2008 ENGINE

Engine Controls and Fuel - 2.0L - HHR

SPECIFICATIONS

TEMPERATURE VERSUS RESISTANCE

°C	°F	OHMS
Temperature vs Resistance Values (Approximate)		
150	302	47
140	284	60
130	266	77
120	248	100
110	230	132
100	212	177
90	194	241
80	176	332
70	158	467
60	140	667
50	122	973
45	113	1188
40	104	1459
35	95	1802
30	86	2238
25	77	2796
20	68	3520
15	59	4450
10	50	5670
5	41	7280
0	32	9420
-5	23	12300
-10	14	16180
-15	5	21450

-20	-4	28680
-30	-22	52700
-40	-40	100700

ALTITUDE VERSUS BAROMETRIC PRESSURE

Altitude Measured in Meters (m)	Altitude Measured in Feet (ft)	Barometric Pressure Measured in Kilopascals (kPa)
Determine your altitude by contacting a local weather station or by using another reference source.		
4267	14,000	56-64
3962	13,000	58-66
3658	12,000	61-69
3353	11,000	64-72
3048	10,000	66-74
2743	9,000	69-77
2438	8,000	71-79
2134	7,000	74-82
1829	6,000	77-85
1524	5,000	80-88
1219	4,000	83-91
914	3,000	87-95
610	2,000	90-98
305	1,000	94-102
0	0 Sea Level	96-104
-305	-1,000	101-105

IGNITION SYSTEM SPECIFICATIONS

Application	Specification	
	Metric	English
Ignition Type	Coil-On-Plug	
Firing Order	1-3-4-2	

Spark Plug Type	GM P/N 12590701	
Spark Plug Torque	17-23 N.m	12.5-17 lb ft
Spark Plug Gap	0.9-0.75 mm	0.035-0.030 in

FASTENER TIGHTENING SPECIFICATIONS

Application	Specification	
	Metric	English
Accelerator Pedal Position (APP) Sensor Nut	10 N.m	89 lb in
Air Cleaner Front Bolt/Nut	10 N.m	89 lb in
Air Cleaner Outlet Duct Clamp	4 N.m	35 lb in
Air Inlet Screen Support Nut	10 N.m	89 lb in
Brake Pipe	20 N.m	15 lb ft
Camshaft Position Actuator Solenoid Valve Bolt	10 N.m	89 lb in
Camshaft Position (CMP) Sensor Bolt	10 N.m	89 lb in
Charge Air Cooler Bolt	9 N.m	80 lb in
Charge Air Cooler Hose Clamp	5 N.m	44 lb in
Charge Air Cooler Pipe Clamp	5 N.m	44 lb in
Charge Air Cooler Pipe Bolt	7 N.m	62 lb in
Charge Air Cooler Rear Bracket Nut	9 N.m	80 lb in
Charge Air Bypass Solenoid Bolt	10 N.m	89 lb in
Crankshaft Position (CKP) Sensor Bolt	10 N.m	89 lb in
Engine Coolant Temperature (ECT) Sensor	20 N.m	15 lb ft
Evaporative Emission (EVAP) Canister Purge Solenoid Bolt	10 N.m	89 lb in
Fuel Feed Pipe Bolt	10 N.m	89 lb in
Fuel Feed Pipe Fitting	30 N.m	22 lb ft
Fuel Fill Hose Clamp	2.5 N.m	22 lb in
Fuel Fill Pipe Ground Strap Bolt	9 N.m	80 lb in
Fuel Fill Pipe to Housing Bolt	1.5 N.m	13 lb in
Fuel Injector Fuel Rail Fuel Pressure Sensor	33 N.m	25 lb ft
Fuel Pump Module Access Cover Bolt	10 N.m	89 lb in

Fuel Rail Bolt	22 N.m	16 lb ft
Fuel Tank Strap/Support Bolt	22 N.m	16 lb ft
Heated Oxygen Sensor (HO2S)	42 N.m	31 lb ft
High Pressure Fuel Feed Pipe Fitting	32 N.m	24 lb ft
High Pressure Fuel Pump Cover Bolt	10 N.m	89 lb in
High Pressure Fuel Pump Bolt	15 N.m	11 lb ft
Ignition Coil Bolt	10 N.m	89 lb in
Intake Air Pressure and Temperature Sensor Bolt	9 N.m	80 lb in
Knock Sensor	25 N.m	18 lb ft
Manifold Absolute Pressure (MAP) Sensor Bolt	10 N.m	89 lb in
Mass Air Flow (MAF) Sensor Screw	0.6 N.m	5 lb in
Spark Plug	20 N.m	15 lb ft
Throttle Body Bolt	10 N.m	89 lb in

SCHEMATIC AND ROUTING DIAGRAMS

EVAPORATIVE EMISSIONS HOSE ROUTING DIAGRAM

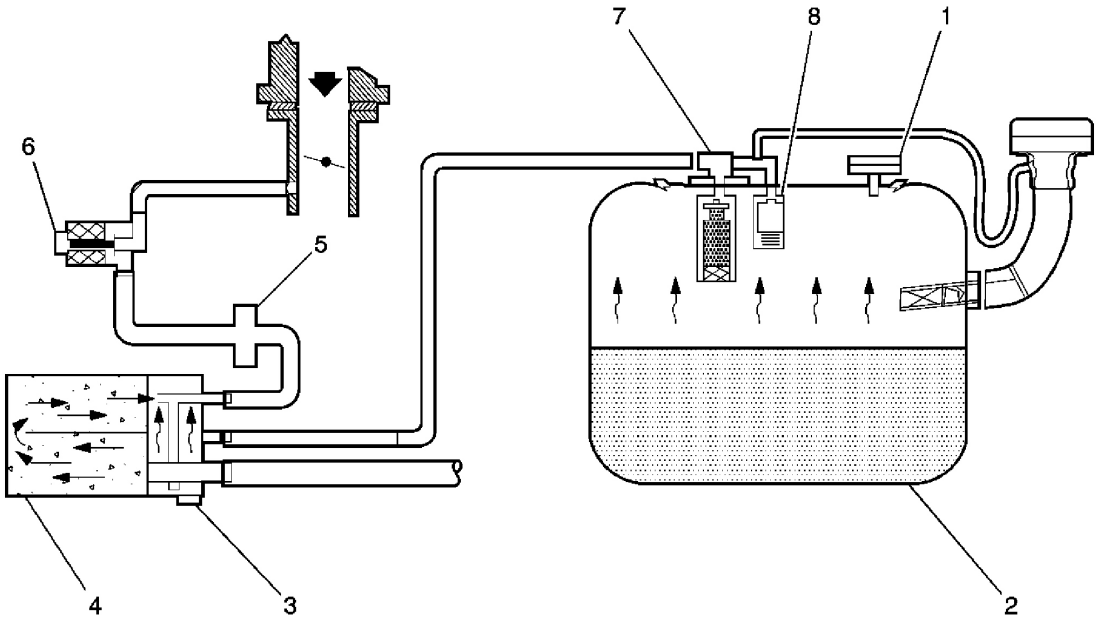


Fig. 1: Evaporative Emissions Hose Routing Diagram
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
1	Fuel Tank Pressure (FTP) Sensor
2	Fuel Tank
3	Evaporative Emission (EVAP) Vent Solenoid Valve
4	EVAP Canister
5	Purge Flow Check Valve
6	EVAP Purge Solenoid Valve
7	Fill Limit Vent Valve (FLVV)
8	Grade Vent Valve

ENGINE CONTROLS SCHEMATICS

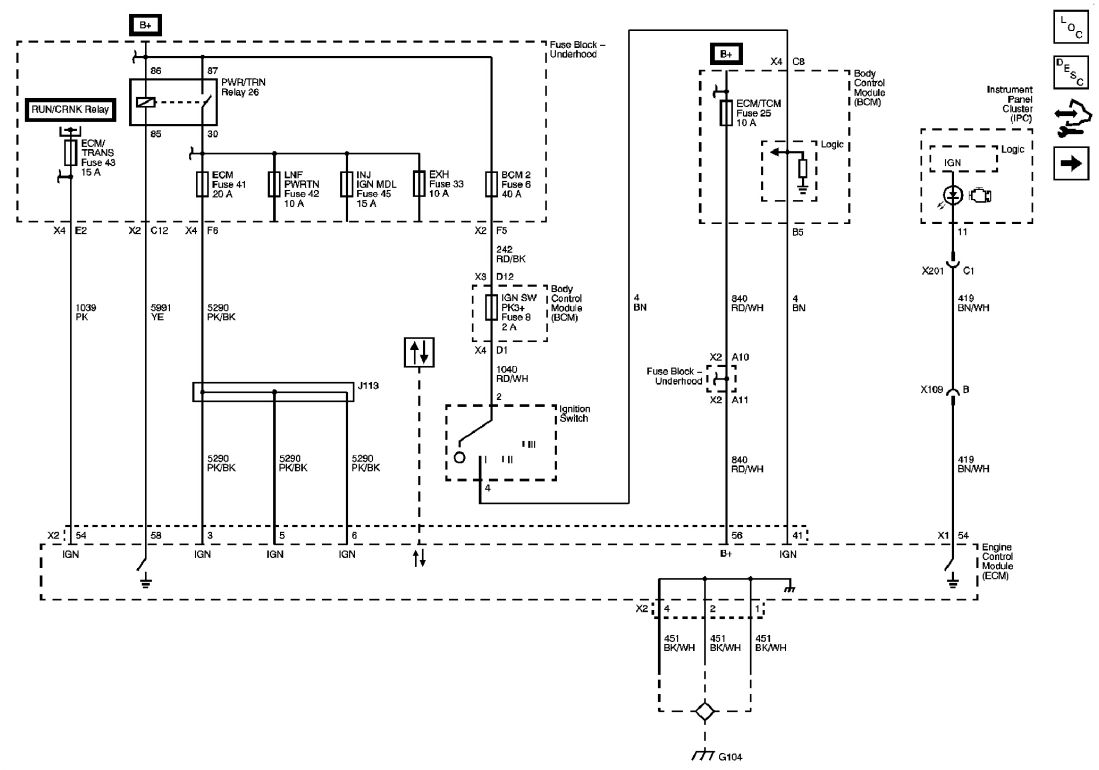


Fig. 2: Data Link, Ground, MIL And Power - Schematic
Courtesy of GENERAL MOTORS CORP.

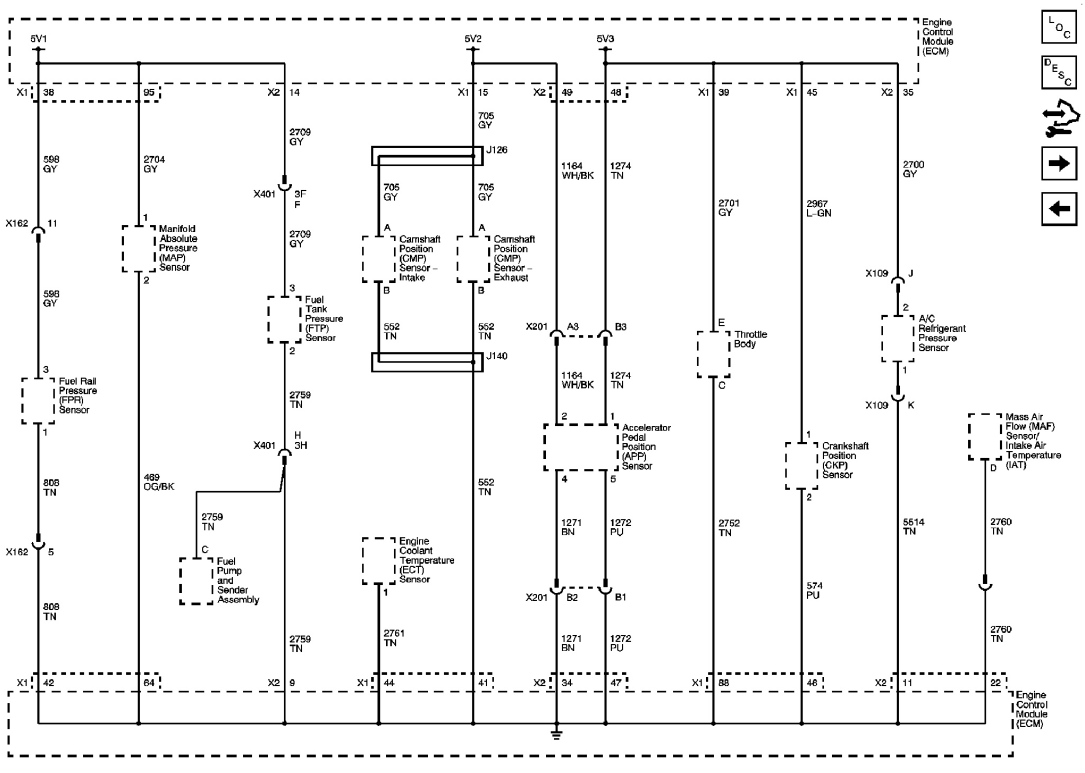


Fig. 3: Engine Data Sensors - 5-Volt And Low Reference - Schematic
Courtesy of GENERAL MOTORS CORP.

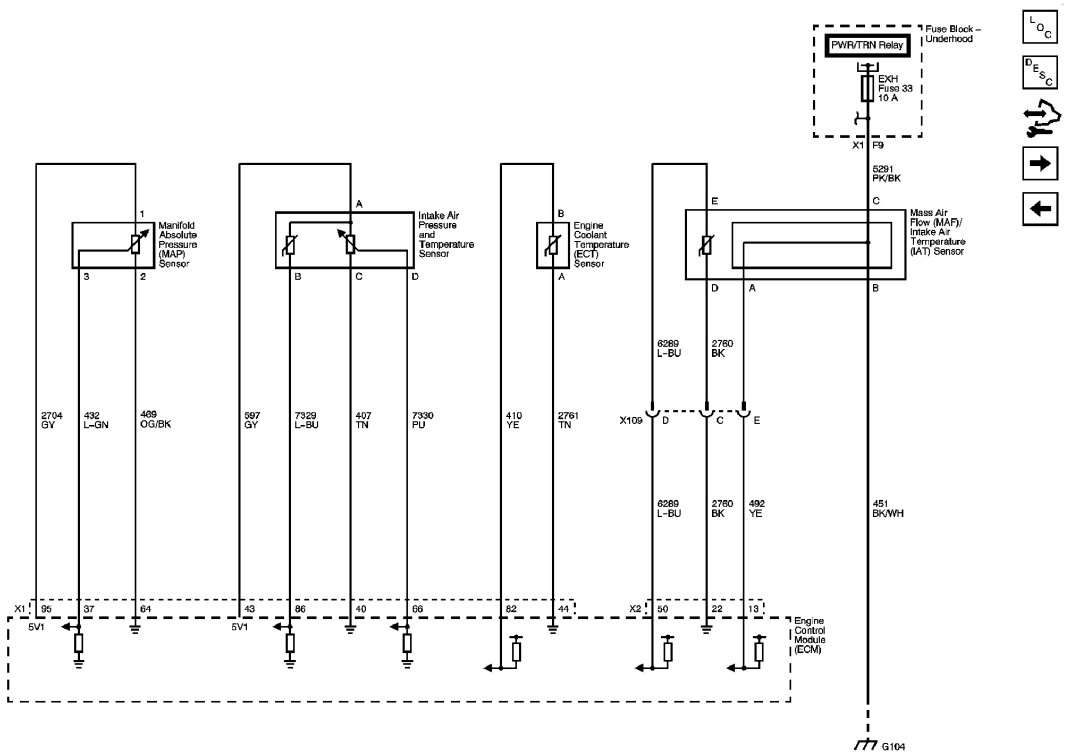


Fig. 4: Engine Data Sensors - Pressure, Temperature And MAF/IAT - Schematic

Courtesy of GENERAL MOTORS CORP.

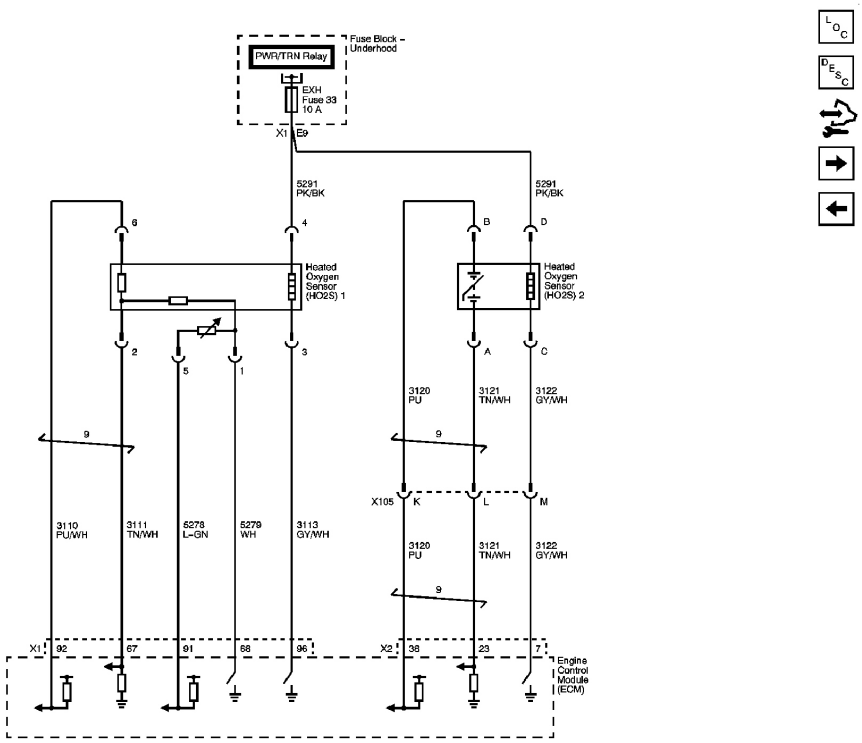


Fig. 5: Engine Data Sensors - Oxygen Sensors - Schematic
Courtesy of GENERAL MOTORS CORP.

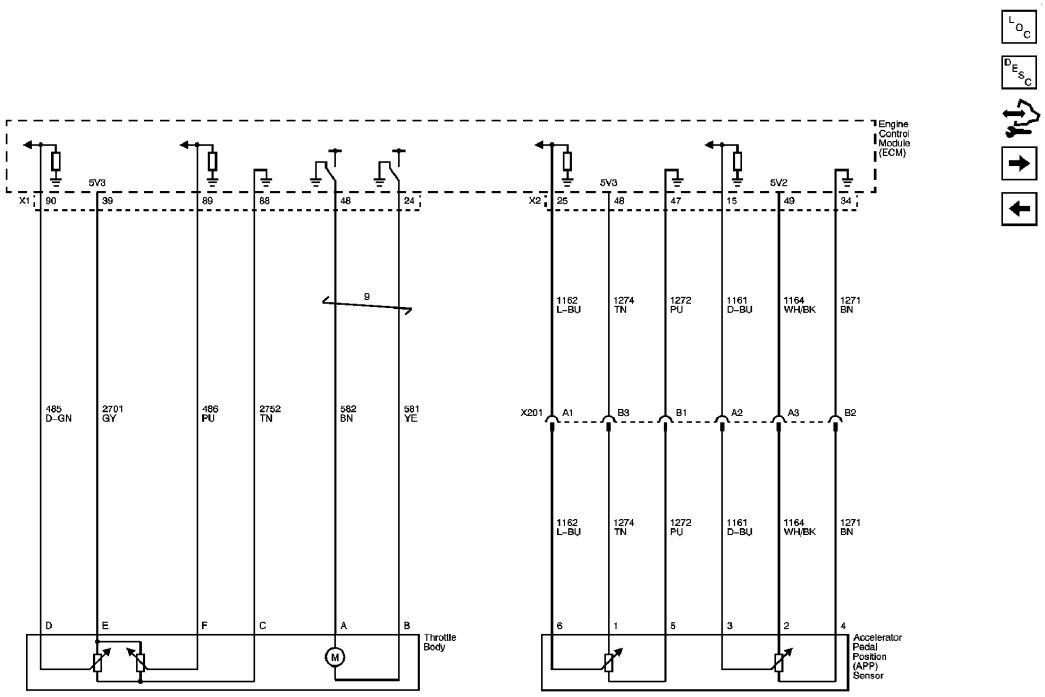


Fig. 6: Engine Data Sensors - APP And TAC - Schematic
Courtesy of GENERAL MOTORS CORP.

