

1. Aftertreatment Fuel Pressure 1 (AFTFP1) sensor
2. O-ring
3. AFT doser module
4. O-ring
5. Aftertreatment Fuel Shutoff Valve (AFTFSV)

NOTE: Do steps 4 and 5 only if AFTFP1 or AFTFSV are leaking or if AFT sensor is being replaced.

CAUTION: To prevent engine damage, all fuel exposed O-rings and O-ring seals must be replaced with biodiesel compatible O-rings and O-ring seals. The specific Navistar P/N must be used for service.

4. Loosen and remove AFTFP1 (Figure 148) (Item 1) from AFT doser module (Figure 148) (Item 3) and discard O-ring (Figure 148) (Item2).
5. Loosen and remove AFTFSV (Figure 148) (Item 5) and discard O-ring (Figure 148) (Item 4).

AFTFI Coolant Supply Tube Assembly

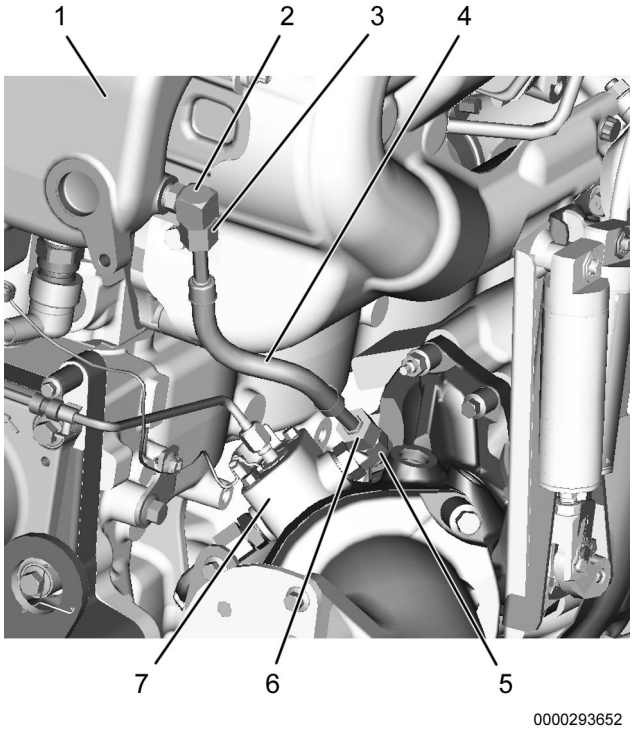

Figure 149 AFTFI Coolant Supply Tube Assembly

1. Coolant Manifold
2. 90 degree adjustable fitting
3. AFTFI coolant supply tube nut
4. AFTFI coolant supply tube assembly
5. 90 degree adjustable fitting
6. AFTFI coolant supply tube nut
7. Aftertreatment Fuel Injector (AFTFI) assembly

1. Loosen the AFTFI coolant supply tube nut (Figure 149) (Item 6) and disconnect AFTFI coolant supply tube assembly (Figure 149) (Item 4) from tube 90 degree adjustable fitting (Figure 149) (Item 5).
2. Loosen AFTFI coolant supply tube nut (Figure 149) (Item 3) and disconnect AFTFI coolant

supply tube assembly from 90 degree adjustable fitting (Figure 149) (Item 2) at coolant manifold (Figure 149) (Item 1).

3. Remove AFTFI coolant supply tube assembly.

NOTE: Perform following steps only if 90 degree adjustable fittings are leaking.

4. Remove 90 degree adjustable fitting (Figure 149) (Item 6) from AFTFI assembly (Figure 149) (Item 7).
5. Remove 90 degree adjustable fitting(Figure 149) (Item 2) from coolant manifold (Figure 149) (Item 1).

AFTFI Coolant Return Tube Assembly

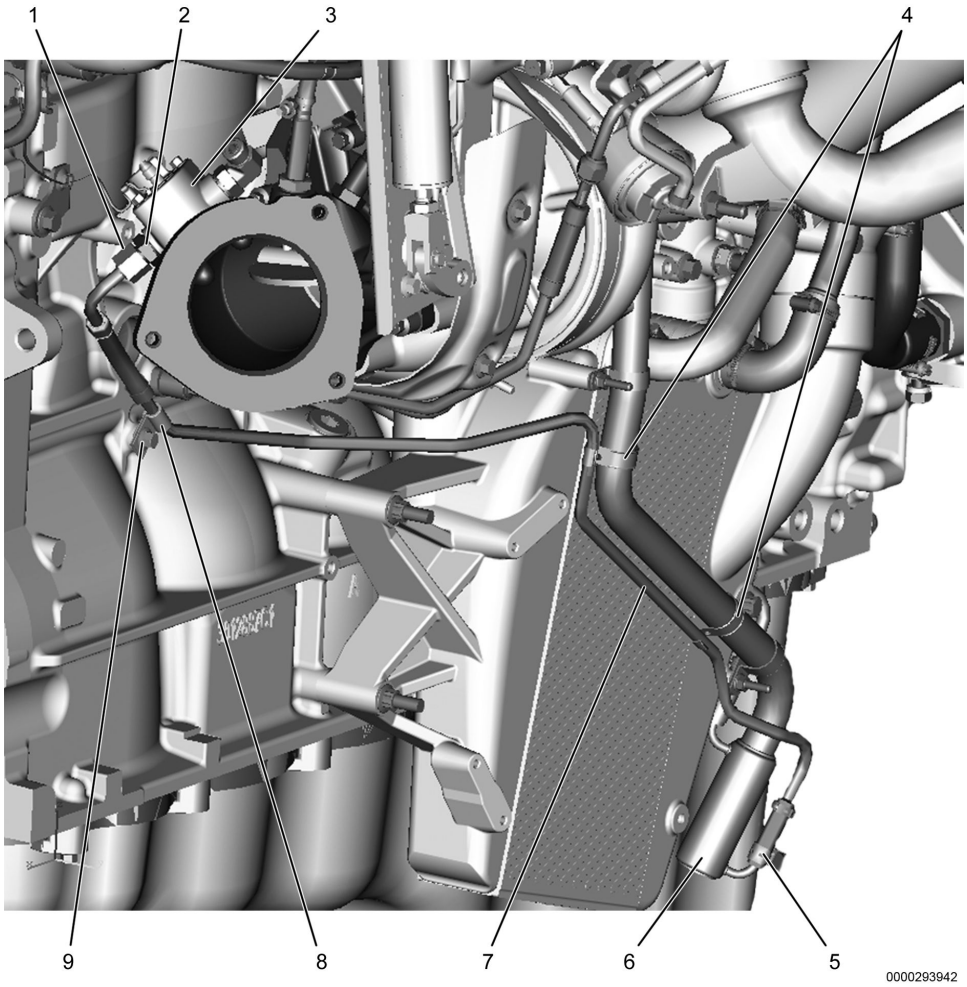

Figure 150 AFTFI Coolant Return Tube Assembly

1. Straight fitting
2. Aftertreatment Fuel Injector (AFTFI) assembly
3. AFTFI coolant return tube assembly
4. Tube clamp (2)
5. Open breather tube
6. Hose clamp (spring type)
7. M8 x 16 bolt
8. Pipe single cushion clamp
9. AFTFI coolant return tube nut

1. Loosen AFTFI coolant return tube nut (Figure 150) (Item 9) and disconnect AFTFI coolant return tube assembly (Figure 150) (Item 3) from straight fitting (Figure 150) (Item 1).
2. Remove M8 x 16 bolt (Figure 150) (Item 7) from pipe single cushion clamp (Figure 150) (Item 8). Separate clamp from AFTFI coolant return tube assembly as necessary.
3. Release AFTFI coolant return tube assembly (Figure 150) (Item 3) from two tube clamps (Figure 150) (Item 4) at open breather tube (Figure 150) (Item 5).
4. Loosen hose clamp (spring type) (Figure 150) (Item 6). Separate AFTFI coolant return tube assembly from open breather tube. Remove from engine.

NOTE: Do step 5 only if straight fitting is leaking.

5. Remove straight fitting (Figure 150) (Item 1) from AFTFI assembly (Figure 150) (Item 2).

Aftertreatment Fuel Injector (AFTFI) Assembly

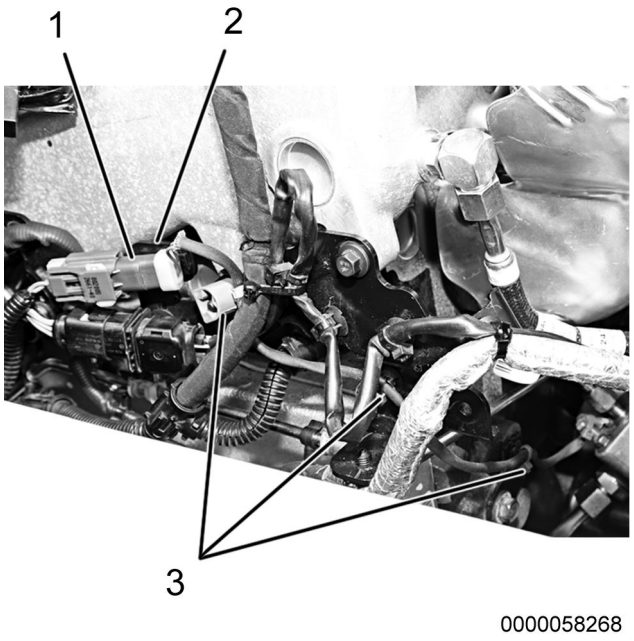

Figure 151 AFTFI Harness and Connections

1. Aftertreatment Fuel Injector (AFTFI) connector
2. AFTFI connector mounting bracket
3. AFTFI harness fasteners (3)

NOTE: This Engine Service Manual is written for complete engine teardown. If removing AFTFI only, do not drain cooling system and do not remove engine cover (dog house). Access AFTFI from under vehicle.

1. Press release tab to disconnect wiring harness lead from AFTFI connector (Figure 151) (Item 1).
2. Disconnect AFTFI connector from AFTFI connector mounting bracket (Figure 151) (Item 2).
3. Disconnect three AFTFI harness fasteners (Figure 151) (Item 3).

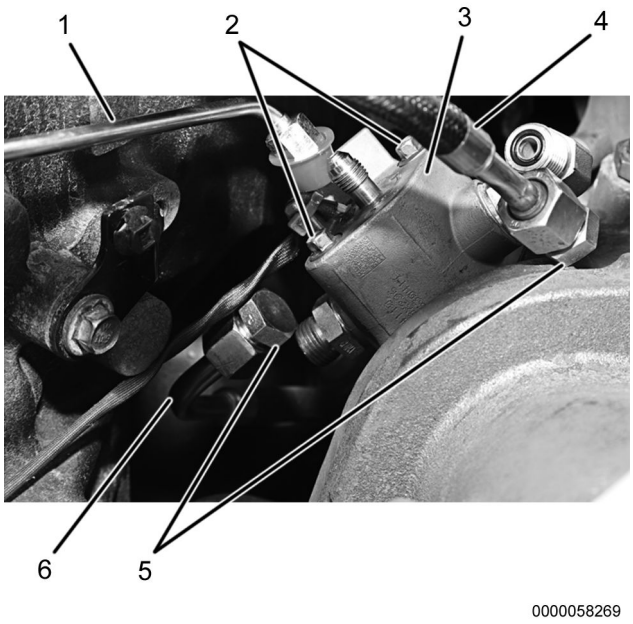

Figure 152 AFTFI Connections (Disconnected)

1. Fuel supply line
2. AFTFI M6 mounting bolts (2)
3. Aftertreatment Fuel Injector (AFTFI)
4. Coolant supply line
5. AFTFI Coolant Line Plugs (2)
6. Coolant return line

4. Disconnect fuel supply line (Figure 152) (Item 1), and use Air and Fuel Cap and Plug Kit ZTSE4891 to cap line. Discard O-rings.
5. Disconnect coolant supply line(Figure 152) (Item 4) and coolant return line (Figure 152) (Item 6). Discard O-rings.
6. Install two AFTFI Coolant Line Plugs (Figure 152) (Item 5) onto coolant supply and return line.
7. Open the BLUE vent valve on the Vacuum Module.

CAUTION: To prevent component damage, keep AFTFI and related components clean and protected from damage until ready to install. Protect the injector nozzle tip, sealing surfaces, and threaded surfaces. Do not let dirt, debris, lubricants, or water get into fuel or coolant passages. Do not blow compressed air into injector fuel passage. If protection caps are used, they should be new, or ultrasonically cleaned before using.

CAUTION: To prevent component damage, do not drop AFTFI (especially nozzle tip) onto a hard surface. If this happens, replace the injector.

8. Remove two AFTFI M6 mounting bolts (Item 2).
9. Remove AFTFI as an assembly from turbocharger exhaust outlet pipe. Discard metal gasket and fibrous insulator.

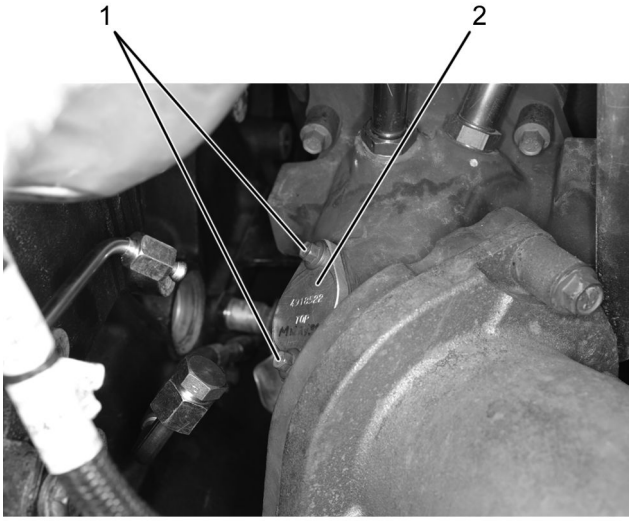

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Figure 153 AFTFI Block Off Plate and Bolts

1. AFTFI block off plate bolt (2)
2. AFTFI block off plate

10. Install AFTFI Block Off Plate 12-559-01-05 (Figure 153) (Item 2) onto turbocharger exhaust outlet pipe using two AFTFI Block Off Plate Bolts 12-55-01-04 (Figure 153) (Item 1).

Cleaning and Inspection

Aftertreatment Fuel Injector (AFTFI) Cleaning

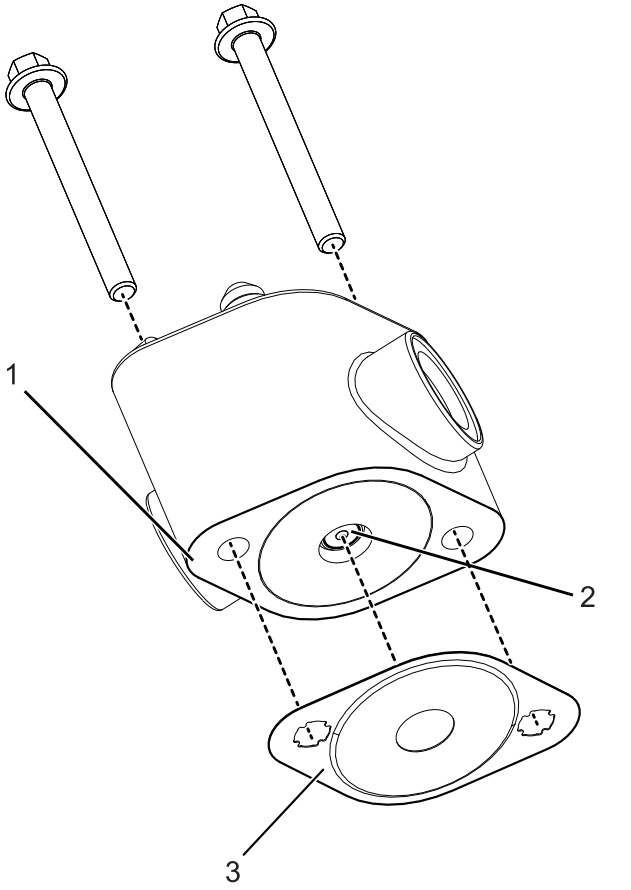

Figure 154 Aftertreatment Fuel Injector (AFTFI) Assembly

1. AFTFI assembly
2. Injector nozzle tip
3. AFTFI Gasket
4. Raised sealing lip

CAUTION: To prevent component damage, cleaning of the AFTFI assembly using cleaner or solvents is NOT recommended. Do not blast the injector with compressed air. Do not pull or otherwise manipulate the injector nozzle tip.

1. Inspect AFTFI assembly (Figure 154) (Item 1) and injector nozzle tip (Figure 154) (Item 2) for cracks and other damage. If damage is present, replace AFTFI assembly.
2. Use Fuel Injector Tip Cleaning Brush ZTSE4301 to clean any carbon buildup that may be present on the injector nozzle tip.

Exhaust Back Pressure Valve Housing Cleaning

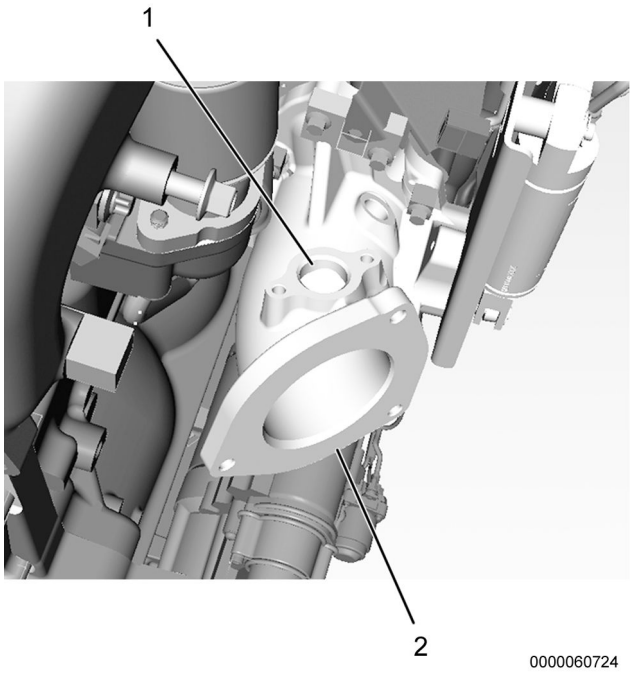

Figure 155 Exhaust Back Pressure Valve Housing

1. AFTFIport
2. Exhaust back pressure valve housing

CAUTION: To prevent damage to the aftertreatment system or plugging of the PDOC / DOC / DPF, ensure no carbon debris remains in AFTFI port upon completion of steps 1 and 2.

1. Carefully remove carbon from the AFTFI port (Figure 155) (Item 1) on the exhaust back pressure valve housing (Figure 155) (Item 2) with a chisel or other appropriate tool. Remove debris with a shop vac.

Installation

Aftertreatment Fuel Injector (AFTFI) Assembly

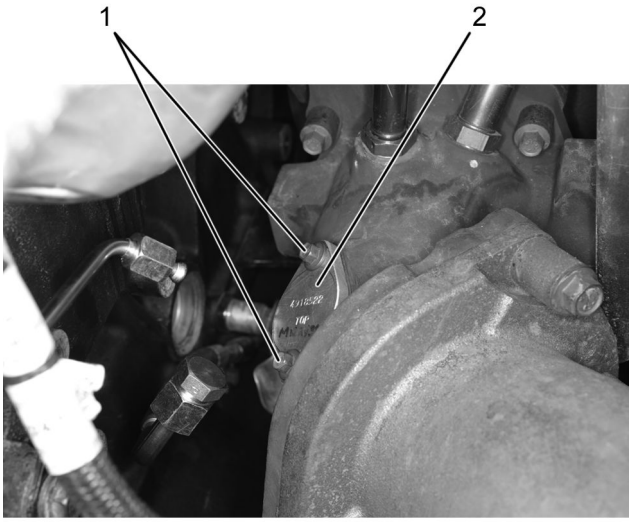

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Figure 156 AFTFI Block Off Plate and Bolts

1. AFTFI Block Off Plate Bolt (2)
2. AFTFI Block Off Plate

NOTE: When installing the AFTFI gasket , the raised seal lip must face down toward the exhaust back pressure valve housing.

1. Remove two AFTFI Block Off Plate Bolts (page 133) 12-55-01-04 (Item 1) and AFTFI Block Off Plate ((page 133) Item 2) from turbocharger exhaust outlet pipe.

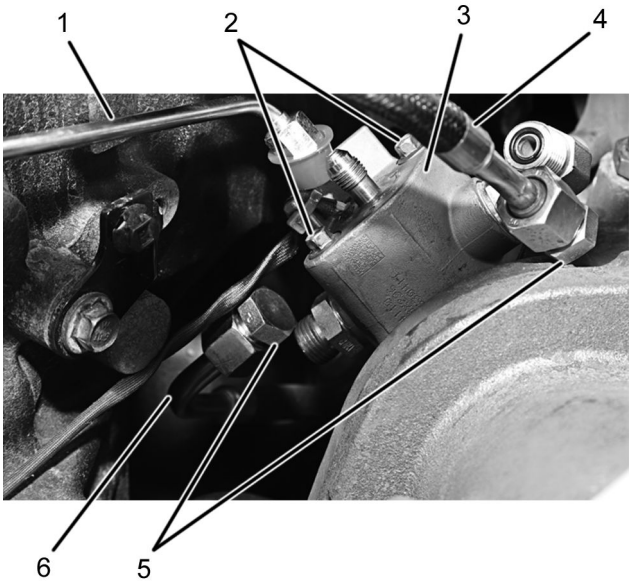

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Figure 157 AFTFI Connections (Disconnected)

1. Fuel supply line
2. AFTFI M6 mounting bolts (2)
3. Aftertreatment Fuel Injector (AFTFI)
4. Coolant supply line
5. AFTFI Coolant Line Plugs (2)
6. Coolant return line

2. Install AFTFI (Figure 157) (Item 3), metal gasket, and fibrous insulator as an assembly onto turbocharger exhaust outlet pipe.
3. Install two AFTFI M6 mounting bolts (Figure 157) (Item 2).
4. Close BLUE vent valve on Vacuum Module.
5. Remove two AFTFI Coolant Line Plugs (Figure 157) (Item 5) onto coolant supply and return line.
6. Install new O-ring on coolant supply line (Figure 157) (Item 4) and install coolant supply line onto AFTI.
7. Install new O-ring on coolant return line (Figure 157) (Item 6) and install coolant return line onto AFTI.
8. Remove air and fuel cap from fuel supply line (Figure 157) (Item 1).
9. Install new O-ring onto fuel supply line and connect onto AFTFI.

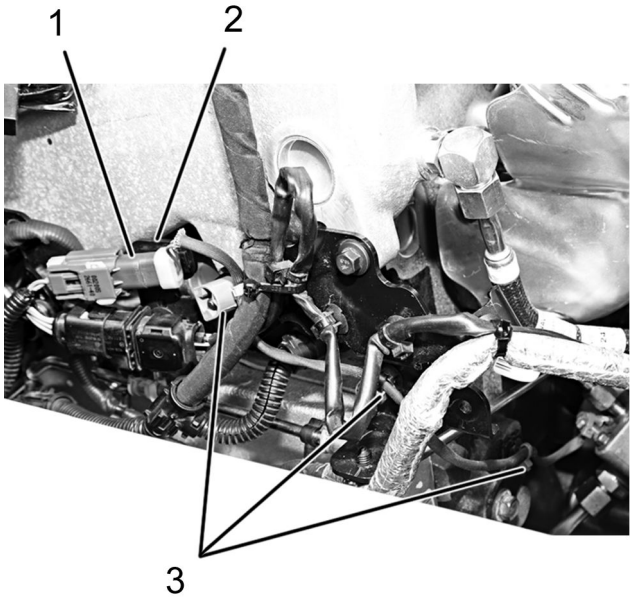

Figure 158 AFTFI Harness and Connections

1. Aftertreatment Fuel Injector (AFTFI) connector
2. AFTFI connector mounting bracket
3. AFTFI harness fasteners (3)

10. Connect three AFTFI harness fasteners (Figure 158) (Item 3).
11. Connect AFTFI connector (Figure 158) (Item 1) to AFTFI connector mounting bracket (Figure 158)(Item 2).
12. Connect wiring harness lead from AFTFI connector (Figure 158) (Figure 50) (Item 1).

AFTFI Coolant Return Tube Assembly

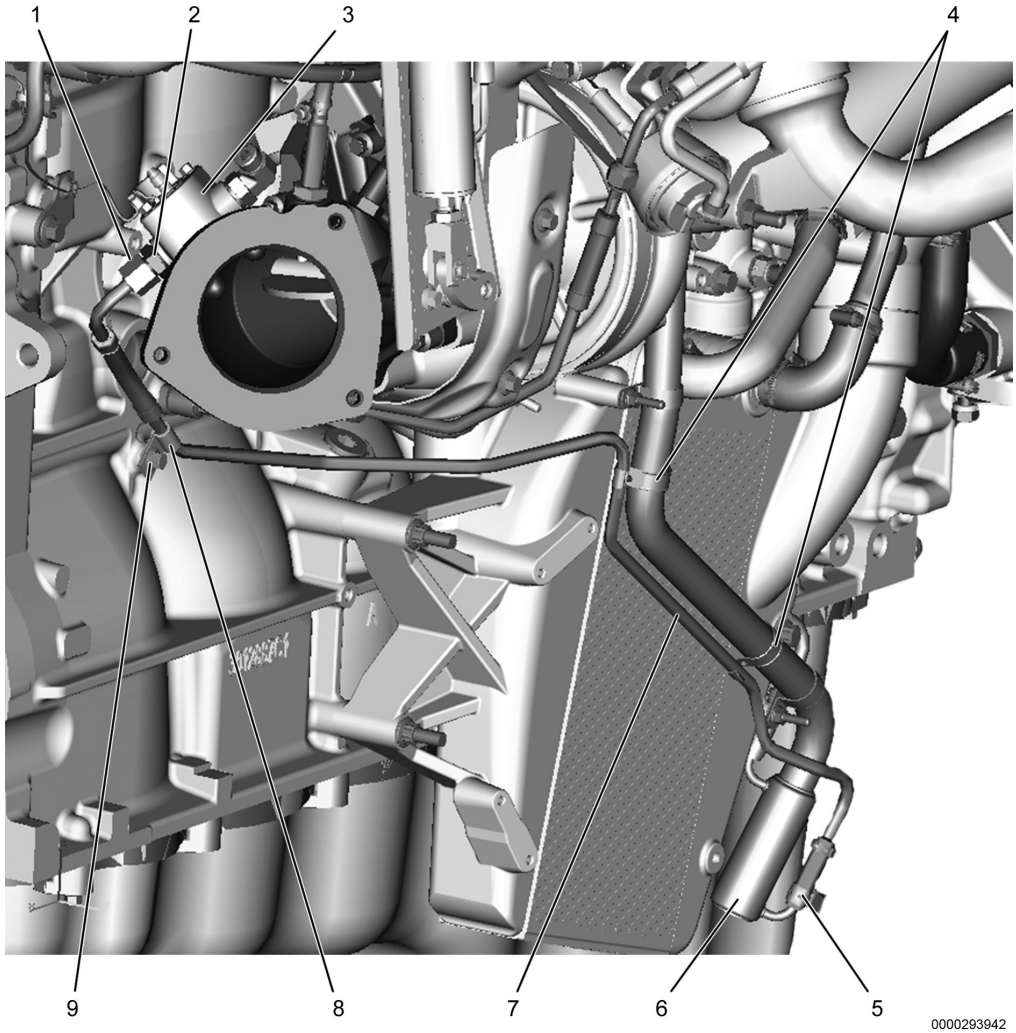

Figure 159 AFTFI Coolant Return Tube Assembly

1. AFTFI coolant return tube nut
2. Aftertreatment Fuel Injector (AFTFI) assembly
3. Straight fitting
4. Tube clamp (2)
5. Hose clamp (spring type)
6. Open breather tube
7. AFTFI coolant return tube assembly
8. Pipe single cushion clamp
9. M8 x 16 bolt

NOTE: Do steps 1 and 2 if straight fitting was removed. Otherwise, skip to step 3.

1. Install straight fitting (Figure 159) (Item 2) onto AFTFI (Figure 159) (Item 3) and tighten fitting to maintain alignment and clearance for AFTFI coolant return tube assembly (Figure 159) (Item 7).
2. Tighten straight fitting to 11 lbf·ft (15 N·m).
3. Position AFTFI coolant return tube assembly onto open breather tube (Figure 159) (Item 6) nipple, two tube clamps (Figure 159) (Item 4) on open breather tube and pipe single cushion clamp (Item 8).

4. Install M8 x 16 bolt (Figure 159) (Item 9) through pipe single cushion clamp (Figure 159) (Item 8) and tighten to 23 lbf·ft (31 N·m).
5. Snap AFTFI coolant return tube assembly into two tube clamps (Figure 159) (Item 4) and install hose clamp (spring type) (Figure 159) (Item 5) to secure tube to open breather tube.
6. Tighten AFTFI coolant return tube nut onto straight fitting. Align fitting as needed to reduce tube stress and to not contact other components. Tighten tube nut and straight fitting each to 13 lbf·ft (17.5 N·m).

AFTFI Coolant Supply Tube Assembly

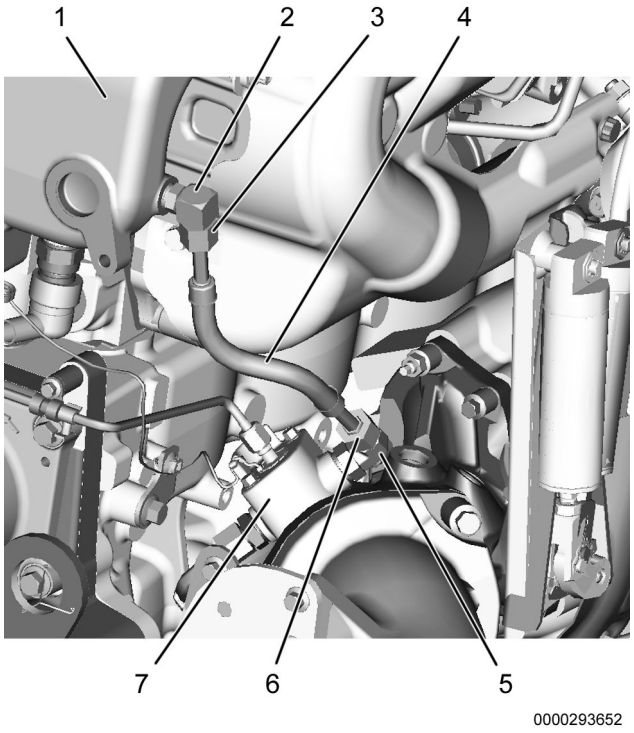

Figure 160 AFTFI Coolant Supply Tube Assembly

1. Coolant Manifold
2. 90 degree adjustable fitting
3. AFTFI coolant supply tube nut
4. AFTFI coolant supply tube assembly
5. 90 degree adjustable fitting
6. AFTFI coolant supply tube nut
7. Aftertreatment Fuel Injector (AFTFI) assembly

1. If previously removed, loosely install 90 degree adjustable fitting (Figure 160) (Item 2) into coolant manifold (Figure 160) (Item 1).
2. Loosely install AFTFI coolant supply tube nut (Figure 160) (Item 3 onto 90 degree adjustable fitting at coolant manifold.

NOTE: Do step 3 if tube M10 elbow fitting was removed. Otherwise, skip to step 5.

3. Loosely install 90 degree adjustable fitting (Figure 160) (Item 5) onto AFTFI assembly (Figure 160) (Item 7) and adjust to maintain alignment and clearance for AFTFI coolant supply tube assembly.
4. Loosely install AFTFI coolant supply tube nut (Figure 160) (Item 6) onto 90 degree adjustable fitting (Figure 160) (Item 5) (align fitting as needed) on AFTFI assembly.
5. Tighten AFTFI coolant supply tube nut s and 90 degree adjustable fittings to 13 lb·ft (17.5 N·m).

Aftertreatment (AFT) Fuel Doser Module

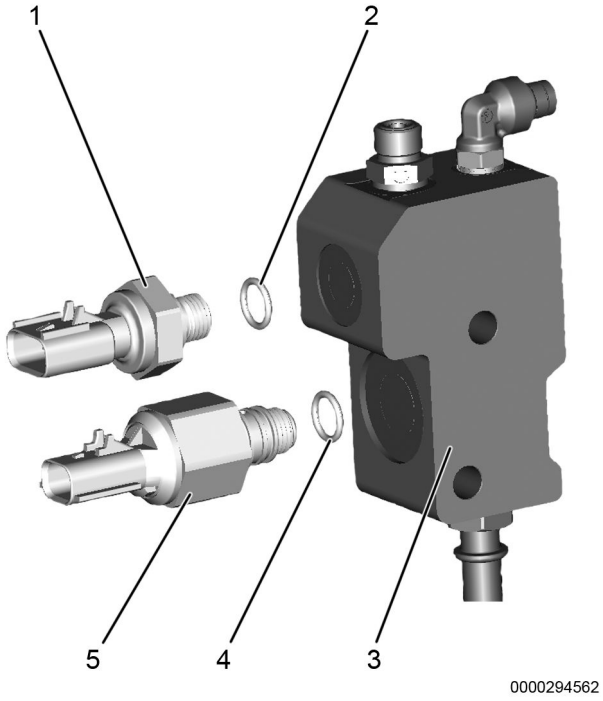

Figure 161 AFT Fuel Doser Module, AFTFP1, and AFTFSV1

1. Aftertreatment Fuel Pressure 1 (AFTFP1) sensor
2. O-ring
3. AFT fuel doser module
4. Aftertreatment Fuel Shutoff Valve (AFTFSV)
5. O-ring (# 011)
6. O-ring seal

NOTE: Do steps 1 through 4 only if AFTFP1 or AFTFSV are leaking or if AFT sensor is being replaced.

CAUTION: To prevent engine damage, all fuel exposed O-rings and O-ring seals must be replaced with biodiesel compatible O-rings and O-ring seals. The specific Navistar P/N must be used for service.

1. Lubricate new O-ring (Figure 161) (Item 2) and install onto AFTFP1 (Figure 161) (Item 1).
2. Install and tighten AFTFP1 into AFT fuel doser module (Figure 161) (Item 3).
3. Lubricate new O-ring (Figure 161) (Item 4) and install onto AFTFSV (Figure 161) (Item 5).
4. Install and tighten AFTFSV (Item 5) into AFT fuel doser module.

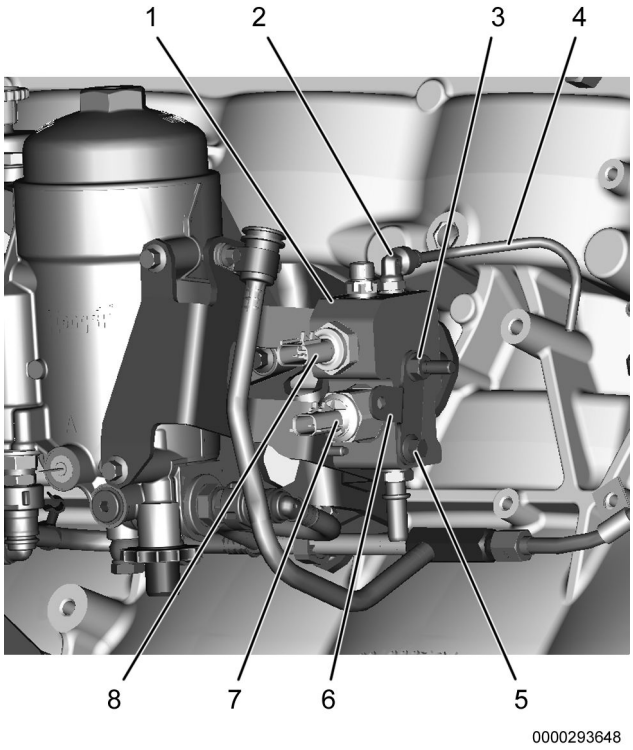

Figure 162 AFT Fuel Doser Module

1. Aftertreatment (AFT) fuel doser module
2. Aftertreatment Purge Air Valve (AFTPAV) supply tube connector
3. 8 x 60 stud bolt
4. Aftertreatment Purge Air Valve (AFTPAV) supply tube
5. M8 x 65 bolt
6. Harness support bracket
7. Aftertreatment Fuel Doser Module (AFTFSV) fuel shutoff valve connector
8. Aftertreatment Fuel Pressure Sensor 1 (AFTFP1) connector

5. Install harness support bracket (Item 6) and AFT fuel doser module (Item 1) and secure with M8 x 60 stud bolt (Item 3) and M8 x 65 hex flange bolt (Item 5).
6. Tighten bolts to 23 lbf•ft (31 N•m).
7. Connect AFTPAV supply tube (Item 4) to 90 degree connector (Item 2) on AFT fuel doser module.

8. Connect harness connectors to AFTFP1 (Item 8) and AFTFSV (Item 7).

Aftertreatment Purge Air Valve (AFTPAV) Assembly

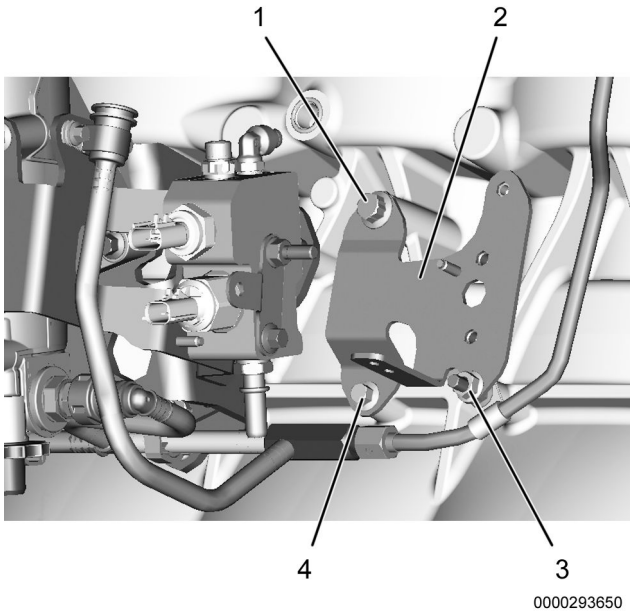

Figure 163 AFTPAV support bracket

1. M10 x 16 bolt
2. AFTPAV support bracket
3. M8 nut
4. M8 x 16 bolt

1. Install AFTPAV support bracket (Figure 163) (Item 2).
2. Install M10 x 16 bolt (Figure 163) (Item 1), M8 x 16 bolt (Figure 163) (Item 4), and M8 nut (Figure 163) (Item 3) and tighten to 23 lbf•ft (31 N•m).

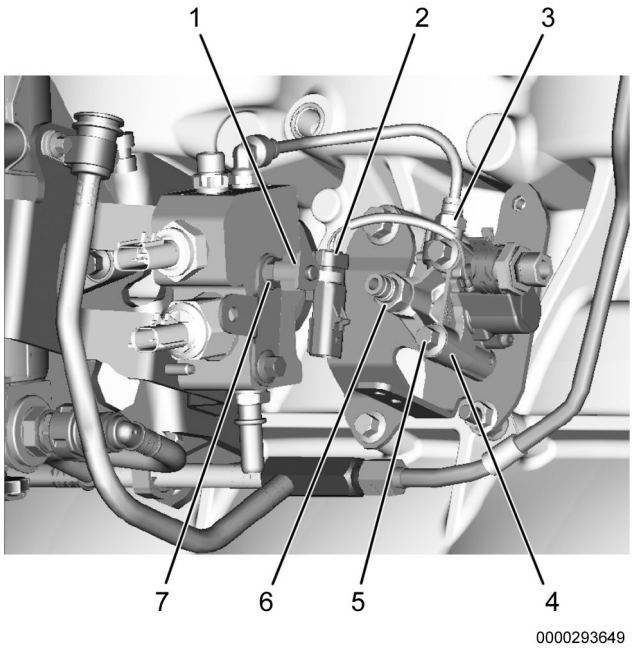

Figure 164 AFTPAV Assembly

1. Harness retainer
2. AFTPAV connector
3. AFTPAV supply tube connector
4. Aftertreatment Purge Air Valve (AFTPAV) assembly
5. M8 x 60 hex flange bolt (2)
6. AFTPAV air supply line quick-connect fitting
7. M8 x 60 stud bolt

3. Install AFTPAV assembly (Item 4).
4. Install two M8 x 60 bolts (Item 5) and tighten to 23 lbf•ft (31 N•m).
5. Install formed air tube (0.25”) to quick connect fitting (Item 3).
6. Install AFTPAV connector (Item 2) together with harness retainer (Item 1) to M8 x 60 Stud bolt (Item 7).

Supply Fuel After Filter Hose and Tubes

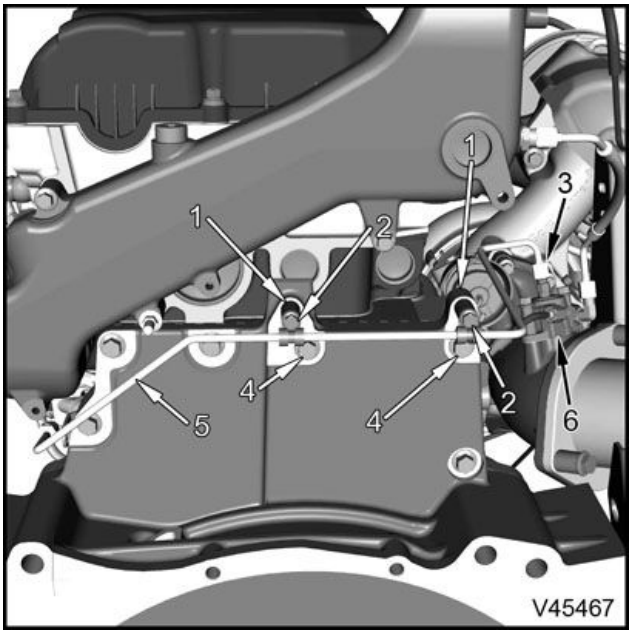

Figure 165 AFTFI Fuel 2 Tube Assembly

1. 6.6 x 15 x 23 spacer (2)
2. M6 x 40 bolt (2)
3. AFTFI fuel 2 tube assembly nut
4. P 6 x 15 clamp (2)
5. AFTFI fuel 2 tube assembly
6. Aftertreatment Fuel Injector (AFTFI) assembly

1. Position AFTFI fuel 2 tube assembly onto engine.
2. Connect AFTFI fuel 2 tube assembly onto hydrocarbon injector assembly.
3. Install two M6 x 40 bolts, 2 clamps and two 6.6 x 15 x 23 spacers. Tighten bolts to standard torque (page 547).
4. Using a wrench, hold the hydrocarbon injector assembly hex to keep it from rotating. Tighten AFTFI fuel 2 tube nut to special torque (page 141), while holding the injector body hex.

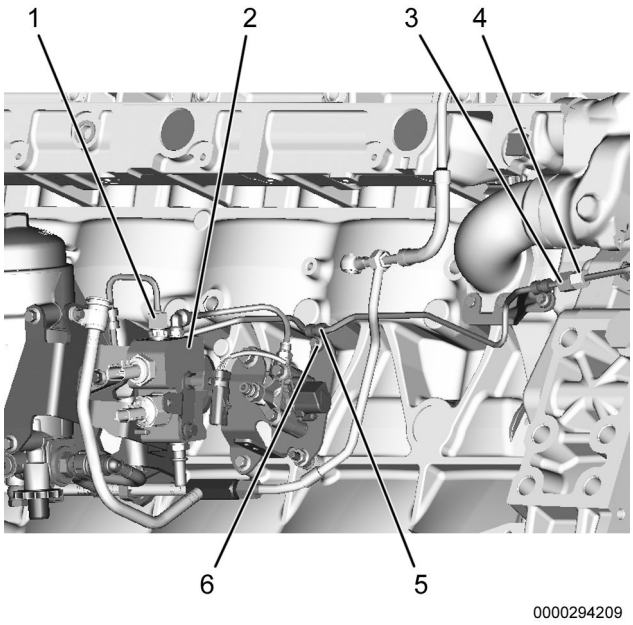

Figure 166 AFTFI fuel 1 and 2 tube assemblies

1. AFTFI fuel 1 tube assembly nut
2. Downstream Injection (DSI) unit
3. AFT fuel doser module
4. AFTFI fuel 1 tube assembly nut
5. AFTFI fuel 2 tube assembly fitting (brazed to tube)
6. P-clamp (2)
7. M6 x 16 bolt (2)

5. Position AFTFI fuel 1 tube assembly to engine. Loosely connect fuel 1 tube with fuel 2 tube and DSI unit.
6. Install two M6 x 16 bolts, one M10 x 16 bolt, two P 6 x 15 clamps and cushioned 1/4 inch diameter clamp. Tighten bolts to standard torque (page 547).

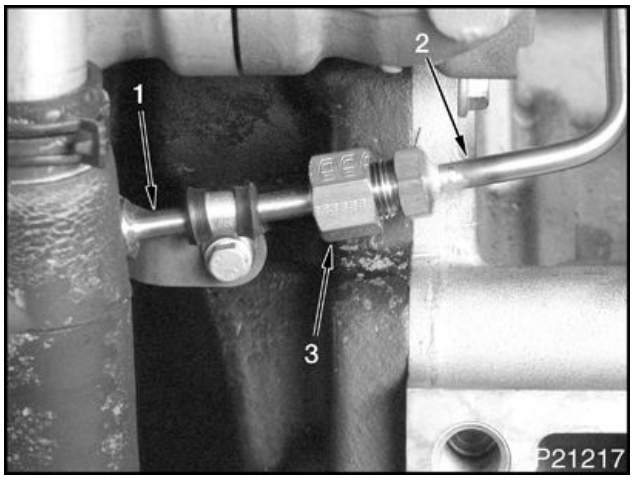

Figure 167 Fuel Supply Assembly Connection

1. AFTFI fuel 1 tube assembly
2. AFTFI fuel 2 tube assembly
3. AFTFI fuel 1 tube assembly nut
4. M6 x 16 bolt

7. Tighten AFTFI fuel 1 tube assembly nut at AFTFI fuel 2 tube nut (brazed) to special torque (page 141).
8. Tighten AFTFI fuel 1 tube assembly nut at AFTFI to special torque (page 141).
9. Connect clamp from fuel drain tube to AFTFI fuel 1 tube assembly.

Special Torque

Coolant supply (straight) fitting at coolant manifold	35 N·m (26 lb·ft)
Fitting (quick-connect adapter) at DSI unit	35 N·m (26 lb·ft)
Fitting (straight union orifice) at DSI unit	35 N·m (26 lb·ft)
AFTI coolant supply and return tube nut at tube M10 elbow fittings	15 N·m (11 lb·ft)
AFTI coolant supply tube nut at coolant manifold	25 N·m (18 lb·ft)
AFTI fuel 1 tube assembly nut at AFTI fuel 2 tube fitting (brazed)	25 N·m (18 lb·ft)
AFTI fuel 1 tube assembly nut at DSI unit	25 N·m (18 lb·ft)
AFTI fuel 2 tube assembly nut at hydrocarbon injector assembly	18 N·m (13 lb·ft)
Hydrocarbon injector assembly M8 x 45 bolt	See tightening steps in procedure.
Hydrocarbon injector assembly body to assembly	20 N·m (15 lb·ft)
PDOC V-band clamp	7 N·m (62 lb·in)
PDOC M10 x 50 bolts	36 N·m (27 lb·ft)
M10 x 25 bolts	31 N·m (23 lb·ft)
PDOC M10 x 50 bolts	36 N·m (27 lb·ft)
Tube M10 elbow fittings at hydrocarbon injector assembly	17.5 N·m (13 lb·ft)

Special Service Tools

Description	Tool Number
Coolant Block Off Plug	12–559–02–01
Coolant Management Tool	KL5007NAV
Disposable Air and Fuel Caps	ZTSE4891
Fuel Line Disconnect Tool 11.8 mm	ZTSE4773
P-80® rubber lubricant or equivalent	Obtain locally
Fuel Injector Tip Cleaning Brush	ZTSE4301

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Exploded Views

Control System

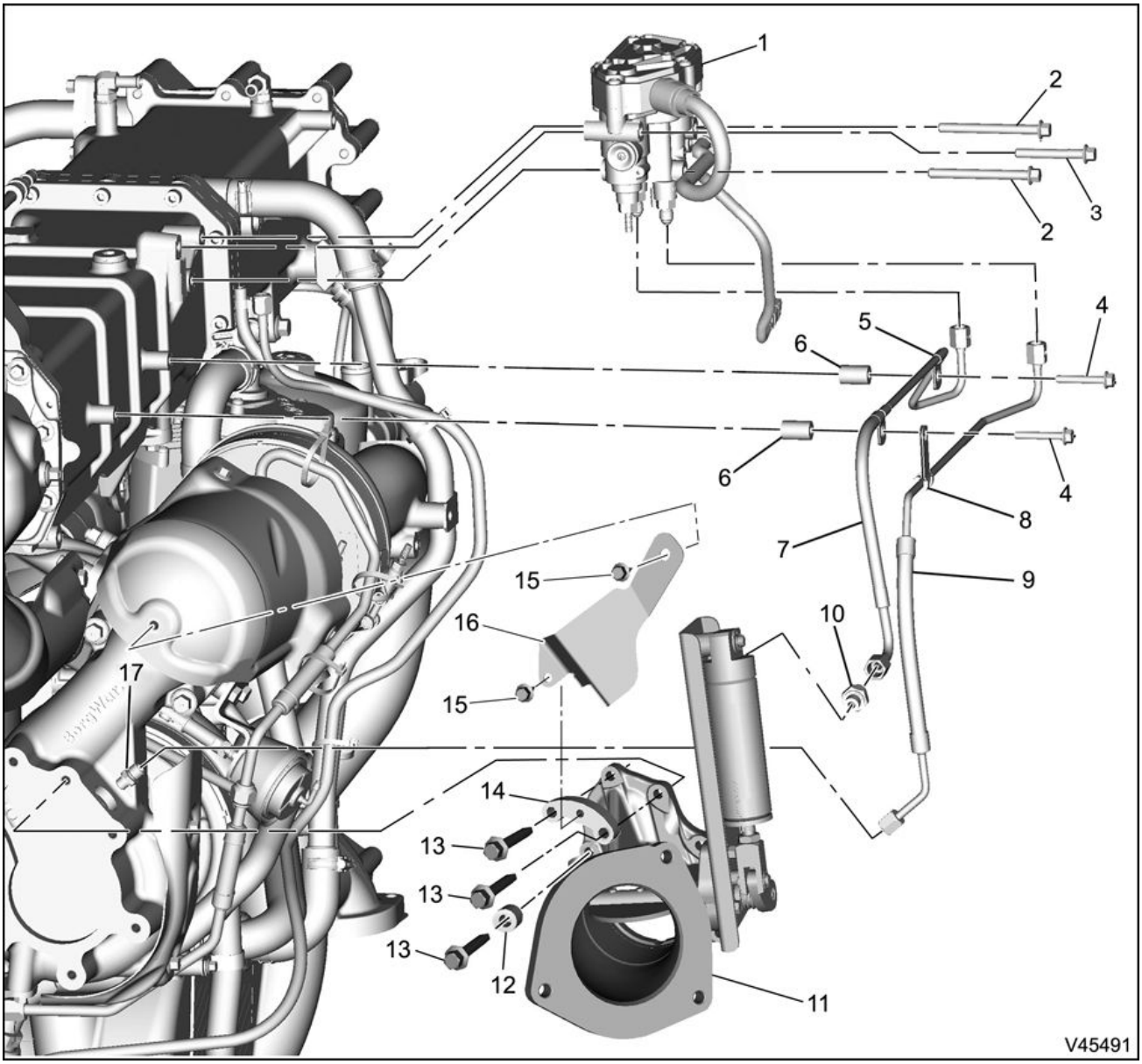

Figure 168 Exhaust back pressure control system

1. Air control valve (ACV) [updated]
2. M8 x 85 bolt (2)
3. M8 x 65 bolt (if equipped)
4. M6 x 40 bolt
5. Exhaust back pressure valve tube bracket (2)
6. Spacer
7. Exhaust back pressure valve tube assembly
8. Tube bracket
9. TC1 turbine outlet pressure (TC1TOP) sensor tube assembly
10. Flare M10 x 1.5 (37 degree) fitting
11. Exhaust back pressure valve assembly
12. Spacer (5)
13. M8 x 45 bolt (7)
14. Heat shield spacer
15. M8 x 16 bolt
16. Heat shield
17. Flare M10 x M12 (24 degree) fitting

Removal

Warnings

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.

WARNING: To prevent personal injury or death, wear safety glasses with side shields.

NOTE: When performing specific component removal, only remove components necessary for access.

For complete engine tear down, refer to the following service sections for information on removal of components prior to this section:

- **Engine Electrical**
- **Aftertreatment System**

Air Control Valve (ACV)

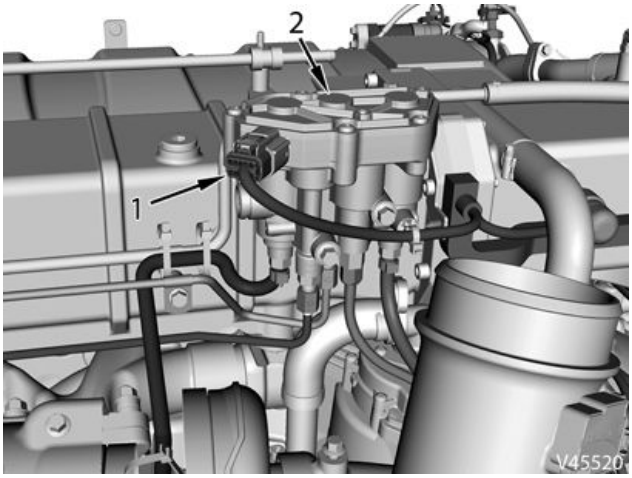

Figure 169 Early production ACV

1. 10-way electrical connector
2. Air Control Valve (ACV) housing

Figure 170 Updated ACV with pigtail harness

1. Pigtail harness
2. Air Control Valve (ACV)

NOTE: Various Air Control Valves (ACV) have been used on this engine. Early production ACVs have the 10-way electrical connector (Figure 169) (Item 1) on the ACV housing (Figure 169) (Item 2) , and updated 3-bolt ACVs (Figure 170) (Item 2) have a pigtail harness (Figure 170) (Item 1) that relocates the 10-way pigtail connector.

NOTE: If engine has an early production 2-bolt EGRV coolant supply tube (Figure 177), install a new 3-bolt EGRV coolant supply tube (Figure 178).

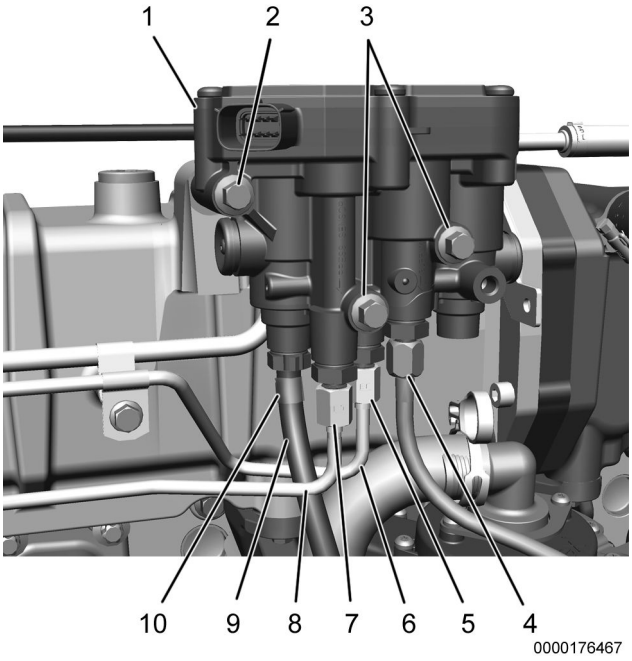

Figure 171 Early production 3-bolt Air Control Valve (ACV), bolts, and tube connections

1. ACV (early production)
2. M8 x 65 bolt (if equipped)
3. M8 x 85 bolt (2)
4. Air supply tube nut
5. Exhaust back pressure tube nut
6. Exhaust back pressure valve tube
7. TC1TOP sensor tube nut
8. TC1 turbine outlet pressure (TC1TOP) sensor tube
9. High-pressure wastegate actuator hose
10. Crimp clamp

CAUTION: Relieve system pressure before loosening air supply tube valve.

1. Loosen air supply tube nut (Figure 171) (Item 4) from ACV (Figure 171) (Item 1). Disconnect air supply tube.
2. Remove crimp clamps (Figure 171) (Item 10 that secures High-pressure (HP) and Low-pressure (LP) (if equipped) wastegate actuator hoses (Figure 171) (Item 9). Discard crimp clamps and disconnect hoses from the ACV.

3. Loosen TC1TOP sensor tube nut (Figure 171) (Item 7) and exhaust back pressure tube nut (Figure 171) (Item 5). Disconnect tubes from ACV.

NOTE: The LP wastegate actuator is installed only on early production models, is not functional, and the hose can be removed and left off.

4. If equipped, remove and discard the LP wastegate actuator hose.
5. Remove one M8 x 65 bolt (Figure 171) (Item 2) (if equipped), two M8 x 85 bolts (Figure 171) (Item 3), and ACV.

Exhaust Back Pressure Valve Actuator and TC1 Turbine Outlet Pressure Sensor Tubes

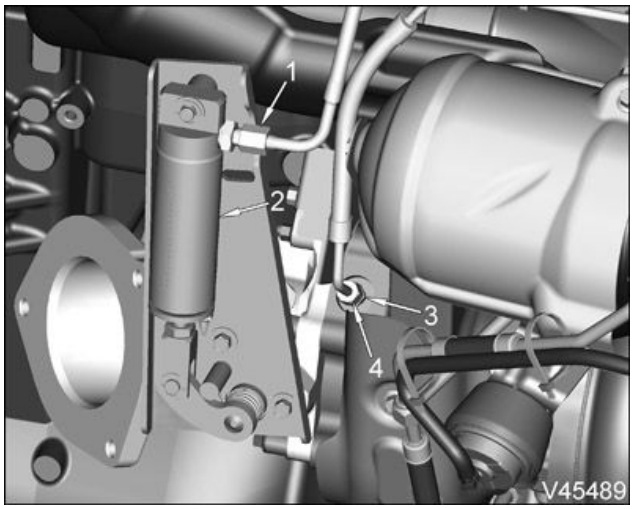

Figure 172 Exhaust back pressure valve actuator and TC1 turbine outlet pressure (TC1TOP) sensor tubes

1. Exhaust back pressure valve tube nut
2. Exhaust back pressure valve actuator
3. TC1TOP sensor tube nut
4. M10 x M12 flare fitting (24 degree)

1. Loosen exhaust back pressure valve tube nut from exhaust back pressure valve actuator and disconnect tube.
2. Loosen TC1TOP sensor tube nut from low-pressure turbocharger housing flare M10 x M12 (24 degree) fitting and disconnect tube.
3. If necessary, remove M10 x M12 flare fitting (24 degree).

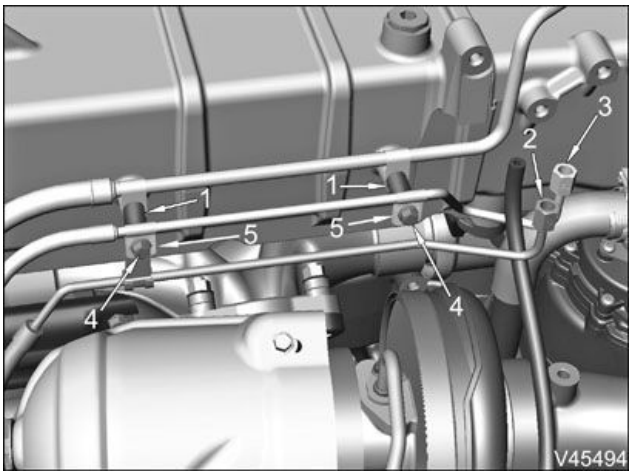

Figure 173 TC1TOP sensor tube and exhaust back pressure valve tube (typical)

1. TC1TOP sensor tube bracket
2. TC1TOP sensor tube
3. Exhaust back pressure valve tube
4. M6 x 40 bolt (2)
5. Exhaust back pressure valve tube bracket (2)

4. Remove two M6 x 40 bolts, exhaust back pressure valve tube and TC1TOP sensor tube.

Exhaust Back Pressure Valve Assembly

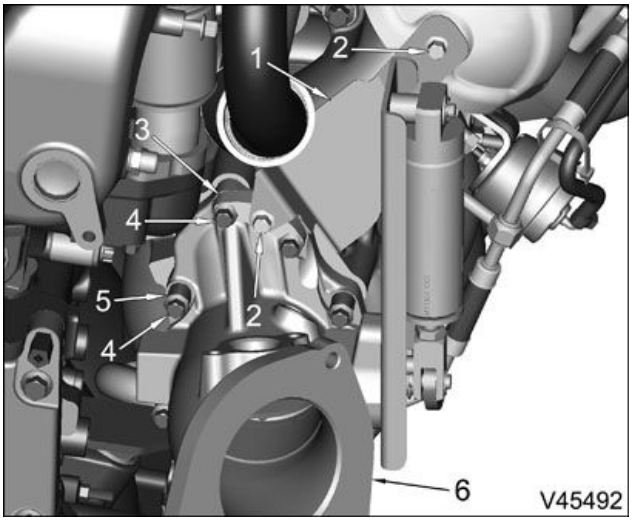

Figure 174 Exhaust back pressure valve Assembly

1. Heat shield
2. M8 x 16 bolt (2)
3. Heat shield spacer
4. M8 x 45 bolt (7)
5. Spacer (5)
6. Exhaust back pressure valve assembly

1. Remove two M8 x 16 bolts that secure the heat shield to the HP turbocharger and exhaust back pressure valve assembly.
2. Remove heat shield.
3. Remove seven M8 x 45 bolts, the heat shield spacer, five spacers, and exhaust back pressure valve assembly.

Installation

Exhaust Back Pressure Valve Assembly

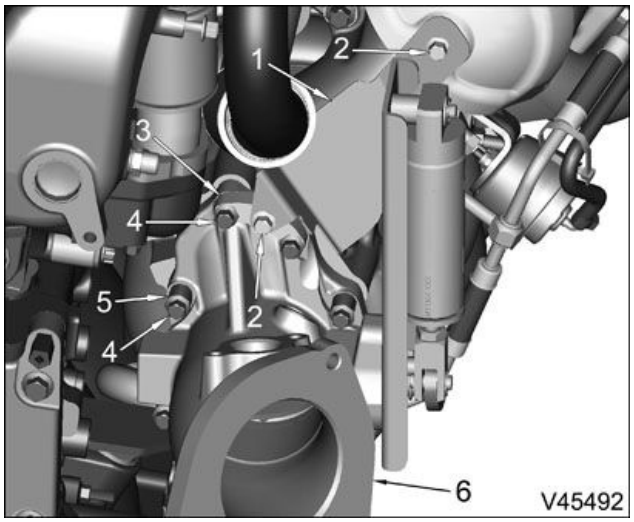

Figure 175 Exhaust back pressure valve Assembly

1. Heat shield
2. M8 x 16 bolt (2)
3. Heat shield spacer
4. M8 x 45 bolt (7)
5. Spacer (5)
6. Exhaust back pressure valve assembly

1. Position the exhaust back pressure valve assembly, install five spacers, the heat shield spacer, and seven M8 x 45 bolts.
2. Tighten M8 x 45 bolts to standard torque (page 547).
3. Position heat shield, and install two M8 x 16 bolts. Tighten M8 x 16 bolts to standard torque (page 547).

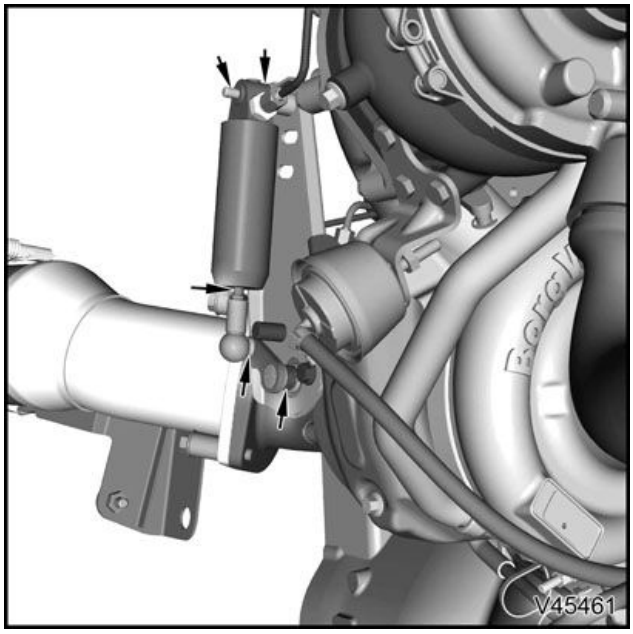

Figure 176 Exhaust back pressure valve actuator lubrication points

4. Apply Superlub™ synthetic high heat lubricant (page 156) or equivalent to areas indicated.

Air Control Valve (ACV)

NOTE: Early production 2-bolt Air Control Valves (ACVs) that have the 10-way electrical connector on the ACV housing , should not be updated with 3-bolt ACVs that have a pigtail harness unless the valve has failed.

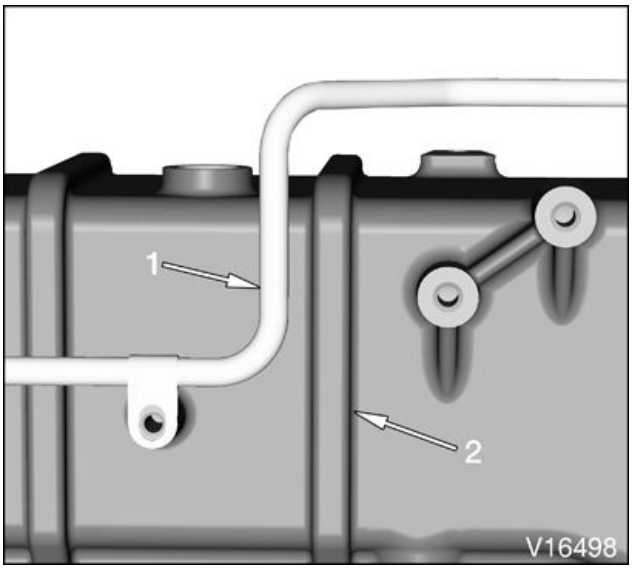

Figure 177 EGRV coolant supply tube and EGR cooler (2-bolt early production)

1. EGRV coolant supply tube assembly (Early production)
2. EGR cooler casting rib

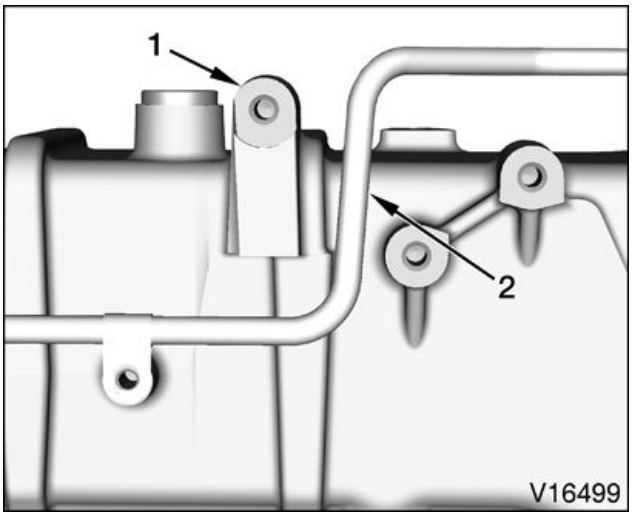

Figure 178 EGRV coolant supply tube and EGR cooler (Updated 3-bolt version)

1. EGR cooler third ACV mounting bolt boss (if equipped)
2. EGRV coolant supply tube assembly (updated version)

1. Determine if the EGRV coolant supply tube assembly (Figure 177) (Item 1) is the early production 2-bolt version (Figure 177)(Item 2) or the updated 3-bolt version (Figure 178) (Item 1).
   - If engine has an early production 2-bolt EGRV coolant supply tube assembly, obtain EGRV Coolant Supply Tube Kit and install a new updated 3-bolt EGRV coolant supply tube assembly.

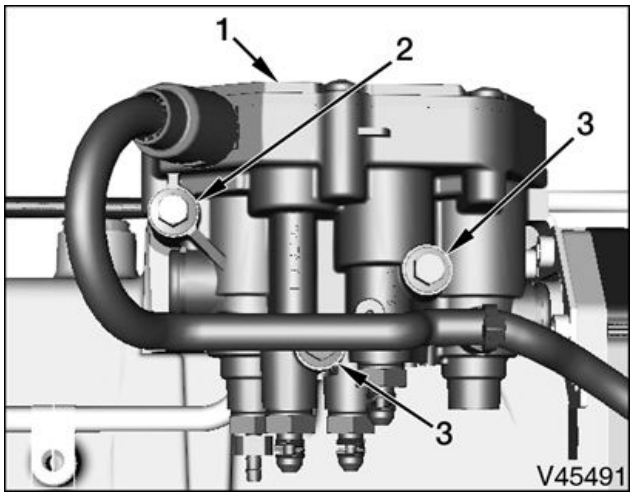

Figure 179 Air control valve tubes and hoses

1. Air Control Valve (ACV)
2. M8 x 65 bolt
3. M8 x 85 bolt (2)

2. Position new ACV onto the EGR cooler and install two saved M8 x 85 bolts finger tight. Tighten bolts to 23 lb·ft (31 N·m).
   - If EGR cooler has a third ACV mounting bolt boss, install new M8 x 65 bolt. Tighten bolt to 23 lb·ft (31 N·m).
   - If EGR cooler does not have a third ACV mounting bolt boss, the M8 x 65 bolt is not used.

Exhaust Back Pressure Valve Actuator and TC1 Turbine Outlet Pressure Sensor Tubes

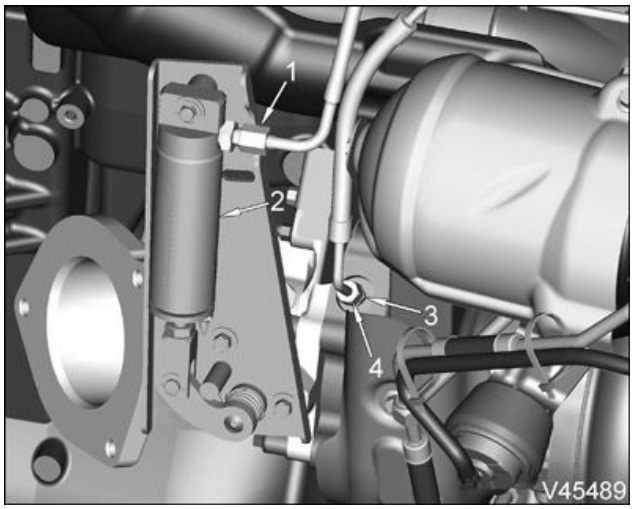

Figure 180 Exhaust back pressure valve actuator and TC1 turbine outlet pressure (TC1TOP) sensor tubes

1. Exhaust back pressure valve tube nut
2. Exhaust back pressure valve actuator
3. TC1TOP sensor tube nut
4. M10 x M12 flare fitting (24 degree)

1. Install exhaust back pressure valve tube nut (Figure 180) (Item 1) onto exhaust back pressure valve actuator (Figure 180) (Item 2). Leave loose at this time.
2. If removed, install and tighten M10 x M12 flare fitting (24 degree) (Figure 180) (Item 4) to 13 lb·ft (17.5 N·m).
3. Position TC1TOP sensor tube nut (Figure 180) (Item 3) to low-pressure turbocharger housing M10 x M12 flare fitting (24 degree). Leave loose at this time.

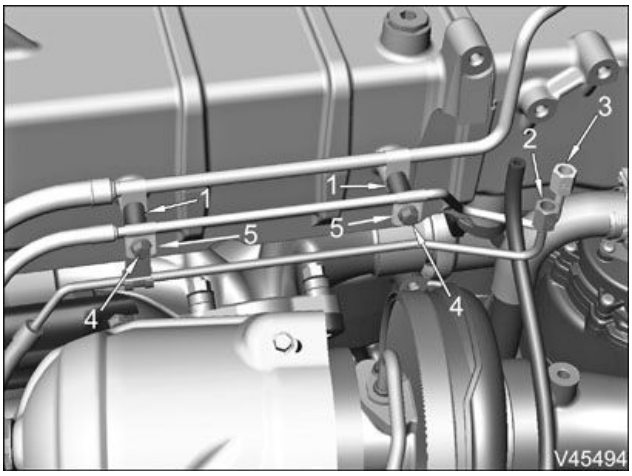

Figure 181 TC1TOP sensor tube and exhaust back pressure valve tube (typical)

1. TC1TOP sensor tube bracket
2. TC1TOP sensor tube
3. Exhaust back pressure valve tube
4. M6 x 40 bolt (2)
5. Exhaust back pressure valve tube bracket (2)

4. Position exhaust back pressure valve tube (Figure 181) (Item 3) and TC1TOP sensor tube (Figure 181) (Item 2) against EGR cooler. Using two M6 x 40 bolts (Figure 181) (Item 4) and two spacers, secure tubes to EGR cooler. Tighten bolts to 115 lb·in (13 N·m).

Figure 182 Air control valve tubes and hoses

1. M8 x 65 bolt
2. M8 x 85 bolt (2)
3. Low-pressure wastegate actuator port (not used)
4. Air supply (from air tank)
5. Exhaust back pressure valve tube
6. High-pressure (HP) wastegate actuator
7. Pressure sensor tube assembly [Turbocharger 1 Turbine Outlet Pressure (TC1TOP)]

5. Connect exhaust back pressure valve tube (Figure 182) (Item 5) and pressure sensor tube assembly (TC1TOP) (Figure 182) (Item 7) to ACV. Tighten tube nuts to 133 lb·in (15 N·m).
6. Connect air supply (Figure 182) (Item 4) to ACV. Tighten air supply tube nut to 106 lb·in (12 N·m).
7. Slide a new crimp clamp onto HP wastegate actuator hose and connect hose to ACV. Secure hose with crimp clamp using Clamp Pliers (LIS30800).

NOTE: The LP wastegate actuator is installed only on early production models, is not functional, and the hose can be removed and left off.

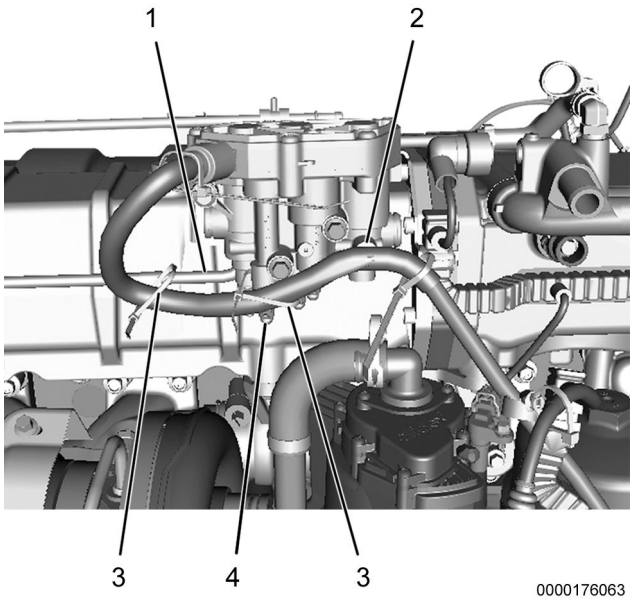

Figure 183 ACV pigtail harness attachment locations

1. Exhaust back pressure valve tube
2. ACV boss
3. High temperature tie strap (2)
4. Turbocharger 1 Turbine Outlet Pressure (TC1TOP) port

8. Install fir tree connector into ACV boss (Figure 183) (Item 2).
9. Install high temperature tie strap (Figure 183) (Item 3) around TC1TOP port (Figure 183) (Item 4) and ACV pigtail harness.
10. Install high temperature tie strap around exhaust back pressure valve tube (Figure 183) (Item 1) and ACV pigtail harness.

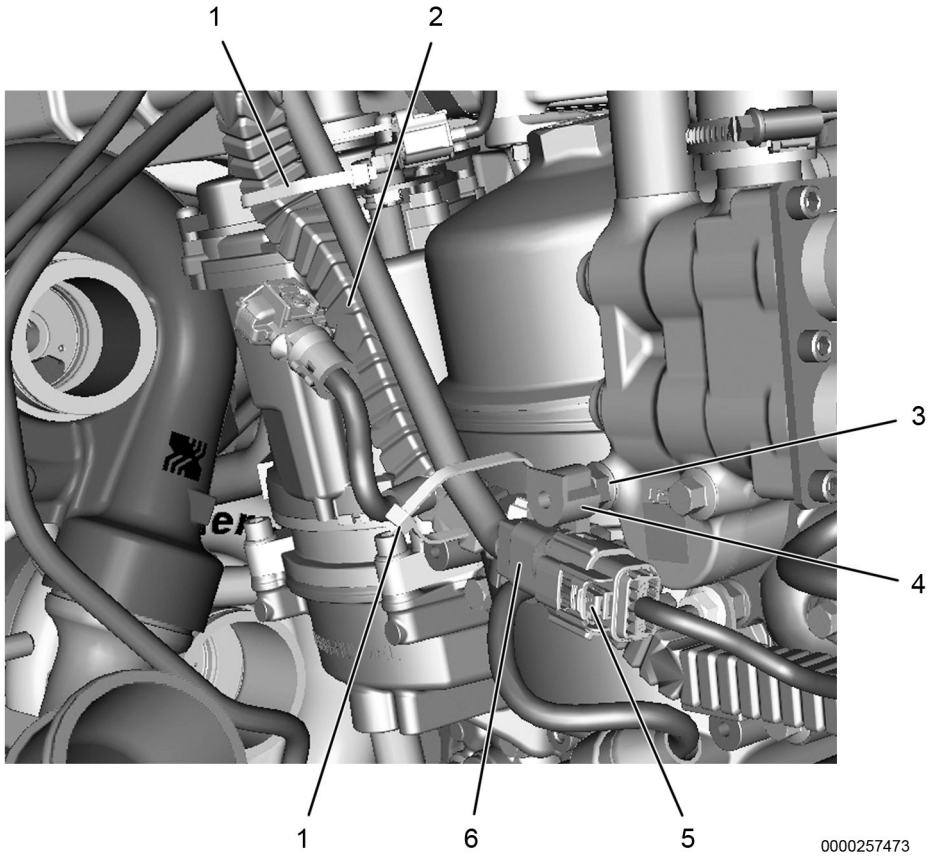

Figure 184 ACV harness routing and tie strap locations

1. Tie straps (2)
2. Engine harness
3. M8 x 50 stud
4. M6-M8 zip-tie harness retainer
5. Engine harness 10–way connector
6. ACV harness 10–way connector

11. Push ACV harness 10-way connector (Figure 184) (Item 6) onto the engine harness 10-way connector (Figure 184) (Item 5) until a click is heard, and pull gently to verify that the 10-way connector is securely latched.
12. Install M6-M8 zip-tie harness retainer (Figure 184) (Item 4) to ACV harness 10-way connector.
13. Secure ACV harness and engine harness with two tie straps (Figure 184) (Item 1) as shown.
14. Attach M6-M8 zip-tie harness retainer to M8 x 50 stud (Figure 184) (Item 3).
15. Cut all tie straps flush to head.

Special Torque

Air supply tube (at bulkhead fitting)	17.5 N·m (13 lb·ft)
Air supply tube nut (at air control valve)	12 N·m (106 lb·in)
Exhaust back pressure valve tube nut (at actuator)	15 N·m (11 lb·ft)
Exhaust back pressure valve tube nut (at air control valve)	15 N·m (11 lb·ft)
Flare M10 x M12 (24 degree) fitting	17.5 N·m (13 lb·ft)
TC1TOP sensor tube nut (at air control valve)	15 N·m (11 lb·ft)
TC1TOP sensor tube nut at flare M10 x M12 (24 degree) fitting	15 N·m (11 lb·ft)

Special Service Tools

Description	Tool Number
Crimping pliers	Obtain locally
Superlub™ synthetic high heat lubricant	Obtain locally

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Exploded Views

Turbochargers and Charge Air Cooler Assembly

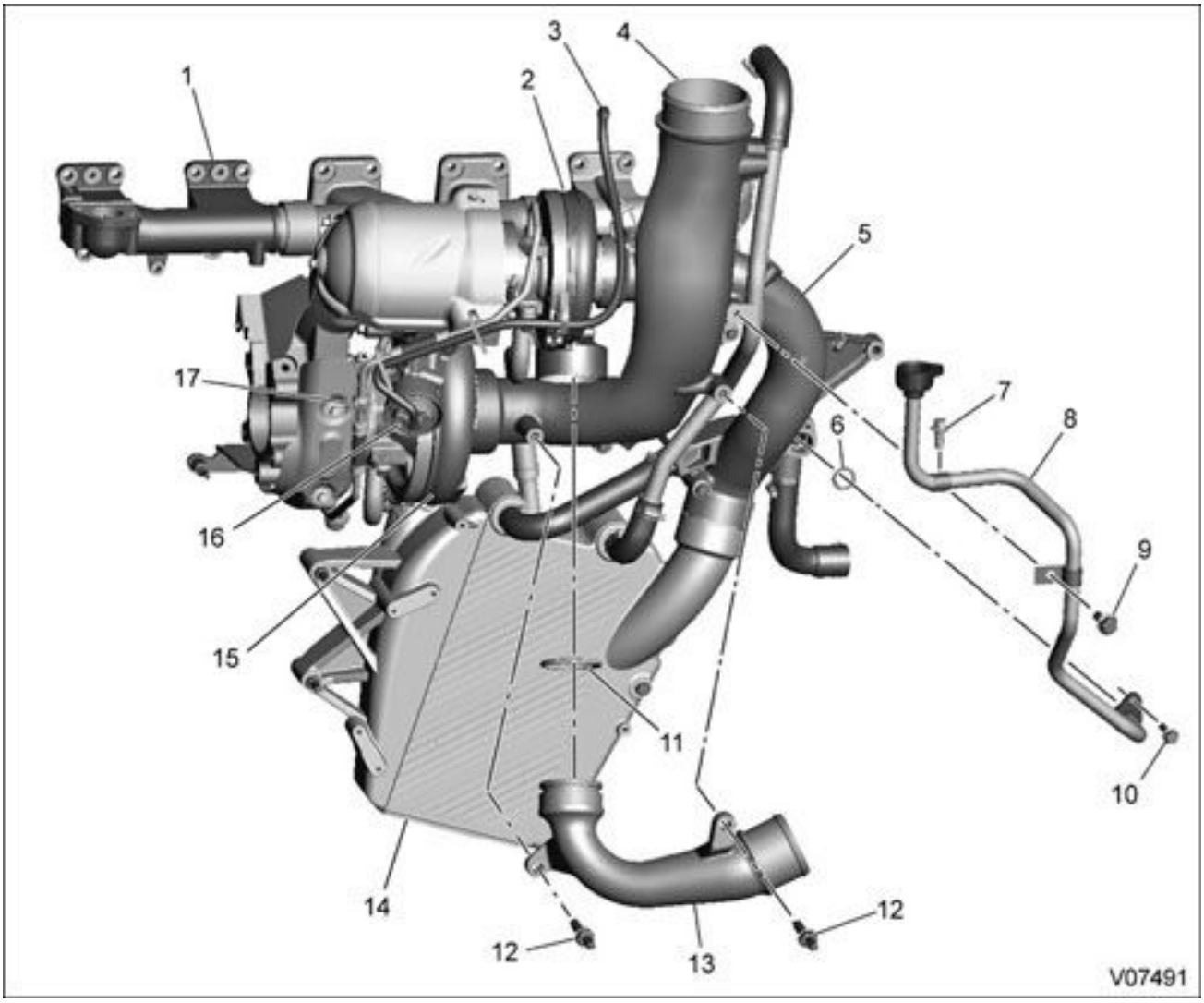

Figure 185 Turbochargers and charge air cooler assembly.

1. Rear exhaust manifold
2. High-pressure turbocharger assembly
3. High-pressure wastegate hose
4. Air inlet duct
5. High-Pressure (HP) turbocharger air supply duct
6. O-ring
7. M8 x 16 bolt
8. Cab heater return tube assembly
9. M8 x 20 bolt
10. M6 x 20 bolt
11. Inlet (and outlet) high-pressure compressor seal
12. M10 x 20 x 40 stud bolt (2)
13. High-pressure (HP) compressor out duct
14. Low-Pressure Charge Air Cooler (LPCAC)
15. Low-Pressure (LP) turbocharger assembly
16. High-pressure wastegate actuator
17. Turbocharger oil supply tube assembly

Coolant Tube, Coolant Hoses and Low-Pressure Charge Air Cooler (LPCAC)

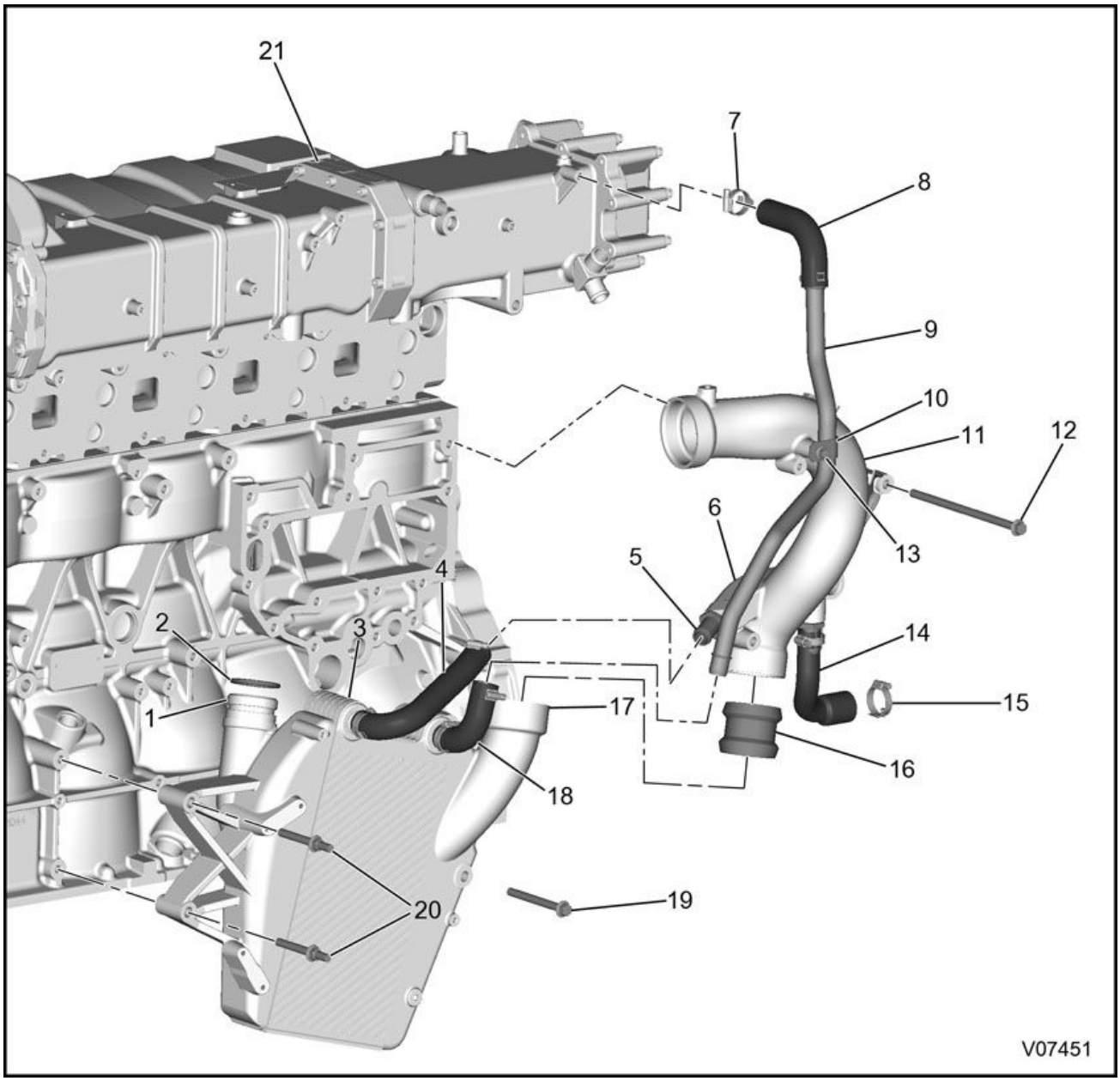

Figure 186 Coolant tube, coolant hoses and Low-Pressure Charge Air Cooler (LPCAC).

1. LPCAC air inlet
2. Intake O-ring (low-pressure turbocharger to LPCAC)
3. Low-Pressure Charge Air Cooler (LPCAC)
4. Coolant return hose (CAC to coolant return duct)
5. M24 x 1.5 threaded fitting (2)
6. Coolant return duct (integral with air supply duct)
7. 3/4 inch constant torque hose clamp (7)
8. Coolant return hose (at EGR cooler)
9. Coolant tube (EGR cooler to LPCAC)
10. Tube support
11. High-Pressure (HP) turbocharger air supply duct
12. M10 x 200 bolt (2)
13. M8 x 20 bolt
14. Coolant return hose (to water distribution housing)
15. Hose clamp (1 inch worm gear)
16. 72.2 x 60 (DMR) tube seal (extension tube)
17. LPCAC air outlet (to HP turbocharger air supply duct)
18. Coolant hose (coolant tube to CAC water inlet)
19. M10 x 100 bolt
20. Ground stud bolt (2)
21. EGR cooler assembly

Turbocharger Oil Supply Tube and Support Bracket

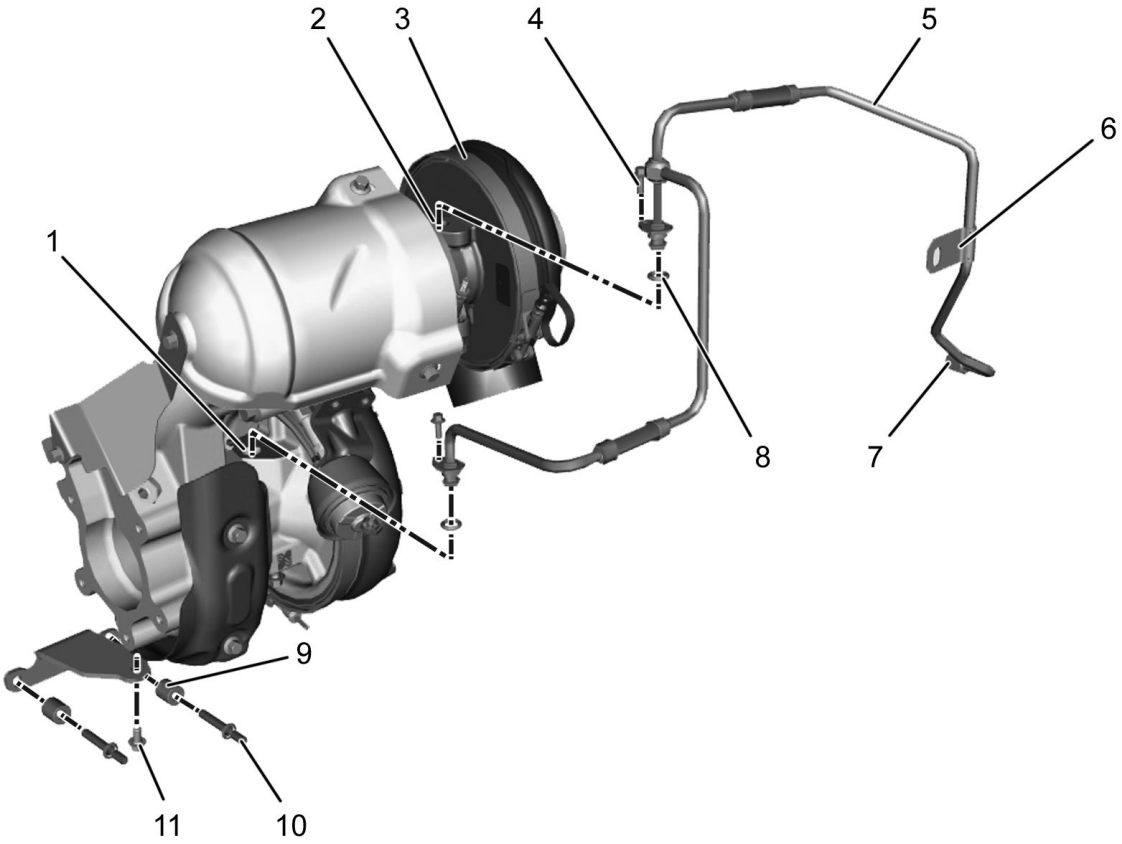

Figure 187 Turbocharger oil supply tube and support bracket.

1. Low-pressure turbocharger oil supply port
2. High-pressure turbocharger oil supply port
3. High-pressure turbocharger assembly
4. M6 X 16 bolt (2)
5. Oil supply tube
6. Oil supply tube bracket
7. Oil supply tube T-fitting flare nut
8. Turbocharger supply seal (2)
9. 19 x 20 spacer (2)
10. M8 X 40 Bolt
11. M8 X 16 bolt

Turbocharger Oil Return Tubes

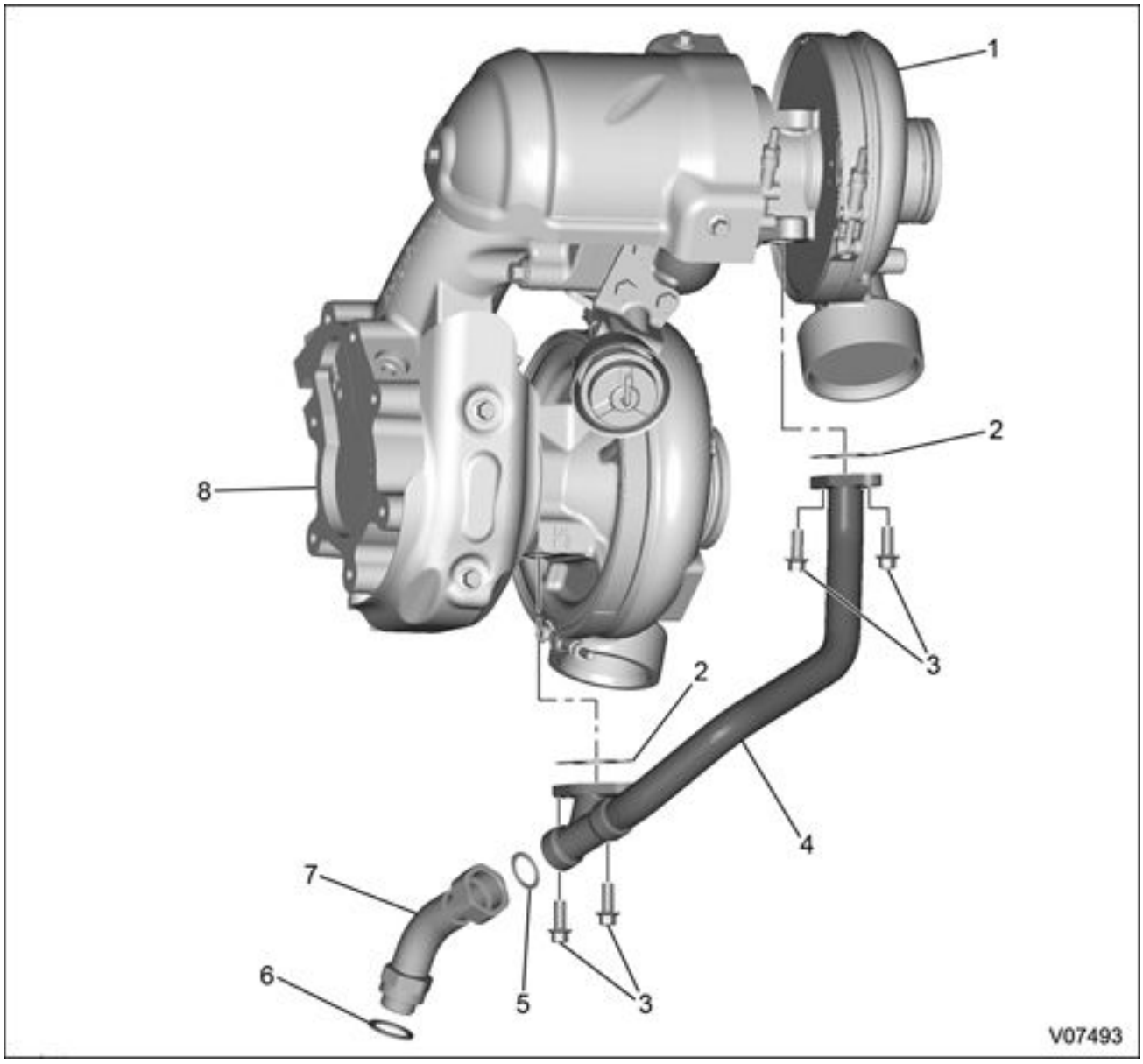

Figure 188 Turbocharger oil return tubes.

1. High-Pressure (HP) turbocharger assembly
2. Turbocharger oil drain gasket (2)
3. M8 x 20 bolt (4)
4. Oil return high-pressure turbocharger tube
5. Metric bonded seal washer
6. 24.7 x 32 seal ring
7. Oil return low-pressure turbocharger tube
8. Low-Pressure (LP) turbocharger assembly

Air Inlets, Wastegate High-Pressure Actuator, and Air Control Valve

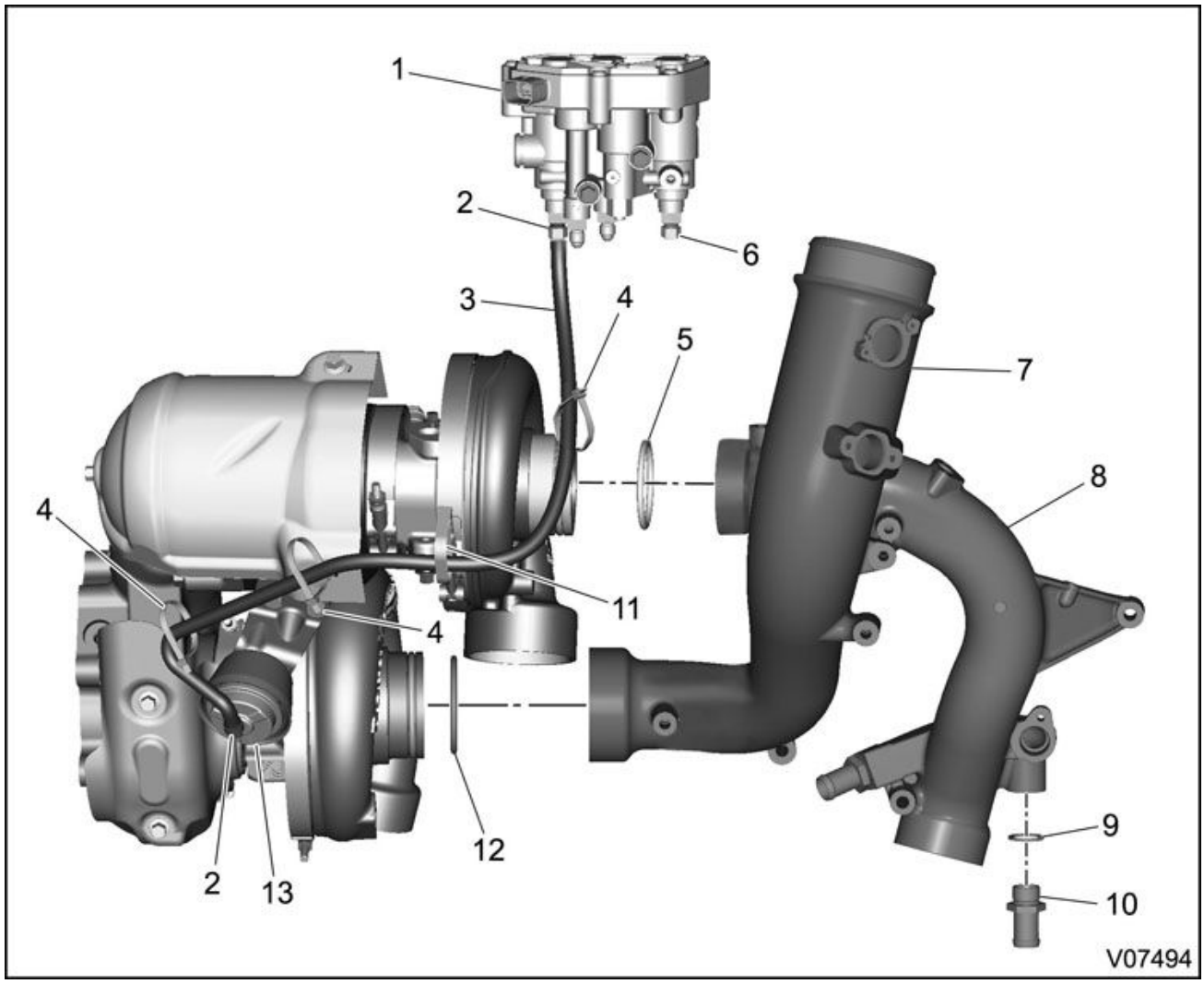

Figure 189 Air inlets, wastegate high-pressure actuator, and air control valve.

1. Air Control Valve (ACV) assembly
2. 12.3 x 7 crimp clamp (2)
3. High-pressure wastegate hose
4. Cable lock strap (3)
5. Inlet high-pressure compressor seal
6. Plug (if equipped)
7. Air inlet duct
8. High-Pressure (HP) turbocharger air supply duct
9. Seal ring (2)
10. M24 threaded fitting (2)
11. Tie strap
12. Inlet low-pressure compressor seal
13. High-Pressure (HP) turbocharger wastegate actuator

Turbochargers

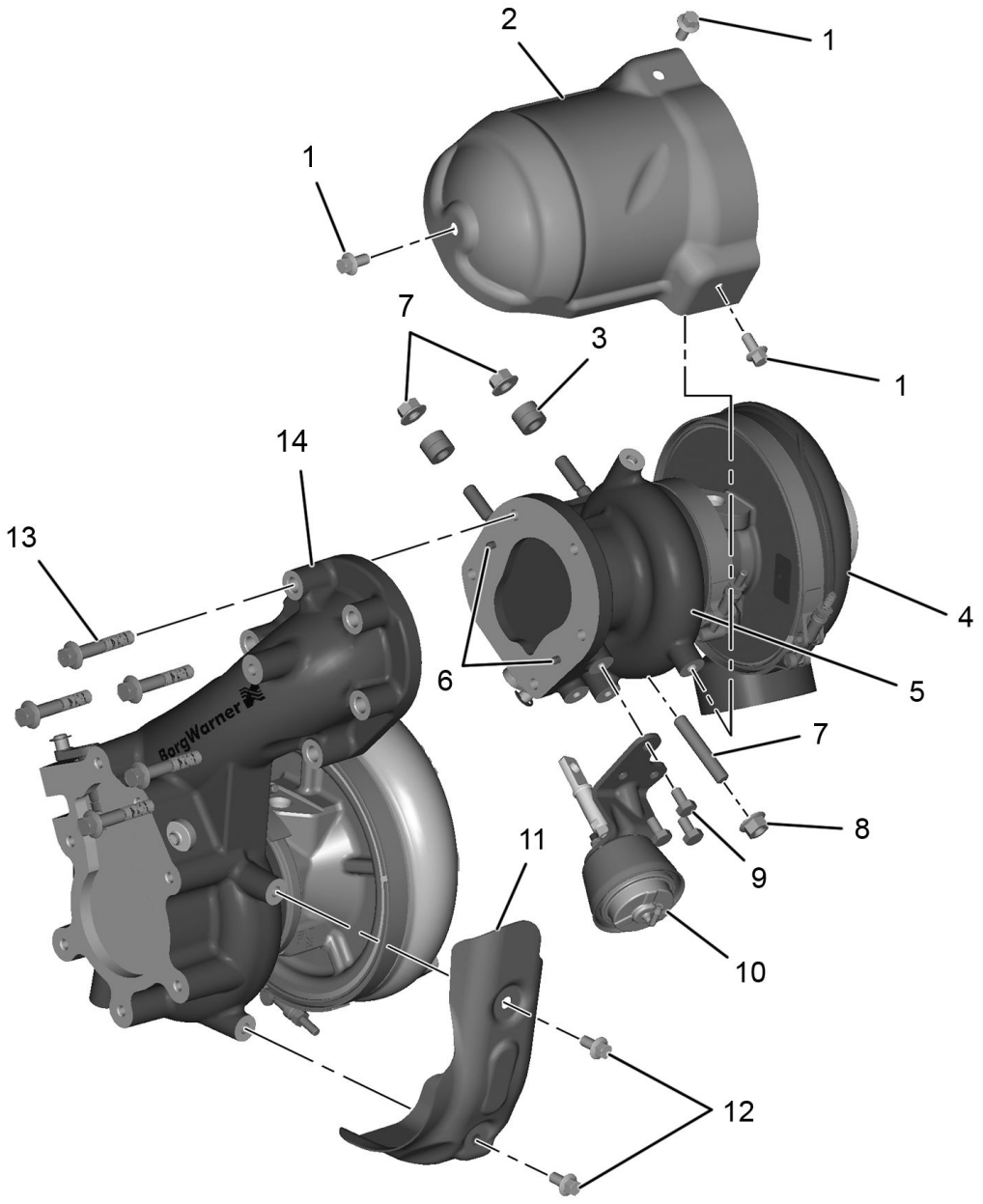

Figure 190 Turbochargers.

1. M8 x 16 bolt (3)
2. High-pressure turbocharger heat shield
3. 10.5 x 20 x 15 sleeve (2)
4. High-Pressure (HP) turbocharger center section
5. High-Pressure (HP) turbocharger turbine housing
6. Dowel pin (2)
7. M10 x 45 stud
8. M10 nut (3)
9. M8 x 14 bolt (6)
10. High-Pressure (HP) turbocharger wastegate actuator
11. Turbocharger heat shield
12. M8 x 16 bolt (2)
13. M10 x 55 bolt (5)
14. Low-Pressure (LP) turbocharger assembly

Individual Component Removal

Overview

This section provides instruction for removal of individual turbocharger components when not doing a complete engine teardown. For turbocharger component removal during a complete engine teardown follow Removal (Complete Engine Teardown) Section.

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.

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.

High-Pressure (HP) Turbocharger Center Section

Overview

This section provides instruction specifically for removal of the high-pressure turbocharger center section when Not doing a complete engine teardown.

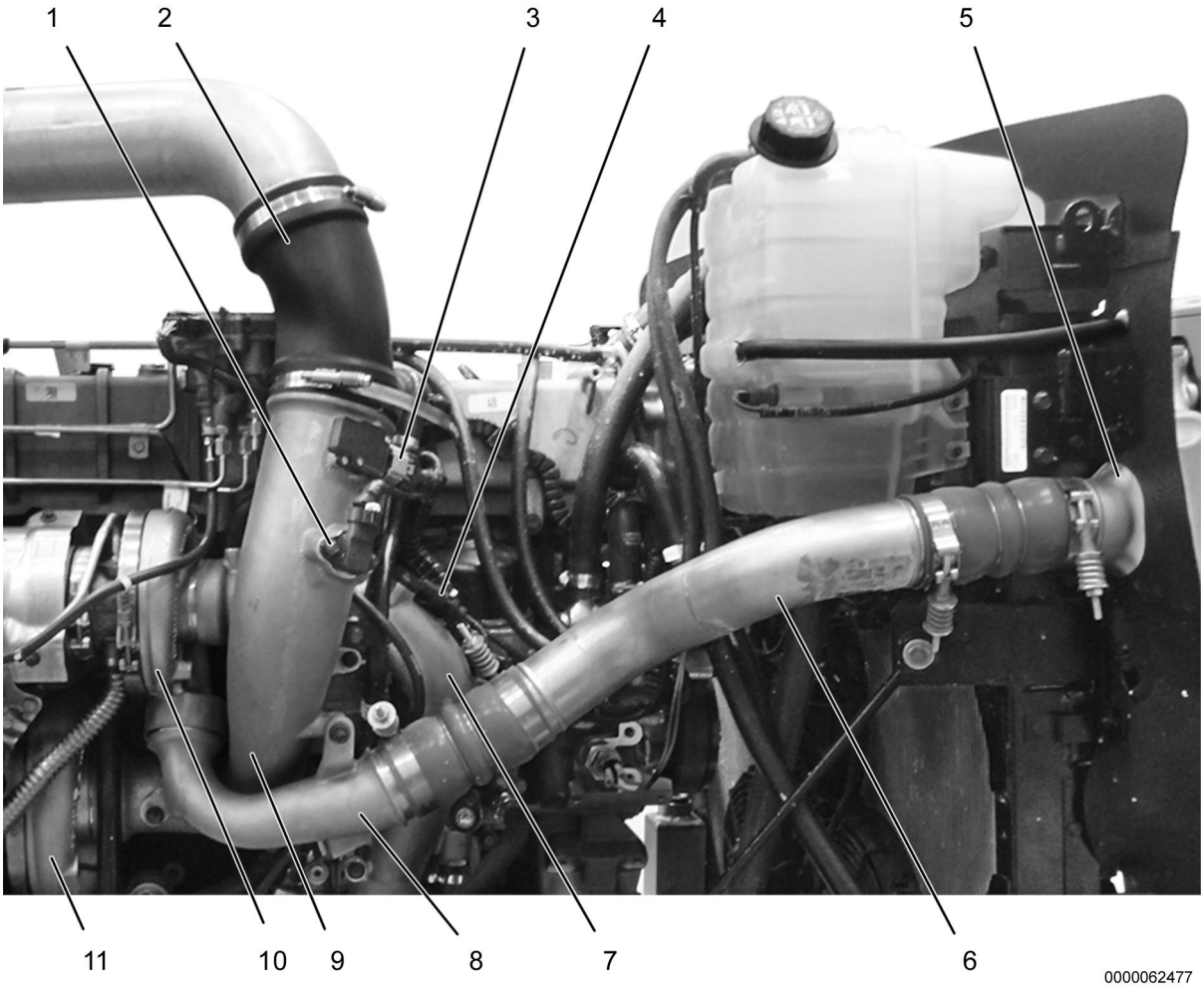

Figure 191 High-Pressure (HP) and Low-Pressure (HP) Turbochargers and Connections.

1. Intake Air Temperature (IAT) sensor
2. Air inlet connecting hose
3. Mass Air Flow (MAF) sensor
4. Turbocharger 2 Compressor Inlet Pressure (TC2CIP) sensor
5. High-Pressure Charge Air Cooler (HPCAC)
6. High-Pressure Charge Air Cooler (HPCAC) pipe
7. HP turbocharger air supply duct
8. HP compressor out duct
9. Air inlet duct
10. HP Turbocharger
11. LP Turbocharger

1. Using Coolant Management Tool KL5007NAV (page 205), drain coolant. Place suitable coolant drain pan under truck.
2. Remove air inlet connecting hose (Figure 191) (Item 2).
3. Remove HPCAC pipe (Figure 191) (Item 6) from HPCAC (Figure 191) (Item 5) and HP compressor out duct (Figure 191) (Item 8).
4. Install cap (Disposable Air and Fuel Caps) ZTSE4891 (page 205) on HPCAC.
5. Disconnect engine harness connectors at IAT sensor, MAF sensor (if equipped), and TC2CIP sensor (Figure 191) (Items 1, 3, and 4), and EOP sensor (Figure 192) (Item 10) and secure engine harness out of the way.
6. Remove HP compressor out duct.
7. Remove air inlet duct (Figure 191) (Item 9) and install a clean cap on inlet to LP turbocharger (Figure 191) (Item 11).

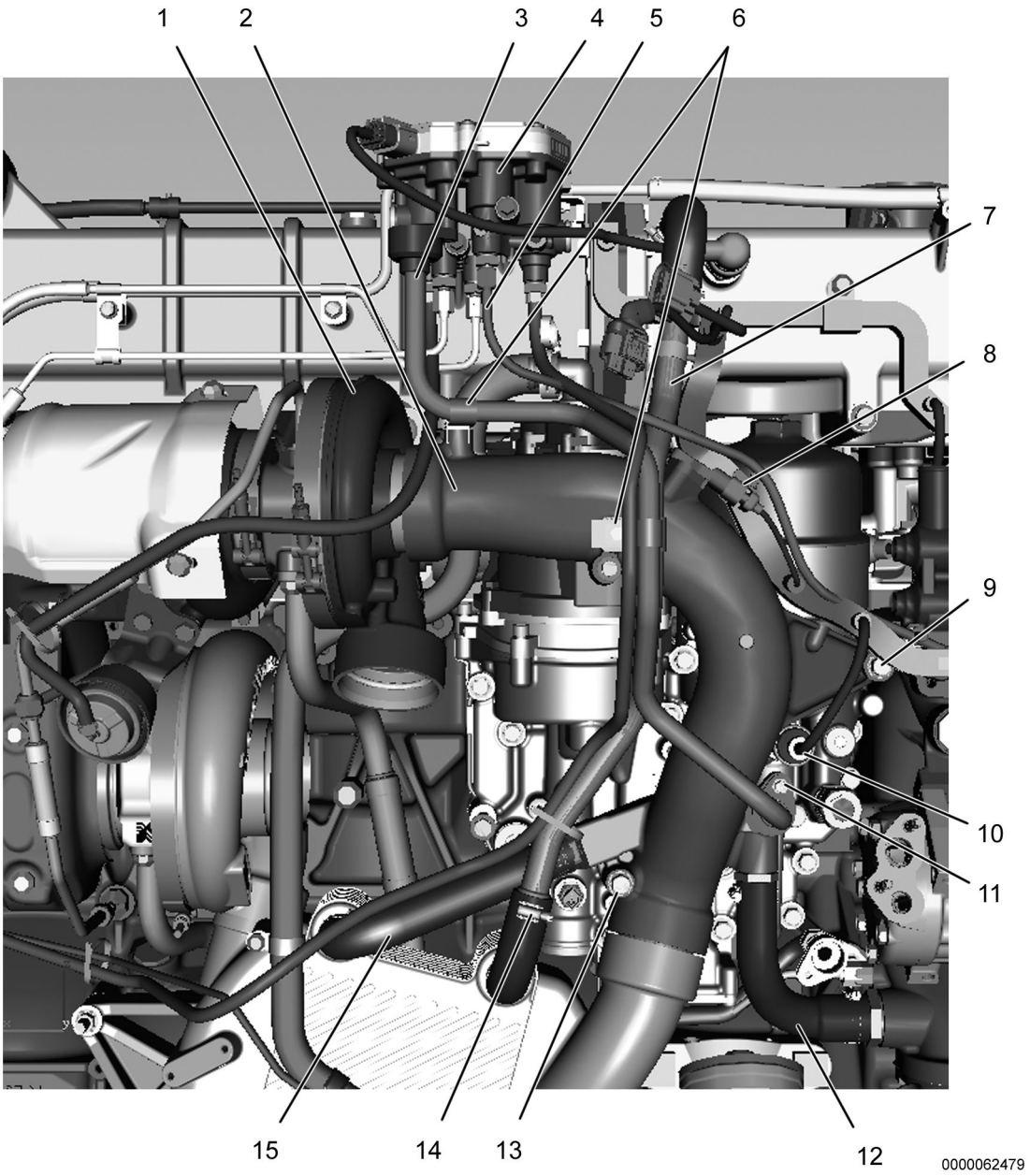

Figure 192 HP Turbocharger and Connections.

1. High-Pressure (HP) turbocharger assembly
2. HP turbocharger air supply duct
3. Cab heater return tube assembly
4. Air Control Valve (ACV) assembly
5. Air supply tube
6. M8 x 20 bolt (2)
7. Coolant tube (EGR cooler to LPCAC)
8. Turbocharger 2 Compressor Inlet Pressure (TC2CIP) sensor
9. M10 x 200 bolt
10. Engine Oil Pressure (EOP) sensor
11. M6 x 20 bolt
12. Coolant return hose
13. M10 x 200 bolt
14. Clamp (2)
15. Coolant return hose

8. Disconnect air supply tube (Figure 192) (Item 5) from Air Control Valve (ACV) (Figure 192) (Item 4) and secure out of the way.
9. Remove two bolts (Figure 192) (Item 6) securing cab heater return tube (Figure 192) (Item 3) and coolant tube (EGR cooler to LPCAC) (Figure 192) (Item 7).
10. Remove bolt (Figure 192) (Item 11) and position cab heater return tube out of the way.
11. Remove two clamps (Figure 192) (Item 14) and coolant tube (EGR cooler to LPCAC).
12. Disconnect coolant return hoses (Figure 192) (Items 12 and 15) from HP turbocharger air supply duct (Figure 192) (Item 2).

NOTE: Do not remove HP turbocharger air supply duct from HP turbocharger (Figure 192) (Item 1) at this time.

13. Remove two mounting bolts (Figure 192) (Items 9 and 13) from HP turbocharger air supply duct.

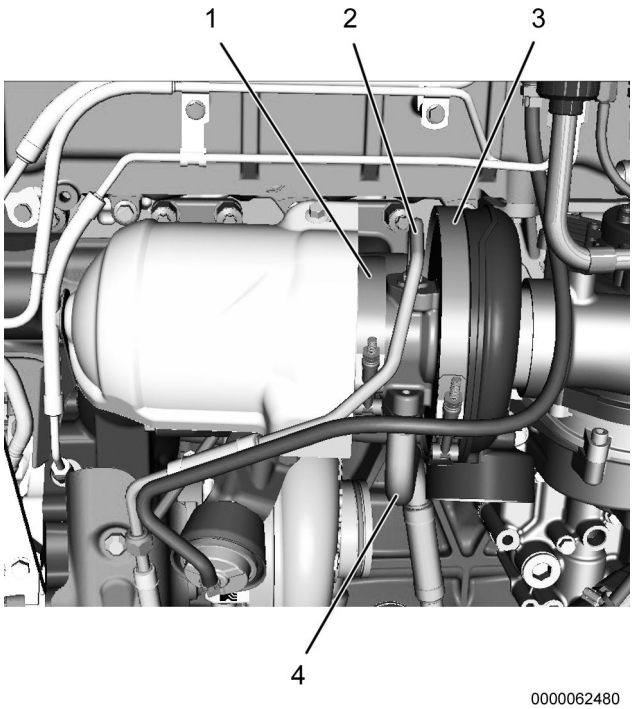

Figure 193 High-Pressure (HP) Turbocharger.

1. V-band clamp (turbine housing)
2. Turbocharger oil supply tube assembly
3. V-band clamp (compressor housing)
4. Turbocharger oil return tube

CAUTION: To prevent engine damage, do not reuse turbocharger oil supply tube.

14. Remove oil supply and oil return tubes (Figure 193) (Items 2 and 4). Discard oil supply tube. See Turbocharger Oil Return and Oil Supply Tubes (page 176).

    If oil supply tube will not come out of high-pressure turbocharger due to seizure, cut oil supply tube into two pieces and leave line in high-pressure turbocharger for ease of removal, then discard oil supply tube.

NOTE: Disconnect coolant hoses and pipes before removing HP turbocharger air supply duct.

15. Remove V-band clamp (turbine housing) (Figure 193) (Item 1). Discard V-band clamp.

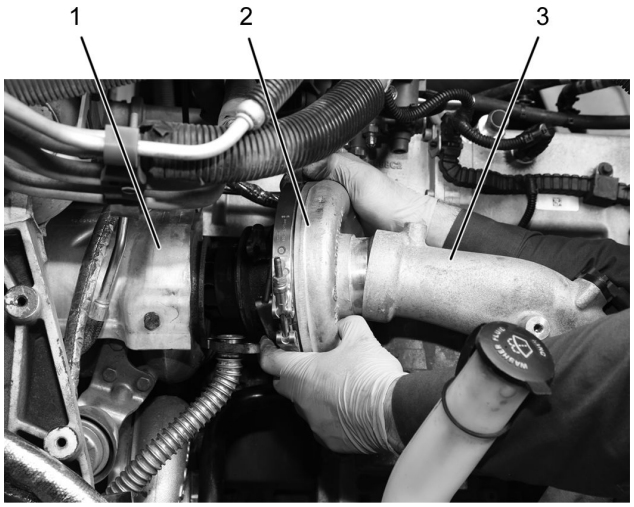

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Figure 194 HP Turbocharger Center Section Removal.

1. HP turbocharger turbine housing
2. HP turbocharger center section
3. HP turbocharger air supply duct

CAUTION: Be careful to avoid damage to turbine blades.

16. Using a soft-blow mallet, gently tap HP turbocharger center section (Figure 194) (Item 2) until loose.
17. Pull on HP turbocharger center section, maneuvering it straight out until free from turbine housing (Figure 194) (Item 1).
18. Remove HP turbocharger center section and HP turbocharger air supply duct (Figure 194) (Item 3) from engine together as a unit.
19. Separate HP turbocharger center section and HP turbocharger air supply duct. Discard 72.2 x 60 (DMR) tube seal.

Removal (Complete Engine Teardown)

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.

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.

High-Pressure (HP) Wastegate Hose

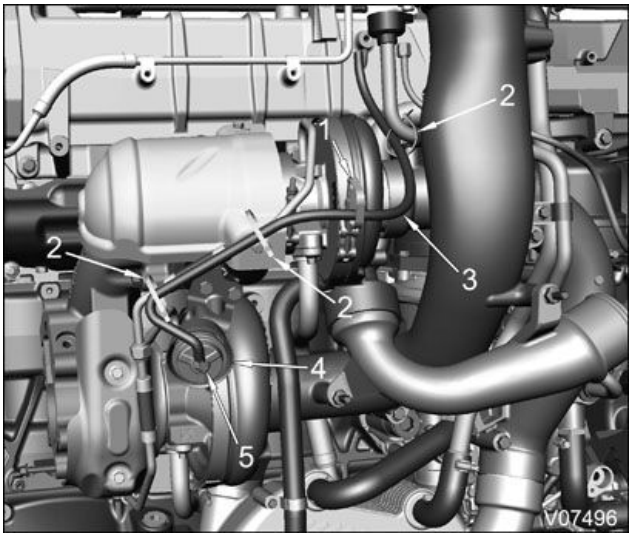

Figure 195 High-Pressure (HP) wastegate Hose.

1. Tie strap
2. Cable lock strap (3)
3. High-Pressure (HP) wastegate hose
4. High-Pressure (HP) wastegate
5. 12.3 x 7 crimp clamp

1. Cut and remove crimp clamp on HP wastegate hose on HP wastegate actuator and discard crimp clamp.
2. Cut and discard three cable lock straps.
3. Note routing of HP wastegate hose for later reassembly. Remove HP wastegate hose.
4. Inspect HP wastegate hose for damage or deformation and replace if necessary.

Low-Pressure Charge Air Cooler (LPCAC)

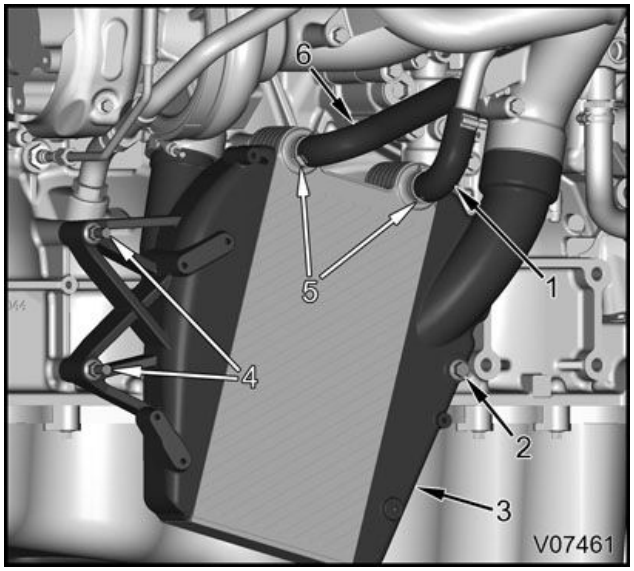

Figure 196 LPCAC and coolant hose connections.

1. Coolant hose (supply)
2. M10 x 100 bolt
3. Low-Pressure Charge Air Cooler (LPCAC)
4. M10 stud bolt (2)
5. 3/4 inch constant torque hose clamp (2)
6. Coolant return hose

NOTE: See Oil Centrifuge (page 282) for removal of the open breather tube assembly and related components.

1. Loosen 3/4 inch hose clamp and disconnect coolant hose (supply) from LPCAC.
2. Loosen 3/4 inch hose clamp and disconnect coolant return hose from LPCAC.
3. Remove M10 x 100 bolt from LPCAC.
4. Remove two M10 stud bolts from LPCAC.
5. Pull down to separate LPCAC from LP turbocharger and air supply HP turbocharger duct.

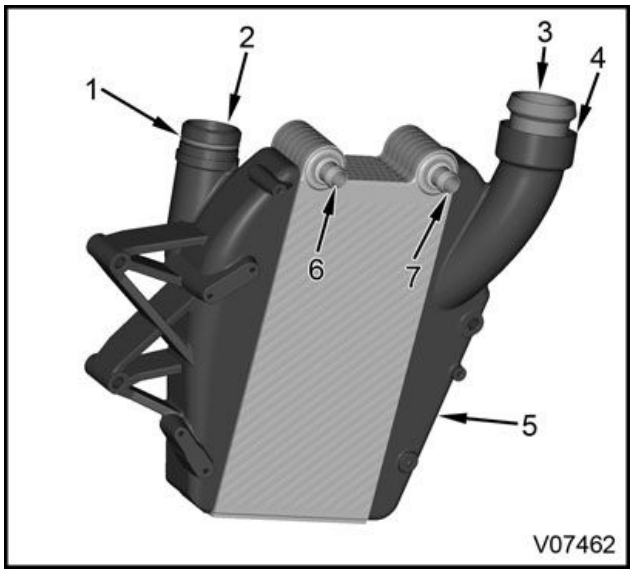

Figure 197 LPCAC connections.

1. O-ring seal
2. LPCAC air inlet
3. 72.2 x 60 (DMR) tube seal (extension tube)
4. LPCAC air outlet
5. LPCAC
6. Coolant return
7. Coolant supply

6. Remove LPCAC from engine.

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

7. Remove 72.2 x 60 (DMR) tube seal (extension tube) from LPCAC. Do so by inserting pry bar handle (or wooden dowel) into tube seal and carefully prying side-to-side to lift tube from LPCAC. Inspect sealing surfaces of tube seal and LPCAC. Discard if damaged.
8. Remove O-ring seal from LPCAC and discard.

Low-Pressure Charge Air Cooler (LPCAC) Coolant Tube and Hoses

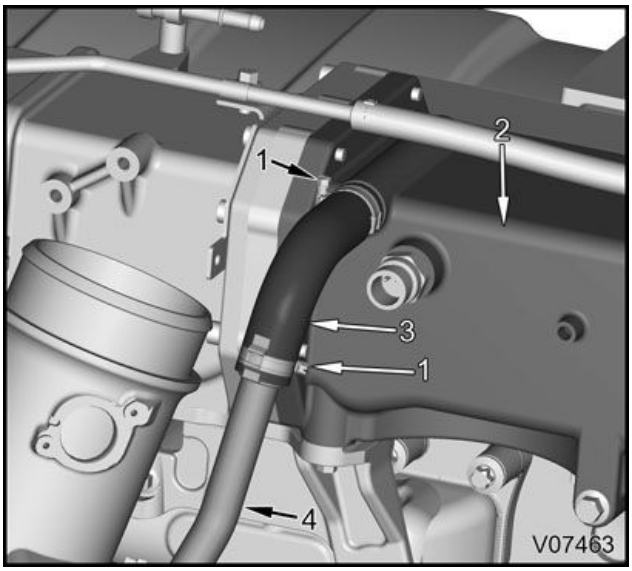

Figure 198 Coolant return hose.

1. 3/4 inch constant torque hose clamp (2)
2. Low temperature housing (EGR cooler)
3. Coolant return hose
4. Coolant tube

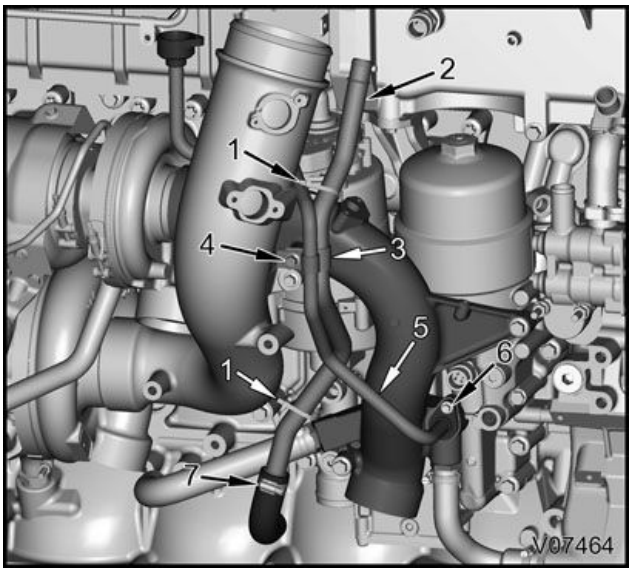

Figure 199 Coolant and cab heater tubes.

1. Cable lock strap (2)
2. Coolant tube
3. Tube support
4. M8 x 20 bolt
5. Cab heater return tube assembly
6. M6 x 20 bolt
7. 3/4 inch constant torque hose clamp

1. Loosen two 3/4 inch hose clamps.
2. Disconnect coolant return hose from low temperature housing and coolant tube.
3. Cut two cable lock straps from coolant tube.
4. Remove M8 x 20 bolt to release coolant tube support and cab heater return tube assembly retainer.
5. Remove M8 x 16 bolt and tube support behind air inlet duct. Remove M6 x 20 bolt to release cab heater return tube assembly and remove tube. Remove and discard O-ring.
6. Loosen 3/4 inch hose clamp and disconnect coolant tube from coolant hose. Remove coolant tube.

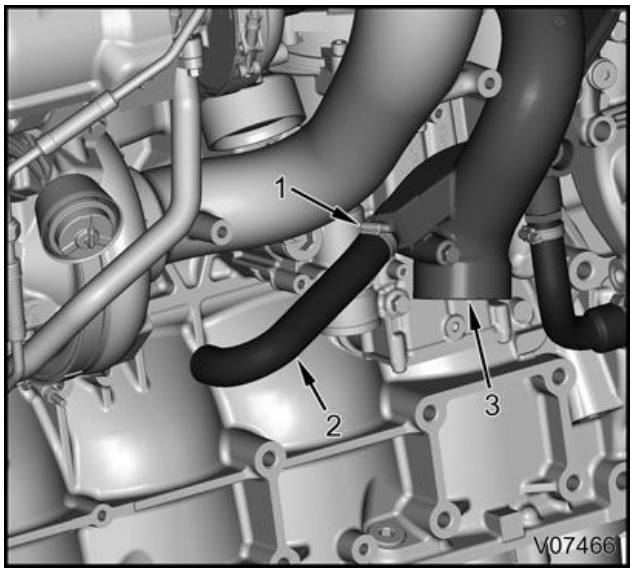

Figure 200 Coolant return hose (at HP turbocharger air supply duct).

1. 3/4 inch constant torque hose clamp
2. Coolant return hose
3. High-Pressure (HP) turbocharger air supply duct (coolant return integral with duct)

7. Loosen 3/4 inch hose clamp and disconnect coolant hose from HP turbocharger air supply duct.

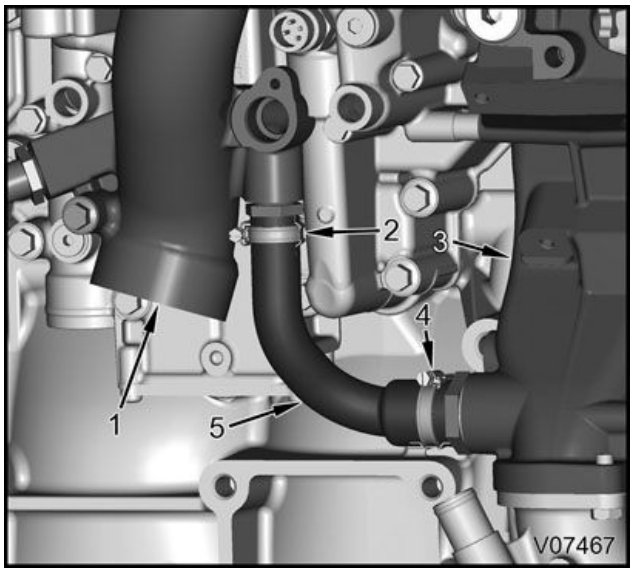

Figure 201 Coolant return hose (air supply duct to water distribution housing).

1. High-Pressure (HP) turbocharger air supply duct (coolant return integral with duct)
2. 3/4 inch constant torque hose clamp
3. Water distribution housing
4. 1 inch worm gear hose clamp
5. Coolant return hose

8. Loosen 3/4 inch hose clamp, 1 inch hose clamp and disconnect coolant return hose from air supply duct and water distribution housing.

High-Pressure (HP) Compressor Out Duct and Air Inlet Duct

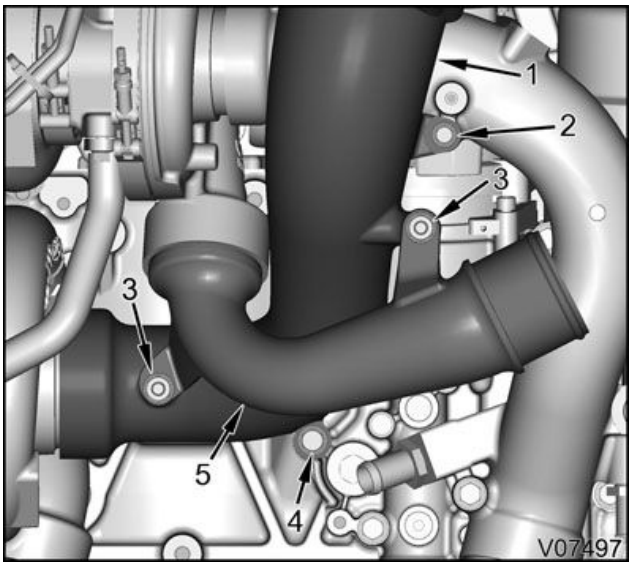

Figure 202 HP compressor out duct and air inlet duct.

1. Air inlet duct
2. M8 x 45 bolt
3. M10 x 20 x 40 stud bolt (2)
4. M10 x 140 bolt
5. HP compressor out duct

1. Remove two M10 x 20 x 40 stud bolts.
2. Disconnect HP compressor out duct from HP turbocharger compressor outlet. Remove from engine.

NOTE: The high-pressure compressor inlet seal is used in two places on the high-pressure compressor including both compressor inlet and outlet.

3. Remove high-pressure compressor inlet seal from compressor out duct and discard.
4. Remove M8 x 45 bolt and M10 x 140 bolt. Remove air inlet duct from low-pressure turbocharger.
5. Remove LP compressor inlet seal from LP turbocharger compressor inlet and discard.

High-Pressure Turbocharger Air Supply Duct

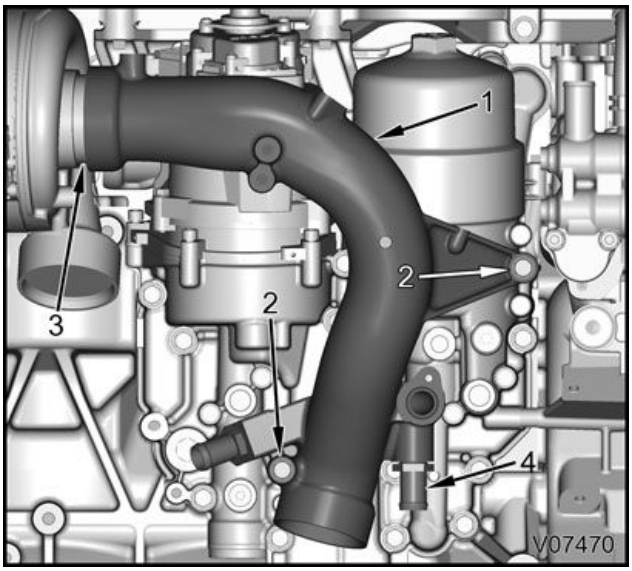

Figure 203 High-Pressure (HP) turbocharger air supply duct.

1. HP turbocharger air supply duct
2. M10 x 200 bolt (2)
3. High-pressure compressor inlet seal
4. M24 threaded fitting

1. Remove two M10 x 200 bolts and HP turbocharger air supply duct from HP turbocharger.
2. Remove HP compressor inlet seal and discard.
3. Only if required, remove M24 threaded fitting and discard seal ring.

Turbocharger Oil Return and Oil Supply Tubes

Overview

This section describes removal of turbocharger oil supply tubes after turbocharger oil supply tube retrofit. If configuration does not match this section see TSI in Appendix D .

1. Remove air intake and pipe, if not already done.
2. Remove CAC pipe from high-pressure charge air cooler and high-pressure turbocharger outlet elbow, if not already done.
3. Remove high-pressure turbocharger outlet elbow from high-pressure turbocharger, if not already done.
4. Remove air inlet duct from low-pressure turbocharger, if not already done.

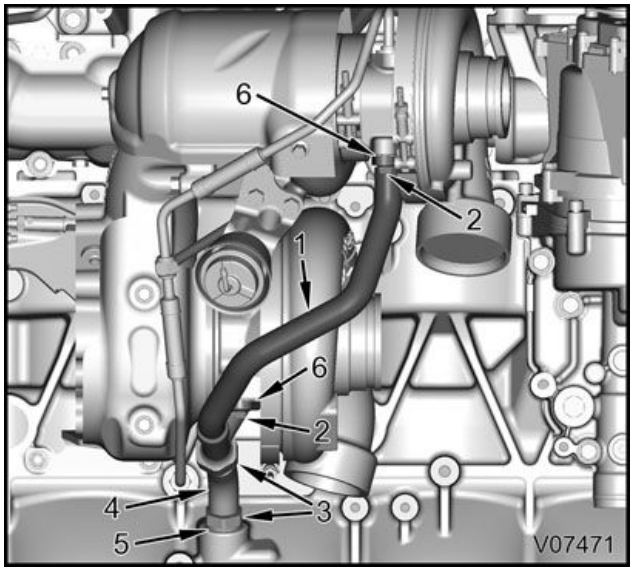

Figure 204 Turbocharger oil return tubes.

1. High-Pressure (HP) turbocharger oil return tube
2. M8 x 20 bolt (4)
3. Oil return tube fittings (2)
4. Low-Pressure (LP) turbocharger oil return tube
5. 24.7 x 32 seal ring
6. Turbocharger oil drain gasket (2)

5. Loosen LP turbocharger oil return tube fitting nut from HP turbocharger oil return tube.
6. Remove four M8 x 20 bolts and disconnect HP oil return tube from HP and LP turbocharger and LP oil return tube.
7. Remove and discard two turbocharger oil drain gaskets.
8. Remove and discard bonded seal washer between HP and LP turbocharger oil return tubes.
9. Remove LP turbocharger oil return tube from crankcase and discard 24.7 x 32 seal ring.

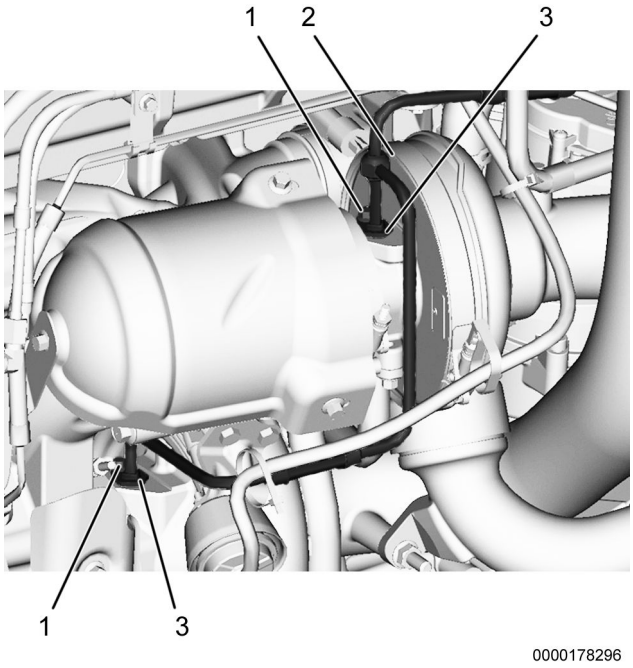

Figure 205 Turbocharger Oil Supply Tube.

1. M6 X 16 bolt (2)
2. High-pressure turbocharger
3. Oil supply tube flange(s)

10. Remove two M6 X 16 bolts (Figure 205) (Item 1). Retain bolts for future use.

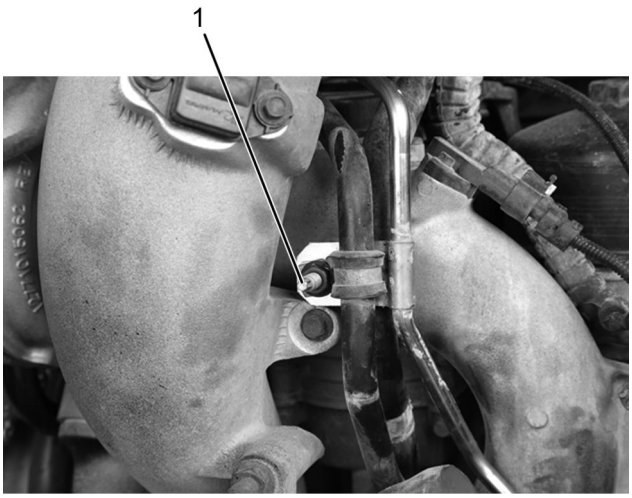

Figure 206 Heater and Cooler Line Bracket Stud Bolt.

1. M8 stud bolt

11. Remove M8 stud bolt (Figure 206) (Item 1) from heater and cooler line brackets (Figure 207) (Item 4).

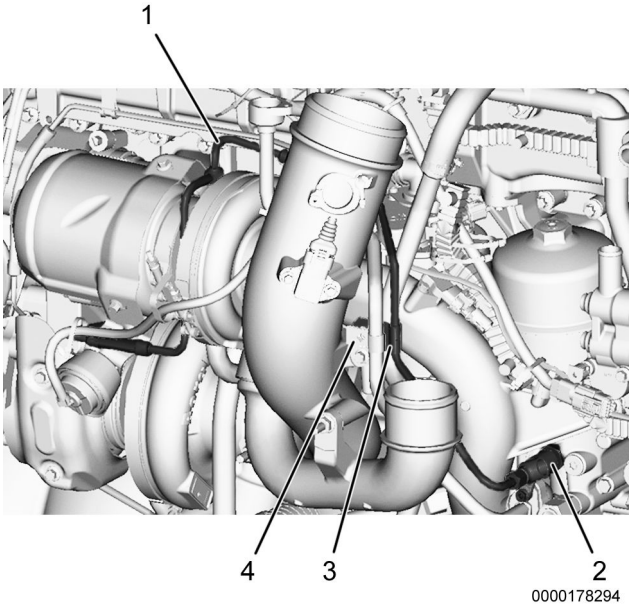

Figure 207 Turbocharger Oil Supply Tube.

1. Turbocharger oil supply tube
2. Oil supply T-fitting
3. Turbocharger oil supply tube bracket
4. Heater and cooler line brackets

CAUTION: To prevent engine damage, do not reuse turbocharger oil supply tube.

12. Remove turbocharger oil supply tube (Figure 207) (Item 1) from LP turbocharger, HP turbocharger, and oil supply T-fitting (Figure 207) (Item 2) and discard oil supply tube.

    If oil supply tube will not come out of the high-pressure turbocharger due to seizure, cut the oil supply tube into two pieces and leave the line in high-pressure turbocharger for ease of removal, then discard oil supply tube pieces.

Turbocharger Heat Shields

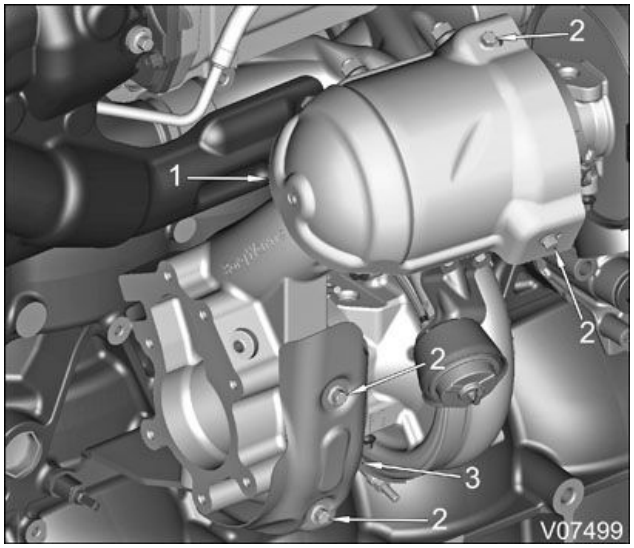

Figure 208 Turbocharger heat shields.

1. HP turbocharger heat shield
2. M8 x 16 bolt (4)
3. Turbocharger heat shield

1. Remove two M8 x 16 bolts and HP turbocharger heat shield.
2. Remove two M8 x 16 bolts and turbocharger heat shield.

Turbocharger Support Bracket

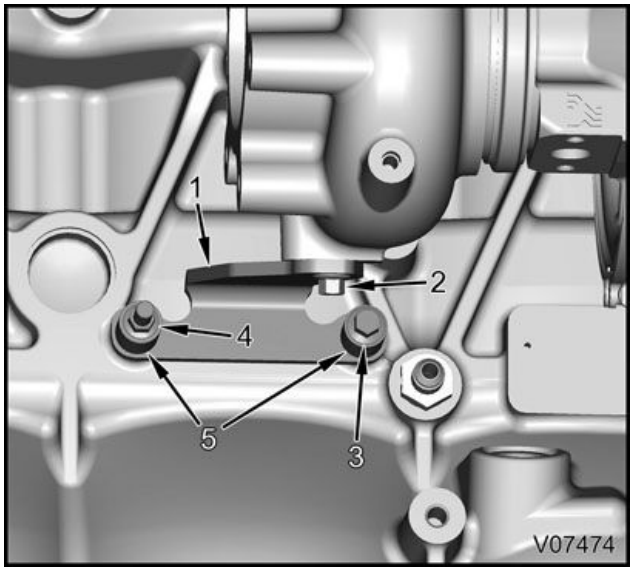

Figure 209 Turbocharger support bracket.

1. Turbocharger support bracket
2. M8 x 16 bolt
3. M8 x 40 bolt
4. M8 x 40 x 15 stud bolt
5. 19 x 20 spacer (2)

1. Remove M8 x 16 bolt at bottom of LP turbocharger.
2. Remove M8 x 40 bolt, M8 x 40 x 15 stud bolt, two spacers and support bracket.

High-Pressure (HP) Turbocharger Wastegate Actuator

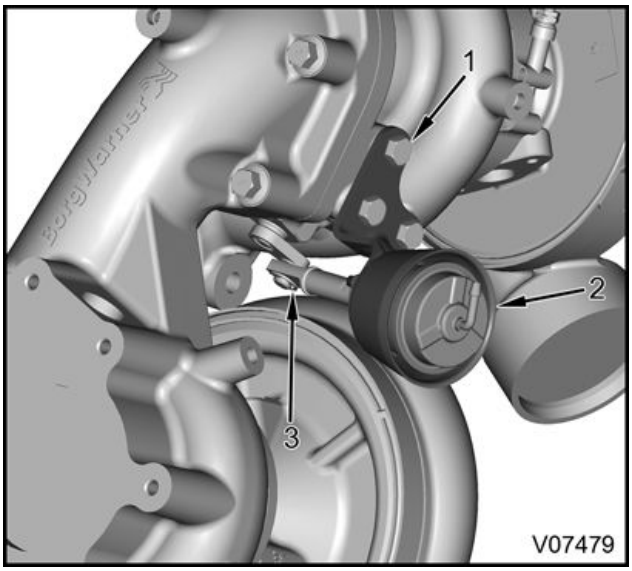

Figure 210 High-Pressure (HP) wastegate actuator.

1. M8 x 14 bolt (3)
2. HP wastegate actuator
3. C-clip

NOTE: It is not necessary to remove the HP wastegate actuator to remove the turbocharger. The turbocharger and HP wastegate actuator can be removed as an assembly.

1. Remove C-clip from HP actuator wastegate linkage.
2. Remove three M8 x 14 bolts.
3. Remove HP wastegate actuator.

Turbocharger Mounting

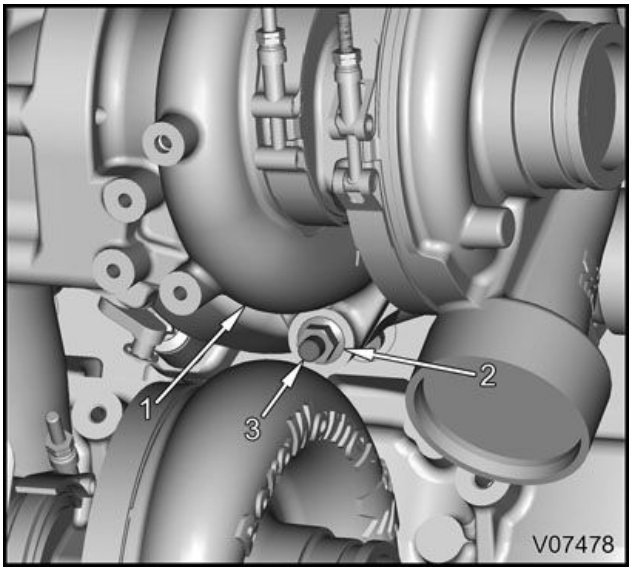

Figure 211 HP turbocharger mounting (lower nut).

1. HP turbocharger assembly
2. M10 nut
3. M10 x 45 stud

WARNING: To prevent personal injury or death, use suitable lifting equipment and get help to remove or install the turbochargers.

1. Get help from an assistant to support turbochargers during removal. Remove M10 nut.

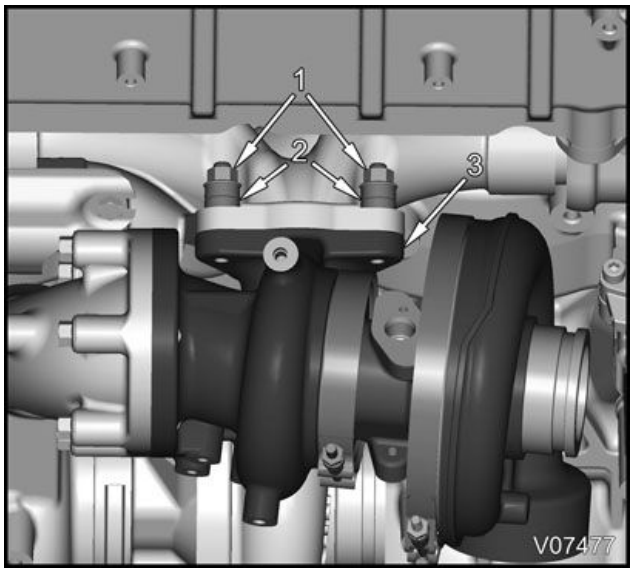

Figure 212 High-Pressure (HP) turbocharger mounting (upper nuts and sleeves).

