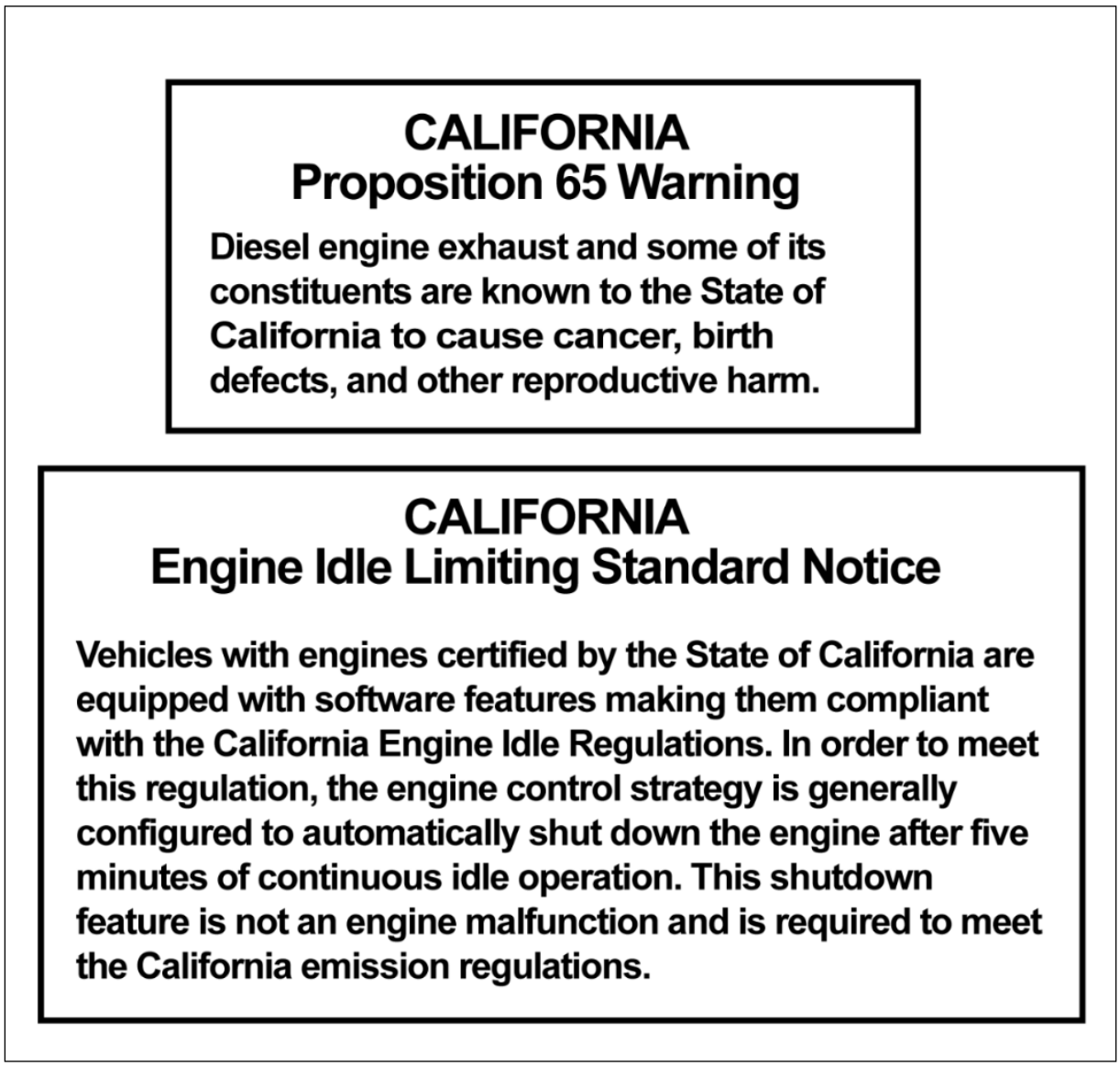
General Information

1.1 California Proposition 65 Warning and Engine Idle Notice



material is removed. Detroit does not recommend any specific chemical for this purpose. Follow the cleaner manufacturer's instructions. Make sure the cleaning solution is safe for the material being cleaned.

The part must be rinsed with water or steam cleaned after the solvent is used. It is best to wait to solvent or steam clean any component until it is almost ready for installation. This will minimize the possibility of debris contamination and accumulation of rust or oxidation.

> **WARNING**
>
> EYE INJURY
>
> To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

Parts should be dried with compressed air after being cleaned and rinsed. Blow the rinse water out of any screw holes.

1.6.5 Steam Cleaning

> **WARNING**
>
> FIRE HAZARD
>
> Do not power wash or steam clean the engine bay in the area of vehicle electrical components, unless specified by vehicle manuals or service literature. Power washing/steam cleaning can permanently damage these components, which could result in fire, personal injury, or property damage.

A steam cleaner is a necessary item in a large shop and is useful for removing heavy accumulations of grease and dirt from the exterior of the engine and its subassemblies.

> **WARNING**
>
> EYE INJURY
>
> To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

Parts should be dried with compressed air after being cleaned and rinsed. Blow the rinse water out of any screw holes

1.6.6 Rust Prevention

If parts are not to be used immediately after cleaning, coat them with a suitable rust preventive compound. The rust preventive compound must be removed before installing the parts onto an engine.

1.6.7 Tool Cleaning

Any special service tools used for internal engine, lubrication, or fuel system repairs should be kept clean to avoid debris contamination. Tools can attract just as much dirt and contaminants as engine parts. Fuel system tools should also be stored in sealed containers as an additional cleanliness measure.

1.9.12 Fire

Keep a charged fire extinguisher within reach. Be sure you have the correct type of extinguisher for the situation. The correct fire extinguisher types for specific working environments are listed in the following table.

Fire Extinguisher	Work Environment
Type A	Wood, Paper, Textile and Rubbish
Type B	Flammable Liquids
Type C	Electrical Equipment

1.9.13 Cleaning Agent

Avoid the use of carbon tetrachloride as a cleaning agent because of the harmful vapors that it releases. Ensure the work area is adequately ventilated. Use protective gloves, goggles or face shield, and apron.

⚠WARNING

PERSONAL INJURY

To avoid injury from harmful vapors or skin contact, do not use carbon tetrachloride as a cleaning agent.

Exercise caution against burns when using oxalic acid to clean the cooling passages of the engine.

1.9.14 Working on a Running Engine

When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns.

CAUTION

PERSONAL INJURY

To avoid injury from unguarded rotating and moving engine components, check that all protective devices have been reinstalled after working on the engine.

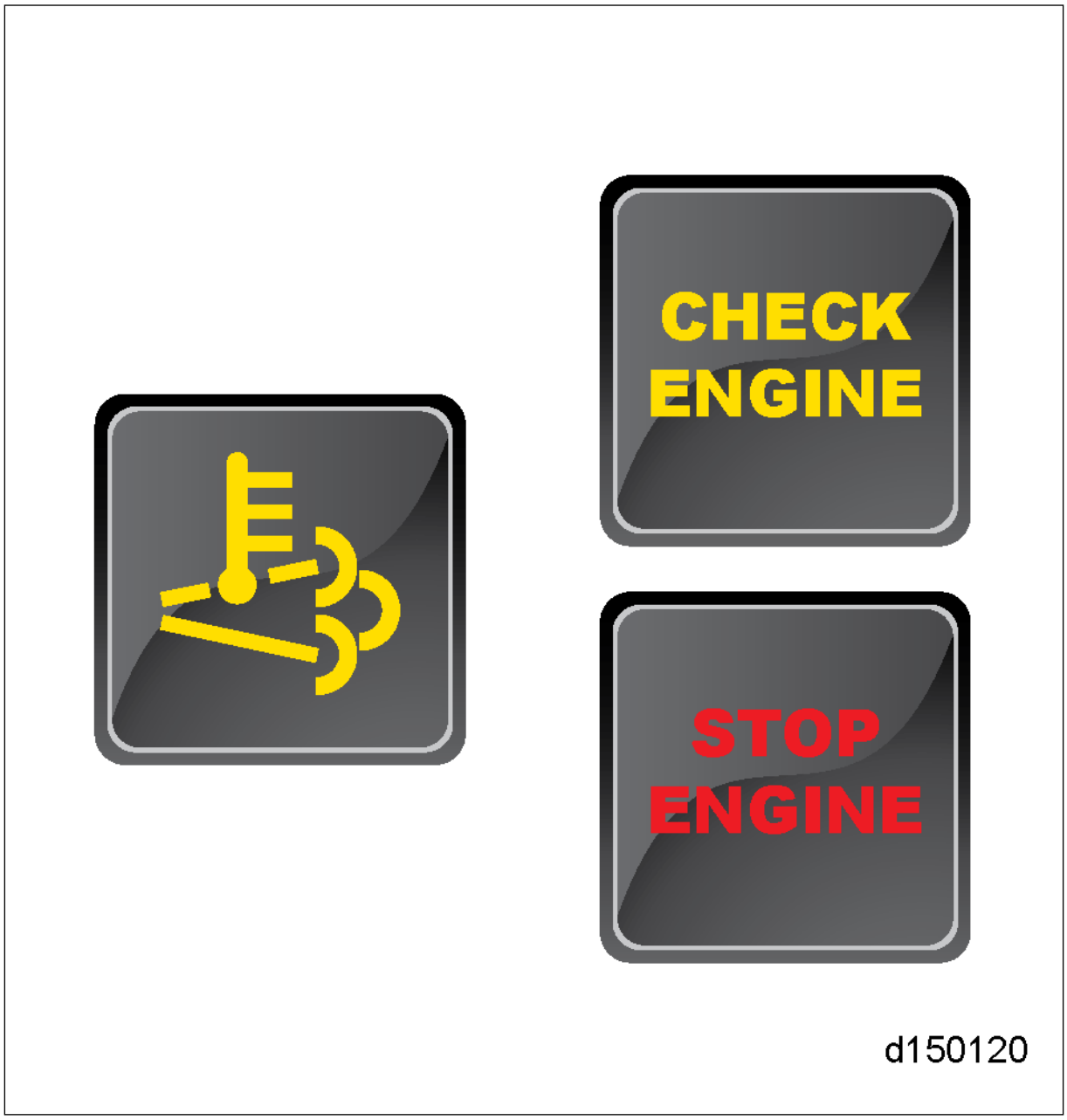
⚠WARNING

PERSONAL INJURY

To avoid injury, use care when working around moving belts and rotating parts on the engine.

1.9.15 Turbocharger Compressor Inlet Shield

A turbocharger compressor inlet shield, is available and must be used anytime the engine is operated with the air inlet piping removed. The shield helps to prevent foreign objects from entering and damaging the turbocharger and will prevent the mechanic from accidentally touching the turbocharger impeller.



2.1.10 Performing a Parked Regeneration

Perform a Parked Regeneration as follows:

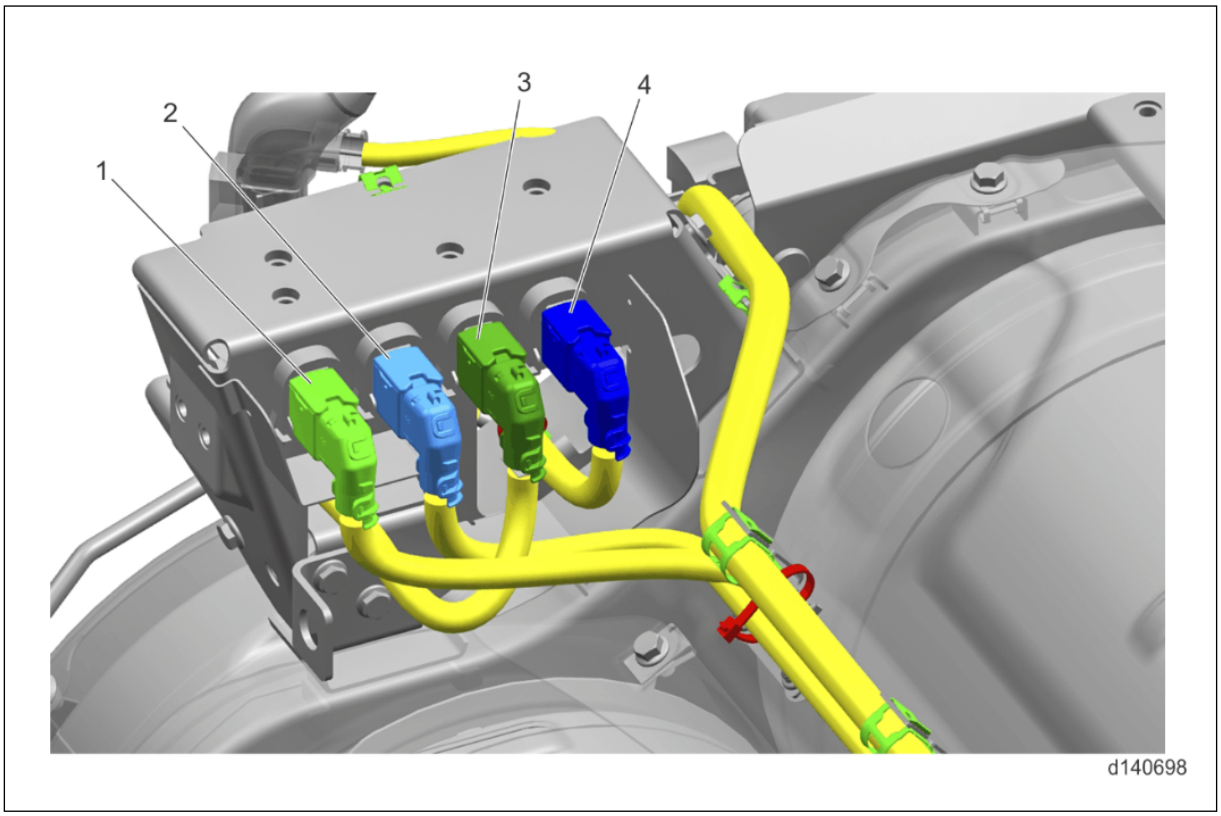
Note : Under factory default settings, when the Diesel Particulate Filter (DPF) Regeneration Lamp is not illuminated, the regeneration request switch is disabled.

Note : The driver MUST stay with the vehicle throughout the regeneration process.

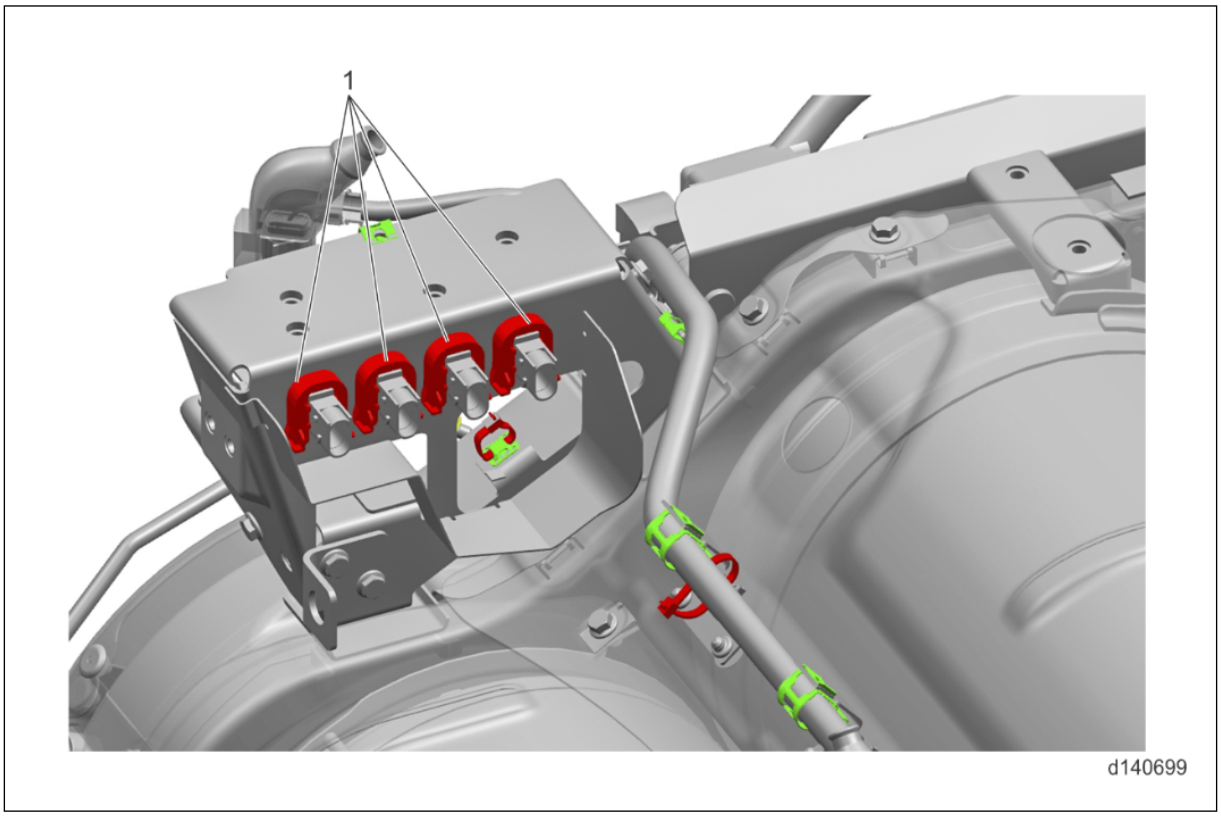
Note : Not all vehicles may be equipped with a Regeneration Request Switch due to application or user specification.

Note : The procedure will take approximately 30 to 45 minutes (depending on the amount of soot accumulated in the DPF).

When the parked regeneration request is accepted, the Diesel Particulate Filter (DPF) Regeneration lamp will turn ON one time for one second and then turn off for the remainder of the parked regeneration. The High Exhaust System Temperature (HEST) lamp will flash for one second every ten seconds and eventually become solid when



9. Remove the retaining clips (1) that secure the DOC inlet temperature, DOC outlet temperature, DPF outlet temperature sensor and SCR outlet temperature sensor harness connectors to the mounting bracket.



5. Remove the Diesel Oxidation Catalyst (DOC) inlet pressure sensor tube (1) by loosening the tube nut and removing it from the DOC inlet pressure port.

2.4.6 Inspection of the Diesel Oxidation Catalyst Inlet Pressure Sensor Tube

1. Inspect fitting and sensor port threads for damage. Repair/replace as needed.
2. Inspect the Diesel Oxidation Catalyst (DOC) Inlet Pressure Sensor Tube for leaks, cracks, blockages, or other damage. Clean or replace as needed.

2.4.7 Installation of the Diesel Oxidation Catalyst Inlet Pressure Sensor Tube

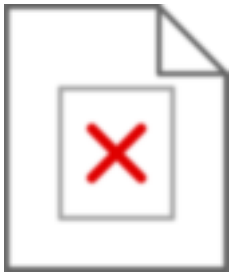
Note : DO NOT use excessive amounts of copper paste; copper paste will squeeze out during installation.

1. Apply copper paste on the tube nut threads, then install into the port on the 1-BOX™ configuration.

NOTICE

DO NOT over-tighten the tube nut; damage to threads may occur.

2. Install the DOC inlet pressure sensor tube (1) into the fitting. Torque tube nut to 12 N·m (9 lb·ft).



3. Install Diesel Oxidation Catalyst (DOC) inlet pressure sensor tube (1) into DOC inlet pressure port. Torque tube nut to 12 N·m (9 lb·ft).
4. Install the right-side steps.