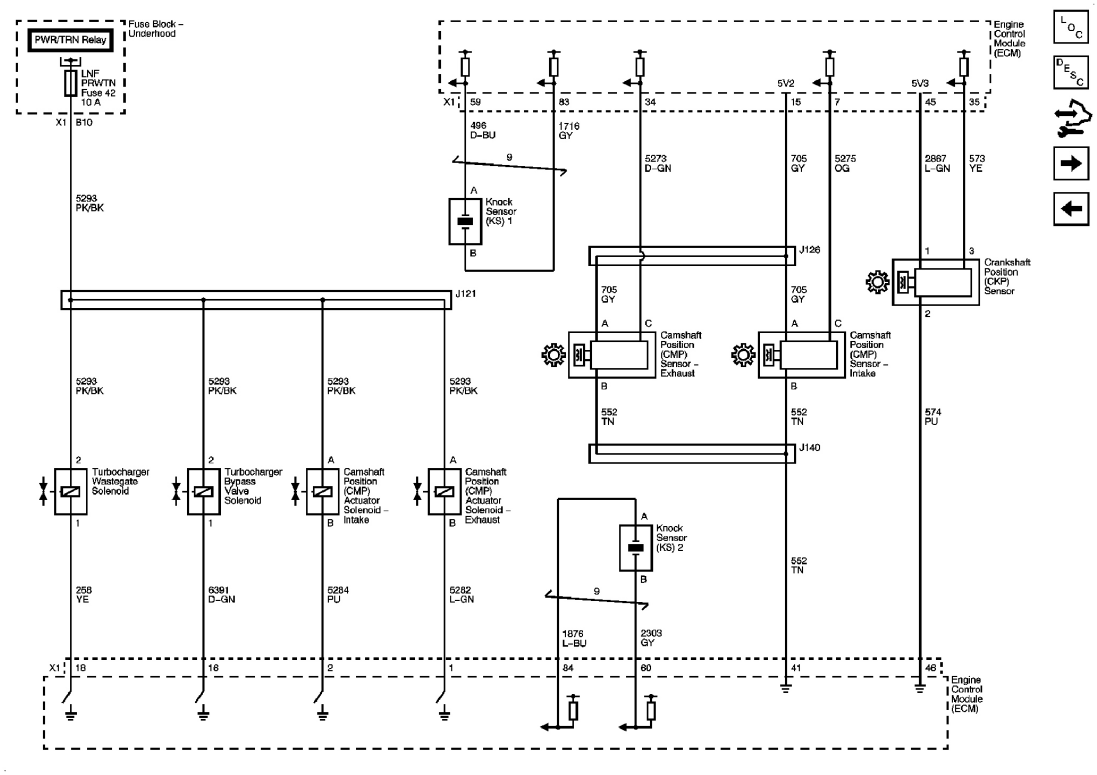


Fig. 7: Ignition Controls - Sensors - Schematic
Courtesy of GENERAL MOTORS CORP.

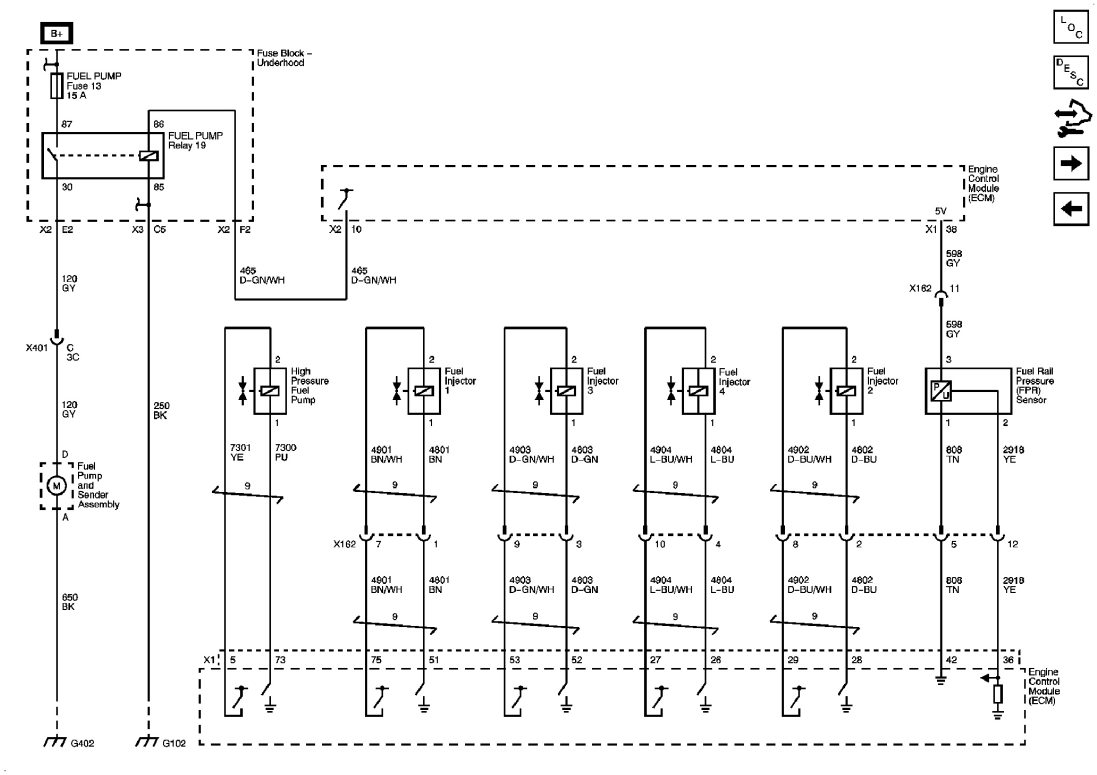


Fig. 8: Fuel Controls - Fuel Pump Controls And Fuel Injectors - Schematic
Courtesy of GENERAL MOTORS CORP.

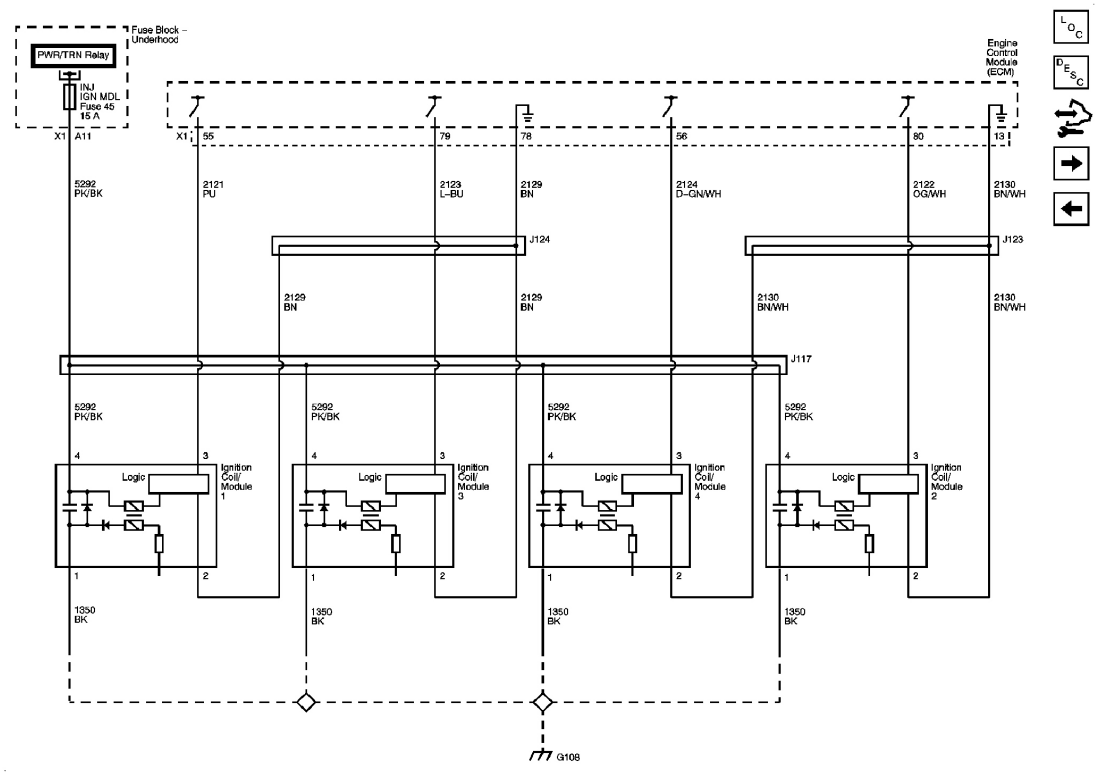


Fig. 9: Ignition Controls - Ignition System - Schematic
Courtesy of GENERAL MOTORS CORP.

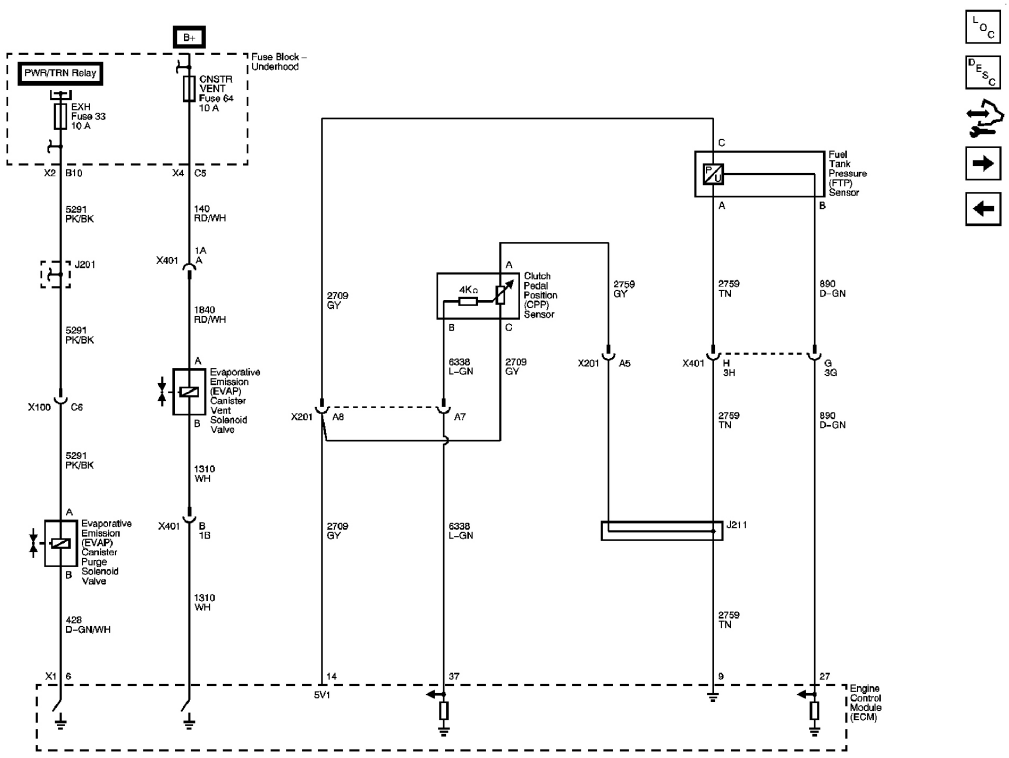


Fig. 10: Fuel Controls - EVAP Controls - Schematic
Courtesy of GENERAL MOTORS CORP.

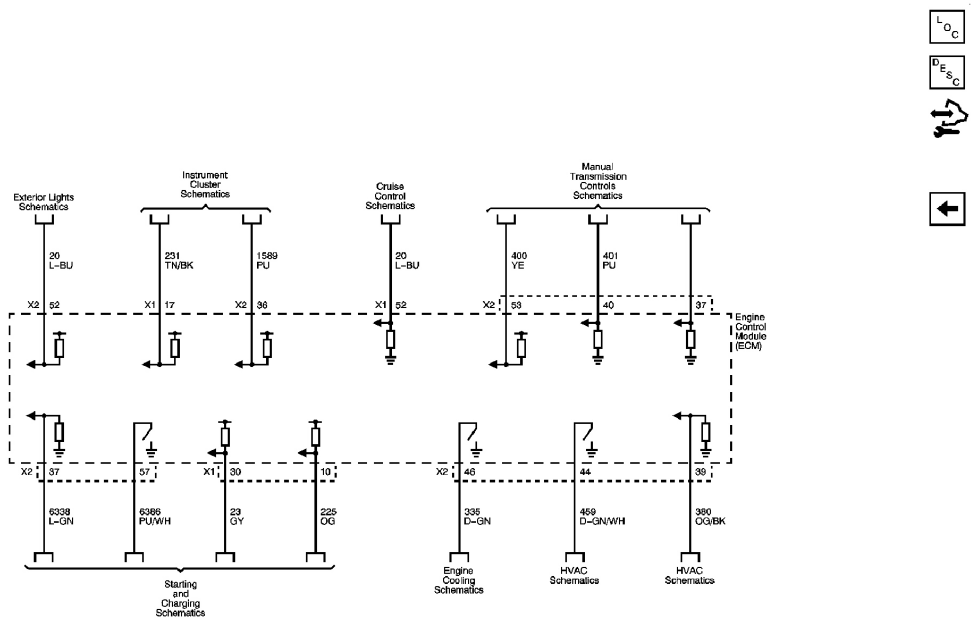


Fig. 11: Controlled/Monitored Subsystem References - Schematic
Courtesy of GENERAL MOTORS CORP.

DIAGNOSTIC INFORMATION AND PROCEDURES

DIAGNOSTIC CODE INDEX

DIAGNOSTIC CODE INDEX

DTC	Description
DTC P0010 or P0011	P0010: Intake Camshaft Position (CMP) Actuator Solenoid Control Circuit P0011: Intake Camshaft Position (CMP) System Performance
DTC P0013 or P0014	P0013: Exhaust Camshaft Position (CMP) Actuator Solenoid Control Circuit P0014: Exhaust Camshaft Position (CMP) System Performance
DTC P0016 or P0017	P0016: Crankshaft Position (CKP) - Intake Camshaft

	Position (CMP) Correlation P0017: Crankshaft Position (CKP) - Exhaust Camshaft Position (CMP) Correlation
DTC P0030, P0031, P0032, P0053, or P0135	P0030: HO2S Heater Control Circuit Sensor 1 P0031: HO2S Heater Control Circuit Low Voltage Sensor 1 P0032: HO2S Heater Control Circuit High Voltage Sensor 1 P0053: HO2S Heater Resistance Sensor 1 P0135: HO2S Heater Performance Sensor 1
DTC P0033, P0034, or P0035	P0033: Turbocharger Bypass Valve Solenoid Control Circuit P0034: Turbocharger Bypass Valve Solenoid Control Circuit Low Voltage P0035: Turbocharger Bypass Valve Solenoid Control Circuit High Voltage
DTC P0036, P0037, P0038, or P0141	P0036: HO2S Heater Control Circuit Sensor 2 P0037: HO2S Heater Control Circuit Low Voltage Sensor 2 P0038: HO2S Heater Control Circuit High Voltage Sensor 2 P0141: HO2S Heater Performance Sensor 2
DTC P0087, P0088, or P0089	P0087: Fuel Rail Pressure (FRP) Too Low P0088: Fuel Rail Pressure (FRP) Too High P0089: Fuel Pressure Regulator Performance
DTC P0090, P0091, or P0092	P0090: Fuel Pressure Regulator Control Circuit P0091: Fuel Pressure Regulator Solenoid 1 Control Circuit Low Voltage P0092: Fuel Pressure Regulator Solenoid 1 Control Circuit High Voltage
DTC P0096, P0097, P0098, or P0099	P0096: Intake Air Temperature (IAT) Sensor 2 Performance P0097: Intake Air Temperature (IAT) Sensor 2 Circuit Low Voltage P0098: Intake Air Temperature (IAT) Sensor 2 Circuit

	High Voltage P0099: Intake Air Temperature (IAT) Sensor 2 Circuit Intermittent
DTC P0100, P0102, or P0103	P0100: Mass Air Flow (MAF) Sensor Circuit P0102: Mass Air Flow (MAF) Sensor Circuit Low Frequency P0103: Mass Air Flow (MAF) Sensor Circuit High Frequency
DTC P0101	P0101: Mass Air Flow (MAF) Sensor Performance
DTC P0106	P0106: Manifold Absolute Pressure (MAP) Sensor Performance
DTC P0107 or P0108	P0107: Manifold Absolute Pressure (MAP) Sensor Circuit Low Voltage P0108: Manifold Absolute Pressure (MAP) Sensor Circuit High Voltage
DTC P0112, P0113, or P0114	P0112: Intake Air Temperature (IAT) Sensor Circuit Low Voltage P0113: Intake Air Temperature (IAT) Sensor Circuit High Voltage P0114: Intake Air Temperature (IAT) Sensor Circuit Intermittent
DTC P0116	P0116: Engine Coolant Temperature (ECT) Sensor Performance
DTC P0117, P0118, or P0119	P0117: Engine Coolant Temperature (ECT) Sensor Circuit Low Voltage P0118: Engine Coolant Temperature (ECT) Sensor Circuit High Voltage P0119: Engine Coolant Temperature (ECT) Sensor Circuit Intermittent
DTC P0121, P0122, or P0123	P0121: Throttle Position (TP) Sensor 1 Performance P0122: Throttle Position (TP) Sensor 1 Circuit Low Voltage P0123: Throttle Position (TP) Sensor 1 Circuit High Voltage
DTC P0128	P0128: Engine Coolant Temperature (ECT) Below

	Thermostat Regulating Temperature
DTC P0130-P0133, P2195, P2196, or 2297	P0130: HO2S Circuit Closed Loop (CL) Performance Sensor 1 P0131: HO2S Circuit Low Voltage Sensor 1 P0132: HO2S Circuit High Voltage Sensor 1 P0133: HO2S Slow Response Sensor 1 P2195: HO2S Signal Biased Lean Sensor 1 P2196: HO2S Signal Biased Rich Sensor 1 P2297: HO2S Performance During Decel Fuel Cut-Off (DFCO) Sensor 1
DTC P0137, P0138, P013A, P013E, P0140, P2232, P2270, or P2271	P0137: HO2S Circuit Low Voltage Sensor 2 P0138: HO2S Circuit High Voltage Sensor 2 P013A: HO2S Slow Response Rich to Lean Sensor 2 P013E: HO2S Delayed Response Rich to Lean Sensor 2 P0140: HO2S Circuit Insufficient Activity Sensor 2 P2232: HO2S Signal Circuit Shorted to Heater Circuit Sensor 2 P2270: HO2S Signal Stuck Lean Sensor 2 P2271: HO2S Signal Stuck Rich Sensor 2
DTC P0191, P0192, or P0193	P0191: Fuel Rail Pressure (FRP) Sensor Performance P0192: Fuel Rail Pressure (FRP) Sensor Circuit Low Voltage P0193: Fuel Rail Pressure (FRP) Sensor Circuit High Voltage
DTC P0201-P0204, P0261, P0262, P0264, P0265, P0267, P0268, P0270, P0271, P2146, P2149, P2152, or P2155	P0201: Injector 1 Control Circuit P0202: Injector 2 Control Circuit P0203: Injector 3 Control Circuit P0204: Injector 4 Control Circuit P0261: Injector 1 Control Circuit Low Voltage P0262: Injector 1 Control Circuit High Voltage P0264: Injector 2 Control Circuit Low Voltage P0265: Injector 2 Control Circuit High Voltage P0267: Injector 3 Control Circuit Low Voltage P0268: Injector 3 Control Circuit High Voltage

	P0270: Injector 4 Control Circuit Low Voltage P0271: Injector 4 Control Circuit High Voltage P2146: Injector Positive Voltage Control Circuit Group 1 P2149: Injector Positive Voltage Control Circuit Group 2 P2152: Injector Positive Voltage Control Circuit Group 3 P2155: Injector Positive Voltage Control Circuit Group 4
DTC P0221, P0222, or P0223	P0221: Throttle Position (TP) Sensor 2 Performance P0222: Throttle Position (TP) Sensor 2 Circuit Low Voltage P0223: Throttle Position (TP) Sensor 2 Circuit High Voltage
DTC P0234 or P0299	P0234: Turbocharger Engine Overboost P0299: Turbocharger Engine Underboost
DTC P0236, P0237, or P0238	P0236: Turbocharger Boost System Performance P0237: Turbocharger Boost Sensor Circuit Low Voltage P0238: Turbocharger Boost Sensor Circuit High Voltage
DTC P0243, P0245, or P0246	P0243: Turbocharger Wastegate Solenoid Control Circuit P0245: Turbocharger Wastegate Solenoid Control Circuit Low Voltage P0246: Turbocharger Wastegate Solenoid Control Circuit High Voltage
DTC P029D, P02A1, P02A5, or P02A9	P029D: Injector 1 Leak P02A1: Injector 2 Leak P02A5: Injector 3 Leak P02A9: Injector 4 Leak
DTC P0300-P0304	P0300: Engine Misfire Detected P0301: Cylinder 1 Misfire Detected P0302: Cylinder 2 Misfire Detected