1. M10 nut (2)
2. 10.5 x 20 x 15 sleeve (2)
3. HP turbocharger mounting flange

2. Remove two M10 nuts and two 10.5 x 20 x 15 sleeves.
3. Remove turbochargers from middle exhaust manifold.

Disassembly

Turbochargers

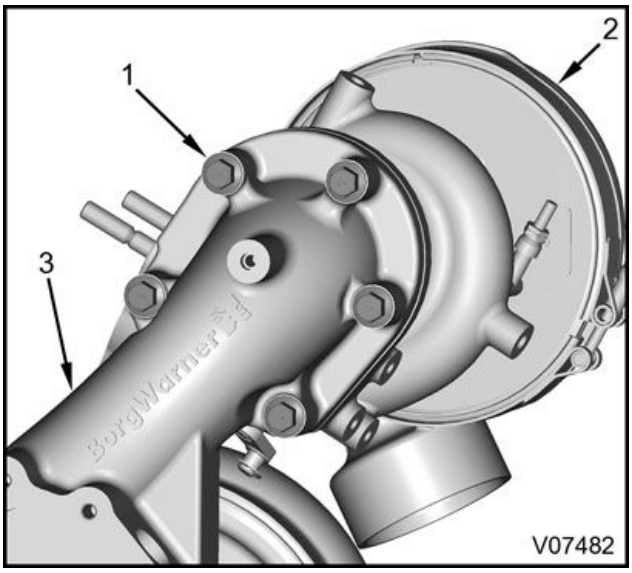

Figure 213 High-Pressure (HP) and Low-Pressure (LP) turbocharger connection.

1. M10 x 55 bolt (5)
2. HP turbocharger assembly
3. LP turbocharger assembly

1. Remove five M10 x 55 bolts and separate HP turbocharger from LP turbocharger.
2. Inspect mating flanges and two dowel pins for damage. Replace if necessary.

Cleaning, Inspection, and Testing

Turbochargers and Related Parts Cleaning

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

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

1. Clean ducting between air inlet duct and air cleaner assembly with soap and then, steam clean. Dry all ducting with filtered compressed air.
2. Clean Low-Pressure Charge Air Cooler (LPCAC), air inlet duct, and high-pressure turbocharger duct with filtered compressed air.

NOTE: Do not reuse turbocharger oil supply tube. Install new.

3. Clean turbocharger oil return tube with a non-chlorinated solvent and a nylon brush. Dry tubes with filtered compressed air. Replace any damaged tubes.
4. Clean all gasket and O-ring sealing surfaces.

High-Pressure (HP) Turbocharger Turbine Housing Cleaning

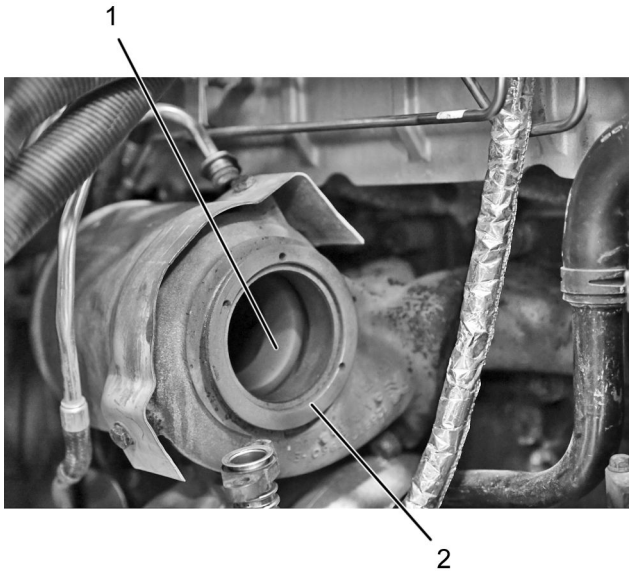

Figure 214 HP Turbocharger Turbine Housing.

1. HP turbocharger turbine housing
2. HP turbocharger turbine housing exterior flange

1. Using suitable solvent and clean emery cloth, clean inside HP turbocharger turbine housing (Figure 214) (Item 1) and HP turbocharger turbine housing exterior flange (Figure 214) (Item 2).

Turbocharger Inspection

CAUTION: To prevent engine damage, do not damage compressor impeller or turbine wheel. If either is damaged, a new turbocharger must be installed.

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

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

3. Turn shafts by hand and check for impeller and wheel rub in the housings.

Low-Pressure Charge Air Cooler (LPCAC) Pressure Test — correction

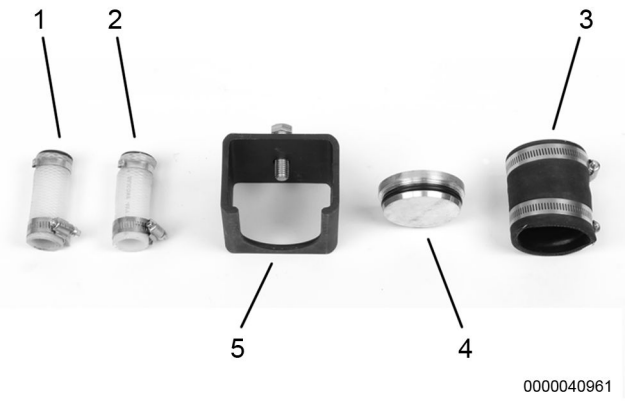

Figure 215 Charge Air Cooler Test Kit ZTSE6042

1. Coolant Port Plug (with 1/4” NPT hole), ZTSE6042-1
2. Coolant Port Plug (solid), ZTSE6042-2
3. Air Inlet Plug (with 1/4” NPT hole), ZTSE6042-3
4. Air Outlet Disc Plug, ZTSE6042-4
5. Air Outlet Disc Plug Retaining Bracket, ZTSE6042-4A
6. empty — delete

1. Remove LPCAC from engine.

WARNING: To prevent personal injury or death, ensure Charge Air Cooler Test Kit components are tightened properly; otherwise, they can explode while LPCAC is under pressure.

WARNING: To prevent personal injury or death, ensure LPCAC air inlet and outlet, O-rings are removed and that no lubricant is on sealing surface. O-ring and lubricant can cause the LPCAC Pressure Test Kit components to explode while LPCAC is under pressure.

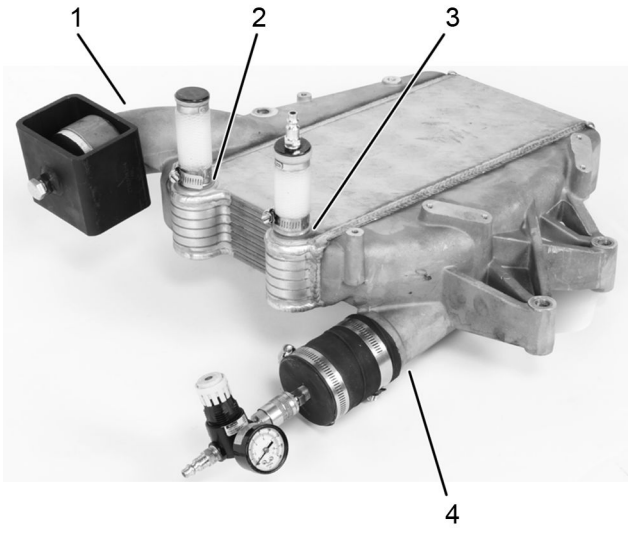

Figure 216 Pressure test on air side of LPCAC

1. LPCAC air outlet
2. LPCAC coolant return port
3. LPCAC coolant supply port
4. LPCAC air inlet

2. Attach Charge Air Cooler Test Kit to LPCAC.
   - Obtain 3-inch couplers and clamps locally.
3. Cover LPCAC air outlet (Figure 216) (Item 1) with Air Outlet Disc Plug ZTSE6042-4.
4. Install Air Outlet Disc Plug Retaining Bracket ZTSE6042-4A on top of ZTSE6042-4. Tighten clamping bolt to seal LPCAC air outlet.
5. Attach Air Inlet Plug (with 1/4″ NPT hole) ZTSE6042-3 to LPCAC air inlet (Figure 216) (Item 4), and tighten clamps.
6. Attach Coolant Port Plug (solid) ZTSE6042-2 to LPCAC coolant return port (Figure 216) (Item 2). Tighten clamp.
7. Attach Coolant Port Plug (with 1/4″ NPT hole) ZTSE6042-1 to LPCAC coolant supply port (Figure 216) (Item 3). Tighten clamp.

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

8. Connect locally obtained regulator with shop air source, and pressurize the air side of LPCAC to 30 psi (207 kPa).
9. Spray a soapy water solution on LPCAC. Look for leaks from hose connections, LPCAC, or test components.
10. If a leak is detected on LPCAC or test gauge pressure drops, replace LPCAC.

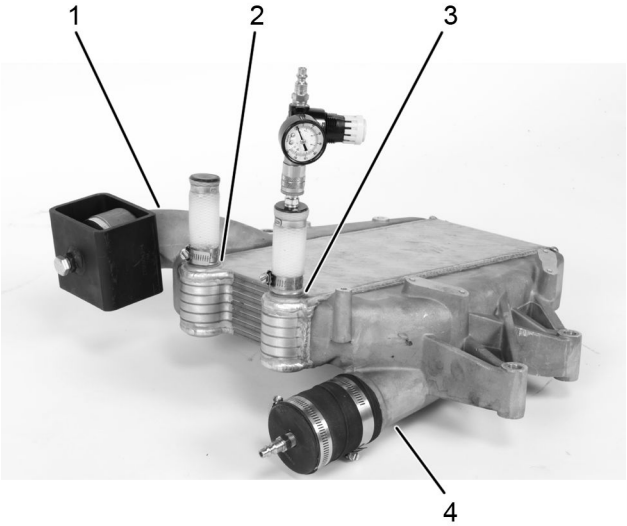

Figure 217 Pressure test on coolant side of Low-Pressure Charge Air Cooler (LPCAC)

1. LPCAC air outlet
2. LPCAC coolant return port
3. LPCAC coolant supply port
4. LPCAC air inlet

11. Connect regulator with shop air source, and pressurize the coolant side of LPCAC to 30 psi (207 kPa).
12. Spray a soapy water solution on LPCAC. Look for leaks from hose connections, LPCAC, or test components.
13. If a leak is detected on LPCAC or test gauge pressure drops, replace LPCAC.
14. Remove Charge Air Cooler Test Kit from LPCAC.

High-Pressure Charge Air Cooler (HPCAC) Pressure Test

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

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

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields.

Figure 218 CAC Cleaning Adapter Kit (Off Chassis) 09-925-01 With CAC Pressure Test Kit ZTSE4341 Installed

1. CAC Pressure Test Kit ZTSE4341

NOTE: Optional Charge Air Cooler (CAC) Pressure Test Kit ZTSE4341 (Figure 218) (Item 1) shown installed in the CAC Cleaning Adapter Kit 09-925-01 carrying case. CAC Pressure Test Kit is not part of CAC Cleaning Adapter Kit , but allows for storage in the carrying case.

1. Remove High-Pressure Charge Air Cooler (HPCAC) from vehicle. See appropriate Radiator / Cooling System Service Manual.
2. Place HPCAC on a flat surface.

3. Visually inspect HPCAC for cracks, holes, and other damage. If cracked or damaged, replace HPCAC.

⚠ WARNING: To prevent personal injury or death, clean all hoses and other pressure test components of oil, grease, or other lubricants before connecting.

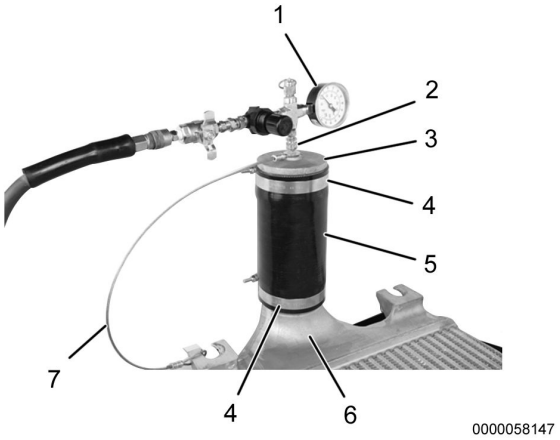

Figure 219 CAC Pressure Test Kit Installed on HPCAC Outlet

1. Gauge / regulator assembly
2. Quick disconnect fitting
3. Gauge coupler
4. T-clamp (2)
5. Large hose
6. High-Pressure Charge Air Cooler (HPCAC) outlet
7. Safety cable

4. Install large hose (Figure 219) (item 5) and T-clamp onto HPCAC outlet (Figure 219) (item 6). Tighten T-clamp (Figure 219) (item 4) securing large hose to HPCAC outlet to 55 lb·in (6.2 N·m).
5. Install gauge coupler (Figure 219) (item 3) and T-clamp onto large hose. Tighten T-clamp securing gauge coupler to large hose to 55 lb·in (6.2 N·m).
6. Connect safety cable (Figure 219) (item 7) to a known good anchor point.
7. Attach gauge / regulator assembly (Figure 219) (item 1) onto quick disconnect fitting (Figure 219) (item 2).

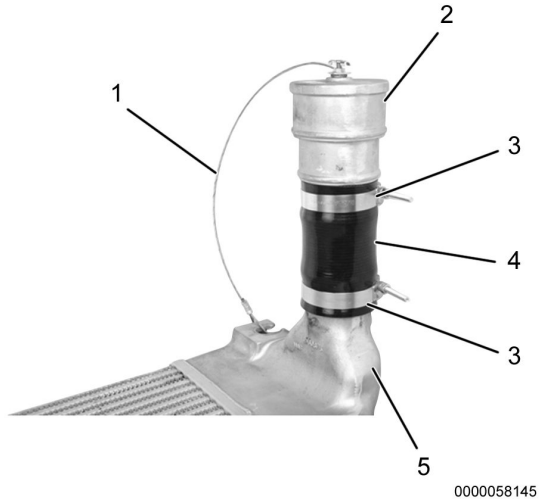

Figure 220 Bleed-Off Coupler Installed On HPCAC Inlet

1. Safety cable
2. Bleed-off coupler
3. T-clamp (2)
4. Small hose
5. High-Pressure Charge Air Cooler (HPCAC) Inlet

8. Install small hose (Figure 220) (Item 4) and T-clamp (Figure 220) (Item 3) onto HPCAC inlet (Figure 220) (Item 5). Tighten T-clamp (Figure 220) (Item 3) securing small hose to HPCAC inlet to 55 lb·in (6.2 N·m).
9. Install bleed-off coupler (Figure 220) (Item 2) and T-clamp onto small hose. Tighten T-clamp securing bleed-off coupler to small hose to 55 lb·in (6.2 N·m).
10. Connect safety cable (Figure 220) (Item 1) to a known good anchor point.

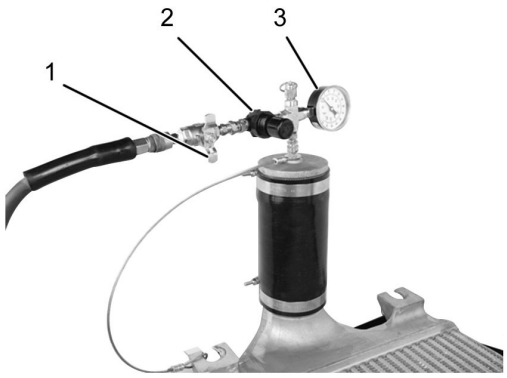

Figure 221 Gauge / Regulator Assembly Connections

1. Air valve
2. Air regulator knob
3. Gauge

⚠ WARNING: To prevent personal injury or death, attach safety cables to High-Pressure Charge Air Cooler (HPCAC) or a known good anchor point.

CAUTION: Adjust air regulator valve to minimum setting before connecting shop air supply. Accidentally applying high-pressure can damage tool components or the High-Pressure Charge Air Cooler (HPCAC).

11. Connect filtered shop air supply to air valve (Figure 221) (item 1) on gauge / regulator assembly.

⚠ WARNING: To prevent personal injury or death, increase air pressure slowly to prevent coupler blowing-out during testing.

12. Open air valve slightly, and slowly increase air pressure until gauge (Figure 221) (Item 3) reads 30 psi (205 kPa). If needed, adjust air regulator knob (Figure 221) (Item 2) as follows until gauge reads 30 psi (205 kPa):
    a. Pull air regulator knob outward to unlock.
    b. Turn air regulator knob to adjust pressure to 30 psi (205 kPa).
    c. Push air regulator knob inward back into locked position.
13. Close air valve and monitor gauge pressure for 15 seconds.
    - If air pressure drops more than 5 psi (34 kPa), replace HPCAC.
    - If air pressure drops 5 psi (34 kPa) or less, perform cleaning procedure. See High-Pressure Charge Air Cooler (HPCAC) Cleaning (page 188)
14. Repeat steps 12 and 13 three times to verify results.

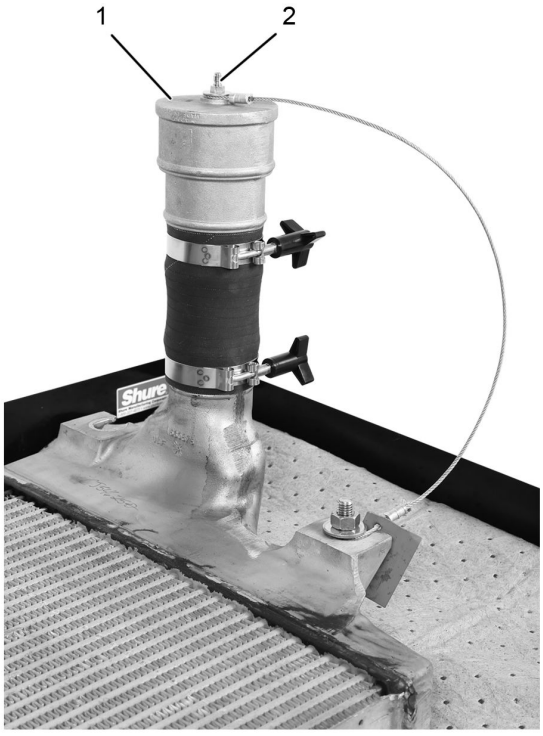

Figure 222 Bleed-Off Coupler Components

1. Bleed-off coupler
2. Bleed-off valve

⚠ WARNING: To prevent personal injury or death, relieve air pressure through bleed-off valve slowly before removing test equipment.

15. Slowly turn bleed-off valve (Figure 222) (Item 2) on bleed-off coupler (Figure 222) (Item 1) counterclockwise, and release air from system.
16. Disconnect filtered shop air supply from air valve on gauge / regulator assembly.

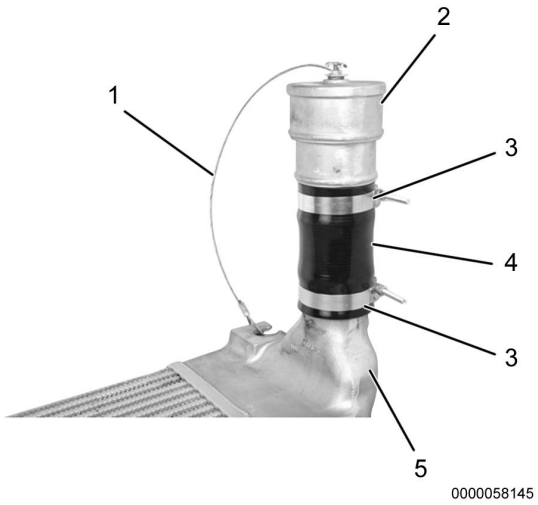

Figure 223 Bleed-Off Coupler Installed On HPCAC Inlet

1. Safety cable
2. Bleed-off coupler
3. T-clamp (2)
4. Small hose
5. High-Pressure Charge Air Cooler (HPCAC) inlet

17. Disconnect safety cable (Figure 223) (Item 1) from anchor point.
18. Remove bleed-off coupler (Figure 223) (Item 2) and T-clamp (Figure 223) (Item 4) from small hose.
19. Remove small hose (Figure 223) (item 4) and T-clamp from HPCAC inlet (Figure 223) (item 5).

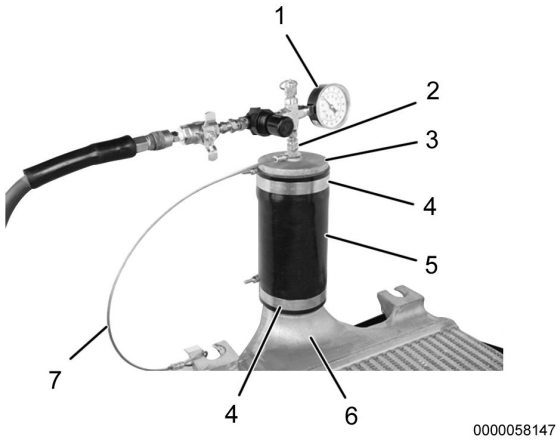

Figure 224 CAC Pressure Test Kit Installed on HPCAC Outlet

1. Gauge / regulator assembly
2. Quick disconnect fitting
3. Gauge coupler
4. T-clamp (2)
5. Large hose
6. High-Pressure Charge Air Cooler (HPCAC) outlet
7. Safety cable

20. Remove gauge / regulator assembly (Figure 224) (item 1) from quick disconnect fitting (Figure 224) (item 2).
21. Remove safety cable (Figure 224) (item 7) from anchor point.
22. Remove gauge coupler (Figure 224) (item 3) and T-clamp (Figure 224) (Item 4) from large hose (Figure 224) (Item 5).
23. Remove large hose and T-clamp from HPCAC outlet (Figure 224) (item 6).

High-Pressure Charge Air Cooler (HPCAC) Cleaning

Figure 225 Cleaning Management System 12-353-01 Components

1. Timer 12-353-01-01
2. Heater 12-353-01-8
3. FLOW FROM PUMP hose 12-353-01-02
4. Front EGR cooler cleaning adapter 12-353-01-04
5. Cam-lock cap 12-353-01-06
6. Rear EGR cooler cleaning adapter 12-353-01-05
7. FLOW RETURN hose 12-353-01-3
8. Air blower 12-353-01-7
9. Container 12-353-01-17
10. HEATER / PUMP Switch Assembly 12-353-01-9

1. Clean the Cleaning Management System container (Figure 225) (Item 9) before use.

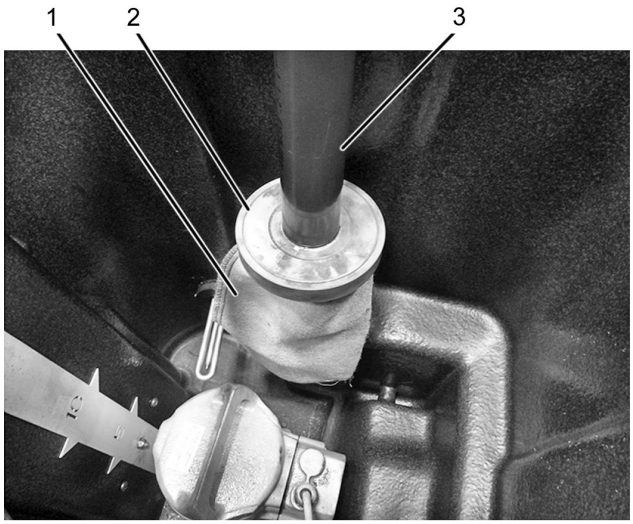

Figure 226 CMS Filter and Components

1. Filter sock
2. Coupler
3. Flow return tube

2. Inspect and clean the filter sock (Figure 226) (Item 1). Replace as needed.
    a. Loosen coupler (Figure 226) (Item 2) on flow return tube (Figure 226) (Item 3).
    b. Remove filter from coupler.
    c. Install filter in coupler.
    d. Tighten coupler on flow return tube. Torque only needs to be hand tight.

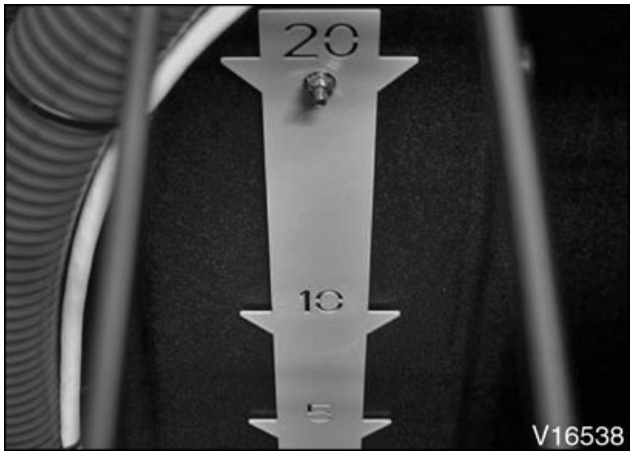

Figure 227 Level Gauge

3. Add 5 US gal (19L) of tap water to Cleaning Management System (CMS) reservoir first, followed by 5 US gal (19L) of EGR cleaning fluid 2512460C1.
4. Turn On the heating element by positioning PUMP / HEATER switch (Figure 225) (Item 10) CMS to HEATER. Allow temperature to reach approximately 130°F (54°C).

NOTE: If not already done, remove High-Pressure Charge Air Cooler (HPCAC) from vehicle and place on a flat surface. See appropriate Radiator / Cooling System Service Manual.

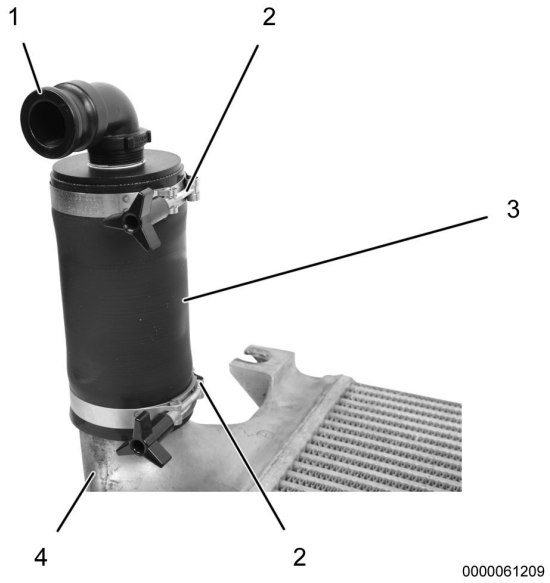

Figure 228 CAC Cleaning Adapter Kit 09-925-01 Installed on HPCAC Outlet

1. CAC adapter 09-925-01-01
2. T-clamp (2)
3. Large hose
4. High-Pressure Charge Air Cooler (HPCAC) outlet

5. With High-Pressure Charge Air Cooler (HPCAC) on a flat surface, install large hose (Figure 228) (item 3) and T-clamp (Figure 228) (item 2) onto HPCAC outlet (Figure 228) (item 4). Tighten T-clamp securing large hose to HPCAC outlet to 55 lb·in (6.2 N·m).
6. Install CAC adapter (Figure 228) (item 1) and T-clamp onto large hose. Tighten T-clamp securing CAC adapter to large hose to 55 lb·in (6.2 N·m).

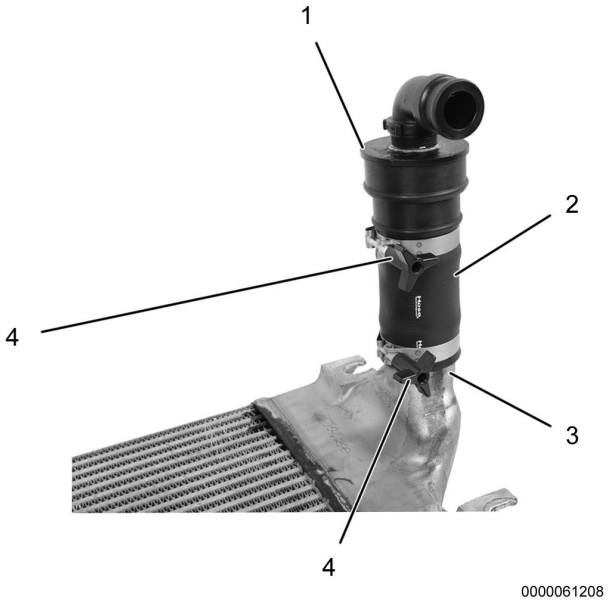

Figure 229 CAC Cleaning Adapter Kit 09-925-01 Installed on HPCAC Inlet

1. CAC adapter 09-925-01-01
2. Small hose
3. High-Pressure Charge Air Cooler (HPCAC) inlet
4. T-clamp (2)

7. Install small hose (Figure 229) (item 2) and T-clamp (Figure 229) (item 4) onto HPCAC inlet (Figure 229) (item 3). Tighten T-clamp securing small hose to HPCAC inlet to 55 lb·in (6.2 N·m).
8. Install CAC adapter (Figure 229) (item 1) and T-clamp onto small hose. Tighten T-clamp securing CAC adapter to small hose to 55 lb·in (6.2 N·m).

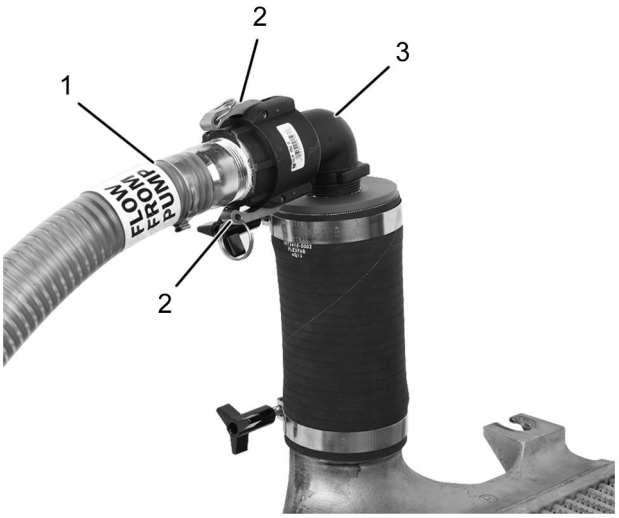

Figure 230 FLOW FROM PUMP Hose Connected

1. FLOW FROM PUMP hose
2. Lever (2)
3. CAC adapter

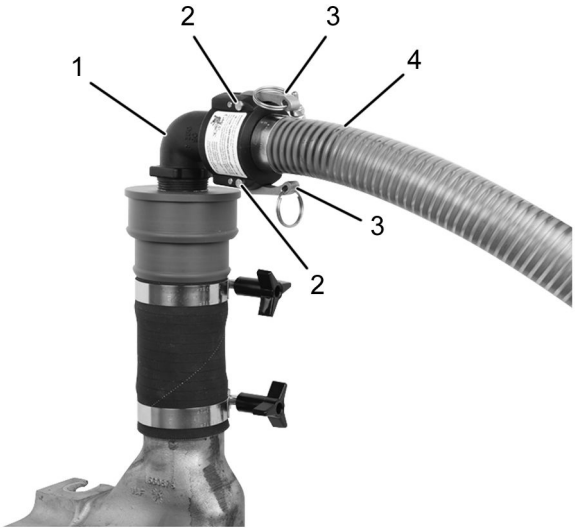

Figure 231 FLOW RETURN Hose Connected

1. CAC adapter
2. Pin (2)
3. Lever (2)
4. FLOW RETURN hose

Back-Flush With Water and EGR Cleaning Fluid:

9. Slide FLOW FROM PUMP hose (Figure 230) (item 1) onto CAC adapter (Figure 230) (item 3) until it bottoms out. Then push both levers (Figure 230) (item 2) on FLOW FROM PUMP hose inward to secure FLOW FROM PUMP hose to CAC adapter. Pull outward on FLOW FROM PUMP hose to verify it is securely attached.
10. Slide FLOW RETURN hose (Figure 231) (item 4) onto CAC adapter (Figure 231) (item 1) until it bottoms out. Then push both levers (Figure 231) (item 3) on FLOW RETURN hose inward to secure FLOW RETURN hose to CAC adapter. Pull outward on FLOW RETURN hose to verify it is securely attached.
11. Set and start timer (Figure 225) (Item 1) on CMS to 20 minutes, position PUMP / HEATER switch (Figure 225) (Item 10) to PUMP, and allow CMS to back-flush HPCAC.
12. After back-flush is complete, position PUMP / HEATER switch to OFF.
13. Press both pins (Figure 231) (item 2) inward on levers securing FLOW RETURN hose to CAC adapter, while simultaneously pulling out on levers. Remove FLOW RETURN hose from CAC adapter.
14. Press both pins inward on levers securing FLOW FROM PUMP hose to CAC adapter, while simultaneously pulling out on levers. Remove FLOW FROM PUMP hose from CAC adapter.

Forward-Flush With Water and EGR Cleaning Fluid:

15. Slide FLOW RETURN hose onto CAC adapter until it bottoms out. Then push both levers on FLOW RETURN hose inward to secure FLOW RETURN hose to CAC adapter. Pull outward on FLOW RETURN hose to verify it is securely attached.
16. Slide FLOW FROM PUMP hose onto CAC adapter until it bottoms out. Then push both levers on FLOW FROM PUMP hose inward to secure FLOW FROM PUMP hose to CAC adapter. Pull outward on FLOW FROM PUMP hose to verify it is securely attached.
17. Set and start timer on CMS to 20 minutes, position PUMP / HEATER switch to PUMP, and allow CMS to forward-flush HPCAC.
18. After forward-flush is complete, position PUMP / HEATER switch to OFF.
19. Press both pins inward on levers securing FLOW FROM PUMP hose to CAC adapter, while simultaneously pulling out on levers. Remove FLOW FROM PUMP hose from CAC adapter.
20. Press both pins inward on levers securing FLOW RETURN hose to CAC adapter, while simultaneously pulling out on levers. Remove FLOW RETURN hose from CAC adapter.
21. Drain and clean CMS.

Back-Flush With Water:

22. Add 10 US gal (38L) of tap water to Cleaning Management System (CMS) reservoir.
23. Slide FLOW FROM PUMP hose (Figure 230) (item 1) onto CAC adapter (Figure 230) (item 3) until it bottoms out. Then push both levers (Figure 230) (item 2) on FLOW FROM PUMP hose inward to secure FLOW FROM PUMP hose to CAC adapter. Pull outward on FLOW FROM PUMP hose to verify it is securely attached.
24. Slide FLOW RETURN hose (Figure 231) (item 4) onto CAC adapter (Figure 231) (item 1) until it bottoms out. Then push both levers (Figure 231) (item 3) on FLOW RETURN hose inward to secure FLOW RETURN hose to CAC adapter. Pull outward on FLOW RETURN hose to verify it is securely attached.
25. Set and start timer on CMS to 10 minutes, position PUMP / HEATER switch to PUMP, and allow CMS to back-flush HPCAC.
26. After back-flush is complete, position PUMP / HEATER switch to OFF.
27. Press both pins (Figure 231) (item 2) inward on levers securing FLOW RETURN hose to CAC adapter, while simultaneously pulling out on levers. Remove FLOW RETURN hose from CAC adapter.
28. Press both pins inward on levers securing FLOW FROM PUMP hose to CAC adapter, while simultaneously pulling out on levers. Remove FLOW FROM PUMP hose from CAC adapter.
29. Tip HPCAC on it's side, and drain remaining water into a suitable container.
30. Drain and clean CMS.

Forward-Flush With Water:

31. Slide FLOW RETURN hose onto CAC adapter until it bottoms out. Then push both levers on FLOW RETURN hose inward to secure FLOW RETURN hose to CAC adapter. Pull outward on FLOW RETURN hose to verify it is securely attached.
32. Slide FLOW FROM PUMP hose onto CAC adapter until it bottoms out. Then push both levers on FLOW FROM PUMP hose inward to secure FLOW FROM PUMP hose to CAC adapter. Pull outward on FLOW FROM PUMP hose to verify it is securely attached.
33. Set and start timer on CMS to 10 minutes, position PUMP / HEATER switch to PUMP, and allow CMS to forward-flush HPCAC.
34. After forward-flush is complete, position PUMP / HEATER switch to OFF.
35. Press both pins inward on levers securing FLOW FROM PUMP hose to CAC adapter, while simultaneously pulling out on levers. Remove FLOW FROM PUMP hose from CAC adapter.
36. Press both pins inward on levers securing FLOW RETURN hose to CAC adapter, while simultaneously pulling out on levers. Remove FLOW RETURN hose from CAC adapter.

37. Tip HPCAC on it's side, and drain remaining water into a suitable container.
38. Drain and clean CMS.
39. Dry HPCAC with filtered compressed air.

Installation

Turbocharger Mounting

⚠ WARNING: To prevent personal injury or death, use suitable lifting equipment and get help to remove or install the turbochargers.

⚠ WARNING: To prevent personal injury or death, do not allow the turbochargers to hang by the lower stud and nut alone. Support the assembly until the upper sleeves and nuts are installed.

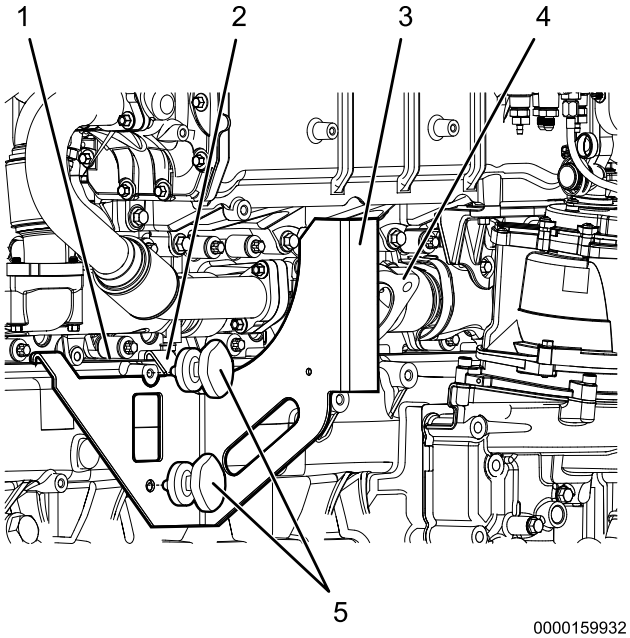

Figure 232 Turbocharger alignment tool installation

1. Crankcase-to-cylinder head deck
2. Tab
3. Turbo Alignment Bracket (ZTSE6041)
4. Middle exhaust manifold
5. Hand screw (2)

1. Install Turbo Alignment Bracket ZTSE6041 (Figure 232) (Item 3) on engine with tabs (Figure 232) (Item 2) seated on crankcase-to-cylinder head deck (Figure 232) (Item 1).
2. Thread tool hand screws (Figure 232) (Item 5) into crankcase boss and tighten to secure bracket in place.

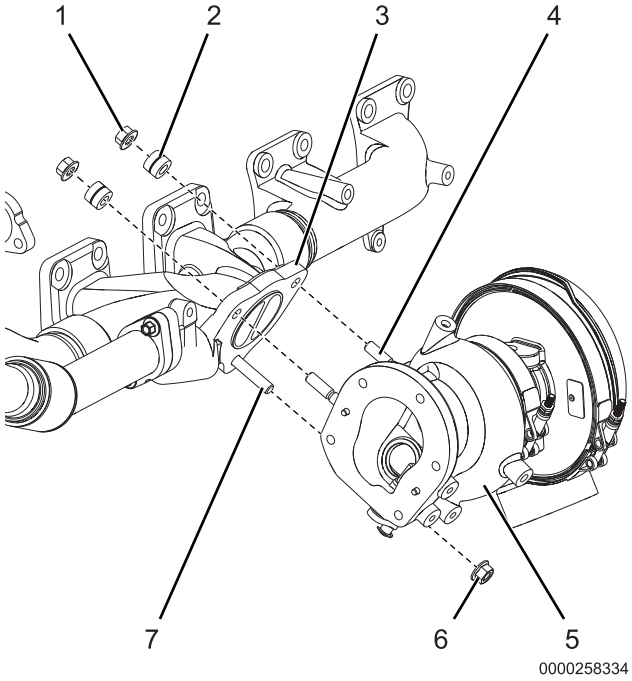

Figure 233 High-Pressure (HP) turbocharger mounting stud alignment (engine not shown)

1. M10 nut (2)
2. 10.5 x 20 x 15 sleeve (2)
3. Middle exhaust manifold
4. Upper mounting stud (2)
5. HP turbocharger
6. M10 nut
7. M10 x 45 stud

3. With help of an assistant, align three studs (Figure 233) (Items 4, 7) and position HP turbocharger (Figure 233) (Item 5) to middle exhaust manifold (Figure 233) (Item 3).
4. With turbocharger supported in place, install two 10.5 x 20 x 15 sleeves (Figure 233) (Item 2) and two new M10 nuts (Figure 233) (Item 1) on upper mounting studs (Figure 233) (Item 4). Finger-tighten nuts.
5. Install new M10 nut (Figure 233) (Item 6) on M10 x 45 stud (Figure 233) (Item 7), finger tight.

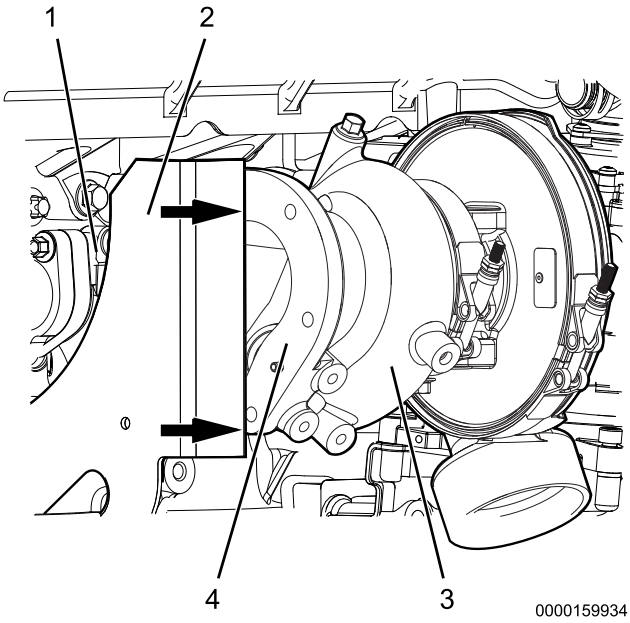

Figure 234 High-Pressure (HP) turbocharger alignment check

1. Middle exhaust manifold
2. Turbo Alignment Bracket (ZTSE6041)
3. HP turbocharger
4. Turbine exhaust outlet flange

NOTE: When installing HP turbocharger, turbine exhaust outlet flange must be aligned square with turbo alignment bracket to ensure proper installation of HP turbocharger air supply duct, HP compressor out duct, LP turbocharger, and air inlet duct.

6. Align turbine exhaust outlet flange (Figure 234) (Item 4) square with turbo alignment bracket (Figure 234) (Item 2).
7. With turbine exhaust outlet flange aligned square with Turbo Alignment Bracket, tighten three M10 nuts to 45 lb·ft (62 N·m).
8. Remove Turbo Alignment Bracket from engine.

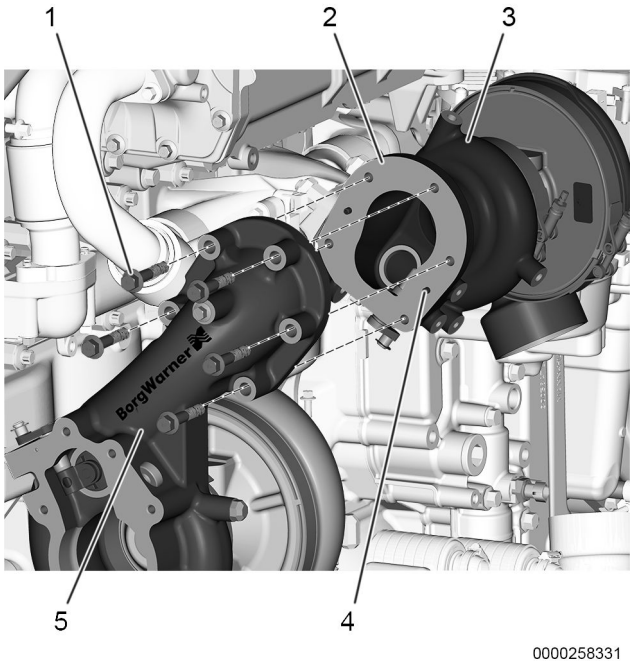

Figure 235 LP turbocharger installation

1. M10 x 55 bolt (5)
2. HP turbocharger turbine outlet flange
3. HP turbocharger assembly
4. Dowel pin (2)
5. LP turbocharger assembly

9. Align two dowel pins (Figure 235) (Item 4) and support LP turbocharger (Figure 235) (Item 5) in position on HP turbocharger turbine outlet flange (Figure 235) (Item 2).
10. Install five new M10 x 55 bolts (Figure 235) (Item 1) and tighten to 35 lb·ft (47 N·m).

Turbocharger Support Bracket

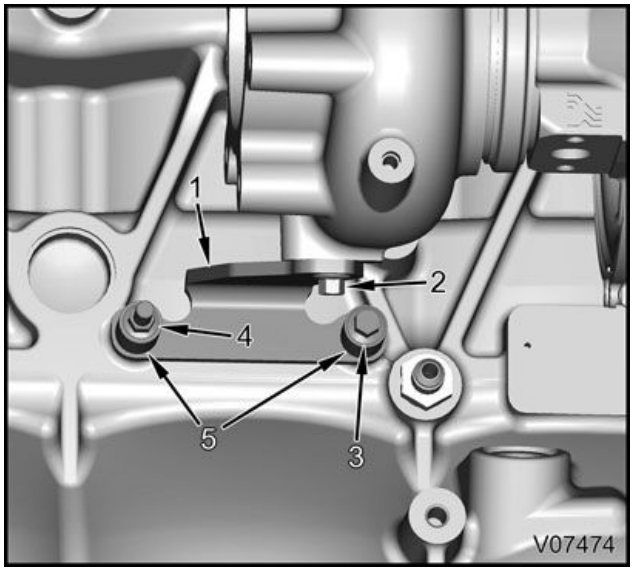

Figure 236 Turbocharger support bracket.

1. Turbocharger support bracket
2. M8 x 16 bolt
3. M8 x 40 bolt
4. M8 x 40 x 15 stud bolt
5. 19 x 20 spacer (2)

CAUTION: The turbocharger support bracket must be installed; if the bracket is not installed, the turbochargers or exhaust manifold could crack.

1. Position turbocharger support bracket and install two 19 x 20 spacers, M8 x 40 x 15 stud bolt and M8 x 40 bolt.
2. Install M8 x 16 bolt into bottom of turbocharger. Tighten three bolts to standard torque (page 547).

High-Pressure (HP) Turbocharger Wastegate Actuator

NOTE: If HP wastegate actuator was removed from turbocharger, do the following:

⚠ WARNING: Failure to observe the following warning may cause property damage, personal injury, or death. To prevent personal injury or death, wear safety glasses with side shields.

NOTE: Check linkage movement for the HP wastegate actuator, using a hand pump or shop air regulated to no more than 345 kPa (50 psi).

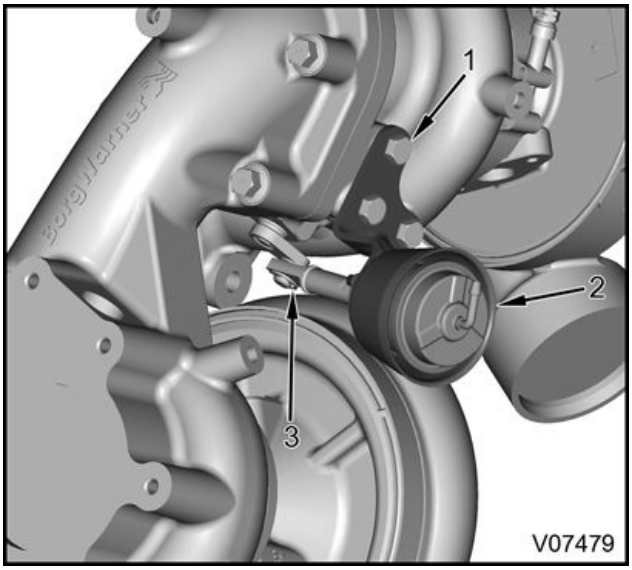

Figure 237 High-pressure (HP) wastegate actuator.

1. M8 x 14 HP bolt (3)
2. HP wastegate actuator
3. C-clip

1. Position HP wastegate actuator with hose port facing up and install three M8 x 14 bolts.
2. Tighten three bolts to special torque (page 205).
3. Position wastegate HP actuator linkage on wastegate lever pin.
4. Install actuator linkage C-clip on wastegate lever pin.

⚠ WARNING: Failure to observe the following warning may cause property damage, personal injury, or death. To prevent personal injury or death, wear safety glasses with side shields.

NOTE: Check linkage movement for the HP wastegate actuator, using a hand pump or shop air regulated to no more than 345 kPa (50 psi).

5. Attach air source to HP wastegate actuator and operate actuator through full range and check for free movement. There should be smooth operation without binding. If operation is not smooth, loosen pushrod jam nut and retighten. Recheck movement.

Turbocharger Heat Shields

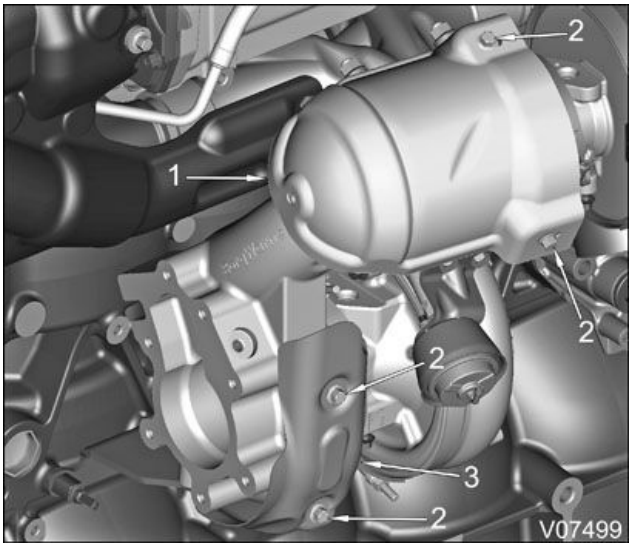

Figure 238 Turbocharger heat shields.

1. HP turbocharger heat shield
2. M8 x 16 bolt (4)
3. Turbocharger heat shield

1. Position turbocharger heat shield and install two M8 x 16 bolts. Tighten bolts to standard torque (page 547).
2. Install HP turbocharger heat shield and three M8 x 16 bolts. Tighten bolts to standard torque (page 547).

Turbocharger Oil Return and Oil Supply Tubes

Overview

This section describes installation of turbocharger oil return and oil supply tubes after turbocharger oil supply tube retrofit. If configuration does not match this section or was not completed during removal, finish installation of TSI in Appendix D .

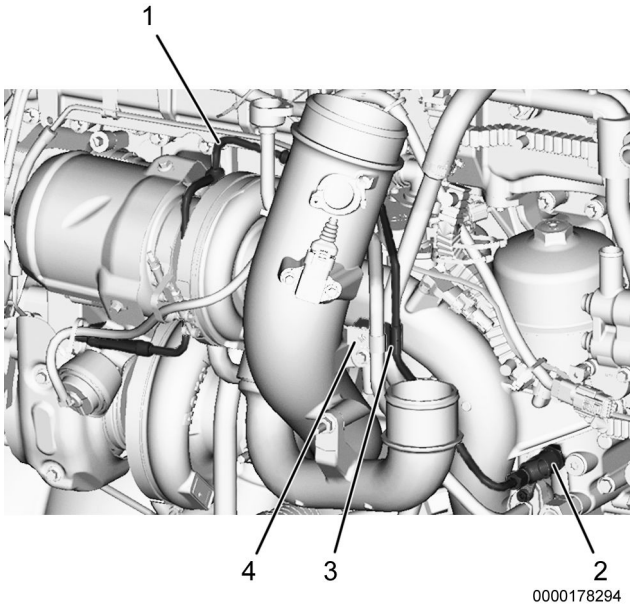

Figure 239 Turbocharger Oil Supply Tube.

1. Turbocharger oil supply tube
2. Oil supply T-fitting
3. Turbocharger oil supply tube bracket
4. Heater and cooler line brackets

CAUTION: To prevent engine damage, install new turbocharger oil supply tube assembly if turbocharger oil supply tube assembly is removed.

NOTE: Do not tighten bolts or flare nuts at this time.

1. Align oil supply tube (Figure 239) (Item 1) with oil supply T-fitting (Figure 239) (Item 2) and turbocharger oil supply openings.
2. Loosely install oil supply tube flare nut end on oil supply T-fitting.
3. Position oil supply tube bracket (Figure 239) (Item 3) between heater and cooler line brackets (Figure 239) (Item 4).

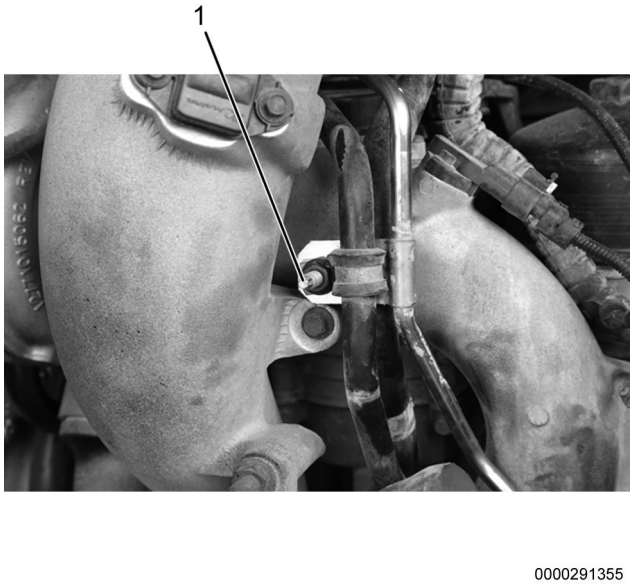

Figure 240 Heater and Cooler Line Bracket Stud Bolt.

1. M8 stud bolt

4. Install M8 stud bolt (Figure 240) (Item 1) through oil supply tube bracket, heater and cooler line brackets, and to high-pressure turbocharger air inlet duct. Torque stud bolt to 23 lb-ft (31 N·m).

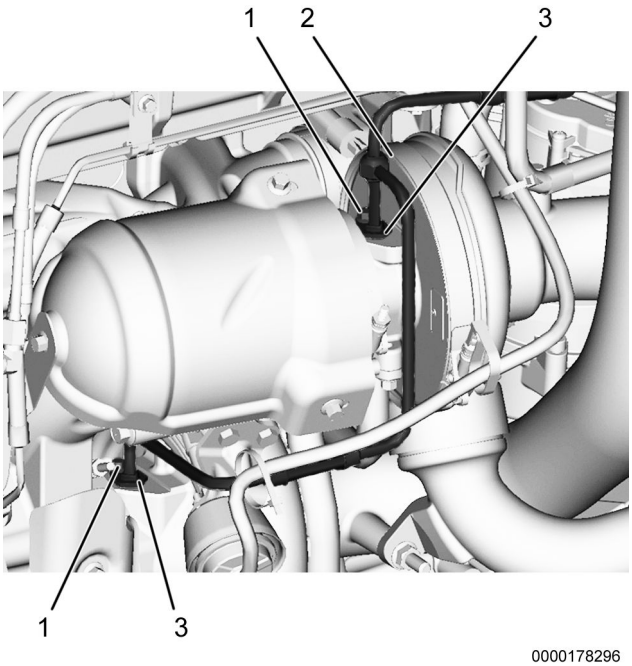

Figure 241 Turbocharger Oil Supply Tube.

1. M6 X 16 bolt (2)
2. High-pressure turbocharger
3. Oil supply tube flange(s)

5. Lubricate turbocharger oil supply tube O-rings with P-80® rubber lubricant or equivalent.
6. Press oil supply tube fittings with O-rings installed into openings on high-pressure turbocharger (Figure 241) (Item 2) and low-pressure turbocharger.
7. Align oil supply tube flanges (Figure 241) (Item 3) and loosely install two M6 X 16 bolts (Figure 241) (Item 1). Torque bolts (2) to 10 lb·ft (13 N·m).

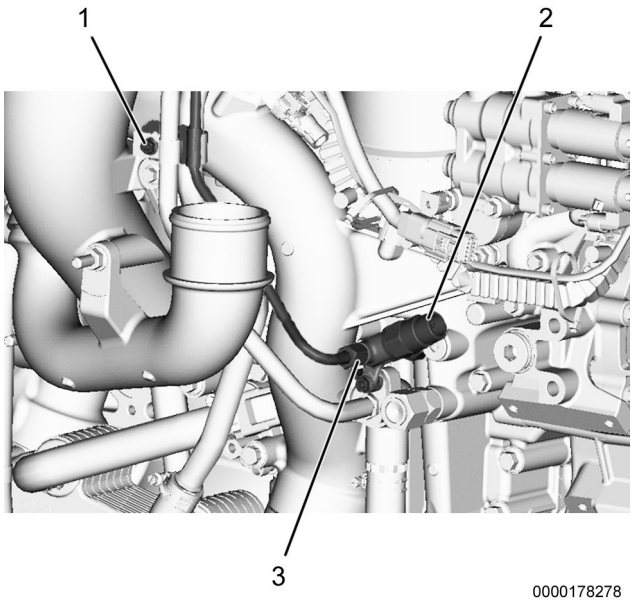

Figure 242 Oil Supply Tube T-fitting Flare Nut.

1. M8 nut
2. Engine Oil Pressure (EOP) sensor
3. Oil supply tube T-fitting flare nut

8. Install M8 nut (Figure 242) (Item 1) over supply tube bracket, heater and cooler line brackets and stud bolt in high-pressure turbocharger air inlet duct. Torque nut to 23 lb·ft (31 N·m)
9. Install oil supply tube T-fitting flare nut (Figure 242) (Item 3) to T-fitting. Torque flare nut to 19 lb·ft (26 N·m)
10. Install LP turbocharger oil return tube with new 24.7 x 32 seal ring into crankcase. Snug fitting only until final tightening.
11. Connect HP turbocharger oil return tube to LP turbocharger oil return tube with new bonded seal washer. Snug fitting only until final tightening.
12. Position HP turbocharger oil return tube with new oil drain gaskets to oil return outlet flanges of LP turbocharger and HP turbocharger.
13. Install four M8 x 20 bolts and tighten bolts to standard torque (page 547).
14. Final tighten LP turbocharger oil return tube fitting nut at crankcase fitting as follows:
    a. Tighten fitting nut to 10 N·m (89 lb·in).
    b. Turn fitting nut an additional 90°.

15. Final tighten HP turbocharger oil return tube fitting nut at LP turbocharger oil return tube as follows:
    a. Tighten fitting nut to 10 N·m (89 lb·in).
    b. Turn fitting nut an additional 90°.

High-Pressure Turbocharger Air Supply Duct

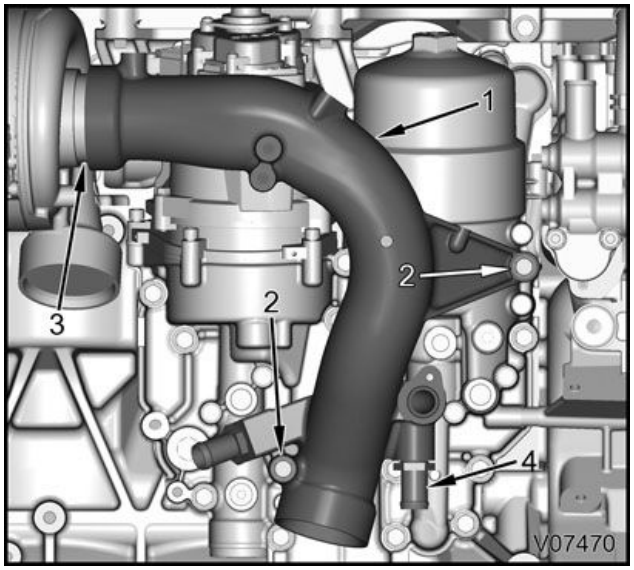

Figure 243 High-pressure (HP) turbocharger air supply duct.

1. HP turbocharger air supply duct
2. M10 x 200 bolt (2)
3. High-pressure compressor inlet seal
4. M24 threaded fitting

1. Lubricate new high-pressure compressor inlet seal with P-80® rubber lubricant or equivalent (page 205) and install over HP turbocharger compressor inlet groove.
2. Install HP turbocharger air supply duct along with two M10 x 200 bolts. Tighten bolts to standard torque (page 547).
3. If previously removed, install new seal ring and M24 threaded fitting and tighten to special torque (page 205).

High-Pressure (HP) Compressor Out Duct and Air Inlet Duct

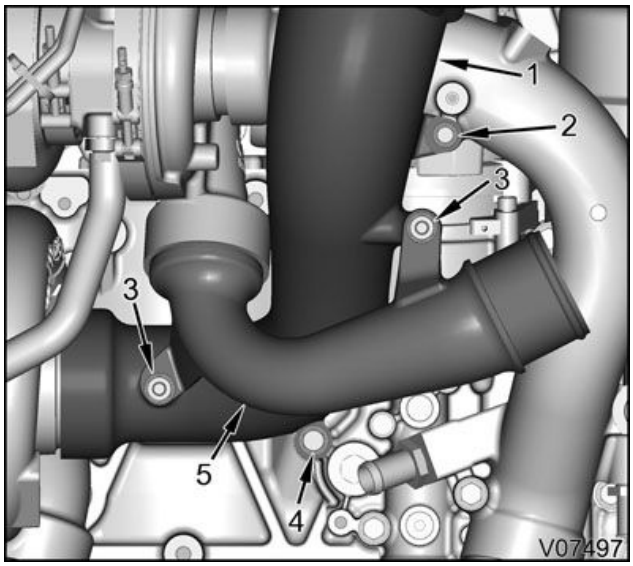

Figure 244 HP compressor out duct and air inlet duct.

1. Air inlet duct
2. M8 x 45 bolt
3. M10 x 20 x 40 stud bolt (2)
4. M10 x 140 bolt
5. HP compressor out duct

1. Lubricate a new LP compressor inlet seal with P-80® rubber lubricant or equivalent (page 205) and install seal over LP turbocharger compressor inlet.
2. Install air inlet duct to LP turbocharger. Install M8 x 45 bolt and M10 x 140 bolt. Tighten bolts to standard torque (page 547).

NOTE: The high-pressure compressor inlet seal is used in two places on the high-pressure turbocharger compressor including both compressor inlet and outlet.

3. Lubricate new HP compressor inlet seal with P-80® rubber lubricant or equivalent (page 205) and install into groove in compressor out duct.
4. Install HP compressor out duct into HP turbocharger air outlet, install two M10 x 20 x 40 stud bolts and tighten to standard torque (page 547).

Low-Pressure Charge Air Cooler (LPCAC) Coolant Tube and Hoses

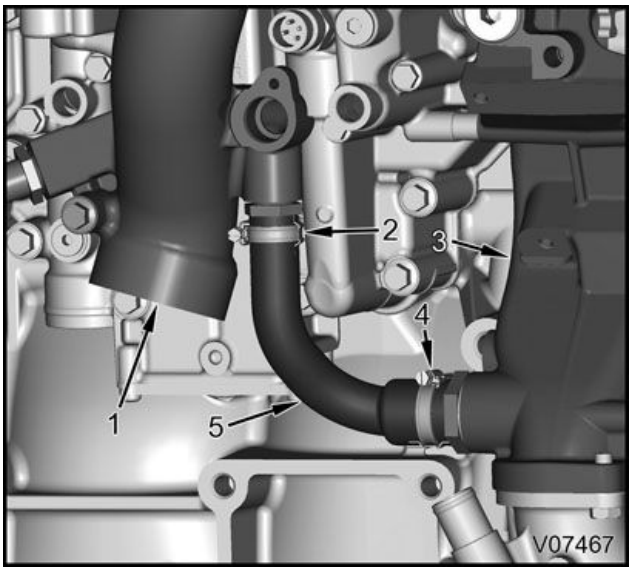

Figure 245 Coolant return hose (air supply duct to water distribution housing).

1. High-pressure (HP) turbocharger air supply duct (coolant return integral with duct)
2. 3/4 inch worm gear hose clamp
3. Water distribution housing
4. 1 inch worm gear hose clamp
5. Coolant return hose

1. Install coolant return hose to water distribution housing and air supply duct. Install 3/4 inch hose clamp and 1 inch hose clamp. Tighten 3/4 inch and 1 inch hose clamps to special torque (page 205).

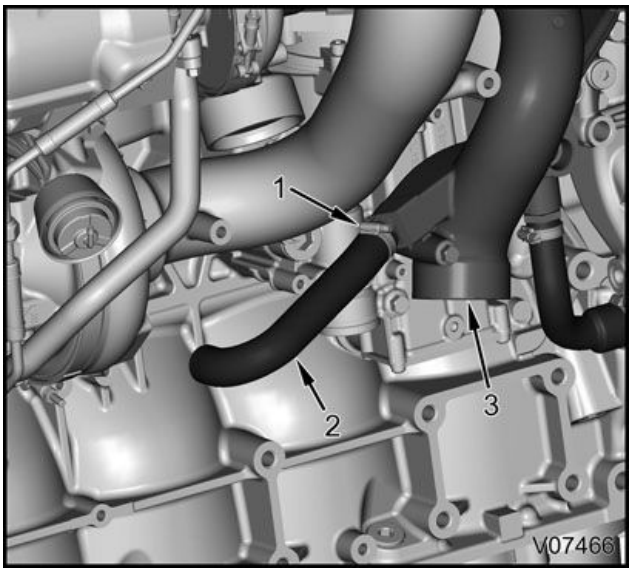

Figure 246 Coolant return hose (High-pressure turbocharger air supply duct).

1. 3/4 inch worm gear hose clamp
2. Coolant return hose
3. Air supply HP turbocharger duct (coolant return integral with duct)

2. Install coolant return hose to air supply HP turbocharger duct. Install 3/4 inch hose clamp and loosely tighten at this time.

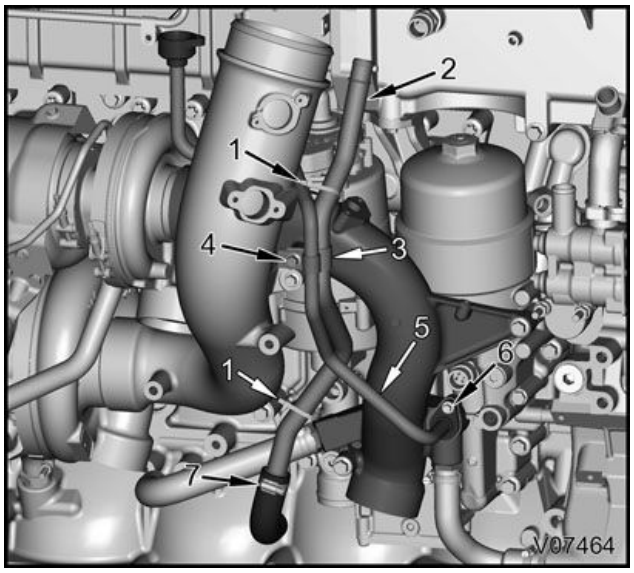

Figure 247 Coolant and cab heater tubes.

1. Cable lock strap (2)
2. Coolant tube
3. Tube support
4. M8 x 20 bolt
5. Cab heater return tube assembly
6. M6 x 20 bolt
7. 3/4 inch constant torque hose clamp

3. Lubricate new cab heater return tube O-ring with P-80® rubber lubricant or equivalent (page 205).
4. Install a new O-ring onto cab heater return tube assembly.
5. Position cab heater return tube assembly and install M6 x 20 bolt and M8 x 20 bolt through tube support behind air inlet duct. Tighten bolts to standard torque (page 547).
6. Install coolant hose onto lower end of coolant supply tube. Install 3/4 inch hose clamp onto hose and loosely tighten at this time.
7. Position coolant tube support and cab heater return tube assembly retainer and install M8 x 20 bolt. Tighten bolt to standard torque (page 547).

NOTE: Two cable lock straps are installed later after LP wastegate hose is installed to secure hose to coolant tube.

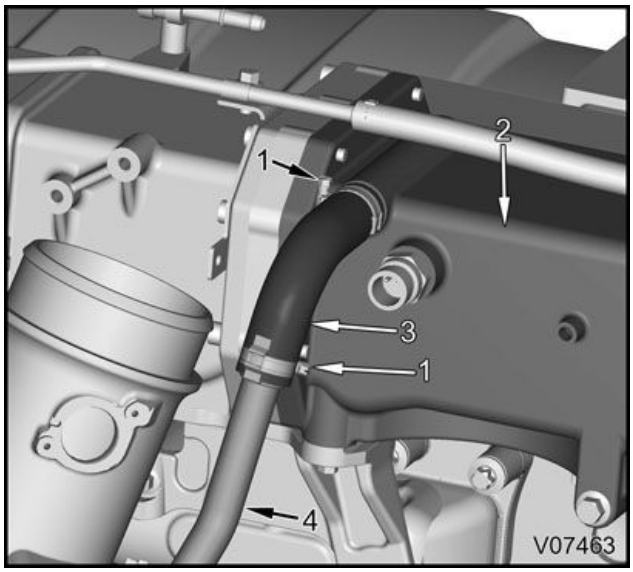

Figure 248 Coolant return hose.

1. 3/4 inch worm gear hose clamp (2)
2. Low-temperature housing (EGR cooler)
3. Coolant return hose
4. Coolant tube

8. Install coolant hose and two 3/4 inch hose clamps between coolant tube and low-temperature housing (EGR cooler).
9. Tighten clamps to special torque (page 205).

Low-Pressure Charge Air Cooler (LPCAC)

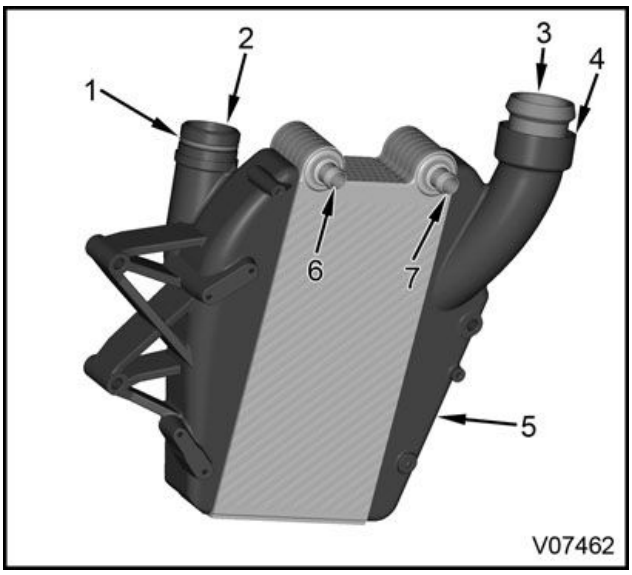

Figure 249 LPCAC.

1. O-ring seal
2. LPCAC air inlet
3. 72.2 x 60 (DMR) tube seal (extension tube)
4. LPCAC air outlet
5. Low-Pressure Charge Air Cooler (LPCAC)
6. Coolant return
7. Coolant supply

1. Lubricate 72.2 x 60 (DMR) tube seal (extension tube) with P-80® rubber lubricant or equivalent (page 205) and install into LPCAC using Extension Tube Installer (page 205).
2. Lubricate new O-ring seal with P-80® rubber lubricant or equivalent (page 205) and install O-ring at LPCAC air inlet.

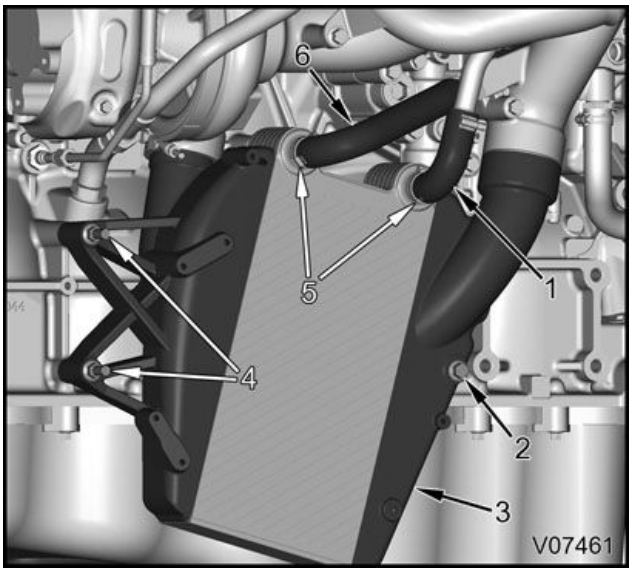

Figure 250 LPCAC and coolant hose connections.

1. Coolant hose (supply)
2. M10 x 100 bolt
3. LPCAC
4. Ground stud bolt (2)
5. 3/4 inch worm gear hose clamp (2)
6. Coolant return hose

3. Install LPCAC to engine until tube seal (extension tube) and O-ring are fully engaged with air duct and LP turbocharger.
4. Install two M10 stud bolts and M10 x 100 bolt. Tighten bolts to standard torque (page 547).
5. Connect coolant return hose to LPCAC and install 3/4 inch hose clamp.
6. Tighten two coolant return hose clamps to special torque (page 205).
7. Connect coolant (supply) hose to LPCAC and install 3/4 inch hose clamp.
8. Tighten two coolant (supply) hose clamps to special torque (page 205).

High-Pressure (HP) Wastegate Hose

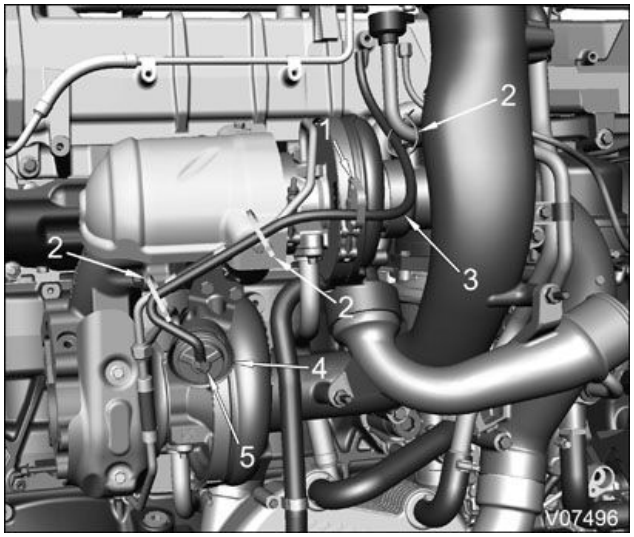

Figure 251 High-pressure (HP) wastegate hose.

1. Tie strap
2. Cable lock strap (3)
3. High-pressure (HP) wastegate hose
4. High-pressure (HP) wastegate
5. 12.3 x 7 crimp clamp

NOTE: Replace HP wastegate hose if damaged or deformed.

1. Route HP hose onto engine as noted during removal.
2. Slip crimp clamp over hose and connect HP wastegate hose to HP wastegate actuator fitting.
3. Install three cable lock straps and tie strap to secure HP wastegate hose to turbocharger oil supply tube and EGRV coolant supply tube.
4. Slip crimp clamp over hose and connect HP wastegate hose to air control valve. See "Exhaust Back Pressure Control" for procedure.
5. Using crimping pliers (page 205), tighten the crimp clamps on each end of HP wastegate hose.

Special Torque

3/4 inch and 1 inch worm gear hose clamps	3.5 N·m (31 lb·in)
High-pressure-to-low-pressure turbine bolts, M10 x 55	47 N·m (35 lb·ft)
High-pressure wastegate actuator bolts, M8 x 14	16 N·m (12 lb·ft)
Male stud connector	70 N·m (52 lb·ft)
M10 Nut	62 N·m (45 lb·ft)
M24 threaded fitting	60 N·m (44 lb·ft)
Oil return low-pressure turbocharger tube (at crankcase)	See tightening steps in procedure (page 198).
Oil return low-pressure turbocharger tube fitting nut	See tightening steps in procedure (page 198).
Turbocharger oil supply tube assembly fitting nut to male stud connector	27 N·m (20 lb·ft)

Special Service Tools

Description	Tool Number
3-inch couplers and clamps	Obtain locally
Charge Air Cooler Test Kit	ZTSE6042
Crimping pliers	Obtain locally
Extension Tube Installer	ZTSE6043
P-80® rubber lubricant or equivalent	Obtain locally
Turbo Alignment Bracket	ZTSE6041
Disposable Air and Fuel Caps	ZTSE4891
Coolant Management Tool	KL5007NAV

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Exploded Views

Power Steering and One-Cylinder Air Compressor

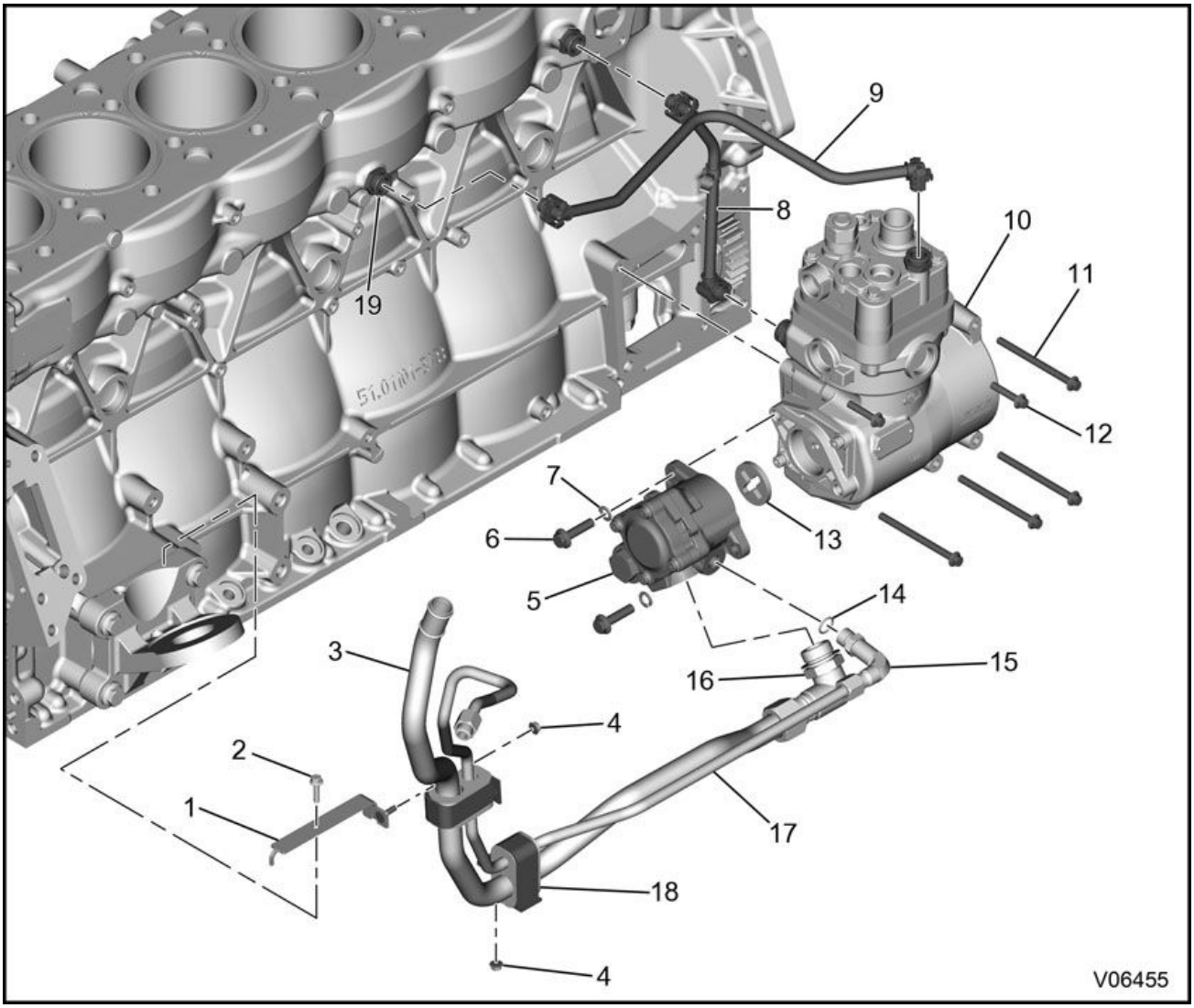

Figure 252 One-cylinder air compressor and power steering system (typical)

1. Extension clip
2. M6 x 25 bolt
3. Power steering (low-pressure) tube assembly
4. M6 x 1.0 nut (2)
5. Power steering pump
6. M10 x 40 bolt (2)
7. Lock washer (10 mm) (2)
8. Return coolant tube assembly
9. Return coolant hose assembly
10. Air compressor
11. M8 x 110 bolt (4)
12. M8 x 40 bolt (2)
13. Power steering pump adapter
14. O-ring seal
15. 1/2” 90 degree tube elbow
16. 1-1/16” 90 degree elbow
17. Power steering (high-pressure) tube assembly
18. Support bracket
19. M16 straight union (2)

Optional two-cylinder compressors are available. Although compressor housings are longer, compressor and power steering line connections to crankcase and chassis are similar to one-cylinder compressors.

Power Steering and Two-Cylinder Air Compressor

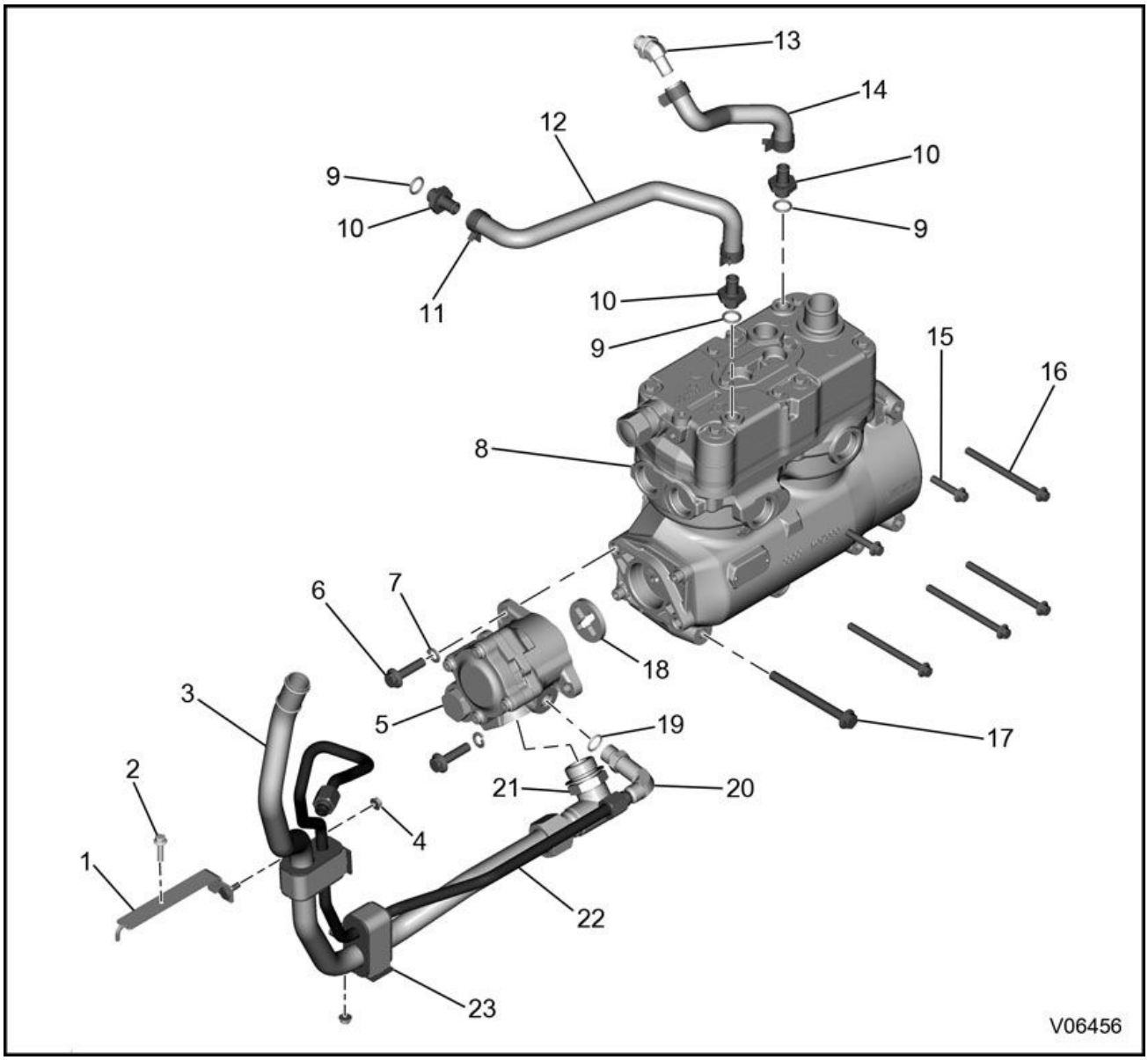

Figure 253 Optional two-cylinder air compressor and power steering system (typical)

1. Extension clip
2. M6 x 25 bolt
3. Power steering (low-pressure) tube assembly
4. M6 x 1.0 nut (2)
5. Power steering pump
6. M10 x 40 bolt (2)
7. Lock washer (10 mm) (2)
8. Air compressor
9. O-ring seal (3)
10. M16 straight fitting (3)
11. 21 mm constant-tension clamp (4)
12. Coolant return hose
13. M16 45 degree fitting
14. Coolant supply hose
15. M8 x 40 bolt (2)
16. M8 x 110 bolt (4)
17. M10 x 110 bolt
18. Power steering pump adapter
19. O-ring seal
20. 1/2” tube 90 degree elbow
21. 1-1/16”-12ST 90 degree elbow
22. Power steering (high-pressure) tube assembly
23. Support bracket

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

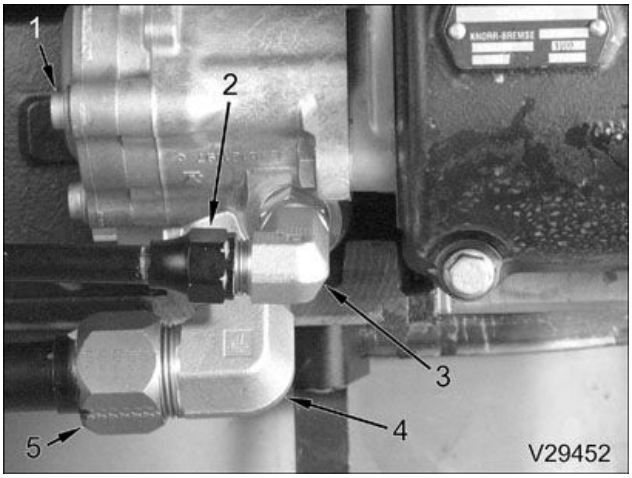

Figure 254 Power steering pump and Pressure tubes

1. Power steering pump
2. High-pressure tube fitting nut
3. 1/2" 90 degree tube elbow
4. 1-1/6" 90 degree tube elbow
5. Low-pressure tube fitting nut

1. Place a drain pan under the power steering pump to catch any fluid.
2. Loosen high-pressure tube fitting nut and disconnect tube from 1/2" 90 degree tube elbow.
3. Loosen low-pressure tube fitting nut and disconnect tube from 1-1/16" 90 degree elbow.

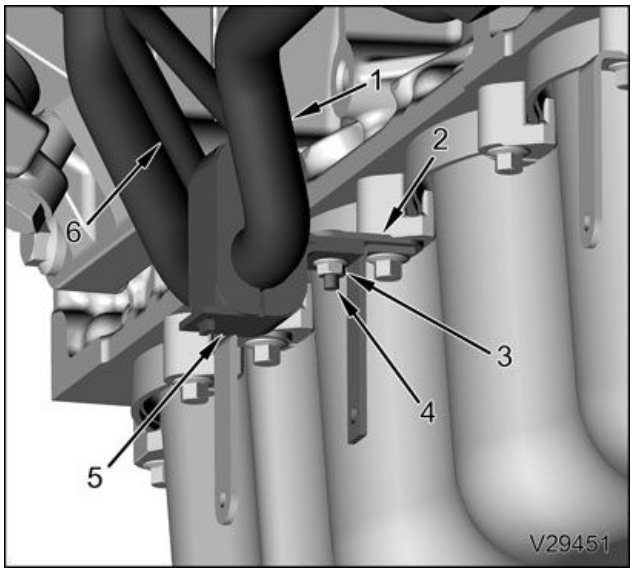

Figure 255 Pressure tubes support bracket

1. Power steering (low-pressure) tube assembly
2. Extension clip
3. M6 nut
4. M6 x 20 stud
5. Rear support bracket
6. Power steering (high-pressure) tube assembly

4. Remove rear support bracket M6 nut from extension clip stud at the oil pan.
5. If equipped, remove front support bracket M6 nut from support bracket.
6. Remove high-pressure and low-pressure tubes as an assembly.

NOTE: If replacing high-pressure and low-pressure tubes, do steps 7 and 8.

7. Remove the rear support brackets and rubber isolator from the high-pressure and low-pressure tubes.
8. If equipped, remove front support brackets and rubber isolator from the high-pressure 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.

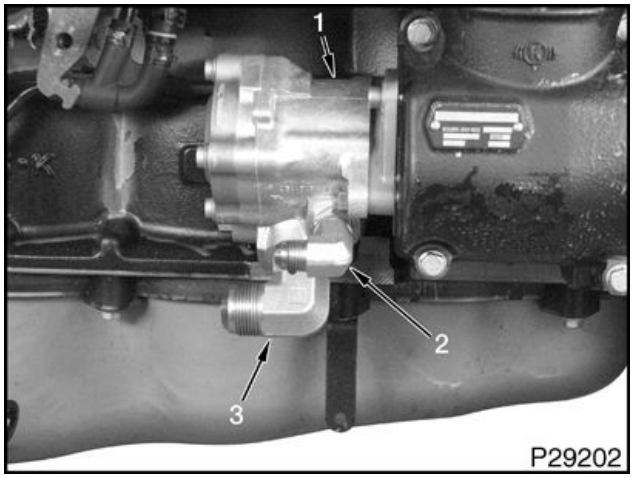

Figure 256 Power steering pump and 90 degree elbows

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

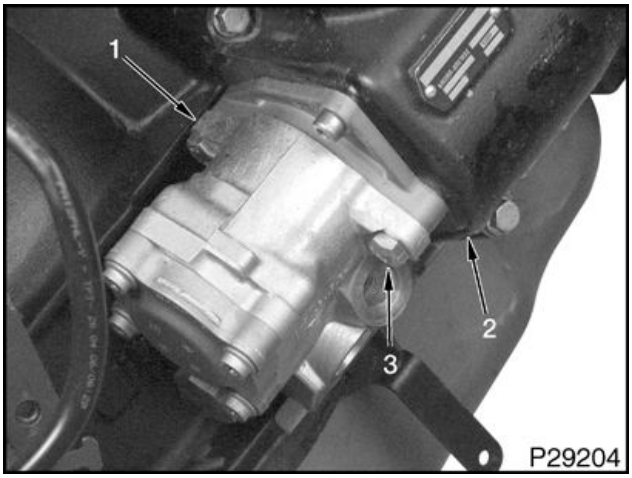

Figure 257 Power steering pump

1. Power steering pump
2. Air compressor
3. M10 x 40 bolt and lock washer (2)

1. Remove two M10 x 40 bolts, lock washers and power steering pump.
2. Check pump collar O-ring for damage and replace as necessary.

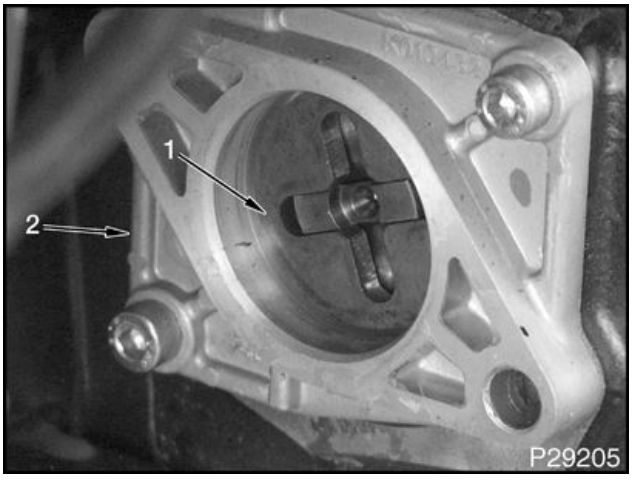

Figure 258 Power steering pump adapter

1. Power steering pump adapter
2. Air compressor

3. Remove power steering pump adapter from air compressor bore.

Air Compressor Coolant Hoses

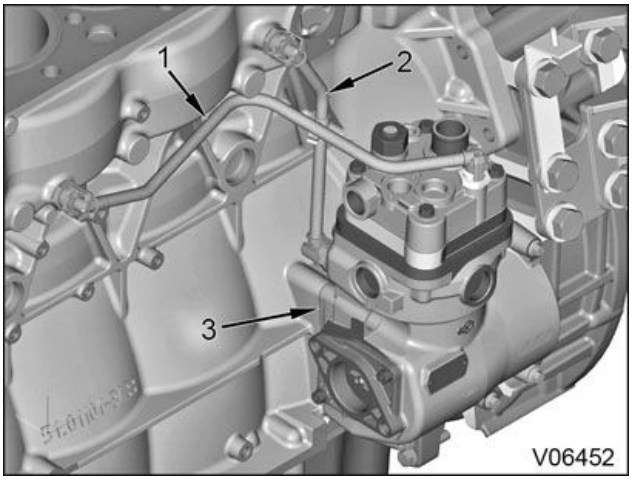

Figure 259 Air compressor coolant hoses

1. Coolant return hose
2. Coolant return tube (one cylinder air compressor) or Coolant supply hose (two cylinder air compressor)
3. Air compressor

1. Place suitable container under air compressor to collect any residual coolant.

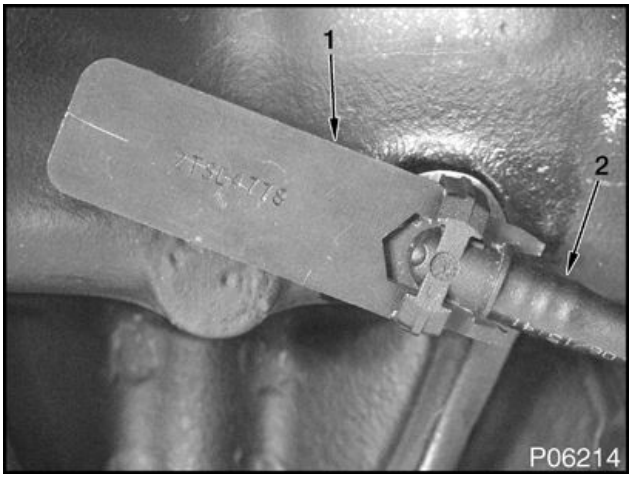

Figure 260 Air compressor coolant hose removal

1. Coolant Line Release Tool
2. Coolant hose

2. Insert Coolant Line Release Tool (page 219) into retaining clips of air compressor coolant hose and remove from crankcase.

3. Using Coolant Line Release Tool, release and remove air compressor coolant tube from air compressor.
4. Recycle or dispose of any coolant according to applicable regulations.

Air Compressor

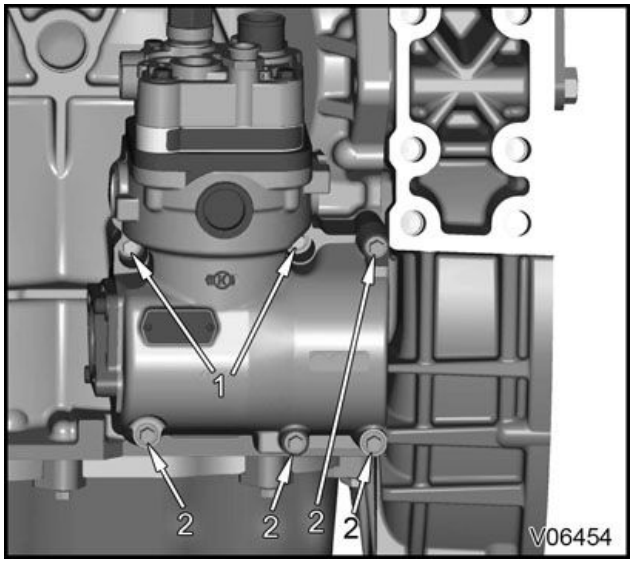

Figure 261 Air compressor (typical)

1. M8 x 40 bolt (2)
2. M8 x 110 bolt (4)

WARNING: To prevent personal injury or death, get assistance to remove and install the air compressor and power steering pump assembly.

NOTE: For two-cylinder air compressor only, an additional M10 x 110 bolt is located in the air compressor mounting hole next to the power steering pump.

1. For one-cylinder air compressor, remove two M8 x 40 bolts and four M8 x 110 bolts.
2. For two-cylinder air compressor, remove two M8 x 40 bolts, four M8 x 110 bolts and M10 x 110 bolt.
3. 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 sealing surfaces of air compressor. Use a scraper to clean sealing material from the sealing surfaces.
3. Use only hot water to clean all hoses and tubes.

Installation

Air Compressor

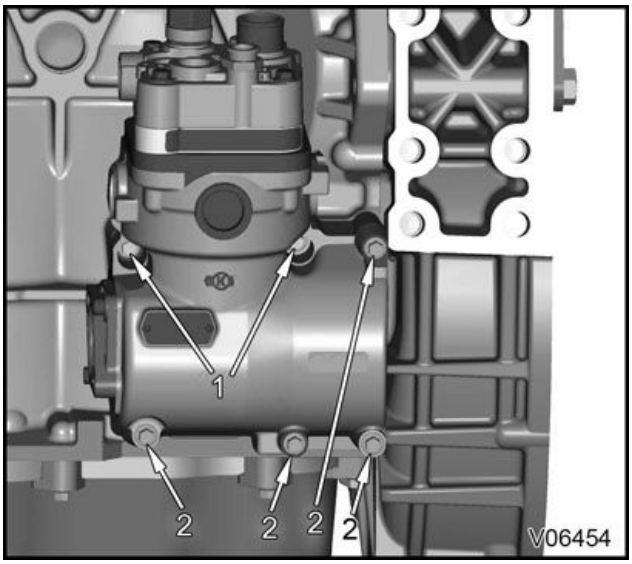

Figure 262 Air compressor (typical)

1. M8 x 40 bolt (2)
2. M8 x 110 bolt (4)

WARNING: To prevent personal injury or death, get assistance to remove and install the air compressor and power steering pump assembly.

NOTE: For two-cylinder air compressor only, an additional M10 x 110 bolt is located in the mounting hole next to the power steering pump.

1. Apply Loctite® 515 to crankcase and air compressor mating surface.
2. For one-cylinder air compressor, position air compressor and install two M8 x 40 bolts and four M8 x 110 bolts. Tighten bolts to special torque (page 219).
3. For two-cylinder air compressor, position air compressor and install two M8 x 40 bolts, four M8 x 110 bolts and M10 x 110 bolt. Tighten bolts to special torque (page 219).

Air Compressor Coolant Hoses

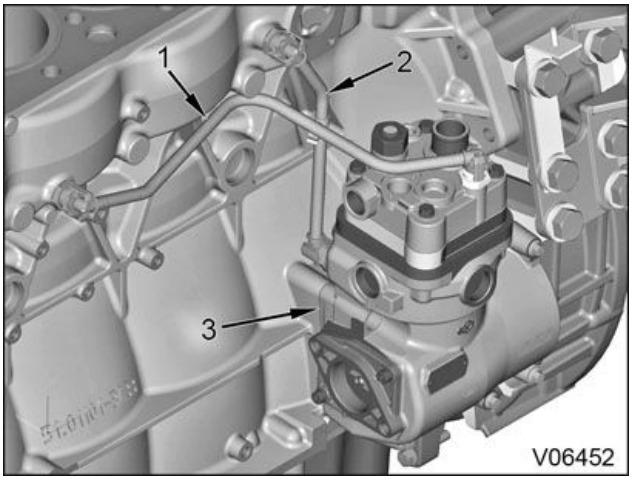

Figure 263 Air compressor coolant hoses

1. Coolant return hose
2. Coolant return tube (one-cylinder air compressor) or Coolant supply hose (two-cylinder air compressor)
3. Air compressor

1. Depending on compressor model, straight and 45° coolant fittings are used. If loosened, tighten fittings as follows:

One-cylinder compressors

- Tighten M16 straight fittings (at crankcase or air compressor) to special torque (page 219).
- If equipped, tighten M16 45° fitting (at crankcase) to special torque (page 219).
- If equipped, tighten M18 straight fittings (at air compressor) to special torque (page 219).

Two-cylinder compressors

- Tighten M16 straight fittings (at crankcase or air compressor) to special torque (page 219).
- If equipped, tighten M16 45° fitting (at crankcase or air compressor) to special torque (page 219).

2. Check air compressor coolant supply and return hose O-rings before installation. Replace O-rings as needed.
3. Place coolant supply hose in position between crankcase and air compressor coolant fittings.

4. Press down on quick-connect fittings until a click is heard to install hose. Lightly pull on hose to make sure it is locked.
5. Repeat steps 3 and 4 to install air compressor coolant return hose.

Power Steering Pump

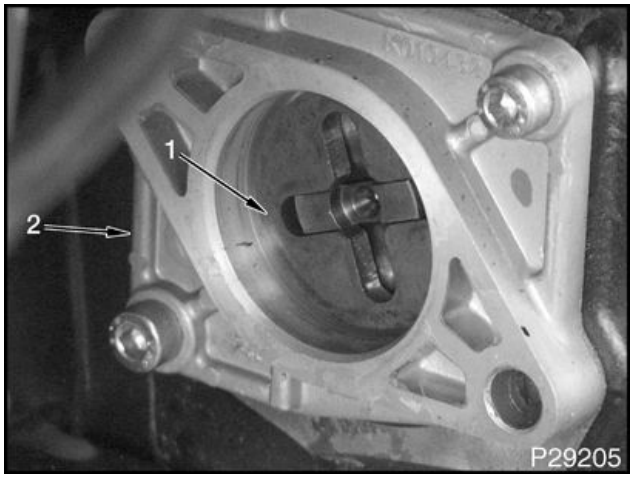

Figure 264 Power steering pump adapter

1. Power steering pump adapter
2. Air compressor

1. Install power steering pump adapter to air compressor bore.

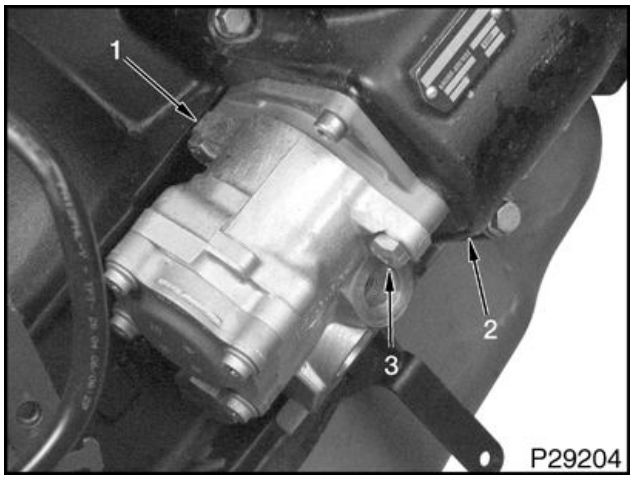

Figure 265 Power steering pump (typical)

1. Power steering pump
2. Air compressor
3. M10 x 40 bolt (2)

2. If pump collar O-ring was removed or damaged, install a new O-ring. Lubricate the new O-ring with P80® rubber lubricant (page 219) or equivalent.
3. Install power steering pump and two M10 x 40 bolts. Tighten bolts to special torque (page 219).

Power Steering Elbows

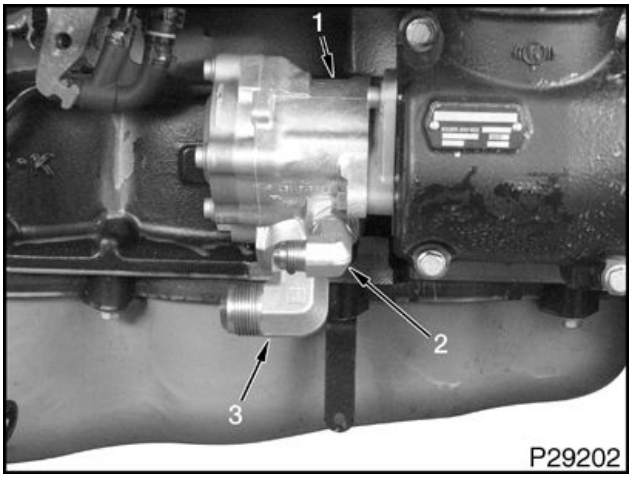

Figure 266 Power steering elbows

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-pressure and low-pressure tubes were replaced, do steps 1 and 2.

1. If equipped and removed, install front support brackets and rubber isolator onto the high- and low-pressure tubes.
2. If removed, install rear support brackets and rubber isolator onto the high- and low-pressure tubes.

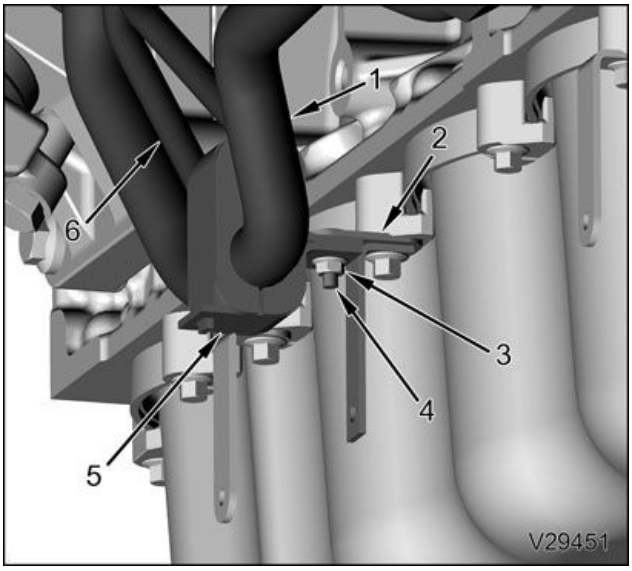

Figure 267 Pressure tubes support bracket

1. High- and low-pressure tube assembly
2. Extension clip
3. M6 x 1.0 nut
4. M6 x 20 bolt
5. Rear support bracket
6. Power steering (high-pressure) tube assembly

3. Position high-pressure and low-pressure tube as an assembly. Install M6 x 1.0 nut onto extension clip stud to secure rear support bracket at the oil pan. Tighten nut to standard torque (page 547).
4. If equipped, install front support bracket to extension clip stud on front engine support and secure with M6 x 1.0 flange nut. Tighten nut to standard torque (page 547).

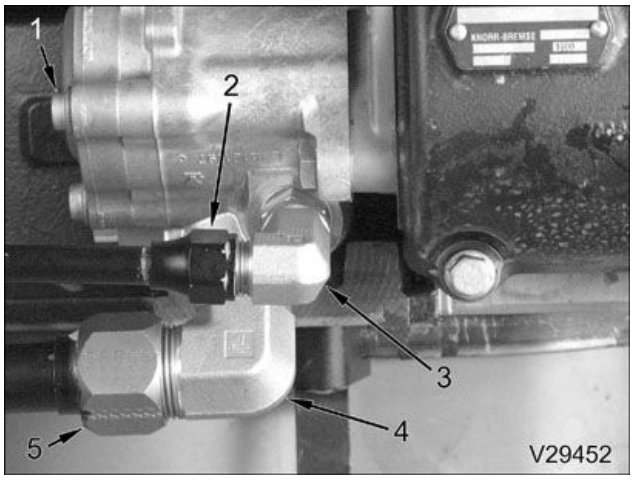

Figure 268 Pressure tubes

1. Power steering pump
2. High-pressure tube
3. 1/2” 90 degree tube elbow
4. 1-1/16” 90 degree elbow
5. Low-pressure tube

NOTE: Do the following steps if fittings were removed or if power steering pump was replaced.

5. Loosely install the high-pressure tube fitting nut to the elbow. Using an appropriate size wrench to hold the elbow, tighten 1/2" 90 degree tube elbow lock nut to special torque (page 219).
6. Loosely install the low-pressure tube fitting nut to the elbow. Using an appropriate size wrench to hold the elbow, tighten 1-1/16" 90 degree elbow lock nut to special torque (page 219).
7. Tighten the high-pressure and low-pressure tube fitting nuts to special torque (page 219).

Special Torque

1-1/16" 90 degree elbow lock nut	55 N·m (40 lb·ft)
1/2" 90 degree tube elbow lock nut	45 N·m (33 lb·ft)
Air compressor M8 x 40, M8 x 110 bolt (one cylinder)	35 N·m (26 lb·ft)
Air compressor M8 x 40, M8 x 110 bolt (two cylinder)	31 N·m (23 lb·ft)
(Two cylinder) Air compressor M10 x 110 bolt	67 N·m (49 lb·ft)
High-pressure tube fitting nut	62 N·m (45 lb·ft)
M16 straight fitting	35 N·m (26 lb·ft)
M16 45° fitting	17.5 N·m (13 lb·ft)
M18 straight fitting	37.5 N·m (28 lb·ft)
Low-pressure tube fitting nut	164 N·m (120 lb·ft)
Power steering pump M10 x 40 bolt	67 N·m (49 lb·ft)

Special Service Tools

Description	Tool Number
Coolant Line Release Tool	ZTSE4778
Loctite® 515	Obtain locally
P80® rubber lubricant or equivalent	Obtain locally

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Exploded Views

High-pressure Fuel Lines

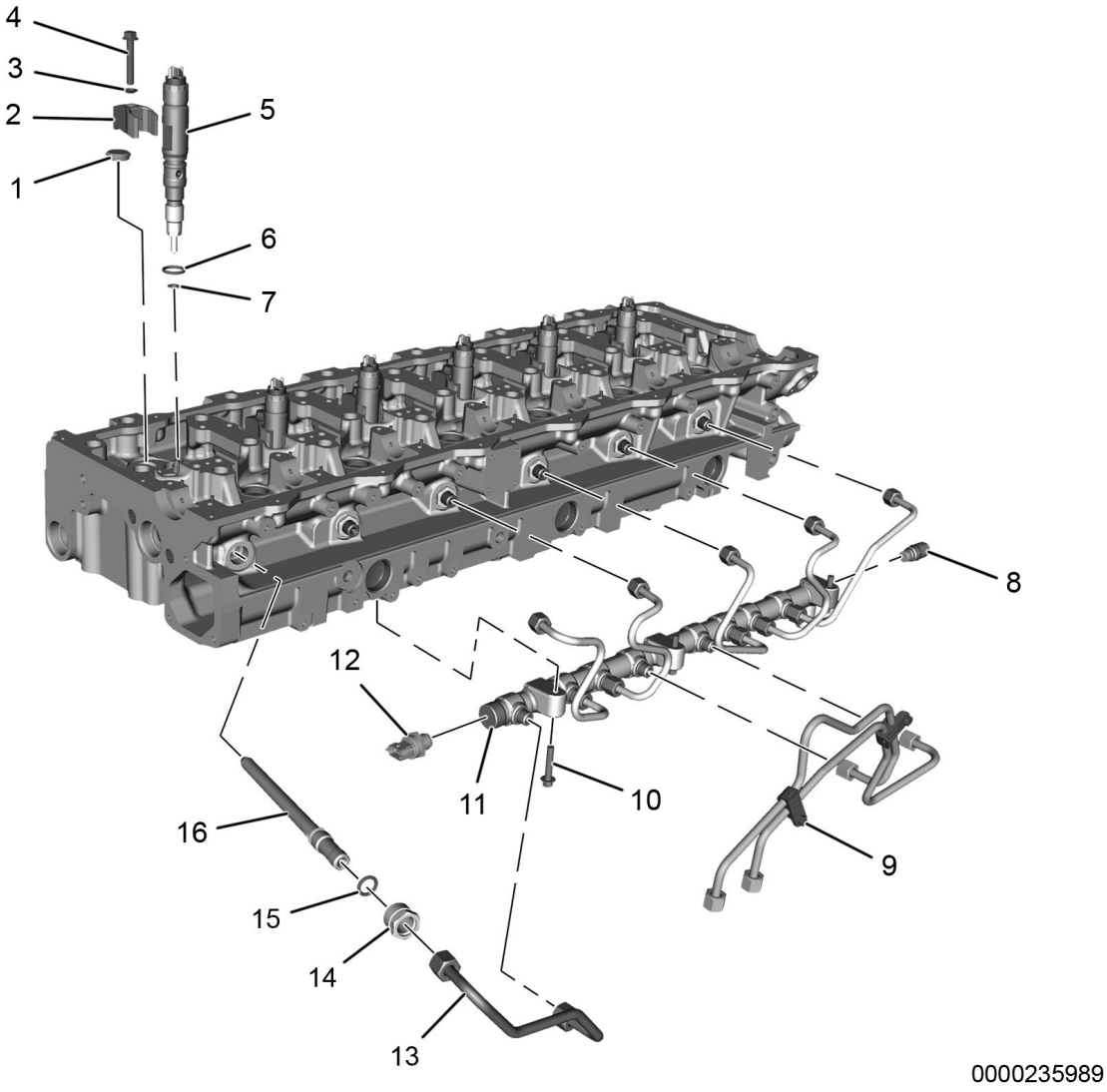

Figure 269 High-pressure fuel lines

1. Thrust washer (6)
2. Injector hold-down clamp (6)
3. Rounded washer (6)
4. M8 x 50 bolt (6)
5. Injector (6)
6. 3 x 20.9 ID O-ring (6)
7. Combustion washer (6)
8. Pressure limiting valve (fuel rail)
9. High-Pressure Fuel Pump (HPFP) to rail supply tube damper assembly
10. M8 x 40 bolt (3)
11. Fuel rail
12. Fuel rail pressure sensor
13. High-pressure rail to injector tube assembly (6)
14. High-pressure connector retaining nut (6)
15. 13.5 x 3 O-ring (6)
16. High-pressure connector body (6)

Fuel Supply and Drain (Return) Lines

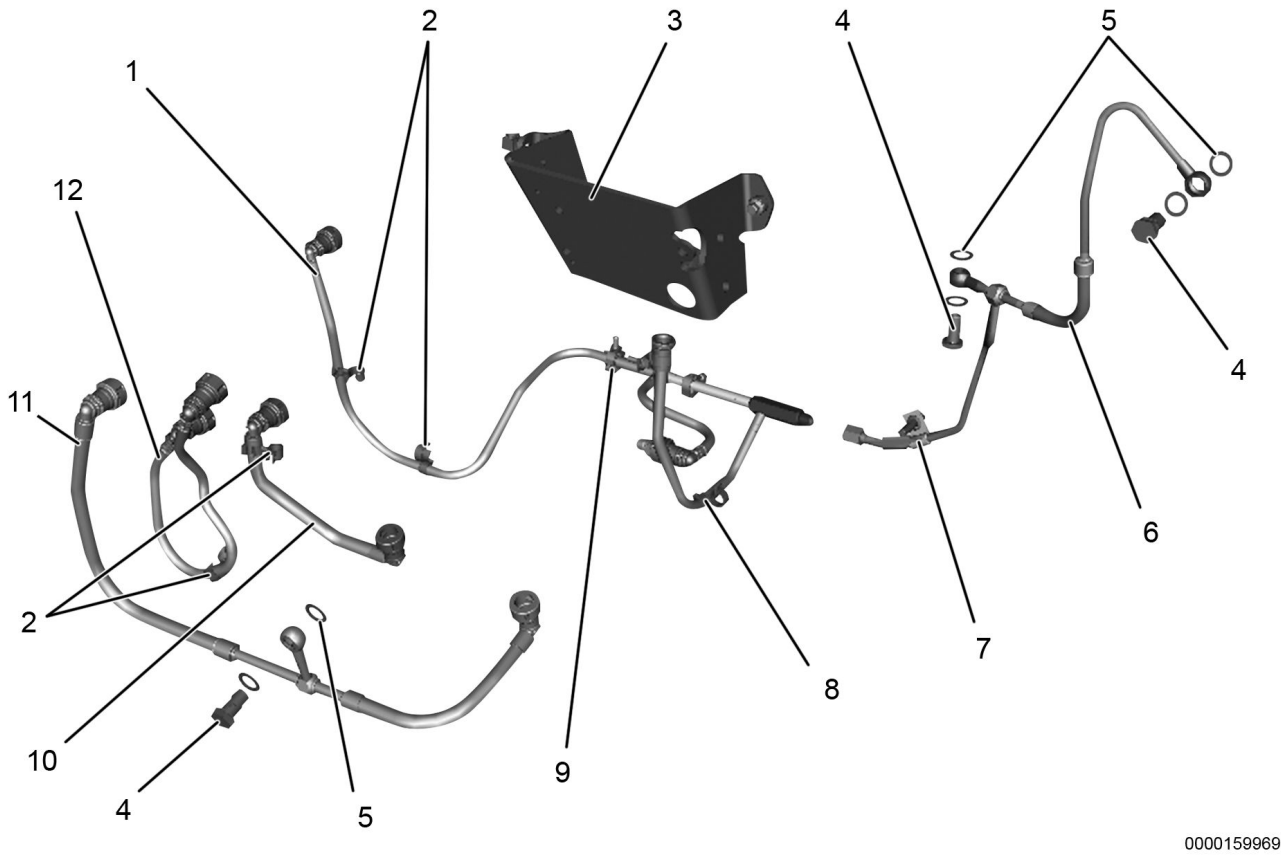

Figure 270 Fuel supply and drain (return) lines

1. Fuel drain (return) hose assembly
2. C-clip
3. Fuel filter bracket assembly with brace
4. M14 banjo bolt (3)
5. Seal ring, 14.7 x 22 (6)
6. Fuel drain (return) tube assembly
7. Closed (P) clamp and 8 x 16 bolt
8. Wiring clip
9. 8 x 13 single retainer
10. Pre-filter fuel supply hose (assembly)
11. After-filter fuel supply hose (assembly)
12. Pre-pump fuel supply hose assembly

Fuel Filter Housing Assembly

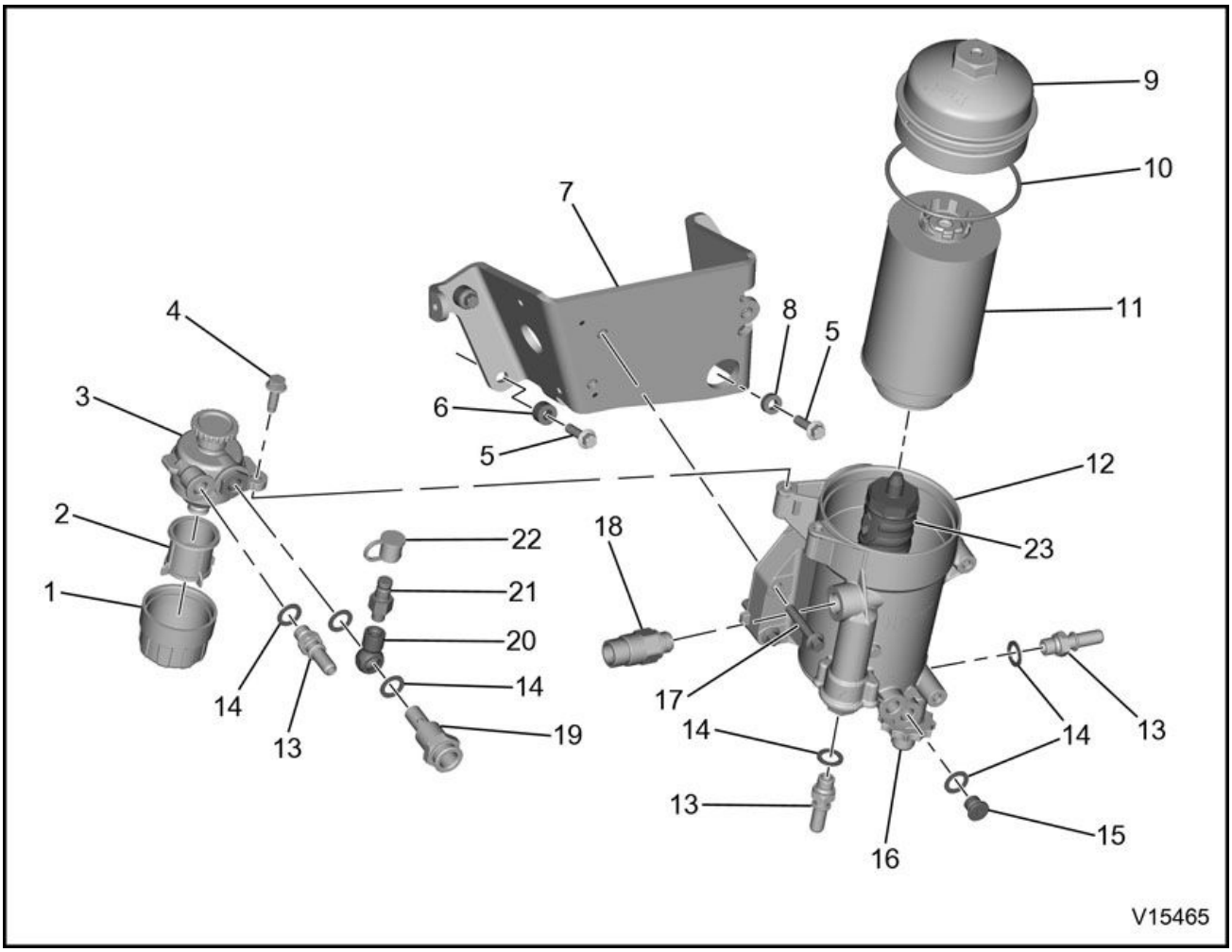

Figure 271 Fuel filter housing assembly

1. Priming cup cap
2. Priming element
3. Fuel primer pump assembly
4. M8 x 25 bolt (2)
5. M8 x 30 bolt (4)
6. 9 ID x 18 OD x 10.5 spacer (3)
7. Fuel filter bracket assembly with brace
8. 9 ID x 17 OD x 6.5 spacer
9. Fuel filter cap
10. Fuel filter cap O-ring
11. Fuel filter element
12. Fuel filter housing assembly
13. Threaded union (3)
14. Seal ring, 14.7 x 22 (12)
15. M14 x 1.5 hex socket plug
16. Fuel filter drain plug
17. M8 x 45 bolts (3)
18. Fuel Delivery Pressure (FDP) sensor
19. Fuel supply adapter
20. Banjo fitting
21. Check valve (quick connect)
22. Dust cap
23. Fuel filter stand pipe

High-pressure Fuel Pump and Drive Housing

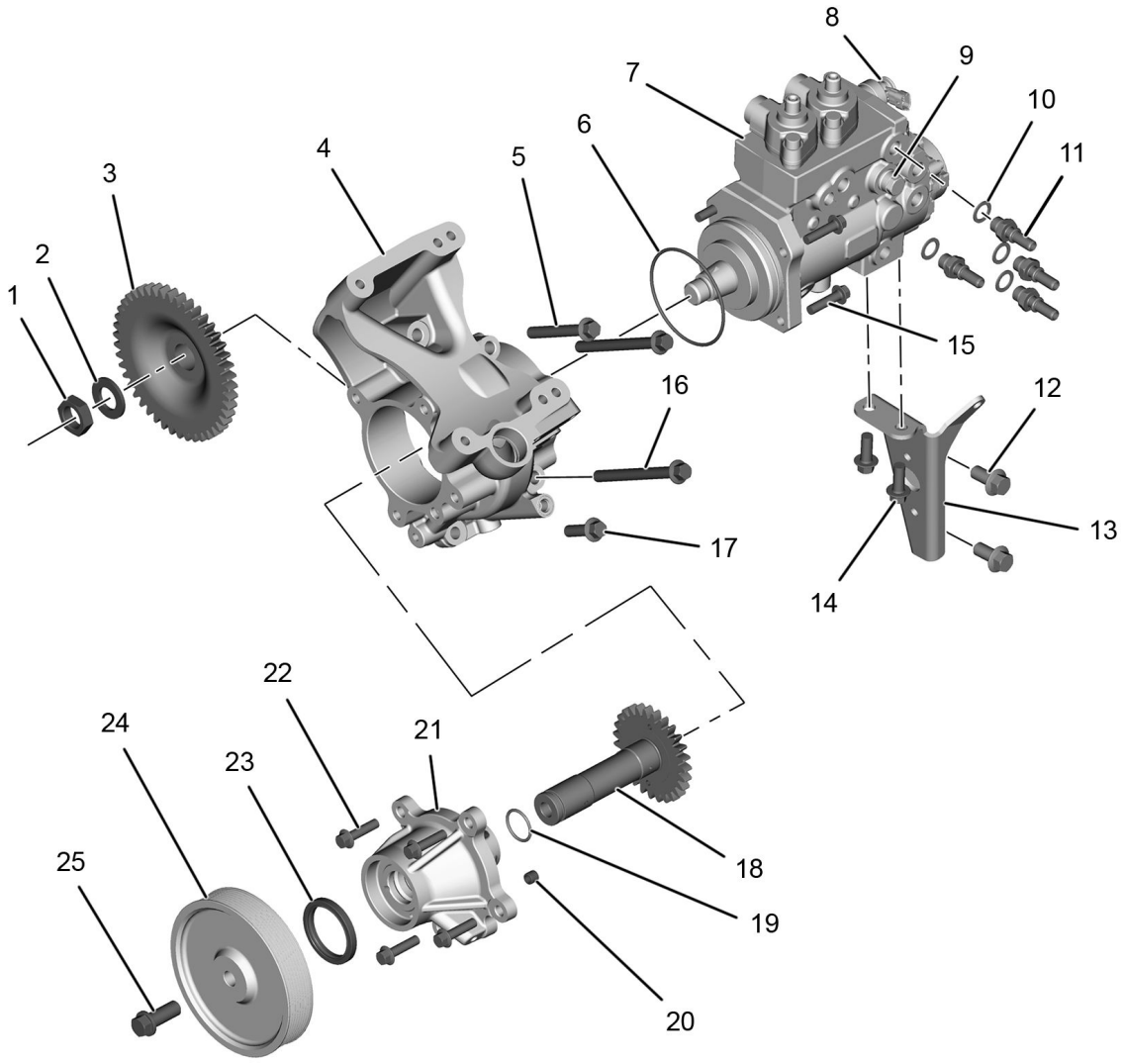

Figure 272 High-Pressure Fuel Pump (HPFP) and drive housing

1. M24 jam nut
2. Washer, 25 x 44 x 4
3. HPFP gear
4. Drive housing
5. M12 x 90 bolt
6. 100 x 3.349 O-ring
7. High-pressure fuel pump
8. Fuel Pressure Control Valve (FPCV)
9. Piston Overflow Valve (KUEV)
10. Seal ring, 16.7 x 24 (4)
11. Quick-connect M16 x 1.5 connector (4)
12. M14 x 30 bolt (2)
13. High-pressure (fuel) pump support
14. M12 x 30 bolt (2)
15. M10 x 40 bolt (4)
16. M12 x 130 bolt (2)
17. M12 x 40 bolt
18. Drive belt shaft
19. 30.2 x 3 O-ring
20. Sleeve
21. High-pressure pump (drive belt) pulley housing
22. M10 x 40 bolt (4)
23. 55 x 70 x 8 radial shaft seal
24. High-pressure pump (drive belt) pulley
25. M16 x 40 LH bolt (left-hand thread)

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

WARNING: To prevent personal injury or death, do not turn ignition key to ON if fuel system parts are removed or disconnected. Activation of the fuel pump could spill fuel and create a fire.

NOTE: When performing specific component removal, only remove components necessary for access.

For complete engine tear down, refer to the following service sections for information on removal of components prior to this section.

- **Engine Electrical**
- **Inlet Air Heater**
- **Aftertreatment System**
- **Turbochargers**

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.

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.

CAUTION: To prevent engine damage, plug component connections immediately after each fuel line is removed.

1. If not already done, disconnect air supply line from harness 21-way connector bracket.

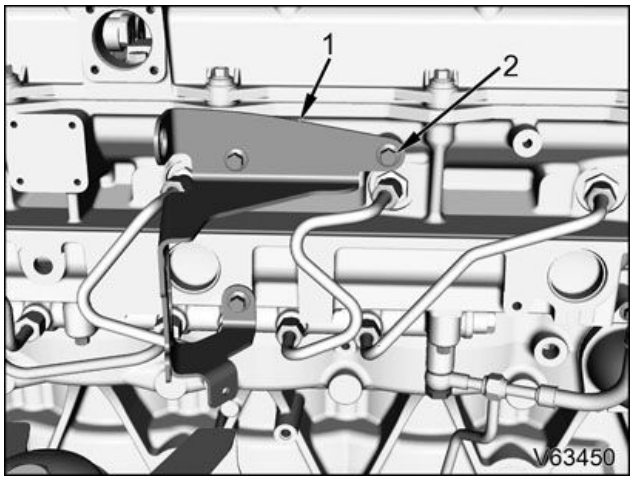

Figure 273 Harness connector bracket

1. Harness 21-way connector bracket
2. M8 x 16 bolt (3)

2. Remove three M8 x 16 bolts and harness 21-way connector bracket.

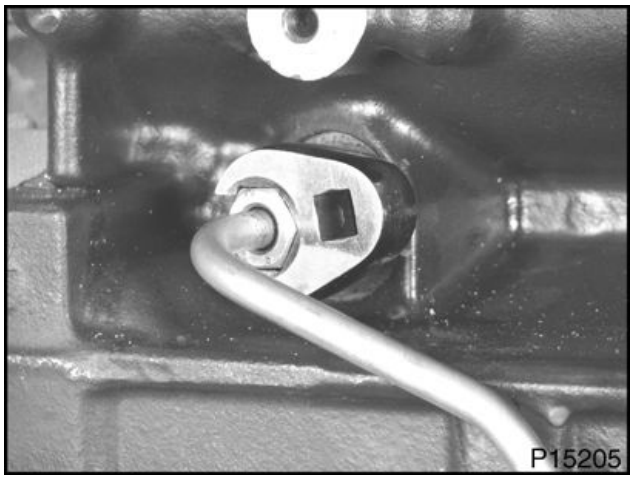

Figure 274 Crowfoot wrench (typical)

3. Obtain a crowfoot wrench (page 276) for removal of all high-pressure fuel lines.

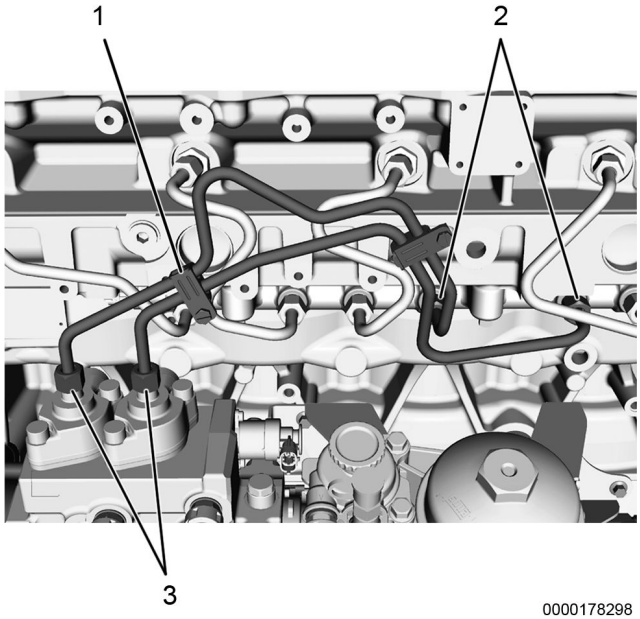

Figure 275 HPFP to rail supply tube damper assembly

1. HPFP to rail supply tube damper assembly
2. Line fitting nut at fuel rail
3. Line fitting nut at HPFP (2)
4. Orientation band

4. Loosen line fitting nuts at HPFP (Figure 275) (Item 3) and fuel rail (Figure 275) (Item 2) and remove HPFP to rail supply tube damper assembly (Figure 275) (Item 1). Cap open fuel pump and fuel rail connections with clean Disposable Air and Fuel Caps (page 276).

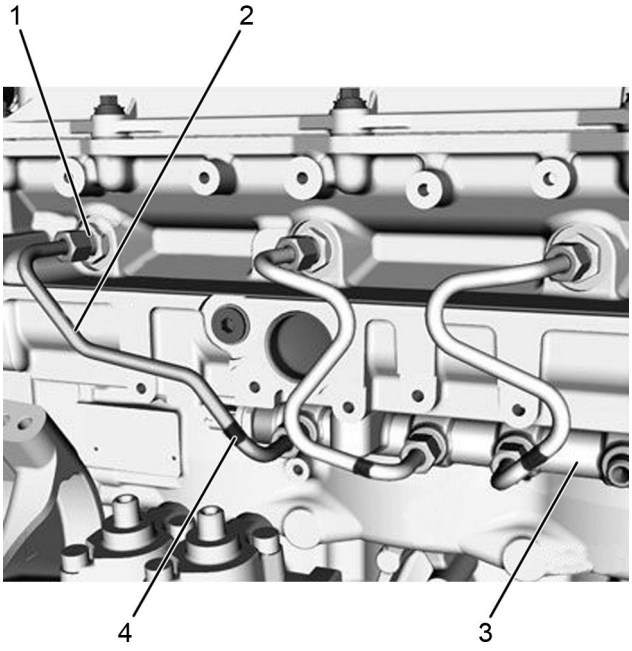

Figure 276 High-pressure rail to injector tube assembly

1. Cylinder 1 high-pressure connector body and retaining nut
2. Cylinder 1 high-pressure rail to injector tube assembly
3. Fuel rail

5. Loosen injector 1 high-pressure rail to injector tube assembly fitting nuts at cylinder head and fuel rail.

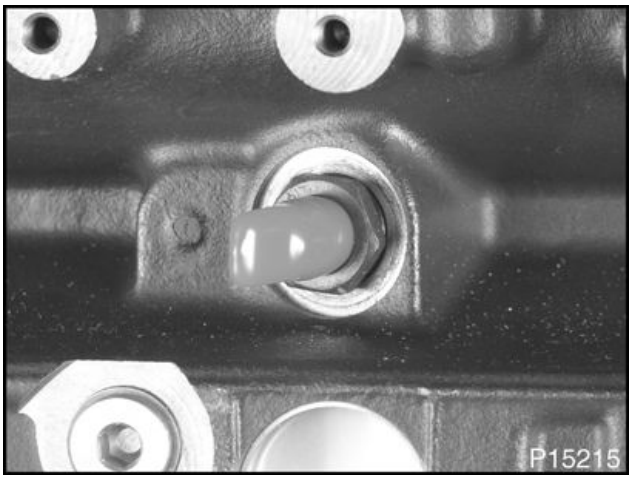

Figure 277 Fuel cap on high-pressure connector body (typical)

6. Remove and discard cylinder 1 high-pressure rail to injector tube assembly. Cap open high-pressure connector body and fuel rail connections with clean Disposable Air and Fuel Caps (page 276).

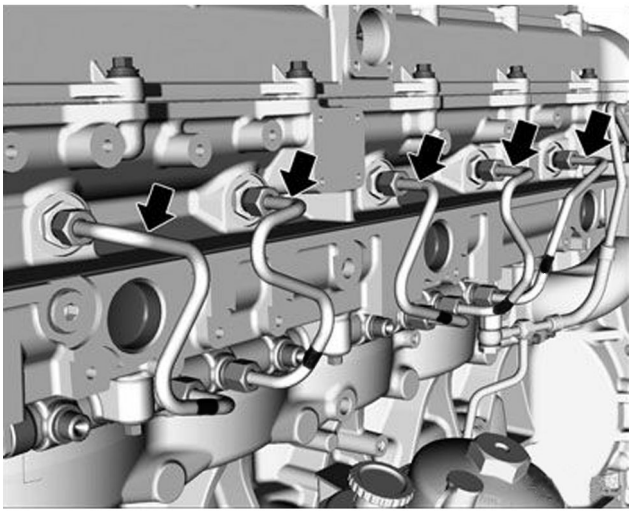

Figure 278 Cylinders 2-6 high-pressure rail to injector tubes

7. Remove high-pressure rail to injector tube assemblies for cylinders 2 through 6. Cap open high-pressure connector body and fuel rail connections.

Injector and Fuel Drain (Return) Lines

NOTE: It is not necessary to disassemble the fuel drain lines unless individual components are leaking or damaged.

CAUTION: To prevent engine damage, plug component connections immediately after each fuel line is removed.

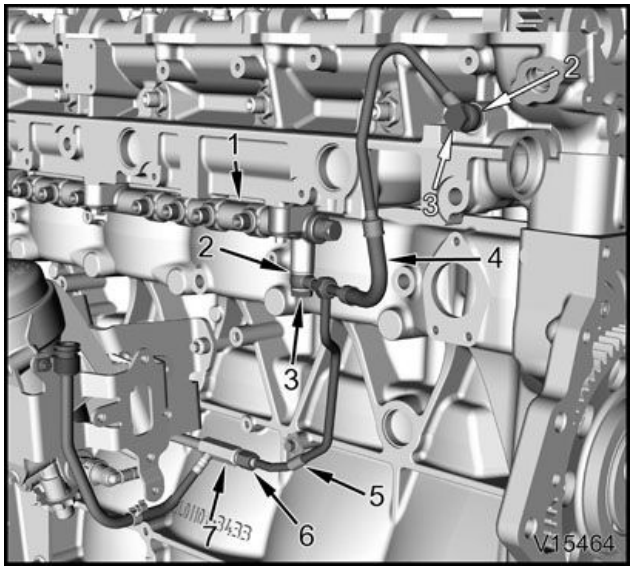

Figure 279 Fuel drain (return) tube

1. Fuel rail
2. 14.7 x 22 seal ring (4)
3. M14 banjo bolt (2)
4. Fuel drain tube
5. M8 x 16 bolt and closed (P) clamp assembly
6. Line fitting nut
7. Fuel drain hose (hex manifold tee)

1. Remove M8 x 16 bolt and closed (P) clamp securing fuel drain tube to crankcase.
2. Loosen fuel drain line fitting nut at the fuel return hex manifold tee and disconnect tube from fuel return line.
3. Remove M14 banjo bolt and two 14.7 x 22 seal rings to disconnect fuel drain tube at fuel rail. Discard seal rings.
4. Remove M14 banjo bolt and 14.7 x 22 seal rings connecting fuel drain tube at cylinder head. Remove fuel drain tube and discard seal rings.

Fuel Rail Assembly

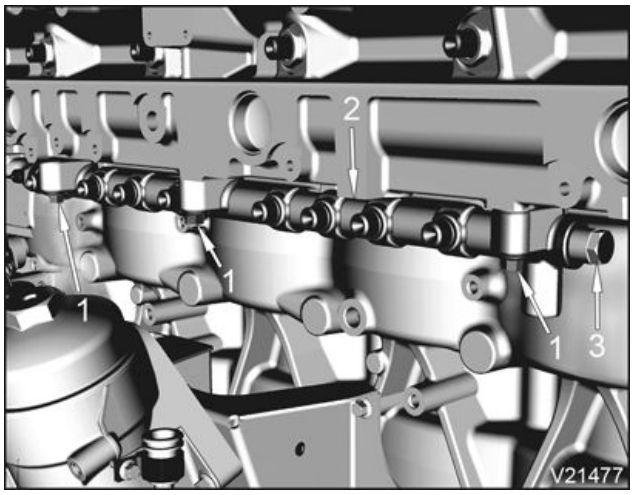

Figure 280 Fuel rail and pressure limiting valve

1. M8 x 40 bolt (3)
2. Fuel rail assembly
3. Pressure limiting valve

WARNING: To prevent personal injury or death, the engine must be stationary for at least 5 minutes to allow for system depressurization, before doing work on the high-pressure fuel system.

NOTE: The pressure limiting valve should not be removed from the fuel rail assembly. Replace the entire fuel rail assembly if the pressure limiting valve is defective. Use ServiceMaxx® to verify fuel pressure following the procedure in the *Engine Diagnostic Manual* .

1. Support fuel rail to prevent it from falling during removal.
2. Remove three M8 x 40 bolts and remove fuel rail from cylinder head.

Fuel Primer Pump Assembly

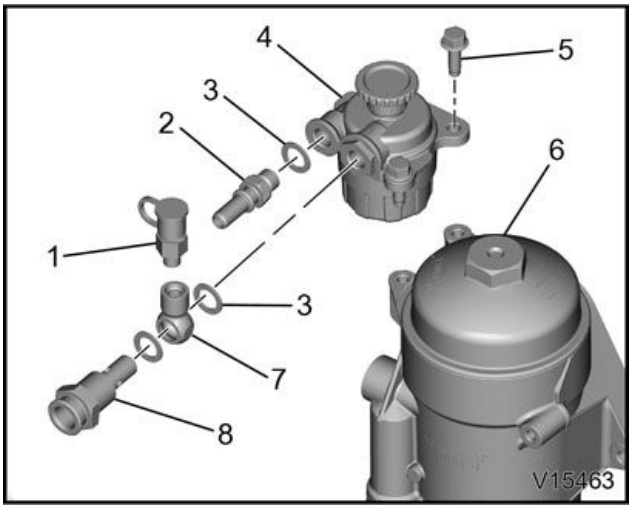

Figure 281 Fuel primer pump assembly

1. Check valve
2. Threaded union
3. 14.7 x 22 seal ring (3)
4. Fuel primer pump assembly
5. M8 x 25 bolt (2)
6. Fuel filter housing
7. Banjo fitting
8. Fuel supply adapter

1. If removed from fuel filter housing, install fuel primer pump assembly and two M8 x 25 bolts. Tighten bolts to special torque (page 275).

NOTE: If fuel primer pump assembly was replaced or fittings were previously removed, continue with step 2.

2. Install banjo fitting with two new 14.7 x 22 seal rings and fuel supply adapter in fuel primer pump assembly inlet port. Tighten adapter to special torque (page 275).
3. Install check valve on banjo fitting. Tighten check valve to special torque (page 275) and install dust cap.
4. Install threaded union and 14.7 x 22 seal ring in fuel primer pump assembly outlet port. Tighten threaded union to special torque (page 275).

Fuel Supply and Drain (Return) Lines

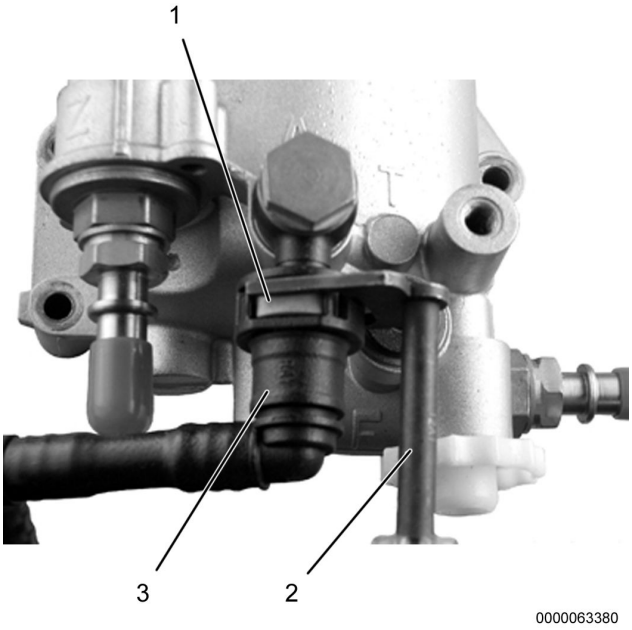

Figure 282 Fuel Line Disconnect Tool ZTSE4773 11.8 mm (Typical)

1. Release button (2)
2. Fuel Line Disconnect Tool ZTSE4773 11.8 mm
3. Quick-connect 90° fitting

CAUTION: To prevent engine damage, plug component connections immediately after each fuel line is removed.

NOTE: Use Fuel Line Disconnect Tool 11.8 mm (page 276) to disconnect all Low-Pressure (LP) fuel line quick-connect fittings.

1. Slide Fuel Line Disconnect Tool (Figure 282) (Item 2) over release buttons (Figure 282) (Item 1) on quick connect 90° fitting (Figure 282) (Item 3).
2. Pull quick-connect 90° fitting to disconnect.

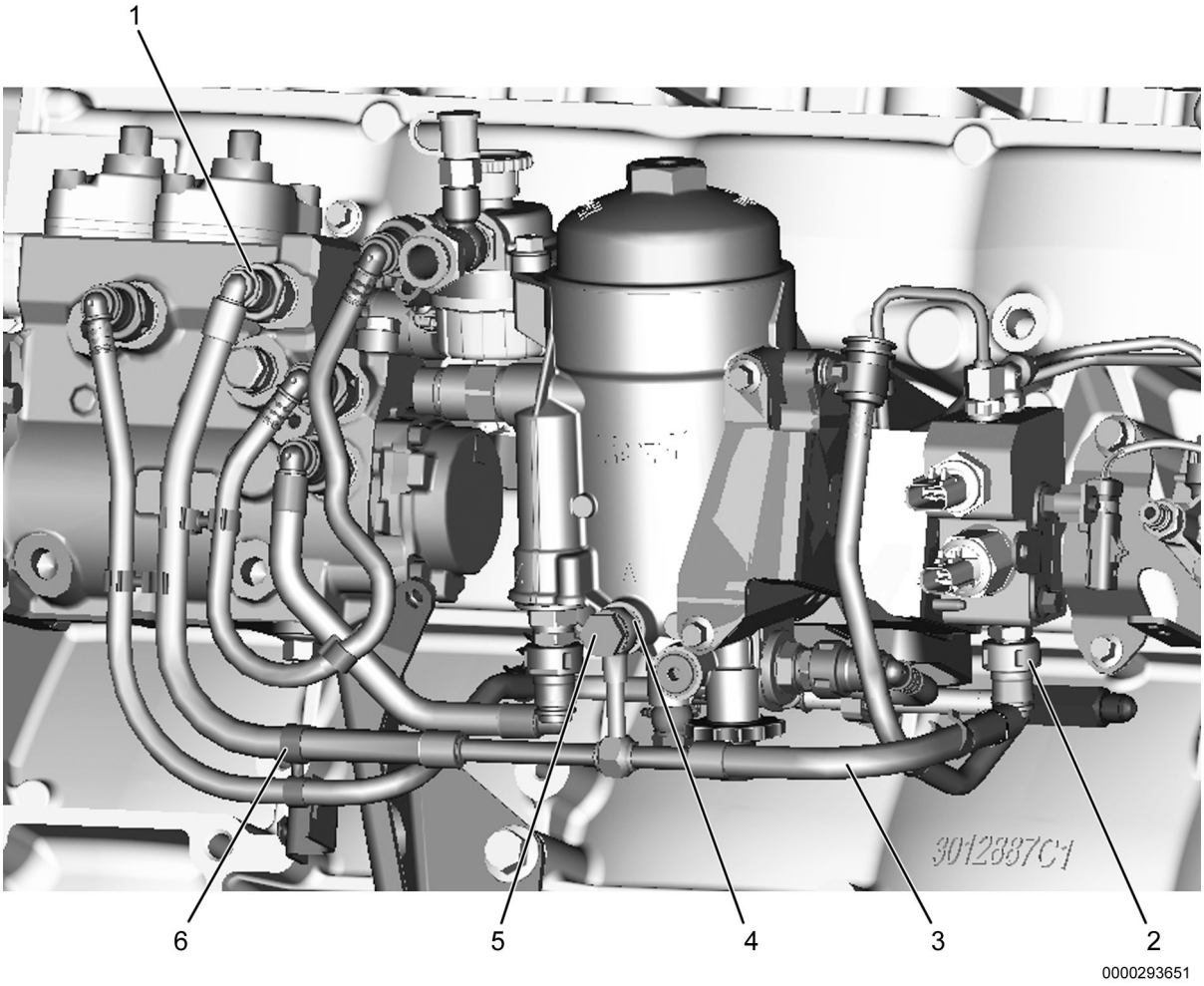

Figure 283 After-Filter Fuel Supply Hose Connections

1. Quick-connect 90° fitting (at high-pressure fuel pump inlet)
2. Quick-connect 90° fitting (at Aftertreatment (AFT) fuel doser module)
3. After-filter fuel supply hose
4. 14.7 x 22 mm seal rings (2)
5. M14 banjo bolt
6. C-clip (3)

3. Disconnect after-filter fuel supply hose assembly quick-connect 90° fittings at high-pressure fuel pump inlet (Figure 283) (Item 1) and at AFT fuel doser module (Figure 283) (Item 2). .
4. Cap openings using clean Disposable Air and Fuel Caps ZTSE4891.
5. Remove c-clips (Figure 283) (Item 5) , M14 banjo bolt (Figure 283) (Item 5), 4.7 x 22 mm seal rings (Figure 283) (Item 4) and remove after-filter fuel supply hose assembly (Figure 283) (Item 3). Discard seal rings.

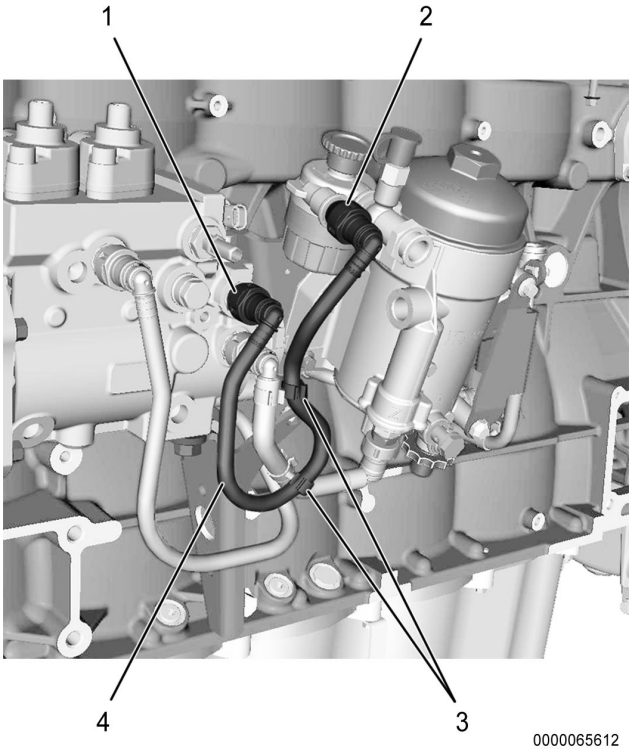

Figure 284 Pre-Pump Fuel Supply Hose Connections

1. Quick-connect 90° fitting (at HPFP)
2. Quick-connect 90° fitting (at primer pump)
3. C-clip (2)
4. Pre-pump fuel supply hose

6. Disconnect pre-pump fuel supply hose assembly quick-connect 90° fittings at HPFP (Figure 284) (Item 1) and at fuel primer pump assembly (Figure 284) (Item 2). Remove c-clips (Figure 284) (Item 3) and hose (Figure 284) (Item 4), and cap openings.

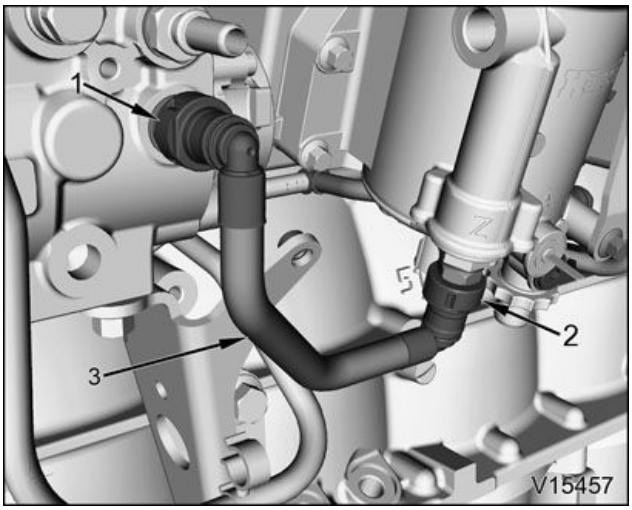

Figure 285 Pre-Filter Fuel Supply Hose Connections

1. Quick-connect 90° fitting (at HPFP)
2. Quick-connect 90° fitting (at fuel filter housing)
3. Pre-filter fuel supply hose

7. Disconnect pre-filter fuel supply hose assembly quick-connect 90° fittings at HPFP (Figure 285) (Item 1) and at fuel filter housing (Figure 285) (Item 2). Remove hose (Figure 285) (Item 3) and cap openings.

