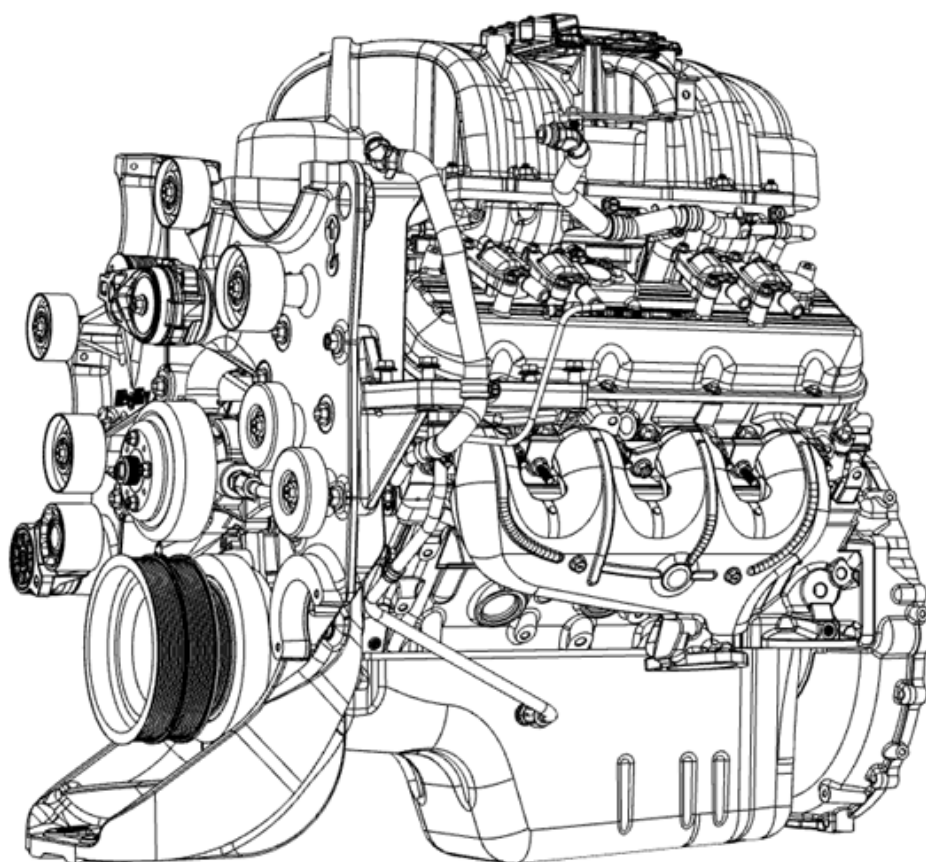




# **488LPI** Propane Autogas Engine Electrical and Sensors Service Manual



DSM.0053 Ver. 1.0  
May 26, 2022

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## Preface

This manual is designed as a support document for trained technicians in the maintenance and service procedures of the 488LPI™ propane autogas engine and fuel system provided by Hexagon Agility®.

No attempt shall be made to install, maintain, or repair this product until this manual and all referenced supporting documentation have been read and fully understood.

Original Equipment Manufacturer (OEM) parts not serviced by Hexagon Agility® may be obtained by contacting Freightliner Custom Chassis Corporation or Thomas Built Buses.

Fuel system warranty or non-warranty product support may be obtained by calling or emailing Hexagon Agility® Customer Care and Technical Services (CCTS).

Please provide **your name, phone number, email address, and complete vehicle information: VIN, year, make, model, mileage, unit number, vehicle owner, and current vehicle location.** A service advisor will contact you to arrange vehicle repair or ship a part.

### **⚠ WARNING**

**All parts must adhere to the accepted standards and ratings as specified by Hexagon Agility®. Use of any part that is not approved by Hexagon Agility® is not recommended and may compromise the integrity and safety of the system.**

### **NOTICE**

**Do not remove components from original packaging until necessary. Any components that are to be reinstalled must be thoroughly cleaned, inspected, and stored in a satisfactory manner until reinstallation.**

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## Acronyms

CKP	crankshaft position sensor
CMP	camshaft position sensor
ECM	electronic control module
ETC	electronic throttle control sensor
ECT	engine coolant temperature sensor
EVAP	evaporative emissions
FPT	fuel pressure/temperature sensor
LPG	liquid propane gas
LPI	Liquid Propane Injection
MAP	manifold absolute pressure sensor
MAF	mass air flow sensor
TSM	torque security module

## Safety

Hexagon Agility® provides safety guidelines to ensure the safety of personnel servicing and / or operating liquid propane gas<sup>1</sup> (LPG) equipment. All personnel involved must adhere to industry standards, specialized training, and all federal, state, and municipal laws and regulations.

Hexagon Agility® minimizes potential hazards through state-of-the art design and testing practices. Always observe the procedures and recommendations of this manual.

Due to the presence of high-pressure and flammable fuel, LPG fuel systems are a form of hazardous energy storage.

### Warning and Signal Words Used in this Manual



**WARNING** indicates a hazardous situation which, if not avoided, could result in death or serious injury.



**CAUTION** indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.



**NOTICE** is used to address practices not related to physical injury, such as best practices or tips to help an operation or procedure go smoothly and prevent equipment damage.



**Critical Characteristic**

Product feature directly affects:

- Safety of vehicle users, people nearby and maintenance personnel, or
- Regulatory compliance.

### Qualified Personnel

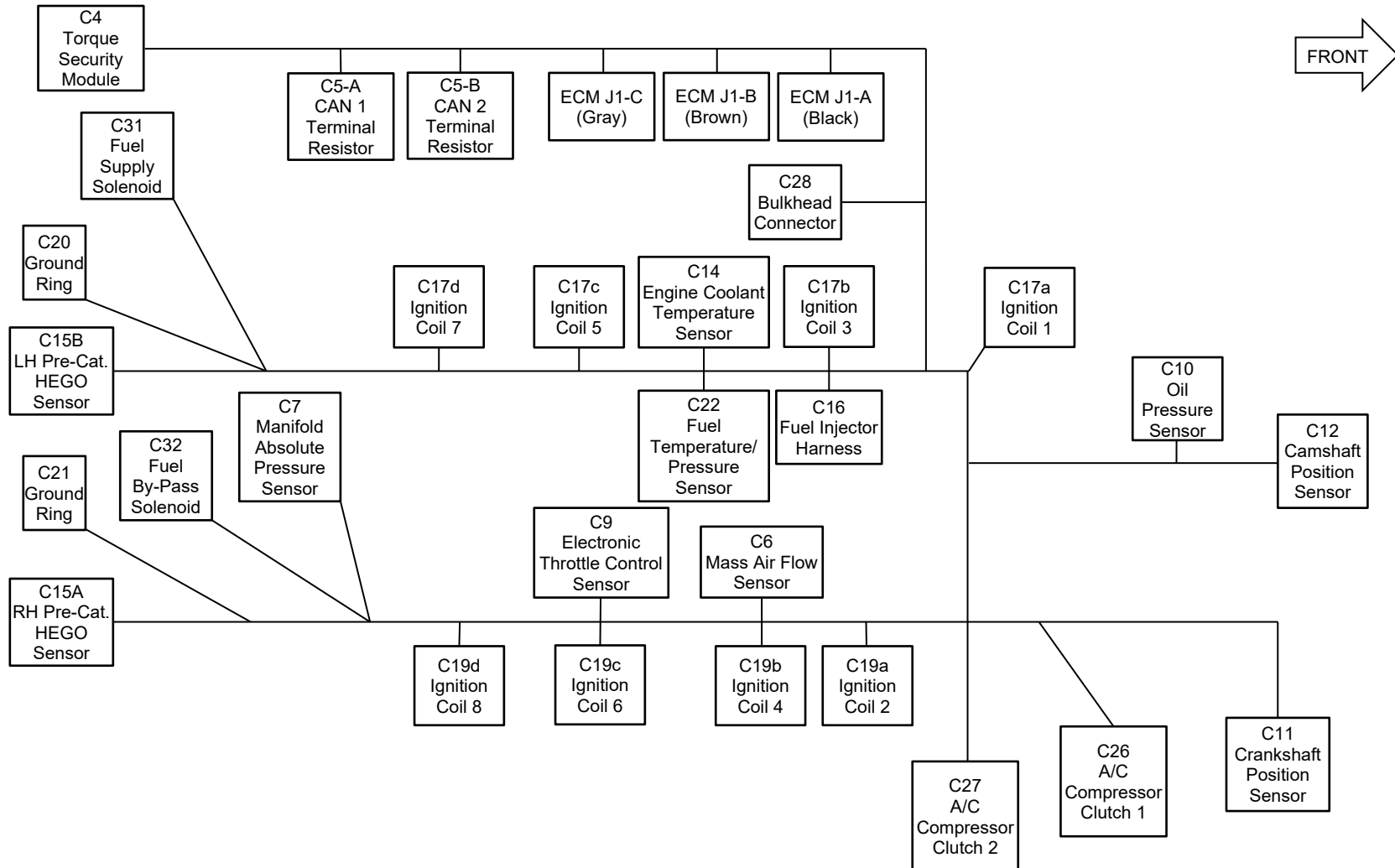
LPG systems must be maintained and inspected exclusively by trained personnel with qualifications in accordance with the applicable codes.



