Summary of Changes

Section Updated	Description
Inlet Air Heater System	• Installation procedure updated to reflect correct installation of the IAHFI in the air intake throttle duct.
Aftertreatment System	• Pre-Diesel Oxidation Catalyst (PDOC) – PDOC bracket and clamp updated with new parts. • Hydrocarbon Injector (HCI) / Aftertreatment Fuel Injector (AFI) Assembly – Added information regarding correct orientation of AFI gasket (raised seal lip facing down toward exhaust back pressure valve housing). • Special Torque- PDOC clamp torque updated.
Turbochargers	• Improved installation procedure and graphics in Turbocharger Mounting .
Fuel System	• Fuel Supply and Drain (Return) Lines – Updated removal and installation procedures to reflect relocation of c-clips. C-clips were relocated due to a rub condition that existed between the fuel filter supply line and the low pressure pump supply line. • High-Pressure Fuel Pump (HPFP) and Drive Housing – HPFP removal and installation procedures updated to reflect removal of HPFP drive pulley and pulley housing off-vehicle. • Fuel Pressure Control Valve (FPCV)and Piston Overflow Valve (KUEV) – Procedures added for removal and installation of the FPCV and KEUV.
Cylinder Head, Camshaft and Valve Train	• Valve Lash Adjustment Procedure – A note has been added identifying the proper service interval for valve lash adjustment. • Upper Valve Cover and Base – Tightening sequence added for 18 valve cover base screws with dampers.
Power Cylinders	• Piston and Connecting Rod Installation – Steps for checking proper connecting rod to rod cap orientation. Also a caution and step has been added regarding cleaning fractured mating surfaces of the connecting rod and rod cap.

TABLE OF CONTENTS

Foreword

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

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

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

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

MaxxForce® 11 and 13 and N13 with SCR *Engine Operation and Maintenance Manual*

MaxxForce® 11 and 13 *Engine Service Manual* (EPA 10)
MaxxForce® 11 and 13 *Engine Diagnostic Manual* (EPA 10)

MaxxForce® 11 and 13 *Hard Start and No Start Diagnostics Form* (EPA 10)

MaxxForce® 11 and 13 *Performance Diagnostics Form* (EPA 10)

MaxxForce® 11 and 13 *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.

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.

Table of Contents

Engine Identification

Engine Serial Number

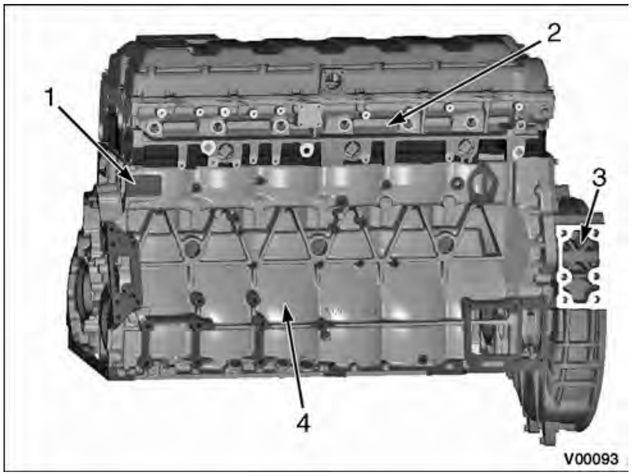

Figure 1 Engine serial number

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

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

Engine Serial Number Examples

MaxxForce® 11: 106HM2XXXXXXX

MaxxForce® 13: 125HM2XXXXXXX

MaxxForce® 11: 106HM2YXXXXXXX

MaxxForce® 13: 125HM2YXXXXXXX

Engine Serial Number Codes

106 – Engine displacement (10.5 L)
125 – Engine displacement (12.4 L)
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

Figure 2 2012 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
- 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:

- Air compressor
- Air conditioning compressor
- Alternator
- Cooling fan clutch
- Engine Control Module (ECM)
- High-pressure (HP) fuel pump
- Power steering pump
- Starter motor
- Turbochargers

Engine Specifications

MaxxForce® 11 and 13 Diesel Engines	
Engine Configuration	4 stroke, inline six cylinder diesel
Advertised brake horsepower @ rpm	
• MaxxForce® 11	See EPA exhaust emission label
• MaxxForce® 13	See EPA exhaust emission label
Peak torque @ rpm	
• MaxxForce® 11	See EPA exhaust emission label
• MaxxForce® 13	See EPA exhaust emission label
Displacement	
• MaxxForce® 11	10.5 L (641 in^3)
• MaxxForce® 13	12.4 L (758 in^3)
Compression ratio	
• MaxxForce® 11	16.5:1
• MaxxForce® 13	17.0:1
Stroke	
• MaxxForce® 11	155 mm (6.10 in)
• MaxxForce® 13	166 mm (6.54 in)
Bore (sleeve diameter)	
• MaxxForce® 11	120 mm (4.72 in)
• MaxxForce® 13	126 mm (4.96 in)

Total engine weight (dry weight without trim or accessories)	
• MaxxForce® 11	1087 kgs (2392 lbs)
• MaxxForce® 13	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)	
• MaxxForce® 11	40 L (42 qts)
• MaxxForce® 13	40 L (42 qts)
Lube system capacity (overhaul only, with filter)	
• MaxxForce® 11	44 L (46 qts)
• MaxxForce® 13	44 L (46 qts)
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 key 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 and useful life of the engine.
    - For Navistar®, this is the EPA 2010 MaxxForce® 13 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 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 MaxxForce® 11 and 13 diesel engines are 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. For 2010, the camshaft has been redesigned to incorporate six additional lobes. These new lobes are used with the engine brake housings for operation of the MaxxForce® Engine Brake.

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

The one-piece crankcase 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 MaxxForce® 11 and 13 engines also use an engine oil cooler and a cartridge-style engine oil filter, which are located 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 (IAHFS), and the Downstream Injection (DSI) unit.