	P0303: Cylinder 3 Misfire Detected P0304: Cylinder 4 Misfire Detected
DTC P0324, P0326, P0327, P0328, P0331, P0332, or P0333	P0324: Knock Sensor (KS) Performance P0326: Knock Sensor (KS) 1 Performance P0327: Knock Sensor (KS) 1 Circuit Low Voltage P0328: Knock Sensor (KS) 1 Circuit High Voltage P0331: Knock Sensor (KS) 2 Performance P0332: Knock Sensor (KS) 2 Circuit Low Voltage P0333: Knock Sensor (KS) 2 Circuit High Voltage
DTC P0335, P0336, or P0338	P0335: Crankshaft Position (CKP) Sensor Circuit P0336: Crankshaft Position (CKP) Sensor Performance P0338: Crankshaft Position (CKP) Sensor Circuit High Duty Cycle
DTC P0341, P0342, or P0343	P0341: Intake Camshaft Position (CMP) Sensor Performance P0342: Intake Camshaft Position (CMP) Sensor Circuit Low Voltage P0343: Intake Camshaft Position (CMP) Sensor Circuit High Voltage
DTC P0351-P0354	P0351: Ignition Coil 1 Control Circuit P0352: Ignition Coil 2 Control Circuit P0353: Ignition Coil 3 Control Circuit P0354: Ignition Coil 4 Control Circuit
DTC P0366, P0367, or P0368	P0366: Exhaust Camshaft Position (CMP) Sensor Performance P0367: Exhaust Camshaft Position (CMP) Sensor Circuit Low Voltage P0368: Exhaust Camshaft Position (CMP) Sensor Circuit High Voltage
DTC P0420	P0420: Catalyst System Low Efficiency
DTC P0442	P0442: Evaporative Emission (EVAP) System Small Leak Detected
DTC P0443, P0449, P0458, P0459, P0498,	P0443: Evaporative Emission (EVAP) Purge Solenoid Control Circuit

or P0499	P0449: Evaporative Emission (EVAP) Vent Solenoid Control Circuit P0458: Evaporative Emission (EVAP) Purge Solenoid Control Circuit Low Voltage P0459: Evaporative Emission (EVAP) Purge Solenoid Control Circuit High Voltage P0498: Evaporative Emission (EVAP) Vent Solenoid Control Circuit Low Voltage P0499: Evaporative Emission (EVAP) Vent Solenoid Control Circuit High Voltage
DTC P0446	P0446: Evaporative Emission (EVAP) Vent System Performance
DTC P0450-P0453	P0450: Fuel Tank Pressure (FTP) Sensor Circuit P0451: Fuel Tank Pressure (FTP) Sensor Performance P0452: Fuel Tank Pressure (FTP) Sensor Circuit Low Voltage P0453: Fuel Tank Pressure (FTP) Sensor Circuit High Voltage
DTC P0455	P0455: Evaporative Emission (EVAP) System Large Leak
DTC P0496	P0496: Evaporative Emission System Flow During Non-Purge
DTC P0497	P0497: Evaporative Emission System Low Purge Flow
DTC P0506 or P0507	P0506: Idle Speed Low P0507: Idle Speed High
DTC P050A	P050A: Cold Start Idle Air Control System Performance
DTC P0601-P0606, P062B, P064D, P167A, P167D, P2105, or P2610	P0601: Control Module Read Only Memory (ROM) P0602: Control Module Not Programmed P0603: Control Module Long Term Memory Reset P0604: Control Module Random Access Memory (RAM) P0606: Control Module Internal Performance P062B: Control Module Fuel Injector Control Performance

	P064D: Control Module HO2S 1 System Performance P167A: Control Module HO2S 1 System Performance P167D: Control Module Ignition Coil Internal Circuit P2105: Throttle Actuator Control (TAC) System - Forced Engine Shut-down P2610: Control Module Ignition OFF Timer Performance
DTC P0627, P0628, or P0629	P0627: Fuel Pump Relay Control Circuit P0628: Fuel Pump Relay Control Circuit Low Voltage P0629: Fuel Pump Relay Control Circuit High Voltage
DTC P0638, P1551, P2100, P2101, P2119, or P2176	P0638: Throttle Actuator Control (TAC) Command Performance P1551: Throttle Valve Rest Position Not Reached During Learn P2100: Throttle Actuator Control (TAC) Motor Control Circuit P2101: Control Module Throttle Actuator Position Performance P2119: Throttle Closed Position Performance P2176: Minimum Throttle Position Not Learned
DTC P0641, P0642, P0643, P0651, P0652, P0653, P0697, P0698 or P0699	P0641: 5-Volt Reference 1 Circuit P0642: 5-Volt Reference 1 Low Voltage P0643: 5-Volt Reference 1 High Voltage P0651: 5-Volt Reference 2 Circuit P0652: 5-Volt Reference 2 Low Voltage P0653: 5-Volt Reference 2 High Voltage P0697: 5-Volt Reference 3 Circuit P0698: 5-Volt Reference 3 Low Voltage P0699: 5-Volt Reference 3 High Voltage
DTC P0650	P0650: Malfunction Indicator Lamp (MIL) Control Circuit
DTC P0685, P0686, P0687, P0689, or P0690	P0685: Engine Controls Ignition Relay Control Circuit P0686: Engine Controls Ignition Relay Control Circuit Low Voltage P0687: Engine Controls Ignition Relay Control Circuit

	High Voltage P0689: Engine Controls Ignition Relay Feedback Circuit Low Voltage P0690: Engine Controls Ignition Relay Feedback Circuit High Voltage
DTC P0700	P0700: Transmission Control Module (TCM) Requested MIL Illumination
DTC P2088 or P2089	P2088: Intake Camshaft Position (CMP) Actuator Solenoid Control Circuit Low Voltage P2089: Intake Camshaft Position (CMP) Actuator Solenoid Control Circuit High Voltage
DTC P2090 or P2091	P2090: Exhaust Camshaft Position (CMP) Actuator Solenoid Control Circuit Low Voltage P2091: Exhaust Camshaft Position (CMP) Actuator Solenoid Control Circuit High Voltage
DTC P2096, P2177, or P2187	P2096: Post Catalyst Fuel Trim System Low Limit Bank 1 P2177: Fuel Trim System Lean at Cruise or Accel P2187: Fuel Trim System Lean at Idle
DTC P2097, P2178, or P2188	P2097: Post Catalyst Fuel Trim System High Limit Bank 1 P2178: Fuel Trim System Rich at Cruise or Accel P2188: Fuel Trim System Rich at Idle
DTC P2122 or P2123	P2122: Accelerator Pedal Position (APP) Sensor 1 Circuit Low Voltage P2123: Accelerator Pedal Position (APP) Sensor 1 Circuit High Voltage
DTC P2127 or P2128	P2127: Accelerator Pedal Position (APP) Sensor 2 Circuit Low Voltage P2128: Accelerator Pedal Position (APP) Sensor 2 Circuit High Voltage
DTC P2138	P2138: Accelerator Pedal Position (APP) Sensor 1-2 Correlation
DTC P2199	P2199: Intake Air Temperature (IAT) Sensor 1-2 Correlation

DTC P2227, P2228, or P2229	P2227: Barometric Pressure (BARO) Sensor Performance P2228: Barometric Pressure (BARO) Sensor Circuit Low Voltage P2229: Barometric Pressure (BARO) Sensor Circuit High Voltage
DTC P2237, P2243, P2251, or P2626	P2237: HO2S Pumping Current Control Circuit Sensor 1 P2243: HO2S Reference Voltage Circuit Sensor 1 P2251: HO2S Low Reference Circuit Sensor 1 P2626: HO2S Pumping Current Trim Circuit Sensor 1
DTC P2261	P2261: Turbocharger Bypass Valve Stuck Closed
DTC P2544	P2544: Transmission Torque Request Circuit
DTC P2300, P2301, P2303, P2304, P2306, P2307, P2309, or P2310	P2300: Ignition Coil 1 Control Circuit Low Voltage P2301: Ignition Coil 1 Control Circuit High Voltage P2303: Ignition Coil 2 Control Circuit Low Voltage P2304: Ignition Coil 2 Control Circuit High Voltage P2306: Ignition Coil 3 Control Circuit Low Voltage P2307: Ignition Coil 3 Control Circuit High Voltage P2309: Ignition Coil 4 Control Circuit Low Voltage P2310: Ignition Coil 4 Control Circuit High Voltage

REPAIR INSTRUCTIONS

ENGINE CONTROL MODULE REPLACEMENT

NOTE:

- **Turn the ignition OFF when installing or removing the control module connectors and disconnecting or reconnecting the power to the control module (battery cable, powertrain control module (PCM)/engine control module (ECM)/transaxle control module (TCM) pigtail, control module fuse, jumper cables, etc.) in order to prevent internal control module damage.**
- **Control module damage may result when the metal case contacts battery voltage. DO NOT contact the**

control module metal case with battery voltage when servicing a control module, using battery booster cables, or when charging the vehicle battery.

- **In order to prevent any possible electrostatic discharge damage to the control module, do no touch the connector pins or the soldered components on the circuit board.**
- **Remove any debris from around the control module connector surfaces before servicing the control module. Inspect the control module connector gaskets when diagnosing or replacing the control module. Ensure that the gaskets are installed correctly. The gaskets prevent contaminant intrusion into the control module.**
- **The replacement control module must be programmed.**

IMPORTANT: It is necessary to record the remaining engine oil life. If the replacement module is not programed with the remaining engine oil life, the engine oil life will default to 100 percent. If the replacement module is not programmed with the remaining engine oil life, the engine oil will need to be changed at 5 000 km (3,000 mi) from the last engine oil change.

Removal Procedure

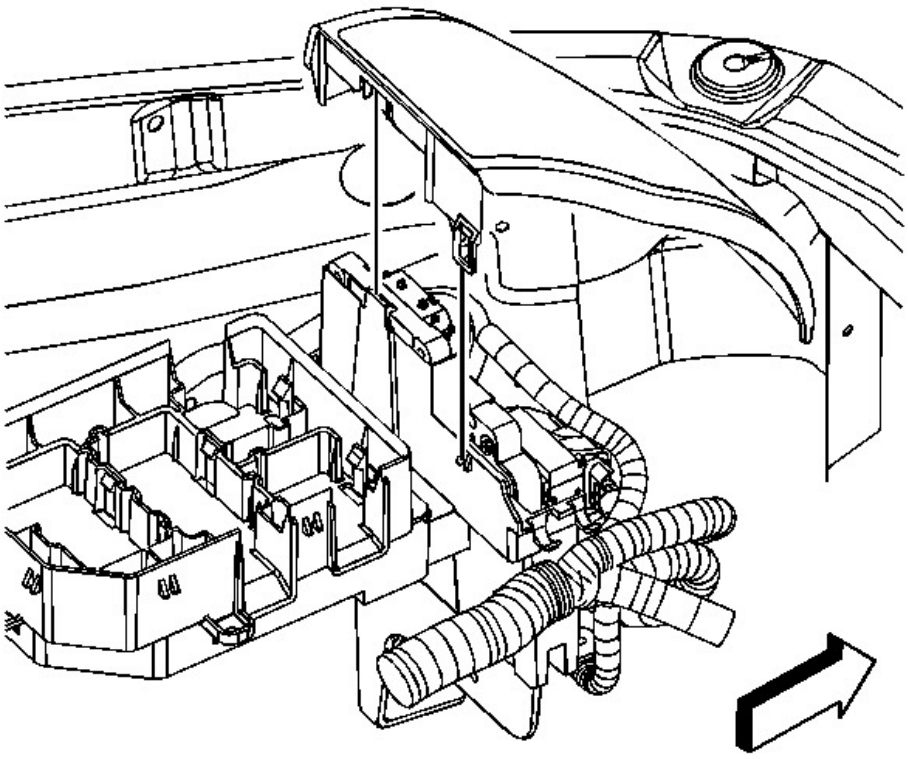


Fig. 12: ECM/TCM Cover
Courtesy of GENERAL MOTORS CORP.

1. Using a scan tool, retrieve the percentage of remaining engine oil. Record the remaining engine oil life.
2. Disconnect the negative battery cable. Refer to **Battery Negative Cable Disconnection and Connection** .
3. Remove the ECM/TCM cover.

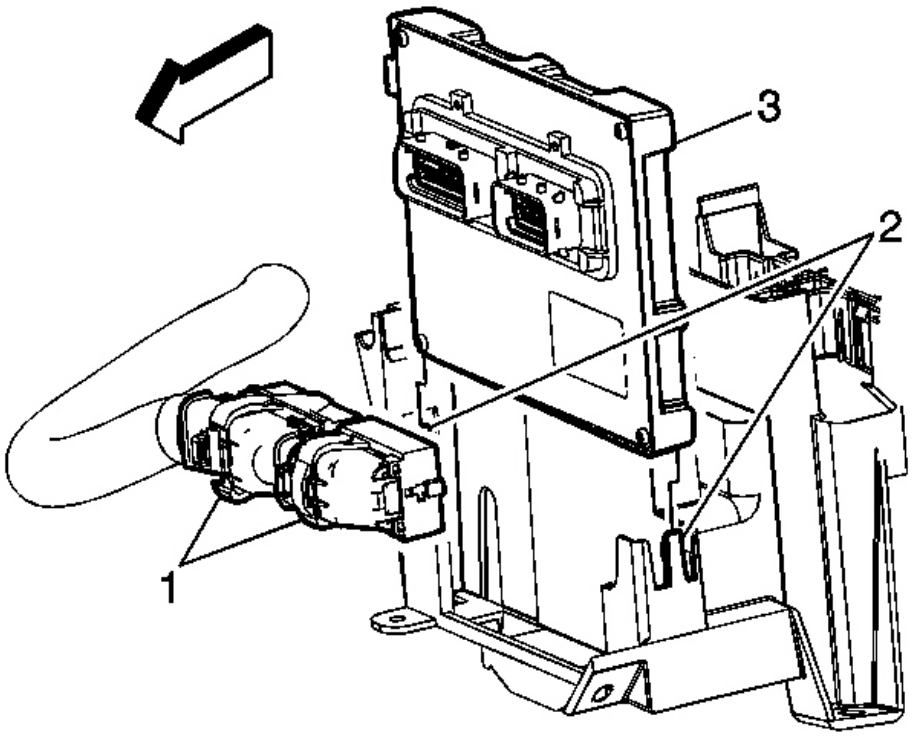


Fig. 13: ECM Electrical Connector
Courtesy of GENERAL MOTORS CORP.

4. Disconnect the ECM electrical connectors (1).

NOTE: Control module damage may result when the metal case contacts battery voltage. DO NOT contact the control module metal case with battery voltage when servicing a control module, using battery booster cables or when charging the vehicles battery.

5. Disengage the plastic retainer tabs (2) and remove the ECM (3).

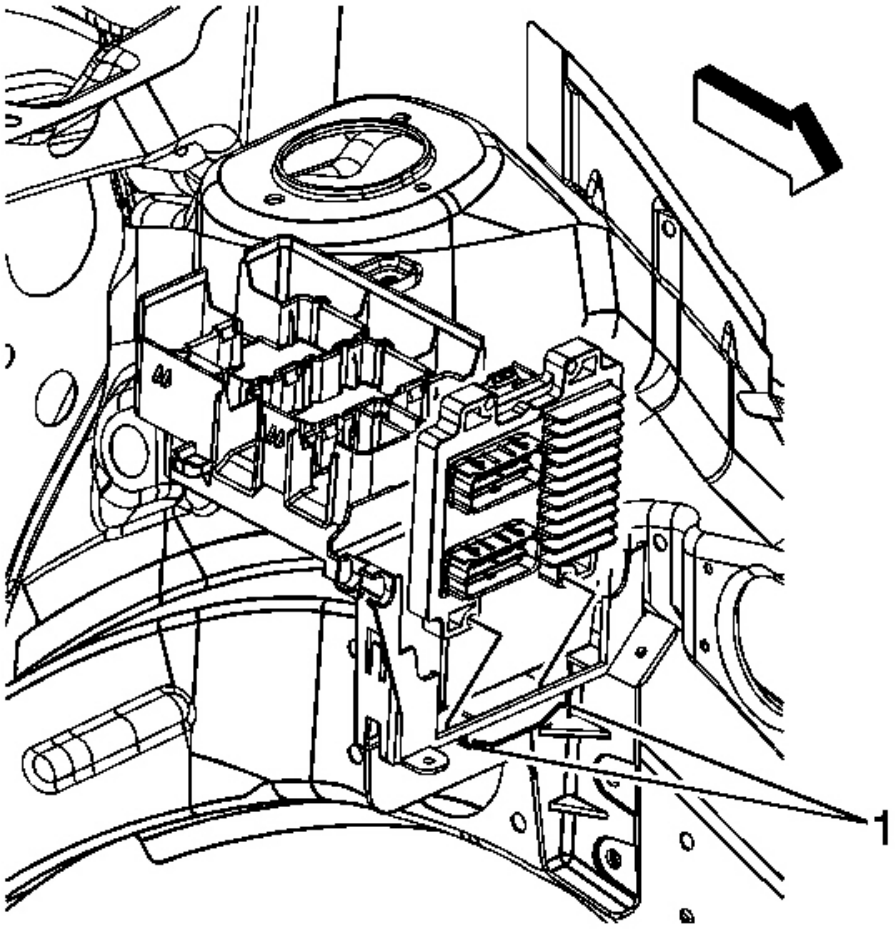


Fig. 14: View Of ECM Retaining Tab
Courtesy of GENERAL MOTORS CORP.

6. Release the retaining tab (1) in order to release the ECM from the underhood

junction block bracket.

Installation Procedure

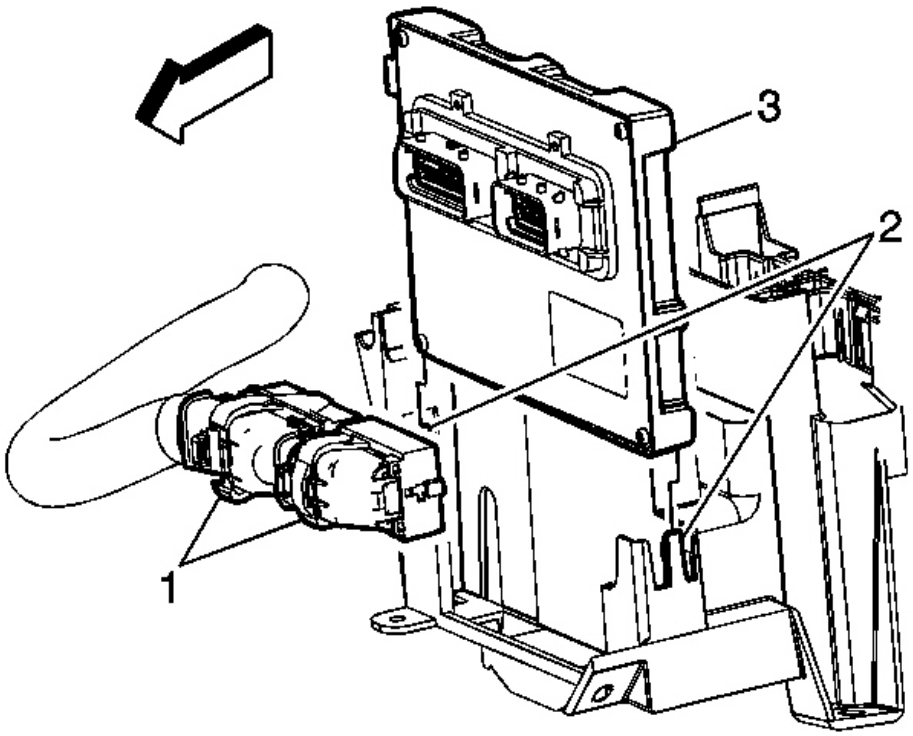


Fig. 15: ECM Electrical Connector
Courtesy of GENERAL MOTORS CORP.

NOTE: Control module damage may result when the metal case contacts battery voltage. DO NOT contact the control module metal case with battery voltage when servicing a control module, using battery booster

cables or when charging the vehicles battery.

1. Install the ECM (3) by pushing straight down until the tabs (2) lock.
2. Connect the ECM electrical connectors (1).

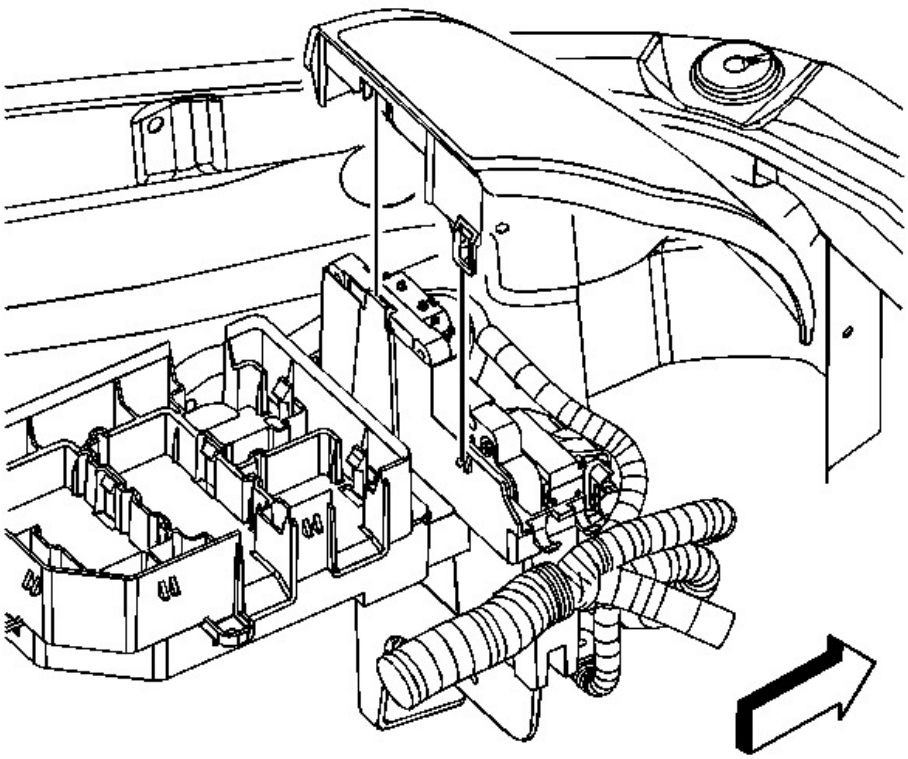


Fig. 16: ECM/TCM Cover
Courtesy of GENERAL MOTORS CORP.

3. Install the ECM/TCM cover.
4. Connect the negative battery cable. Refer to **Battery Negative Cable**

Disconnection and Connection .