CAUTION

ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

5. Connect the batteries.

2.4.8 Removal of the Diesel Particulate Filter Outlet Pressure Sensor Tube

1. Shut off engine and apply the parking brake, chock the wheels, and perform any other applicable safety steps.

CAUTION

ELECTRICAL SHOCK

Tool Part Number	Tool Description	Image
W470589060900	NOx Sensor Socket	 d580205

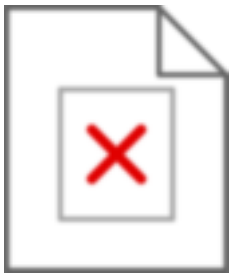
Note : DO NOT use excessive amounts of copper paste; copper paste will squeeze out during installation.

1. Apply copper paste to the threads of the NOx sensor, but do not allow any to get on the sensor probe.

NOTICE

DO NOT over-tighten sensors; damage to threads may occur.

2. Install the Selective Catalytic Reduction (SCR) outlet NOx sensor (1) to the 1-BOX™ configuration. Use the NOx sensor socket and torque to 50 N·m (37 lb·ft).

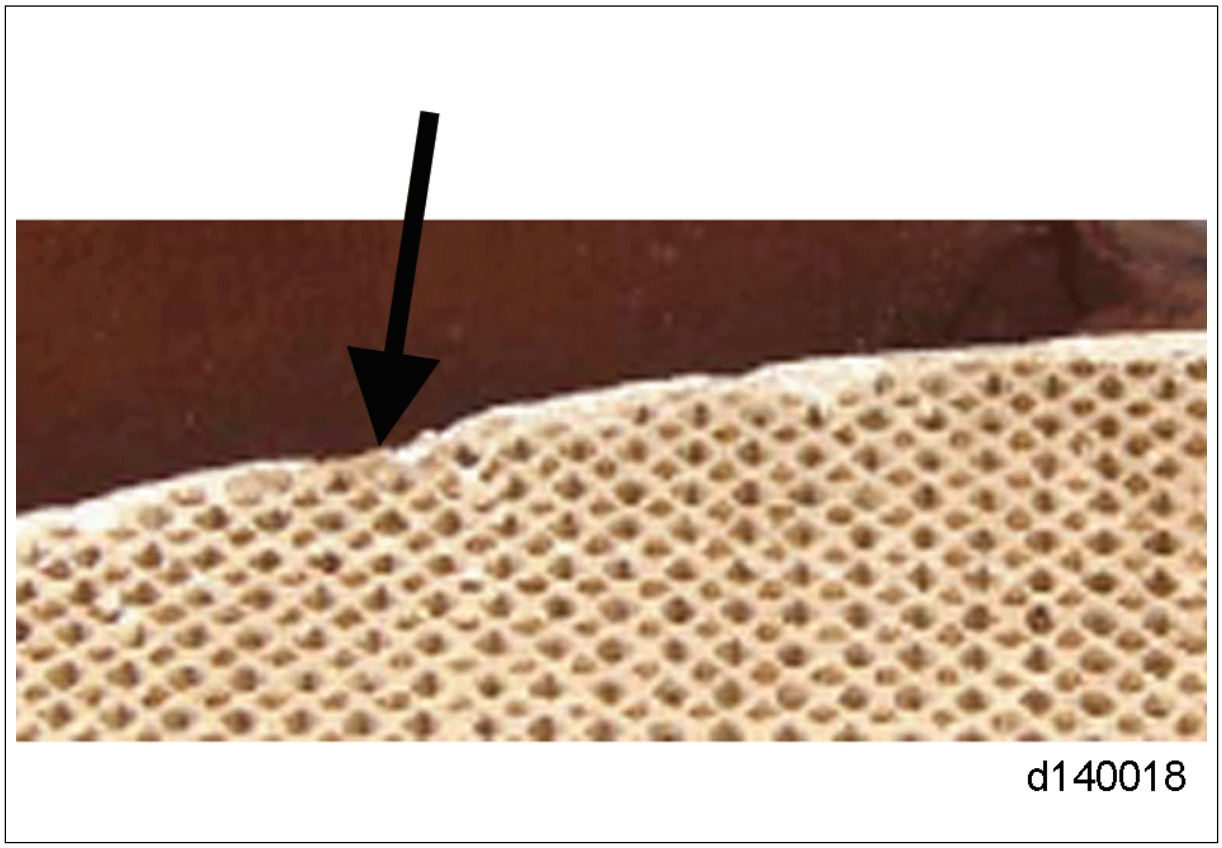


3. Install the SCR Outlet NOx sensor Electronic Control Unit (ECU) (6) onto the upper Aftertreatment Control Module (ACM) protective cover (5) using the mounting bolts and nuts. Torque to 9 N·m (7 lb·ft).
4. Route the SCR outlet NOx sensor wiring harness between ACM protective cover support brackets and install nylon straps to properly secure the harness.
5. Install the upper ACM protective cover and torque nuts to 10 N·m (7 lb·ft).
6. Connect the soot sensor ECU electrical connector (4).
7. Install right-side steps.

CAUTION

ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

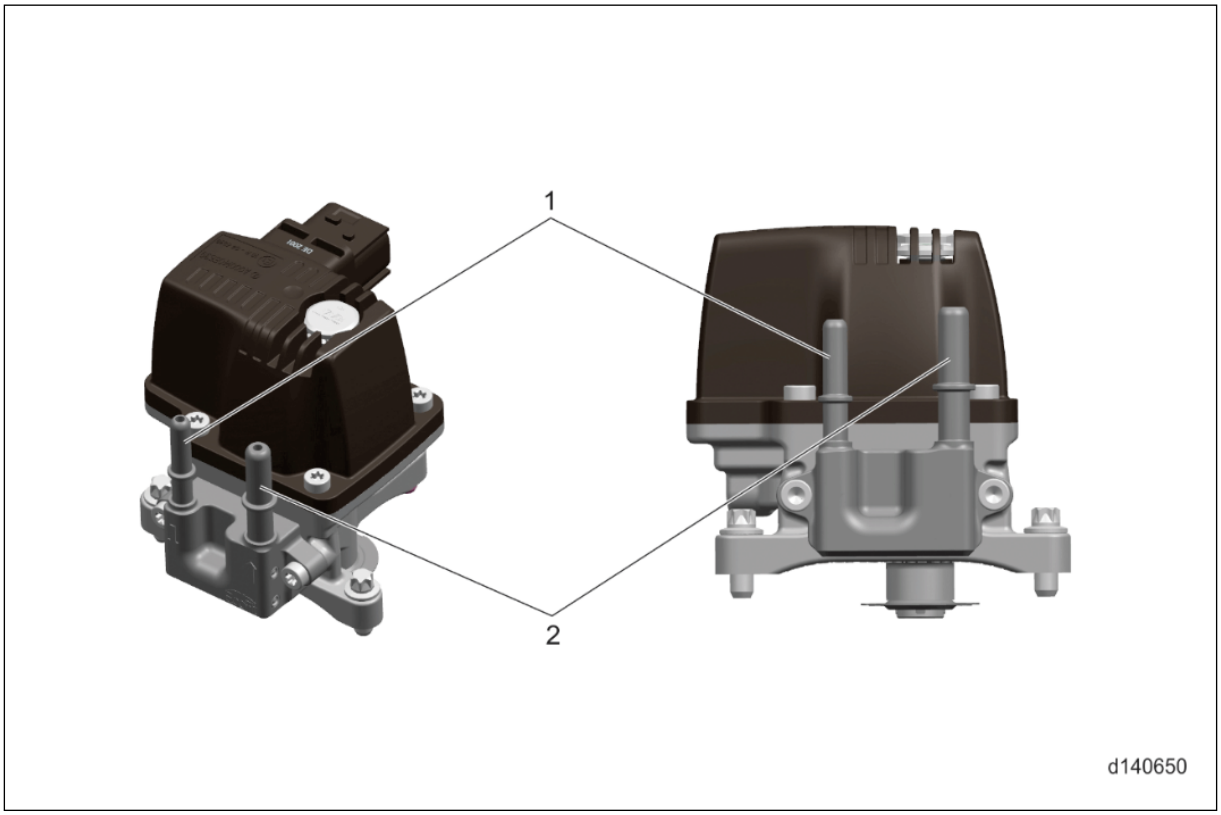


2. Inspect the DOC for movement of the substrate inside the housing. This condition is known as slippage, where the matting has released the substrate due to pressure and may cause damage to the substrate and the temperature sensor if the parts come in contact. If the DOC substrate has slipped and is in contact with or within ½ inch of the temperature sensor, replace the DOC.

CAUTION
ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Disconnect the batteries.
3. If necessary, remove right-side steps.
4. Disconnect the DEF supply and return lines from the doser inlet (1) and doser outlet (2) fittings.



5. Disconnect the DEF doser electrical connector (1).

2.7 Diesel Exhaust Fluid Lines

2.7.1 Removal of the Diesel Exhaust Fluid Lines

Remove as follows:

NOTICE

When required, discard fluids in accordance with Environmental Protection Agency (EPA) regulations.

⚠WARNING

PERSONAL INJURY

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

⚠WARNING

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

⚠WARNING

ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

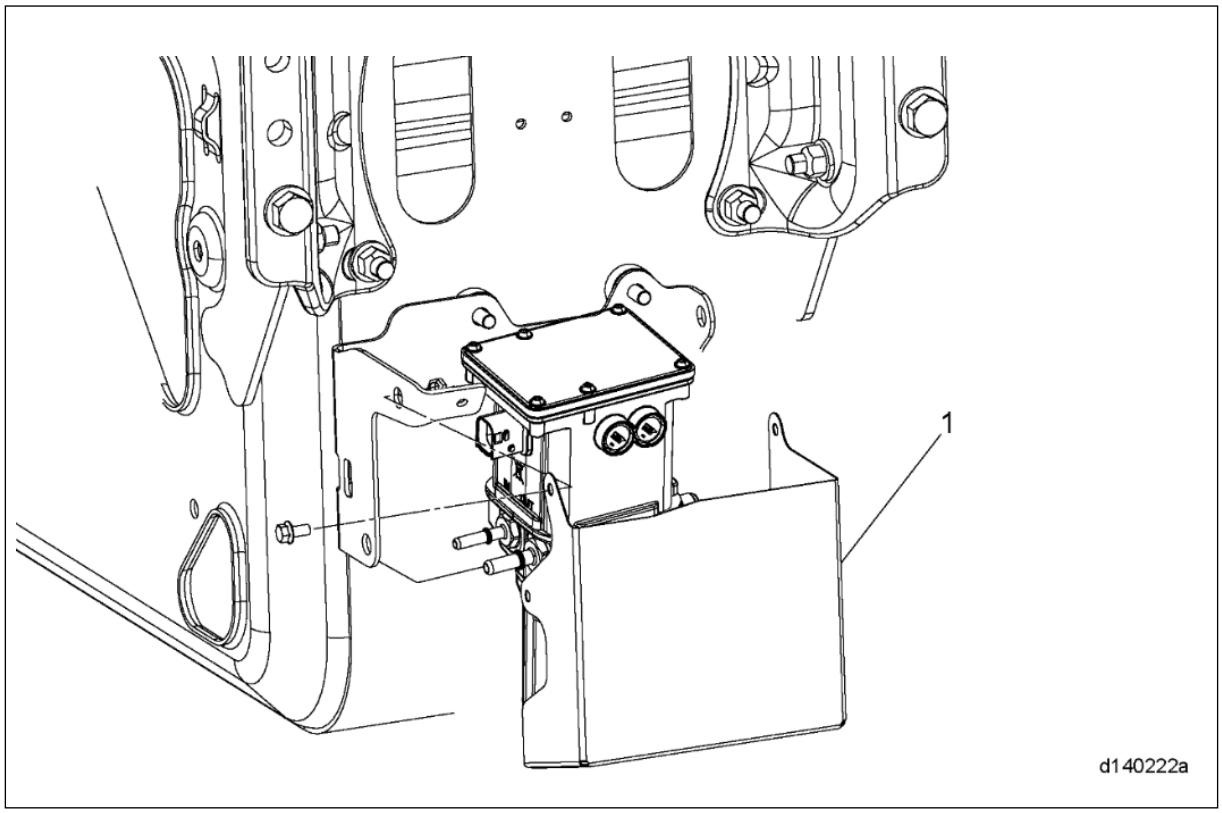
1. Shut off engine and apply the parking brake, chock the wheels, and perform any other applicable safety steps.

CAUTION

ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Disconnect the batteries.
3. If necessary, remove the right side steps.
4. Place drain pans underneath the DEF pump and the DEF dosing unit to catch any draining fluids.
5. Disconnect the DEF line heater electrical connector at the DEF pump.



9. Fill the cooling system. Refer to section "Cooling System Fill Procedure".

CAUTION
ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

10. Connect the batteries.

WARNING

PERSONAL INJURY

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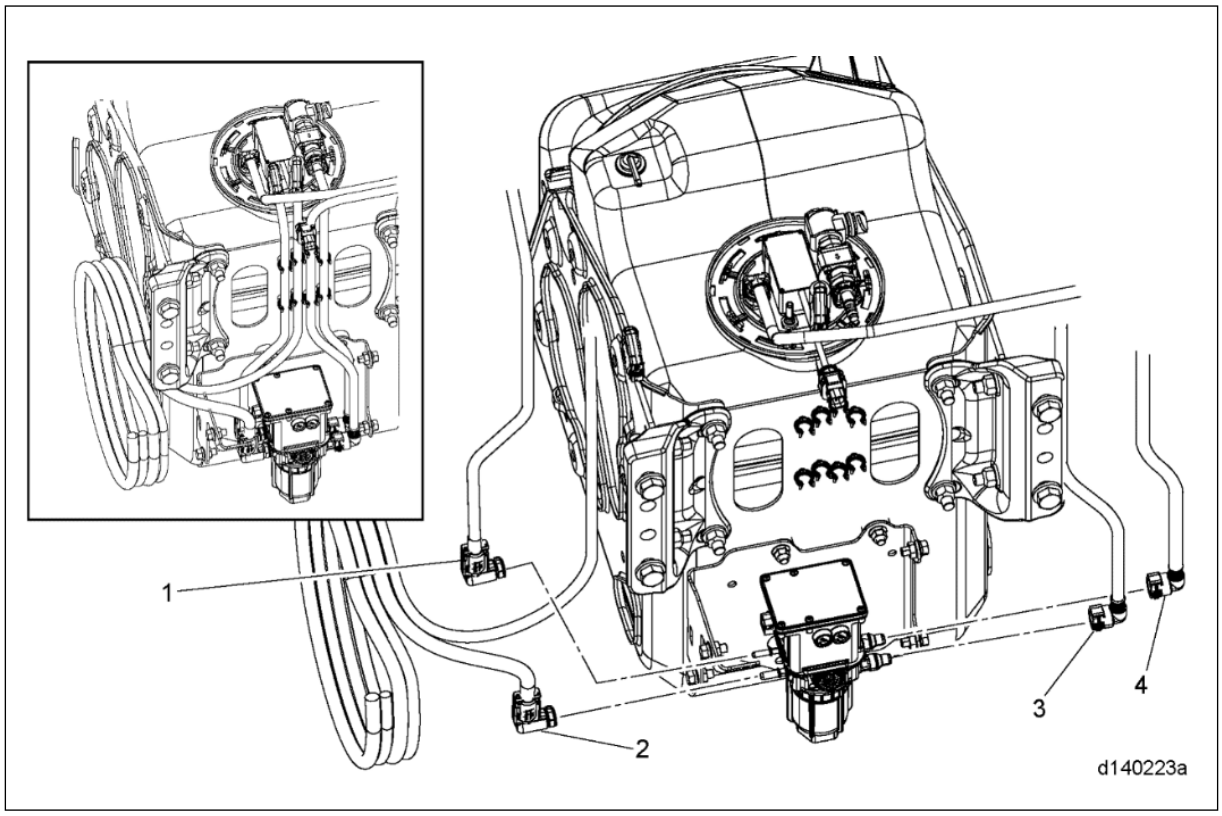
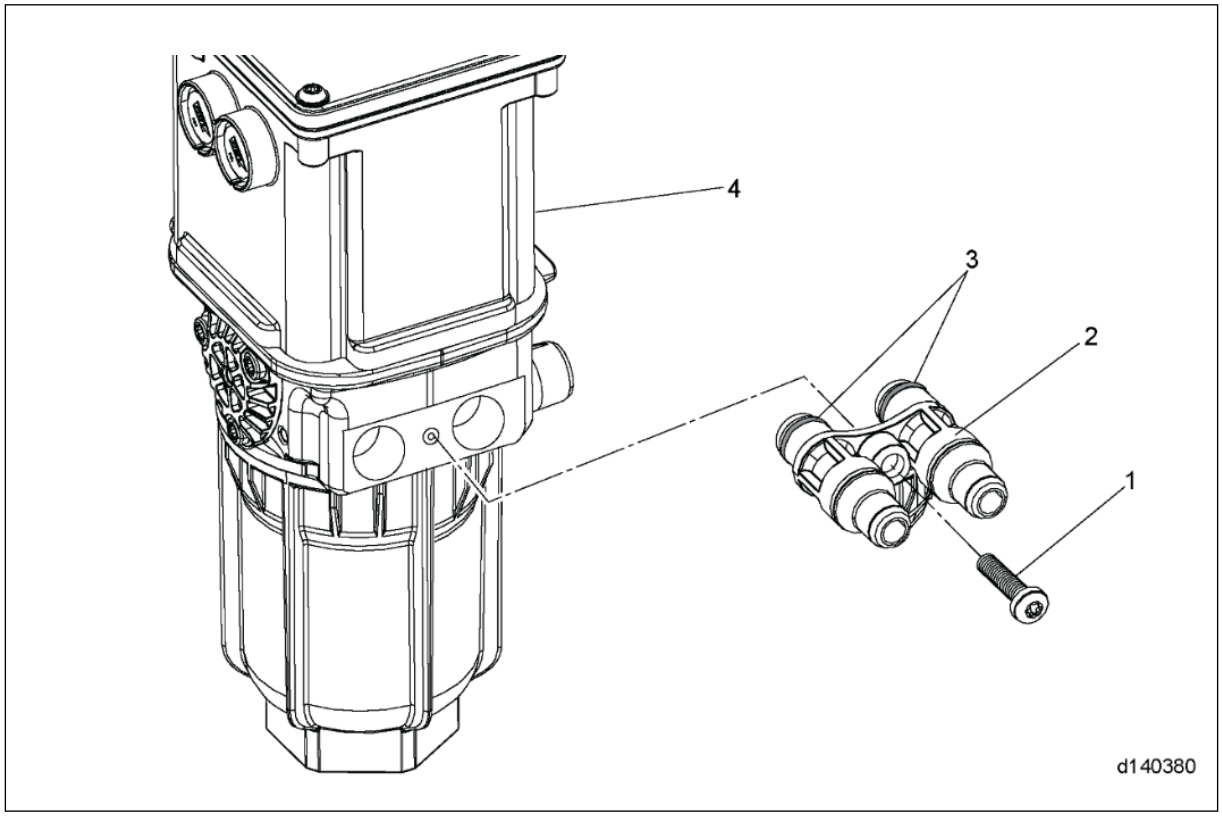
WARNING

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.