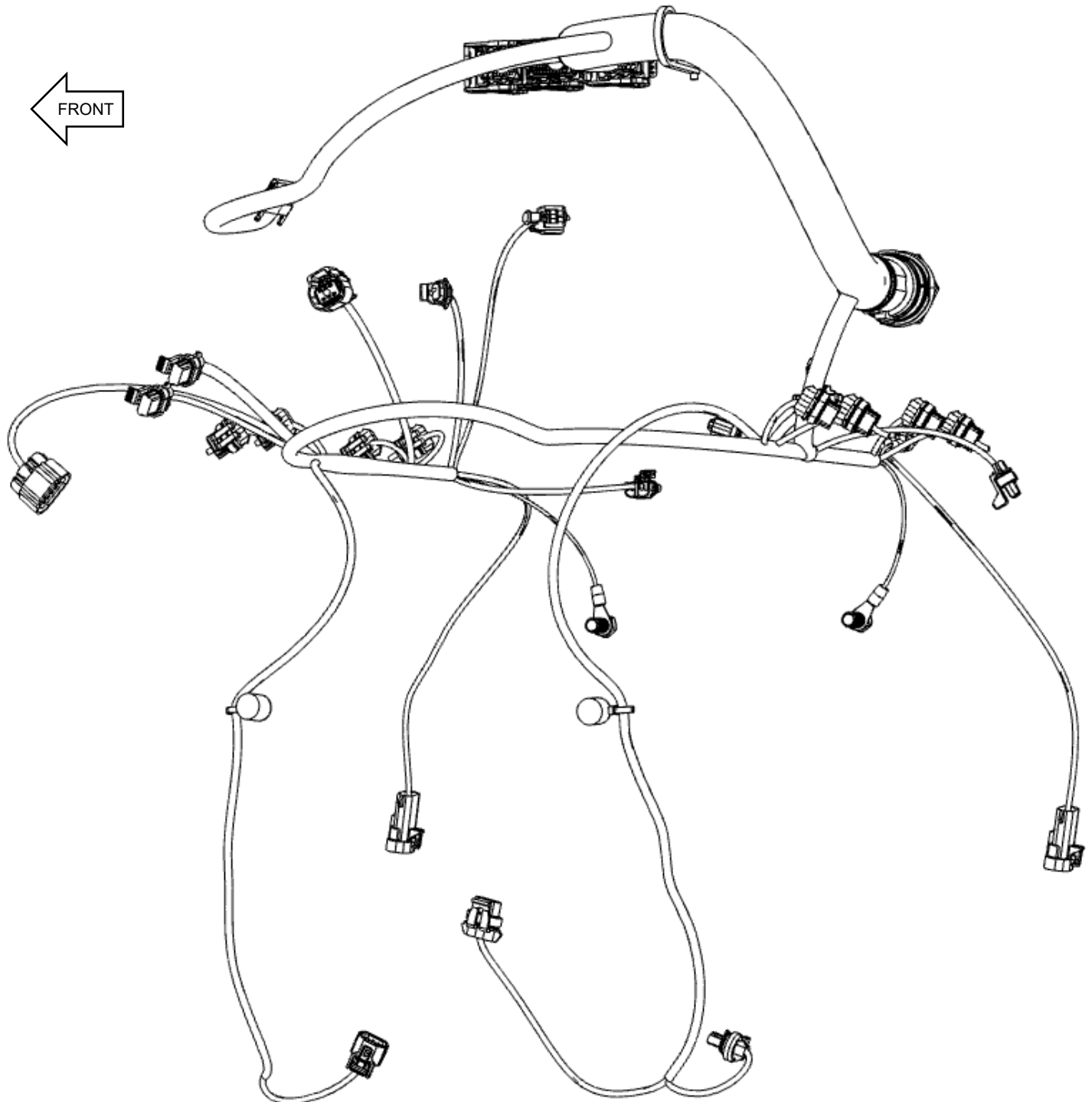
**Individuals involved in any aspect of LPG fuel system maintenance, emergency response, servicing or testing must be properly trained. Individuals who are not trained are not permitted to service, maintain, test, or inspect a system.**

<sup>1</sup> LPG used for automotive applications is often referred to as “propane autogas.”

# Engine Harness Component Diagram



## Repair Procedures





# Camshaft Position (CMP) Sensor Replacement

## DESCRIPTION AND OPERATION

The Camshaft Position (CMP) Sensor uses electromagnetic field variations to detect Camshaft Sprocket rotation and speed to report Camshaft position to the ECM (Electronic Control Module).

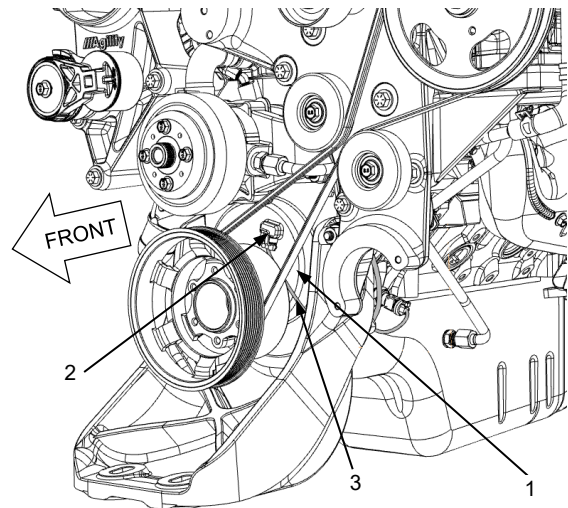
The CMP Sensor bolts to the Front Engine Cover and connects to the Engine Wiring Harness.

## REMOVAL PROCEDURE

1. Secure vehicle on an approved lift and lift vehicle.
2. Verify engine is off.
3. Disconnect CMP Sensor Electrical Connector (2) from Engine Harness (3). *Figure 1*
4. Remove CMP Sensor Retaining Bolt (*not shown*) from Engine Front Cover (1). *Figure 1*
5. Remove CMP Sensor from Engine Front Cover (1). *Figure 1*
6. Inspect CMP Sensor and O-ring for wear, cracks or other damage.

### **NOTICE**

**CMP Sensor must be replaced if O-ring is damaged.**



*Figure 1:*  
Camshaft (CMP) Sensor Electrical Connector location (2), Engine Harness (3), Engine Front Cover (1)

## INSTALLATION PROCEDURE

1. Lubricate CMP Sensor O-ring with clean engine oil.
2. Install CMP Sensor in Front Engine Cover (1). *Figure 1*
3. Install and tighten CMP Sensor Retaining Bolt (*not shown*). Refer to [Electrical Component & Sensor Torque Specifications](#).
4. Connect CMP Sensor Electrical Connector (2) to Engine Harness (3). *Figure 1*
5. Lower vehicle.
6. Verify proper operation.

# Crankshaft Position (CKP) Sensor Replacement

## DESCRIPTION AND OPERATION

The Crankshaft Position (CKP) Sensor detects crankshaft rotation and speed by monitoring the Crankshaft Reluctor Wheel to report crankshaft position to the ECM (Electronic Control Module).

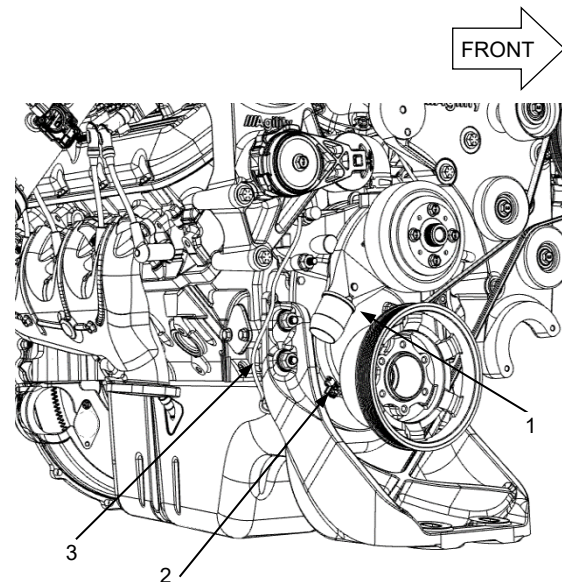
The CKP Sensor bolts into the passenger side of the Engine Front Cover and connects to the Engine Wiring Harness.

## REMOVAL PROCEDURE

1. Secure vehicle on approved lift and raise vehicle.
2. Verify engine is off.
3. Disconnect CKP Sensor Electrical Connector (2) from Engine Harness (3). *Figure 1*
4. Remove CKP Sensor Retaining Bolt (*not shown*) from Engine Front Cover (1). *Figure 1*
5. Remove CKP Sensor from Engine Front Cover (1). *Figure 1*
6. Inspect CKP Sensor and O-ring (*not shown*) for wear, cracks or other damage.