5. Program the ECM. Refer to **Control Module References** .

ENGINE COOLANT TEMPERATURE SENSOR REPLACEMENT

Removal Procedure

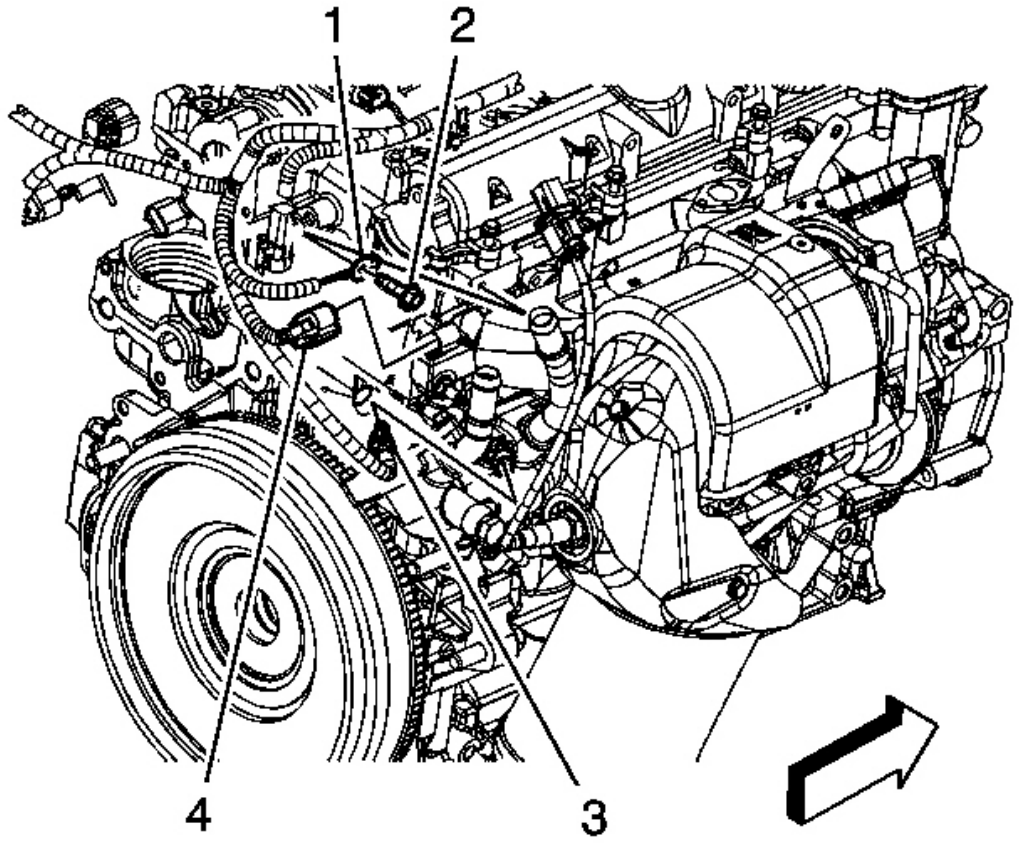


Fig. 17: Engine Wiring Harness Electrical Connector & ECT Sensor
Courtesy of GENERAL MOTORS CORP.

1. Partially drain the cooling system. Refer to **Cooling System Draining and Filling (GE 47716 Fill)** or **Cooling System Draining and Filling (Static Fill-LNF)** .
2. Remove the heat shield from the around the electrical connector, if necessary.

3. Disconnect the engine wiring harness electrical connector (3) from the engine coolant temperature (ECT) sensor.

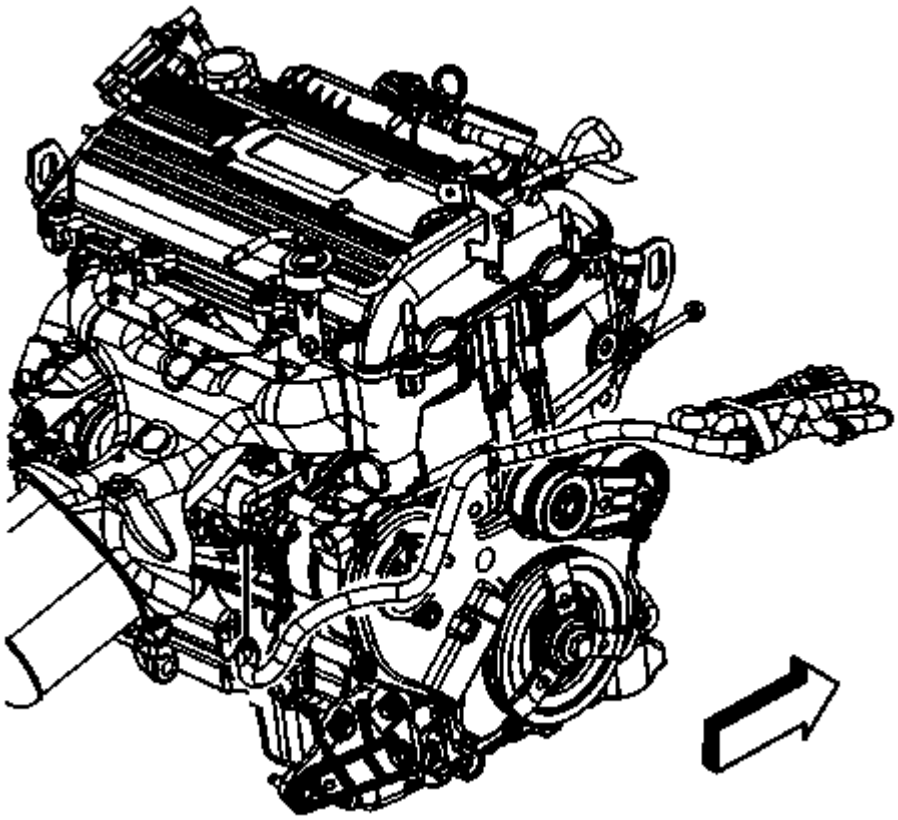


Fig. 18: ECT Sensor
Courtesy of GENERAL MOTORS CORP.

4. Remove the ECT.

Installation Procedure

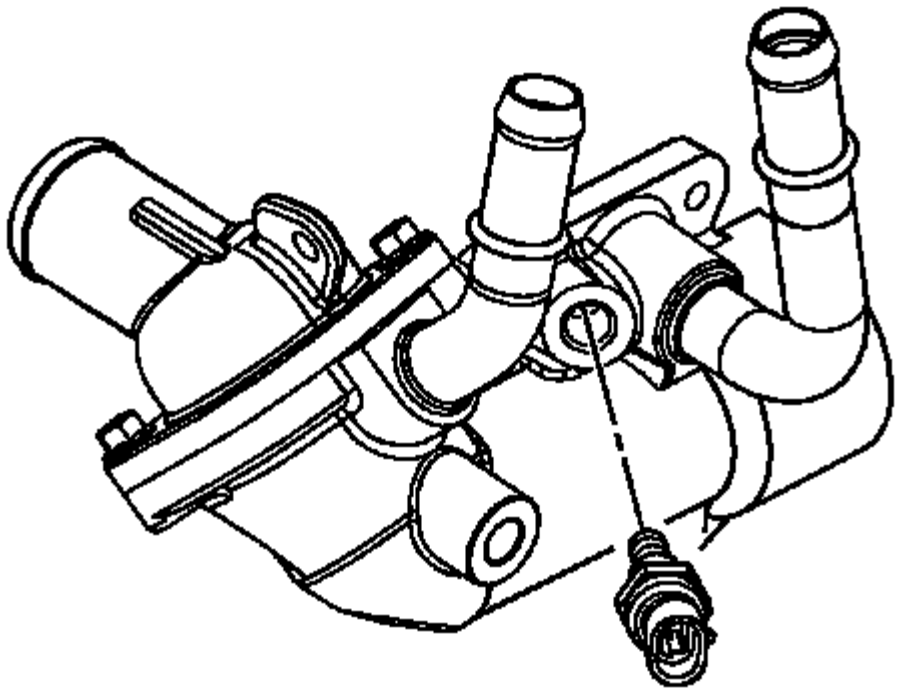


Fig. 19: ECT Sensor
Courtesy of GENERAL MOTORS CORP.

NOTE: Refer to Fastener Notice .

1. Install the ECT.

   Tighten: Tighten the sensor to 20 N.m (15 lb ft).

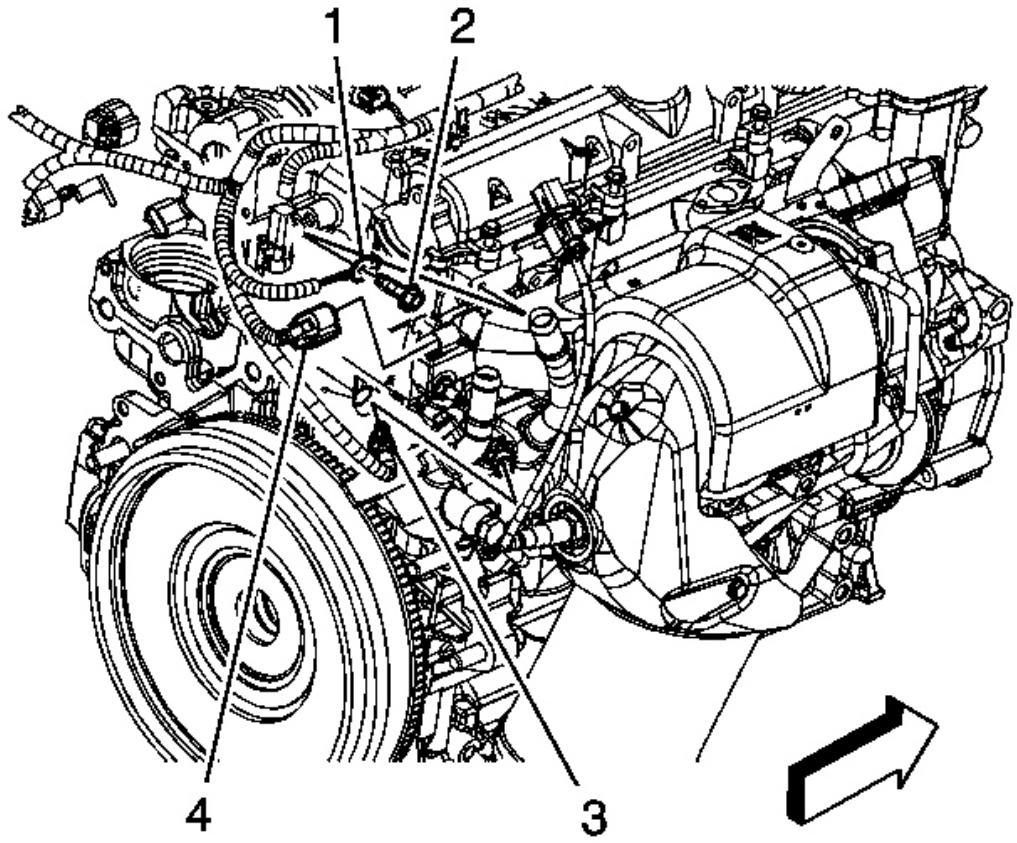


Fig. 20: Engine Wiring Harness Electrical Connector & ECT Sensor
Courtesy of GENERAL MOTORS CORP.

2. Connect the engine wiring harness electrical connector (3) to the ECT sensor.
3. Install the heat shield around the electrical connector, if necessary.
4. Fill the cooling system as needed. Refer to **Cooling System Draining and Filling (GE 47716 Fill)** or **Cooling System Draining and Filling (Static Fill-LNF)** .

MASS AIRFLOW SENSOR REPLACEMENT

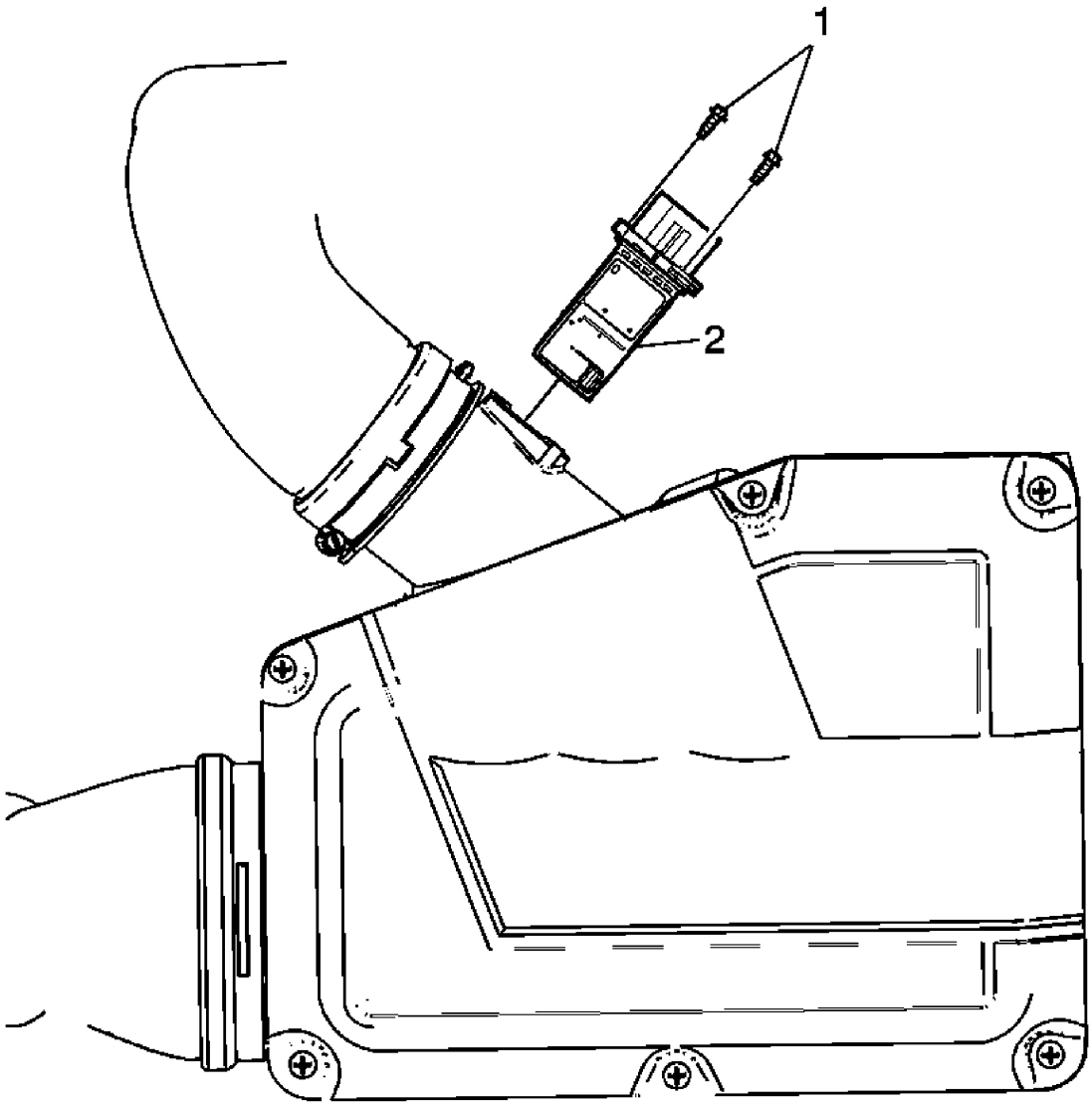


Fig. 21: Mass Airflow Sensor
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
Preliminary Procedure: Disconnect the negative cable. Refer to **Battery Negative Cable Disconnection and Connection** .	
1	Mass Airflow (MAF) Sensor Screw (Qty: 2) **NOTE:** **Refer to Fastener Notice .**

	Tighten: 0.6 N.m (5 lb in)
2	MAF Sensor

MANIFOLD ABSOLUTE PRESSURE SENSOR REPLACEMENT

Removal Procedure

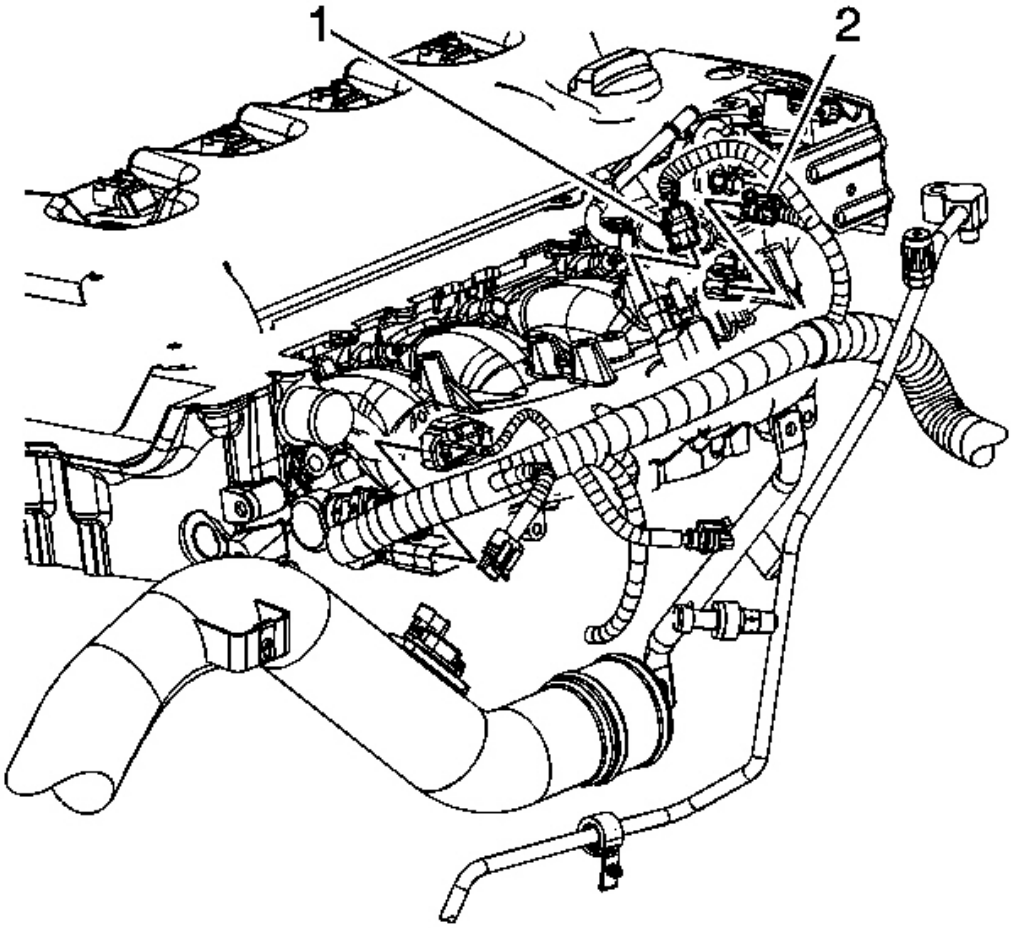


Fig. 22: MAP Sensor Connector
Courtesy of GENERAL MOTORS CORP.

1. Disconnect the engine wiring harness electrical connector (2) from the manifold absolute pressure (MAP) sensor.

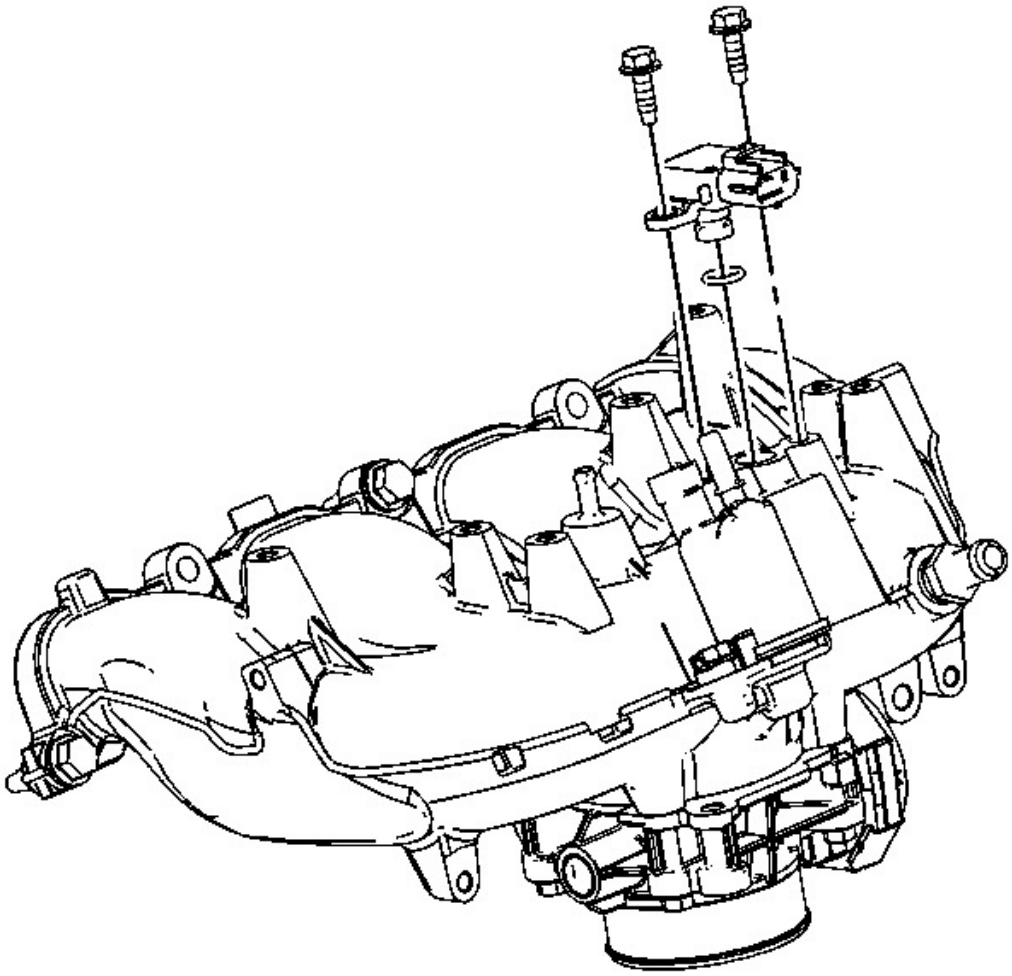


Fig. 23: MAP Sensor
Courtesy of GENERAL MOTORS CORP.