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 limiting valve.

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

MaxxForce® 11 and 13 engines use a dual stage, fixed geometry turbocharger assembly. The high-pressure (HP) turbocharger includes a pneumatically operated wastegate. Each stage uses a Charge Air Cooler (CAC). 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 stream in the air inlet duct. The dual stage EGR cooler provides regulated cooling of the EGR gases before entering the air intake 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 directly through the side of the crankcase.

The inlet air heater assist system warms the incoming air supply prior to and during cranking.

The MaxxForce® Engine Brake by Jacobs® is optional for both MaxxForce® 11 and 13 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 the temperature of the 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 ECM using one Diesel Oxidation Catalyst Inlet Temperature (DOCIT) sensor positioned at the DOC inlet, and one Diesel Oxidation Catalyst Outlet Temperature (DOCOT) sensor positioned at the DOC outlet.
- 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 ECM using one Diesel Particulate Filter Outlet Temperature (DPFOT) sensor located at the outlet of the DPF, and one Diesel Particulate Filter Differential Pressure (DPFDP) sensor located on or near the DPF.

Engine Component Locations

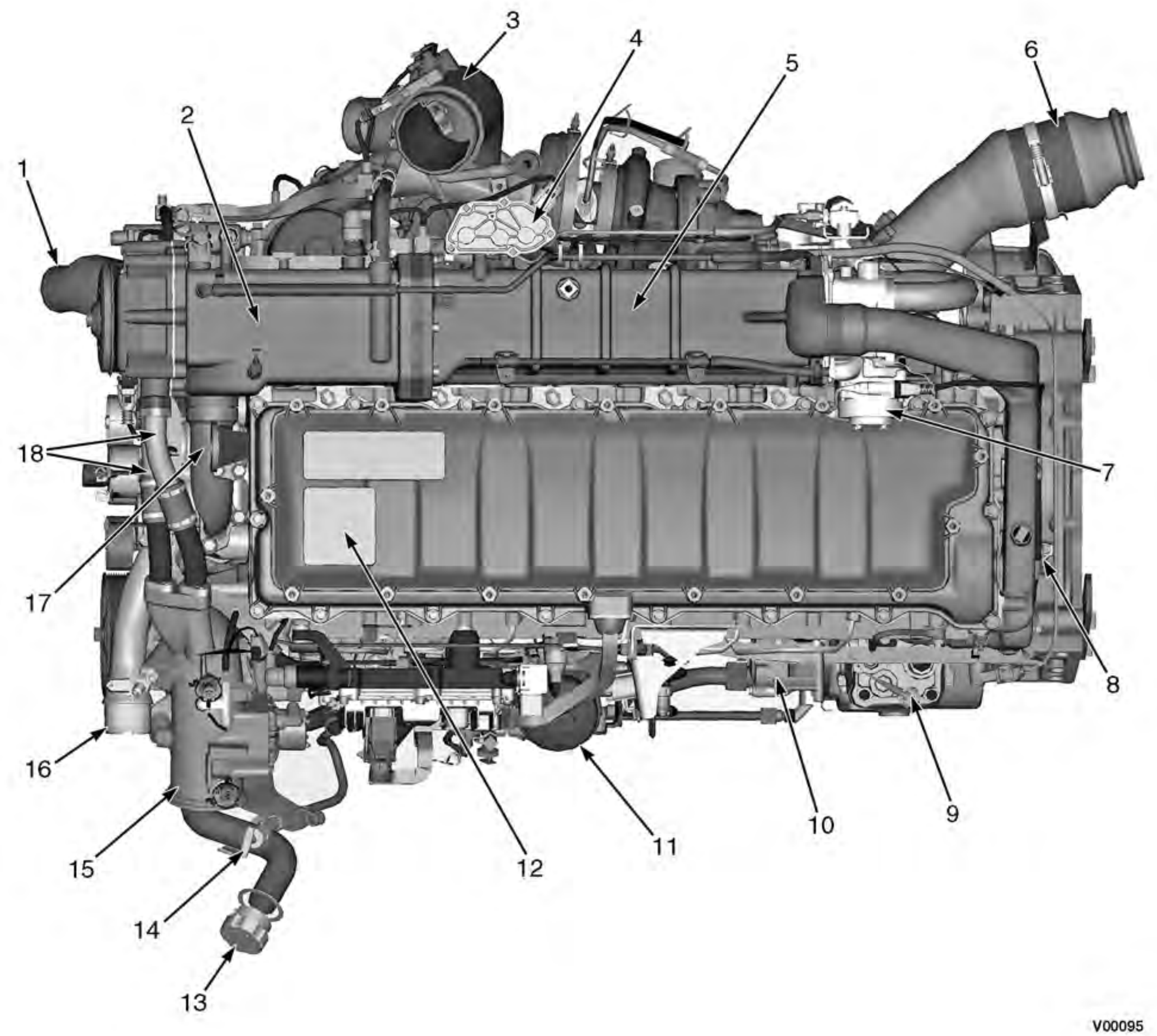

Figure 3 Component location – top view

1. Engine coolant inlet
2. Exhaust Gas Recirculation (EGR) cooler (low temperature stage)
3. Air intake duct
4. Air Control Valve (ACV) assembly
5. EGR cooler (high temperature stage)
6. Pre-DOC assembly (PDOC)
7. EGR Valve (EGRV)
8. Crankshaft Position (CKP) Sensor
9. Air compressor
10. Power steering pump
11. Engine mounted secondary fuel filter access
12. Emission label (location)
13. Engine oil fill
14. Engine oil level gauge
15. Intake throttle duct assy
16. Engine coolant outlet
17. EGR cooler outlet pipe (coolant)
18. EGR cooler outlet tubes (gases)