### **NOTICE**

**CKP Sensor must be replaced if O-ring is damaged.**



*Figure 1:*  
Camshaft (CKP) Sensor Electrical Connector location (2), Engine Front Cover (1), Engine Harness (3)

## **INSTALLATION PROCEDURE**

1. Lubricate CKP Sensor O-ring (*not shown*) with clean engine oil.
2. Install CKP Sensor in Front Engine Cover (1). *Figure 1*
3. Install and tighten CKP Sensor Retaining Bolt (*not shown*). Refer to [\*Electrical Component & Sensor Torque Specifications\*](#).
4. Connect CMP Sensor Electrical Connector (2) to Engine Harness (3). *Figure 1*
5. Lower vehicle.
6. Verify proper operation.

# Engine Control Module (ECM) Replacement

## DESCRIPTION AND OPERATION

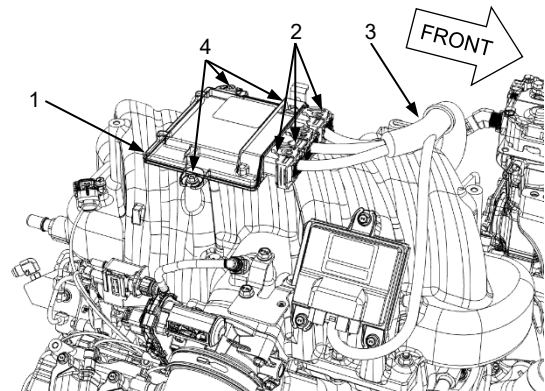
The Engine Control Module (ECM) monitors and directs engine operation. The ECM connects to the Engine Harness via three (3) electrical connectors and attaches to the Upper Intake Manifold using three (3) bolts.

### **NOTICE**

**ECMs are unique to each vehicle and must be programmed according to Vehicle Equipment Programming Stations (VEPS). Please contact Hexagon Agility®.**

## REMOVAL PROCEDURE

1. Secure vehicle.
2. Ignition OFF.
3. Disconnect ECM Engine Harness Electrical Connectors (2) from Electronic Control Module (ECM) (1). *Figure 1*
4. Remove three (3) ECM Mounting Bolts (4). *Figure 1.*
5. Remove ECM (1) from Upper Intake Manifold (6). *Figure 2*



*Figure 1:*  
ECM (1), Engine Harness ECM Electrical Connectors (2), Engine Harness (3), ECM Mounting Bolts (4)

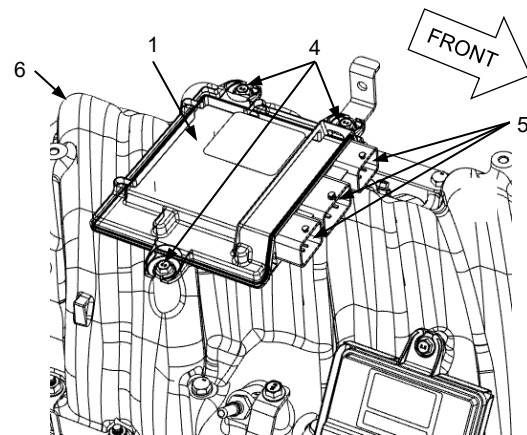
## INSTALLATION PROCEDURE

1. Install ECM (1) on Upper Intake Manifold (6) using three (3) ECM Mounting Bolts (4) and tighten. *Figures 1 & 2. Refer to [Electrical Component & Sensor Torque Specifications](#).*
2. Connect three (3) Engine Harness Electrical Connectors (2) to ECM Electrical Connector locations (5).

### **NOTICE**

**Verify connector security locks are firmly in place. Figures 1 & 2**

3. Verify proper operation.



*Figure 2:*  
ECM (1), ECM Electrical Connector locations (5), ECM Mounting Bolts (4)

# Engine Coolant Temperature (ECT) Sensor Replacement

## DESCRIPTION AND OPERATION

The Engine Coolant Temperature (ECT) Sensor measures coolant temperature using variable resistance with temperature and sends readings to the Engine Control Module (ECM). The ECM uses ECT data and inputs from other sensors to adjust fuel injection and ignition timing.

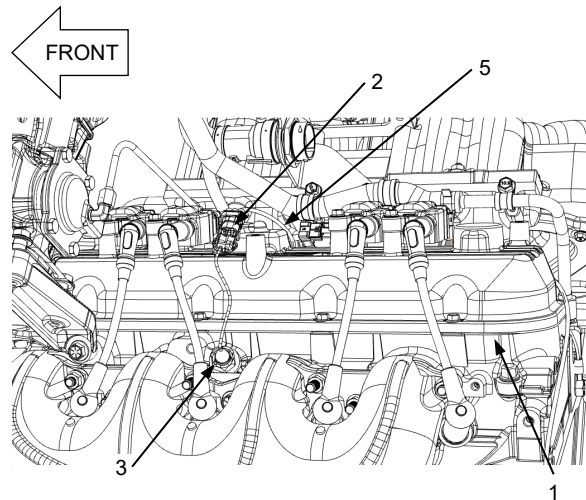
The ECT sensor attaches to the Engine Harness via a pigtail connector and threads into the middle of the driver side Cylinder Head.

## REMOVAL PROCEDURE

1. Secure vehicle.
2. Ignition OFF.
3. Drain cooling system below level of Engine Coolant Temperature (ECT) Sensor. *Follow OEM procedure.*
4. Disconnect ECT Sensor Pigtail Electrical Connector (2) from Engine Harness (5). *Figure 1*
5. Remove ECT Sensor (3) from driver side Cylinder Head (1) using a socket. *Figure 1*

### **NOTICE**

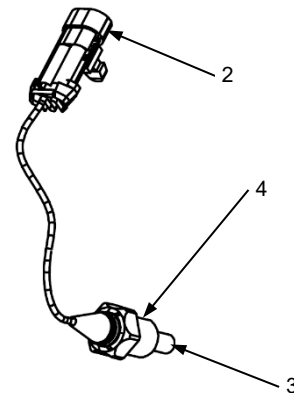
**Handle ECT Sensor carefully.**



*Figure 1:*  
ECT Sensor Pigtail Electrical Connector (2),  
ECT Sensor (3), Engine Harness (5),  
Driver side Cylinder Head (1)

## INSTALLATION PROCEDURE

1. Apply sealant to ECT Sensor Threads (4). *Figure 2*
2. Install ECT Sensor (3) in driver side Cylinder Head (1) using a socket. *Figure 1. Refer to [Electrical Component & Sensor Torque Specifications](#).*
3. Connect ECT Sensor Pigtail Electrical Connector (2) to Engine Harness (5). *Figure 1*
4. Fill cooling system. *Follow OEM procedure.*
5. Clean any spilled fluids.
6. Verify proper operation.



*Figure 2:*  
ECT Sensor (3), ECT Sensor Pigtail Electrical  
Connector (2), ECT Sensor Threads (4)

# Engine Harness Replacement

## DESCRIPTION AND OPERATION

The Engine Harness connects the Electronic Control Module (ECM) to various electronic components including engine sensors, ignition coils, fuel injectors, and relays. Additionally, the Engine Harness connects to OEM vehicle wiring via the C28 Bulkhead Connector.

### **NOTICE**

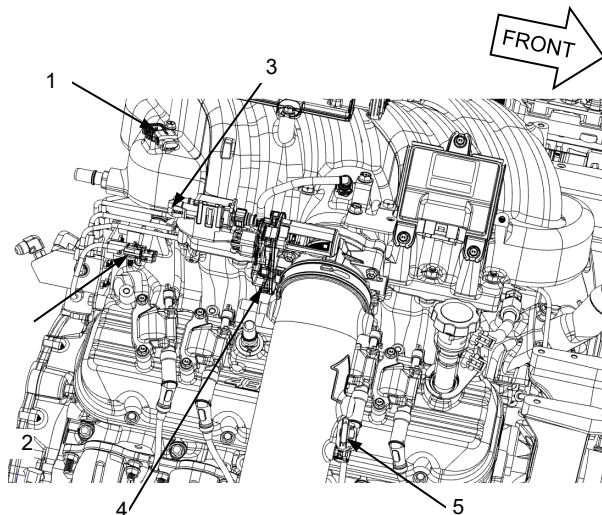
When making many engine repairs it may be necessary to partially or completely remove the Engine Harness. This may require removing wire harness clips and retainers; always replace any retaining devices to prevent harness contact with hot surfaces or rotating parts and minimize rubbing and chafing of the harness.