2. Remove the MAP sensor bolts.
3. Remove the MAP sensor and O-ring seal from the intake manifold.

Installation Procedure

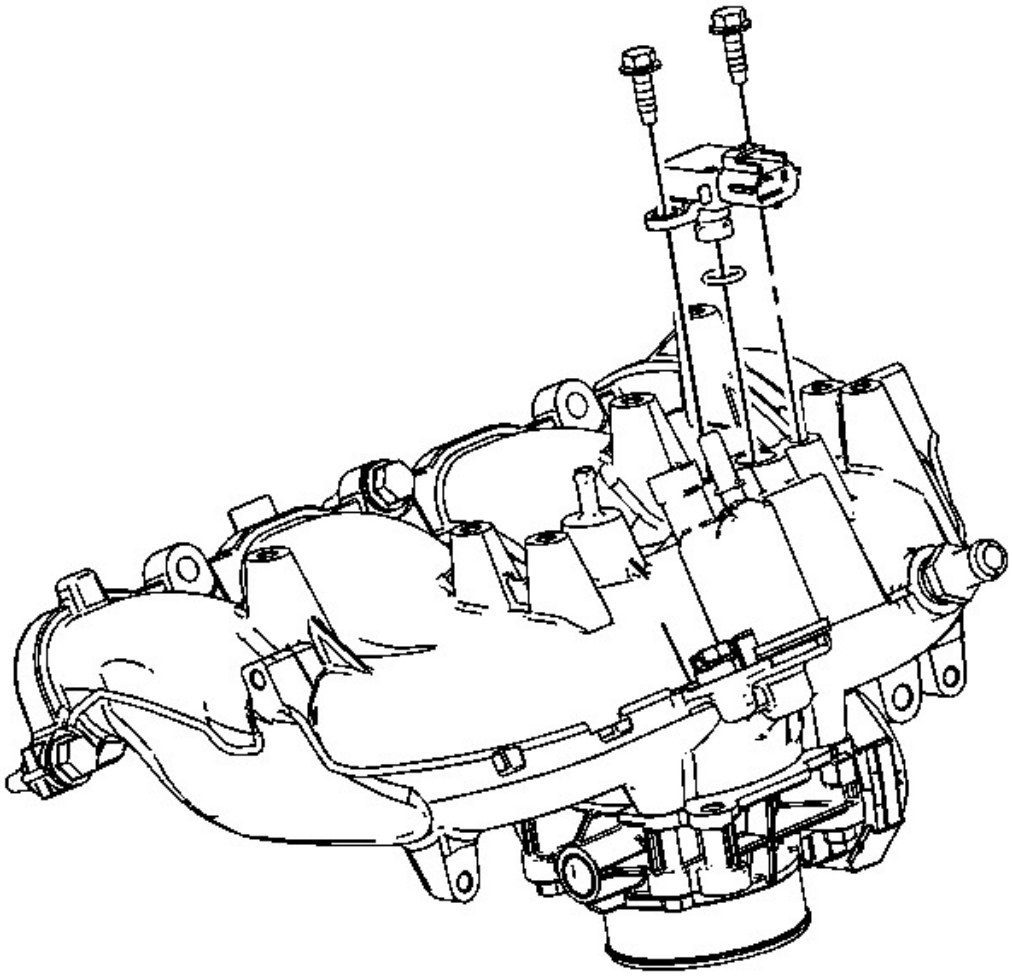


Fig. 24: MAP Sensor
Courtesy of GENERAL MOTORS CORP.

1. Lubricate the O-ring seal with clean engine oil.
2. Install the MAP sensor to the intake manifold.

NOTE: Refer to Fastener Notice .

3. Install the MAP sensor bolts.

Tighten: Tighten the bolts to 10 N.m (89 lb in).

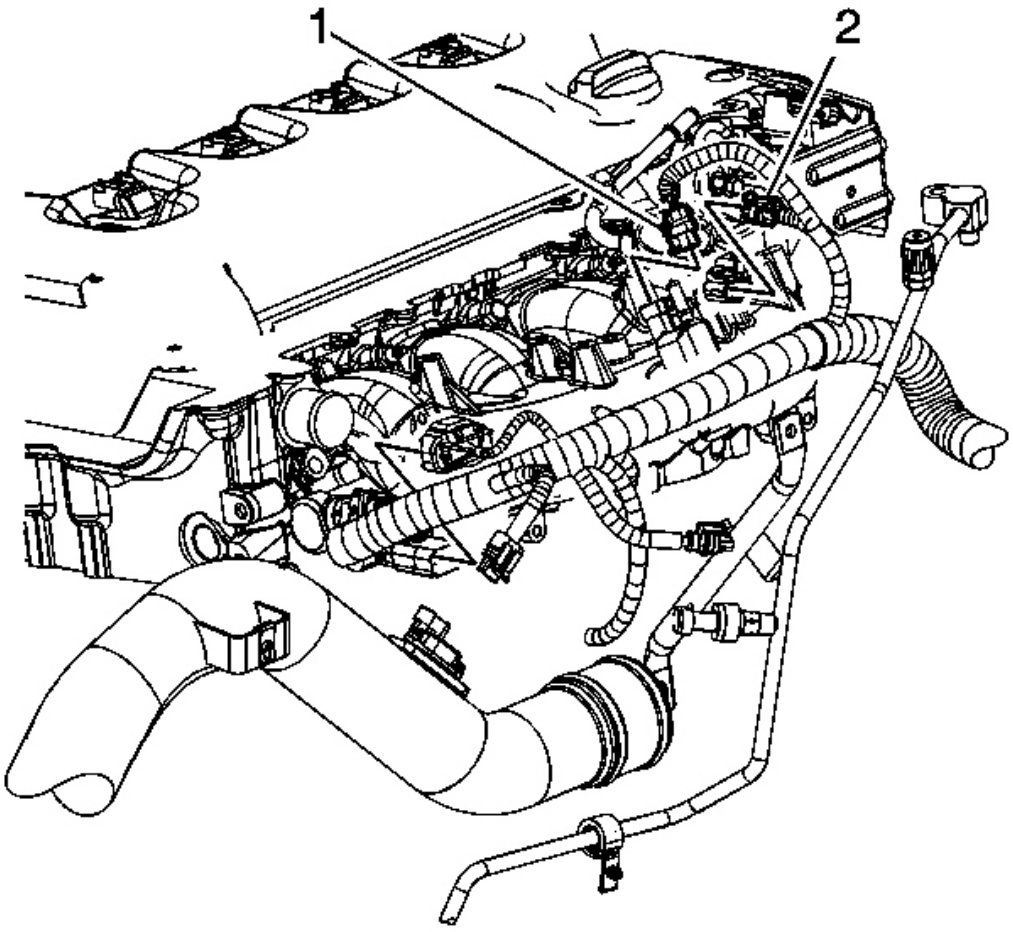


Fig. 25: MAP Sensor Connector
Courtesy of GENERAL MOTORS CORP.

4. Connect the engine wiring harness electrical connector (2) to the MAP sensor.

HEATED OXYGEN SENSOR 1 REPLACEMENT

Tools Required

J 39194 Oxygen Sensor Wrench. See **Special Tools**.

Removal Procedure

NOTE: The oxygen sensor uses a permanently attached pigtail and connector. Do not remove the pigtail from the oxygen sensor. Damage to or removal of the pigtail connector could affect proper operation of the oxygen sensor.

NOTE: The use of excessive force may damage the threads in the exhaust manifold/pipe.

IMPORTANT:

- **The in-line connector and louvered end must be kept clear of grease, dirt or other contaminants. Avoid using cleaning solvents of any type. DO NOT drop or roughly handle the heated oxygen sensor (HO2S).**
- **The HO2S may be difficult to remove when the engine temperature is less than 48°C (120°F).**

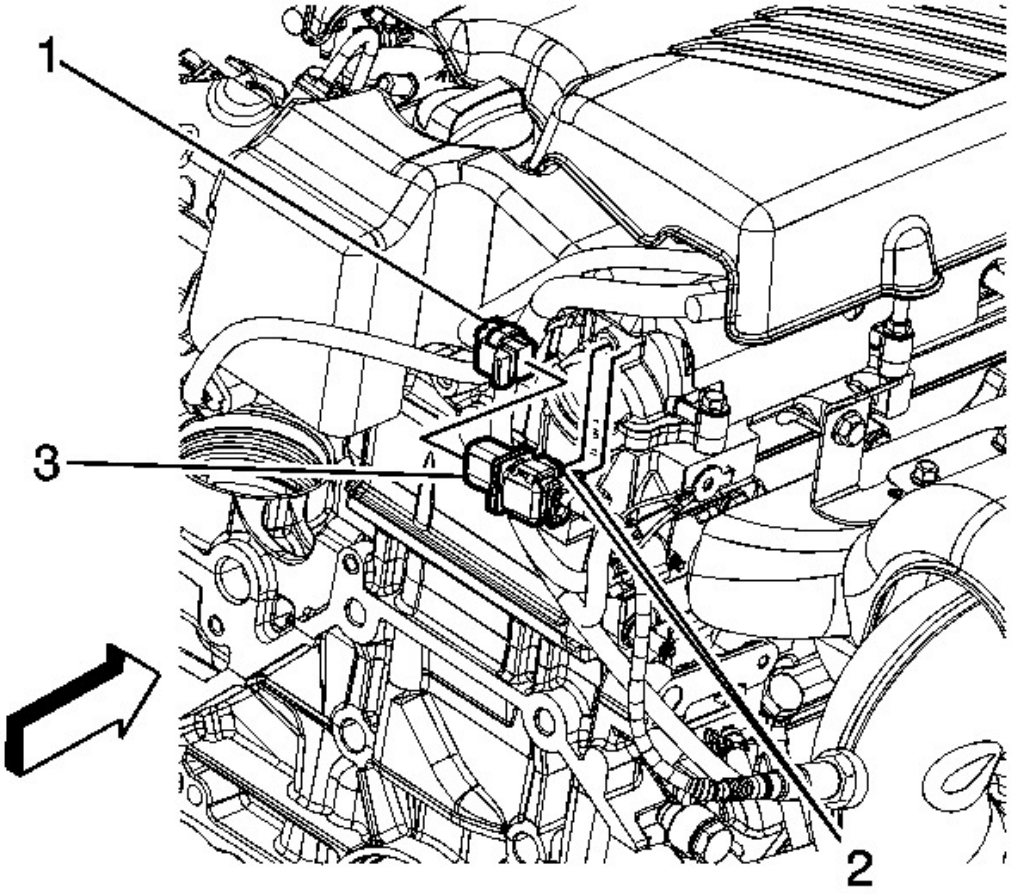


Fig. 26: CPA Retainer & HO2S 1 Connector Clip
Courtesy of GENERAL MOTORS CORP.

1. Open the hood.
2. Remove the connector position assurance (CPA) retainer.
3. Disconnect the engine wiring harness electrical connector (1) from the HO2S electrical connector (3).
4. Remove the HO2S electrical connector clip (2) from the camshaft cover.

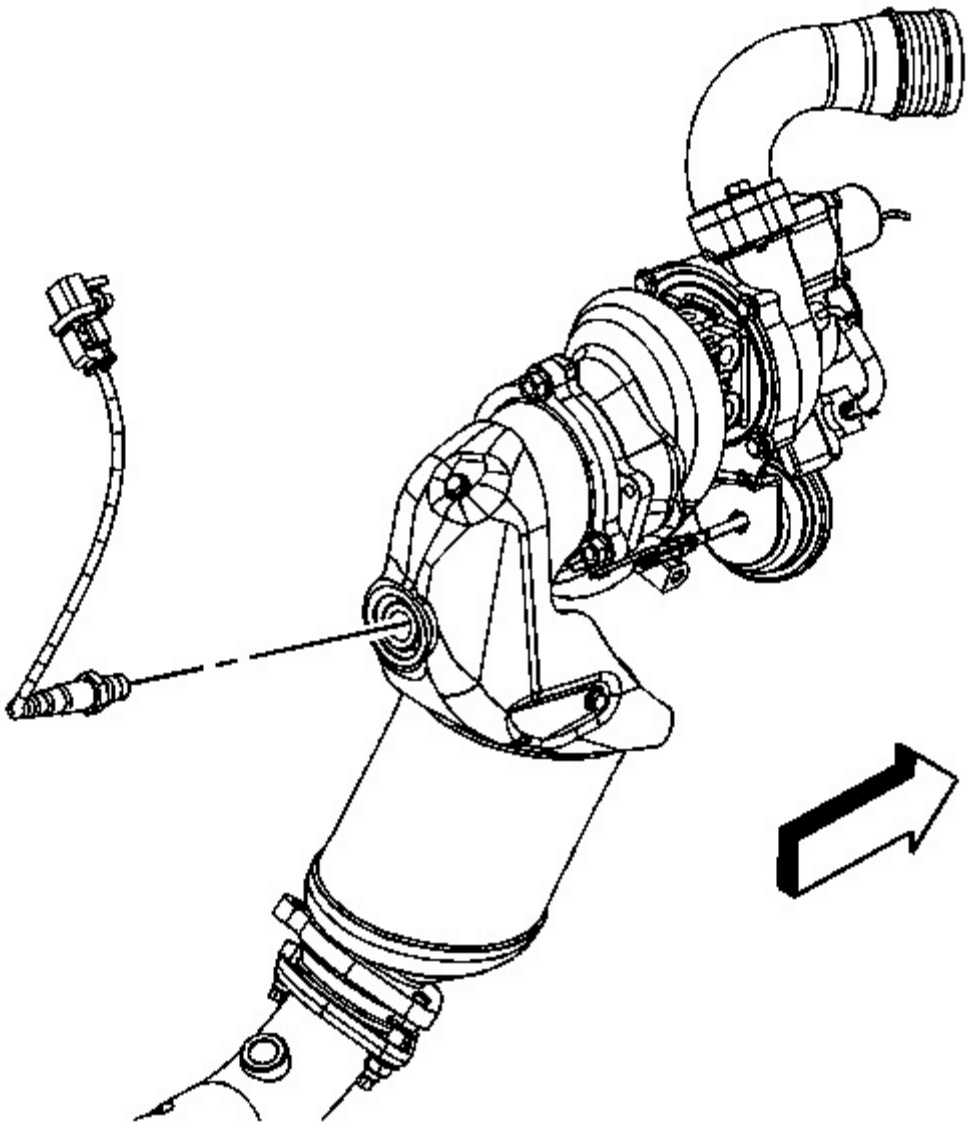


Fig. 27: View Of HO2S 1
Courtesy of GENERAL MOTORS CORP.

5. Using the **J 39194** , remove the position 1 HO2S. See **Special Tools**.

Installation Procedure

IMPORTANT: A special anti-seize compound is used on the HO2S threads. The compound consists of a liquid graphite and glass beads. The graphite will burn away, but the glass beads will remain, making the sensor easier to remove. New or service sensors will have the compound applied to the threads. If a sensor is removed and is to be reinstalled, the threads must have an anti-seize compound applied before installation.

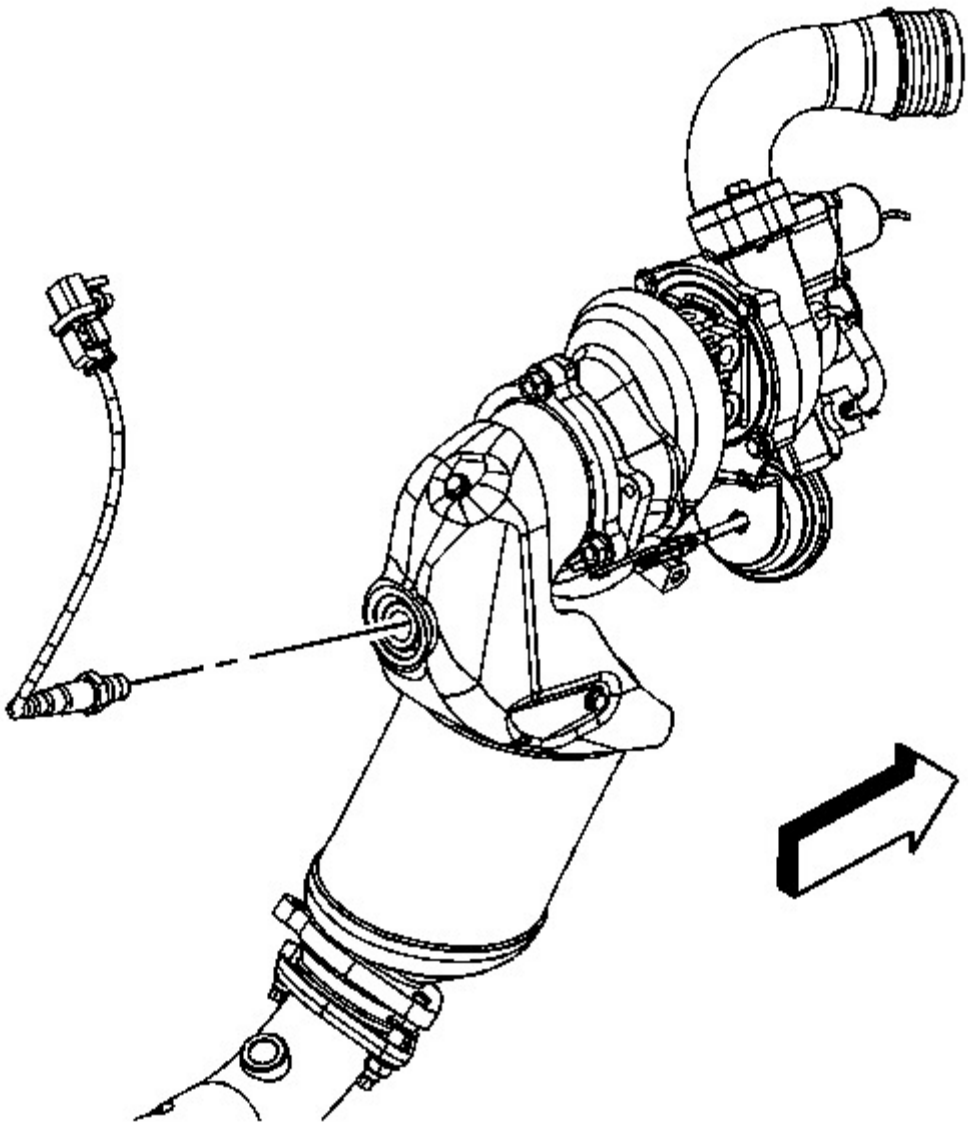


Fig. 28: View Of HO2S 1
Courtesy of GENERAL MOTORS CORP.

NOTE: Refer to Fastener Notice .

1. If reinstalling the old HO2S, coat the threads with anti-seize compound GM

P/N 12377953 or equivalent.

2. Using the **J 39194** , install the position 1 HO2S. See **Special Tools**.

   Tighten: Tighten the sensor to 42 N.m (31 lb ft).

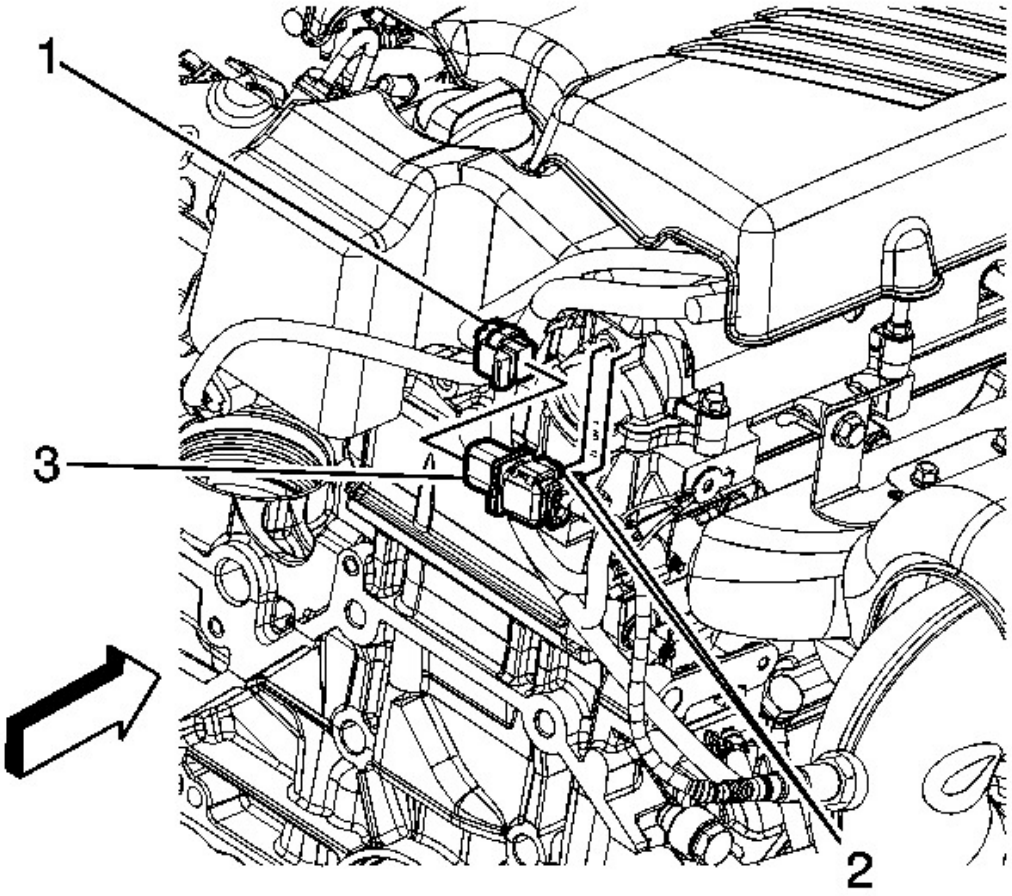


Fig. 29: CPA Retainer & HO2S 1 Connector Clip
Courtesy of GENERAL MOTORS CORP.