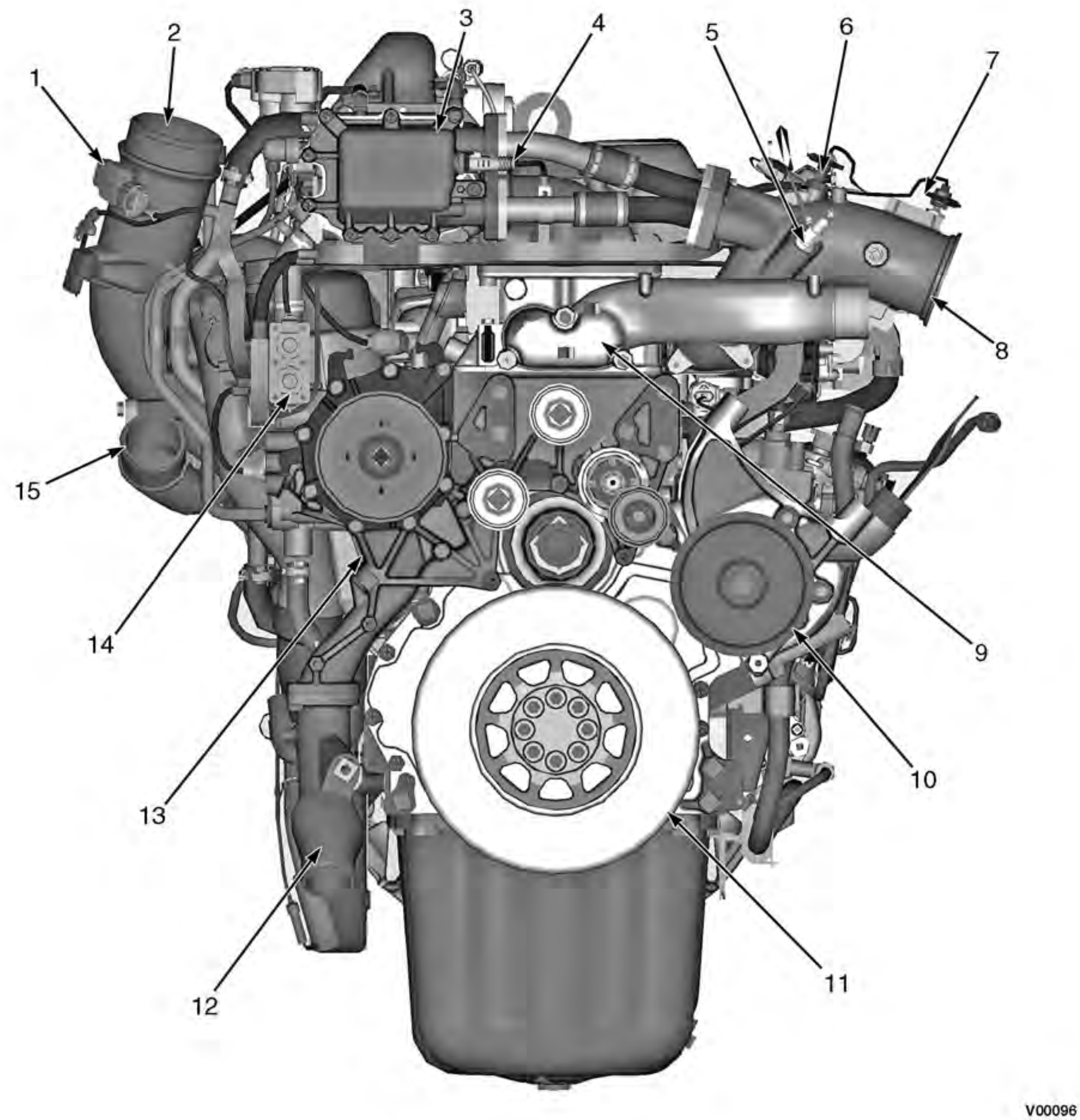

Figure 4 Component location – front view

1. Mass Air Flow (MAF) sensor
2. Air inlet duct
3. EGR cooler
4. EGR Temperature (EGRT) sensor
5. Inlet Air Heater Fuel Igniter (IAHFI)
6. Intake Manifold Pressure (IMP) sensor
7. Charge Air Cooler Outlet Temperature (CACOT) sensor
8. Intake throttle duct assy
9. Thermostat housing
10. HP pump pulley
11. Vibration damper
12. Water engine inlet
13. Water distribution housing.
14. Coolant Control Valve (CCV)
15. HP turbocharger compressor outlet