### **NOTICE**

When removing connectors, never pull on the wire harness; only pull on the connect

## REMOVAL PROCEDURE

1. Secure vehicle.
2. Verify engine is cool.
3. Disconnect negative (–) Battery Cable.
4. Disconnect Engine Harness from the following passenger side engine electrical components shown in Figure 1:
  - a) C7 Manifold Absolute Pressure (MAP) Sensor (1)
  - b) C30 EVAP Purge Solenoid (2)
  - c) C32 Fuel By-Pass Solenoid (3)
  - d) C9 Electronic Throttle Control (ETC) (4)
  - e) C6 Mass Air Flow (MAF) Sensor (5)



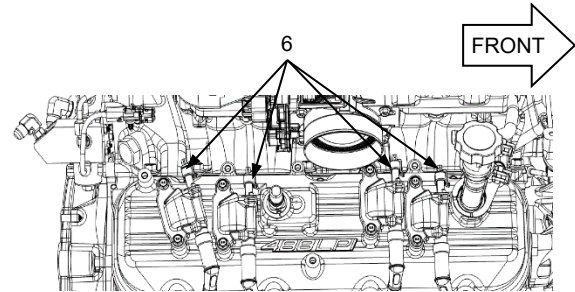
*Figure 1:*  
Manifold Absolute Pressure (MAP) Sensor (1)  
EVAP Purge Solenoid (2), Fuel By-Bass Solenoid (3),  
Electronic Throttle Control (ETC) (4), and  
Mass Air Flow (MAF) Sensor (5) connector locations



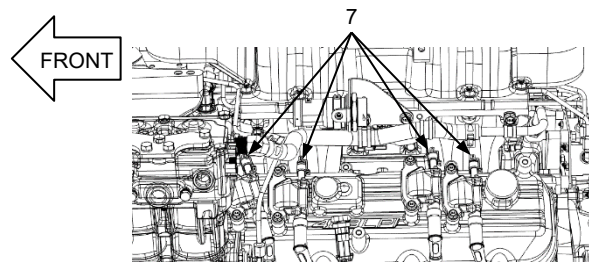
5. Disconnect C19 Connectors (6) from Ignition Coils 2, 4, 6, 8. *Figure 2*
6. *If equipped:* Disconnect C26 and C27 Air Conditioner Compressor Clutch Connector(s) (*not shown*).
7. Disconnect Engine Harness from driver side component connectors as follows:

- a. C17 Connectors (7) from Ignition Coils 1, 3, 5, 7. *Figure 3*
- b. C22 Fuel Rail Pressure/Temperature (FTP) Sensor (8). *Figure 4*
- c. C14 Engine Coolant Temperature (ECT) Sensor connector (9). *Figure 5*
- d. C16 Fuel Injector Harness Connector (10). *Figure 5*
- e. C31 Fuel Supply Solenoid connector (11) at rear of manifold. *Figure 6*

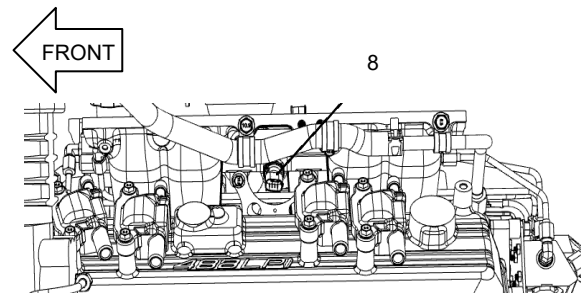
8. Raise vehicle.
9. Disconnect Engine Harness connector from the following front engine sensors:
  - a) C11 Crankshaft (CKP) Sensor (12). *Figure 7*
  - b) C12 Camshaft (CMP) Sensor (13). *Figure 8*
  - c) C10 Oil Pressure Sensor (14). *Figure 8*
10. Remove Engine Harness Stud Cap Retaining Bolts (15). *Figure 9*
11. Disconnect C15B LH and C15A RH Pre-Catalyst Heated Exhaust Gas Oxygen (HEGO) Sensor connectors (16) & (17). *Figure 10*
12. Remove Retaining Bolts (18) securing Engine Harness Ground Connector Rings C20 and C21 (from rear of Cylinder Heads. *Figure 11*
13. Lower vehicle.



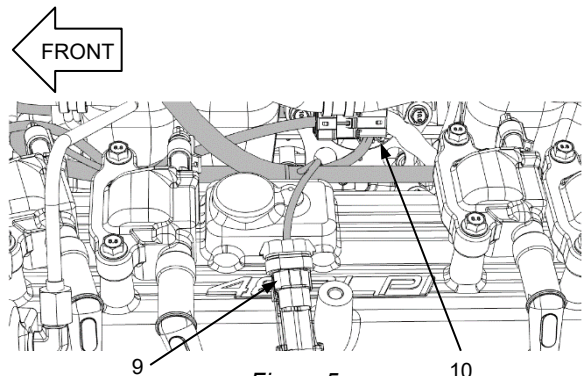
*Figure 2:*  
Passenger side Ignition Coil connector (6) locations.  
**NOTE:** Intake Air Tube not shown for clarity.



*Figure 3:*  
Driver side Ignition Coil connector (7) locations



*Figure 4:*  
Fuel Rail Pressure/Temperature (FTP) Sensor (8) location



*Figure 5:*  
Engine Coolant Temperature (ECT) Sensor connector (9) and C16 Fuel Injector Harness connector (10) locations

14. Disconnect C4 TSM Connector (20) and J1-A, J1-B and J1-C ECM Connectors (21). *Figure 12*
15. Disconnect C28 Bulkhead Connector (22). *Figure 13*
16. Remove Zip Tie Stud Fastener securing Engine Harness to Upper Intake Manifold (*not shown*).
17. Remove all Nylon Push Fasteners AKA “Christmas tree pins” and Zip Ties securing Engine Harness carefully.

### NOTICE

**Inspect fasteners for damage and save for Engine Harness Installation.**

18. Carefully remove Engine Harness.

### NOTICE

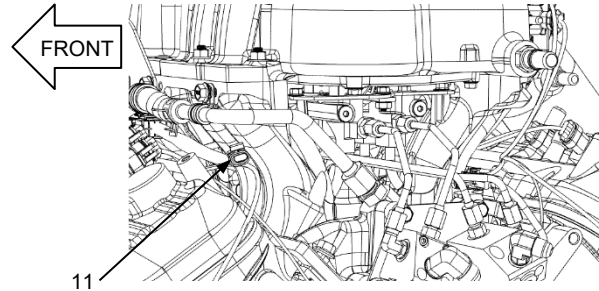
**Inspect Engine Harness for damage.**

## INSTALLATION PROCEDURE

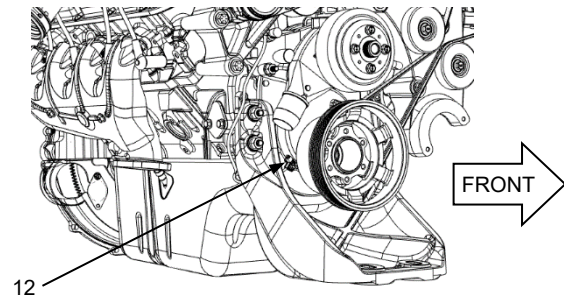
### NOTICE

**Apply dielectric grease to all connectors and verify connector security locks are firmly in place.**

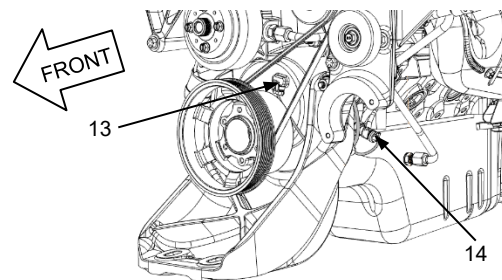
1. Connect C28 Bulkhead Connector (22). *Figure 13*
2. Connect C4 Torque Security Module (TSM) connector (20) and J1-A, J1-B and J1-C ECM connectors (21). *Figure 12*
3. Connect C31 Fuel Supply Solenoid (11). *Figure 6*
4. Connect C16 Fuel Injector Harness Connector (10). *Figure 5*
5. Connect C14 ECT Sensor connector (9). *Figure 5*
6. Connect C22 FTP Sensor (8). *Figure 4*
7. Connect C17 Connectors (7) to Ignition Coils 1, 3, 5, 7. *Figure 3*
8. *If equipped:* Connect C26 and C27 Air Conditioner Compressor Clutch Connector(s) (*not shown*).



