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Aftertreatment System Design and Function

9700, PrevH, PrevX

Aftertreatment System, Design and Function

This service bulletin describes the design and function of the aftertreatment systems used on US2010 emissions Volvo vehicles. These systems include the exhaust gas recirculation (EGR) system, the aftertreatment diesel particulate filter (DPF) system, and the aftertreatment selective catalytic reduction (SCR) system.

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Note: Information is subject to change without notice. Illustrations are used for reference only and can differ slightly from the actual vehicle being serviced. However, key components addressed in this information are represented as accurately as possible.

Design and Function

Emissions Aftertreatment System (EATS)

The aftertreatment system consists of engine and exhaust components and sensors that work together to lower emissions to meet the US2010 emission requirements for the heavy truck industry. This bulletin describes the main Aftertreatment systems and components, such as the aftertreatment diesel particulate filter (DPF) system, the exhaust gas recirculation (EGR) system and the aftertreatment selective catalytic reduction (SCR) system, and how they work together to lower emissions and improve fuel economy.

System Components and Operations

Exhaust Gas Recirculation (EGR) System

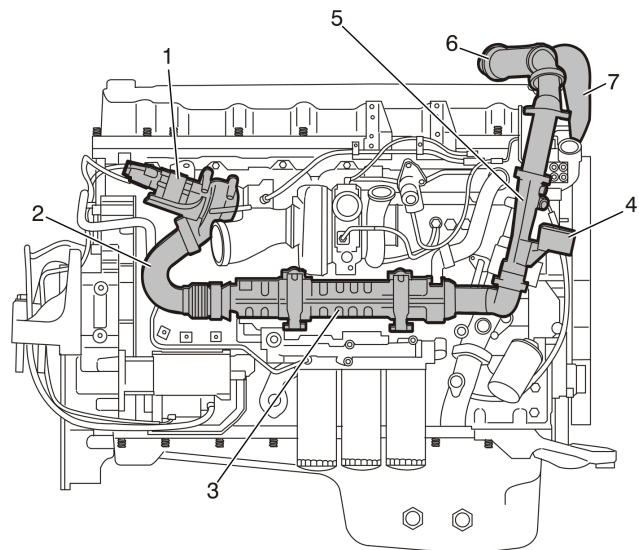
The EGR system is designed to recirculate exhaust gases into the combustion chambers to reduce the nitrogen oxide (NOx) emissions.

The NOx content increases with higher combustion temperatures. Recirculating cooled exhaust gases reduces the temperature in the combustion chamber and lowers the level of NOx emissions. To do this, the pressure must be higher in the exhaust side than in the inlet side and is controlled by the variable geometry turbocharger (VGT).

An EGR valve is mounted on the exhaust manifold. This valve is controlled by the oil pressure and regulates the recirculation of exhaust gases.

A portion of the exhaust gas is redirected from the exhaust manifold into the EGR cooler, through the Venturi tube, which measures the gas flow, and into the EGR mixing chamber. There, the exhaust gas is mixed with intake air cooled by the charge air cooler before it goes into the intake manifold.

The amount of recirculated exhaust gases is controlled by the engine control module (ECM) and depends on engine load, engine coolant temperature (ECT) and other various factors.



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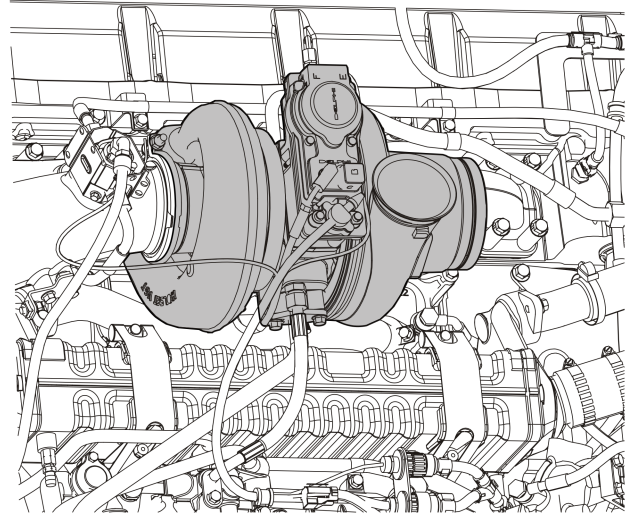
- 1 EGR Valve
- 2 EGR Valve Exhaust Pipe
- 3 EGR Cooler
- 4 EGR Differential Pressure Sensor
- 5 Venturi Tube
- 6 Crossover Pipe
- 7 EGR Mixing Chamber

Variable Geometry Turbocharger (VGT)

The VGT regulates the charge air pressure and drives the exhaust gas recirculation (EGR) system. The turbocharger lowers emissions, provides optimum fuel consumption and increases power output. The speed of the gases entering the turbine controls the turbocharger function. The gas speed is controlled by an electronic actuator. Engine coolant cools the turbocharger bearing housing and the actuator.

The VGT has a set of vanes and a sliding nozzle ring that maintain sufficient back pressure in the exhaust manifold to properly operate the EGR system. Back pressure is required to push the exhaust gases into the pressurized intake air at the EGR mixer.

The turbocharger sliding nozzle ring controls the exhaust back pressure for proper operation of the EGR system and for enhanced braking. When the variable geometry nozzle mechanism is fully closed, the turbocharger performs as an exhaust brake.