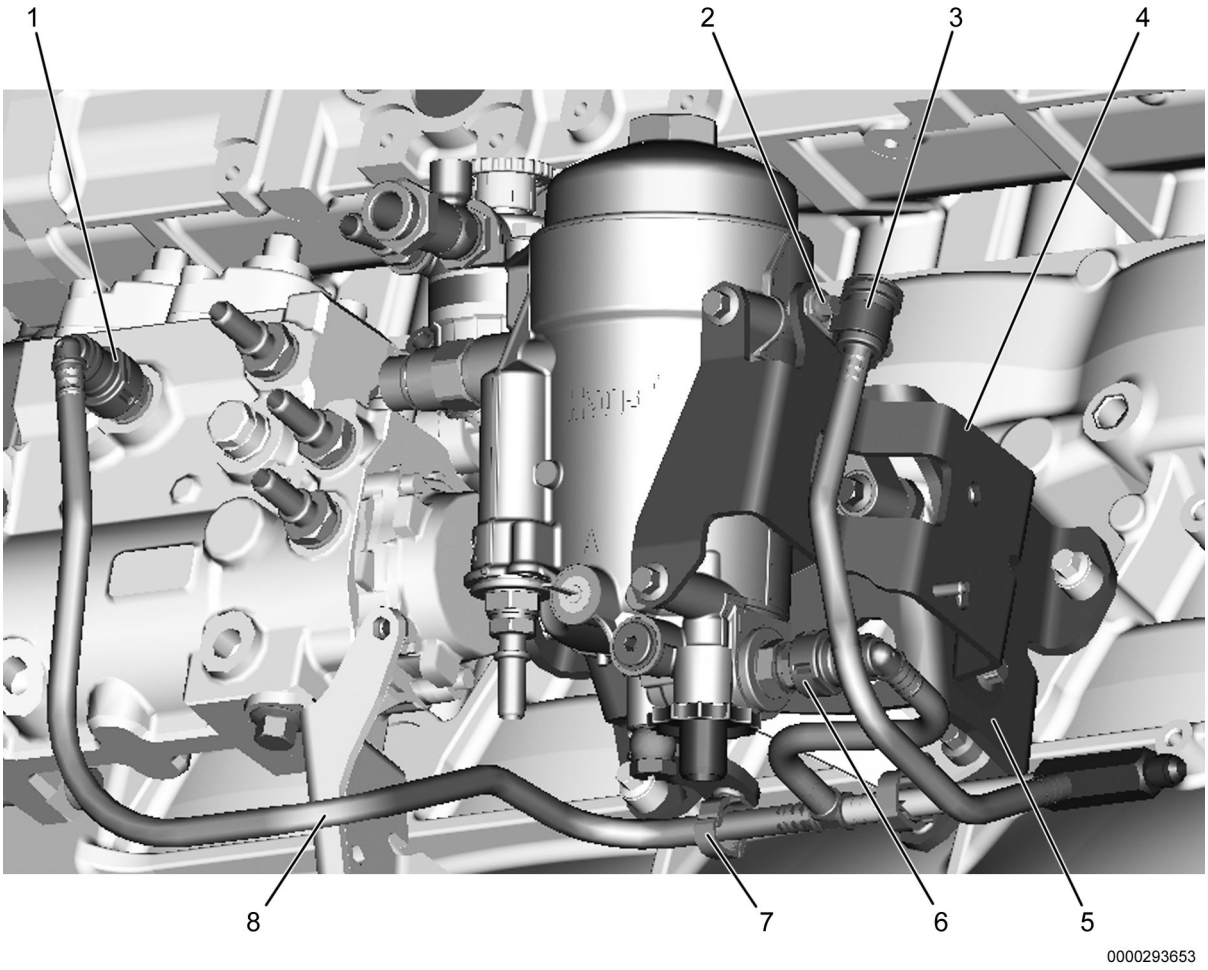

Figure 286 Fuel Drain Hose Connections

1. Quick-connect 90° fitting (at high-pressure fuel pump return)
2. M6 x 16 bolt
3. Closed (P) clamp
4. AFT fuel doser module bracket
5. Fuel filter housing bracket
6. Quick-connect 90° fitting (at fuel filter housing)
7. 8 x 13 single retainer (2)
8. Fuel drain hose

8. Remove M6 x 16 bolt (Figure 286) (Item 2) and closed (P) clamp (Figure 286) (Item 3).
9. Disconnect fuel drain hose assembly quick-connect 90° fittings at high-pressure fuel pump return (Figure 286) (Item 1) and at fuel filter housing (Figure 286) (Item 6).
10. Cap openings using clean Disposable Air and Fuel Caps ZTSE4891.
11. Disconnect 8 x 13 single retainers (Figure 286) (Item 7) and remove fuel drain hose (Figure 286) (Item 8) from engine.

Fuel Primer Pump Assembly

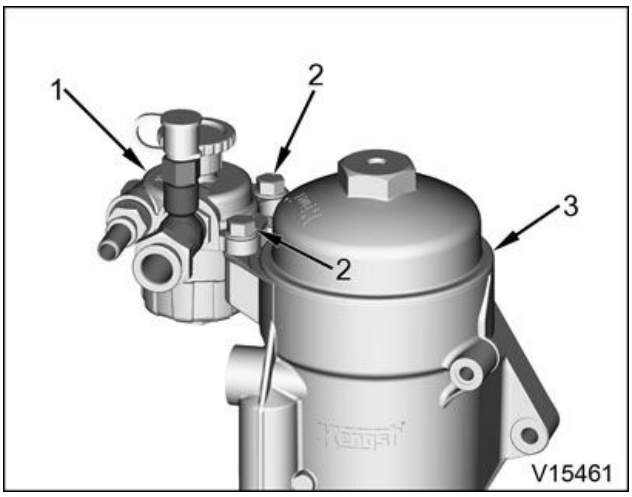

Figure 287 Fuel primer pump assembly

1. Fuel primer pump assembly
2. M8 x 25 bolt (2)
3. Fuel filter housing

NOTE: The fuel primer pump assembly can be removed as an assembly along with the fuel filter housing. If the fuel primer pump assembly is to be replaced, remove two M8 x 25 bolts and remove pump assembly from filter housing.

1. Remove two M8 x 25 bolts.
2. Remove fuel primer pump assembly from fuel filter housing.

Fuel Filter Housing Assembly

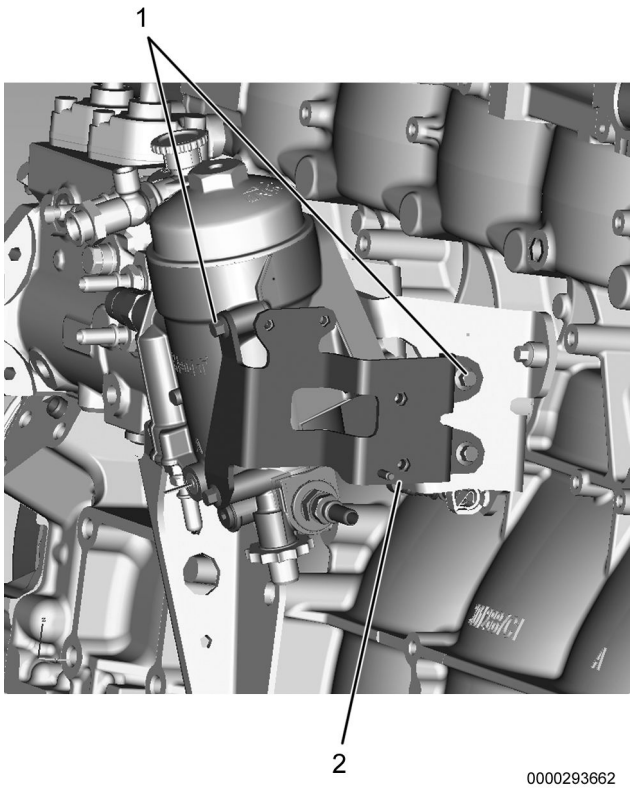

Figure 288 AFT Fuel Doser Module bracket

1. M8 x 16 bolts (3)
2. AFT fuel doser module bracket

1. Remove four M8 x 20 bolts (Figure 288) (Item 1) and remove AFT fuel doser module bracket (Figure 288) (Item 2).

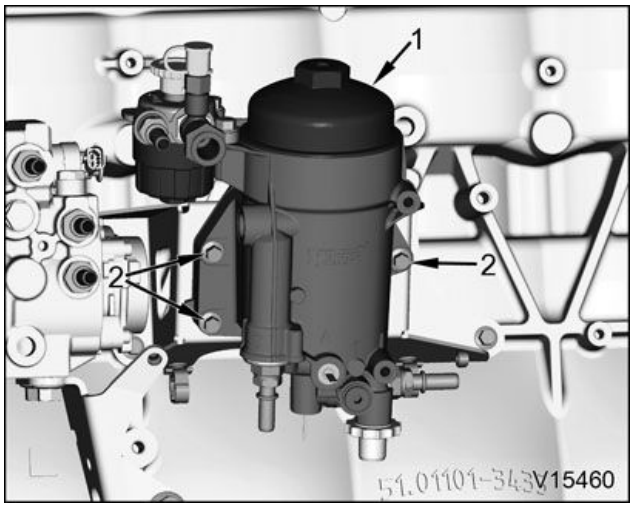

Figure 289 Fuel filter housing assembly

1. Fuel filter housing assembly
2. M8 x 45 bolt (3)

2. Remove three M8 x 45 bolts and remove fuel filter housing assembly.

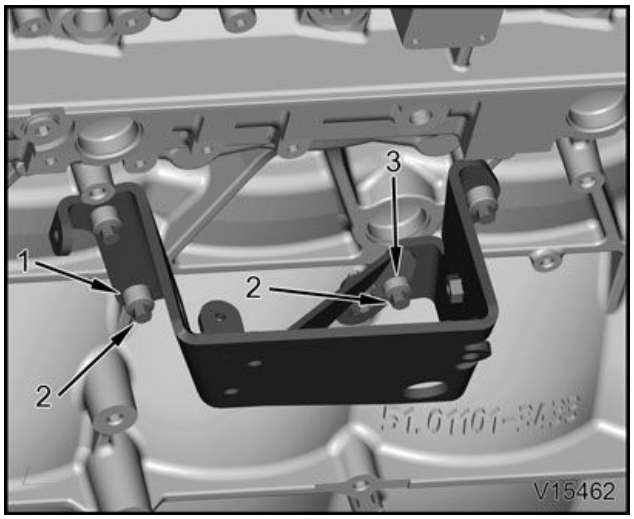

Figure 290 Fuel filter bracket assembly

1. 9 ID x 18 OD x 10.5 spacer (3)
2. M8 x 30 bolt (4)
3. 9 ID x 17 OD x 6.5 spacer

3. Remove four M8 x 30 bolts and spacers; remove fuel filter bracket from crankcase.

Fuel Filter Stand Pipe Replacement

If diagnostic testing indicated replacement of the fuel filter stand pipe, remove the stand pipe and replace with new following this procedure.

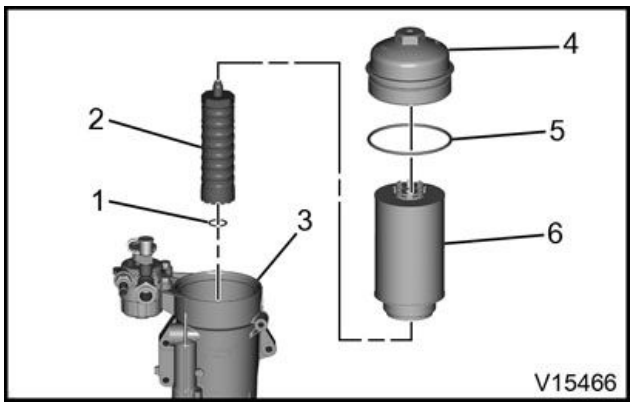

Figure 291 Fuel Filter Stand Pipe

1. Stand pipe O-ring
2. Stand pipe
3. Fuel filter housing
4. Fuel filter cap
5. Fuel filter cap O-ring
6. Fuel filter element

1. Remove fuel filter cap and O-ring.
2. Using an appropriate wrench, loosen and remove stand pipe from housing.
3. Remove O-ring from center tube at bottom of stand pipe.
4. Apply P-80® rubber lubricant or equivalent (page 276) to new O-ring and install O-ring on center tube in bore at bottom of stand pipe.
5. Insert stand pipe into housing assembly and carefully thread pipe into bore in bottom of housing.
6. Tighten the stand pipe to special torque (page 275).
7. Apply P-80® rubber lubricant or equivalent (page 276) to filter cap O-ring and place in position in housing O-ring groove.
8. Insert new filter element in filter housing.
9. Install filter cap and tighten to special torque (page 275).

Radial Shaft Seal

NOTE: Do not remove HPFP pulley if removing HPFP.

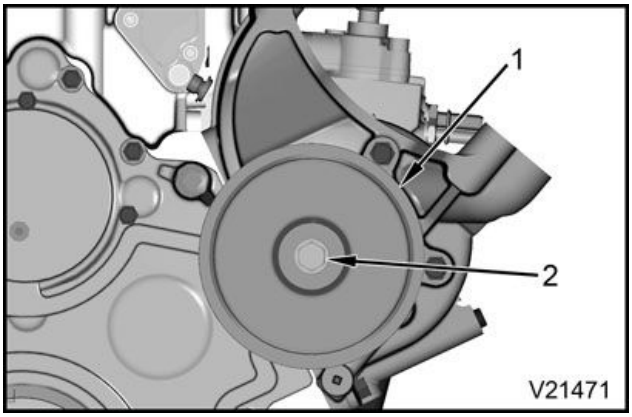

Figure 292 HPFP Pulley

1. HPFP pulley
2. M16 x 40 LH bolt (left-hand thread)

1. Remove M16 x 40 LH bolt (Figure 292) (Item 2). Clean any sealer off of bolt threads.
2. Remove HPFP pulley (Figure 292) (Item 1) from drive belt shaft assembly. Clean any sealer from shaft and pulley.

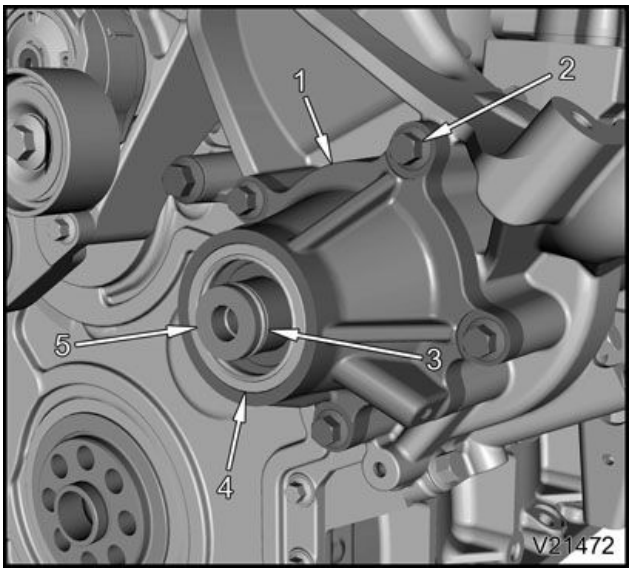

Figure 293 HPFP Pulley Housing and Seal

1. HPFP pulley housing
2. M10 x 40 bolt (4)
3. 30.2 x 3 O-ring
4. 55 x 70 x 8 radial shaft seal
5. Drive belt shaft

3. With an awl and hammer, punch two holes 180° apart in radial shaft seal.
4. Thread a slide hammer (page 276) with correct size screw into one of the two holes.
5. Slide hammer until one side of seal begins to pull out of housing. Move slide hammer to other hole and repeat until radial shaft seal is removed.

Fuel Pressure Control Valve (FPCV)

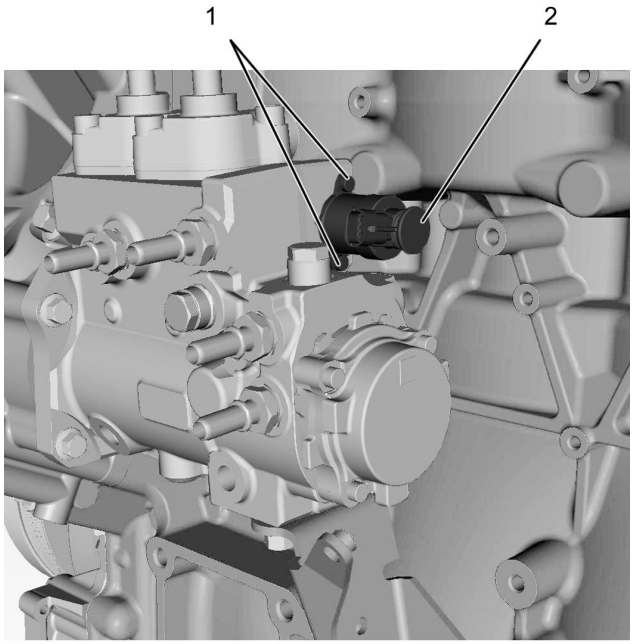

Figure 294 FPCV

1. Screw (2)
2. Fuel Pressure Control Valve (FPCV)

1. Remove two screws (Figure 294) (Item 1) securing FPCV (Figure 294) (Item 2) to High-Pressure Fuel Pump (HPFP).
2. Remove FPCV from HPFP housing.

Piston Overflow Valve (KUEV)

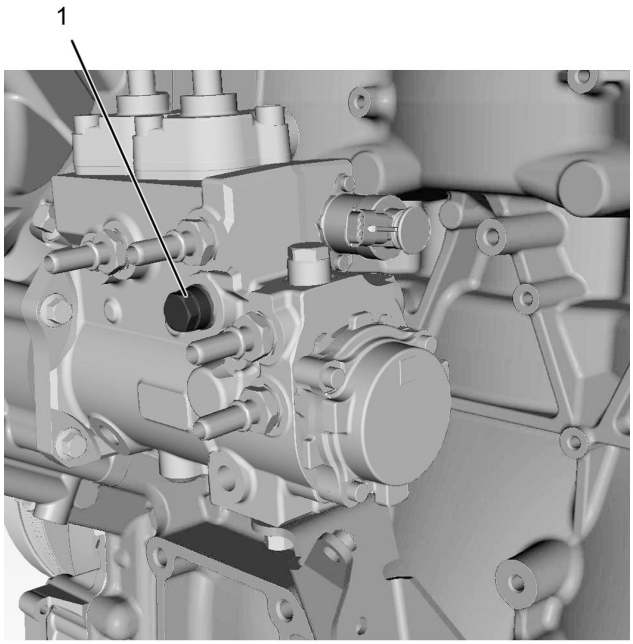

Figure 295 KUEV

1. Piston Overflow Valve (KUEV)

1. Remove KUEV (Figure 295) (Item 1) from High-Pressure Fuel Pump (HPFP) housing.

High-pressure Fuel Pump (HPFP) and Drive Housing

NOTE: The High-Pressure Fuel Pump (HPFP) and drive housing can be removed as an assembly without removing the fuel filter assembly or HPFP pulley.

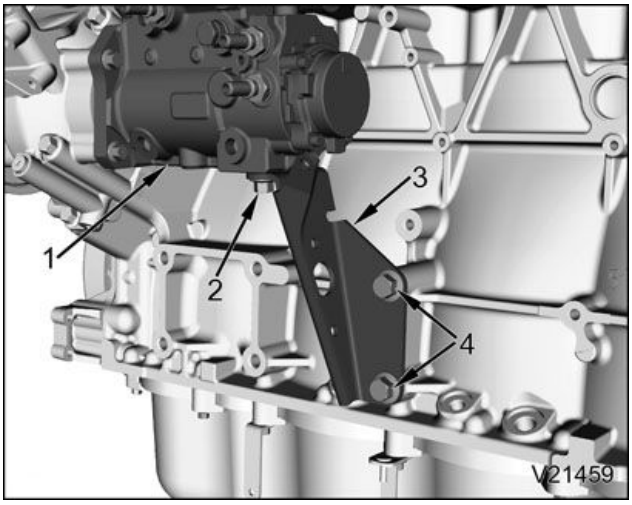

Figure 296 HPFP Support Bracket

1. HPFP
2. M12 x 30 bolt (2)
3. Support bracket
4. M14 x 30 bolt (2)

1. Remove two M12 x 30 (Figure 296) (Item 2) and two M14 x 30 (Figure 296) (Item 4) bolts and remove support bracket (Figure 296) (Item 3) from below HPFP (Figure 296) (Item 1).

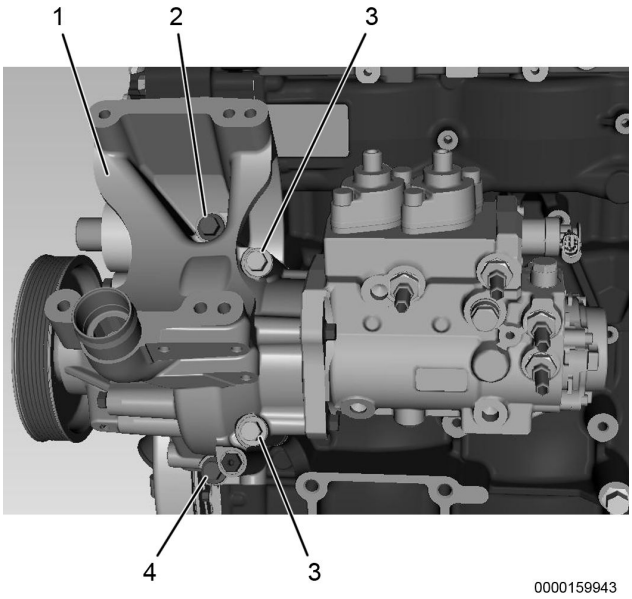

Figure 297 HPFP and Drive Housing

1. Drive housing
2. M12 x 90 bolt
3. M12 x 130 bolt (2)
4. M12 x 40 bolt

2. Remove M12 x 40 (Figure 297) (Item 4), M12 x 90 (Figure 297) (Item 2), and two M12 x 130 bolts (Figure 297) (Item 3) and remove HPFP and drive housing assembly (Figure 297) (Item 1) from crankcase.

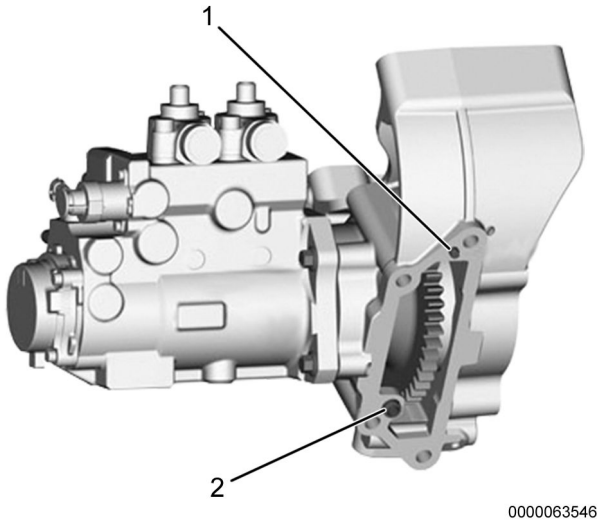

Figure 298 Dowel Pin and Sleeve

1. Dowel pin
2. Sleeve

NOTE: A dowel pin (Figure 298) (Item 1) and sleeve (Figure 298) (Item 2) is used to ensure correct placement of drive housing on the engine block. Holding Plate ZTSE6044 may be bolted to the drive housing with the dowel pin and sleeve in place.

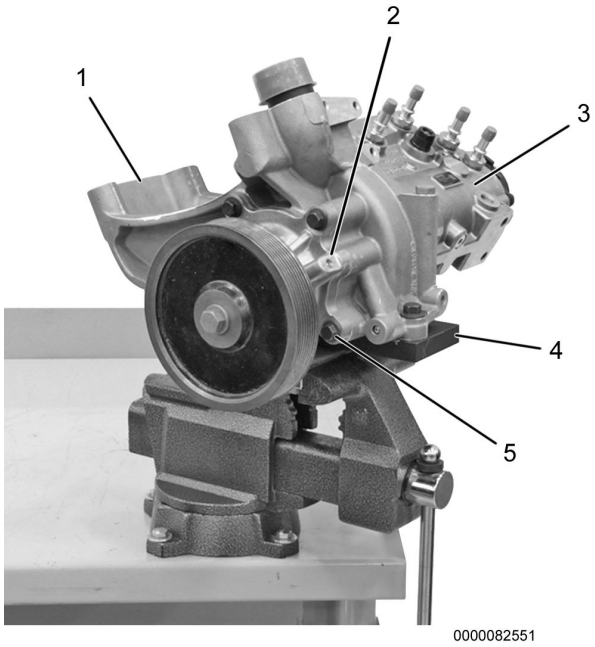

Figure 299 Drive Housing Secured to Holding Plate ZTSE6044

1. Drive housing
2. HPFP pulley housing
3. HPFP
4. Holding Plate ZTSE6044
5. M10 x 40 bolt (4)

3. Secure Holding Plate (Figure 299) (Item 4) in a vise.
4. Install drive housing (Figure 299) (Item 1) and HPFP (Figure 299) (Item 3) to Holding Plate with M12 x 40, M12 x 90 and two M12 x 130 bolts. Tighten bolts to 77 lb·ft (105 N·m). Holding Plate will prevent the HPFP gear from turning while loosening the M24 jam nut.
5. Remove four M10 x 40 bolts (Figure 299) (Item 5) and remove HPFP pulley housing (Figure 299) (Item 2) from drive housing.

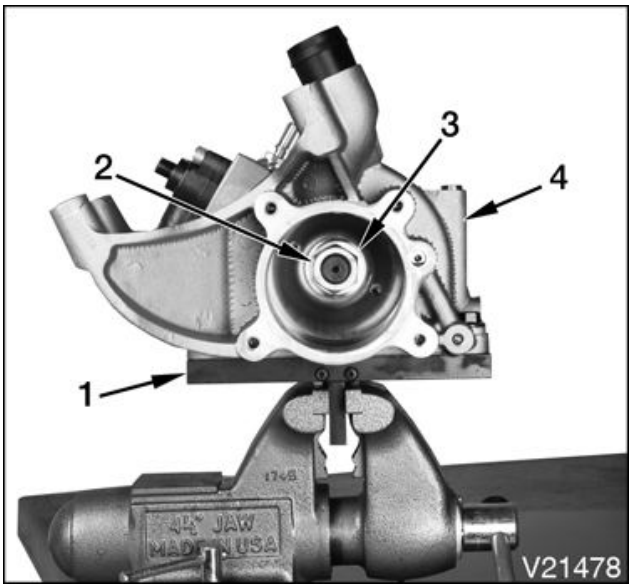

Figure 300 Drive Housing With HPFP Pulley Housing Removed

1. Holding Plate
2. M24 jam nut
3. 25 x 44 x 4 washer
4. Drive housing and HPFP

6. Remove the M24 jam nut (Figure 300) (Item 2) and 25 x 44 x 4 washer (Figure 300) (Item 3) securing HPFP gear to pump shaft.

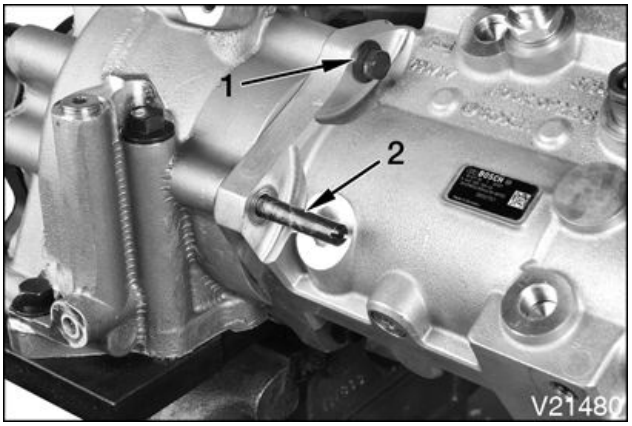

Figure 301 HPFP Guide Studs

1. M10 x 40 bolt (4)
2. Guide Stud 12–454–01–2 (2)

7. Remove four M10 x 40 bolts (Figure 301) (Item 2). Install two Guide Studs (Figure 301) (Item 2) on opposite sides of the HPFP.

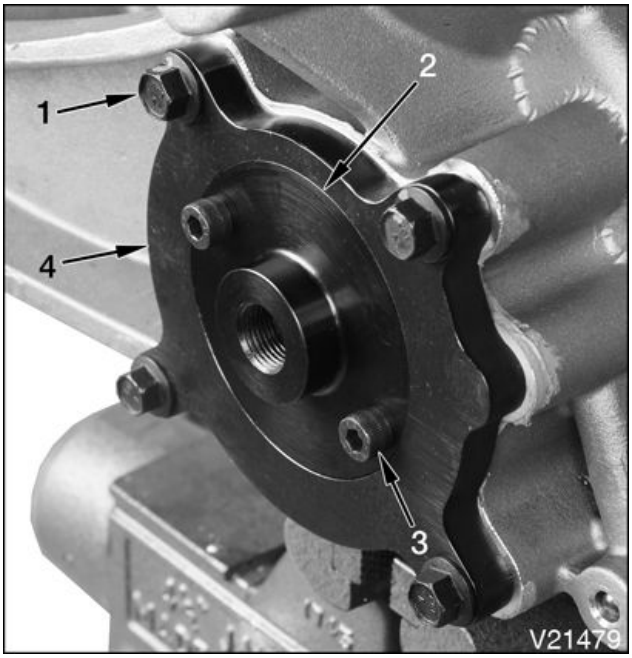

Figure 302 HPFP Removal Tool 12–454–01 On Drive Housing

1. M10 x 40 bolt (4)
2. Forcing Screw Adapter (flush with Forcing Screw Adapter Holding Plate) 12–454–01–4
3. Socket Head Bolt 12–454–01–3 (2)
4. Forcing Screw Adapter Holding Plate 12–454–01–1

8. Install Forcing Screw Adapter Holding Plate (Figure 302) (Item 4) on drive housing with four M10 x 40 bolts (Figure 302) (Item 1). Tighten M10 x 40 bolts to 46 lb·ft (62 N·m).
9. Place two Socket Head Bolts (Figure 302) (Item 3) through Forcing Screw Adapter (Figure 302) (Item 2) and thread them into holes in HPFP gear. Tighten bolts only until Forcing Screw Adapter is flush with Forcing Screw Adapter Holding Plate.

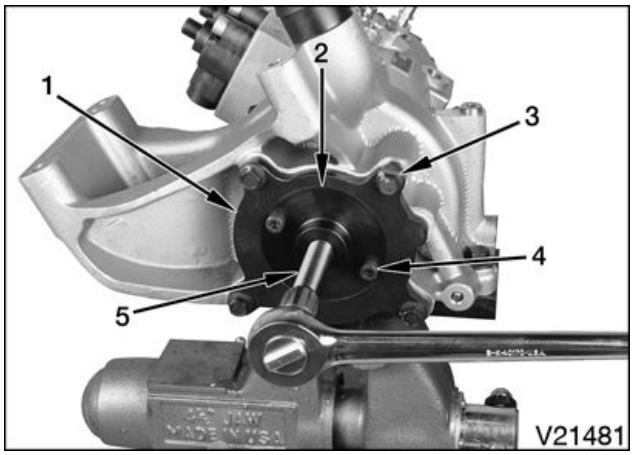

Figure 303 HPFP Removal

1. Forcing Screw Adapter Holding Plate
2. Forcing Screw Adapter
3. M10 x 40 bolt (4)
4. Socket Head Bolt (2)
5. Forcing Screw 12–454–01–5

10. Install Forcing Screw (Figure 303) (Item 5) by hand into Forcing Screw Adapter until it contacts HPFP shaft.
11. Turn Forcing Screw clockwise until HPFP is removed from drive housing.
12. Remove Socket Head Bolts, Forcing Screw Adapter, and Forcing Screw Adapter Holding Plate from drive housing.

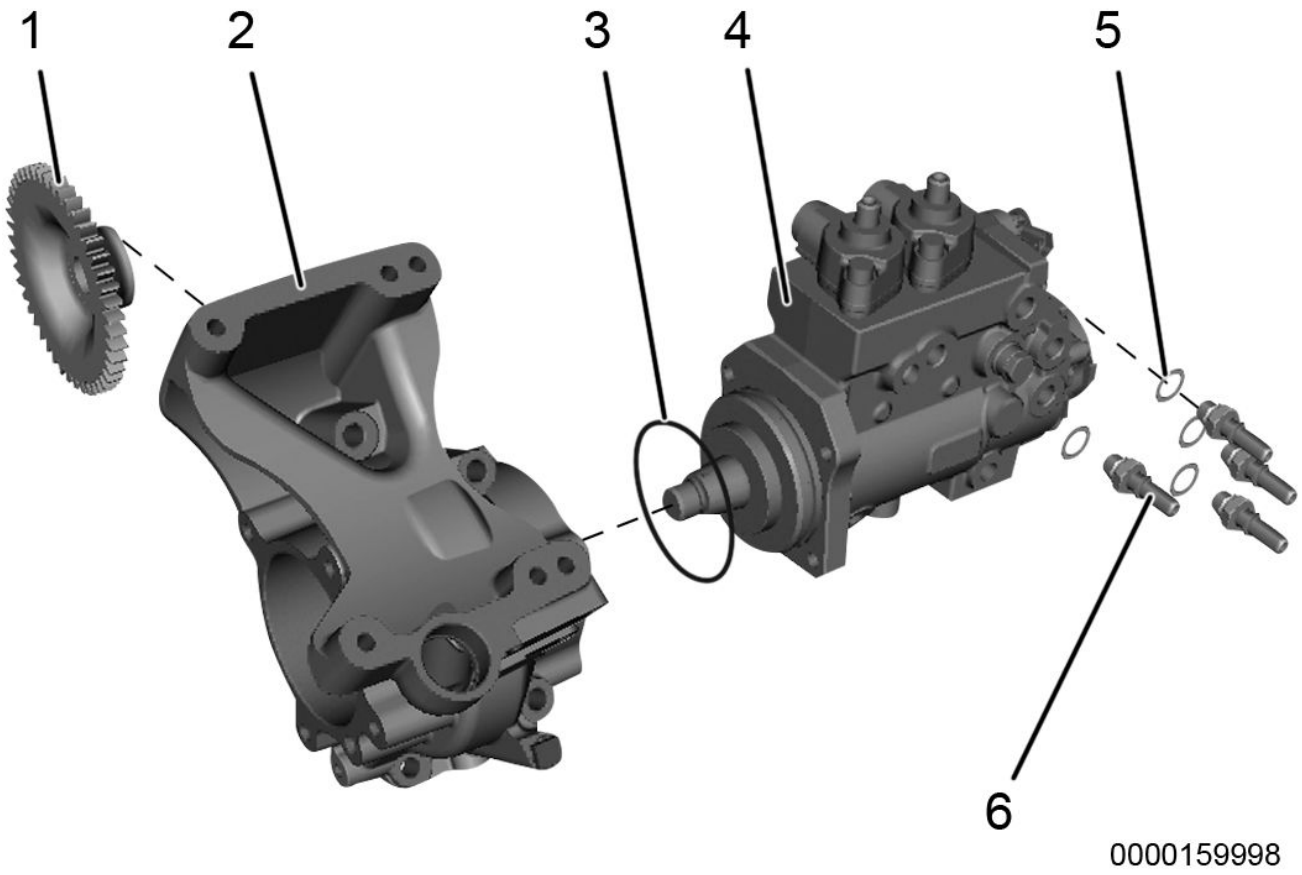

Figure 304 Drive Housing Separated From HPFP

1. HPFP gear
2. Drive housing
3. 100 x 3.349 O-ring
4. HPFP
5. Seal ring, 16.7 x 24 (4)
6. Quick-connect M16 x 1.5 connector (4)

13. Remove drive housing from Holding Plate and remove HPFP gear (Figure 304) (Item 1) from drive housing.
14. Remove and discard 100 x 3.349 O-ring (Figure 304) (Item 3) from HPFP.
15. If required, remove four M16 x 1.5 quick-connect connectors (Figure 304) (Item 6) and discard four 16.7 x 24 seal rings (Figure 304) (Item 5).

Fuel Injectors

CAUTION: To prevent engine damage, remove injectors before removing cylinder head.

CAUTION: To prevent engine damage, do not use power tools to remove or install fuel injector clamp bolts. Threads will be damaged if a bolt or nut is rotated too quickly.

CAUTION: To prevent engine damage, install new injector O-ring and combustion washer before installing injector.

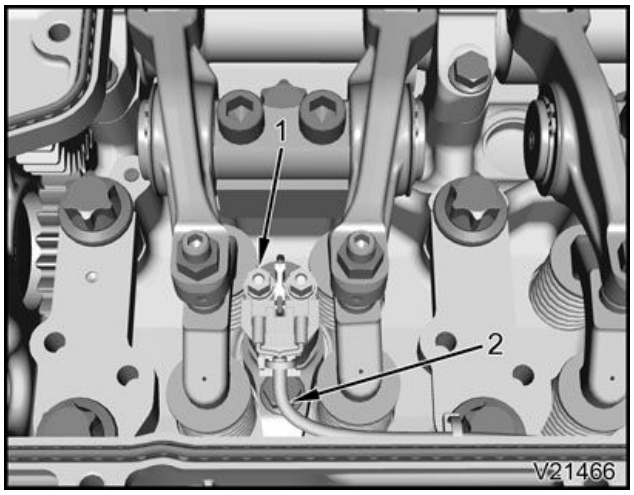

Figure 305 Fuel injector connections

1. Injector harness nuts (12)
2. Engine 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.

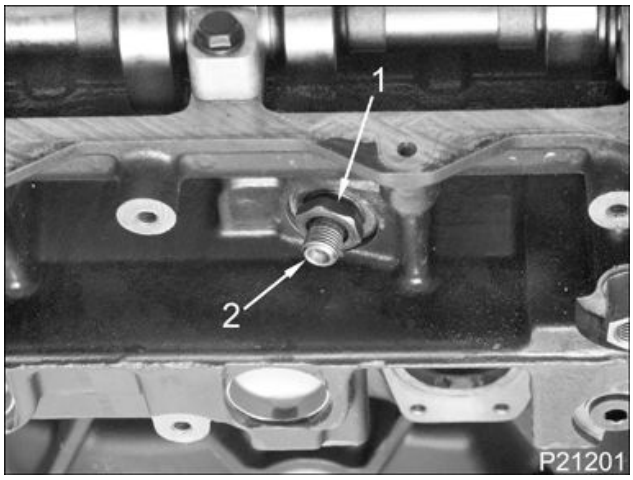

Figure 306 High-pressure connector body (typical)

1. Retaining high-pressure connector nut (6)
2. High-pressure connector body (6)

2. Remove six retaining high-pressure connector nuts.
3. Remove and discard six high-pressure connector bodies.
4. Cover cylinder head high-pressure connector body bores with appropriate size plugs from Disposable Air and Fuel Caps (page 276).

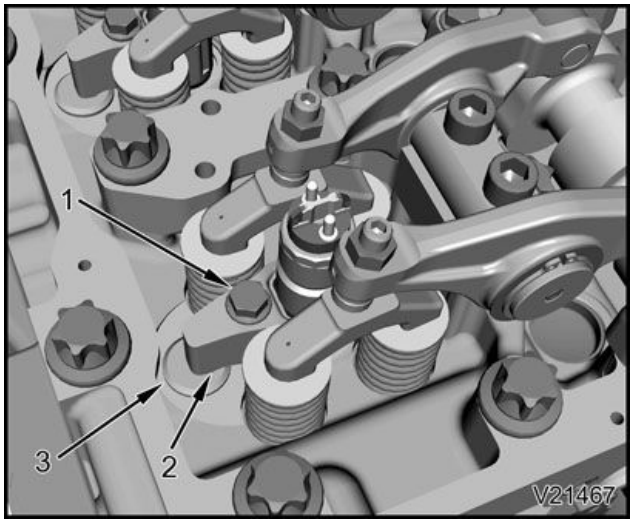

Figure 307 Injector hold-down clamp

1. M8 x 50 bolt (6) and rounded washer (6)
2. Injector hold-down clamp (6)
3. Thrust washer (6)

5. Remove six M8 x 50 hold-down clamp bolts and rounded washers.
6. Remove six thrust washers.

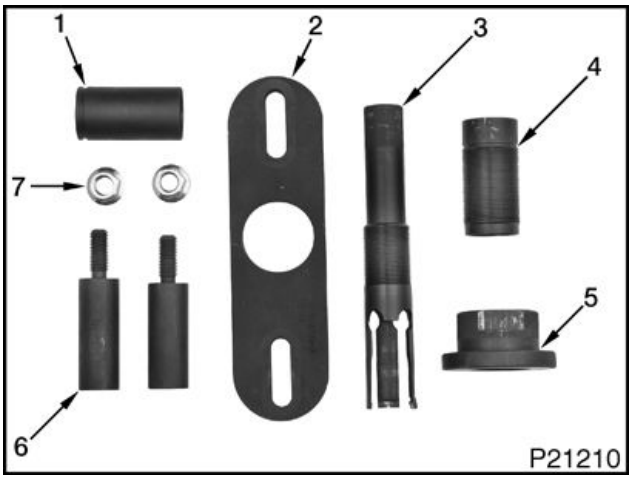

Figure 308 Injector Puller

1. Clamping sleeve
2. Extractor plate
3. Extractor
4. Knurled nut
5. Extractor nut
6. Plate column (2)
7. Plate column nuts (2)

7. Use Injector Puller (page 276) to remove injectors.

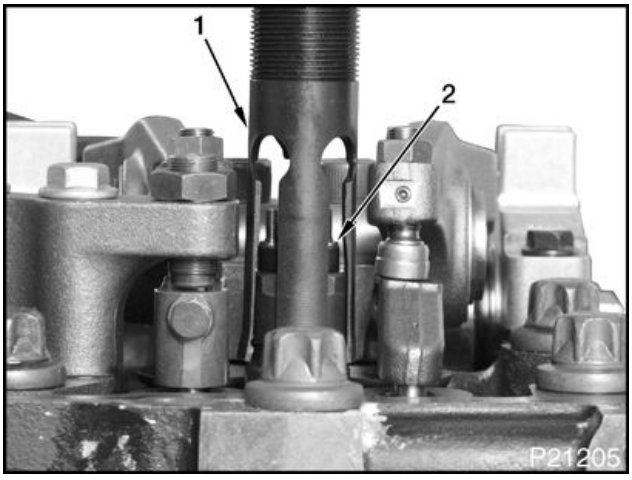

Figure 309 Injector extractor (typical)

1. Extractor (part of Injector Puller)
2. Injector

8. Install extractor on injector.

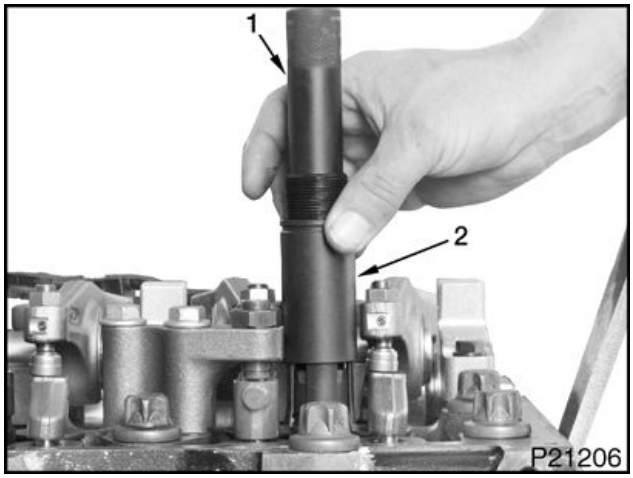

Figure 310 Clamping sleeve on extractor (typical)

1. Extractor
2. Clamping sleeve

9. Slide clamping sleeve over extractor.

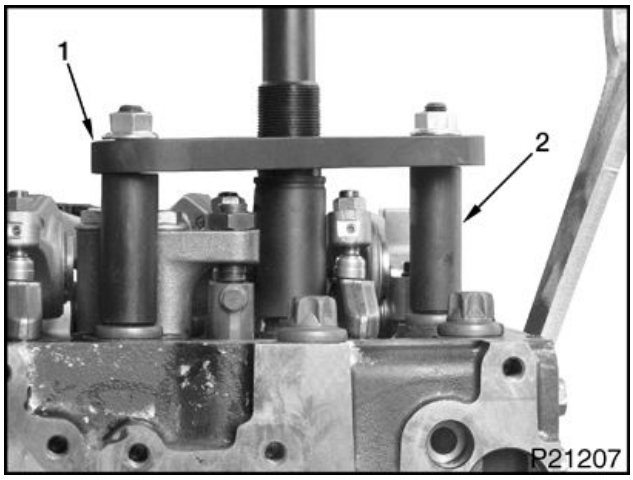

Figure 311 Extractor plate and plate columns (typical)

1. Extractor plate
2. Plate column (2)

10. Position two plate columns on two opposite cylinder head bolts, and slide extractor plate over extractor and plate columns.

11. Install and finger-tighten plate column nuts on plate columns.

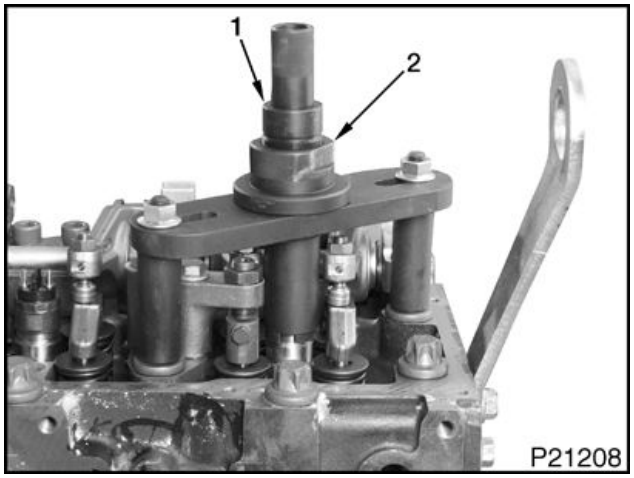

Figure 312 Extractor nut (typical)

1. Knurled nut
2. Extractor nut

12. Install knurled nut and extractor nut with the extractor nut backed out.
13. Hold knurled nut and tighten extractor nut to remove injector, combustion washer and hold-down clamp.

NOTE: Make sure that no combustion washer remains in the injector bore after the injector is removed.

14. Cover cylinder head injector bore with appropriate size plugs from Disposable Air and Fuel Caps (page 276).

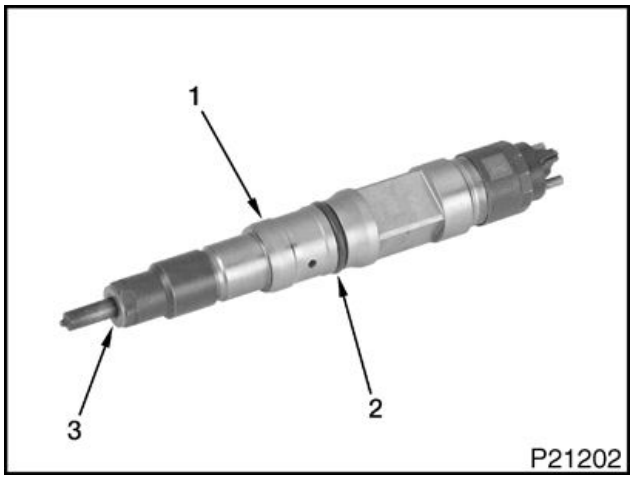

Figure 313 Injector seals (typical)

1. Injector assembly
2. 3 x 20.9 ID O-ring
3. Combustion washer

15. Using a small non-metallic hand tool, carefully remove and discard combustion washer and O-ring. Wipe injector nozzle with a lint-free cloth.

CAUTION: To prevent engine damage, do not clean fuel injectors with parts solvent or other chemicals.

16. Clean injector tip with Fuel Injector Tip Cleaning Brush (page 276).
17. Insert injector into Fuel Injector Cup (page 276), and place in Fuel Injector Rack Holder (page 276).

Cleaning and Inspection

Low-pressure and High-pressure Fuel System Components

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.

Fuel Injector Bore

1. Use Injector Sleeve Brushes (page 276) 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 wiring harness for kinked wires or terminals. Replace harness if kinks are found. Kinked wires can result in oil leaking in between the harness protective foam covering and the wires.

Installation

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 to remove or install fuel injector clamp bolts. Threads will be damaged if a bolt or nut is rotated too quickly.

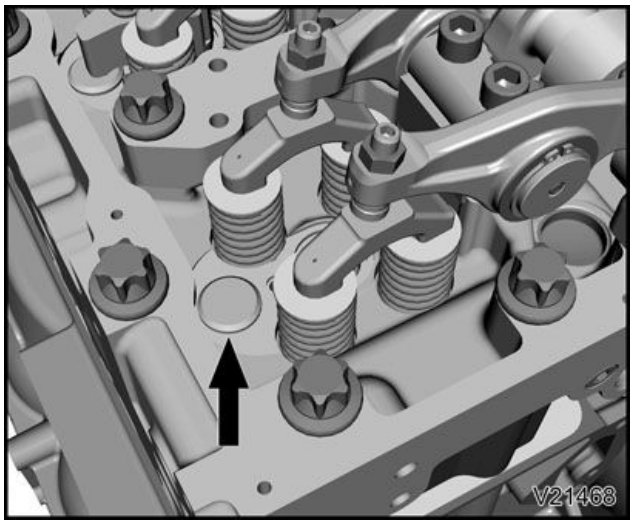

Figure 314 Thrust washer

CAUTION: To prevent engine damage, verify all thrust washers are properly installed in cylinder head.

1. Install six thrust washers on cylinder head.

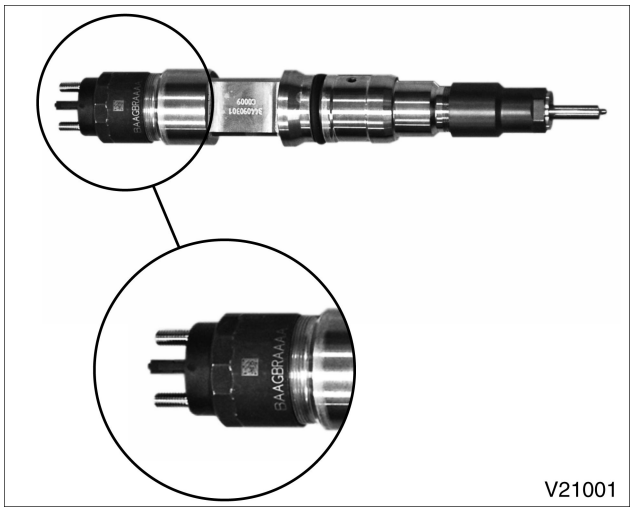

Figure 315 Injection Quantity Adjustment (IQA) code

NOTE: The Injection Quantity Adjustment (IQA) code is printed in capital letters and numbers near the top of the fuel injector.

2. Record the IQA code of each new fuel injector and its corresponding cylinder number so the new code can be programed into the ECM, after fuel injectors are installed.

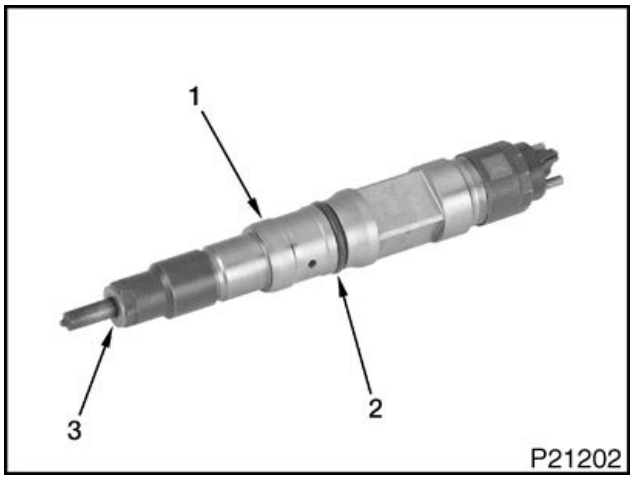

Figure 316 Injector seals (typical)

1. Injector assembly
2. 3 x 20.9 ID O-ring
3. Combustion washer

CAUTION: To prevent engine damage, install new injector O-ring and combustion washer before installing injector.

3. Install a new combustion washer onto injector tip.
4. Lubricate a new 3 x 20.9 ID O-ring with clean engine oil and install in recess at mid-point of injector.

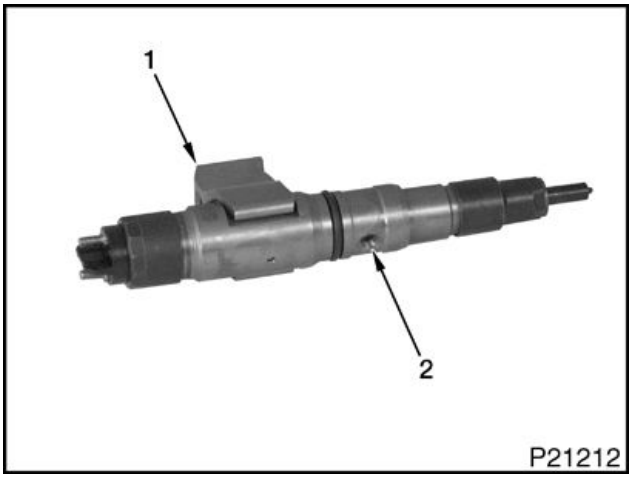

Figure 317 Injector and injector hold-down clamp orientation (typical)

1. Injector hold-down clamp
2. Injector fuel inlet opening

5. Slide injector into hold-down clamp with injector fuel inlet opening on opposite side of hold-down clamp.

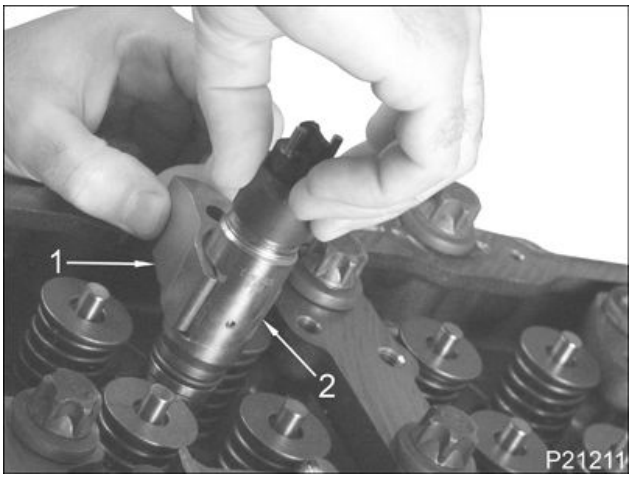

Figure 318 Injector and injector hold-down clamp installation (typical)

1. Injector hold-down clamp
2. Injector

CAUTION: To prevent engine damage, align injector and hold-down clamp correctly with cylinder head. Do not twist injector when inserting injector into cylinder head.

NOTE: Make sure injector bore in cylinder head is clean and no old combustion washer remains inside the bore.

6. Install injector by lowering injector and hold-down clamp as one unit into injector bore.
7. Using Injector Installer (page 276), firmly press injector and hold-down clamp and make sure injector is fully seated into cylinder head.

CAUTION: To prevent engine damage, six new high-pressure connector bodies must be installed and aligned before tightening M8 x 50 bolts for six fuel injectors.

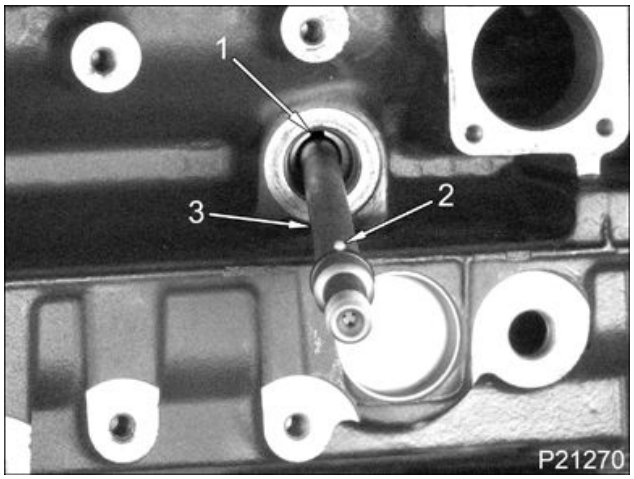

Figure 319 Alignment of high-pressure connector body (typical)

1. Notch in cylinder head
2. Locating ball
3. High-pressure connector body

8. Align locating ball on each new high-pressure connector body with notch in cylinder head and install six new high-pressure connector bodies.

Injector hold-down clamp (M8 x 50 bolts)

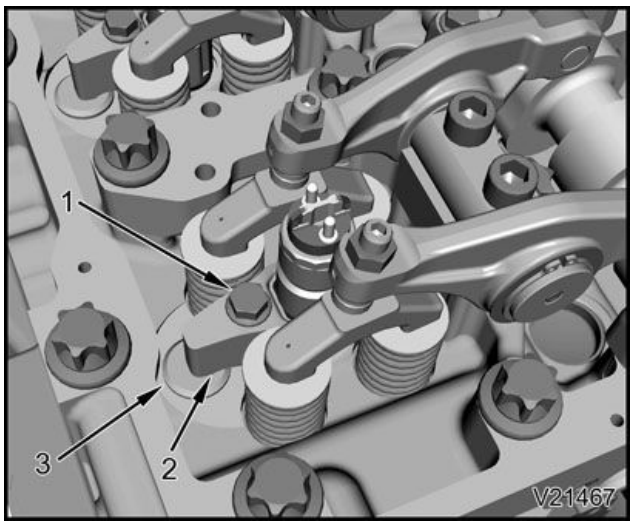

Figure 320 Injector hold-down clamp bolt

1. M8 x 50 bolt (6) and rounded washer (6)
2. Injector hold-down clamp (6)
3. Thrust washer (6)

9. Install six rounded washers and M8 x 50 bolts finger tight.

High-pressure connector body (retaining nuts)

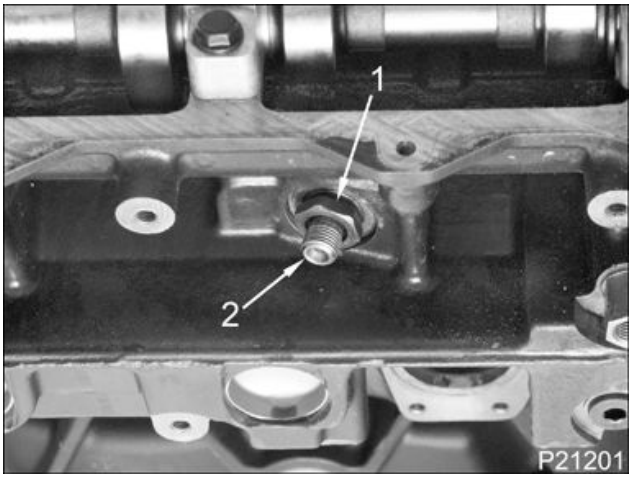

Figure 321 High-pressure connector body (typical)

1. High-pressure connector retaining nut (6)
2. High-pressure connector body (6)

10. Install six high-pressure connector retaining nuts and tighten nuts to 55 N·m (41 lb·ft).
11. Completely loosen six high-pressure retaining nuts; then, retighten nuts to 10 N·m (89 lb·in).

Injector hold-down clamp (Final torque of M8 x 50 bolts)

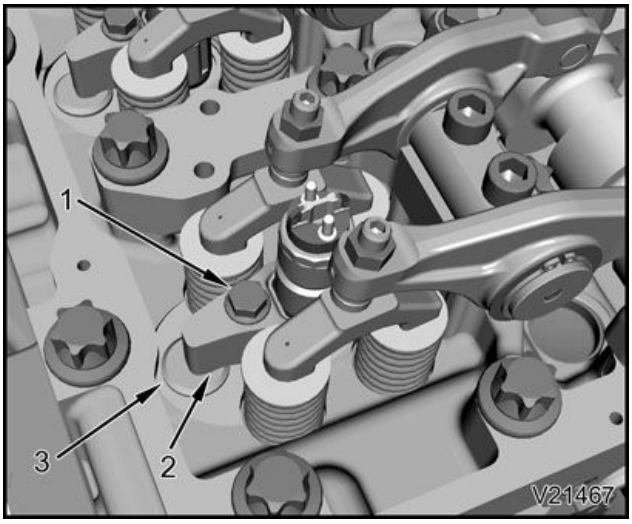

Figure 322 Injector hold-down clamp bolt

1. M8 x 50 bolt (6) and rounded washer (6)
2. Injector hold-down clamp (6)
3. Thrust washer (6)

12. Tighten six M8 x 50 injector hold-down clamp bolts to 25 N·m (18 lb·ft).
13. Tighten six M8 x 50 injector hold-down clamp bolts an additional 90°.

High-pressure connector body (Final torque of retaining nuts)

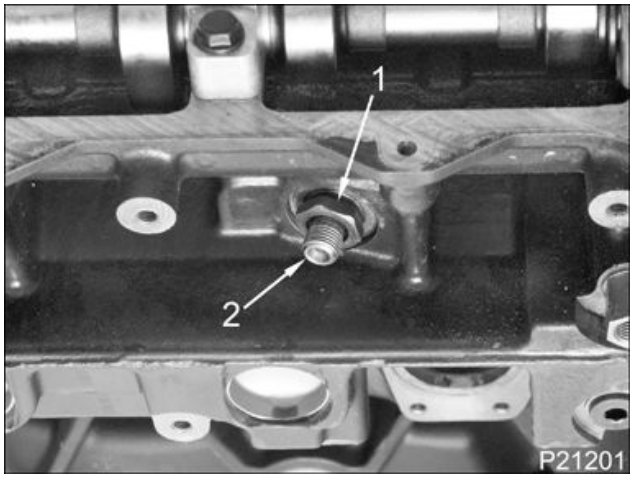

Figure 323 High-pressure connector body (typical)

1. High-pressure connector retaining nut (6)
2. High-pressure connector body (6)

14. Tighten six high-pressure connector retaining nuts to 20 N·m (15 lb·ft).
15. Tighten six high-pressure connector retaining nuts an additional 32°.

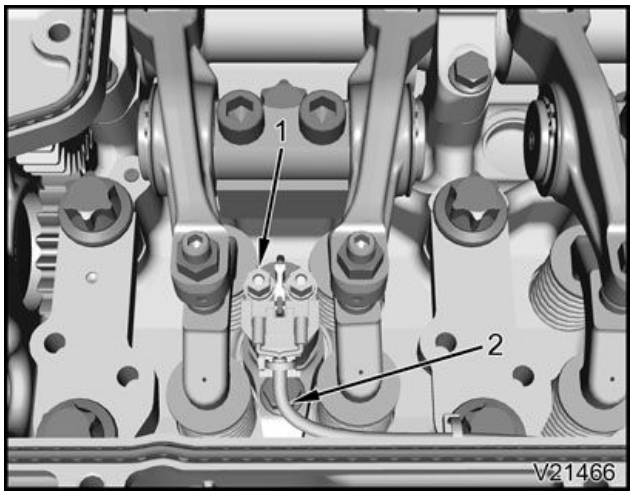

Figure 324 Injector connections

1. Injector harness nuts (12)
2. Engine 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 1.8 N·m (16 lb·in).

CAUTION: To prevent engine damage, verify injector harness wires are not pinched or rubbing against the engine brake housing or rocker arm assembly.

16. 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 275).
17. See Navistar® N13 *Engine Diagnostic Manual* Performance Diagnostics section, for instructions on how to program the Engine Control Module (ECM), using ServiceMaxx™, with Injection Quantity Adjustment (IQA) codes for fuel injectors being replaced.

High-Pressure Fuel Pump (HPFP) and Drive Housing

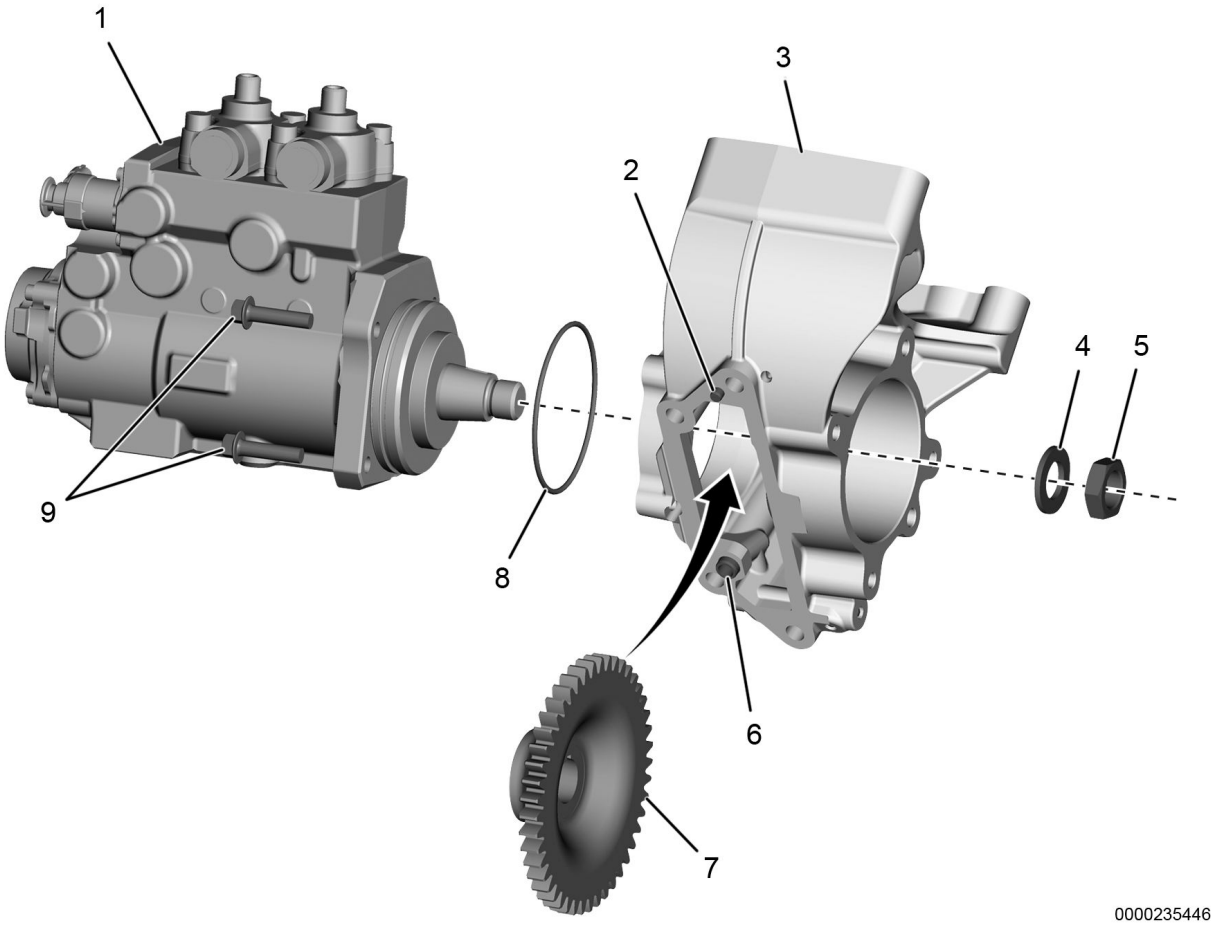

Figure 325 High-Pressure Fuel Pump (HPFP) and Drive Housing Assembly

1. HPFP
2. Dowel pin
3. Drive housing
4. 25 x 44 x 4 washer
5. M24 jam nut
6. Sleeve
7. HPFP gear
8. 100 x 3.349 O-ring
9. M10 x 40 bolts (4)

1. Install a new 100 x 3.349 O-ring (Figure 325) (Item 8) on fuel pump mounting flange collar.

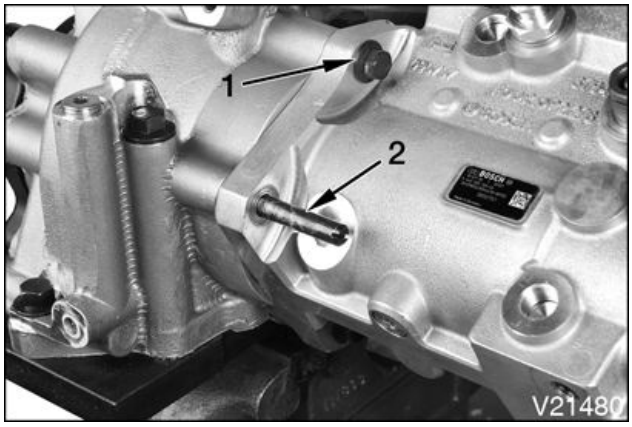

Figure 326 HPFP Guide Studs

1. M10 x 40 bolt (4)
2. Guide Stud 12–454–01–2 (2)

2. Install two Guide Studs (Figure 326) (Item 2) on opposite sides of HPFP.
3. Place HPFP gear (Figure 325) (Item 7) into drive housing and position drive housing on pump.
4. Remove two Guide Studs from HPFP.
5. Install four M10 x 40 bolts (Figure 326) (Item 1) hand-tight.
6. Install 25 x 44 x 4 washer (Figure 325) (Item 4) and M24 jam nut (Figure 325) (Item 5), hand-tight to secure gear on HPFP shaft.

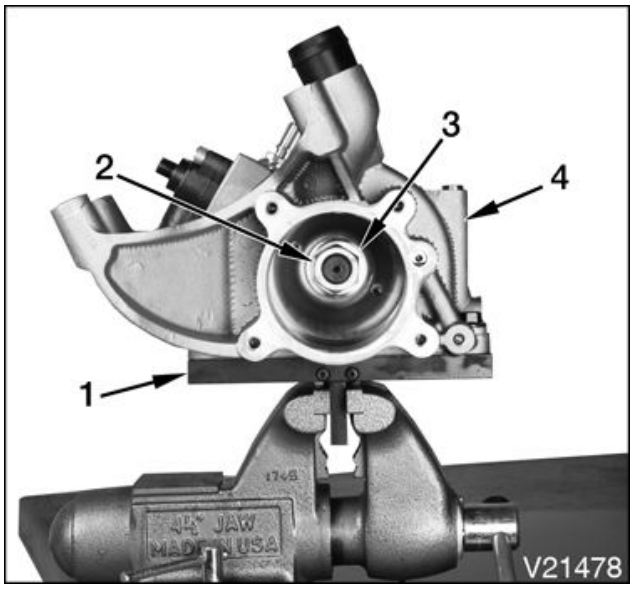

Figure 327 Drive Housing With HPFP Pulley Housing Removed

1. Holding Plate ZTSE6044
2. M24 jam nut
3. 25 x 44 x 4 washer
4. Drive housing and HPFP

7. Secure Holding Plate (Figure 327) (Item 1) in a vise.
8. Install drive housing and HPFP (Figure 327) (Item 4) to Holding Plate with M12 x 40, M12 x 90 and two M12 x 130 bolts. Tighten bolts to 77 lb·ft (105 N·m). Holding Plate will prevent the HPFP gear from turning while tightening the M24 jam nut (Figure 327) (Item 2).
9. Tighten M24 jam nut to 210 lb·ft (285 N·m).

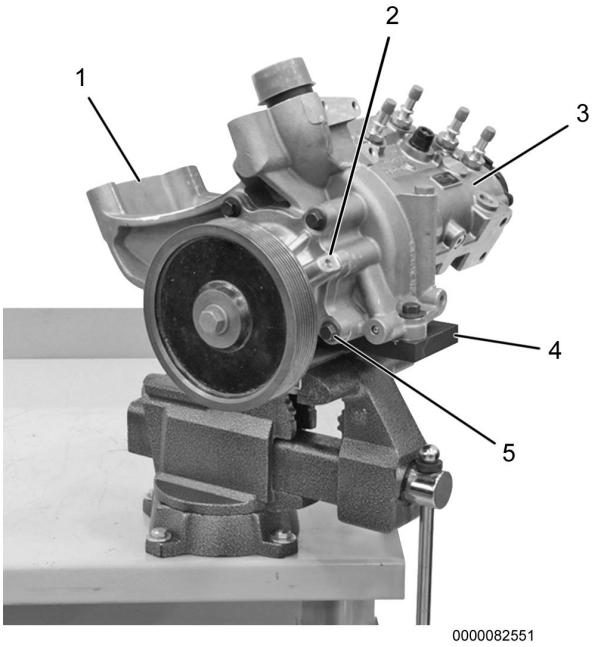

Figure 328 Drive Housing Secured to Holding Plate

1. Drive housing
2. HPFP pulley housing
3. HPFP
4. Holding Plate
5. M10 x 40 bolt (4)

10. Tighten four M10 x 40 bolts (Figure 328) (Item 5) to 46 lb·ft (62 N·m) to secure HPFP pulley housing (Figure 328) (Item 2) to drive housing (Figure 328) (Item 1).
11. Remove drive housing and HPFP from Holding Plate (Figure 328) (Item 4).

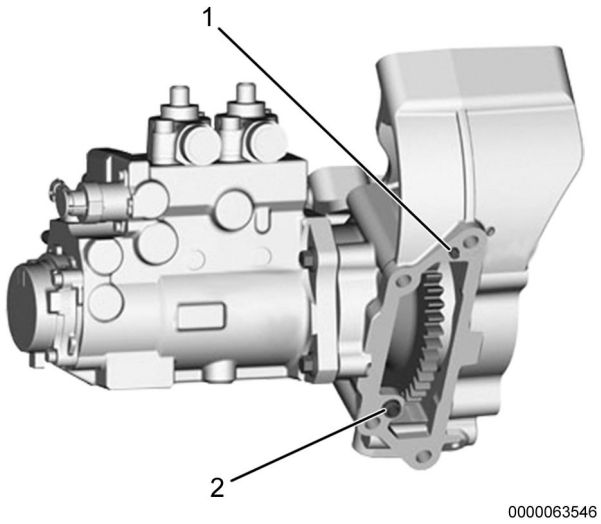

Figure 329 Dowel Pin and Sleeve Placement

1. Dowel pin
2. Sleeve

12. Check that dowel pin (Figure 329) (Item 1) and sleeve (Figure 329) (Item 2) are properly seated in drive housing or crankcase.

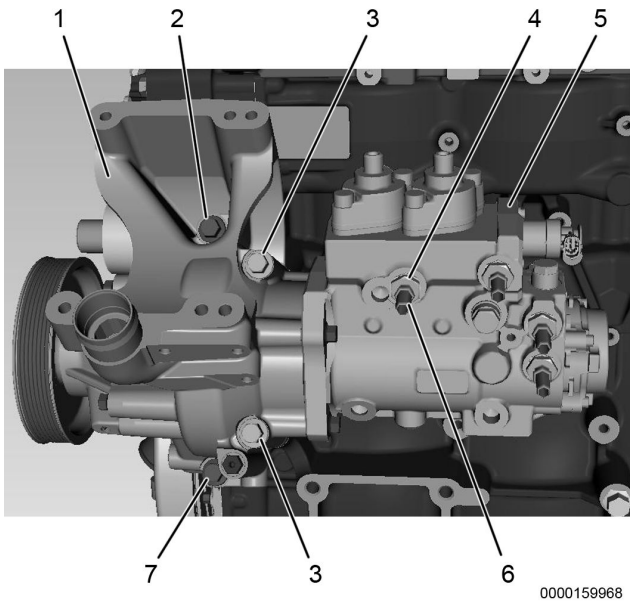

Figure 330 HPFP and Drive Housing

1. Drive housing
2. M12 x 90 bolt
3. M12 x 130 bolt (2)
4. 16.7 x 24 seal ring (4)
5. HPFP
6. Quick-connect M16 x 1.5 connector (4)
7. M12 x 40 bolt

13. If required, install four M16 x 1.5 quick-connect connectors (Figure 330) (Item 6) with new 16.7 x 24 seal rings (Figure 330) (Item 4). Tighten connectors to 22 lb·ft (30 N·m).
14. Apply Loctite® 515 to mating surfaces of drive housing and crankcase.
15. Position HPFP (Figure 330) (Item 5) and drive housing assembly (Figure 330) (Item 1) on crankcase using care to align pump drive gear with idler gear. Install M12 x 40 (Figure 330) (Item 7), M12 x 90 (Figure 330) (Item 2), and two M12 x 130 bolts (Figure 330) (Item 3) and tighten bolts to 77 lb·ft 105 (N·m).

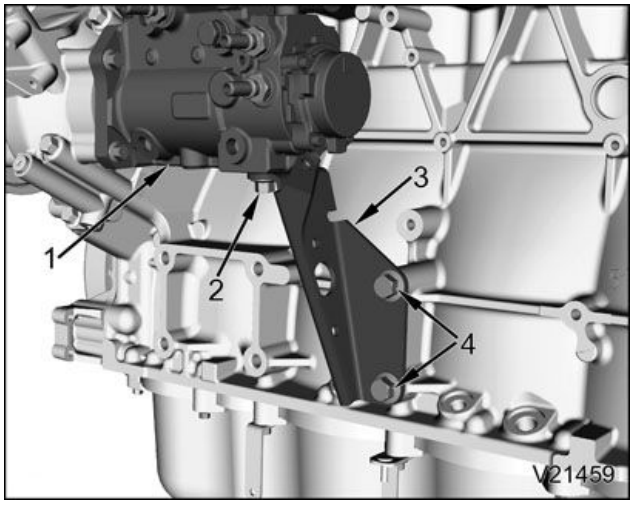

Figure 331 HPFP and Support (Bracket)

1. HPFP
2. M12 x 30 bolt (2)
3. Support (bracket)
4. M14 x 30 bolt (2)

16. Place support bracket (Figure 331) (Item 3) in position below HPFP (Figure 331) (Item 1) and install two M12 x 30 (Figure 331) (Item 2) and two M14 x 30 bolts (Figure 331) (Item 4).
17. Tighten two M12 x 30 bolts to 79 lb·ft (107 N·m).
18. Tighten two M14 x 30 bolts to 126 lb·ft (172 N·m).

CAUTION: To prevent damage to the High-Pressure Fuel Pump (HPFP), do not start the engine until the fuel system is properly primed. The Fuel System Priming Tool should be used to prime the fuel system. If the Fuel System Priming Tool is not available, prime the fuel system using the hand primer pump method. See Fuel System Priming (page 267).

Radial Shaft Seal

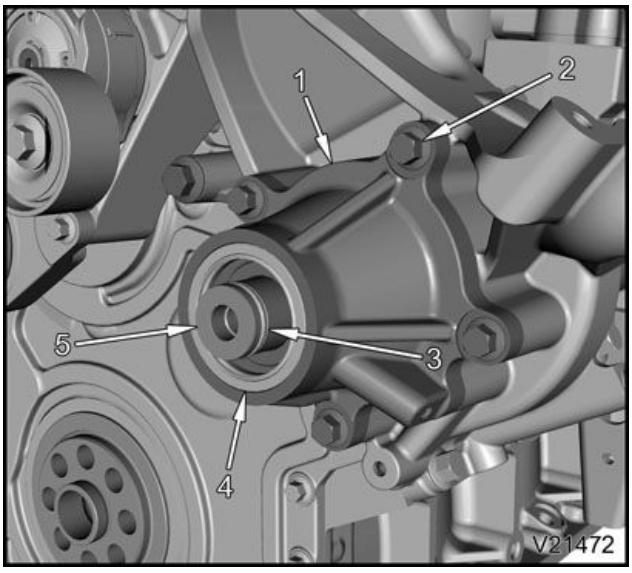

Figure 332 HPFP Pulley Housing and Seal

1. HPFP pulley housing
2. M10 x 40 bolt (4)
3. 30.2 x 3 O-ring
4. 55 x 70 x 8 radial shaft seal
5. Drive belt shaft

NOTE: Apply Loctite® 515(page 276) to joining surfaces of HPFP pulley housing (Figure 332) (Item 1) and drive housing if removed.

1. If removed, install four M10 x 40 bolts (Figure 332) (Item 2) and tighten to 46 lb·ft (62 N·m).
2. Using Fan Hub/High Pressure Drive Seal Installer ZTSE6066 (page 276), drive new 55 x 70 x 8 radial shaft seal (Figure 332) (Item 4) into housing. Seal is fully installed when tool bottoms out on housing.

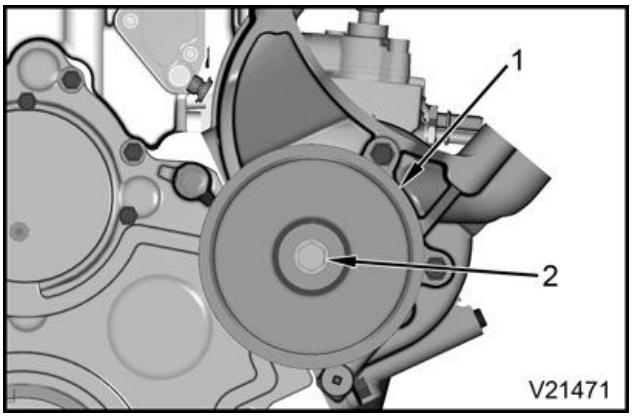

Figure 333 HPFP Pulley

1. High-pressure pump pulley
2. M16 x 40 LH bolt (left-hand thread)

3. Install HPFP pulley (Figure 333) (Item 1) onto drive belt shaft.
4. Install M16 x 40 LH bolt (Figure 333) (Item 2). Tighten bolt to 207 lb·ft (280 N·m).

Piston Overflow Valve (KUEV)

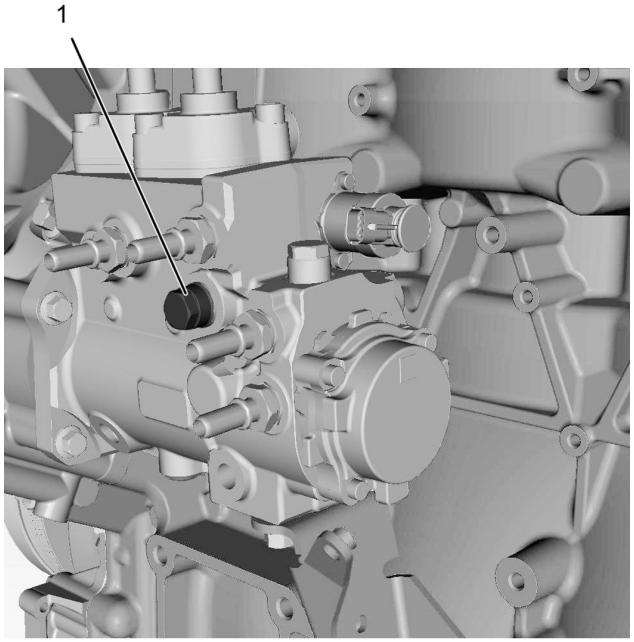

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Figure 334 KUEV

1. Piston Overflow Valve (KUEV)

1. Install KUEV into High-Pressure Fuel Pump (HPFP) housing. Tighten to 37 lb·ft (49 N·m).

Fuel Pressure Control Valve (FPCV)

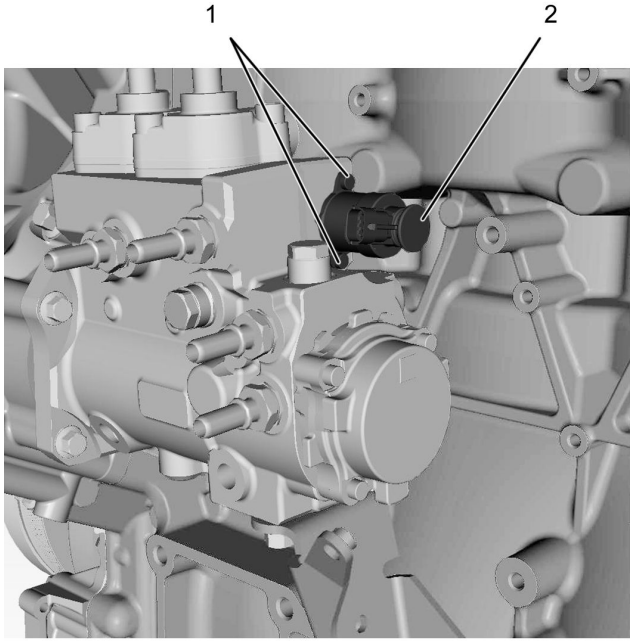

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Figure 335 FPCV

1. Screw (2)
2. Fuel Pressure Control Valve (FPCV)

1. Install FPCV (Figure 335) (Item 2) into High-Pressure Fuel Pump (HPFP) housing.
2. Tighten two screws (Figure 335) (Item 1) to 71 lb·in (8 N·m).

Fuel Filter Housing Assembly

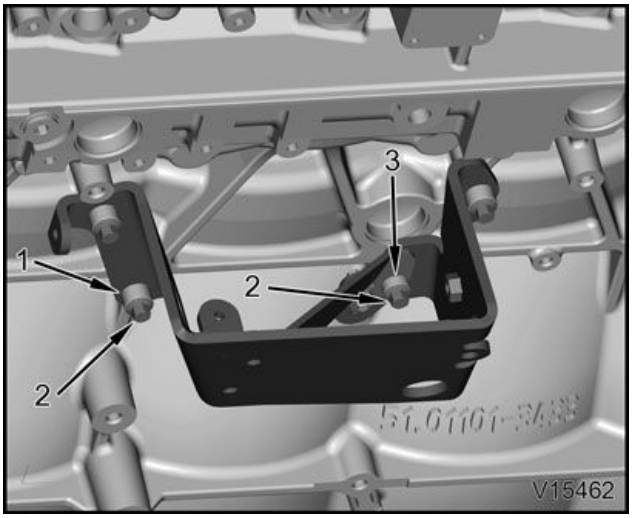

Figure 336 Fuel filter bracket assembly

1. 9 ID x 18 OD x 10.5 spacer (3)
2. M8 x 30 bolt (4)
3. 9 ID x 17 OD x 6.5 spacer

1. If removed, position fuel filter bracket assembly with brace on crankcase and install four M8 x 30 bolts and spacers. Tighten bolts to special torque (page 275).

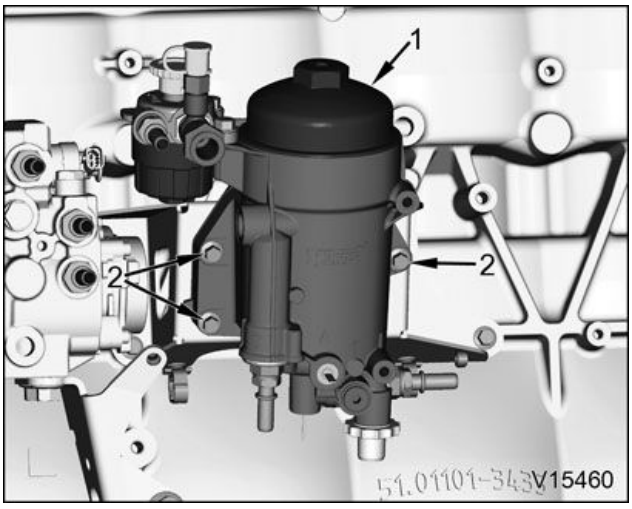

Figure 337 Fuel filter housing assembly

1. Fuel filter housing assembly
2. M8 x 45 bolts (3)

2. Install fuel filter housing assembly and three M8 x 45 bolts. Tighten bolts to special torque (page 275).

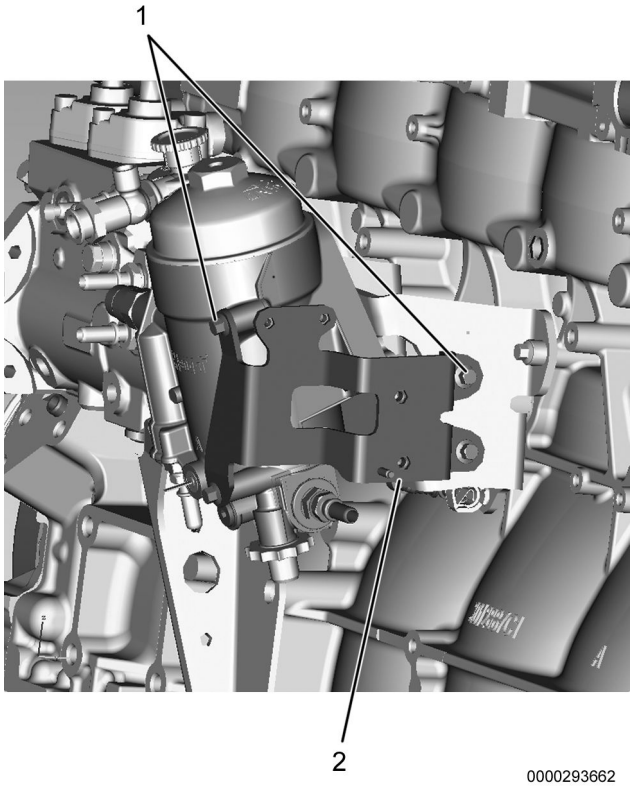

Figure 338 AFT Fuel Doser Module bracket (typical)

1. M8 x 16 bolts (3)
2. AFT Fuel Doser Module bracket

3. Position AFT Fuel Doser Module bracket (Figure 338) (Item 2) on filter housing and install four M8 x 16 bolts (Figure 338) (Item 1). Tighten bolts to 23 lbf·ft (31 N·m).

Fuel Primer Pump Assembly

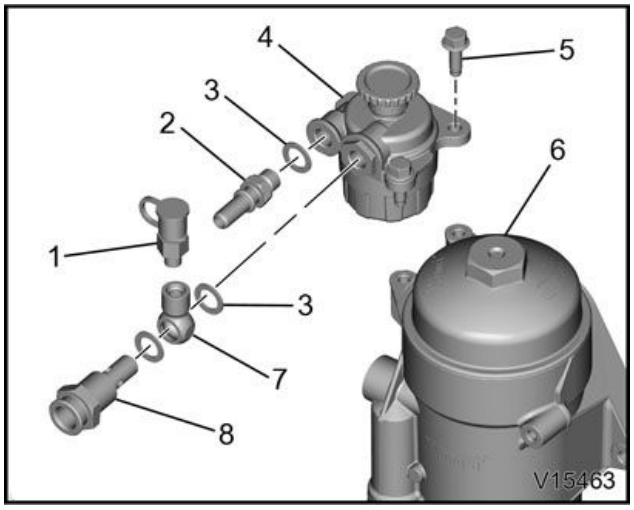

Figure 339 Fuel primer pump assembly

1. Check valve
2. Threaded union
3. 14.7 x 22 seal ring (3)
4. Fuel primer pump assembly
5. M8 x 25 bolt (2)
6. Fuel filter housing
7. Banjo fitting
8. Fuel supply adapter

1. If removed from fuel filter housing, install fuel primer pump assembly and two M8 x 25 bolts. Tighten bolts to special torque (page 275).

NOTE: If fuel primer pump assembly was replaced or fittings were previously removed, continue with step 2.

2. Install banjo fitting with two new 14.7 x 22 seal rings and fuel supply adapter in fuel primer pump assembly inlet port. Tighten adapter to special torque (page 275).
3. Install check valve on banjo fitting. Tighten check valve to special torque (page 275) and install dust cap.
4. Install threaded union and 14.7 x 22 seal ring in fuel primer pump assembly outlet port. Tighten threaded union to special torque (page 275).

Fuel Supply and Drain (Return) Lines

CAUTION: To avoid fuel system damage, verify all retainers and c-clips are installed in correct position as shown, to prevent fuel line rubbing and leaks.

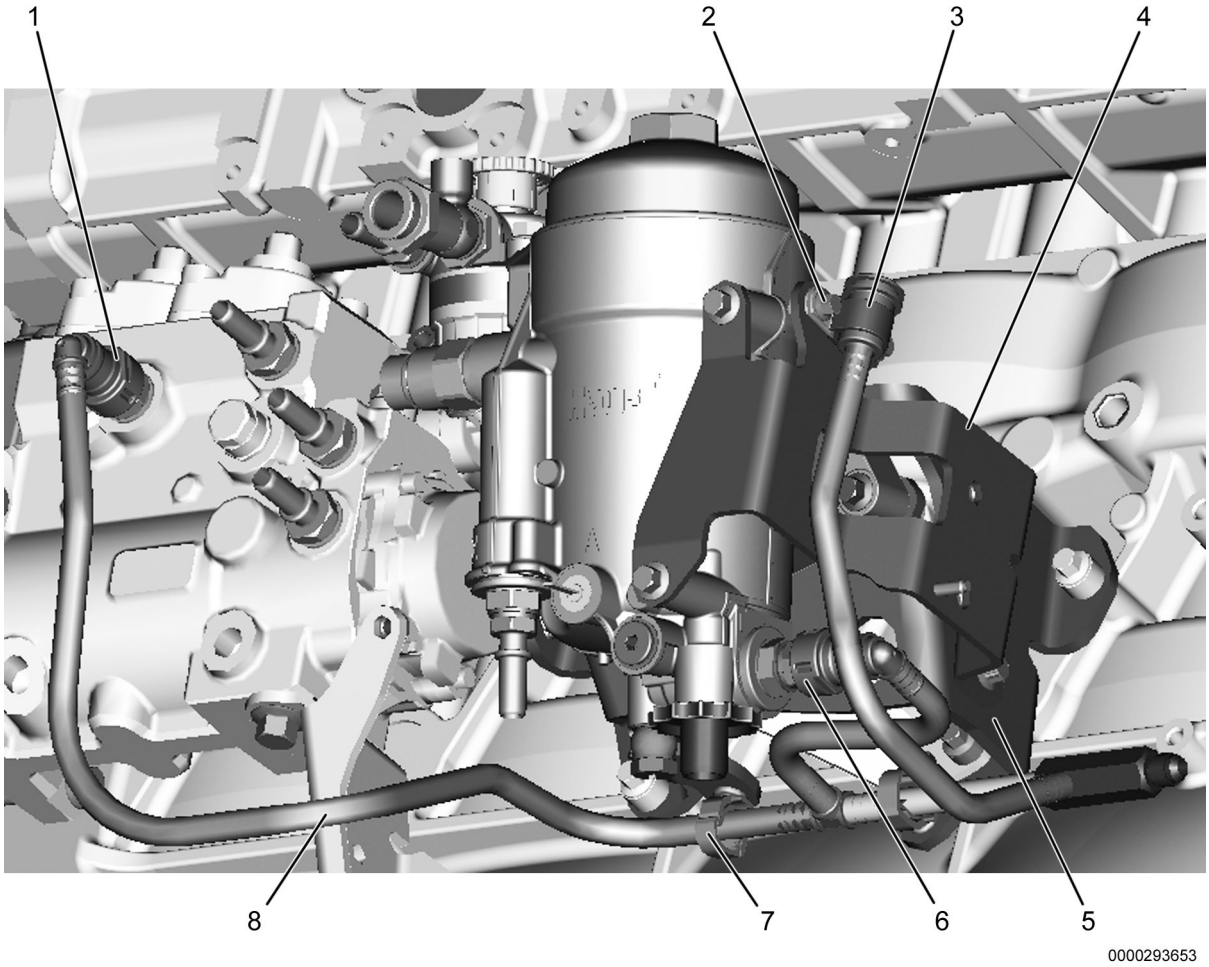

Figure 340 Fuel Drain Hose Retainers (Typical)

1. Quick-connect 90° fitting (at high-pressure fuel pump return)
2. M6 x 16 bolt
3. Closed (P) clamp
4. AFT fuel doser module bracket
5. Fuel filter housing bracket
6. Quick-connect 90° fitting (at fuel filter housing)
7. 8 x 13 single retainer (2)
8. Fuel drain return hose

1. Check that O-rings are in place in fuel drain quick-connect 90° fittings (Items 1 and 4) and not damaged. Replace as necessary.
2. Place fuel drain hose (Figure 340) (Item 8) in position at bottom of fuel filter housing bracket (Figure 340) (Item 5) and attach to bracket with two 8 x 13 single retainers (Figure 340) (Item 7).
3. Connect fuel drain hose at high pressure fuel pump inlet by pushing on quick-connect 90° fitting f4650009059 (Item 1) until an audible click is heard. Pull quick-connect fitting to make sure it is seated.
4. Connect fuel drain hose to fuel filter housing by pushing on quick-connect 90° fitting (Figure

340) (Item 6) until an audible click is heard. Pull quick-connect fitting to make sure it is seated.

5. Install closed (P) clamp (Figure 340) (Item 3) and M6 x 16 bolt (Figure 340) (Item 2) to attach end fitting of fuel drain hose from hex manifold tee to AFT fuel doser module bracket (Figure 340) (Item 4). Tighten bolt to 115 lb·in (13 N·m).
6. Cap unconnected end of hex manifold tee using Disposable Air and Fuel Caps ZTSE4891 to prevent dirt from entering fuel system until final connection with injector and fuel rail drain tube is made.

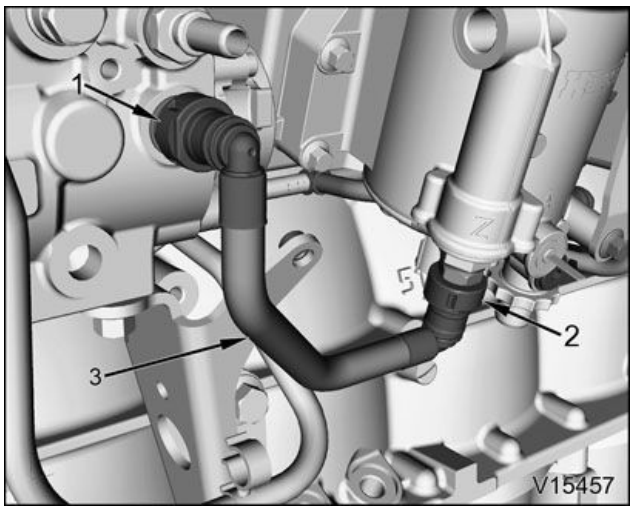

Figure 341 Pre-Filter Fuel Supply Hose Assembly

1. Quick-connect 90° fitting (at HPFP)
2. Quick-connect 90° fitting (at fuel filter housing)
3. Pre-filter fuel supply hose

7. Check that O-rings are in place in pre-filter fuel supply quick-connect 90° fittings and not damaged. Replace as necessary.
8. Install pre-filter fuel supply hose (Figure 341) (Item 3). Push on quick-connect 90° fitting at HPFP (Figure 341) (Item 1) until an audible click is heard. Pull quick-connect fitting to make sure it is seated. Repeat the procedure for the quick-connect 90° fitting at fuel filter housing (Figure 341) (Item 2).

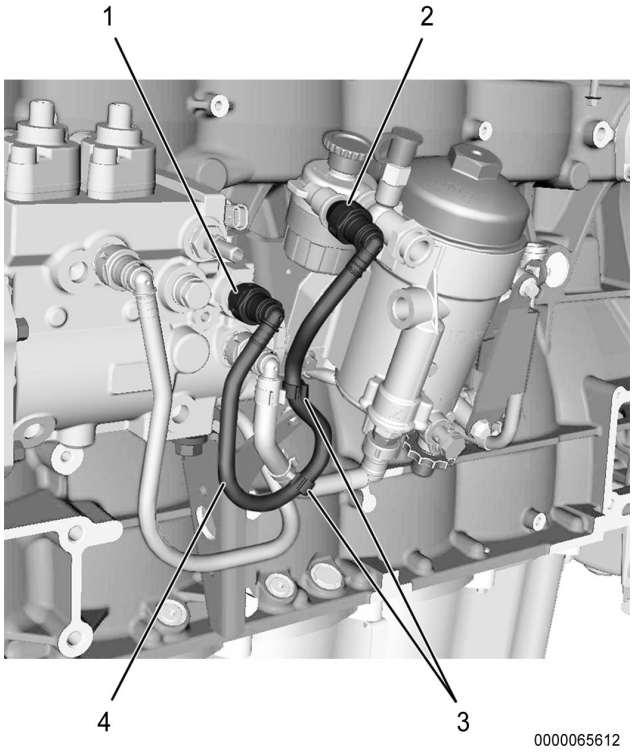

Figure 342 Pre-Pump Fuel Supply Hose Assembly

1. Quick-connect 90° fitting (at HPFP)
2. Quick-connect 90° fitting (at fuel primer pump)
3. C-clip (2)
4. Pre-pump fuel supply hose

9. Check that O-rings are in place in pre-pump fuel supply hose quick-connect 90° fittings and not damaged. Replace as necessary.
10. Install pre-pump fuel supply hose (Figure 342) (Item 4). Push on quick-connect 90° fitting at HPFP (Figure 342) (Item 1) until an audible click is heard. Pull quick-connect fitting to make sure it is seated. Repeat the procedure for the quick-connect 90° fitting at fuel primer pump assembly (Figure 342) (Item 2).

CAUTION: Install c-clips in location shown (Figure 342) to prevent damage to fuel lines.

11. Install c-clips (Figure 342) (Item 3) between pre-pump fuel supply hose and pre-filter fuel supply hose.

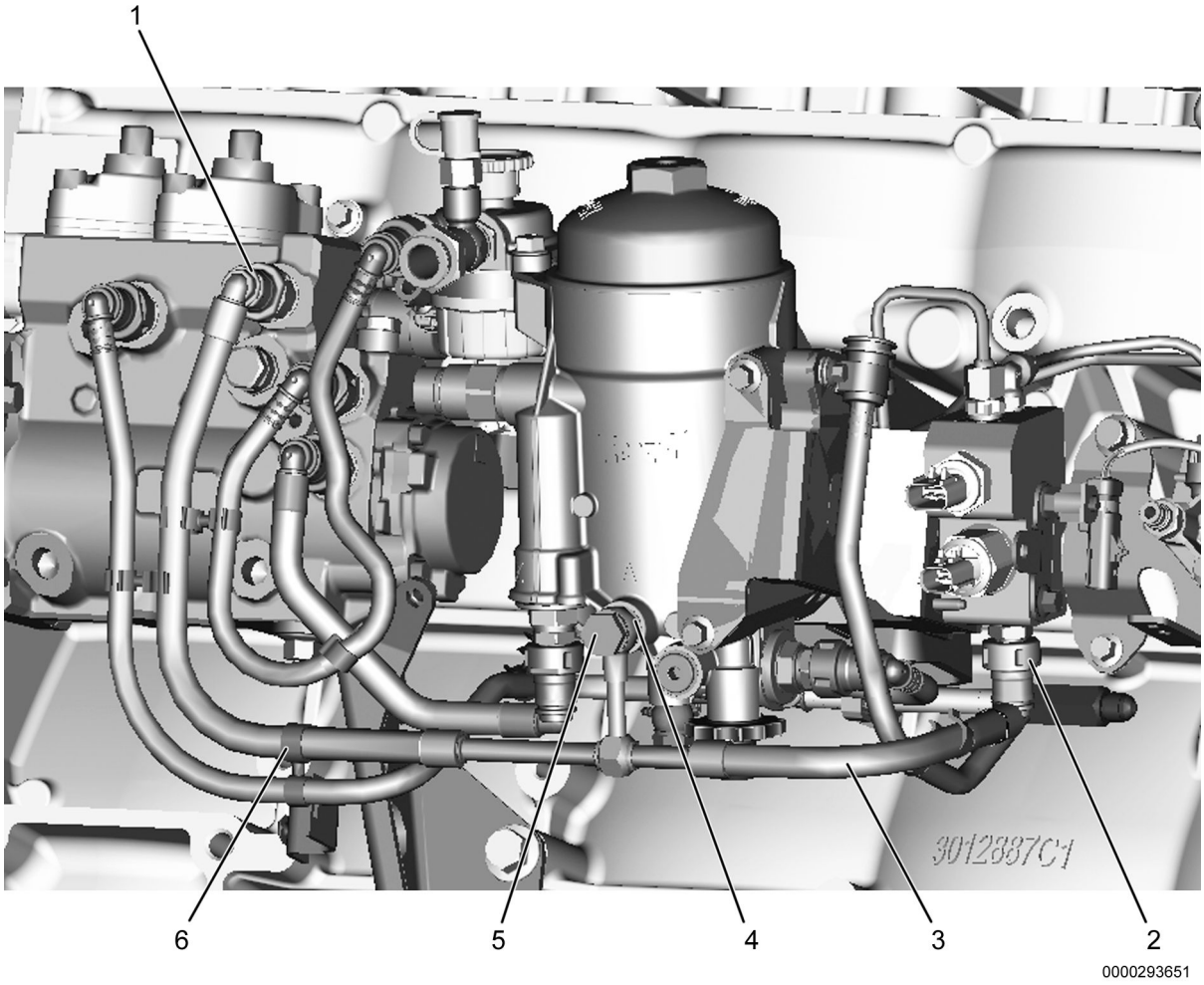

Figure 343 After-Filter Fuel Supply Hose Connections

1. Quick-connect 90° fitting (at high-pressure fuel pump inlet)
2. Quick-connect 90° fitting (at Aftertreatment (AFT) fuel doser module)
3. After-filter fuel supply hose
4. 14.7 x 22 mm seal rings (2)
5. M14 banjo bolt
6. C-clip (2)

12. Check that O-rings are in place in after-filter fuel supply hose quick-connect 90° fittings and not damaged. Replace as necessary.
13. Install after-filter fuel supply hose (Figure 343) (Item 3). Position banjo fitting with two new 14.7 x 22 seal rings (Figure 343) (Item 4) at filter housing and install M14 banjo bolt (Figure 343) (Item 5).
14. Tighten banjo bolt to 22lb·ft (30 N·m).
15. Push on quick-connect 90° fitting at high-pressure fuel pump inlet (Figure 343) (Item 1) until an audible click is heard. Pull quick-connect fitting to make sure it is seated.

CAUTION: Install c-clips in location shown to prevent damage to fuel lines.

16. Install C-clips (Figure 343) (Item 6) between after filter fuel supply hose and fuel drain hose.
17. Cap quick-connect 90° connector at AFT fuel doser module (Figure 343) (Item 2) to prevent dirt from entering fuel system until final connection to metering valve can be made.

Fuel Rail Assembly

NOTE: The pressure limiting valve should not be removed from the fuel rail assembly. Replace the entire fuel rail assembly if the pressure limiting valve is defective. Use ServiceMaxx® to verify fuel pressure following the procedure in the *Engine Diagnostic Manual.*

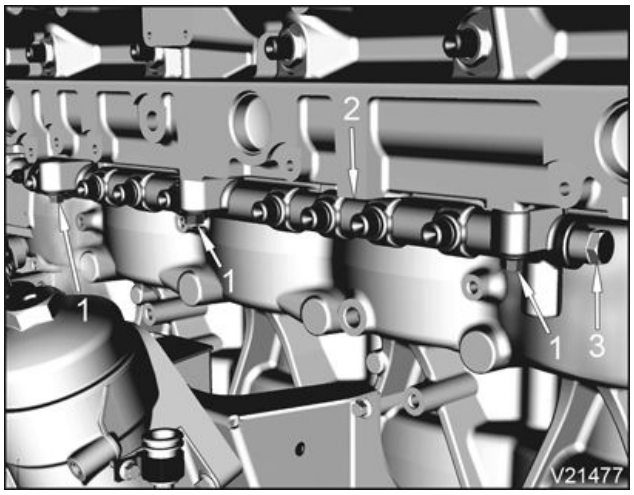

Figure 344 Fuel rail and pressure limiting valve

1. M8 x 40 bolt (3)
2. Fuel rail assembly
3. Pressure limiting valve

1. Support fuel rail assembly in position against underside of cylinder head. Install and hand tighten three M8 x 40 bolts.
2. Tighten bolts to special torque (page 275).

Injector and Fuel Drain (Return) Lines

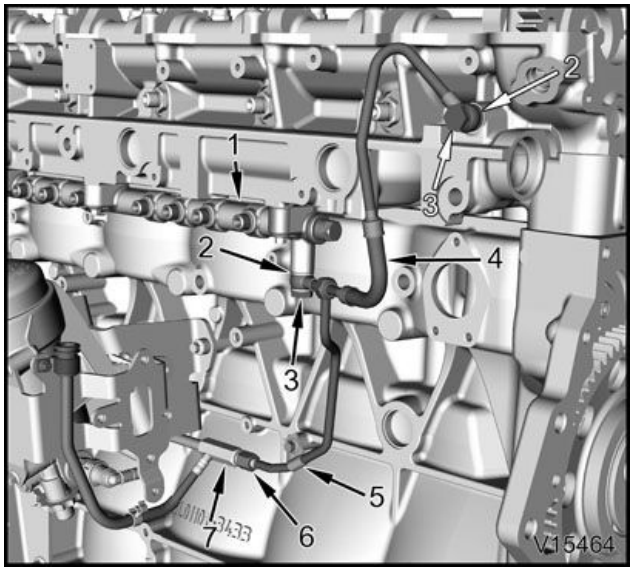

Figure 345 Fuel drain tube connections

1. Fuel rail
2. 14.7 x 22 seal ring (4)
3. M14 banjo bolt (2)
4. Fuel drain tube
5. M8 x 16 bolt and closed (P) clamp assembly
6. Line fitting nut
7. Fuel drain hose (hex manifold tee)

1. Install M14 banjo bolt with two new 14.7 x 22 seal rings to connect fuel drain tube to cylinder head. Do not tighten at this time.
2. Install M14 banjo bolt with two new 14.7 x 22 seal rings to connect fuel drain tube to fuel rail. Do not tighten at this time.

NOTE: Use a backup wrench when tightening fitting nut on hex manifold tee.

3. Connect fuel drain tube to fuel return hex manifold tee at fuel filter bracket. Tighten drain line fitting nut to special torque (page 275).
4. Tighten fuel drain tube M14 banjo bolts at fuel rail and cylinder head to special torque (page 275).
5. Install closed (P) clamp and M8 x 16 bolt to secure drain tube to crankcase. Tighten bolt to standard torque (page 547).

High-pressure Fuel Lines

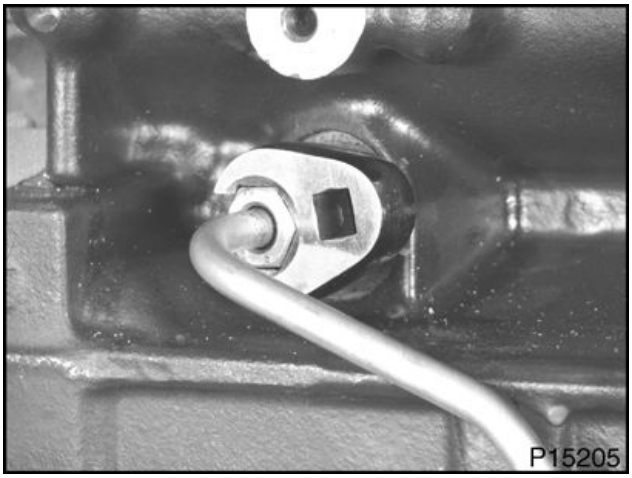

Figure 346 Crowfoot wrench (typical)

1. Obtain a crowfoot wrench (page 276) to connect all high-pressure fuel line fittings. When using a crowfoot wrench to tighten fittings, calculate the torque compensation to match specific wrench configuration. See Using a Torque Wrench Extension (Using a Torque Wrench Extension, page 548)

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.

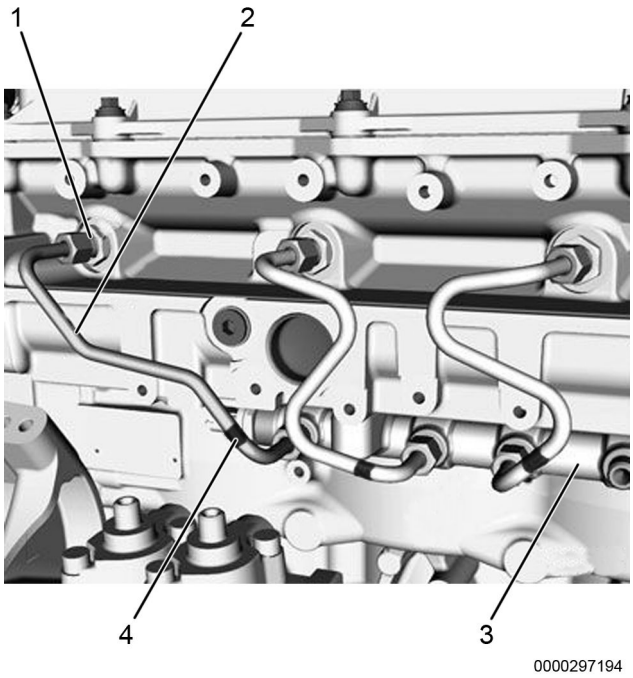

Figure 347 Cylinder 1 high-pressure rail to injector tube assembly

1. Cylinder 1 high-pressure connector body and retaining nut
2. Cylinder 1 high-pressure rail to injector tube assembly
3. Fuel rail
4. Orientation band

NOTE: Install high-pressure rail to injector tube assembly with band side of assembly connected to fuel rail.

2. Install new high-pressure rail to injector tube assembly (Figure 347) (Item 2) for cylinder 1 between fuel rail and cylinder head, with band (Figure 347) (Item 4) side of assembly connected to fuel rail (Figure 347) (Item 3).
3. Hand tighten line fitting nut at fuel rail and high-pressure connector body.

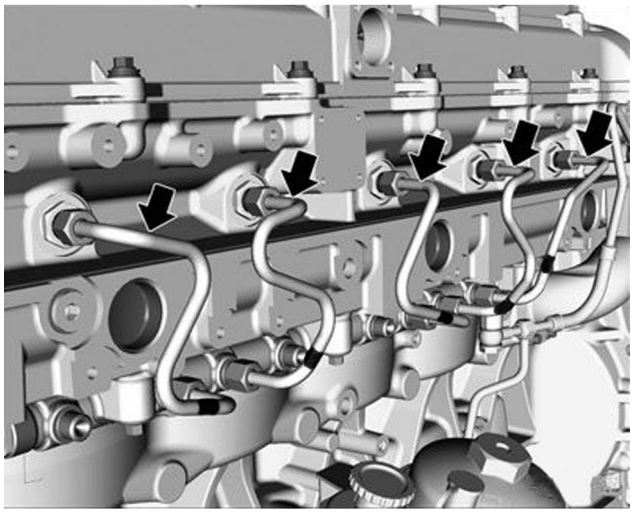

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Figure 348 Cylinders 2-6 high-pressure fuel tubes

4. Repeat step 2 to install new high-pressure rail to injector tube assemblies for cylinders 2 through 6.

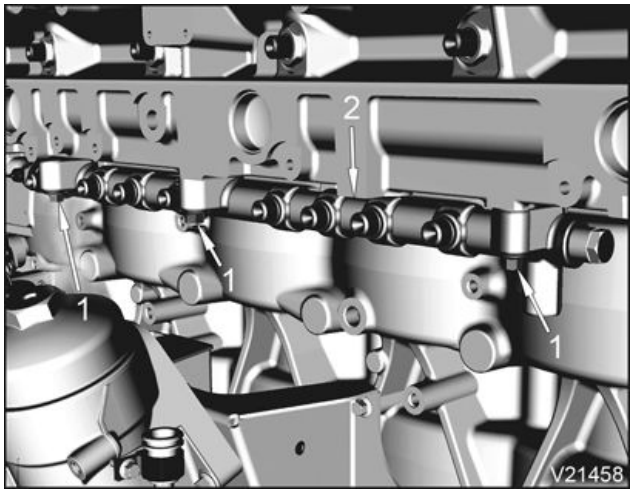

Figure 349 Fuel rail assembly

1. M8 x 40 bolt (3)
2. Fuel rail

Fuel rail assembly (M8 x 40 bolts)

5. Tighten three M8 x 40 bolts to 35 N·m (26 lb·ft).

High-pressure rail to injector tube assemblies (fittings)

6. Tighten fittings (cylinders 1–6) to 23 N·m (17 lb·ft).
7. Tighten fittings, an additional 60°.

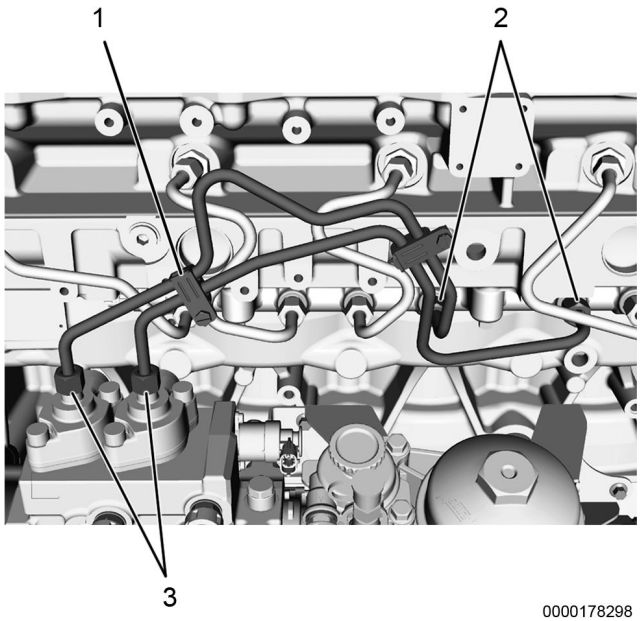

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Figure 350 HPFP to rail supply tube damper assembly

1. HPFP to rail supply tube damper assembly
2. Line fitting nut at fuel rail
3. Line fitting nut at HPFP (2)

CAUTION: To prevent engine damage, replace HPFP to rail supply tube damper assembly as an assembly.

8. Install new HPFP to rail supply tube damper assembly (Figure 350) (Item 1) between high-pressure fuel pump and fuel rail.
9. Tighten line fitting nuts at HPFP (Figure 350) (Item 3) and fuel rail (Figure 350) (Item 2).

High-pressure pump to rail tube assemblies (fittings)

10. Tighten fittings to 23 N·m (17 lb·ft).
11. Tighten fittings, an additional 60°.

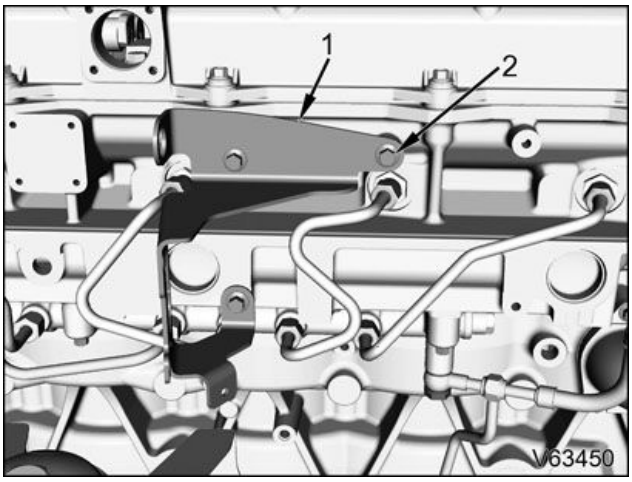

Figure 351 Harness 21-way connector bracket

1. Harness 21-way connector bracket
2. M8 x 16 bolt (3)

12. Install harness 21-way connector bracket and three M8 x 16 bolts. Tighten bolts to standard torque (page 547)
13. Connect air supply line to harness 21-way connector bracket.

Filter and Fuel Strainer Element

Refer to Navistar® N13 *Engine Operation and Maintenance Manual* for filter element and fuel strainer element service procedures.

Fuel System Priming

Fuel System Priming Tool Method

CAUTION: To prevent damage to the high-pressure fuel pump, do not start the engine until the fuel system is properly primed. The Fuel System Priming Tool should be used to prime the fuel system. If the Fuel System Priming Tool is not available, prime the fuel system using the hand primer pump method.

1. Obtain Fuel System Priming Tool (page 276).

NOTE: Fuel System Priming Tool ball valves should be in the closed position, unless suction and pressure hoses are connected to the vehicle fuel system.

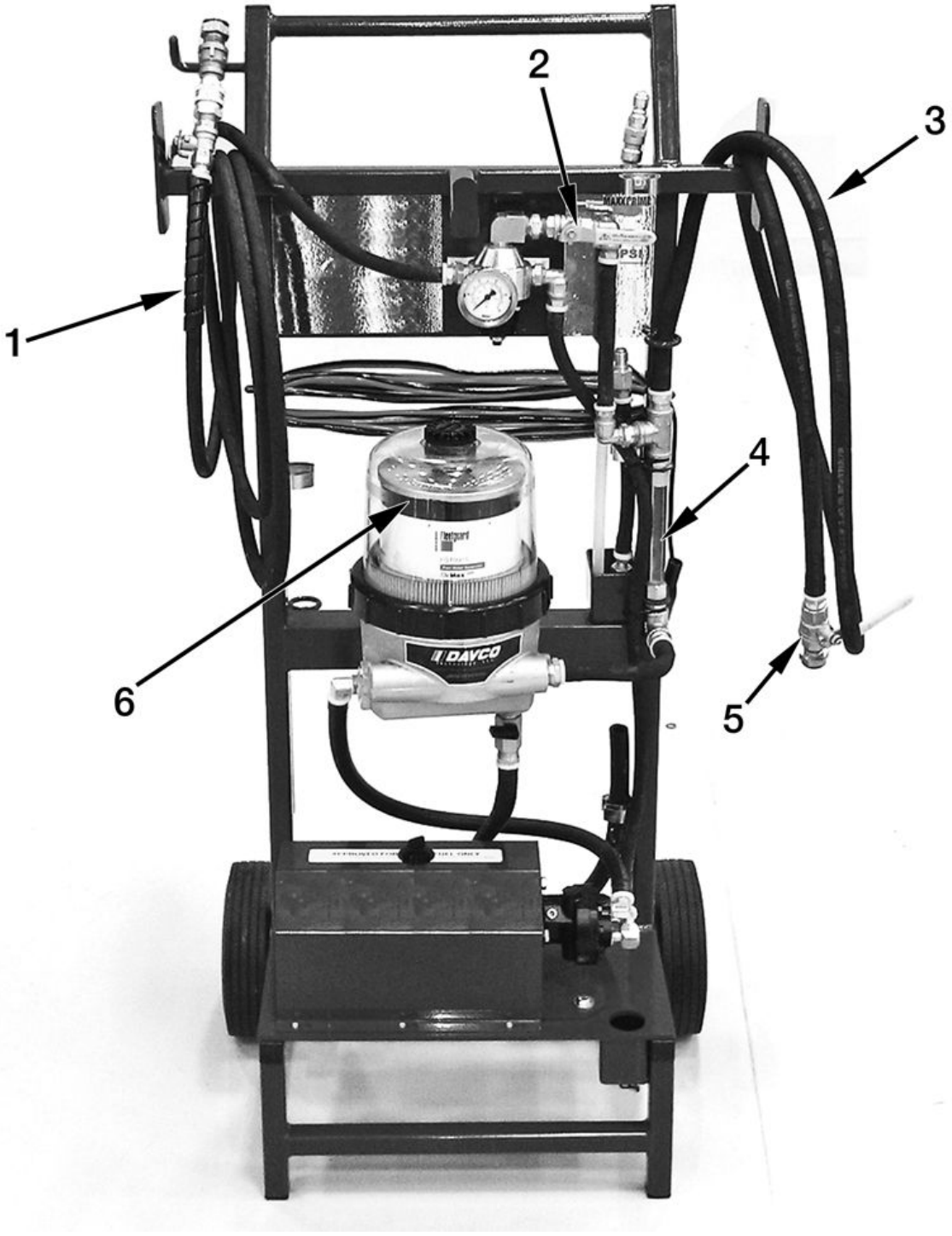

Figure 352 Fuel System Priming Tool

1. Pressure hose
2. Pressure regulator selector lever
3. Suction hose
4. Sight glass
5. Ball valve (2)
6. Filler cap (filter housing)

CAUTION: To prevent damage to fuel system components, make sure pressure regulator handle is in the 50 psi (345 kPa) position (as shown) when servicing Navistar® N13 engines.

2. Fill Fuel System Priming Tool fuel filter housing with clean diesel fuel, the first time the tool is used and any time there is no diesel fuel in the filter housing.
3. Put a fuel drain pan under the chassis mounted primary fuel filter / water separator.
4. If necessary, fill the chassis mounted fuel filter with clean diesel fuel. Fill the cartridge type filter from the top or pump the hand primer button for the spin-on type filter.

NOTE: For different vehicles the chassis mounted primary fuel filter / water separator is mounted in different locations than what is shown in (Figure 354) and (Figure 355).

NOTE: The Fuel System Priming Tool will work with either of the primary fuel filter / water separators shown in (Figure 353) or (Figure 354).

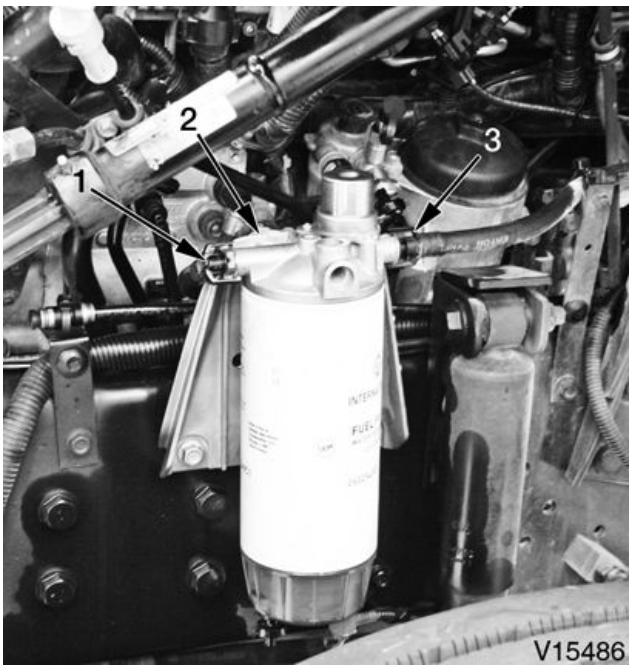

Figure 353 Chassis mounted primary fuel filter / water separator (optional)

1. Fuel output to engine
2. Chassis mounted primary fuel filter / water separator
3. Fuel input from tank

Figure 354 Chassis mounted primary fuel filter / water separator (typical)

1. Chassis mounted primary fuel filter / water separator
2. Fuel input from tank
3. Fuel output to engine

5. Disconnect fuel supply line to engine (fuel output to engine) by pushing red release tab and pulling line off the primary fuel filter housing (Figure 355).

Figure 355 Chassis mounted primary fuel filter / water separator (typical)

1. Fuel supply line to engine
2. Red release tab

6. Connect Fuel System Priming Tool suction hose to the primary fuel filter output (Figure 356).

Figure 356 Fuel Priming Tool suction hose connected to primary fuel filter output

1. Fuel supply line to engine
2. Fuel System Priming Tool suction hose
3. Ball valve (closed)

7. Connect Fuel System Priming Tool pressure hose to the fuel supply line to engine (Figure 357).

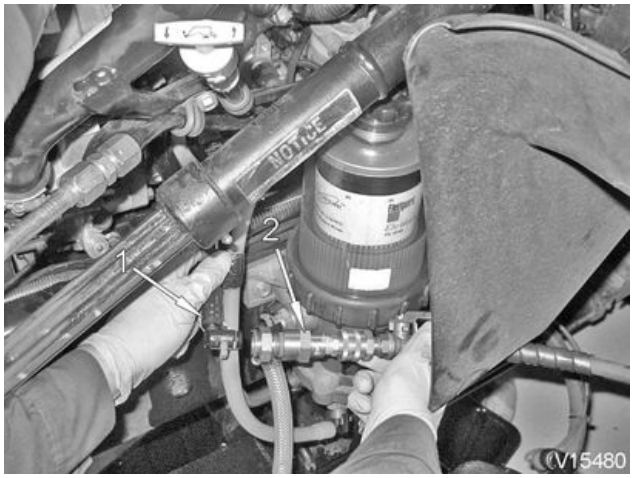

Figure 357 Connecting Fuel System Priming Tool pressure hose to the fuel supply line to engine

1. Fuel supply line to engine
2. Fuel System Priming Tool pressure hose

Figure 358 Ball valves closed

1. Pressure hose ball valve closed
2. Suction hose ball valve closed

8. Open pressure and suction hose ball valves (Figure 359) .

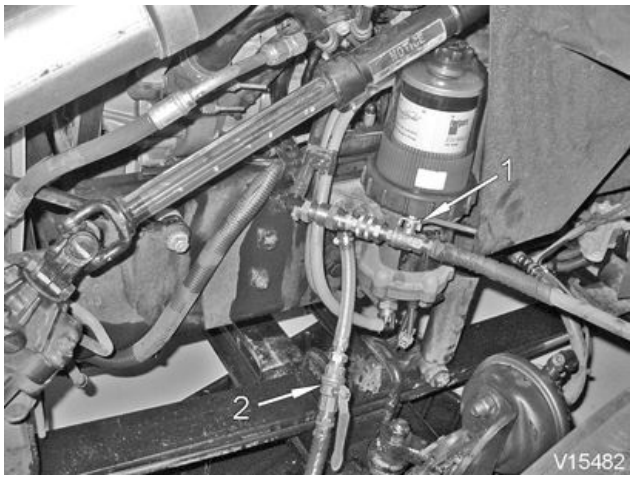

Figure 359 Ball valves open

1. Pressure hose ball valve open
2. Suction hose ball valve open

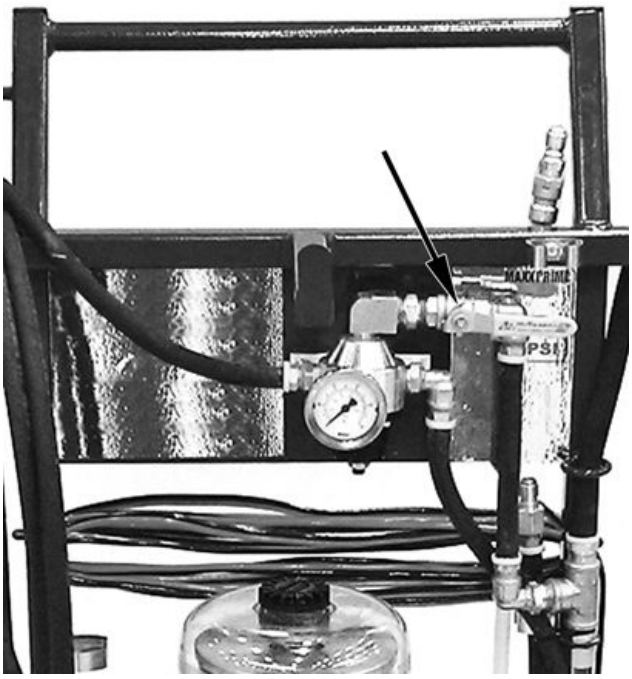

Figure 360 Pressure regulator selector lever

9. Set Fuel System Priming Tool pressure regulator selector lever to 50 psi (345 kPa) (Figure 360).

Figure 361 Fuel System Priming Tool connected to vehicle and electrical power

10. Connect electrical power and press the Fuel System Priming Tool power button (Figure 361).
11. Run Fuel System Priming Tool for a minimum of 2 minutes after no bubbles are visible in the sight glass (Figure 362).

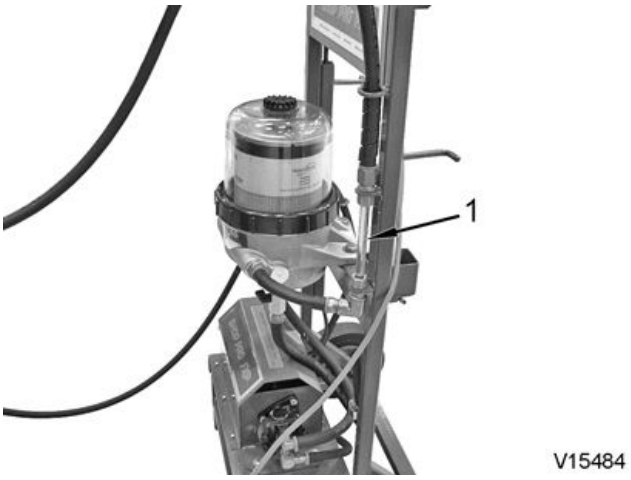

Figure 362 Fuel System Priming Tool sight glass

1. Sight glass

12. Turn Fuel System Priming Tool off.
13. Close pressure and suction hose ball valves (Figure 358).

Figure 363 Ball valves closed

1. Pressure hose ball valve closed
2. Suction hose ball valve closed

14. Disconnect Fuel System Priming Tool pressure and suction hoses.
15. Connect fuel supply line to engine to the chassis mounted primary fuel filter / water separator (Figure 364).

Figure 364 Chassis mounted primary fuel filter / water separator

1. Fuel supply line to engine
2. Red release tab

16. Install left front fender assembly and bracket.

Hand Primer Pump Method

NOTE: Priming the fuel system by hand is not necessary if the Fuel System Priming Tool was used to prime the fuel system.

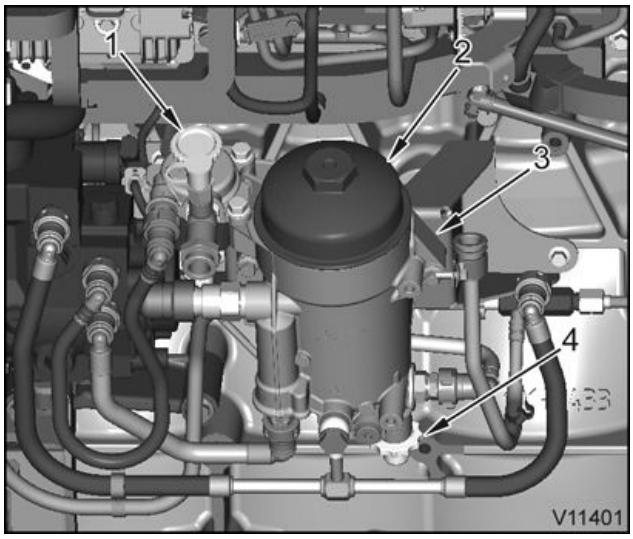

Figure 365 Fuel primer pump

1. Fuel primer pump
2. Fuel filter cover
3. Fuel filter housing
4. Water drain valve (closed)

1. Prime engine at hand primer pump:
   A. Turn the fuel primer pump knob counterclockwise to unlock the pump stem.
   B. Pump the fuel priming pump a minimum of 250 times (approximately 2 minutes). Continue pumping even after higher pumping force is required. Make sure to raise and lower the knob completely on each stroke.
   C. After priming, depress the fuel primer pump knob fully and turn the fuel primer pump knob clockwise until tight to secure the pump stem.

CAUTION: To prevent engine damage, if engine fails to start after 20 seconds of cranking, stop cranking engine and wait two minutes to allow the starter motor to cool.

2. Start engine and check for fuel leaks. Let engine run for 2 minutes. If engine does not start after 20 seconds of cranking, wait 2 minutes before trying to start the engine again. If the engine does not start, reprime the low-pressure fuel system using the above procedure.

3. Install left front fender assembly and bracket.
4. Flip up and secure front bumper (if equipped).
5. Close and secure hood.
6. Remove wheel chocks.

Specifications

Fuel strainer filtration	300 microns
Fuel filter element filtration	3-5 microns

Special Torque

Banjo bolt, M14	30 N·m (22 lb·ft)
Check valve	35 N·m (26 lb·ft)
Closed (P) clamp and M6 x 16 bolt	13 N·m (115 lb·in)
Forcing Screw Adapter Holding Plate M10 x 40 bolts	27 N·m (20 lb·ft)
Fuel drain line fitting nut	26 N·m (19 lb·ft)
Fuel filter bracket M8 x 30 bolt	35 N·m (26 lb·ft)
Fuel filter housing assembly M8 x 45 bolt	35 N·m (26 lb·ft)
Fuel filter cap	25 N·m (18 lb·ft)
Fuel filter stand pipe	12 N·m (106 lb·in)
Fuel Pressure Control Valve (FPCV) screws	8 N·m (71 lb·in)
Fuel primer pump assembly M8 x 25 bolt	30 N·m (22 lb·ft)
Fuel rail M8 x 40 bolt	35 N·m (26 lb·ft)
Fuel strainer cover	10 N·m (89 lb·in)
Fuel supply adapter	30 N·m (22 lb·ft)
High-pressure connector (body) retaining nut	See tightening steps in procedure
Drive housing M12 x 40, M12 x 90, M12 x 130 bolt	105 N·m (77 lb·ft)
High-pressure fuel pump M10 x 40 bolt	62 N·m (46 lb·ft)
High-pressure fuel pump M24 jam nut	285 N·m (210 lb·ft)
High-pressure fuel pump support M14 x 30 bolt	172 N·m (126 lb·ft)
High-pressure pump to rail tube assembly line fitting nuts	See tightening steps in procedure
High-pressure rail to injector line fitting nut	See tightening steps in procedure
High-pressure pump pulley housing M10 x 40 bolt	62 N·m (46 lb·ft)
High-pressure pump pulley M16 x 40 LH bolt	280 N·m (207 lb·ft)
Holding plate M12 bolts	47 N·m (35 lb·ft)
Injector harness nut	1.8 N·m (16 lb·in)
Injector hold-down clamp M8 x 50 bolt	See tightening steps in procedure
Piston Overflow Valve (KUEV)	49 N·m (37 lb·ft)
Pressure limiting valve	110 N·m (81 lb·ft)
Quick-connect M16 x 1.5 connector	30 N·m (22 lb·ft)
Support bracket M12 x 30 bolts	107 N·m (79 lb·ft)
Threaded unions (M14 x 1.5)	30 N·m (22 lb·ft)

Special Service Tools

Description	Tool Number
Crowfoot wrench	Obtain locally
Disposable Air and Fuel Caps	ZTSE4891
Fan Hub/High Pressure Drive Seal Installer	ZTSE6066
Forcing Screw	12-454-01-05
Forcing Screw Adapter	12-454-01-04
Forcing Screw Adapter Holding Plate	12-454-01-01
Fuel Injector Cups	ZTSE4892
Fuel Injector Rack Holder	ZTSE4299B
Fuel Injector Tip Cleaning Brush	ZTSE4301
Fuel Line Disconnect Tool 11.8 mm	ZTSE4773
Fuel System Priming Tool	15-922-01
Guide Stud	12-454-01-02
High-Pressure Pump Removal Tool	12-454-01
Holding Plate	ZTSE6044
Injector Installer	ZTSE4777
Injector Puller	ZTSE4770
Injector Sleeve Brushes	ZTSE4751
Loctite® 515	Obtain locally
P80® Rubber Lubricant or equivalent	Obtain locally
Socket Head Bolt	12-454-01-03
Slide hammer	Obtain locally

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Exploded Views

Oil Module Assembly

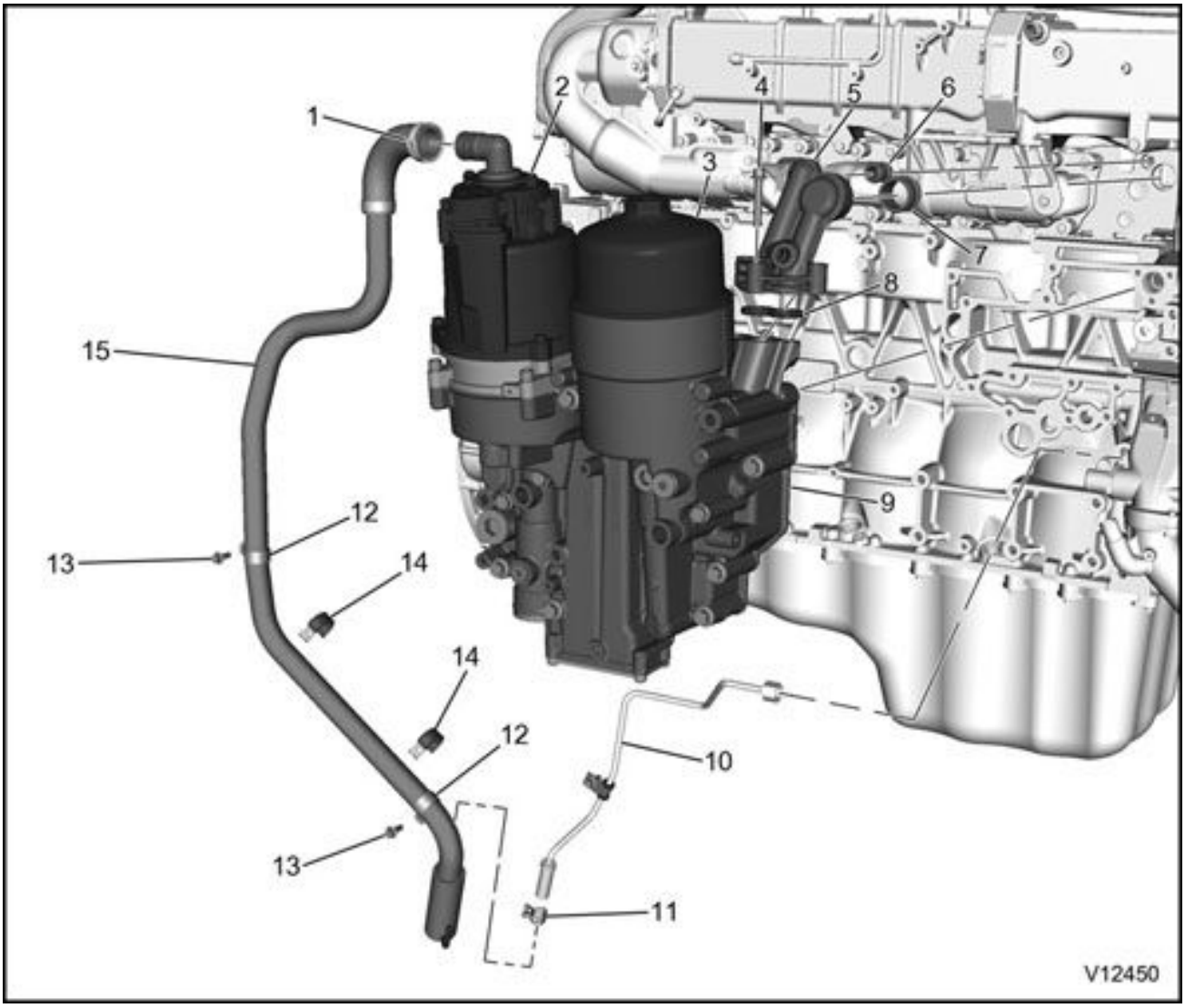

Figure 366 Oil module assembly

1. Clamp (spring)
2. Oil centrifuge
3. Filter cover
4. M8 x 45 bolt (3)
5. Oil module flange
6. Extension tube (DMR20 x DN14)
7. Extension tube (DMR37 x DN29)
8. Seal (formed)
9. Oil module assembly
10. Heater return tube assembly
11. Hose clamp (spring)
12. Tube clamp (2)
13. M6 x 16 bolt (2)
14. Tube clamp (2)
15. Open breather tube assembly

Oil Module

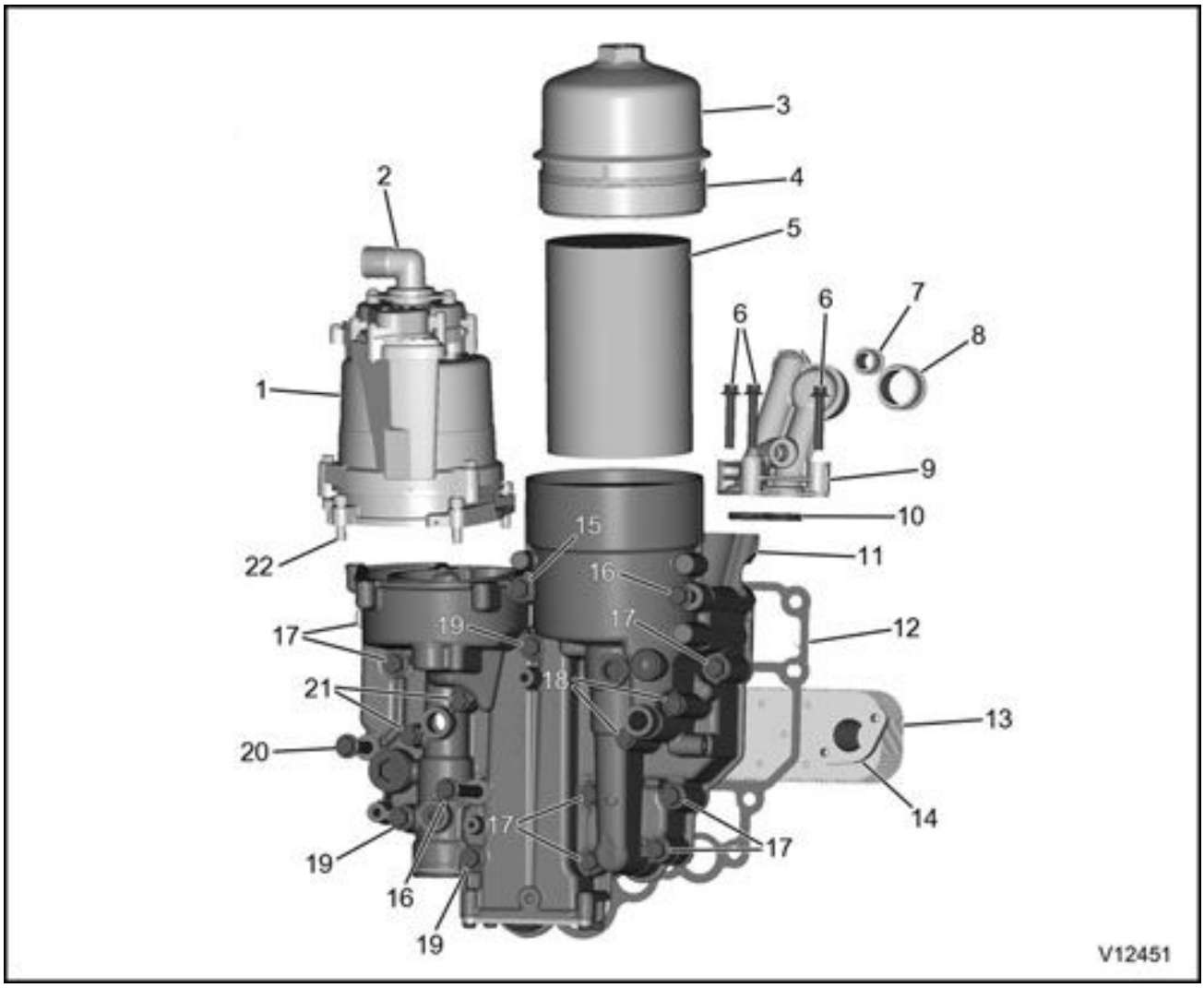

Figure 367 Oil module

1. Oil centrifuge
2. Open breather tube connection
3. Filter cover
4. O-ring seal
5. Oil filter
6. M8 x 45 bolt (3)
7. Extension tube (DMR20 x DN14)
8. Extension tube (DMR37 x DN29)
9. Oil module flange
10. Seal (formed)
11. Oil module assembly
12. Oil module gasket
13. Oil cooler
14. Oil cooler gasket (2)
15. M10 x 170 bolt
16. M10 x 200 bolt (2)
17. M10 x 80 bolt (7)
18. M8 x 90 bolt (2)
19. M10 x 110 bolt (3)
20. M10 x 140 bolt
21. M8 x 45 bolt (2)
22. M6 socket head bolt (4)

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: When performing specific component removal, only remove components necessary for access.

For complete engine tear down, refer to the following service sections for information on removal of components prior to this section.

- **Engine Electrical**
- **Turbochargers**
- **Fuel System**

Oil Filter Cover and Filter

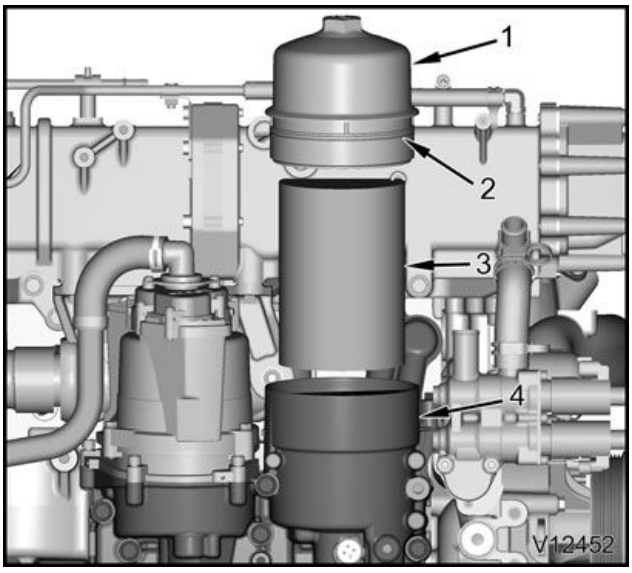

Figure 368 Oil filter cover

1. Filter cover
2. O-ring seal
3. Oil filter
4. Oil module assembly

1. Place absorbent material under the engine and oil module assembly.
2. Unscrew oil filter cover from oil module using a 36 mm wrench.
3. Rotate oil filter element slightly and remove oil filter from filter cover.
4. Remove and discard O-ring seal from exterior of oil filter cover.
5. Dispose of oil filter according to local regulations.

Oil Centrifuge

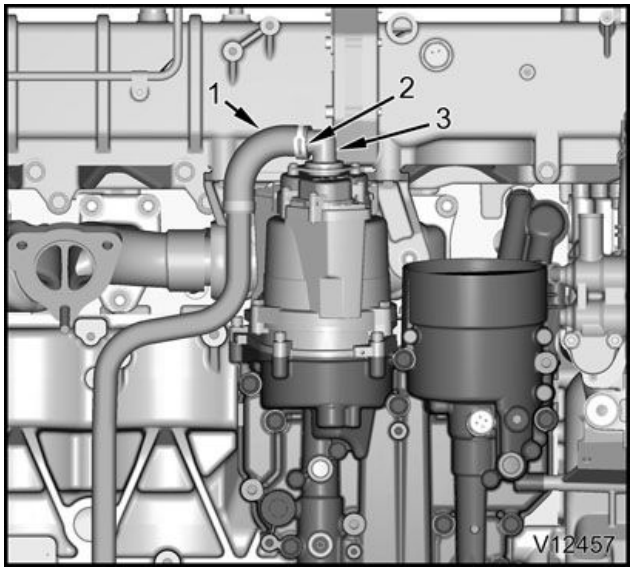

Figure 369 Open breather tube assembly

1. Open breather tube assembly
2. Clamp (spring)
3. Oil centrifuge outlet

1. Release spring clamp and disconnect open breather tube assembly from oil centrifuge outlet.

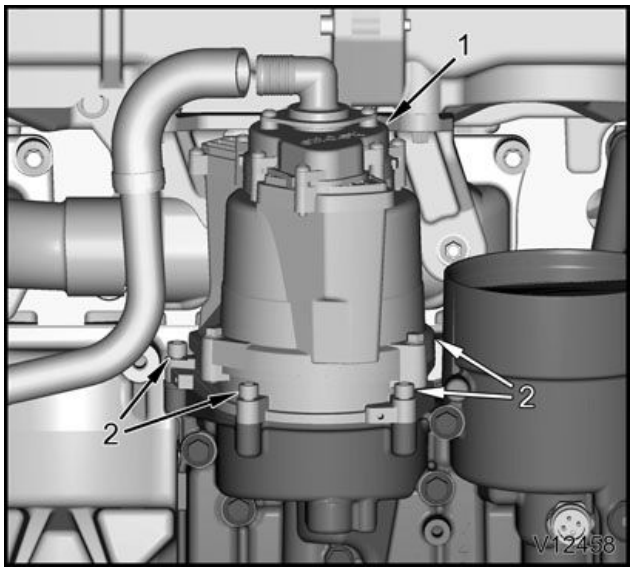

Figure 370 Oil centrifuge

1. Oil centrifuge
2. M6 socket head bolt (4)

2. Remove four M6 socket head bolts from oil centrifuge base and remove oil centrifuge and base as an assembly.
3. Remove seal ring from oil centrifuge base. Discard ring if damaged or leaking.