3. Connect the engine wiring harness electrical connector (1) to the HO2S electrical connector (3).
4. Install the HO2S electrical connector clip (2) to the camshaft cover.
5. Install the CPA retainer.

6. Close the hood.

HEATED OXYGEN SENSOR 2 REPLACEMENT

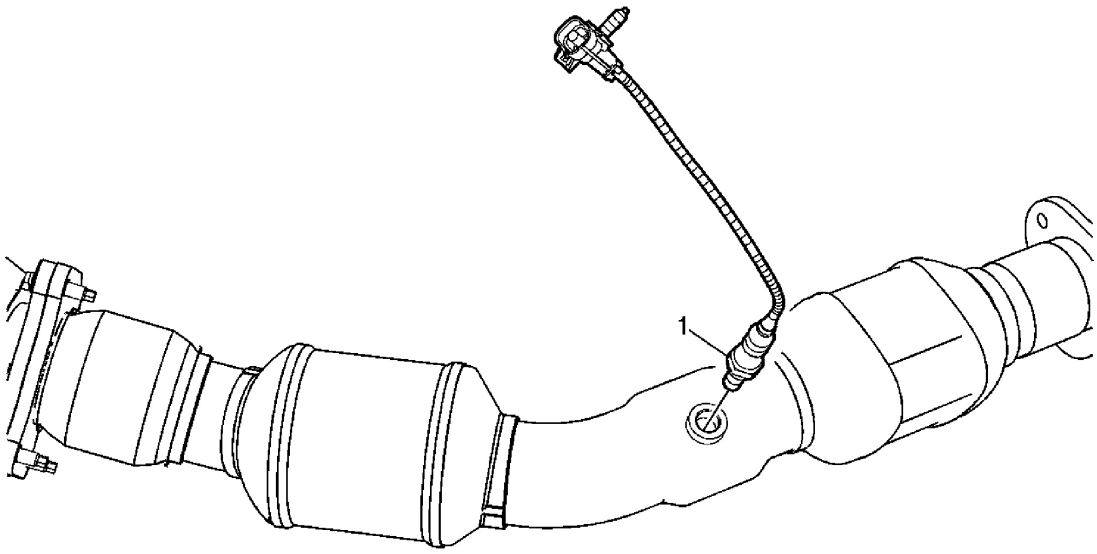


Fig. 30: Heated Oxygen Sensor
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
Preliminary Procedure: Raise and support the vehicle. Refer to **Lifting and Jacking the Vehicle** .	
	Heated Oxygen Sensor **NOTE:** **The oxygen sensor uses a permanently attached pigtail and connector. Do not remove the pigtail from the oxygen sensor. Damage to or removal of the pigtail connector could affect proper operation of the oxygen sensor.** **NOTE:** **The use of excessive force may damage the threads in the exhaust manifold/pipe.** **NOTE:** **Refer to Heated Oxygen Sensor Resistance Learn Reset Notice .** **NOTE:** **Refer to Fastener Notice .**

1	**Procedure:** Disconnect the electrical connector. **Tip:** • The in-line connector and louvered end must be kept clear of grease, dirt or other contaminants. Avoid using cleaning solvents of any type. DO NOT drop or roughly handle the heated oxygen sensor (HO2S). • The HO2S may be difficult to remove when the engine temperature is less than 48°C (120°F). • A special anti-seize compound is used on the HO2S threads. The compound consists of a liquid graphite and glass beads. The graphite will burn away, but the glass beads will remain, making the sensor easier to remove. New or service sensors will have the compound applied to the threads. If a sensor is removed and is to be reinstalled, the threads must have an anti-seize compound applied before installation. **Tighten:** 42 N.m (31 lb ft) **Special Tools:** **J 39194** Oxygen Sensor Wrench. See **Special Tools**.

ACCELERATOR PEDAL POSITION SENSOR REPLACEMENT

Removal Procedure

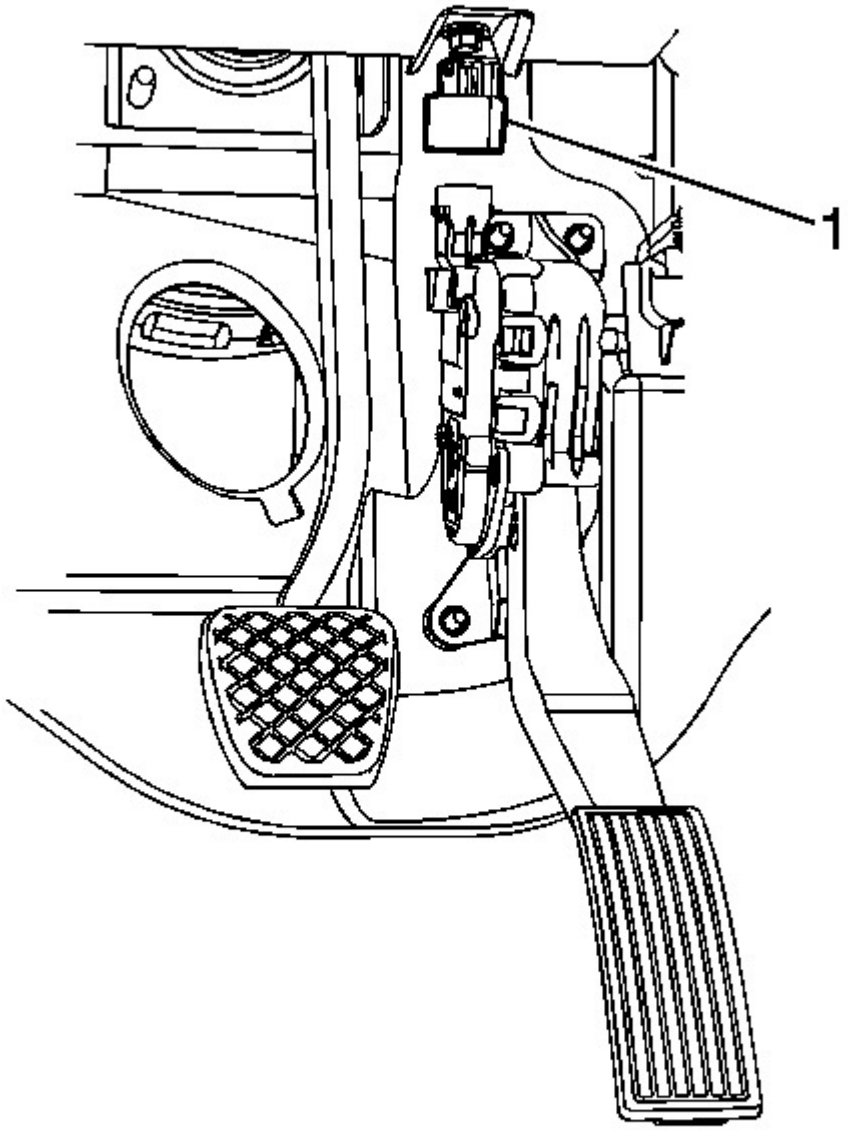


Fig. 31: APP Sensor Electrical Connector
Courtesy of GENERAL MOTORS CORP.

1. Remove the insulator panel. **Instrument Panel Insulator Replacement** .
2. Disconnect the accelerator pedal position (APP) sensor electrical connector (1).

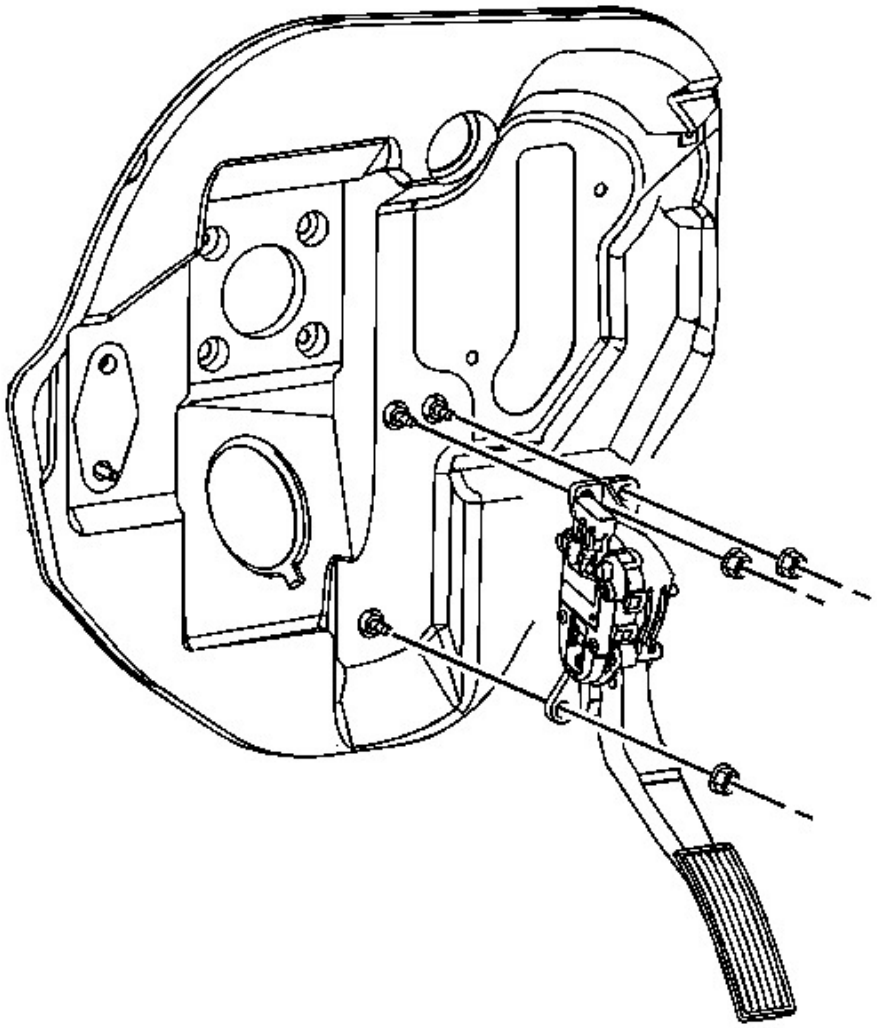


Fig. 32: Identifying APP Sensor
Courtesy of GENERAL MOTORS CORP.

3. Remove the APP sensor nuts.
4. Remove the APP sensor.

Installation Procedure

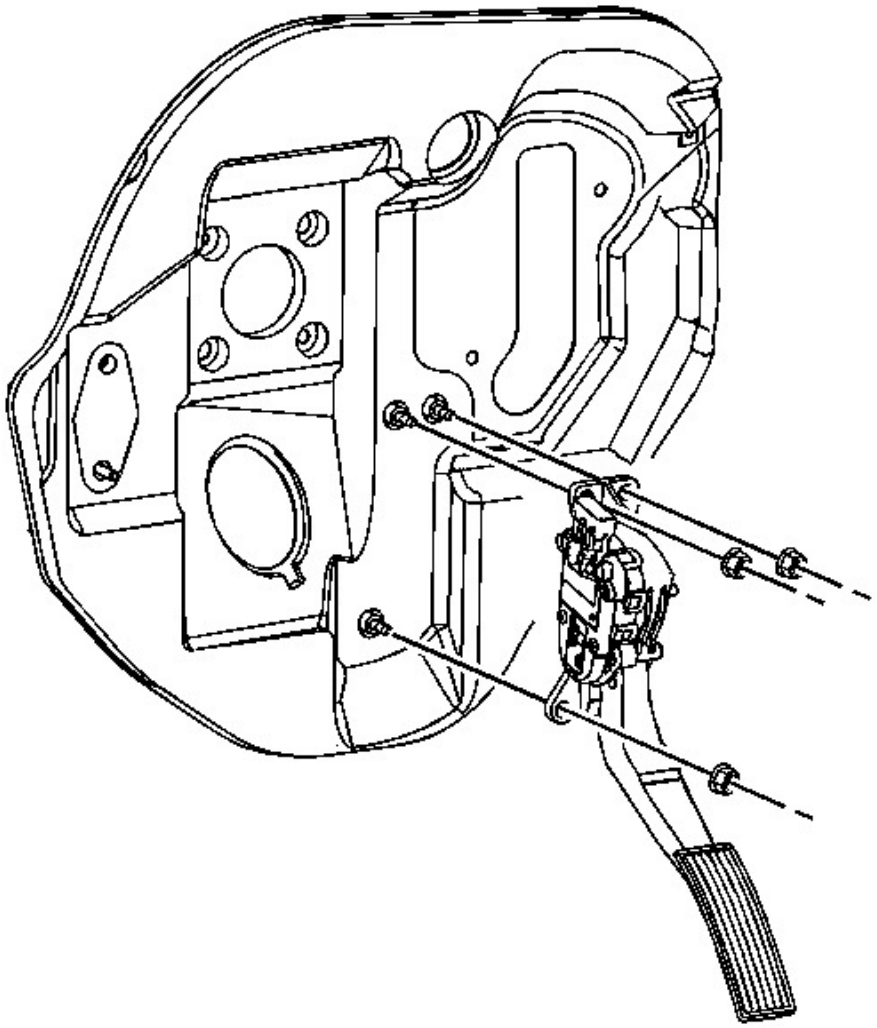


Fig. 33: Identifying APP Sensor
Courtesy of GENERAL MOTORS CORP.

1. Install the APP sensor.

   NOTE: Refer to Fastener Notice .

2. Install the APP sensor nuts.

   Tighten: Tighten the nuts to 10 N.m (89 lb in).

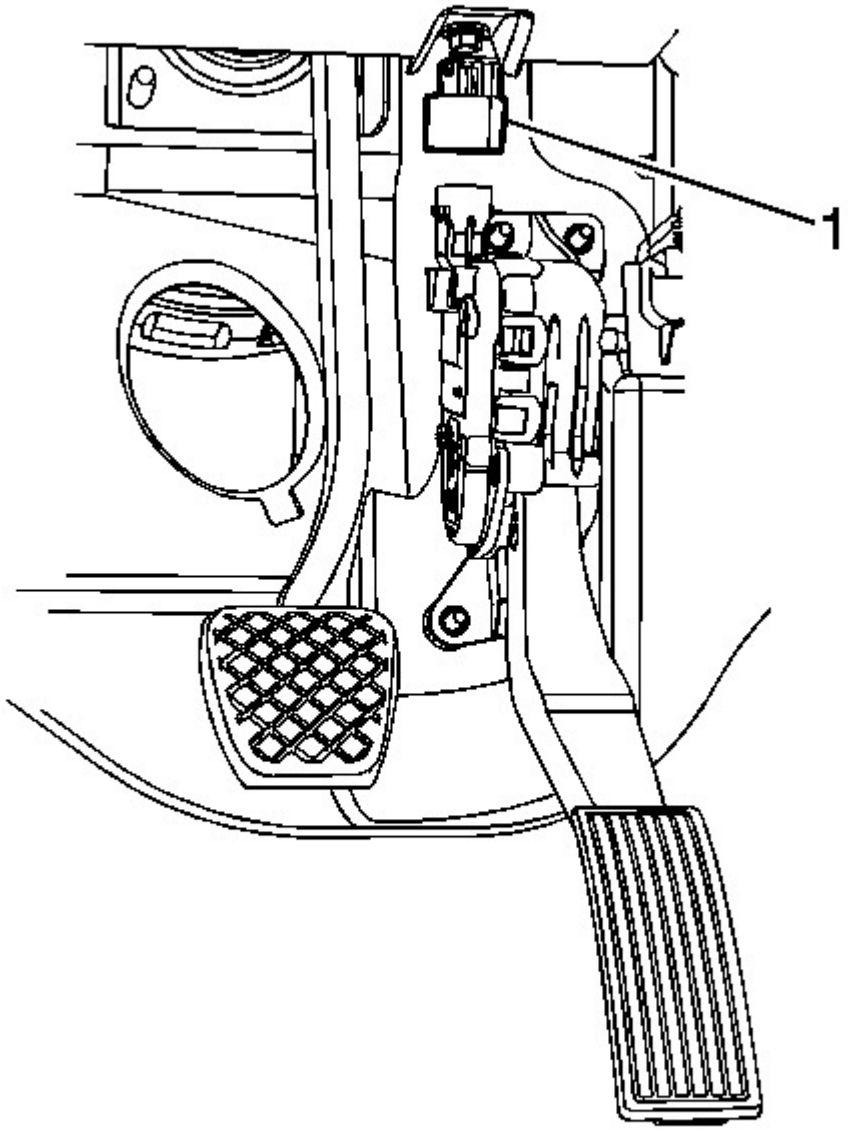


Fig. 34: APP Sensor Electrical Connector
Courtesy of GENERAL MOTORS CORP.

3. Connect the APP sensor electrical connector (1).
4. Install the insulator panel. **Instrument Panel Insulator Replacement** .

THROTTLE BODY ASSEMBLY REPLACEMENT

Removal Procedure

NOTE: Do not use solvent of any type when cleaning the gasket surfaces on the intake manifold and the throttle body assembly, as damage to the gasket surfaces and throttle body assembly may result.
Use care in cleaning the gasket surfaces on the intake manifold and the throttle body assembly, as sharp tools may damage the gasket surfaces.

NOTE: Do not use any solvent that contains Methyl Ethyl Ketone (MEK). This solvent may damage fuel system components.

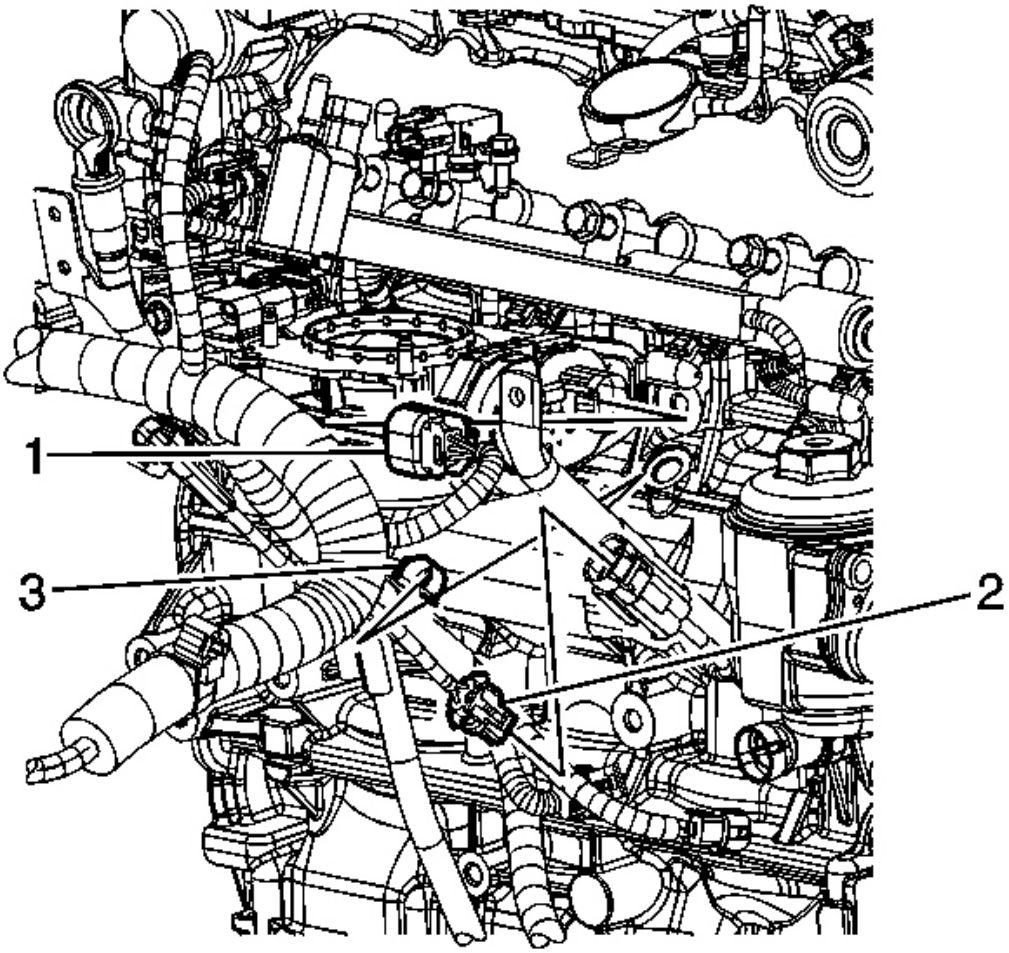


Fig. 35: ETC Connector
Courtesy of GENERAL MOTORS CORP.

1. Remove the charge air cooler outlet pipe. Refer to **Charge Air Cooler Outlet Pipe Replacement**.
2. Disconnect the engine wiring harness electrical connector (1) from the electronic throttle control (ETC).