8. Remove the screw (1) securing the coolant connector fitting (2) to the Diesel Exhaust Fluid (DEF) pump module (4).



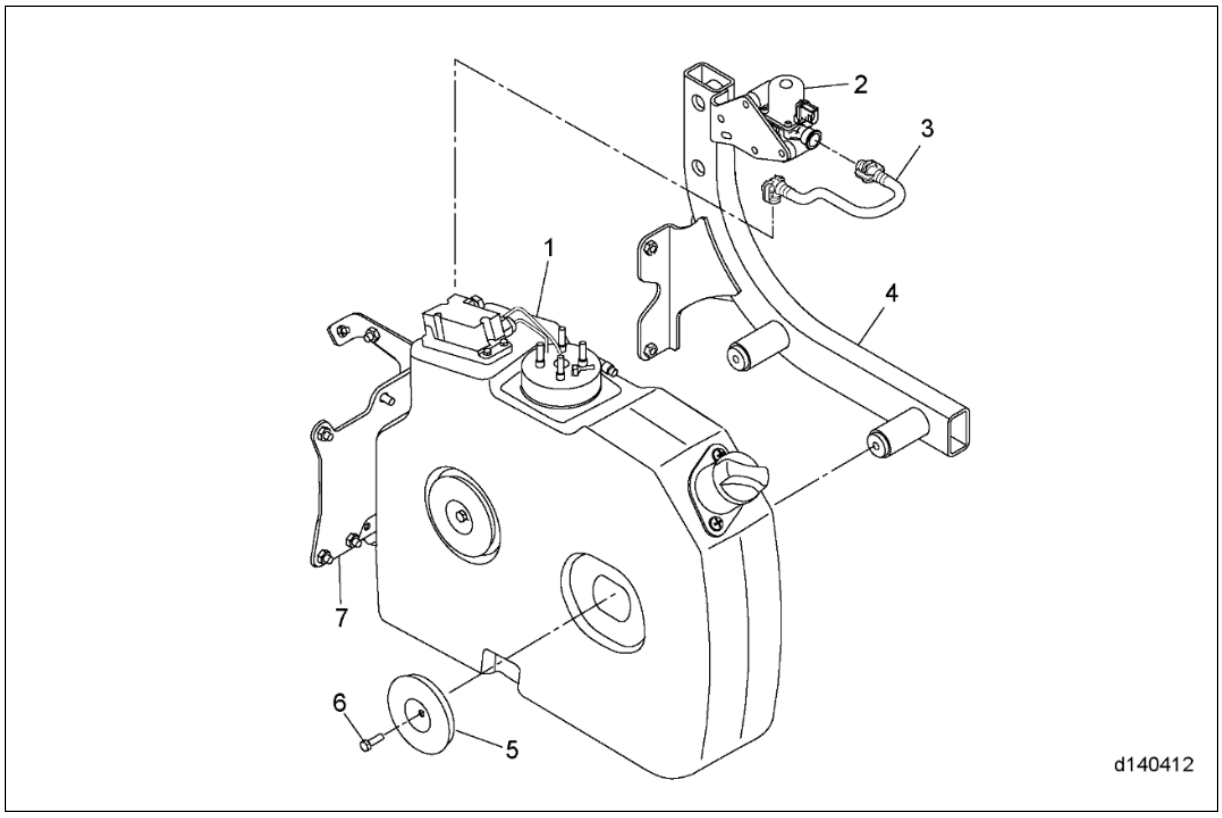
10. Remove the DEF tank retaining washers (5) from the DEF tank mounting studs.
11. Slide the DEF tank (1) off the mounting studs.

2.9.3 Inspection of the Six-Gallon Diesel Exhaust Fluid Tank

1. Inspect the Diesel Exhaust Fluid (DEF) Tank for cracks or damage. Repair or replace as needed.
2. Inspect the DEF tank mounting brackets for damage. Replace as needed.

2.9.4 Installation of the Six-Gallon Diesel Exhaust Fluid Tank

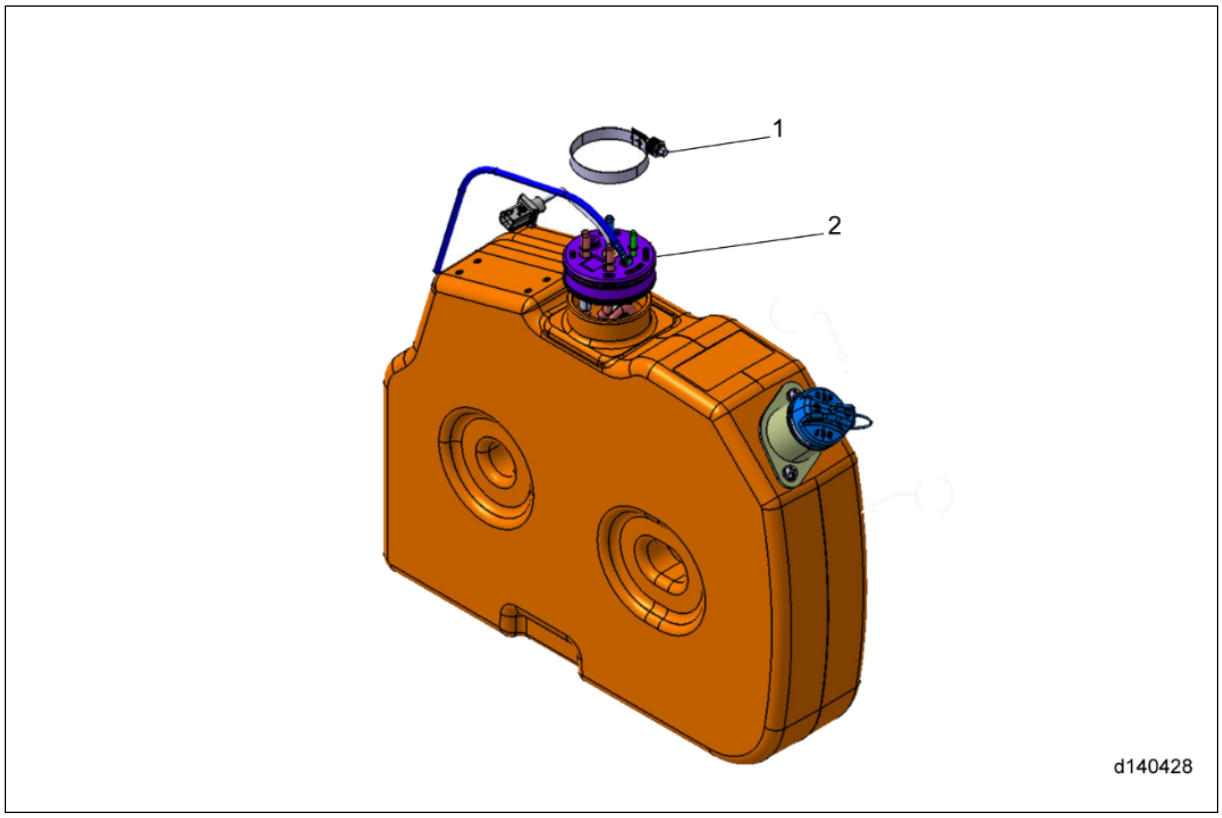
1. Slide the tank (1) onto the mounting studs.



2. Install the Diesel Exhaust Fluid (DEF) tank retaining washers (5) onto the tank mounting studs.
3. Install cap screws (6) onto the mounting studs, securing the DEF tank and retaining washers on the mounting studs. Torque to 25 N·m (18 lb·ft).
4. Connect the coolant supply and return lines to the coolant ports on the DEF tank header.
5. Remove any white DEF crystals from the DEF ports on the DEF tank header and the DEF line fittings.
6. Connect the DEF supply and return lines to the DEF inlet and outlet ports on the DEF tank header.
7. Connect the DEF Level /Temperature Sensor electrical connector.
8. Fill the DEF tank to the appropriate level using saved DEF or new DEF if the saved DEF was contaminated.
9. Fill the cooling system. Refer to section *"Cooling System Fill Procedure."*

CAUTION
ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch



5. Remove the header unit (2) from the tank by pulling the assembly straight up, then tilting it to pull the horizontal end clear of the tank.

2.10.6 Inspection of the Six-Gallon Diesel Exhaust Fluid Tank Header Unit

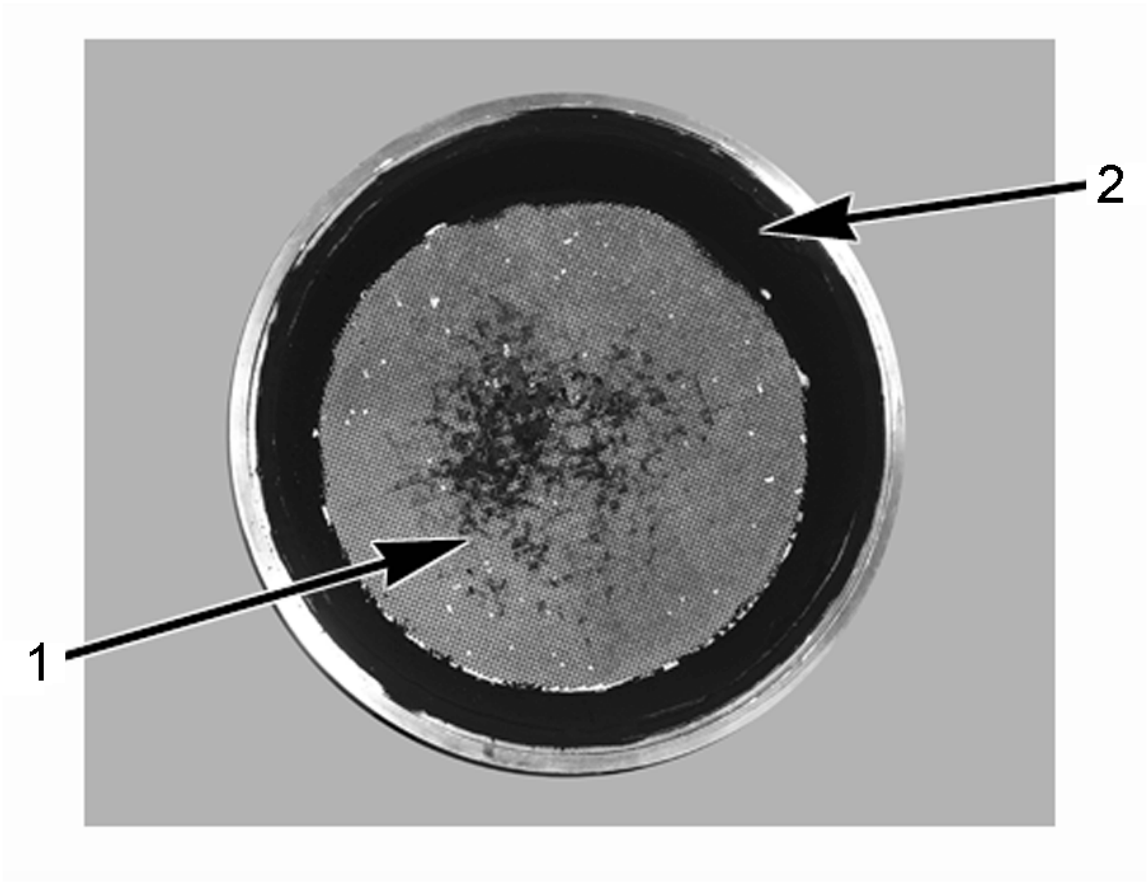
1. Inspect the Diesel Exhaust Fluid (DEF) line connectors and fittings for DEF crystals. Clean or flush as needed.
2. Inspect the coolant line connectors and fittings for damage or blockages. Clean or replace as needed.
3. Inspect the DEF level/DEF temperature sensor for damage.
4. Inspect the DEF tank header body for damage. Replace as needed.

2.10.7 Installation of the Six-Gallon Diesel Exhaust Fluid Tank Header Unit

The DEF header unit on vehicles with a six-gallon DEF tank is secured to the top of the tank, and contains the DEF level sensor, DEF temperature sensor and coolant and DEF lines.

Install as follows:

1. Install the DEF tank header (2) by tilting it to insert the horizontal end into the tank. Once the horizontal segment is inside the tank, tilt the header unit back to vertical.



NOTICE

The most important means to qualify a failed or damaged filter is by visual inspection of the substrate. Additional failure modes detectable by visual inspection are: burn-through, substrate fractures, cell fusion, and cell damage. Diesel particulate filters that exhibit these conditions are also considered unusable, not cleanable, and may fail to perform correctly in their application. If these failure modes are detected during inspection of the DPF, replace it.

8. The substrate shown below has experienced a burn-through. The face of the filter has been partially melted, and the cell structure has been converted to molten ceramic. Filters that have experienced a burn-through are non-serviceable. Replace the DPF.

2.13 Hydrocarbon Doser Block Feed Line

2.13.1 Removal of the Hydrocarbon Doser Block Feed Line

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

CAUTION
ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Disconnect the batteries.
3. Open the hood.
4. Drain the fuel system. Refer to section " *Draining the Fuel System Prior to Repair* ".
5. Remove the air compressor resonator. Refer to section " *Removal of the Air Compressor Resonator* ".
6. Remove the Motor Control Module (MCM) and position the 120-pin connector to the side. Refer to section " *Removal of the Motor Control Module* ".
7. Remove the low pressure fuel pump lines. Refer to section " *Removal of the Low Pressure Fuel Pump Lines* ".
8. Remove the Hydrocarbon (HC) doser block feed line from the HC doser block and discard sealing washers.
9. Remove the HC doser block feed line from the fuel filter module and discard the sealing washers.

2.13.2 Installation of the Hydrocarbon Doser Block Feed Line

⚠WARNING

PERSONAL INJURY

All hardware components must be installed to the specified torque and must be maintained in the proper orientatiaon while torqueing. Not following this procedure may result in failure of the fuel line, potentially causing fire and/or personal injury.

1. Using new sealing washers, loosely install the Hydrocarbon (HC) doser block feed line to the fuel filter module and HC doser block.
2. Position the HC doser block feed line in the 11 o’clock position as shown in the Figure below.

10. Close the hood.

> **⚠ WARNING**
>
> PERSONAL INJURY
>
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> **⚠ WARNING**
>
> PERSONAL INJURY
>
> To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

> **⚠ WARNING**
>
> ENGINE EXHAUST
>
> To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

11. Start the engine.

Note : It may take more than one purge attempt to completely purge all of the air from the fuel line. Do not exceed three purge attempts.

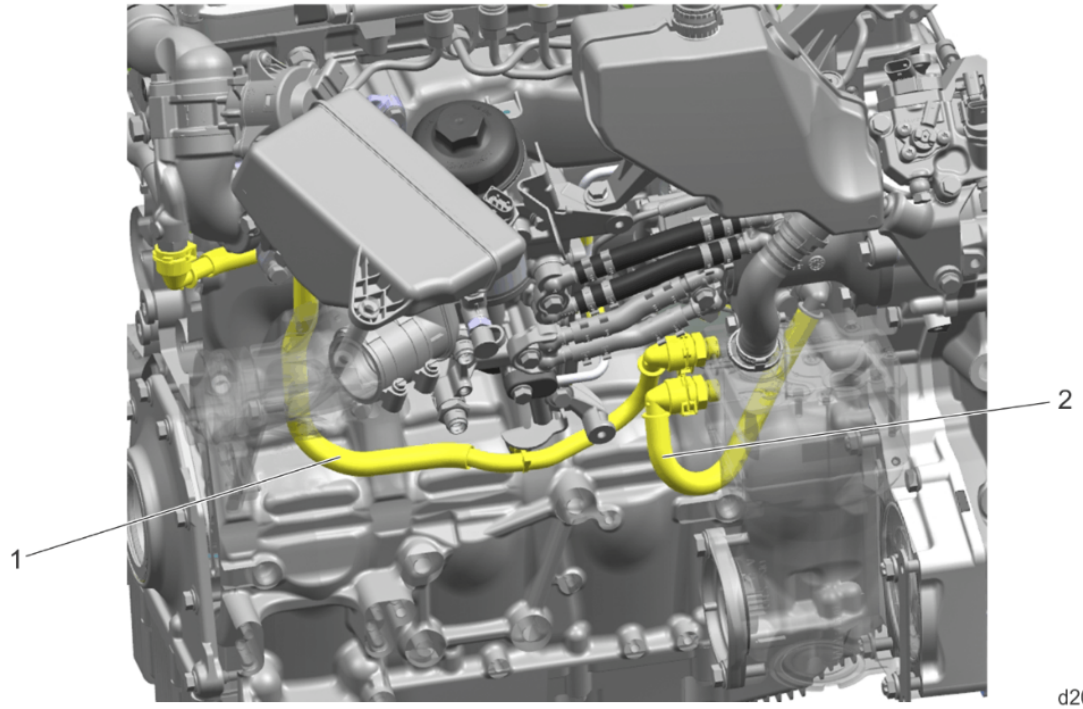
12. Use the HC fuel doser command to run the purge function in DiagnosticLink to purge all the air from the doser valve and line.
13. Check for any fuel leaks.

Air Compressor

3.1 Air Compressor Coolant Lines

3.1.1 Description and Operation of the Air Compressor Coolant Return Line

1. Air Compressor Coolant Return Line
2. Air Compressor Coolant Supply Line



3.1.2 Removal of the Air Compressor Coolant Return Line

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

CAUTION
ELECTRICAL SHOCK

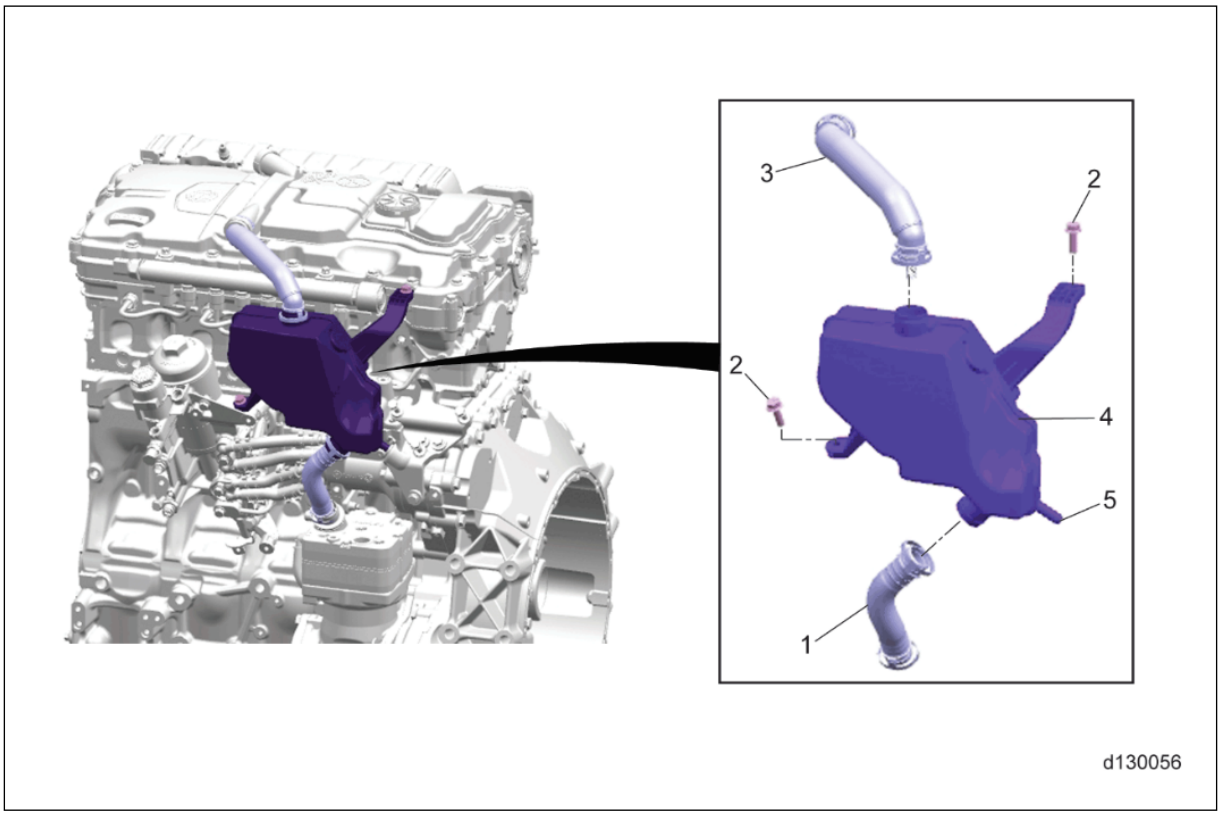
To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Disconnect batteries.
3. Open hood.
4. If needed, remove the bumper end(s).
5. Drain the cooling system. Refer to section "Cooling System Drain Procedure".