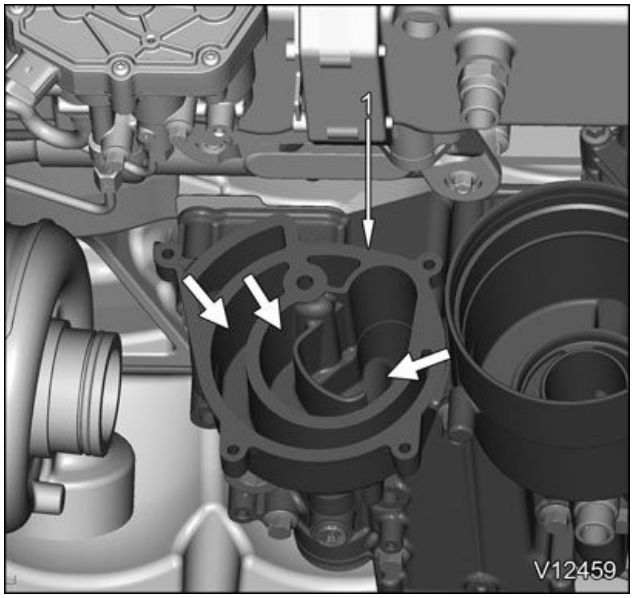

Figure 371 Oil module assembly oil passageways

1. Oil module assembly

4. Inspect oil module assembly oil passageways. Clean any obstructions or dirt as necessary.

Oil Module Assembly

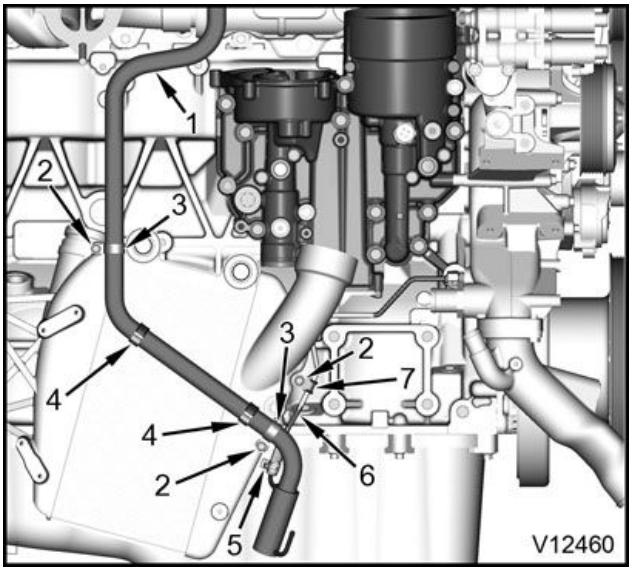

Figure 372 Open breather tube and heater return tube

1. Open breather tube assembly
2. M6 x 16 bolt (3)
3. Tube clamp (2)
4. Tube clamp (2) (for hydrocarbon injector (HCI) coolant return tube assembly)
5. Hose clamp (spring type)
6. Heater return tube assembly
7. Pipe single cushioned clamp

1. Remove two tube clamp M6 x 16 bolts securing open breather tube to low-pressure charge air cooler (LPCAC).
2. If not previously done, unclip two tube clamps securing HCI coolant return tube assembly to open breather tube assembly.

CAUTION: To prevent engine damage, when manipulating the open breather tube assembly, do not create a severe bend to the elbow hose that connects the tube to the oil module centrifuge outlet. The hose can crack.

3. If not previously done, release hose clamp (spring type) securing HCI coolant return tube assembly and disconnect tube from open breather tube.
4. Remove hose clamp (spring type) securing heater return tube to open breather tube assembly. Remove open breather tube assembly.
5. Remove M6 x 16 bolt and pipe single cushioned clamp securing heater return tube to LPCAC.
6. Loosen tube nut securing heater return tube to straight fitting on water distribution housing. Remove heater return tube.

CAUTION: To prevent engine damage, drain all coolant from the engine through the radiator when removing the oil module assembly. Coolant can enter the oil sump and contaminate the engine oil. Engine oil must be drained and replaced after oil module removal and installation, before the engine is started.

7. Drain coolant from engine through radiator.

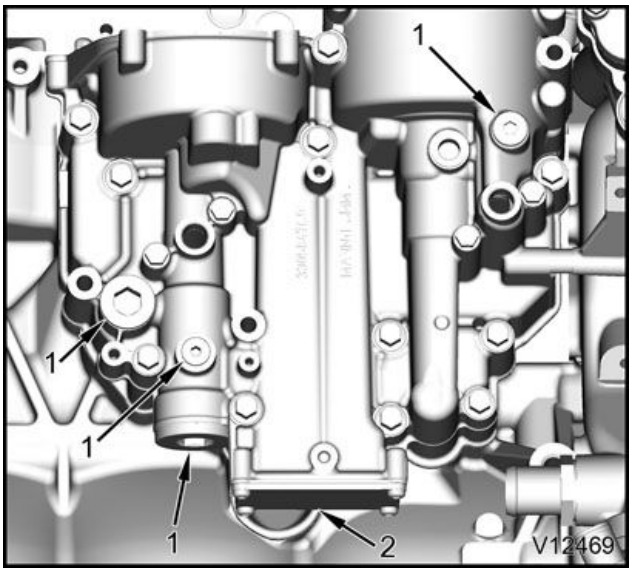

Figure 373 Oil module assembly (non-servicable items)

1. Plug (with seal)
2. Bottom cover

CAUTION: To prevent engine damage, do not remove oil module assembly plugs, seals or bottom cover to drain the coolant or oil. These parts are not serviceable.

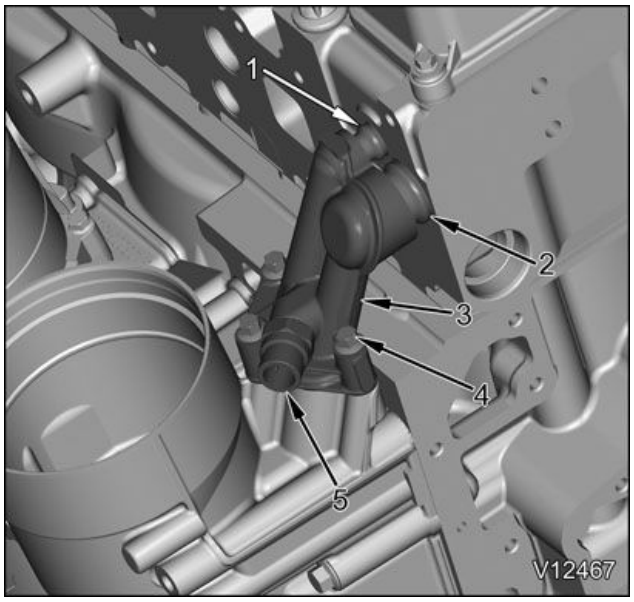

Figure 374 Oil module flange

1. Extension tube (DMR20 x DN14)
2. Extension tube (DMR37 x DN29)
3. Oil module flange
4. M8 x 45 bolt (3)
5. Engine oil temperature sensor

8. If not previously done, disconnect engine oil temperature sensor connector. Remove engine oil temperature sensor from oil module flange if needed. See "ENGINE ELECTRICAL" for procedure.
9. Remove three M8 x 45 bolts then remove oil module flange by pulling away from cylinder head to disengage extension tubes. Discard the oil module flange seal (formed).

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

10. Remove DMR20 x DN14 and DMR37 x DN29 extension tubes. Inspect for damage. Replace as necessary.

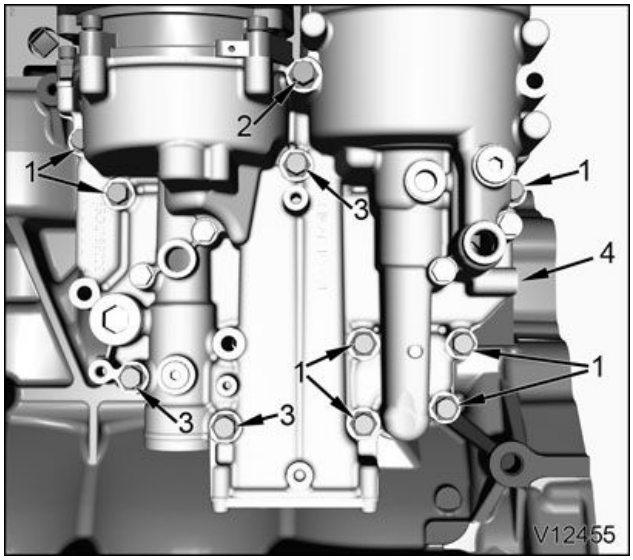

Figure 375 Oil module assembly

1. M10 x 80 bolt (7)
2. M10 x 170 bolt
3. M10 x 110 bolt (3)
4. M8 x 150 bolt location (from water pump) includes 9 x 16 x 15 spacer

11. Remove seven M10 x 80 bolts, three M10 x 110 bolts, M10 x 170 bolt, M8 x 150 bolt (from water pump into front side of oil module assembly) and 9 x 16 x 15 spacer (between oil module assembly and water distribution housing).
12. Remove oil module assembly and gasket from engine. Discard oil module assembly gasket.

Oil Cooler

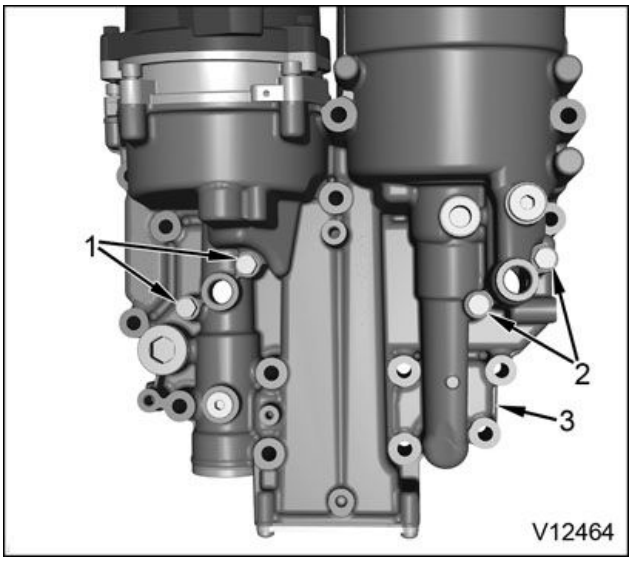

Figure 376 Oil cooler bolts

1. M8 x 45 bolt (2)
2. M8 x 90 bolt (2)
3. Oil module assembly

1. Remove two M8 x 45 and two M8 x 90 bolts.

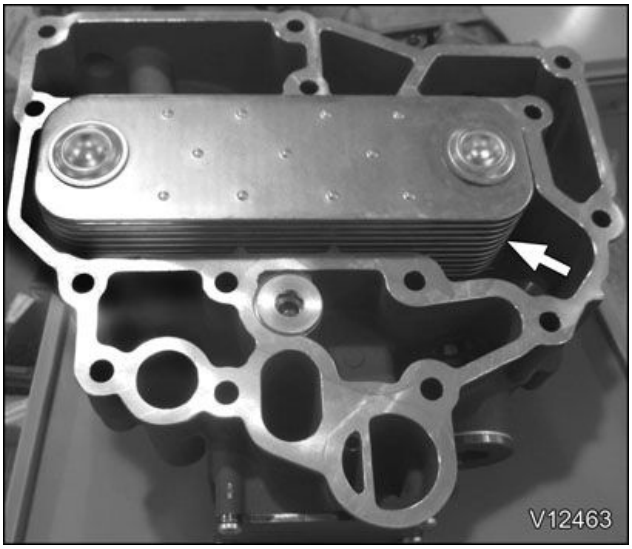

Figure 377 Oil cooler

2. Remove oil cooler from oil module assembly.

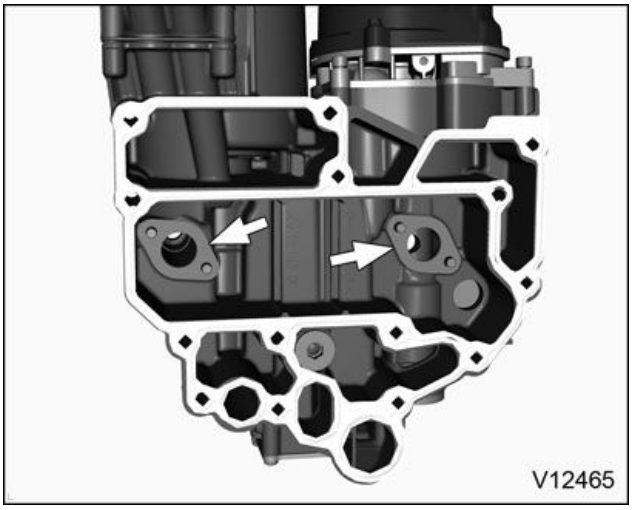

Figure 378 Oil cooler gaskets

3. Remove two oil cooler gaskets from oil module assembly. Discard gaskets.

Oil Pressure Relief Valve

NOTE: Perform this procedure if replacing oil pressure relief valve for oil pressure-related issues.

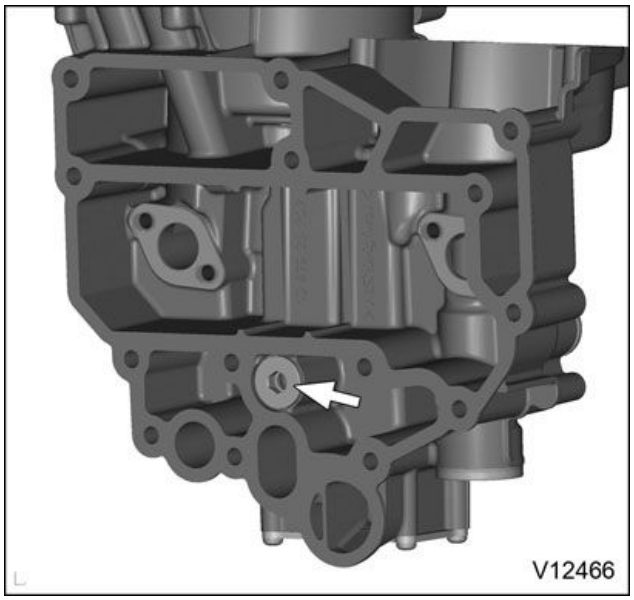

Figure 379 Oil pressure relief valve

1. Remove oil pressure relief valve. Clean and inspect oil pressure relief valve. Replace if necessary.

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 oil cooler in suitable solvent.
   - Flush and drain oil cooler to remove any residue. Dry components with filtered compressed air.

Oil Cooler Leak Test

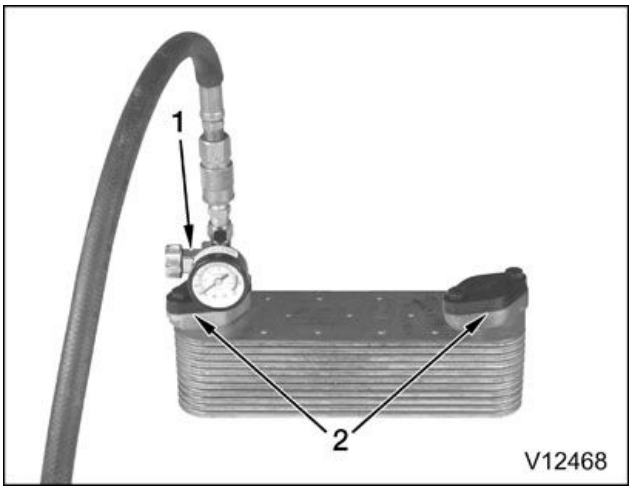

Figure 380 Engine oil cooler pressure test

1. Air pressure regulator
2. Engine Oil Cooler Pressure Test Plate

1. Install Engine Oil Cooler Pressure Test Plate (page 293) onto oil cooler.

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

2. Attach an air pressure regulator (page 293) to Engine 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 large container of clean water.
4. Inspect oil cooler and test plate for leaks. If test plate fittings leak, tighten fittings and continue looking for leaks. Air bubbles at any location from oil cooler indicate leaks. Replace oil cooler if leaking.
5. Dry oil cooler using filtered compressed air.

Extension Tubes

1. Wipe extension tubes clean and inspect for tears, cuts or other damage to sealing surfaces. Replace as necessary.

Oil Centrifuge

1. Clean the oil centrifuge and inspect for damage. Replace as necessary.

Installation

Oil Pressure Relief Valve

NOTE: Perform this procedure if oil pressure relief valve is removed.

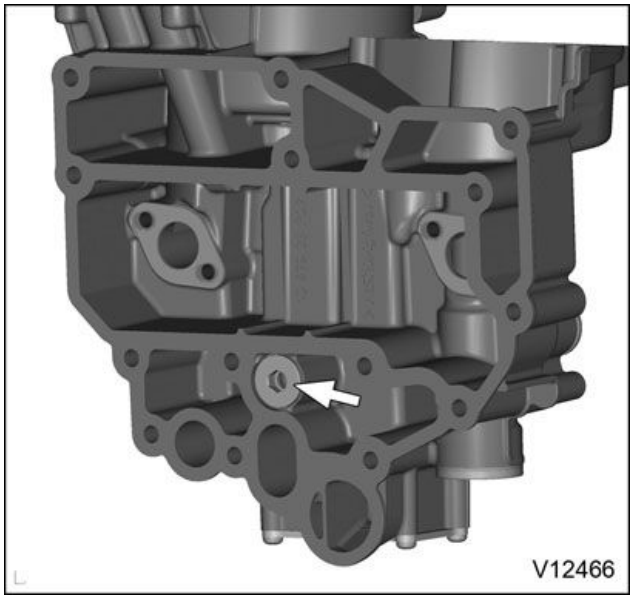

Figure 381 Oil pressure relief valve

1. Install oil pressure relief valve. Tighten valve to special torque (page 293).

Oil Cooler

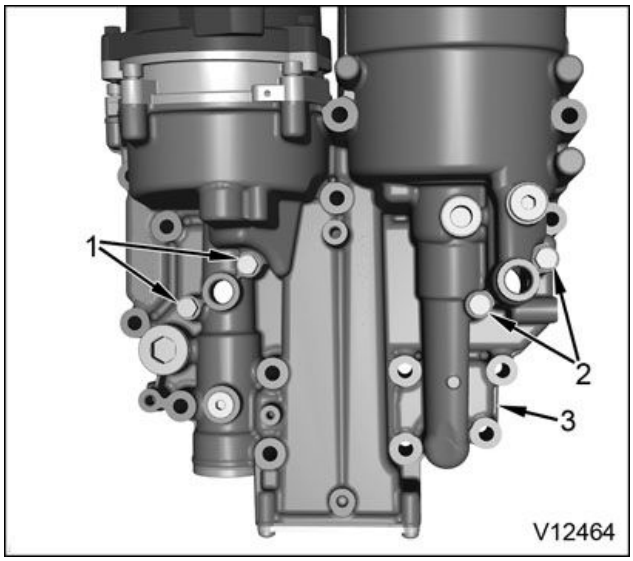

Figure 382 Oil cooler bolts

1. M8 x 45 bolt (2)
2. M8 x 90 bolt (2)
3. Oil module assembly

1. Install two M8 x 45 and two M8 x 90 bolts through oil module assembly.

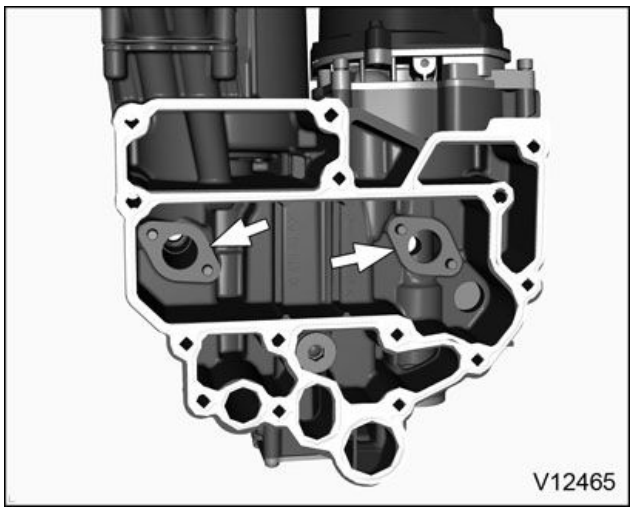

Figure 383 Oil cooler gaskets

2. Install new oil cooler gaskets over threads of installed bolts.

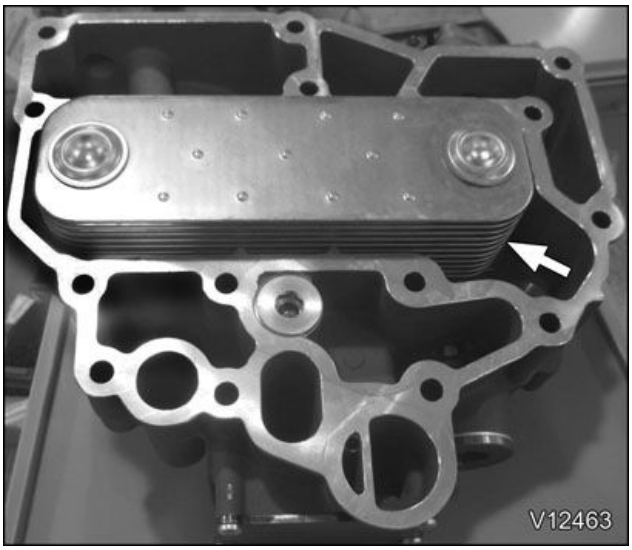

Figure 384 Oil cooler installation

3. Install oil cooler over gaskets and into oil module. Hand-tighten bolts.

   NOTE: Ensure gaskets remain in place during cooler installation.

   Tighten two M8 x 45 and two M8 x 90 bolts to special torque (page 293).

Oil Module Assembly

1. Position new gasket onto oil module assembly.

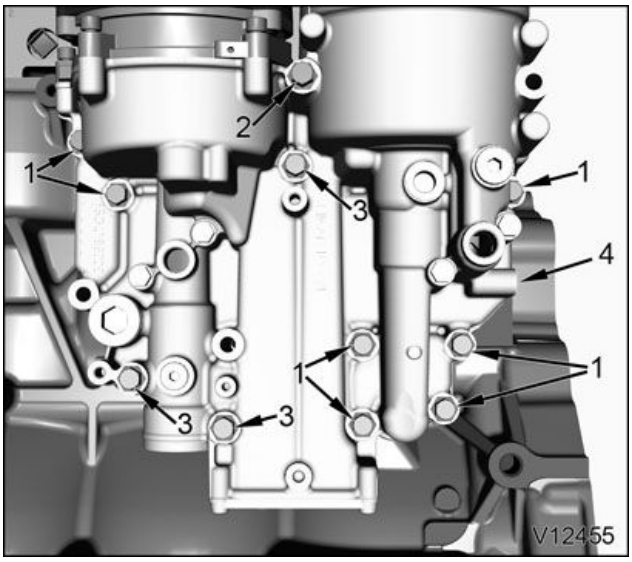

Figure 385 Oil module assembly

1. M10 x 80 bolt (7)
2. M10 x 170 bolt
3. M10 x 110 bolt (3)
4. M8 x 150 bolt location (from water pump) includes 9 x 16 x 15 spacer

CAUTION: To prevent engine damage, do not use any silicone or other sealant when installing oil module assembly.

2. Position oil module assembly and install seven M10 x 80 bolts, M10 x 170 bolt and three M10 x 110 bolts.
3. Tighten oil module bolts to special torque (page 293).
4. Place 9 x 16 x 15 spacer between water distribution housing and oil module assembly.
5. Install M8 x 150 bolt through water pump assembly, water distribution housing, spacer and into front side of oil module assembly. Tighten M8 x 150 bolt to special torque (page 293).

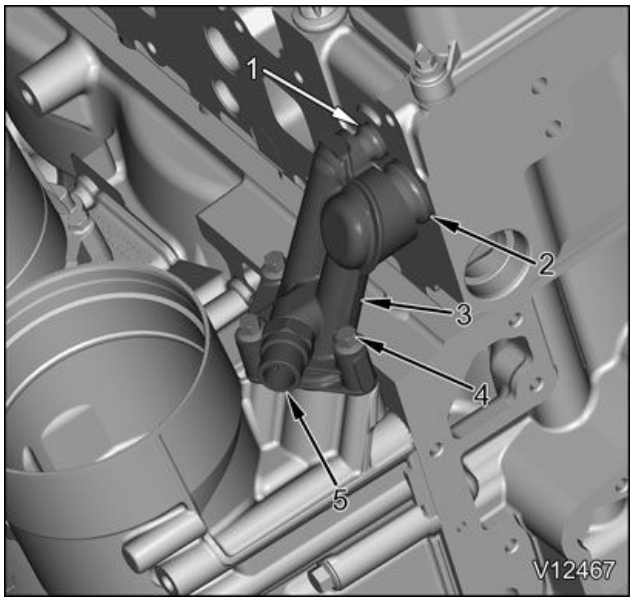

Figure 386 Oil module flange

1. Extension tube (DMR20 x DN14)
2. Extension tube (DMR37 x DN29)
3. Oil module flange
4. M8 x 45 bolt (3)
5. Engine oil temperature sensor

6. Lubricate sealing surfaces of DMR20 x DN14 and DMR37 x DN29 extension tubes with P-80® rubber lubricant or equivalent (page 293) and insert into oil module flange.
7. Install extension tubes into oil module flange using Extension Tube Installer Large and Extension Tube Installer Small (page 293).
8. Position oil module with new formed seal onto oil module while gently pushing extension tubes into cylinder head. Install three M8 x 45 bolts. Tighten bolts to special torque (page 293).
9. If not previously done, install engine oil temperature sensor into oil module flange if needed. See "ENGINE ELECTRICAL" for procedure. Connect temperature sensor electrical connector.

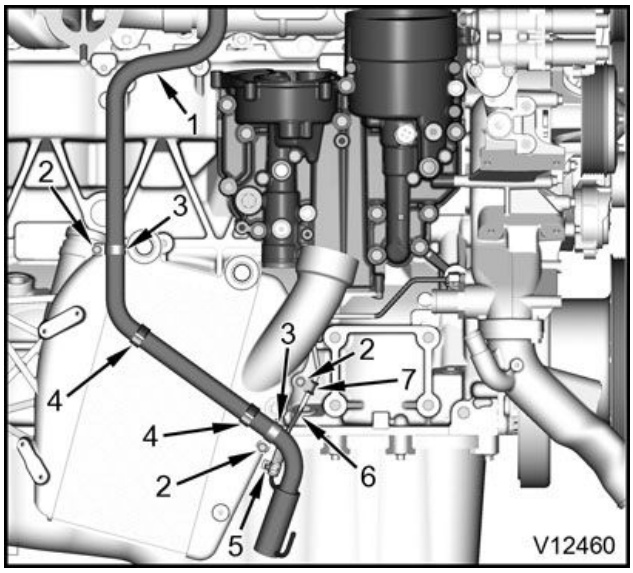

Figure 387 Open breather tube and heater return tube

1. Open breather tube assembly
2. M6 x 16 bolt (3)
3. Tube clamp (2)
4. Tube clamp (2) (for HCI coolant return tube assembly)
5. Hose clamp (spring type)
6. Heater return tube assembly
7. Pipe single cushioned clamp

10. Install two tube clamps onto open breather tube. Position open breather tube assembly to LPCAC and install two M6 x 16 bolts. Tighten bolts to special torque (page 293).
11. If not previously done, snap two tube clamps over open breather tube assembly and HCI coolant return tube assembly.
12. If not previously done, install HCI coolant return tube onto open breather tube assembly and install hose clamp (spring type). See HCI Coolant Return Tube (page 135).
13. Position heater return tube assembly to straight fitting on water distribution housing and loosely tighten tube nut.
14. Install pipe single cushioned clamp onto heater return tube assembly and install M6 x 16 bolt into LPCAC and tighten to special torque (page 293).

15. Install heater return tube assembly hose onto open breather tube and install hose clamp (spring type).
16. Tighten heater return tube assembly tube nut to special torque (page 293).

Oil Centrifuge

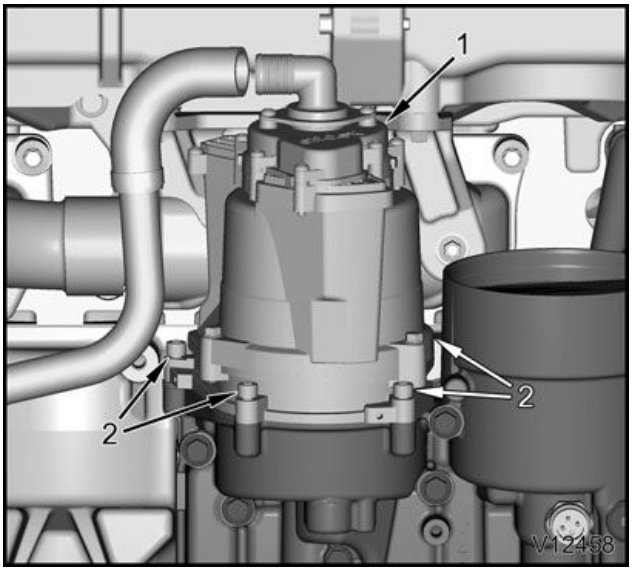

Figure 388 Oil centrifuge

1. Oil centrifuge
2. M6 socket head bolt (4)

1. Install centrifuge with base and new formed seal. Lubricate new formed seal with clean engine oil.
2. Install four M6 socket head bolts. Tighten bolts to standard torque (page 547).

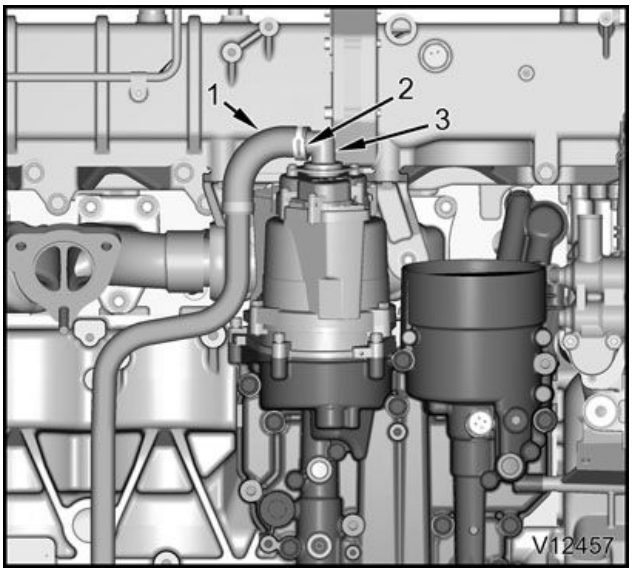

Figure 389 Open breather tube assembly

1. Open breather tube assembly
2. Clamp (spring)
3. Oil centrifuge outlet

3. Slide spring clamp over open breather tube assembly.
4. Connect open breather tube assembly to centrifuge outlet.
5. Install spring clamp and tighten.

Oil Filter Cover and Filter

1. Lubricate new O-ring with clean engine oil and install onto exterior of oil filter cover.
2. Install oil filter into oil filter cover.

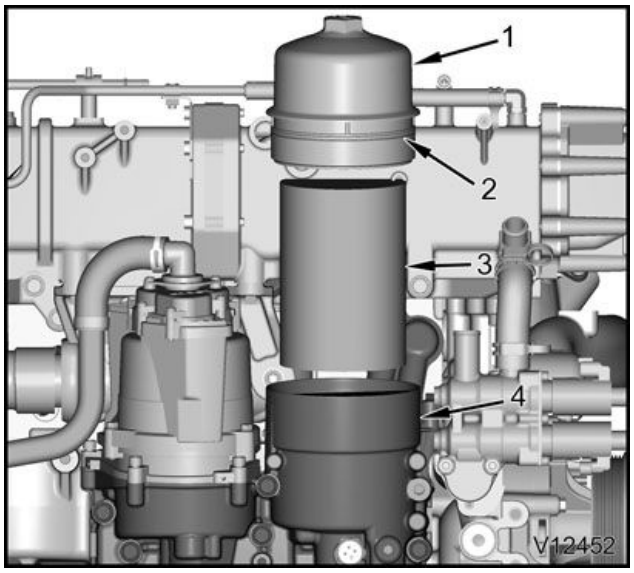

Figure 390 Oil filter cover

1. Filter cover
2. O-ring seal
3. Oil filter
4. Oil module assembly

3. Install oil filter, O-ring seal and oil filter cover as an assembly into oil module. Tighten 36mm cover hex to special torque (page 293).

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

CAUTION: To prevent engine damage, do not start or allow engine to run until first changing engine oil.

4. Drain and replace engine oil with recommended type and amount. See *Engine Operation and Maintenance Manual* for oil type, capacity and fill procedure.

5. Replace engine coolant with recommended type and amount. See *Engine Operation and Maintenance Manual* for coolant type, capacity and fill procedure.

NOTE: Three additional bolts secure the oil module assembly. These bolts are installed along with the HP turbo air supply duct (two M10 x 200 bolts) and the air inlet duct for the LP turbocharger (one M10 x 140 bolt). See "TURBOCHARGERS" for procedures.

Special Torque

Heater return tube assembly bolt, M6 x 16	13 N·m (115 lb·in)
Heater return tube assembly tube nut	11 N·m (97 lb·in)
Oil cooler bolts, M8 x 45 and M8 x 90	25 N·m (18 lb·ft)
Oil filter cover	40 N·m (30 lb·ft)
Oil module assembly bolts, M10 x 80, M10 x 170 and M10 x 110	65 N·m (48 lb·ft)
Oil module flange bolts, M8 x 45	24 N·m (18 lb·ft)
Oil pressure relief valve	40 N·m (30 lb·ft)
Open breather tube assembly bolt, M6 x 16	13 N·m (115 lb·in)
Water pump bolt, M8 x 150 (front side of oil module)	35 N·m (26 lb·ft)

Special Service Tools

Description	Tool Number
Air pressure regulator	Obtain locally
Extension Tube Installer Large	ZTSE6051-1
Extension Tube Installer Small	ZTSE6051-2
Engine Oil Cooler Pressure Test Plate	ZTSE6063
P-80® rubber lubricant or equivalent	Obtain locally

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Exploded Views

EGR Coolant Manifold and Elbow

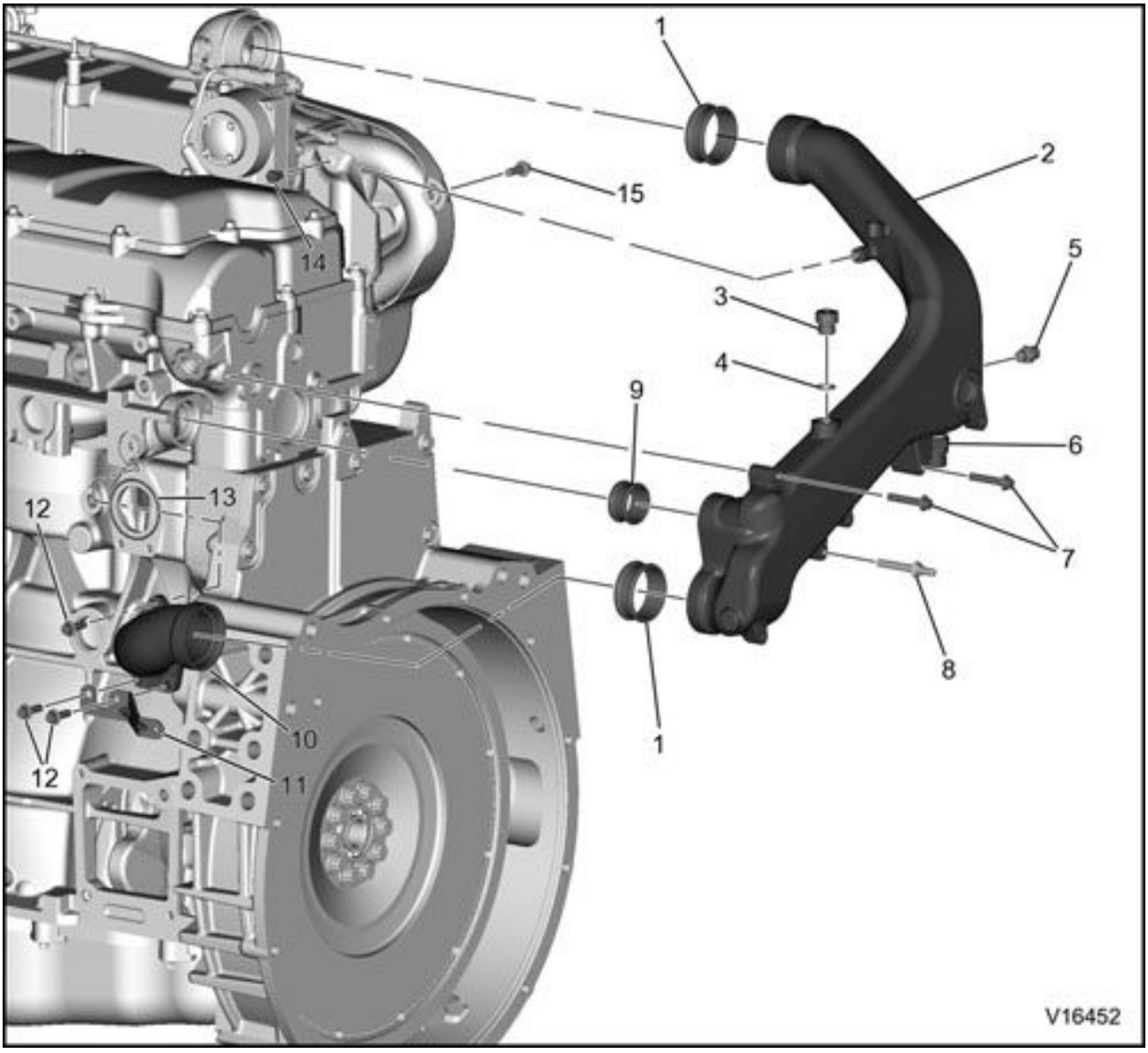

Figure 391 EGR coolant manifold and elbow

1. Extension tube (DMR62 x 51) (2)
2. Coolant manifold
3. M18 O-ring boss plug
4. Seal
5. Coolant supply fitting (to hydrocarbon injector)
6. Engine Coolant Temperature (ECT1) sensor
7. M8 x 45 bolt (2)
8. M8 x 50 x 16 stud bolt
9. Extension tube (DMR44 x 35)
10. Coolant elbow
11. Hydrocarbon injector fuel supply (tube) bracket
12. M8 x 25 bolt (3)
13. 60 x 3 O-ring
14. M8 x 18 bolt
15. M8 x 25 heat-resistant bolt

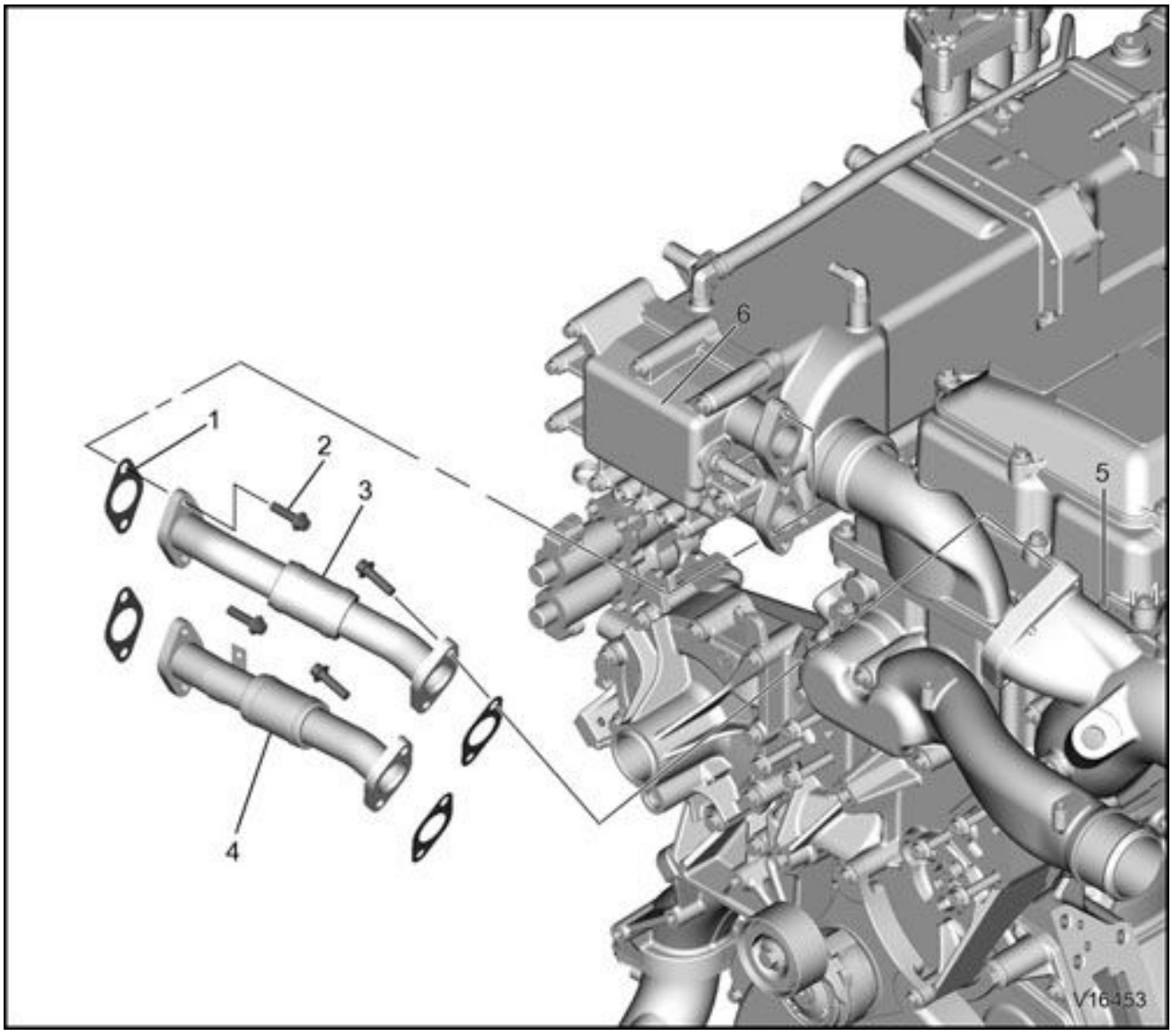

Figure 392 EGR outlet tubes (cylinders 1-3 and cylinders 4-6)

1. EGR outlet gasket (4)
2. M8 x 30 bolt (8)
3. EGR outlet (cylinders 1-3) tube
4. EGR outlet (cylinders 4-6) tube
5. Air intake throttle duct (horizontal)
6. EGR module cover

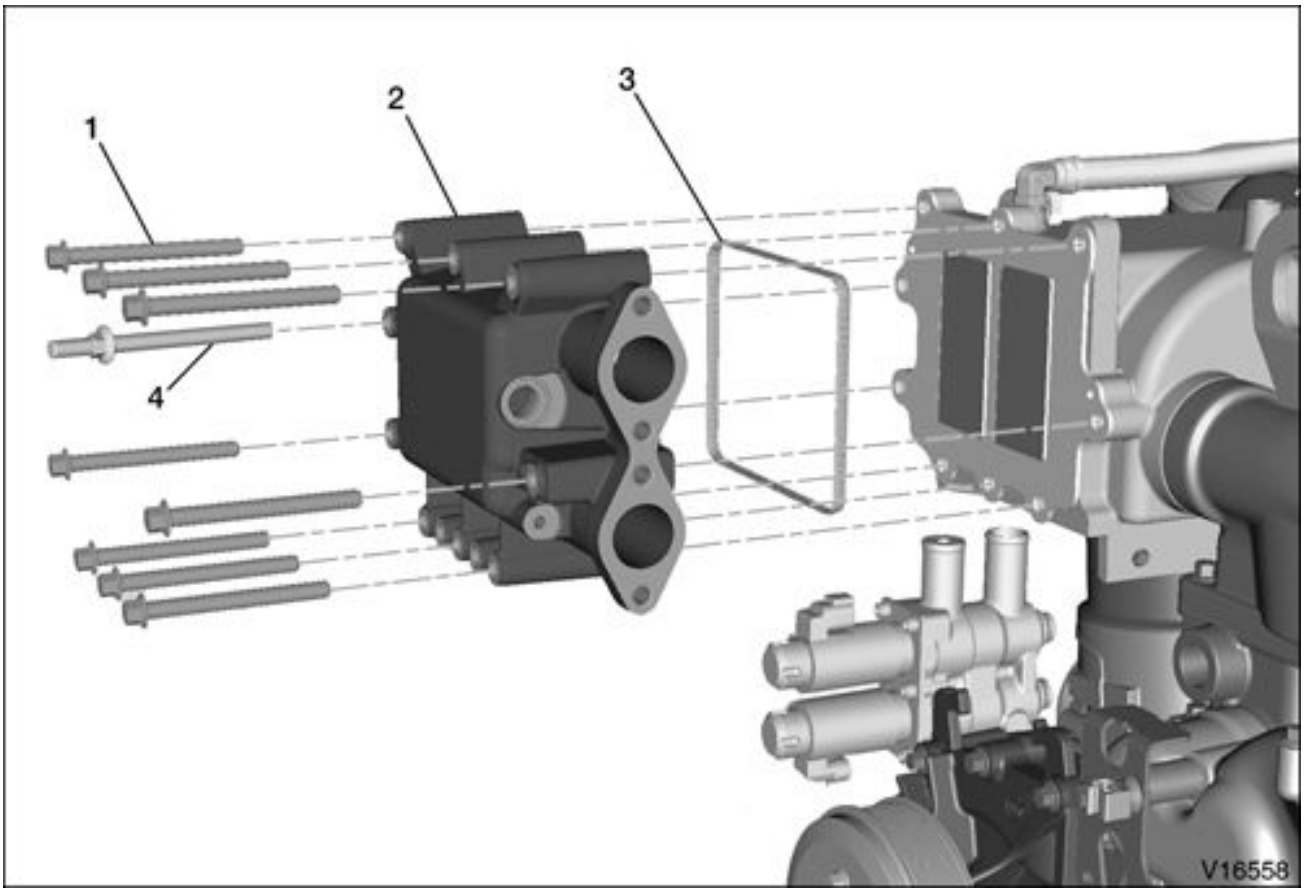

Figure 393 EGR module cover

1. M8 x 85 bolt (9)
2. EGR module cover
3. EGR cover outlet seal
4. M8 x 90 stud bolt

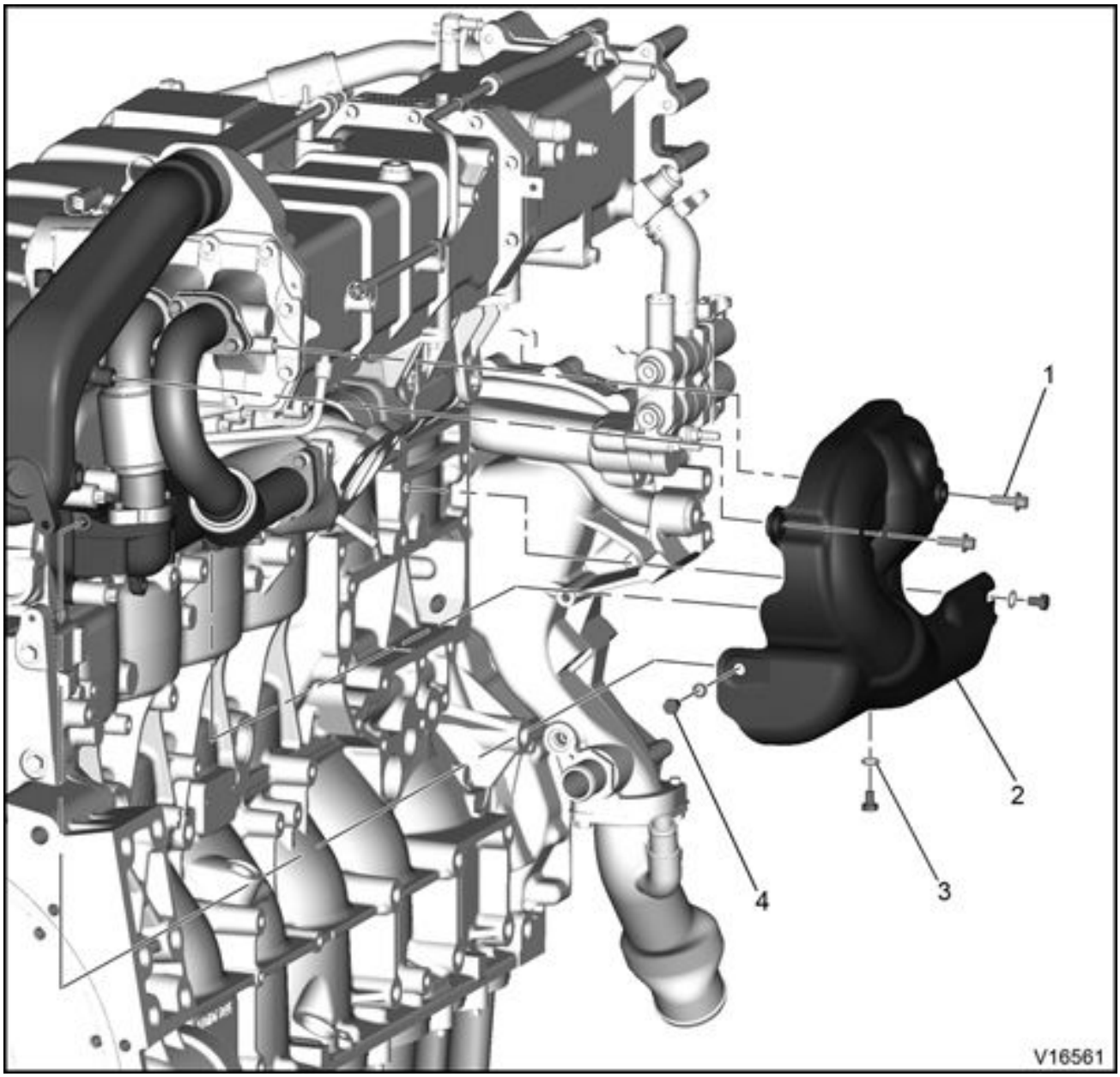

Figure 394 EGR inlet tube heat protection shield

1. M8 x 25 heat-resistant bolt (2)
2. Heat protection (cylinders 4-6) shield
3. 8.4 x 16 x 1.6 washer (3)
4. M8 x 12 bolt (3)

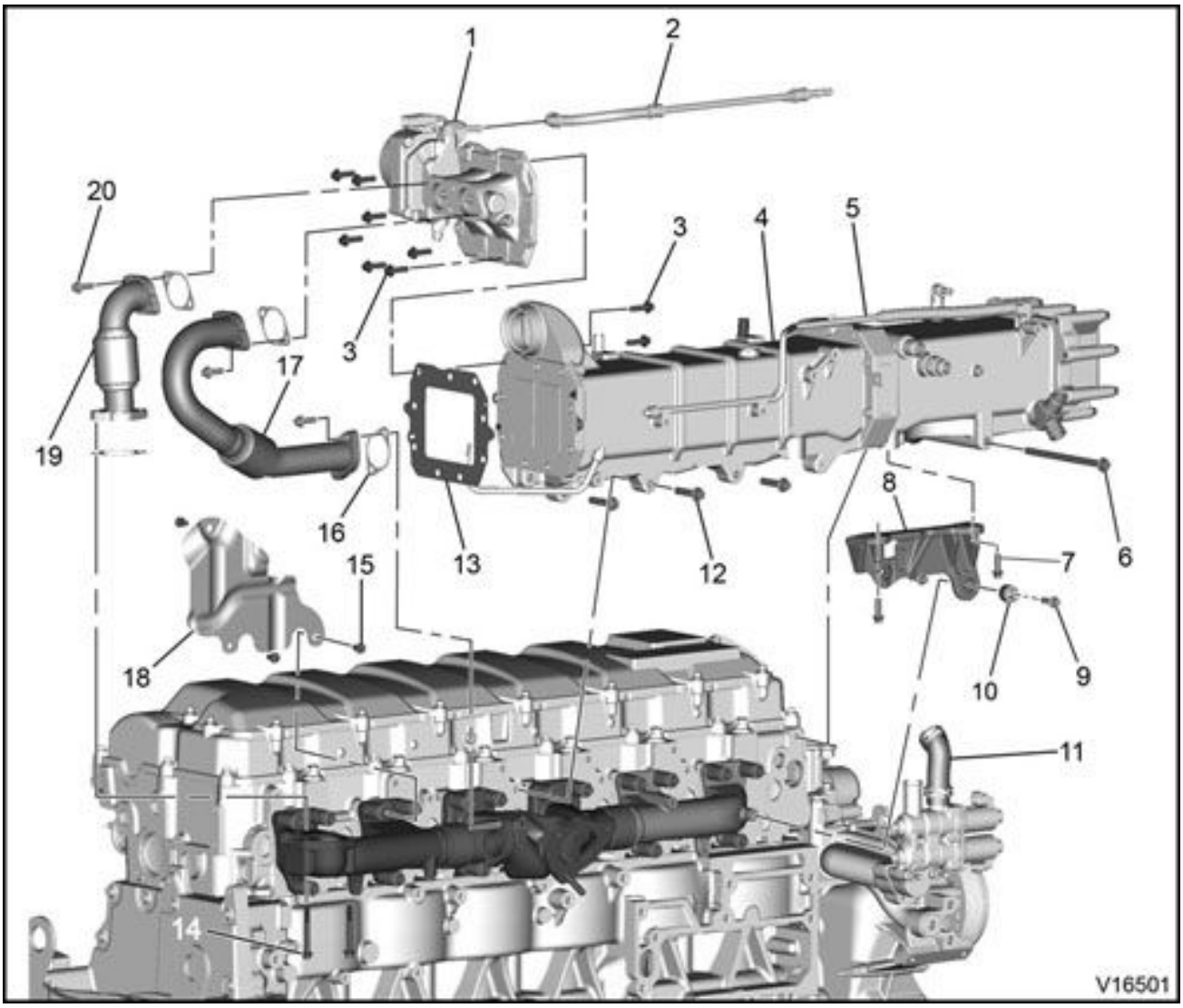

Figure 395 EGR system components

1. EGR dual flap valve
2. EGR valve coolant return tube assembly
3. M8 x 30 heat-resistant bolt (9)
4. EGR cooler assembly
5. EGR valve coolant supply tube assembly
6. M10 x 170 bolt
7. M8 x 25 heat-resistant bolt (2)
8. EGR cooler bracket
9. M8 x 25 heat-resistant bolt (2)
10. Spacer
11. Low-temperature EGR hose assembly
12. M10 x 45 bolt (6)
13. EGR dual flap valve gasket
14. M8 x 65 heat-resistant bolt (2)
15. M8 x 12 bolt (3)
16. Tube EGR gasket (4)
17. Inlet EGR (cylinders 1-3) tube
18. Heat protection EGR shield
19. Inlet EGR (cylinders 4-6) tube
20. M8 x 25 heat-resistant bolt (6)

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: When performing specific component removal, only remove components necessary for access.

For complete engine tear down, refer to the following service sections for information on removal of components prior to this section.

- **Engine Electrical**
- **Front Cover, Fan Drive, Cooling System and Related Components**
- **Turbochargers**
- **Oil Cooler, Filter Housing and Crankcase Ventilation**

Coolant Manifold

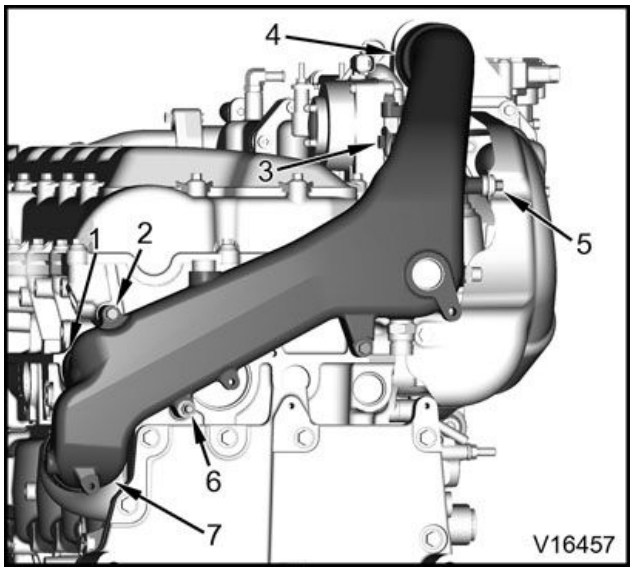

Figure 396 Coolant manifold

1. Extension tube (DMR44 x 35)
2. M8 x 45 bolt (2)
3. M8 x 12 bolt
4. Extension tube (DMR62 x 51)
5. M8 x 25 heat-resistant bolt
6. M8 x 50 x 16 stud bolt
7. Extension tube (DMR62 x 51)

1. Remove M8 x 12 bolt securing heat protection EGR shield to coolant manifold.
2. Remove heat protection (cylinders 4-6) shield M8 x 25 heat-resistant bolt.
3. Remove two M8 x 45 bolts, one M8 x 50 x 16 stud bolt and coolant manifold.

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

4. Remove two DMR62 x 51 and one DMR44 x 35 extension tubes. Pry the tubes out using a wood or plastic hammer handle or similar tool. Inspect extension tube sealing surfaces for damage. Replace as needed.

Coolant Elbow

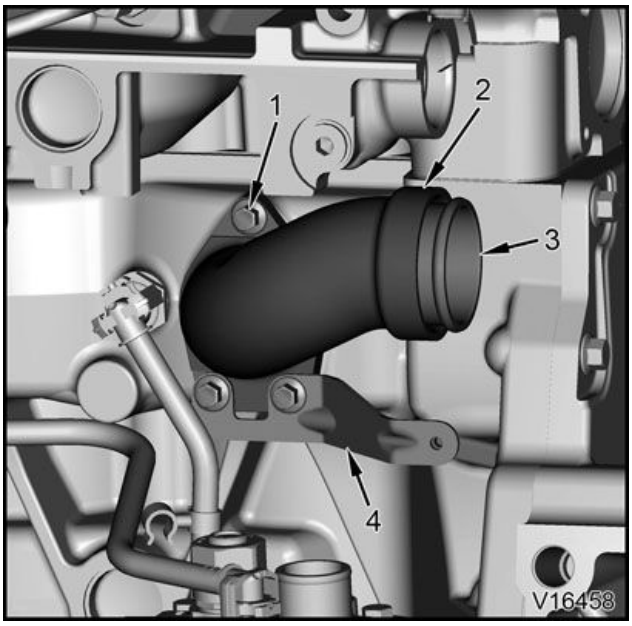

Figure 397 Coolant elbow

1. M8 x 25 bolt (3)
2. Coolant elbow
3. Extension tube (DMR62 x 51)
4. Hydrocarbon injector fuel supply (tube) bracket

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

1. Remove DMR62 x 51 extension tube from coolant elbow. Pry the tubes out using a wood or plastic hammer handle or similar tool. Inspect extension tube sealing surfaces for damage. Replace as needed.
2. Remove two lower M8 x 25 bolts and hydrocarbon injector fuel supply (tube) bracket.
3. Remove upper M8 x 25 bolt and coolant elbow. Remove and discard 60 x 3 O-ring.

EGR Cooler Bracket

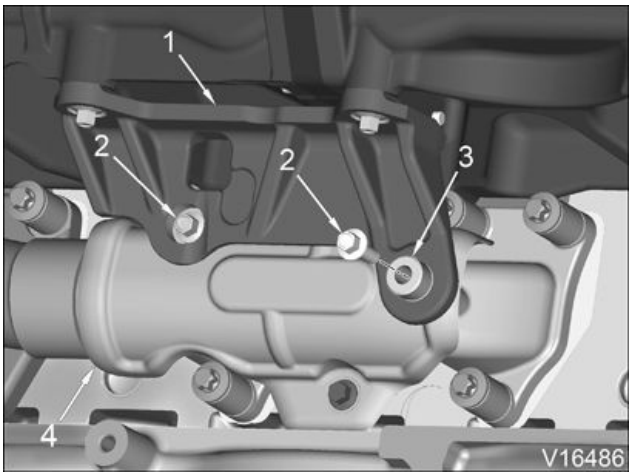

Figure 398 EGR cooler bracket

1. EGR cooler bracket
2. M8 x 25 heat-resistant bolt (2)
3. Spacer
4. Heat protection shield (at front exhaust manifold)

1. Remove and discard two M8 x 25 heat-resistant bolts that secure the EGR cooler bracket to front exhaust manifold.
2. Remove spacer.
3. Leave cooler bracket attached to EGR cooler.

EGR Outlet Tubes

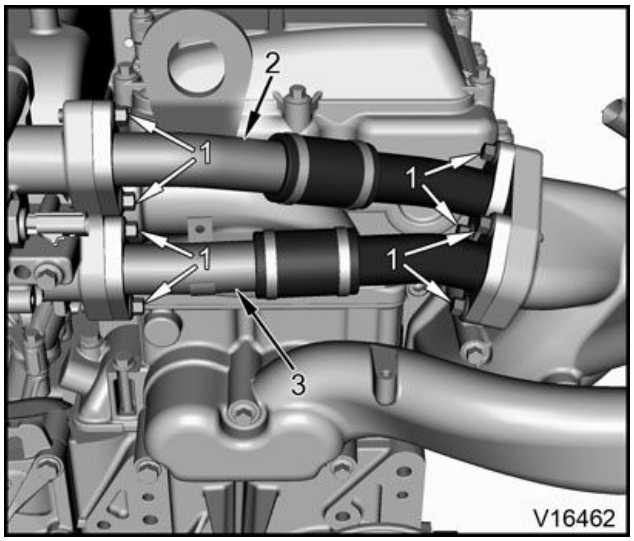

Figure 399 EGR outlet tubes

1. M8 x 30 bolt (8)
2. EGR outlet (cylinders 1-3) tube
3. EGR outlet (cylinders 4-6) tube

1. Remove four M8 x 30 bolts securing the EGR outlet (cylinders 4-6) tube.
2. Remove EGR outlet (cylinders 4-6) tube and discard tube gaskets.
3. Remove four M8 x 30 bolts securing the EGR outlet (cylinders 1-3) tube.
4. Remove EGR outlet (cylinders 1-3) tube and discard tube gaskets.

EGR Module Cover

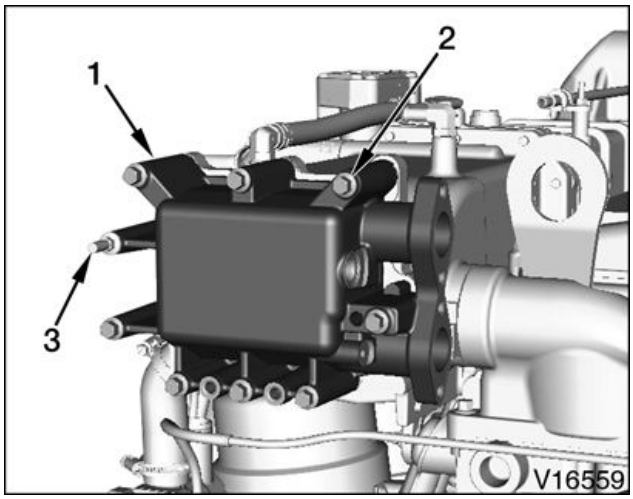

Figure 400 Front of EGR module

1. EGR module cover
2. M8 x 85 bolt (8)
3. M8 x 90 stud bolt

1. Remove eight M8 x 85 bolts and one M8 x 90 stud bolt. Remove EGR module cover.

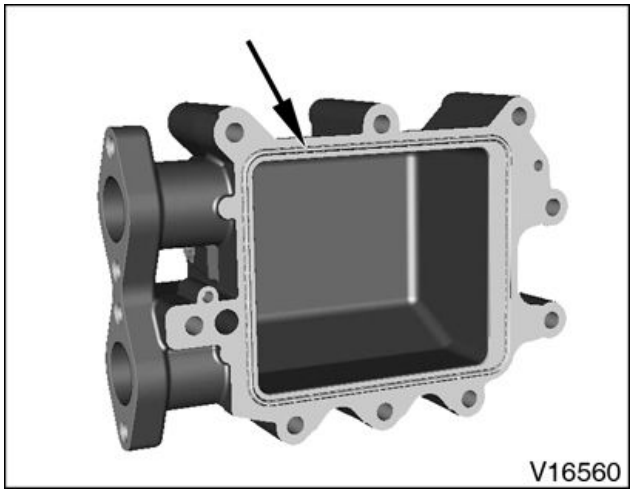

Figure 401 EGR cover outlet seal

2. Remove EGR cover outlet seal from EGR module cover. Save seal for installation.

Heat Protection (Cylinders 4-6) Shield

1. If not already done, remove Hydrocarbon Injector (HCI) coolant supply tube assembly. See HCI Coolant Supply Tube Assembly (page 127).
2. If not already done, remove HCI coolant return tube assembly. See HCI Coolant Return Tube Assembly .
3. If not already done, remove HCI / Aftertreatment Fuel Injector (AFI) assembly. See HCI / AFI Assembly (page 130).

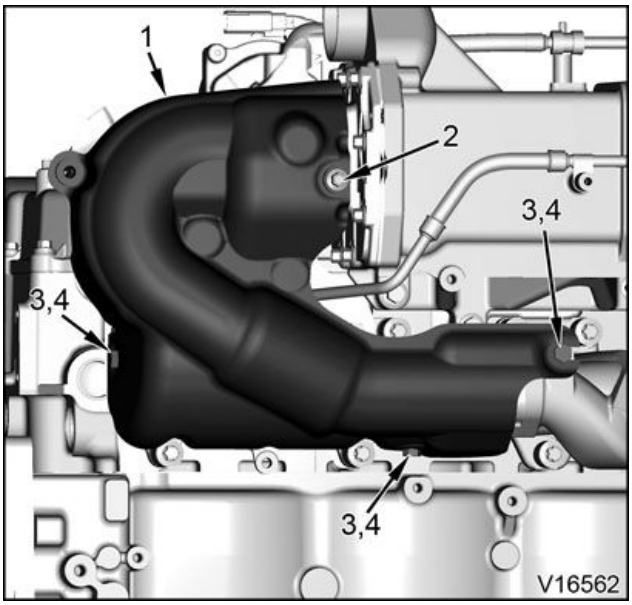

Figure 402 Heat protection (cylinders 4-6) shield

1. Heat protection (cylinders 4-6) shield
2. M8 x 25 heat-resistant bolt
3. M8 x 12 bolt (3)
4. 8.4 x 16 x 1.6 washer (3)

4. Remove three M8 x 12 bolts (Figure 402) (Item 3), and three 8.4 x 16 x 1.6 washers (Figure 402) (Item 4).
5. Remove M8 x 25 heat-resistant bolt (Figure 402) (Item 2), and remove heat protection shield (Figure 402) (Item 1).

EGR Inlet Tubes

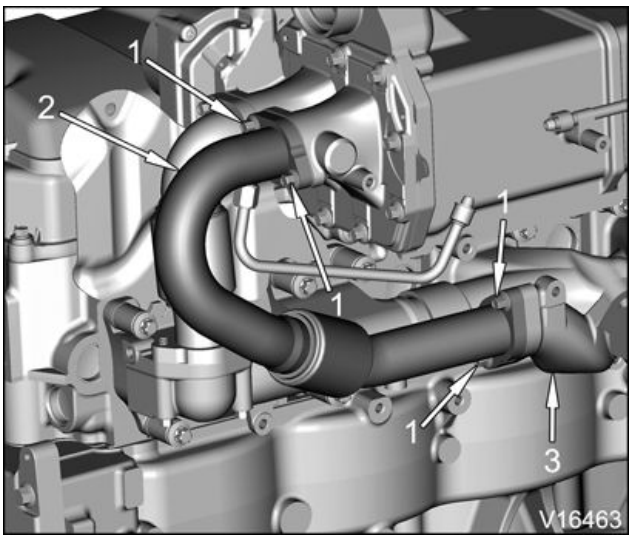

Figure 403 EGR inlet (cylinders 1-3) tube

1. M8 x 25 heat-resistant bolt (4)
2. EGR inlet (cylinders 1-3) tube
3. Middle exhaust manifold

1. Remove four M8 x 25 heat-resistant bolts.
2. Remove EGR inlet tube (cylinders 1-3) and two gaskets. Discard gaskets.

CAUTION: To prevent engine damage, cover opening in the rear manifold to prevent dirt, debris, and objects from entering rear manifold.

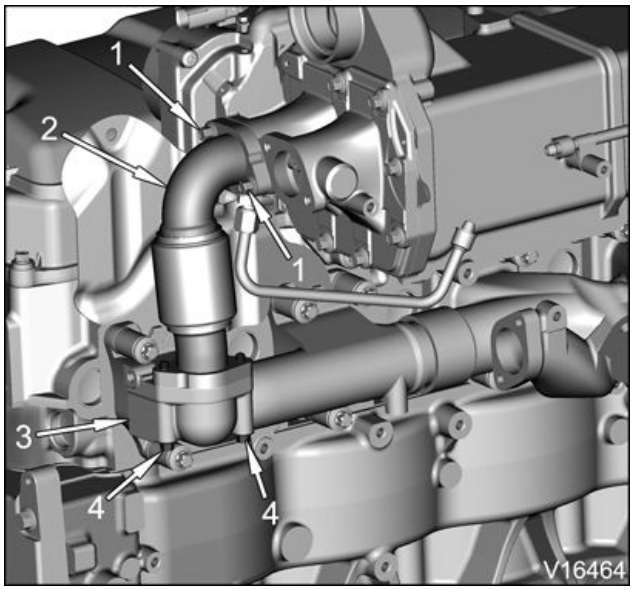

Figure 404 EGR inlet (cylinders 4-6) tube

1. M8 x 25 heat-resistant bolt (2)
2. EGR inlet (cylinders 4-6) tube
3. Rear exhaust manifold
4. M8 x 65 heat-resistant bolt (2)

3. Remove two M8 x 25 heat-resistant bolts.
4. Remove two M8 x 65 heat-resistant bolts.
5. Remove EGR inlet (cylinders 4-6) tube and two tube gaskets. Discard gaskets.

CAUTION: To prevent engine damage, cover opening in the rear manifold to prevent dirt, debris, and objects from entering rear manifold.

Heat Protection EGR Shield

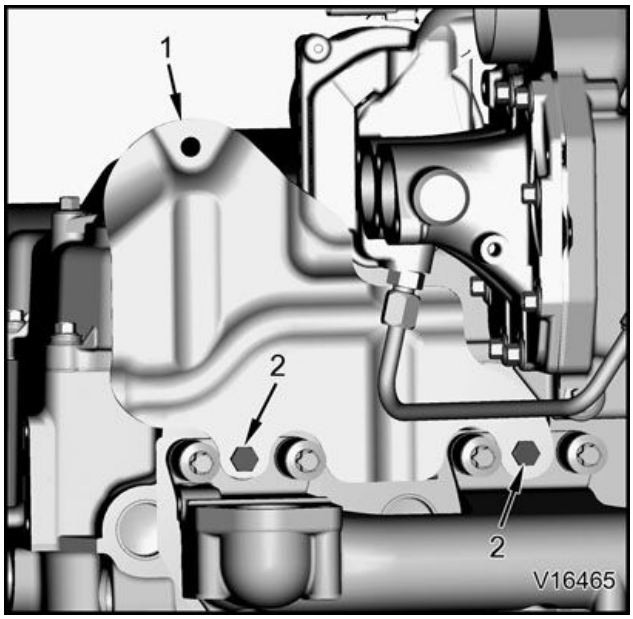

Figure 405 Heat protection EGR shield

1. Heat protection EGR shield
2. M8 x 12 bolt (2)

1. Remove two M8 x 12 bolts at rear exhaust manifold.
2. Remove heat protection EGR shield.

EGR Dual Flap Valve

NOTE: If removing complete EGR cooler assembly for disassembly of engine, removal of EGR dual flap valve is not required.

NOTE: The EGR dual flap valve can be removed as an in-vehicle service.

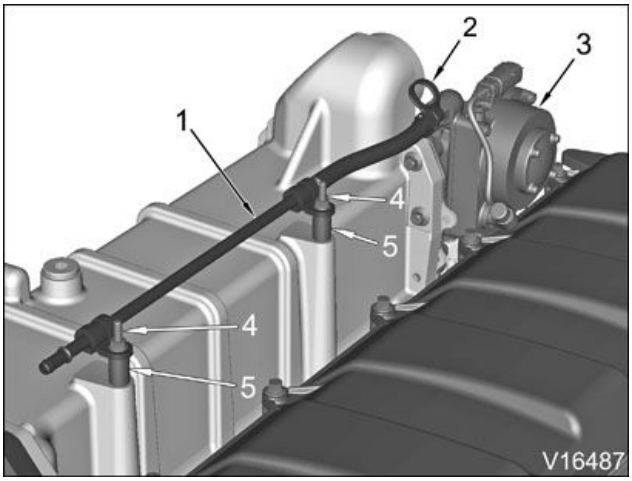

Figure 406 EGR valve coolant return tube assembly and EGR dual flap valve

1. EGR valve coolant return tube assembly
2. Spring clamp
3. EGR dual flap valve
4. M6 x 45 x 15 stud (2)
5. 6 x 15 x 23 spacer (2)

NOTE: Drain coolant from EGR cooler assembly before removal.

1. Remove two M6 x 45 x 15 stud bolts and two 6 x 15 x 23 spacers.
2. Disconnect coolant return tube spring clamp and EGR valve coolant return tube assembly from EGR dual flap valve.

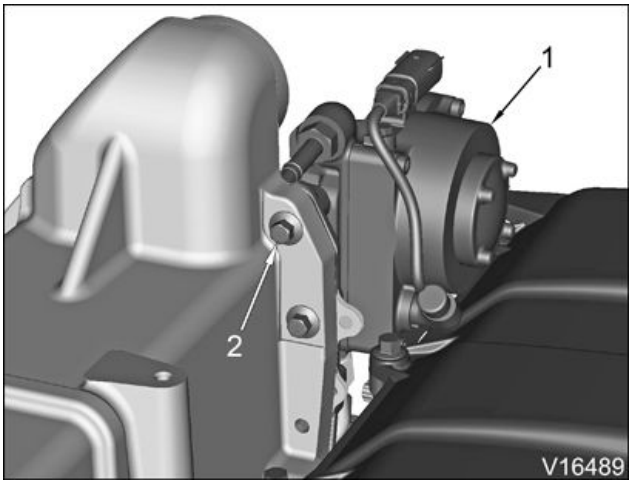

Figure 407 EGR dual flap valve and rear mounting bolts

1. EGR dual flap valve
2. M8 x 30 heat-resistant bolt (2)

3. Remove and discard two M8 x 30 heat-resistant bolts.

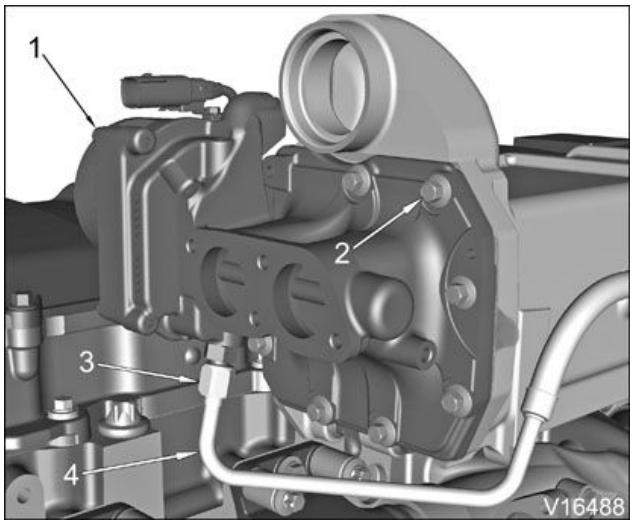

Figure 408 EGR dual flap valve, front mounting bolts, and EGR valve coolant supply tube assembly

1. EGR dual flap valve
2. M8 x 30 heat-resistant bolt (7)
3. EGR valve coolant supply tube nut
4. EGR valve coolant supply tube assembly

4. Loosen tube nut and disconnect EGR dual flap valve coolant supply tube from bottom of EGR dual flap valve.
5. Remove and discard seven M8 x 30 heat-resistant bolts.
6. Remove EGR dual flap valve.
7. Remove and discard EGR dual flap valve gasket.

EGR Cooler Assembly

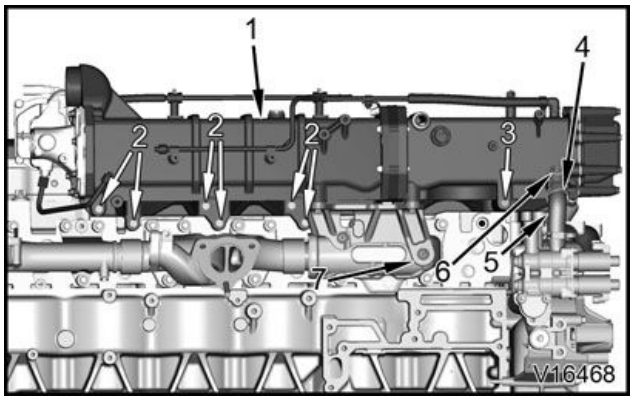

Figure 409 EGR cooler assembly

1. EGR cooler assembly
2. M10 x 45 bolt (6)
3. M10 x 170 bolt
4. Spring clamp
5. Low-temperature EGR hose assembly
6. Y-fitting (to deaeration port hoses)
7. EGR cooler bracket

1. Disconnect low-temperature EGR hose assembly spring clamp and hose from EGR cooler assembly.
2. Remove six M10 x 45 bolts, one M10 x 170 bolt and EGR cooler assembly.

Disassembly and Assembly of EGR Cooler

EGR Cooler High-Temperature or Low-Temperature Side Replacement

1. Obtain EGR Cooler Alignment Tool (page 330) .

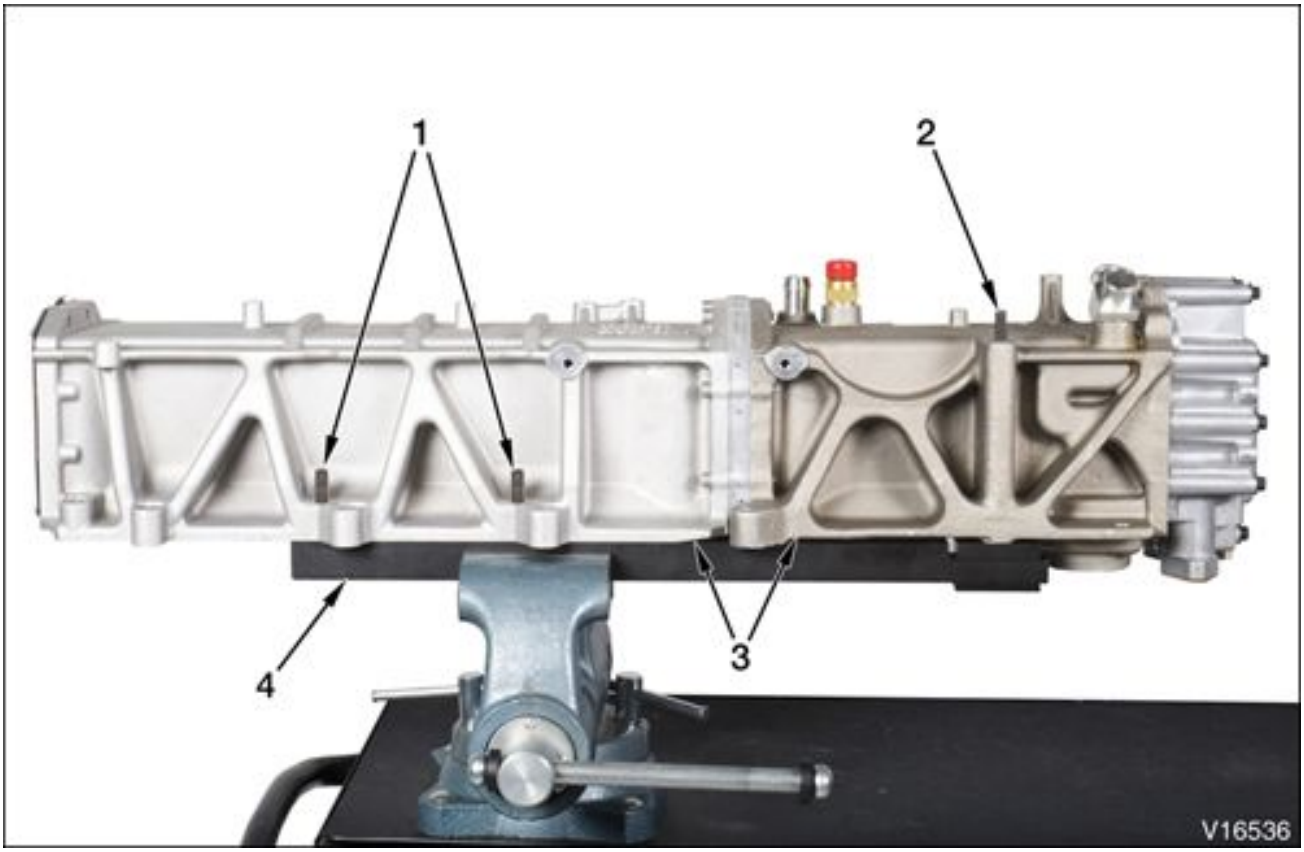

Figure 410 EGR cooler assembly

1. High-Temperature (HT) EGR cooler mounting stud
2. Low-Temperature (LT) EGR cooler mounting stud
3. Notch in tool
4. EGR Cooler Alignment Tool

2. Install EGR Cooler Alignment Tool into a suitable bench vise
3. Install the EGR cooler assembly onto the EGR Cooler Alignment Tool with two shorter mounting studs through High-Temperature (HT) EGR cooler and longer mounting stud through Low-Temperature (LT) EGR cooler.

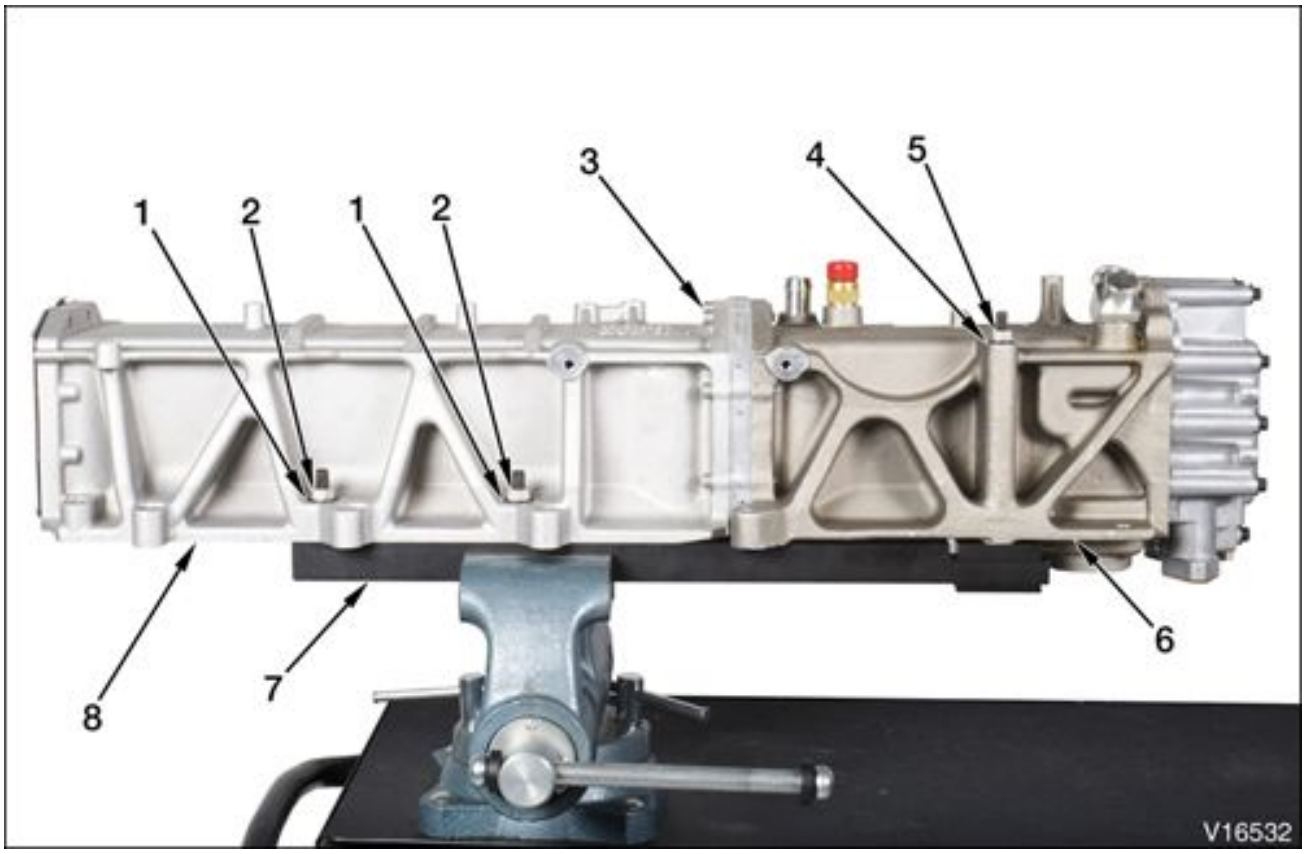

Figure 411 EGR cooler assembly

1. 1. 7/16 SAE flat washer
2. 7/16-14 nut
3. M8 x 50 hex socket screw (9)
4. 3/8 SAE flat washer
5. 3/8-16 nut
6. LT EGR cooler
7. EGR Cooler Alignment Tool
8. HT EGR cooler

4. Install two 7/16 SAE flat washers and two 7/16-14 nuts onto two HT EGR cooler mounting studs of the EGR Cooler Alignment Tool. Tighten nuts to special torque (page 330).
5. Install 3/8 SAE flat washer and 3/8-16 nut onto LT EGR mounting stud of the EGR Cooler Alignment Tool. Tighten nuts to special torque (page 330).
6. Remove nine M8 x 50 hex socket screws. Discard screws.

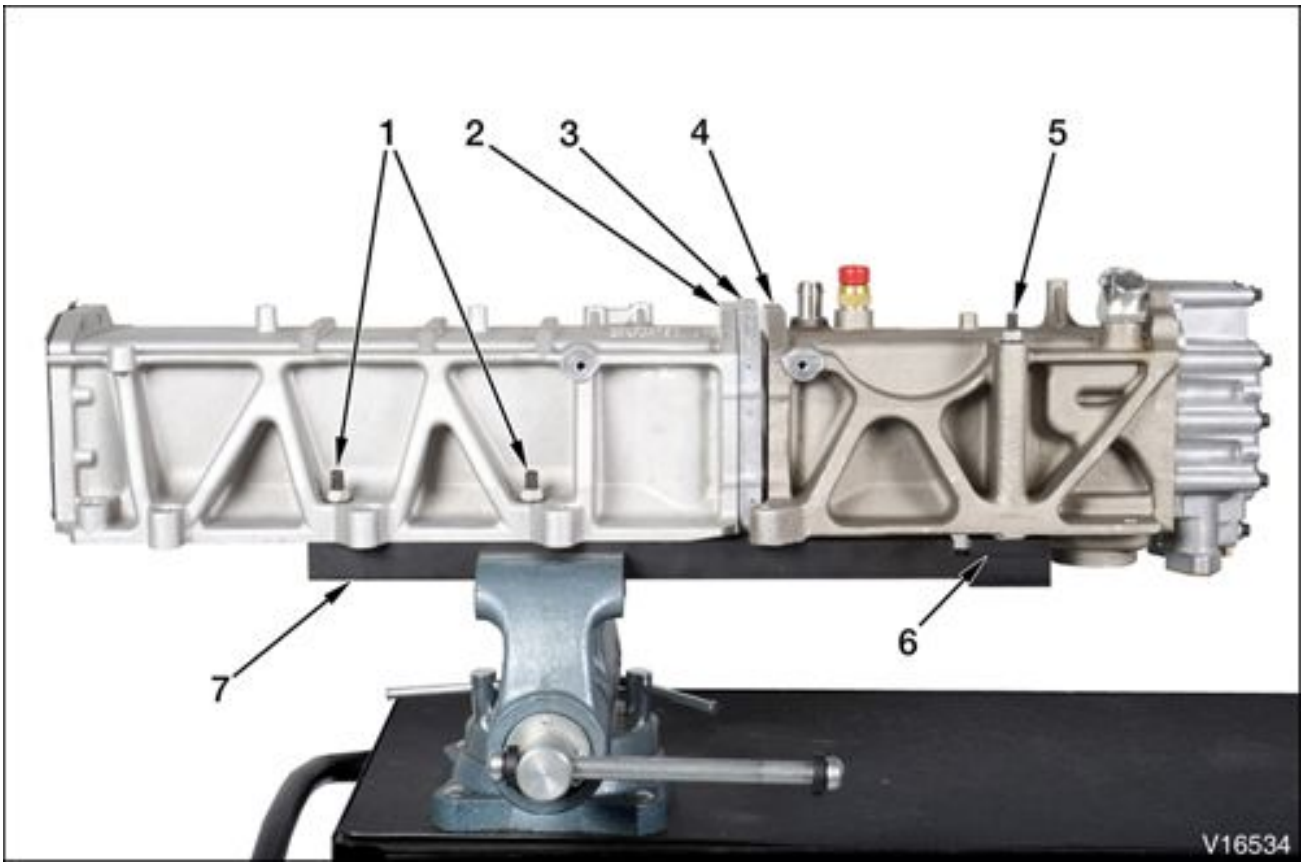

Figure 412 EGR cooler assembly

1. HT EGR cooler mounting stud
2. HT EGR cooler
3. LT EGR cooler
4. 3/8 SAE flat washer
5. LT EGR cooler mounting stud
6. Slider
7. EGR Cooler Alignment Tool

NOTE: Do not remove the mid-plate from the HT EGR cooler. Disturbing the sealing surfaces could cause a leak.

WARNING: To prevent personal injury or death, be sure bench vise is clamped sufficiently to keep EGR Alignment Tool and EGR Cooler Assembly from falling.

7. Separate LT EGR cooler from mid-plate along the slider of EGR Cooler Alignment Tool.
8. Remove the two 7/16-14 nuts, and two 7/16 SAE flat washers, or the 3/8-16 nut and 3/8 SAE flat washer (Figure 411) from mounting stud(s) through the cooler half to be replaced.
9. Loosen but do not remove fasteners on mounding stud(s) on the other cooler half.
10. Remove the cooler half to be replaced from EGR Cooler Alignment Tool.

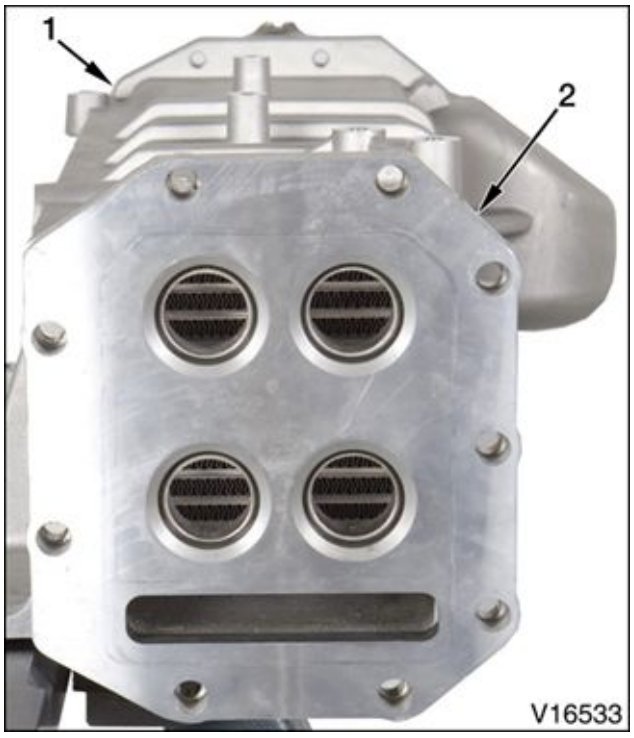

Figure 413 HT EGR cooler and mid-plate

1. HT EGR cooler
2. Mid-plate

11. Clean mating surfaces on HT EGR Cooler and LT EGR Cooler of any debris and contaminants.
12. Install replacement cooler half over the appropriate mounting stud(s) of EGR Cooler Alignment Tool.
13. Install the two 7/16-14 nuts and two 7/16 SAE flat washers, or the 3/8-16 nut and 3/8 SAE flat washer (Figure 411) to mounting studs (Figure 412). Tighten nut(s) finger tight.

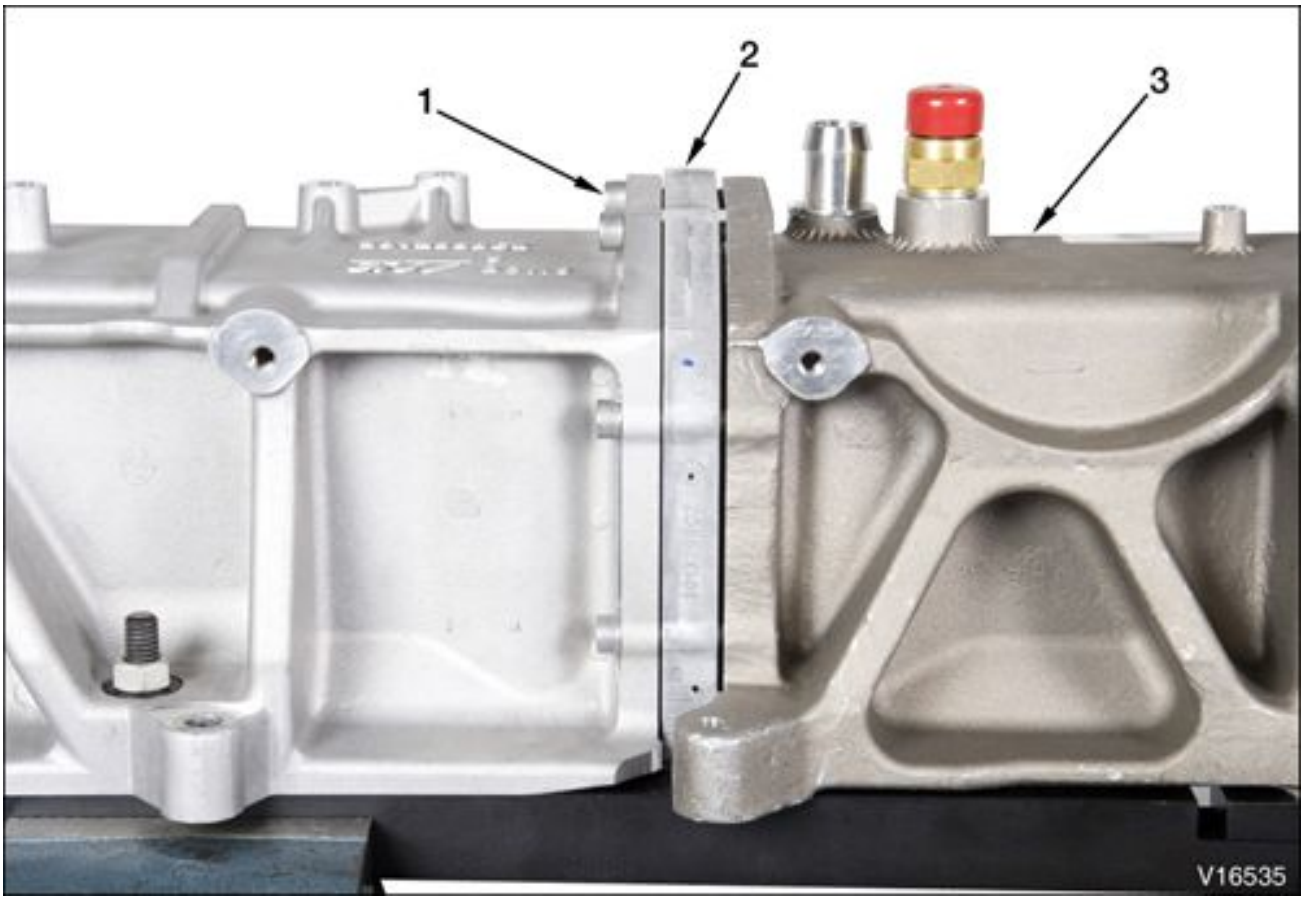

Figure 414 Center of EGR cooler assembly

1. 1. M8 x 50 hex cap screw (9)
2. Mid-plate
3. LT EGR cooler

14. Slide the LT EGR cooler along the EGR Cooler Alignment Tool slider (Figure 412) until the LT EGR cooler seal contacts flush with the mid-plate surface.

NOTE: Be sure any EGR cooler assembly brackets are installed during assembly of HT EGR cooler and LT EGR cooler.

15. Install EGR cooler assembly bracket(s) and nine new M8 x 50 hex socket screws. Tighten screws finger tight.
16. Tighten two 7/16-14 nuts (Figure 411) on HT EGR cooler mounting studs to special torque (page 330).
17. Tighten 3/8-16 nut (Figure 411) on LT EGR cooler mounting stud to special torque (page 330).

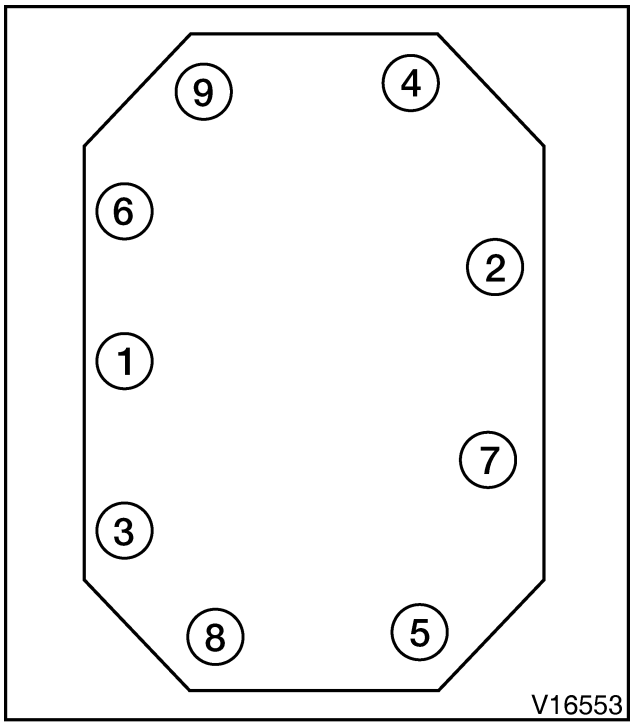

Figure 415 Hex socket screw torque sequence

18. Tighten nine M8 x 50 hex socket screws using the following two step torque sequence:
    A. Tighten M8 x 50 hex socket screws in sequence 1 through 9 to 20 N·m (15 lb·ft).
    B. Tighten M8 x 50 hex socket screws in sequence 1 through 9 to 31 N·m (23 lb·ft).
19. Remove two 7/16-14 nuts, two 7/16 SAE flat washers, 3/8-16 nut, and 3/8 SAE flat washer (Figure 411) from mounting studs of EGR Cooler Alignment Tool. Save fasteners.
20. Remove the EGR cooler assembly from the EGR Cooler Alignment Tool.
21. Remove EGR Cooler Alignment Tool from bench vise.
22. Store fasteners with EGR Cooler Alignment Tool for reuse.

Cleaning, Inspection and Testing

EGR System Components Cleaning

1. Using steam, clean all carbon from ends of EGR dual flap valve, coolant manifold and coolant elbow at rear.

CAUTION: To prevent engine damage, do not use steam to clean EGR cooler assembly heat exchanger cores.

2. Using steam, clean EGR cooler coolant return manifold at front. Clean all EGR cooler assembly coolant ports.
3. Inspect EGR system components for cracks and damage. Replace worn or damaged parts.

EGR Cooler Assembly Cleaning

Figure 416 Cleaning Management System 12-353-01 components

1. Timer 12–353–01–1
2. Heater 12–353–01–8
3. FLOW FROM PUMP hose 12–353–01–2
4. Front EGR cooler cleaning adapter 12–353–01–4
5. Cam-lock cap 12–353–01–6
6. Rear EGR cooler cleaning adapter 12–353–01–5
7. FLOW RETURN hose 12–353–01–3
8. Air blower 12–353–01–7
9. Container 12–353–01–17
10. HEATER / PUMP Switch Assembly 12–353–01–9

1. Make sure container is clean.
2. Inspect and clean the filter sock. Replace as needed.
    a. Loosen coupler on flow return tube
    b. Remove filter from coupler
    c. Install filter in coupler
    d. Tighten coupler on flow return tube. Torque only needs to be hand tight

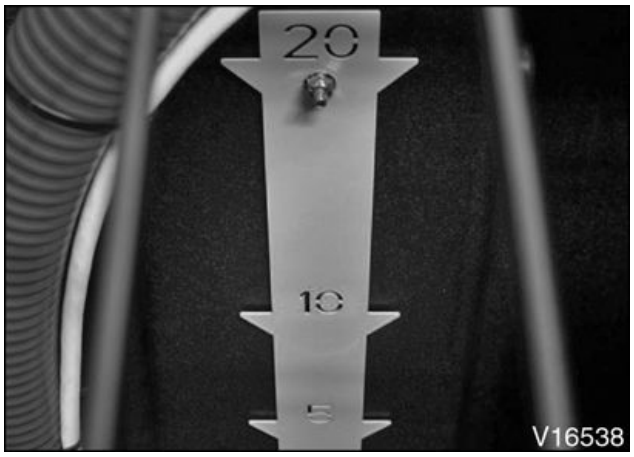

Figure 417 Level gauge

3. Add 5 US gal (19 L) of EGR Cooler Cleaning Solution and 5 US gal (19 L) of tap water to the container.

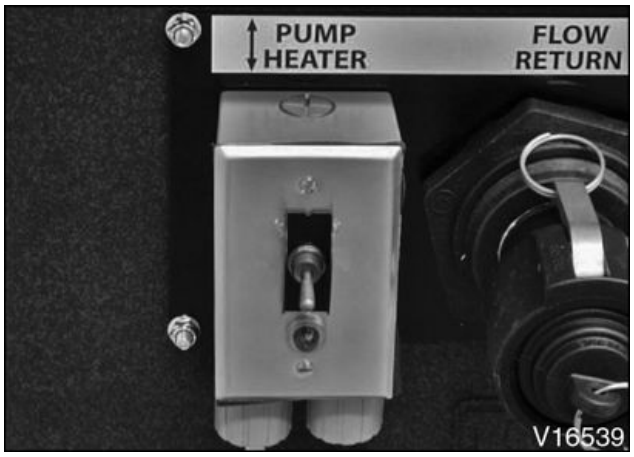

Figure 418 PUMP / HEATER switch

4. Turn on the heating element by simultaneously pulling the HEATER / PUMP Switch Assembly outward and moving to heater position.

NOTE: The heating element has a thermostat that will regulate the temperature. When the amber light on the switch housing goes out, the fluid is up to temperature.

5. Disassemble the truck to gain access to the front and rear of the EGR cooler assembly.
6. Allow engine to cool and use the Coolant Management Tool (page 330) to drain engine coolant to a level below the EGR cooler assembly.
7. Remove coolant manifold from EGR cooler assembly and thermostat housing. See Coolant Manifold (page 302).
8. Remove heat protection (cyclinders 4-6) shield. See Heat Protection (cyclinders 4-6) Shield (page 305)
9. Remove EGR inlet tubes. See EGR Inlet Tubes (page 305)
10. Remove EGR dual flap valve from EGR cooler assembly. See EGR Dual Flap Valve (page 307).
11. Remove EGR outlet (cylinders 4-6) tube, and EGR outlet (cylinders 1-3) tube from EGR cooler assembly and intake throttle duct assembly. See EGR Outlet (cylinders 4-6) Tube, and EGR Outlet (cylinders 1-3) Tube (page 304)
12. Disconnect EGRT sensor electrical connector.
13. Remove EGR module cover from EGR cooler assembly. See EGR Module Cover (page 304).
14. Inspect the O-rings on the front and rear EGR cooler cleaning adapters to be sure there is no damage that would cause a leak.

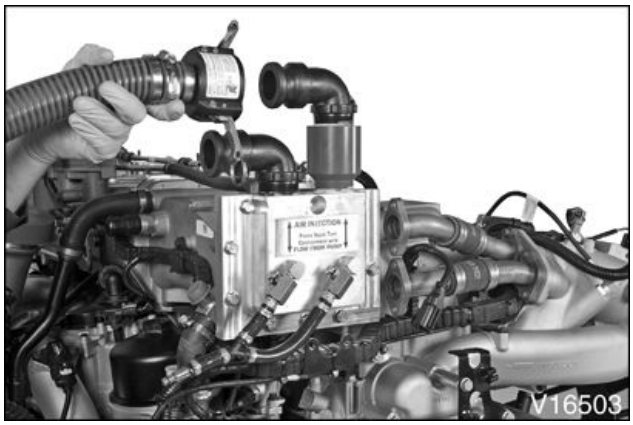

Figure 419 Front EGR cooler cleaning adapter

15. Install the front EGR cooler cleaning adapter. Tighten bolts to special torque (page 330).

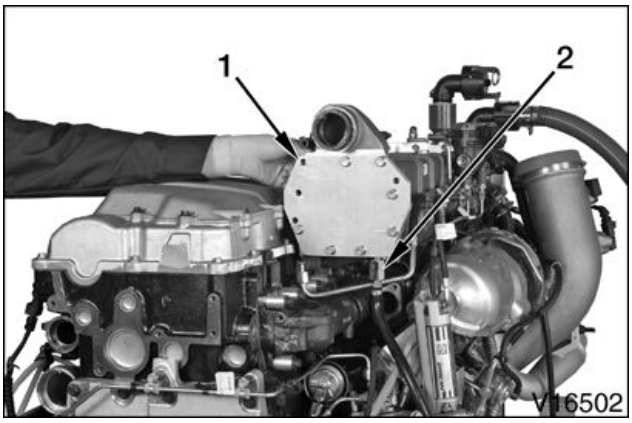

Figure 420 Rear EGR cooler cleaning adapter

1. Rear EGR cooler cleaning adapter
2. Drain valve

16. Install the rear EGR cooler cleaning adapter. Tighten bolts to special torque (page 330).
17. Be sure the drain valve is in the closed position.

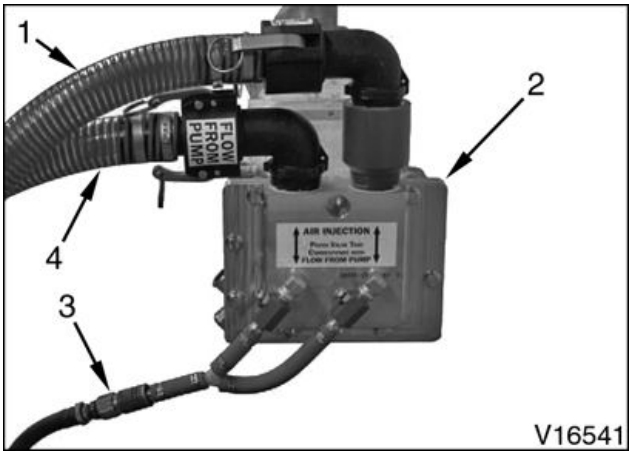

Figure 421 Front of EGR cooler

1. FLOW RETURN hose
2. Front cooler cleaning adapter
3. Air injection fitting
4. FLOW FROM PUMP hose

18. Connect one end of the FLOW FROM PUMP hose to the respective hose connection of the container and the opposite hose end to the front EGR cooler cleaning adapter hose connection.
19. Connect one end of the FLOW RETURN hose to the respective hose connection of the container and the opposite hose end to the remaining front EGR cooler cleaning adapter hose connection.
20. Connect air line to air injection fitting.

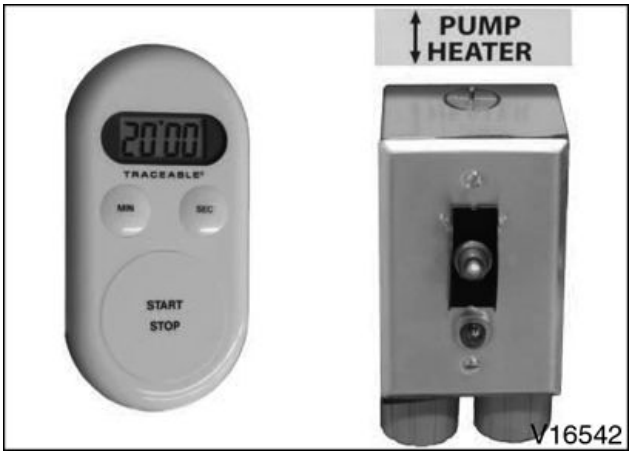

Figure 422 Timer and HEATER/PUMP switch

21. Set the timer for 20 minutes, start timer and turn on pump by moving the HEATER / PUMP switch to PUMP.

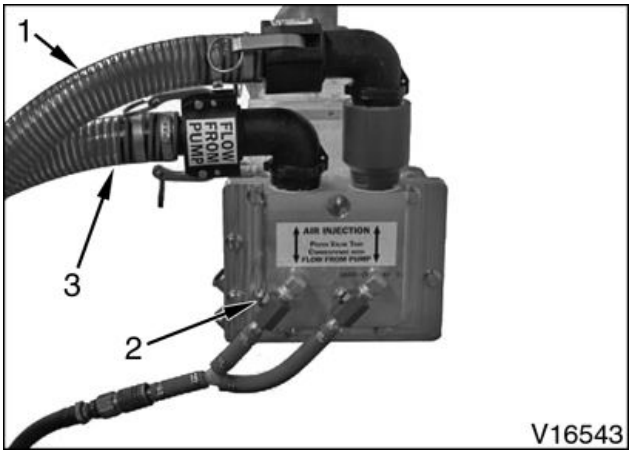

Figure 423 Front of EGR cooler

1. FLOW RETURN hose
2. Front EGR cooler cleaning adapter
3. Air injection button valve

NOTE: Be sure to push only the air injection button valve that corresponds with the FLOW FROM PUMP hose.

22. At the 5, 10, and 15 minute mark, press the air injection button valve on the front EGR cooler

cleaning adaptor to introduce bursts of air at a one second on, two seconds off interval. Be sure to push the air injection button valve that corresponds with the FLOW FROM PUMP hose.

23. After 20 minutes has expired, turn off the pump by moving the PUMP / HEATER switch to the middle position.

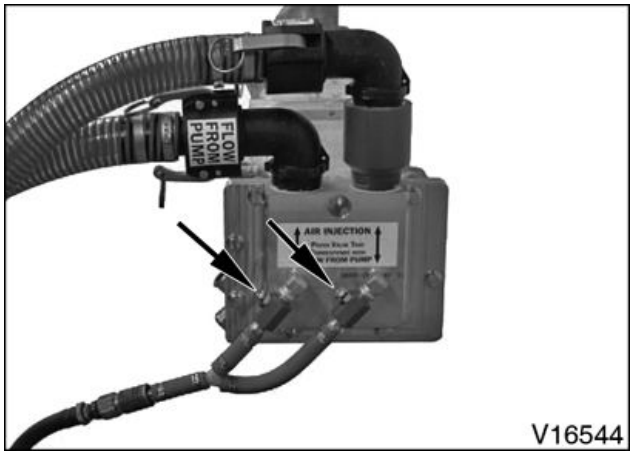

Figure 424 Air injection button valves

24. Press the air injection button valves on both sides independently to purge some of the EGR Cooler Cleaning Solution from the hoses. This will minimize spills when disconnecting the hoses.

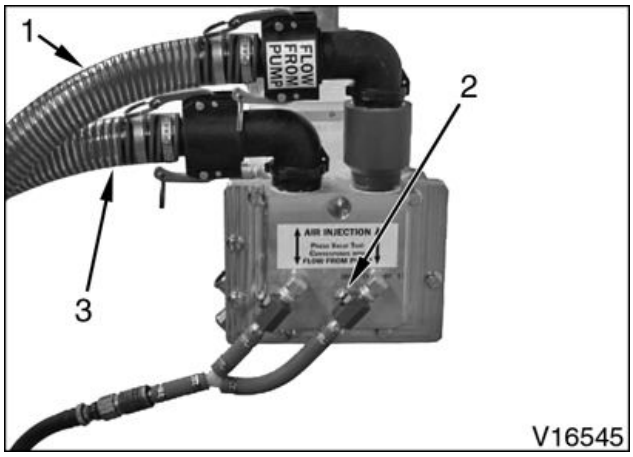

Figure 425 Front of EGR cooler

1. FLOW FROM PUMP hose
2. Air injection button valve
3. FLOW RETURN hose

25. Disconnect and reverse the hose connections at the front EGR cooler cleaning adaptor and repeat steps 21 through 24.

26. Verify pump and heater are switched off. PUMP / HEATER switch should be in the middle position.

Flushing Procedure

Figure 426 Draining used EGR Cooler Cleaning Solution

27. Remove the FLOW RETURN hose from the container and place hose end into a suitable drain or disposal container.

⚠ WARNING: The hose running to the drain will be under pressure. Be sure it is secure before proceeding.

28. Turn on pump by moving the HEATER / PUMP switch to PUMP to remove as much of the used EGR Cooler Cleaning Solution as possible.
29. Turn off pump by moving the HEATER / PUMP switch to the middle position.
30. Remove the FLOW FROM PUMP hose from the container.
31. Using the attached caps, cap each hose connection on the Cleaning Management System.
32. Clean the container by spraying it with clean tap water while the unit is tipped onto its front face. Be sure all the EGR Cooler Cleaning Solution is out of the reservoir.

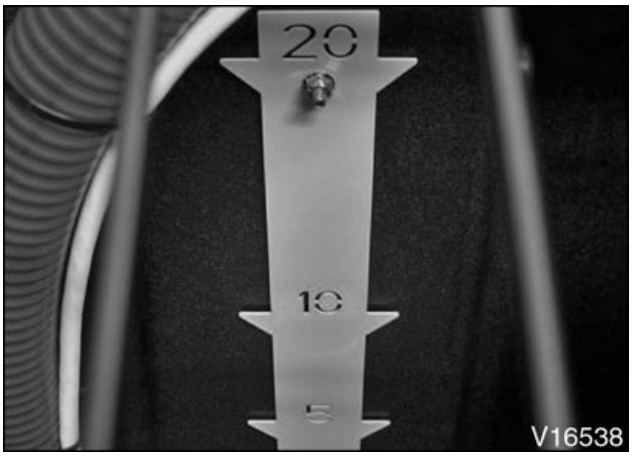

Figure 427 Cleaning Management System volume gauge

33. Fill the container with clean tap water to the 20 gallon mark on the volume gauge.
34. Reconnect the FLOW FROM PUMP hose to the container with the FLOW RETURN hose still in a suitable drain or disposal container.

⚠ WARNING: The hose running to the drain will be under pressure. Be sure it is secure before proceeding.

35. Turn on pump by simultaneously pulling the HEATER / PUMP Switch Assembly outward and moving to PUMP position until all of the clean water has been flushed through the EGR cooler.
36. Turn off pump by moving the HEATER / PUMP switch to the middle position.

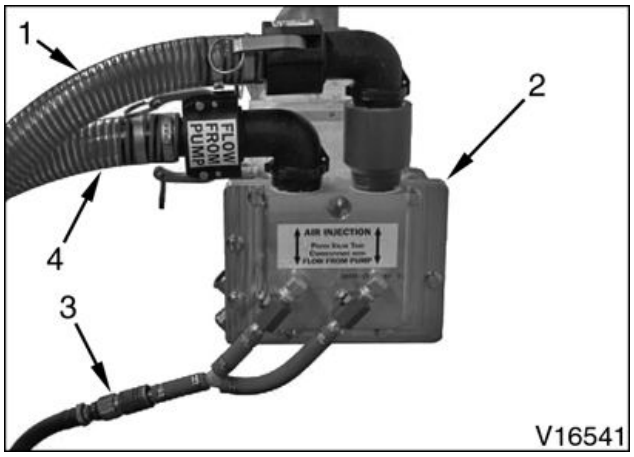

Figure 428 Front of EGR cooler

1. FLOW RETURN hose
2. Front cooler cleaning adapter
3. Air injection fitting
4. FLOW FROM PUMP hose

37. Reverse the FLOW FROM PUMP and FLOW RETURN hoses on the front EGR cooler cleaning adapter
38. Repeat steps 32 through 36.
39. Disconnect the FLOW RETURN hose from the front EGR cooler cleaning adapter.
40. Disconnect the FLOW FROM PUMP hose from the container.

Purging Fluids / Equipment Removal Instructions

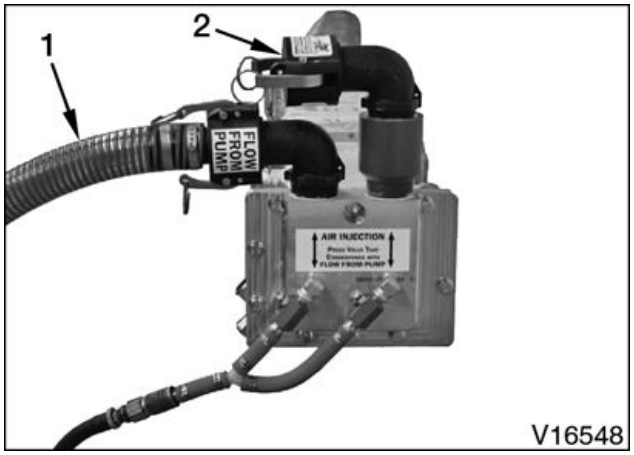

Figure 429 Front of EGR cooler

1. FLOW FROM PUMP hose
2. Cam-lock cap

NOTE: Be sure the cam-lock cap is installed properly to prevent discharge of fluid.

41. Install a cam-lock cap on the open port of the front EGR cooler cleaning adapter.

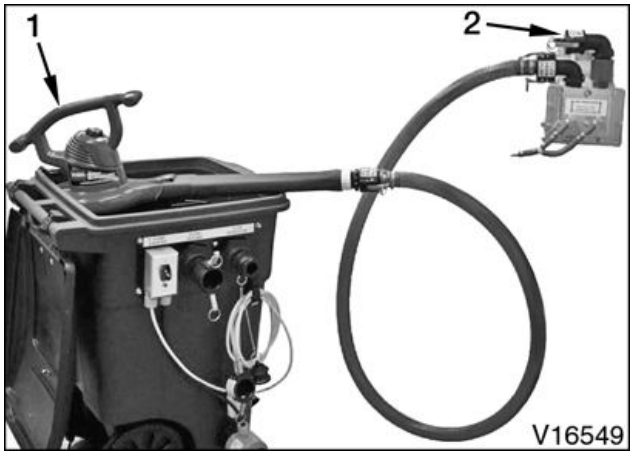

Figure 430 Air blower connection

1. Air blower
2. Cam-lock cap

42. Attach the air blower to the FLOW FROM PUMP hose.

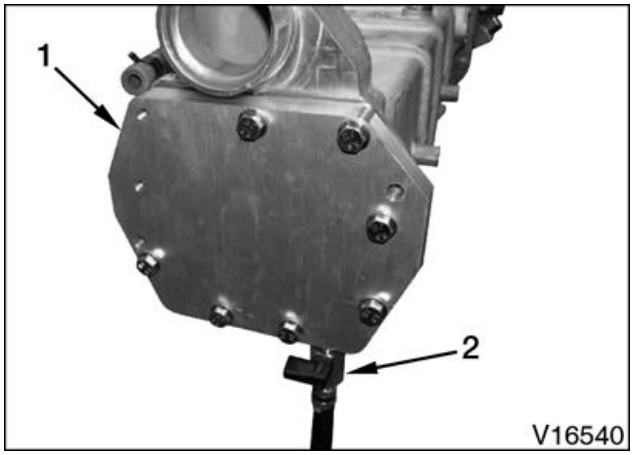

Figure 431 Rear of EGR cooler

1. Rear EGR cooler cleaning adaptor
2. Drain valve

43. Open the drain valve on the rear EGR cooler cleaning adaptor.

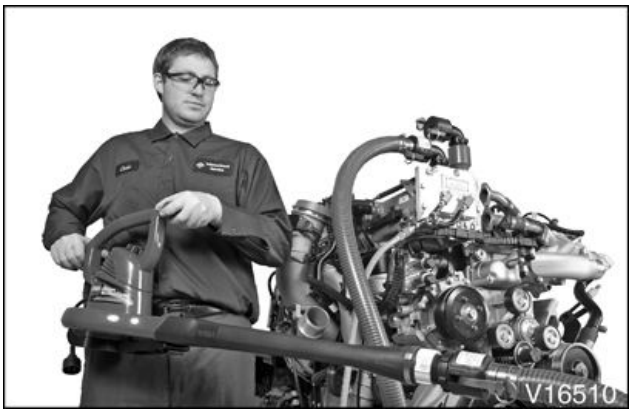

Figure 432 Blower connected

44. Run the blower on maximum power until the water coming out of the drain valve of rear EGR cooler cleaning adapter is at a dripping state.

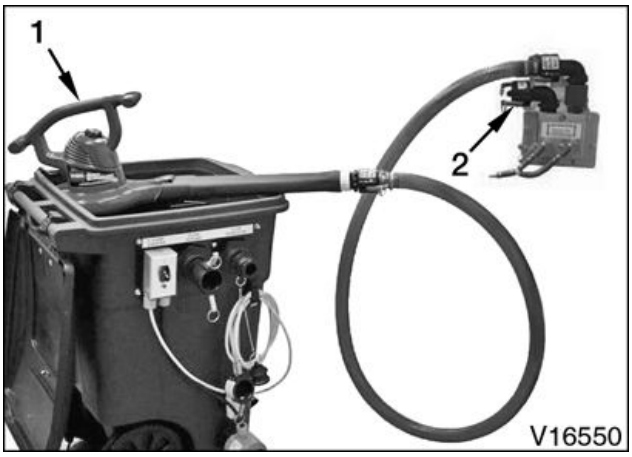

Figure 433 Cam-lock cap and air blower

1. Air blower
2. Cam-lock cap

45. Reverse the cam-lock cap and the FLOW FROM PUMP hose and repeat step 44.

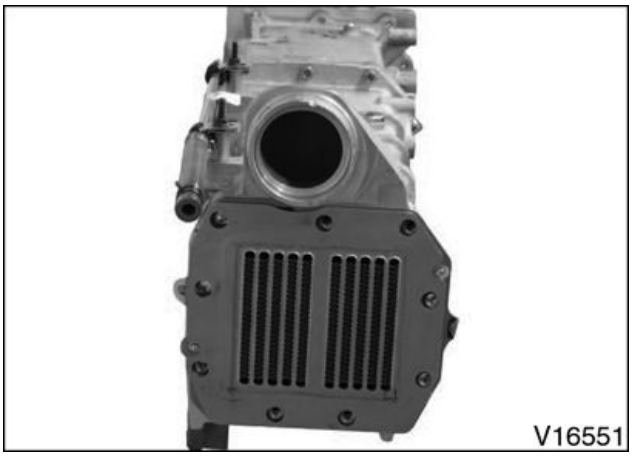

Figure 434 Rear of EGR cooler

NOTE: Protect the inside of the truck from spray coming from the end of the EGR Cooler for the following steps.

46. Remove the rear EGR cooler cleaning adaptor.

47. Run the air blower on maximum power until there is no EGR Cooler Cleaning Solution coming from the rear of the EGR cooler assembly.

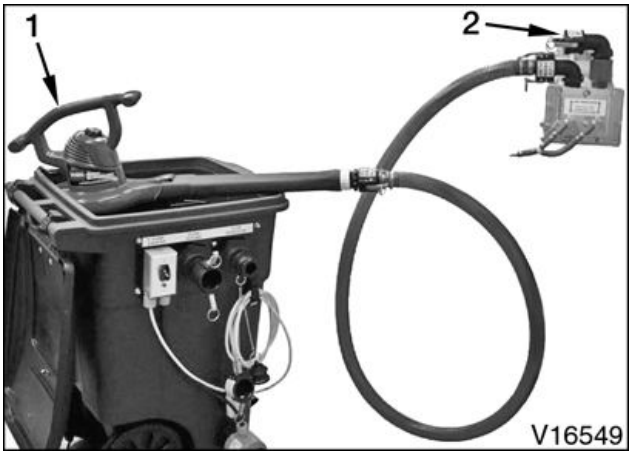

Figure 435 Cam-lock cap and air blower

1. Air blower
2. Cam-lock cap

48. Reverse the cam-lock cap and the FLOW FROM PUMP hose on the front EGR cooler cleaning adaptor (Figure 435).

49. Run the air blower on maximum power until there is no EGR Cooler Cleaning Solution coming from the rear of the EGR cooler assembly.
50. The cleaning of the EGR cooler assembly is now complete. Remove the front EGR cooler cleaning adaptor.
51. Install EGR module cover on EGR cooler assembly. See EGR Module Cover (page 327).
52. Connect EGRT sensor electrical connector.
53. Install EGR outlet (cylinders 4-6) tube, and EGR outlet (cylinders 1-3) tube (page 327) to EGR cooler assembly and intake throttle duct assembly.
54. Check EGR outlet tube hose clamps for looseness. Tighten tube hose clamps to special torque (page 330).
55. Install EGR dual flap valve on EGR cooler assembly. See EGR Dual Flap Valve (page 323).
56. Install EGR inlet tubes. See EGR Inlet Tubes (page 325).
57. Install heat protection (cyclinders 4-6) shield. See Heat Protection (cyclinders 4-6) Shield (page 326).
58. Install coolant manifold to EGR cooler assembly and thermostat housing. See Coolant Manifold (page 329).

EGR Cooler Assembly Leak Test

1. Obtain Exhaust Gas Recirculation (EGR) Cooler Leak Detection Tool (page 330).
2. Follow the directions included with the tool to determine if the EGR cooler assembly has any leaks.
3. If any leaks are found, replace the defective part of the EGR cooler assembly. See EGR Cooler High-Temperature or Low-Temperature Side Replacement (page 309).

Installation

EGR Cooler Assembly

NOTE: Install or connect exterior components to the EGR cooler as necessary. When installing a replacement EGR cooler assembly, transfer necessary components from the cooler being replaced.

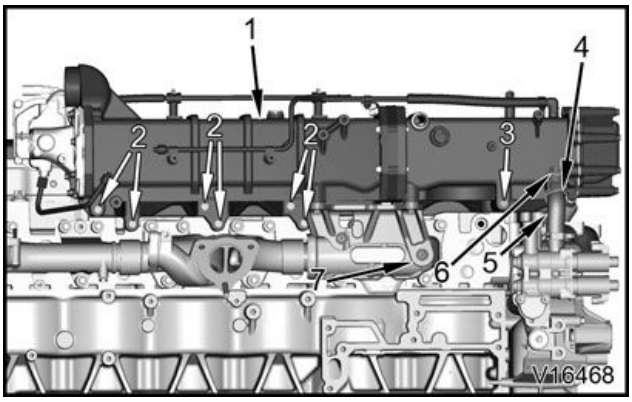

Figure 436 EGR cooler assembly

1. EGR cooler assembly
2. M10 x 45 bolt (6)
3. M10 x 170 bolt
4. Spring clamp
5. Low-temperature EGR hose assembly

1. Install EGR cooler assembly, six M10 x 45 bolts and M10 x 170 bolt. Tighten bolts to special torque (page 330).
2. Connect low-temperature EGR hose assembly to EGR cooler assembly. Position and install spring clamp to secure hose.

EGR Dual Flap Valve

NOTE: Complete this procedure only if the EGR dual flap valve was removed from EGR cooler assembly.

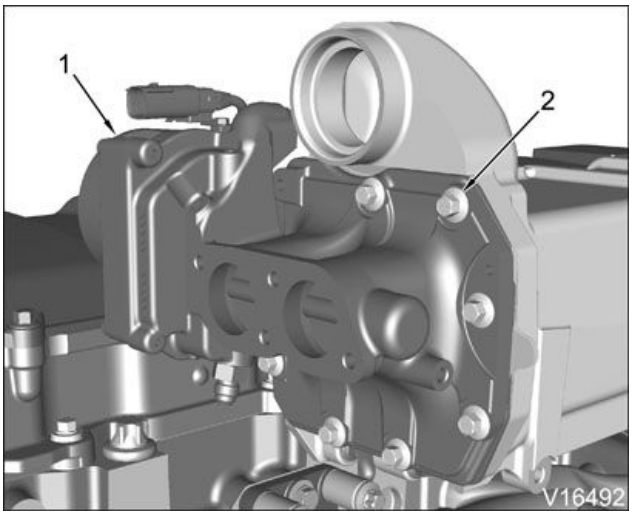

Figure 437 EGR dual flap valve

1. EGR dual flap valve
2. M8 x 30 heat-resistant bolt (7)

1. Install a new gasket.
2. Position EGR dual flap valve and install seven new M8 x 30 heat-resistant bolts. Tighten bolts finger tight.

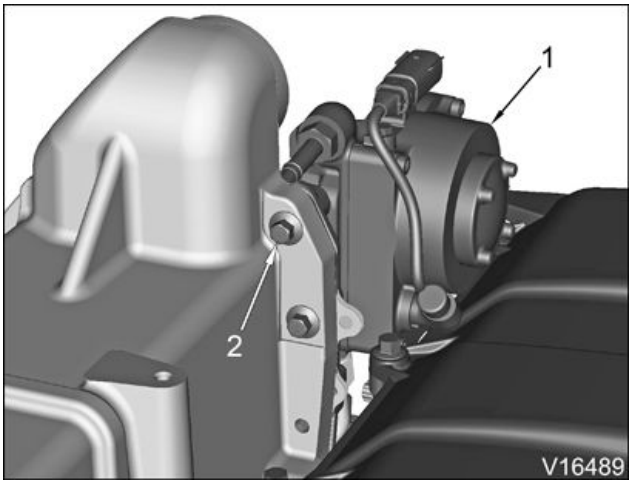

Figure 438 EGR dual flap valve and rear mounting bolts

1. EGR dual flap valve
2. M8 x 30 heat-resistant bolt (2)

3. Install two new M8 x 30 heat-resistant bolts. Tighten bolts finger tight.

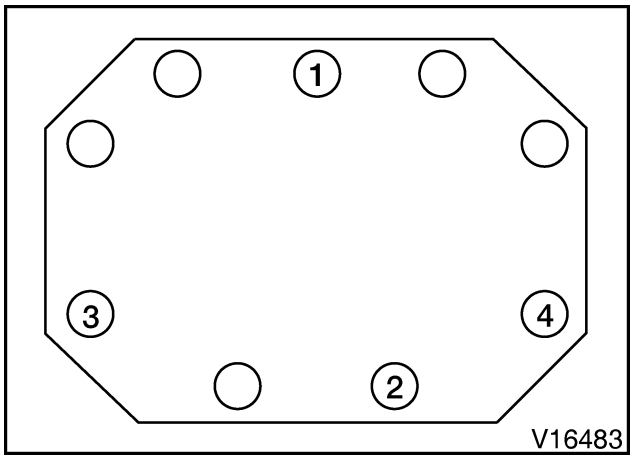

Figure 439 EGR dual flap valve bolt torque sequence (step 1)

4. Tighten the four new M8 x 30 heat resistant bolts in sequence to 5 N·m (45 lb·in).

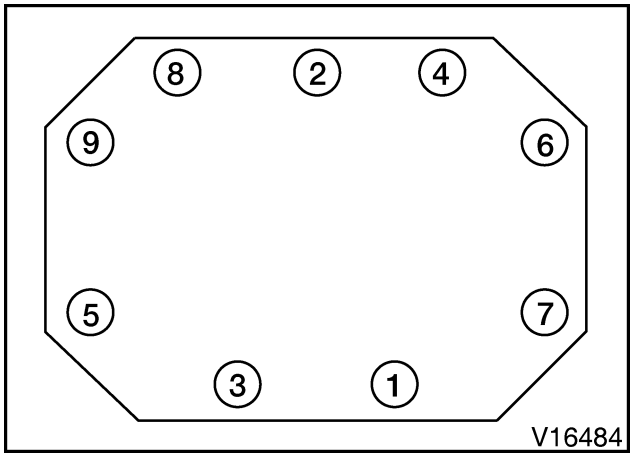

Figure 440 EGR dual flap valve bolt torque sequence (step 2 and 3)

5. Install remaining five new M8 x 30 heat resistant bolts. Tighten nine new M8 x 30 heat resistant bolts in sequence as follows:
   - Tighten bolts to 16 N·m (12 lb·ft).
   - Tighten bolts to 24 N·m (18 lb·ft).

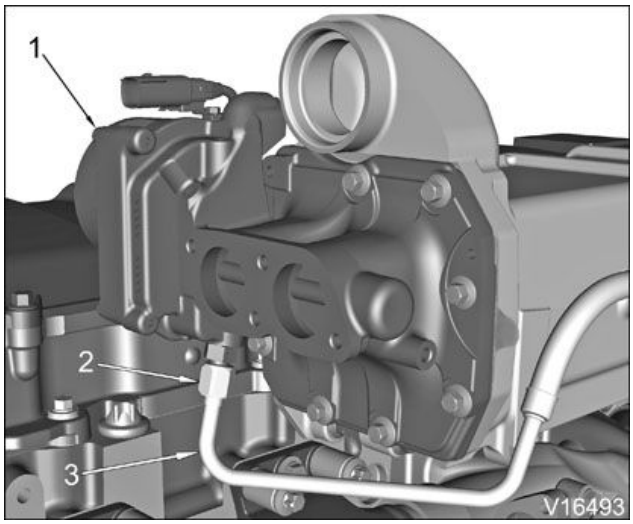

Figure 441 EGR dual flap valve and EGR valve coolant supply tube assembly

1. EGR dual flap valve
2. EGR valve coolant supply tube nut
3. EGR valve coolant supply tube assembly

6. Attach EGR valve coolant supply tube nut to EGR valve and tighten to special torque (page 330).

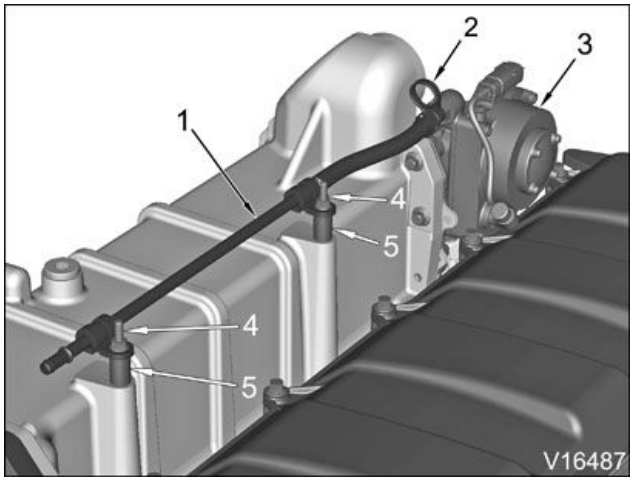

Figure 442 EGR valve coolant return tube assembly and EGR dual flap valve

1. EGR valve coolant return tube assembly
2. Spring clamp
3. EGR dual flap valve
4. M6 x 45 x 15 stud (2)
5. 6 x 15 x 23 spacer (2)

7. Attach EGR valve coolant return tube to EGR valve and secure tube with spring clamp.
8. Install two 6 x 15 x 23 spacers and two M6 x 45 x 15 stud bolts.
9. Tighten M6 x 45 x 15 stud bolts to standard torque (page 547).

Heat Protection EGR Shield

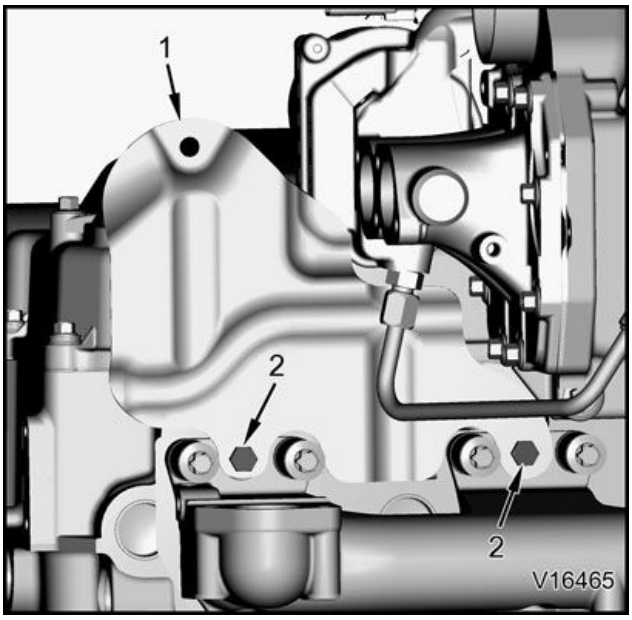

Figure 443 Heat protection EGR shield

1. Heat protection EGR shield
2. M8 x 12 bolt (2)

1. Install heat protection EGR shield and two M8 x 12 bolts at rear exhaust manifold. Tighten bolts to standard torque (page 547).

EGR Inlet Tubes

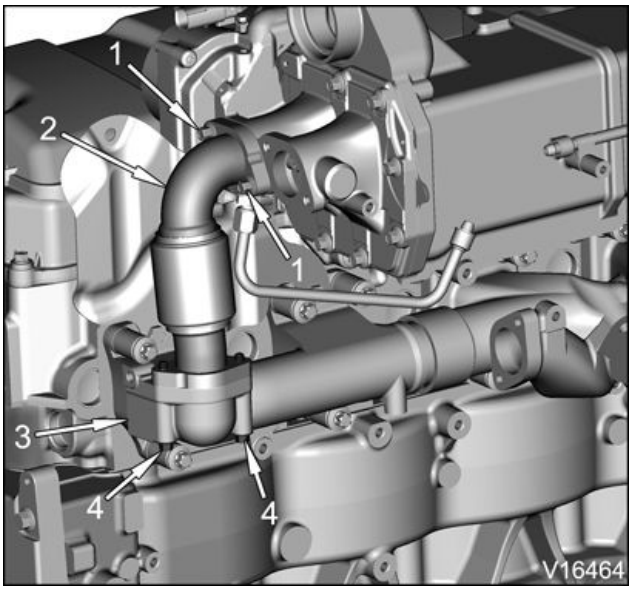

Figure 444 EGR inlet (cylinders 4-6) tube

1. M8 x 25 heat-resistant bolt (2)
2. EGR inlet (cylinders 4-6) tube
3. Rear exhaust manifold
4. M8 x 65 heat-resistant bolt (2)

1. Position two new EGR inlet (cylinders 4-6) tube gaskets, one to EGR valve and one to rear exhaust manifold.
2. Install EGR inlet (cylinders 4-6) tube, two M8 x 25 and two M8 x 65 heat-resistant bolts. Tighten bolts to 16 N·m (12 lb·ft).

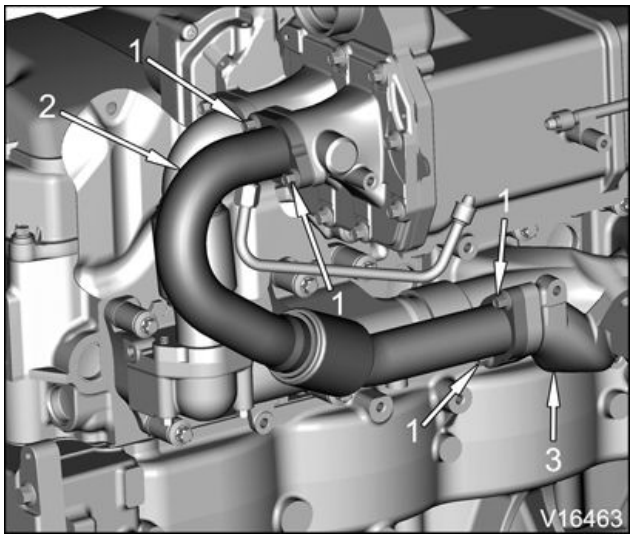

Figure 445 EGR inlet (cylinders 1-3) tube

1. M8 x 25 heat-resistant bolt (4)
2. EGR inlet (cylinders 1-3) tube
3. Middle exhaust manifold

3. Position two new EGR inlet (cylinders 1-3) tube gaskets, one to EGR valve and one to middle exhaust manifold.
4. Install EGR inlet (cylinders 1-3) tube and four M8 x 25 heat-resistant bolts. Tighten bolts to 16 N·m (12 lb·ft).

EGR Inlet (cylinders 4-6) Tube and EGR Inlet (cylinders 1-3) Tube

5. Tighten eight heat-resistant bolts to 24 N·m (18 lb·ft).

Heat Protection (Cylinders 4-6) Shield

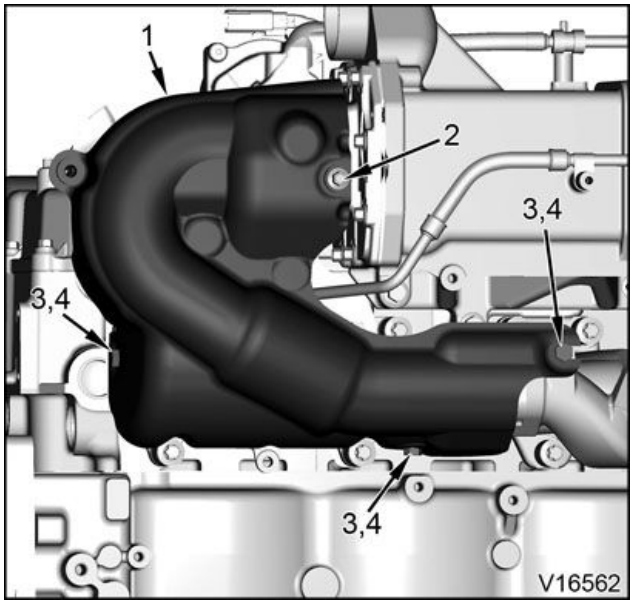

Figure 446 Heat protection (cylinders 4-6) shield

1. Heat protection (cylinders 4-6) shield
2. M8 x 25 heat-resistant bolt
3. M8 x 12 bolt (3)
4. 8.4 x 16 x 1.6 washer (3)

1. Install heat protection shield with three M8 x 12 bolts, and three 8.4 x 16 x 1.6 washers. Tighten bolts finger tight.
2. Install M8 x 25 heat-resistant bolt finger tight.
3. Tighten M8 x 12 bolts, and M8 x 25 heat-resistant bolts to special torque (page 330).

EGR Module Cover

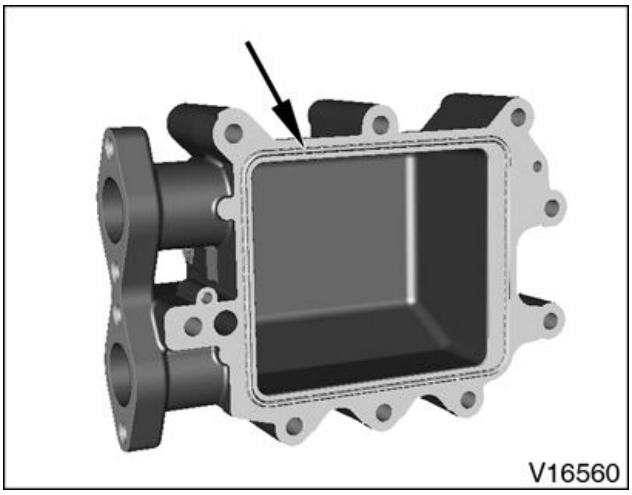

Figure 447 EGR cover outlet seal

1. Install EGR cover outlet seal into EGR module cover.

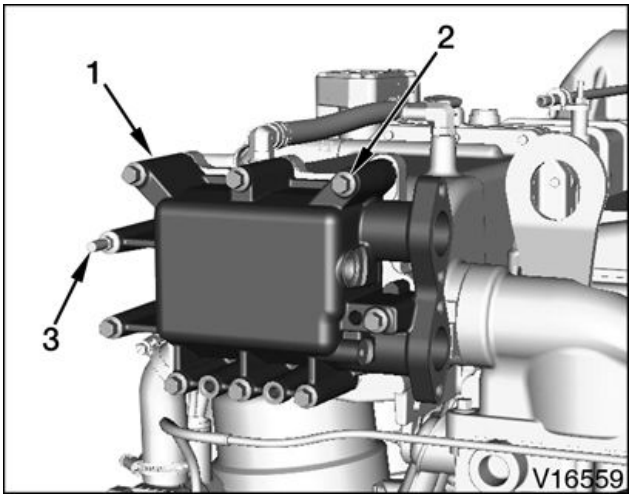

Figure 448 Front of EGR module

1. EGR module cover
2. M8 x 85 bolt (8)
3. M8 x 90 stud bolt

2. Install eight M8 x 85 bolts and one M8 x 90 stud bolt. Tighten bolts in a crisscross pattern to special torque (page 330).

EGR Outlet Tubes

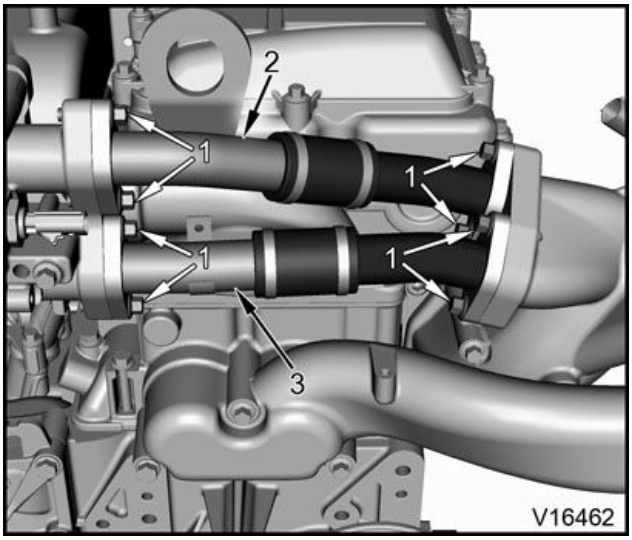

Figure 449 EGR outlet tubes

1. M8 x 30 bolt (8)
2. EGR outlet (cylinders 1-3) tube
3. EGR outlet (cylinders 4-6) tube

1. Install EGR outlet (cylinders 4-6) tube, two new tube gaskets and four M8 x 30 bolts. Tighten bolts to standard torque (page 547).
2. Install EGR outlet (cylinders 1-3) tube, two new tube gaskets and four M8 x 30 bolts. Tighten bolts to standard torque (page 547).
3. Check EGR outlet tube hose clamps for looseness. Tighten tube hose clamps to special torque (page 330).

EGR Cooler Bracket

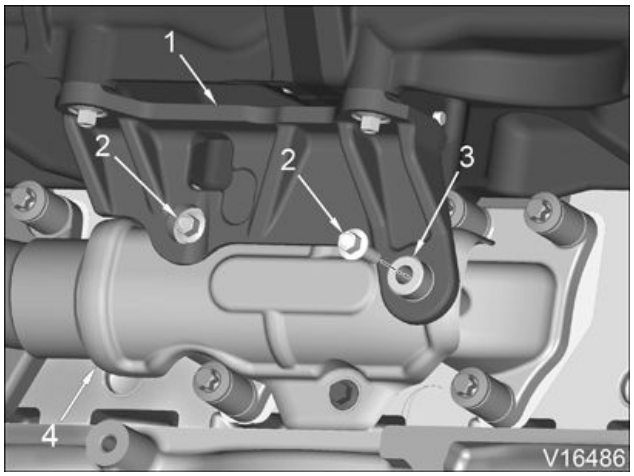

Figure 450 EGR cooler bracket

1. EGR cooler bracket
2. M8 x 25 heat-resistant bolt (2)
3. Spacer
4. Heat protection shield (at front exhaust manifold)

1. Install two EGR cooler bracket M8 x 25 lower heat-resistant bolts.
2. Tighten bolts to standard torque (page 547).

Coolant Elbow

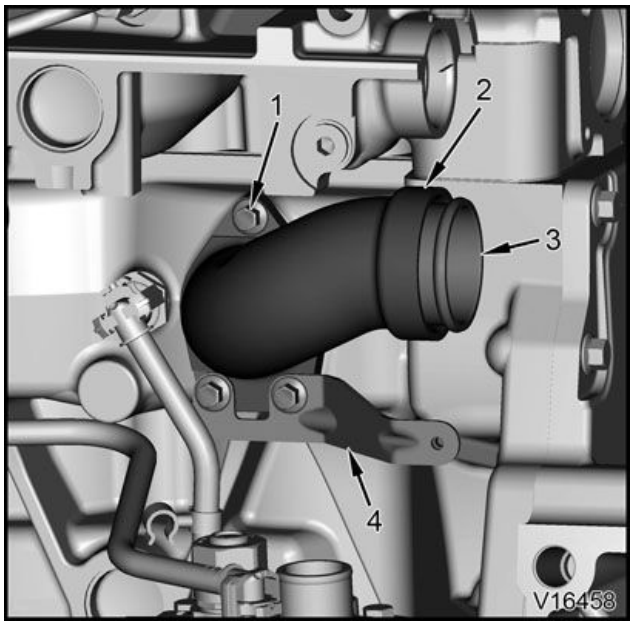

Figure 451 Coolant elbow

1. M8 x 25 bolt (3)
2. Coolant elbow
3. Extension tube (DMR62 x 51)
4. Hydrocarbon injector fuel supply (tube) bracket

1. Install new 60 x 3 O-ring. Install coolant elbow and loosely install upper M8 x 25 bolt.
2. Install HCI supply bracket and loosely install two lower M8 x 25 bolts.
3. Tighten three coolant elbow bolts to standard torque (page 547).
4. Lubricate sealing surfaces of extension tube (DMR62 x 51) with P-80® rubber lubricant or equivalent (page 330). Install extension tube (DMR62 x 51) to coolant elbow using Extension Tube Installer Large (page 330).

NOTE: Alternatively, install extension tube (DMR62 x 51) into coolant manifold.

Coolant Manifold

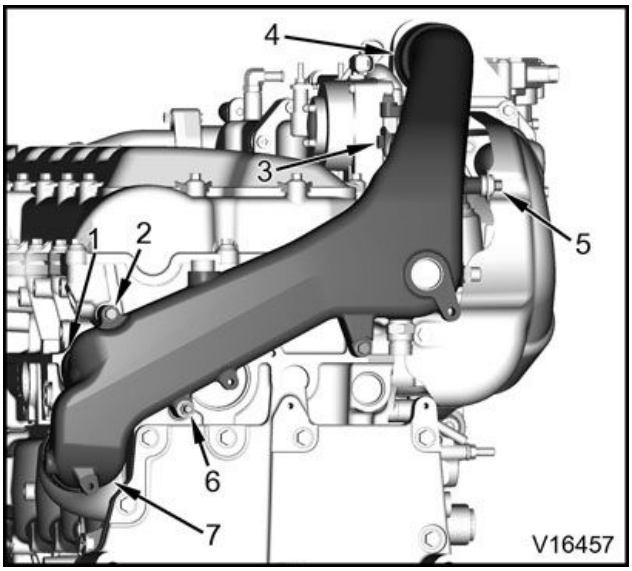

Figure 452 Coolant manifold

1. Extension tube (DMR44 x 35)
2. M8 x 45 bolt (2)
3. M8 x 18 bolt
4. Extension tube (DMR62 x 51)
5. M8 x 25 heat-resistant bolt
6. M8 x 50 x 16 stud bolt
7. Extension tube (DMR62 x 51)

1. Lubricate two extension tubes (DMR62 x 51 and DMR44 x 35) sealing surfaces with P-80® rubber lubricant or equivalent (page 330).
2. Install extension tube (DMR62 x 51) and extension tube (DMR44 x 35) into coolant manifold using Extension Tube Installer Large and Extension Tube Installer Small (page 330).
3. Install coolant manifold using two M8 x 45 bolts, one M8 x 50 x 16 stud bolt and one M8 x 25 heat-resistant bolt (at heat protection (cylinder 4-6) shield). Tighten M8 x 25 heat-resistant bolt to special torque (page 330). Tighten two M8 x 45 bolts and one M8 x 50 x 16 stud bolt to special torque (page 330).
4. Install one M8 x 18 bolt and tighten to special torque (page 330).