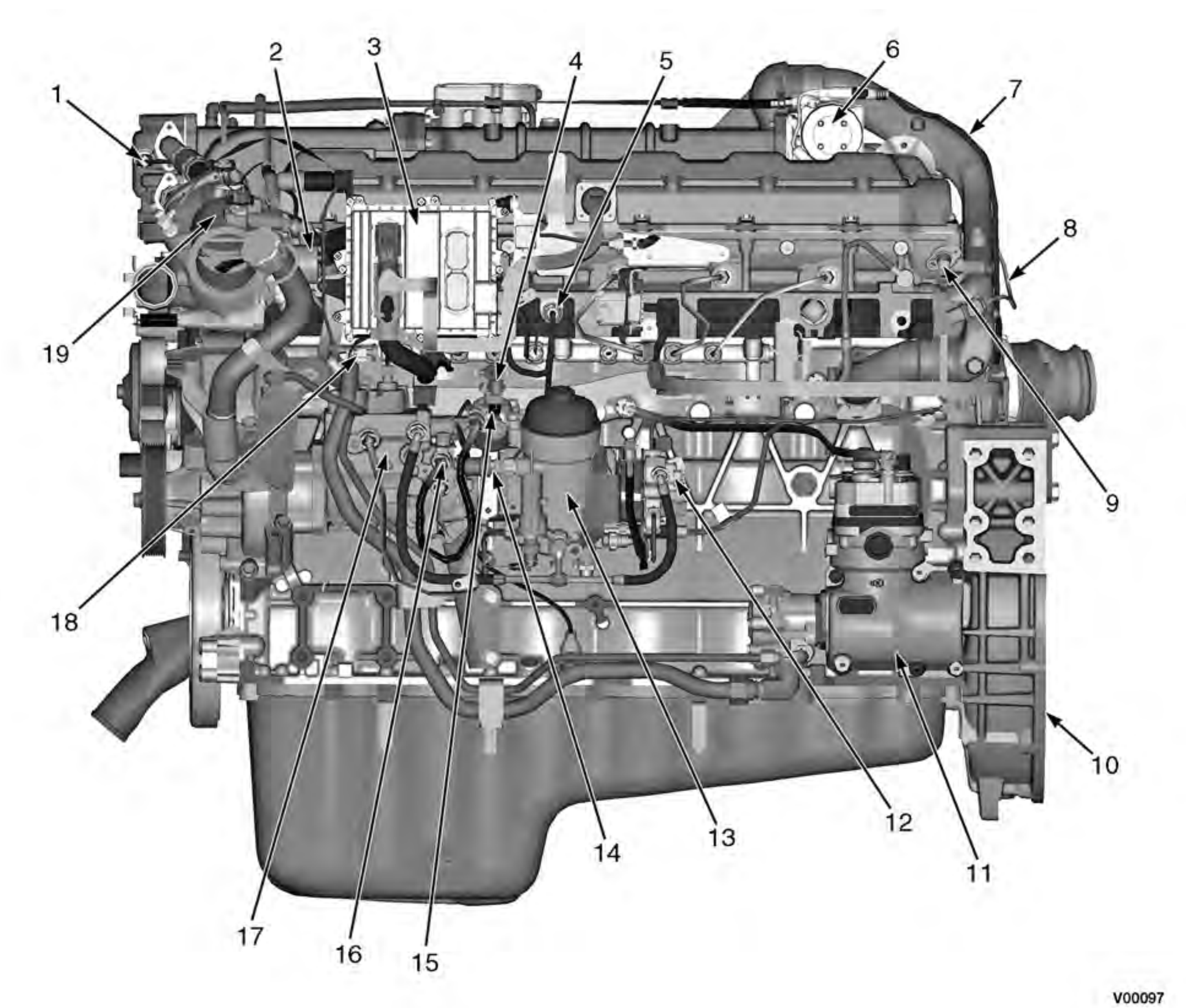

Figure 5 Component location – left view

1. EGRT sensor
2. Engine Throttle Valve (ETV)
3. ECM
4. Low Pressure (LP) fuel pressure test port
5. Intake Manifold Temperature (IMT)
6. EGRV
7. EGR cooler coolant manifold
8. Oxygen Sensor harness
9. Camshaft Position (CMP) sensor
10. Flywheel Housing
11. Air Compressor
12. DSI unit
13. Engine mounted secondary fuel filter access
14. Fuel Delivery Pressure (EDP) sensor
15. Fuel primer pump assembly
16. LP fuel pump
17. HP fuel pump
18. Fuel Rail Pressure (FRP) sensor
19. Intake throttle duct assembly