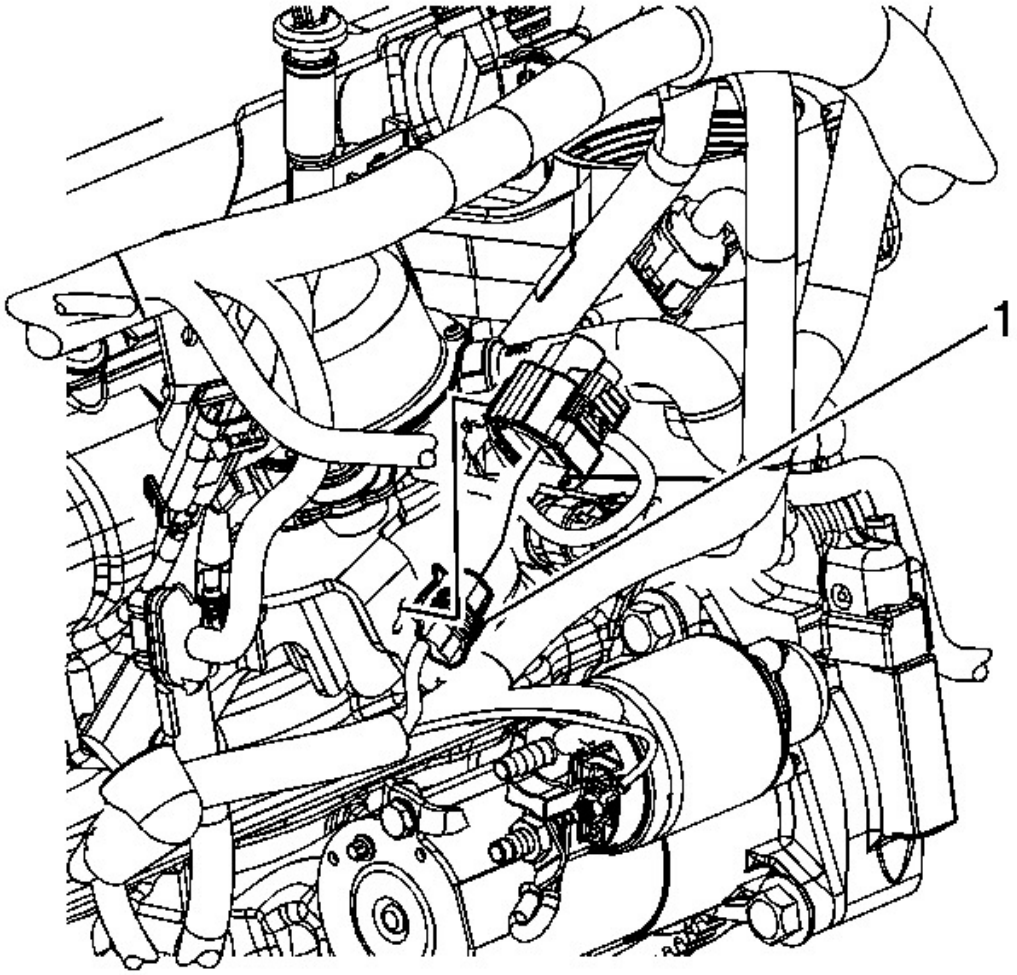


Fig. 36: Brake Booster Auxiliary Pump Connector
Courtesy of GENERAL MOTORS CORP.

3. Disconnect the engine wiring harness electrical connector (1) from the brake booster auxiliary pump.
4. Remove the brake booster auxiliary pump electrical connector clip from the bracket.

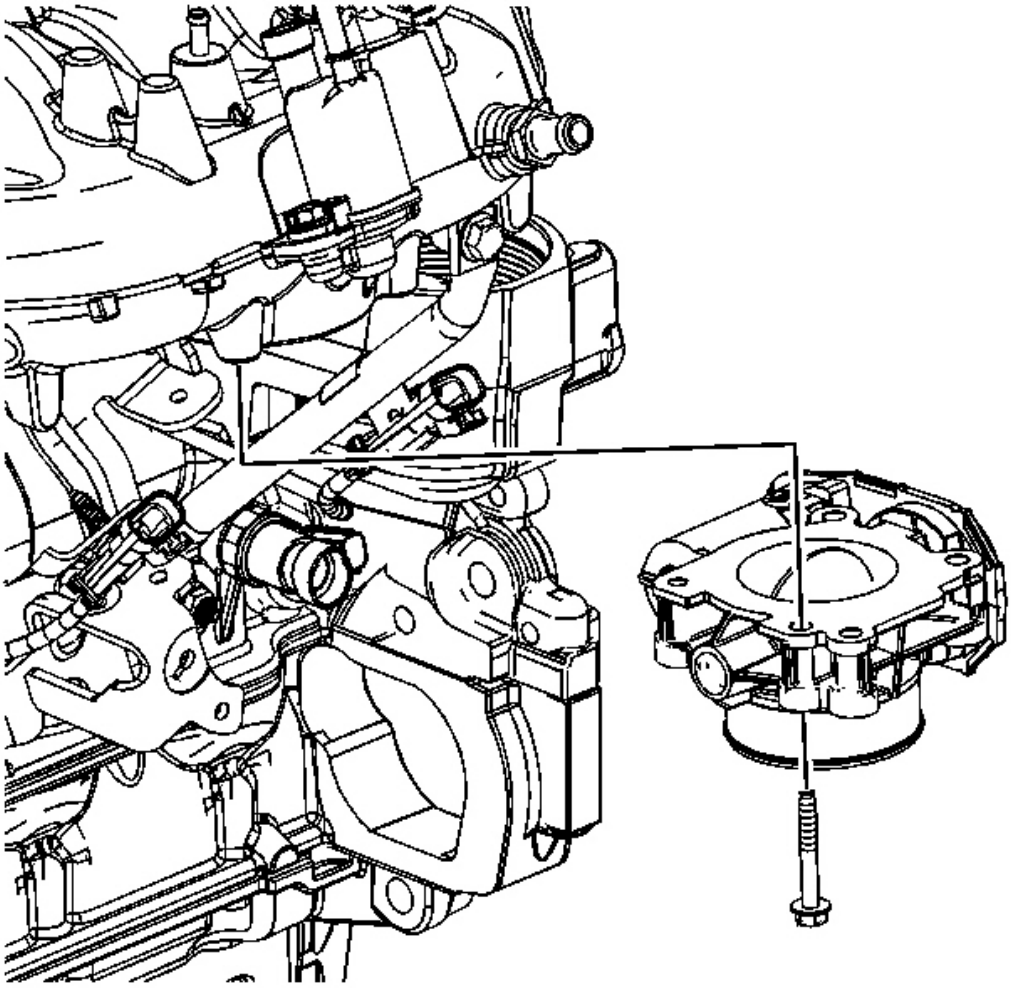


Fig. 37: Throttle Body & Bolts
Courtesy of GENERAL MOTORS CORP.

5. Remove the throttle body bolts.
6. Remove the throttle body and seal from the intake manifold.

Installation Procedure

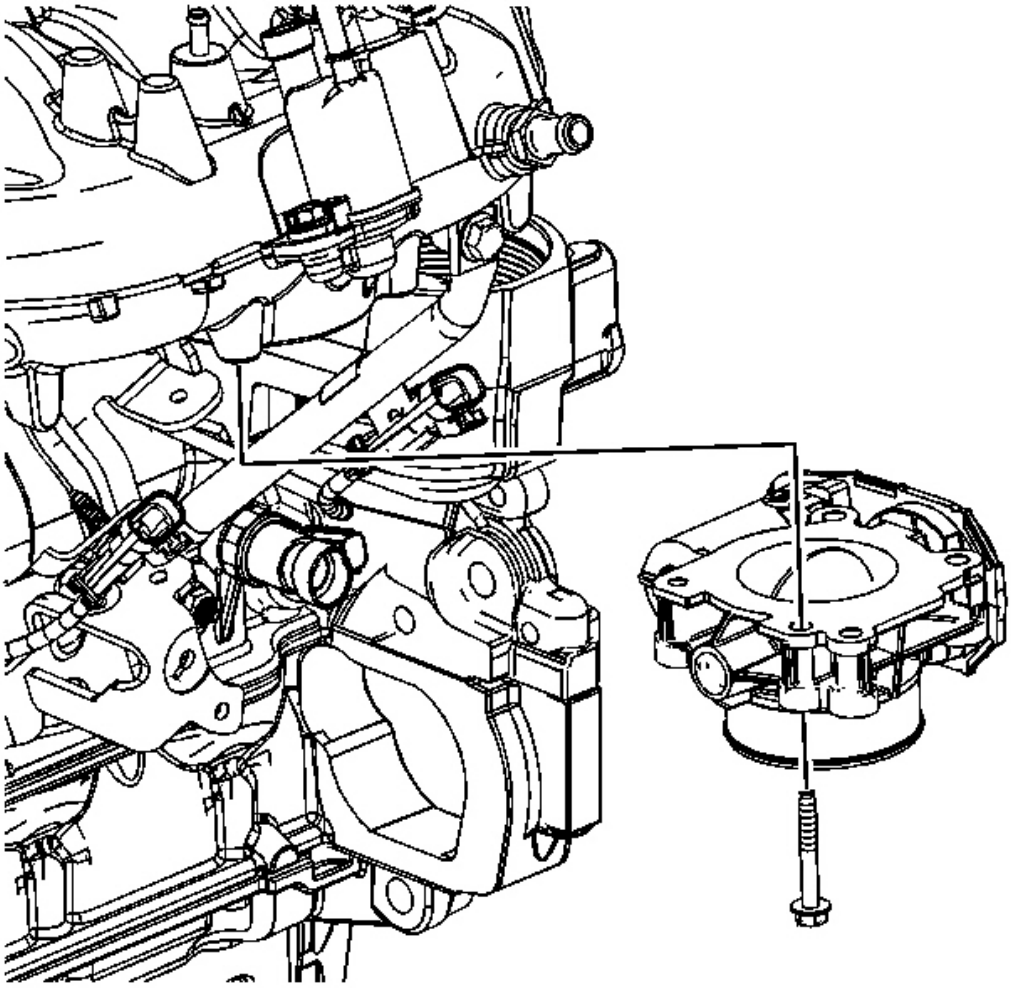


Fig. 38: Throttle Body & Bolts
Courtesy of GENERAL MOTORS CORP.

1. Inspect the throttle body seal, and replace if necessary.
2. Position the throttle body to the intake manifold.

NOTE: Refer to Fastener Notice .

3. Install the throttle body bolts.

Tighten: Tighten the bolts to 10 N.m (89 lb in).

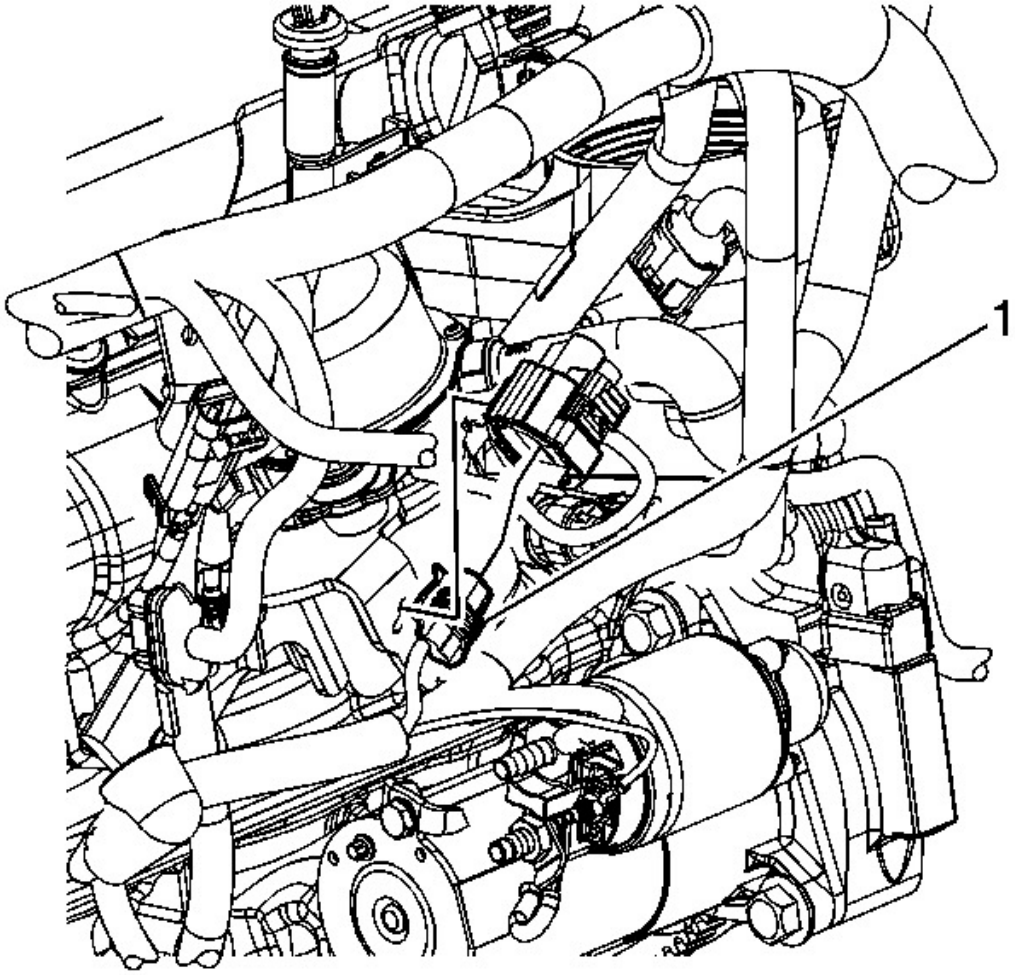


Fig. 39: Brake Booster Auxiliary Pump Connector
Courtesy of GENERAL MOTORS CORP.

4. Connect the engine wiring harness electrical connector (1) to the brake booster auxiliary pump.
5. Install the brake booster auxiliary pump electrical connector clip to the bracket.

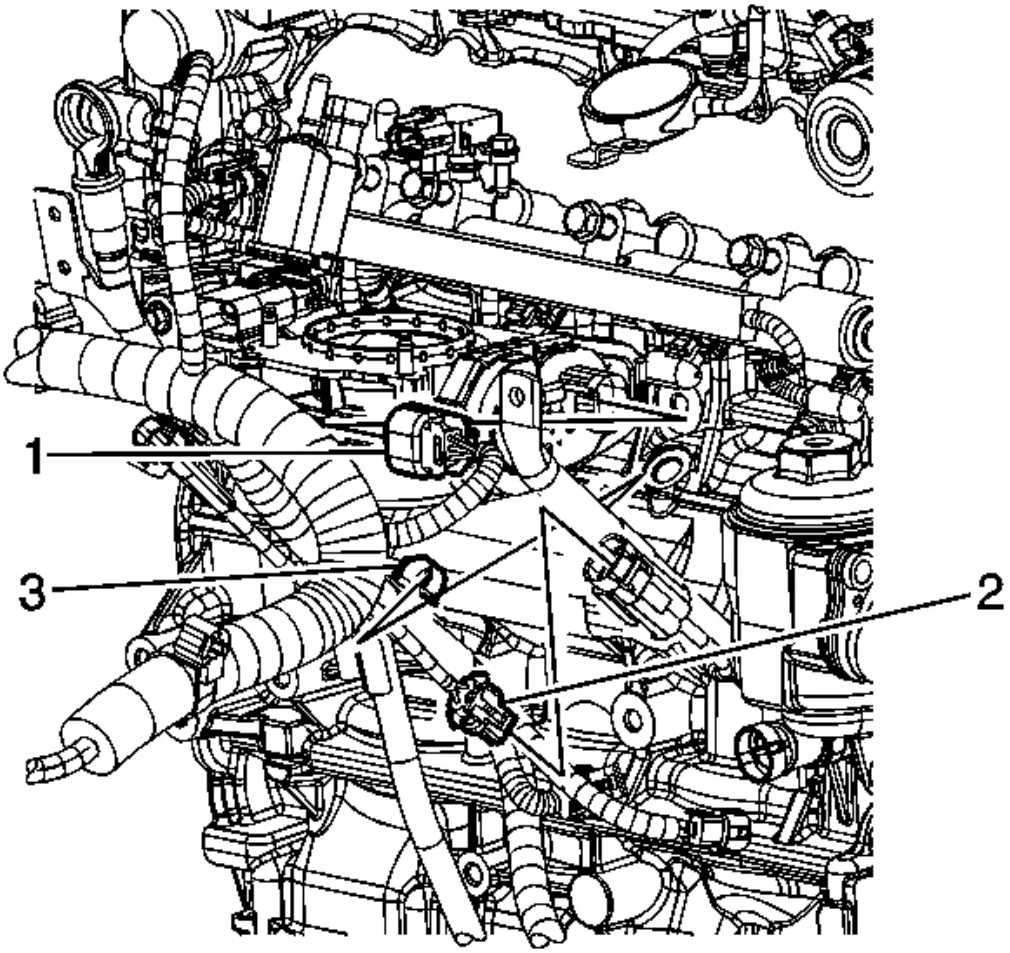


Fig. 40: ETC Connector
Courtesy of GENERAL MOTORS CORP.

6. Connect the engine wiring harness electrical connector (1) to the ETC.
7. Install the charge air cooler outlet pipe. Refer to **Charge Air Cooler Outlet Pipe Replacement**.

THROTTLE BODY CLEANING

NOTE: Do not insert any tools into the throttle body bore in order to avoid damage to the throttle valve plate.

NOTE: Do not use any solvent that contains Methyl Ethyl Ketone (MEK). This solvent may damage fuel system components.

1. Remove the throttle body. Refer to **Throttle Body Assembly Replacement**.
2. Inspect the throttle body bore and the throttle valve plate for deposits. You must open the throttle valve in order to inspect all of the surfaces.
3. Clean the throttle body bore and the throttle valve plate using a clean shop towel with GM Top Engine Cleaner P/N 1052626 (Canadian P/N 993026) or AC-Delco Carburetor Tune-up Conditioner P/N X66-P, or an equivalent product.
4. Install the throttle body. Refer to **Throttle Body Assembly Replacement**.

FUEL PRESSURE RELIEF (WITHOUT CH 48027)

CAUTION: Refer to Gasoline/Gasoline Vapors Caution .

CAUTION: Remove the fuel tank cap and relieve the fuel system pressure before servicing the fuel system in order to reduce the risk of personal injury. After you relieve the fuel system pressure, a small amount of fuel may be released when servicing the fuel lines, the fuel injection pump, or the connections. In order to reduce the risk of personal injury, cover the fuel system components with a shop towel before disconnection. This will catch any fuel that may leak out. Place the towel in an approved container when the disconnection is complete.

1. If the fuel system requires repair, prevent fuel spillage by removing the fuel pump fuse. Refer to **Electrical Center Identification Views** .
2. Loosen the fuel fill cap in order to relieve the fuel tank vapor pressure.
3. Remove the engine cover, if required.
4. Remove the fuel rail service port cap.
5. Wrap a shop towel around the fuel rail service port and using a small flat-

bladed tool, depress (open) the fuel rail test port valve.

6. Remove the shop towel from around the fuel rail service port, and place in an approved gasoline container.
7. Install the fuel rail service port cap.
8. Install the engine cover, if required.
9. Tighten the fuel fill cap.

FUEL PRESSURE RELIEF (WITH CH 48027)

Special Tools

CH-48027 Digital Pressure Gage. See **Special Tools**.

CAUTION: Refer to Gasoline/Gasoline Vapors Caution .

CAUTION: Remove the fuel tank cap and relieve the fuel system pressure before servicing the fuel system in order to reduce the risk of personal injury. After you relieve the fuel system pressure, a small amount of fuel may be released when servicing the fuel lines, the fuel injection pump, or the connections. In order to reduce the risk of personal injury, cover the fuel system components with a shop towel before disconnection. This will catch any fuel that may leak out. Place the towel in an approved container when the disconnection is complete.

1. If the fuel system requires repair, prevent fuel spillage by removing the fuel pump fuse. Refer to **Electrical Center Identification Views** .

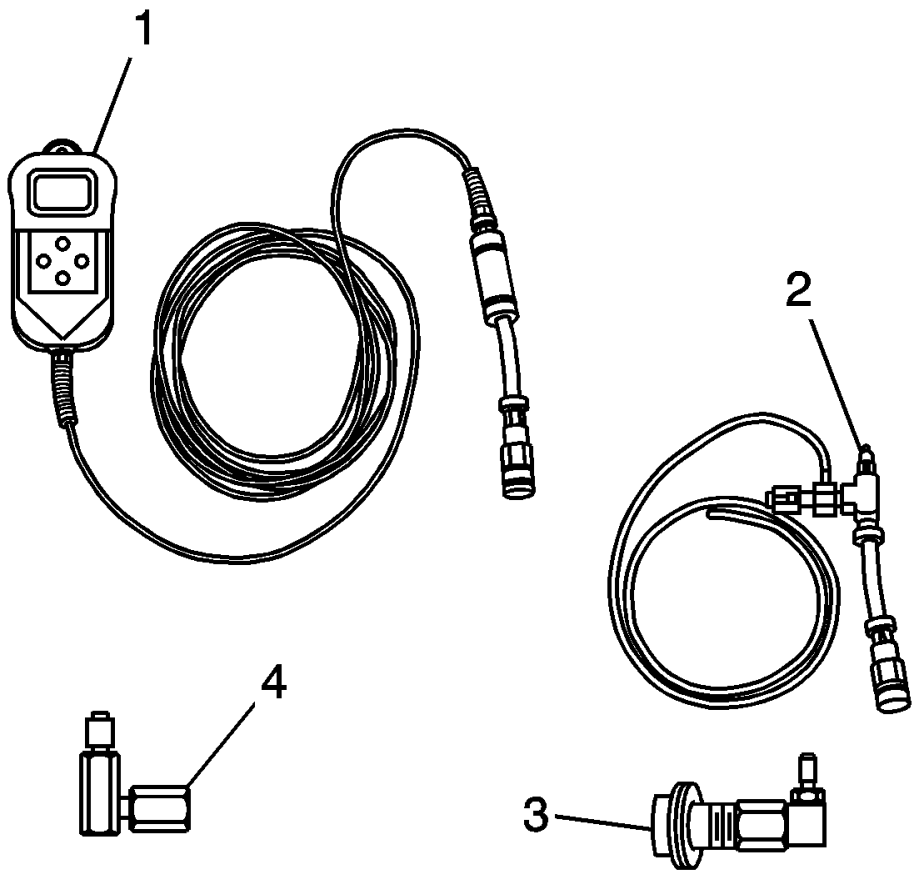


Fig. 41: View Of Digital Pressure Gauge, Special Tools & Components
Courtesy of GENERAL MOTORS CORP.