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Aftertreatment Diesel Particulate Filter (DPF) System

Simplified Concept

US2010 emissions engines utilize an aftertreatment diesel particulate filter (DPF) system to meet US2010 emissions particulate matter regulations. The engine exhaust contains particulate matter, most of which gets trapped in the aftertreatment DPF. Eventually, the particulate matter has to be oxidized (burned). The aftertreatment DPF system design uses the following two methods to oxidize accumulated particulate matter.

- Aftertreatment DPF Passive Regeneration
- Aftertreatment DPF Forced Stationary Regeneration using the aftertreatment hydrocarbon doser when passive regeneration is insufficient

The system maximizes aftertreatment operating conditions for passive regeneration while maintaining the system's ability to begin forced stationary regeneration when it is required. Forced stationary regeneration is a backup when passive regeneration is insufficient. The intention is to minimize the number of forced stationary regenerations.

Strategy

Passive regeneration occurs when the exhaust gas temperature (EGT) at the DPF inlet and the NOx to particulate matter ratio are high enough to oxidize the particulate matter. Passive regeneration is a slow reaction. Once it starts it can be a continuous process.

Forced stationary regeneration is a faster reaction that takes approximately 25 minutes to completely oxidize accumulated particulate matter. The engine control module (ECM) controls forced stationary regeneration with input from the aftertreatment control module (ACM). The ECM determines when to begin a forced stationary regeneration, controls the correct fuel quantity from the aftertreatment hydrocarbon doser based on temperature limits, and determines when to end a forced stationary regeneration. A heat mode is activated that allows the EGT to rise to the minimum temperature needed for a forced stationary regeneration.

Activation

When passive regeneration occurs the driver is not aware of it. Passive regeneration does not change engine operation.

Forced stationary regeneration has to be started by the driver with a dashboard switch when a warning light flashes and there is "regeneration needed" message. The driver can not start the forced stationary regeneration without notification from the engine.

Deactivation

- Passive regeneration: ignition key in the OFF position
- Forced stationary regeneration: ignition key in the OFF position or parking break OFF, vehicle speed greater than 2 km/hr (1 mph), gear engaged/pedal

After-Market Service

WARNING

The service technician must make sure that the vehicle is in a safe location. The high temperatures created during the aftertreatment DPF regeneration process can cause a fire if flammable materials are too close to the exhaust pipe or muffler. Serious personal injury can result and the vehicle or equipment can be damaged.

CAUTION

The following precautions should be considered before handling the diesel particulate filter (DPF) components:

- A. Wear suitable eye protection.
- B. Wear suitable overalls or apron and heavy-duty gloves to avoid skin contact.
- C. Wear suitable respirator to avoid inhalation.
- D. Ensure adequate ventilation.

Ash is the residue from the noncombustible part of the particulate matter and accumulates in the filter. Lubrication oil consumed by the engine is usually the source of ash. Filters must be cleaned to avoid excessive back pressure. The DPF has been sized to meet or exceed the EPA service interval regulations of 240 000 km (150,000 miles) or 4,500 hours. The normal DPF filter insert replacement interval is 400 000 km (250,000 miles).

A trained service technician at a service center will determine if the aftertreatment DPF ash load is excessive and if the filter should be removed from the aftertreatment DPF and replaced. If the aftertreatment DPF ash load is below the removal level, the service technician can run a manual stationary aftertreatment DPF regeneration using Tech Tool.

The aftertreatment diesel oxidation catalyst (DOC) is not serviceable.

Aftertreatment Diesel Particulate Filter (DPF)

The aftertreatment DPF with diesel oxidation catalyst (DOC) and particulate trap reduces the emission of particulates (soot), hydrocarbons (HC) and carbon monoxide (CO).

Only Ultra Low Sulphur Diesel with a sulphur limit of 15 parts per million may be used to prevent clogging the aftertreatment DPF. **The maximum allowable blend of biodiesel is 5%.**

In the aftertreatment DPF system, soot is trapped in a catalyzed ceramic monolith particulate filter with noble metal coating. The aftertreatment DPF is regenerated passively or actively by an aftertreatment hydrocarbon doser that injects diesel fuel to burn the exhaust gases by catalytic reaction. This reduces the amount of soot and extends the life of the aftertreatment DPF.

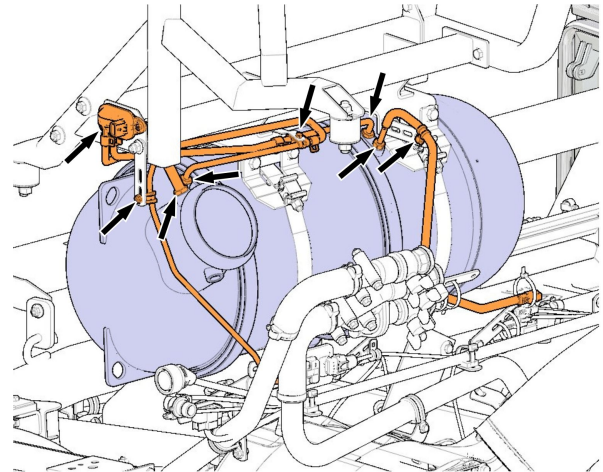
The aftertreatment DPF system is designed to primarily use passive aftertreatment DPF regeneration, which removes soot from the monolith by a catalytic reaction process that does not use additional fuel.

If the duty cycle is more “stop-and-go”, passive aftertreatment DPF regeneration might be insufficient to remove soot. Then a forced stationary regeneration will be necessary.

To increase the exhaust gas temperature (EGT) and maintain it during the heat mode required by forced stationary regeneration, an engine turbocharger compressor bypass valve is connected to the compressor side of the turbocharger. It recirculates part of the warm charge air from the outlet to the inlet of the turbocharger. A solenoid valve turns the bypass valve on or off.