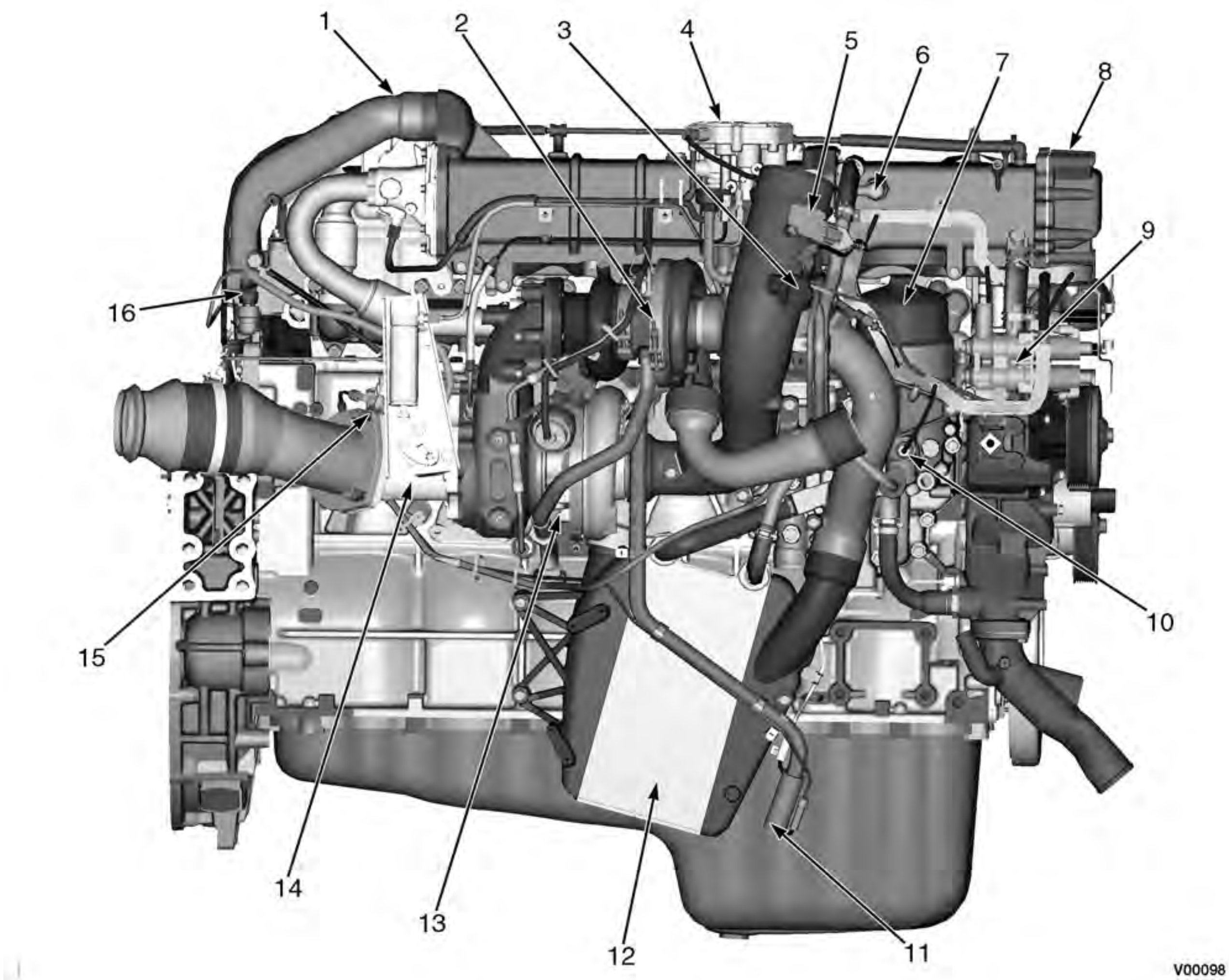

Figure 6 Component location – right view

1. EGR cooler coolant manifold
2. HP turbocharger
3. Humidity Sensor (HS) / Inlet Air Temperature (IAT) sensor
4. Air Control Valve (ACV) assembly
5. MAF sensor (if equipped)
6. Engine Coolant Temperature 2 (ECT2)
7. Oil filter cap
8. EGR Cooler
9. CCV
10. Engine Oil Pressure (EOP) sensor
11. Crankcase Oil Separator (CCOS)
12. Low-Pressure Charge Air Cooler (LPCAC)
13. LP Turbocharger
14. Engine Back Pressure Valve (EBPV)
15. Hydrocarbon Injector (HCI) assembly
16. Engine Coolant Temperature 1 (ECT1) sensor

Air Management System

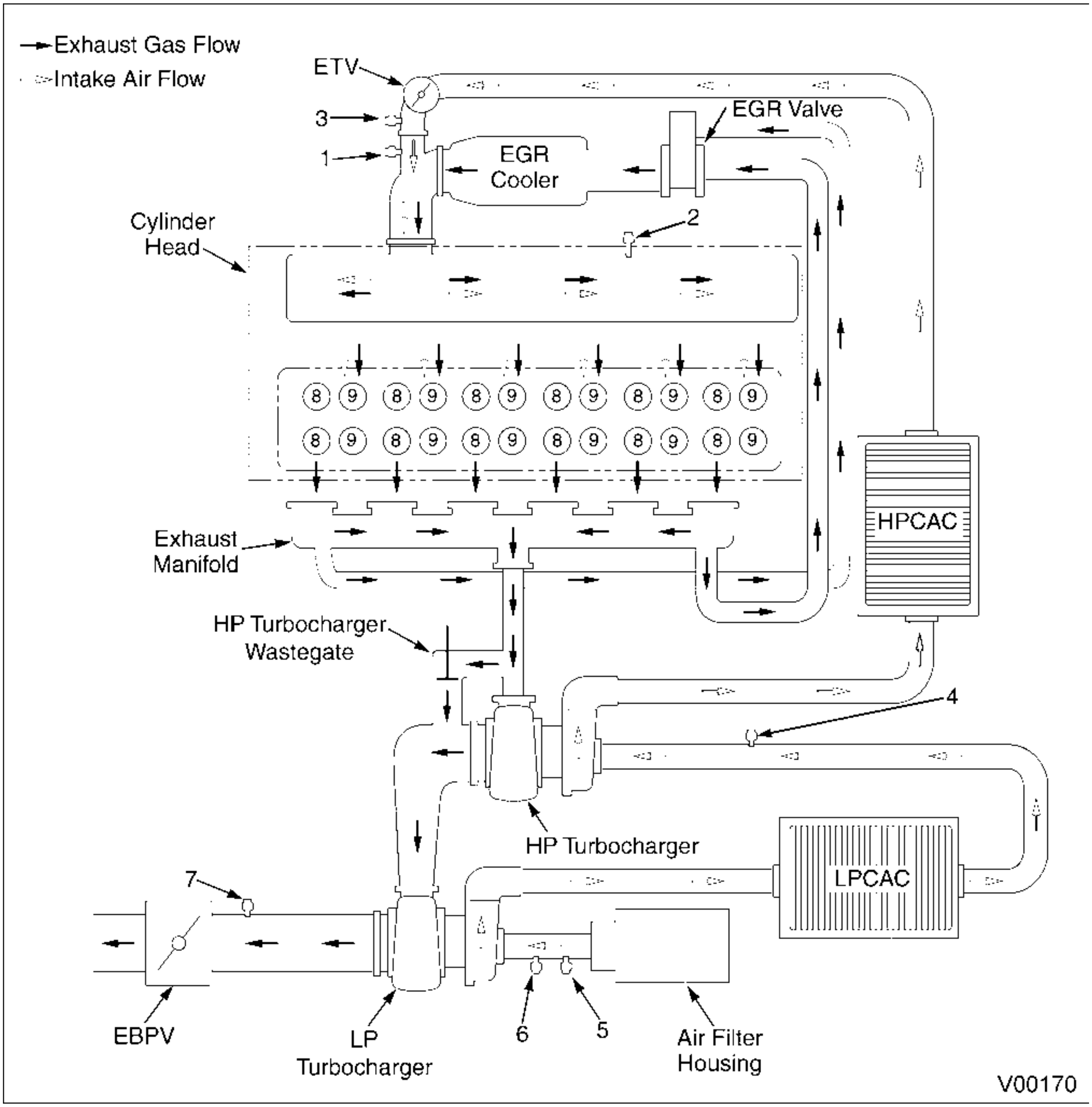

Figure 7 Air Management System

1. EGRT sensor
2. IMP sensor
3. Charge Air Cooler Outlet Temperature (CACOT)
4. LP Boost/LP Temperature sensor
5. MAF sensor (if equipped)
6. Humidity Sensor (HS) / Inlet Air Temperature (IAT) sensor
7. Oxygen Sensor (O2S)
8. Exhaust Valve
9. Intake Valve

Airflow

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

If the 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 assist system rapidly 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 EBPV.