3.3 Air Compressor Resonator

3.3.1 Description and Operation of the Air Compressor Resonator

The air compressor resonator (4) is found on the air compressor fresh air intake side and connects to the fresh air pass-through at the rocker cover. An upper and lower hose are used to create this connection.



The air compressor resonator requires no maintenance. Sound and vibration produced normally by the air compressor fresh air intake are now dampened.

3.3.2 Removal of the Air Compressor Resonator

⚠WARNING

PERSONAL INJURY

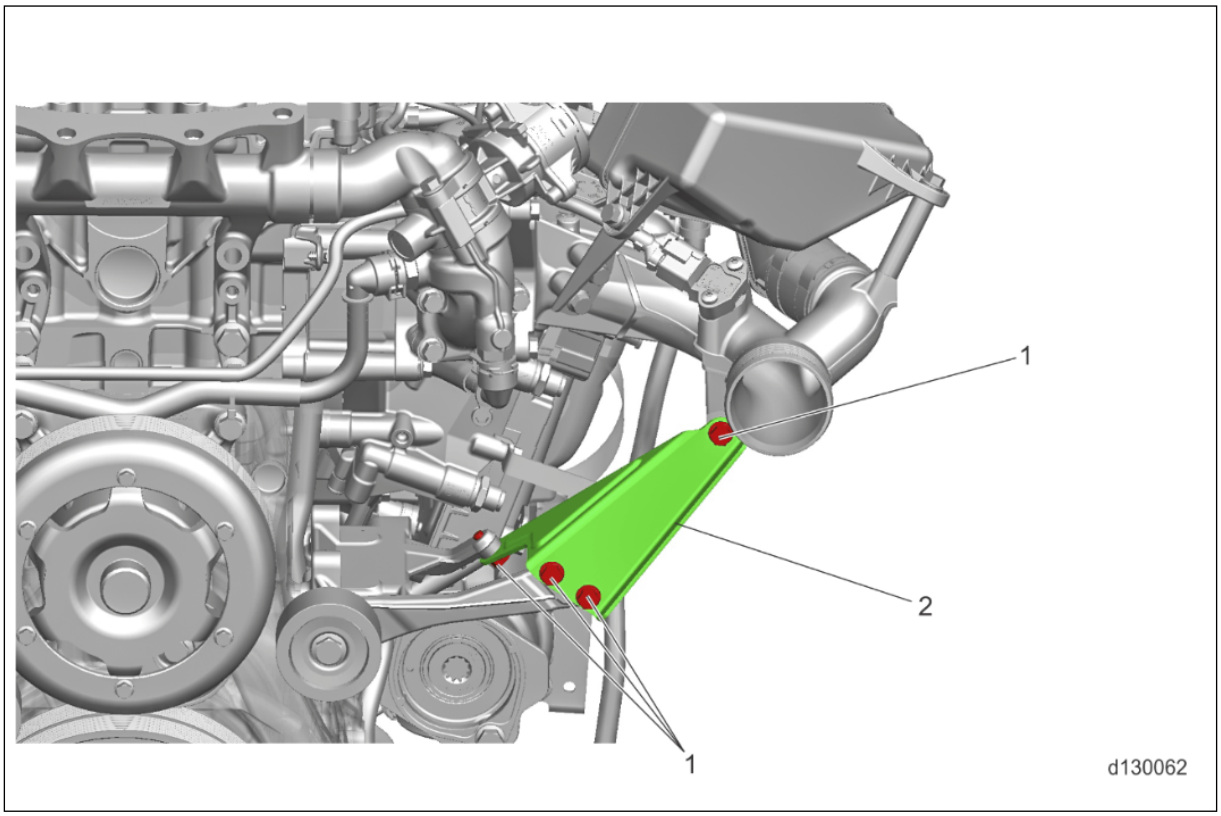
To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

⚠WARNING

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.



9. Remove the cold boost pipe mounting bolts.
10. Remove the cold boost pipe and discard the mounting seal.
11. If replacing the cold boost pipe, remove the intake pressure/temperature sensor and retain for installation. Refer to section “Removal of the Intake Pressure/Temperature Sensor.”

4.2.3 Inspection of the Cold Boost Pipe

1. Inspect for any cracks or casting flaws. Replace as needed.
2. Inspect mounting bolts for any damaged threads. Replace as needed.
3. Clean oil residue as needed. Further cleaning may be required upstream if standing oil residue is found.

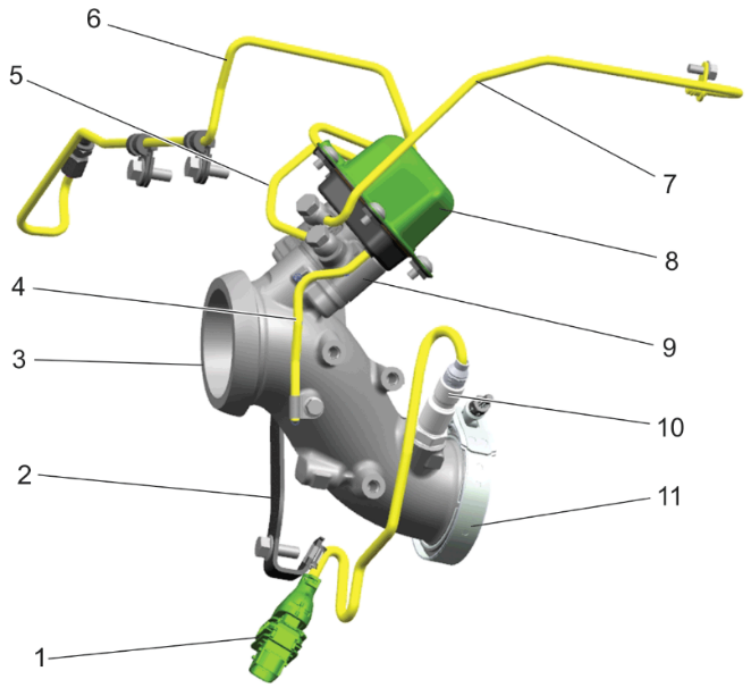
4.2.4 Installation of the Cold Boost Pipe

1. If removed, install the intake pressure/temperature sensor (3) at the cold boost pipe (4). Refer to section “Installation of the Intake Pressure/Temperature Sensor”.

4.5 Turbocharger Outlet Pipe

4.5.1 Removal of the Turbocharger Outlet Pipe

1. Oxygen Sensor Electrical Connector
2. Turbocharger Outlet Pipe Support Bracket
3. Turbocharger Outlet Pipe
4. Hydrocarbon Fuel Doser Drain Pipe
5. Hydrocarbon Fuel Doser Coolant Supply Line
6. Hydrocarbon Fuel Doser Fuel Supply Line
7. Hydrocarbon Fuel Doser Coolant Return Line
8. Protective Cover
9. Hydrocarbon Fuel Doser Housing
10. Oxygen Sensor
11. Front Turbocharger Outlet Pipe Clamp



Service Tools Used in the Procedure		
Tool Number	Description	Photo
DSN930E16015	Oxygen Sensor Socket	

Remove as follows:

NOTICE

Coolant is a hazardous material and needs to be disposed in an environmentally responsible manner.

6. Collect the used antifreeze in a suitable container and if necessary, dispose of the solution in an environmentally responsible manner according to state and federal Environmental Protection Agency (EPA) recommendations.
7. Close drain plug. Torque to 5 N·m (44 lb·in).

3. Open the hood.
4. If necessary, remove the bumper end(s).
5. Drain the coolant. Refer to section "Cooling System Drain Procedure".
6.
7. Remove the turbocharger compressor outlet pipe. Refer to section "Removal of the Turbocharger Compressor Outlet Pipe."
8. Remove the poly-V belt from the water pump pulley. Refer to section "Removal of the Poly-V-Belts".
9. Remove the coolant thermostat and upper radiator hose. Refer to section "Removal of the Coolant Thermostat".
10. Disconnect and position aside the DEF heater line at the thermostat housing.
11. Disconnect and position aside the heater core line at the coolant housing.
12. Disconnect the Exhaust Gas Recirculation (EGR) delivery elbow coolant return line at the water pump.
13.

6.7.3 Inspection of the Water Pump

1. Clean the water pump and surrounding area.
2. Drain the cooling system. Refer to section "Cooling System Drain Procedure".
3. Remove the water pump. Refer to section "Removal of the Water Pump".
4.
5. Inspect the blades (3) on the water pump for cracks or damage; replace the pump if damaged.
6. Inspect the bearings in the pump for a sloppy, tight, or choppy feeling; replace the pump if damaged.

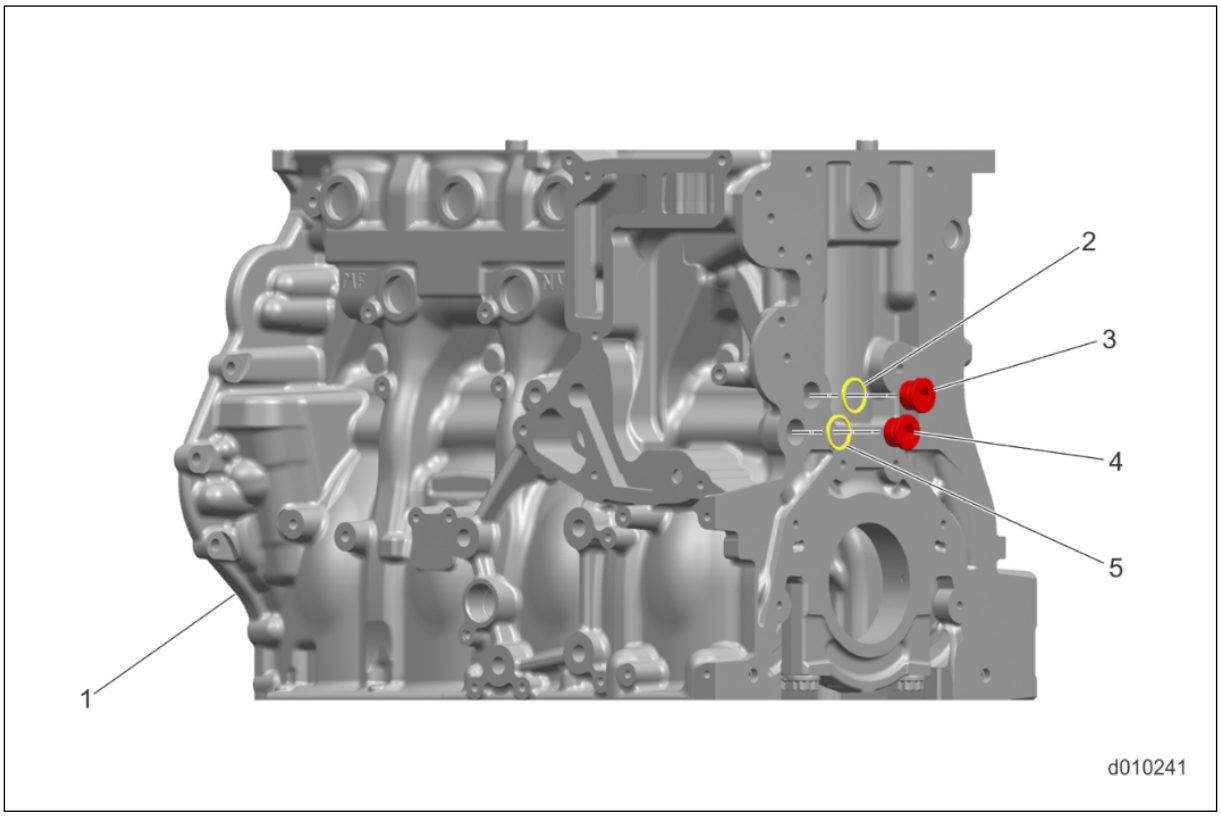
6.7.4 Installation of the Water Pump

1.
2. Install the water pump (4) to the oil coolant module (2) with six bolts (1) and torque to 20 N·m (15 lb·ft).
3. Connect the Exhaust Gas Recirculation (EGR) delivery elbow coolant return line at the thermostat housing. Torque to 30 N·m (22 lb·ft).
4. Install the poly-V belt onto the water pump pulley. Refer to section "Installation of the Poly-V-Belts".
5. Install the coolant thermostat and upper radiator hose. Refer to section "Installation of the Coolant Thermostat".
6. Connect the DEF heater line at the thermostat housing.
7. Connect the heater core line at the coolant housing.
8. Install the turbocharger compressor outlet pipe. Refer to section "Installation of the Turbocharger Compressor Outlet Pipe."

CAUTION
ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

9. Connect the batteries.
10. Fill the cooling system. Refer to section "Cooling System Fill Procedure".
11. If removed, install bumper end(s).



10. Carefully clean the sealing surface of the cylinder block using a brush and suitable cleaner.
11. Remove any debris caused by the cleaning.
12. Install new sealing rings onto the threaded oil gallery plugs.
13. Install the threaded plugs into the cylinder block hand-tight
14. Torque the oil gallery plugs to 75 N·m (55 lb·ft).
15. Install the idler pulley No. 1 (fan drive). Refer to section "Installation of Idler Pulley No. 1 (Fan Drive)."
16. Install the fan hub pulley. Refer to section "Installation of the Fan Hub Pulley".
17. Install the fan drive belt. Refer to section "Installation of the Fan Drive Belt."
18. Install the engine cooling fan and fan shroud. Refer to the OEM procedure.

CAUTION
ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

19. Reconnect the batteries.

⚠WARNING

PERSONAL INJURY

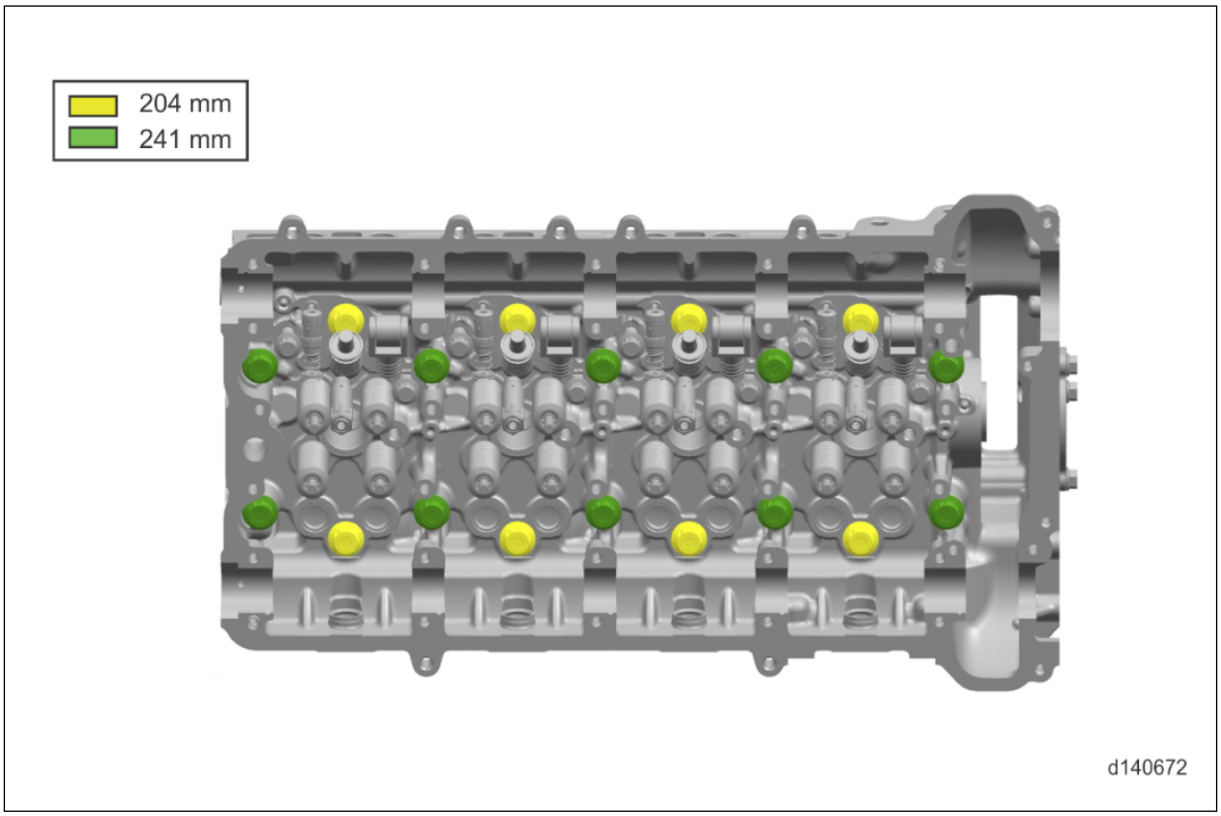
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

NOTICE

The weight of the cylinder head assembly is approximately 113 kg. (250 lbs).