Special Torque

Coolant manifold, M8 x 18 bolt	22 N·m (16 lb·ft)
Coolant manifold, M8 x 25 heat–resistant bolt	24 N·m (18 lb·ft)
Coolant manifold, M8 x 45 bolt and M8 x 50 x 16 stud bolt	35 N·m (26 lb·ft)
EGR dual flap valve, M8 x 30 heat-resistant bolt	See tightening steps in procedure.
EGR inlet (cylinders 1-3) tube, M8 x 25 heat-resistant bolt	See tightening steps in procedure.
EGR inlet (cylinders 4-6) tube, M8 x 25 heat-resistant bolt	See tightening steps in procedure.
EGR module cover, M8 x 85 bolts and M8 x 90 stud bolt	24 N·m (18 lb·ft)
EGR outlet tube hose clamps	5 N·m (45 lb·in)
EGR valve coolant supply tube nut	26 N·m (19 lb·ft)
Front EGR cooler cleaning adapter M8 bolts	24 N·m (18 lb·ft)
Heat protection (cylinders 4–6) shield, M8 x 25 heat–resistant bolts	24 N·m (18 lb·ft)
HT EGR cooler mounting studs 7/16 - 14 nuts	41 N·m (30 lb·ft)
Leak Detection Plate KL20060-4 M8 x 30 bolts	24 N·m (18 lb·ft)
Low-temperature and high-temperature EGR coolers, M8 x 55 hex socket screws	See tightening steps in procedure.
LT EGR cooler mounting studs 3/8 - 14 nuts	41 N·m (30 lb·ft)
Rear EGR cooler cleaning adapter M8 bolts	24 N·m (18 lb·ft)

Special Service Tools

Description	Tool Number
Cleaning Management System	12-353-01
Coolant Management Tool	KL5007NAV
EGR Cooler Alignment Tool	12-892-01A
Exhaust Gas Recirculation (EGR) Cooler Leak Detection Tool	KL 20060 NAV
Extension Tube Installer Large	ZTSE6046
Extension Tube Installer Small	ZTSE6047
P-80® rubber lubricant or equivalent	Obtain locally

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Exploded Views

Exhaust Manifold

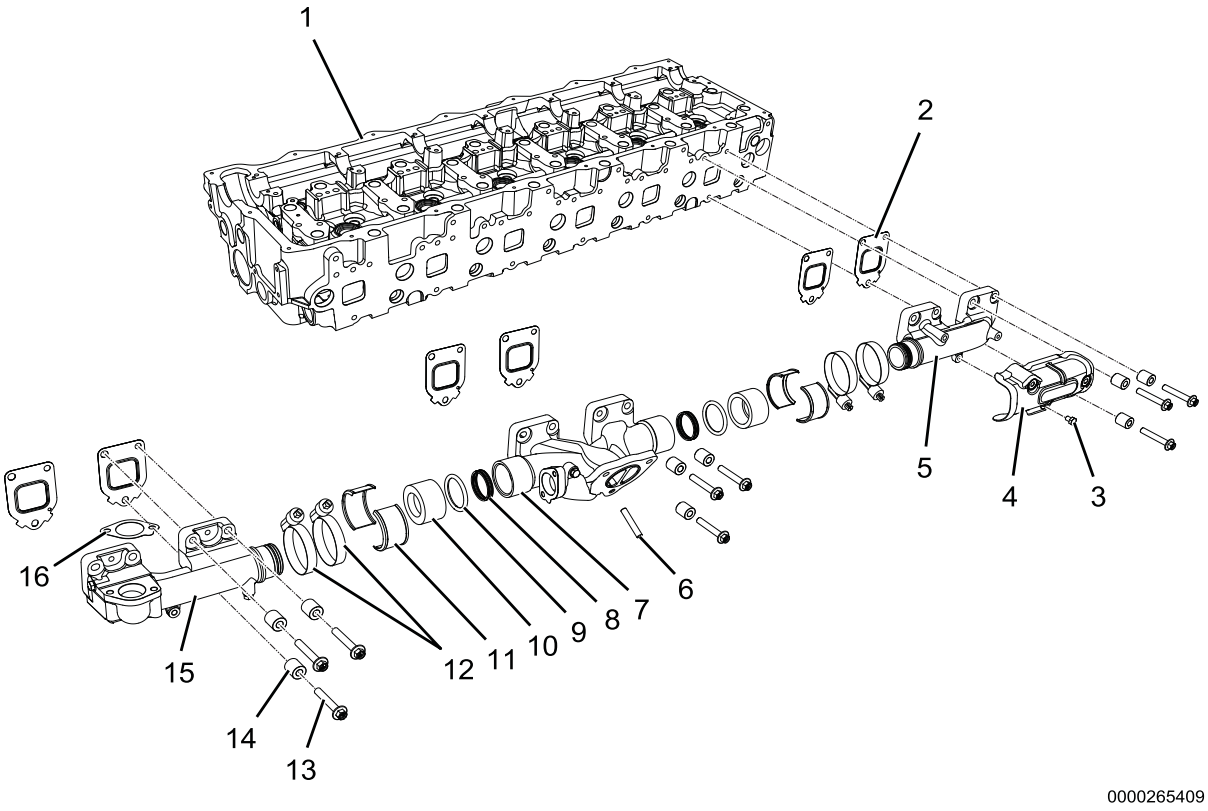

Figure 453 Exhaust manifold

1. Cylinder head
2. Exhaust manifold gasket (6)
3. M8 x 12 bolt
4. Heat protection shield
5. Front exhaust manifold
6. M10 x 45 stud
7. Middle exhaust manifold
8. Multipiece (FEY) ring (4)
9. Seal packing (2)
10. Ceramic mat wrap assembly (2)
11. Shield (4)
12. Ring seal clamp (4)
13. M10 x 57 Torx® bolt (18)
14. Sleeve spacer (18)
15. Rear exhaust manifold
16. Exhaust gas recirculation tube gasket (2)

Air Intake Throttle Horizontal Duct

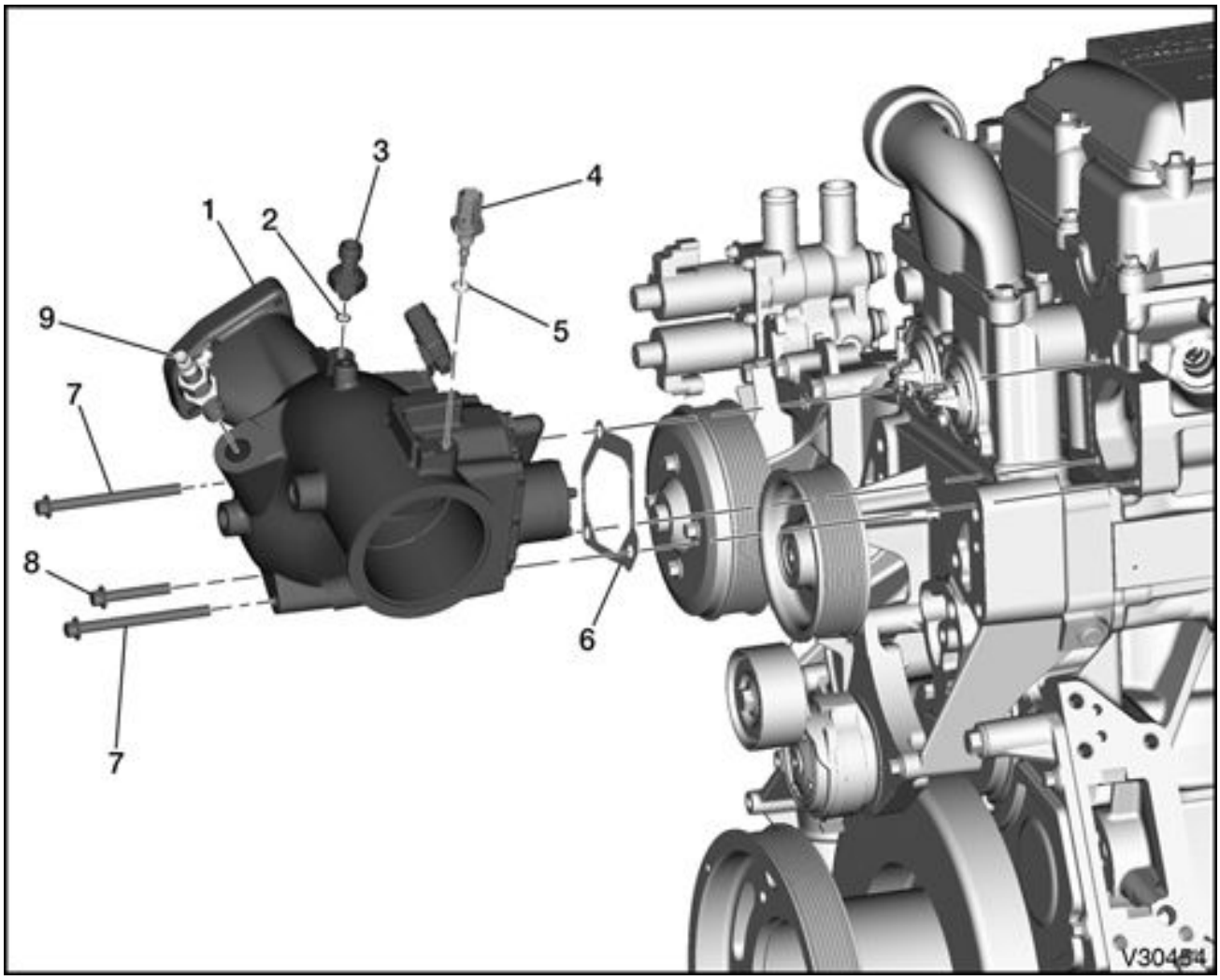

Figure 454 Air intake throttle horizontal duct

1. Air intake throttle horizontal duct
2. Sensor O-ring
3. Intake manifold pressure sensor
4. Charge air cooler outlet temperature sensor
5. O-ring
6. Intake throttle gasket
7. M8 x 100 bolt (2)
8. M8 x 50 bolt
9. Inlet Air Heater Fuel Igniter (IAHFI)

Air Intake Throttle Vertical Duct

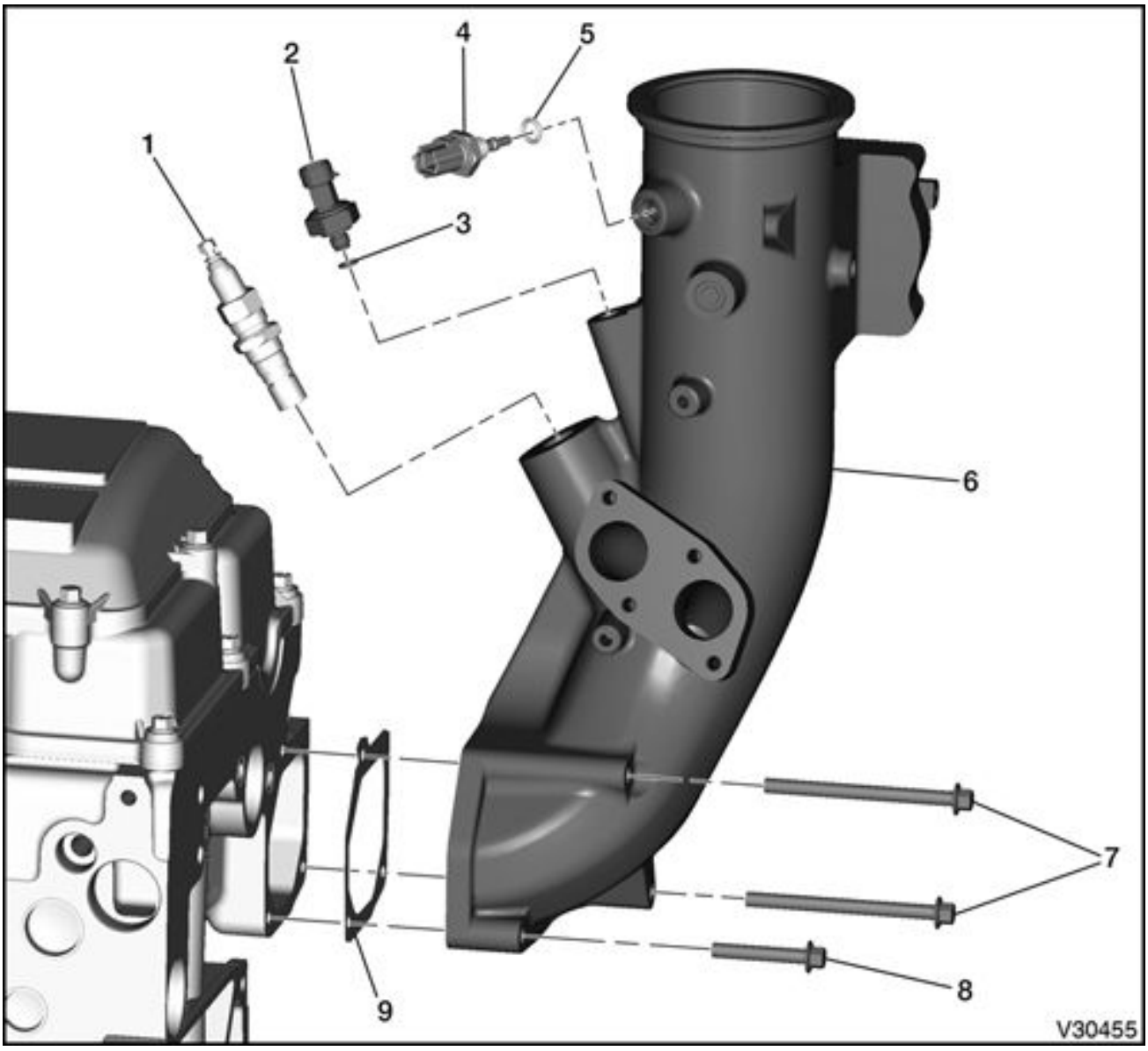

Figure 455 Air intake throttle vertical duct

1. Inlet Air Heater Fuel Igniter (IAHFI)
2. Intake manifold pressure sensor
3. O-ring
4. Charge air cooler outlet temperature sensor
5. Sensor O-ring
6. Air intake throttle vertical duct
7. M8 x 100 bolt (2)
8. M8 x 50 bolt
9. Intake throttle gasket

Removal

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

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

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

WARNING: To prevent personal injury or death, 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: When performing specific component removal, only remove components necessary for access.

For complete engine tear down, refer to the following service sections for information on removal of components prior to this section.

- **Engine Electrical**
- **Inlet Air Heater**
- **Aftertreatment System**
- **Exhaust Back Pressure Control**
- **Turbochargers**
- **Oil Cooler, Filter Housing, and Crankcase Ventilation**
- **Exhaust Gas Recirculating (EGR) System**
- **Front Cover, Fan Drive, Cooling System, and Related Components**

Exhaust Manifold Heat Shield

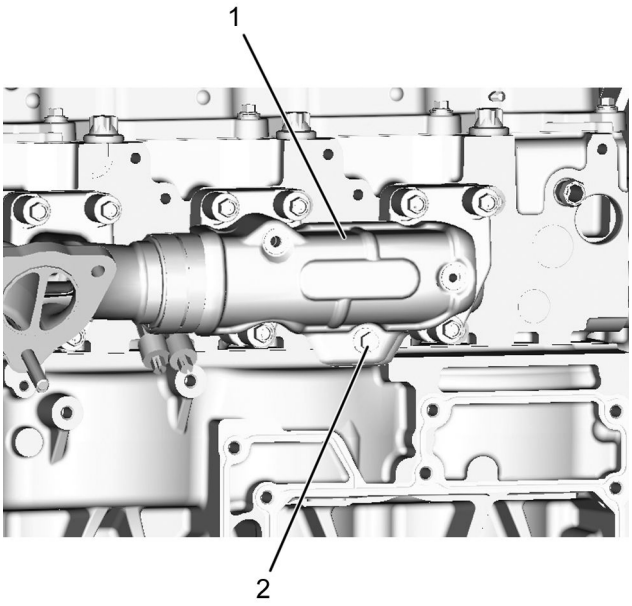

Figure 456 Heat protection shield

1. Heat protection shield (at front exhaust manifold)
2. M8 x 12 bolt

1. Remove M8 x 12 bolt (Figure 456) (Item 2) that secures the heat protection shield (Figure 456) (Item 1) to the front exhaust manifold and remove heat protection shield.

Front Exhaust Manifold Cuff Assembly

NOTE: If engine is not equipped with exhaust manifold cuff assembly, proceed to Exhaust Manifold (page 341).

NOTE: Early production front exhaust manifolds have one ring seal clamp, and updated front exhaust manifolds have two ring seal clamps.

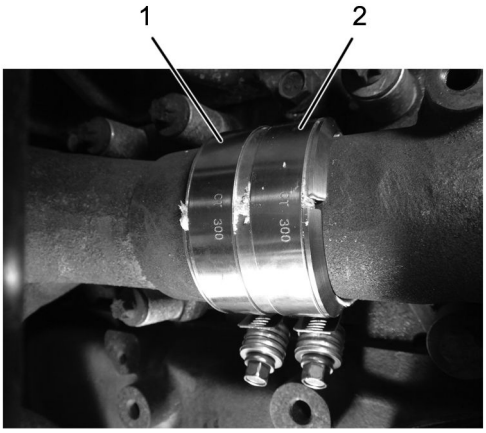

Figure 457 Updated Front Exhaust Manifold Cuff Assembly (two clamp version)

1. Ring seal clamp #2
2. Ring seal clamp #1

1. Remove and discard ring seal clamp(s) (Figure 457) (Items 1, 2) from front exhaust manifold.

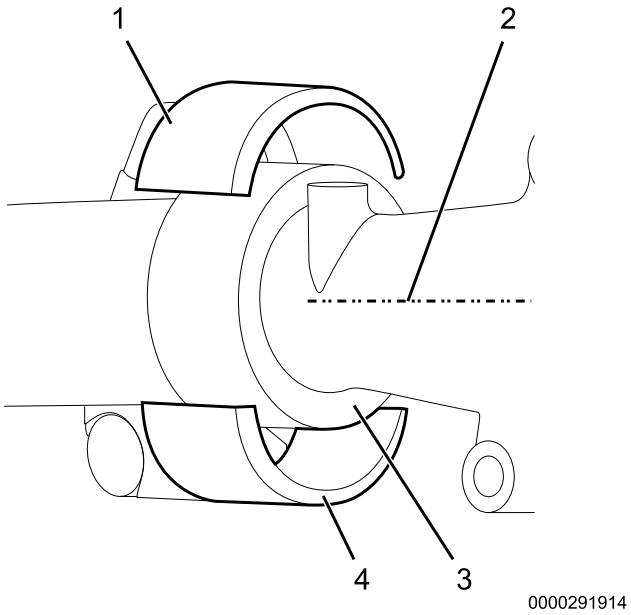

Figure 458 Front Exhaust Manifold Shields

1. Exhaust manifold shield (2)
2. Manifold midpoint
3. Seal Packing
4. Beveled flange

2. Remove and discard two exhaust manifold shields (Figure 458) (Item 1).

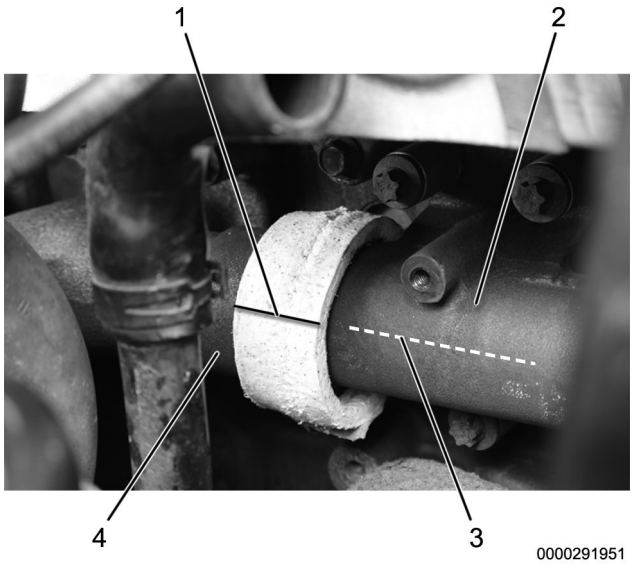

Figure 459 Front Exhaust Manifold Ceramic Mat Wrap Assembly

1. Ceramic mat wrap assembly
2. Front exhaust manifold
3. Manifold midpoint
4. Middle exhaust manifold

3. Remove and discard front exhaust manifold ceramic mat wrap assembly (Figure 459) (Item 1).

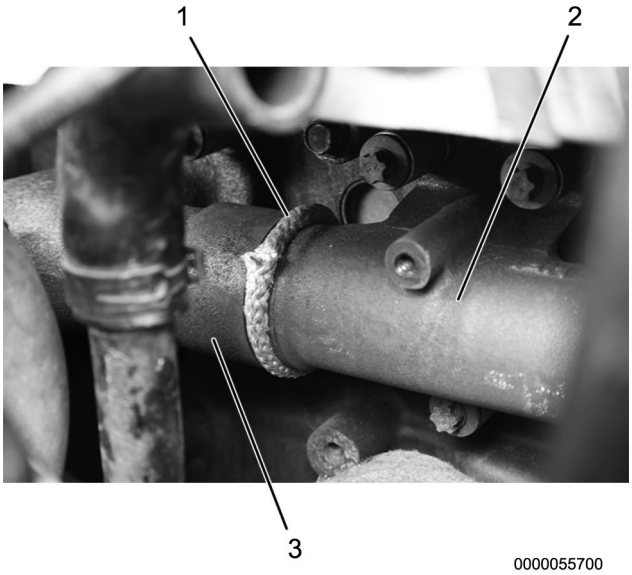

Figure 460 Front Exhaust Manifold Seal Packing

1. Seal packing
2. Front exhaust manifold
3. Middle exhaust manifold

4. Remove and discard exhaust manifold seal packing (Figure 460) (Item 1).

Rear Exhaust Manifold Cuff Assembly

NOTE: If engine is not equipped with exhaust manifold cuff assembly, proceed to Exhaust Manifold (page 341).

NOTE: Early production front exhaust manifolds have one ring seal clamp, and updated front exhaust manifolds have two ring seal clamps.

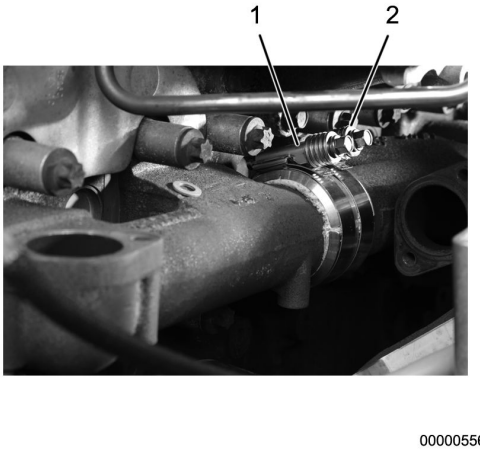

Figure 461 Updated Rear Exhaust Manifold Cuff Assembly (two clamp version)

1. Ring seal clamp #2
2. Ring seal clamp #1

1. Remove and discard ring seal clamp(s) (Figure 461) (Items 1, 2) from rear exhaust manifold.

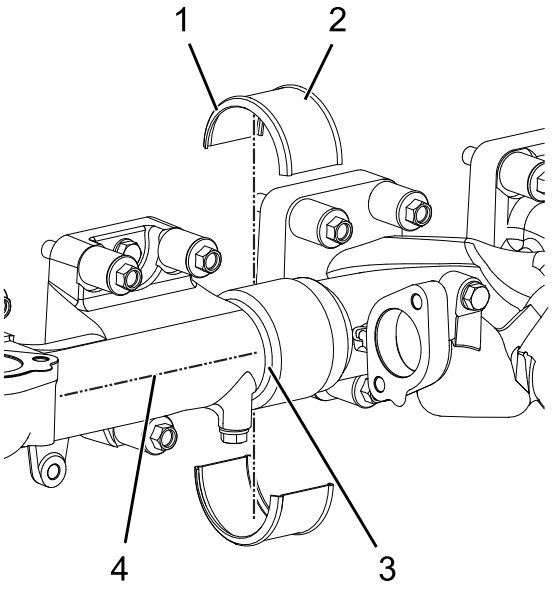

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Figure 462 Rear Exhaust Manifold Shields

1. Beveled flange
2. Exhaust manifold shield (2)
3. Seal packing
4. Manifold midpoint

2. Remove and discard two exhaust manifold shields (Figure 462) (Item 2).

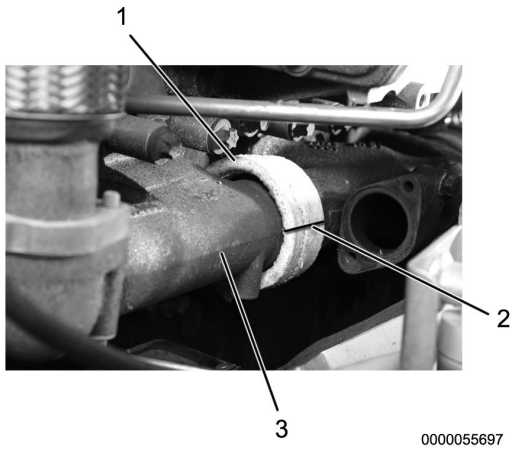

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Figure 463 Rear Exhaust Manifold Ceramic Mat Wrap Assembly

1. Ceramic mat wrap assembly
2. Ceramic mat wrap joint
3. Manifold midpoint

3. Remove and discard rear exhaust manifold ceramic mat wrap assembly (Figure 463) (Item 1).

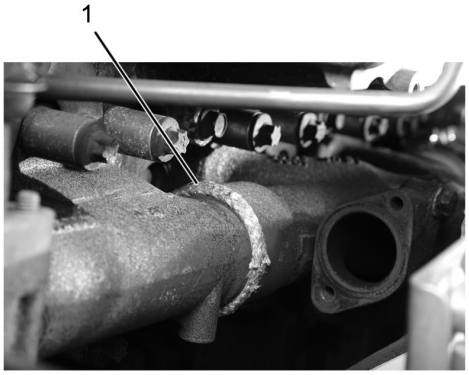

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Figure 464 Rear Exhaust Manifold Seal Packing

1. Seal packing

4. Remove and discard exhaust manifold seal packing (Figure 464) (Item 1).

Exhaust Manifold

CAUTION: To prevent engine damage, do not reuse sleeve spacers or exhaust manifold bolts.

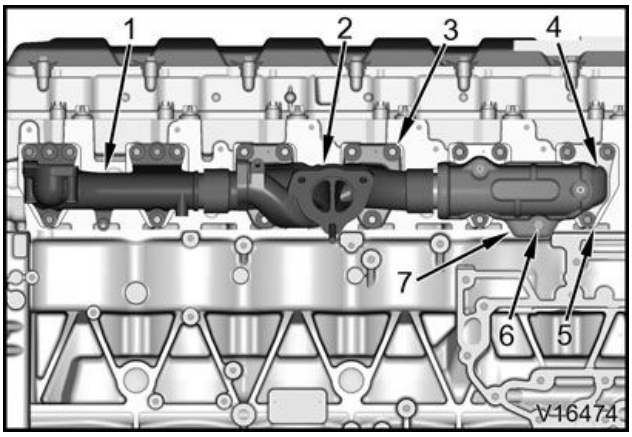

Figure 465 Exhaust manifold (typical)

1. Rear exhaust manifold
2. Middle exhaust manifold
3. M10 x 57 Torx® bolt and sleeve spacer (18)
4. Front exhaust manifold
5. Exhaust manifold gasket (6)
6. M8 x 12 bolt
7. Heat protection shield

1. Remove 18 M10 x 57 Torx® bolts and 18 sleeve spacers. Discard bolts and spacers after removal.
2. Remove exhaust manifold assembly and discard six exhaust manifold gaskets.

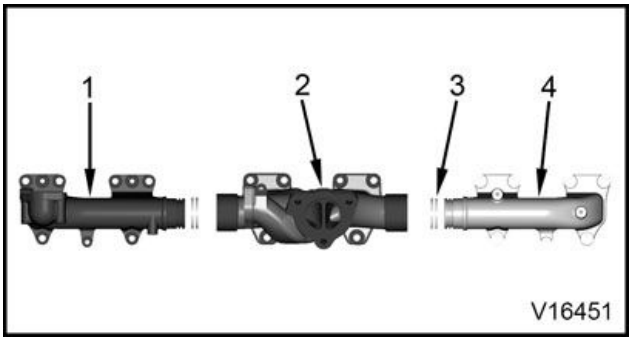

Figure 466 Exhaust manifolds

1. Rear exhaust manifold
2. Middle exhaust manifold
3. Multipiece (FEY) ring (4)
4. Front exhaust manifold

3. Separate front and rear exhaust manifold sections from middle exhaust manifold.
4. Remove and discard multipiece (FEY) rings from front and rear exhaust manifolds.

Air Intake Throttle Duct

CAUTION: To prevent engine damage, make sure gasket debris and dirt do not enter cylinder head opening.

1. Remove glow plug from air intake throttle duct. See “INLET AIR HEATER SYSTEM” for procedure.
2. Remove temperature sensor and air pressure sensor from air intake throttle duct. See “ENGINE ELECTRICAL” for procedures.

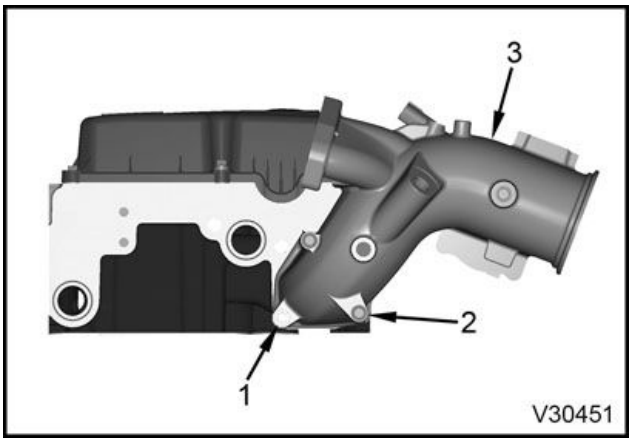

Figure 467 Air intake throttle horizontal duct

1. M8 x 50 bolt
2. M8 x 100 bolt (2)
3. Air intake throttle horizontal duct

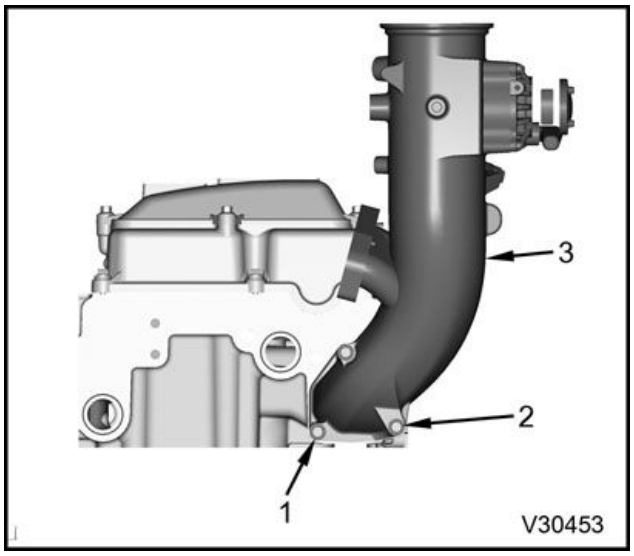

Figure 468 Air intake throttle vertical duct

1. M8 x 50 bolt
2. M8 x 100 bolt (2)
3. Air intake throttle vertical duct

3. Remove M8 x 50 bolt and two M8 x 100 bolts. Depending on application, remove either air intake throttle horizontal or vertical duct.
4. Remove and discard intake throttle gasket.

Cleaning, Inspection and Testing

Air Intake Throttle Duct and Exhaust Manifolds

NOTE: Do not use air tools or abrasive pads to clean aluminum parts.

NOTE: Normal exhaust manifold sealing surface wear or minor leaks at the FEY ring joints do not require manifold section replacement.

CAUTION: If engine is not equipped with exhaust manifold cuff assembly, install front and rear exhaust manifold cuff assembly.

Air intake throttle duct and three exhaust manifold sections are castings and may be cleaned with steam or suitable non-caustic solvents.

1. Clean cylinder head, air intake throttle duct and exhaust manifold gasket sealing surfaces.
2. Clean multipiece (FEY) ring grooves and sealing surfaces of the exhaust manifold sections.

Manifold Warp Test for Exhaust Manifolds

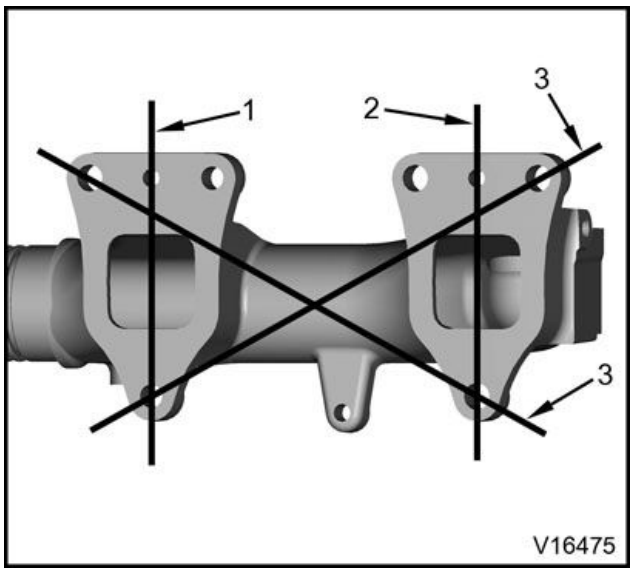

Figure 469 Exhaust manifold section warp test

1. Left
2. Right
3. Diagonally

1. Use a straightedge and feeler gauge (page 352) to check seating surface flatness of three exhaust manifold sections.
2. Check for flatness across left, right and diagonally of each exhaust manifold section individually. See Specification (page 352).
3. If specification is not met, replace individual exhaust manifold section. Do not resurface.

Installation

Air Intake Throttle Duct

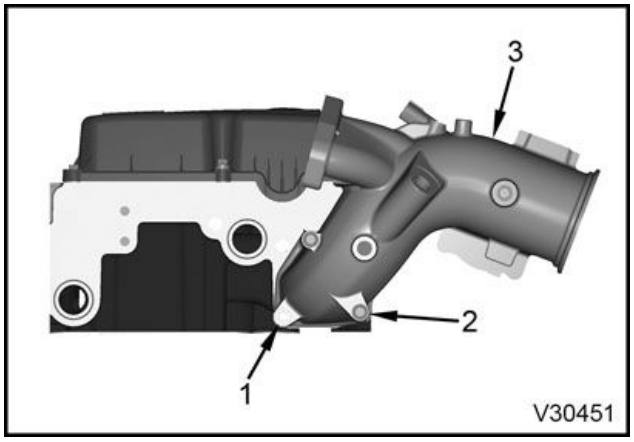

Figure 470 Air intake throttle horizontal duct

1. M8 x 50 bolt
2. M8 x 100 bolt (2)
3. Air intake throttle horizontal duct

1. If equipped with horizontal air intake throttle duct, install intake throttle gasket (Figure 454) (item 6), horizontal air intake throttle duct, M8 x 50 bolt and two M8 x 100 bolts. Tighten bolts to standard torque (page 547).

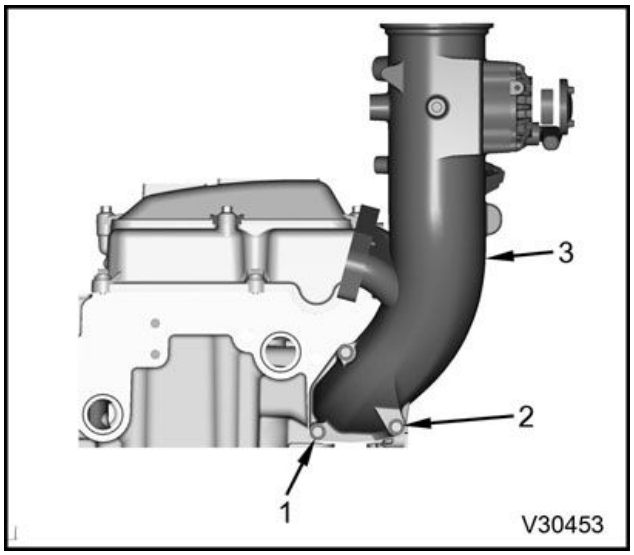

Figure 471 Air intake throttle vertical duct

1. M8 x 50 bolt
2. M8 x 100 bolt (2)
3. Air intake throttle vertical duct

2. If equipped with vertical air intake throttle duct, install intake throttle gasket (Figure 455) (item 9), vertical air intake throttle duct, M8 x 50 bolt, and two M8 x 100 bolts. Tighten bolts to standard torque (page 547).
3. Install charge air cooler outlet temperature sensor and intake manifold pressure sensor to air intake throttle duct. See Charge Air Cooler Outlet Temperature (CACOT) Sensor (page 100) and Intake Manifold Pressure (IMP) Sensor (page 99).
4. Install Inlet Air Heater Fuel Igniter (IAHFI) to air intake throttle duct. See Inlet Air Heater Fuel Igniter (IAHFI) and Fuel Supply Inlet Air Heater Hose (Inlet Air Heater Fuel Igniter (IAHFI) and Fuel Supply Inlet Air Heater Hose, page 116).

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 sleeve spacers or exhaust manifold bolts.

NOTE: Do not apply anti-seize compound to threads.

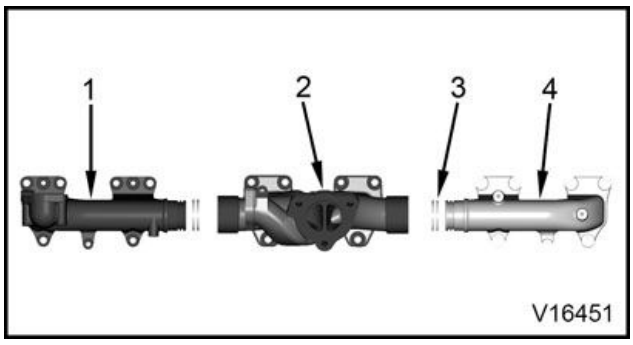

Figure 472 Exhaust manifold

1. Rear exhaust manifold
2. Middle exhaust manifold
3. Multipiece (FEY) ring (4)
4. Front exhaust manifold

NOTE: Each multipiece (FEY) ring replacement comes as four individual rings. There are two multipiece rings (two sets of four rings) for each front and rear exhaust manifold section. This results in four sets of four individual rings or 16 total individual rings for a complete exhaust manifold assembly. Each set of four rings in an exhaust manifold groove must have the ring gaps indexed 90 degrees apart (3, 6, 9 and 12 o'clock position), to ensure the ring gaps are not aligned.

1. Install four new multipiece (FEY) rings, two to the front exhaust manifold and two to the rear exhaust manifold, using FEY Rings Installation Tools (page 352). Refer to the tool kit installation instructions. Each multipiece ring (four individual rings) must be positioned with the four individual ring gaps at 3, 6, 9 and 12 o'clock position within each exhaust manifold ring groove.
2. Install the front and rear exhaust manifolds into the middle exhaust manifold.

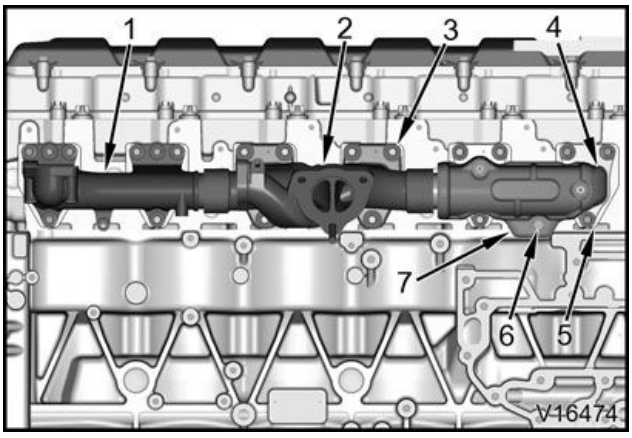

Figure 473 Exhaust manifold

1. Rear exhaust manifold
2. Middle exhaust manifold
3. M10 x 57 Torx® bolt and sleeve spacers (18)
4. Front exhaust manifold
5. Manifold exhaust gasket (6)
6. M8 x 12 bolt
7. Heat protection shield

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.

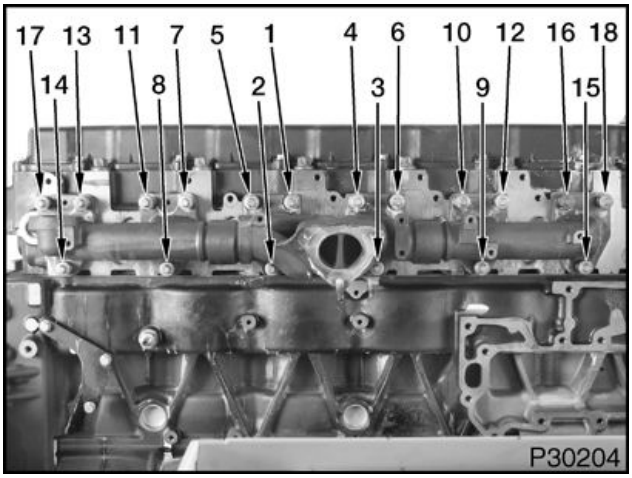

Figure 474 Exhaust manifold tightening sequence

4. Install 18 new M10 x 57 Torx® bolts and 18 new sleeve spacers.
   a. Tighten all bolts to 40 N·m (30 lb·ft) using tightening sequence shown.
   b. Turn all bolts an additional 90° using tightening sequence shown.

Front Exhaust Manifold Cuff Assembly

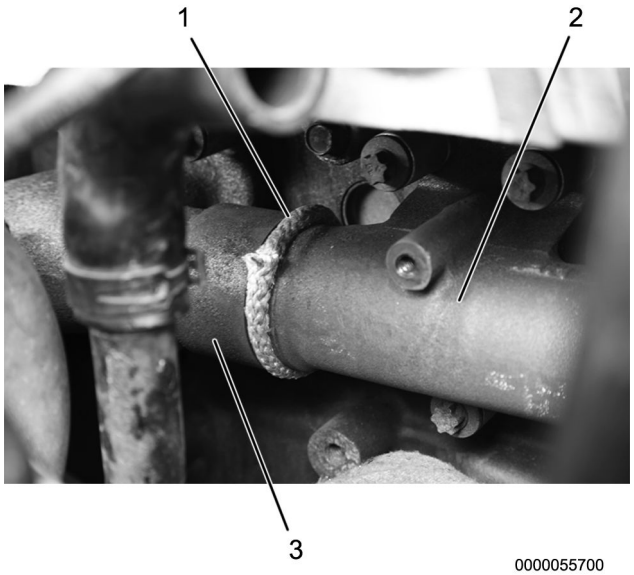

Figure 475 Front Exhaust Manifold Seal Packing

1. Seal packing
2. Front exhaust manifold
3. Middle exhaust manifold

CAUTION: If engine was not originally equipped with front exhaust manifold cuff assembly, install new front exhaust manifold cuff assembly.

1. Wrap seal packing (Figure 475) (Item 1) around manifold ring joint and align so that seal ends meet at top of manifold.
2. Press seal packing tightly into joint with fingers.

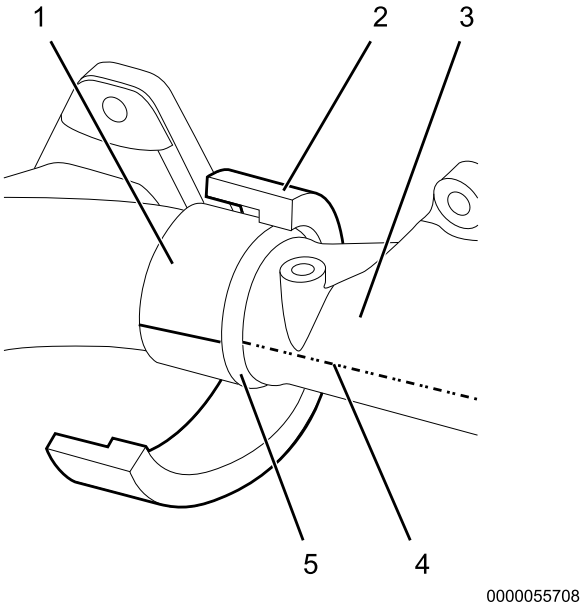

Figure 476 Front Exhaust Manifold Ceramic Mat Wrap Assembly

1. Middle exhaust manifold
2. Ceramic mat wrap assembly
3. Front exhaust manifold
4. Manifold midpoint
5. Seal packing

CAUTION: To avoid engine damage, wrap thick end of ceramic mat wrap assembly over seal packing end.

3. Wrap joint between front exhaust manifold (Figure 476) (Item 3) and middle exhaust manifold (Figure 476) (Item 1) and seal packing (Figure 476) (Item 5) with ceramic mat wrap assembly (Figure 476) (Item 2), covering seal packing with thick end of ceramic mat wrap assembly.

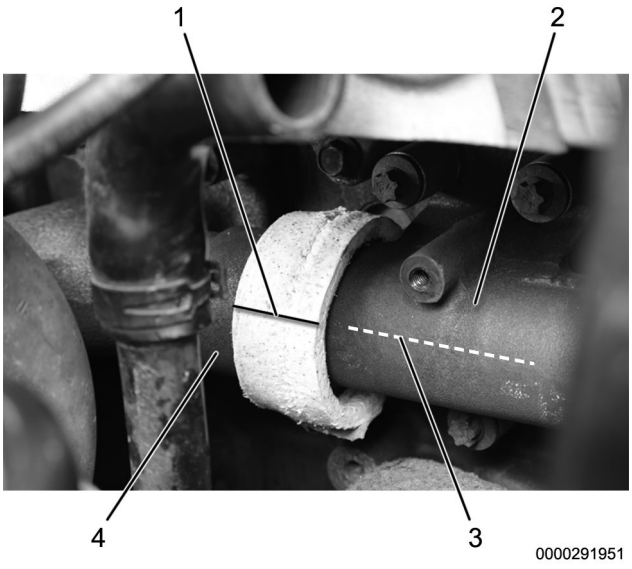

Figure 477 Front Exhaust Manifold Ceramic Mat Wrap Assembly Alignment

1. Ceramic mat wrap assembly joint
2. Front exhaust manifold
3. Manifold midpoint
4. Middle exhaust manifold

4. Align ceramic mat wrap joint (Figure 477) (Item 1) with manifold midpoint (Figure 477) (Item 3).

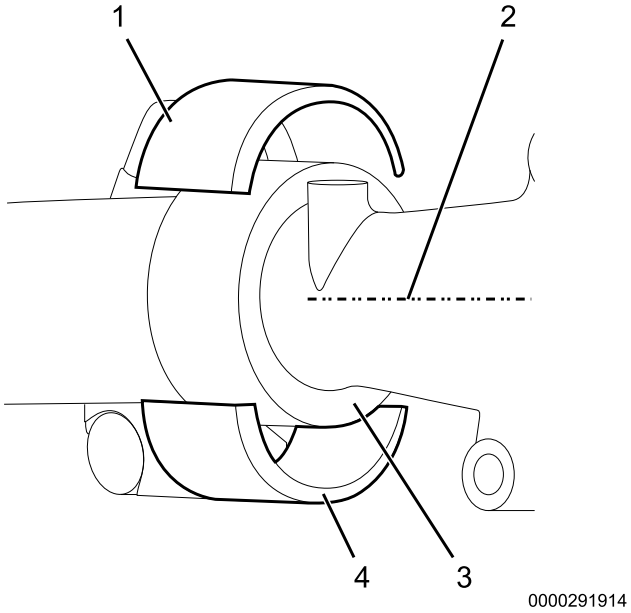

Figure 478 Front Exhaust Manifold Shields

1. Exhaust manifold shield (2)
2. Manifold midpoint
3. Sealing pack
4. Beveled flange

CAUTION: Install two shield halves with beveled flange on seal packing end side.

5. Install two shield halves (Figure 478) (Item 1) with beveled flange (Figure 478) (Item 4) on sealing pack (Figure 478) (Item 3) end, and align joint with manifold midpoint (Figure 478) (Item 2).

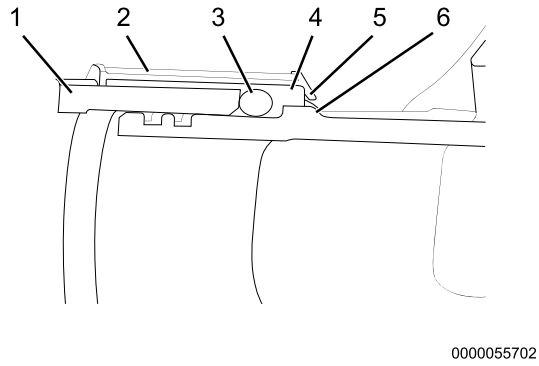

Figure 479 Front Exhaust Manifold Cuff Assembly Cross Section

1. Middle exhaust manifold
2. Exhaust manifold shield
3. Seal packing
4. Ceramic mat wrap assembly
5. Beveled flange
6. Front exhaust manifold

6. Verify that exhaust manifold shield (Figure 479) (Item 2) completely covers ceramic mat wrap assembly (Figure 479) (Item 4), and ceramic mat wrap assembly overlaps seal packing (Figure 479) (Item 3).

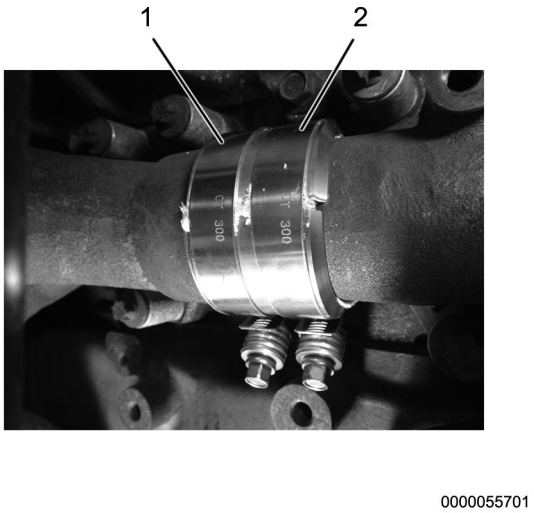

Figure 480 Front Exhaust Manifold Ring Seal Clamps

1. Ring seal clamp #2
2. Ring seal clamp #1

NOTE: If engine has an early production front exhaust manifold cuff assembly with one ring seal clamp, install an updated front exhaust manifold cuff assembly with two ring seal clamps.

NOTE: Ring seal clamp alignment must match the clamp alignment as shown (Figure 480) to allow for proper exhaust manifold heat shield installation.

7. Install ring seal clamp #1 (Figure 480) (Item 2) on seal packing end (right side) of shield.
8. Tighten ring seal clamp #1 to take up slack.
9. Install ring seal clamp #2 (Figure 480) (Item 1).
10. Alternately tighten each ring seal clamp until shield is snug, keeping shield aligned with manifold midpoint.
11. Tighten ring seal clamps to 70 lb·in (8 N·m).

Rear Exhaust Manifold Cuff Assembly

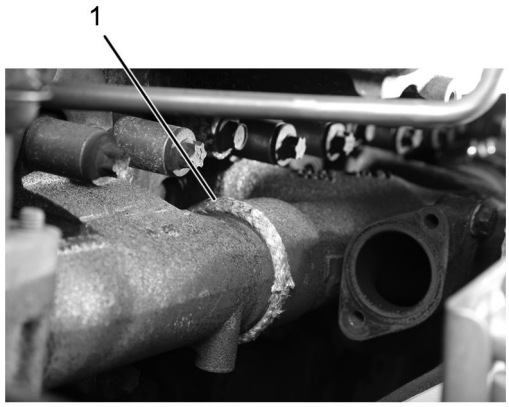

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Figure 481 Rear Exhaust Manifold Seal Packing

1. Seal packing

CAUTION: If engine was not originally equipped with rear exhaust manifold cuff assembly, install new rear exhaust manifold cuff assembly.

1. Wrap seal packing (Figure 481) (Item 1) around manifold ring joint and align so that seal ends meet at top of manifold.
2. Press seal packing tightly into joint with fingers.

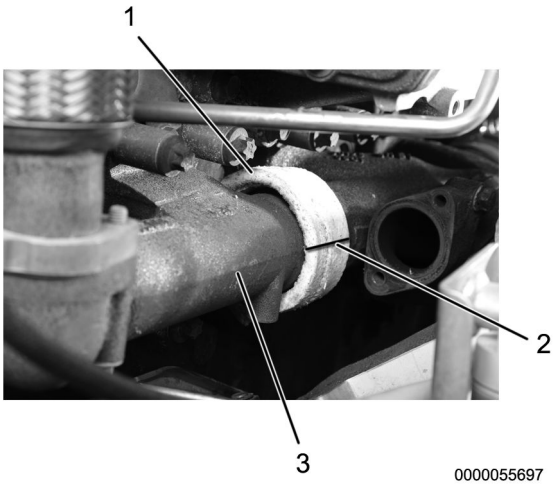

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Figure 482 Rear Exhaust Manifold Ceramic Mat Wrap Assembly

1. Ceramic mat wrap assembly
2. Ceramic mat wrap joint
3. Manifold midpoint

CAUTION: To avoid engine damage, wrap thick end of ceramic mat wrap assembly over seal packing end.

3. Wrap joint between rear exhaust manifold and middle exhaust manifold and seal packing with ceramic mat wrap assembly (Figure 482) (Item 1), covering seal packing with thick end of ceramic mat wrap assembly.
4. Align ceramic mat wrap joint (Figure 482) (Item 2) with manifold midpoint (Figure 482) (Item 3).

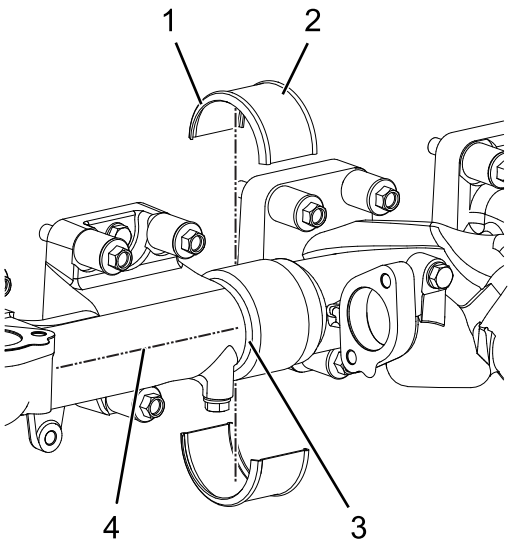

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Figure 483 Exhaust Manifold Shields

1. Beveled flange
2. Exhaust manifold shield (2)
3. Seal packing
4. Manifold midpoint

CAUTION: Install two shield halves with beveled flange on seal packing end side.

5. Install two exhaust manifold shields (Figure 483) (Item 2) with beveled flange (Figure 483) (Item 1) on seal packing (Figure 483) (Item 3) end, and align joint with manifold midpoint (Figure 483) (Item 4).

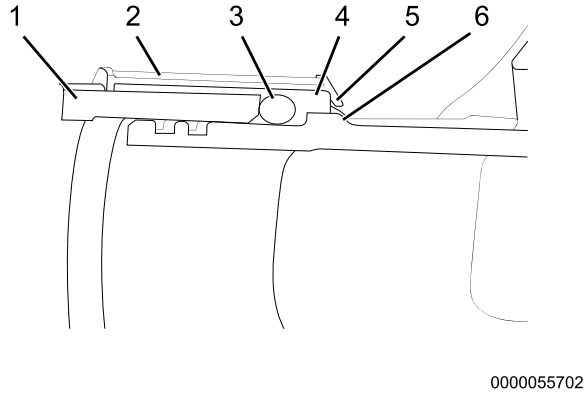

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Figure 484 Exhaust Manifold Cuff Assembly Cross Section

1. Female manifold
2. Exhaust manifold shield
3. Seal packing
4. Ceramic mat wrap assembly
5. Beveled flange
6. Male manifold

6. Verify exhaust manifold shield (Figure 484) (Item 2) completely covers ceramic mat wrap assembly (Figure 484) (Item 4), and ceramic mat wrap assembly overlaps seal packing (Figure 484) (Item 3).

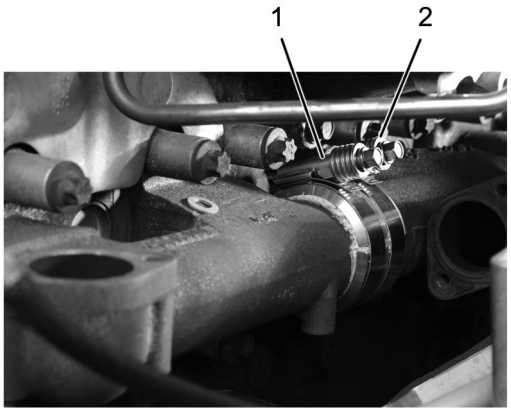

Figure 485 Rear Exhaust Manifold Ring Seal Clamps

1. Ring seal clamp #1
2. Ring seal clamp #2

NOTE: If engine has an early production front exhaust manifold cuff assembly with one ring seal clamp, install an updated front exhaust manifold cuff assembly with two ring seal clamps.

7. Install ring seal clamp #1 (Figure 485) (Item 1) on seal packing end (left side) of shield.
8. Tighten ring seal clamp #1 to take up slack.
9. Install ring seal clamp #2 (Figure 485) (Item 2).
10. Alternately tighten each ring seal clamp until shield is snug, keeping shield aligned with manifold midpoint.
11. Tighten ring seal clamps to 70 lb-in (8 N·m).

Exhaust Manifold Heat Shield

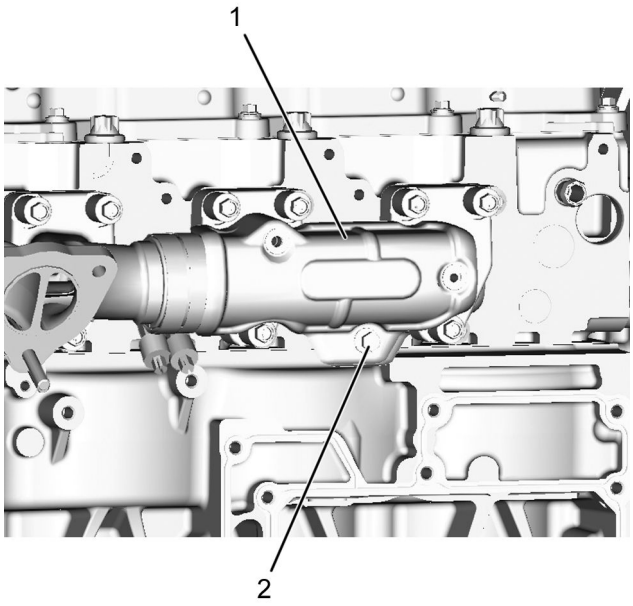

Figure 486 Heat protection shield

1. Heat protection shield (at front exhaust manifold)
2. M8 x 12 bolt

1. Install heat protection shield (Figure 486) (Item 1) to exhaust manifold.
2. Install M8 x 12 bolt (Figure 486) (Item 2). Tighten bolt to 23 lb·ft (31 N·m).

Specifications

Exhaust manifold maximum allowable warpage	0.1 mm (0.003 in)

Special Torque

Exhaust manifold Torx® bolts, M10 x 57	(Installation, page 344)
M8 x 12 bolt	31 N·m (23 lb·ft)

Special Service Tools

Description	Tool Number
Feeler gauge	Obtain locally
FEY Rings Installation Tools	ZTSE6030
Straightedge	Obtain locally

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Exploded Views

High Mount Fan Drive System and Vibration Damper

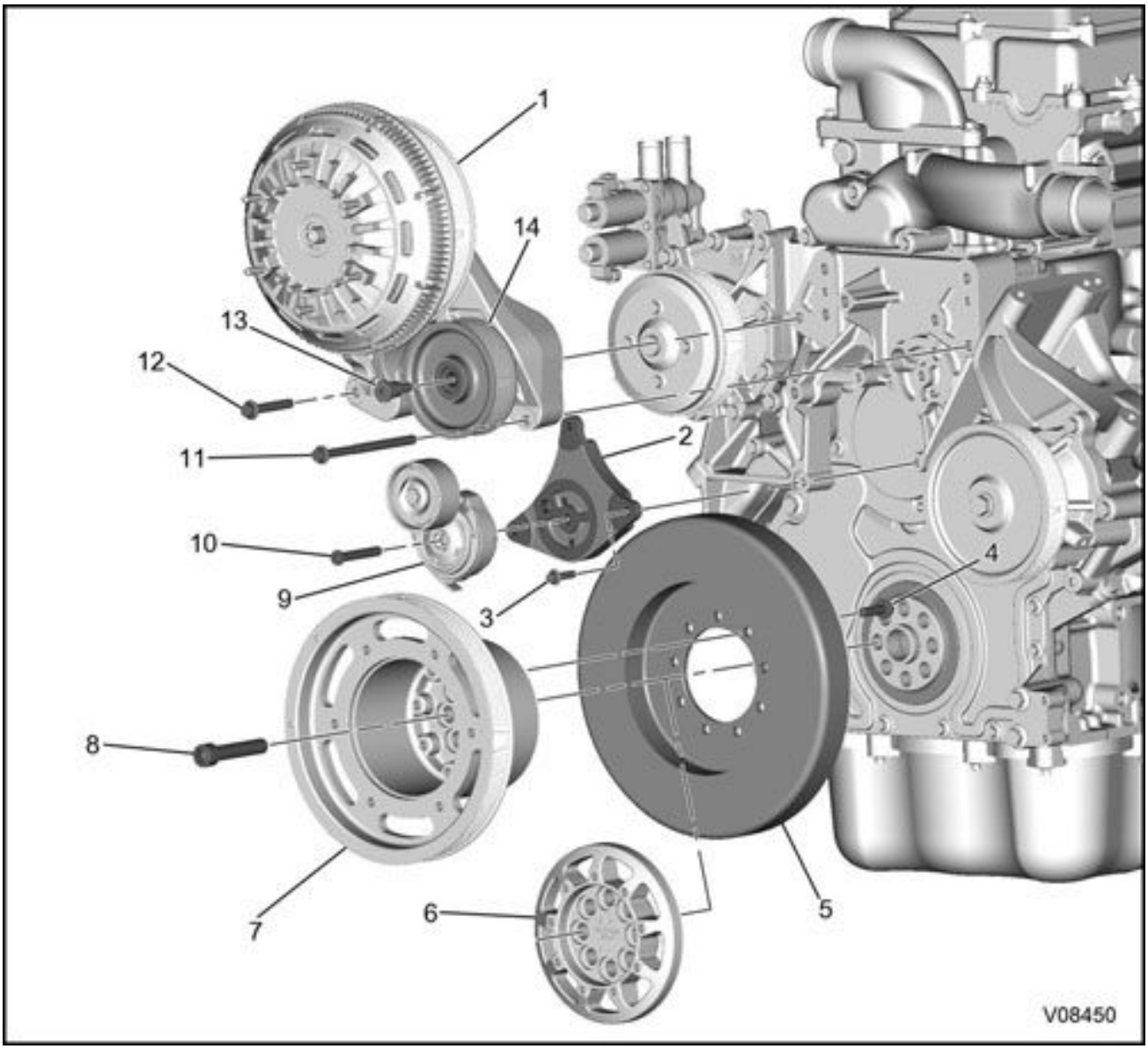

Figure 487 High mount fan drive system and vibration damper

1. Fan drive clutch assembly
2. Tensioner bracket
3. M8 x 30 bolt (3)
4. M10 x 35 bolt (9)
5. Vibration damper
6. Damper hub (low mount fan only)
7. Fan drive pulley (high mount fan only)
8. M16 x 85 socket-head screw (8)
9. Fan drive tensioner assembly
10. M10 x 70 countersunk screw
11. M10 x 150 bolt - 12.9 (5)
12. M10 x 65 bolt
13. Shoulder bolt
14. Pulley assembly

Accessory Drive System (Typical)

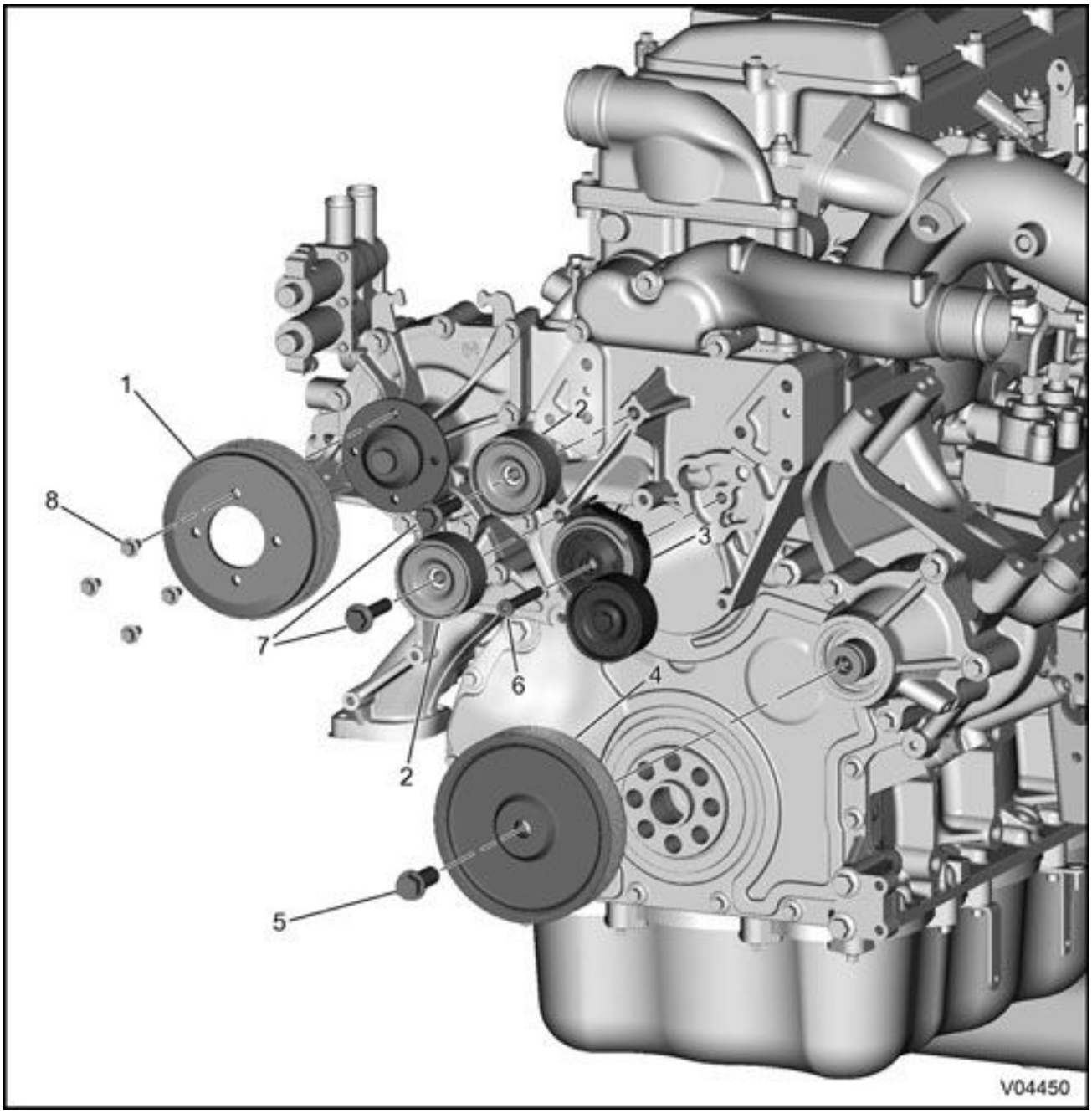

Figure 488 Accessory drive system (typical)

1. Water pump pulley
2. Idler pulley (2)
3. Automatic belt tensioner
4. High-pressure pump pulley (accessory belt drive)
5. M16 x 40 bolt
6. M10 x 70 countersunk screw
7. M12 x 55 bolt (2)
8. M8 x 16 bolt (4)

Thermostat Assembly and Coolant Outlet Manifold (Low Mount Fan)

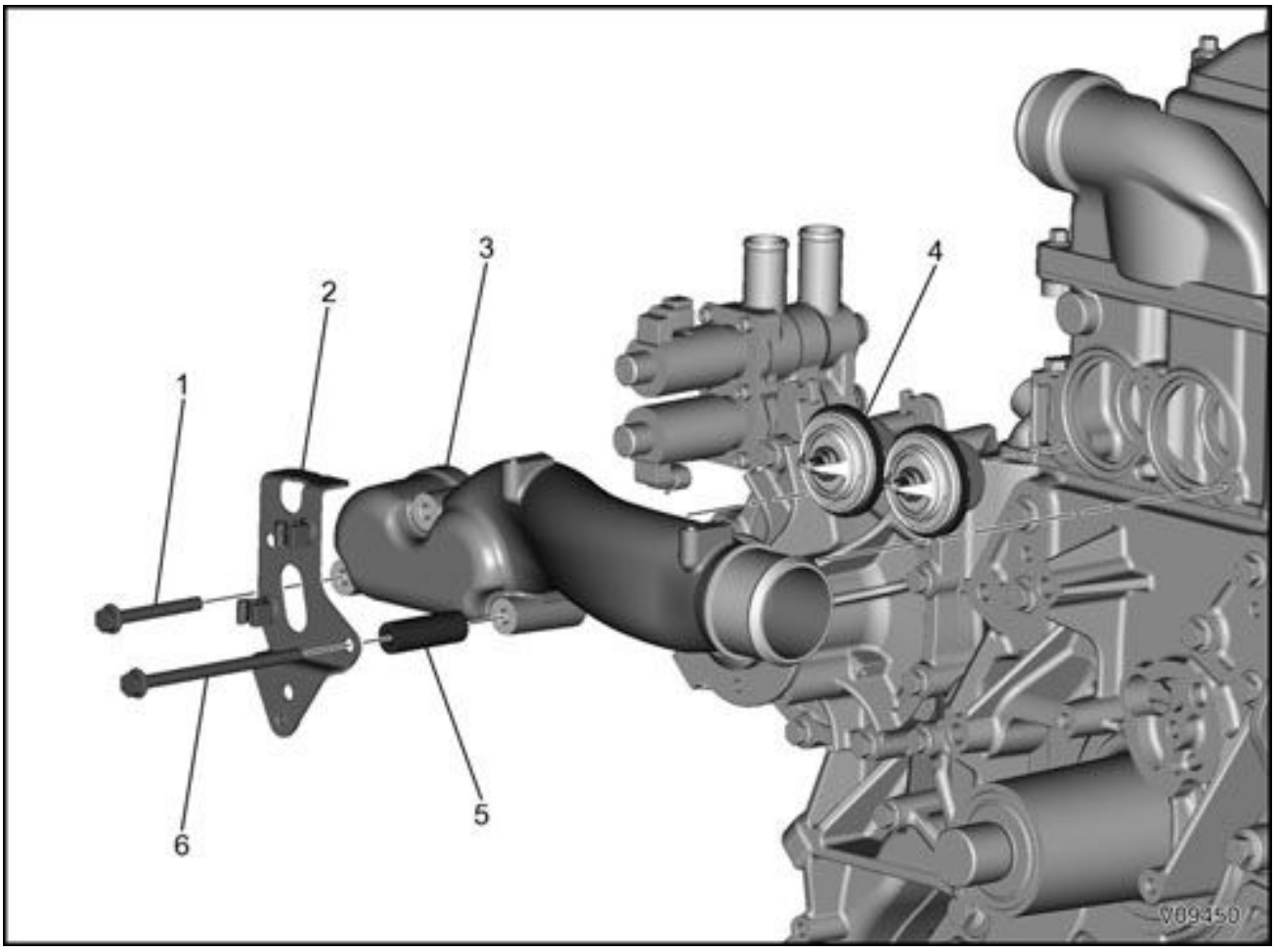

Figure 489 Thermostat assembly and coolant outlet manifold (low mount fan)

1. M8 x 70 bolt
2. Fan coupling bracket assembly
3. Coolant outlet manifold
4. Thermostat assembly (2)
5. Bushing (2)
6. M8 x 130 bolt (2)

Thermostat Assembly and Coolant Outlet Manifold (High Mount Fan)

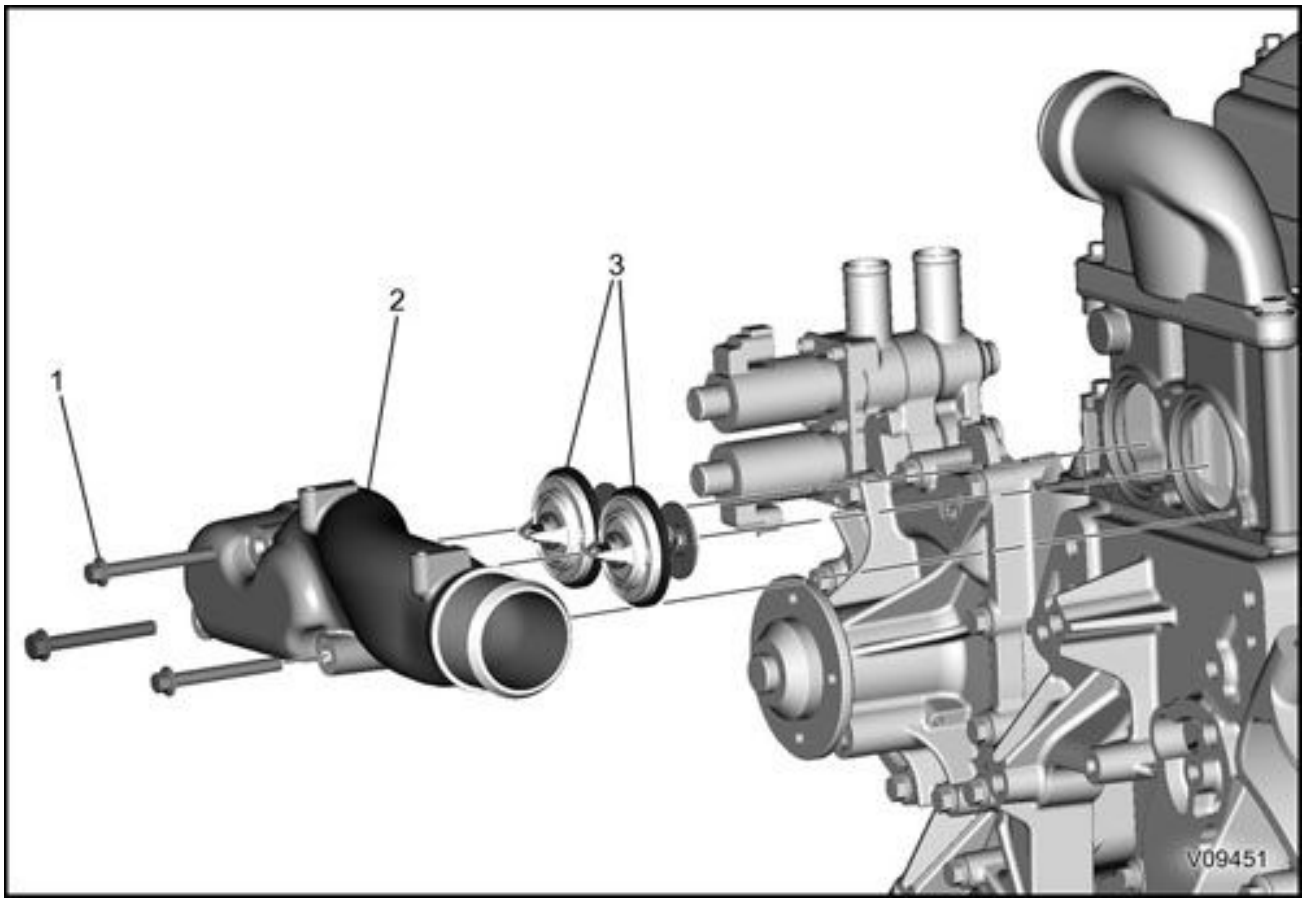

Figure 490 Thermostat assembly and coolant outlet manifold (high mount fan)

1. M8 x 70 bolt (3)
2. Coolant outlet manifold (to radiator)
3. Thermostat assembly (2)

Water Pump Assembly, Coolant Control Valve (CCV), Water Distribution Housing, Thermostat Housing and EGR Cooler Return Manifold

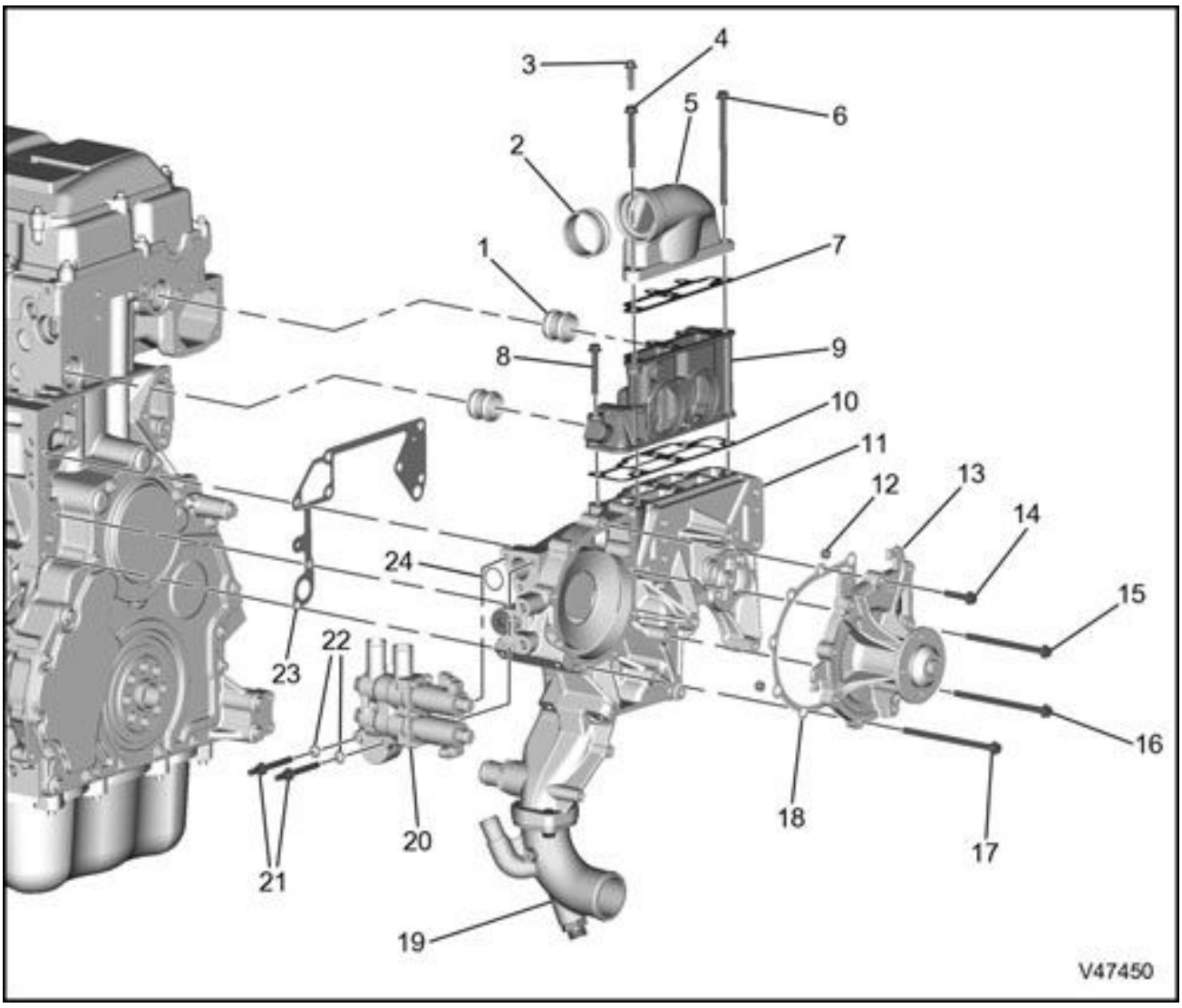

Figure 491 Water pump assembly, Coolant Control Valve (CCV), water distribution housing, thermostat housing and EGR cooler return manifold

1. Extension tube (DMR40 / DN32F) (2)
2. Extension tube (DMR62 / 51)
3. M8 x 30 bolt
4. M8 x 75 bolt
5. EGR cooler return manifold
6. M8 x 145 bolt (4)
7. Housing thermostat gasket
8. M8 x 60 bolt
9. Thermostat housing
10. Gasket
11. Water distribution housing
12. Dowel (2)
13. Water pump assembly
14. M8 x 40 bolt (7)
15. M8 x 130 bolt
16. M8 x 150 bolt (2)
17. M8 x 150 bolt (tightens into oil module assembly)
18. Water pump gasket
19. Engine water inlet
20. CCV assembly
21. M8 x 60 stud bolt (2)
22. Lock washer (2)
23. Housing coolant distribution gasket
24. O-ring

Front Belt-Driven Fan Cover (High Mount Fan)

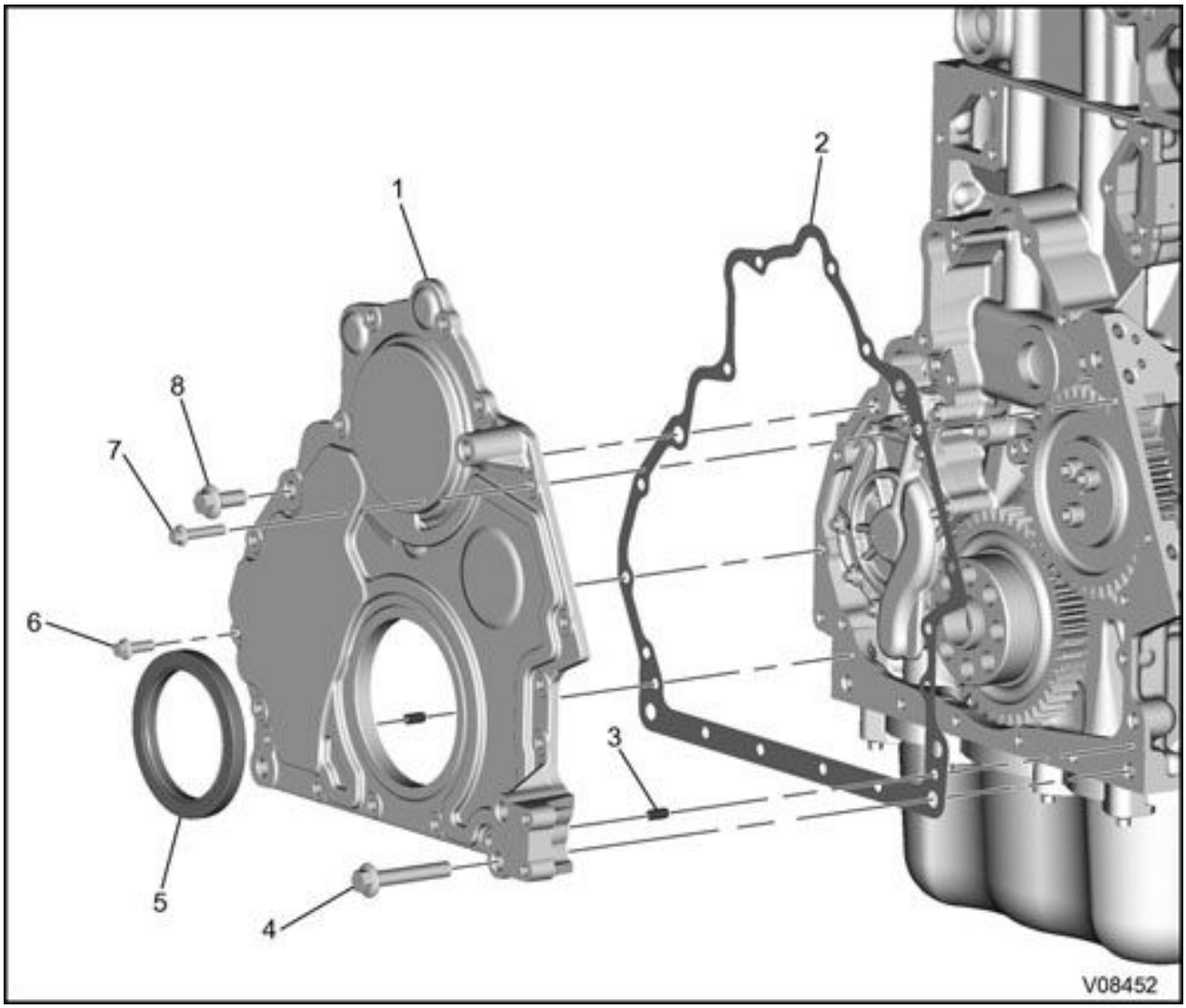

Figure 492 Front belt-driven fan cover (high mount fan)

1. Front belt driven fan cover
2. Front cover gasket
3. Dowel pin (2)
4. M12 x 75 bolt (3)
5. Radial shaft seal
6. M8 x 25 bolt (13)
7. M8 x 40 bolt (2)
8. M12 x 30 bolt (2)

Front Gear-driven Fan Cover (Low Mount Fan)

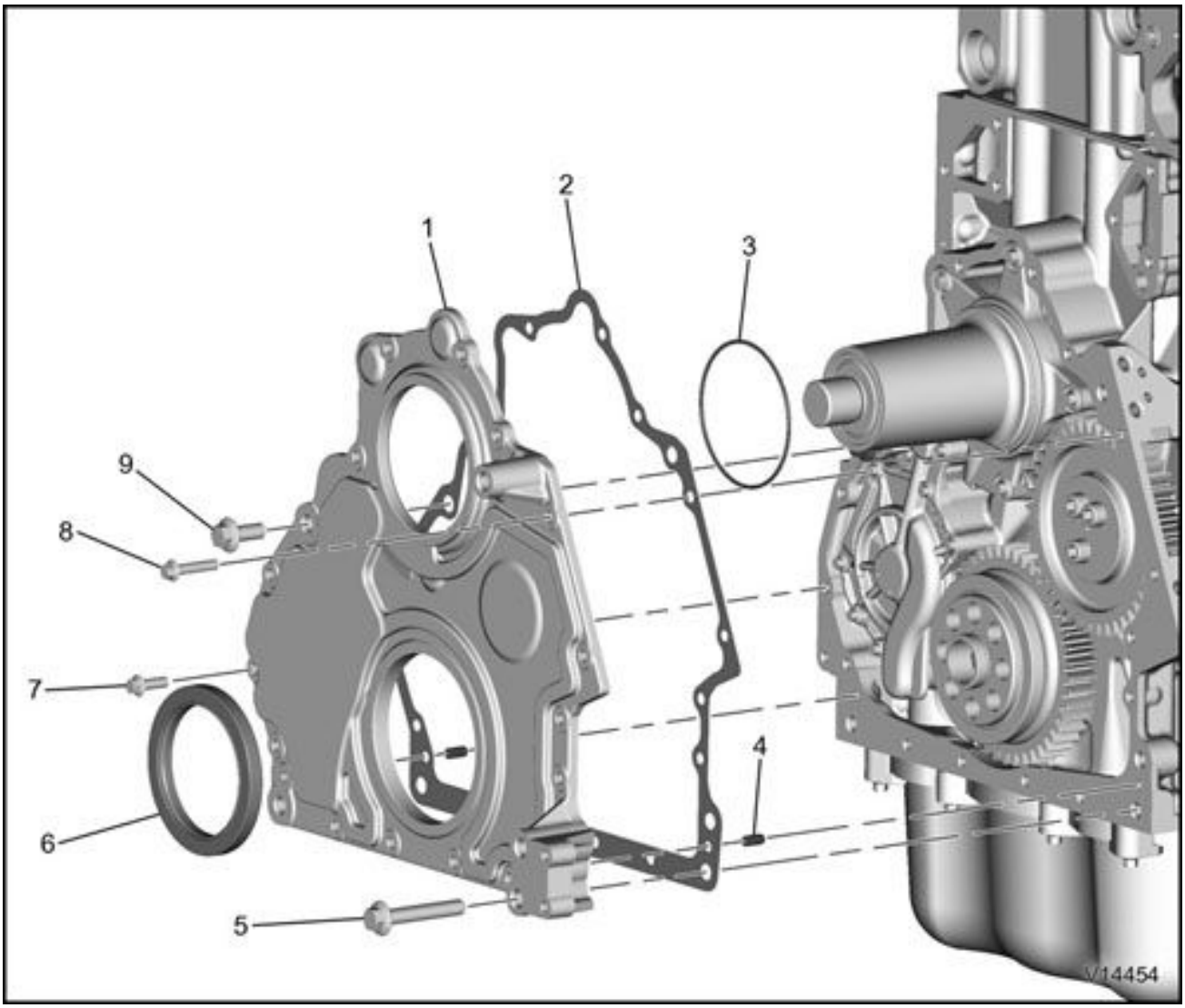

Figure 493 Front gear-driven fan cover (low mount fan)

1. Front gear driven fan cover
2. Front cover gasket
3. O-ring 108 x 3
4. Dowel pin (2)
5. M12 x 75 bolt (3)
6. Radial shaft seal
7. M8 x 25 bolt (13)
8. M8 x 40 bolt (2)
9. M12 x 30 bolt (2)

Fan Low Mount Drive (Typical)

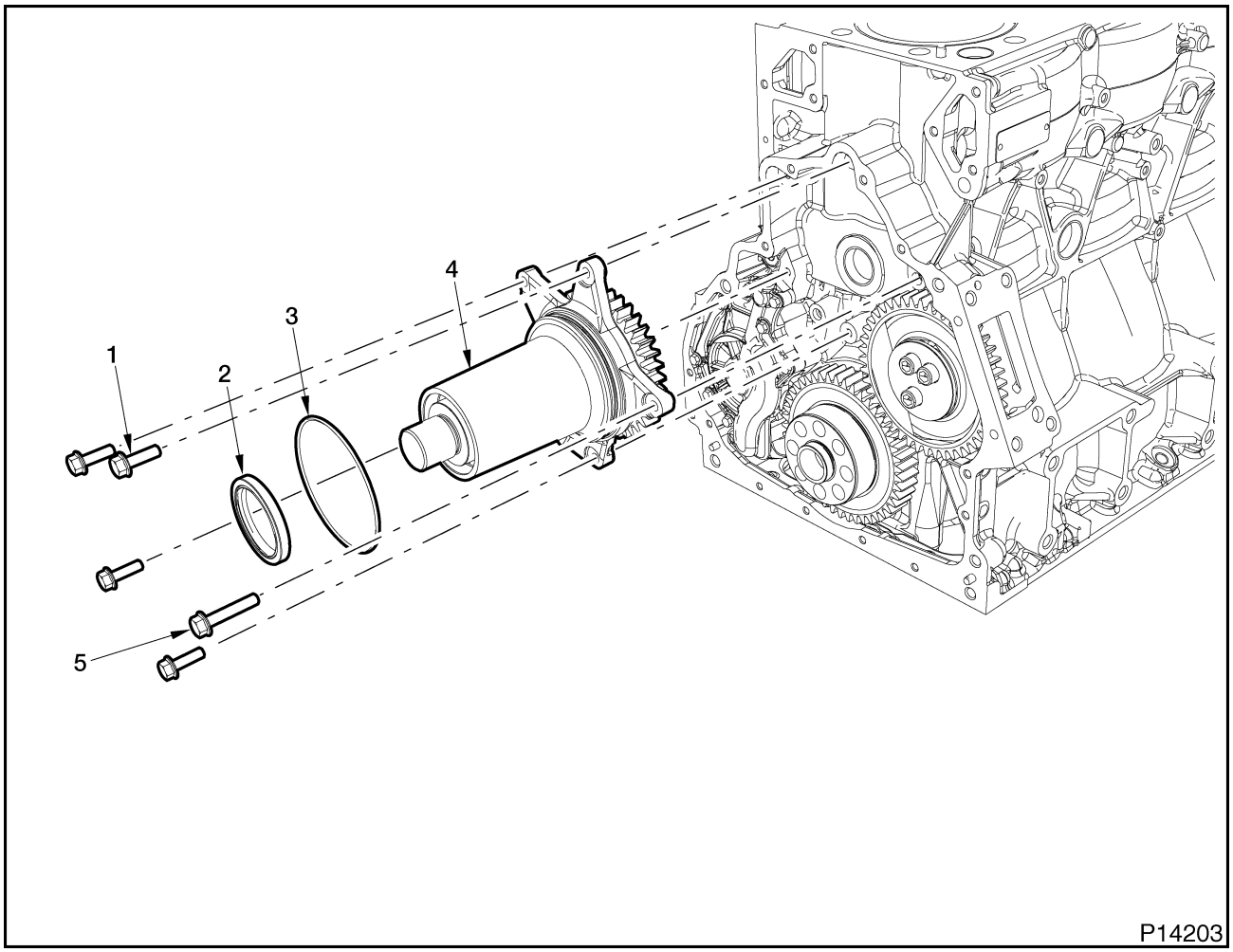

Figure 494 Fan low mount drive (typical)

1. M8 x 25 bolt (4)
2. Radial shaft seal
3. O-ring 108 x 3
4. Fan low mount drive assembly
5. M8 x 40 bolt

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: When performing specific component removal, only remove components necessary for access.

For complete engine tear down, refer to the following service sections for information on removal of components prior to this section.

- **Engine Electrical**
- **Exhaust Gas Recirculation (EGR) System**

Pulley (High Mount Fan)

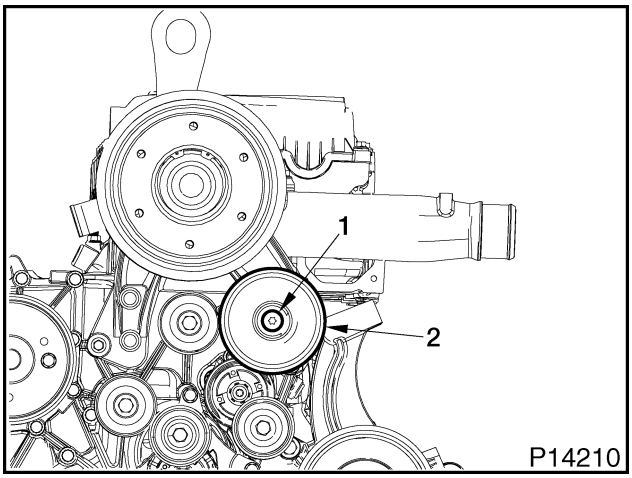

Figure 495 Pulley assembly

1. Shoulder bolt
2. Pulley assembly

1. Remove shoulder bolt and pulley assembly.

Tensioner Bracket (High Mount Fan)

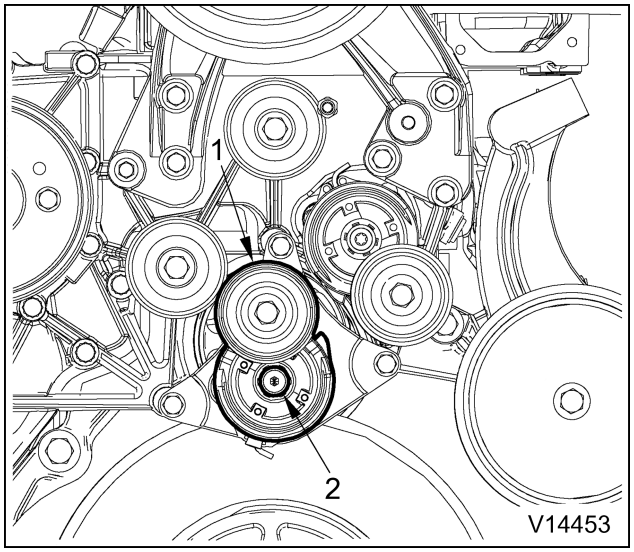

Figure 496 Fan drive tensioner assembly (high mount)

1. Fan drive tensioner assembly
2. M10 x 70 countersunk screw

1. Remove M10 x 70 countersunk screw and fan drive tensioner.

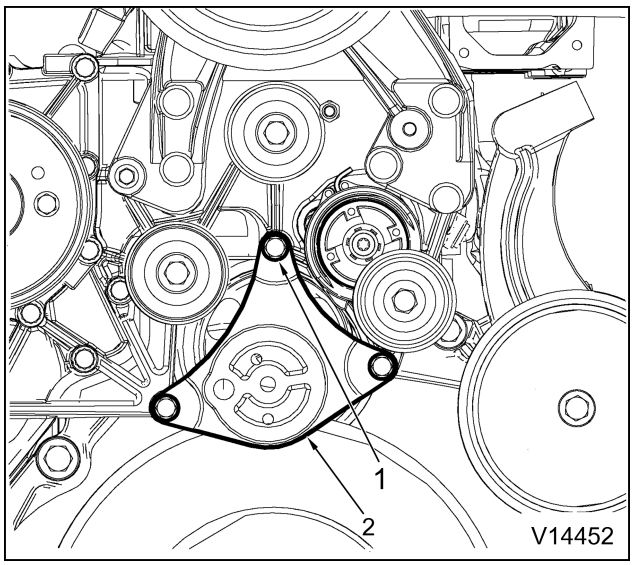

Figure 497 Tensioner bracket

1. M8 x 30 bolt (3)
2. Tensioner bracket

2. Remove three M8 x 30 bolts and tensioner bracket.

High Mount Fan Drive

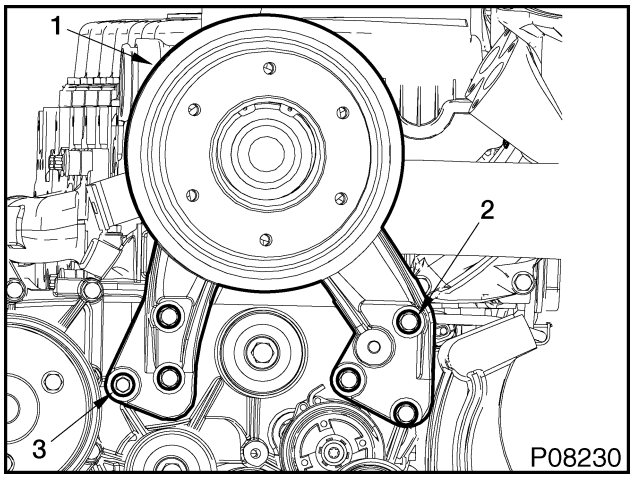

Figure 498 Fan drive clutch assembly (typical)

1. Fan drive clutch assembly
2. M10 x 150 - 12.9 bolt (5)
3. M10 x 65 bolt

1. Disconnect air line from back of fan drive clutch assembly.
2. Remove five M10 x 150 - 12.9 bolts and M10 x 65 bolt. Remove fan drive clutch.
3. Discard six M10 bolts.

Coolant Outlet Manifold and Thermostat Assembly

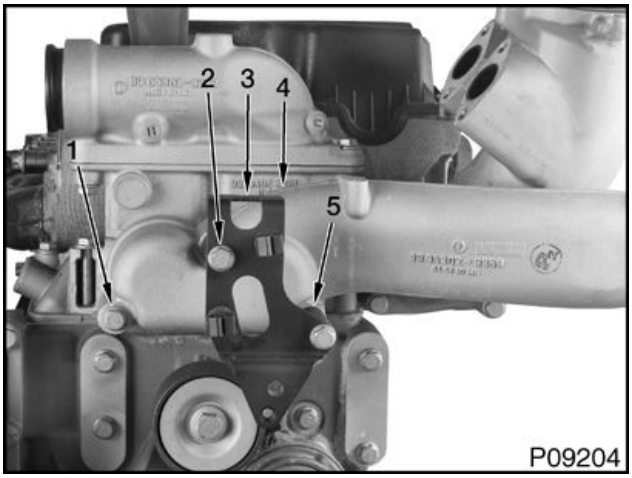

Figure 499 Coolant outlet manifold (low mount fan)

1. M8 x 70 bolt
2. M8 x 130 bolt (2)
3. Fan coupling bracket
4. Coolant outlet manifold
5. Bushing (2)

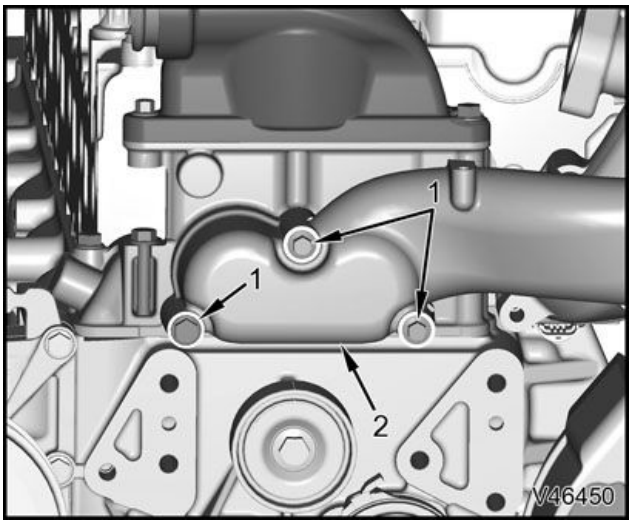

Figure 500 Coolant outlet manifold (high mount fan)

1. M8 x 70 bolt (3)
2. Coolant outlet manifold

1. Remove coolant outlet manifold bolts as follows.
   a. If equipped with low mount fan, remove M8 x 70 bolt, two M8 x 130 bolts, bracket and two bushings.
   b. If equipped with high mount fan, remove three M8 x 70 bolts.
2. Remove coolant outlet manifold.

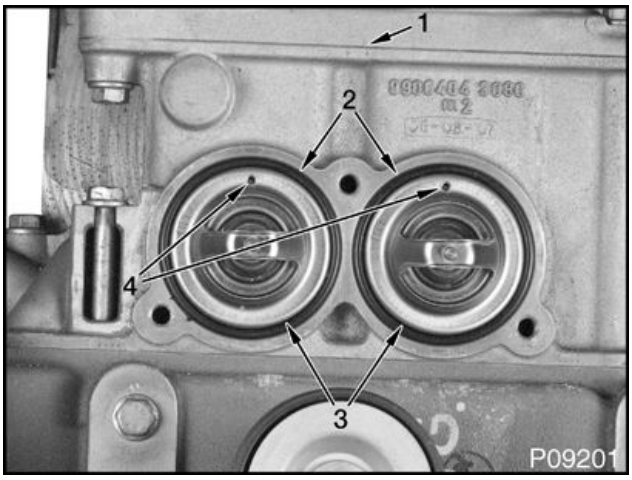

Figure 501 Thermostat assembly

1. Thermostat housing
2. Seals (part of thermostat assembly) (2)
3. Thermostat assembly (2)
4. Ball valves (part of thermostat assembly)

3. Remove two thermostat assemblies from thermostat housing.

Automatic Belt Tensioner and Idler Pulleys

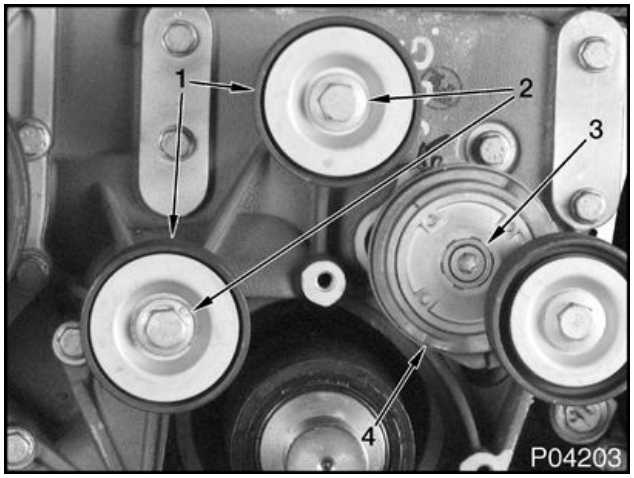

Figure 502 Automatic belt tensioner and idler pulleys (typical)

1. Idler pulley (2)
2. M12 x 55 bolt (2)
3. M10 x 70 countersunk screw
4. Automatic belt tensioner

1. Remove two M12 x 55 bolts and idler pulleys.

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.

Water Pump Assembly and Pulley

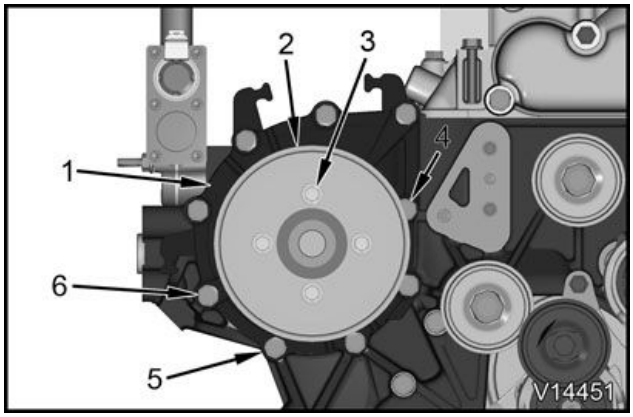

Figure 503 Water pump assembly and pulley

1. Water pump assembly
2. Water pump pulley
3. M8 x 16 bolt (4)
4. M8 x 130 bolt
5. M8 x 150 bolt
6. M8 x 40 bolt (7)

1. Remove four M8 x 16 bolts and water pump pulley.

NOTE: If the oil module is removed, the M8 x 150 bolt is also removed.

2. Remove M8 x 130, M8 x 150 and seven M8 x 40 bolts.

CAUTION: To prevent engine damage, do not drop water pump impeller or hit impeller with hard objects.

3. Remove water pump assembly and discard water pump gasket.

Vibration Damper

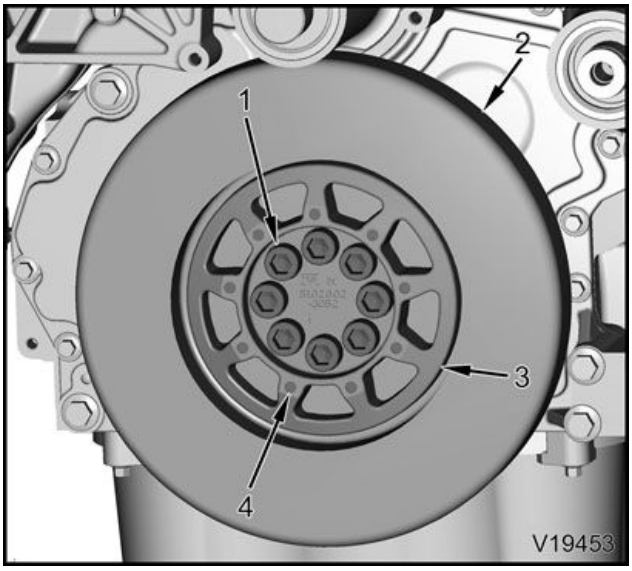

Figure 504 Vibration damper (low mount fan with damper hub)

1. M16 x 85 socket-head cap screw (8)
2. Vibration damper
3. Damper hub
4. M10 x 35 bolt (9)

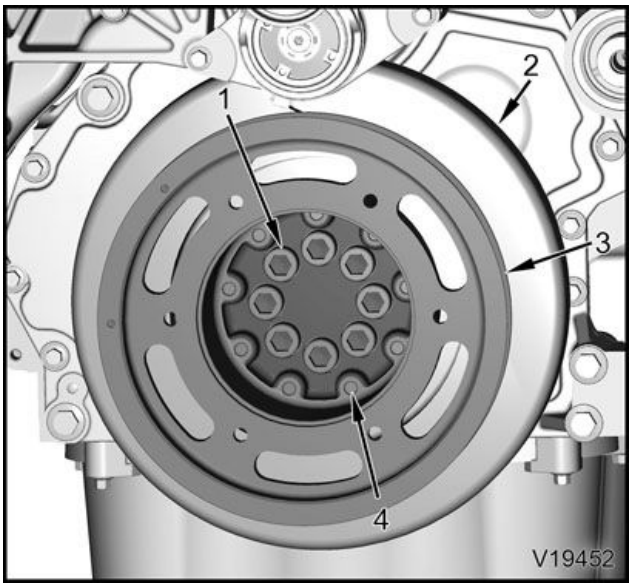

Figure 505 Vibration damper (high mount fan with fan drive pulley)

1. M16 x 85 socket-head cap screw (8)
2. Vibration damper
3. Fan drive pulley
4. M10 x 35 bolt (9)

WARNING: To prevent personal injury or death, support the vibration damper when removing bolts. The damper can easily slide off the crankshaft.

NOTE: If equipped with high mount fan, remove fan drive pulley and vibration damper together. If equipped with low mount fan, remove damper hub and vibration damper together.

1. Remove eight M16 x 85 socket-head cap screws.
2. Remove vibration damper with damper hub or fan drive pulley as an assembly.
3. For vibration damper replacement only, remove damper hub or fan drive pulley by removing nine M10 x 35 bolts.

Coolant Control Valve (CCV) Assembly

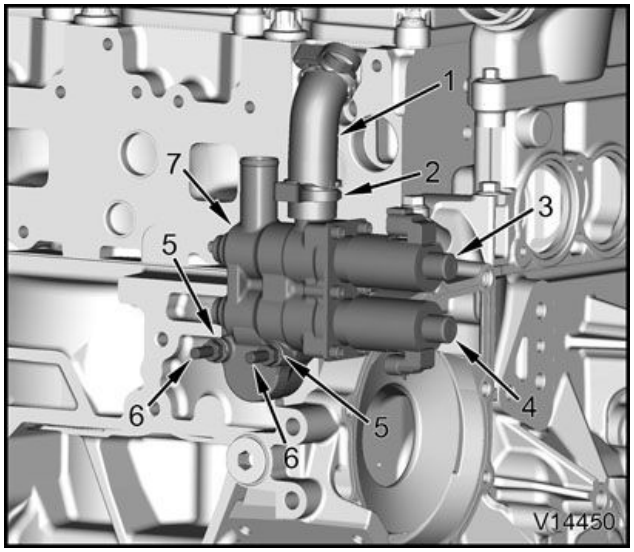

Figure 506 CCV assembly

1. Low temperature hose assembly
2. Hose clamp (spring type)
3. Coolant Mixer Valve (CMV)
4. Coolant Flow Valve (CFV)
5. Lock washer (2)
6. M8 x 60 stud bolt (2)
7. CCV assembly

1. Release hose clamp (spring type) and remove low temperature hose assembly from CCV assembly.
2. Remove two M8 x 60 stud bolts, two lock washers, CCV assembly and O-ring. Discard O-ring.

Thermostat Housing

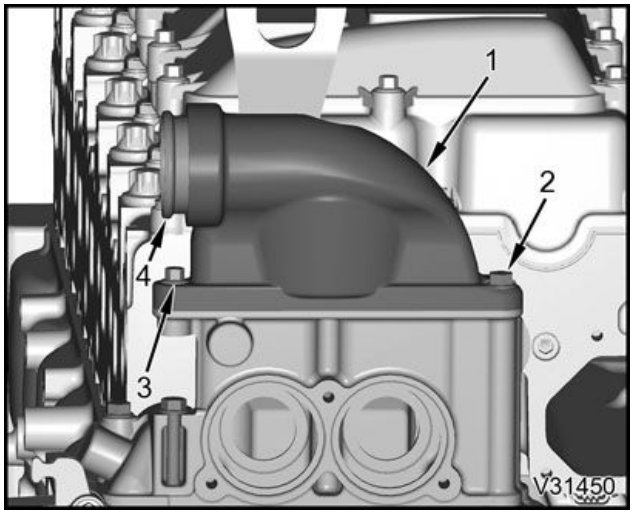

Figure 507 EGR cooler return manifold

1. EGR cooler return manifold
2. M8 x 145 bolt (4)
3. M8 x 30 bolt
4. Extension tube (DMR62 / 51)

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

1. Remove extension tube (DMR62 / 51) from manifold. Inspect extension tube for damage, replace as needed.
2. Remove four M8 x 145 bolts and one M8 x 30 bolt.
3. Remove EGR cooler return manifold and discard gasket.

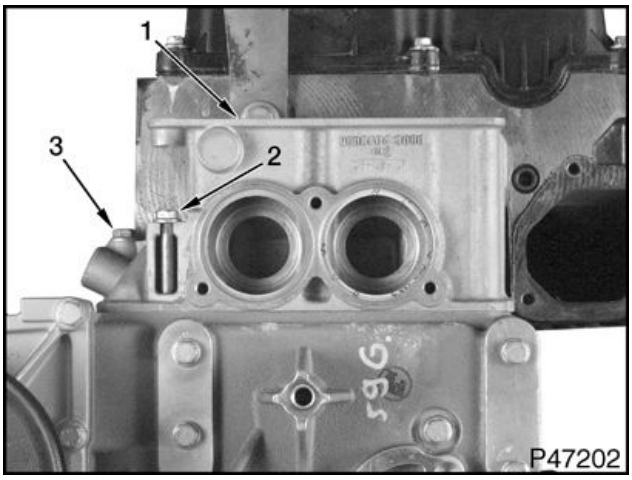

Figure 508 Thermostat housing

1. Thermostat housing
2. M8 x 75 bolt
3. M8 x 60 bolt

4. Remove M8 x 75 bolt and M8 x 60 bolt.
5. Remove thermostat housing and discard gasket.

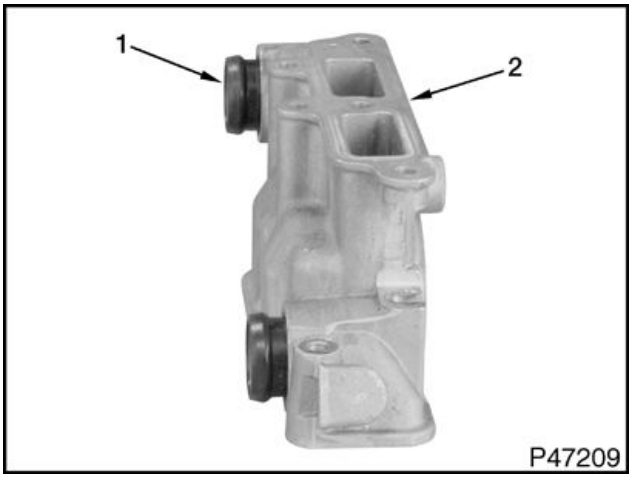

Figure 509 Thermostat housing

1. Extension tube (DMR40 / DN32F) (2)
2. Thermostat housing

CAUTION: To prevent engine damage, do not remove extension tubes by grabbing sealing surface with pliers or other tools that can mar the surface.

6. Remove two extension tubes (DMR40 / DN32F) from thermostat housing using a wood-handled tool. Gently pry the extension tubes out until removed. Inspect extension tubes for damage, replace as needed.

Water Distribution Housing

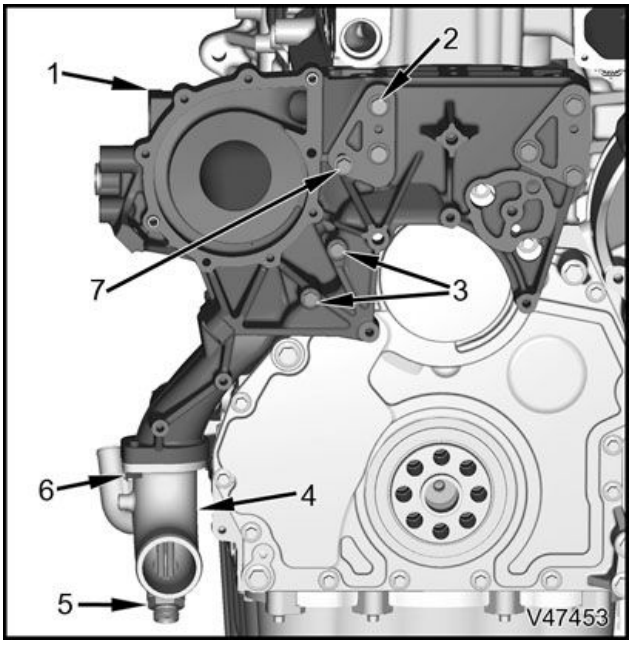

Figure 510 Water distribution housing

1. Water distribution housing
2. M10 x 110 bolt with low mount fan drive or M10 x 150 - 12.9 bolt with high mount fan drive (5)
3. M8 x 150 bolt (2)
4. Engine water inlet (94°)
5. Coolant heater
6. M10 x 30 bolt (2)
7. M10 x 65 bolt (only with high mount fan)

1. Remove two M8 x 150 bolts.
   - If equipped with low mount fan drive, five M10 x 110 bolts.
   - If equipped with high mount fan drive, five M10 x 150 - 12.9 bolts and one M10 x 65 bolt. (These bolts are removed with high mount fan drive clutch assembly removal.)
2. Remove water distribution housing and discard gasket.

3. Remove two M10 x 30 bolts and separate engine water inlet from water distribution housing. Remove and discard gasket.
4. Remove coolant heater from engine water inlet as needed.

Front Belt- or Gear-Driven Fan Cover Radial Shaft Seal

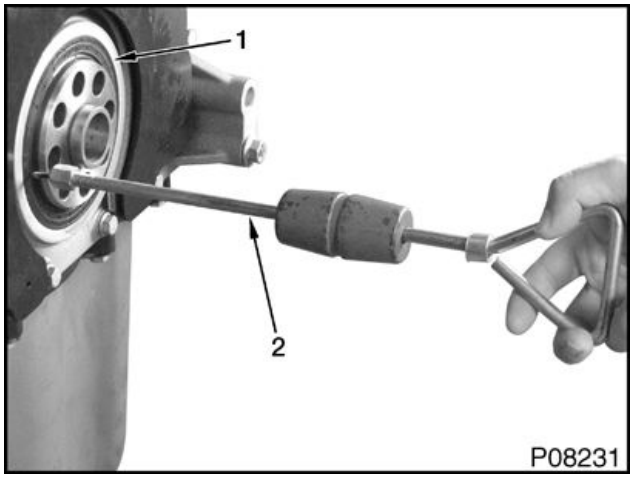

Figure 511 Radial shaft seal removal

1. Radial shaft seal
2. Slide hammer

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 382) 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.

Front Belt- or Gear-Driven Fan Cover

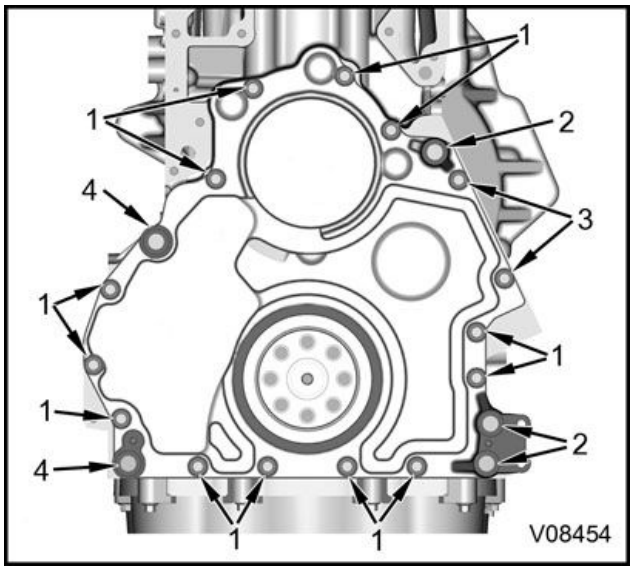

Figure 512 Front belt- or gear-driven fan cover bolts (high mount cover shown)

1. M8 x 25 bolt (13)
2. M12 x 75 bolt (3)
3. M8 x 40 bolt (2)
4. M12 x 30 bolt (2)

WARNING: To prevent personal injury or death, use a suitable lifting device and get help when removing, lowering and installing the front cover.

1. Remove two M8 x 40 bolts, two M12 x 30 bolts, three M12 x 75 bolts and 13 M8 x 25 bolts.
2. Remove front belt- or gear-driven fan cover and front cover gasket from crankcase dowels. Discard front cover gasket.

Radial Shaft Seal (Fan Low Mount Drive)

WARNING: To prevent personal injury or death, wear safety glasses with side shields.

1. With an awl and hammer, punch two holes 180° apart in radial shaft seal.

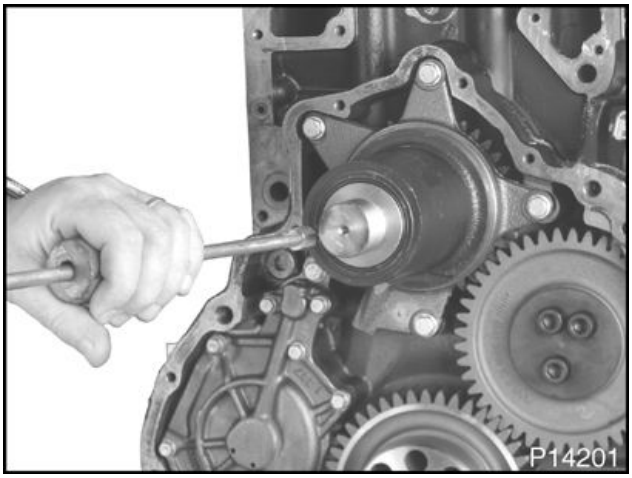

Figure 513 Radial shaft seal removal

2. Thread a slide hammer (page 382) 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.

Fan Low Mount Drive Assembly

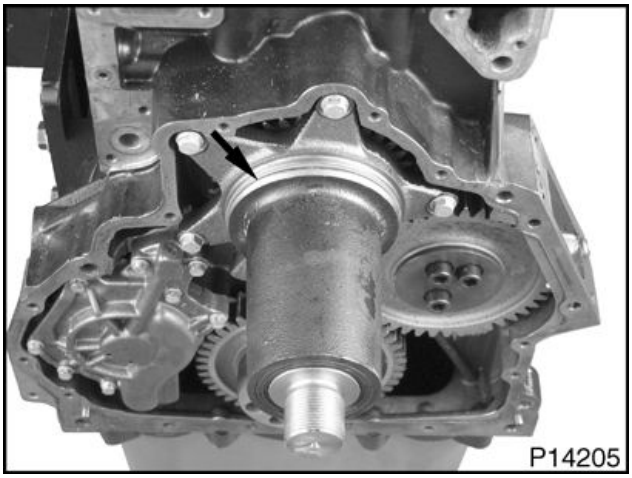

Figure 514 O-ring 108 x 3

1. Remove and discard O-ring 108 x 3.

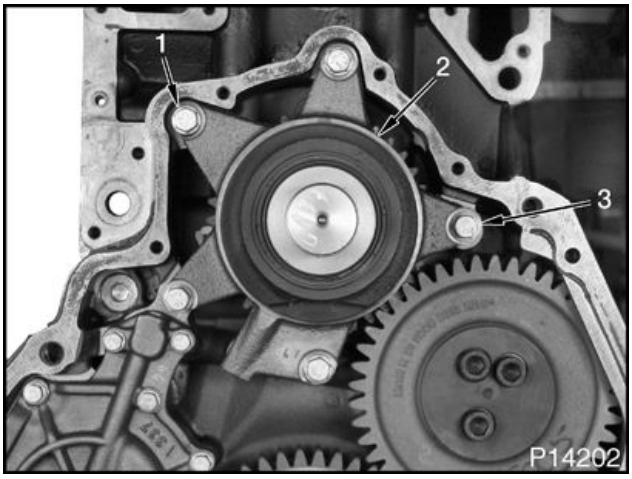

Figure 515 Fan low mount drive assembly

1. M8 x 25 bolt (4)
2. Fan low mount drive assembly
3. M8 x 40 bolt

2. Remove four M8 x 25 bolts, one M8 x 40 bolt and fan low mount drive assembly.

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 water distribution housing, water pump, coolant outlet manifold, thermostat housing and front belt- or gear-driven fan 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, water distribution housing, water pump assembly, coolant outlet manifold, thermostat housing and front belt- or gear-driven fan cover.
4. Inspect water distribution housing, coolant outlet manifold, vibration damper and front belt- or gear-driven fan cover for damage, contamination or excessive wear. Replace parts if required.
5. Inspect belt automatic tensioners and pulleys to make sure tensioner arms and pulleys are properly in line with the fan drive belt and accessory drive belt and not coming apart. Make sure tensioner arms are not binding and pulley bearings are not loose. Replace belt tensioners if required.
6. Inspect idler pulleys to make sure pulleys are properly in line with the fan drive belt and accessory drive belt and not coming apart. Replace idler pulleys if required.
7. Inspect thermostat assemblies. If thermostat assembly elements are stuck open, damaged, cracked or not opening properly, replace thermostat assemblies.
8. Inspect water pump assembly. Wiggle water pump assembly hub and shaft. If water pump assembly bearing has excess play, replace water pump assembly. Inspect water distribution housing and water pump assembly for coolant leaks. Replace if leaking.

Installation

Fan Low Mount Drive Assembly

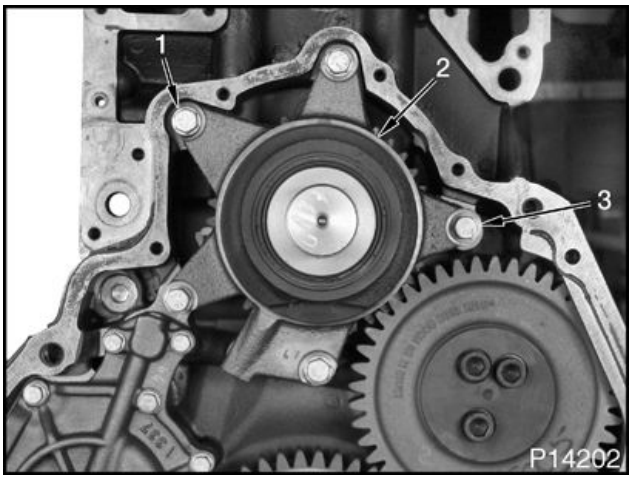

Figure 516 Fan low mount drive assembly

1. M8 x 25 bolt (4)
2. Fan low mount drive assembly
3. M8 x 40 bolt

1. Install fan low mount drive, M8 x 40 bolt and four M8 x 25 bolts. Tighten bolts to standard torque (page 547).

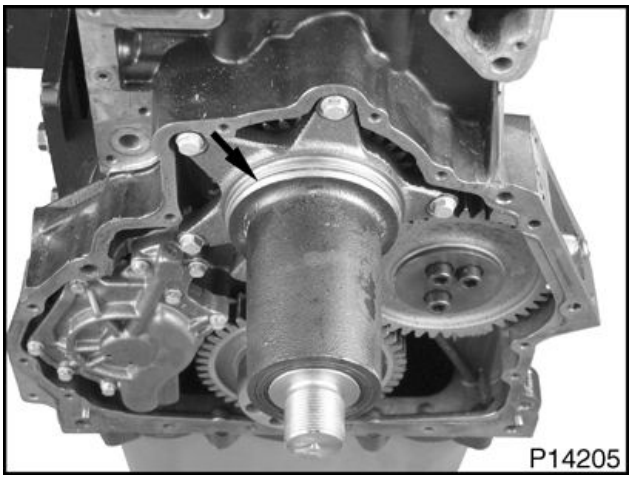

Figure 517 O-ring 108 x 3

2. Lubricate new O-ring 108 x 3 with clean engine oil and install on fan low mount drive assembly.

Radial Shaft Seal (Fan Low Mount Drive)

1. Lubricate radial shaft seal with clean engine oil.

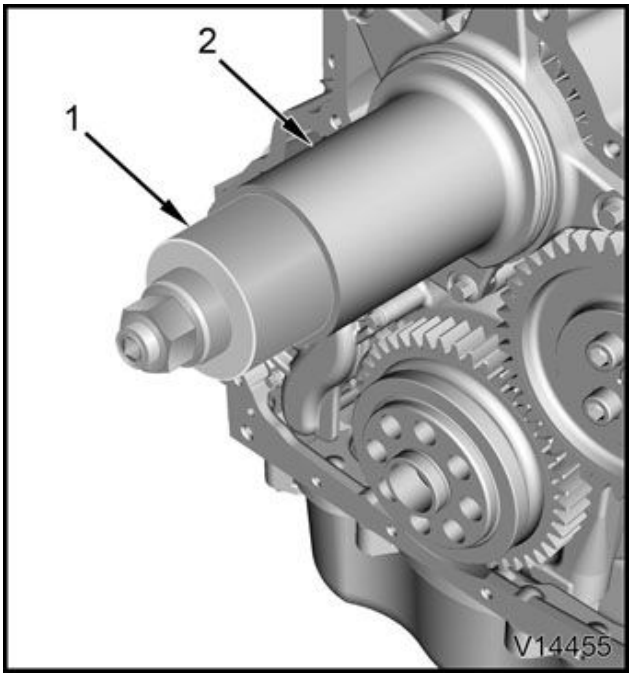

Figure 518 Radial shaft seal installation

1. Fan Seal Installer
2. Fan low mount drive assembly

2. Using Fan Seal Installer (page 382), install new radial shaft seal until fully seated.

Front Belt- or Gear-Driven Fan Cover

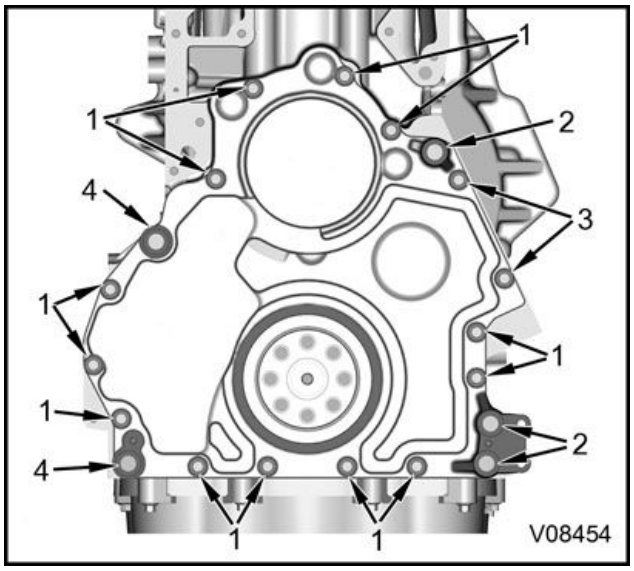

Figure 519 Front belt- or gear-driven fan cover bolts (typical)

1. M8 x 25 bolt (13)
2. M12 x 75 bolt (3)
3. M8 x 40 bolt (2)
4. M12 x 30 bolt (2)

WARNING: To prevent personal injury or death, use a suitable lifting device and get help when removing, lowering and installing the front cover.

1. Position a new front cover gasket on crankcase dowels.
2. Install front cover on crankcase dowels.
3. Install two M8 x 40 bolts, two M12 x 30 bolts, three M12 x 75 bolts and 13 M8 x 25 bolts in locations shown. Tighten M8 bolts to standard torque (page 547). Tighten M12 bolts to special torque (page 382).

Front Belt- or Gear-Driven Fan Cover Radial Shaft Seal

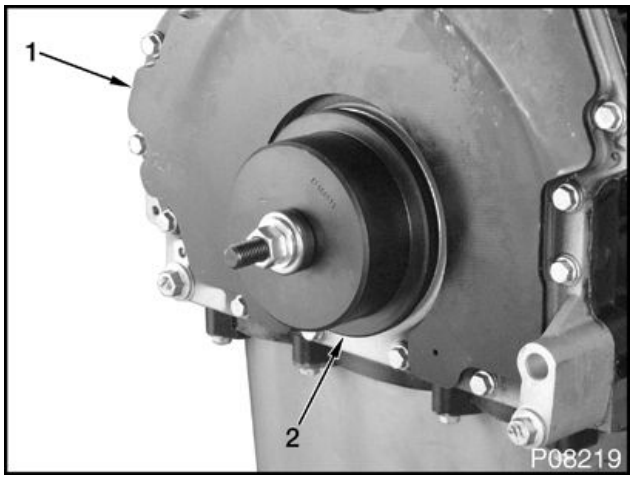

Figure 520 Radial shaft seal installation (typical)

1. Front belt- or gear-driven fan 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 382), install a new radial shaft seal into the front cover.
   a. Install inner hub of tool to crankshaft flange. Use two bolts provided to secure 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.

Water Distribution Housing

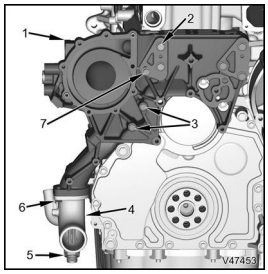

Figure 521 Water distribution housing

1. Water distribution housing
2. M10 x 110 bolt with low mount fan drive or M10 x 150 bolt - 12.9 with high mount fan drive (5)
3. M8 x 150 bolt (2)
4. Engine water inlet (94°)
5. Coolant heater
6. M10 x 30 bolt (2)
7. M10 x 65 bolt (only with high mount fan)

1. Install coolant heater into engine water inlet as needed. Tighten to special torque (page 382).
2. Install new gasket and install engine water inlet and two M10 x 30 bolts to water distribution housing. Tighten bolts to special torque (page 382).
3. Lubricate a new water distribution housing gasket with clean coolant and install into water distribution housing.
4. Install water distribution housing and secure as follows:
   - If equipped with low mount fan drive, use five M10 x 110 bolts.
   - If equipped with high mount fan drive, use five M10 x 150 - 12.9 bolts and one M10 x 65 bolt. (These bolts are installed with high mount fan drive clutch assembly installation.)

   Tighten low mount fan drive bolts to special torque (page 382).

Thermostat Housing

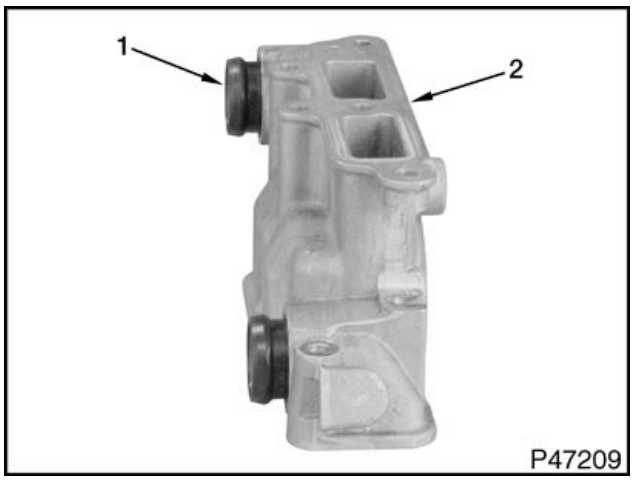

Figure 522 Thermostat housing

1. Extension tube (DMR40 / DN32F) (2)
2. Thermostat housing

1. Lubricate sealing surfaces of two extension tubes (DMR40 / DN32F) with P-80® rubber lubricant or equivalent (page 382) and install into thermostat housing using Extension Tube Installer Small (page 382).

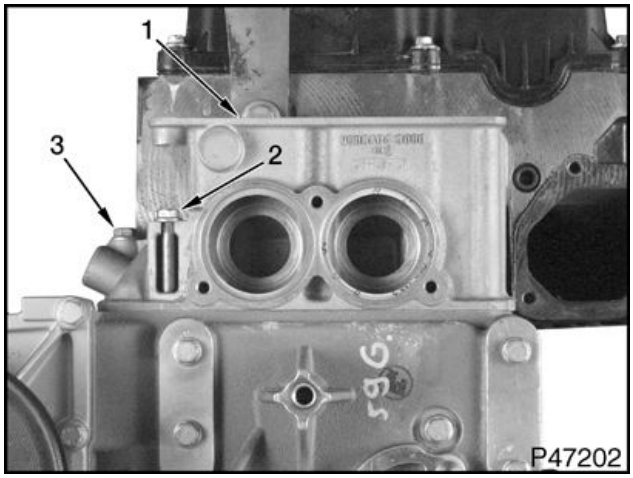

Figure 523 Thermostat housing

1. Thermostat housing
2. M8 x 75 bolt
3. M8 x 60 bolt

2. Install new gasket and thermostat housing.

3. Install M8 x 75 bolt and M8 x 60 bolt. Do not tighten bolts until EGR cooler return manifold is installed.

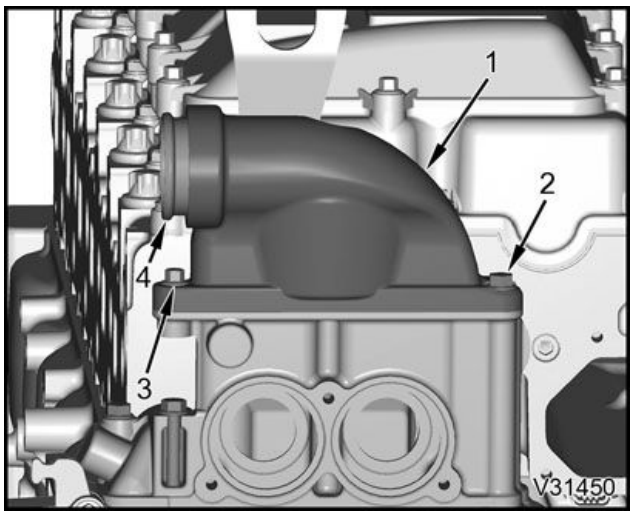

Figure 524 EGR cooler return manifold

1. EGR cooler return manifold
2. M8 x 145 bolt (4)
3. M8 x 30 bolt
4. Extension tube (DMR62 / 51)

4. Install new thermostat housing gasket and EGR cooler return manifold.
5. Install four M8 x 145 bolts and one M8 x 30 bolt. Tighten bolts to special torque (page 382).
6. Tighten M8 x 75 and M8 x 60 thermostat housing bolts to standard torque (page 547).
7. Lubricate sealing surfaces of extension tube (DMR62 / 51) with P-80® rubber lubricant or equivalent (page 382) and install into EGR cooler return manifold using Extension Tube Installer Large (page 382).

Coolant Control Valve (CCV) Assembly

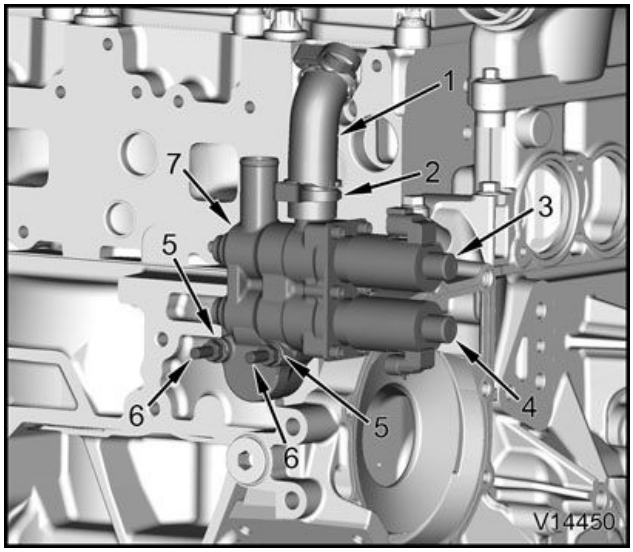

Figure 525 CCV assembly

1. Low temperature EGR hose assembly
2. Hose clamp (spring type)
3. Coolant Mixer Valve (CMV)
4. Coolant Flow Valve (CFV)
5. Lock washer (2)
6. M8 x 60 stud bolt (2)
7. CCV assembly

1. Install a new O-ring on the CCV assembly.
2. Install CCV assembly, two lock washers and two M8 x 60 stud bolts. Tighten stud bolts to special torque (page 382).
3. Install low temperature hose assembly and secure with hose clamp (spring type).

Vibration Damper

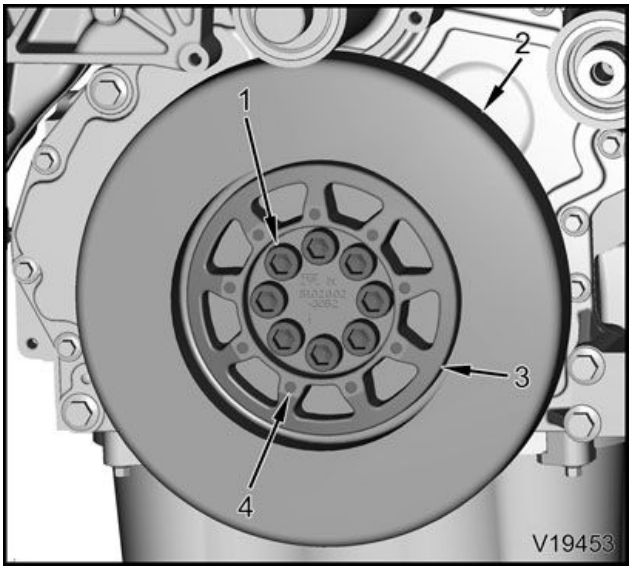

Figure 526 Vibration damper (low mount fan with damper hub)

1. M16 x 85 socket-head cap screw (8)
2. Vibration damper
3. Damper hub
4. M10 x 35 bolt (9)

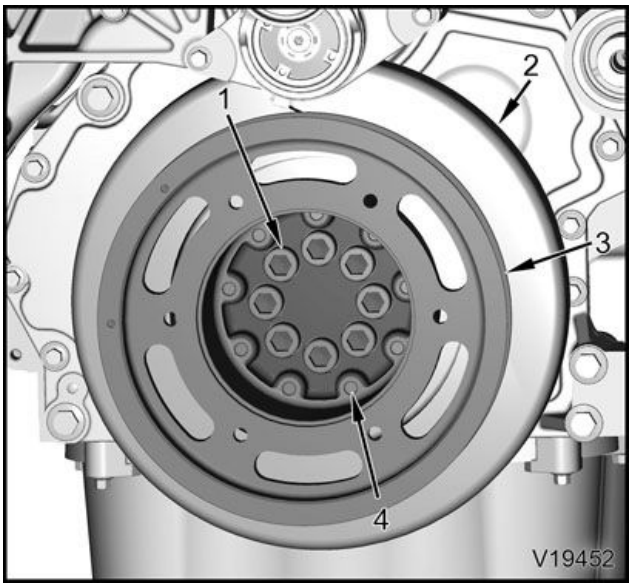

Figure 527 Vibration damper (high mount fan with fan drive pulley)

1. M16 x 85 socket-head cap screw (8)
2. Vibration damper
3. Fan drive pulley
4. M10 x 35 bolt (9)

NOTE: Install damper hub or fan drive pulley and vibration damper together as an assembly.

1. If previously disassembled, assemble damper hub or fan drive pulley to vibration damper with nine M10 x 35 bolts. Tighten bolts to special torque (page 382).
2. Install vibration damper assembly.
3. Install eight M16 x 85 socket-head cap screws. Using a crisscross pattern, tighten screws as follows.
   a. Tighten socket-head cap screws to 150 N·m (111 lb·ft).
   b. Angle-tighten socket-head cap screws an additional 90°.

Water Pump Assembly and Pulley

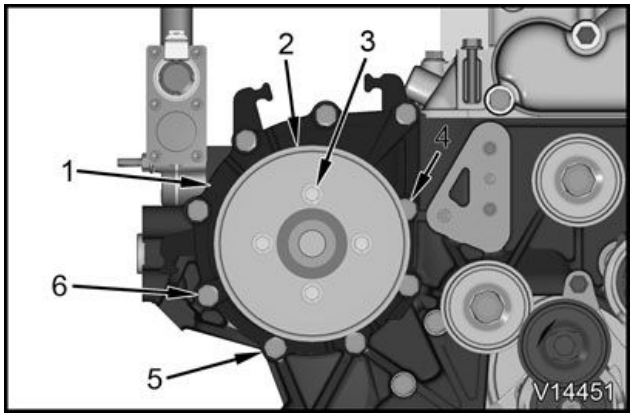

Figure 528 Water pump assembly and pulley

1. Water pump assembly
2. Water pump pulley
3. M8 x 16 bolt (4)
4. M8 x 130 bolt
5. M8 x 150 bolt
6. M8 x 40 bolt (7)

NOTE: If the oil module is removed, the M8 x 150 bolt is installed along with oil module.

1. Lubricate a new water pump gasket with clean coolant and install onto water pump.
2. Install water pump and secure with one M8 x 130, one M8 x 150 and seven M8 x 40 bolts in location shown. Tighten M8 bolts to special torque (page 382).
3. Install water pump pulley and four M8 x 16 bolts. Tighten bolts to special torque (page 382).

Automatic Belt Tensioner and Idler Pulley

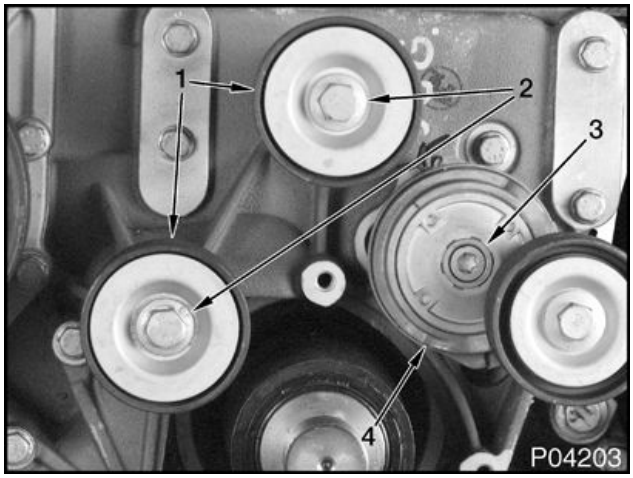

Figure 529 Automatic belt tensioner and idler pulley (typical)

1. Idler pulley (2)
2. M12 x 55 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 382).
2. Install two idler pulleys and two M12 x 55 bolts. Tighten bolts to special torque (page 382).

Coolant Outlet Manifold and Thermostat Assembly

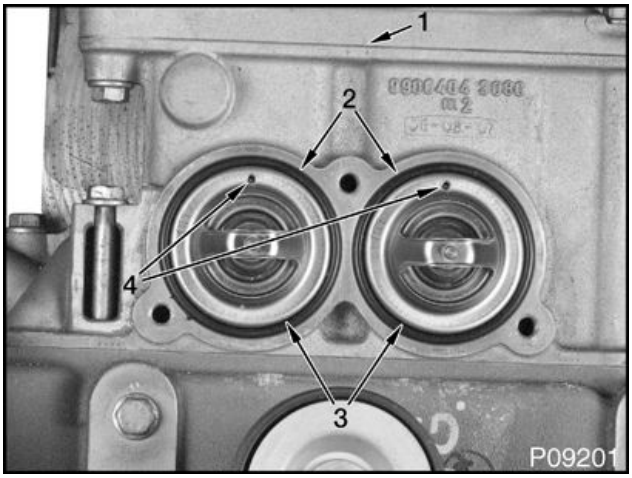

Figure 530 Thermostat assembly

1. Thermostat housing
2. Seals (part of thermostat assembly) (2)
3. Thermostat assembly (2)
4. Ball valves (part of thermostat assembly)

1. Install two thermostat assemblies into thermostat housing with ball valves at 12 o'clock position.

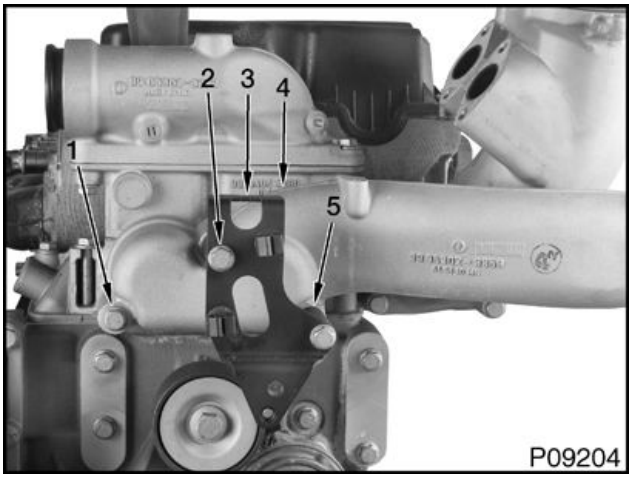

Figure 531 Coolant outlet manifold (low mount fan)

1. M8 x 70 bolt
2. M8 x 130 bolt (2)
3. Fan coupling bracket
4. Coolant outlet manifold
5. Bushing (2)

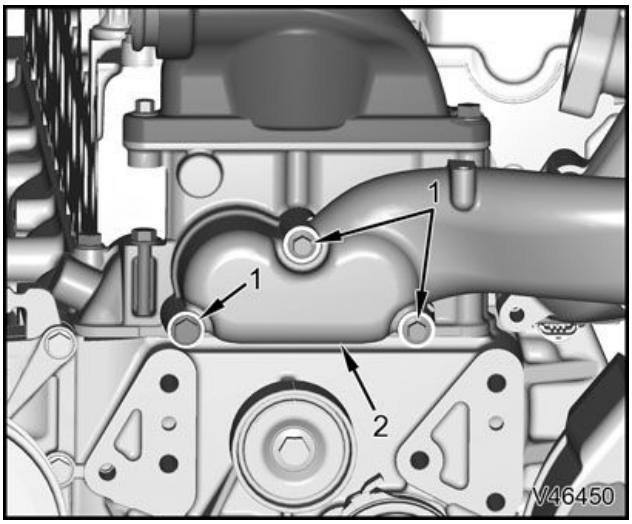

Figure 532 Coolant outlet manifold (high mount fan)

1. M8 x 70 bolt (3)
2. Coolant outlet manifold

2. Install coolant outlet manifold.
3. If equipped with low mount fan, install bracket and two bushings.
4. Install coolant outlet manifold bolts as follows.
   a. If equipped with low mount fan, install one M8 x 70 bolt and two M8 x 130 bolts. Tighten bolts to special torque (page 382).
   b. If equipped with high mount fan, install three M8 x 70 bolts. Tighten bolts to special torque (page 382).

High Mount Fan Drive

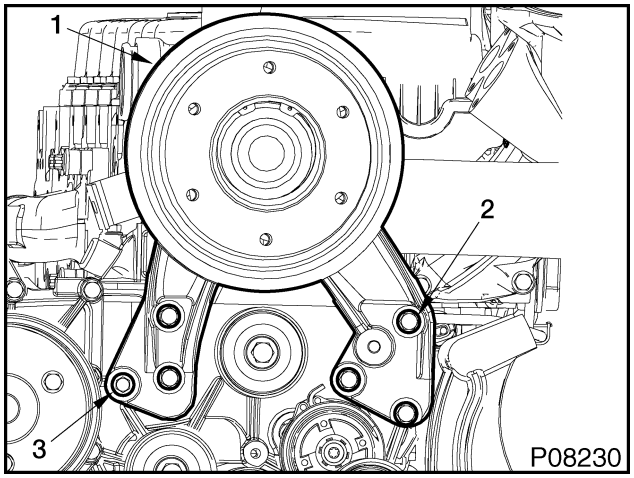

Figure 533 Fan drive clutch assembly (typical)

1. Fan drive clutch assembly
2. M10 x 150 - 12.9 bolt (5)
3. M10 x 65 bolt

CAUTION: To prevent engine damage, clean and blow dry crankcase bolt holes with filtered compressed air. Debris or fluids in bolt holes may cause binding and incorrect bolt torque.

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

1. Using filtered compressed air, clean thread holes of fan drive clutch assembly.
2. Install fan drive clutch assembly and five new M10 x 150 - 12.9 and one new M10 x 65 bolt with engine oil lightly applied to threads.