The DPF is mounted above the engine at the back of the bus. There are two NOx sensors used with US2010 emissions engines. One is mounted on the DPF outlet pipe and the other is mounted on the pipe after the selective catalytic reduction (SCR) unit. Refer to the aftertreatment SCR system section of this bulletin for more details about SCR.

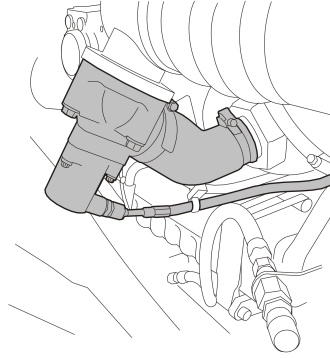
The aftertreatment DPF continuously oxidizes particles trapped in it. Some of the particles trapped in the aftertreatment DPF are inorganic material (ash) that can't be oxidized. The aftertreatment DPF must be serviced, because the ash will eventually build up, block the filter, and create exhaust gas back pressure. This increases fuel consumption and can cause derate, excessive engine wear or damage, and aftertreatment DPF damage.



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Engine Turbocharger Compressor Bypass Valve

Lower torque levels require more heat for efficient aftertreatment diesel particulate filter (DPF) regeneration. The engine turbocharger compressor bypass valve can create higher exhaust gas temperatures (EGTs) by reducing turbocharger effectiveness. The bypass valve recirculates boosted air back into the turbocharger compressor inlet. This raises the EGT and maintains the aftertreatment diesel oxidation catalyst (DOC) temperature at a level that allows DPF regeneration.



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Aftertreatment Hydrocarbon Dosing System

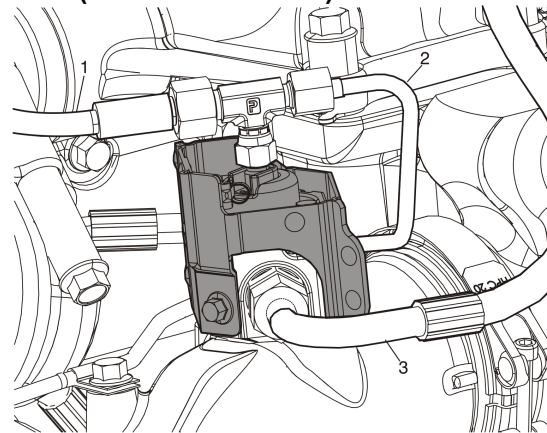
The aftertreatment hydrocarbon doser injects diesel fuel into the exhaust stream to increase the exhaust gas temperature (EGT) to the range needed for forced aftertreatment diesel particulate filter (DPF) regeneration when passive DPF regeneration is insufficient to prevent a high soot level in the filter. The engine control module (ECM) notifies the driver that a forced stationary regeneration is needed so the driver can start it with a switch on the dashboard. A service technician can start it manually in a safe location. The aftertreatment hydrocarbon doser is also used when the vehicle is moving to heat up the system and quickly get the engine in compliance with US2010 emissions requirements. At idle this is done by adjusting the engine timing and fuel delivery to increase EGT.

Aftertreatment Hydrocarbon Dosing System Components (Previous Version)

US2010 emissions compliant engines have a continuous air purge system which removes any fuel remaining in the doser after aftertreatment DPF regeneration. When the engine is operating, there is a constant flow of air through the doser. The secondary vehicle air system, which is off when the engine is off, supplies the air. The main components of the previous system are:

- Chassis-mounted pressure regulator with inlet filter
- Doser-mounted check valve assembly
- Air and fuel supply tubes and hoses
- Air dryer cartridge with coalescing element
- Air shut-off valve

The secondary air system sends air to the in-line filter mounted on the pressure regulator inlet. The pressure regulator lowers the air pressure from chassis pressure, 620-825 kPa (90-120 psi), to approximately 220 kPa (32 psi). Air from the regulator flows through a one-way check valve with a filter screen, which prevents back-flow to the regulator. Air then flows through the doser and into the engine exhaust stream. Fuel is also sent to the doser check valve through a one-way check valve. The ECM controls air and fuel flow to the doser. The shut-off valve prevents air leakage into the fuel system when the ignition switch is in the OFF position.



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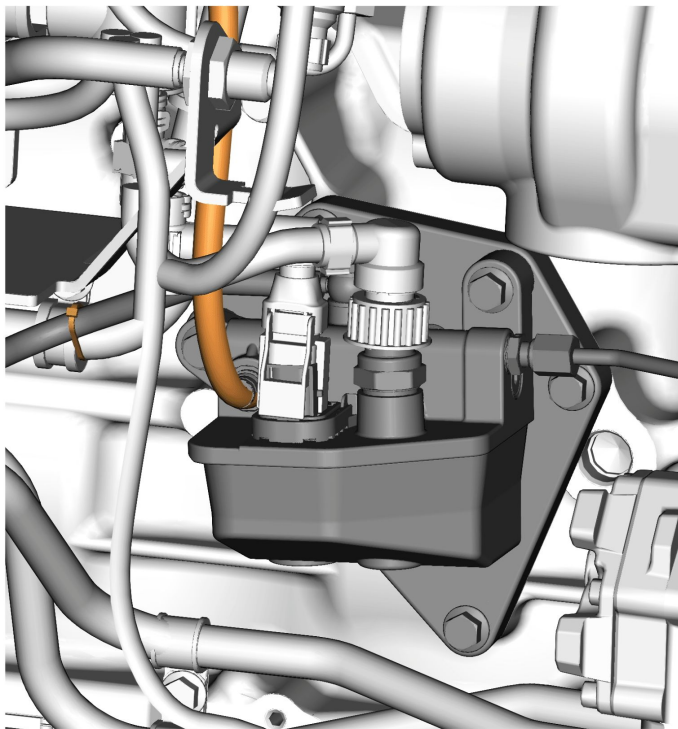
- 1 Air Line
- 2 Fuel Line
- 3 Coolant Line