The EBPV is operated by 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 systems flow through the EBPV, then through the vehicle Aftertreatment (AFT) system, and out the exhaust tail pipe.

Turbochargers

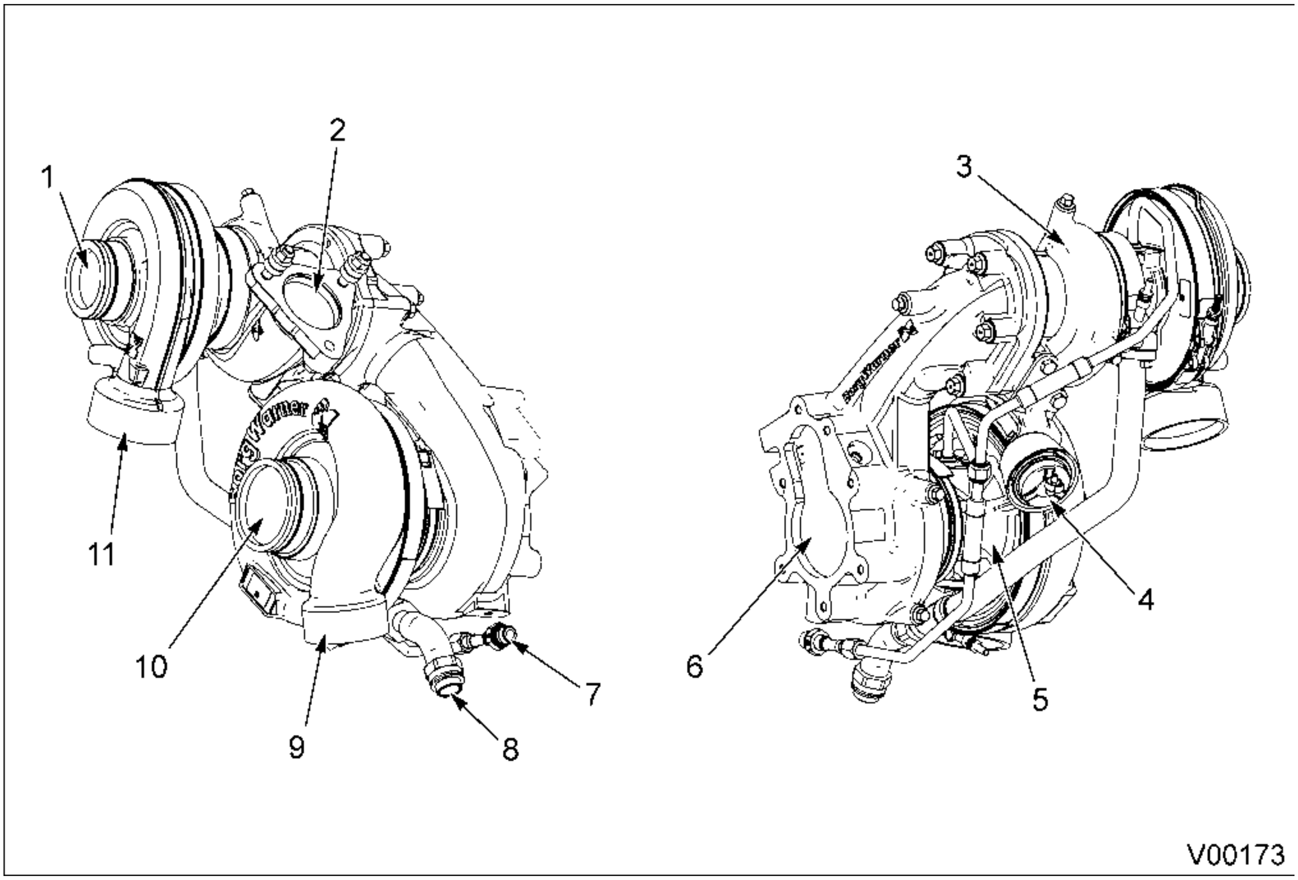

Figure 8 High and low-pressure turbocharger components

1. HP turbocharger compressor inlet
2. HP turbocharger turbine inlet
3. HP turbocharger
4. HP turbocharger wastegate actuator
5. LP turbocharger
6. LP turbocharger turbine outlet
7. Oil supply line
8. Oil return line
9. LP turbocharger compressor outlet
10. LP turbocharger compressor inlet
11. HP turbocharger compressor outlet

MaxxForce® 11 and 13 engines are equipped with a pneumatically regulated two-stage turbocharging system. The HP and LP turbochargers are installed 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 LPCAC. Cooled LP air then enters the HP compressor, where it is further compressed and directed into the HPCAC. Compressed air then goes through the 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 directly 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, controlled by a pneumatic actuator. The wastegate regulates boost by controlling the amount of exhaust gases that bypass the HP turbine. When boost demand is low, the wastegate opens, 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 Pressure (TC2CIP)

Air Control Valve (ACV)

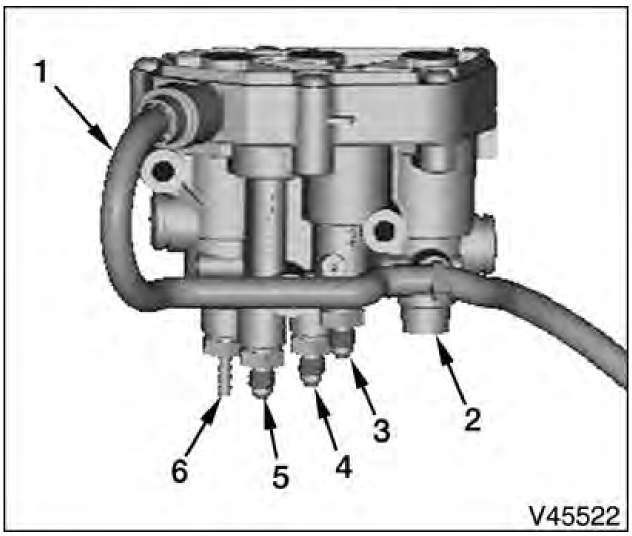

Figure 9 Air Control Valve (ACV) connections

1. Pigtail harness (to engine sensor harness connector)
2. Plug
3. Vehicle air supply port
4. EBPV control port
5. TC1TOP sensor port
6. HP turbocharger wastegate control port

The ACV assembly contains the HP turbocharger wastegate control port, 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. The air supply port is connected to the vehicle's air system.