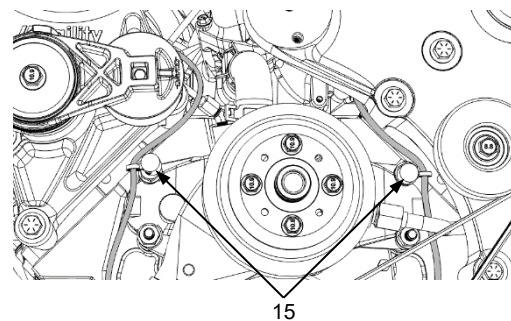
*Figure 6:*  
Fuel Supply Solenoid connector (11) location



*Figure 7:*  
Crankshaft Position (CKP) Sensor connector (12)




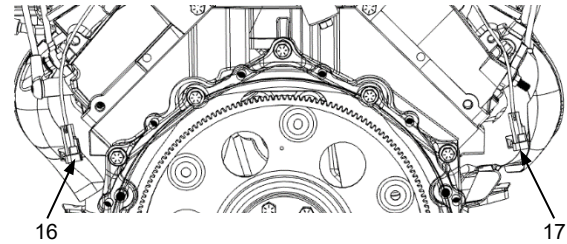
*Figure 8:*  
Camshaft Position (CMP) Sensor connector (13) and  
Oil Pressure Sensor (14) locations



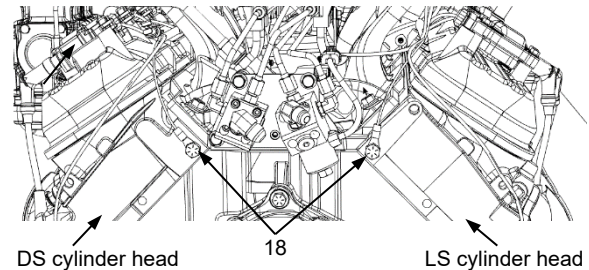
*Figure 9:*  
Engine Harness Cap Stud Retaining Bolt (15) locations



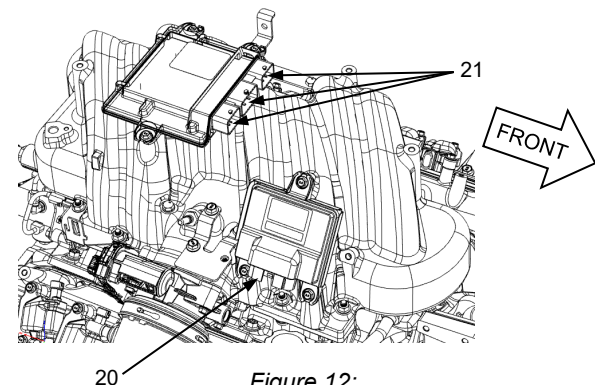
9. Connect C19 Connectors (6) to Ignition Coils 2, 4, 6, 8. *Figure 2*
10. Connect the following components shown in *Figure 1* to the Engine Harness:
  - a) C7 MAP Sensor (1)
  - b) C30 EVAP Purge Solenoid (2)
  - c) C32 Fuel By-Pass Solenoid (3)
  - d) C9 ETC Sensor (4)
  - e) C6 MAF Sensor (5)
11. Raise vehicle.
12. Connect the following engine front sensors to the Engine Harness:
  - a) C11 CKP Sensor (12). *Figure 7*
  - b) C12 CMP Sensor (13). *Figure 8*
  - c) C10 Oil Pressure Sensor (14). *Figure 8*
13. Install Engine Harness Stud Cap Bolts (15). *Figure 9*
14. Install Zip Tie Stud Fastener to secure Engine Harness to Upper Intake Manifold (*not shown*).
15. Install all Nylon Push Fasteners AKA “Christmas tree pins” and Zip Ties to secure Engine Harness.
-  **Replace any missing/damaged fasteners.**
16. Connect C15B LH and C15A RH HEGO Sensor connectors (16) & (17). *Figure 10*
17. Install Engine Harness Ground Connector Ring C20 and C21 Retaining Bolts (18) on rear of Cylinder Heads. *Figure 11. Refer to [Electrical Component and Sensor Torque Specifications](#).*
18. Lower vehicle.
19. Reconnect negative (–) Battery Cable.
20. Verify proper operation.



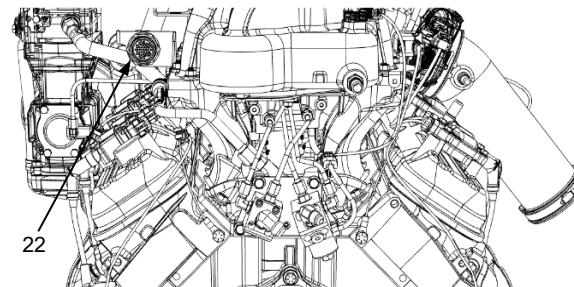
*Figure 10:*  
LH and RH Pre-Cat Heated Exhaust Gas Oxygen (HEGO) Sensor connectors (16) & (17)



*Figure 11:*  
C20 & C21 Ground Ring Retaining Bolt (18) locations.



*Figure 12:*  
ECM Connector J1-A, J1-B & J-1C (21) and C4 Torque Security Module (TSM) connector (20) locations



*Figure 13:*  
C28 Bulkhead Connector (22) location

# EVAP Purge Solenoid Replacement

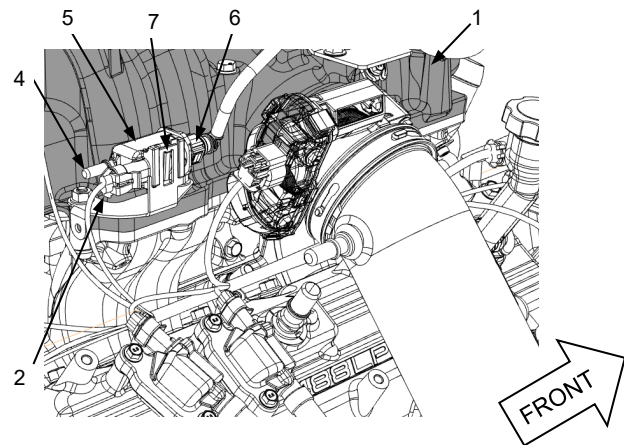
## DESCRIPTION AND OPERATION

The EVAP Purge Solenoid connects to the EVAP Emissions Cannister via a hose connection and is also plumbed into the Upper Intake Manifold to consume any fuel system propane vapor.

The EVAP Purge Solenoid attaches to the Engine Harness using an electrical connector and is mounted on a bracket on passenger side of the Upper Intake Manifold. Two Upper Intake Manifold Retaining Nuts secure the EVAP Purge Solenoid Bracket to the Upper Intake Manifold.

## REMOVAL PROCEDURE

1. Secure vehicle and verify engine is off.
2. Disconnect EVAP Purge Solenoid Electrical Connector (2) from Engine Harness. *Figure 1*
3. Disconnect EVAP Purge Hose (*not shown*) from EVAP Purge Solenoid (5) at Hose Connector (4). *Figure 1*
4. Disconnect EVAP Purge Solenoid to Intake Line Fitting (6) from EVAP Purge Solenoid (5). *Figure 1*
5. Remove EVAP Purge Solenoid (5) from EVAP Purge Solenoid Bracket Clip (7). *Figure 1*



*Figure 1:*  
EVAP Purge Solenoid (5), Electrical Connector (2),  
Hose Connector (4), Solenoid to Intake Line Fitting  
(6), Bracket Clip (7), Upper Intake Manifold (1)

## INSTALLATION PROCEDURE

1. Install EVAP Purge Solenoid (5) on Solenoid Bracket Clip (7). *Figure 1*
2. Connect EVAP Purge Solenoid to Intake Line Fitting (6) to EVAP Purge Solenoid (5). *Figure 1*
3. Connect EVAP Purge Hose (*not shown*) to EVAP Purge Solenoid (5) at Hose Connector (4). *Figure 1*

### **NOTICE**

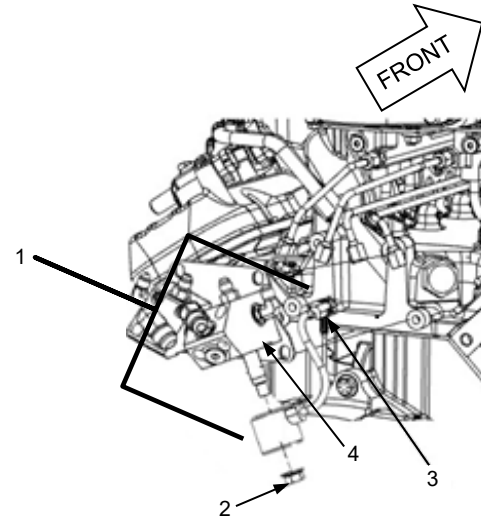
**Apply dielectric grease to electrical connector.**

4. Connect EVAP Purge Solenoid Electrical Connector (2) to Engine Harness Connector (1). *Figure 1*
5. Verify proper operation.