Aftertreatment Hydrocarbon Dosing System Components (New Version)

The main components of the new system are:

- Aftertreatment hydrocarbon dosing module
- Aftertreatment hydrocarbon doser
- Air and fuel supply tubes and hoses
- Chassis-mounted pressure regulator with inlet filter
- Air dryer cartridge with coalescing element

The aftertreatment hydrocarbon dosing module contains three non-serviceable valves, the aftertreatment fuel shutoff valve, aftertreatment purge air valve and aftertreatment hydrocarbon dosing control valve, and a serviceable aftertreatment fuel pressure sensor.

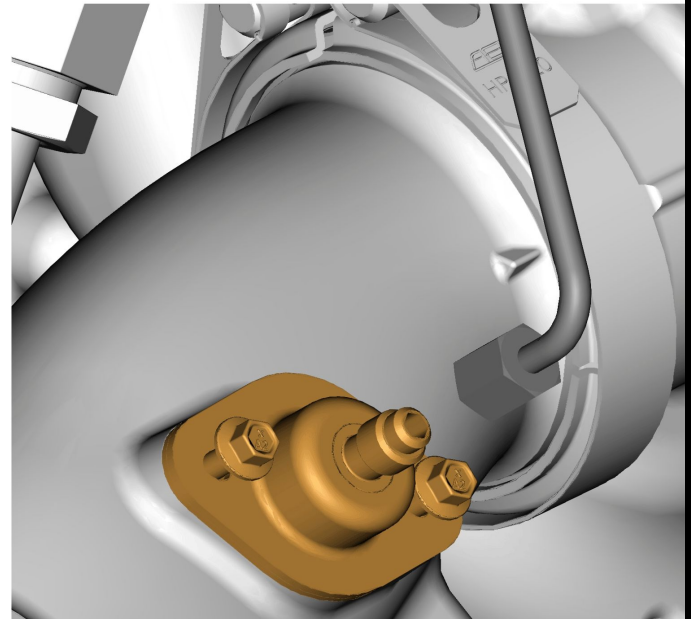


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Aftertreatment Hydrocarbon Dosing Module

The secondary air system sends air to the in-line filter mounted on the pressure regulator inlet. The pressure regulator lowers the air pressure from chassis pressure, 620-825 kPa (90–120 psi), to approximately 220 kPa (32 psi). During air purge operation, the engine control module (ECM) sends a voltage signal to open the aftertreatment purge air valve. This allows air pressure to flow into the aftertreatment hydrocarbon dosing module. The ECM then sends a signal to the aftertreatment hydrocarbon dosing control valve that allows purge air pressure to be monitored by a signal from the aftertreatment fuel pressure sensor to the ECM. The ECM uses this input to determine if the system is operating correctly.

During aftertreatment DPF regeneration, the ECM sends a voltage signal to open the aftertreatment fuel shutoff valve. This allows fuel to flow into the aftertreatment hydrocarbon dosing module. The aftertreatment fuel pressure sensor monitors the fuel pressure value and sends a reference signal to the ECM. The ECM then sends a signal to the aftertreatment hydrocarbon dosing control valve that regulates the amount of fuel delivered to the aftertreatment hydrocarbon doser through the air/fuel line.



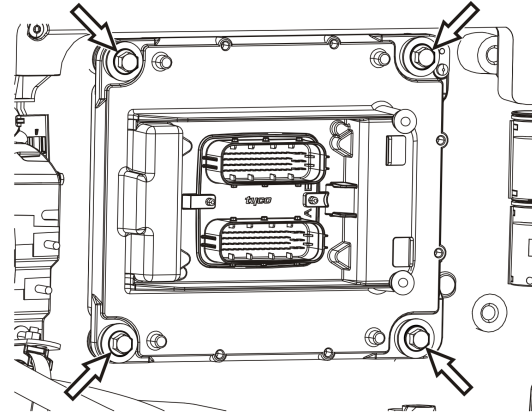
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Aftertreatment Hydrocarbon Doser

Engine Control Module (ECM)

The engine control module (ECM) controls the aftertreatment systems. The ECM monitors elapsed time, distance travelled, fuel consumption, diesel particulate filter (DPF) soot accumulation, and other sensor signals to determine when conditions are right to start an aftertreatment DPF regeneration.

The ECM also monitors all the valves and components that are required to make sure that aftertreatment DPF regeneration is controlled and successful. These include, but are not limited to, control of the engine turbocharger compressor bypass valve, the turbocharger actuator and the exhaust gas recirculation (EGR) valve position. Control of these and other components is essential for a successful aftertreatment DPF regeneration.



W2005598

Engine Control Module

Emission Control Sensors

The engine control module (ECM), in combination with the aftertreatment control module (ACM), controls the aftertreatment systems by analyzing the data it receives from sensors located throughout the systems. Included are sensors that monitor the variable geometry turbocharger (VGT), exhaust gas recirculation (EGR) system, engine coolant, engine position, aftertreatment diesel particulate filter (DPF) and aftertreatment selective catalytic reduction (SCR). Chassis-mounted sensors are also required, including those that monitor the ambient air temperature (AAT). Examples of some of the main sensors are listed below. Sensors may vary depending on the system used.