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

When an increase in boost is required, the ECM supplies PWM voltage to close the control valve. This reduces air pressure to the wastegate control valve causing the watsegate to move in the closed direction, resulting in increased boost.

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 EPBV actuator.

Boost Control

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

Low-Pressure Charge Air Cooler (LPCAC)

The LPCAC is installed between the HP and LP turbochargers, and is mounted to the lower right side of the engine. The LPCAC air inlet is connected to the low-pressure 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 directly to the intake throttle duct.

High-Pressure Boost Pressure (HPBP) Sensor

This sensor monitors the pressure of the charge air entering the duct. The primary function of the sensor is to provide information used to ensure proper boost control. It is also used as part of EGR control.

Pressure sensor works by providing an analog voltage output to the ECM which is proportional to pressure being applied to an internal diaphragm in the sensor. The sensor is connected to the control module through the Reference Voltage (VREF), signal, and signal ground wires. A transfer function contained in the ECM software converts the analog voltage to a pressure value which is then used by software strategies requiring the pressure information.

The ECM continuously monitors the pressure sensor output voltage for determination of charge air pressure. High and low diagnostic voltage thresholds are evaluated to ensure that output voltage is within a valid range.

High-Pressure Boost Temperature (HPBT) Sensor

This sensor monitors the temperature of the charge air entering the 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 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.

Low-Pressure Boost Pressure (LPBP) Sensor and Low-Pressure Boost Temperature (LPBT) Sensor

This is a combination pressure and temperature sensor.

This sensor is a dual function sensor that detects pressure and temperature of the charge air entering the HP compressor. It is installed in the piping between the 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 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 that the output voltage is within a valid range.

Exhaust Gas Recirculation (EGR) System

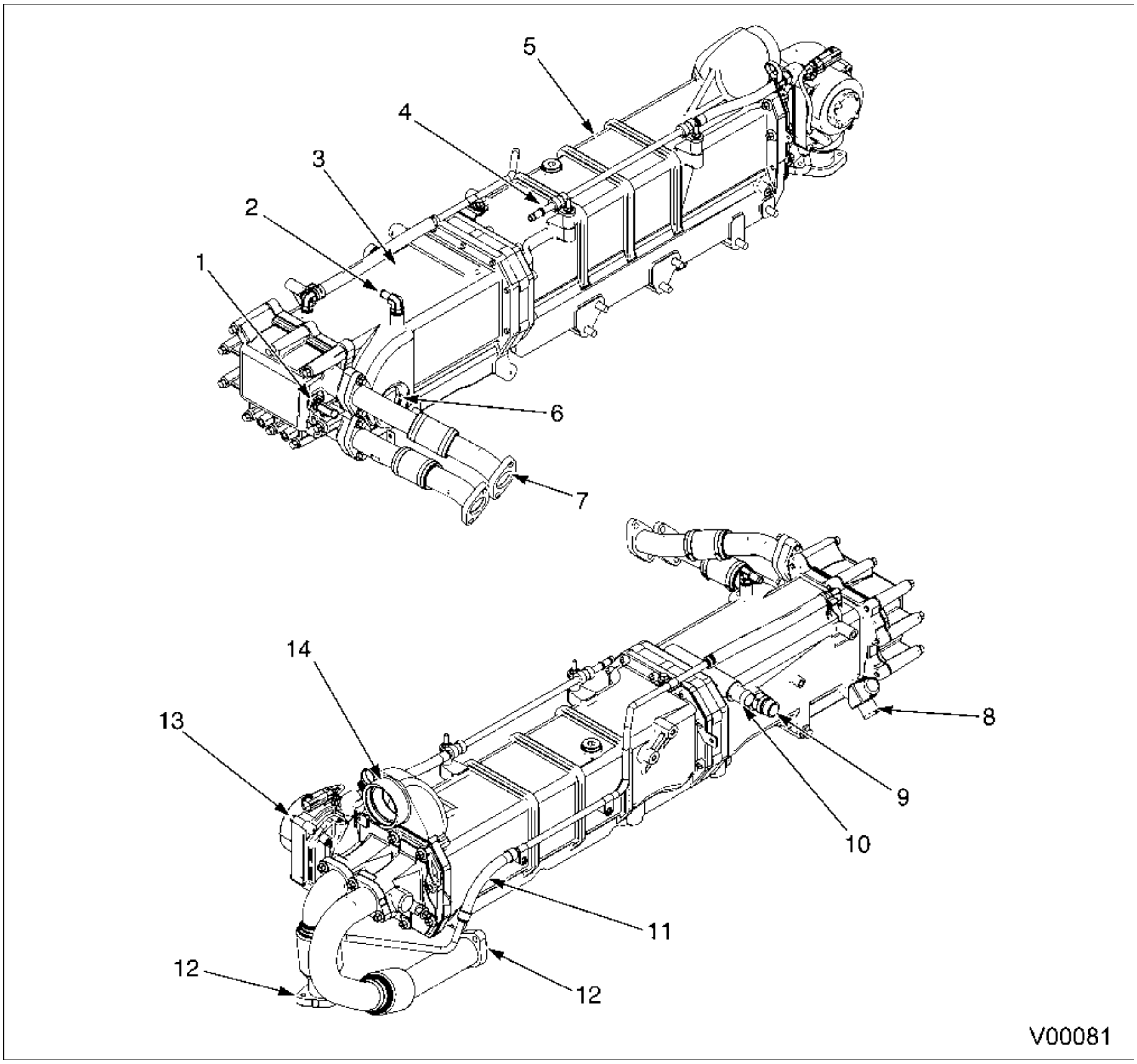

Figure 10 EGR system components

1. EGRT sensor
2. EGR cooler air bleed (to deariation tank)
3. EGR cooler (low temperature stage)
4. EGRV coolant return line (to deariation 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 ECM monitors signals from the CACOT sensor, Oxygen sensor (O2S), 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