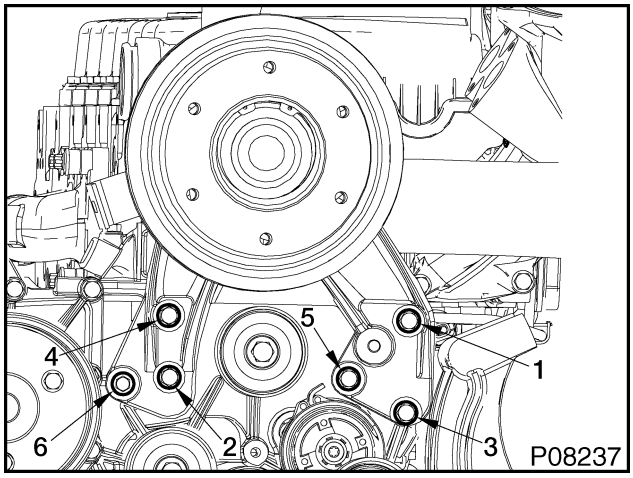

Figure 534 High mount fan drive bolt tightening sequence

3. Tighten M10 bolts using sequence indicated above as follows.
   a. Tighten six M10 bolts to 37 N·m (27 lb·ft).
   b. Re-tighten six bolts to 37 N·m (27 lb·ft).
   c. Angle-tighten five M10 x 150 - 12.9 bolts an additional 90° in sequence.
   d. Tighten M10 x 65 bolt to 62 N·m (46 lb·ft).
4. Connect air line to back of fan drive clutch assembly.

Tensioner Bracket (High Mount Fan)

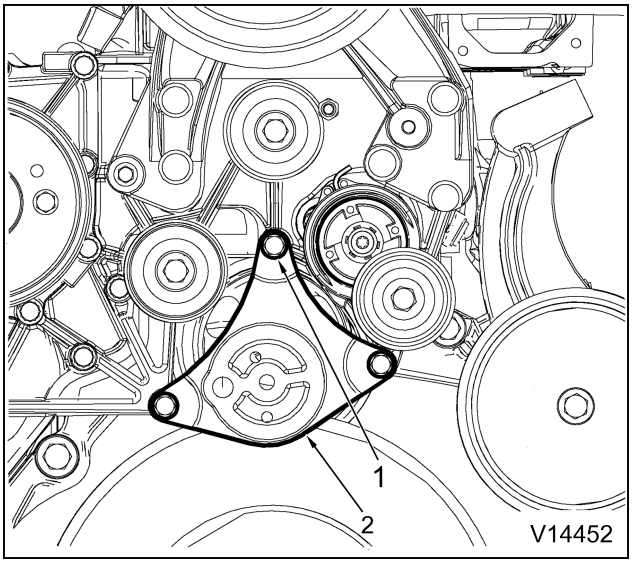

Figure 535 Tensioner bracket

1. M8 x 30 bolt (3)
2. Tensioner bracket

1. Install tensioner bracket and three M8 x 30 bolts. Tighten bolts to standard torque (page 547).

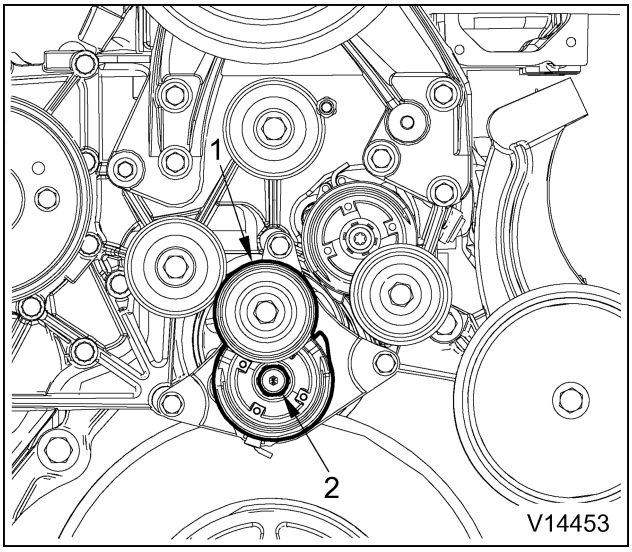

Figure 536 Fan drive tensioner assembly (high mount)

1. Fan drive tensioner assembly
2. M10 x 70 countersunk screw

2. Install fan drive tensioner and M10 x 70 countersunk screw. Make sure locating pin is placed into locating hole. Tighten countersunk screw to special torque (page 382).

Pulley (High Mount Fan)

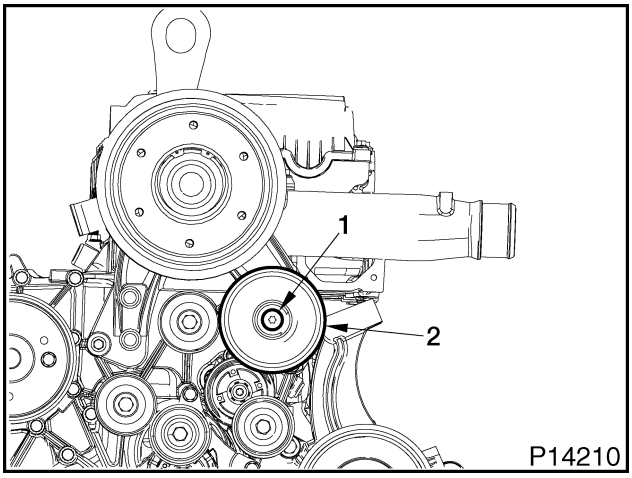

Figure 537 Pulley assembly

1. Shoulder bolt
2. Pulley assembly

1. Install pulley assembly and shoulder bolt. Tighten shoulder bolt to special torque (page 382).

Special Torque

Automatic belt tensioner countersunk screw, M10 x 70	47 N·m (35 lb·ft)
CCV assembly stud bolts (with lock washers), M8 x 60	35 N·m (26 lb·ft)
Coolant heater	41 N·m (30 lb·ft)
Coolant outlet manifold bolts, M8	35 N·m (26 lb·ft)
Damper hub and fan drive pulley bolts to vibration damper, M10 x 35	45 N·m (33 lb·ft)
EGR cooler return manifold bolts, M8	35 N·m (26 lb·ft)
Engine water inlet bolts, M10 x 30	29 N·m (21 lb·ft)
Front belt- or gear-driven fan cover bolts,	
• M12 x 75	115 N·m (85 lb·ft)
• M12 x 30	115 N·m (85 lb·ft)
High mount fan drive clutch assembly bolts, M10	See tightening steps in procedure
High mount fan drive tensioner countersunk screw, M10 x 70	47 N·m (35 lb·ft)
High mount fan pulley assembly shoulder bolt	62 N·m (46 lb·ft)
Idler pulley bolt, M12 x 55	60 N·m (44 lb·ft)
Low mount fan drive bolt, M10 x 110	37 N·m (27 lb·ft)
Vibration damper socket-head cap screws, M16 x 85	See tightening steps in procedure
Water distribution housing bolts, M8	35 N·m (26 lb·ft)
Water pump assembly bolts, M8	35 N·m (26 lb·ft)
Water pump pulley bolts, M8 x 16	17 N·m (13 lb·ft)

Special Service Tools

Description	Tool Number
Extension Tube Installer Large	ZTSE6046
Extension Tube Installer Small	ZTSE6047
Fan Seal Installer	ZTSE6066
Front Crankshaft Seal Installer	ZTSE4873
P-80® rubber lubricant or equivalent	Obtain locally
Slide hammer	Obtain locally

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Exploded Views

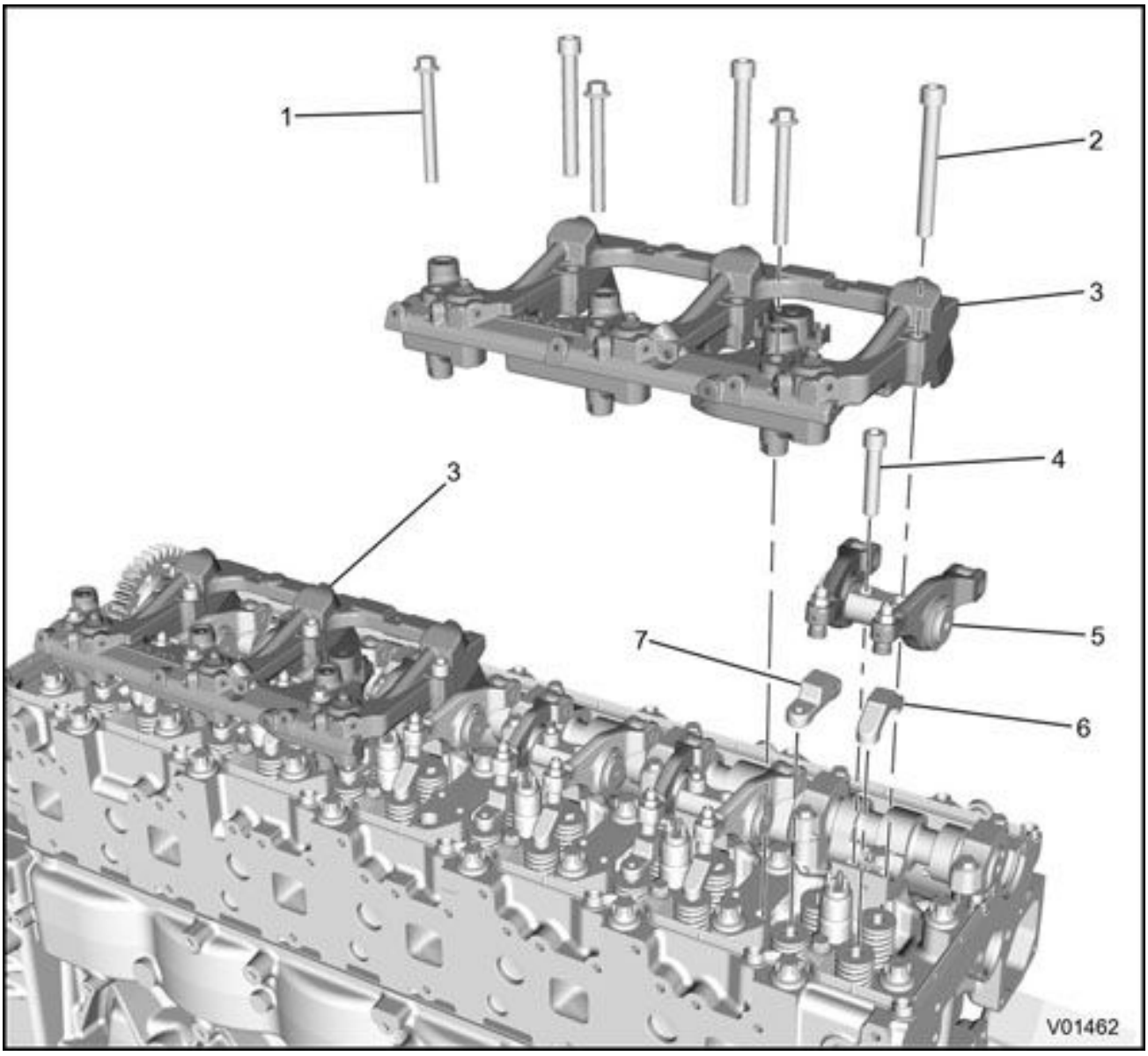

Figure 538 Navistar® N13 engine brake assembly installation

1. M10 x 90 bolt (6)
2. M12 x 100 (socket-head) screw (6)
3. Engine brake housing assembly (2)
4. M12 x 60 (socket-head) screw (6)
5. Intake and exhaust rocker arm assembly (6)
6. Valve bridge (intake) (6)
7. Valve bridge (exhaust) (6)

Navistar® N13 Engine Brake Housing Assembly

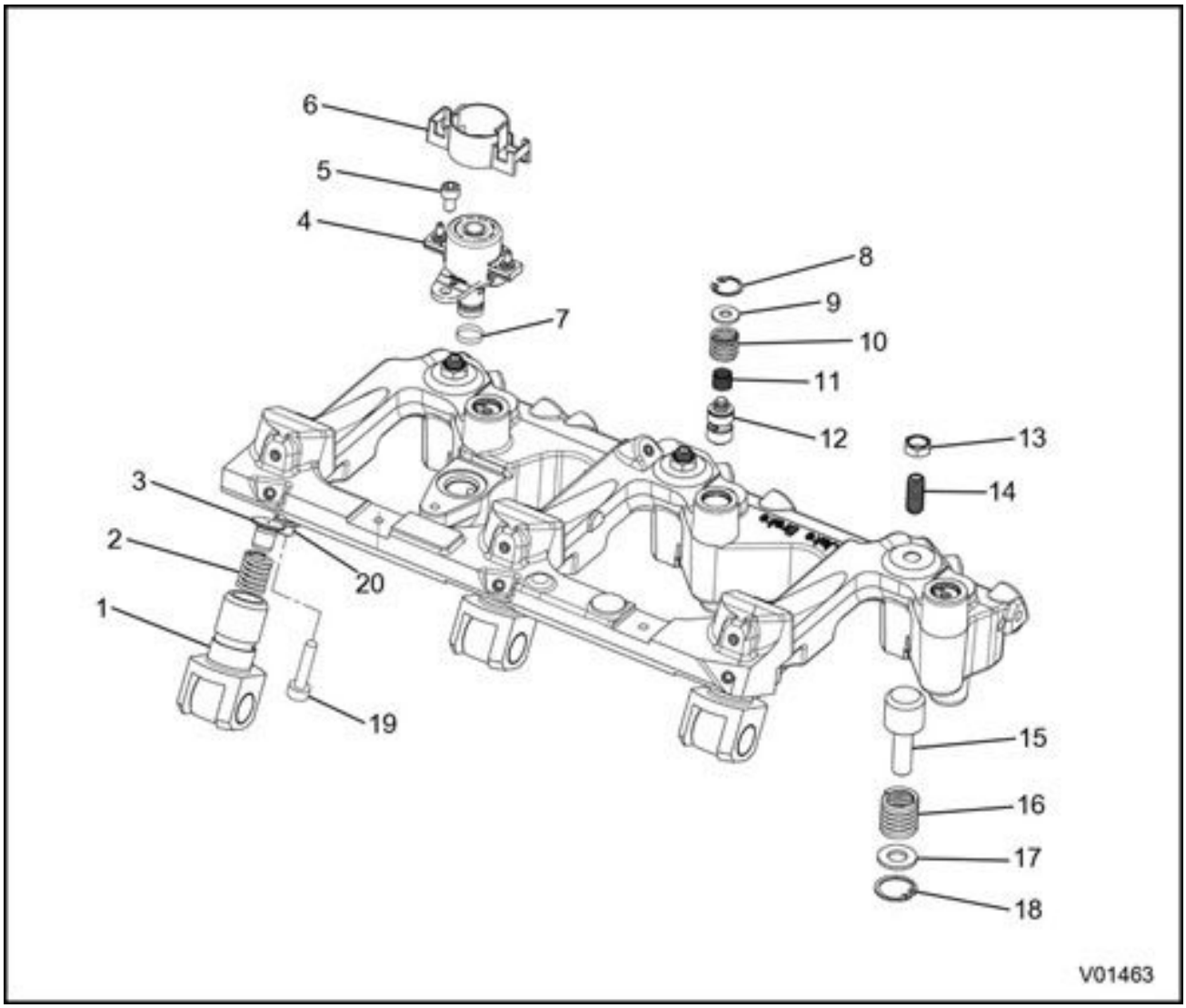

Figure 539 Navistar® N13 engine brake housing assembly

1. Master piston roller assembly
2. Master piston roller spring
3. Master piston spring guide
4. Solenoid assembly
5. M6 x 10 socket-head cap screw
6. Solenoid cover
7. Solenoid screen
8. Control valve retaining ring
9. Control valve cover
10. Outer spring
11. Inner spring
12. Control valve assembly
13. M10 (jam) nut
14. Slave piston adjusting screw
15. Slave piston
16. Slave piston spring
17. Slave piston washer
18. Slave piston retaining ring
19. M6 x 30 master piston guide bolt
20. Master piston guide sleeve

Engine Injector Wiring Harness With Engine Brake Solenoid Leads

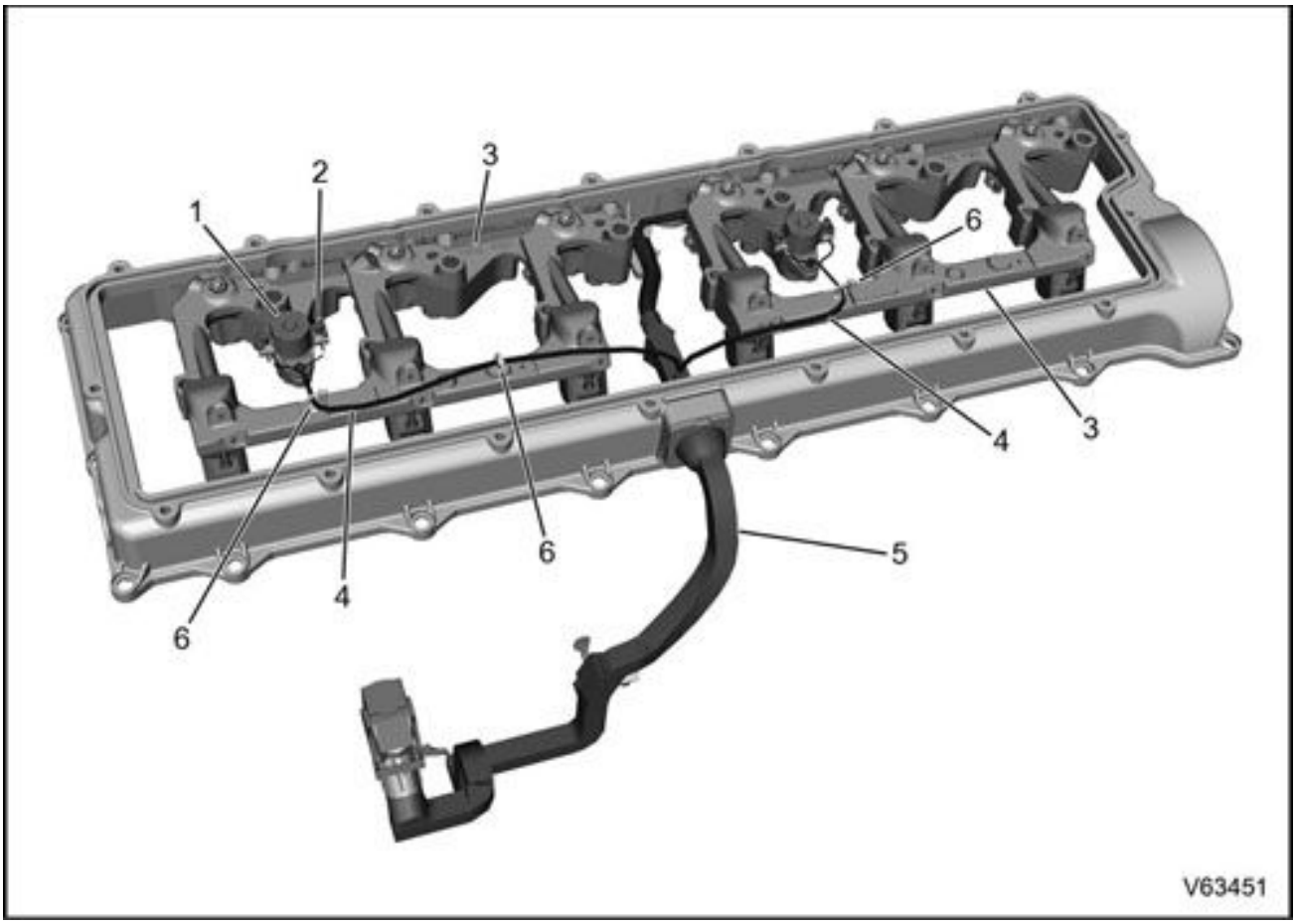

Figure 540 Engine injector wiring harness with engine brake solenoid leads

1. Solenoid assembly (2)
2. Solenoid connector nut (part of harness connector) (4)
3. Engine brake assembly (2)
4. Engine brake solenoid harness connector lead (2)
5. Engine injector harness assembly
6. Tie strap (3)

Removal

Engine Brake Housing Assembly

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

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

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

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

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

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

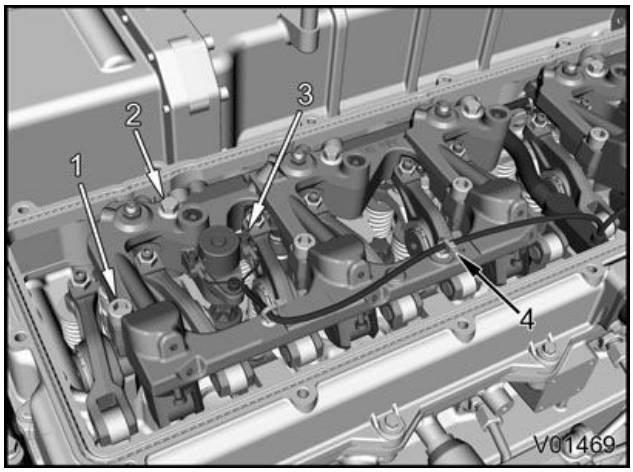

Figure 541 Engine brake assembly

1. M12 x 100 (socket-head) screw (6)
2. M10 x 90 bolt (6)
3. Solenoid connector nut (4)
4. Tie strap (3)

1. Remove upper valve cover. See Upper Valve Cover and Base (page 409).
2. Disconnect brake wiring harness connector leads from solenoid by disengaging two connector nuts on each front and rear engine brake housing assemblies. The connector nuts are retained by the harness connectors.
3. Cut tie straps securing solenoid harness connector leads on front and rear brake housings. Position leads out of the way.
4. Mark housings to indicate front and rear to insure they are reinstalled later in the correct locations.
5. Remove three M12 x 100 socket-head screws and three M10 x 90 bolts and remove front engine brake housing assembly from cylinder head.
6. Repeat step 5 to remove rear brake housing assembly.

Disassembly

NOTE: When disassembling the engine brake housing, keep all component parts together in sets and if reused, reinstall each set back in its original location.

Solenoid

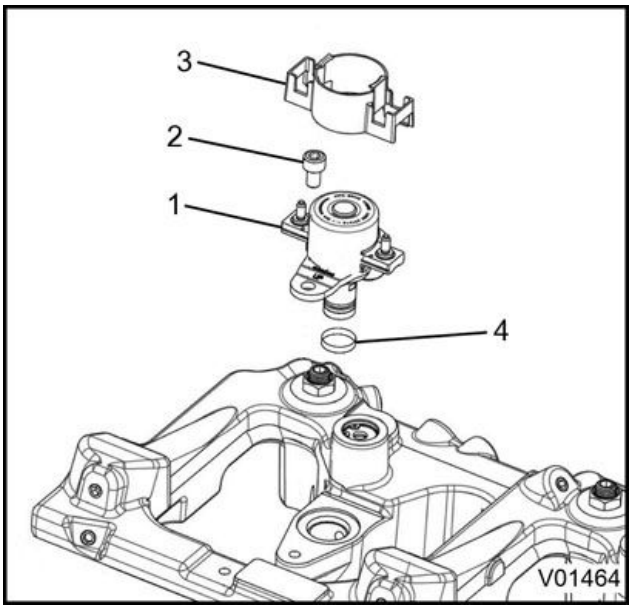

Figure 542 Solenoid

1. Solenoid assembly
2. M6 x 10 socket-head cap screw
3. Solenoid cover
4. Solenoid screen

1. If not already done, loosen connector nuts and disconnect harness connector leads from solenoid.
2. Remove M6 x 10 socket-head cap screw.

NOTE: Cover slides over solenoid and locks onto terminal ends. Cover is removed with solenoid as an assembly.

3. Remove solenoid and cover from brake housing.
4. Remove upper and lower seal rings from solenoid stem. Discard seal rings.
5. Remove and discard solenoid screen.

Control Valve

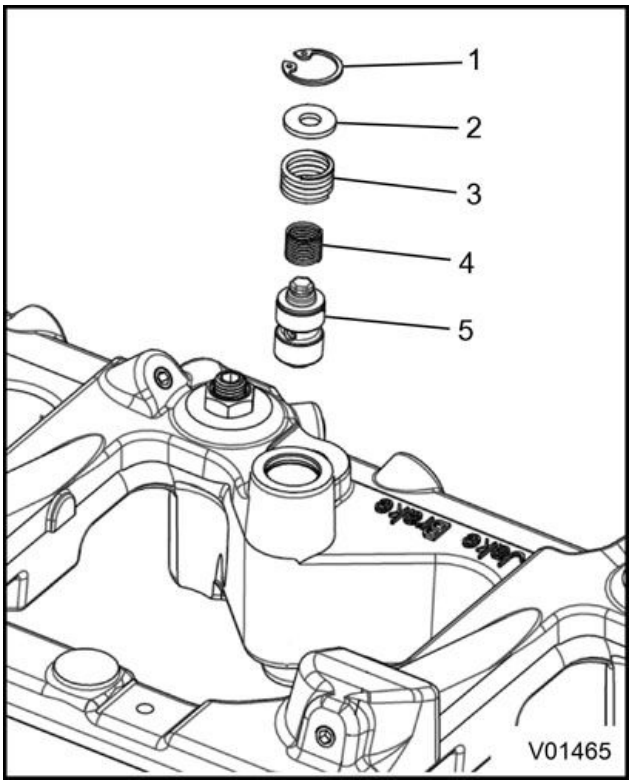

Figure 543 Control valve

1. Control valve retaining ring
2. Control valve cover
3. Outer spring
4. Inner spring
5. Control valve assembly

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields.

NOTE: Use same procedure to remove all control valves from engine.

1. Push down on control valve cover and hold to remove spring pressure from control valve retaining ring. Using suitable snap-ring pliers, remove control valve retaining ring from housing control valve bore. Slowly release control valve cover to relieve spring pressure.
2. Remove control valve cover from valve bore.
3. Using a pick, carefully remove inner and outer springs from bore.

4. Using a magnet or needle-nose pliers, remove control valve from housing bore.

Master Piston

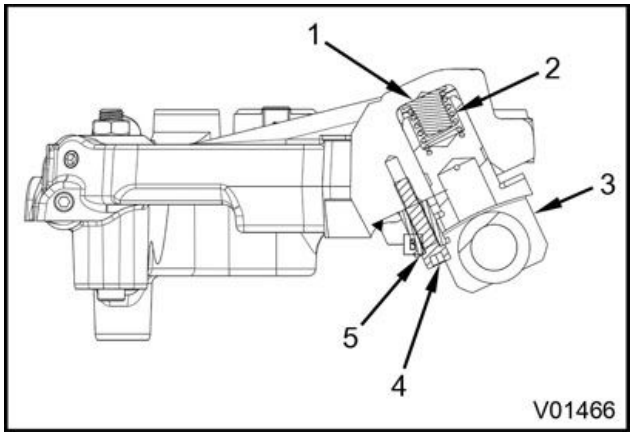

Figure 544 Master piston

1. Master piston spring guide
2. Master piston roller spring
3. Master piston roller assembly
4. M6 x 30 master piston guide bolt
5. Master piston guide sleeve

The master piston group currently is not a serviceable part. If a fault condition is traced to a malfunctioning master piston, replace brake housing assembly.

Slave Piston

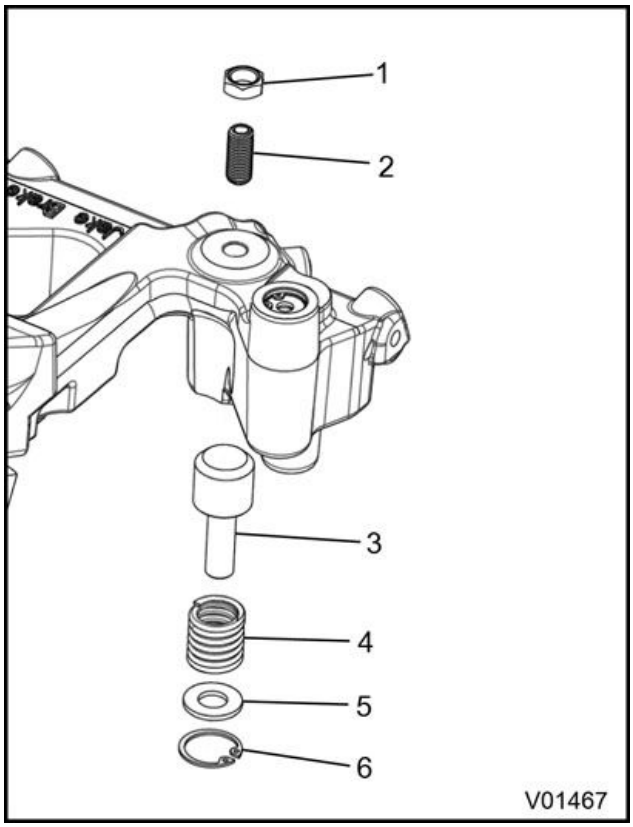

Figure 545 Slave piston

1. M10 (jam) nut
2. Slave piston adjusting screw
3. Slave piston
4. Slave piston spring
5. Slave piston washer
6. Slave piston retaining ring

⚠ WARNING: To prevent personal injury or death, use Jacobs® Slave Piston Removal Tool to remove or install slave piston. Slave piston springs are under heavy compression.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields.

1. Remove M10 jam nut and back out slave piston adjusting screw until slave piston is fully retracted.

Use same procedure to remove all slave pistons from the engine.

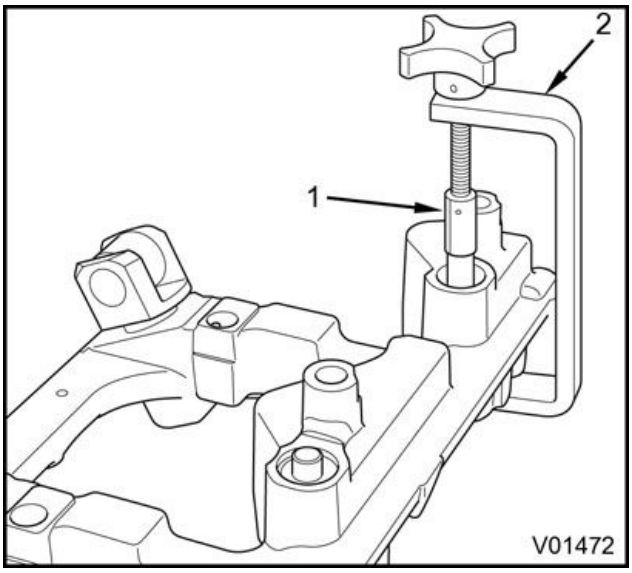

Figure 546 Slave Piston Removal Tool

1. Clamp screw collar
2. Slave Piston Removal Tool

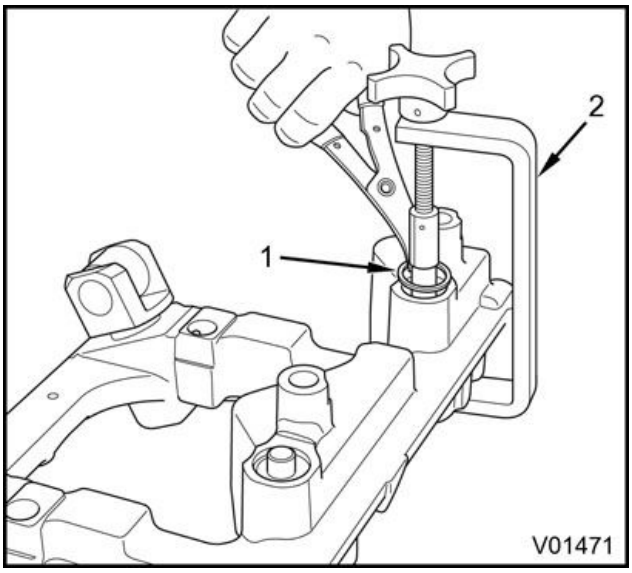

Figure 547 Slave piston retaining ring

1. Slave piston retaining ring
2. Slave Piston Removal Tool

2. Place Jacobs® Slave Piston Removal Tool in position with hole in tool clamp bracket over slave piston adjusting screw and clamp screw collar over slave piston stem.
3. Slowly tighten clamp screw until collar contacts slave piston washer. Continue tightening clamp screw to compress slave piston spring and relieve spring pressure against slave piston retaining ring.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields.

4. Using snap-ring pliers, remove slave piston retaining ring from piston bore.
5. Slowly loosen tool clamp screw to release slave piston spring pressure and remove tool.
6. Grasp piston stem and remove slave piston, spring and washer.
7. Remove slave piston adjusting screw.

Cleaning and Inspection

Solenoid Assembly Check

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

1. Clean brake housings, control valve assemblies, master piston rollers, slave pistons and springs with a suitable non-caustic solvent.
2. Blow parts dry using filtered compressed air.
3. Inspect brake housings for cracks. Replace as required.
4. Check for missing or loose pipe plugs at sides and ends of brake housings. If pipe plugs are missing or loose, replace brake housing assembly.
5. Inspect master piston rollers and associated camshaft lobes for excessive wear, spalling and galling. Replace complete brake housing assembly if any master piston roller is determined unacceptable to reuse. If camshaft lobes for engine brake have excessive wear, spalling or galling, replace camshaft.
6. Inspect slave pistons, springs and control valve assembly for worn or damaged parts. Replace parts that are broken or deformed.
7. Inspect slave piston bores in brake housing. Insert slave pistons in respective bores and check for free movement without binding. If there is binding, replace brake housing assembly.
8. Inspect control valve assembly bores in brake housing. Insert control valve assemblies in respective bores and check for free movement without binding. If there is binding, replace brake housing assembly.

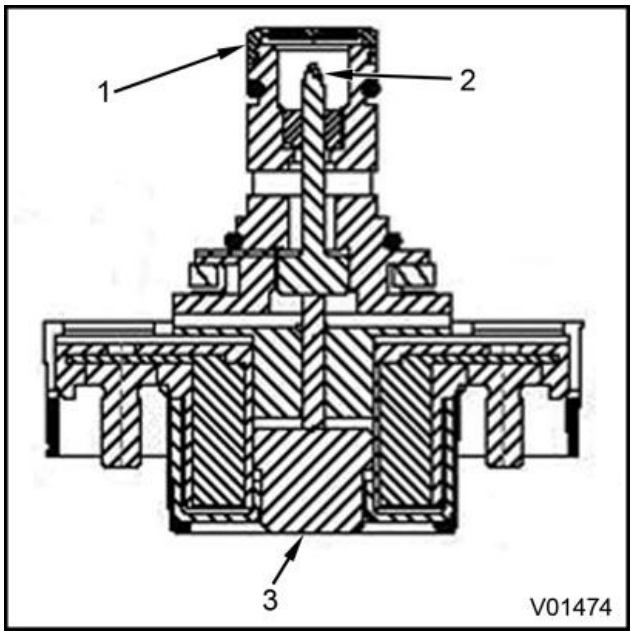

Figure 548 Solenoid assembly check

1. Solenoid screen (removed for check)
2. Pin
3. Button of armature

9. Hold solenoid assembly upside down in hand so you can look into the end where the solenoid screen was removed. Move button of armature with finger while looking into the open end to verify pin moves freely within the solenoid assembly. If pin does not move freely, replace solenoid.
10. Using an ohmmeter, check solenoid assembly resistance per the following steps:
    - Check resistance across the two terminals. If resistance is out of specification (page 398), replace solenoid assembly.
    - Check resistance from each terminal to the solenoid can. This should be an “open circuit.” If a resistance is measured, replace solenoid assembly.

Assembly

Slave Piston

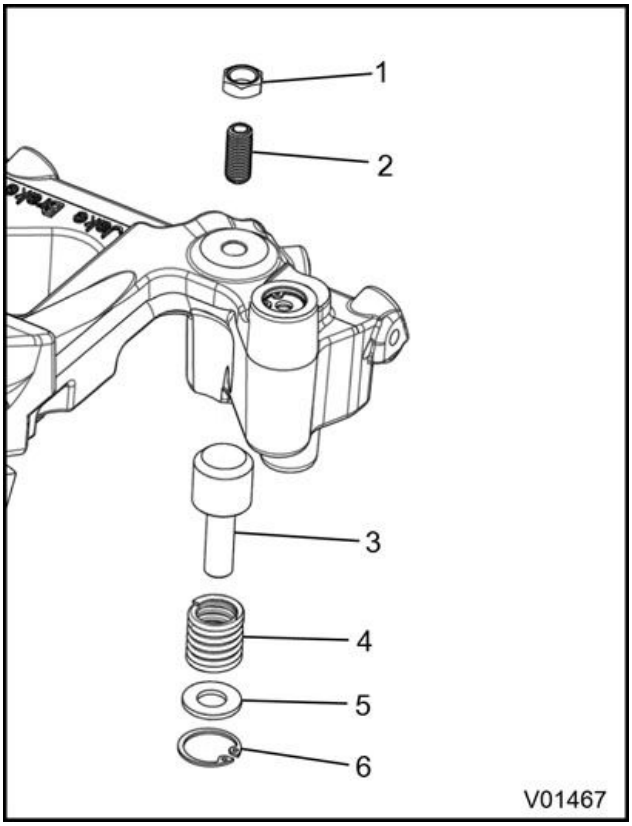

Figure 549 Slave piston

1. M10 (jam) nut
2. Slave piston adjusting screw
3. Slave piston
4. Slave piston spring
5. Slave piston washer
6. Slave piston retaining ring

1. Check that housing slave piston bore is clean, free of any residue and debris.
2. Lubricate slave piston, spring and washer with clean engine oil.
3. Assemble slave piston spring, washer and retaining ring on slave piston stem.
4. Insert slave piston, spring and washer assembly into housing bore.

NOTE: Retaining ring with proper orientation must be placed on stem before using Jacobs® Slave Piston Removal Tool to compress spring in housing bore.

⚠ WARNING: To prevent personal injury or death, use Jacobs® Slave Piston Removal Tool to remove or install slave piston. Slave piston springs are under heavy compression.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields.

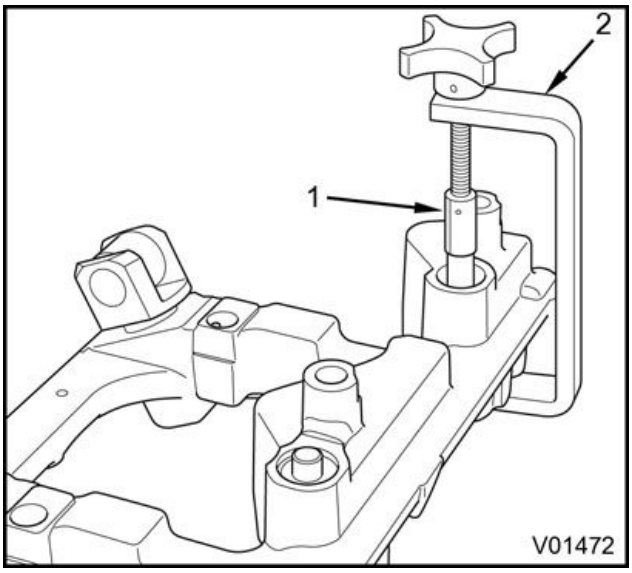

Figure 550 Slave Piston Removal Tool

1. Clamp screw collar
2. Slave Piston Removal Tool

5. Place slave piston retaining ring, oriented with sharp side up (away from washer), in position over slave piston stem. Install Jacobs® Slave Piston Removal Tool with clamp screw collar on slave piston stem.
6. Slowly tighten clamp screw until screw collar contacts slave piston washer. Continue tightening clamp screw to compress piston spring until washer is approximately 1/32 inch below retaining ring groove.

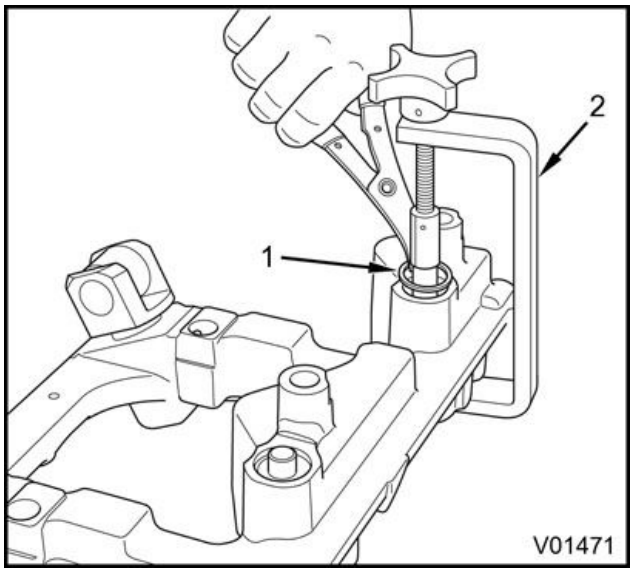

Figure 551 Slave Piston Removal Tool

1. Slave piston retaining ring
2. Slave Piston Removal Tool

7. Using snap-ring pliers, install slave piston retaining ring in bore ring groove. Ensure retaining ring is oriented with sharp side up (away from washer). Rotate retaining ring to ensure that it is properly seated in groove.
8. Slowly loosen tool clamp screw to release piston spring pressure and remove tool.
9. Install slave piston adjusting screw and jam nut. Do not tighten jam nut.

Master Piston

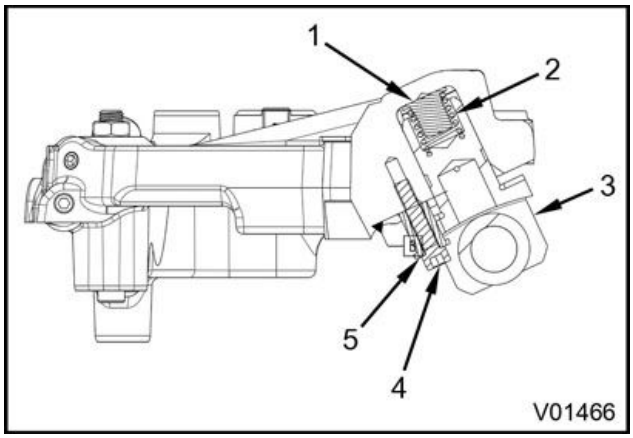

Figure 552 Master piston

1. Master piston spring guide
2. Master piston roller spring
3. Master piston roller assembly
4. M6 x 30 master piston guide bolt
5. Master piston guide sleeve

The master piston group currently is not a serviceable part. If a fault condition is traced to a malfunctioning master piston, replace brake housing assembly.

Control Valve

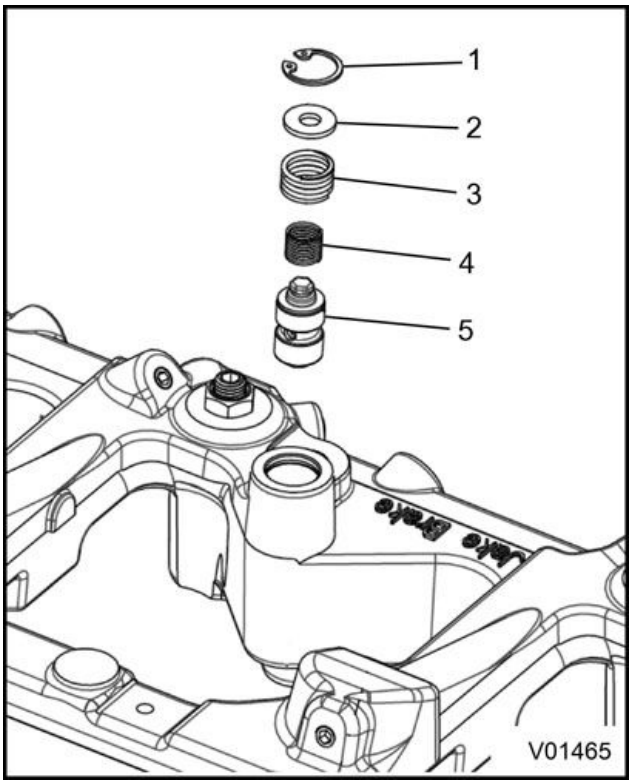

Figure 553 Control valve

1. Control valve retaining ring
2. Control valve cover
3. Outer spring
4. Inner spring
5. Control valve assembly

1. Check that housing control valve bore is clean, free of any residue and debris.
2. Lubricate control valve assembly and springs with clean engine oil.
3. With hex stud end up, insert control valve assembly into housing bore. Ensure control valve assembly moves smoothly and freely down bore.
4. Insert inner and outer springs into bore. Make sure that springs are properly seated with inner spring on control valve and outer spring on step of control valve bore.
5. Install control valve cover over springs.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields.

6. Using snap-ring pliers, install control valve retaining ring in housing bore to contain control valve assembly. Ensure retaining ring is installed with sharp side up (away from control valve cover). Rotate retaining ring to insure that it is properly seated in groove.

Solenoid

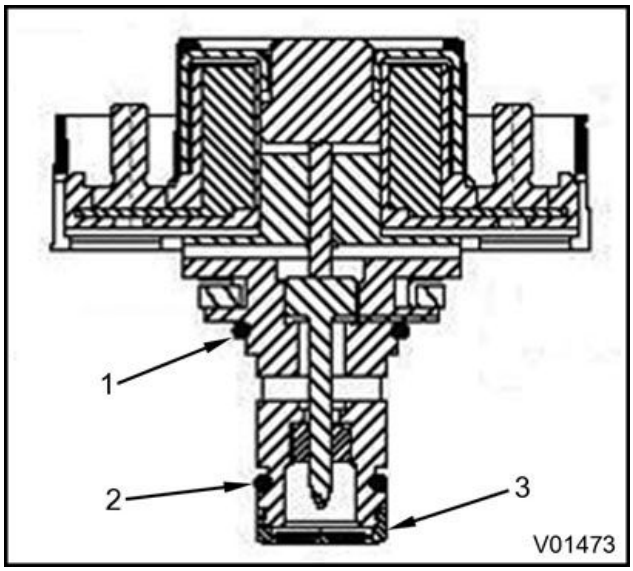

Figure 554 Solenoid seal rings

1. Upper seal ring
2. Lower seal ring
3. Solenoid screen

1. Install new upper and lower seal rings in ring grooves on solenoid stem. Lubricate seal rings with clean engine oil.
2. Clip solenoid screen on bottom of solenoid stem.

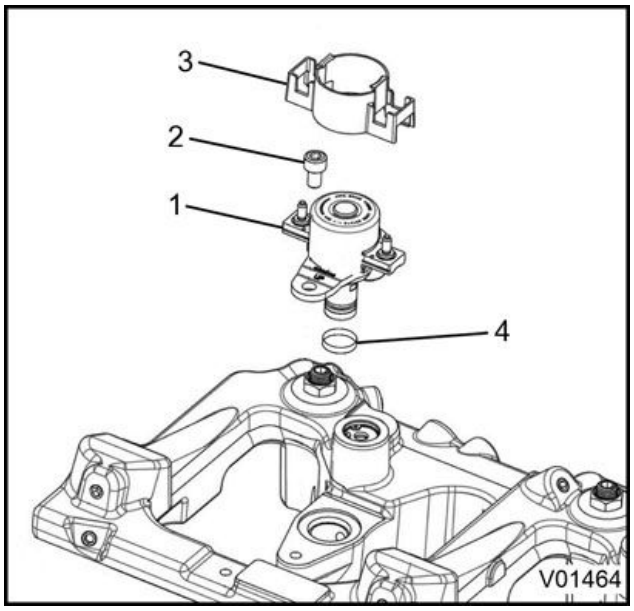

Figure 555 Solenoid

1. Solenoid assembly
2. M6 x 10 socket-head cap screw
3. Solenoid cover
4. Solenoid screen

3. Place solenoid in position on brake housing. Using hand pressure, press solenoid into bore until it snaps into place.
4. If removed, install solenoid cover on solenoid.
5. Install M6 x 10 socket-head cap screw. Tighten screw to special torque (page 398).

Installation

Engine Brake Housing Assembly

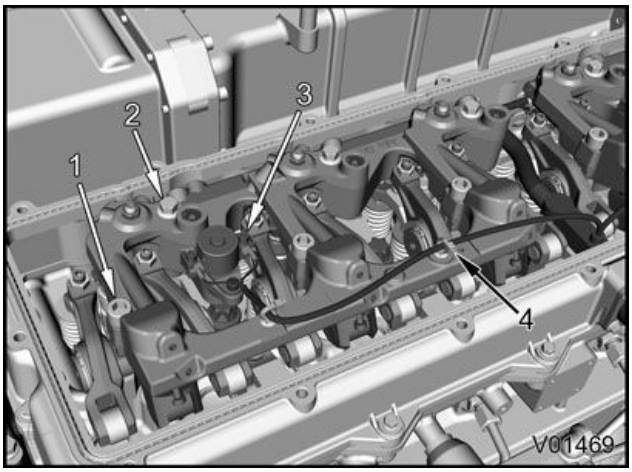

Figure 556 Engine brake assembly

1. M12 x 100 (socket-head) screw (6)
2. M10 x 90 bolt (6)
3. Solenoid connector nut (4)
4. Tie strap (3)

CAUTION: To prevent engine damage, verify injector harness wires are not pinched or rubbing against the engine brake housing or rocker arm assembly.

1. Carefully place previously marked front engine brake housing assembly in front position over camshaft and valve train.
2. Install three M12 x 100 socket-head screws and three M10 x 90 bolts. Tighten bolts to special torque (page 398).
3. Repeat steps 1 and 2 to install previously marked rear engine brake housing assembly in rear position over camshaft and valve train.

CAUTION: To prevent engine damage, do not over torque nuts on wiring harness connector leads. Too much torque will damage solenoid terminals.

4. Connect brake wiring harness connector leads to solenoid on front and rear engine brake housing assemblies. Make sure harness terminal connectors are in straight alignment with harness. Hold terminal connectors stationary to avoid twisting and tighten connector nuts to special torque (page 398).
5. Install two tie straps to secure solenoid harness connector lead on front brake housing and one tie strap to secure harness connector lead on rear brake housing.
6. Adjust engine brake lash. See Engine Brake Lash Adjustment (page 397).
7. Install upper valve cover. See Upper Valve Cover and Base (page 431).

Engine Brake Lash Adjustment

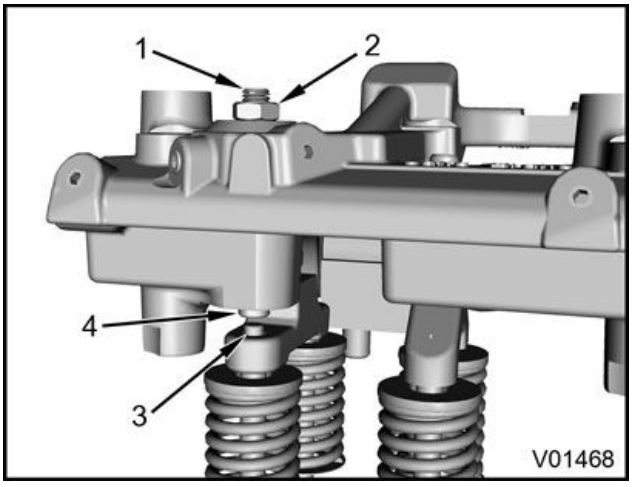

Figure 557 Engine brake lash adjustment

1. Slave piston adjusting screw
2. M10 (jam) nut
3. Actuator pin (in exhaust valve bridge)
4. Slave piston

See Valve Lash Adjustment (page 407) for procedure covering both valve lash and engine brake lash adjustments on engines so equipped.

Specifications

Temperature	Solenoid resistance
Cold — 25 ˚ C (77 ˚ F)	8.7–10 ohms
Hot — 121 ˚ C (250 ˚ F)	12–15.5 ohms

Special Torque

Brake housing M10 x 90 bolt	75 N·m (55 lb·ft)
Brake housing M12 x 100 (socket-head) screw	105 N·m (77 lb-ft)
Brake housing solenoid harness connector nut	3.5 N·m (31 lb·in)
Slave piston adjusting screw M10 (jam) nut	25 N·m (18 lb·ft)
Solenoid M6 x 10 socket-head cap screw	12.5 N·m (110 lb·in)

Special Service Tools

Description	Tool Number
Jacobs® Slave Piston Removal Tool	ZTSE6068

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Exploded Views

Valve Cover and Base

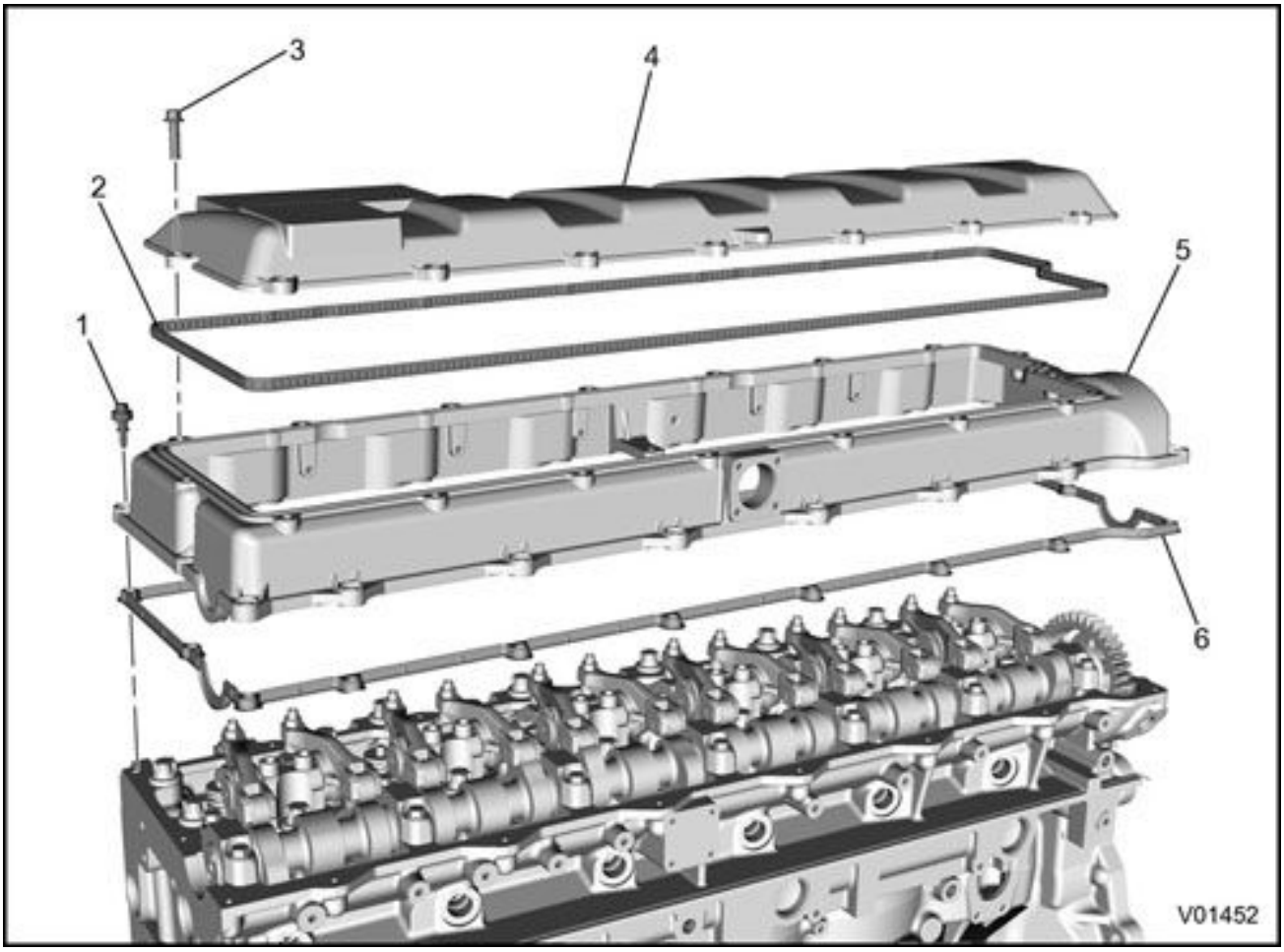

Figure 558 Valve cover and base

1. Screw with damper (18)
2. Upper valve (cover) gasket
3. M8 x 30 bolt (17)
4. Upper valve cover
5. Valve cover base
6. Valve cover (base) gasket

Rocker Arm Assembly And Valve Bridges (Non-Brake)

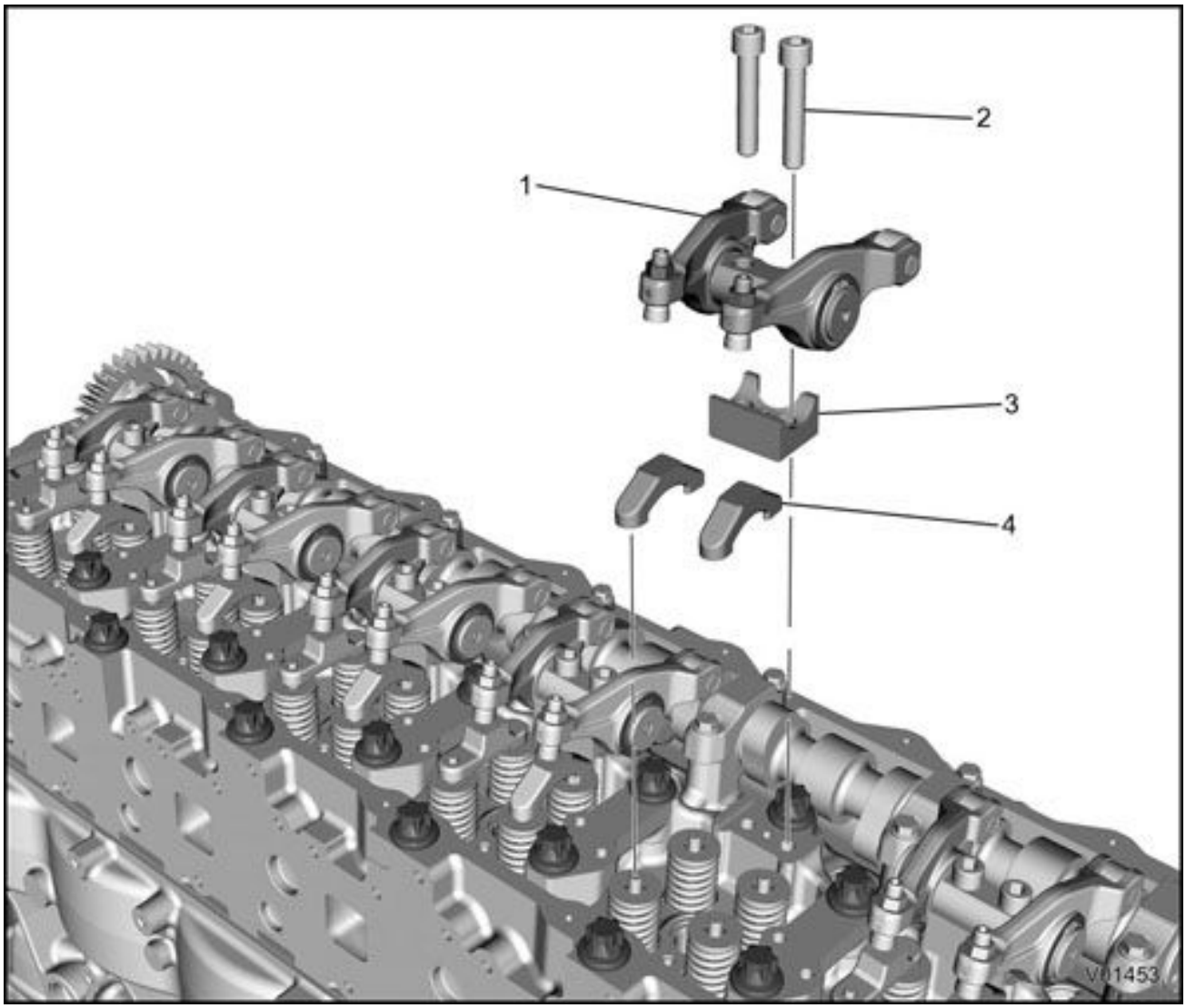

Figure 559 Rocker arm assembly and valve bridges (non-brake)

1. Intake and exhaust rocker arm assembly (6)
2. M12 x 60 (socket-head) screw (12)
3. Rocker bearing block (6)
4. Valve bridge (intake and exhaust) (12)

NOTE: Rocker arm assemblies and valve bridges shown and covered in this section represent the standard non-brake engine configuration. For engines with optional engine brake, refer to Navistar® N13 Engine Brake by Jacobs section for procedures.

Camshaft and Cylinder Head Idler Gear

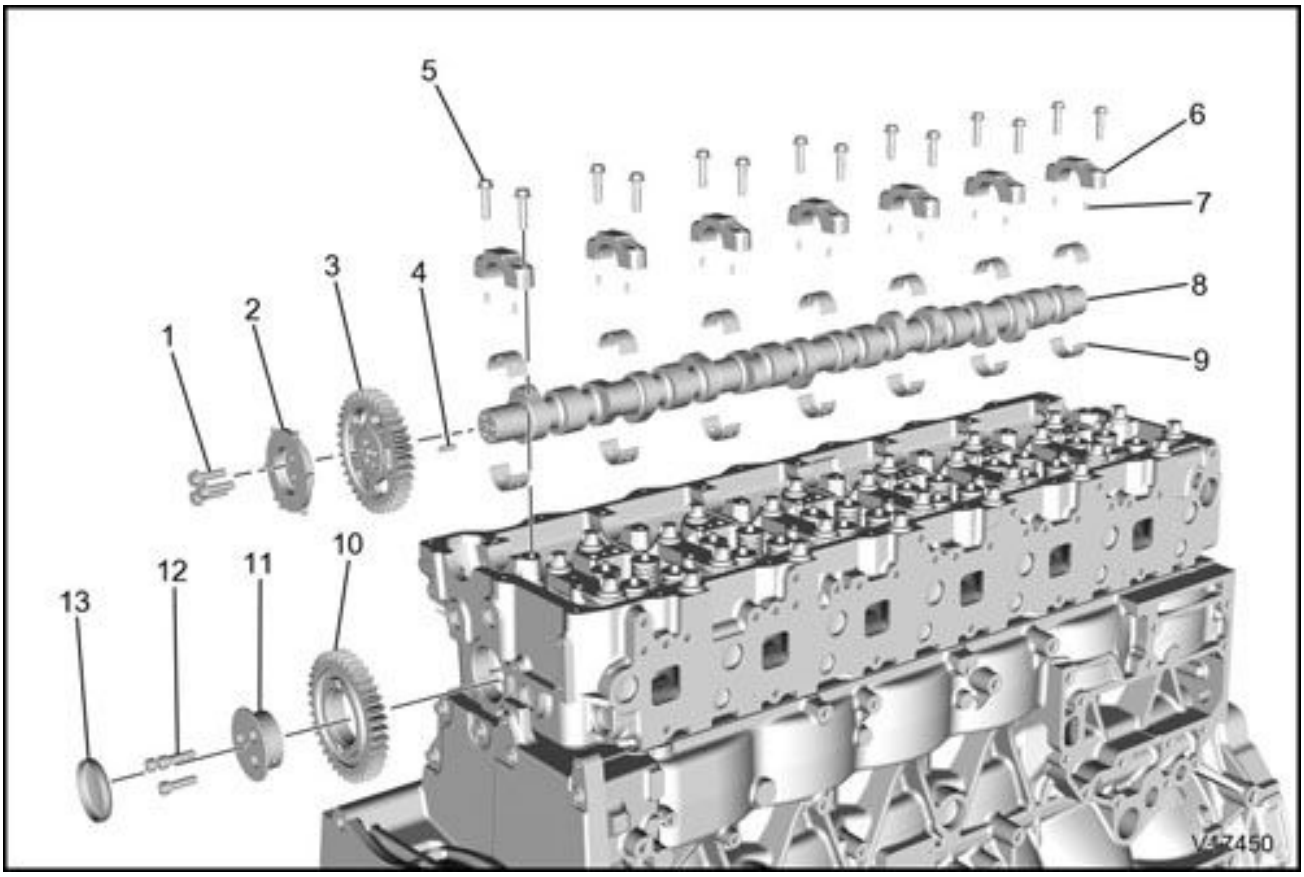

Figure 560 Camshaft and cylinder head idler gear

1. M8 x 30 bolt (3)
2. Camshaft timing disc (pulse wheel)
3. Camshaft gear
4. Timing (M6 x 20 dowel) pin
5. M8 x 35 bolt (14)
6. (Camshaft) bearing cap (7)
7. 4H x 8 x 10 dowel pin (14)
8. Camshaft
9. Bearing shell (14)
10. Cylinder head idler gear
11. Small gear shaft
12. M8 x 30 socket-head cap screw (3)
13. DMR 63.10 cup plug

Cylinder Head

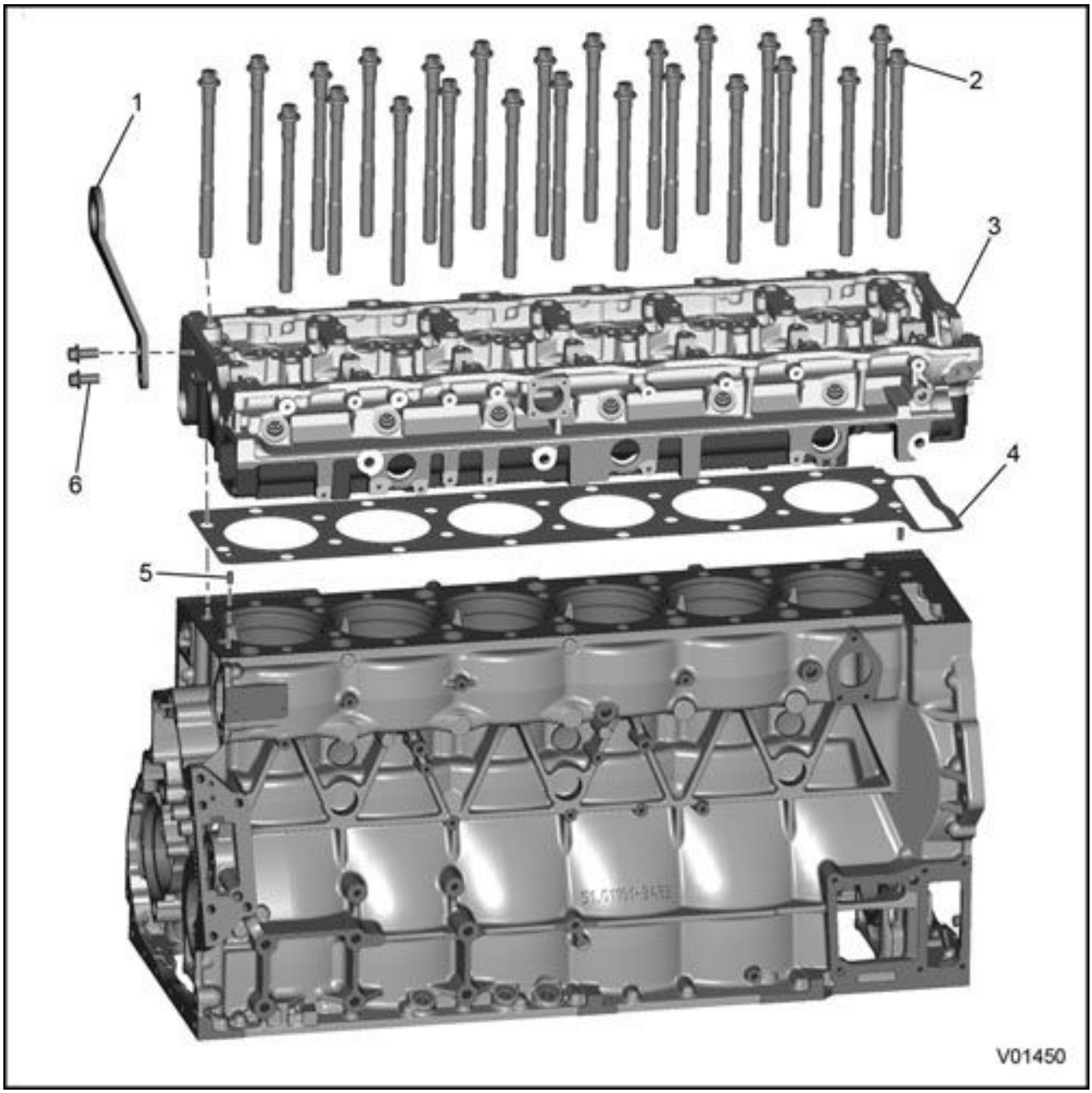

Figure 561 Cylinder head

1. Front lifting eye
2. M18 x 2 x 246 Torx® bolt (26)
3. Cylinder head
4. Cylinder head gasket
5. Dowel pin (2)
6. M12 x 25 bolt (2)

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 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, 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.

Crankshaft Rotation Procedure

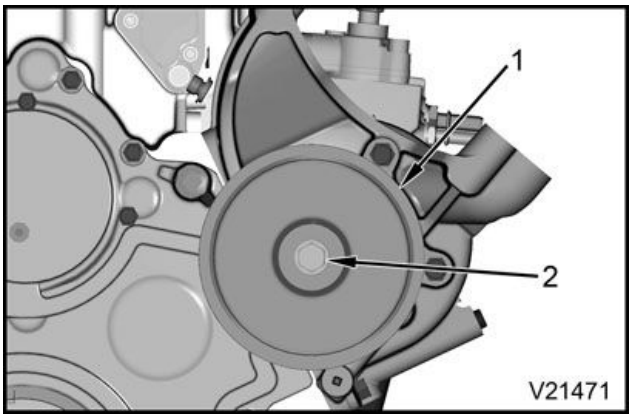

Figure 562 High-pressure pump pulley

1. High-pressure pump pulley
2. M16 x 40 LH bolt (left-hand thread)

NOTE: The crankshaft can be rotated using the M16 x 40 LH bolt (left-hand thread) on the high-pressure pump pulley. Care must be used to ensure the bolt is not loosened while the crankshaft is rotated.

1. Adjust a torque wrench to 162 N·m (120 lb-ft).
2. Place a 19 mm socket on the torque wrench.
3. Slowly rotate the M16 x 40 LH bolt (left-hand thread) bolt clockwise. Stop pulling if the torque wrench clicks. Torque in excess of 162 N·m (120 lb-ft) may cause the bolt to loosen. Continue rotating to desired position when compression leaks down and less force is needed to rotate the crankshaft.

Cylinder No. 1 TDC Procedure

1. Remove the upper valve cover and base. See Upper Valve Cover and Base (page 409).

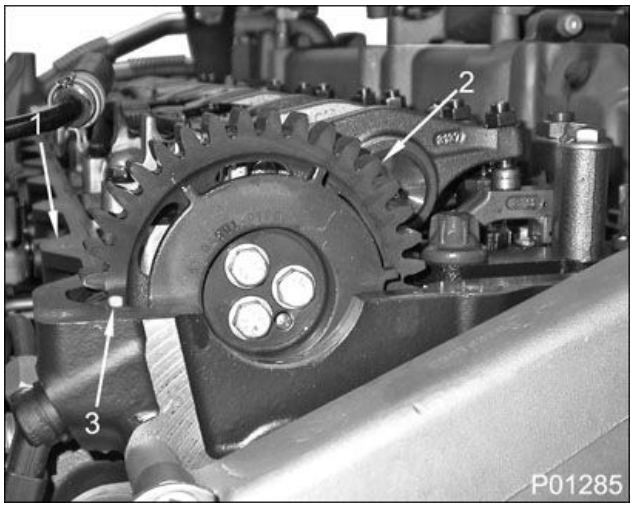

Figure 563 Camshaft gear timing mark

1. Valve cover surface
2. Camshaft gear
3. Timing mark

2. Rotate 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. See Crankshaft Rotation Procedure (page 405).

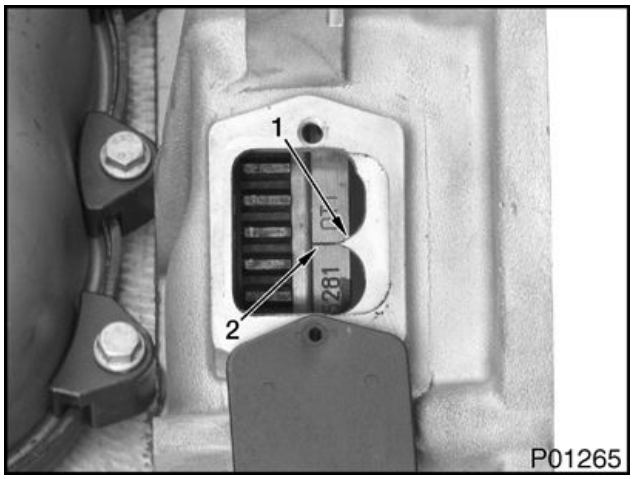

Figure 564 Flywheel housing timing index (typical)

1. Flywheel housing timing index
2. Flywheel timing mark

3. Remove timing hole cover from lower side of flywheel housing.
4. Rotate crankshaft in direction needed to align the flywheel timing mark with flywheel housing timing index.
5. 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.

6. If flywheel and camshaft gear marks are not in agreement, the large idler gear has slipped. See Rear Timing Gears (page 480) for procedure to install a new large idler 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.

NOTE: Valve lash must be set with engine cold and cylinder head assembled to crankcase.

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 29 (page 408).

Valve Lash Adjustment Procedure

NOTE: Valve lash must be set with engine cold and cylinder head assembled to crankcase.

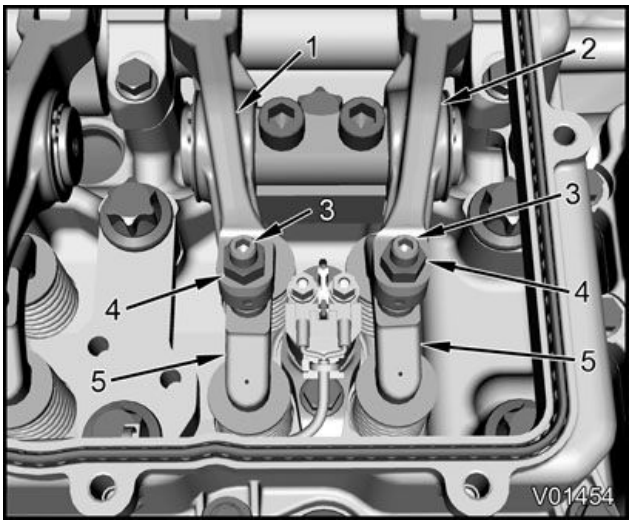

Figure 565 Valve Lash Adjustment (Typical)

1. Exhaust rocker arm
2. Intake rocker arm
3. Adjusting screw
4. Valve lash adjustment M10 nut
5. Valve bridge (intake/exhaust)

NOTE: Adjust engine valve lash and engine brake lash at 120,000 miles (190,000 km), 300,000 miles (480,000 km), then every 300,000 miles (480,000 km) thereafter.

1. Do Valve Overlap Procedure (page 406).
2. Loosen valve lash adjustment M10 nut (Figure 565) (Item 4) on intake rocker arm (Figure 565) (item 2).
3. Insert Lash Gauge ZTSE6076–5A 0.5 mm (0.020 in) between intake valve bridge (Figure 565) (Item 5) and adjusting screw (Figure 565) (Item 3), and tighten adjusting screw until a slight drag on Lash Gauge 0.5 mm (0.020 in) is felt.
4. Hold adjusting screw in position and tighten valve lash adjustment M10 nut to 33 lb·ft (45 N·m).

NOTE: If equipped with Navistar® N13 engine brake, go to step 6 to adjust exhaust valve lash and engine brake lash. If no engine brake, continue to step 5.

5. For engines without brake, adjust exhaust valve lash as follows:
   a. Loosen valve lash adjustment M10 nut on exhaust rocker arm (Figure 565) (item 1).
   b. Insert Lash Gauge ZTSE6076–7A 0.8 mm (0.031 in) between exhaust valve bridge and adjusting screw and tighten adjusting screw until a slight drag on Lash Gauge 0.8 mm (0.031 in) is felt.
   c. Hold adjusting screw in position and tighten exhaust valve lash adjustment M10 nut to 33 lb·ft (45 N·m).
   d. Go to step 6.

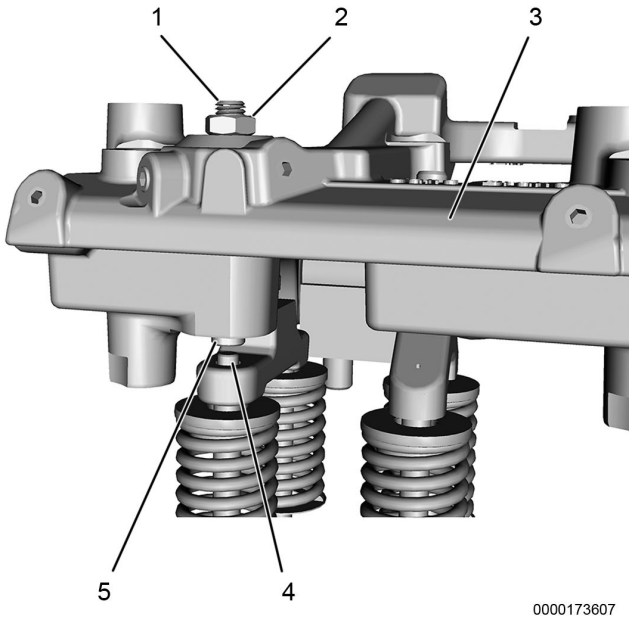

Figure 566 Brake Lash Adjustment (Equipped with Navistar® N13 Engine Brake)

1. Slave piston adjusting screw
2. Brake lash adjustment M10 (jam) nut
3. Engine brake housing assembly
4. Actuator pin (in exhaust valve bridge)
5. Slave piston

6. For engines with Navistar® N13 engine brake, adjust exhaust valve lash and engine brake lash as follows:
   a. Loosen brake lash adjustment M10 (jam) nut (Figure 566) (Item 2) on engine brake housing assembly (Figure 566) (Item 3), and back out slave piston adjusting screw (Figure 566) (Item 1) so slave piston no longer contacts valve bridge.
   b. Loosen valve lash adjustment M10 nut on exhaust rocker arm (Figure 565) (item 1).
   c. Insert Lash Gauge 0.8 mm (0.031 in) on exhaust rocker arm between exhaust valve bridge (Figure 565) (Item 5) and adjusting screw, and tighten adjusting screw (Figure 565) (Item 4) until a slight drag on Lash Gauge 0.8 mm (0.031 in) is felt.
   d. Hold adjusting screw in position and tighten exhaust valve lash adjustment M10 nut to 33 lb·ft (45 N·m).
   e. Insert Lash Gauge 0.8 mm (0.031 in) on engine brake housing assembly between slave piston (Figure 566) (Item 5) and bridge actuator pin (Figure 566) (Item 4).
   f. Turn adjusting screw in until slave piston contacts Lash Gauge 0.8 mm (0.031 in) and a slight drag on Lash Gauge 0.8 mm (0.031 in) is felt.
   g. Using a 5 mm Allen wrench, hold slave piston adjusting screw to prevent from turning and tighten jam nut to 33 lb·ft (45 N·m).

Table 1

Cylinder at TDC compression	Companion cylinder in valve overlap
1	6
5	2
3	4
6	1
2	5
4	3

7. 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. See (Crankshaft Rotation Procedure, page 405). For each cylinder positioned at TDC compression, the companion cylinder will be in valve overlap as shown in following table.

Removal

NOTE: When performing specific component removal, only remove components necessary for access.

For complete engine tear down, refer to the following service sections for information on removal of components prior to this section.

- **Engine Electrical**
- **Turbochargers**
- **Air Compressor and Power Steering**
- **Fuel System**
- **Oil Cooler, Filter Housing and Crankcase Ventilation**
- **Exhaust Gas Recirculation (EGR) System**
- **Air Intake Throttle Duct and Exhaust Manifold**
- **Front Cover, Fan Drive, Cooling System and Related Components**

Upper Valve Cover and Base

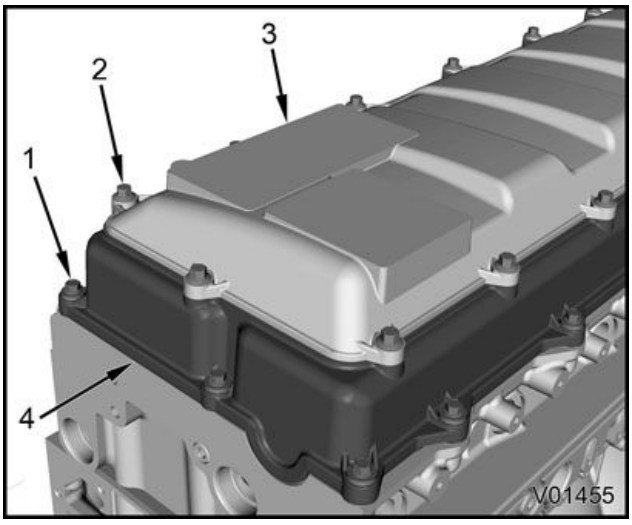

Figure 567 Upper Valve Cover and Base

1. Screw with damper (18)
2. M8 x 30 bolt (17)
3. Upper valve cover
4. Valve cover base

CAUTION: To prevent engine damage, do not use power tools to remove or install valve cover bolts. Threads will be damaged if a bolt or nut is rotated too quickly.

NOTE: The upper valve cover can be removed separately or as an assembly with the valve cover base depending on work being performed. If it is being removed as an assembly, start with step 2.

1. Remove 17 M8 x 30 bolts (Figure 567) (Item 2) and remove upper valve cover (Figure 567) (Item 3) from base (Figure 567) (Item 4).

NOTE: The valve cover base screws can only be removed from valve cover as assemblies with the dampers. Screws and dampers should only be removed from cover if replacing the valve cover gasket.

2. Release 18 screws with dampers (Figure 567) (Item 1) from cylinder head. Do not completely remove screws from valve cover at this time.
3. Remove valve cover base (or assembly) from cylinder head.

NOTE: Valve cover gaskets can be reused and do not require removal from valve cover base unless damaged.

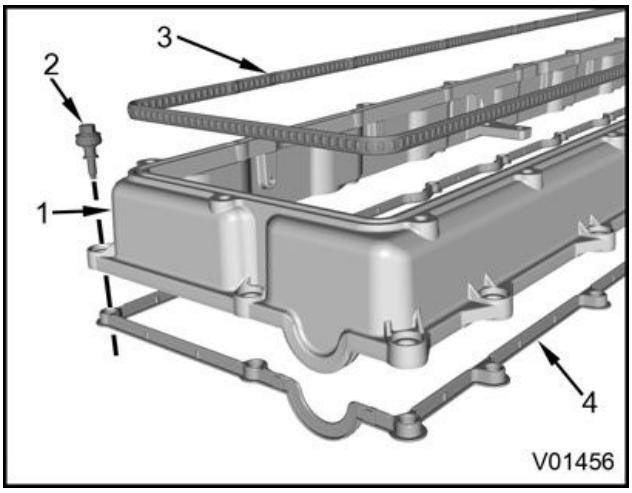

Figure 568 Valve Cover Gaskets

1. Valve cover base
2. Screw with damper (18)
3. Upper valve cover gasket
4. (Lower) valve cover gasket

4. Inspect upper (Figure 568) (Item 3) and lower (Figure 568) (Item 4) valve cover gaskets for damage. If damaged, replace as follows:
   a. Upper gasket — remove from groove in upper surface of valve cover base (Figure 568) (Item 1) and discard gasket.
   b. Lower gasket — completely remove 18 screws with dampers (Figure 568) (Item 2) to release gasket from bottom of valve cover base. Discard gasket.

Rocker Arm Assembly (Non-Brake Engine)

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

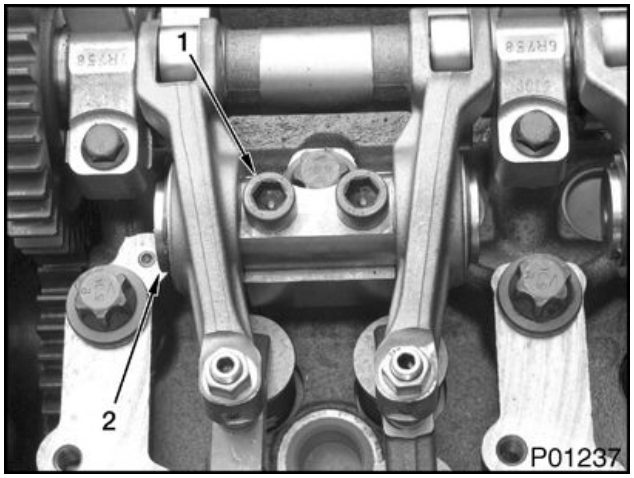

Figure 569 Rocker Arm Assembly (Typical)

1. M12 x 60 (socket-head) screw (12)
2. Rocker arm assembly (6)

1. Mark rocker arm assemblies (Figure 569) (Item 2) 1 through 6 so each assembly can be installed in its original cylinder location.
2. Remove 12 M12 x 60 socket-head screws (Figure 569) (Item 1).
3. Remove six rocker arm assemblies.

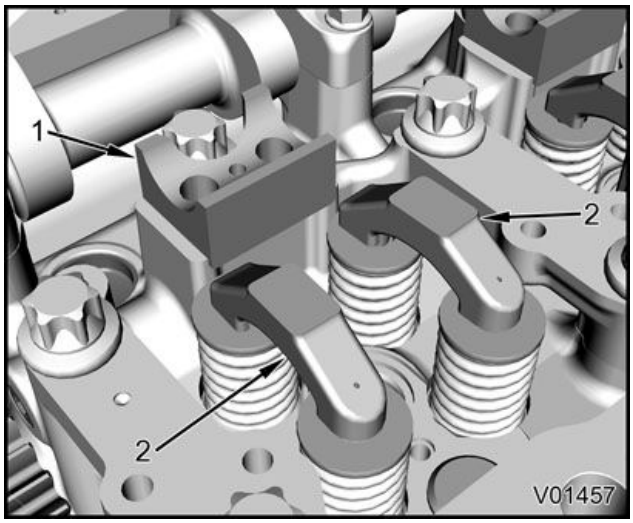

Figure 570 Rocker Bearing Block and Valve Bridges

1. Rocker bearing block (6)
2. Valve bridge (12)

4. Mark rocker bearing blocks (Figure 570) (Item 1) 1 through 6 so each block can be installed in its original cylinder location.
5. Remove six rocker bearing blocks.
6. Mark valve bridges (Figure 570) (Item 2) so each bridge can be installed in its original location and orientation.
7. Remove 12 valve bridges.

Camshaft

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

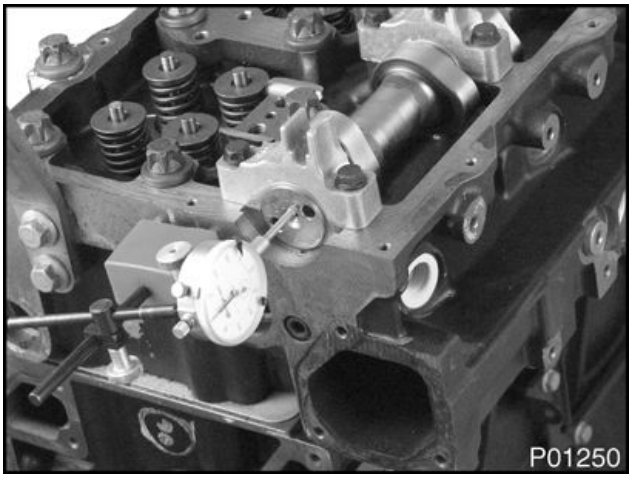

Figure 571 Camshaft end play check (typical)

1. Check camshaft end play as follows:
   a. Mount dial indicator with magnetic base (page 434) 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 camshaft end play specification (page 433).
   d. If end play exceeds specified limits, install a new camshaft.

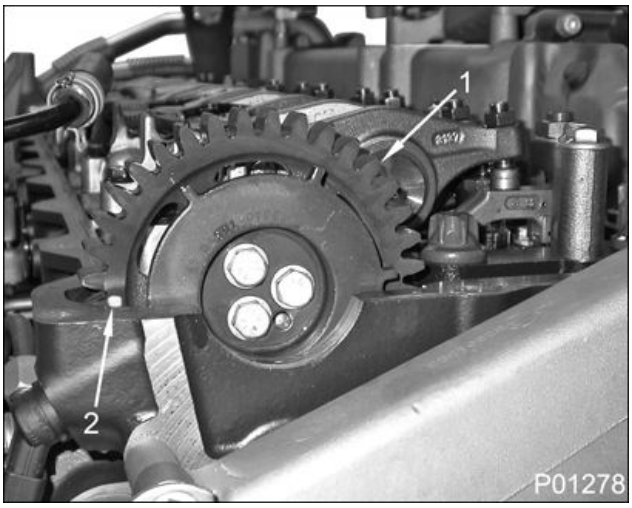

Figure 572 Camshaft timing mark (typical)

1. Camshaft gear
2. Timing mark

2. Turn engine crankshaft in direction of engine rotation until timing mark on camshaft gear is aligned with cylinder head surface.

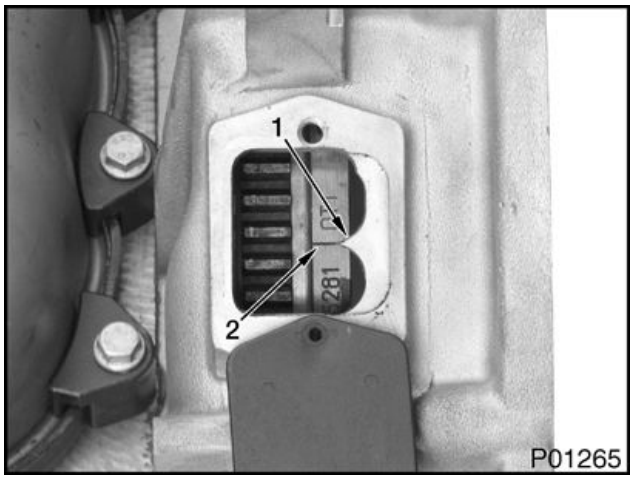

Figure 573 Flywheel housing timing index (typical)

1. Flywheel housing timing index
2. Flywheel timing mark

3. Remove timing hole cover 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 large idler gear slippage. Install a new large idler gear. See Rear Timing Gears (page 480) section of this manual for procedures to replace large idler gear.
   - If timing mark on flywheel is aligned with flywheel housing timing index, continue to next step.

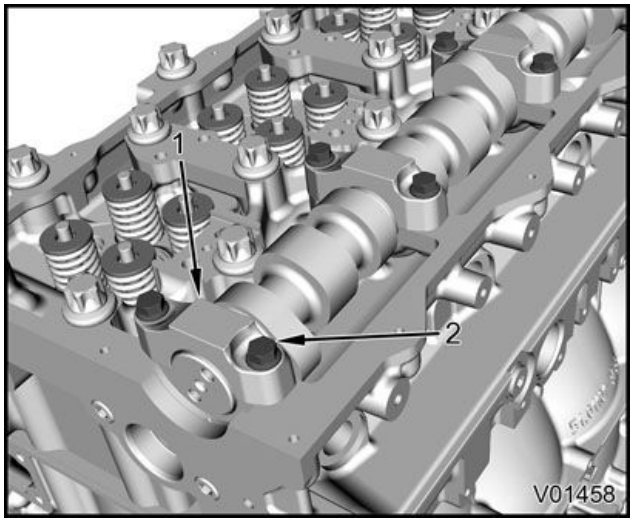

Figure 574 Camshaft bearing caps

1. Camshaft bearing cap (7)
2. M8 x 35 bolt (14)

4. Remove 14 M8 x 35 bolts.
5. Remove seven camshaft bearing caps from the cylinder head. Mark each bearing cap with location number and orientation.

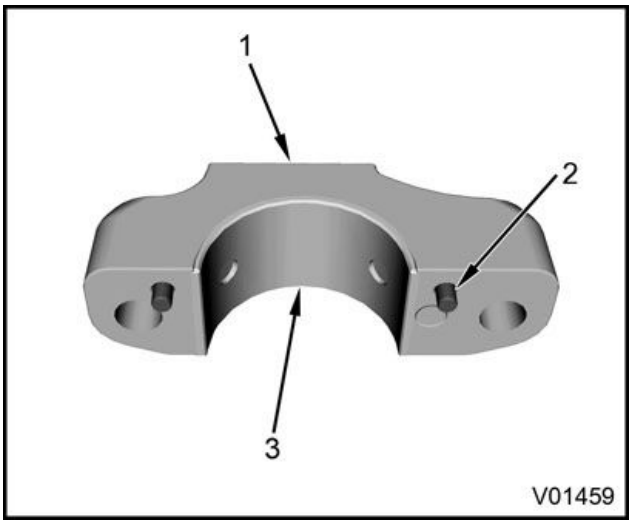

Figure 575 Camshaft bearing cap and bearing shell (typical)

1. Camshaft bearing cap
2. 4H x 8 x 10 dowel pin (2)
3. Bearing shell

6. Remove seven bearing shells from camshaft bearing caps. Mark each bearing shell with camshaft bearing cap number and orientation.
7. If damaged, remove 14 - 4H x 8 x 10 dowel pins from seven camshaft bearing caps.
8. Remove camshaft.
9. Remove seven lower bearing shells from cylinder head. Mark each bearing shell with camshaft bearing cap number and orientation.

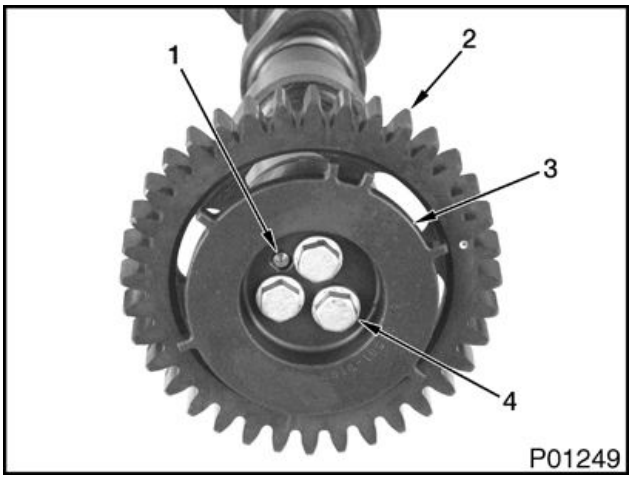

Figure 576 Camshaft gear and camshaft timing disc (pulse wheel)

1. Timing (M6 x 20 dowel) pin
2. Camshaft gear
3. Camshaft timing disc (pulse wheel)
4. M8 x 30 bolt (3)

10. Remove three M8 x 30 bolts.
11. Remove camshaft timing disc and camshaft gear.
12. If damaged, remove timing pin from camshaft.

Cylinder Head

CAUTION: To prevent engine damage, remove fuel injectors before removing cylinder head.

1. Remove six fuel injectors. See Fuel Injectors (page 244).

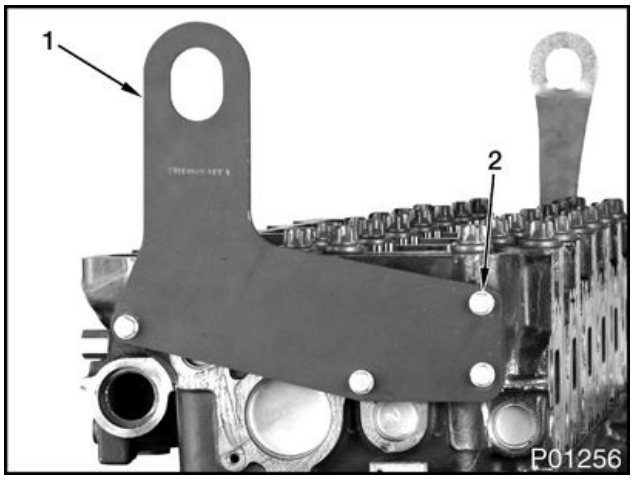

Figure 577 Cylinder Head Lifting Bracket

1. Cylinder Head Lifting Bracket
2. M8 x 20 class 10.9 bolt (4)

2. Position Cylinder Head Lifting Bracket (page 434) on rear end of cylinder head.
3. Install four M8 x 20 class 10.9 bolts (page 434). Tighten bolts to standard torque (page 547).

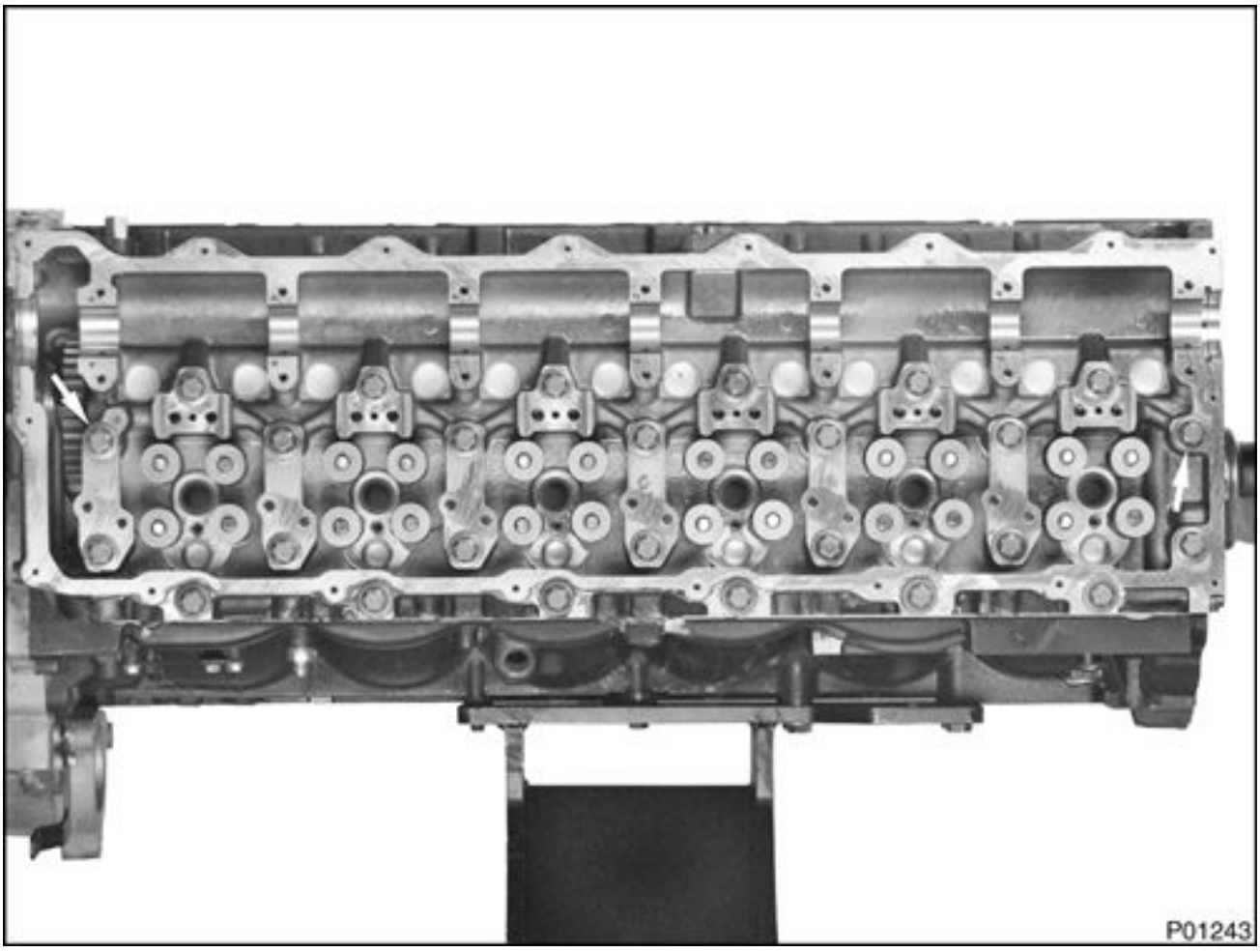

Figure 578 Cylinder head bolts

4. Use Head Bolt Torx® Socket (page 434) and working in a circular pattern, loosen, remove, and discard 26 M18 x 246 Torx® bolts. Begin with the outer bolts and move inward.

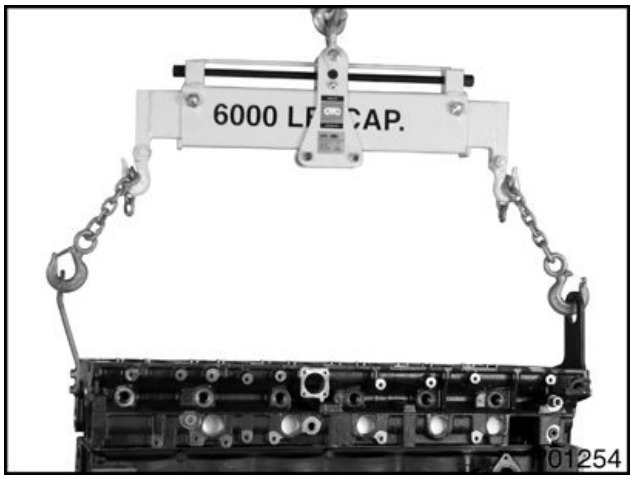

Figure 579 Cylinder head removal

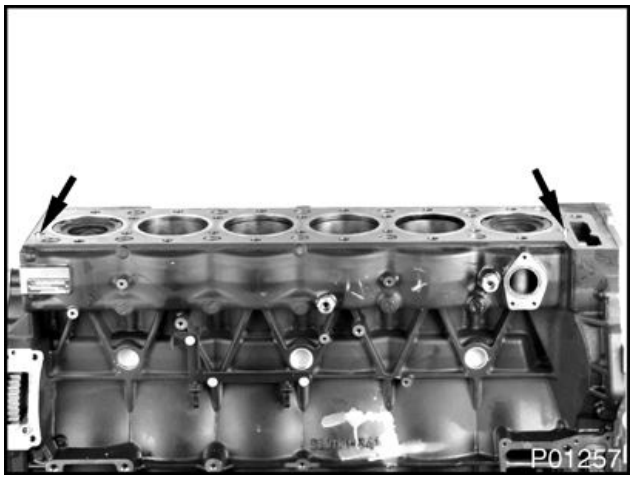

Figure 580 8 mm dowel pin (2)

5. Lift cylinder head using a suitable lifting device.

WARNING: To prevent personal injury or death, use a hoist rated for the weight of the cylinder head and follow the manufacturer's operative and safety instructions. Attach safety lifting hooks to the cylinder head lifting bracket and lifting eye.

CAUTION: To prevent engine damage, do not scratch gasket surface of cylinder head.

CAUTION: To prevent engine damage, carefully set cylinder head on wooden blocks to protect the cylinder head idler gear.

6. Place cylinder head on a clean, non-metallic surface.
7. Remove four M8 x 20 class 10.9 bolts and Cylinder Head Lifting Bracket (page 434).
8. Remove and discard cylinder head gasket.
9. If damaged, remove two 8 mm dowel pins.

Cylinder Head Idler Gear

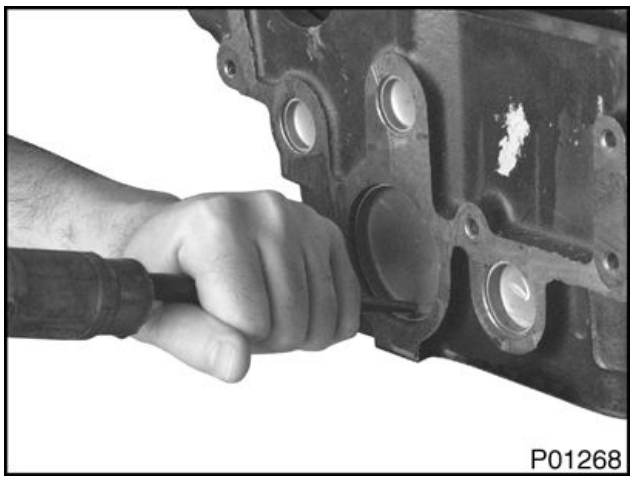

Figure 581 DMR 63.10 cup plug removal

1. Use a punch to knock in bottom of DMR 63.10 cup plug. Remove and discard cup plug.

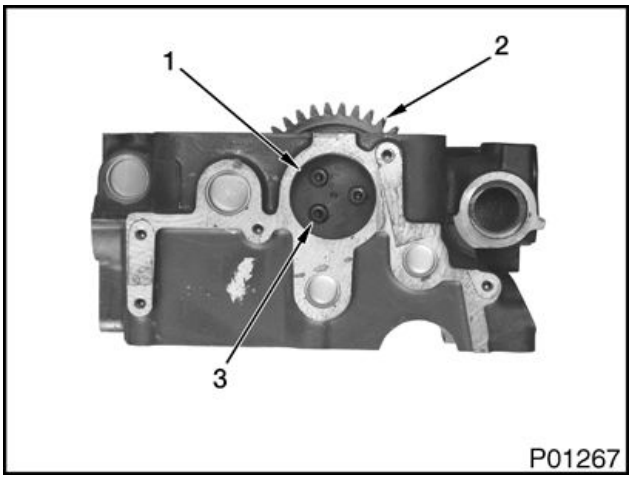

Figure 582 Cylinder head idler gear

1. Small gear shaft
2. Cylinder head idler gear
3. M8 x 30 socket-head cap screw (3)

2. Remove three M8 x 30 socket-head cap screws, small gear shaft and cylinder head idler gear.

CAUTION: To prevent engine damage, check piston protrusion before installing cylinder head.

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: Do not use chlorinated solvents on cylinder head bolts. If parts are not cleaned thoroughly, parts will corrode over time. Be sure parts are clean, dry and free of 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 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.

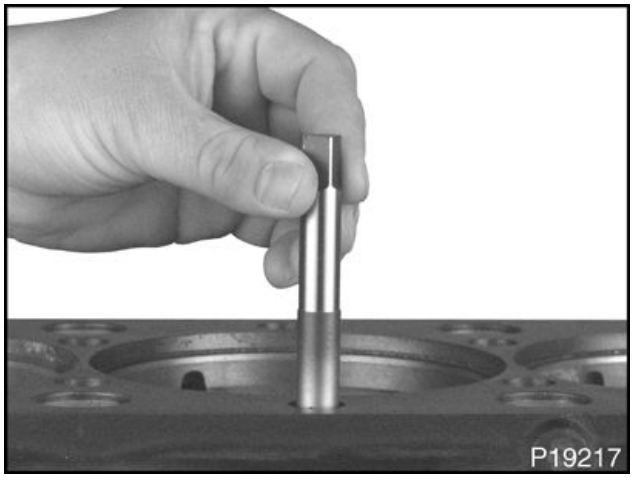

Figure 583 Head bolt bottoming tap (typical)

5. Clean cylinder head bolt holes in crankcase with Head Bolt Bottoming Tap (page 434).
6. Clean out debris with filtered compressed air.

Camshaft Bearings

1. With camshaft removed, install previously marked bearings and camshaft bearing caps. Tighten M8 x 35 bolts to special torque (page 433).

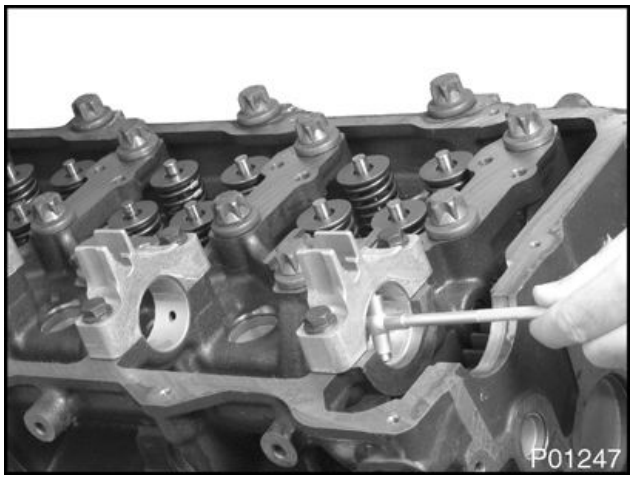

Figure 584 Camshaft bearing check (typical)

2. Use a telescoping gauge set (page 434) and a 1 - 2 inch micrometer (page 434) to measure camshaft bearing inside diameter. If inside diameter does not meet specification (page 433), install new camshaft bearings.

Fuel Injector Bore

1. Use Injector Sleeve Brushes (page 434) 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.

Valves Leak Test

NOTE: Position wooden blocks so the view of all the intake and exhaust valve heads and valve seat areas is not restricted.

1. Position cylinder head on wooden blocks with cylinder head gasket surface facing down.

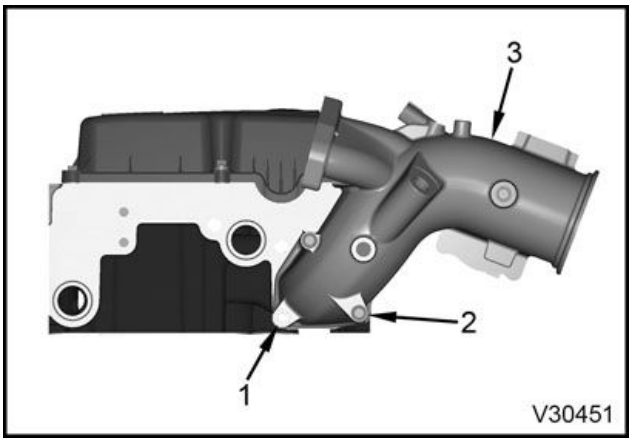

Figure 585 Air intake throttle duct (typical)

1. M8 x 50 bolt
2. M8 x 100 bolt (2)
3. Air intake throttle duct

2. Apply Loctite® 5900 sealant or equivalent (page 434) to joining surfaces of air intake throttle duct and cylinder head.
3. Install air intake throttle duct.
4. Install M8 x 50 bolt and two M8 x 100 bolts. Tighten bolts to standard torque (page 547).
5. Spray mineral spirits into exhaust ports.
6. Pour mineral spirits into air intake throttle duct until intake manifold inside cylinder head is filled.

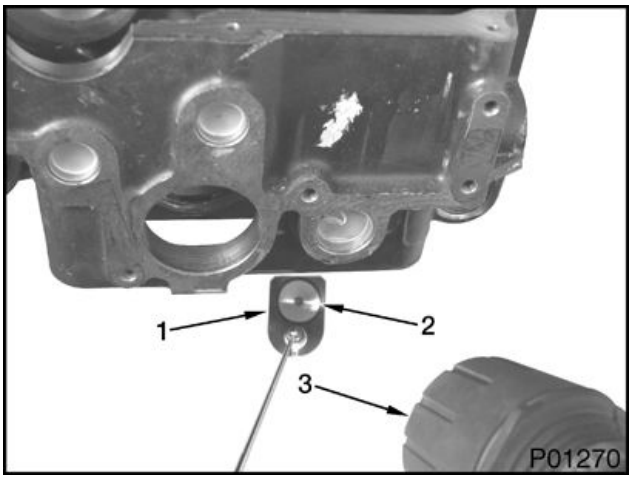

Figure 586 Leak inspection

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 valves leak test using mineral spirits.

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.

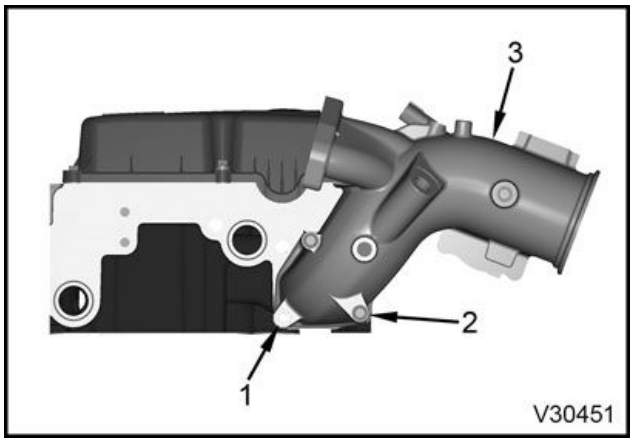

Figure 587 Air intake throttle duct

1. M8 x 50 bolt
2. M8 x 100 bolt (2)
3. Air intake throttle duct

8. Position a suitable container under air intake throttle duct to catch mineral spirits. M8 x 50 bolt and two M8 x 100 bolts.
9. Remove air intake throttle duct.
10. Lift rear end of cylinder head to drain all remaining mineral spirits out of the intake manifold.

Installation

Cylinder Head Idler Gear

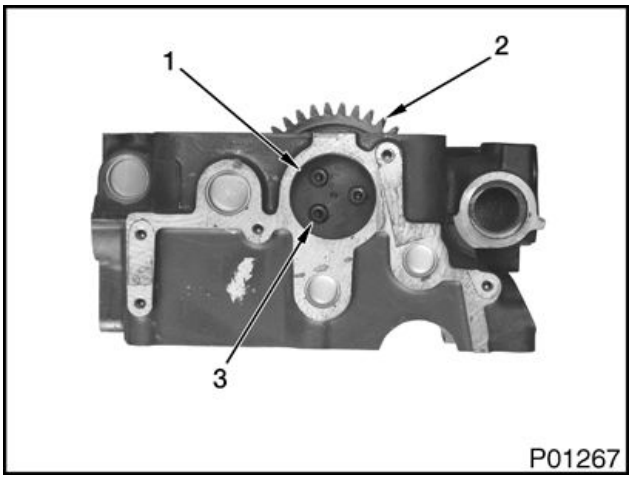

Figure 588 Cylinder head idler gear

1. Small gear shaft
2. Cylinder head idler gear
3. M8 x 30 socket-head cap screw (3)

1. Install small gear shaft and cylinder head idler gear.
2. Install three M8 x 30 socket-head cap screws. Tighten screws to special torque (page 433).
3. Clean cylinder head mating surfaces for cylinder head idler gear DMR 63.10 cup plug.
4. Apply Loctite® 262™ Threadlocker (page 434) to the outside edge of new cylinder head idler gear cup plug.

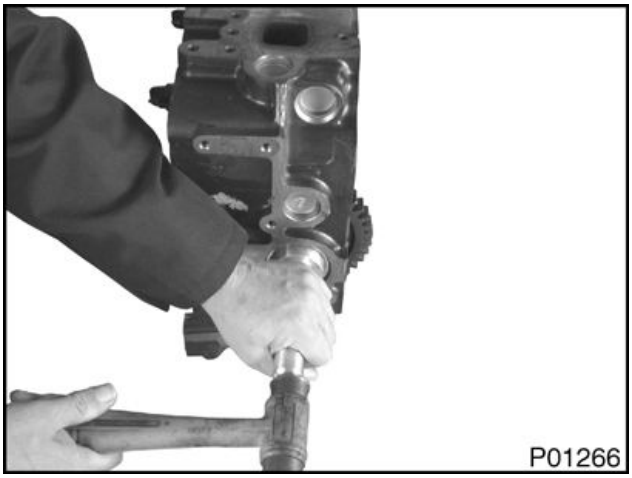

Figure 589 DMR 63.10 cup plug installation

5. Drive new cup plug into the hole using a Bearing Installer (page 434) approximately 6 mm (0.25 in) smaller in diameter than the cup plug.
6. Recess cup plug 2.3 mm (0.9 in) below the machined surface.

Cylinder Head

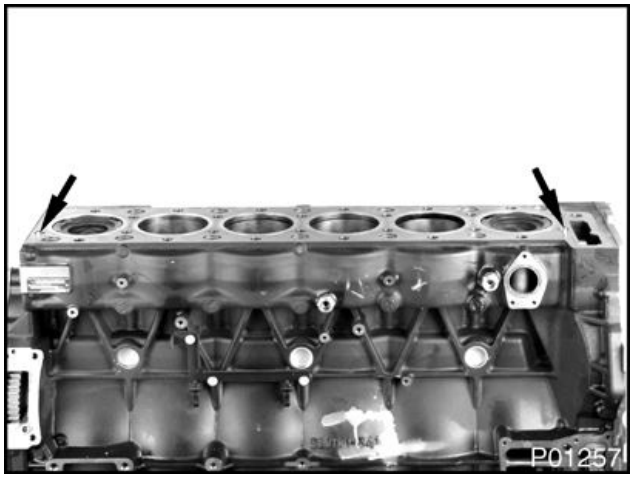

Figure 590 8 mm dowel pin (2)

1. If previously removed, install two 8 mm dowel pins in crankcase.

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

CAUTION: Do not use chlorinated solvents on cylinder head bolts. If parts are not cleaned thoroughly, parts will corrode over time. Be sure parts are clean, dry and free of 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 and contaminants from cylinder head gasket mating surfaces. If debris is not removed, a faulty seal between the cylinder head, gasket and crankcase 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.

CAUTION: To prevent engine damage, check piston protrusion before installing cylinder head.

2. Check piston protrusion. See Preliminary Checks (page 490).

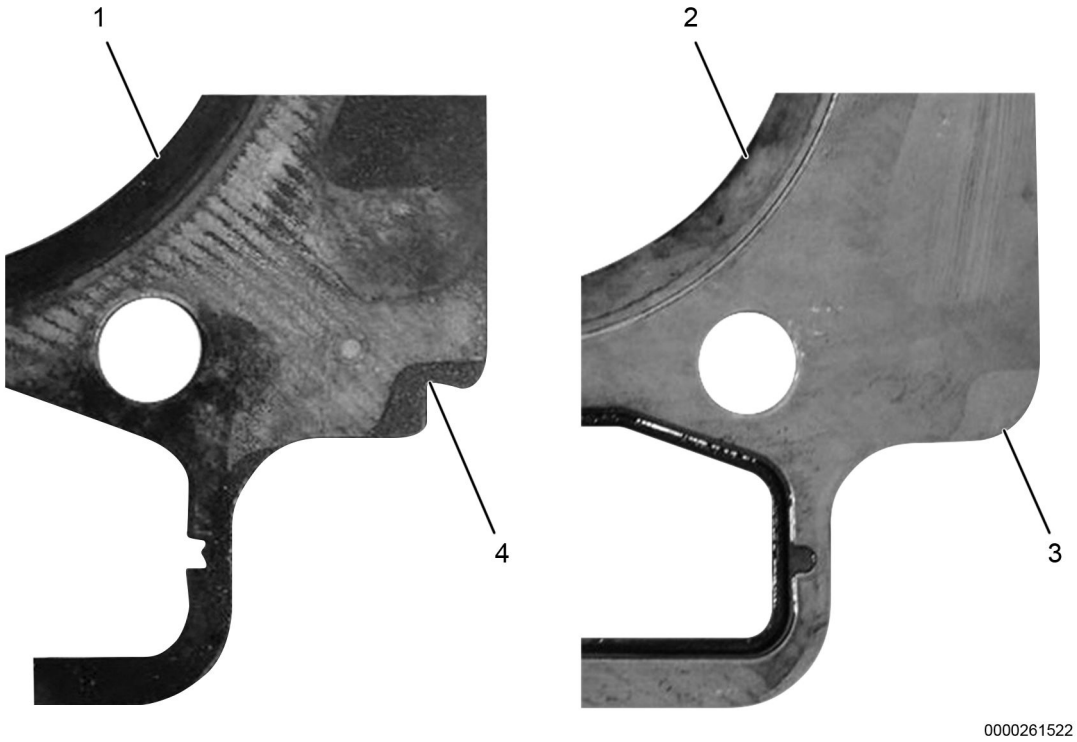

Figure 591 Cylinder head gasket

1. Navistar® N13 cylinder head gasket
2. MaxxForce® 11 cylinder head gasket
3. Right rear corner
4. Notch at right rear corner

CAUTION: To prevent engine damage, install correct cylinder head gasket for application.

3. Verify correct cylinder head gasket isused for application. Navistar® N13 cylinder head gaskets (Figure 591) (Item 1) have a notch at the right rear corner (Figure 591) (Item 4).
4. Install a new cylinder head gasket on crankcase, over dowel pins.

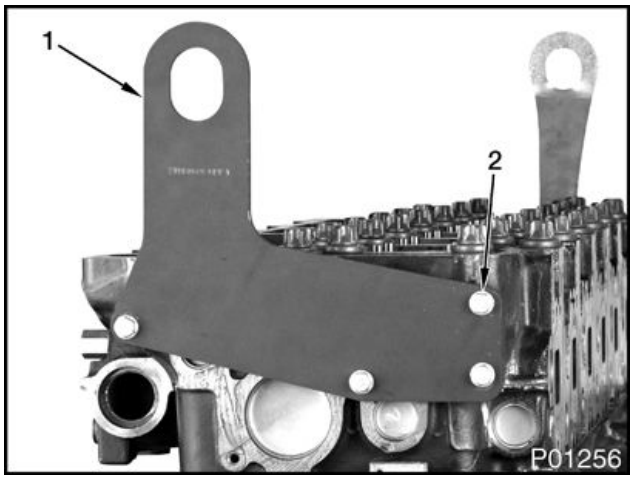

Figure 592 Cylinder Head Lifting Bracket

1. Cylinder Head Lifting Bracket
2. M8 x 20 class 10.9 bolt (4)

5. Position Cylinder Head Lifting Bracket (page 434) on rear end of cylinder head.
6. Install four M8 x 20 class 10.9 bolts (page 434). Tighten bolts to standard torque (page 547).

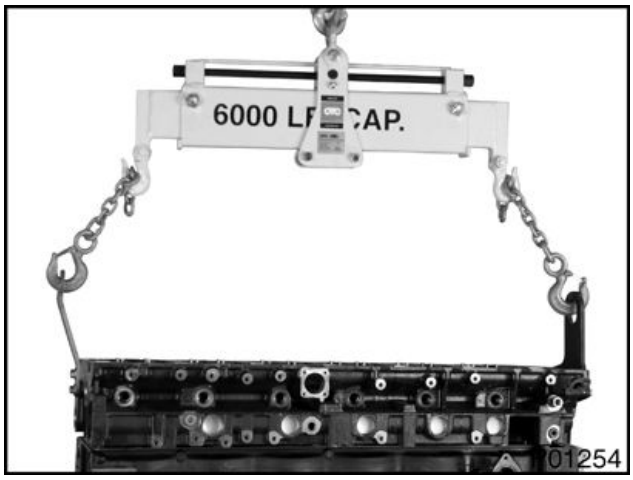

Figure 593 Cylinder head installation

WARNING: To prevent personal injuries or death, use a hoist rated for the weight of the cylinder head and follow the manufacturer's operation and safety instructions. Attach safety lifting hooks to the cylinder head lifting bracket and lifting eye.

CAUTION: To prevent engine damage, do not drop or slide cylinder head on cylinder head gasket. This can damage the cylinder head gasket, dowel pins and the cylinder head idler gear.

7. Attach an appropriate hoist and lifting hooks to cylinder head lifting bracket and lifting eye.
8. Lower cylinder head onto crankcase and align cylinder head alignment dowels in the crankcase with dowel holes in the cylinder head.

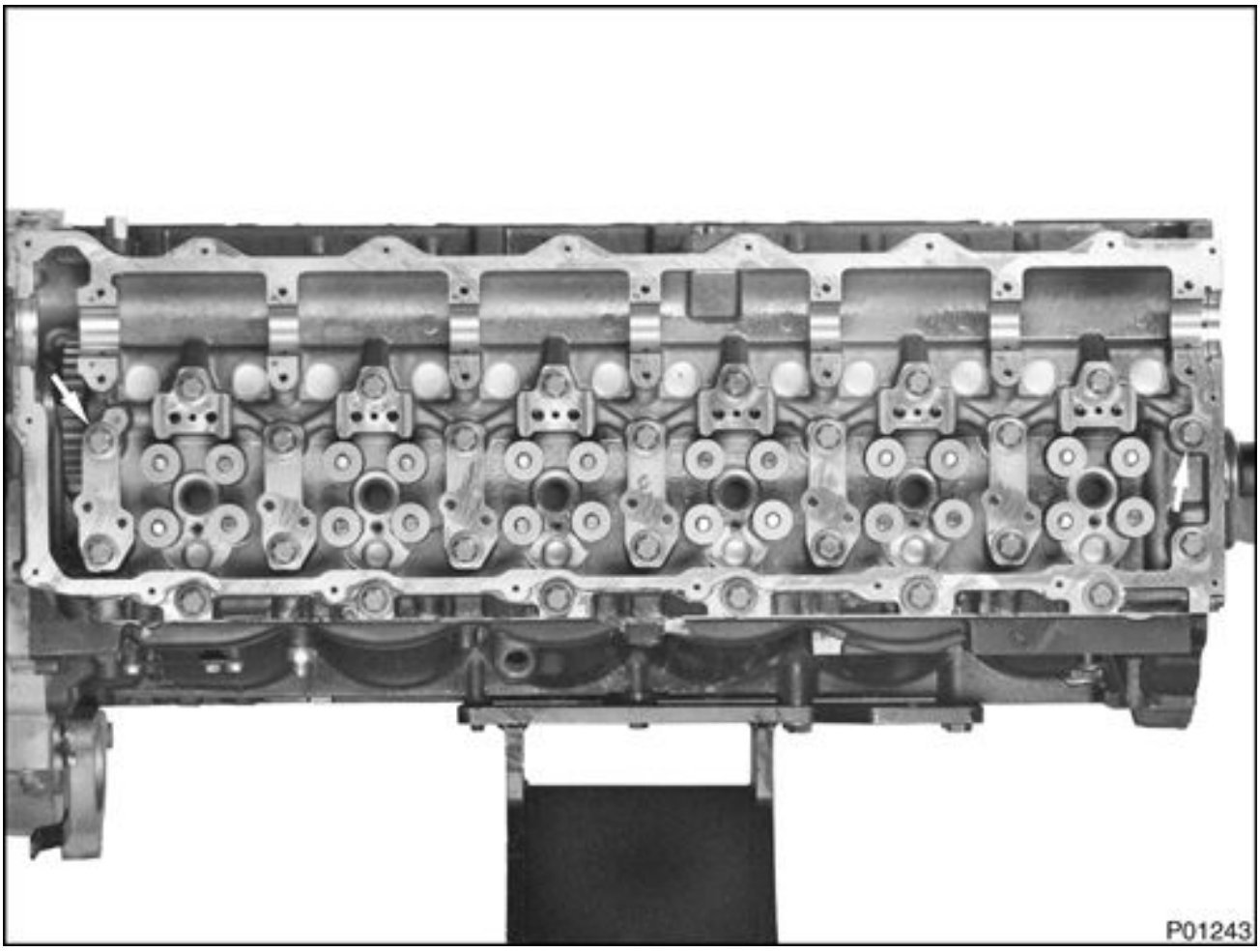

Figure 594 Cylinder head bolts

CAUTION: To prevent engine damage, install new cylinder head bolts when installing cylinder head. Apply a light coat of clean engine oil to new bolt threads and under bolt head. Too much oil will cause hydrostatic lock and give incorrect torque reading. Do not use anti-seize compound, grease, or any other lubricant on cylinder head bolt threads.

9. Install 26 new lightly lubricated M18 x 246 Torx® bolts. Do not tighten bolts at this time.
10. Remove four M8 x 20 class 10.9 bolts and Cylinder Head Lifting Bracket (page 434).

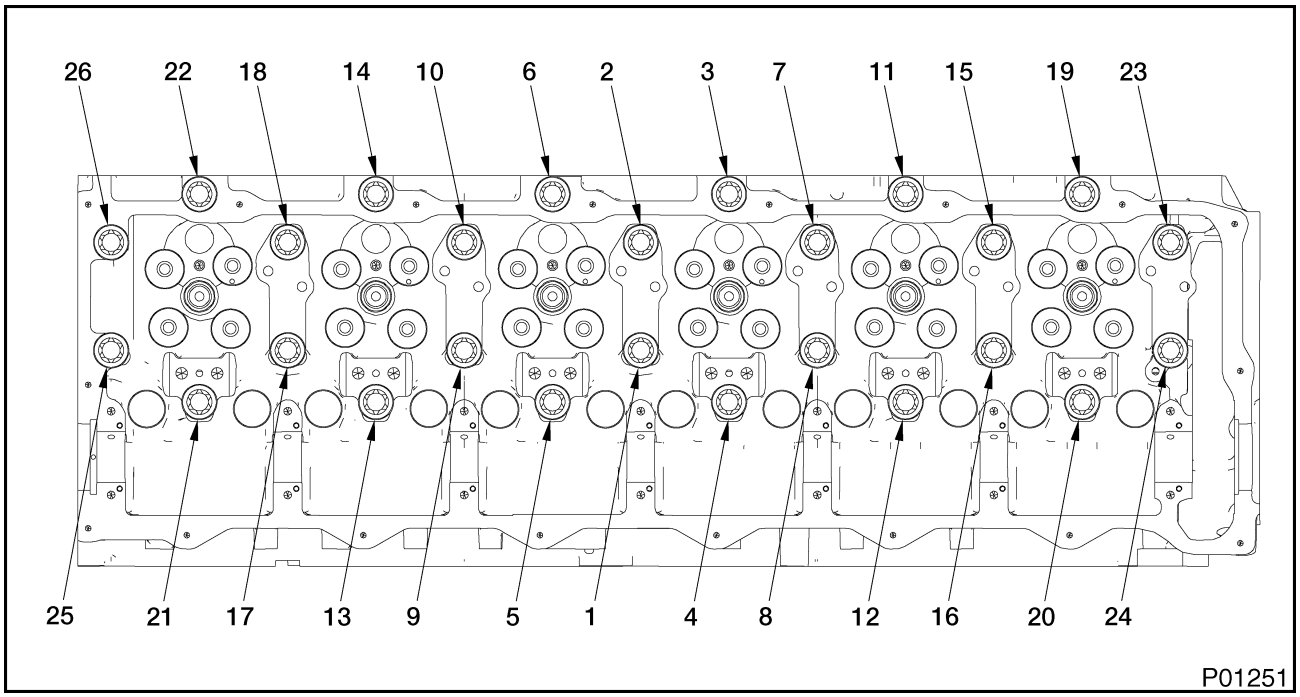

Figure 595 Cylinder head bolt tightening sequence

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.

11. Use Head Bolt Torx® Socket (page 434) to tighten the M18 x 246 Torx® bolts in sequence indicated above as follows:
    1. Hand-tighten Torx® bolts.
    2. Tighten Torx® bolts numbered 1 through 26 to 10 N·m (89 lb·in) in numerical sequence as shown.
    3. Tighten Torx® bolts numbered 1 through 26 to 150 N·m (111 lb·ft) in numerical sequence.
    4. Tighten Torx® bolts numbered 1 through 26 to 300 N·m (221 lb·ft) in numerical sequence.
    5. Rotate Torx® bolts numbered 1 through 26 an additional 90° (1/4 turn) clockwise in numerical sequence.
    6. Rotate Torx® bolts numbered 1 through 26 an additional 90° (1/4 turn) clockwise in numerical sequence for second time.
    7. Rotate Torx® bolts numbered 1 through 26 an additional 90° (1/4 turn) clockwise in numerical sequence for third time.

Camshaft

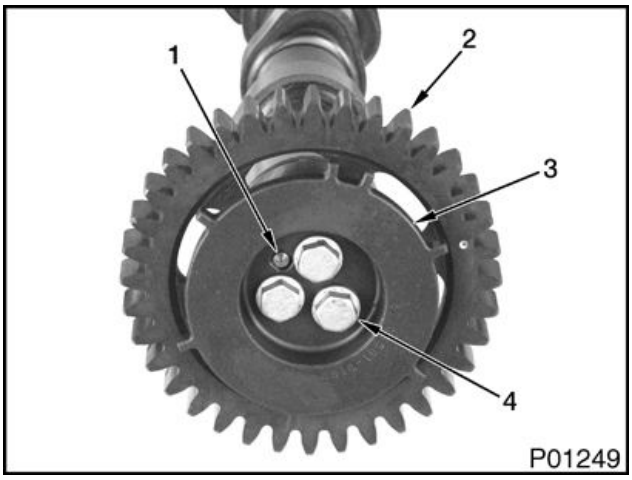

Figure 596 Camshaft gear and camshaft timing disc (pulse wheel)

1. Timing (M6 x 20 dowel) pin
2. Camshaft gear
3. Camshaft timing disc (pulse wheel)
4. M8 x 30 bolt (3)

1. If previously removed, install timing (M6 x 20 dowel) pin into camshaft.
2. Align camshaft gear with timing pin and install on camshaft.
3. Align camshaft timing disc with timing pin and install on camshaft.
4. Install and finger-tighten three M8 x 30 bolts.

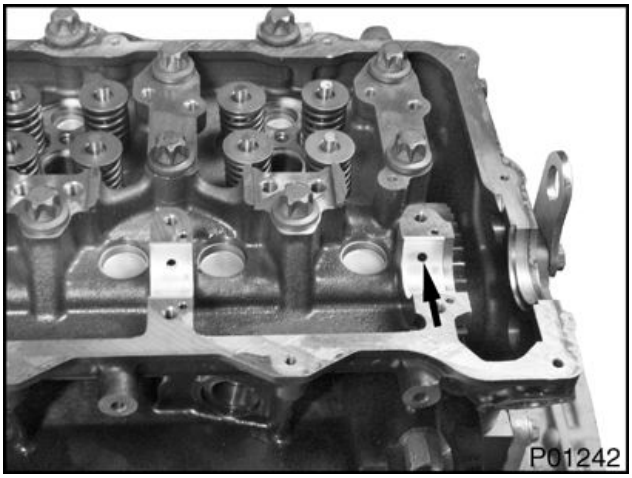

Figure 597 Camshaft lower bearing shell oil hole alignment (typical)

NOTE: If original camshaft bearings 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 bearings on cylinder head. Make sure oil holes in bearings are aligned with oil holes in cylinder head bearing support.
6. Rotate crankshaft so cylinder number 1 is positioned at TDC. See Crankshaft Rotation Procedure (page 405).

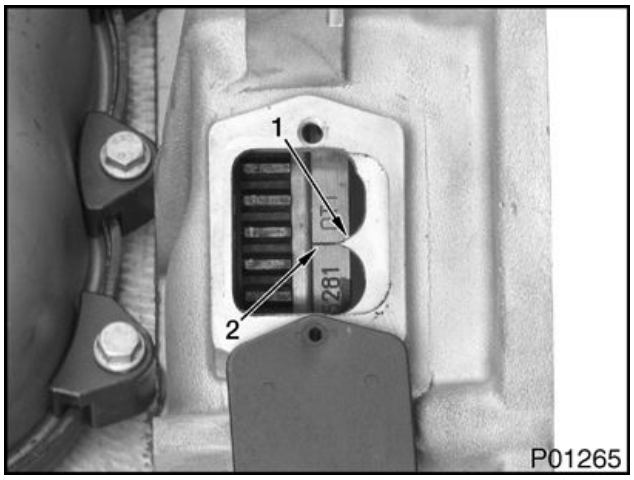

Figure 598 Flywheel housing timing index (typical)

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.

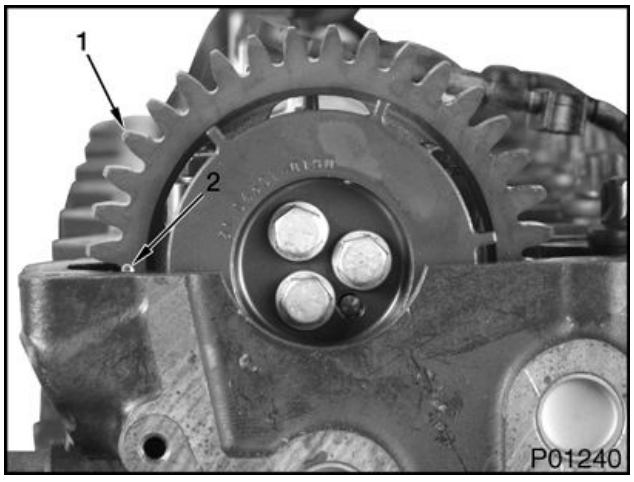

Figure 599 Camshaft timing mark (typical)

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.

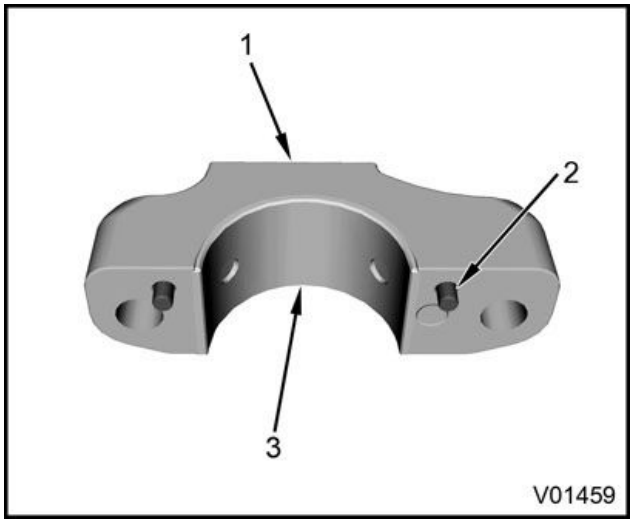

Figure 600 Camshaft bearing cap and bearing shell

1. Camshaft bearing cap
2. 4H x 8 x 10 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 - 4H x 8 x 10 dowel pins into seven camshaft bearing caps.

NOTE: If original bearings are installed, make sure each is placed as previously marked in its original location and orientation.

10. Install seven new or previously marked bearing shells on camshaft bearing caps.

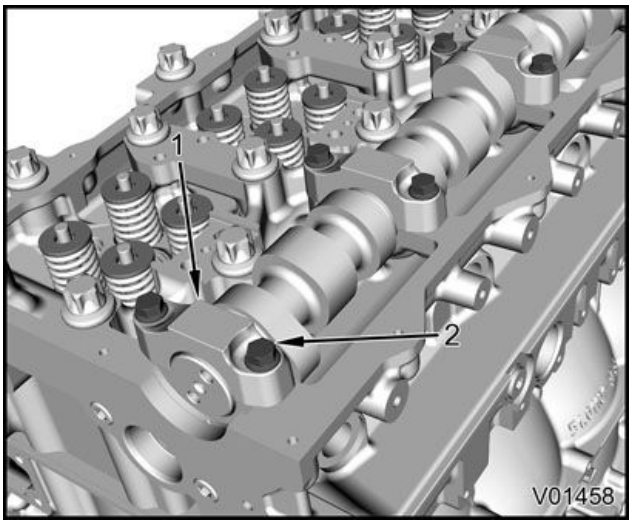

Figure 601 Camshaft bearing caps

1. Camshaft bearing cap (7)
2. M8 x 35 bolt (14)

11. Install seven previously marked camshaft bearing caps with each placed in its original location and orientation.
12. Install 14 M8 x 35 bolts. Tighten bolts to special torque (page 433).

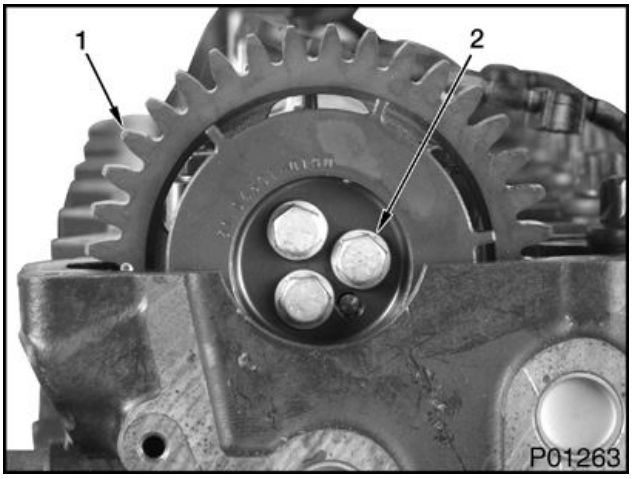

Figure 602 Camshaft gear bolts tightening

1. Camshaft gear
2. M8 x 30 bolt (3)

13. Tighten three M8 x 30 bolts to 15 N·m (133 lb·in).
14. Tighten three M8 x 30 bolts an additional 90° (1/4 turn).

Rocker Arm Assembly (Non-Brake Engine)

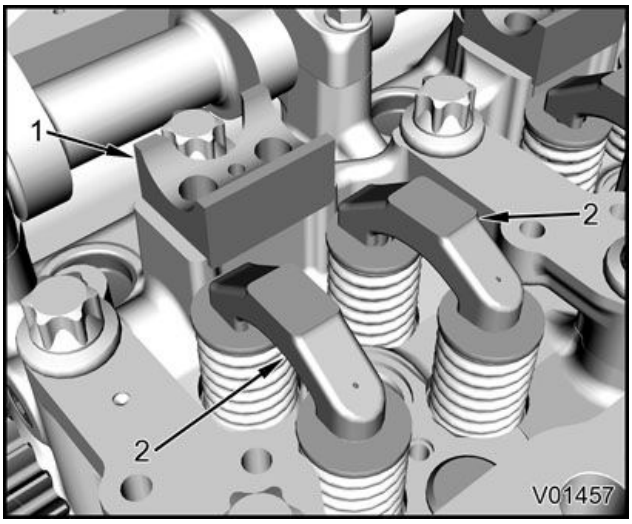

Figure 603 Rocker Bearing Block and Valve Bridges

1. Rocker bearing block (6)
2. Valve bridge (12)

NOTE: If original valve bridges are installed, make sure each is placed as previously marked in its original location.

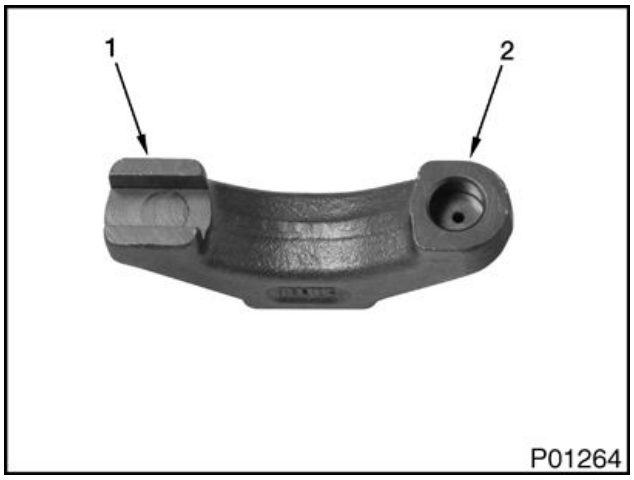

Figure 604 Valve Bridge Orientation (Typical)

1. Camshaft side
2. Exhaust manifold side

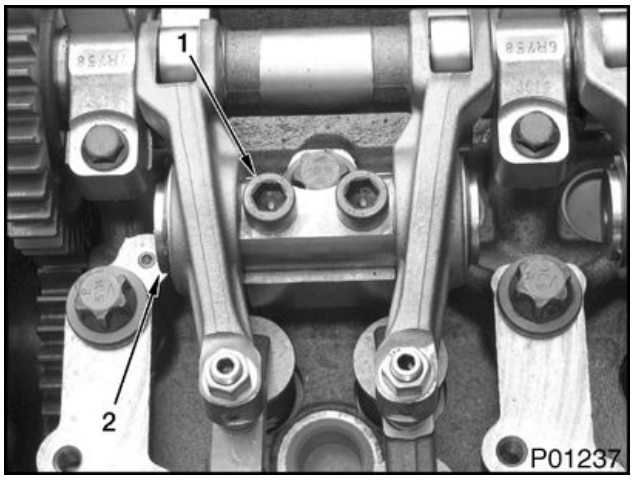

Figure 605 Rocker Arm Assembly (Typical)

1. M12 x 60 (socket-head) screw (12)
2. Rocker arm assembly (6)

1. Place 12 new or previously marked valve bridges on intake and exhaust valves with milled end oriented toward camshaft.

NOTE: If original rocker bearing blocks are installed, make sure each is placed as previously marked in its original location.

2. Install six new, or previously marked rocker bearing blocks.

NOTE: If original rocker arm assemblies are installed, make sure each is placed as previously marked in its original location.

3. Install six new or previously marked rocker arm assemblies (Figure 605) (Item 2).
4. Install 12 M12 x 60 socket-head screws (Figure 605) (Item 1). Tighten screws to 77 lb·ft (105 N·m).
5. Adjust valve lash. See Cylinder No. 1 TDC Procedure (page 405).

Upper Valve Cover and Base

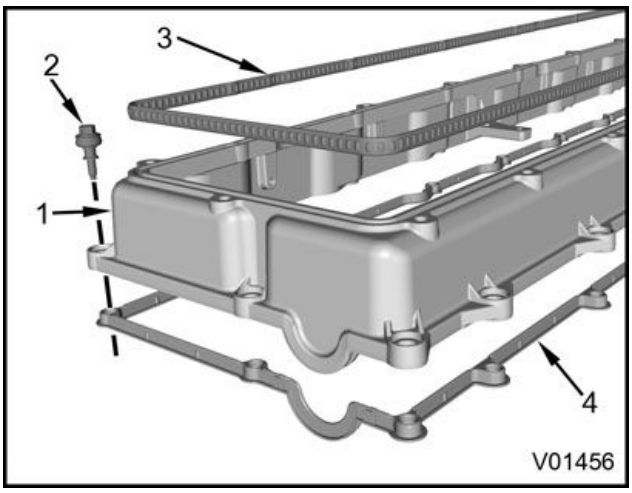

Figure 606 Valve Cover Gaskets

1. Valve cover base
2. Screw with damper (18)
3. Upper valve cover gasket
4. (Lower) valve cover gasket

1. Apply Loctite® 5127 sealant (page 434) at sharp corners and curved surfaces to joining surfaces of cylinder head and lower valve cover gasket (Figure 606) (Item 4).
2. If necessary, install a new lower and/or upper valve cover gasket (Figure 606) (Item 3).
3. If previously removed, install 18 screws with dampers (Figure 606) (Item 2) in valve cover base (Figure 606) (Item 1) and through lower valve cover gasket.

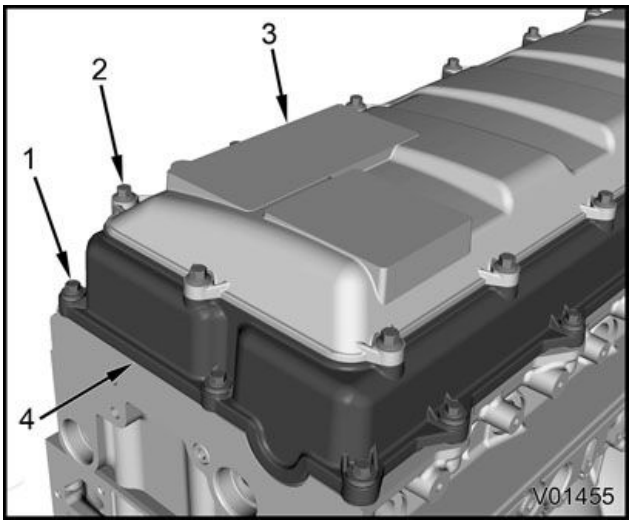

Figure 607 Upper Valve Cover and Base

1. Screw with damper (18)
2. M8 x 30 bolt (17)
3. Upper valve cover
4. Valve cover base

CAUTION: To prevent engine damage, do not use power tools to remove or install valve cover bolts. Threads will be damaged if a bolt or nut is rotated too quickly.

4. Install valve cover base (Figure 607) (Item 4) on cylinder head and finger tighten 18 screws with dampers (Figure 607).

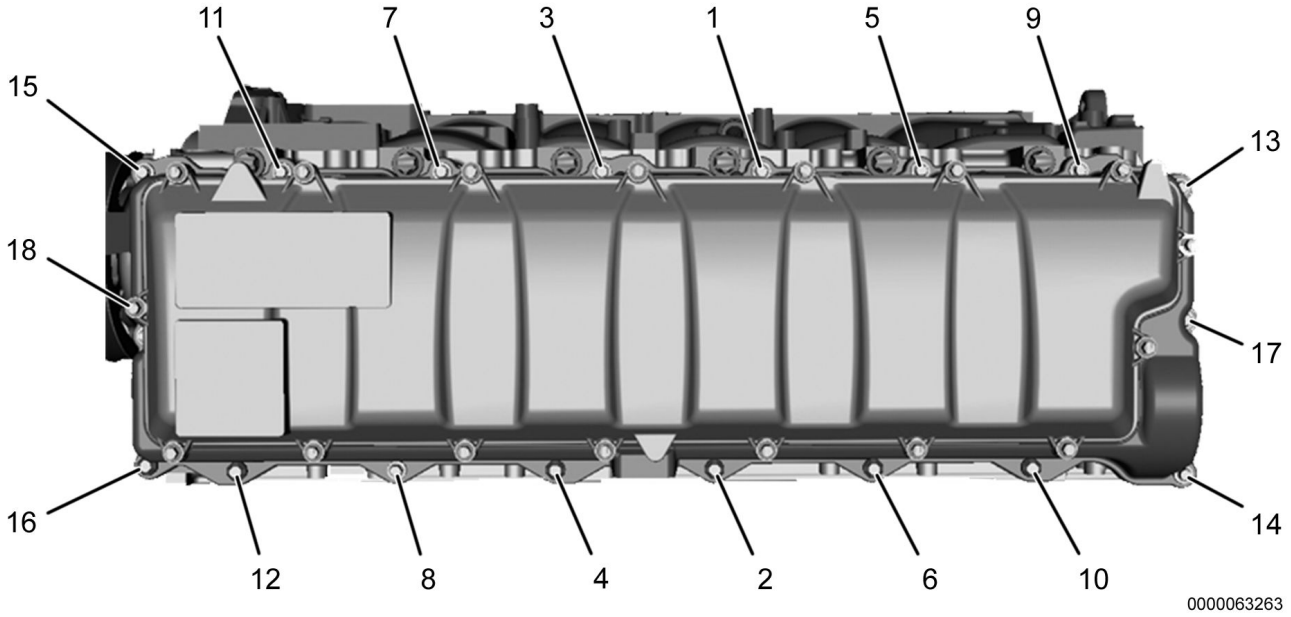

Figure 608 Valve Cover Base Tightening Sequence

5. Tighten 18 screws with dampers (Figure 607) (Item 1) in sequence shown above (Figure 608). Tighten to 97 lb·in (11 N·m).
6. If removed, install upper valve cover (Figure 607) (Item 3) on valve cover base.
7. Install 17 M8 x 30 bolts (Figure 607) (Item 2) and tighten to 80 lb·in (9 N·m).