# Fuel By-Pass Solenoid Replacement

## REMOVAL PROCEDURE

1. Secure vehicle outdoors in a safe location.
2. Bleed Fuel Lines. *Refer to [Fuel Line Bleed Procedure](#).*
3. Bring vehicle into service area and secure.
4. Remove Upper Intake Manifold. *Refer to [Upper Intake Manifold Replacement](#).*
5. Disconnect Fuel By-pass Solenoid (1) Electrical Connector (3). *Figure 1*
6. Remove Fuel By-pass Solenoid Connector Retaining Clip from the Fuel Distribution Block Mounting Bracket.
7. Remove Fuel By-pass Solenoid Retaining Nut (2). *Figure 1*
8. Slide Fuel By-pass Solenoid (3) off Pressure Regulator on passenger side Fuel Distribution Block (4). *Figure 1*



*Figure 1:*  
Fuel By-pass Solenoid (1) with Electrical Connector (3) and Retaining Nut (2); Passenger side Fuel Distribution Block (4)

## INSTALLATION PROCEDURE

1. Install Fuel By-pass Solenoid (1) on Pressure Regulator on passenger side Fuel Distribution Block (4). *Figure 1*
2. Install Fuel By-pass Solenoid Retaining Nut (2). *Figure 1. Refer to [Fuel System Torque and Tightening Specifications](#).*
3. Install Fuel By-pass Solenoid Connector Retaining Clip on Fuel Distribution Block Mounting Bracket.
4. Connect Fuel By-pass Solenoid (1) Electrical Connector (3). *Figure 1*
5. Install Upper Intake Manifold. *Refer to [Upper Intake Manifold Replacement](#).*
6. Verify proper operation.

# Fuel Pressure/Temperature (FTP) Sensor Replacement

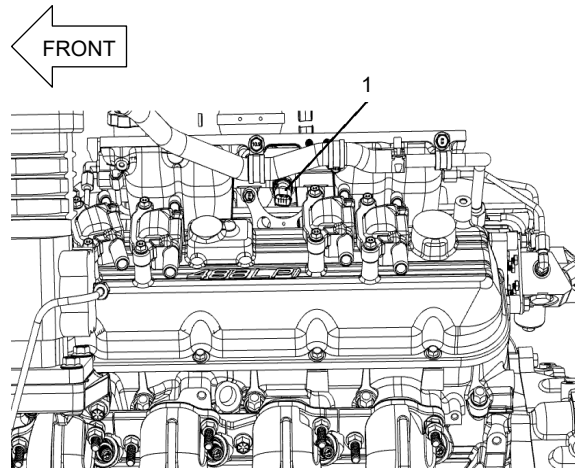
## DESCRIPTION AND OPERATION

The Fuel Pressure/Temperature (FPT) Sensor provides critical real time fuel temperature and fuel pressure readings to the Electronic Control Module (ECM). An ECM algorithm uses FPT data to adjust base fuel calculation.

A malfunctioning FPT Sensor could result in incorrect fuel delivery to the engine. This can lead to a rough running engine along with possible Check Engine Light or other Malfunction Indicator Light illumination.

## REMOVAL PROCEDURE

1. Secure vehicle outdoors in a safe location.
2. Bleed Fuel Lines. *Refer to [Fuel Line Bleed Procedure](#).*
3. Bring vehicle into service bay and secure.
4. Using a trim removal tool, walk Fuel Injector Harness Connector *Clip* (not shown) off its bracket.
5. Disconnect C16 Fuel Injector Harness Connector and secure out of the way. *Refer to [Engine Harness Schematic and Connector End Views](#).*
6. Disconnect Fuel Pressure/Temperature (FPT) Sensor Electrical Connector (3). *Figure 2*
7. Remove FPT Sensor (1) from driver side Fuel Rail (2) using a deep well socket and extension. *Figures 1 & 2*



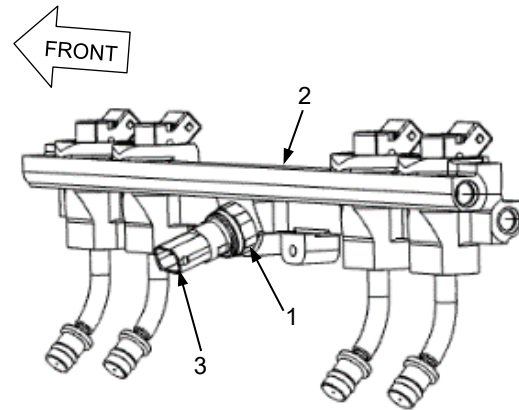
*Figure 1:*  
Fuel Pressure/Temperature (FTP) Sensor (1) location  
on driver side fuel rail

### **NOTICE**

**Inspect FPT Sensor O-ring for damage; replace O-ring as necessary.**

## **INSTALLATION PROCEDURE**

1. Install FPT Sensor (1) in driver side Fuel Rail (2) using a deep well socket and extension. *Figure 1. Refer to [Electrical Components & Sensors Torque Specifications](#).*
2. Connect FPT Sensor Electrical Connector (3). *Figure 2*
3. Connect C16 Fuel Injector Harness Connector.
4. Connect Fuel Injector Harness Connector Clip to its bracket.
5. Reinstall Fuel Supply and Fuel Return Lines. *Refer to [Fuel Line Bleed Procedure](#).*
6. Verify proper operation.



*Figure 2:*  
Driver side Fuel Rail (2) shown off Engine  
detailing FPT Sensor (1) and FPT Sensor  
Electrical Connector (3)



# Ignition Coil Replacement

## DESCRIPTION AND OPERATION

Eight (8) individual Ignition Coils deliver high voltage to each of the Spark Plugs via short Spark Plug Wires.

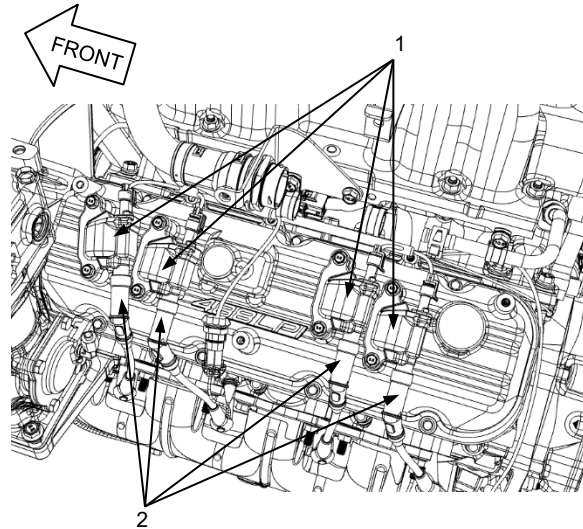
## REMOVAL PROCEDURE

1. Secure vehicle.
2. Disconnect Spark Plug Wire(s) (2) at Ignition Coil(s) (1) using a Spark Plug Removal Tool. *Figure 1. Refer to [Spark Plug Wire Replacement](#).*

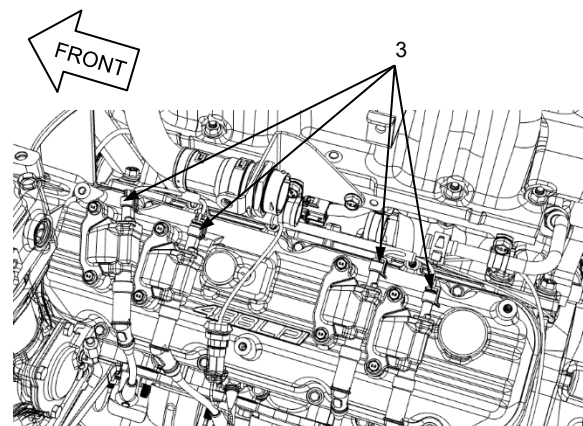
### **NOTICE**

**Use caution to avoid damage to Spark Plug Wire or Boot Connector.**

3. Disconnect Ignition Coil Harness Connector(s) (3). *Figure 2*
4. Remove two (2) Ignition Coil Mounting Bolts (4) from each Ignition Coil (1). *Figure 3*
5. Remove Ignition Coil(s) (1) from Valve Rocker Cover Mounting Bosses (5). *Figure 3*



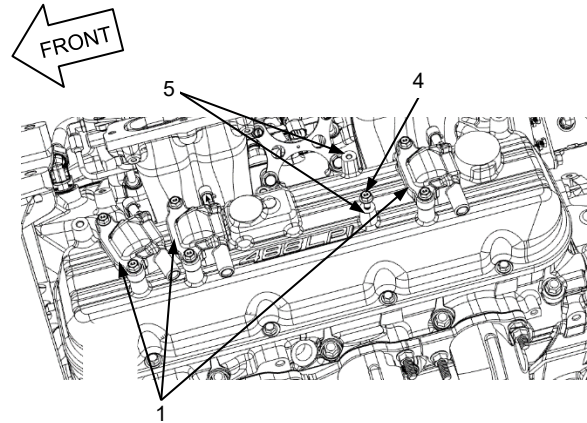
*Figure 1:*  
Ignition Coils (1) and Spark Plug Wires (2).  
**NOTE:** Driver side shown; passenger side similar.



*Figure 2:*  
Ignition Coil Harness Connectors (3).  
**NOTE:** Driver side shown; passenger side similar.