Exhaust gas from the exhaust manifold flows through the EGR inlet tubes to the EGRV. When EGR function is activated, the EGRV opens and allows exhaust gas to enter the EGR cooler. Cooled exhaust gas flows from the front of the EGR cooler, 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, ETV, and O2S. The EGRV contains a 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, located inside the EGRV, monitors and provides an EGRV position signal to the ECM.

The O2S is installed in the exhaust, in front of the aftertreatment fuel injector. The O2S has a heater element that heats the sensor to its normal operating temperature of 780 °C (1436 °F). During initial engine warm-up, the O2S heater element is activated only after the 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

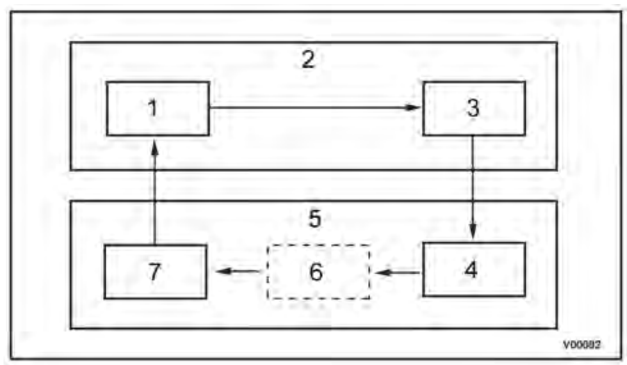

Figure 11 EGRV position control

1. EGR position monitored by ECM
2. 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 the engine warm-up period and before the O2S reaches its normal operating temperature, the EGR system operates in open loop. In open loop, the EGR system is controlled by the ECM based on the charge air temperature, engine coolant temperature, engine speed, and load conditions.

EGR – Closed Loop

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

EGR Flow Cooling

The EGR system includes a two-stage EGR cooler, allowing the ECM to regulate EGR Cooler temperatures. The ECM monitors intake manifold temperature through the Exhaust Gas Recirculation Temperature 1 (EGRT1) sensor and to regulate EGR flow temperatures, the CCV regulates coolant flow through the LTR. Refer to Cooling System in this section for more information.

Aftertreatment (AFT) System

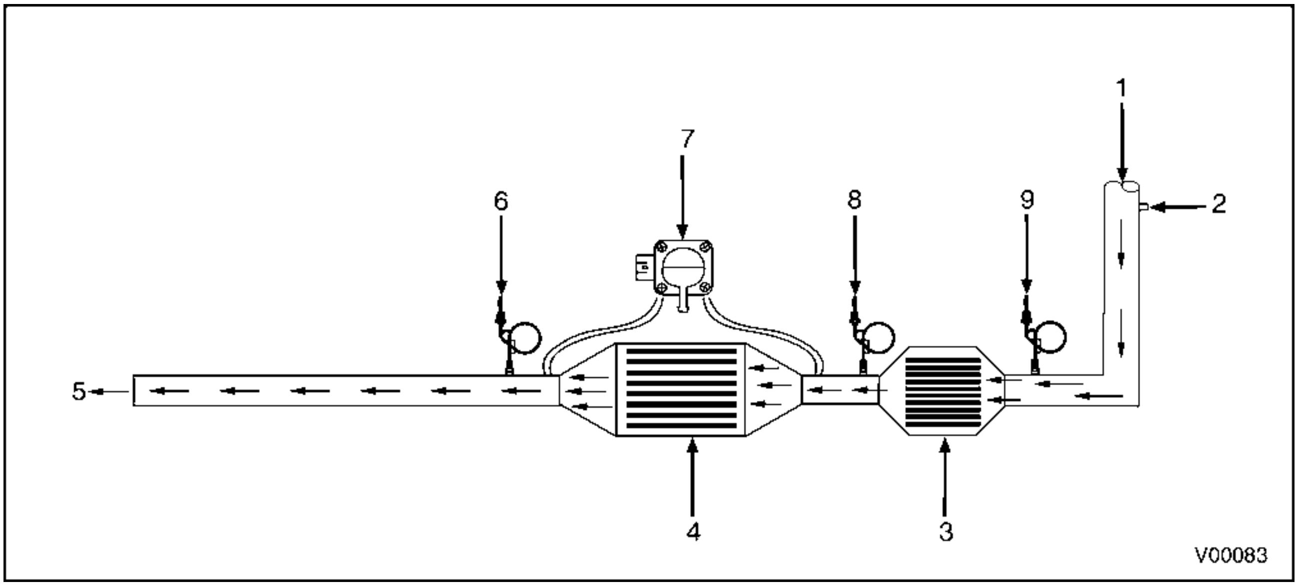

Figure 12 AFT system overview

1. Pre-DOC exhaust flow
2. Hydrocarbon Injector (HCI) assembly
3. DOC
4. DPF
5. Exhaust out to tail pipe
6. DPFOT sensor
7. DPFDP sensor
8. DOCOT sensor
9. DOCIT sensor

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.

The AFT system performs the following functions:

- Monitors exhaust gas temperatures DOC in, DOC out, and DPF out temperature and delta pressure across the DPF. 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
- AFT control system initiates regeneration automatically when DPF is full with soot and control engine operating parameters to increase temperature to have successful regeneration
- Maintains vehicle and engine performance during regeneration