Specifications

Camshaft	
Camshaft bearing inside diameter	39.925 – 39.950 mm (1.57185 – 1.57283 in)
Camshaft end play	0.25 – 0.85 mm (0.0098 – 0.0334 in)
Valve Lash Adjustment	
Exhaust valve clearance	0.8 mm (0.0315 in)
Intake valve clearance	0.5 mm (0.0197 in)
Cylinder Head Idler Gear Cup Plug	
Cup plug, DMR 63.10	Recess 2.3 mm (0.9 in)

Special Torque

Camshaft gear M8 x 30 bolt	See tightening steps in procedure
(Camshaft) bearing cap M8 x 35 bolt	25 N·m (18 lb·ft)
Cylinder head idler gear M8 x 30 socket-head cap screw	30 N·m (22 lb·ft)
Cylinder head M18 x 246 Torx® bolt	See tightening steps in procedure
Rocker arm assembly M12 x 60 (socket-head) screw	105 N·m (77 lb·ft)
Upper valve cover M8 x 30 bolt	9 N·m (80 lb·in)
Valve cover base screw with damper	11 N·m (97 lb·in)
Valve lash adjustment M10 nut	45 N·m (33 lb·ft)

Special Service Tools

Description	Tool Number
1 - 2 inch micrometer	Obtain locally
Bearing installer	Obtain locally
Connecting Rod Bolt Torx® Socket	ZTSE4835
Cylinder Head Lifting Bracket	ZTSE4869
Dial indicator with magnetic base	Obtain locally
Feeler gauge (Jacobs® 96-020949)	Obtain from Jacobs
Head Bolt Bottoming Tap	ZTSE4855
Head Bolt Torx® Socket	ZTSE4787
Injector Sleeve Brushes	ZTSE4751
Lash Gauge 0.5 mm (0.020 in)	ZTSE6076-5A
Lash Gauge 0.8 mm (0.031 in)	ZTSE6076-7A
Loctite® 262™ Threadlocker	Obtain locally
Loctite® 5127 sealant	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 Views

Flywheel Housing and Flywheel (Manual Transmission)

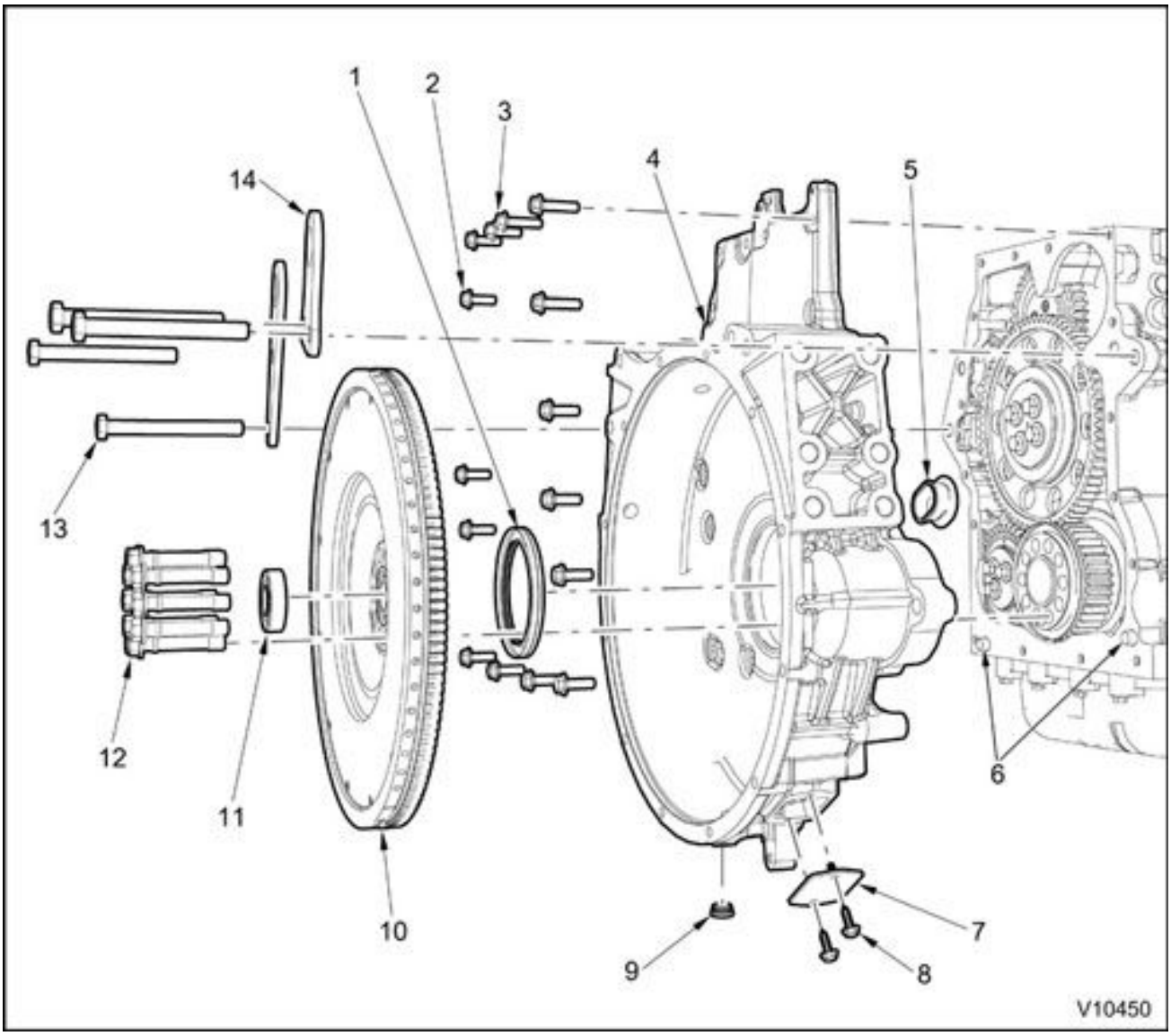

Figure 609 Flywheel housing and flywheel (manual transmission)

1. Radial shaft ring seal
2. M10 x 30 bolt (12)
3. M10 x 40 bolt (3)
4. Flywheel housing
5. 56/48 x 19 plug (converter bolt access)
6. Dowel pin (2)
7. Timing hole cover
8. Tapping screw (2)
9. Plug
10. Flywheel assembly
11. Pilot bearing
12. 12PT flange bolt (10)
13. M16 x 150 bolt (4)
14. Lifting eye (2)

Flywheel and Flexplate Assembly (Automatic Transmission)

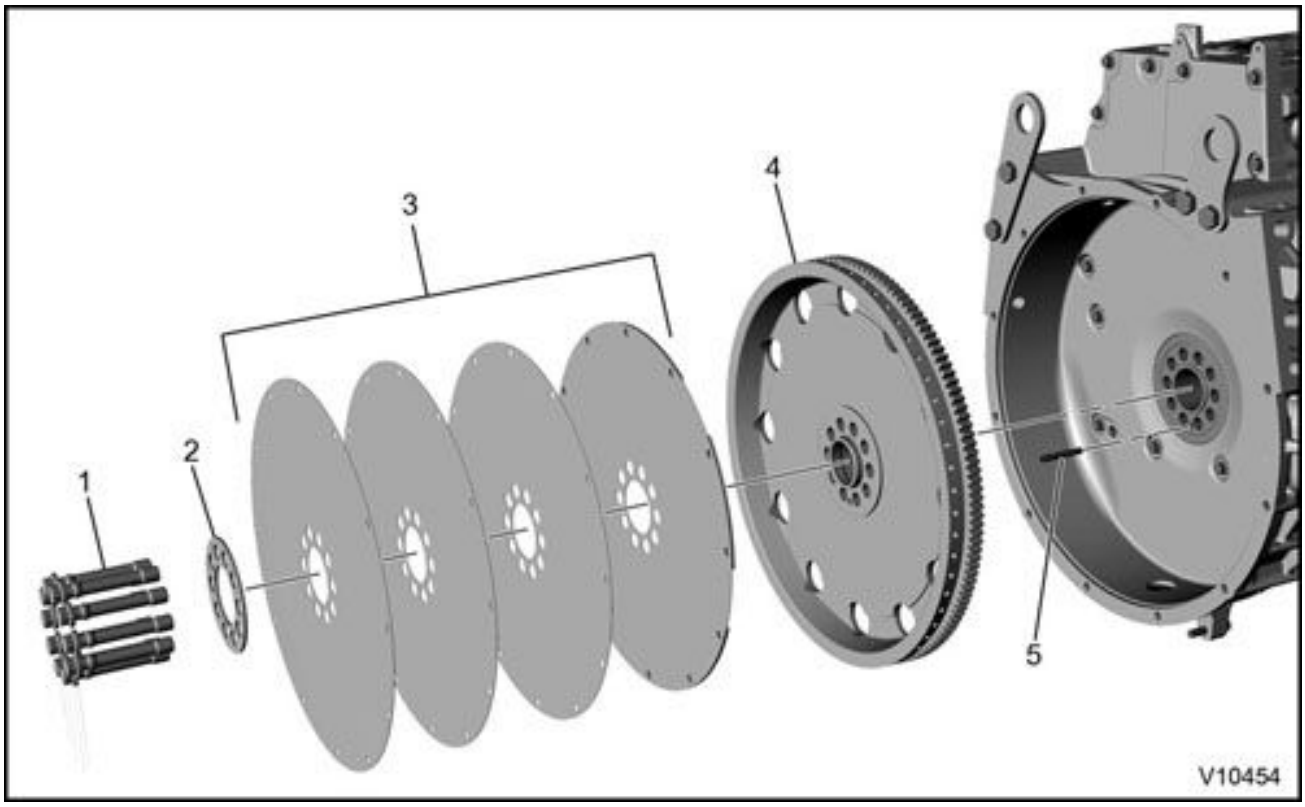

Figure 610 Flywheel and flexplate assembly (automatic transmission)

1. 12PT flange bolt (10)
2. Wear plate (reinforcement ring)
3. Flexplate assembly
4. Flywheel assembly
5. 8 x 60-ST pin

Rear Engine Mounts

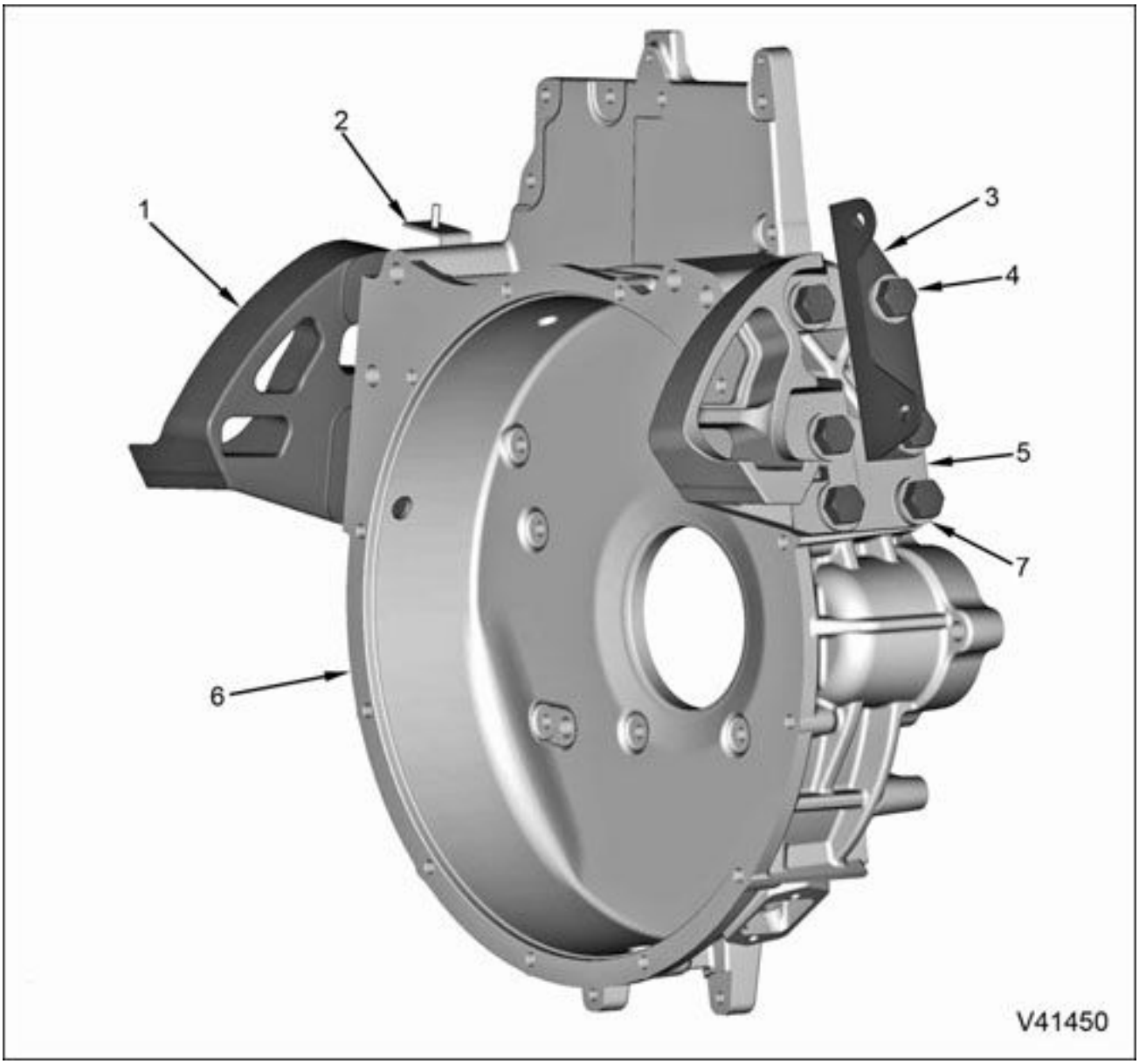

Figure 611 Rear engine mounts

1. Left offset engine mounting support
2. Extension assembly
3. PDO base bracket
4. 3/4” x 2” bolt (12)
5. Right offset engine mounting support
6. Flywheel housing
7. 3/4” washer (12)

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 section for information on removal of components prior to this section:

- **Aftertreatment System**

Preliminary Checks and Measurements

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.

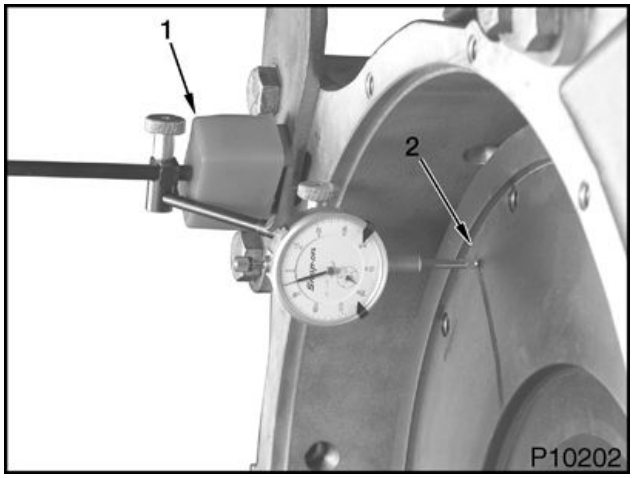

Figure 612 Flywheel surface runout

1. Dial indicator with magnetic base
2. Flywheel

1. Attach dial indicator with magnetic base (page 452) 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, zero dial indicator.
3. While pushing inward on the flywheel to eliminate crankshaft end play, slowly rotate crankshaft one complete revolution. See Crankshaft Rotation Procedure (page 405). Compare total dial indicator variation (highest - lowest reading) to specification (page 452).

Pilot Bearing

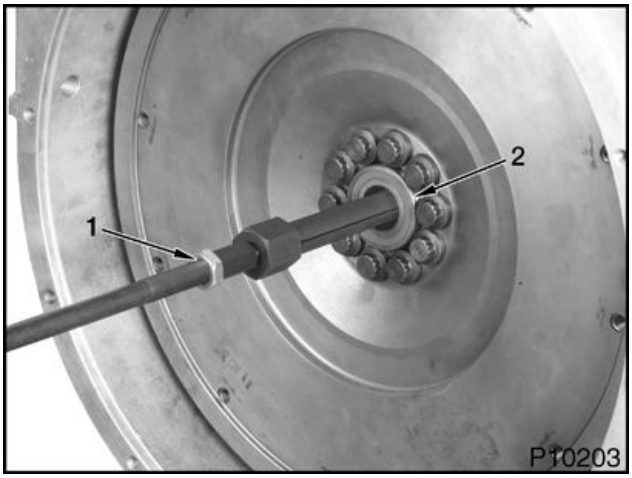

Figure 613 Pilot bearing removal (typical)

1. Slide hammer and blind hole puller
2. Pilot bearing

1. Using a slide hammer (page 452), install blind hole puller (page 452), into pilot bearing.
2. Tap slide hammer and remove pilot bearing.

Flywheel (Manual Transmission)

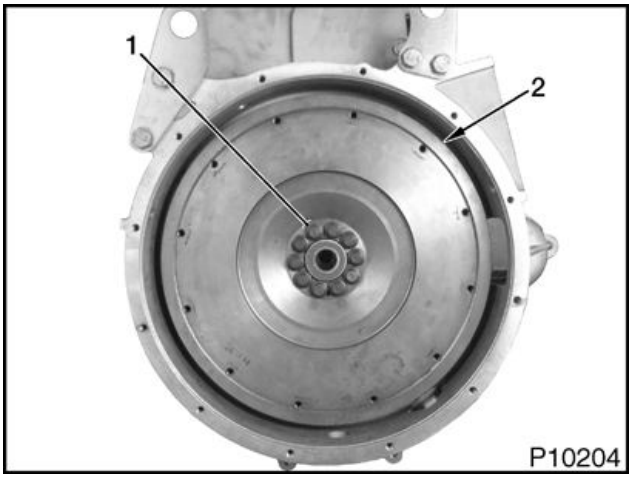

Figure 614 Flywheel removal

1. 12PT flange bolt (10)
2. Flywheel assembly

1. Remove transmission and torque converter assembly. (See transmission manufacturer's service publications.)
2. Remove and discard two 12PT flange bolts at approximately 3 o'clock and 9 o'clock position.
3. Install two guide pins (make locally) into crankshaft flange.
4. Remove and discard remaining eight 12PT flange bolts.
5. Slide wear plate (reinforcement ring) and four flexplates off guide pins.
6. Slide flywheel assembly off guide pins and out of flywheel housing.
7. Remove guide pins from crankshaft flange.

Flywheel and Flexplate Assembly (Automatic Transmission)

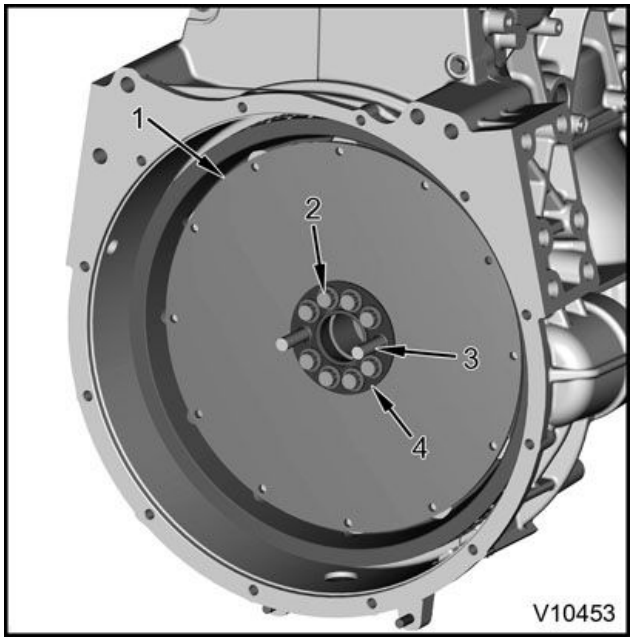

Figure 615 Flywheel and flexplate assembly

1. Flexplate and flywheel assembly
2. 12PT flange bolt (10)
3. Guide pin (2)
4. Wear plate (reinforcement ring)

1. Remove transmission and torque converter assembly. (See transmission manufacturer's service publications.)
2. Remove and discard two 12PT flange bolts, 180 degrees from each other (approximately 3 o'clock and 9 o'clock positions).
3. Install two guide pins (made locally) in place of two removed 12PT flange bolts.
4. Remove and discard the remaining eight 12PT flange bolts.

NOTE: The individual components of the flexplate assembly are non-servicable. Replace the flexplate as an assembly.

5. Slide wear plate (reinforcement ring) and four flexplates off guide pins.
6. Slide flywheel assembly off guide pins and out of flywheel housing.
7. Remove guide pins from crankshaft flange.

Radial Shaft Ring Seal

WARNING: To prevent personal injury or death, wear safety glasses with side shields.

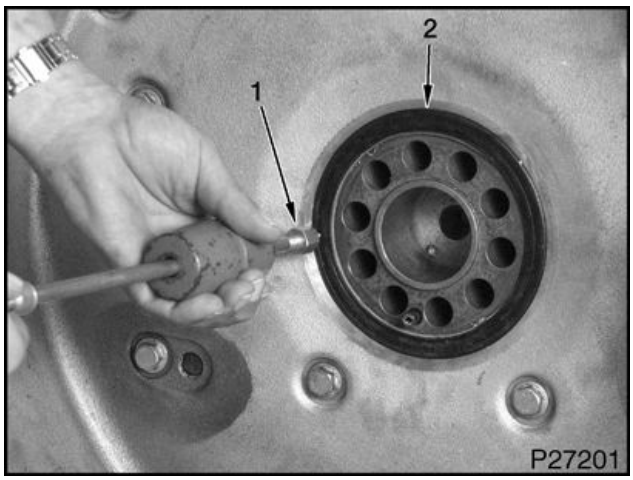

Figure 616 Radial shaft ring seal removal

1. Slide hammer
2. Radial shaft ring seal

1. With an awl and hammer, punch two holes 180° apart in radial shaft ring seal.
2. Thread a slide hammer (page 452) 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 seal is completely removed.

Lifting Eyes

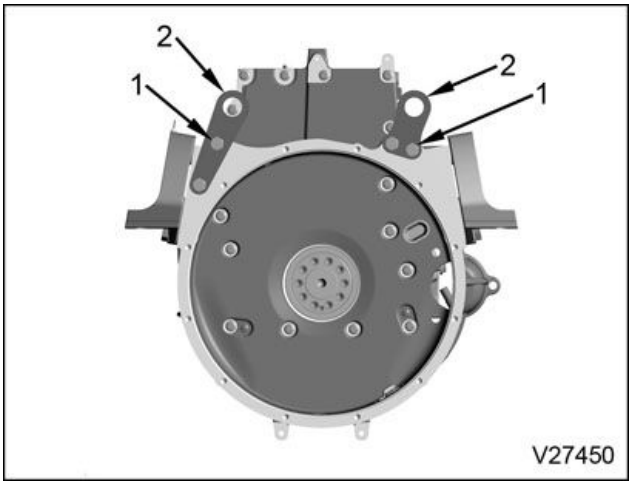

Figure 617 Lifting eye

1. M16 x 150 bolt (4)
2. Lifting eye (2)

1. Remove four M16 x 150 bolts.
2. Remove two lifting eyes.

Flywheel Housing

WARNING: To prevent personal injury or death, support the flywheel housing before removing bolts and breaking sealant bond between flywheel housing and crankcase.

WARNING: To prevent personal injury or death, get help when removing or installing the flywheel housing.

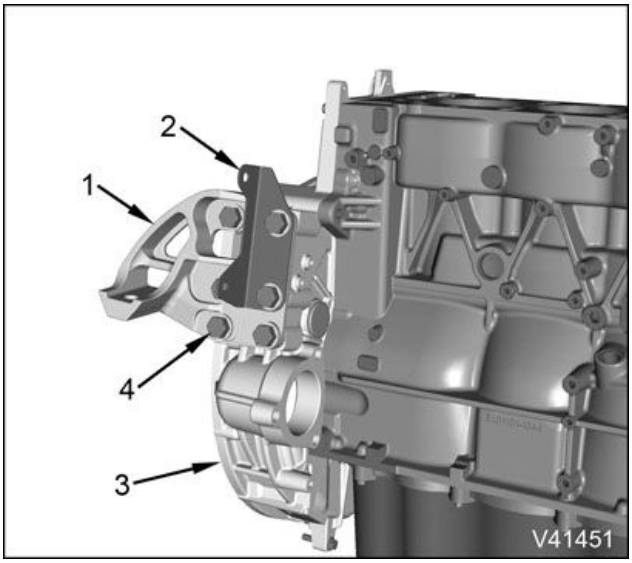

Figure 618 Right offset engine mounting support assembly

1. Right offset engine mounting support
2. PDO base bracket
3. Flywheel housing
4. 3/4" x 2” bolt with 3/4” washer (6)

1. Remove six 3/4" x 2” bolts with washers, PDO base bracket and engine mounting support from right side of flywheel housing.
2. Remove 3/4" x 2” bolts with washers, extension bracket and engine mounting support from the left side of flywheel housing.

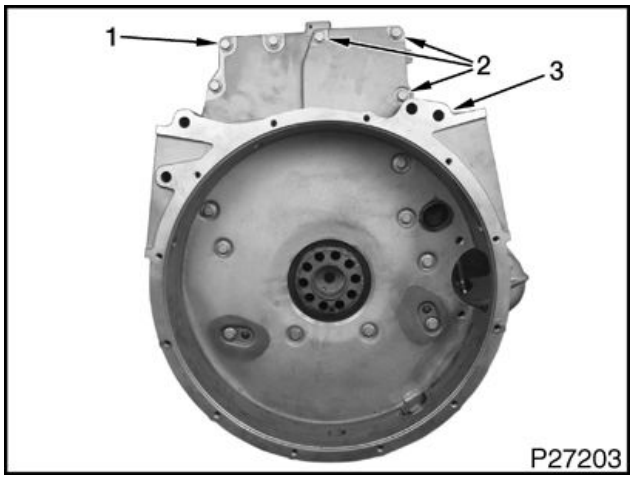

Figure 619 Flywheel housing (typical)

1. M10 x 30 bolt (12)
2. M10 x 40 bolt (3)
3. Flywheel housing

WARNING: To prevent personal injury or death, support the flywheel housing before removing bolts and breaking sealant bond between housing and crankcase.

3. Remove 12 M10 x 30 and three M10 x 40 bolts from flywheel housing.
4. 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.

5. Remove flywheel housing with aid of an assistant.

Cleaning and Inspection

All Components

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

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.
3. Wash flywheel, flexplate (if equipped) 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.

Flywheel and Flexplate Assemblies

1. Inspect flywheel for cracks around webbing and bolt holes.
2. Inspect flywheel for extensive heat cracks and scoring.
3. If equipped, inspect flexplate for cracks, damage or warpage. Replace if required.
4. Inspect all ring gear teeth for starter pinion damage.
5. 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.

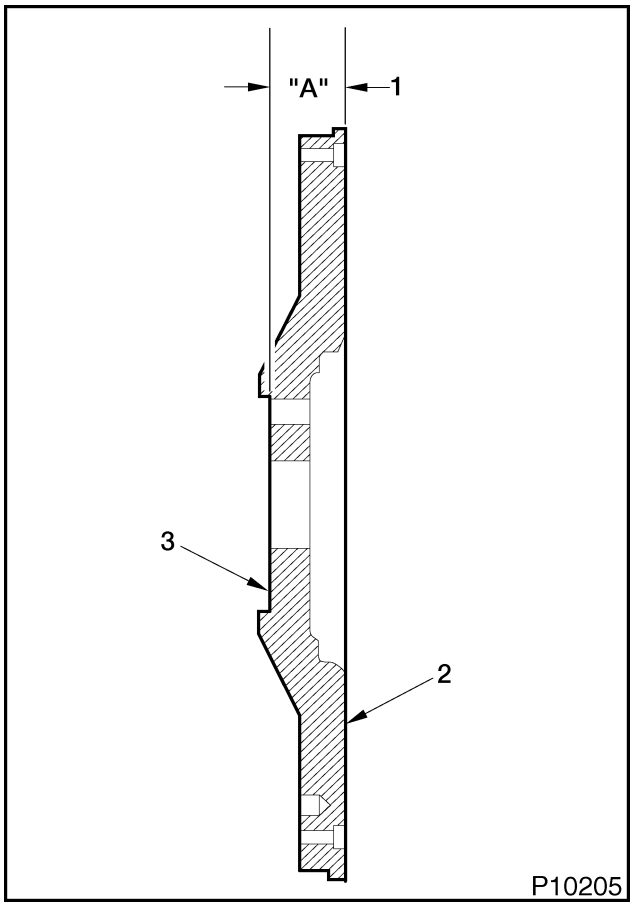

Figure 620 Flywheel surface dimension (typical)

1. Flywheel thickness (dimension “A”)
2. Clutch disc mounting face
3. Crankshaft timing gear face

NOTE: Flywheel resurfacing information is provided for guidance only. Navistar, Inc. 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.
2. Using 1-2 inch micrometer (page 452), measure flywheel thickness and compare to minimum required thickness specification (dimension “A”) (page 452). 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.

Installation

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.

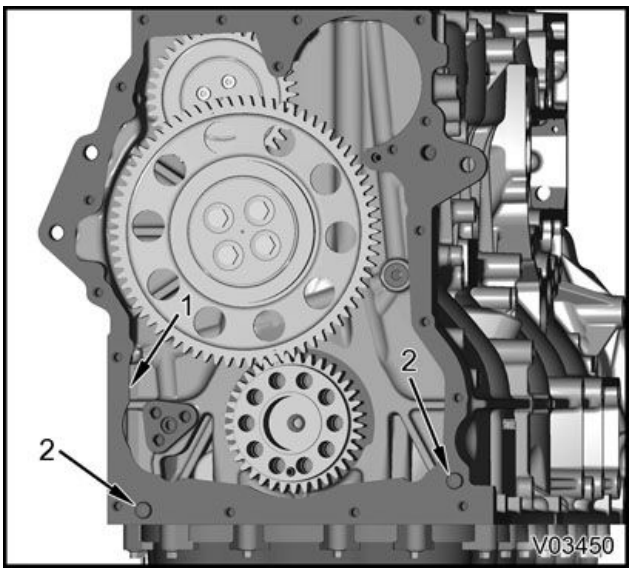

Figure 621 Flywheel housing to crankcase alignment dowel pins

1. Flywheel housing to crankcase mating surface
2. Flywheel housing to crankcase dowel pin (2)

1. Verify flywheel housing alignment dowels are installed into the crankcase and are not damaged. Replace as necessary.

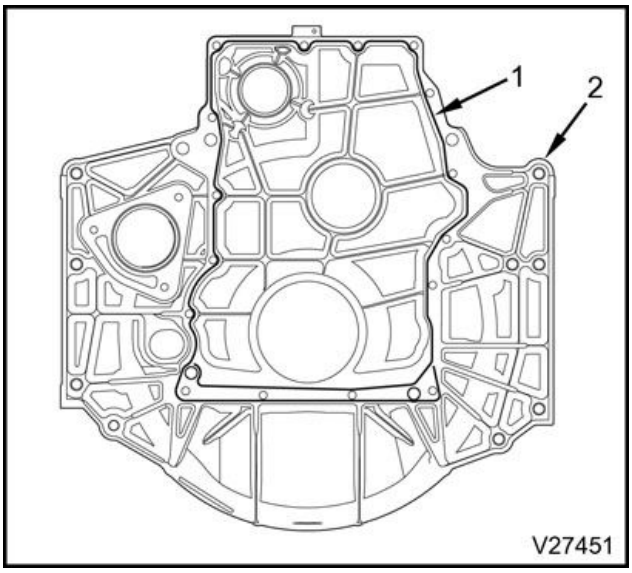

Figure 622 Flywheel housing sealant application

1. Apply sealant on mating surface
2. Front of flywheel housing

2. Apply Loctite 5900 or Wacker® A–442 RTV sealant (page 452) to mating surfaces of flywheel housing and crankcase.

⚠ WARNING: To prevent personal injury or death, get help when removing or installing the flywheel housing.

3. Install flywheel housing to crankcase with the aid of an assistant.

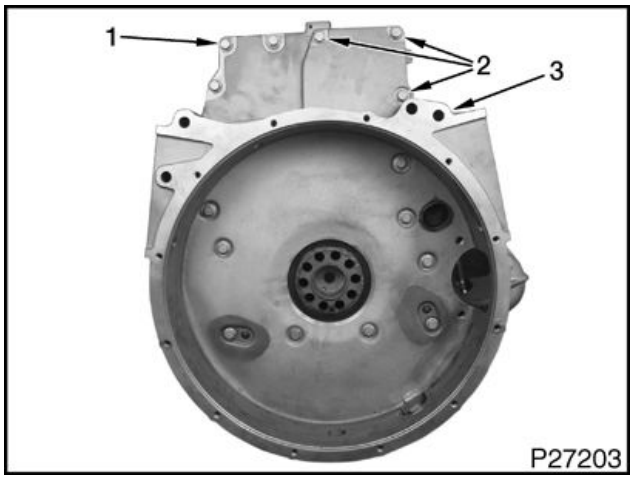

Figure 623 Flywheel housing (typical)

1. M10 x 30 bolt (12)
2. M10 x 40 bolt (3)
3. Flywheel housing

4. Install 12 M10 x 30 and three M10 x 40 flywheel housing bolts. Tighten bolts to special torque (page 452).

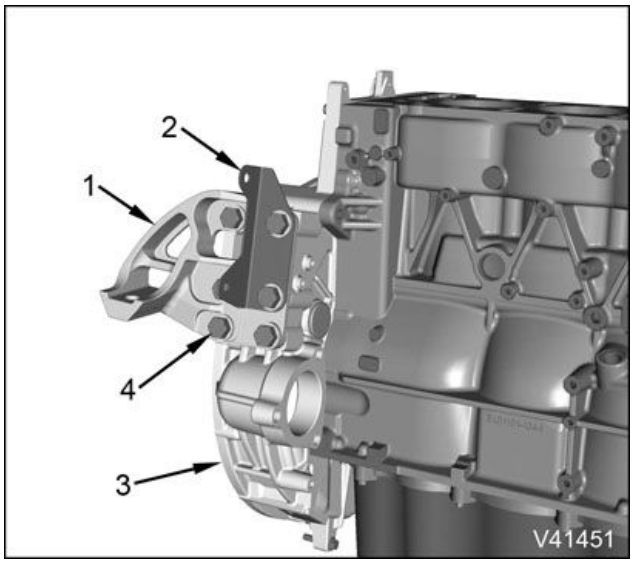

Figure 624 Right offset engine mounting support assembly

1. Right offset engine mounting support
2. PDO base bracket
3. Flywheel housing
4. 3/4" x 2” bolt with 3/4” washer (6)

5. Install 3/4" x 2” bolts, washer, extension bracket and rear engine mount on left side of flywheel housing. Tighten to standard torque (page 547).
6. Install 3/4" x 2” bolts, washer, PDO base bracket and engine mounting support on right side of flywheel housing. Tighten to standard torque (page 547).

Lifting Eyes

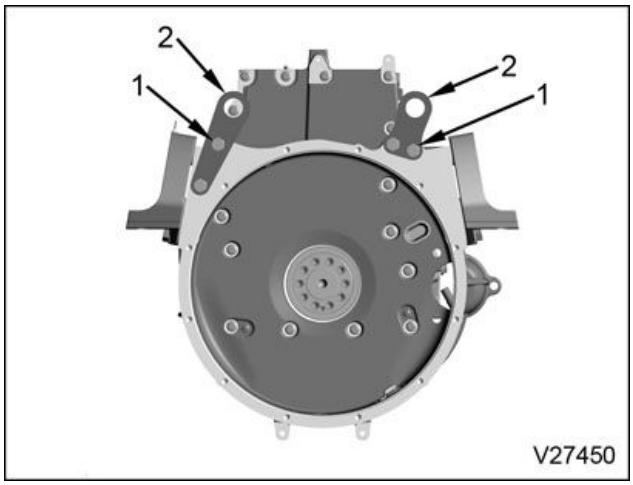

Figure 625 Lifting eyes

1. M16 x 150 bolt (4)
2. Lifting eye (2)

1. Install two lifting eyes.
2. Install four M16 x 150 lifting eye bolts. Tighten bolts to special torque (page 452).

Radial Shaft Ring Seal

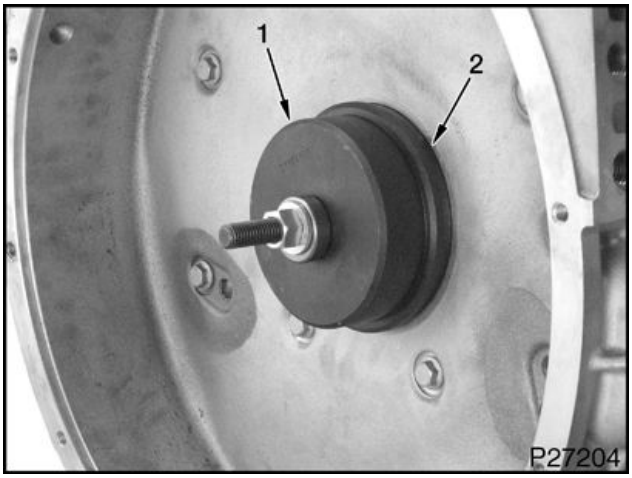

Figure 626 Radial shaft ring seal installation (typical)

1. Rear Oil Seal Installer
2. Radial shaft ring seal

CAUTION: To avoid damage to the radial shaft ring seal, do not touch inner seal lip or allow oil or grease on any part of the seal during installation.

1. Using Rear Oil Seal Installer (page 452), install ring 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 seal. When tool bottoms out, seal is fully installed.

Flywheel Assembly (Manual Transmission)

1. Install two guide pins (made locally) into crankshaft flange at approximately 3 o'clock and 9 o'clock position.

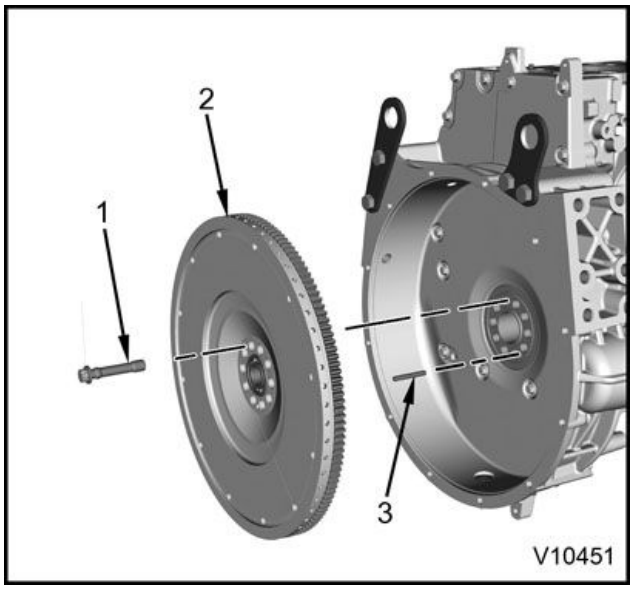

Figure 627 Flywheel assembly and bolts

1. 12PT flange bolt (10)
2. Flywheel assembly
3. 8 x 60-ST pin

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 12PT flange bolts to secure flywheel assembly to crankshaft.
4. Remove both guide pins and loosely install two remaining new 12PT flange bolts.

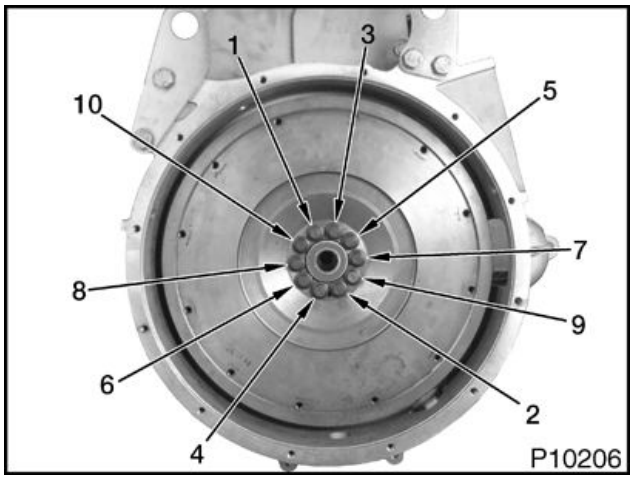

Figure 628 Flywheel bolt tightening sequence

NOTE: For proper flywheel installation, follow the correct tightening sequence while keeping the crankshaft from turning.

5. Tighten 12PT flange bolts using sequence indicated above as follows:
   a. Tighten bolts to 110 N·m (81 lb·ft).
   b. Angle tighten bolts 90°.
   c. Angle tighten bolts an additional 90°.

Pilot Bearing (Flywheel)

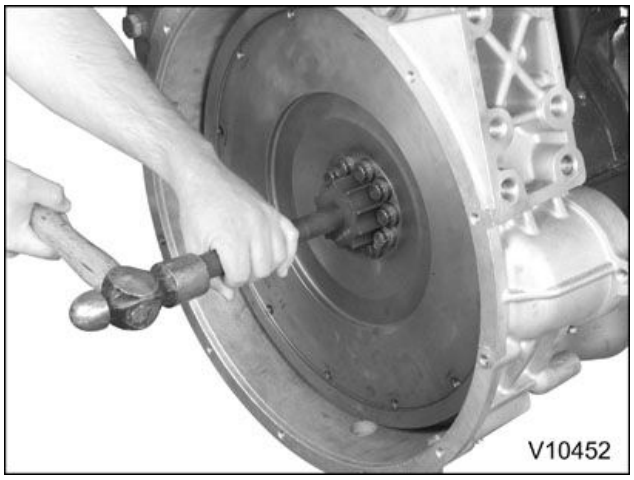

Figure 629 Pilot Bearing Installation Tool

1. Place pilot bearing in flywheel bore.
2. Using Pilot Bearing Installation Tool (page 452), tap pilot bearing into flywheel. When tool bottoms out, pilot bearing is fully installed.

Flywheel and Flexplate Assembly (Automatic Transmission)

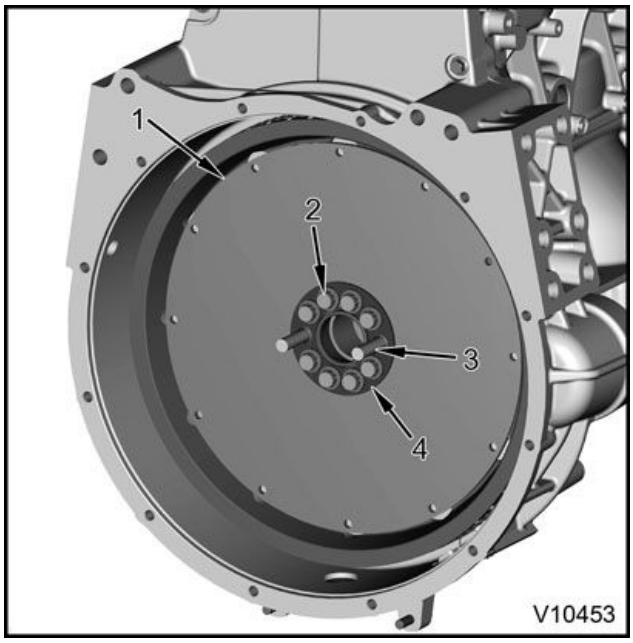

Figure 630 Flywheel and flexplate assembly

1. Flexplate and flywheel assembly
2. 12PT flange bolt (10)
3. Guide pin (2)
4. Wear plate (reinforcement ring)

1. Install two guide pins (made locally) into crankshaft flange 180° apart (approximately 3 o'clock and 9 o'clock positions).
2. Align crankshaft timing gear pin hole in flywheel assembly with crankshaft 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.

NOTE: The individual components of the flexplate assembly are non-servicable. Replace the flexplate as an assembly.

3. Slide flexplate assembly over guide pins.
4. Slide wear plate (reinforcement plate) over guide pins with logo and part number visible towards rear and install eight new 12PT flange bolts hand tight.
5. Remove guide pins and install remaining two 12PT flange bolts.

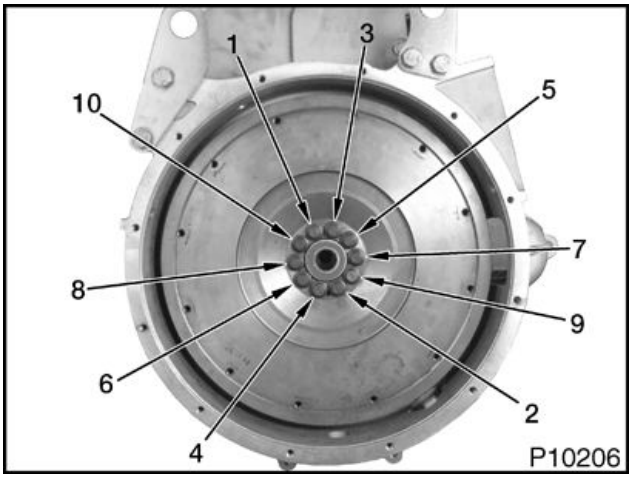

Figure 631 Flywheel and flexplate assembly bolt tightening sequence (typical)

NOTE: For proper flywheel installation, follow the correct tightening sequence while keeping the crankshaft from turning.

6. Tighten 12PT flange bolts using sequence above as follows:
   a. Tighten bolts to 110 N•m (81 lb·ft).
   b. Angle tighten bolts 90°
   c. Angle tighten bolts an additional 90°.

Specifications

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

12PT flange bolts	See tightening steps in procedure.
Flywheel housing bolts, M10 x 30 and M10 x 40	65 N·m (48 lb·ft)
Lifting eye bolts, M16 x 150	280 N·m (207 lb·ft)
Timing hole cover screws	2 N·m (18 lb·in)

Special Service Tools

Description	Tool Number
1-2 inch micrometer	Obtain locally
Blind hole puller	Obtain locally
Brake cleaner (non-caustic)	Obtain locally
Dial indicator with magnetic base	Obtain locally
Loctite 5900®	Obtain locally
Wacker® A–442 RTV sealant	Obtain locally
Pilot Bearing Installation Tool	ZTSE4898
Rear Oil Seal Installer	ZTSE4875
Slide hammer	Obtain locally

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Exploded Views

Oil Pan (Front Sump Shown, Rear Sump Similar, Typical)

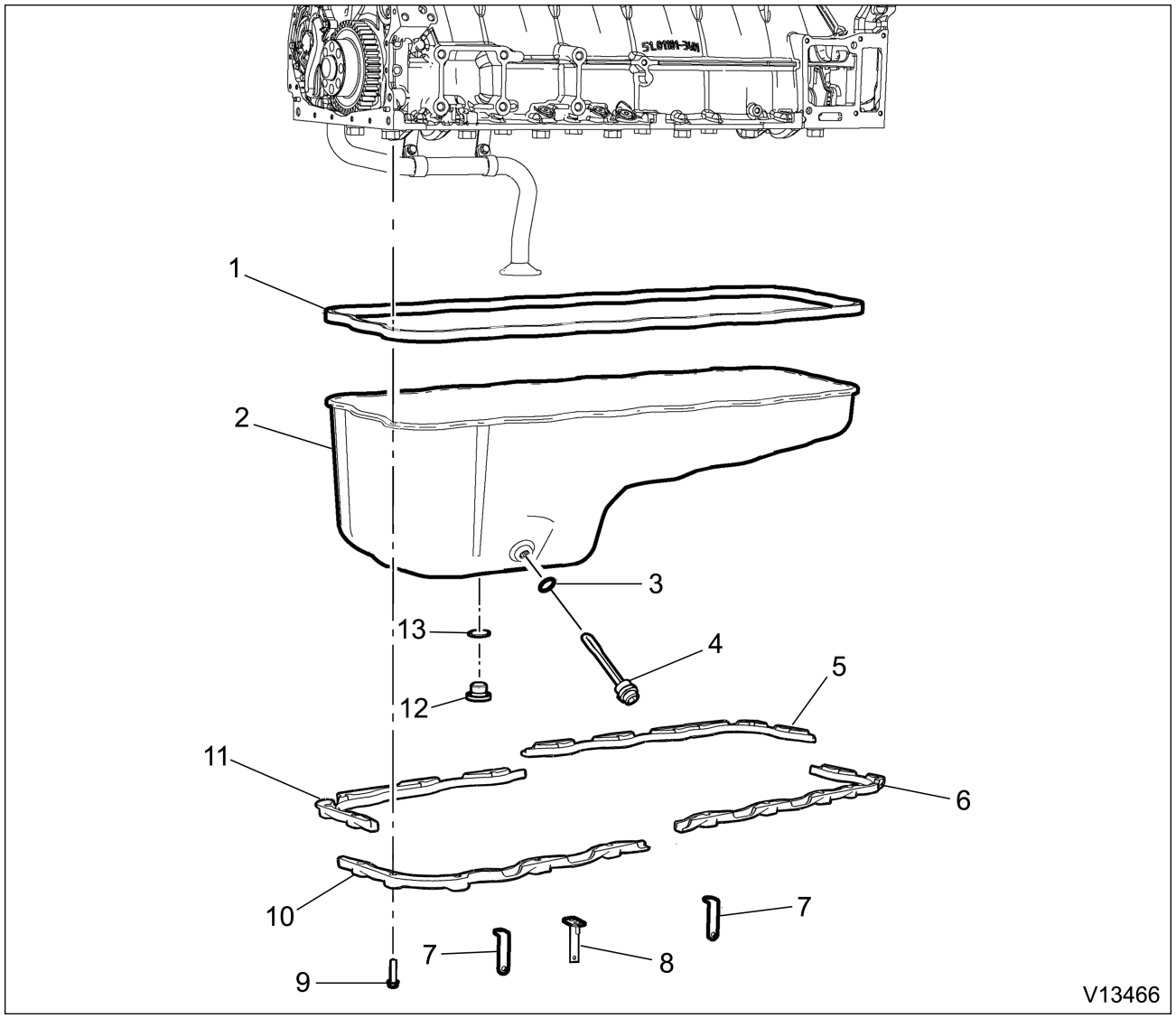

Figure 632 Oil pan (front sump shown, rear sump similar, typical)

1. Oil pan gasket
2. Oil pan (front sump)
3. O-ring (heater, optional)
4. Oil pan heater element (optional)
5. Oil pan clamp – rear right 461 mm (18 in)
6. Oil pan clamp – rear left 461 mm (18 in)
7. Cooling tube bracket (2) (right angle)
8. Extension bracket support (T-bracket)
9. M8 x 40 bolt (22)
10. Oil pan clamp – front left 599 mm (23.5 in)
11. Oil pan clamp – front right 599 mm (23.5 in)
12. Oil drain M27 x 2 plug
13. O-ring (32.92 x 3.53)

Oil Pickup Tube - Front Sump (Typical)

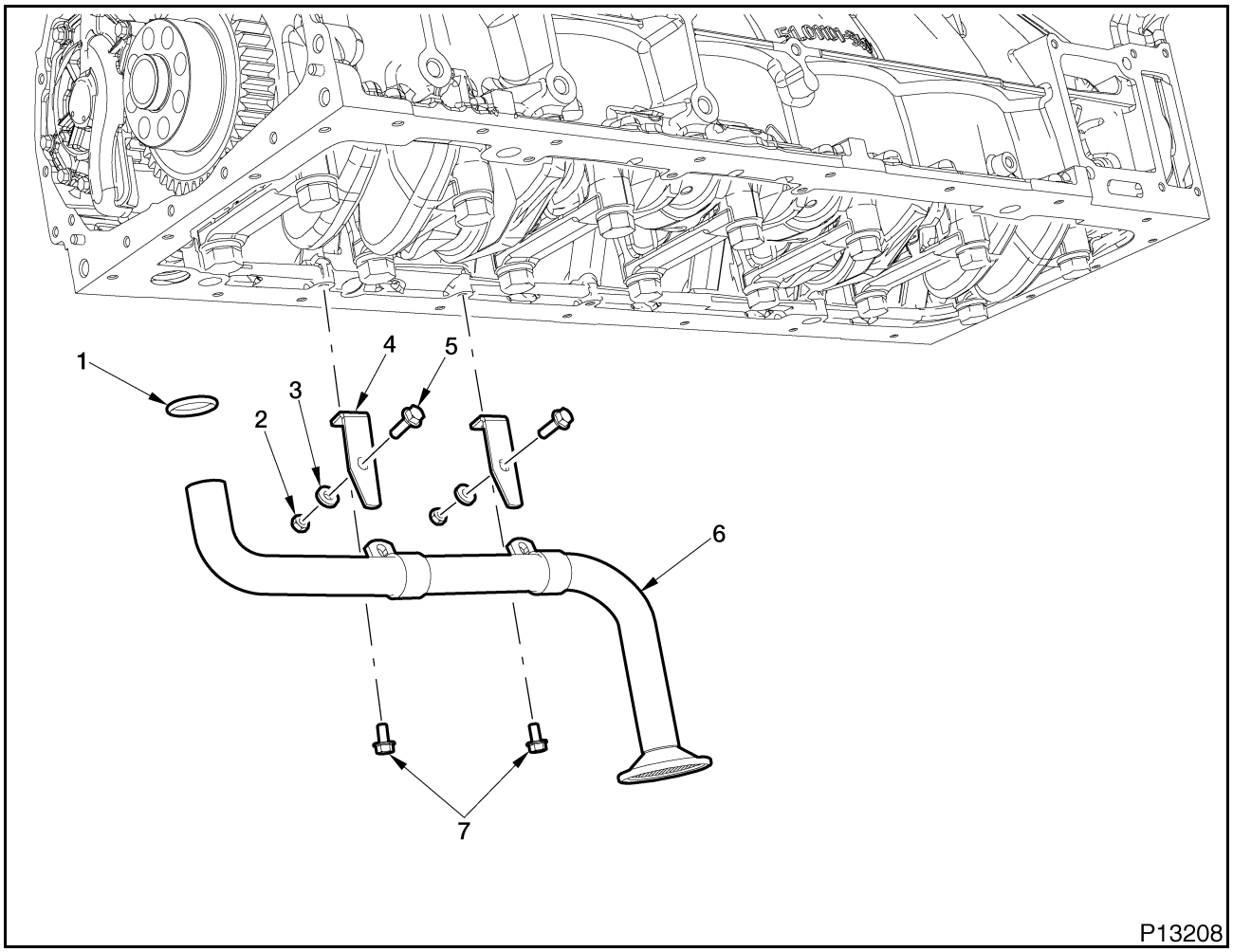

Figure 633 Oil pickup tube - Front sump (typical)

1. O-ring, 32 x 5
2. Prevailing torque nut (M8) (2)
3. D9/19/4 washer (2)
4. Oil pickup tube support (2)
5. M8 x 25 bolt (2)
6. Pickup oil tube
7. M8 x 16 bolt (2)

Removal

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

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

WARNING: To prevent personal injury or death, shift 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 section for information on removal of components prior to this section.

- **Engine Electrical — required for preheater removal.**

Oil Pan

1. Remove oil drain plug and O-ring and drain oil into a suitable container.
2. If equipped, remove oil pan heater element and discard O-ring.
3. Recycle or dispose of oil according to applicable regulations.

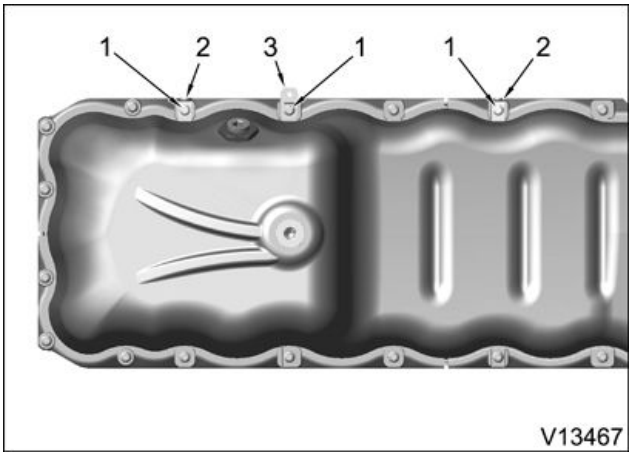

Figure 634 Cooling tube brackets and extension bracket support (typical)

1. M8 x 40 bolt (3)
2. Cooling tube bracket (right angle) (2)
3. Extension bracket support (T-bracket)

4. Remove three M8 x 40 bolts, two cooling tube brackets, and one extension bracket support.

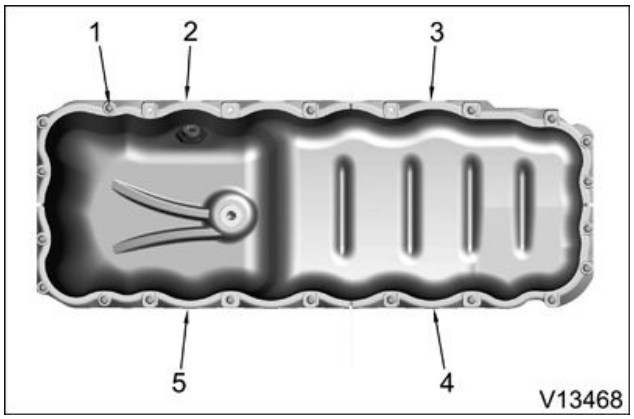

Figure 635 Oil pan clamps (typical)

1. M8 x 40 bolt (19)
2. Oil pan clamp – front left 599 mm (23.5 in)
3. Oil pan clamp – rear left 461 mm (18 in)
4. Oil pan clamp – rear right 461 mm (18 in)
5. Oil pan clamp – front right 599 mm (23.5 in)

5. Remove 19 M8 x 40 bolts.
6. Remove four oil pan clamps.
7. Remove oil pan and oil pan gasket as an assembly.
8. Clean and inspect the oil pan gasket. Discard gasket if damaged.

Oil Pickup Tube — Front Sump

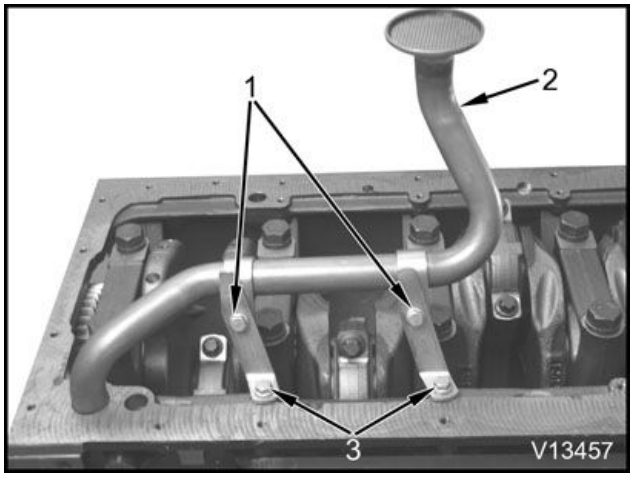

Figure 636 Oil pickup tube (front sump, typical)

1. M8 x 25 bolt (2)
2. Oil pickup tube
3. M8 x 16 bolt (2)

1. Remove two M8 x 16 bolts and pickup tube with supports as an assembly.
2. Only if required, remove the two M8 x 25 bolts, prevailing torque nuts, D9/19/4 washers and oil pickup tube supports.

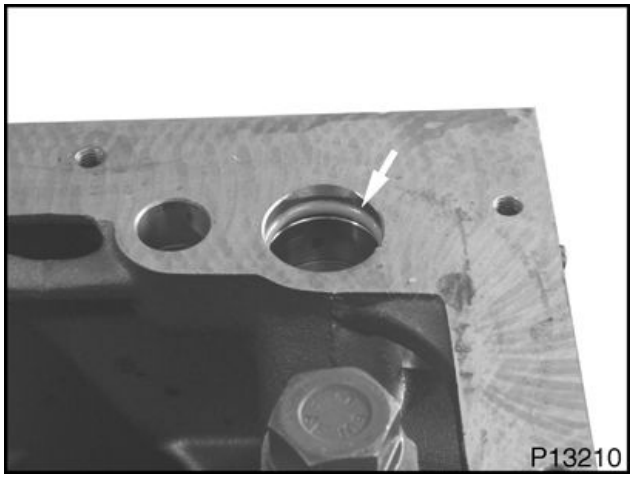

Figure 637 Oil pickup tube O-ring

3. Remove and discard oil pickup tube O-ring.

Oil Recovery

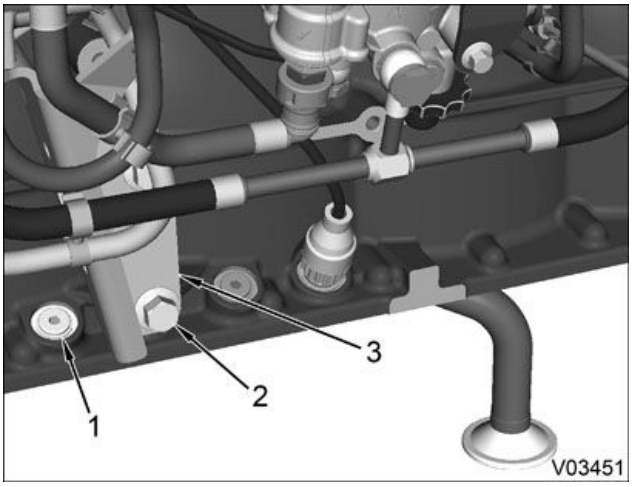

Figure 638 High-pressure pump support and plug

1. Plug
2. M14 x 30 bolt (2)
3. High-pressure pump support

1. Remove and save two M14 x 30 bolts that secure the high-pressure pump support.
2. Remove and save two M12 x 30 bolts that secure the high-pressure pump support. to the bottom of high-pressure pump.
3. Remove and save the high-pressure support.
4. Remove plug from crankcase. Discard plug and seal ring.

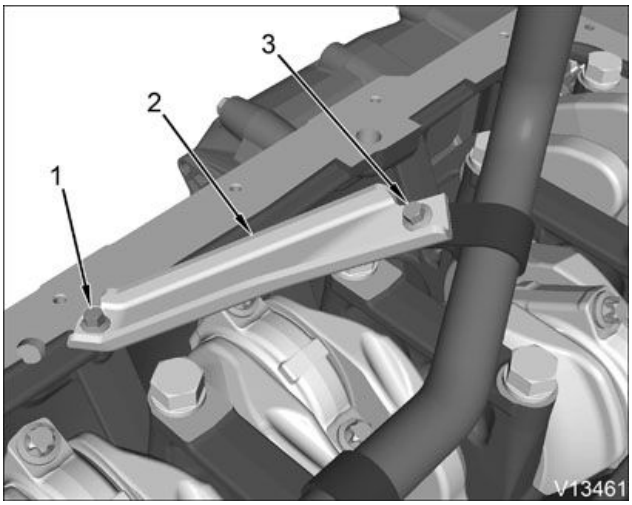

Figure 639 Oil pickup tube

1. M8 x 16 bolt
2. Oil pickup tube support
3. M8 x 25 bolt and M8 nut

5. Remove M8 x 25 bolt and M8 nut that secure the oil pickup tube support to the clamp on the oil pickup tube. Discard M8 x 25 bolt; save M8 nut.
6. Remove and discard M8 x 16 bolt that secures other end of oil pickup tube support .
7. Remove and save oil pickup tube support.

Oil Pickup Tube — Rear Sump

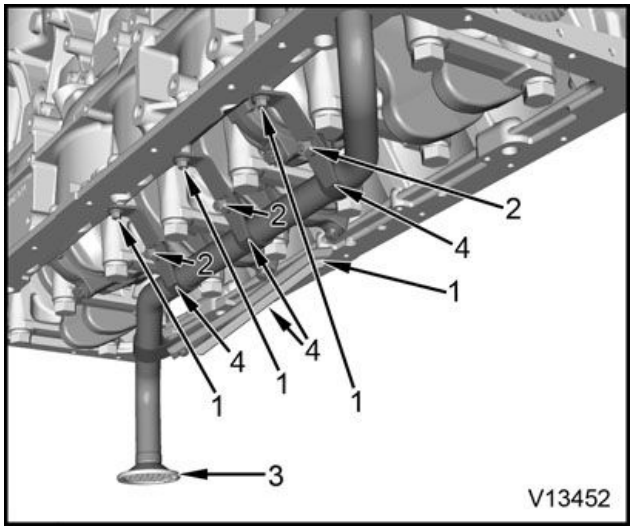

Figure 640 Oil pickup tube (rear sump)

1. M8 x 16 bolt (4)
2. M8 x 25 bolt (3)
3. Oil pickup tube
4. Tube support

1. Remove four M8 x 16 bolts holding oil pickup tube supports to crankcase.
2. Remove oil pickup tube and supports as an assembly.
3. Only if required, remove M8 x 25 bolts, prevailing torque nuts and D9/19/4 washers and supports.

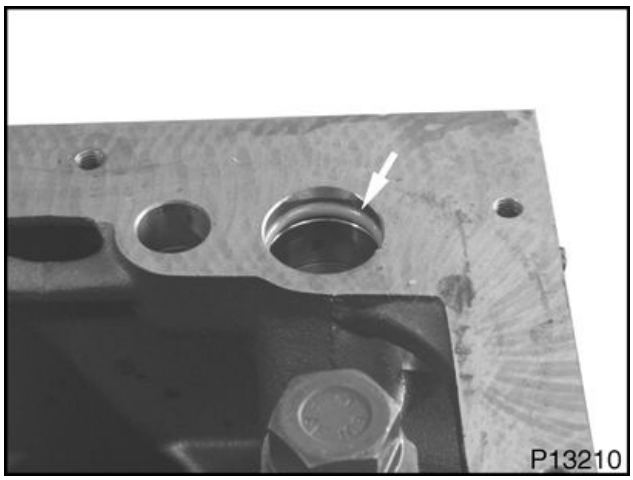

Figure 641 Oil pickup tube O-ring

4. Remove and discard oil pickup tube O-ring.

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 Pan

1. Inspect bottom of oil pan for metallic debris or other evidence of engine damage. Investigate any abnormalities as required.
2. Clean oil pan with a suitable solvent.
3. Dry with filtered compressed air.
4. Inspect oil pan for warping, dents and cracks. Replace the oil pan if necessary.

Oil Pickup Tube

1. Clean oil pickup tube and supports with a suitable solvent.
2. Dry with filtered compressed air.
3. Inspect oil pickup tube and supports for cracks, damage or pickup screen blockage. Replace if necessary.

Installation

Oil Pickup Tube — Front Sump

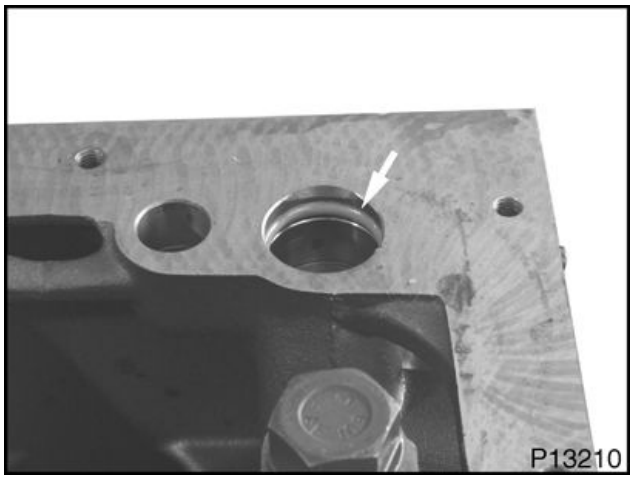

Figure 642 Oil pickup tube O-ring

1. Install a new oil pickup tube O-ring. Lubricate O-ring with clean engine oil.

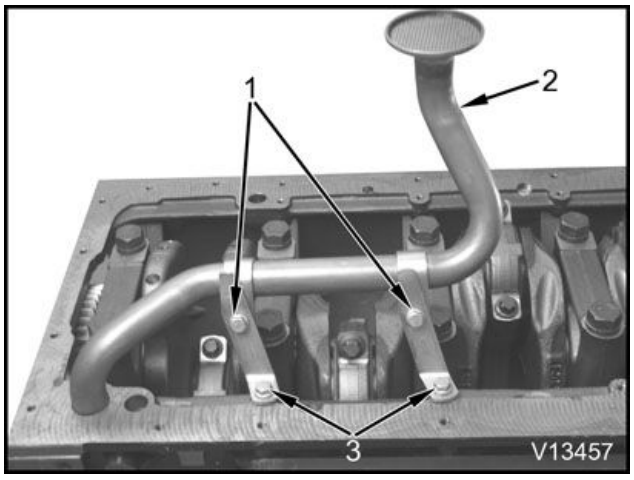

Figure 643 Oil pickup tube (front sump, typical)

1. M8 x 25 bolt (2)
2. Oil pickup tube
3. M8 x 16 bolt (2)

2. If required, position two oil pickup tube supports and loosely install two M8 x 25 bolts, prevailing torque nuts and D9/19/4 washers.
3. Install oil pickup tube and two M8 x 16 bolts.
4. Tighten two M8 x 16 bolts to standard torque (page 547).
5. Tighten two prevailing torque nuts (M8) and M8 x 25 bolts to standard torque (page 547).

Oil Pickup Tube — Rear Sump

1. Lubricate a new oil pickup tube O-ring with clean engine oil and install onto tube.

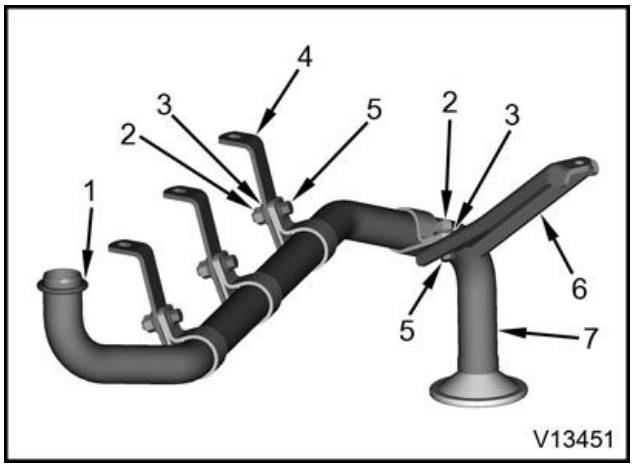

Figure 644 Rear sump oil tube assembly

1. O-ring, 32 x 5
2. Prevailing torque nut (4)
3. D9/19/4 washers (4)
4. Supports (short) (3)
5. M8 x 25 bolt (4)
6. Support (long)
7. Oil pickup tube

2. If oil pickup tube supports were removed, loosely install with four M8 x 25 bolts, D9/19/4 washers and prevailing torque nuts.
3. Install oil pickup tube and supports as an assembly.

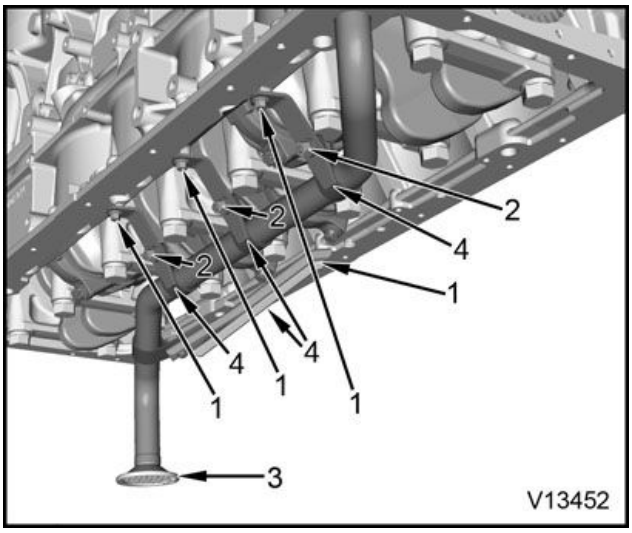

Figure 645 Oil pickup tube

1. M8 x 16 bolts (4)
2. M8 x 25 bolts (3)
3. Oil pickup tube
4. Tube support

4. Install four M8 x 16 bolts through oil pickup tube supports.
5. Tighten four M8 x 16 bolts to standard torque (page 547).
6. Tighten three M8 x 25 bolts and prevailing torque nuts to standard torque (page 547).

Oil Recovery

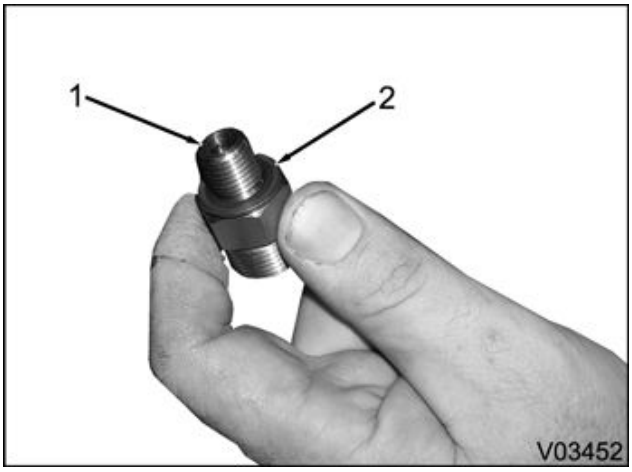

Figure 646 Straight fitting assembly and seal ring

1. Straight fitting assembly
2. Seal ring

1. Lubricate new seal ring with clean engine oil and put ring onto new straight fitting assembly.

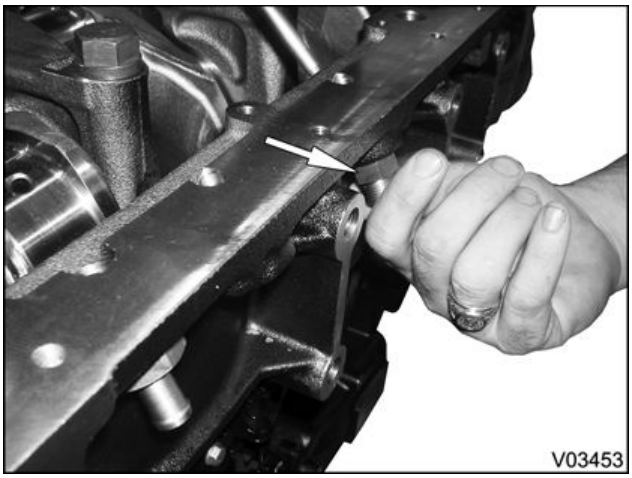

Figure 647 Straight fitting assembly

2. Thread straight fitting assembly into the crankcase (where plug was removed in Figure 1) and tighten fitting to 55 N·m (40 lb·ft).

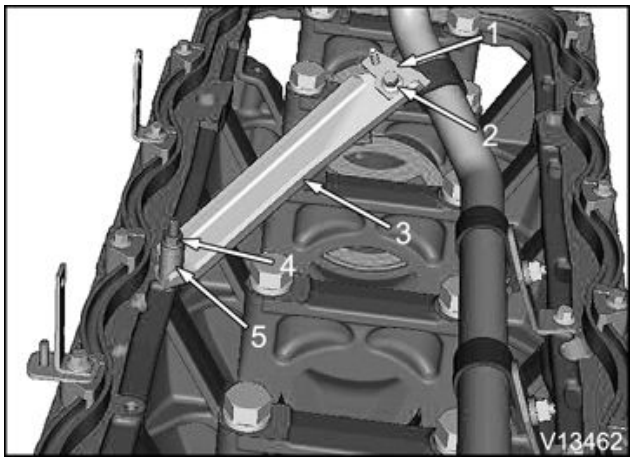

Figure 648 Oil recovery support assembly and oil pickup tube

1. Oil recovery support assembly (includes M6 x 20 stud)
2. M8 x 30 bolt and M8 nut
3. Oil pickup tube support
4. M8 x 50 stud bolt
5. Spacer (30 mm)

3. Position new oil recovery support assembly onto saved oil pickup tube support. Secure by installing a new M8 x 30 bolt and saved M8 nut. Tighten nut to 13 N·m (115 lb·in).
4. Position new 30 mm spacer onto other end of oil pickup tube support and install new M8 x 50 stud bolt. Tighten bolt to 31 N·m (23 lb·ft).

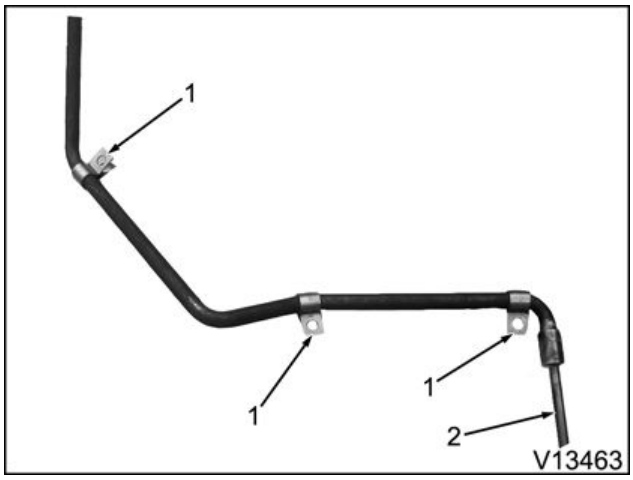

Figure 649 P-clamps on oil recovery tube

1. P-clamp (3)
2. Brazed end

5. Position three new P-clamps onto mew oil recovery tube as shown.

Figure 650 Oil recovery tube (brazed end)

6. Coat brazed end of oil recovery tube with P80® rubber lubricant or equivalent.
7. Insert brazed end of oil recovery tube into straight fitting assembly in crankcase; position P-clamp onto M6 x 20 stud in oil recovery support and P-clamp onto M8 x 50 stud bolt.

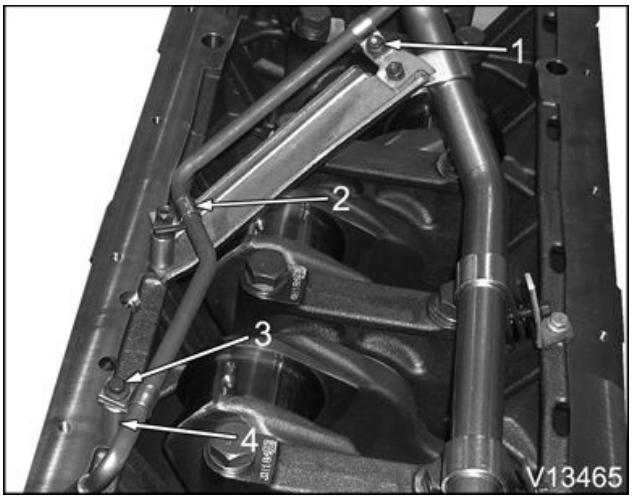

Figure 651 P-clamps

1. M6 nut
2. M8 nut
3. M8 x 60 bolt
4. Spacer (43 mm)

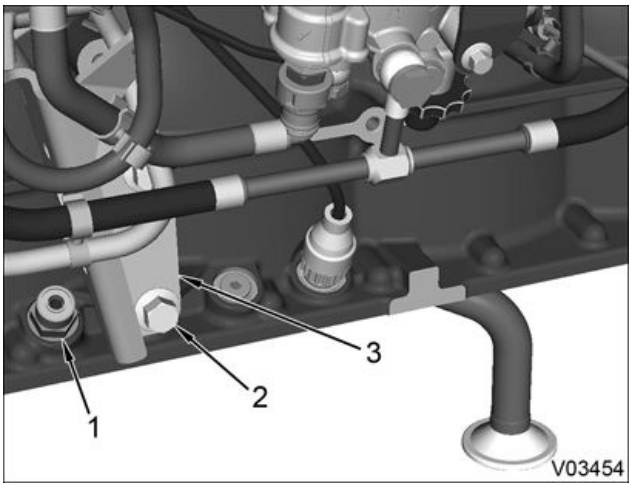

Figure 652 High-pressure pump support and straight fitting assembly

1. Straight fitting assembly
2. M14 x 30 bolt (2)
3. High-pressure pump support

8. Install new M6 nut onto M6 x 20 stud on oil recovery support.
9. Install new M8 nut onto M8 x 50 stud bolt.
10. Position new 43 mm spacer under P-clamp and install new M8 x 60 bolt.
11. Tighten M8 nut and M8 x 60 bolt to 31 N·m (23 lb·ft).
12. Tighten M6 nut to 13 N·m (115 lb·in).
13. Install high-pressure pump support.
14. Secure the high-pressure pump support to the bottom of the high-pressure pump using the previously saved M12 x 30 bolts. Hand tighten bolts.
15. Secure the high-pressure pump support to the crankcase using the previously saved M14 x 30 bolts. Hand tighten bolts.
16. Tighten M12 x 30 bolts to 105 N·m (77 lb·ft).
17. Tighten M14 x 30 bolts to 172 N·m (126 lb·ft).

Oil Pan

1. Lubricate new or old oil pan gasket with clean engine oil and Install oil pan gasket onto oil pan.
2. Position oil pan and oil pan gasket as an assembly onto the crankcase.

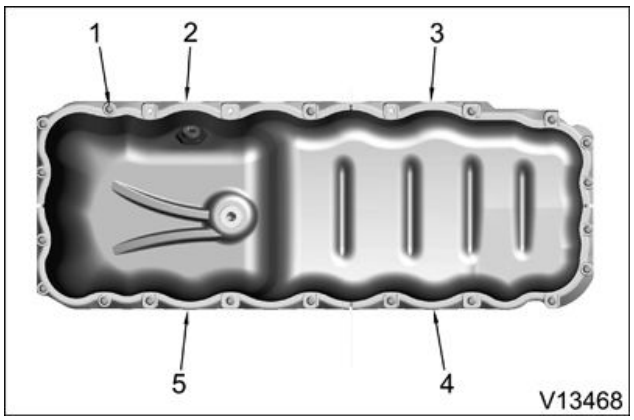

Figure 653 Oil pan clamps (typical)

1. M8 x 40 bolt (19)
2. Oil pan clamp – front left 599 mm (23.5 in)
3. Oil pan clamp – rear left 461 mm (18 in)
4. Oil pan clamp – rear right 461 mm (18 in)
5. Oil pan clamp – front right 599 mm (23.5 in)

3. Installfour oil pan clamps and 19 M8 x 40 bolts (Figure 653). Do not installtwo cooling tube brackets, one extension bracket support, and three M8 x 40 bolts (Figure 654).
4. Hand tighten 19 M8 x 40 bolts.

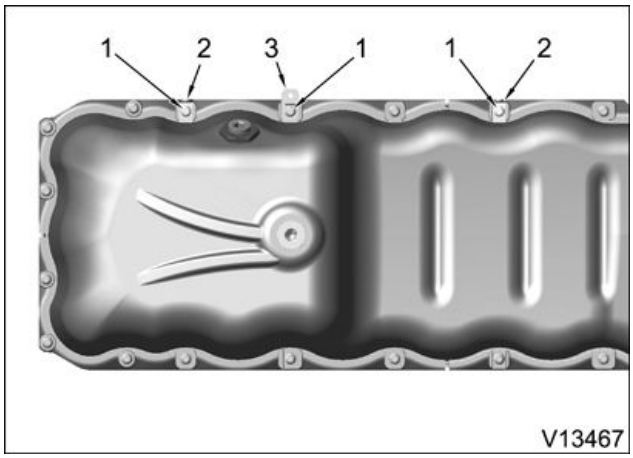

Figure 654 Cooling tube brackets and extension bracket support (typical)

1. M8 x 40 bolt (3)
2. Cooling tube bracket (right angle bracket) (2)
3. Extension bracket support (T-bracket)

5. Position two cooling tube brackets, and one extension bracket, install and hand tighten three M8 x 40 bolts.

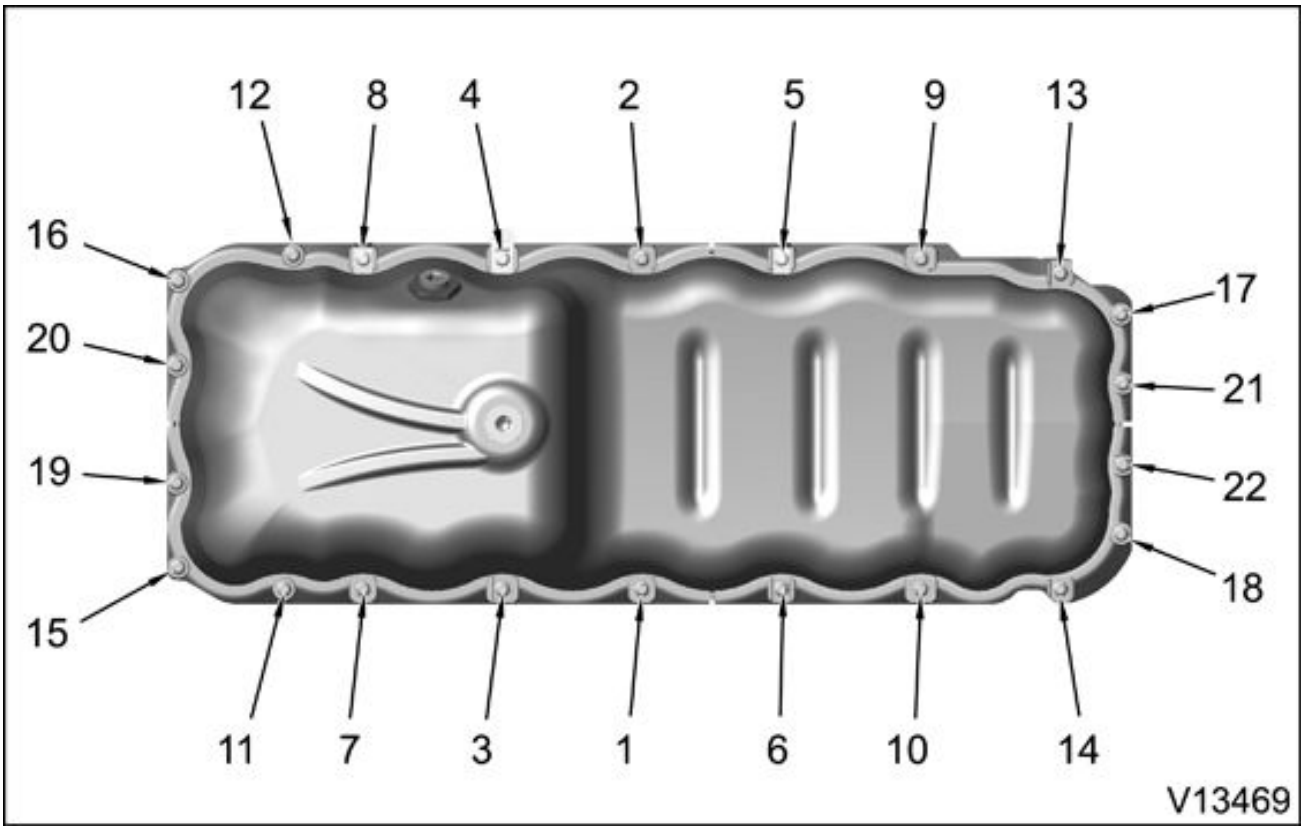

Figure 655 Torque sequence for oil pan bolts

6. Follow the torque sequence and tighten 22 M8 x 40 bolts to 10 N·m (89 lb·in).
7. Tighten 22 M8 x 40 bolts in sequence to 35 N·m (26 lb·ft).
8. Retighten 22 M8 x 40 bolts in sequence to 35 N·m (26 lb·ft).
9. If engine is equipped with oil pan heater element, lubricate a new O-ring with clean engine oil and install heater element into the oil pan. Tighten heater element to special torque (page 468).

   If engine is not equipped with an oil pan heater element, install (oil pan heater drain plug) with a new O-ring lubricated with clean engine oil. Tighten plug to special torque (page 468).
10. Lubricate a new oil pan drain plug O-ring with clean engine oil and put O-ring on the M27 x 2 drain plug.
11. Install M27 x 2 drain plug and tighten to special torque (page 468).

Special Torque

Drain plug, M27 x 2	75 N·m (55 lb·ft)
Oil pan bolts, M8 x 40	See tightening steps in procedure.
Oil pan heater element or replacement drain plug	75 N·m (55 lb·ft)

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Exploded Views

Oil Pump

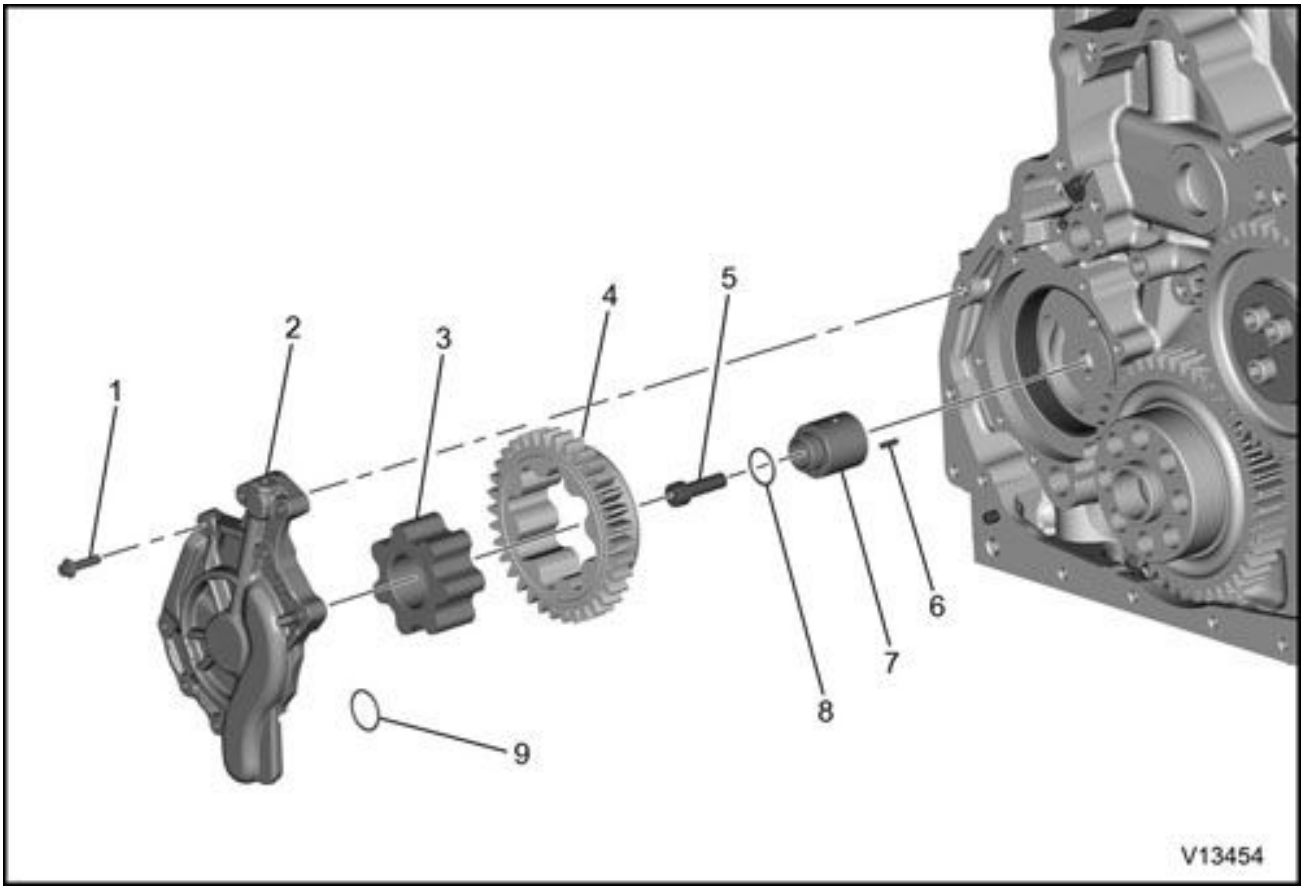

Figure 656 Oil pump

1. M6 x 25 bolt (8)
2. Oil pump cover
3. Pinion (gear) for oil pump
4. (Oil pump) ring gear
5. M10 x 35 socket-head cap screw
6. Spring pin 4 x 14 ST
7. Axle for pinion (oil pump)
8. O-ring 22 x 2
9. O-ring 25.12 x 1.78

Front Timing Gears (Typical)

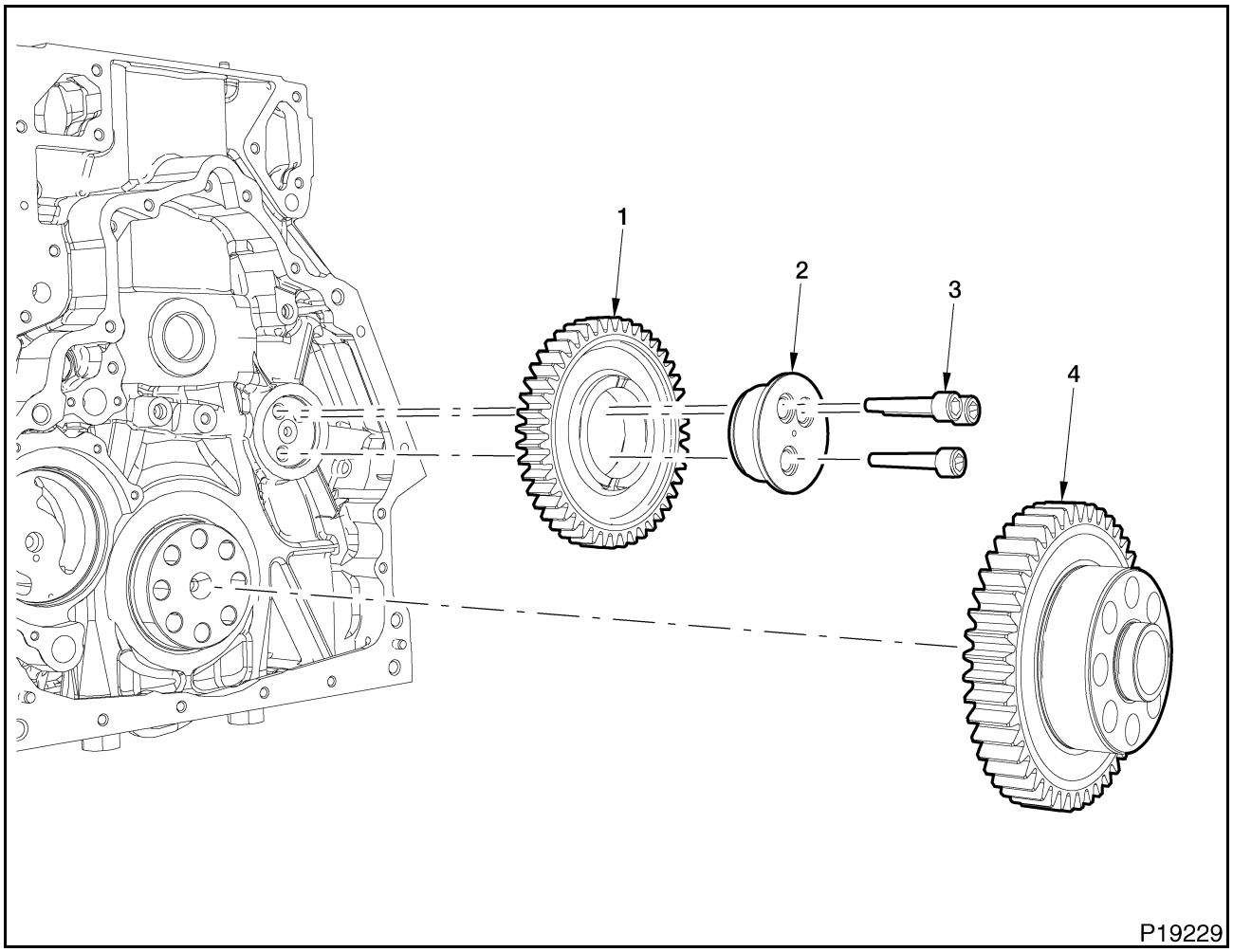

Figure 657 Front timing gears (typical)

1. (Front) idler gear
2. Gear stud (not flywheel side)
3. M12 x 50 socket-head cap screw (3)
4. Front crank gear

Rear Timing Gears

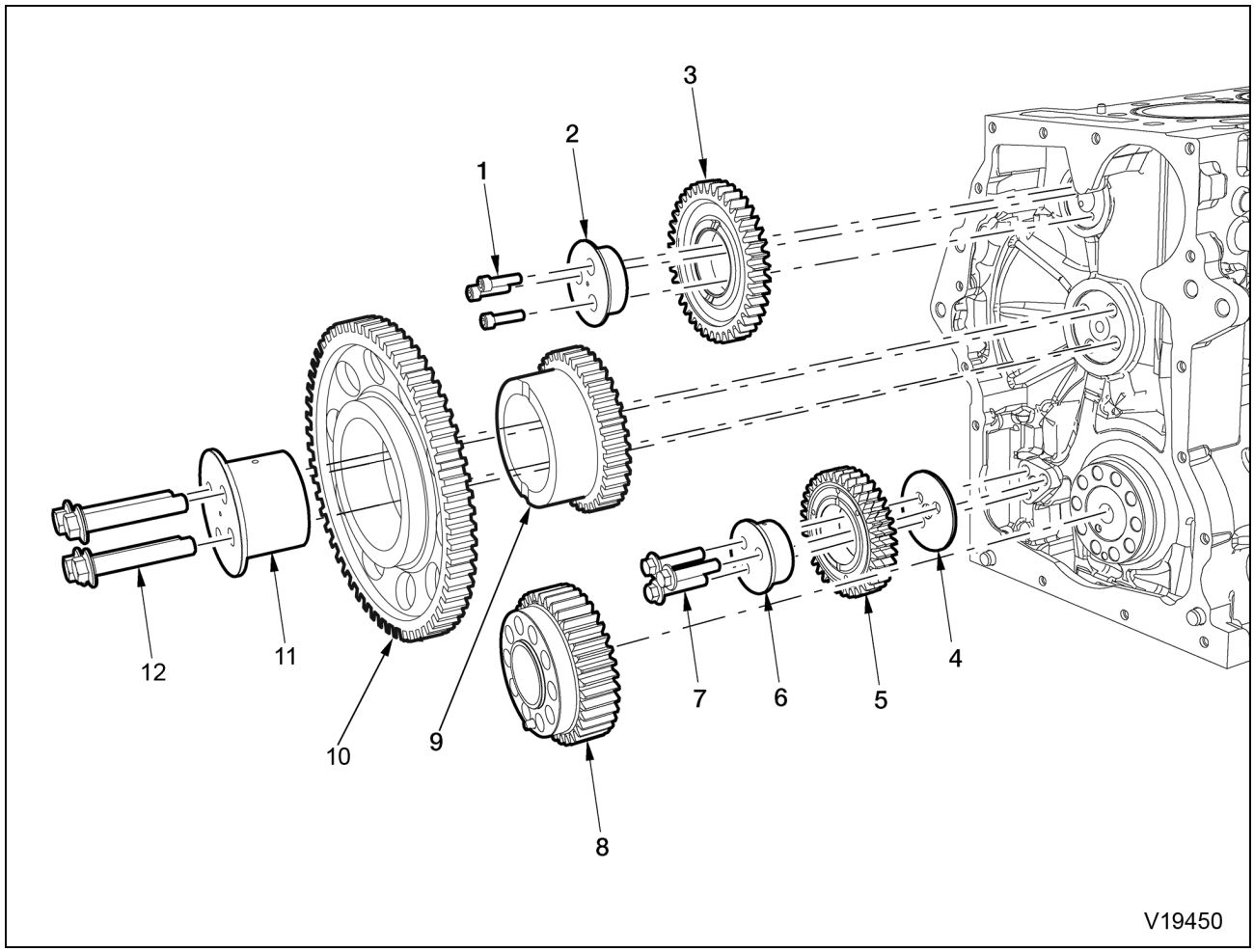

Figure 658 Rear timing gears

1. M8 x 30 socket-head cap screw (3)
2. Gear stud small
3. Crankcase idler gear
4. Thrust washer (for gear stud air compressor)
5. Air compressor coupled idler gear assembly
6. Air compressor gear stud
7. M12 x 55 bolt (3)
8. Rear crank gear assembly
9. Small idler gear
10. Large idler gear
11. Gear stud big
12. M14 x 80 bolt (4)

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: When performing specific component removal, only remove components necessary for access.

For complete engine tear down, refer to the following service sections for information on removal of components prior to this section.

- **Front Cover, Fan Drive, Cooling System and Related Components**
- **Cylinder Head, Camshaft and Valve Train**
- **Flywheel and Flywheel Housing**

Preliminary Checks

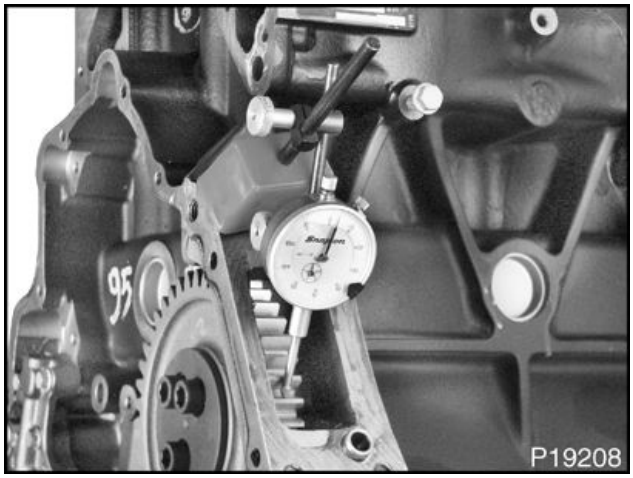

Figure 659 (Front) idler gear backlash measurement (typical)

1. Rotate engine and look for any damaged gear teeth. See Crankshaft Rotation Procedure(page 405). Replace damaged gears as necessary.
2. Place dial indicator with magnetic base (page 484) on front of crankcase with indicator tip on front idler gear. Position dial indicator tangent (90°) relative to plane of gear tooth.
3. Turn front idler gear clockwise and zero dial indicator.
4. Turn front idler gear back and forth while reading dial indicator. Compare dial indicator reading with specifications (page 484).
5. If front idler gear backlash exceeds specification, replace gear.

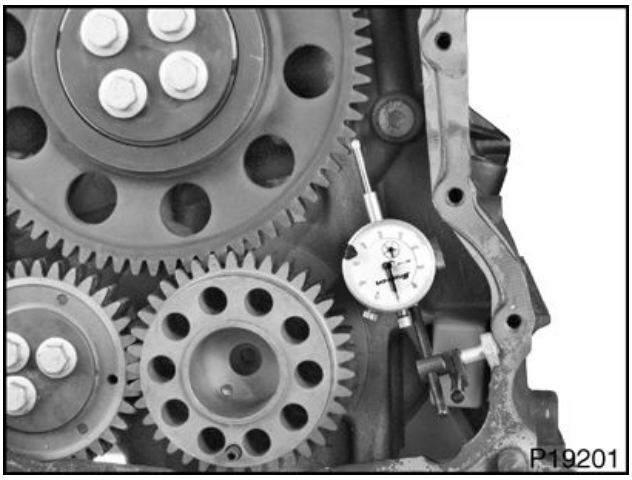

Figure 660 (Rear) large idler gear backlash measurement (typical)

6. Place dial indicator with magnetic base (page 484) on rear of crankcase with indicator tip on large idler gear tooth. Position dial indicator tangent (90°) relative to plane of gear tooth.
7. Turn large idler gear clockwise and zero dial indicator.
8. Turn large idler gear back and forth while reading dial indicator. Compare dial indicator reading with specifications (page 484).
9. If backlash exceeds specification, replace large idler gear.

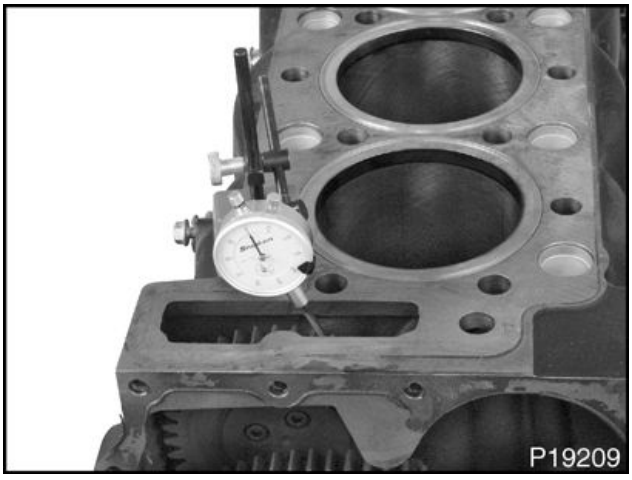

Figure 661 Crankcase idler gear backlash measurement (typical)

10. Place dial indicator with magnetic base (page 484) on top rear of crankcase with indicator tip on crankcase idler gear. Position dial indicator tangent (90°) relative to plane of gear tooth.
11. Turn crankcase idler gear clockwise and zero dial indicator.
12. Turn crankcase idler gear back and forth while reading dial indicator. Compare dial indicator reading with specifications (page 484).
13. If crankcase idler gear backlash exceeds specification, replace crankcase idler gear.

Oil Pump

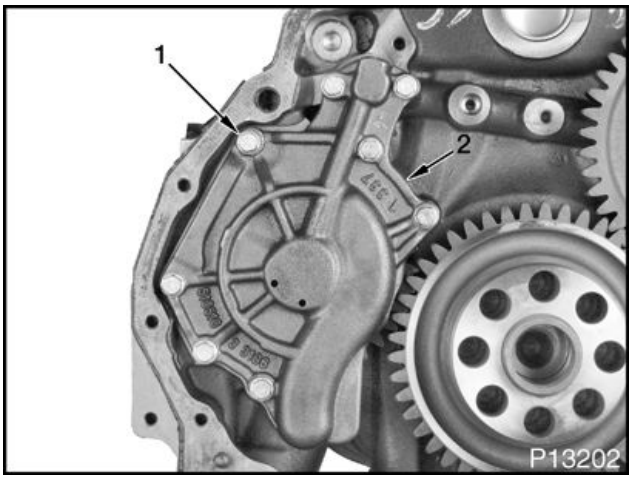

Figure 662 Oil pump cover (typical)

1. M6 x 25 bolt (8)
2. Oil pump cover

1. Remove eight M6 x 20 bolts or M6 x 25 bolts.
2. Remove oil pump cover.
3. Remove and discard O-ring.

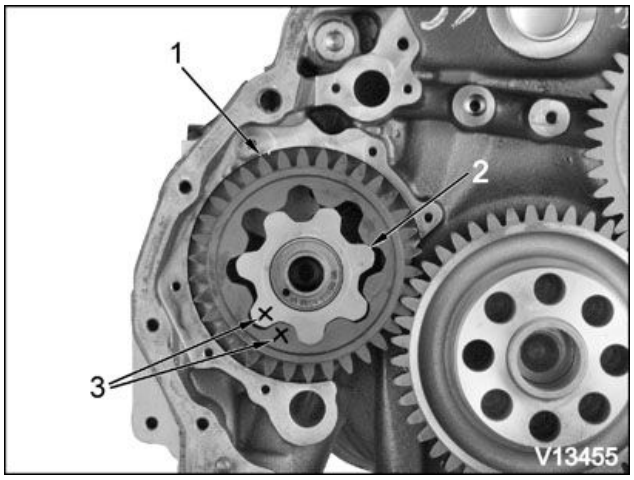

Figure 663 Oil pump pinion (gear) and ring gear

1. (Oil pump) ring gear
2. Oil pump pinion (gear)
3. Marks for reassembly (towards front)

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

4. Use a permanent marker to mark the front of oil pump pinion (gear) and ring gear for correct assembly orientation.
5. Remove oil pump pinion gear and ring gear.

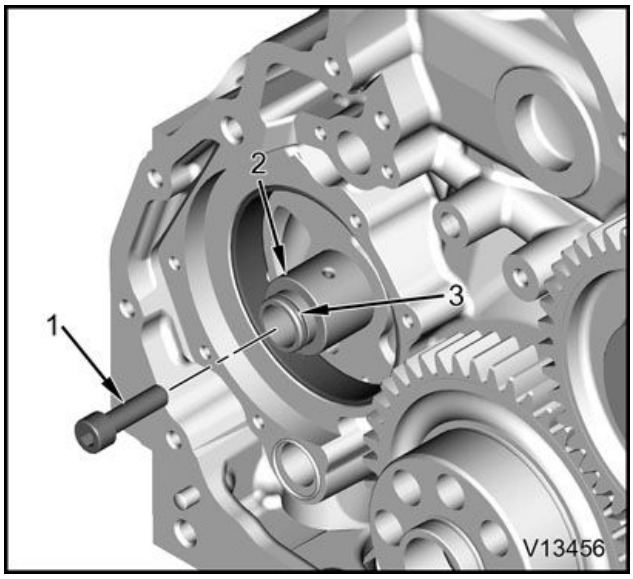

Figure 664 (Oil pump) pinion axle

1. M10 x 35 socket-head cap screw
2. (Oil pump) pinion axle
3. O-ring 22 x 2

6. Remove M10 x 35 socket-head cap screw and oil pump pinion axle.
7. Remove and discard O-ring 22 x 2.

Front Crank Gears

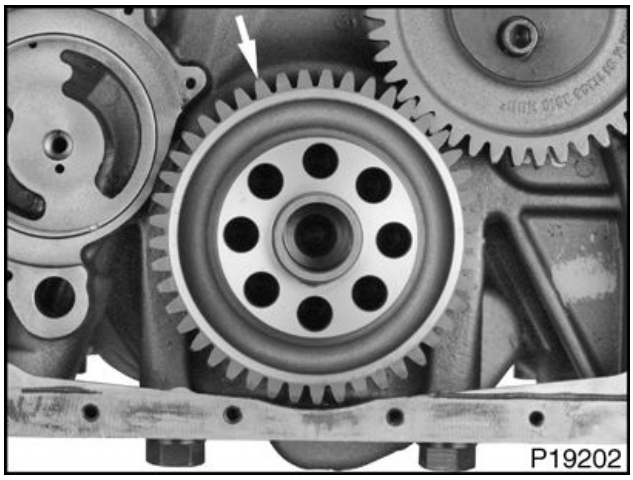

Figure 665 Front crank gear (typical)

1. Using a gear puller (page 484), remove front crank gear.

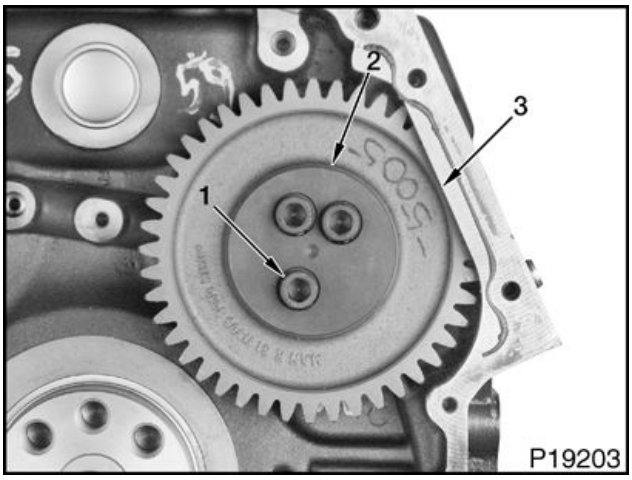

Figure 666 (Front) idler gear (typical)

1. M12 x 50 socket-head cap screw (3)
2. Gear stud (front idler)
3. Idler gear

2. Remove three M12 x 50 cap screws, gear stud and idler gear.

Rear Timing Gears

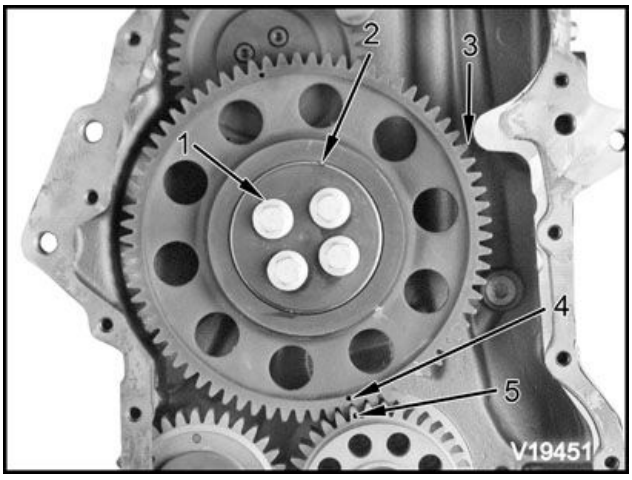

Figure 667 Idler gear assembly and timing marks

1. M14 x 80 bolt (4)
2. Big gear stud
3. Large idler gear
4. Timing mark (large idler gear)
5. Timing mark (rear crank gear)

1. Remove four M14 x 80 bolts, big gear stud and idler gear assembly.

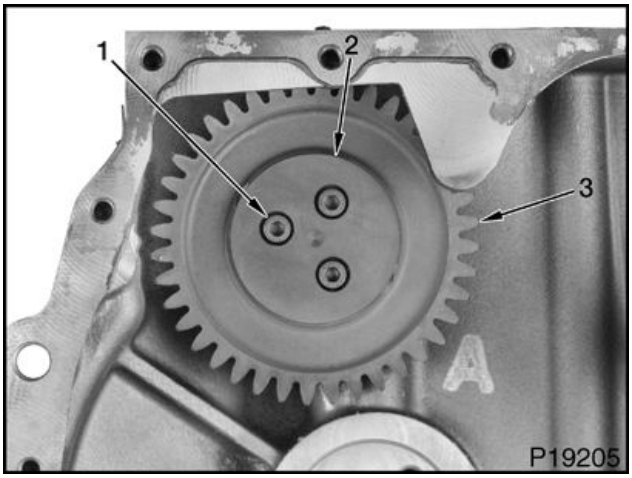

Figure 668 Crankcase idler gear (typical)

1. M8 x 30 socket-head cap screw (3)
2. Small gear stud
3. Crankcase idler gear

2. Remove three M8 x 30 cap screws, small gear stud and crankcase idler gear.

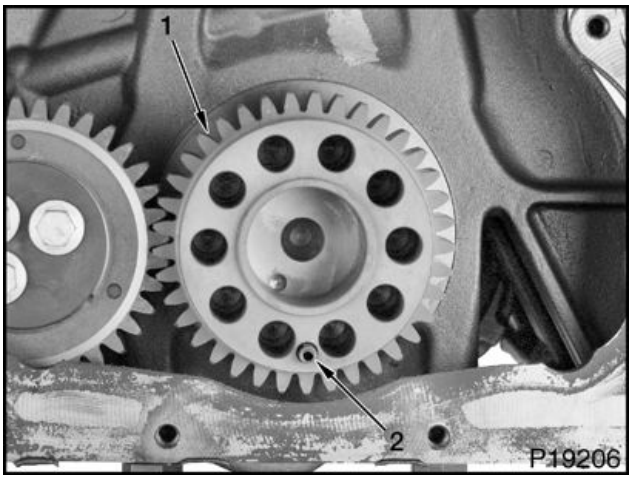

Figure 669 Rear crank gear assembly (typical)

1. Rear crank gear
2. Pin 8 x 60-ST

3. Using a gear puller (page 484), remove rear crank gear assembly.

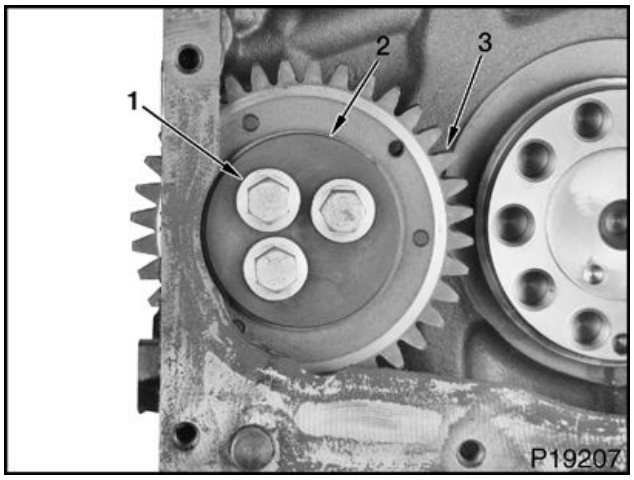

Figure 670 Air compressor coupled idler gear assembly (typical)

1. M12 x 55 bolt (3)
2. Air compressor gear stud
3. Air compressor idler gear assembly

4. Remove three M12 x 55 bolts and air compressor gear stud, air compressor idler gear assembly and thrust washer for air compressor gear stud (not shown, behind gear assembly).

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 shafts for worn or damaged bearing surfaces. Replace as necessary.

Oil Pump

1. Wash all parts thoroughly in a suitable solvent.
2. Dry with filtered compressed air.
3. Inspect pinion (gear) for oil pump, oil pump ring gear and oil pump cover for nicks, burrs or scoring.
4. Replace any damaged components.
5. Temporarily install oil pump components in crankcase without O-ring and tighten M6 x 25 bolts to standard torque (page 547). See Oil Pump (page 482).

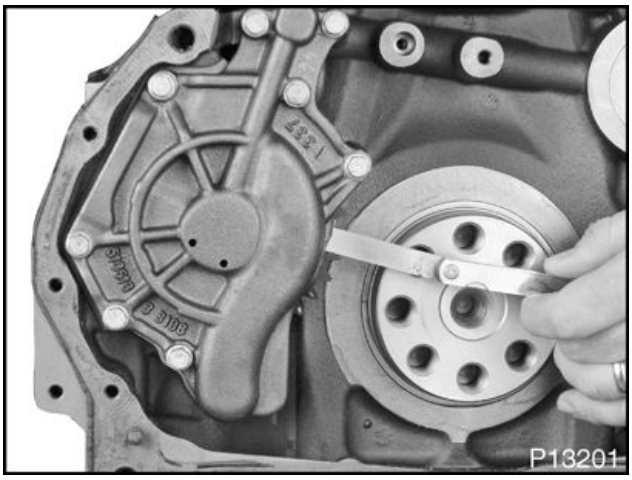

Figure 671 Pinion (gear) for oil pump and ring gear end play measurement (typical)

6. Using a feeler gauge (page 484), 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 484), replace oil pump cover, pinion (gear) for oil pump and ring gear as a set.
8. Remove oil pump components for final assembly.

Installation

Rear Timing Gears

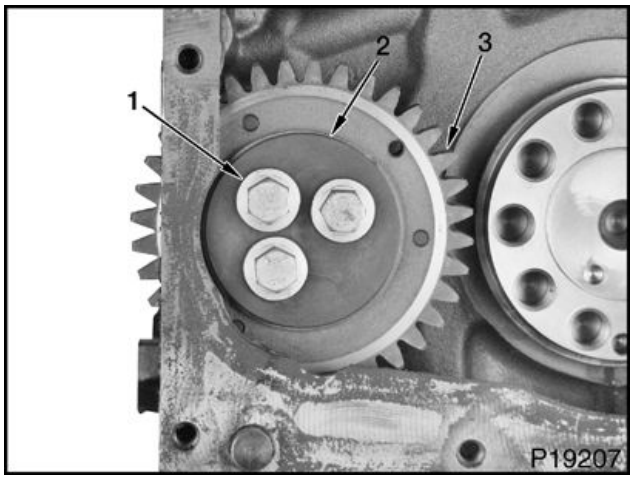

Figure 672 Air compressor coupled idler gear assembly (typical)

1. M12 x 55 bolt (3)
2. Air compressor gear stud
3. Air compressor idler gear assembly

CAUTION: To prevent engine damage, install thrust washer for air compressor gear stud 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 coupled idler gear assembly.
2. Install three M12 x 55 bolts. Tighten bolts to special torque (page 484).

Figure 673 Crankshaft alignment pin hole (typical)

3. Rotate crankshaft so that alignment pin hole is at 6 o'clock position. See Crankshaft Rotation Procedure (page 405). This positions cylinder No. 1 at Top Dead Center (TDC).

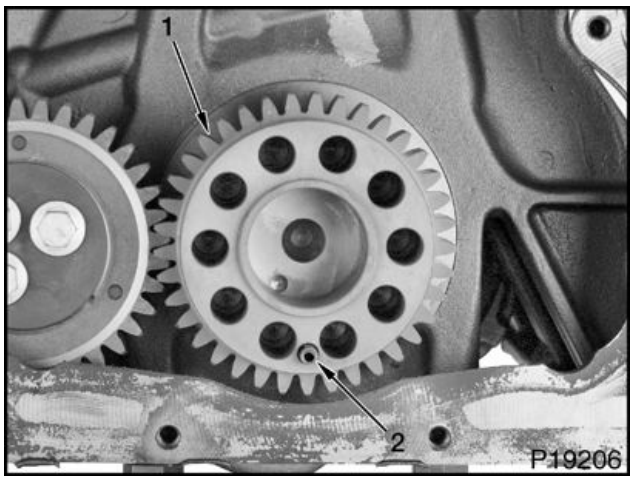

Figure 674 Rear crank gear assembly (typical)

1. Rear crank gear
2. Pin 8 x 60-ST

WARNING: To prevent personal injury or death, wear safety glasses with side shields.

4. Using a hammer and brass drift, install rear crank gear so pin in gear engages crankshaft alignment pin hole.

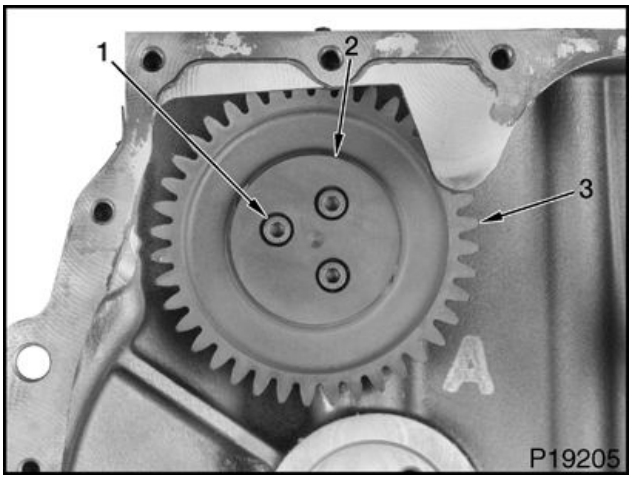

Figure 675 Crankcase idler gear (typical)

1. M8 x 30 socket-head cap screw (3)
2. Small gear stud
3. Crankcase idler gear

CAUTION: To prevent engine damage, insert the crankcase idler gear into the crankcase with the flatter contact surface facing outwards.

5. Install crankcase idler gear and small gear stud.
6. Install three crankcase idler gear M8 x 30 socket-head cap screws. Tighten cap screws to special torque (page 484).

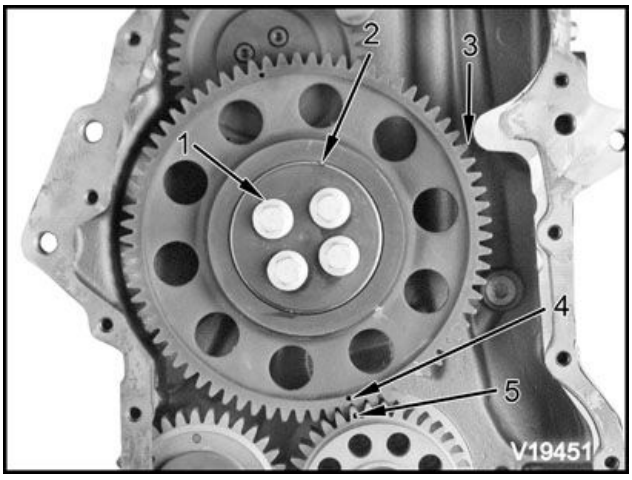

Figure 676 Large Idler gear assembly and timing marks

1. M14 x 80 bolt (4)
2. Big gear stud
3. Large idler gear
4. Timing mark (large idler gear)
5. Timing mark (rear crank gear)

NOTE: Large idler gear has two timing marks 180° apart; either may be used.

7. Install big gear stud and large idler gear, aligning timing mark with timing mark on rear crank gear (flywheel side).
8. Install four M14 x 80 bolts. Tighten bolts to special torque (page 484).

Front Timing Gears

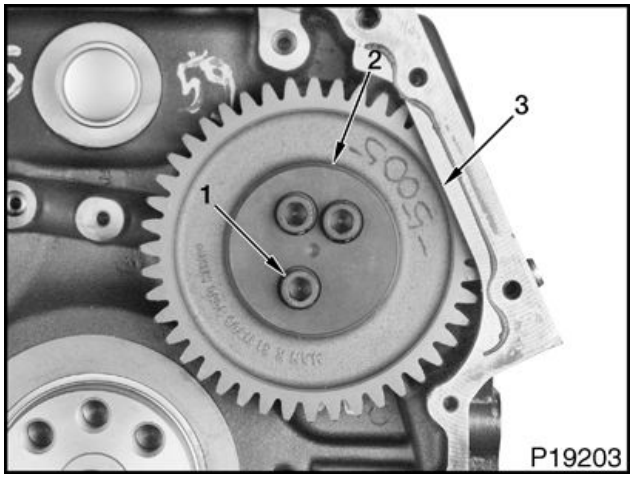

Figure 677 (Front) idler gear (typical)

1. M12 x 50 socket-head cap screw (3)
2. Gear stud (not flywheel side)
3. Idler gear

1. Install idler gear and gear stud.
2. Install three front idler gear M12 x 50 cap screws. Tighten screws to special torque (page 484).

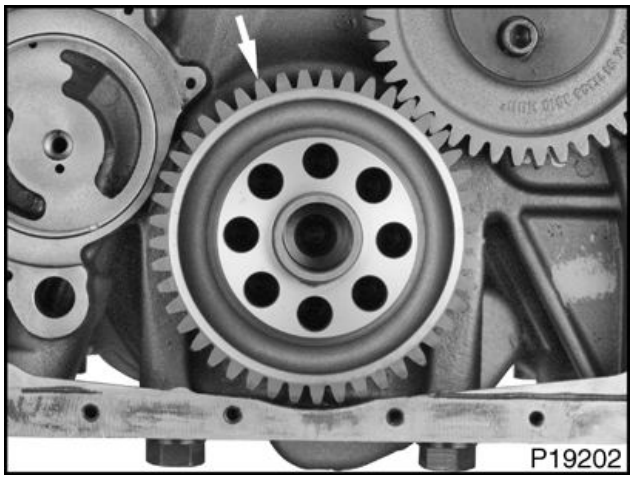

Figure 678 Front crank gear (typical)

3. Install two suitable alignment bolts 180° apart through front crank gear into front of crankshaft.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields.

4. Using a hammer and brass drift, carefully install front crank gear.
5. Remove two alignment bolts.

Oil Pump

1. Lubricate new O-ring 22 x 2 with clean engine oil and install oil pump pinion axle.

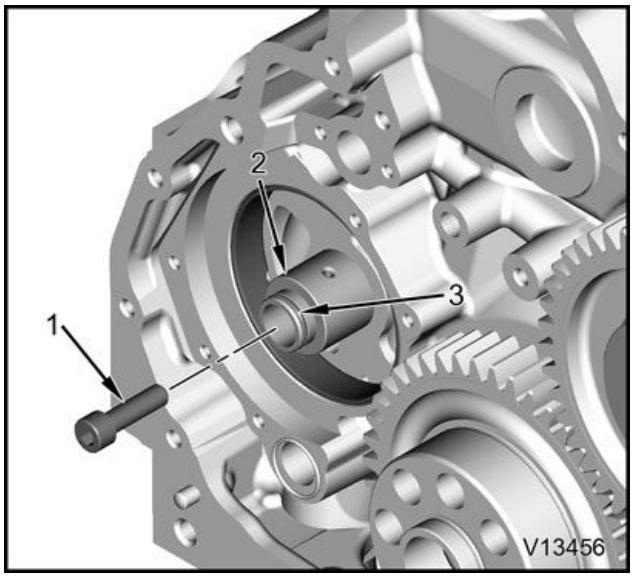

Figure 679 Pinion axle (oil pump)

1. M10 x 35 socket-head cap screw
2. Pinion axle (oil pump)
3. O-ring 22 x 2

2. Install oil pump pinion axle and M10 x 35 cap screw. Tighten screw to special torque (page 484).

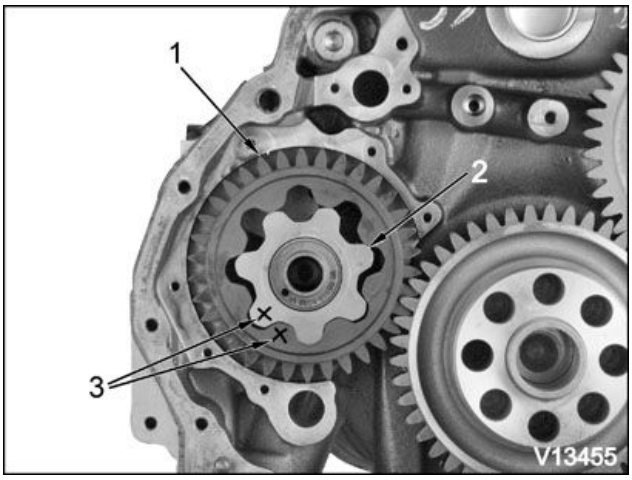

Figure 680 Pinion (gear) for oil pump and ring gear

1. (Oil pump) ring gear
2. Pinion (gear) for oil pump
3. Marks for reassembly (toward front)

3. Lubricate pinion (gear) for oil pump and ring gear with clean engine oil.
4. Install pinion gear and 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.

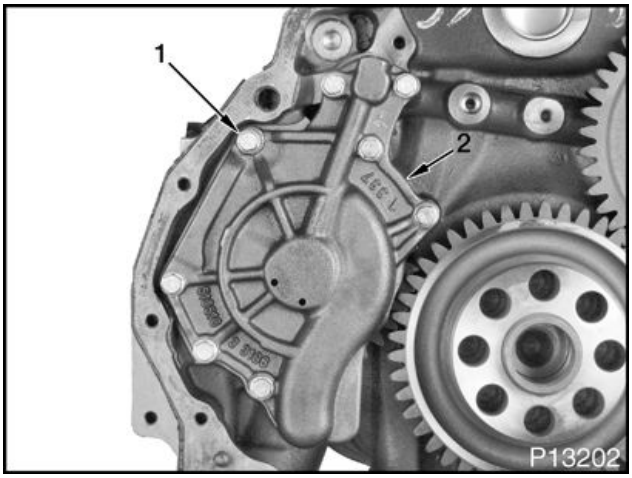

Figure 681 Oil pump cover (typical)

1. M6 x 25 bolt (8)
2. Oil pump cover

6. Install oil pump cover.
7. Install eight M6 x 20 or M6 x 25 bolts. Tighten bolts to standard torque (page 547).

Specifications

Oil Pump and Timing Gears

Front Timing Gears	
(Front) idler gear backlash	0.057 - 0.183 mm (0.0022 - 0.0072 in)
Oil Pump	
Oil pump pinion (gear) and ring gear end play	0.030 - 0.120 mm (0.0012 - 0.0047 in)
Rear Timing Gears	
Idler larger gear backlash	0.052 - 0.176 mm (0.0020 - 0.0069 in)
Large idler gear backlash	0.052 - 0.176 mm (0.0020 - 0.0069 in)

Special Torque

Air compressor coupled idler gear, M12 x 55 bolts	107 N·m (79 lb·ft)
Crankcase idler gear, M8 x 30 socket-head cap screws	30 N·m (22 lb·ft)
(Front) idler gear, M12 x 50 socket-head cap screws	105 N·m (77 lb·ft)
Larger idler gear, M14 x 80 bolts	175 N·m (129 lb·ft)
Oil pump pinion axle, M10 x 35 socket-head cap screw	65 N·m (48 lb·ft)

Special Service Tools

Description	Tool Number
Dial indicator with magnetic base	Obtain locally
Feeler gauge	Obtain locally
Gear puller	Obtain locally

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Exploded Views

Piston and Connecting Rod (Typical) and Cylinder Sleeve

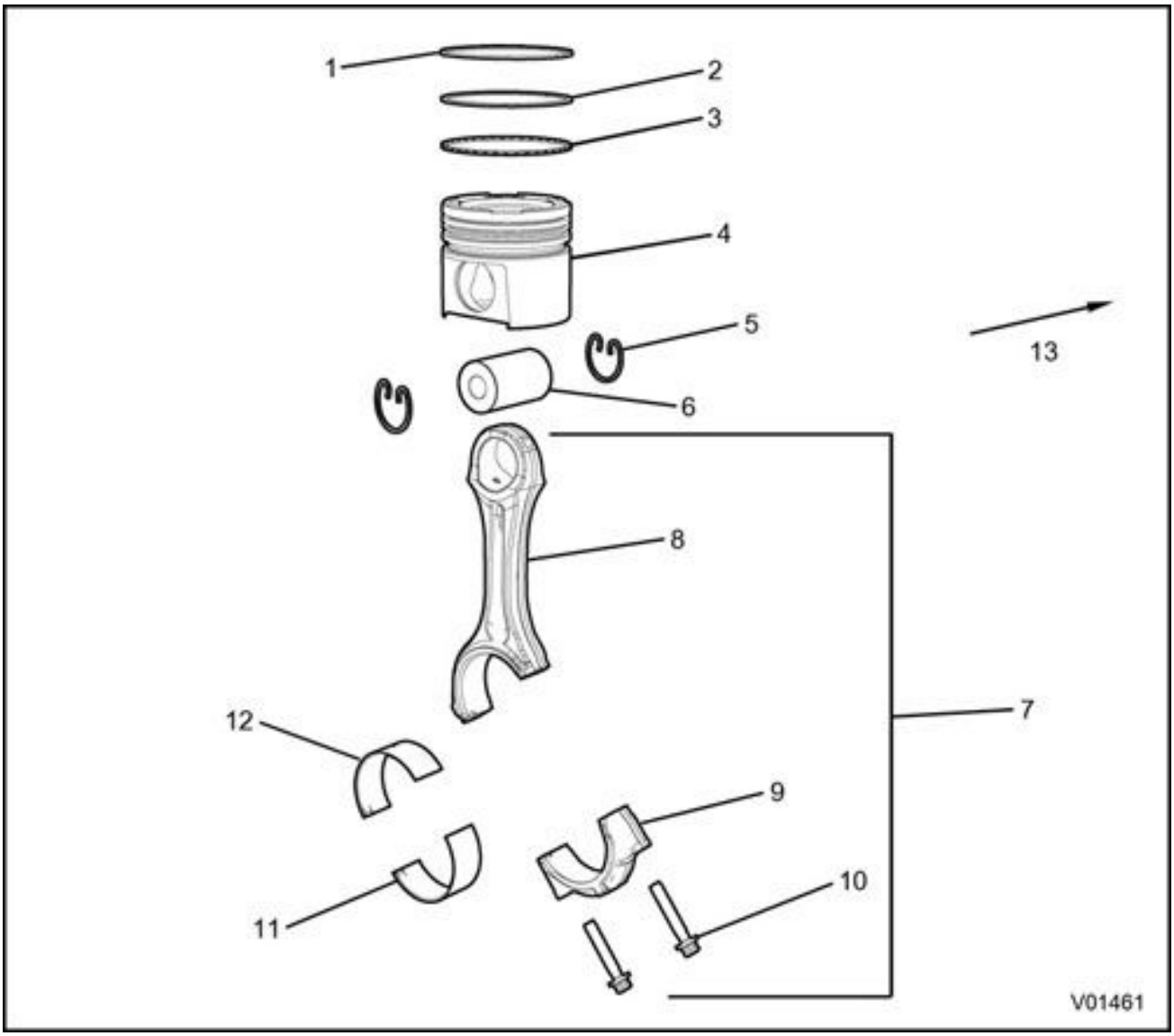

Figure 682 Piston and connecting rod (typical)

1. Compression top ring (6)
2. Taper face compression ring (6)
3. Bevelled oil ring (6)
4. Piston (6)
5. Piston pin retainer (12)
6. Piston pin (6)
7. Connecting rod assembly (6) (includes items 8, 9, 10)
8. Connecting rod
9. Connecting rod cap
10. Connecting rod bolt (2 each assembly)
11. Connecting rod bearing, lower (6)
12. Connecting rod bearing, upper (6)
13. Front of engine

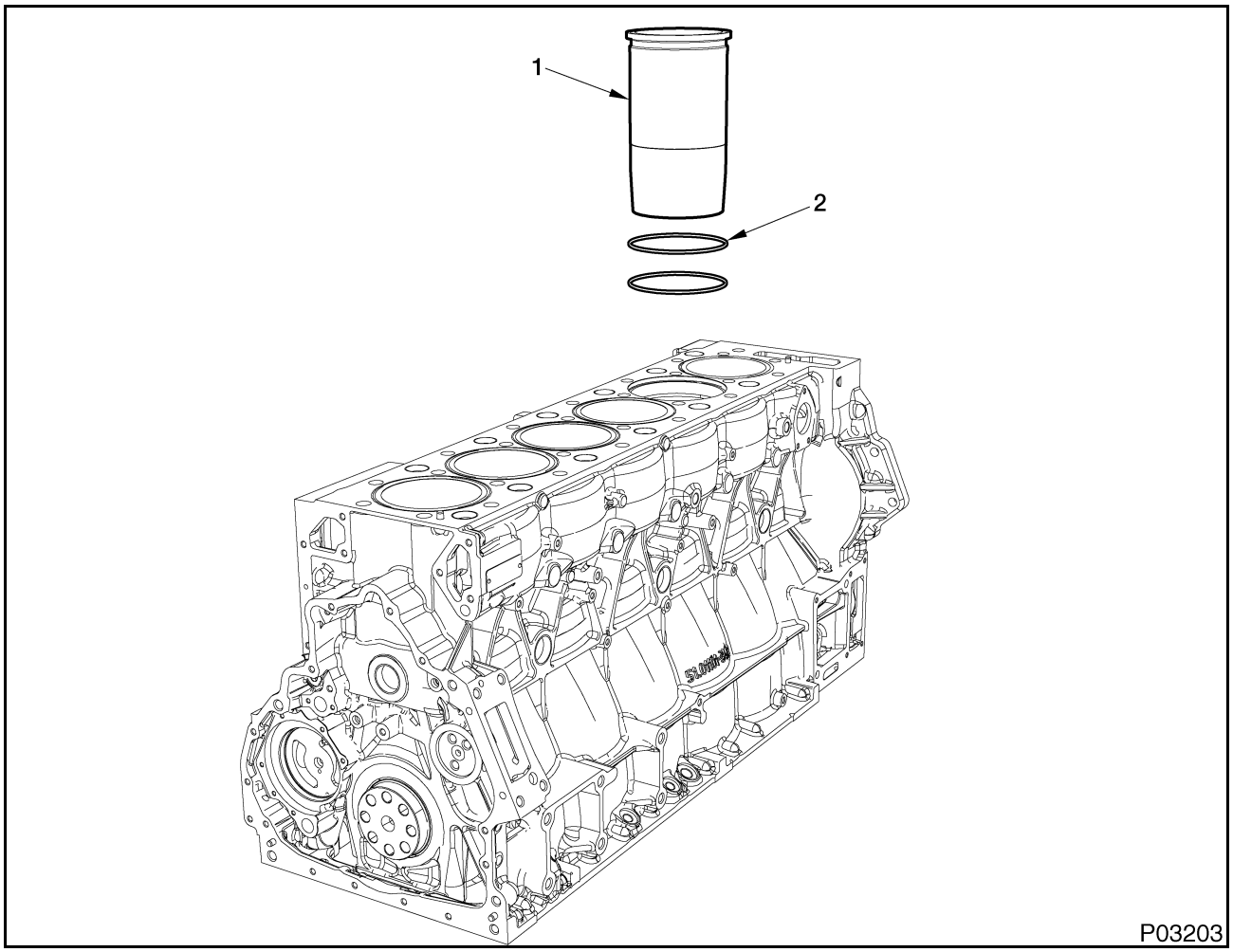

Figure 683 Cylinder sleeve

1. Cylinder sleeve (6)
2. Cylinder sleeve O-ring (12)

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: When performing specific component removal, only remove components necessary for access.

For complete engine tear down, refer to the following service sections for information on removal of components prior to this section.

- **Engine Electrical**
- **Inlet Air Heater**
- **Aftertreatment System**
- **Navistar® N13 Engine Brake by Jacobs**
- **Turbochargers**
- **Fuel System**
- **Oil Cooler, Filter Housing, and Crankcase Ventilation**
- **Exhaust Gas Recirculating (EGR) System**
- **Air Intake Throttle 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.

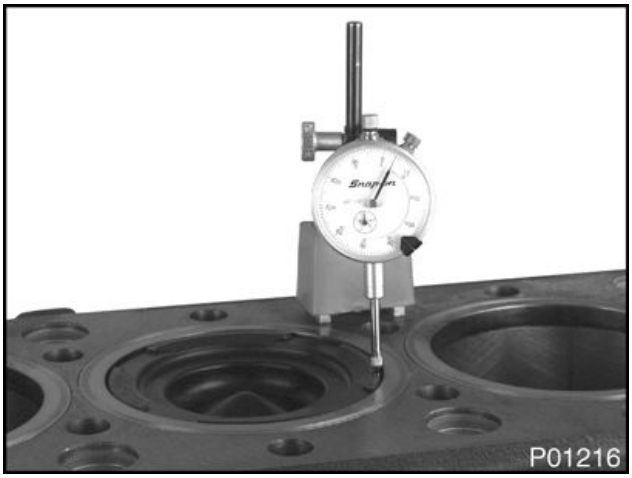

Figure 684 Piston protrusion check

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.
   b. Zero dial indicator with magnetic base (page 504) 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). Push down on piston crown before taking reading. 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. Push down on piston crown before taking reading. Read maximum protrusion on dial indicator.
   g. Average the two readings. Replace piston and connecting rod if protrusion is not within specification (page 503).

Piston and Connecting Rod

CAUTION: To prevent engine damage, check for a carbon ridge on top of cylinder sleeves. If found, remove carbon ridge with a suitable tool before removing rod and piston assemblies.

1. Scrape carbon ridge from top of cylinder bore, if necessary. Use care not to damage sleeve bore surface.

CAUTION: To prevent engine damage, mark with permanent marker or tag each connecting rod and cap with the correct cylinder number. This engine has “cracked” (fractured) type 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, install connecting rod cap and connecting rod with matching serial numbers on the same side. If the rod cap is reversed or not installed on its matching connecting rod, the fractured mating surfaces will be damaged. A new connecting rod assembly must be installed. Do NOT attempt to reuse a rod that has been misassembled to its cap, assembled with the wrong cap or has been cross-threaded while attempting assembly. Serious engine damage can result.

2. Rotate crankshaft to position journals for removal of connecting rod assemblies. Mark connecting rod locations.

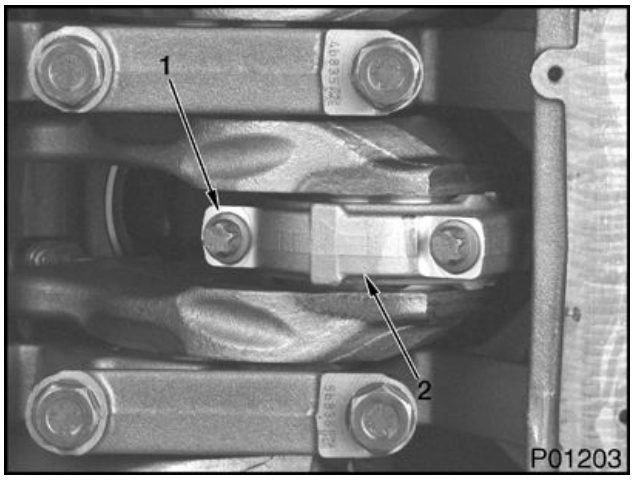

Figure 685 Connecting rod cap

1. Connecting rod bolt M12 x 64 (2)
2. Connecting rod 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 Exhaust Manifold Bolt Torx® Socket (page 504), remove two connecting rod bolts and connecting rod cap. Save bolts 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 piston cooling jet when removing connecting rod and piston assembly. If jet is bent during piston assembly or removal, replace jet.

4. Remove piston and connecting rod assemblies from cylinder sleeves as follows:
   a. Rotate engine to a vertical position.
   b. Use a wooden or plastic handle and push piston and connecting rod assembly from cylinder sleeve.
   c. Once piston rings are free of cylinder bore, remove piston and connecting rod assembly from cylinder sleeve.
   d. Mark each piston and rod assembly with cylinder number from which each was removed, using a permanent marker.

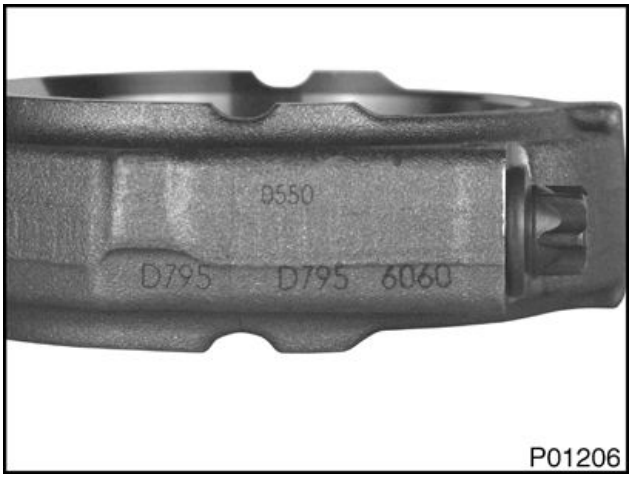

Figure 686 Correct connecting rod and cap joint fit

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

NOTE: Upper connecting rod bearings have an oil hole and lower connecting rod bearings do not.

5. Remove connecting rod upper and lower bearings by pushing out. Mark connecting rod bearings for position and orientation and set aside for inspection.

Piston Disassembly

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields.

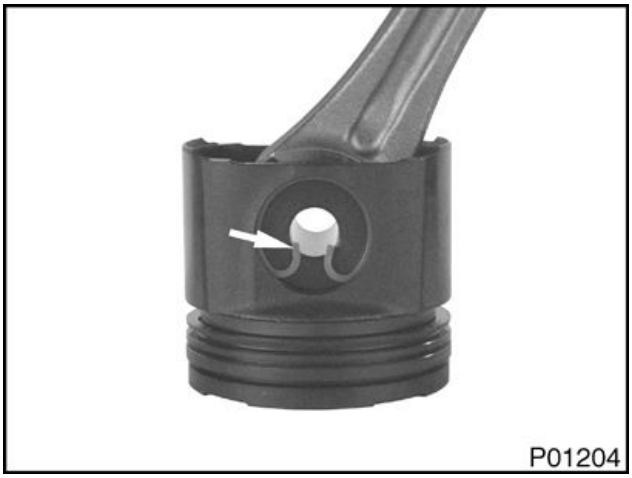

Figure 687 Piston pin retainer (typical)

1. Using a pair of pliers, remove two piston pin retainers.

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 688 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 504), remove top compression ring, taper face compression ring, and bevelled oil ring.

Cylinder Sleeves

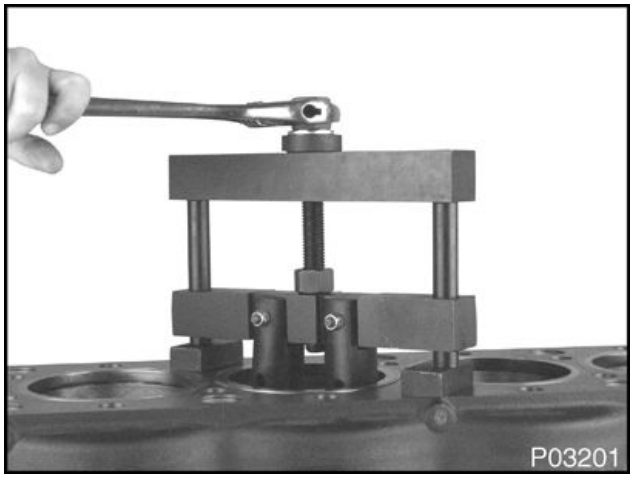

Figure 689 Cylinder sleeve removal

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

NOTE: Care must be taken not to damage piston cooling jets during cylinder sleeve removal.

1. Remove six cylinder sleeves from crankcase as follows:
   a. Insert Cylinder Sleeve Puller (page 504) into cylinder sleeve.
   b. Engage removal tool hooks under bottom edge of cylinder sleeve.
   c. Position removal tool feet diagonally on crankcase deck surface.
   d. Turn threaded shaft clockwise to extract cylinder sleeve.
   e. Mark cylinder sleeves for position and set aside for inspection.
2. Remove and discard two cylinder sleeve O-rings from each crankcase cylinder sleeve.

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
   - Piston pin retainers
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 690 Second and third ring groove clearance check (typical)

NOTE: It is not possible to measure side clearance of top compression 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 504) to measure side clearance between ring and groove.
   c. Compare taper face compression ring side clearance to specification (page 503). Excessive side clearance indicates ring groove wear and requires piston replacement.
3. Check side clearance of bevelled oil ring groove as follows:
   a. Place edge of a new bevelled oil ring in its respective ring groove. Roll bevelled oil ring all around ring groove to ensure ring is free in its groove.
   b. With edge of bevelled oil ring in the bevelled oil ring groove, use a feeler gauge (page 504) to measure side clearance between ring and groove.
   c. Compare bevelled oil ring side clearance to specification (page 503). Excessive side clearance indicates ring groove wear and requires piston replacement.

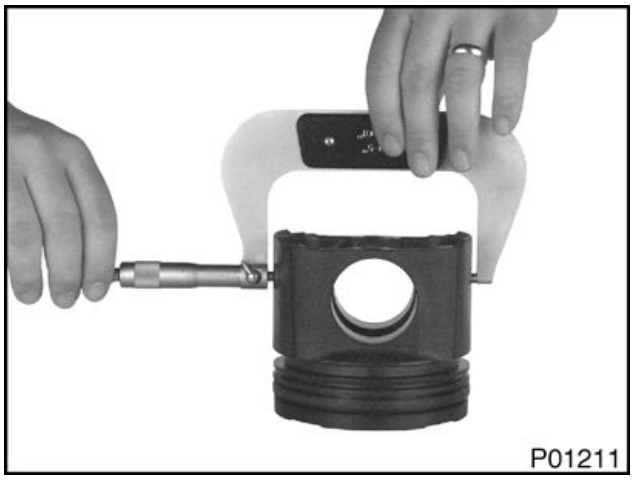

Figure 691 Piston skirt diameter measurement

4. Using a 4 - 5 inch micrometer (page 504), measure diameter of piston at intervals given in specifications (page 503). 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.

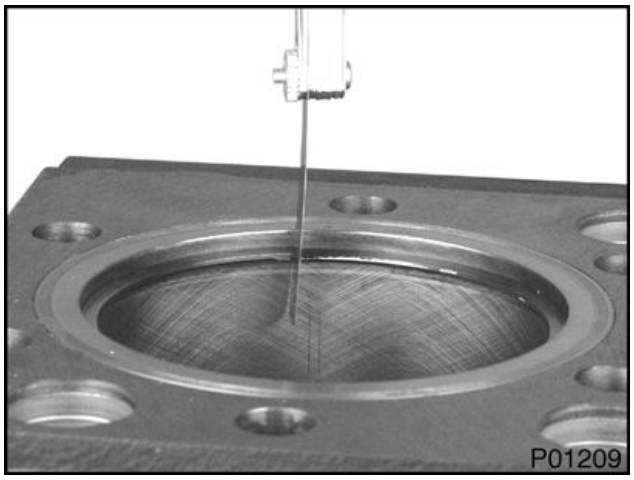

Figure 692 Piston ring end gap clearance in cylinder bore

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 504) to measure ring gap between ends of each piston ring.
   c. If gap ring does not meet specification (page 503), select another ring or recheck cylinder sleeve wear.

Connecting Rod Inspection

CAUTION: To prevent engine damage, do not allow fractured mating surfaces of the connecting rod or connecting rod cap to contact any surface other than its matched fractured surface. Contacting any other surface could cause misalignment of the mating surface, resulting in connecting rod bearing and engine failure.

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 bolt 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 693 Inside diameter of piston pin bore

3. Inspect connecting rod piston pin bore for wear as follows:
   a. Using a telescoping gauge (page 504) and a 2 - 3 inch micrometer (page 504), measure piston pin bore at two locations 90° apart.
   b. If inside diameter of piston pin bore exceeds specification (page 503), replace connecting rod.

Connecting Rod Bore Check

CAUTION: To prevent engine damage, do not use power tools to remove or install connecting rod cap bolts. Threads will be damaged if a bolt or nut is rotated too quickly.

1. Lightly lubricate USED connecting rod bolts with clean engine oil. Assemble cap to connecting rod without bearings. Tighten bolts to an initial torque of 100 N·m (74 lb·ft).
2. Rotate each rod bolt 90° clockwise (1/4 turn).

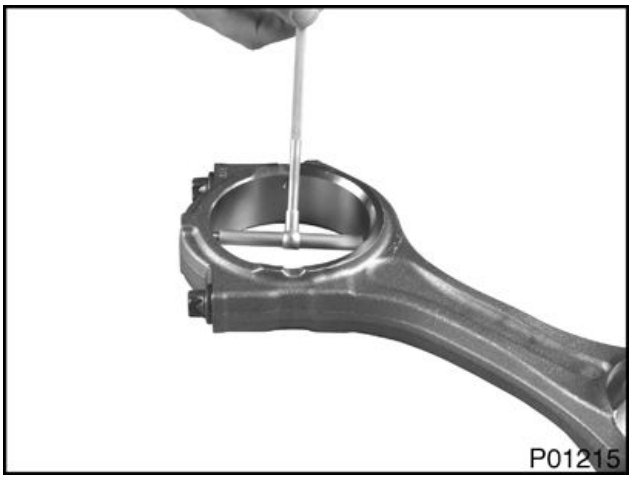

Figure 694 Connecting rod bore measurement

3. Using a telescoping gauge (page 504) and a 3 - 4 inch micrometer (page 504), measure connecting rod bearing bore diameter in three locations. If connecting rod bore diameter does not meet specification (page 503), replace connecting rod.
4. After all connecting rod bores are inspected, disassemble connecting rods and discard used connecting rod bolts.
5. 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 assembly as necessary.