## **INSTALLATION PROCEDURE**

1. Install Ignition Coil(s) (1) on Valve Rocker Cover Coil Mount Bosses (5). *Figure 2*
2. Install two (2) Ignition Coil Mounting Bolts (4) per Ignition Coil (1) and tighten. *Figure 3. Refer to [Electrical Component & Sensor Torque Specifications](#).*
3. Connect Ignition Coil Electrical Connector(s) (9). *Figure 2*
4. Connect Spark Plug Wire(s) (2) to Ignition Coil(s) (1). *Figure 1. Refer to [Spark Plug Wire Replacement](#).*
5. Verify proper operation.



*Figure 3:*

Driver side Ignition Coils #1, #3 and #7 (1).

**NOTE:** Ignition Coil #5 removed to show Valve Cover Coil Mount Bosses (5) and Coil Mounting Bolt (4).

# Manifold Absolute Pressure (MAP) Sensor Replacement

## DESCRIPTION AND OPERATION

The Manifold Absolute Pressure (MAP) Sensor is a three (3) wire sensor that provides a signal to the Engine Control Module (ECM) based on pressure changes in the Intake Manifold. Pressure changes occur dependent on a combination of engine speeds, throttle openings, air temperature, and barometric pressure. The ECM supplies five (5) volts to the MAP Sensor on the 5 V Reference Circuit and Ground on the Low Reference Circuit.

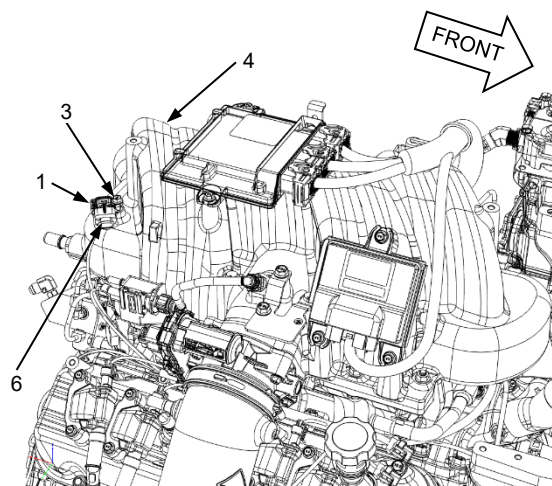
The MAP Sensor provides a signal to the ECM on the Signal Circuit relative to intake pressure changes. The MAP Sensor Signal is low during idle or deceleration. The MAP Sensor Signal is high during Ignition ON, Engine OFF, or at Wide Open Throttle (WOT). The MAP Sensor also measures barometric pressure (BARO). This occurs with Ignition ON, Engine OFF. The BARO reading may also be updated whenever the Throttle Position Sensor (TPS) is at Wide Open Throttle.

## REMOVAL PROCEDURE

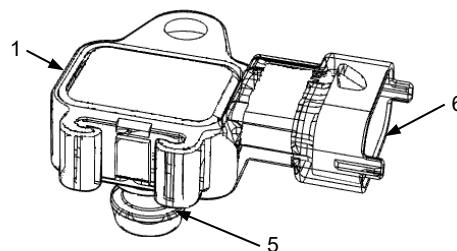
1. Secure vehicle.
2. Verify engine is off.
3. Disconnect Manifold Absolute Pressure (MAP) Sensor (1) Electrical Connector (6) from Engine Harness Connector (*not shown*). *Figures 1 & 2*
4. Remove MAP Sensor Mounting Bolt (3). *Figure 1.*
5. Remove MAP Sensor (1) from Upper Intake Manifold (4). *Figure 1*
6. Inspect MAP Sensor O-Ring Seal (5) for tears, dryness, or cracks. *Figure 2*

### **NOTICE**

**If O-ring is damaged, the MAP Sensor must be replaced.**



*Figure 1:*  
Manifold Absolute Pressure (MAP) Sensor (1),  
MAP Sensor Electrical Connector (6),  
MAP Sensor Mounting Bolt (3),  
Upper Intake Manifold (4)



*Figure 2:*  
Manifold Absolute Pressure (MAP) Sensor (1),  
MAP Sensor O-Ring Seal (5),  
MAP Sensor Electrical Connector (6)



## **INSTALLATION PROCEDURE**

1. Lightly coat MAP Sensor O-Ring Seal (5) with clean engine oil before installing sensor.  
*Figure 2*

### **NOTICE**

**Apply clean engine oil with a sponge or a brush. To prevent sensor blockage, avoid dipping MAP Sensor port directly into liquid.**

2. Install MAP Sensor (1) on Upper Intake Manifold (4). *Figure 1*
3. Install MAP Sensor Mounting Bolt (3) and tighten. *Figure 1. Refer to [Electrical Component & Sensor Torque Specifications](#).*
4. Connect MAP Sensor Electrical Connector (6) to Engine Harness Connector (2).  
*Figures 1 & 2*
5. Verify proper operation.

# Mass Air Flow (MAF) Sensor Replacement

## DESCRIPTION AND OPERATION

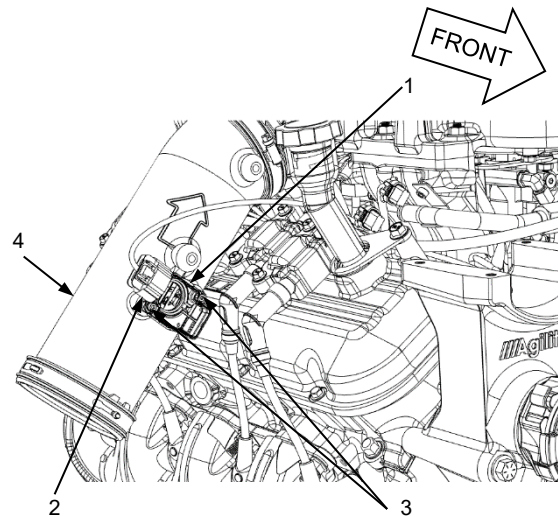
The Mass Air Flow (MAF) Sensor provides a variable signal to the Engine Control Module (ECM) dependent on the amount of air that is moving through the sensor to the engine. Powered by battery voltage and ground, the MAF Sensor also incorporates an Intake Air Temperature (IAT) Sensor. The ECM supplies 5 V to the MAF Sensor on the Signal Circuit which the sensor uses to produce a frequency signal for the ECM.

## REMOVAL PROCEDURE

1. Secure vehicle.
2. Disconnect Mass Air Flow (MAF) Sensor (1) from Engine Harness Electrical Connector (2). *Figure 1*
3. Remove two (2) MAF Mounting Bolts (3) and Washers (*not shown*). *Figure 1*
4. Remove Mass Air Flow Sensor (1) from Air Intake Tube (4). *Figure 1*

### **NOTICE**

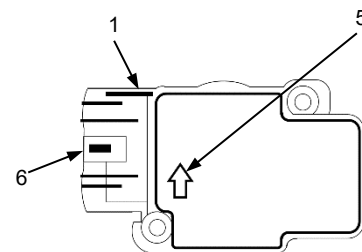
**Inspect MAF Sensor (1) O-ring (*not shown*) for cracks, dryness or tears; if damage is found, MAF Sensor must be replaced.**



*Figure 1:*  
Mass Airflow (MAF) Sensor (1),  
MAF Sensor Electrical Connector (2),  
MAF Sensor Mounting Bolts (3),  
Intake Air Tube (4)

## INSTALLATION PROCEDURE

1. Apply a thin coat of clean engine oil to MAF Sensor O-Ring (*not shown*).
2. Install MAF Sensor (1) on Air Intake Tube (4). *Figure 1*
3. Verify MAF Sensor Flow Direction Arrow (5) points at Throttle Body. *Figure 2*
4. Install two (2) MAF Mounting Bolts (3) and Washers (*not shown*) and tighten. *Figure 1. Refer to [Engine Electrical & Sensor Torque Specifications](#).*
5. Connect MAF (1) to Engine Harness Electrical Connector (2) at MAF Connector (6). *Figures 1 & 2*
6. Verify proper operation.