48. Attach suitably rated chains and eyelets to the cylinder head. An example is shown below.

d010215



15. Tighten the cylinder head mounting bolts using the torque sequence shown. Torque the bolts (1 to 18) in five steps as follows:

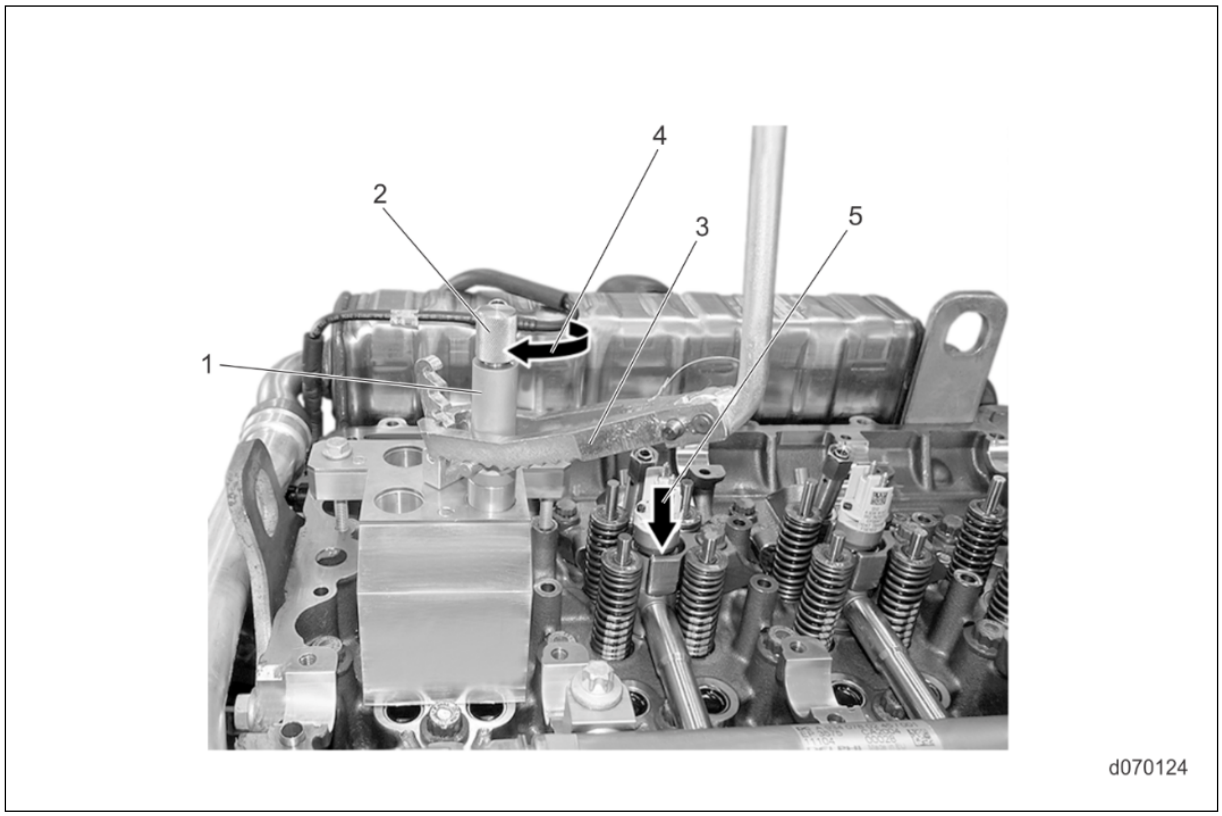
    15.a 20 N·m (15 lb·ft).

    15.b 70 N·m (52 lb·ft).

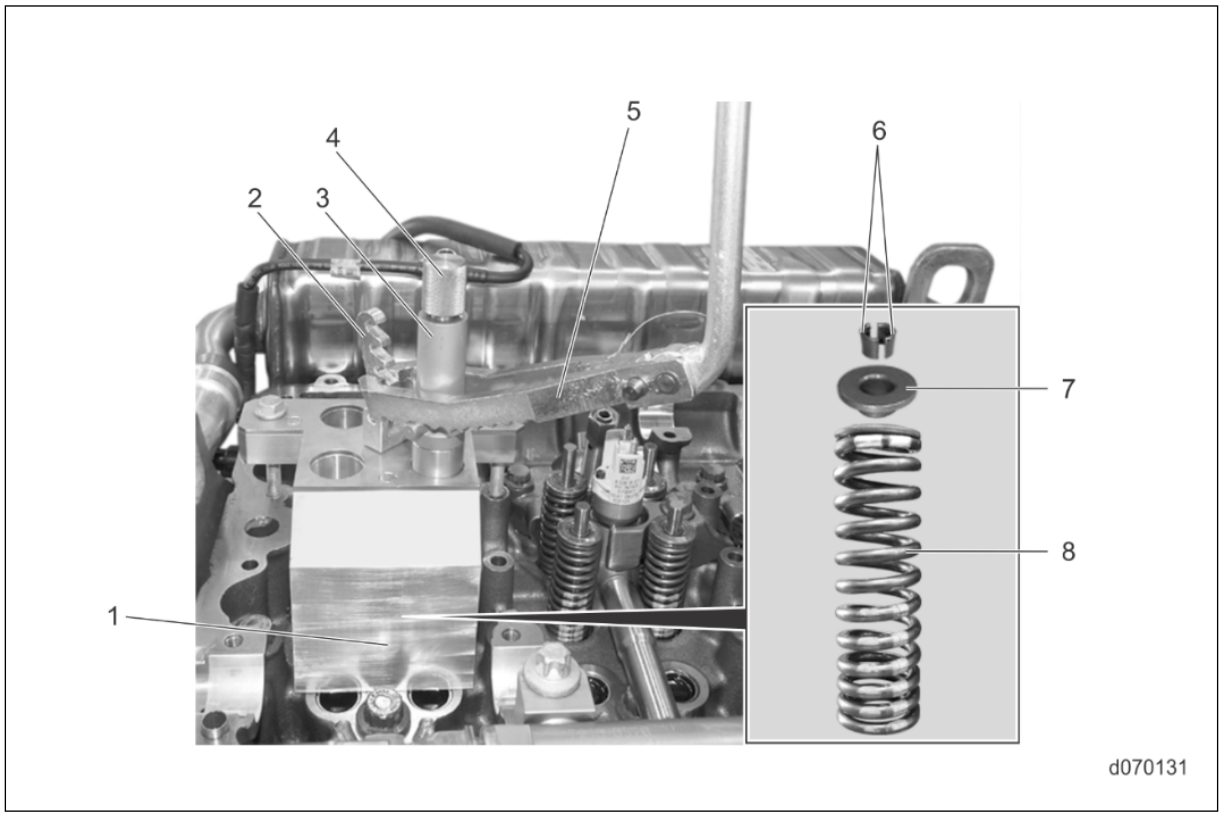
    15.c 150 N·m (111 lb·ft).

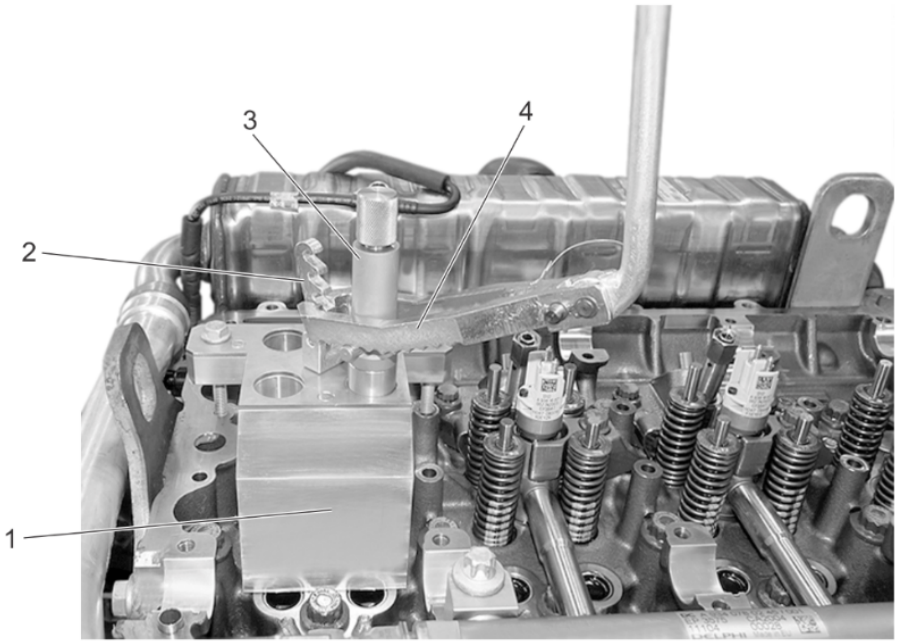
    15.d 90° torque turn.

    15.e 90° torque turn.



16. Pull the thrust fork (5) downwards all the way. During this process the valve locks (6) are released and captured in the assembly cartridge (3).





8. Hook the thrust fork with attached handle (4) onto the thrust fork anchor (2) using the teeth. Make sure the thrust fork is positioned low enough to have leverage for valve spring removal. Insert the locking pin into the thrust fork to lock the handle in place.
9. Align the teeth on the thrust fork (4) with the pegs on the assembly cartridge (3).
10. Press slightly downward on the thrust fork handle (arrow 5). Simultaneously turn the screw (2) clockwise (arrow 4) until the split tip of the assembly cartridge latches between the valve locks. This will be noticeable while turning the screw.

7.3 Engine Replacement Procedures

7.3.1 Removal of the Complete Powertrain Assembly

When possible, this is the preferred method for removing an engine for service outside of the chassis. The engine, cooling package and transmission will be removed as an assembly. It is recommended to remove the package as complete as possible to improve efficiency.

Note : The instructions listed below are powertrain removal instructions based on a Freightliner M2 106 model truck with a GHG17 DD5 engine. These instructions will vary, depending on the exact chassis configuration and options.

Remove as follows:

⚠WARNING

PERSONAL INJURY

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

⚠WARNING

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

CAUTION

ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Disconnect the batteries.
3. Remove the hood. Refer to the OEM procedure.
4. Remove the front bumper. Refer to the OEM procedure.
5. Remove the chassis front closing crossmember and tow hooks (in front of the cooling package). Refer to the OEM procedure.

Note : The engine coolant can be reused if it is not contaminated and has been properly maintained.

6. Drain the cooling system. Refer to section " *Cooling System Drain Procedure* ".
7. Remove the air cleaner, air cleaner mounting bracket and inlet to the turbocharger as an assembly. Refer to the OEM procedure.
8. Install a protective cover over the turbocharger inlet.
9. Remove the coolant surge tank.
10. Remove the horns and horn bracket, if necessary.

Note : The main power and ground cables will not be removed with the powertrain assembly.

11. Disconnect the power and ground cables from the support bracket at the flywheel housing.
12. Disconnect the main chassis ground at the right-hand frame rail.

5. Install and tighten the bolts securing the front engine mount to the crossmember. Refer to the OEM procedure.
6. Disconnect the lifting mechanism and remove the lifting chains from the engine lifting brackets.
7. Route and connect the chassis powertrain interface harness and Powertrain Distribution Module (PDM) to the front wall and any other chassis connection points. Refer to the OEM procedures.
8. Connect the fuel supply and return lines to the fuel filter module. Refer to the OEM procedure.
9. Connect the fuel lines to any additional support brackets on the powertrain. Refer to the OEM procedures.
10. Connect the power steering pressure line to the steering gear box. Refer to the OEM procedure.
11. Reposition and install the power steering fluid reservoir onto the mounting bracket. Refer to the OEM procedure.
12. Install the power steering fill line onto the power steering fluid reservoir.
13. Connect the air compressor discharge pipe to the air compressor. Refer to the OEM procedure.
14. Connect the air compressor governor line to the air compressor. Refer to the OEM procedure.
15. Install the Aftertreatment System (ATS) inlet pipe and exhaust bellows pipe onto the engine and ATS. Refer to the OEM procedure.
16. Connect the Air Conditioning (A/C) lines at the junction block, if equipped. Refer to the OEM procedure.
17. Connect the Diesel Exhaust Fluid (DEF) coolant lines to the oil coolant module.
18. Connect the cab heater hoses to the engine.
19. Install the oil pan. Refer to section " *Installation of the Oil Pan* ".
20. Install the fuel line junction bracket onto the transmission. Refer to the OEM procedure.
21. Connect any chassis air lines and electrical connections to the transmission, if equipped. Refer to the OEM procedure.
22. Connect the shift cable to the transmission, if equipped with an automatic transmission. Refer to the OEM procedure.
23. Connect the shifter assembly to the transmission, if equipped with a manual transmission. Refer to the OEM procedure.
24. Connect the driveline to the transmission. Refer to the OEM procedure.
25. Connect the 21-pin powertrain interface harness connector to the Aftertreatment Control Module (ACM) and secure the harness.
26. Route and connect the battery power and ground cables to the flywheel housing support bracket and starting motor.
27. Route and connect the alternator power and ground cables to the flywheel housing support bracket and starting motor.
28. Connect the main chassis ground at the right-hand frame rail.
29. Install any additional brackets and mounting hardware for air lines, fuel lines, electrical harnesses, electrical cables or hoses that attach to the powertrain.
30. Install the horn bracket and horns to the bulkhead. Refer to the OEM procedure.
31. Install the coolant surge tank. Refer to the OEM procedure.
32. Prime and fill the engine lubrication system. Refer to section "Priming the Engine Lubrication System".
33. Remove the protective cover from the turbocharger inlet, if installed.
34. Install the air cleaner, air cleaner mounting bracket and inlet to the turbocharger. Refer to the OEM procedure.

Note : The power steering fluid can be reused if it is not contaminated and has been properly maintained.

35. Fill the power steering reservoir to the proper level.
36. Prime the fuel system. Refer to section “ *Priming the Fuel System* ”.

CAUTION

NOTICE

Use care when installing the engine sensor harness connector to the engine brake solenoid. The connector must be installed straight onto the solenoid. The male pins in the solenoid may bend if the connector is not carefully installed.

4. Connect the engine sensor harness electrical connector to the engine brake solenoid.

CAUTION
ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

5. Connect the batteries.
6. Start the engine and check for oil leaks.
7. Close the hood.

⚠ WARNING

PERSONAL INJURY

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

⚠ WARNING

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

CAUTION

ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Disconnect the batteries.
3. Open the hood.
4. Remove the engine from the chassis. Refer to section "Removal of the Complete Powertrain Assembly".
5. Remove the transmission. Refer to the Original Equipment Manufacturer (OEM) procedure.
6. Remove the Crankshaft Position Sensor (CKP).
7. Remove the flywheel. Refer to section "Removal of the Flywheel".
8. Remove the rear crankshaft oil seal. Refer to section "Removal of the Rear Crankshaft Oil Seal".
9. Remove the battery cable bracket from the flywheel housing.
10. Remove the starting motor. Refer to the OEM procedure.
11. Remove the hydrocarbon fuel doser injector valve fuel feed line. Refer to section "Removal of the Hydrocarbon Fuel Doser Injector Valve Fuel Feed Line".
12. Remove the hydrocarbon fuel doser block. Refer to section "Removal of the Hydrocarbon Fuel Doser Block".
13. Remove the hydrocarbon fuel doser block bracket from the flywheel housing and timing case. Refer to section "Removal of the Hydrocarbon Fuel Doser Block Bracket".
14. Remove the turbocharger outlet. Refer to section "Removal of the Turbocharger Outlet".
15. Remove the air compressor. Refer to section "Removal of the Air Compressor".
16. Disconnect any engine sensor harness attachments to the flywheel housing.

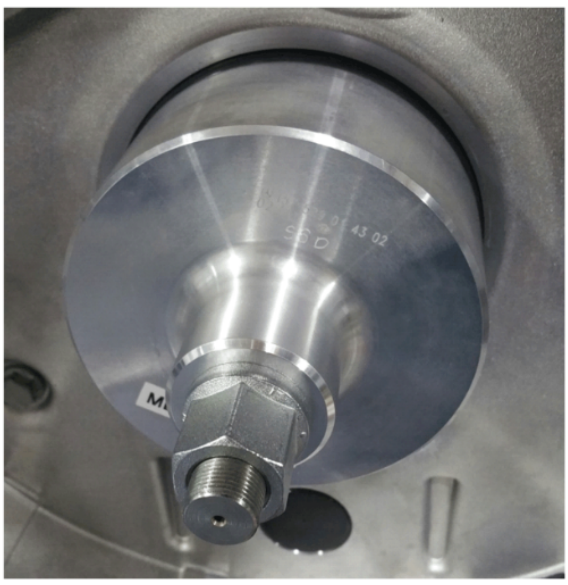
NOTICE

Flywheel housing mounting bolt torque is critical. Oil leaks can occur if fasteners are improperly tightened. If the flywheel housing is being removed for oil leaks, record the location of any fasteners that were not properly tightened. Improperly torqued mounting bolts could be the primary failure.

Note : There are five bolts that run through the cylinder block and timing case and into the flywheel housing.

d010207

7. Install the centering piece from the installer set over the threaded drift and screw on the nut hand-tight. See illustration below.



d010208

CAUTION
ELECTRICAL SHOCK

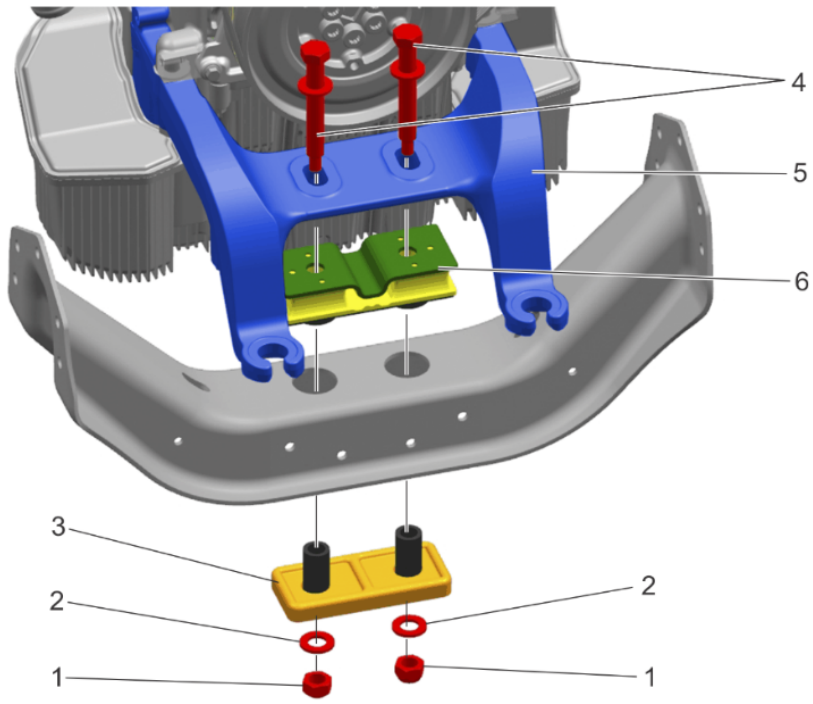
To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Disconnect the batteries.
3. Open the hood.
4. Remove the left-hand bumper end.
5. Remove the frame mounted fuel filter housing. Refer to the OEM procedure.
6. Remove the charge air cooler outlet pipe.
7. Remove the engine cooling fan and fan shroud. Refer to the OEM procedures.
8. Remove the poly-V-belts. Refer to section "Removal of the Poly-V-Belts".
9. Remove the vibration damper. Refer to section "Removal of the Vibration Damper".
10. Clean the area around the front crankshaft oil seal.

NOTICE

Apply grease to the drill bit to capture any shavings.

11. Drill three 3.0 mm (.118 in) diameter holes in the front crankshaft oil seal using the illustration below as a guide. The drilling locations in the seal can be recognized by the three cutouts on the felt cover. See illustration below.



⚠WARNING

BODILY INJURY

To avoid injury from a falling component, ensure an appropriately rated lifting device is used. Moving the component without an appropriately rated lifting device could result in the component falling, which could cause serious personal injury and component damage. Never stand beneath a suspended load.

10. Support the engine with an appropriately rated lifting device (overhead crane or hoist) using the front engine lifter bracket.
11. Remove the isolator (6) and hardware from the Front Engine Mount/Radiator Support (5) and frame.
12. Remove the bolts securing the front engine mount/radiator support to the cylinder block and remove front engine mount/radiator support.