Piston Pin Inspection

1. Inspect piston pins for scoring or wear. Replace as necessary.

Figure 695 Piston pin measurement

2. Using a 2 - 3 inch micrometer (page 504), measure piston pin outside diameter at two locations 90° apart. Measure each end of pin. If outside diameter of any piston pin is less than minimum specification (page 503), replace piston pin.

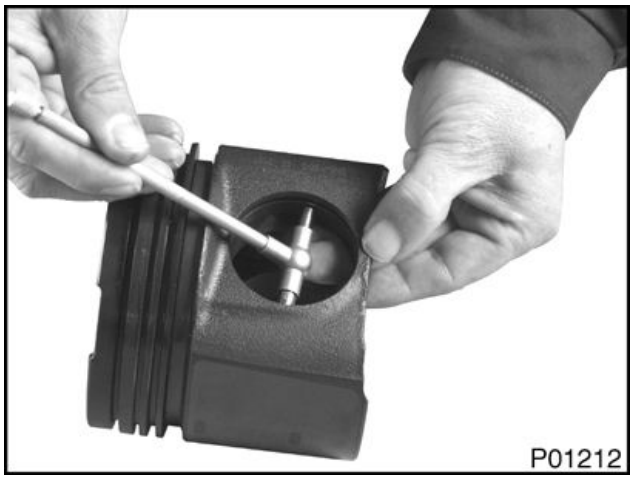

Figure 696 Piston pin bore inside diameter measurement (typical)

NOTE: These pistons have "profiled" pin bores and must be measured carefully to get an accurate result.

NOTE: Measure each piston pin bore inside diameter in front and in rear of piston at one location each, horizontally in the pin bore the specified distance from the center line of the piston.

3. Using a telescoping gauge (page 504) and 2 - 3 inch micrometer (page 504), measure each piston pin bore inside diameter at one location horizontally the specified distance from center of piston. If piston pin bore inside diameter is not within specification (page 503), replace piston.
4. To check piston pin running clearance, subtract outside diameter of piston pin from inside diameter of piston pin bore. If clearance exceeds specification (page 503), replace piston pin and check piston pin clearance using new piston pin.

Cylinder Sleeve Inspection

1. Install six cylinder sleeves (without cylinder sleeve O-rings) into crankcase.

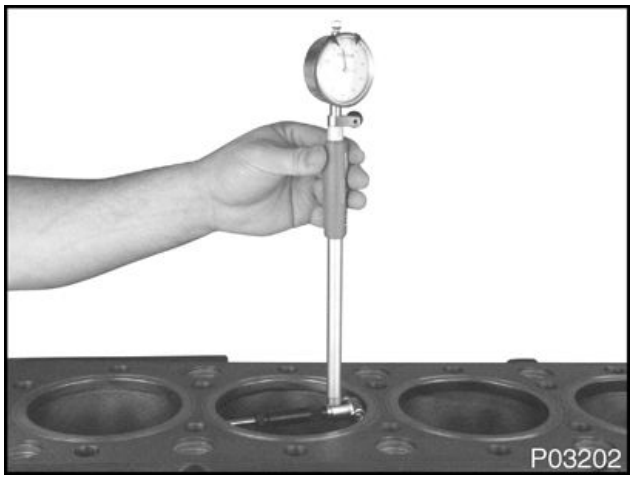

Figure 697 Cylinder sleeve bore measurement

2. Using a dial bore gauge (page 504), measure the cylinder sleeve inside diameter at 120° intervals, at four different depths of cylinder sleeve. If cylinder sleeve inside diameter is not within specification (page 503), replace cylinder sleeve.

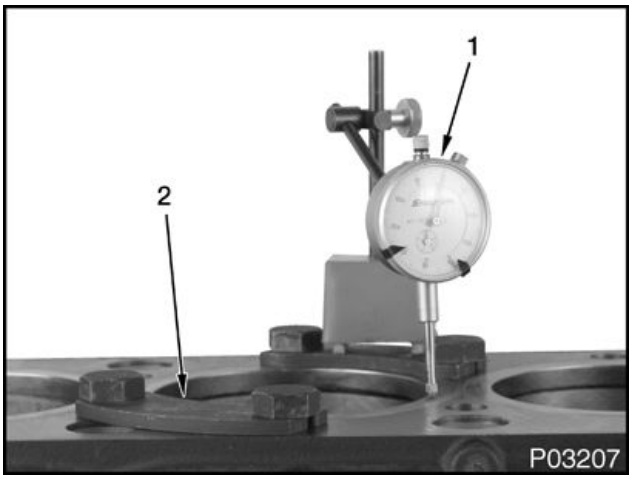

Figure 698 Cylinder sleeve protrusion measurement

1. Dial indicator with magnetic base
2. Sleeve Protrusion Hold Down Clamp

3. Check cylinder sleeve protrusion above crankcase deck as follows:

   a. Install Sleeve Protrusion Hold Down Clamps (page 504) using four included bolts. Torque bolts to special torque (page 503).

   b. Place dial indicator with magnetic base (page 504) on crankcase deck surface.

   c. Position dial indicator tip on crankcase deck adjacent to cylinder sleeve flange. Zero dial indicator.

   d. Carefully pivot dial indicator until tip is resting on cylinder sleeve flange. Record reading.

   e. Measure cylinder sleeve protrusion at three locations evenly spaced around the cylinder sleeve.

   f. If any of the three readings of cylinder sleeve protrusion are not within specification (page 503), fit new cylinder sleeve and repeat steps a through e.

   g. If after trying all available new cylinder sleeves and specification still cannot be met, contact Tech Central at 1-800-336-4500.

   h. Remove six cylinder sleeves and continue with installation.

Installation

Cylinder Sleeves

1. Lubricate two new cylinder sleeve O-rings with clean engine oil and install in crankcase cylinder sleeve bore.
2. Using a soft-faced hammer, install cylinder sleeve by striking evenly until seated.

Piston Assembly

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields.

Figure 699 Piston ring installation (typical)

CAUTION: To prevent engine damage, install piston rings correctly. Both top compression and taper face compression rings have the same identification markings. The marking must face up for the ring to be installed correctly. The taper face compression 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 (obtain locally) , install piston rings. Be careful not to “wind” ring into groove.
   a. Install expansion spring component of bevelled oil ring into bottom piston groove.
   b. Install oil scraper component of bevelled oil 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 top compression 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 crown down so arrow mark stamped on piston crown is at 6 o'clock position.
   c. Using pliers, install one piston pin retainer into groove. Be sure that retainer is fully seated in groove and that tang ends point up.
   d. Hold connecting rod so open end faces 3 o'clock position of piston when installed.
   e. Place connecting rod into piston.

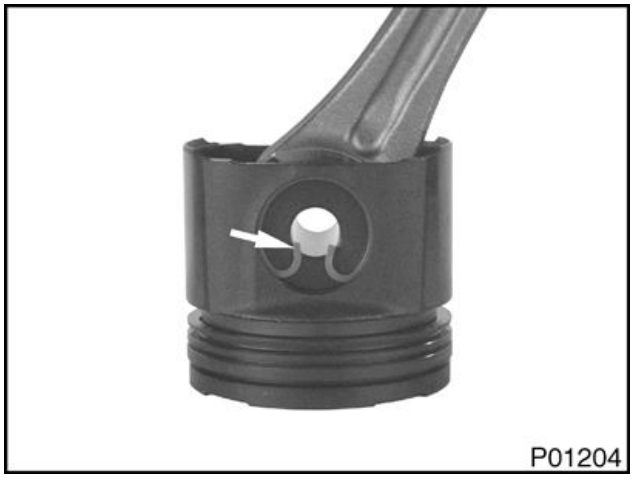

Figure 700 Piston pin retainer

   f. Slide piston pin through piston holes, stopping at installed piston pin retainer.
   g. Using pliers, install second piston pin retainer.

Piston and Connecting Rod

CAUTION: To prevent engine damage, do not allow fractured mating surfaces of the connecting rod or connecting rod cap to contact any surface other than its matched fractured surface. Contacting any other surface could cause misalignment of the mating surface, resulting in connecting rod bearing and engine failure.

1. Verify proper connecting rod orientation. Assemble connecting rod 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.

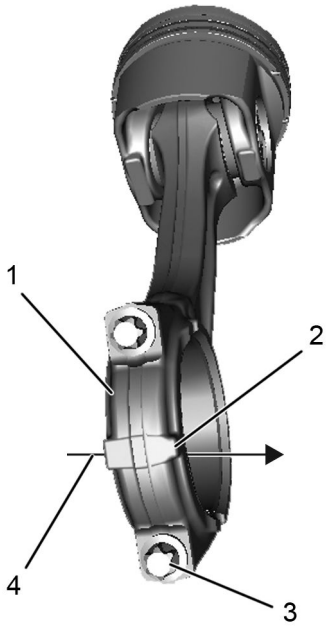

Figure 701 Connecting rod chamfer pointing to front of engine

1. Connecting rod cap
2. Chamfer
3. Connecting rod bolt (2)
4. Arrow pointing to front of engine

2. Secure connecting rod cap (Figure 701) (Item 1) with two connecting rod bolts (Figure 701) (Item 3). Finger-tighten only.
3. Verify chamfer (Figure 701) (Item 2) on connecting rod cap is pointing in same direction as arrow mark stamped on top of piston (Figure 702). If chamfer is not pointing in same direction as arrow mark on piston, reinstall piston on connecting rod (page 498).
4. Remove connecting rod cap from connecting rod.
5. Turn crankshaft so crank pin (connecting rod journal) on the cylinder to receive piston installation is at the bottom of its stroke.
6. Lightly coat piston and piston rings with clean engine oil.
7. Coat cylinder sleeve walls, crankshaft journals and Piston Ring Compressor (obtain locally) with clean engine oil.
8. Place piston in Piston Ring Compressor.

NOTE: Upper connecting rod bearings have an oil hole and lower connecting rod bearings do not.

9. Install connecting rod bearings in connecting rod and cap. Bearings with oil hole go in the upper position. Coat bearings with clean engine oil.

   Be sure that all bearing locator tabs and oil holes are in alignment with connecting rod and cap and that bearings are flush to fractured mating faces of rod and cap.

Figure 702 Arrow mark on piston (typical)

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 piston cooling jet when installing connecting rod and piston assembly. If jet is bent during piston assembly installation, replace jet.

NOTE: Before installing piston and connecting rod assembly, make sure all piston cooling jets are installed.

10. Carefully put piston and piston ring compressor combination and connecting rod assembly in cylinder sleeve with arrow mark facing towards front of engine.

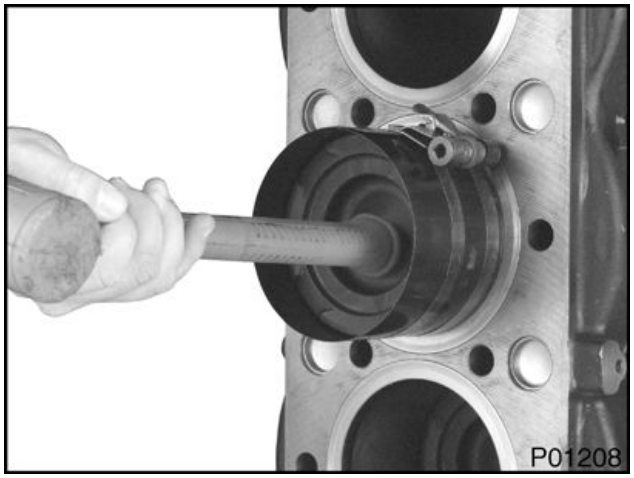

Figure 703 Piston and connecting rod assembly installation (typical)

11. Once piston and connecting rod assembly has been inserted in cylinder sleeve, use a handle (wood or plastic) of a hammer to tap piston into cylinder sleeve. Guide connecting rod in place on crankshaft. Do not let edges of connecting rod or fractured mating face of rod touch the crankshaft journal. Before installing cap with bearing and starting bolts, be sure that bearings are still flush with connecting rod and cap fractured mating faces and have NOT rotated.

CAUTION: To prevent engine damage, lightly lubricate bolt threads and mating surfaces of bolt flanges with clean engine oil. Too much oil causes hydrostatic lock and gives incorrect torque reading.

12. Lightly apply clean engine oil to new bolt threads for connecting rod and upper and lower bearings in cap before installing bolts.

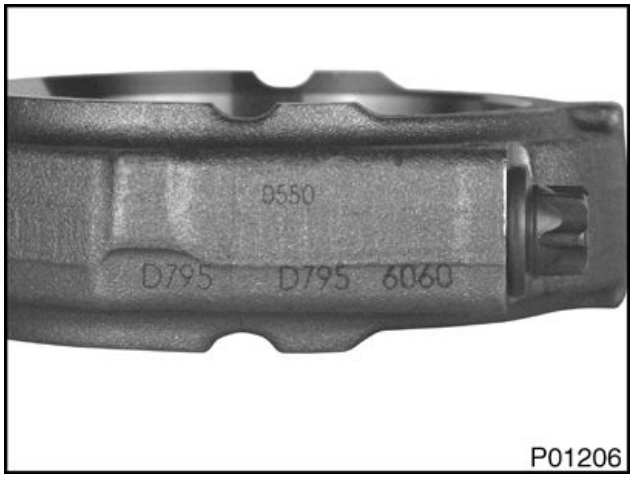

Figure 704 Correct connecting rod and cap joint fit

CAUTION: To prevent engine damage, clean fractured mating surfaces of the connecting rod and rod cap with filtered compressed air.

13. Use filtered compressed air to clean debris from fractured mating surfaces of the connecting rod and rod cap.

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 (connecting rod journal) fillets for damage that would require replacement of the crankshaft.

14. 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.

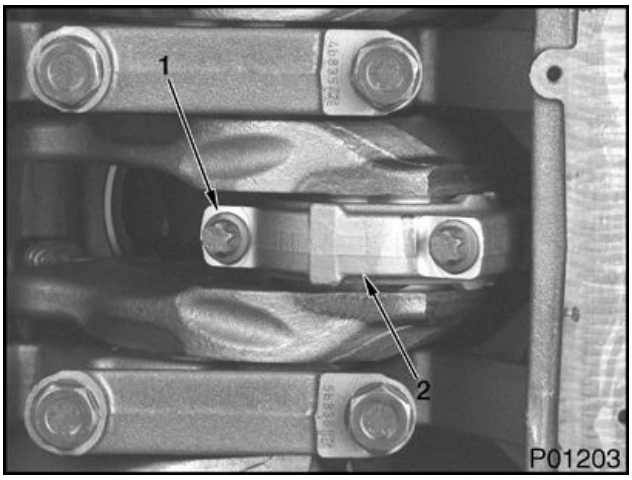

Figure 705 Connecting rod cap (typical)

1. Connecting rod bolt (2)
2. Connecting rod cap

CAUTION: To prevent engine damage, install new connecting rod bolts.

CAUTION: To prevent engine damage, do not use powered tools to install connecting rod bolts; rotating bolts too quickly can damage threads.

CAUTION: To prevent engine damage, do not rotate crankshaft until connecting rod bolts are fully tightened, as this may cause bearings to rotate in place.

15. Install two New connecting rod bolts (Figure 705) (Item 1).
16. Using Exhaust Manifold Bolt Torx® Socket ZTSE4843, tighten connecting rod bolts evenly to an initial torque of 100 N·m (74 lb·ft).
17. Rotate (tighten) connecting rod bolts an additional 90 degrees (1/4 turn).
18. Repeat installation procedure for remaining piston and connecting rod assemblies.

Engine Run-in Procedure

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.

Use the following engine run-in procedure after installing new pistons, piston rings, piston pins, or cylinder sleeves:

1. Start engine and run at low idle with no load. If engine does not exceed 138 kPa (20 psi) oil pressure within 20 to 30 seconds, shutdown engine and correct the problem.
2. Run engine at low idle with no load for 5 minutes and check for any of the following problems:

- Unusual noise
- Coolant leaks
- Oil leaks
- Fuel leaks
- Air leaks
- Excessive exhaust smoke
- Excessive vibration
- Loose turbocharger mounting

3. Turn engine off and correct any of these problems to prevent engine or turbocharger damage.
4. Wait 15 minutes for oil level to stabilize, then check engine oil level. Add oil if needed. See appropriate *Engine Operation and Maintenance Manual* for correct grade and viscosity of engine oil.
5. Start engine and drive vehicle (unloaded) for 30 minutes in city mode, then drive vehicle (unloaded) for an additional 60 minutes in highway mode. Verify no loss in power.
6. Return to idle and check for leaks.
7. Turn off engine and repair any leaks.

Specifications

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 — Navistar® N13	
Skirt diameter measured 26.9 mm from piston bottom edge, 90° to piston pin axis in “window” on skirt graphite layer, where applicable	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, measured horizontally 26 mm from piston center	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 — Navistar® N13	
Top compression ring	
Ring gap	0.4 - 0.55 mm (0.0157 - 0.0217 in)
Taper face compression ring	
Ring gap	1.00 - 1.20 mm (0.0394 - 0.0472 in)
Side clearance	0.09 - 0.13 mm (0.0035 - 0.0051 in)
Bevelled oil 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)
Cylinder sleeve dimensions — Navistar® N13	
Sleeve protrusion	0.050 - 0.085 mm (0.0019 - 0.0033 in)
Sleeve inside diameter (bore)	126 ± 0.01 mm (4.9606 ± 0.0004 in)

Special Torque

Connecting rod bolts	See tightening steps in procedure
Sleeve Protrusion Hold Down Clamp bolts	80 N·m (59 lb·ft)

Special Service Tools

Description	Tool Number
2 - 3 inch micrometer	Obtain locally
3 - 4 inch micrometer	Obtain locally
4 - 5 inch micrometer	Obtain locally
Cylinder Sleeve Puller	ZTSE2536
Dial bore gauge	Obtain locally
Dial indicator with magnetic base	Obtain locally
Exhaust Manifold Bolt Torx® Socket	ZTSE4843
Feeler gauge	Obtain locally
Piston ring compressor	Obtain locally
Piston ring expansion pliers	Obtain locally
Sleeve Protrusion Hold Down Clamps	ZTSE4825
Telescoping gauge	Obtain locally

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Exploded View

Crankcase and Crankshaft

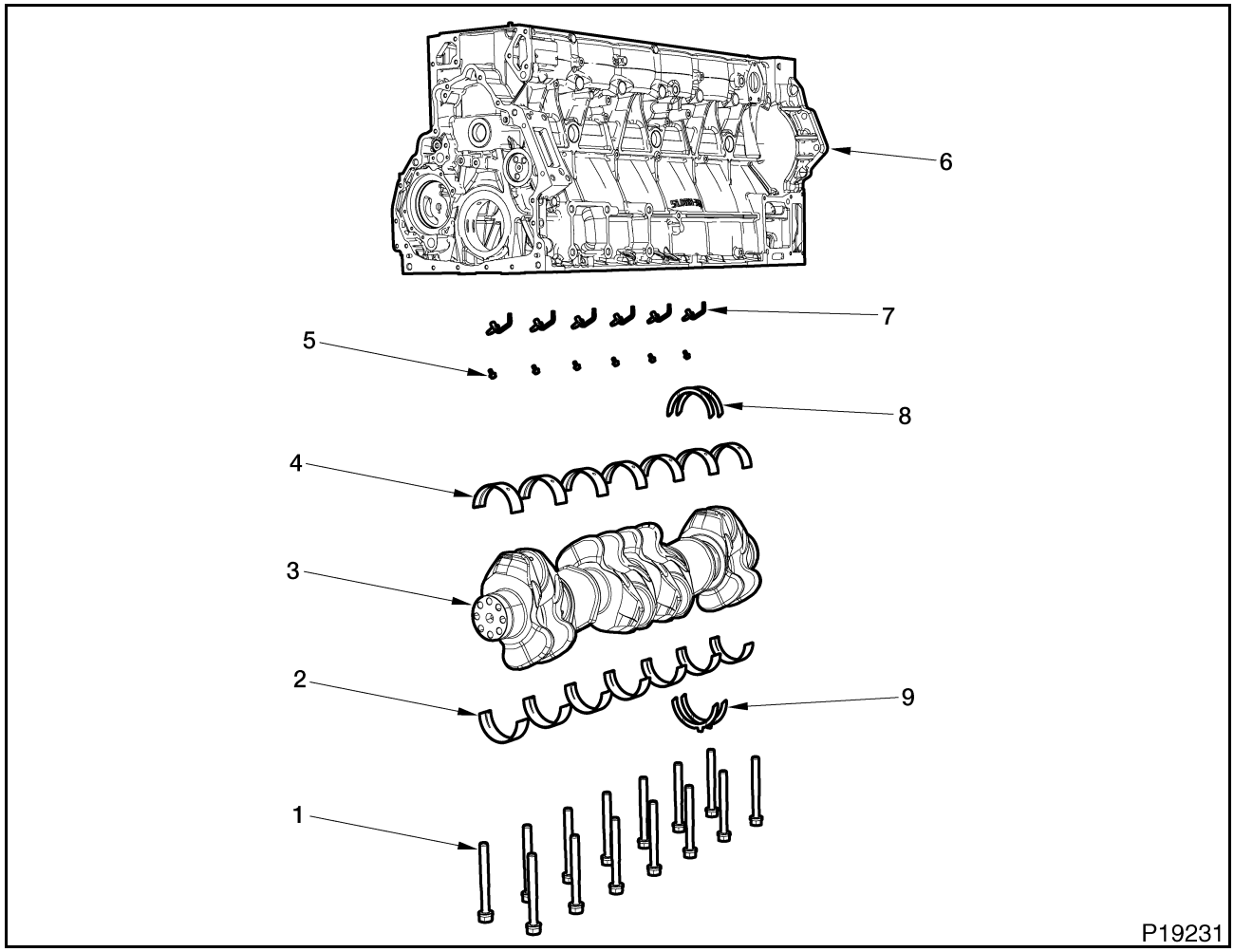

Figure 706 Crankcase and crankshaft

1. M18 x 2 x 160.5 collar bolt (14)
2. Lower main bearing (7)
3. Crankshaft
4. Upper main bearing (with oil hole) (7)
5. M6 x 12 bolt (6)
6. Crankcase
7. Piston cooling jet (6)
8. Upper thrust washer (main bearing) (2)
9. Lower thrust washer (main bearing) (2)

Removal

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

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

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

WARNING: To prevent personal injury or death, 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: When performing specific component removal, only remove components necessary for access.

For complete engine tear down, refer to the following service sections for information on removal of components prior to this section.

- **Engine Electrical**
- **Mounting Engine on Stand**
- **Inlet Air Heater**
- **Aftertreatment System**
- **Exhaust Back Pressure Control**
- **Turbochargers**
- **Air Compressor and Power Steering**
- **Fuel System**
- **Oil Cooler, Filter Housing and Crankcase Ventilation**
- **Exhaust Gas Recirculating (EGR) System**
- **Air Intake Throttle Duct and Exhaust Manifold**
- **Front Cover, Fan Drive, Cooling System and Related Components**
- **Navistar® N13 Engine Brake by Jacobs (if equipped)**
- **Cylinder Head, Camshaft and Valve Train**
- **Flywheel and Flywheel Housing**
- **Oil Pan and Oil Pickup Tube**
- **Oil Pump and Timing Gears**
- **Power Cylinders**

Preliminary Checks

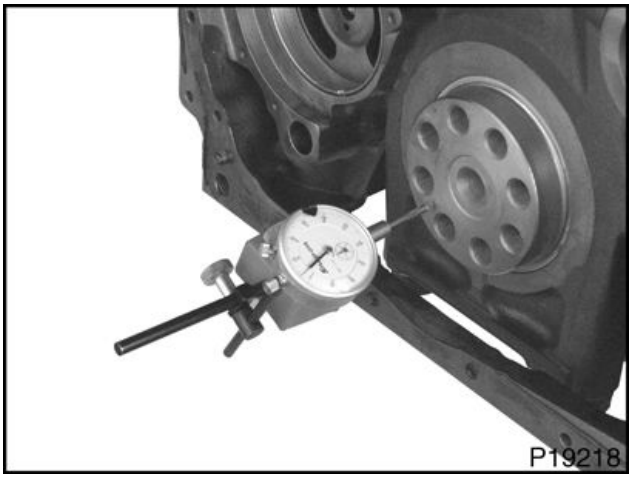

Figure 707 Crankshaft end play

1. Check crankshaft end play as follows:
   a. Mount dial indicator with magnetic base (page 517) 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 specification (page 517).
   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.

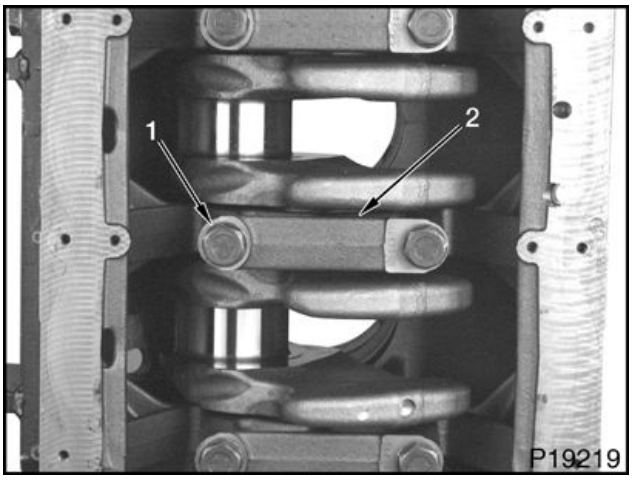

Figure 708 Main bearing caps

1. M18 x 160.5 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 M18 x 160.5 collar bolts and seven main bearing caps. Save bolts for Main Bearings Measurement procedure (page 512).
4. Remove seven lower main bearings and two lower 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 thrust washers on back side (not running surface) and set aside for inspection.

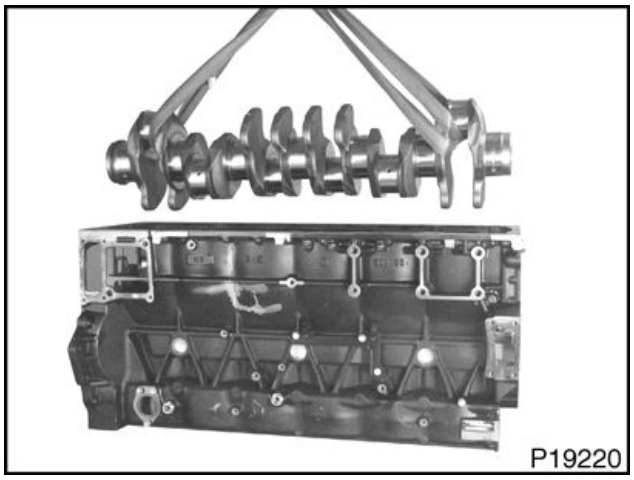

Figure 709 Crankshaft removal

⚠ 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 damage crankshaft.

NOTE: Use only a soft-sided lifting sling. Do not use chains or steel cables.

6. Attach lifting sling (page 517) to crankshaft. Lift crankshaft up and out of crankcase and set aside for inspection.
7. Remove upper main bearings and upper thrust washers from crankcase by pushing out.
8. Number removed upper main bearings and upper thrust washers on back side (not running surface) to match the previously removed lower main bearings and lower thrust washers and set aside for inspection.

Piston Cooling Jets

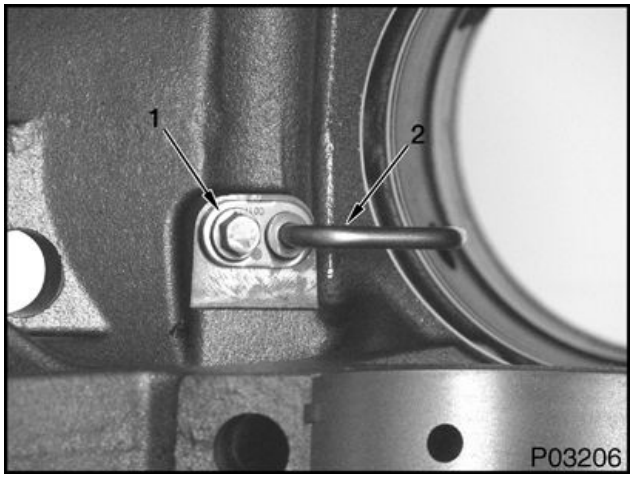

Figure 710 Piston cooling jet

1. M6 x 12 bolt (6)
2. Piston cooling jet (6)

1. Remove six M6 x 12 bolts and six piston cooling jets.

Cleaning, Inspection and Testing

Crankcase

⚠ 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.

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.

CAUTION: To prevent engine damage, do not use 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.

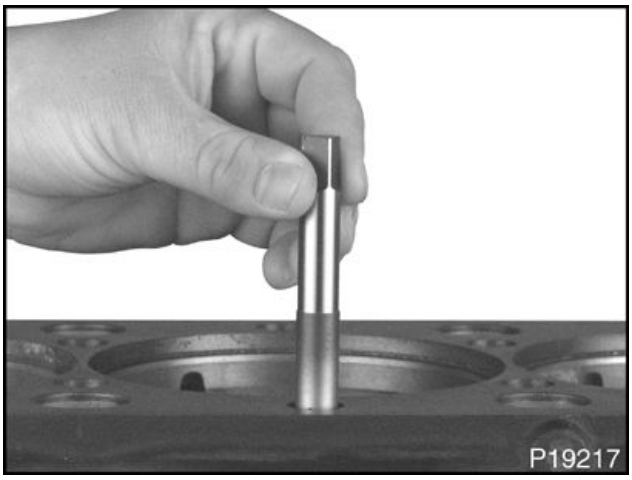

Figure 711 Cylinder head bolt holes

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 (page 517).
4. Clean collar bolt holes with Main Bolt Bottoming Tap (page 517).
5. Clean out debris with filtered compressed air.

Crankshaft Measurement

1. Clean and inspect crankshaft and main bearings.
2. Clean crankshaft with a suitable solvent.
3. Use a stiff nylon brush to clean oil passages in crankshaft. Loosen accumulated dirt, sludge and deposits.
4. Flush oil passages 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).

5. Dry with filtered compressed air.
6. Inspect crankshaft journals (main and connecting rod) for scratches, grooves and scoring.

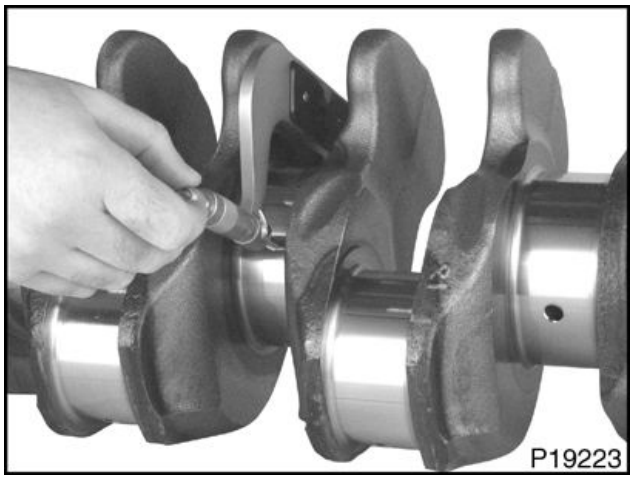

Figure 712 Crankshaft main bearing journal measurement

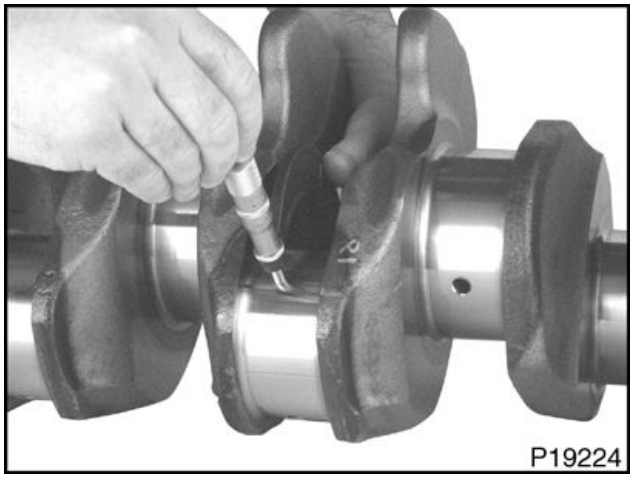

Figure 713 Crankshaft connecting rod bearing journal measurement

CAUTION: To prevent engine damage, do not rework bearings or bearing caps to reduce journal-to-bearing running clearances. Grind or install new crankshaft.

7. Use a 3 - 4 inch micrometer (page 517) to measure diameter of each connecting rod journal, and a 4 - 5 inch micrometer (page 517) 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 517), have crankshaft machined, or replace crankshaft.

Main Bearings Measurement

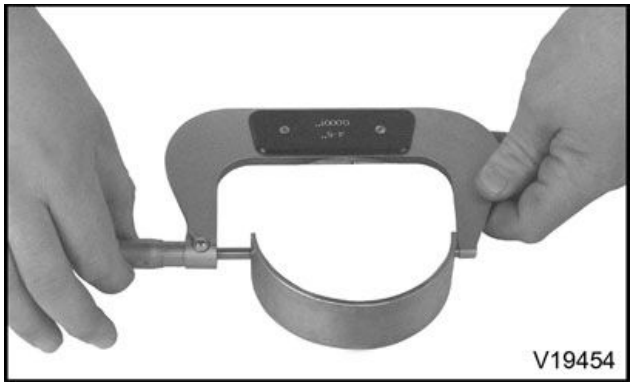

Figure 714 Main bearing uninstalled outside diameter (free spread) measurement

1. Inspect each main bearing for scratches, grooves, scoring, pitting and wear. Replace bearings as required.
2. Using a flat surface, place an individual bearing half on the surface as shown.
3. Using a 4 - 5 inch micrometer (page 517), measure across the ends of the bearing half as shown.
4. If the measurement falls outside of the uninstalled bearing outside diameter (free spread) specification (page 517), replace upper and lower bearing halves as a set. Measure all upper and lower bearing halves and replace bearings as required.
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. Lightly coat used collar bolt threads and under bolt heads with clean engine oil. Do not use new bolts for this inspection procedure.
7. With crankshaft still removed, install seven main bearing caps and 14 previously removed M18 x 160.5 collar bolts.
8. Tighten M18 x 160.5 collar bolts in main bearings caps as follows:

a. Tighten collar bolts at No. 6 main bearing cap to 10 N·m (88 lb·in).

b. Tighten remaining collar bolts to 10 N·m (88 lb·in).

c. Tighten collar bolts at No. 6 main bearing cap to 100 N·m (74 lb·ft).

d. Tighten remaining collar bolts to 100 N·m (74 lb·ft).

e. Tighten collar bolts at No. 6 main bearing cap to 300 N·m (221 lb·ft).

f. Tighten remaining collar bolts to 300 N·m (221 lb·ft).

g. Turn collar No. 6 main bearing cap an additional 90° clockwise.

h. Turn remaining collar bolts an additional 90° clockwise.

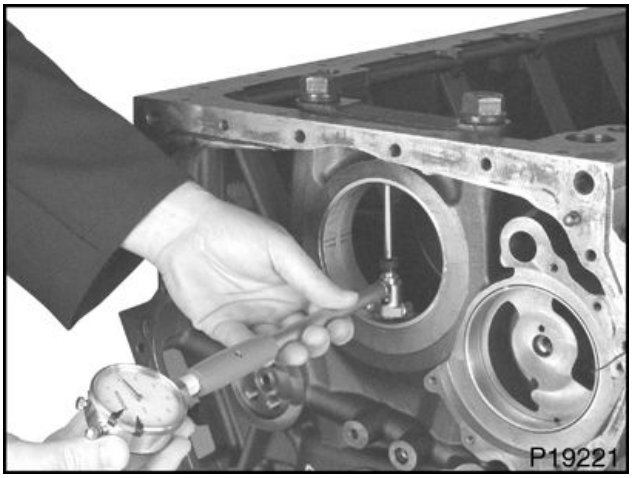

Figure 715 Main bearing installed diameter measurement

9. Using a dial bore gauge (page 517), measure main bearing installed inside diameter. If measurement does not meet specification (page 517), replace main bearings.

10. Remove 14 M18 x 160.5 collar bolts, seven main bearing caps, upper main bearings and lower main bearings. Discard used collar bolts.

Piston Cooling Jets

1. Hold each piston cooling jet under running water. Water should stream from jet 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 piston cooling jets using filtered compressed air. Replace piston cooling jet if blockage cannot be cleared.

3. Replace any cracked or bent jets.

Installation

Piston Cooling Jets

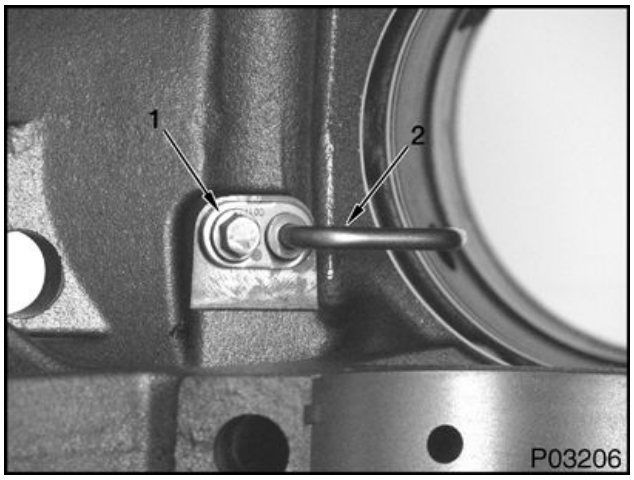

Figure 716 Piston cooling jet

1. M6 x 12 bolt (6)
2. Piston cooling jet (6)

1. Install six piston cooling jets and six M6 x 12 bolts.
2. Tighten bolts to special torque (page 517).

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.

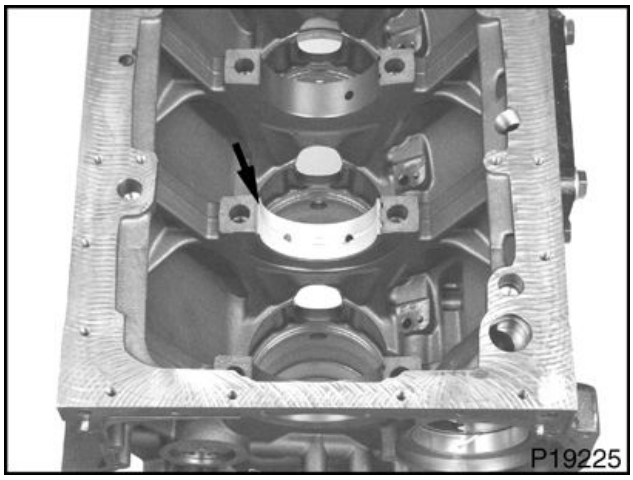

Figure 717 Main bearing

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 running surface of bearings with clean engine oil.

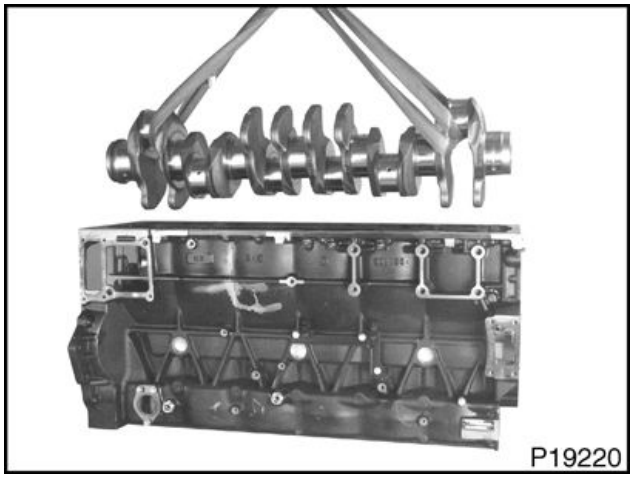

Figure 718 Crankshaft installation

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 damage crankshaft.

NOTE: Use only a soft-sided lifting sling. Do not use chains or steel cables.

4. Attach lifting sling (page 517) to crankshaft. Orient crankshaft with front flange (8 bolt holes) and rear flange (10 bolt holes) at crankcase front and rear, respectively. Carefully lower crankshaft down into crankcase.

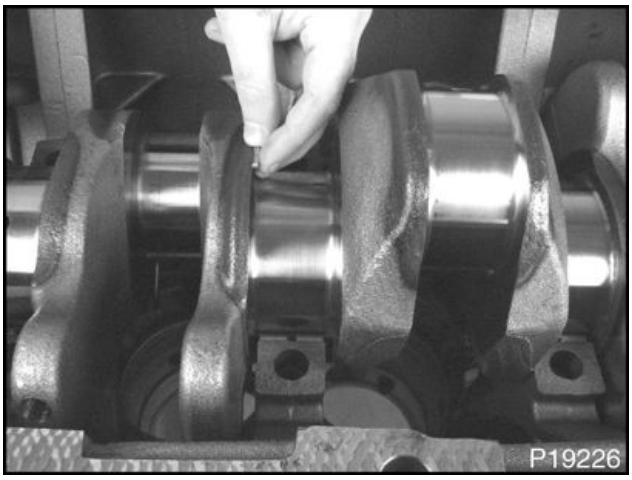

Figure 719 Thrust washer installation

NOTE: Make sure oil grooves on thrust washers face outward towards crankshaft thrust surface.

5. Install two upper thrust washers into crankcase at No. 6 main location as follows:
   a. Set upper thrust washer on top of crankshaft at No. 6 main journal with grooves towards crankshaft thrust surface.
   b. Pivot upper thrust washer around crankshaft and down into position.
6. Install two lower thrust washers onto No. 6 main bearing cap. Make sure lower thrust 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.

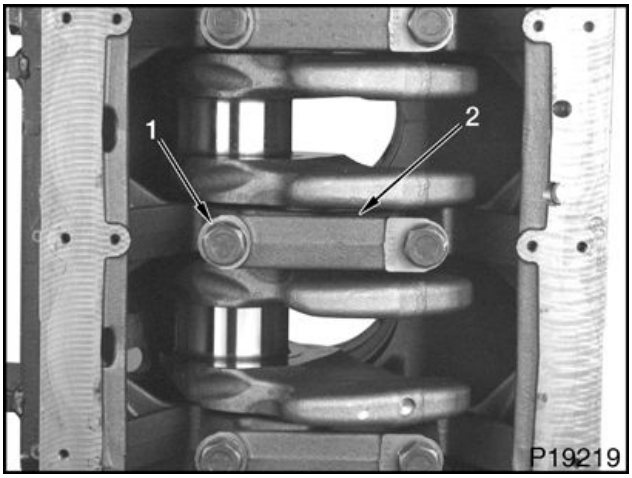

Figure 720 Main bearing caps

1. Collar M18 x 160.5 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 M18 x 160.5 collar bolts.

10. Tighten collar bolts as follows:
    a. Tighten two collar bolts at No. 6 (thrust washer location) main bearing cap to 10 N·m (88 lb·in).
    b. Tighten remaining collar bolts to 10 N·m (88 lb·in).
    c. Rotate crankshaft to verify that crankshaft does not bind. Correct as required.
    d. Tighten two collar bolts at No. 6 (thrust washer location) main bearing cap to 100 N·m (74 lb·ft).
    e. Tighten remaining collar bolts to 100 N·m (74 lb·ft).
    f. Tighten two collar bolts at No. 6 (thrust washer location) main bearing cap to 300 N·m (221 lb·ft).
    g. Tighten remaining collar bolts to 300 N·m (221 lb·ft).
    h. Turn two collar bolts at No. 6 (thrust washer location) main bearing cap bolts an additional 90°.
    i. Turn remaining collar bolts an additional 90°.

Specifications

Crankshaft	
Main Bearing:	
Journal diameter	103.98 - 104.00 mm (4.0937 - 4.0945 in)
Installed bearing inside diameter	104.044 - 104.09 mm (4.0962 - 4.0980 in)
Uninstalled bearing outside diameter (free spread)	111.20 - 112.40 mm (4.3779 - 4.4252 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

Collar bolts (main bearing cap), M18 x 160.5	See tightening procedure and sequence (page 515)
Piston cooling jet bolts, M6 x 12	13 N·m (115 lb·in)

Special Service Tools

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.....521

Abbreviations and Acronyms

A or amp – Ampere
AAT – Ambient Air Temperature
ABDC – After Bottom Dead Center
ABS – Antilock Brake System
AC – Alternating Current
A/C – Air Conditioner
ACC – Air Conditioner Control
ACCEL – Accelerate
ACD – Air Conditioner Demand
ACM – Aftertreatment Control Module
ACT PWR GND – Actuator Power Ground
ACV – Air Control Valve
AF – Air to Fuel ratio
AFT – Aftertreatment
AFTFD – Aftertreatment Fuel Doser
AFTFDH – Aftertreatment Fuel Doser High
AFTFDL – Aftertreatment Fuel Doser Low
AFTFIT – Aftertreatment Fuel Inlet Temperature
AFTFIS – Aftertreatment Fuel Inlet Sensor
AFTFP – Aftertreatment Fuel Pressure
AFTFP1 – Aftertreatment Fuel Pressure 1
AFTFP2 – Aftertreatment Fuel Pressure 2
AFTFSH – Aftertreatment Fuel Shutoff High
AFTFSL – Aftertreatment Fuel Shutoff Low
AFTFSV – Aftertreatment Fuel Shutoff Valve
Amb – Ambient
amp or A – Ampere
AMS – Air Management System
API – American Petroleum Institute
APP – Accelerator Pedal Position
APP1 – Accelerator Pedal Position 1
APP2 – Accelerator Pedal Position 2
ASTM – American Society for Testing and Materials
ATA – American Trucking Association
ATAH – American Trucking Association Link High
ATAL – American Trucking Association Link Low
ATDC – After Top Dead Center
AWG – American Wire Gauge
B+ or VBAT – Battery Voltage
BARO – Barometric Absolute Pressure
BBDC – Before Bottom Dead Center
BDC – Bottom Dead Center
bhp – Brake Horsepower
BOO – Brake On / Off
BPP – Brake Pedal Position
BPS – Brake Pressure Switch
BTDC – Before Top Dead Center
BTU – British Thermal Unit
C – Celsius
CAC – Charge Air Cooler
CACOT – Charge Air Cooler Outlet Temperature
CAN – Controller Area Network
CAP – Cold Ambient Protection
CARB – California Air Resources Board
cc – Cubic centimeter
CCA – Cold Cranking Ampere
CCOSS – Crankcase Oil Separator Speed
cfm – Cubic feet per minute
cfs – Cubic feet per second
CFV – Coolant Flow Valve
CID – Cubic Inch Displacement
CKP – Crankshaft Position
CKPH – Crankshaft Position High
CKPL – Crankshaft Position Low
CKPO – Crankshaft Position Out
cm – Centimeter
CMP – Camshaft Position
CMPH – Camshaft Position High
CMPL – Camshaft Position Low
CMPO – Camshaft Position Out
CMV – Coolant Mixer Valve
CO – Carbon Monoxide
COO – Cruise On / Off switch
CPU – Central Processing Unit
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 Multi-meter
DOC – Diesel Oxidation Catalyst
DOCIT – Diesel Oxidation Catalyst Inlet Temperature
DOCOT – Diesel Oxidation Catalyst Outlet Temperature
DPF – Diesel Particulate Filter
DPFDP – Diesel Particulate Filter Differential Pressure
DPFIT – Diesel Particulate Filter Inlet Temperature
DPFOT – Diesel Particulate Filter Outlet Temperature
DSI – Down Stream Injection
DT – Diesel Turbocharged
DTC – Diagnostic Trouble Code
DTRM – Diesel Thermo Recirculation Module
EBP – Exhaust Back Pressure
EBPD – Exhaust Back Pressure Desired
EBPV – Exhaust Back Pressure Valve
ECB – Engine Compression Brake
ECB1 – Engine Compression Brake 1

ECB2 – Engine Compression Brake 2
ECBP – Engine Compression Brake Pressure
ECI – Engine Crank Inhibit
ECL – Engine Coolant Level
ECM – Engine Control Module
ECM GND – Engine Control Module Ground
ECM PWR – Engine Control Module Power
ECS – Engine Coolant System
ECSR – Engine Controlled Shutdown Request
ECT – Engine Coolant Temperature
ECT1 – Engine Coolant Temperature 1
ECT2 – Engine Coolant Temperature 2
EFAN – Engine Fan
EFC – Engine Fan Control
EFRC – Engine Family Rating Code
EFS – Engine Fan Speed
EFT – Engine Fuel Temperature
EG – Ethylene Glycol
EGC – Electronic Gauge Cluster
EGBP – Exhaust Gas Back Pressure
EGDP – Exhaust Gas Differential Pressure
EGR – Exhaust Gas Recirculation
EGRC – Exhaust Gas Recirculation Control
EGRH – Exhaust Gas Recirculation High control
EGRL – Exhaust Gas Recirculation Low control
EGROT – Exhaust Gas Recirculation Outlet Temperature
EGRP – Exhaust Gas Recirculation Position
EGRT – Exhaust Gas Recirculation Temperature
EGT – Exhaust Gas Temperature
EGT1 – Exhaust Gas Temperature 1
EGT2 – Exhaust Gas Temperature 2
EGT3 – Exhaust Gas Temperature 3
EMI – Electromagnetic Interference
EMP – Exhaust Manifold Pressure
EMT – Exhaust Manifold Temperature
EOL – Engine Oil Level
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
ETC – Engine Throttle Control
ETCH – Engine Throttle Control High
ETCL – Engine Throttle Control Low
ETP – Engine Throttle Position
ETV – Engine Throttle Valve
EWPS – Engine Warning Protection System
F – Fahrenheit
FCV – Fuel Coolant Valve
FDP – Fuel Delivery Pressure
FEL – Family Emissions Limit
fhp – Friction horsepower
FMI – Failure Mode Indicator
FPC – Fuel Pump Control
FPCV – Fuel Pressure Control Valve
fpm – Feet per minute
FPM – Fuel Pump Monitor
fps – Feet per second
FRP – Fuel Rail Pressure
ft – Feet
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 – Hydrocarbons
HEST – High Exhaust System Temperature
HFCM – Horizontal Fuel Conditioning Module
Hg – Mercury
hp – Horsepower
HPCAC – High-Pressure Charge Air Cooler
HPCR – High-Pressure Common Rail
HPFP – High-Pressure Fuel Pump
hr – Hour
HS – Humidity Sensor
Hyd – Hydraulic
IAH – Inlet Air Heater
IAHC – Inlet Air Heater Control
IAHD – Inlet Air Heater Diagnostic
IAHFI – Inlet Air Heater Fuel Igniter
IAHFS – Inlet Air Heater Fuel Solenoid
IAHR – Inlet Air Heater Relay
IAT – Inlet Air Temperature
IC – Integrated Circuit
ICP – Injection Control Pressure
ICPR – Injection Control Pressure Regulator
ICG1 – Injector Control Group 1
ICG2 – Injector Control Group 2
ID – Inside Diameter
IGN – Ignition
ILO – Injector Leak Off
IMP – Intake Manifold Pressure

IMT – Intake Manifold Temperature
in – Inch
inHg – Inch of mercury
inH_2O – Inch of water
INJs – Injectors
IPR – Injection Pressure Regulator
IPR PWR – Injection Pressure Regulator Power
ISC – Interstage Cooler
ISIS – International® Service Information System
IST – Idle Shutdown Timer
ITP – Internal Transfer Pump
J1939H – J1939 Data Link High
J1939L – J1939 Data Link Low
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
lb – Pounds of force
lb/s – Pounds per second
lb ft – Pounds of force per foot
lb in – Pounds of force per inch
lbm – Pounds of mass
LSD – Low Sulfur Diesel
m – Meter
m/s – Meters per second
MAF – Mass Air Flow
MAF GND – Mass Air Flow Ground
MAG – Magnetic
MAP – Manifold Absolute Pressure
MAT – Manifold Air Temperature
mep – Mean effective pressure
mi – Mile
MIL – Malfunction Indicator Lamp
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
O2S – Oxygen Sensor
O2SH – Oxygen Sensor Heater
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
P/N – Part Number
PDOC – Pre-Diesel Oxidation Catalyst
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 Takeoff
PWM – Pulse Width Modulate
PWR – Power (voltage)
qt – Quart
RAM – Random Access Memory
RAPP – Remote Accelerator Pedal Position
RAS – Resume / Accelerate Switch (speed control)
REPTO – Rear Engine Power Takeoff
RFI – Radio Frequency Interference
rev – Revolution
rpm – Revolutions per minute
RPRE – Remote Preset Power Take Off
RSE – Radiator Shutter Enable
RVAR – Remote Variable
SAE – Society of Automotive Engineers®
SCA – Supplemental Cooling Additive
SCCS – Speed Control Command Switches
S – CSFSpeed Control Switch
SHD – Shield (electrical)
SID – Subsystem Identifier
SIG GND – Signal Ground
SIG GNDB – Signal Ground Body
SIG GNDC – Signal Ground Chassis
SIG GNDE – Signal Ground Engine
S/N – Serial Number
SPEEDO – Speedometer

SPN – Suspect Parameter Number
SW – Switch (electrical)
SWBAT – Switch Battery
SYNC – Synchronization
TACH – Tachometer output signal
TBD – To Be Determined
TC2CIS – Turbocharger 2 Compressor Inlet Sensor
TC1TOP – Turbocharger 1 Turbine Outlet Pressure
TC2TOP – Turbocharger 2 Turbine Outlet Pressure
TC1WC – Turbocharger 1 Wastegate Control
TC2WC – Turbocharger 2 Wastegate Control
TCAPE – Truck Computer Analysis of Performance and Economy
TCM – Transmission Control Module
TDC – Top Dead Center
TDE – Transmission Driving Engaged
TOP – Transmission Oil Pressure
TOSS – Transmission Output Shaft Speed
TOT – Transmission Oil Temperature
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
VIGN – Ignition Voltage
VIN – Vehicle Identification Number
VOP – Valve Opening Pressure
VRE – Vehicle Retarder Enable
VREF – Reference Voltage
VREFB – Reference Voltage Body
VREFC – Reference Voltage Chassis
VREFE – Reference Voltage Engine
VSO – Vehicle Speed Output
VSS – Vehicle Speed Sensor
VSSH – Vehicle Speed Sensor High
VSSL – Vehicle Speed Sensor Low
WTSL – Wait to Start Lamp
WEL – Warn Engine Lamp
WIF – Water In Fuel
WIFL – Water In Fuel Lamp
WTEC – World Transmission Electronically Controlled automatic transmissions (Allison)
XCS – Transfercase
XMSN – Transmission

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Terms.....**527**

Terminology

Terms

Accelerator Pedal Position (APP) sensor – A potentiometer sensor that indicates the position of the throttle pedal.

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.

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.

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).

Aftertreatment Fuel Doser (AFTFD) – A part of the Downstream Injection (DSI) unit that sends pressurized fuel to the Hydrocarbon Injector (HCI) assembly to inject fuel into the exhaust pipe.

Aftertreatment (AFT) system – A part of the exhaust system that processes engine exhaust to meet emission requirements and traps particulate matter (soot) to prevent it from leaving the tailpipe.

Air Control Valve (ACV) – Contains the LP turbocharger wastegate control port, HP turbocharger wastegate control port, the EBPV control port, and the TC1TOP port. Although these components are integral to the ACV, each circuit is controlled by the ECM. The ACV controls compressed air for each control valve.

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 device in the ECM that converts an analog signal to a digital signal.

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 – ECM programming strategy to solve engine performance 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.

Camshaft Position (CMP) sensor – A magnetic pickup sensor that provides the ECM with a camshaft speed and position signal.

Carbon Monoxide (CO) – A colorless, odorless, highly poisonous gas that is formed by the incomplete combustion of carbon burning diesel engine. It is present in the exhaust gases of diesel engines.

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**.

Charge Air Outlet Temperature (CACOT) sensor – A thermistor sensor that monitors the temperature of charge air entering the intake air duct.

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 sensors to provide feedback to the ECM. The ECM uses the sensor input to continuously monitor variables and adjust actuators to match engine requirements.

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.

Inlet Air Heater Fuel Igniter (IAHFI) – The IAHFI heats the intake air by vaporizing and igniting fuel in the air inlet duct.

Inlet Air Heater Fuel Solenoid (IAHFS) – As the engine is cranked, the ECM energizes the IAHFS valve, introducing fuel into the IAHFI, which ignites and warms the air being drawn into the engine.

Inlet Air Heater Relay (IAHR) – The IAHR provides voltage to the IAHFI, and is controlled by the ECM.

Controller Area Network (CAN) – A J1939 high speed communication link.

Coolant – A fluid used to transport heat from one point to another.

Coolant level switch – A switch sensor used to monitor coolant level.

Coolant Flow Valve (CFV) – The CFV is ECM controlled and redirects coolant through the fuel cooler, based on EFT, when directed.

Coolant Mixer Valve (CMV) – Controls coolant flow through the low-temperature radiator.

Continuous Monitor Test – An ECM function that continuously monitors the inputs and outputs to ensure that readings are within set limits.

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 Oil Separator Speed (CCOSS) sensor – The CCOSS sensor sends the ECM information about the speed of the crankcase oil separator internal components.

Crankcase pressure – The force of air inside the crankcase against the crankcase housing.

Crankshaft Position (CKP) sensor – A magnetic pickup sensor that determines crankshaft position and speed.

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) – 2010 model year vehicles no longer utilize DTC identification by number. DTCs are now identified using the Suspect Parameter Number (SPN) and Failure Mode Indicator (FMI) identifiers only.

Diesel Particulate Filter (DPF) – A diesel particulate filter, sometimes called a DPF, is a device designed to remove diesel particulate matter or soot from the exhaust gas of a diesel engine.

Diesel Oxidation Catalyst (DOC) – A DOC is part of the diesel exhaust Aftertreatment system. DOCs are devices that use a chemical process to break down pollutants in the exhaust stream into less harmful components. More specifically, DOCs utilize rare metals such as palladium and platinum to reduce hydrocarbon based Soluble Organic Fraction (SOF) and carbon monoxide content of diesel exhaust by simple oxidation. The DOC can be used during an active regeneration to create higher exhaust temperatures, thereby reducing soot in the DPF.

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.

Downstream Injection (DSI) Unit – The DSI unit provides a metered amount of fuel to the Hydrocarbon Injector (HCI) assembly.

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.

Dual Stage Turbocharger – An assembly of two turbochargers (low-pressure and high-pressure) in series to provide a wide range of charge air pressures efficiently.

Duty cycle – A control signal that has a controlled on/off time measurement from 0 to 100%. Normally used to control solenoids.

EGR Cooler – A cooler that allows heat to dissipate from the exhaust gasses before they enter the intake manifold.

Engine Control Module (ECM) – An electronic processor that monitors and controls the engine.

Engine Back Pressure Valve (EBPV) – The ECM commands the EBPV to control the Exhaust Brake.

Engine Compression Brake (ECB) valve – The ECB valve controls pressure entering the brake oil gallery from the high-pressure oil rail gallery. This activates the brake actuator pistons and opens the exhaust valves.

Engine Compression Brake 1 (ECB1) solenoid – The ECB1 solenoid controls pressure entering the brake oil gallery from the high-pressure oil rail gallery.

Engine Compression Brake 2 (ECB2) solenoid – The ECB2 solenoid controls pressure entering the brake oil gallery from the high-pressure oil rail gallery.

Engine Compression Brake Pressure (ECBP) sensor – A high-pressure sensor that provides a feedback signal to the ECM indicating brake control pressure.

Engine Coolant Level (ECL) sensor – A switch sensor that monitors coolant level.

Engine Coolant Temperature 1 (ECT1) sensor – A thermistor sensor that detects engine coolant temperature.

Engine Coolant Temperature 2 (ECT2) sensor – A thermistor sensor that detects engine coolant temperature.

Engine Fuel Temperature (EFT) sensor – A thermistor sensor that measures fuel temperature.

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 Oil Pressure (EOP) sensor – A variable capacitance sensor that measures oil pressure.

Engine Oil Temperature (EOT) sensor – A thermistor sensor that measures oil temperature.

Engine rating – Engine rating includes **Rated hp** and **Rated rpm**.

Engine RUNNING tests – Tests done with the engine running.

Engine Throttle Valve (ETV) and Engine Throttle Position Sensor – The ETV valve is used to control airflow during a regeneration process of the aftertreatment system. The ETV valve is also used to ensure a smooth engine shut down by restricting airflow to the engine at shut down.

Engine Warning Protection System (EWPS) – Safeguards the engine from undesirable operating conditions to prevent engine damage and to prolong engine life.

Exhaust Back Pressure (EBP) – The pressure present in the exhaust system during the exhaust period.

Exhaust Back Pressure Valve (EBPV) – A valve that regulates the amount of air pressure applied to the EBPV pneumatic actuator.

Exhaust brake – A brake device using engine exhaust back pressure as a retarding medium.

Exhaust Gas Recirculation (EGR) – A system used to recirculate a portion of the exhaust gases into the power cylinder in order to reduce oxides of nitrogen.

Exhaust Gas Temperature (EGT) – The temperature of exhaust gases.

Exhaust Gas Recirculation Temperature (EGRT) sensor – A thermistor sensor that detects the exhaust gas temperature entering the EGR cooler.

Exhaust Gas Recirculation (EGR) valve – The EGRV controls the flow of exhaust gases to the intake manifold. The EGRV is integrated with an EGR Position (EGRP) sensor.

Exhaust manifold – Exhaust gases flow through the exhaust manifold to the turbocharger exhaust inlet and are directed to the EGR cooler.

Exhaust Manifold Pressure (EMP) sensor – A variable capacitance sensor used to indicate air pressure in the exhaust manifold.

Exhaust Manifold Temperature (EMT) sensor – A thermistor style sensor used to indicate air temperature in the exhaust manifold.

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.

Failure Mode Indicator (FMI) – Identifies the fault or condition effecting the individual component.

Filter restriction – A blockage, usually from contaminants, that prevents the flow of fluid through a filter.

Flash code – See **Diagnostic Trouble Code (DTC)**.

Fuel Delivery Pressure (FDP) sensor – A variable capacitance sensor that monitors fuel pressure coming from the fuel tank and sends a signal to the ECM.

Fuel inlet restriction – A blockage, usually from contaminants, that prevents the flow of fluid through the fuel inlet line.

Fuel pressure – The force fuel exerts on the fuel system as it is pumped through the fuel system.

Fuel Pressure Control Valve (FPCV) – The FPCV controls the fuel pressure to the fuel rails and is controlled by the ECM. FPCV control depends on fuel pressure and fuel temperature.

Fuel Rail Pressure (FRP) – The amount of pressure in the fuel rail.

Fuel Rail Pressure (FRP) sensor – A variable capacitance sensor that monitors fuel pressure in the fuel rail and sends a signal to the ECM.

Fuel strainer – A pre-filter in the fuel system that keeps larger contaminants from entering the fuel system.

Fuel Volume Control Valve (FVCV) – The FVCV regulates the volume of flow sent to the HPFP. The FVCV allows a sufficient quantity of fuel to be delivered to the HPFP depending on engine load, speed, injector quantity, fuel temperature, and number of injections per cycle.

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.

H-Bridge Circuit – An H-Bridge (bipolar) circuit operates like putting a power source on one side of a motor and connecting the other side of the motor to a ground. This turns the motor. By shifting the leads on the motor, it will turn in the opposite direction.

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 – Transducer that varies its output voltage in response to changes in a magnetic field. Commonly used to time the speed of wheels and shafts.

High-Pressure Fuel Pump (HPFP) assembly – The HPFP is a volumetric pump that supplies fuel at high-pressure. The HPFP is mounted in the rear valley on the top of the engine and is driven by the camshaft.

High-pressure Piezo Common Rail (HPCR) – The HPFP pumps fuel through separate tubes to each fuel rail. Each fuel rail has four fuel tubes, one for each injector, that maintain constant pressure from the high-pressure pump to each injector.

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.

Humidity Sensor (HS) – A sensor that measures the moisture content of filtered air entering the intake system.

Hydrocarbons – Organic compounds consisting of hydrogen and carbon (fuel and oil).

Hydrocarbon InjectorAssembly – Injects fuel into the exhaust system to increase temperature of the exhaust gases.

Injection Pressure Regulator (IPR) valve – A valve that is used to maintain desired injection control pressure.

Injection Control Pressure (ICP) sensor – Provides a feedback signal to the ECM indicating injection control pressure.

Inlet Air Heater (IAH) – The IAH is primarily used to assist in starting the engine during cold weather. In addition, it helps to reduce white smoke emissions by heating the incoming air.

Inlet Air Temperature (IAT) sensor – A thermistor sensor that monitors intake air temperature.

Intake manifold – Engine component that evenly supplies air to each intake port in the cylinder head(s).

Intake Manifold Pressure (IMP) sensor – A variable capacitance sensor used to indicate air pressure in the intake manifold.

Intake Manifold Temperature (IMT) sensor – A thermistor sensor used to indicate air temperature in the intake manifold.

Internal Transfer Pump (ITP) – The ITP is part of the HPFP assembly and driven off the same shaft as the HPFP assembly. The ITP supplies fuel at a slightly higher pressure and flow to the HPFP though the Fuel Volume Control Valve (FVCV). The ITP also provides fuel for cooling and lubrication of the HPFP. Fuel is rerouted as pump return flow through the HPFP cooling and lubrication valve. Pressure is maintained at the inlet of the HPFP piston pump by an ITP regulator.

International NGV Tool Utilized for Next Generation Electronics (INTUNE) – The diagnostics software for chassis related components and systems.

Interstage Cooler (ISC) – Uses cooled coolant to lower the charged air temperature that exits from the turbocharger low-pressure compressor and enters the turbocharger high-pressure compressor.

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).

Low temperature radiator thermostat – Coolant flow to the low temperature radiator is regulated by the low temperature radiator thermostat.

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 run at an overly low RPM for the load being applied.

Manifold Absolute Pressure (MAP) – Boost pressure in the manifold that is a result of the turbocharger.

Manifold Absolute Pressure (MAP) sensor – A variable capacitance sensor that measures boost pressure.

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.

Mass Air Flow – The intake airflow in an engine.

Mass Air Flow (MAF) sensor – The MAF sensor is used for closed loop control of the EGR valve and ITV. The ECM monitors the MAF signal so that the ECM can control the EGR and intake throttle systems.

MasterDiagnostics® (MD) – Diagnostics software for engine related components and systems.

Magnehelic Gauge – A gauge that measures pressure in inches of water.

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

Microprocessor – An integrated circuit in a microcomputer that controls information flow.

Micro Strain Gauge (MSG) Sensor – A MSG sensor measures pressure. Pressure 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.

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 electrical 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 the technician initiates using the EST that is run from a program in the software.

Output Circuit Check (OCC) – An on-demand test done during an Engine OFF self-test to check the continuity of selected actuators.

Oxides of Nitrogen (NOx) – Nitrogen oxides formed by a reaction between nitrogen and oxygen at high temperatures.

Oxygen Sensor (O2S) – A sensor that monitors oxygen levels in the exhaust.

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 (force x distance) is done during a specific time. 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 Modulation (PWM) – Succession of digital electrical pulses, rather than an analog signal. Efficient method of providing power between fully on and fully off.

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.

Return Fuel System – The return fuel system moves unused fuel from the fuel injectors to the fuel cooler. Excess fuel out of the FVCV and the FPCV mix with fuel from the fuel injectors on the way to the fuel cooler.

ServiceMaxx™ software – Diagnostics software for engine related components and systems.

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

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 – The movement of the piston from Top Dead Center (TDC) to Bottom Dead Center (BDC).

Substrate – Material that supports the wash coating or catalytic materials.

Suspect Parameter Number (SPN) – A 19-bit number used to identify the item for which diagnostics are being reported. The SPN is used for multiple purposes, some that are specific to diagnostics are as follows;

- Identify the least repairable subsystem that has failed.
- Identify subsystems or assemblies that may not have hard failures but may be exhibiting abnormal operating performance.
- Identify a particular event or condition that will be reported.
- Report a component and non-standard failure mode.

System restriction (air) – The static pressure differential that occurs at a given airflow 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.

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 to form a voltage signal matched with a temperature value.

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.

Truck Computer Analysis of Performance and Economy (TCAPE) – A computer program that simulates the performance and fuel economy of trucks.

Turbocharger – A turbine driven compressor mounted on the exhaust manifold. The turbocharger increases the pressure, temperature and density of intake air to charge air.

Turbocharger 1 Turbine Outlet Pressure (TC1TOP) sensor – A variable capacitance sensor that monitors exhaust back-pressure.

Turbocharger 2 Compressor Inlet (TC2CIS) sensor – The TC2CIS sensor includes a thermistor sensor that monitors the temperature of charge air entering the HP turbocharger. This sensor also monitors boost pressure for the LP turbocharger.

Turbocharger Wastegate Control (TCWC) solenoid – Controls the TCWC actuator by regulating the amount of charge air pressure supplied to the TCWC actuator. The TCWC solenoid is controlled by signals from the ECM in response to engine speed, required fuel quantity, boost, exhaust back-pressure, and altitude.

Turbocharger 1 Wastegate Control (TC1WC) solenoid – Controls the TC1WC actuator by regulating the amount of charge air pressure supplied to the TC1WC actuator. The TC1WC solenoid is controlled by signals from the ECM in response to engine speed, required fuel quantity, boost, exhaust back-pressure, and altitude. The TC1WC actuator is part of the turbocharger assembly.

Turbocharger 2 Wastegate Control (TC2WC) solenoid – Controls the TC2WC actuator by regulating the amount of charge air pressure supplied to the wastegate actuator. The TC2WC solenoid is controlled by signals from the ECM in response to engine speed, required fuel quantity, boost, exhaust back-pressure, and altitude. The TC2WC actuator is part of the turbocharger assembly.

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.

Water In Fuel (WIF) sensor – A switch sensor that measures the amount of water in the fuel.

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Fuel System

Table 2 Fuel System

Fuel strainer filtration	300 microns
Fuel filter element filtration	3-5 microns

Air Inlet Duct and Exhaust Manifolds

Table 3 Exhaust Manifolds

Exhaust manifold maximum allowable warpage	0.1 mm (0.003 in)

Engine Brake

Table 4 Engine Brake

Solenoid resistance:			
		Cold –	0.1 mm (0.003 in)
Cold — 25˚ C (77˚ F)	8.7–10 ohms		
Hot — 121˚ C (250˚ F)	12–15.5 ohms		

Cylinder Head, Camshaft and Valve Train

Table 5 Cylinder Head, Camshaft and Valve Train

Camshaft	
Camshaft bearing inside diameter	39.925 – 39.950 mm (1.57185 – 1.57283 in)
Camshaft end play	0.25 – 0.85 mm (0.0098 – 0.0334 in)
Valve Lash Adjustment	
Exhaust valve clearance	0.8 mm (0.0315 in)
Intake valve clearance	0.5 mm (0.0197 in)
Cylinder Head Idler Gear Cup Plug	
Cup plug, DMR 63.10	Recess 2.3 mm (0.9 in)

Flywheel and Flywheel Housing

Table 6 Flywheel and Flywheel Housing

Flywheel minimum thickness (dimension “A”)	46 mm (1.811 in)
Flywheel maximum surface runout	0.20 mm (0.0079 in)

Oil Pump, Low Mount Fan Drive, and Timing Gears

Table 7 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 8 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 — Navistar® N13	
Skirt diameter measured 26.9 mm from piston bottom edge, 90° to piston pin axis in “window” on skirt graphite layer, where applicable	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, measured horizontally 26 mm from piston center	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 — Navistar® N13	
Top compression ring	
Ring gap	0.4 - 0.55 mm (0.0157 - 0.0217 in)
Taper face compression ring	
Ring gap	1.00 - 1.20 mm (0.0393 - 0.0472 in)

Table 8 Power Cylinders (cont.)

Side clearance	0.09 - 0.13 mm (0.0035 - 0.0051 in)
Bevelled oil ring	
Ring gap	0.25 - 0.50 mm (0.0098 - 0.0197 in)
Side clearance	0.03 - 0.07 mm (0.0012 - 0.0028 in)
Piston Rings — Navistar® N13	
Top compression ring	
Ring gap	0.4 - 0.55 mm (0.0157 - 0.0217 in)
Taper face compression ring	
Ring gap	1.00 - 1.20 mm (0.0394 - 0.0472 in)
Side clearance	0.09 - 0.13 mm (0.0035 - 0.0051 in)
Bevelled oil 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)
Cylinder sleeve dimensions — Navistar® N13	
Sleeve protrusion	0.050 - 0.085 mm (0.0019 - 0.0033 in)
Sleeve inside diameter (bore)	126 ± 0.01 mm (4.9606 ± 0.0004 in)

Crankcase and Crankshaft

Table 9 Crankcase and Crankshaft

Crankshaft	
Main Bearing:	
Journal diameter	103.98 - 104.00 mm (4.0937 - 4.0945 in)
Installed bearing inside diameter	104.044 - 104.09 mm (4.0962 - 4.0980 in)
Uninstalled bearing outside diameter (free spread)	111.20 - 112.40 mm (4.3779 - 4.4252 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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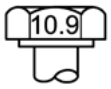
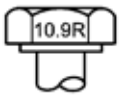
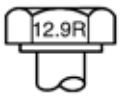
General Torque

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 721 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 722 Special fasteners – Classification and identification

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.

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 lb·in)
8	1.25	31 N·m (23 lb·ft)
10	1.5	62 N·m (45 lb·ft)
12	1.75	107 N·m (79 lb·ft)
14	2	172 N·m (127 lb·ft)
15	2	216 N·m (159 lb·ft)
16	2	266 N·m (196 lb·ft)
18	2.5	368 N·m (272 lb·ft)
20	2.5	520 N·m (384 lb·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 lb·in).

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.

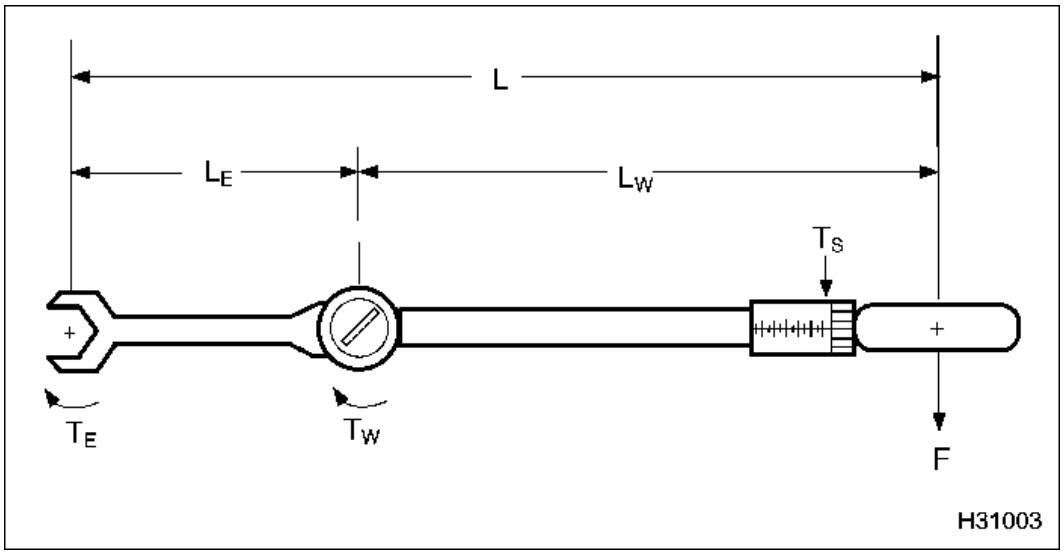


Figure 723 Torque wrench and extension

- 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 lb·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 lb·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 lb·ft (12 inches / (12 inches + 6 inches)

T_S = 65 lb·ft (12 inches / (18 inches)

T_S = 65 lb·ft (0.666)

T_S = 43.33 lb·ft

Special Torques

Mounting Engine on Stand

Table 10 Mounting Engine on Stand

M14 x 50 engine front mount support bolts	225 N·m (166 lb·ft)
Oil drain plug	75 N·m (55 lb·ft)

Engine Electrical

Table 11 Engine Electrical

Camshaft Position (CMP) sensor, M6 x 12 bolt	8 N·m (71 lb·in)
Charger Air Cooler Outlet Temperature (CACOT) sensor	11 N·m (97 lb·in)
Crankcase Oil Separator Speed (CCOSS) sensor, M6 x 14 bolt	10 N·m (89 lb·in)
Crankshaft Position (CKP) sensor, M6 x 16 bolt	8 N·m (71 lb·in)
Engine Control Module (ECM), M6 x 30 bolt	10 N·m (89 lb·in) See procedure for tightening sequence
Engine Control Module (ECM) support, M8 x 40 bolt	13 N·m (115 lb·in)
Engine Coolant Temperature 1 (ECT1) sensor	45 N·m (33 lb·ft)
Engine Coolant Temperature 2 (ECT2) sensor	45 N·m (33 lb·ft)
Engine injector harness retainer clip, M6 x 30 bolt	10 N·m (89 lb·in)
Engine Oil Pressure (EOP) sensor	45 N·m (33 lb·ft)
Engine Oil Temperature (EOT) sensor	45 N·m (33 lb·ft)
Engine sensor harness bracket/clip, M8 x 16 bolt	35 N·m (26 lb·ft)
Exhaust Gas Recirculation Temperature (EGRT) sensor	37 N·m (27 lb·ft)
Fuel Delivery Pressure (FDP) sensor	45 N·m (33 lb·ft)
Humidity / Inlet Air Temperature (IAT) sensor, M6 x 16 bolt	9 N·m (80 lb·in)
Intake Manifold Temperature (IMT) sensor	45 N·m (33 lb·ft)
Intake Manifold Pressure (IMP) sensor	12 N·m (106 lb·in)
Mass Air Flow (MAF) sensor, M4 x 0.7 cap screw	0.36 N·m (3 lb·in)
Oxygen Sensor (O2S)	50 N·m (37 lb·ft)
Fuel Rail Pressure (FRP) sensor	70 N·m (52 lb·ft)
Turbocharger 2 Compressor Inlet Sensor (TC2CIS), M6 x 16 bolt	9 N·m (80 lb·in)

Inlet Air Heater

Table 12 Inlet Air Heater

Banjo 6 (M10 x 1) and 8 (M12 x 1.5) bolts	15 N·m (11 lb·ft)
Banjo M8 x 1 bolt	8 N·m (71 lb·in)
Fuel supply inlet air heater hose fitting nut	10 N·m (11 lb·ft)
Glow plug locking nut	25 N·m (18 lb·ft)
Relay assembly M6 x 20 bolts	10 N·m (89 lb·in)
Solenoid valve M6 x 20 bolts	6 N·m (53 lb·in)

Aftertreatment System

Table 13 Aftertreatment System

Coolant supply (straight) fitting at coolant manifold	35 N·m (26 lb·ft)
Fitting (quick-connect adapter) at DSI unit	35 N·m (26 lb·ft)
Fitting (straight union orifice) at DSI unit	35 N·m (26 lb·ft)
HCI coolant supply and return tube nut at tube M10 elbow fittings	15 N·m (11 lb·ft)
HCI coolant supply tube nut at coolant manifold	25 N·m (18 lb·ft)
HCI fuel 1 tube assembly nut at HCI fuel 2 tube fitting (brazed)	25 N·m (18 lb·ft)
HCI fuel 1 tube assembly nut at DSI unit	25 N·m (18 lb·ft)
HCI fuel 2 tube assembly nut at hydrocarbon injector assembly	18 N·m (13 lb·ft)
Hydrocarbon injector assembly M8 x 45 bolt	See tightening steps in procedure.
Hydrocarbon injector assembly body to assembly (if accidentally loosened during fuel tube nut service)	20 N·m (15 lb·ft)
Metering unit bracket bolt, M8 x 16	31 N·m (23 lb·ft)
PDOC V-band clamp	7 N·m (62 lb·in)
PDOC M10 x 50 bolts	36 N·m (27 lb·ft)
Tube M10 elbow fittings at hydrocarbon injector assembly	17.5 N·m (13 lb·ft)

Exhaust Back Pressure Control

Table 14 Exhaust Back Pressure Control

Air supply tube (at bulkhead fitting)	17.5 N·m (13 lb·ft)
Air supply tube nut (at air control valve)	12 N·m (106 lb·in)
Exhaust back pressure valve tube nut (at actuator)	15 N·m (11 lb·ft)
Exhaust back pressure valve tube nut (at air control valve)	15 N·m (11 lb·ft)
Flare M10 x M12 (24 degree) fitting	17.5 N·m (13 lb·ft)
TC1TOP sensor tube nut (at air control valve)	15 N·m (11 lb·ft)
TC1TOP sensor tube nut at flare M10 x M12 (24 degree) fitting	15 N·m (11 lb·ft)

Turbochargers

Table 15 Turbochargers

3/4 inch and 1 inch worm gear hose clamps	3.5 N·m (31 lb·in)
High-pressure-to-low-pressure turbine bolts, M10 x 55	47 N·m (35 lb·ft)
High-pressure wastegate actuator bolts, M8 x 14	16 N·m (12 lb·ft)
Male stud connector	70 N·m (52 lb·ft)
M24 threaded fitting	60 N·m (44 lb·ft)
Oil return low-pressure turbocharger tube (at crankcase)	See tightening steps in procedure.
Oil return low-pressure turbocharger tube fitting nut	See tightening steps in procedure.
Turbocharger oil supply tube assembly fitting nut to male stud connector	27 N·m (20 lb·ft)

Air Compressor and Power Steering/Fuel Pump

Table 16 Air Compressor and Power Steering/Fuel Pump

1-1/16" 90 degree elbow lock nut	55 N·m (40 lb·ft)
1/2" 90 degree tube elbow lock nut	45 N·m (33 lb·ft)
Air compressor M8 x 40, M8 x 110 bolt (one cylinder)	35 N·m (26 lb·ft)
Air compressor M8 x 40, M8 x 110 bolt (two cylinder)	31 N·m (23 lb·ft)
(Two cylinder) Air compressor M10 x 110 bolt	67 N·m (49 lb·ft)
High-pressure tube fitting nut	62 N·m (45 lb·ft)
M16 straight fitting	35 N·m (26 lb·ft)
M16 45° fitting	17.5 N·m (13 lb·ft)
M18 straight fitting	37.5 N·m (28 lb·ft)
Low-pressure tube fitting nut	164 N·m (120 lb·ft)
Power steering pump M10 x 40 bolt	67 N·m (49 lb·ft)

Fuel System

Table 17 Fuel System

Banjo bolt, M14	30 N·m (22 lb·ft)
Check valve	35 N·m (26 lb·ft)
Forcing screw adapter plate M10 x 40 bolts	27 N·m (20 lb·ft)
Fuel drain line fitting nut	26 N·m (19 lb·ft)
Fuel filter bracket M8 x 30 bolt	35 N·m (26 lb·ft)
Fuel filter housing assembly M8 x 45 bolt	35 N·m (26 lb·ft)
Fuel filter cap	25 N·m (18 lb·ft)
Fuel filter stand pipe	12 N·m (106 lb·in)
Fuel primer pump assembly M8 x 25 bolt	30 N·m (22 lb·ft)
Fuel rail M8 x 40 bolt	35 N·m (26 lb·ft)
Fuel strainer cover	10 N·m (89 lb·in)
Fuel supply adapter	30 N·m (22 lb·ft)
Fuel to rail supply clamp assembly screws	5 N·m (44 lb·in)
High-pressure connector (body) retaining nut	See tightening steps in procedure
Drive housing M12 x 40, M12 x 90, M12 x 130 bolt	105 N·m (77 lb·ft)
High-pressure fuel pump M10 x 40 bolt	62 N·m (46 lb·ft)
High-pressure fuel pump M24 jam nut	285 N·m (210 lb·ft)
High-pressure fuel pump support M14 x 30 bolt	172 N·m (126 lb·ft)
High-pressure pump to rail tube assembly line fitting nuts	See tightening steps in procedure
High-pressure rail to injector line fitting nut	See tightening steps in procedure
High-pressure pump pulley housing M10 x 40 bolt	62 N·m (46 lb·ft)
High-pressure pump pulley M16 x 40 LH bolt	280 N·m (207 lb·ft)
Holding plate M12 bolts	47 N·m (35 lb·ft)
Injector harness nut	1.8 N·m (16 lb·in)
Injector hold-down clamp M8 x 50 bolt	See tightening steps in procedure
Pressure limiting valve	110 N·m (81 lb·ft)
Quick-connect M16 x 1.5 connector	30 N·m (22 lb·ft)
Threaded unions (M14 x 1.5)	30 N·m (22 lb·ft)

Oil Module Assembly

Table 18 Oil Module Assembly

Heater return tube assembly bolt, M6 x 16	13 N·m (115 lb·in)
Heater return tube assembly tube nut	11 N·m (97 lb·in)
Oil cooler bolts, M8 x 45 and M8 x 90	25 N·m (18 lb·ft)
Oil filter cover	40 N·m (30 lb·ft)
Oil module assembly bolts, M10 x 80, M10 x 170 and M10 x 110	65 N·m (48 lb·ft)
Oil module flange bolts, M8 x 45	24 N·m (18 lb·ft)
Oil pressure relief valve	40 N·m (30 lb·ft)
Open breather tube assembly bolt, M6 x 16	13 N·m (115 lb·in)
Water pump bolt, M8 x 150 (front side of oil module)	35 N·m (26 lb·ft)

Exhaust Gas Recirculation (EGR) System

Table 19 EGR System

Coolant manifold, M8 x 18 bolt	22 N·m (16 lb·ft)
Coolant manifold, M8 x 25 heat–resistant bolt	24 N·m (18 lb·ft)
Coolant manifold, M8 x 45 bolt and M8 x 50 x 16 stud bolt	35 N·m (26 lb·ft)
EGR dual flap valve, M8 x 30 heat-resistant bolt	See tightening steps in procedure.
EGR inlet (cylinders 1-3) tube, M8 x 25 heat-resistant bolt	See tightening steps in procedure.
EGR inlet (cylinders 4-6) tube, M8 x 25 heat-resistant bolt	See tightening steps in procedure.
EGR module cover, M8 x 85 bolts and M8 x 90 stud bolt	24 N·m (18 lb·ft)
EGR outlet tube hose clamps	5 N·m (45 lb·in)
EGR valve coolant supply tube nut	26 N·m (19 lb·ft)
Front EGR cooler cleaning adapter M8 bolts	24 N·m (18 lb·ft)
Heat protection (cylinders 4–6) shield, M8 x 25 heat–resistant bolts	24 N·m (18 lb·ft)
HT EGR cooler mounting studs 7/16 - 14 nuts	41 N·m (30 lb·ft)
Leak Detection Plate KL20060-4 M8 x 30 bolts	24 N·m (18 lb·ft)
Low-temperature and high-temperature EGR coolers, M8 x 55 hex socket screws	See tightening steps in procedure.
LT EGR cooler mounting studs 3/8 - 14 nuts	41 N·m (30 lb·ft)
Rear EGR cooler cleaning adapter M8 bolts	24 N·m (18 lb·ft)

Air Inlet Duct and Exhaust Manifolds

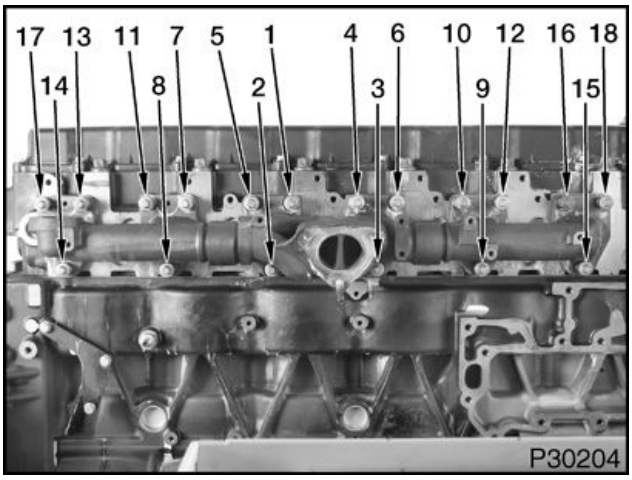


Figure 724 Exhaust manifold tightening sequence

Table 20 Air Intake Throttle Duct and Exhaust Manifolds

Air intake throttle duct bolts, M8	31 N·m (23 lb·ft)
Exhaust manifold Torx® bolts, M10 x 57	See tightening procedure and sequence in steps

Front Cover, High Mount Fan Drive, Cooling System, Related Components

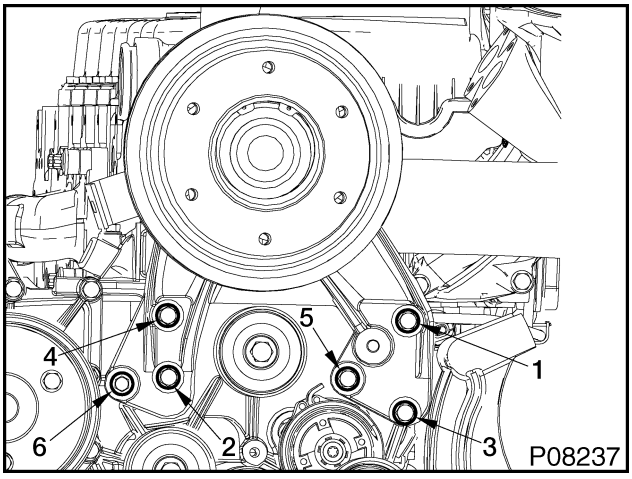


Figure 725 High mount fan drive bolt tightening sequence

Table 21 Front Cover, Fan Drive, Cooling System and Related Components

Automatic belt tensioner countersunk screw, M10 x 70	47 N·m (35 lb·ft)
CCV assembly stud bolts (with lock washers), M8 x 60	35 N·m (26 lb·ft)
Coolant heater	41 N·m (30 lb·ft)
Coolant outlet manifold bolts, M8	35 N·m (26 lb·ft)
Damper hub and fan drive pulley bolts to vibration damper, M10 x 35	45 N·m (33 lb·ft)
EGR cooler return manifold bolts, M8	35 N·m (26 lb·ft)
Engine water inlet bolts, M10 x 30	29 N·m (21 lb·ft)
Front belt- or gear-driven fan cover bolts,	
• M8	31 N·m (23 lb·ft)
• M12 x 75	115 N·m (85 lb·ft)
• M12 x 30	115 N·m (85 lb·ft)
High mount fan drive clutch assembly bolts, M10	See tightening steps in procedure
High mount fan drive tensioner countersunk screw, M10 x 70	47 N·m (35 lb·ft)
High mount fan pulley assembly shoulder bolt	62 N·m (46 lb·ft)
Idler pulley bolt, M12 x 55	60 N·m (44 lb·ft)
Low mount fan drive bolt, M10 x 110	37 N·m (27 lb·ft)
Vibration damper socket-head cap screws, M16 x 85	See tightening steps in procedure
Water distribution housing bolts, M8	35 N·m (26 lb·ft)
Water pump assembly bolts, M8	35 N·m (26 lb·ft)
Water pump pulley bolts, M8 x 16	17 N·m (13 lb·ft)

Engine Brake

Table 22 Engine Brake

Brake housing M10 x 90 bolt	75 N·m (55 lb·ft)
Brake housing M12 x 100 (socket-head) screw	105 N·m (77 lb-ft)
Brake housing solenoid harness connector nut	3.5 N·m (31 lb·in)
Slave piston adjusting screw M10 (jam) nut	25 N·m (18 lb·ft)
Solenoid M6 x 10 socket-head cap screw	12.5 N·m (110 lb·in)

Cylinder Head, Camshaft and Valve Train

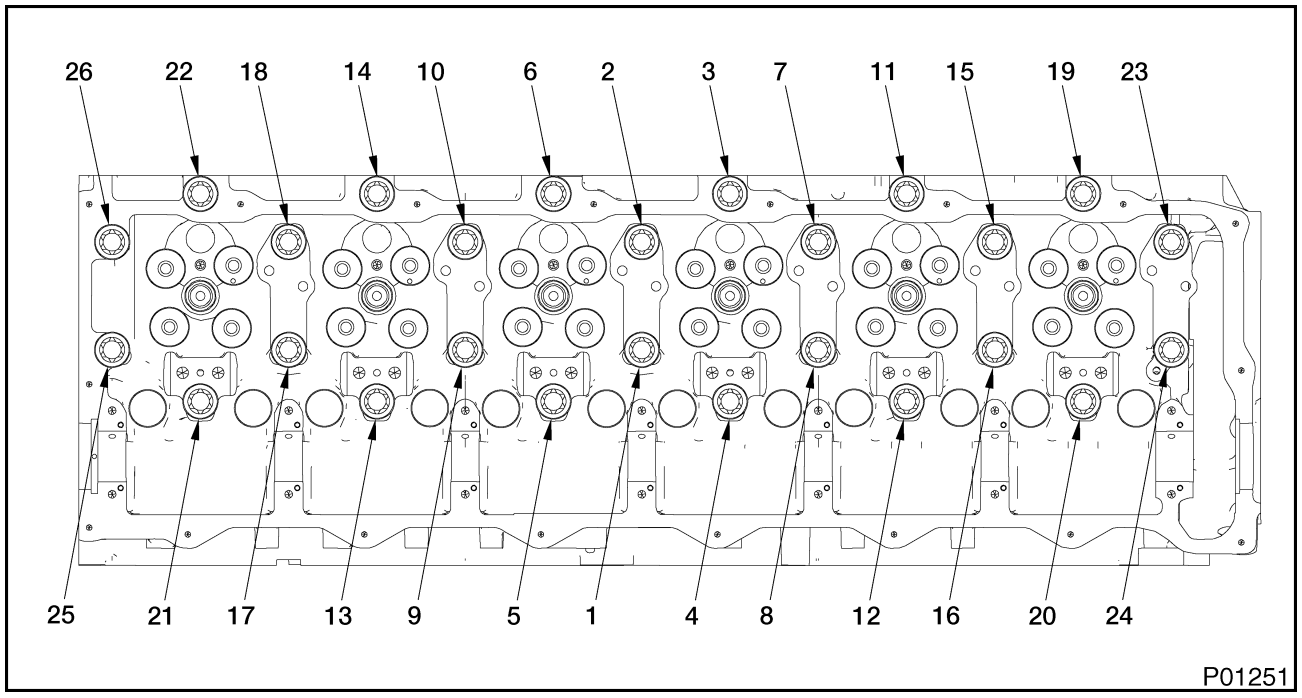


Figure 726 Cylinder Head Bolts Tightening Sequence

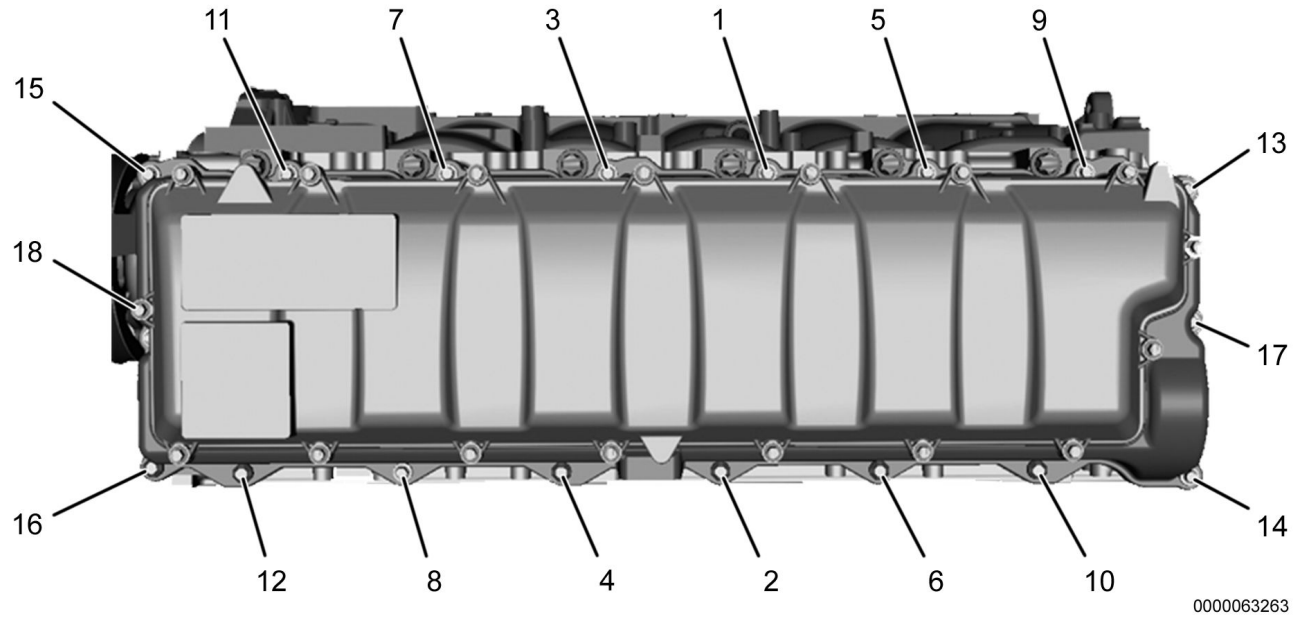


Figure 727 Valve Cover Base Tightening Sequence

Table 23 Cylinder Head, Camshaft and Valve Train

Camshaft gear M8 x 30 bolt	See tightening steps in procedure
(Camshaft) bearing cap M8 x 35 bolt	25 N·m (18 lb·ft)
Cylinder head idler gear M8 x 30 socket-head cap screw	30 N·m (22 lb·ft)
Cylinder head M18 x 246 Torx® bolt	See tightening steps in procedure
Rocker arm assembly M12 x 60 (socket-head) screw	105 N·m (77 lb·ft)
Upper valve cover M8 x 30 bolt	9 N·m (80 lb·in)
Valve cover base screw with damper	11 N·m (97 lb·in)
Valve lash adjustment M10 nut	45 N·m (33 lb·ft)

Flywheel and Flywheel Housing

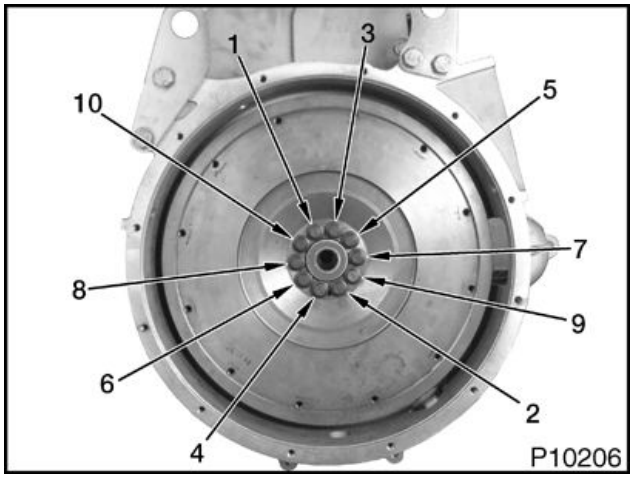


Figure 728 Flywheel bolt tightening sequence

Table 24 Flywheel and Flywheel Housing

12PT flange bolts	See tightening steps in procedure.
Flywheel housing bolts, M10 x 30 and M10 x 40	65 N·m (48 lb·ft)
Lifting eye bolts, M16 x 150	280 N·m (207 lb·ft)
Timing hole cover screws	2 N·m (18 lb·in)

Oil Pan and Oil Suction Tube

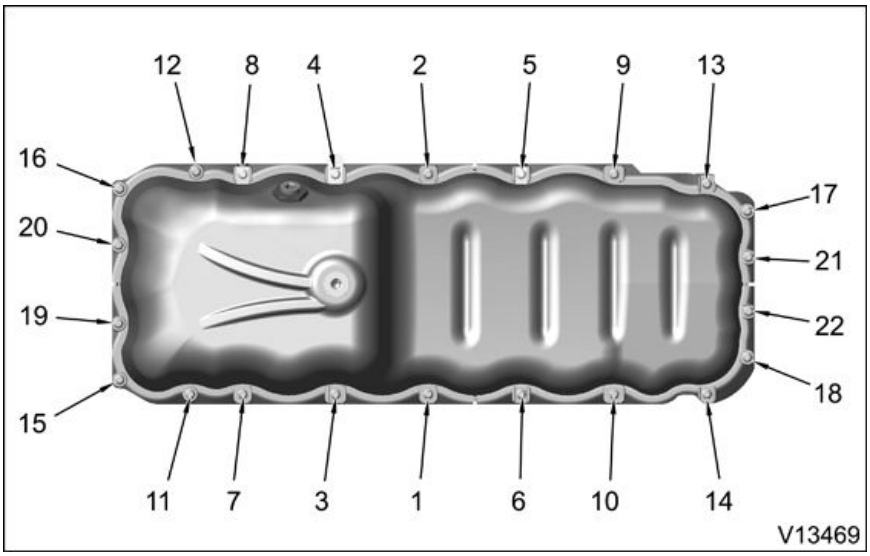


Figure 729 Torque sequence

Table 25 Oil Pan Components

Drain plug, M27 x 2	75 N·m (55 lb·ft)
Oil pan bolts, M8 x 40	See tightening steps in procedure.
Oil pan heater element or replacement drain plug	75 N·m (55 lb·ft)

Oil Pump and Timing Gears

Table 26 Oil Pump and Timing Gears

Air compressor coupled idler gear, M12 x 55 bolts	107 N·m (79 lb·ft)
Axle for pinion (oil pump), M10 x 35 socket-head cap screw	65 N·m (48 lb·ft)
Crankcase idler gear, M8 x 30 socket-head cap screws	30 N·m (22 lb·ft)
(Front) idler gear, M12 x 50 socket-head cap screws	105 N·m (77 lb·ft)
Idler large gear, M14 x 80 bolts	175 N·m (129 lb·ft)

Power Cylinders

Table 27 Power Cylinders

Connecting rod bolts	See tightening steps in procedure
Sleeve Protrusion Hold Down Clamp bolts	80 N·m (59 lb·ft)

Crankcase and Crankshaft

Table 28 Crankcase and Crankshaft

Collar bolts (main bearing cap), M18 x 160.5	See tightening procedure and sequence (page 515)
Piston cooling jet bolts, M6 x 12	13 N·m (115 lb·in)

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Special Tools

Contact Information

For concerns or ordering information regarding special tools for the Navistar® N13 engines, refer to the Service Resource Center on Service Portal, or call 1-800-365-0088.

Mounting Engine on Stand

Table 29 Mounting Engine on Stand

Description	Tool Number
Disposable Air and Fuel Caps	ZTSE4891
Engine Stand Adapter Plate	12-051-01

Engine Electrical

Table 30 Engine Electrical

Description	Tool Number
Disposable Air and Fuel Caps	ZTSE4891

Aftertreatment System

Table 31 Aftertreatment System

Description	Tool Number
Fuel Line Disconnect Tool 11.8 mm	ZTSE4773
P-80® rubber lubricant or equivalent	Obtain locally

Exhaust Back Pressure Control

Table 32 Exhaust Back Pressure Control

Description	Tool Number
Crimping pliers	Obtain locally
Superlub™ synthetic high heat lubricant	Obtain locally

Turbochargers

Table 33 Turbochargers

Description	Tool Number
3-inch couplers and clamps	Obtain locally
Charge Air Cooler Test Kit	ZTSE6042
Crimping pliers	Obtain locally
Extension Tube Installer	ZTSE6043
P-80® rubber lubricant or equivalent	Obtain locally
Turbo Alignment Bracket	ZTSE6041

Air Compressor and Power Steering

Table 34 Air Compressor and Power Steering

Description	Tool Number
Coolant Line Release Tool	ZTSE4778
Loctite® 5900 sealant or Wacker® A-442 RTV	Obtain locally
P80® rubber lubricant or equivalent	Obtain locally

Fuel System

Table 35 Fuel System

Description	Tool Number
Crowfoot wrench	Obtain locally
Disposable Air and Fuel Caps	ZTSE4891
Fan Hub/High Pressure Drive Seal Installer	ZTSE6066
Forcing Screw	12-454-01-05
Forcing Screw Adapter	12-454-01-04
Forcing Screw Adapter Holding Plate	12-454-01-01
Fuel Injector Cups	ZTSE4892
Fuel Injector Rack Holder	ZTSE4299B
Fuel Injector Tip Cleaning Brush	ZTSE4301
Fuel Line Disconnect Tool 11.8 mm	ZTSE4773
Fuel System Priming Tool	15-922-01
Guide Stud	12-454-01-02
High-Pressure Pump Removal Tool	12-454-01
Holding Plate	ZTSE6044
Injector Installer	ZTSE4777
Injector Puller	ZTSE4770
Injector Sleeve Brushes	ZTSE4751
P80® Rubber Lubricant or equivalent	Obtain locally
Socket Head Bolt	12-454-01-03
Wacker® A-442 RTV sealant or equivalent	Obtain locally
Slide hammer	Obtain locally

Oil Cooler, Filter Housing and Crankcase Ventilation

Table 36 Oil Cooler, Filter Housing and Crankcase Ventilation

Description	Tool Number
Air pressure regulator	Obtain locally
Extension Tube Installer Large	ZTSE6051-1
Extension Tube Installer Small	ZTSE6051-2
Engine Oil Cooler Pressure Test Plate	ZTSE6063
P-80® rubber lubricant or equivalent	Obtain locally

Exhaust Gas Recirculation (EGR) System

Table 37 EGR System

Description	Tool Number
Cleaning Management System	12-353-01
Coolant Management Tool	KL5007NAV
EGR Cooler Alignment Tool	12-892-01A
Exhaust Gas Recirculation (EGR) Cooler Leak Detection Tool	KL 20060 NAV
Extension Tube Installer Large	ZTSE6046
Extension Tube Installer Small	ZTSE6047
P-80® rubber lubricant or equivalent	Obtain locally

Air Inlet Throttle Duct and Exhaust Manifold

Table 38 Air Inlet Throttle Duct and Exhaust Manifold

Description	Tool Number
Feeler gauge	Obtain locally
FEY Rings Installation Tools	ZTSE6030
Straightedge	Obtain locally
Wacker® A-442 RTV sealant or equivalent	Obtain locally

Front Cover, Fan Drive, Cooling System and Related Components

Table 39 Front Cover, Fan Drive, Cooling System and Related Components

Description	Tool Number
Extension Tube Installer Large	ZTSE6046
Extension Tube Installer Small	ZTSE6047
Fan Seal Installer	ZTSE6066
Front Crankshaft Seal Installer	ZTSE4873
P-80® rubber lubricant or equivalent	Obtain locally
Slide hammer	Obtain locally

Navistar® N13 Engine Brake by Jacobs

Table 40 Navistar® N13 Engine Brake by Jacobs

Description	Tool Number
Jacobs® Slave Piston Removal Tool	ZTSE6068

Cylinder Head, Camshaft and Valve Train

Table 41 Cylinder Head, Camshaft and Valve Train

Description	Tool Number
1 - 2 inch micrometer	Obtain locally
Bearing installer	Obtain locally
Connecting Rod Bolt Torx® Socket	ZTSE4835
Cylinder Head Lifting Bracket	ZTSE4869
Dial indicator with magnetic base	Obtain locally
Feeler gauge (Jacobs® 96-020949)	Obtain from Jacobs
Head Bolt Bottoming Tap	ZTSE4855
Head Bolt Torx® Socket	ZTSE4787
Injector Sleeve Brushes	ZTSE4751
Lash Gauge 0.5 mm (0.020 in)	ZTSE6076-5A
Lash Gauge 0.8 mm (0.031 in)	ZTSE6076-7A
Loctite® 262™ Threadlocker	Obtain locally
Loctite® 5127 sealant	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 42 Flywheel and Flywheel Housing

Description	Tool Number
1-2 inch micrometer	Obtain locally
Blind hole puller	Obtain locally
Brake cleaner (non-caustic)	Obtain locally
Dial indicator with magnetic base	Obtain locally
Loctite 5900®	Obtain locally
Wacker® A–442 RTV sealant	Obtain locally
Pilot Bearing Installation Tool	ZTSE4898
Rear Oil Seal Installer	ZTSE4875
Slide hammer	Obtain locally

Oil Pump, Fan Drive and Timing Gears

Table 43 Oil Pump, Fan Drive and Timing Gears

Description	Tool Number
Dial indicator with magnetic base	Obtain locally
Feeler gauge	Obtain locally
Gear puller	Obtain locally

Power Cylinders

Table 44 Power Cylinders

Description	Tool Number
2 - 3 inch micrometer	Obtain locally
3 - 4 inch micrometer	Obtain locally
4 - 5 inch micrometer	Obtain locally
Cylinder Sleeve Puller	ZTSE2536
Dial bore gauge	Obtain locally
Dial indicator with magnetic base	Obtain locally
Exhaust Manifold Bolt Torx® Socket	ZTSE4843
Feeler gauge	Obtain locally
Piston ring compressor	Obtain locally
Piston ring expansion pliers	Obtain locally
Sleeve Protrusion Hold Down Clamps	ZTSE4825
Telescoping gauge	Obtain locally

Crankcase and Crankshaft

Table 45 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

Special Tools

Essential Tools

Figure 730 KL 20060 NAV EGR Cooler Pressure Test Kit

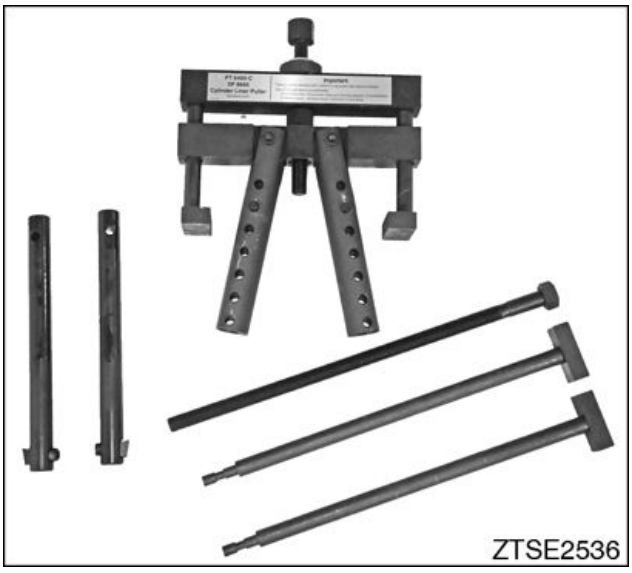

Figure 731 ZTSE2536 Cylinder Sleeve Puller

Figure 732 ZTSE4299B Fuel Injector Rack Holder

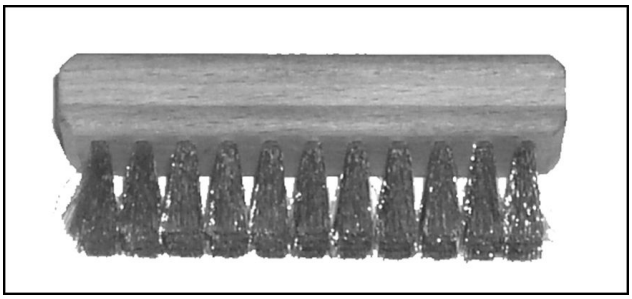

Figure 733 ZTSE4301 Fuel Injector Tip Cleaning Brush

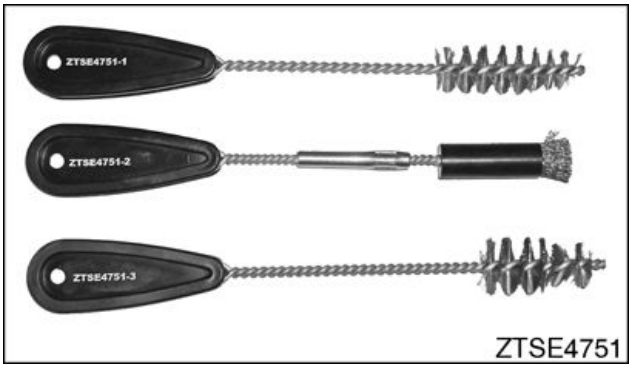

Figure 734 ZTSE4751 Injector Sleeve Brushes

Figure 735 ZTSE4770 injector puller

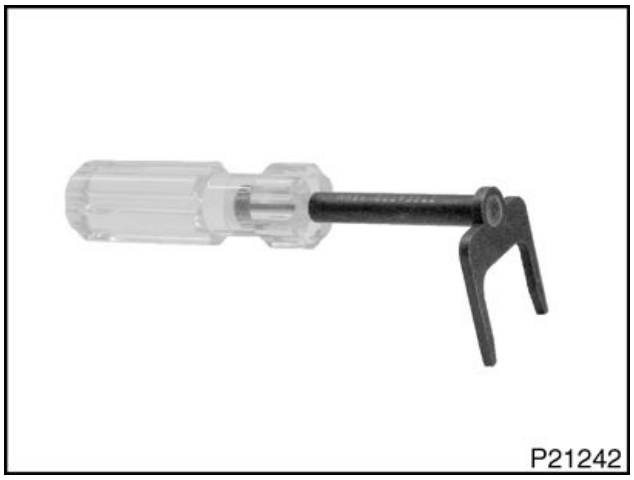

Figure 736 ZTSE4773 fuel line disconnect tool 11.8 mm

Figure 737 ZTSE4777 injector installer

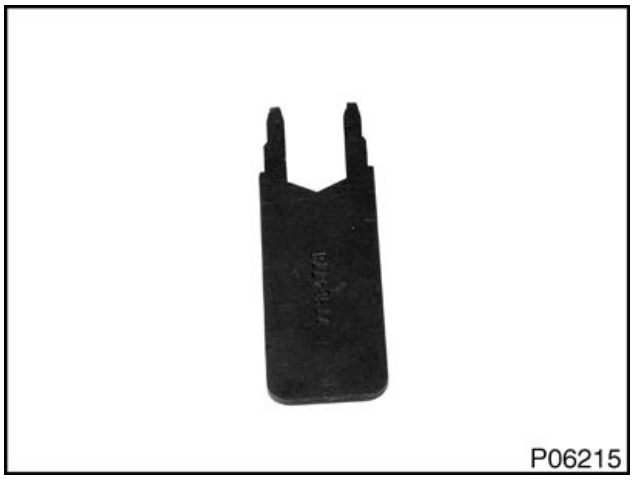

Figure 738 ZTSE4778 coolant line release tool

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Figure 739 12-051-01 Engine Stand Adapter Plate

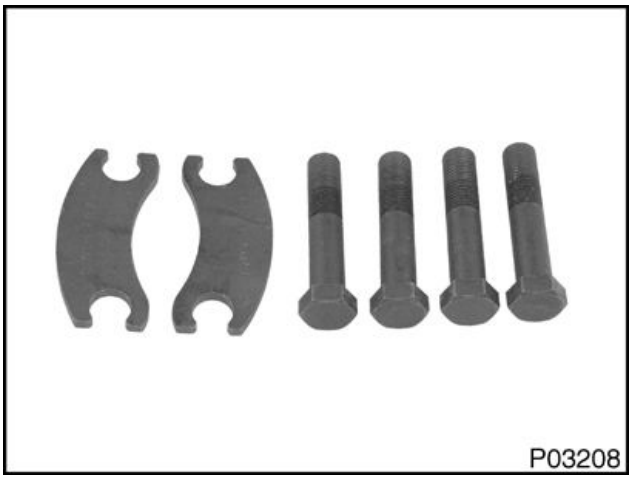

Figure 740 ZTSE4825 Sleeve Protrusion Hold Down Clamps

Figure 741 ZTSE4787 Head Bolt Torx® Socket (E24)

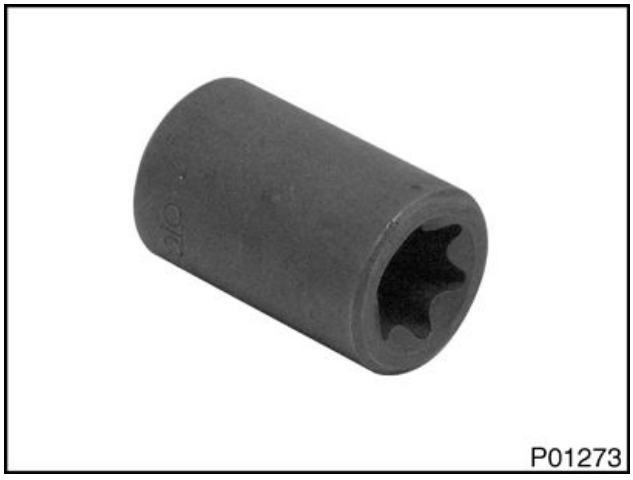

Figure 742 ZTSE4843 Exhaust Manifold Bolt Torx® Socket

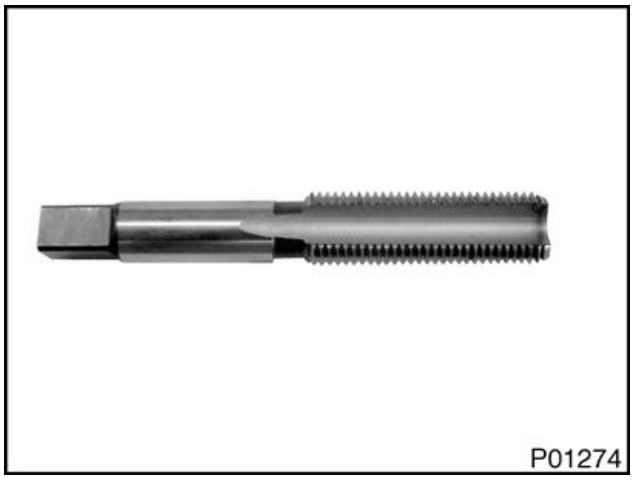

Figure 743 ZTSE4854 Main Bolt Bottoming Tap

Figure 744 ZTSE4855 Head Bolt Bottoming Tap

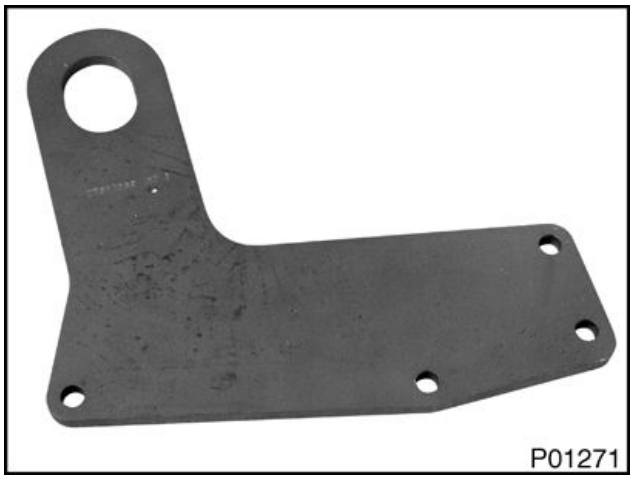

Figure 745 ZTSE4869 Cylinder Head Lifting Bracket

Figure 746 ZTSE4873 Front Crankshaft Seal Installer

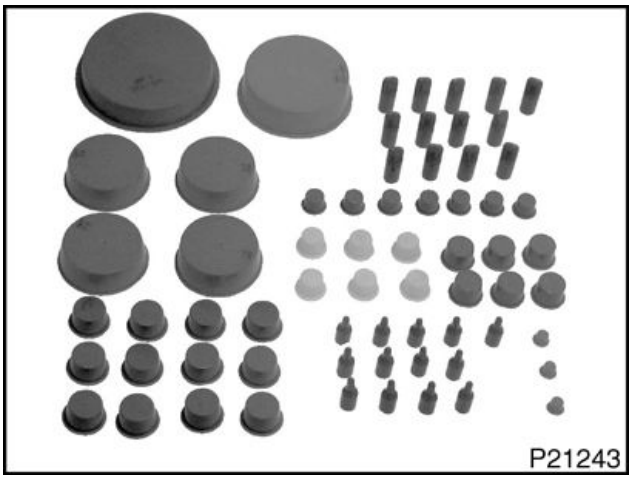

Figure 747 ZTSE4891 Disposable Air and Fuel Caps

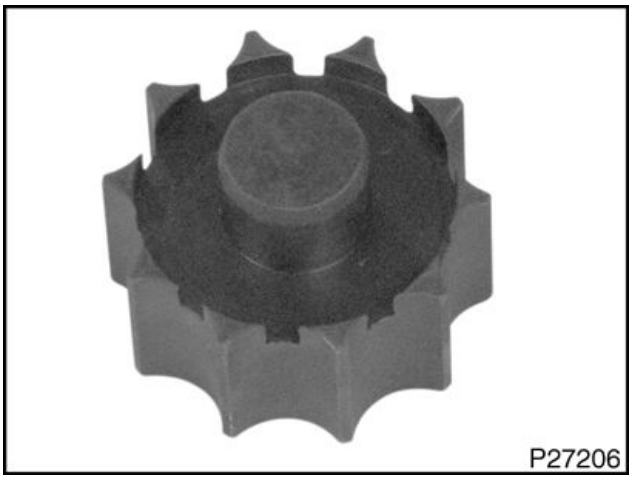

Figure 749 ZTSE4898 Pilot Bearing Installation Tool

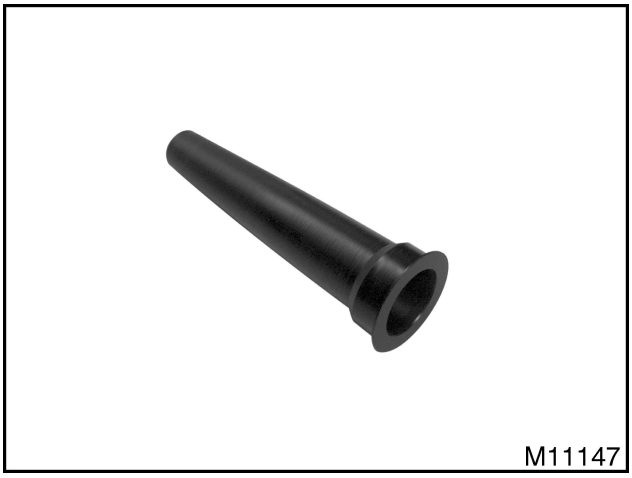

Figure 748 ZTSE4892 Fuel Injector Caps (6)

Figure 750 ZTSE6030 FEY Rings Installation Tools

Figure 751 ZTSE6042 Charger Air Cooler Test Kit

Figure 752 ZTSE6043 Extension Tube Installer

Figure 753 ZTSE6046 Extension Tube Installer Large

Figure 754 ZTSE6047 Extension Tube Installer Small

Figure 755 ZTSE6051–1 Extension Tube Installer Large

Figure 756 ZTSE6051–2 Extension Tube Installer Small

Figure 757 ZTSE6063 Engine Oil Cooler Pressure Test Plate

Figure 758 ZTSE6066 Fan Hub/High Pressure Drive Seal Installer

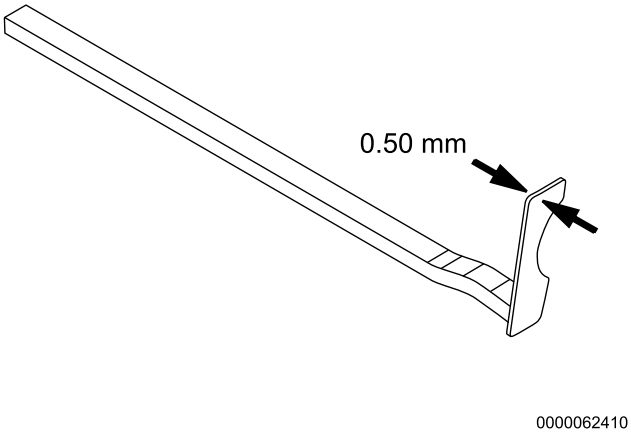

Figure 759 ZTSE6076–5A Lash Gauge

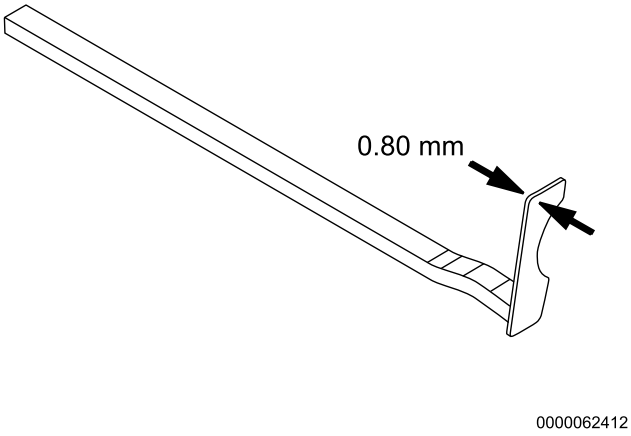

Figure 760 ZTSE6076–7A Lash Gauge

Figure 761 15-922-01 Fuel System Priming Tool

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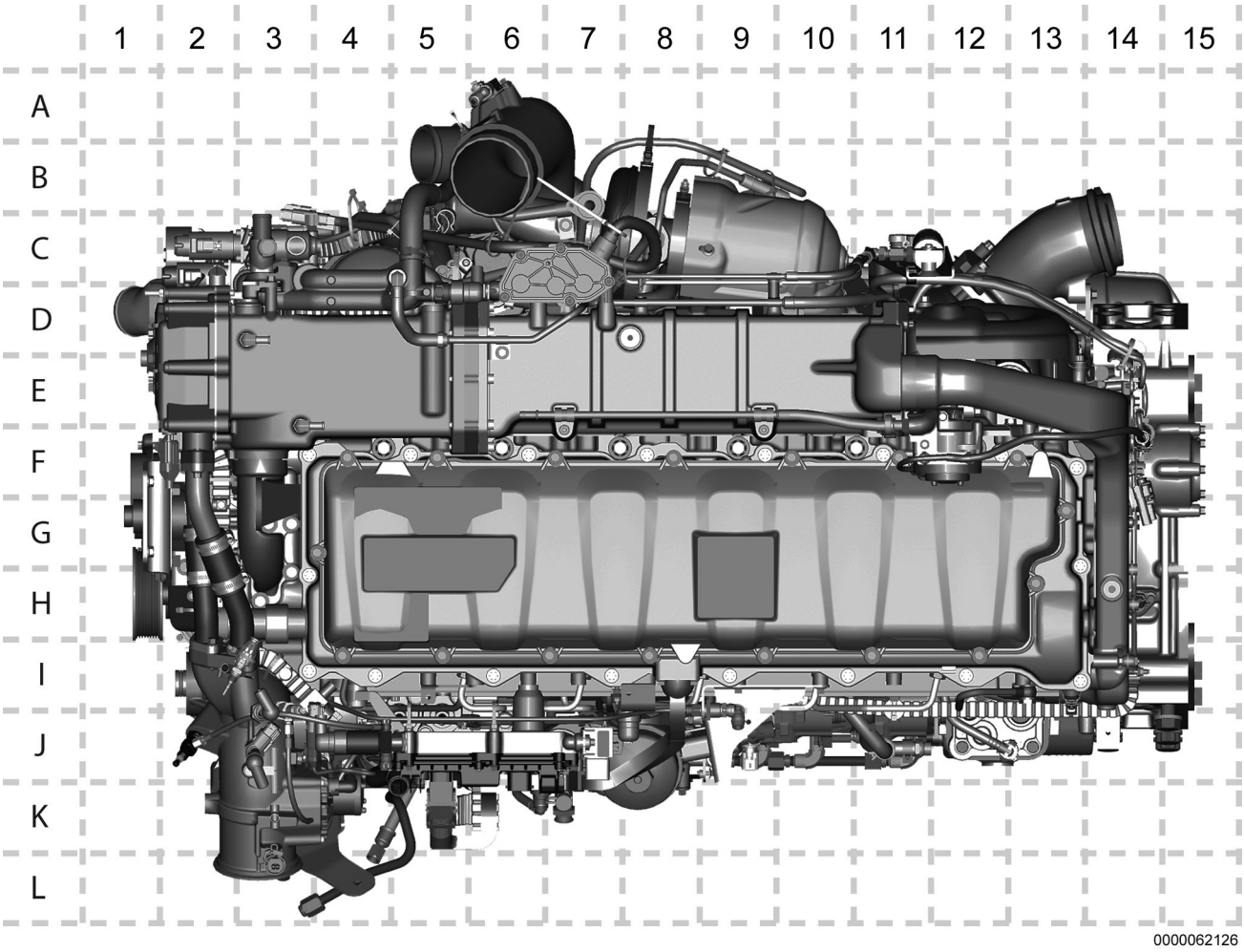
Top View



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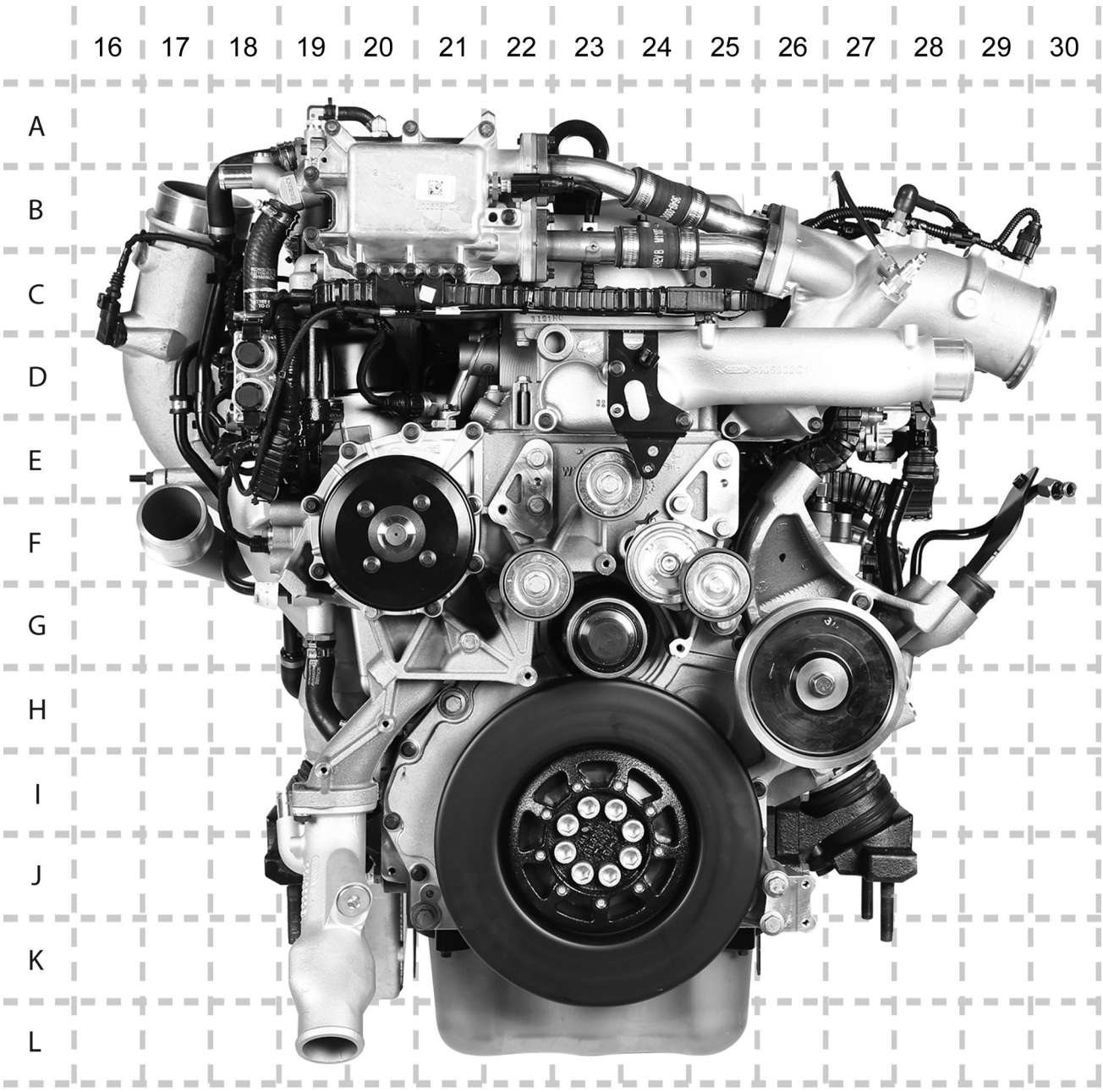
Front View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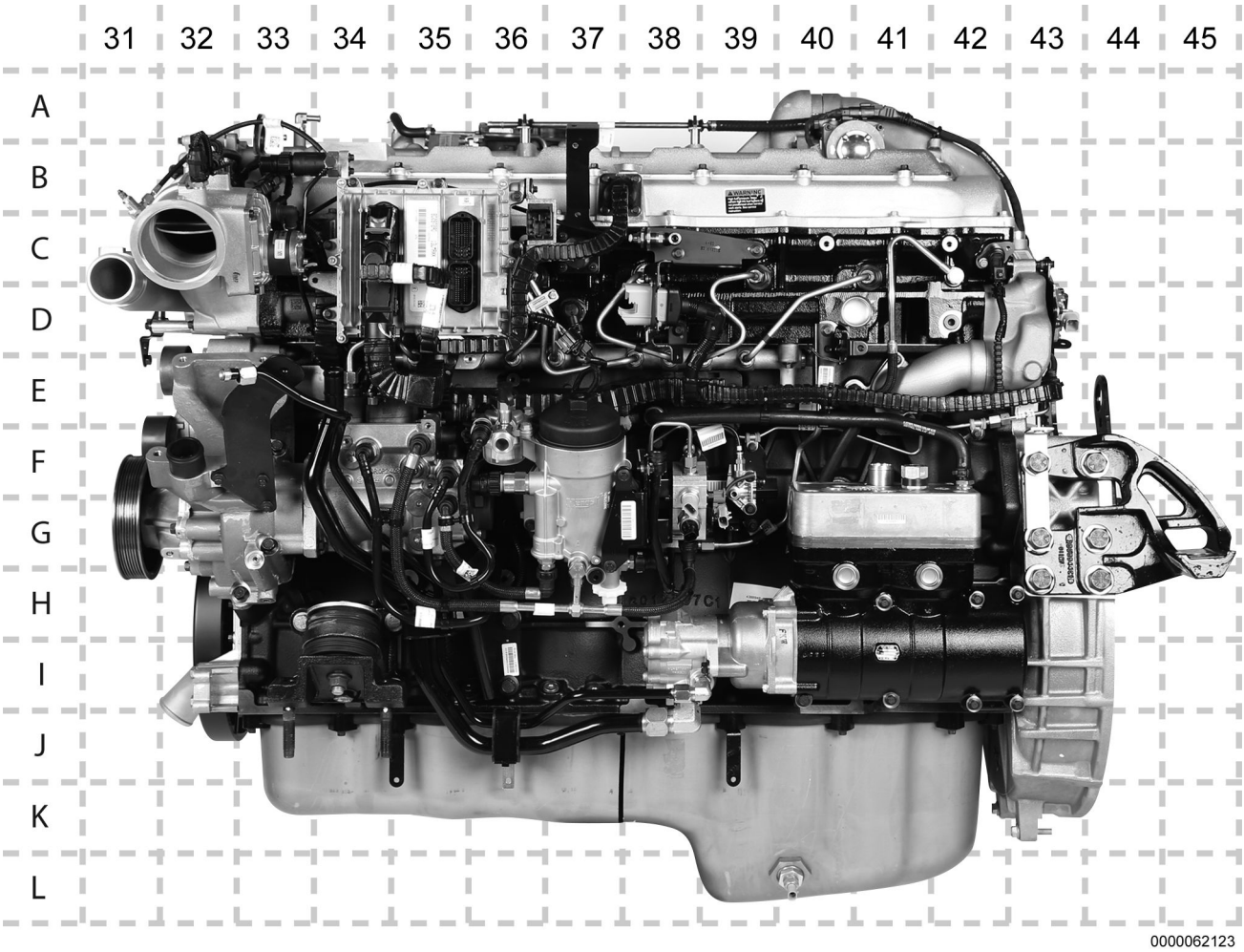
Left Side View



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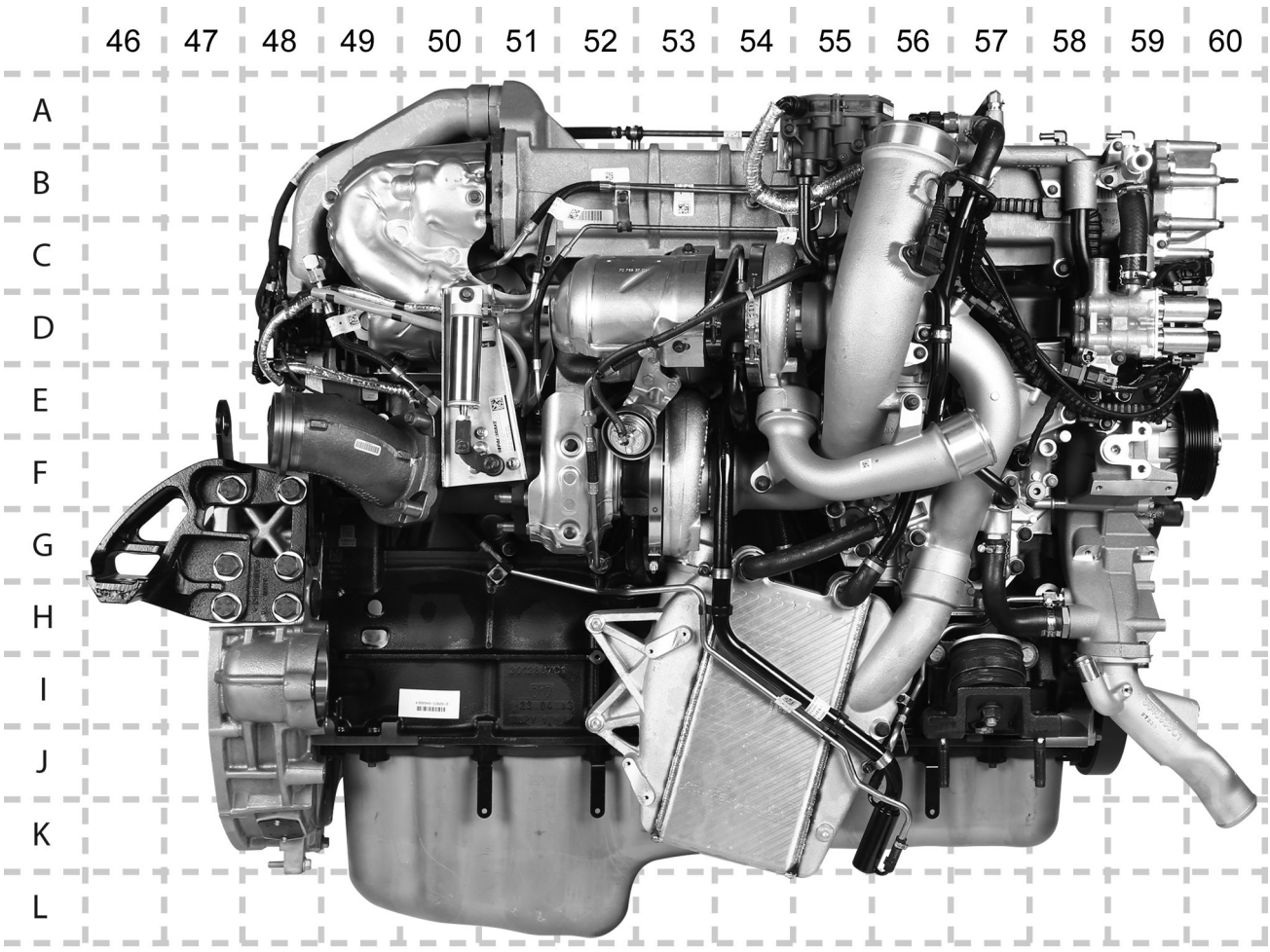
Right Side View



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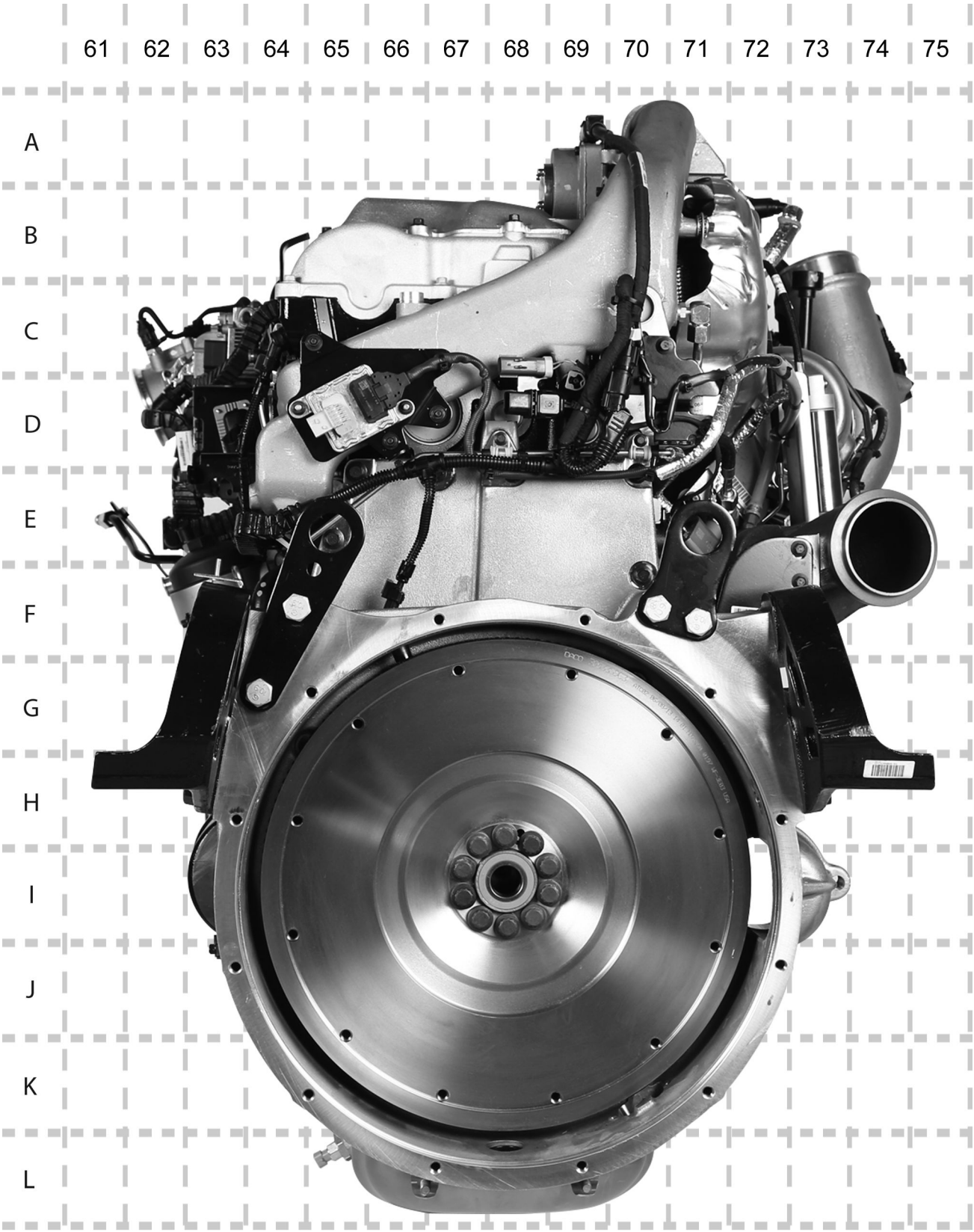
Back View



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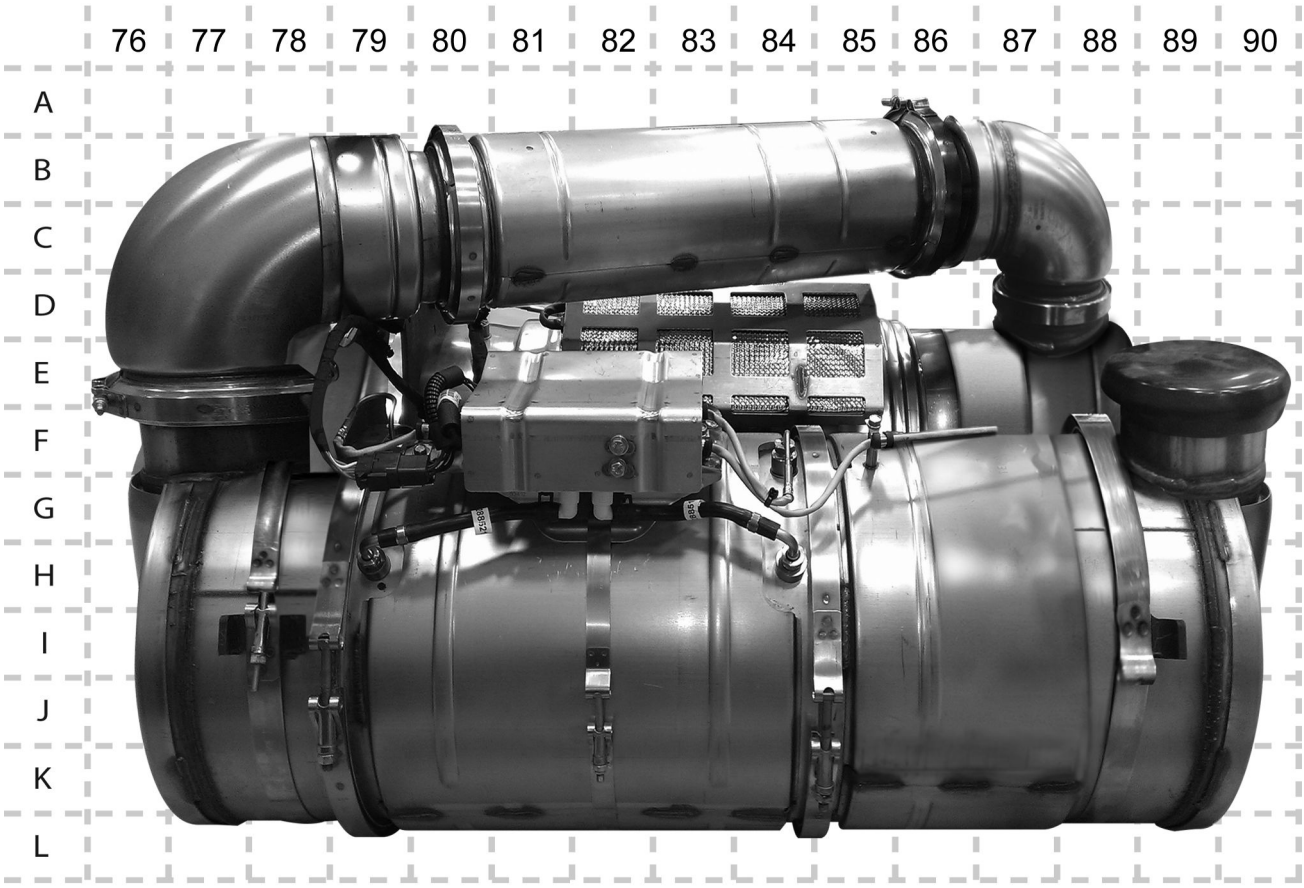
Component Locator Table

Component	Location
Aftertreatment Fuel Doser (AFTFD) Module (AFTFD contains AFTFSV and AFTFP1)	G-38
Aftertreatment Fuel Injector (AFTFI)	E-49
Aftertreatment Purge Air Valve (AFTPAV)	F-39
Air compressor	I-41
Air Control Valve (ACV) Assembly	A-55, C-6
Air inlet duct	B-6, B-17
Camshaft Position (CMP) sensor	C-42
Charge-Air-Cooler Outlet Temperature (CACOT) sensor	B-29, B-32, K-13
Crankcase Oil Separator (CCOS) breather tube	K-55
Coolant Control Valve (CCV) assembly (CCV contains CMV and CFV)	D-18, D-59
Crank Shaft Position (CKP) sensor	F-66
Emission label	G-9
Engine coolant inlet	L-19
Engine coolant outlet	D-28
Engine Control Module (ECM) with Barometric Pressure (BARO) internal sensor	C-35
Engine Coolant Temperature 1 (ECT1) sensor	C-70
Engine Coolant Temperature 2 (ECT2) sensor	B-56 (behind Turbocharger 1 Inlet)
Engine mounted secondary fuel filter	F-37
Engine Oil Level (EOL) sensor	I-37
Engine Oil Pressure (EOP)	F-37
Engine Oil Temperature (EOT) sensor	C-59 (behind CCV), D-21
Engine Throttle Valve (ETV)	C-32
Exhaust Back Pressure Valve (EBPV)	E-50
Exhaust Gas Recirculation (EGR) cooler coolant manifold	E-13
Exhaust Gas Recirculation (EGR) cooler (high temperature stage)	E-10
Exhaust Gas Recirculation (EGR) cooler (low-temperature stage)	E-4
Exhaust Gas Recirculation (EGR) cooler outlet pipe (coolant)	G-3

Exhaust Gas Recirculation (EGR) cooler outlet tubes (gases)	G-2
Exhaust Gas Recirculation Temperature (EGRT) sensor	B-22
Exhaust Gas Recirculation (EGR) Valve	A-40, A-69
Flywheel Housing	I-43
Fuel Delivery Pressure (FDP) sensor	F-36
Fuel Pressure Control Valve (FPCV)	F-36 (back of high-pressure fuel pump)
Fuel primer pump assembly	E-36
Fuel rail Pressure (FRP) sensor (behind ECM, at front of the fuel rail)	D-35
High Pressure (HP) fuel pump	F-35
High Pressure (HP) pump pulley	H-26
High Pressure (HP) turbocharger	D-54
High Pressure (HP) turbocharger compressor outlet	F-56
Humidity / Inlet Air Temperature (IAT) sensor	C-16, C-56
Injector harness	B-37
Inlet Air Heater Fuel Ignitor (IAHFI)	B-31, C-27
Inlet Air Heater Relay (IAHR)	C-37, J-7
Inlet Air Heater Fuel Solenoid (IAHFS)	B-33, J-4
Intake Manifold Pressure (IMP) sensor	B-28
Intake Manifold Temperature (IMT) sensor	D-37, J-3
Intake throttle duct assembly	C-29
Low Pressure Charge Air Cooler (LPCAC)	I-54
Low Pressure (LP) fuel pump	G-35
Low Pressure (LP) fuel pressure test port	E-36
Low Pressure (LP) turbocharger	F-53
NOx IN sensor: (Behind EBPV)	E-50, E-72
NOx IN sensor module	D-65
Oil filter cap	D-57
Oxygen Sensor (O_2S)	E-50 (behind EBPV), E-72
Thermostat housing	D-23
Turbocharger 2 compressor inlet sensor (TC2CIS)	D-56
Vibration damper	J-23
Coolant distribution housing	F-20

SCR Switchback Assembly



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SCR Switchback Assembly Component Locator Table

Component	Location
Ammonia (NH3) sensor	E-83
Ammonia (NH3) sensor module	E-83
Diesel Exhaust Fluid Doser Valve (DEFDV)	C-80
Diesel Oxidation Catalyst (DOC) / DPF Diesel Particulate Filter (DPF) Temperature sensor module	F-82
Diesel Oxidation Catalyst Inlet Temperature (DOCIT)	F-87
Diesel Particulate Filter Differential Pressure (DPFDP) / outlet pressure sensor module	F-82
Diesel Particulate Filter Inlet Temperature (DPFIT)	F-83
Diesel Particulate Filter Outlet Temperature (DPFOT)	F-79
NOx Out sensor	D-77 (behind switchback crossover pipe)
Selective Catalyst Reduction Inlet Temperature (SCRIT)	E-85
Selective Catalyst Reduction Outlet Temperature (SCROT)	E-80
Selective Catalyst Reduction (SCR) temperature sensor module	D-83