1 Turbocharger

- VGT Wheel Speed Sensor
- VGT Position Sensor
- Intake Manifold Pressure (IMP) Sensor
- Intake Manifold Air Temperature Sensor

2 Engine Position

- Camshaft Position (CMP) Sensor
- Crankshaft Position (CKP) Sensor

3 Engine Coolant

- Engine Coolant Temperature (ECT) Sensor

4 Aftertreatment Diesel Particulate Filter (DPF)

- Engine Exhaust Gas Temperature (EGT) Sensor
- Aftertreatment DPF Intake Temperature Sensor
- Aftertreatment DPF Outlet Temperature Sensor
- Aftertreatment DPF Differential Pressure Sensor
- Aftertreatment Outlet NOx Sensor
- Aftertreatment Fuel Pressure Sensor

5 EGR System

- EGR Temperature Sensor
- EGR Differential Pressure Sensor

6 Intake Air Sensors

- Intake Air Temperature (IAT) Sensor
- Ambient Air Temperature (AAT) Sensor
- Barometric Pressure (BARO) Sensor

7 Aftertreatment Selective Catalytic Reduction (SCR) System

- Aftertreatment Diesel Exhaust Fluid (DEF) Dosing Pressure Sensor
- Aftertreatment DEF Tank Temperature Sensor
- Aftertreatment DEF Tank Level Sensor
- Aftertreatment Outlet NOx Sensor

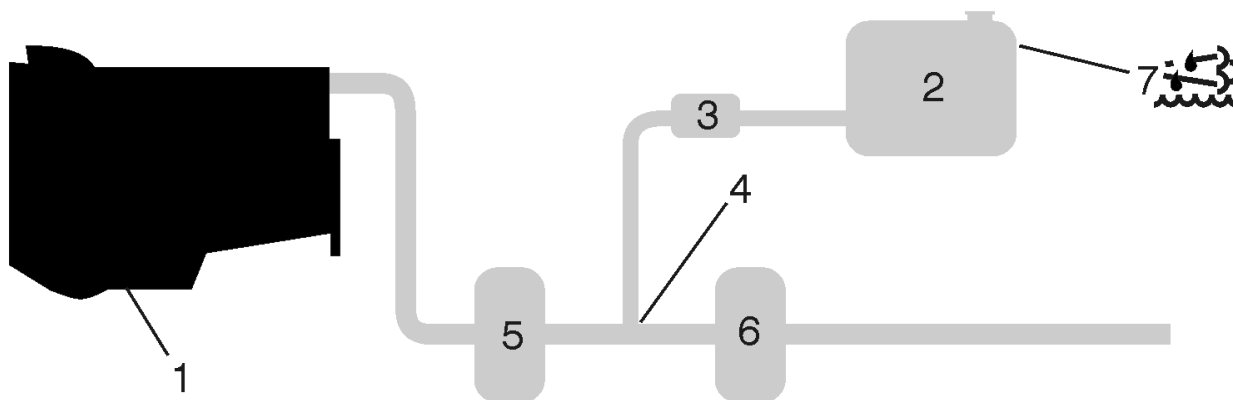
Aftertreatment Selective Catalytic Reduction (SCR) System

US2010 engines use a selective catalytic reduction (SCR) system with diesel exhaust fluid (DEF) dosing to meet US2010 NOx emission regulations, which apply to all heavy duty diesel engines built after January 1, 2010. The new US2010 standards require 83% reduction in nitrogen oxide (NOx) emissions compared to US07 standards. The aftertreatment SCR system reduces NOx emissions.

The SCR system adds DEF to the exhaust stream. The DEF pump (3) pulls DEF from the DEF tank (2) and sends it to the aftertreatment DEF dosing valve (4). The dosing valve injects DEF into the exhaust gases between the aftertreatment diesel particulate filter (DPF) (5) and the aftertreatment SCR catalyst (6). The treated exhaust then enters the SCR Catalyst where the heat in the exhaust

system converts the DEF into ammonia and carbon dioxide. Ammonia is the active substance in the chemical reaction in the SCR catalyst. This chemical reaction occurs at temperatures above 200° C (390° F) and converts nitrogen oxides (NOx) into harmless nitrogen gas and water vapor, which occur naturally in the environment.

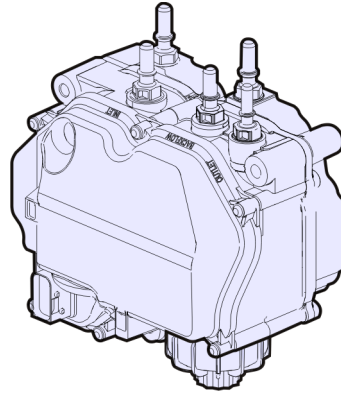
The engine control module (ECM) calculates how much and when DEF should be added to the exhaust gases based on the current engine load. The ECM then signals the aftertreatment control module (ACM), which controls the aftertreatment DEF pump and DEF dosing valve. This process maximizes the reduction of emissions during all engine operating conditions.