*Figure 2:*  
Mass Airflow (MAF) Sensor (1),  
Air Flow Direction Arrow (5),  
Electrical Connector (6)

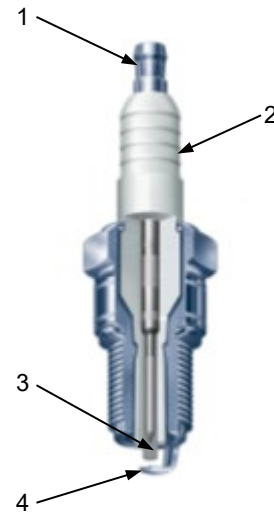
# Spark Plug Inspection

## INSPECTION PROCEDURE

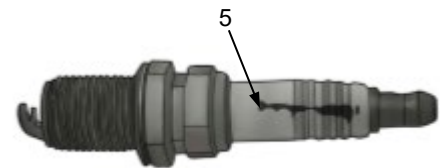
1. Verify vehicle has correct spark plugs installed. Incorrect spark plugs can cause drivability issues. *Refer to [Ignition System Specifications](#) for correct spark plug heat range.*  
Incorrect heat range spark plugs can cause the following conditions:
  - a) Spark plug fouling; replace with hotter plug
  - b) Pre-ignition causing spark plug and/or engine damage; replace with colder plug
2. Inspect Terminal Post (1) for damage:
  - a) Bent or broken terminal post
  - b) Loose terminal; test post by twisting and pulling the post, terminal should not move.
3. Inspect Insulator (2) for the following conditions:
  - a) Carbon tracking or soot. This can cause the electrical charge traveling across the insulator to detonate air/fuel mixture prematurely. *Figure 2*
  - b) Cracks. Inspect porcelain at electrode for cracks. *Figure 3*
4. Inspect Spark Plug Recess in Cylinder Head for the following conditions:
  - a) Moisture such as coolant or engine oil
  - b) Debris, dirty or damaged threads which can cause spark plug not to seat correctly
5. Measure Spark Plug Gap between Center Electrode (3) tip and Side Electrode (4) for correct gap. *Refer to [Ignition System Specifications](#) for gap.*

### **NOTICE**

**An excessively wide gap can cause engine misfires and poor vehicle operation.**



*Figure 1:*  
Spark Plug components:  
Terminal Post (1), Insulator (2),  
Center Electrode (3), Side Electrode (4)



*Figure 2:*  
Spark Plug exhibiting carbon tracking (5)



*Figure 3:*  
Spark Plug with crack (6) in porcelain Insulator

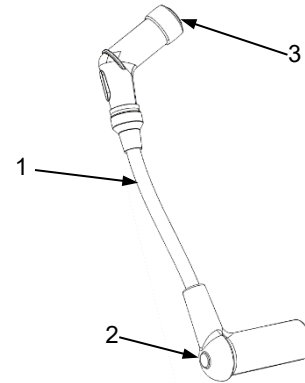
# Spark Plug Wire Inspection

Spark Plug Wires carry high voltage from the Ignition Coils to the Spark Plugs.

To maintain peak engine performance, Spark Plug Wires should be inspected periodically to identify conditions that may affect engine operation.

## **INSPECTION PROCEDURE**

1. Inspect Spark Plug Wires for the following conditions:
  - a) Cuts or tears in outer Wire (1) insulation or Boots (2) and (3)
  - b) Oil contamination of Wire (1) or Spark Plug Boot (2)
  - c) Signs of electrical arcing
  - d) Signs of heat penetration (scorch marks or burns)
  - e) Loose terminals/connectors at Spark Plug Boot (2) or Ignition Coil Boot (3)
  - f) Corrosion on terminals at Spark Plug Boot (2) or Ignition Coil Boot (3)
  - g) Carbon Tracking on terminals at Spark Plug Boot (2) or Ignition Coil Boot (3)



*Figure 1:*  
Spark Plug Wire components:  
Insulated Wire (1), Spark Plug Boot (2),  
Ignition Coil Boot (3)

### **NOTICE**

**Never pull on Spark Plug Wires to remove wire from Spark Plugs or Coils; always grasp the Spark Plug Boot or Coil Boot to remove.**

### **NOTICE**

**Use a Spark Plug Wire Boot Removal Tool to remove Boots from Terminal Connectors.**

2. If any of the above conditions are found, replace damaged Spark Plug Wire and any component connected to it.

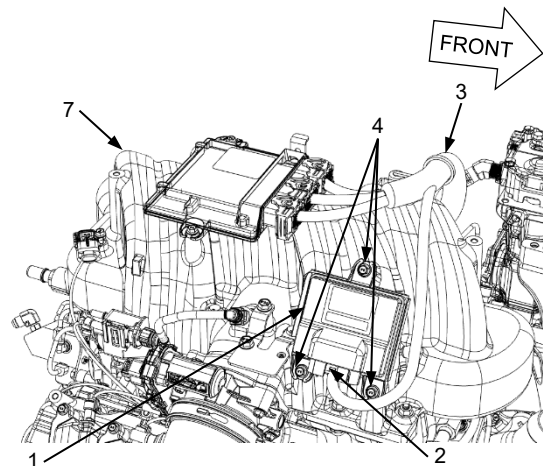
# Torque Security Module (TSM) Replacement

## DESCRIPTION AND OPERATION

The Torque Security Module (TSM) works with the Engine Control Module (ECM) to monitor and direct engine and accessory operation. The TSM connects to the Engine Harness using a single large electrical connector and attaches to the Upper Intake Manifold via a bracket.

## REMOVAL PROCEDURE

1. Secure vehicle.
2. Ignition OFF.
3. Disconnect Torque Security Module (TSM) Engine Harness Electrical Connector (2) from TSM (1). *Figure 1*
4. Remove three (3) TSM Mounting Bolts (4). *Figure 1*
5. Remove TSM (1) and TSM Mounting Bracket (6) from Upper Intake Manifold (7). *Figure 2*
6. Remove TSM (1) from Mounting Bracket (6). *Figure 2*



*Figure 1:*  
TSM (1), Engine Harness TSM Electrical Connector (2), Engine Harness (3), TSM Mounting Bolts (4), Upper Intake Manifold (7)

## INSTALLATION PROCEDURE

1. Install TSM (1) on Mounting Bracket (6). *Figure 2*
2. Install TSM to Upper Intake Manifold (7) using three (3) TSM Mounting Bolts (4) and tighten. *Figures 1 & 2. Refer to [Electrical Component & Sensor Torque Specifications](#).*

### **NOTICE**

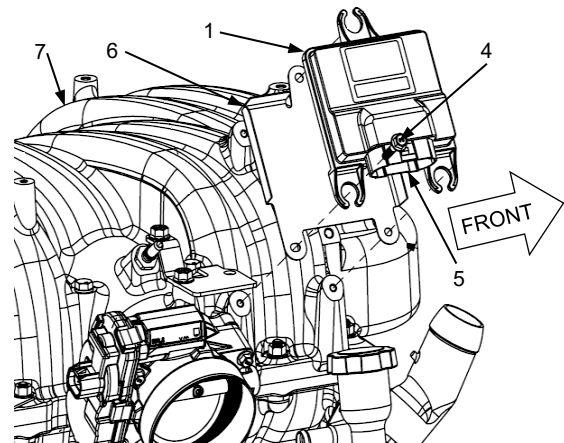
**Apply dielectric grease to connector.**

3. Connect Engine Harness Electrical Connector (2) to TSM Electrical Connector location (5). *Figure 2*

### **NOTICE**

**Verify connector security locks are firmly in place.**

4. Verify proper operation.



*Figure 2:*  
TSM (1), TSM Electrical Connector location (5), TSM Mounting Bolt (4), TSM Mounting Bracket (6), Upper Intake Manifold (7)

# Electrical Components and Sensors

## Torque Specifications

APPLICATION	SPECIFICATION	
	Metric	Standard
Camshaft Position (CMP) Sensor Bolt	12 Nm	9 ft-lbs
Crankshaft Position (CKP) Sensor Bolt	12 Nm	9 ft-lbs
Engine Coolant Temperature (ECT) Sensor	50 Nm	37 ft-lbs
Engine Control Module (ECM) Bolts	15 Nm	11 ft-lbs
Engine Harness Bracket Bolt	25 Nm	18 ft-lbs
Engine Harness Clip Bolt	12 Nm	9 ft-lbs
Engine Harness Ground Rings	F.S.N.S.*	
Fuel Pressure/Temperature (FPT) Sensor	9 Nm	6.5 ft-lbs
Fuel By-pass Solenoid Nut	12 Nm	9 ft-lbs
Ground Strap Bolt	50 Nm	37 ft-lbs
Ignition Coil Bolts	12 Nm	9 ft-lbs
Ignition Coil Wiring Harness Bolt	12 Nm	9 ft-lbs
Manifold Absolute Pressure (MAP) Sensor Bolt	15 Nm	11 ft-lbs
Mass Air Flow (MAF) Sensor Bolts	4 Nm	3 ft-lbs
Oil Level Sensor	20 Nm	15 ft-lbs
Oil Pressure Sensor	30 Nm	23 ft-lbs
Spark Plug	30 Nm	23 ft-lbs
Throttle Body Bolt	15 Nm	11 ft-lbs
Torque Security Module Bracket Bolts	15 Nm	11 ft-lbs

\*F.S.N.S. = Fully Seated, Not Stripped

# Ignition System Specifications

APPLICATION	SPECIFICATIONS
Ignition Type	Individual Ignition Coil
Firing Order	1 – 8 – 7 – 2 – 6 – 5 – 4 – 3
Spark Plug Wire Resistance	170-220 $\Omega$ per 25.4 mm (1.0-in)
Spark Plug Torque*	30 Nm (22 ft-lbs)
Spark Plug Gap	1.14 mm (0.045-in)
Spark Plug Type	Hexagon Agility® p/n 69000567

## NOTICE

\*Hexagon Agility® does not recommend or promote the use any type of anti-seize lubricant on spark plug threads. Plugs should be installed as boxed (dry).

## NOTICE

Do not mix different types of spark plugs.