7.8.3 Inspection of the Front Engine Mount/Radiator Support

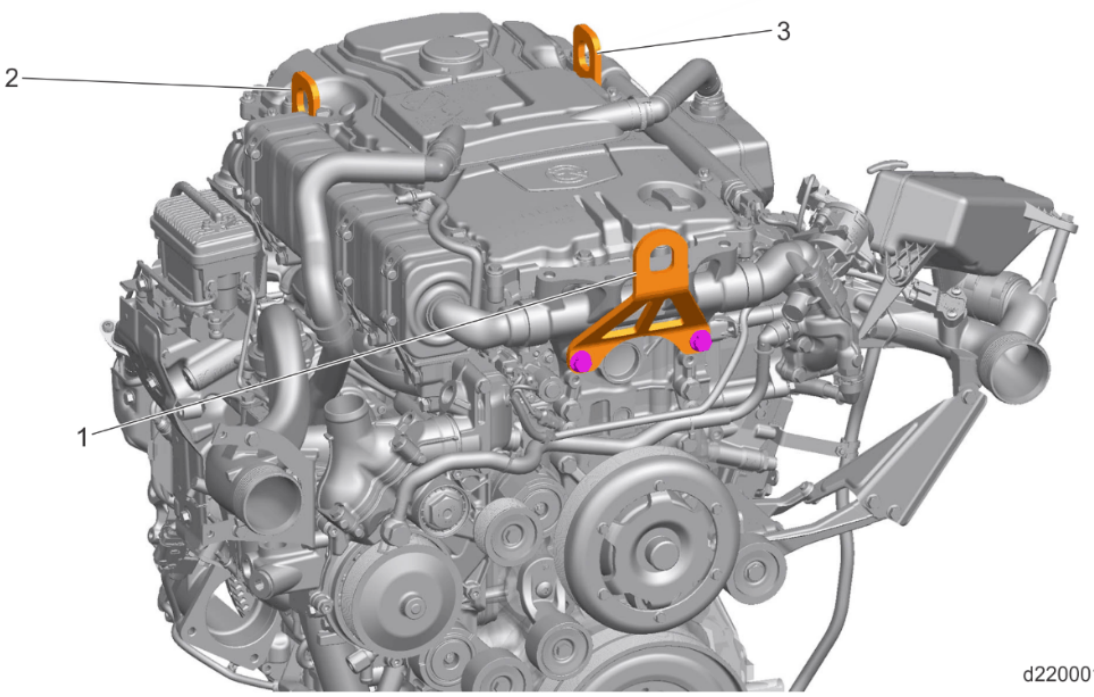
1. Inspect the front engine mount/radiator support (5) for any cracks or casting flaws. Replace as needed.

9. The dot on the gear spindle must be positioned at 12 o’clock.
10. Torque the mounting bolts to 50 N·m (37 lb·ft).
11. Install idler gear No. 5 as an assembly with the gear, spindle and mounting bolt in steps 15 and 16.
12. The dot on the gear spindle (1) must be positioned at 12 o’clock as shown below.

7.11 Lifting Brackets

7.11.1 Description and Operation of the Front Engine Lifting Bracket

1. Front Engine Lifting Bracket
2. Right Engine Lifting Bracket
3. Left Engine Lifting Bracket



7.11.2 Removal of the Front Engine Lifting Bracket

Remove as follows:

⚠WARNING

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

CAUTION

ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch

7.12.3 Disassembly of the Piston and Connecting Rod

1. Damage to the piston assembly or connecting rod requires complete engine replacement at this time. Refer to Technical Service letter 16 TS-19. A replacement engine can be ordered from the Warranty PowerTrain system here: https://extranet-ddc.freightliner.com/ops/warrantyengine/ .

7.12.4 Cleaning of the Piston and Connecting Rod

1. Damage to the piston assembly or connecting rod requires complete engine replacement at this time. Refer to Technical Service letter 16 TS-19. A replacement engine can be ordered from the Warranty PowerTrain system here: https://extranet-ddc.freightliner.com/ops/warrantyengine/ .

7.12.5 Inspection of the Piston, Piston Rings and Connecting Rod

1. Damage to the piston assembly or connecting rod requires complete engine replacement at this time. Refer to Technical Service letter 16 TS-19. A replacement engine can be ordered from the Warranty PowerTrain system here: https://extranet-ddc.freightliner.com/ops/warrantyengine/ .
2. Refer to section *"Inspection of the Cylinder Bores"* if there is damage to the cylinder bores with no apparent damage to the pistons.

7.12.6 Assembly of the Piston and Connecting Rod

1. Damage to the piston assembly or connecting rod requires complete engine replacement at this time. Refer to Technical Service letter 16 TS-19. A replacement engine can be ordered from the Warranty PowerTrain system here: https://extranet-ddc.freightliner.com/ops/warrantyengine/ .

7.12.7 Installation of the Piston and Connecting Rod Assembly

1. Damage to the piston assembly or connecting rod requires complete engine replacement at this time. Refer to Technical Service letter 16 TS-19. A replacement engine can be ordered from the Warranty PowerTrain system here: https://extranet-ddc.freightliner.com/ops/warrantyengine/ .

3. Inspect the rocker arm housing and rocker shaft caps for damage. Repair as necessary.
4. Inspect the exhaust camshaft lobes for excessive wear, deep scratches, and heavy scoring. Replace the camshaft if damaged.
5. Inspect the exhaust rocker arm shaft for excessive wear or damage. Replace the rocker arm shaft assembly if damaged.
6. Inspect the rocker arm shaft locating pin for damage. Replace the rocker arm shaft assembly if damage is found.
7. Inspect the exhaust rocker arms and rollers for damage or heavy scoring. Replace the rocker arm shaft assembly as necessary.
8. Inspect the exhaust rocker arm valve and engine brake adjusting screws and feet for damage. Replace as necessary.

7.13.7 Installation of the Exhaust Rocker Arm Shaft Assembly

1. Intake Rocker Shaft Caps
2. Rocker Arm Shaft Mounting Bolts
3. Exhaust Rocker Arm Shaft Assembly
4. Exhaust Rocker Shaft Caps
5. Injector Harness
6. Intake Rocker Arm Shaft Assembly

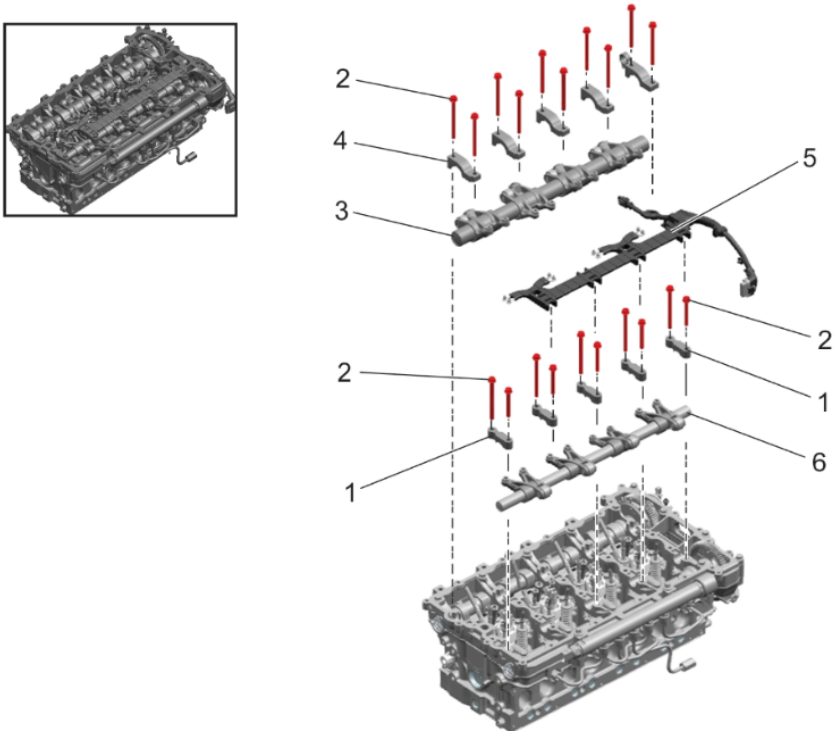
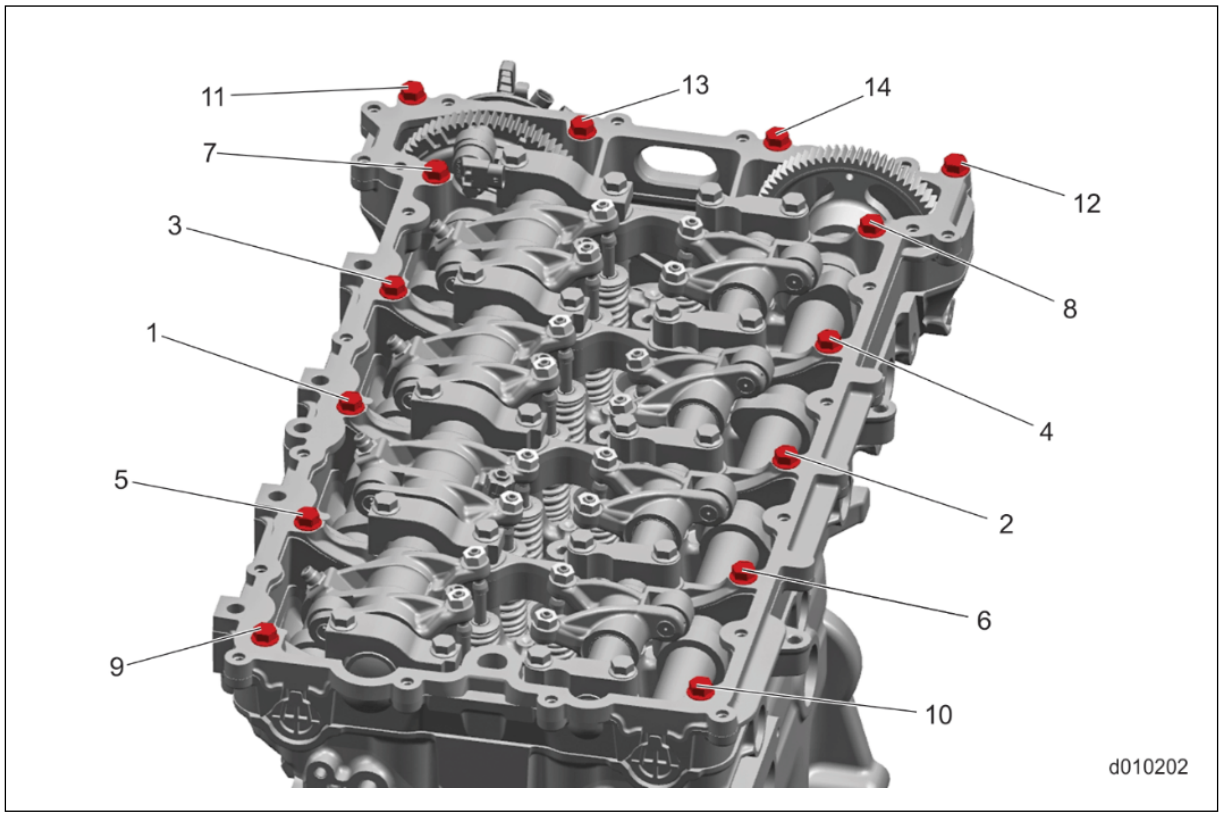


Fig 7.40, Rocker Arms

1. Lubricate the exhaust rocker shaft, rocker arm rollers and adjusting feet with clean engine lubricating oil.



NOTICE

There are two rocker arm housing locating dowels in the cylinder head at the left-front and right-rear. Use care when removing the rocker arm housing to avoid damage.

18. Remove the rocker arm housing by lifting straight up.
19. Remove the two bolts securing the variable camshaft phaser solenoid mounting ring to the rocker arm housing.
20. Remove and discard the rocker arm housing mounting seal.
21. Place the rocker arm housing on a clean and flat surface to avoid damage.
22. Carefully lift straight up on the intake camshaft (2) to remove it from the cylinder head (1).

CAUTION
ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

37. Connect the batteries.
38. Fill the cooling system. Refer to section *“Cooling System Fill Procedure”* .

⚠WARNING

ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

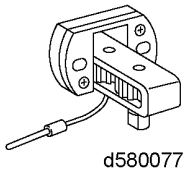
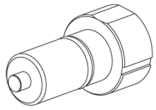
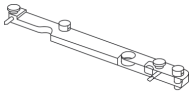
⚠WARNING

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

39. Start the engine and inspect for leaks.
40. Close the hood.

7.14.5 Camshaft Timing Verification

Special Service Tools Used in the Procedure		
Tool Number	**Tool Name**	**Tool Graphic**
W904589046300	Engine Barring Tool	 d580077
W936589001500	TDC Locating Tool	 d580192
W936589002300	Camshaft Timing Tool	 d580191

Verify as follows:

10. Close the hood.

7.17.2 Removal of the Variable Camshaft Phaser Solenoid

1. Variable Camshaft Phaser Solenoid
2. Variable Camshaft Phaser Solenoid Mounting Ring Bolt
3. Variable Camshaft Phaser Solenoid Mounting Ring
4. Variable Camshaft Phaser Solenoid Mounting Seal

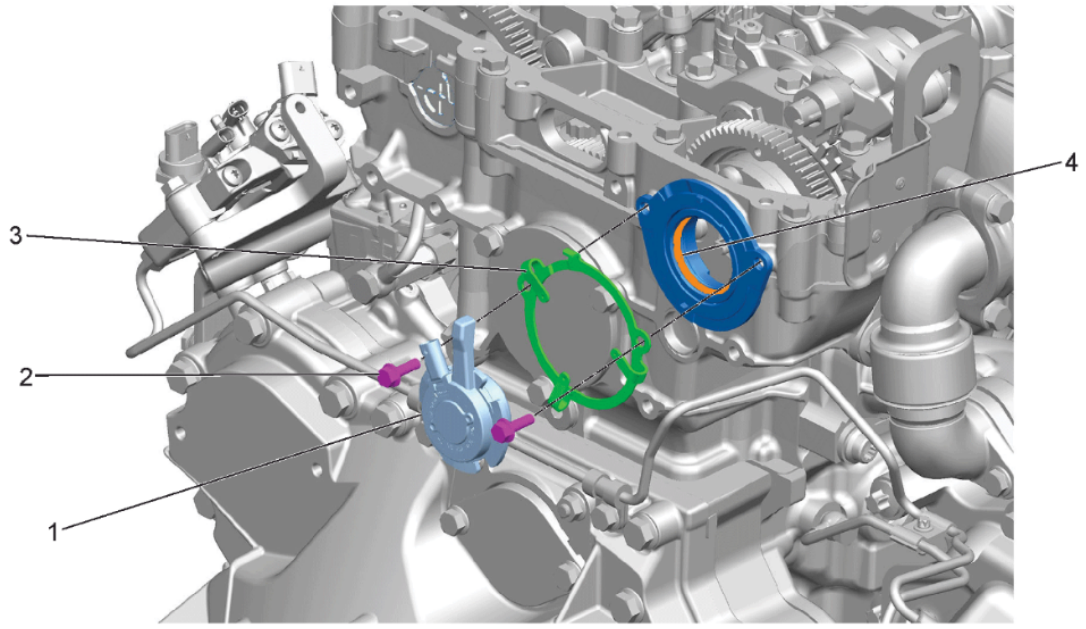


Fig 7.53, Variable Camshaft Phaser Solenoid

⚠WARNING

PERSONAL INJURY

To avoid injury, never remove any engine component while the engine is running.

⚠WARNING

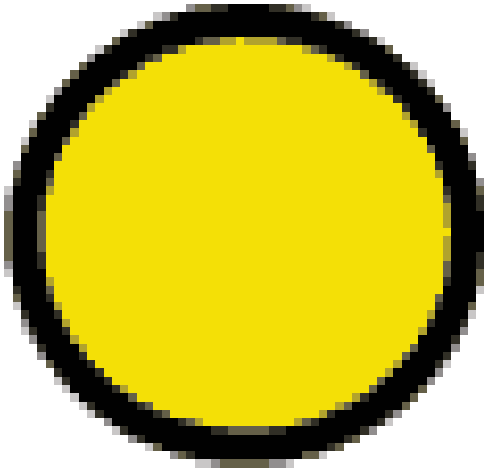
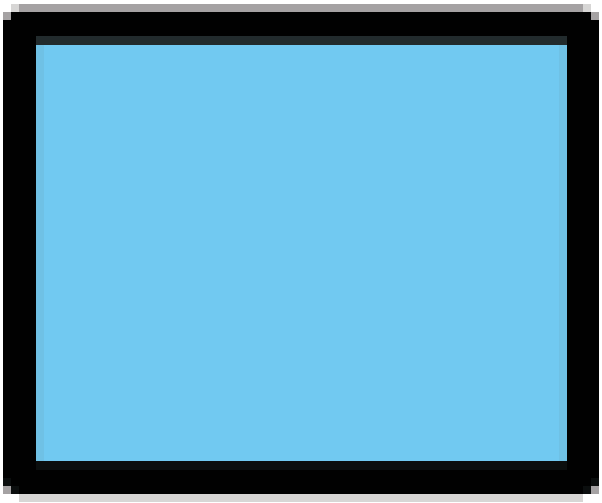
PERSONAL INJURY

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

CAUTION

ELECTRICAL SHOCK

Legend	
	Engine Wiring Harness Mounting Clips
	Electrical Connectors

6. Remove engine wiring harness mounting clips from the front of the engine.
7. Remove the air compressor resonator.
8. Disconnect the following electrical connectors on the left side of the engine:

- Intake Manifold Air Temperature Sensor
- Exhaust Gas Recirculation (EGR) Valve Actuator
- Intake Pressure / Temperature Sensor
- Fuel Rail Pressure Sensor
- Low Pressure Fuel Sensor
- Supply Fuel Temperature Sensor

	Mounting Bolts

4. Connect the following electrical connectors on the right side of the engine:
- Oxygen Sensor
- Turbocharger Wastegate Actuator
- Engine Oil Temperature Sensor
- Engine Oil Pressure Switch
5. Install the turbocharger inlet elbow. Refer to "Installation of the turbo inlet elbow."
6. Install the Air Cleaner Assembly. Refer to OEM procedures.
7. Install the engine wiring harness mounting clips onto the left side of the engine.