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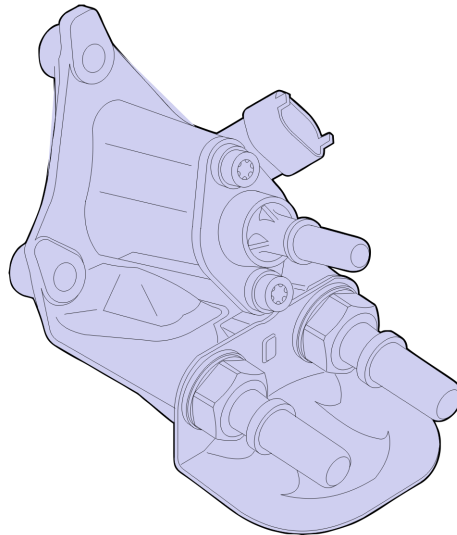
- 1 Diesel Engine
- 2 Aftertreatment DEF Tank
- 3 Aftertreatment DEF Pump
- 4 Aftertreatment DEF Dosing Valve
- 5 Aftertreatment DPF
- 6 Aftertreatment SCR Catalyst
- 7 Aftertreatment DEF Tank Gauge

Aftertreatment Selective Catalytic Reduction (SCR) System Components and Function



W2054664

Aftertreatment DEF Pump



W2038622

Aftertreatment DEF Dosing Valve



W2055491

Aftertreatment SCR Catalyst

The aftertreatment DEF tank level sensor sends a signal to the ACM that tells the ACM that the DEF is above the required minimum level in the DEF tank. The ACM starts the DEF pump, which builds up the system pressure to 900 kPa (130 PSI).

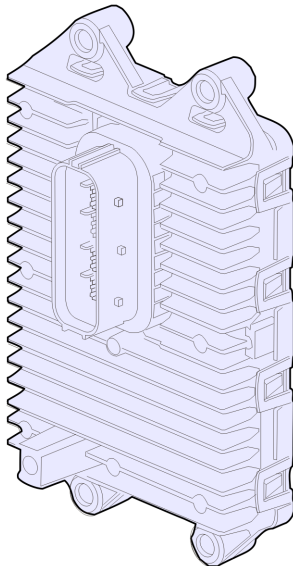
When the SCR system meets certain conditions, the engine control module (ECM) sends a signal to the ACM. The ACM opens the DEF dosing valve, which injects the DEF into the exhaust pipe before the SCR catalyst. The DEF system target pressure of 900 kPa (130 PSI) is maintained by pump motor speed adjustments. A constant overflow of DEF circulates through the backflow orifice to keep the pressure stable.

The high exhaust gas temperature (EGT) converts the DEF into ammonia and carbon dioxide. The ammonia causes a chemical reaction in the SCR catalyst that converts the exhaust gases into nitrogen gas and water vapor.

The nitrogen oxide (NOx) sensor measures the NOx level in the exhaust gases. If the system does not maintain the required emissions level, a warning light appears on the instrument panel in the cab and a diagnostic trouble code (DTC) is stored in the ECM.

The DPF outlet temperature sensor measures the EGT of exhaust gas entering the SCR catalyst. The ACM monitors both DPF outlet temperature and NOx sensor signals, calculates the required DEF dosing amount and activates the DEF dosing valve. After the dosing valve is activated, the correct amount of DEF will be injected into the exhaust stream.

Aftertreatment Control Module (ACM)



W2038621

The DEF is temperature sensitive. A heating loop in the DEF tank contains hot engine coolant and heats the DEF to thaw it if it is frozen and to prevent it from freezing during engine operation. The tank coolant heating loop also heats the DEF pump. The lines to and from the DEF tank are electrically heated and insulated.

A temperature sensor in the DEF tank continuously monitors the temperature in the tank. If the temperature falls below 10° C (50° F), the ACM opens a DEF tank heating valve which allows hot engine coolant to pass through the DEF tank heating loop and the DEF pump. When the DEF reaches a temperature of 15° C (60° F), the DEF tank temperature sensor signals the ACM which closes the valve and stops the heating. If the ambient air temperature (AAT) drops to 4° C (40° F) or less, the DEF line heaters turn on periodically to keep the lines from freezing.

If the system detects a fault that affects the DEF injection process, a malfunction indicator light (MIL) appears on the instrument panel in the cab and a DTC is stored in the ECM.

A gauge on the instrument panel in the cab shows the level of DEF in the tank. When the DEF level in the DEF tank gets low, an aftertreatment DEF tank low level indicator appears. See "Aftertreatment DEF Tank Level — Driver Warning and Inducement", page 15 for more information about low DEF level.

When the engine is shut down, DEF is partly purged from the DEF system. The purging is started by the activation of the aftertreatment DEF return valve and DEF dosing valve and is active for one minute after the engine stops.

The ACM controls the following components in the aftertreatment selective catalytic reduction (SCR) system.

- Aftertreatment Diesel Exhaust Fluid (DEF) Dosing Valve
- Aftertreatment DEF Tank Heater Valve
- Aftertreatment DEF Line Heaters
- Aftertreatment DEF Pump
- Aftertreatment DEF Return Valve
- Aftertreatment DEF Tank Level Sensor

The ACM also monitors the following in the SCR system.

- Aftertreatment DEF Dosing Pressure
- Aftertreatment DEF Tank Temperature
- Aftertreatment DEF Tank Level
- Aftertreatment DPF Intake/Outlet Temperature
- Aftertreatment DPF Differential Pressure
- NOx Sensors

Aftertreatment Diesel Exhaust Fluid (DEF)

WARNING

Do not put diesel fuel in the aftertreatment DEF tank. If diesel fuel is injected into the hot exhaust gases along with the DEF, it could ignite explosively and start a fire, which could cause serious personal injury and damage the exhaust system. The DEF tank filler cap and diesel tank filler cap are labeled and the filler caps, necks and nozzles are different sizes to help prevent the tanks from being filled with the wrong fuel.

WARNING

Aftertreatment DEF is an irritant. Contact with aftertreatment DEF can irritate the skin and eyes. Inhaling aftertreatment DEF mist can cause lung irritation. Avoid aftertreatment DEF contact with skin and eyes. Avoid breathing mist created by aftertreatment DEF spray.

CAUTION

Only use VOLVO approved aftertreatment DEF in the aftertreatment selective catalytic reduction (SCR) system. Do not use DEF that is not approved by VOLVO, because it will damage the aftertreatment system permanently, decrease engine output, possibly damage other engine components and may impact your product warranties.

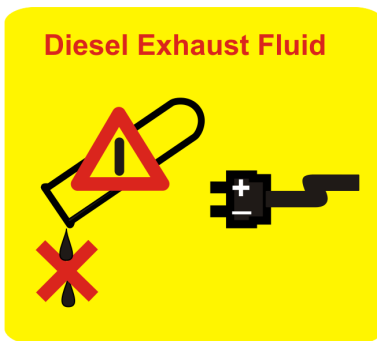
Aftertreatment DEF is a solution of urea crystals and deionized water. Urea is a nitrogen compound that turns into ammonia and carbon dioxide when it is heated. It is colorless, not flammable and freezes at -11° C (12° F). DEF is not dangerous when handled correctly. However, it is highly corrosive to metal, particularly copper and aluminum. See "Aftertreatment DEF Quality — Driver Warning and Inducement", page 16 for more information about DEF quality.

Handling Aftertreatment DEF

CAUTION

When disconnecting lines and components, do not spill aftertreatment DEF onto separated connectors. If this occurs, replace the connectors immediately. Cleaning with water or compressed air will not help as the aftertreatment DEF quickly oxidizes metal and due to capillary action "creeps" along cabling at a speed of about 600 mm/hr (24 in/hr).

When you handle DEF make sure the electrical connectors are either connected or well wrapped in a protective cover if they are disconnected.



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Wrap Exposed Connectors

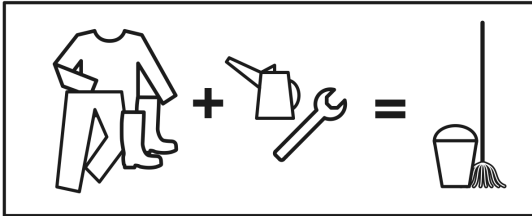
When You Replace A DEF Pump Or DEF Dosing Valve:

- Make sure the system is depressurized.
- Always detach the aftertreatment DEF lines **before** you disconnect the electrical connectors to prevent DEF spillage from entering the connectors.
- Make sure you wrap exposed connectors in a protective cover.
- Make sure you seal the system so the DEF will not crystallize if the system has to be disconnected for several hours. Part number 21376772 is a set of six cap plugs that can be used to plug the fittings on the DEF pump.

Cleaning Tools And Clothing

CAUTION

Make sure to thoroughly clean aftertreatment DEF off of tools and clothes, so that fluid or crystals do not transfer to other components that could be damaged.



T2023003

DEF Spills

WARNING

Aftertreatment DEF spilled onto hot components will quickly vaporize. Turn your face away to avoid serious personal injury. If you **inhale** DEF vapor, move to a location where you can breathe fresh air. Get medical help, if necessary.

Do not flush DEF spillages into a regular drainage system. Dispose of DEF properly according to local regulations.

If DEF **contacts skin**, remove contaminated clothing and rinse skin with plenty of water.

If DEF **contacts eyes**, rinse eyes for several minutes. Get medical help, if necessary.

Do not allow DEF to come into contact with other chemicals.

DEF is not flammable. If it is exposed to high temperatures, it breaks down into ammonia and carbon dioxide.

DEF is highly corrosive to certain metals, including copper and aluminum.

If DEF spills on the vehicle, wipe it off and rinse with water. Spilled DEF can form white crystals on the vehicle. Rinse them off with water.






Aftertreatment DEF Tank Level — Driver Warning and Inducement

Note: See the vehicle operator’s manual for additional information about driver warnings and inducements.

DEF tanks are sized to have no less than twice the diesel fuel tank mileage or hour range.

The vehicle instrument cluster has a permanent Aftertreatment DEF tank level gauge.






Note: Repeated acts of tampering, or a fault that is not repaired correctly, may cause the inducement level to return to the highest level of inducement previously achieved.

Triggers	Diagnostic Trouble Codes	Aftertreatment DEF Tank Low Level Indicator	Inducement
100% to 12% Aftertreatment DEF Tank Level Gauge	None	OFF	None
<=12% Aftertreatment DEF Tank Level Gauge	SPN 5246 FMI 15 SPN 1761 FMI 11	DEF Solid  W2029416	None
0% Aftertreatment DEF Tank Level Gauge (approximately 1% DEF Remaining)	SPN 5246 FMI 16 SPN 1761 FMI 18	DEF Flashing  W2029415	25% Torque Reduction
0% Aftertreatment DEF Tank Gauge Insufficient DEF Pump Pressure Diesel Fuel Refueling >15% Vehicle stationary or shut off for more than 20 minutes	SPN 5246 FMI 0 SPN 4095 FMI 7 SPN 1761 FMI 18	DEF Flashing  W2029415	8 km/h (5 mph) Road Speed Limit (RSL) ¹
DEF tank empty and refueling event with parking brake applied Note: To avoid the Back Stop feature, the DEF tank must be filled to more than 18% of capacity.	SPN 5246 FMI 0 SPN 1761 FMI 18	DEF Flashing  W2029415	8 km/h (5 mph) Road Speed Limit (RSL) ¹
Back Stop Feature	SPN 5246 FMI 0 SPN 1761 FMI 18	DEF Flashing  W2029415	8 km/h (5 mph) Road Speed Limit (RSL) ¹

¹ Vehicle has to be stationary before 8 km/h (5 mph) Road Speed Limit (RSL) becomes Active.