⚠WARNING

PERSONAL INJURY

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

⚠WARNING

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

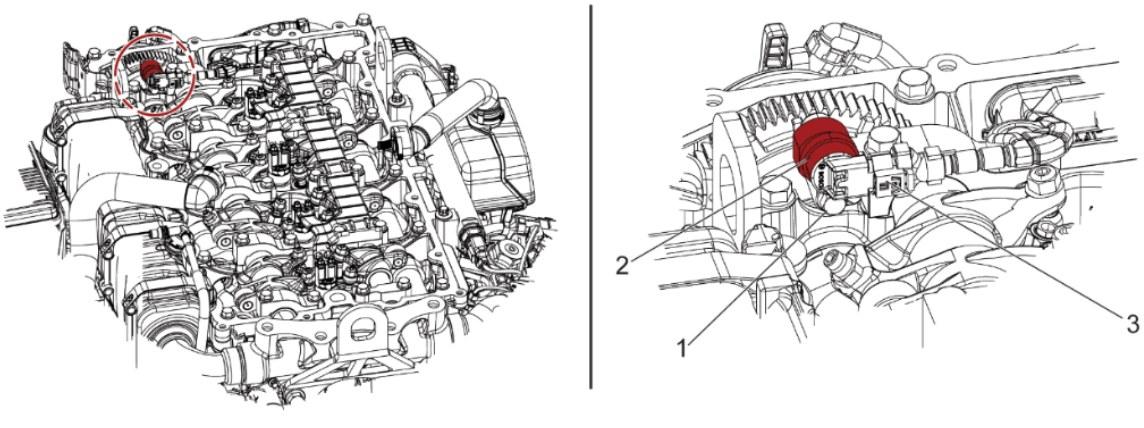
1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

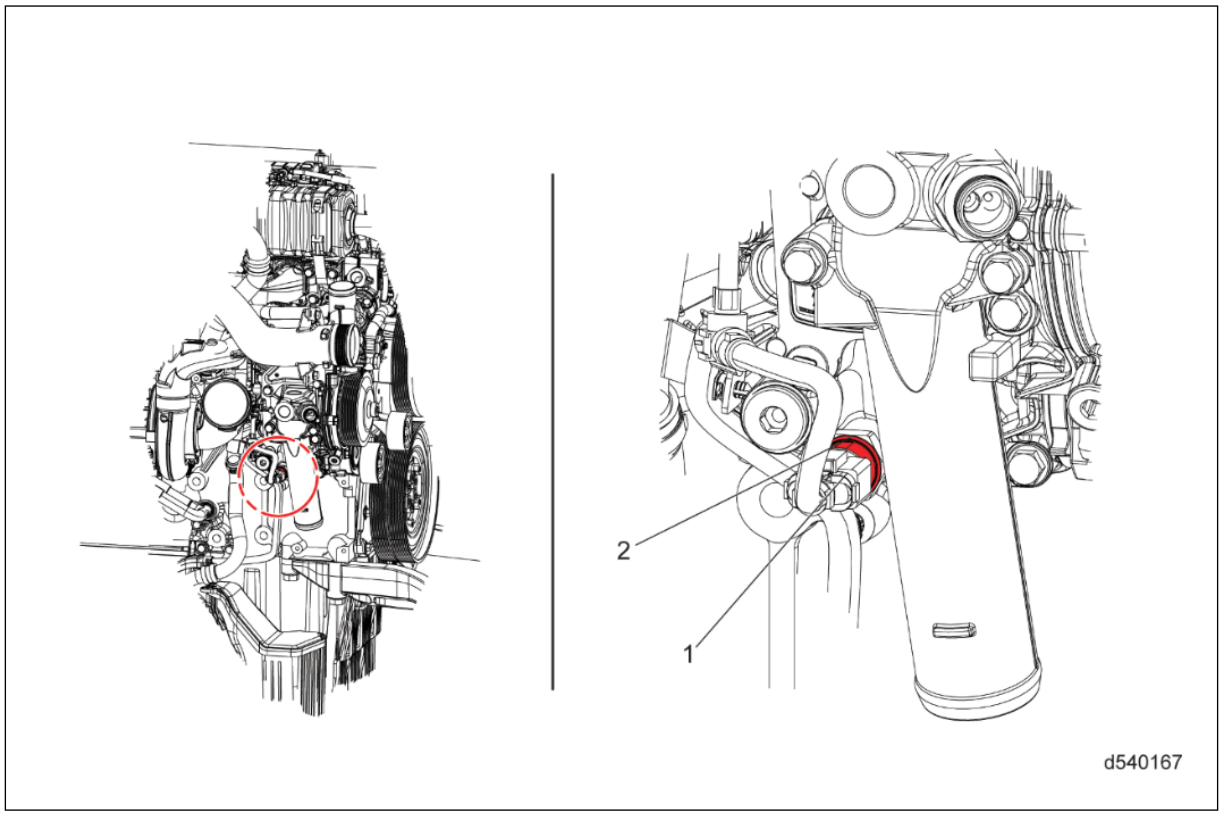
CAUTION

ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Disconnect the batteries.
3. Open the hood.
4. Remove the rocker cover. Refer to section "Removal of the Rocker Cover".
5. Disconnect the Camshaft Position (CMP) sensor electrical connector (3).





2. Connect the oil pressure switch electrical connector (1) and push the gray tab forward to lock the connector onto the sensor.

NOTICE

The engine oil can be reused if it is not contaminated and has been properly maintained.

3. Refill the engine with lubricating oil. Refer to section "Engine Oil Capacities"
4. Close the hood.

CAUTION

ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

5. Connect the batteries.

8.2.14 Description and Operation of the Engine Oil Temperature Sensor

The oil temperature sensor is mounted on the rear of the oil/coolant module. The Motor Control Module (MCM) determines the oil temperature from a signal received from the oil temperature sensor.

1. Mounting Bolts
2. Intake Pressure/Temperature Sensor Electrical Connector
3. Intake Pressure/Temperature Sensor

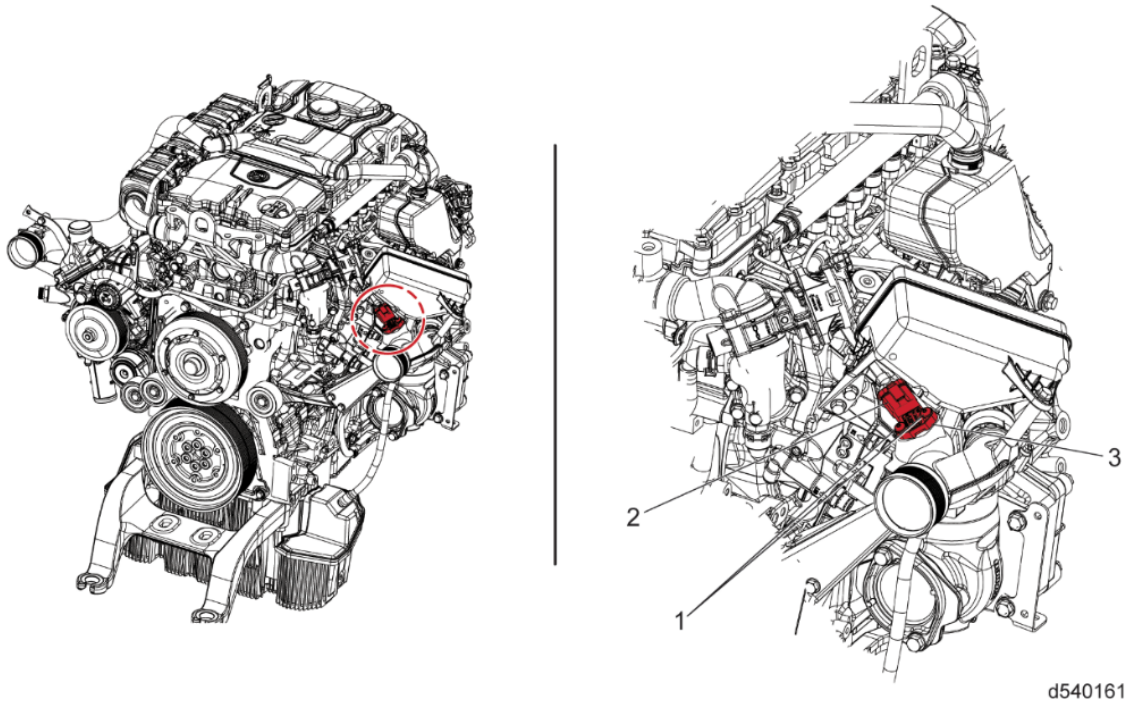


Fig 8.3, Intake Pressure/Temperature Sensor Location

8.2.24 Removal of the Intake Pressure/Temperature Sensor

⚠WARNING

PERSONAL INJURY

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

⚠WARNING

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

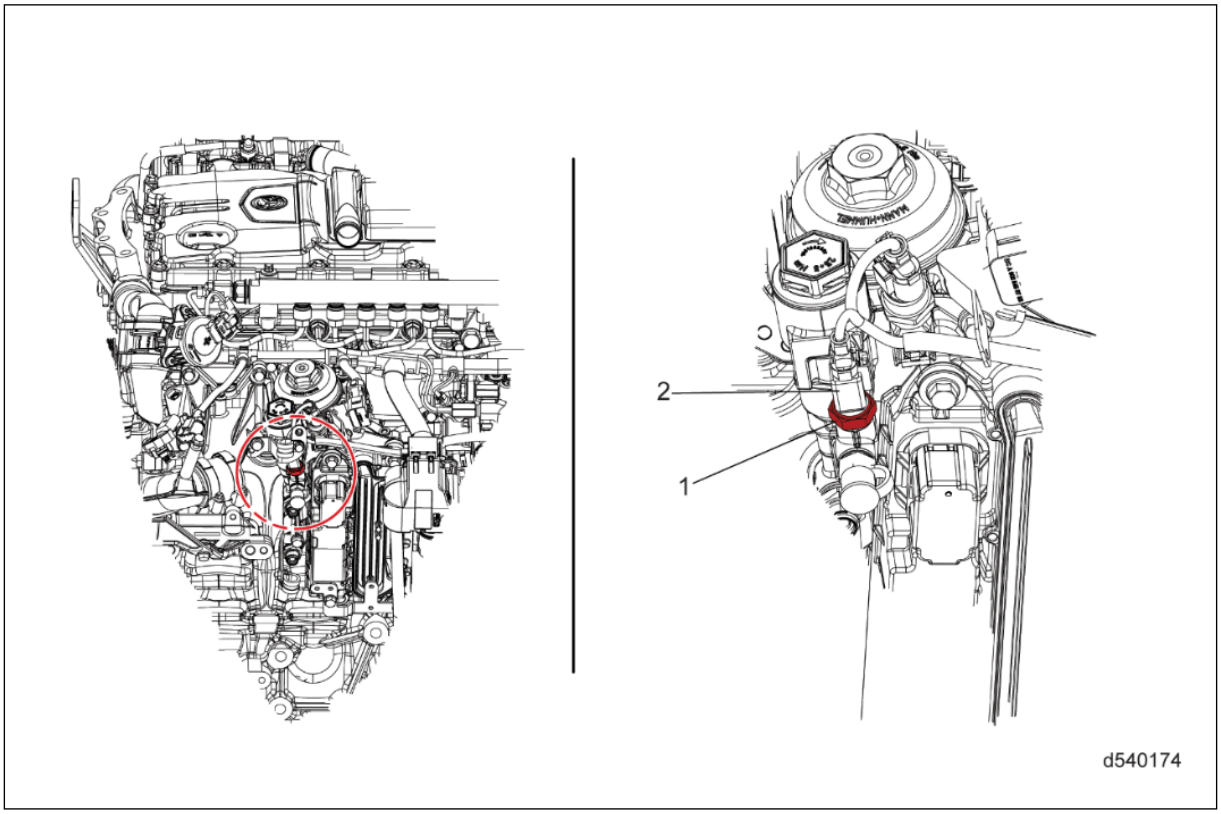
CAUTION

ELECTRICAL SHOCK

CAUTION
ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

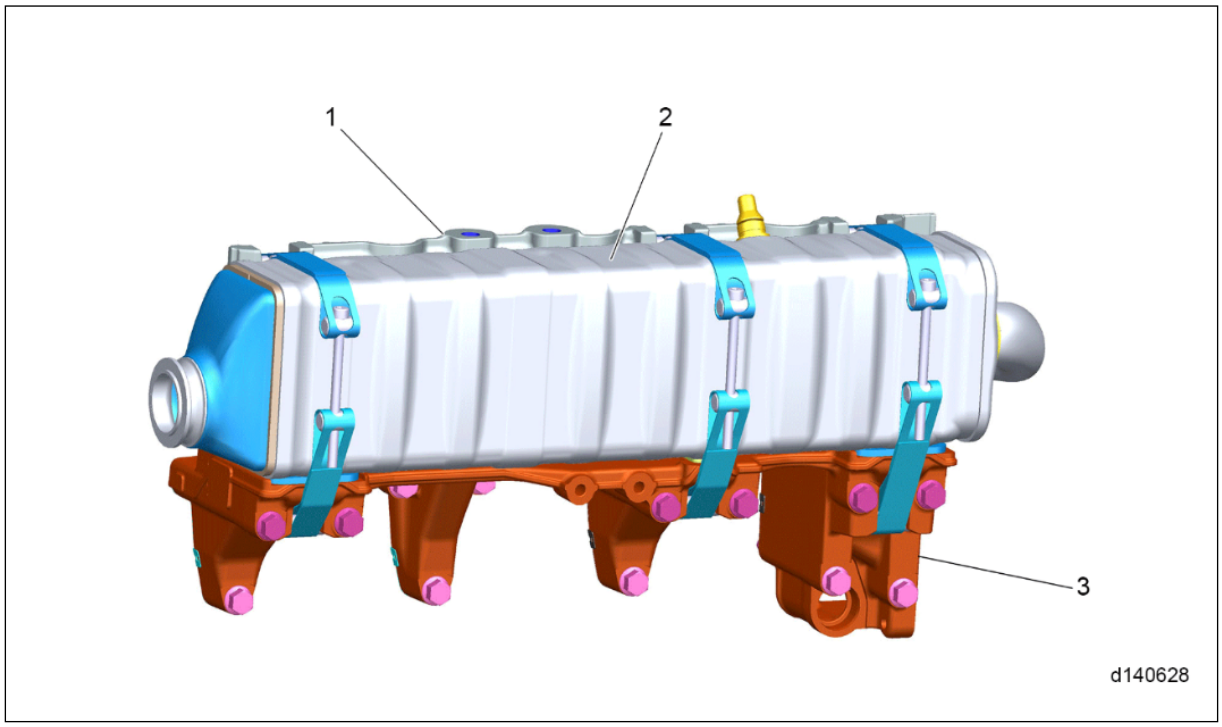
2. Disconnect batteries.
3. Open the hood.
4. Remove the final fuel filter which will allow the fuel filter module to drain.
5. Disconnect the supply fuel temperature sensor electrical connector (2).



6. Remove the supply fuel temperature sensor (1) from the fuel filter module.

8.2.34 Installation of the Supply Fuel Temperature Sensor

1. Install the supply fuel temperature sensor (1) into the fuel filter module. Torque sensor to 25 N·m (18 lb·ft).

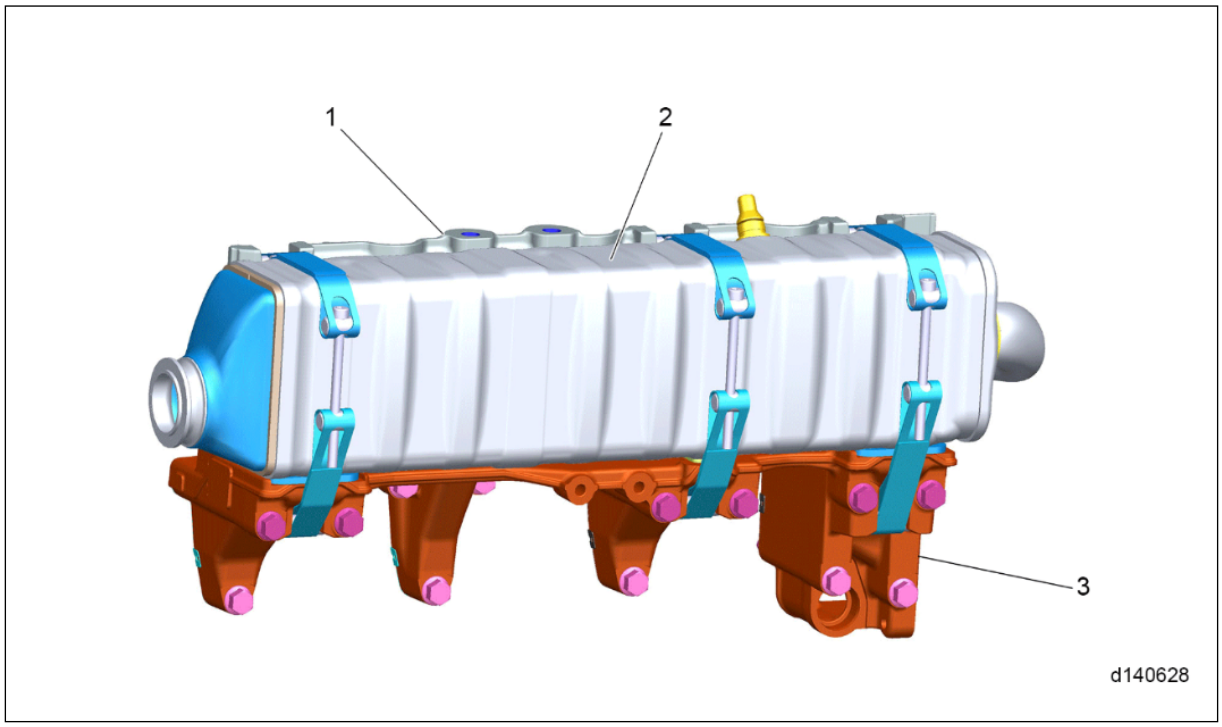


9.1.2 Installation of the Exhaust Gas Recirculation Cooler Bracket

Install as follows:

Note : Verify the Exhaust Gas Recirculation (EGR) cooler bracket has the same orientation as noted during removal.

1. Install the EGR cooler bracket (1). Torque to 25 N·m (18 lb·ft).



9.5 Exhaust Gas Recirculation Hot Pipe

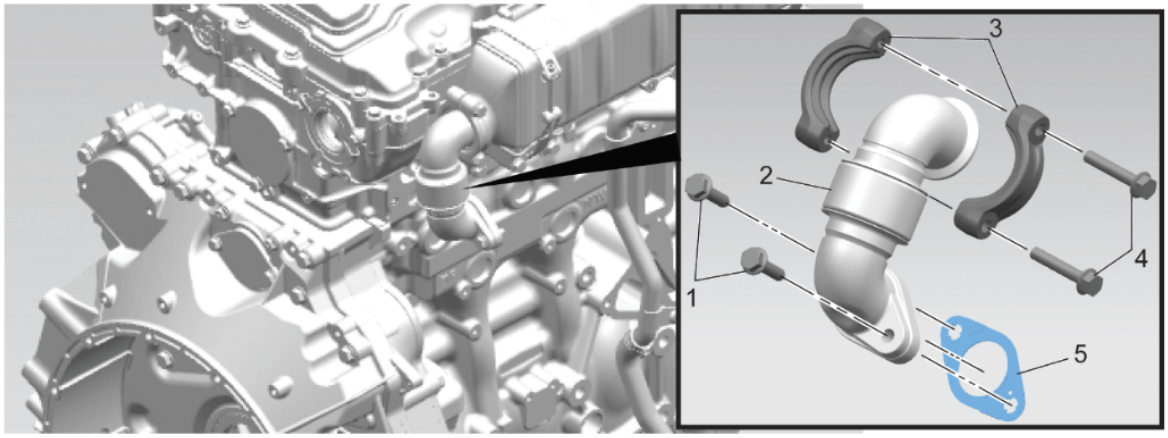
9.5.1 Removal of the DD5 Exhaust Gas Recirculation Hot Pipe

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

CAUTION
ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

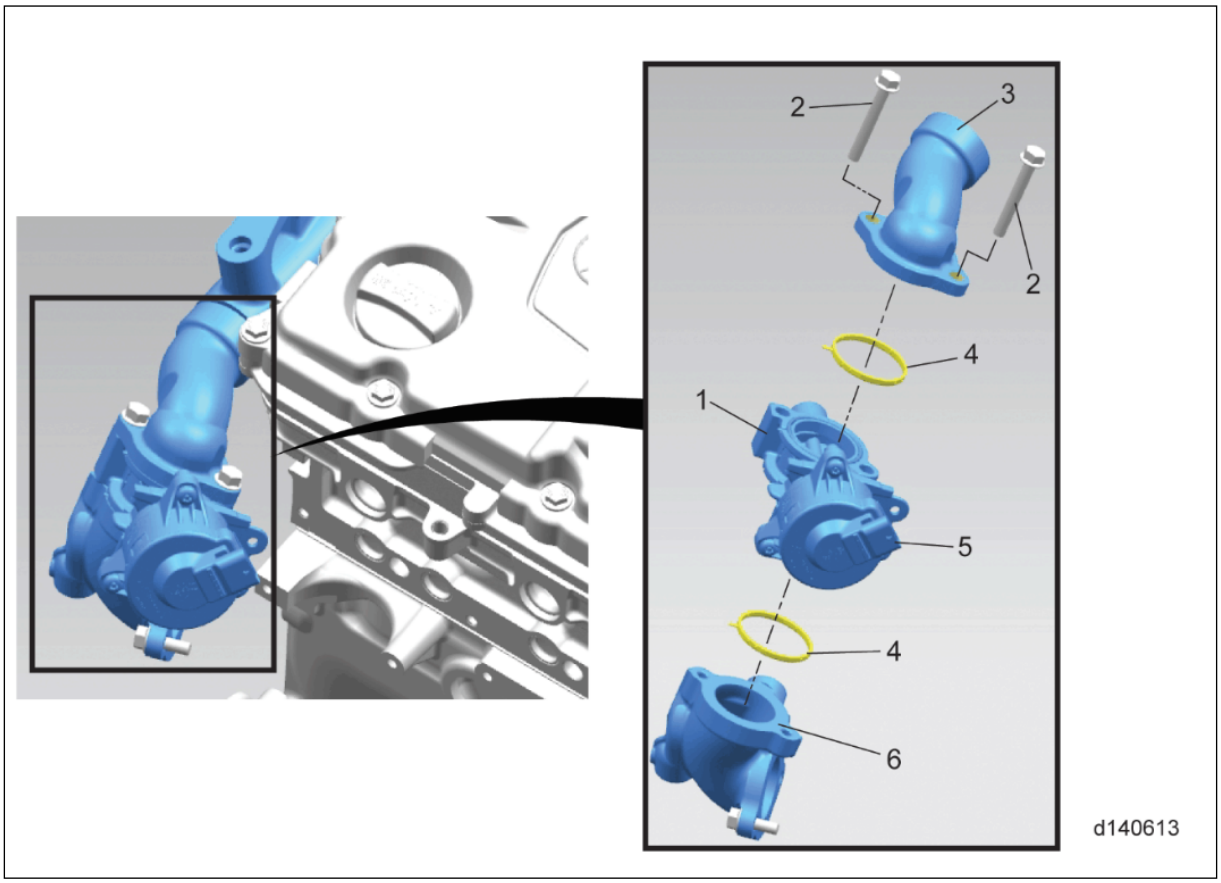
2. Disconnect batteries.
3. Open hood.
4. If needed, remove the bumper end(s).
5. Remove the air cleaner assembly. Refer to Original Equipment Manufacturer (OEM) procedure.
6. Remove the Exhaust Gas Recirculation (EGR) hot pipe heat shield.