Aftertreatment DEF Quality — Driver Warning and Inducement

Note: See the vehicle operator's manual for additional information about driver warnings and inducements.

Triggers	Diagnostic Trouble Codes	Aftertreatment DEF Quality Indicator	Inducement
Good DEF Quality	None	OFF	None
Poor DEF Quality DTC Initial Detected ^{1 2}	SPN 4094 FMI 18 SPN 5246 FMI 15	 W2029417	None
Poor DEF Quality DTC Initial Detected + 1 hour	SPN 4094 FMI 18 SPN 5246 FMI 16	 W2029417	25% Torque Reduction
Poor DEF Quality DTC Initial Detected + 4 hours	SPN 4094 FMI 18 SPN 5246 FMI 16	 W2029417	25% Torque Reduction
Diesel Fuel Refueling Event with Parking Brake ON (>15% fuel level increase) Vehicle stopped or engine shut down for >20 minutes (Back Stop Feature)	SPN 4094 FMI 18 SPN 5246 FMI 0	 W2029417	8 km/h (5 mph) Road Speed Limit (RSL) ³
Key Cycle Before Evaluation Completed/Confirmed DEF Dilution Temporary Exit from 8 km/h (5 mph) Inducement	SPN 4094 FMI 1 SPN 4094 FMI 18	 W2029417	25% Torque Reduction

¹ Based on a confirmed NOx sensor evaluation of measured versus predicted SCR NOx conversion.

² Poor DEF Quality defined as DEF diluted with water in 50/50 proportions.

³ Vehicle has to be stationary before 8 km/h (5 mph) Road Speed Limit (RSL) becomes active.

Exit conditions for DEF Quality "8 km/h (5 mph) road speed limit" Inducement:









First Restart: Return to 25% torque reduction until proper DEF quality evaluation. If poor DEF quality is detected during the next monitoring cycle, then 8 km/h (5 mph) resumed after vehicle is stationary for 20 minutes¹. After one engine restart, Tech Tool is required to exit the 8 km/h (5 mph) RSL.

With Tech Tool Diagnostic Trouble Code (DTC) Clearing: Invoke 25% torque reduction until proper DEF quality evaluation. If poor DEF quality is detected during the next monitoring cycle then 8 km/h (5 mph) resumed after vehicle is stationary for 20 minutes.¹

¹ Chronological time, not engine run time.

Aftertreatment Tampering — Driver Warning and Inducement

Note: See the vehicle operator’s manual for additional information about driver warnings and inducements.

Triggers	Diagnostic Trouble Codes	Aftertreatment DEF Quality Indicator	Inducement
No Fault	None	OFF	None
Tampering Fault Detected	Refer to “SCR System Tampering Types”, page 18 for SCR Tampering DTC	 W2029417	None
Second Drive Cycle with Active DTC	Tampering DTC SPN 5246 FMI 15	 W2029417  W2036007	None
One Hour of Driving with Confirmed Active DTC	Tampering DTC SPN 5246 FMI 16	 W2029417  W2036007	25% Torque Reduction
Four Hours of Driving with Confirmed Active DTC	Tampering DTC SPN 5246 FMI 16	 W2029417  W2036007	25% Torque Reduction
Diesel Fuel Refueling Event with Parking Brake ON (>15% fuel level increase) Vehicle stopped or engine shut down for >20 minutes (Back Stop Feature)	Tampering DTC SPN 5246 FMI 0	 W2029417  W2036007	8 km/h (5 mph) Road Speed Limit (RSL) ¹

¹ Vehicle has to be stationary before 8 km/h (5 mph) Road Speed Limit (RSL) becomes active.

SCR System Tampering Types

SCR System Tampering Type	Diagnostic Trouble Code
Aftertreatment Control Module Disconnected	SPN 1231 FMI 9
Pre-SCR NOx Sensor Disconnected	SPN 3216 FMI 9
Post-SCR NOx Sensor Disconnected	SPN 3226 FMI 9
DEF Pump Disconnected	SPN 4334 FMI 5
DEF Dosing Valve Disconnected	SPN 5394 FMI 5
DEF Level Sensor Disconnected	SPN 1761 FMI 5
DEF Supply Line to DEF Pump Disconnected	SPN 5392 FMI 31
DEF Return Line Blocked or Plugged	SPN 5485 FMI 11
DEF Dosing Line Blocked or Plugged	SPN 5394 FMI 14

Misfilling Diesel or Aftertreatment DEF Tanks

Although diesel fuel and Aftertreatment DEF caps are clearly labeled and filler necks and nozzles are different accidents can happen.

Contamination of fluids by- misfilling of diesel or DEF in the wrong tank may result in vehicle malfunction.

Results of Misfilling DEF in Diesel Tank

- Engine may run poorly or not at all
- Injectors may be damaged
- Exhaust system corrosion may occur between turbocharger and Aftertreatment DPF
- On Board Diagnostic (OBD) Diagnostic Trouble Codes (DTC)

- Costly repairs

Results of Misfilling Diesel in Aftertreatment DEF Tank

- Aftertreatment SCR system may be damaged by diesel
- SCR Catalyst may be damaged by diesel (chemical damage)
- Emissions may be non-compliant
- On Board Diagnostic (OBD) Diagnostic Trouble Codes (DTC)
- Costly repairs