7. Remove the upper marman clamp bolts (4) and outer marman clamp shell. Discard marman clamp shell bolts.

Note : Inner marman clamp shell can only be removed once the Exhaust Gas Recirculation (EGR) hot pipe is removed.

8. Remove lower EGR hot pipe bolts (1).
9. Remove EGR hot pipe (2) and inner marman clamp shell. Discard gasket (5) and marman clamp shells (3).



8. Remove EGR valve mounting bolts (2).
9. Remove EGR valve (1) and discard seal rings (4).

9.8.3 Inspection of the Exhaust Gas Recirculation Valve

1. Visually inspect Exhaust Gas Recirculation Valve (EGR) housing for cracks. Replace if damage is found.
2. Inspect the electrical wiring for chafed or broken wires.
3. Inspect the electrical connector for bent or damaged pins.

9.8.4 Installation of the Exhaust Gas Recirculation Valve

1. Install new seal rings on the Exhaust Gas Recirculation (EGR) valve.
2. Install the EGR valve. There is an arrow on the EGR valve to indicate direction of installation. See figure below.

10.2 Fuel System Draining Procedure

10.2.1 Draining the Fuel System Prior to Repairs

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.

CAUTION
ELECTRICAL SHOCK

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Disconnect the batteries.
3. Open the hood.
4. Remove the fuel tank fill caps to relieve pressure in the fuel tanks. Reinstall the fuel tank fill caps.
5. Using a 36mm socket, unscrew the final filter cap.

NOTICE

Do not tilt the final filter when removing it from the housing. Possible damage to the final filter or stand pipe may occur.

6. Pull the cap and final filter (1) straight up and allow the fuel to drain back.

4. Install the final filter into the fuel filter module.
5. Torque the final filter cap to 25 to 30 N·m (19 to 22 lb·ft).

Note : If a filter service is being performed, replace all other filters before priming.

6. Once all required filters have been changed, prime the fuel system. Refer to section "Priming the Fuel System".

NOTICE

Avoid cleaning (wire brushing etc.) the fuel injector tip spray holes to prevent damage and plugging.

13. Using a clean rag soaked with clean diesel fuel, carefully remove any carbon material from the fuel injector exterior.

NOTICE

Fuel injector O-ring seals, fuel injector clamp bolt and the copper heat protection sleeve are considered one-use items and cannot be reused. Any time a fuel injector is removed, the fuel injector bolt, two fuel injector O-ring seals and copper heat protection sleeve must be replaced with new parts. Failure to replace the O-ring seals, heat protection sleeve and bolt can result in leakage.

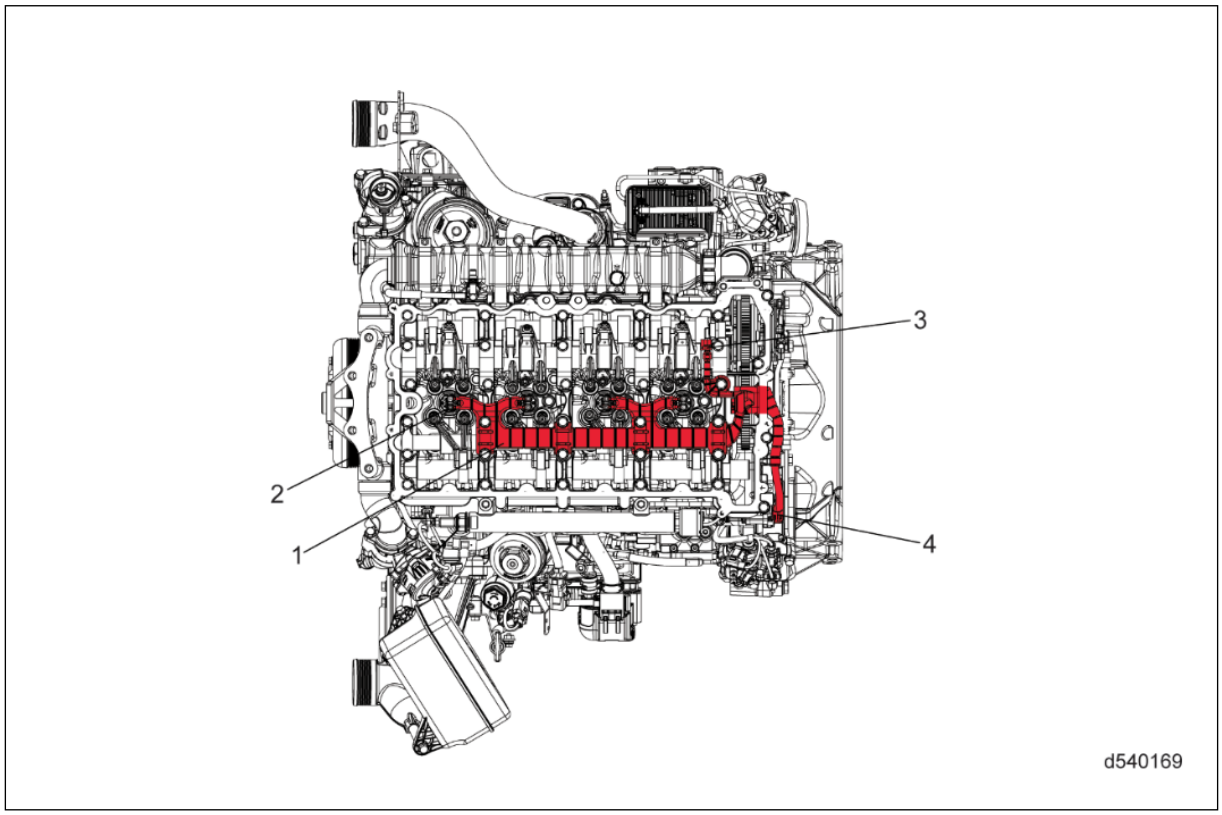
14. Inspect the fuel injector body for visible damage. Replace the fuel injector if damaged.
15. If the fuel injector is intended to be reused, remove and discard the two fuel injector O-rings and the copper sleeve.

10.6.3 Installation of the Fuel Injector

Service Tools Used in the Procedure		
Tool Number	Tool Name	Tool Graphic
W936589003300	Injector Puller	 d580185
W936589013300	Injector Seal Installer	 d580186
W936589033300	Tool Kit	 d580187
		 d580188

Install as follows:

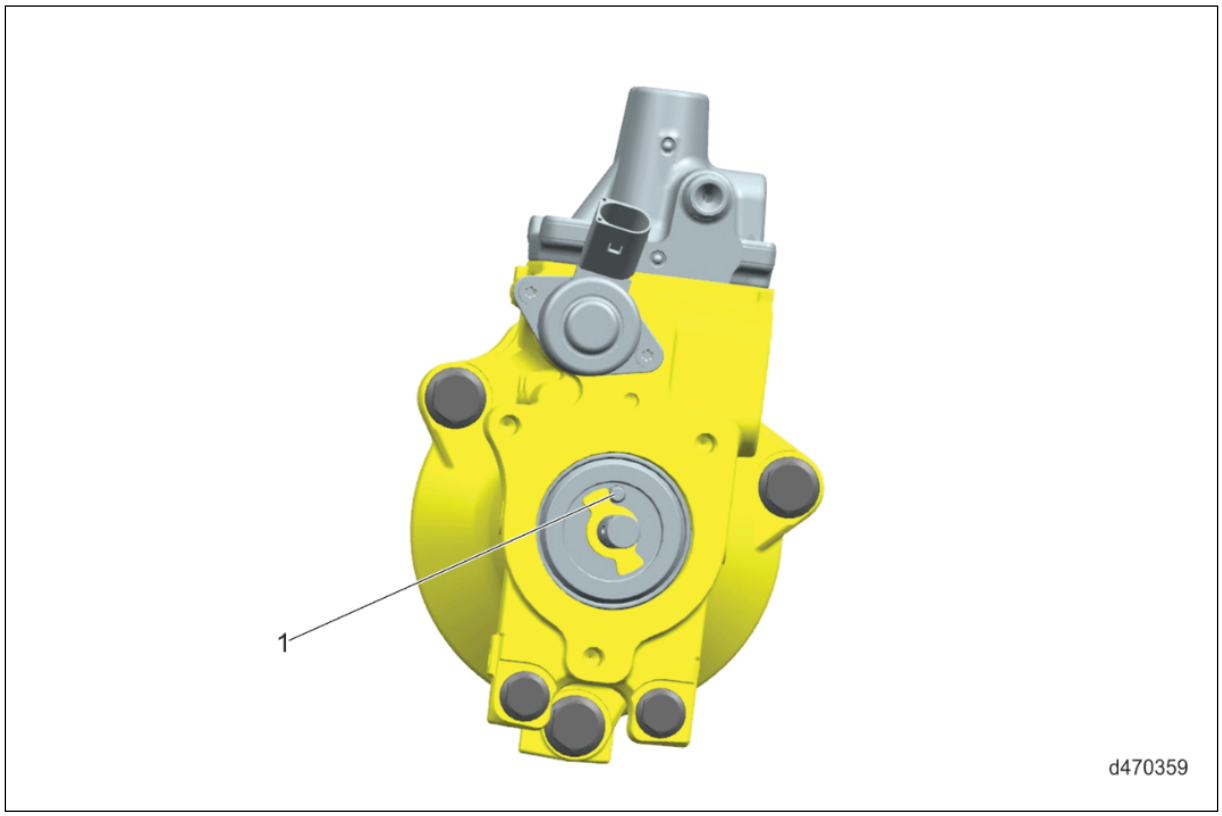
4. Remove the rocker cover. Refer to section "Removal of the Rocker Cover."
5. Remove the terminal nuts (2) on all four injectors.



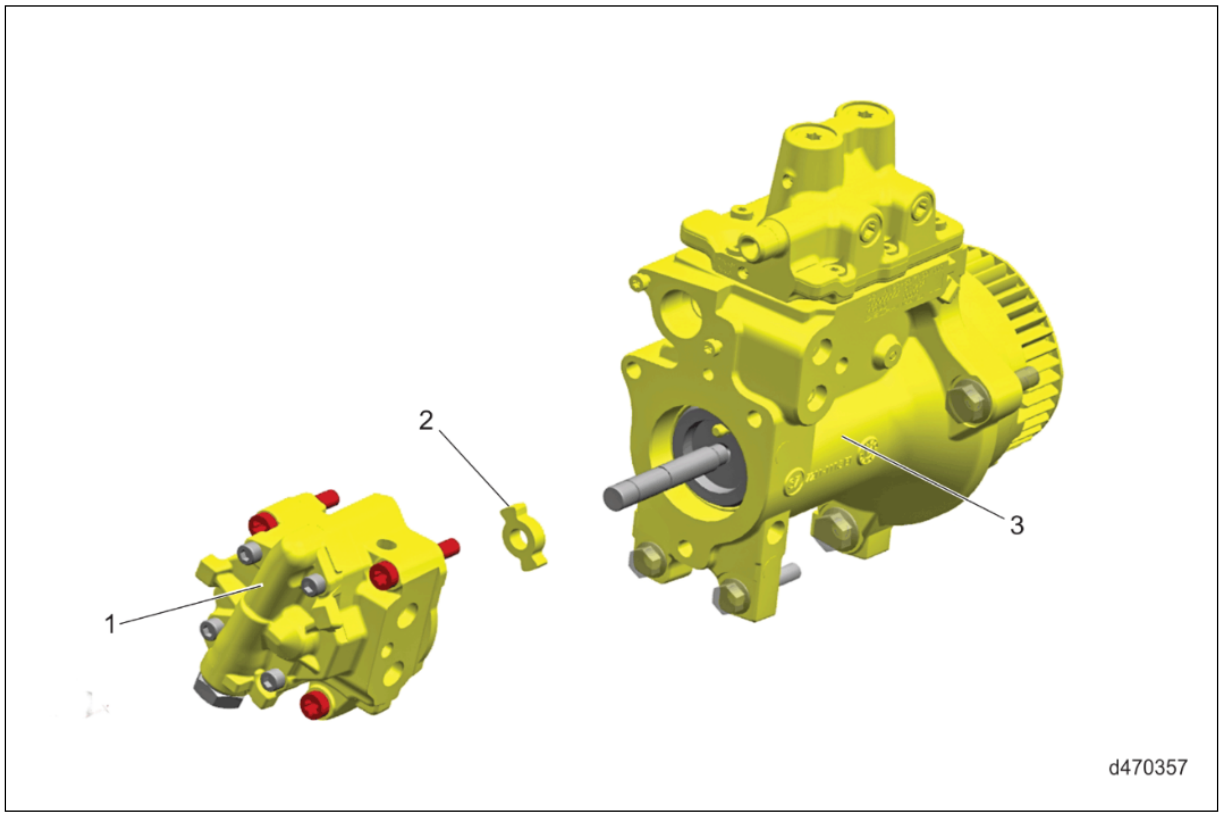
6. Disconnect the camshaft position sensor electrical connector (3).
7. Disconnect the fuel injector wiring harness 16-pin connector (4) from the engine wiring harness.
8. Remove the fuel injector wiring harness (1) from the camshaft housing by pulling up on the tab as indicated on the harness.

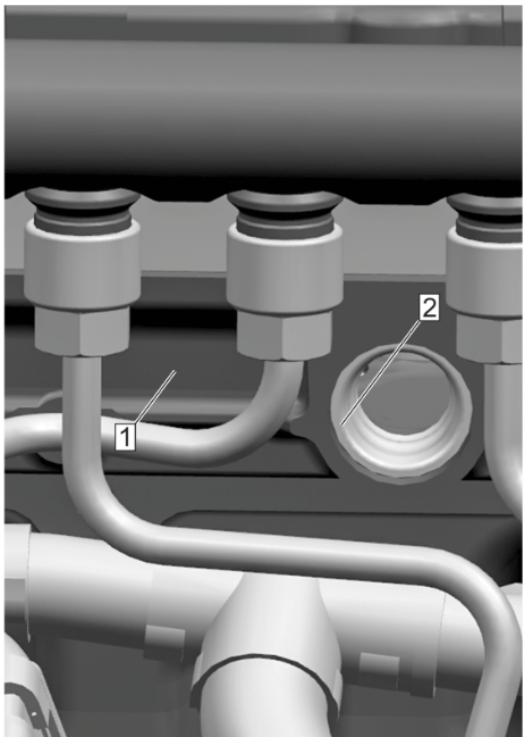
10.8.3 Installation of the Fuel Injector Wiring Harness

1. Install the fuel injector wiring harness into the camshaft housing.



3. Visually inspect the drive coupler (2) and driven key for damage. If damage is found, replace the high pressure fuel pump (3).





2. Lubricate the inside of the new fuel injector line seals with a light coating of clean engine oil.
3. Loosen the fuel rail clamp bolts.

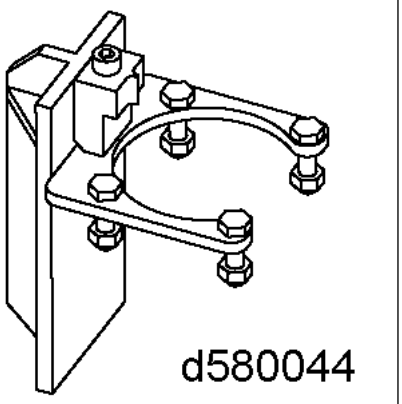
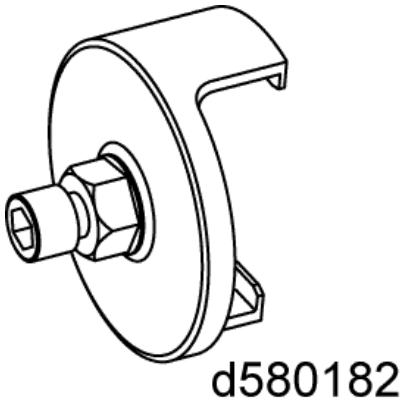
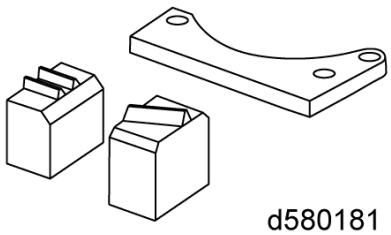
Note : The high pressure fuel injector lines must first be fastened onto the fuel rail and then onto the fuel injector or leaks may occur.

Note : To install the high pressure line on cylinder #2, the high pressure line on cylinder #3 must be installed first.

4. Install the new high pressure fuel injector line (2) onto the fuel rail (3); hand-tighten the fuel injector line nut.

6. Inspect the dowel pin for wear or damage and replace pin if necessary.
7. Remove the high pressure fuel pump from the high pressure pump holding-device tool (W470589084000).

10.13.5 Installation of the High Pressure Fuel Pump Drive Gear

Service Tools Used in the Procedure		
Tool Number	**Tool Description**	**Tool Graphic**
W470589084000	HP pump holding fixture	
W936589053300	Drive gear puller	
W936589003100	HP Pump adaptor and locking tooth	

1. Install the high pressure fuel pump onto the high pressure pump holding-device tool (W470589084000) using adaptor plate and locking tooth tool (W936589003100).