2. Remove the engine cover, if required.
3. Loosen the fuel fill cap in order to relieve the fuel tank vapor pressure.
4. Remove the fuel rail service port cap.

CAUTION: Wrap a shop towel around the fuel pressure connection in order to reduce the risk of fire and personal injury. The towel will absorb any fuel leakage that occurs during the connection of the fuel pressure gage. Place the towel in an approved container when the connection of the fuel pressure gage is complete.

5. Wrap a shop towel around the fuel rail service port.
6. Connect the CH-48027-3 (4) to the fuel rail service port.
7. Connect the CH-48027-2 (2) to the CH-48027-3 (4).
8. Place the hose on the CH-48027-2 (2) into an approved gasoline container.
9. Open the valve on the CH-48027-2 (2) in order to bleed any fuel from the fuel rail.
10. Close the valve on the CH-48027-2 (2).
11. Remove the hose on the CH-48027-2 (2) from the approved gasoline container.

NOTE: Clean all of the following areas before performing any disconnections in order to avoid possible contamination in the system:

- **The fuel pipe connections**
- **The hose connections**
- **The areas surrounding the connections**

IMPORTANT: If relieving the fuel pressure for the fuel pressure gage installation and removal, it is NOT necessary to proceed with the following steps.

12. Disconnect the CH-48027-2 (2) from the CH-48027-3 (4).
13. Disconnect the CH-48027-3 (4) from the fuel rail service port.
14. Remove the shop towel from around the fuel rail service port, and place in an approved gasoline container.
15. Install the fuel rail service port cap.
16. Install the engine cover, if required.
17. Tighten the fuel fill cap.

FUEL PRESSURE GAGE INSTALLATION AND REMOVAL (WITH CH 48027)

Special Tools

CH-48027 Digital Pressure Gage. See **Special Tools**.

Installation Procedure

CAUTION: Refer to Gasoline/Gasoline Vapors Caution .

CAUTION: Remove the fuel tank cap and relieve the fuel system pressure before servicing the fuel system in order to reduce the risk of personal injury. After you relieve the fuel system pressure, a small amount of fuel may be released when servicing the fuel lines, the fuel injection pump, or the connections. In order to reduce the risk of personal injury, cover the fuel system components with a shop towel before disconnection. This will catch any fuel that may leak out. Place the towel in an approved container when the disconnection is complete.

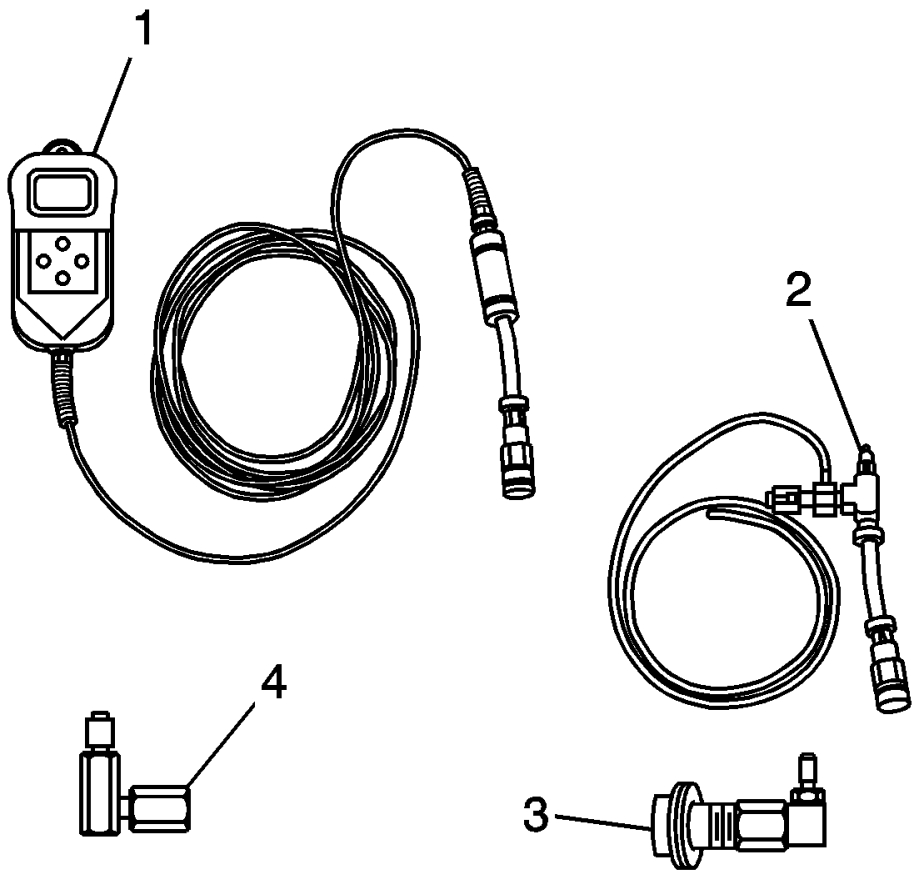


Fig. 42: View Of Digital Pressure Gauge, Special Tools & Components
Courtesy of GENERAL MOTORS CORP.

1. Relieve the fuel system pressure. Refer to **Fuel Pressure Relief (Without CH 48027)** or **Fuel Pressure Relief (With CH 48027)**.
2. Connect the CH-48027-1 (1) to the CH-48027-2 (2).
3. Remove the shop towel from around the fuel rail service port, and place in an approved gasoline container.
4. Perform any tests and/or diagnostics as needed. For the proper usage of the **CH-48027** , refer to the manufacture's directions. See **Special Tools**.

Removal Procedure

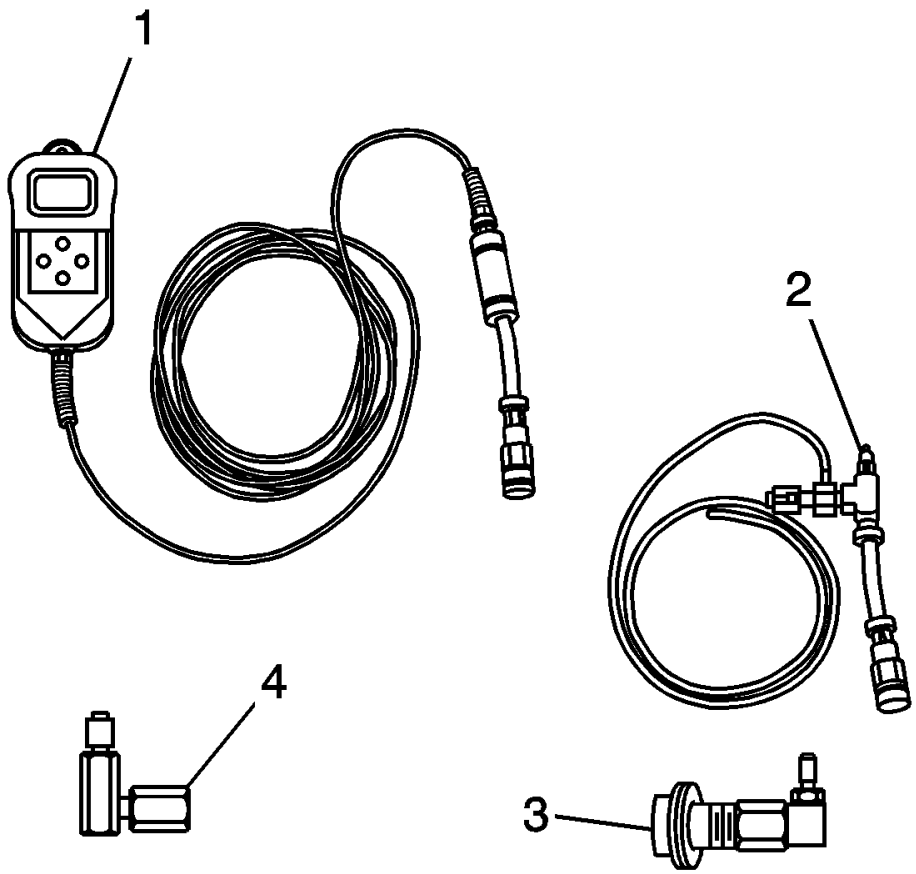


Fig. 43: View Of Digital Pressure Gauge, Special Tools & Components
Courtesy of GENERAL MOTORS CORP.

1. Relieve the fuel system pressure, if required. Perform the following steps:

CAUTION: Wrap a shop towel around the fuel pressure connection in order to reduce the risk of fire and personal injury. The towel will absorb any fuel leakage that occurs during the connection of the fuel pressure gage. Place the towel in an approved container when the connection of the fuel pressure gage is complete.

1. Wrap a shop towel around the fuel rail service port.

2. Place the hose on the CH-48027-2 (2) into an approved gasoline container.
3. Open the valve on the CH-48027-2 (2) in order to bleed any fuel from the fuel rail.
4. Close the valve on the CH-48027-2 (2).
5. Remove the hose on the CH-48027-2 (2) from the approved gasoline container.
6. Remove the shop towel from around the fuel rail service port, and place in an approved gasoline container.

NOTE: Clean all of the following areas before performing any disconnections in order to avoid possible contamination in the system:

- **The fuel pipe connections**
- **The hose connections**
- **The areas surrounding the connections**

2. Disconnect the CH-48027-1 (1) from the CH-48027-2 (2).
3. Disconnect the CH-48027-2 (2) from the CH-48027-3 (4).
4. Disconnect the CH-48027-3 (4) from the fuel rail service port.
5. Install the fuel rail service port cap.
6. Install the engine cover, if required.
7. Tighten the fuel fill cap.

METAL COLLAR QUICK CONNECT FITTING SERVICE

Tool Required

J 37088-A Fuel Line Disconnect Tool Set. See **Special Tools**.

Removal Procedure

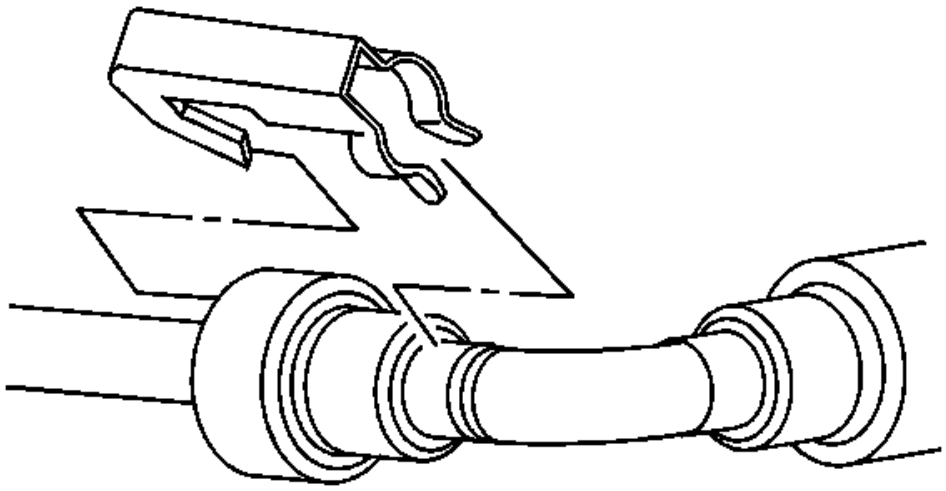


Fig. 44: View Of Quick-Connect Fitting Retainer (Metal Collar)
Courtesy of GENERAL MOTORS CORP.

1. Relieve the low side fuel system pressure. Refer to the **Fuel Pressure Relief (Without CH 48027)** or **Fuel Pressure Relief (With CH 48027)**.
2. Remove the retainer from the quick-connect fitting.

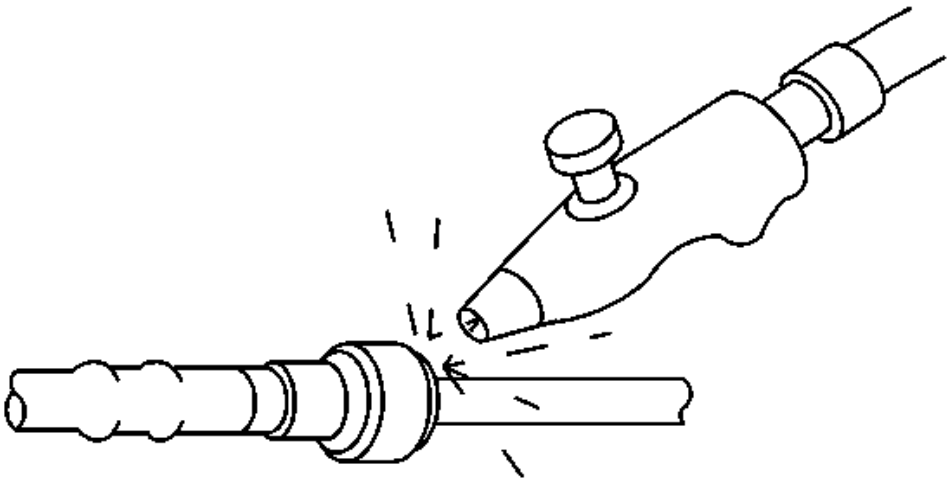


Fig. 45: Blowing Dirt Out Of Fitting (Metal Collar)
Courtesy of GENERAL MOTORS CORP.

CAUTION: Wear safety glasses when using compressed air, as flying dirt particles may cause eye injury.

3. Blow dirt out of the fitting using compressed air.

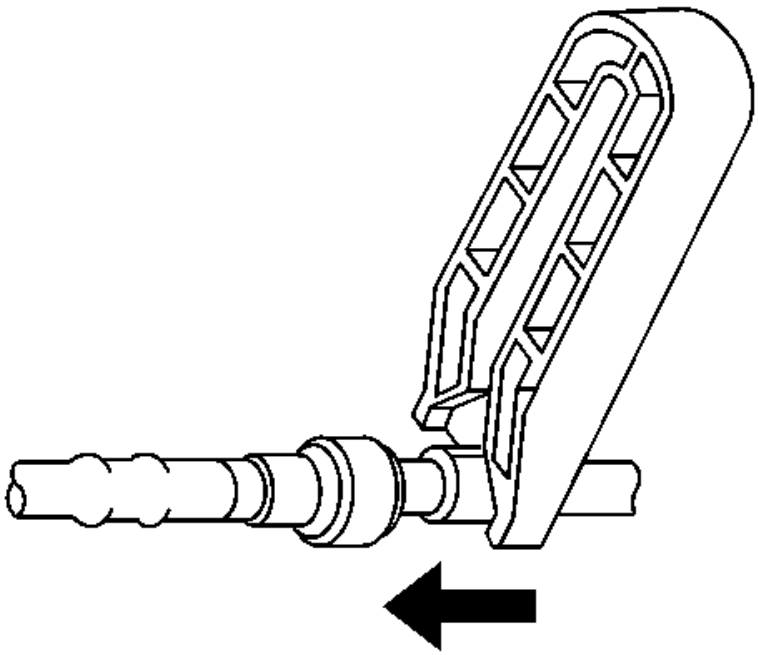


Fig. 46: Releasing Quick Connect Locking Tabs (Metal Collar)
Courtesy of GENERAL MOTORS CORP.

4. Choose the correct tool from the **J 37088-A** for the size of the fitting. See **Special Tools**. Insert the tool into the female connector, then push inward in order to release the locking tabs.

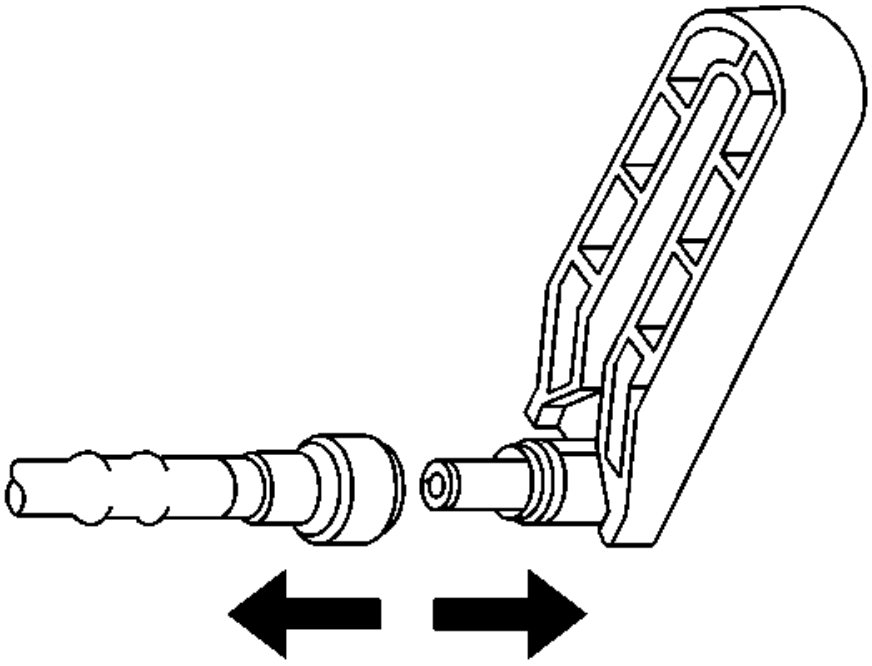


Fig. 47: Releasing Quick Connect Locking Tabs (Metal Collar)
Courtesy of GENERAL MOTORS CORP.

5. Pull the connection apart.

NOTE: If necessary, remove rust or burrs from the fuel pipes with an emery cloth. Use a radial motion with the fuel pipe end in order to prevent damage to the O-ring sealing surface. Use a clean shop towel in order to wipe off the male tube ends. Inspect all the connections for dirt and burrs. Clean or replace the components and assemblies as required.

6. Use a clean shop towel in order to wipe off the male pipe end.

7. Inspect both ends of the fitting for dirt and burrs. Clean or replace the components as required.

Installation Procedure

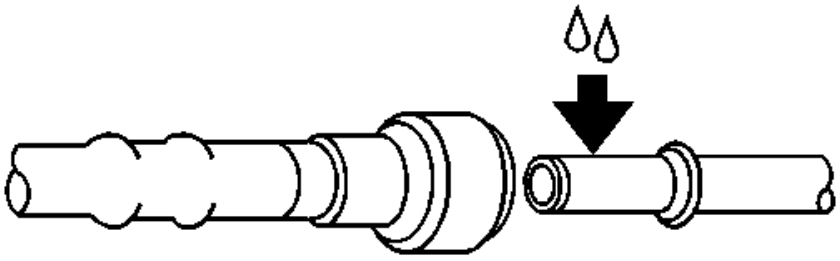


Fig. 48: Oiling Male Pipe Ends (Metal Collar)
Courtesy of GENERAL MOTORS CORP.

CAUTION: In order to reduce the risk of fire and personal injury, before connecting fuel pipe fittings, always apply a few drops of clean engine oil to the male pipe ends.
This will ensure proper reconnection and prevent a possible fuel leak.

During normal operation, the O-rings located in the female connector will swell and may prevent proper reconnection if not lubricated.

1. Apply a few drops of clean engine oil to the male pipe end.

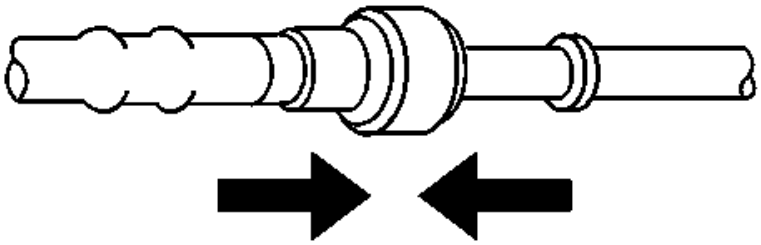


Fig. 49: Assembling Connectors (Metal Collar)
Courtesy of GENERAL MOTORS CORP.

2. Push both sides of the fitting together in order to snap the retaining tabs into place.

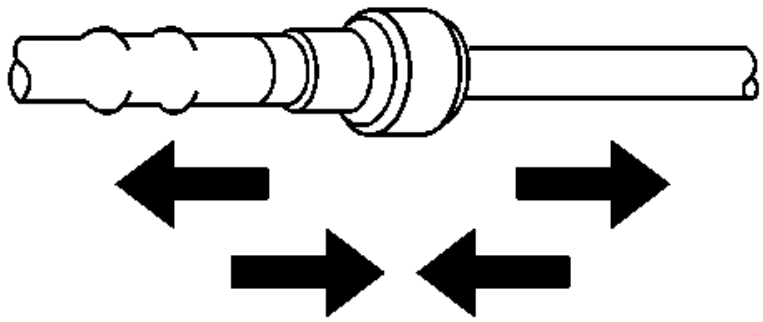


Fig. 50: Ensuring Connection (Metal Collar) Is Secure
Courtesy of GENERAL MOTORS CORP.

3. Once installed, pull on both sides of the fitting in order to make sure the connection is secure.

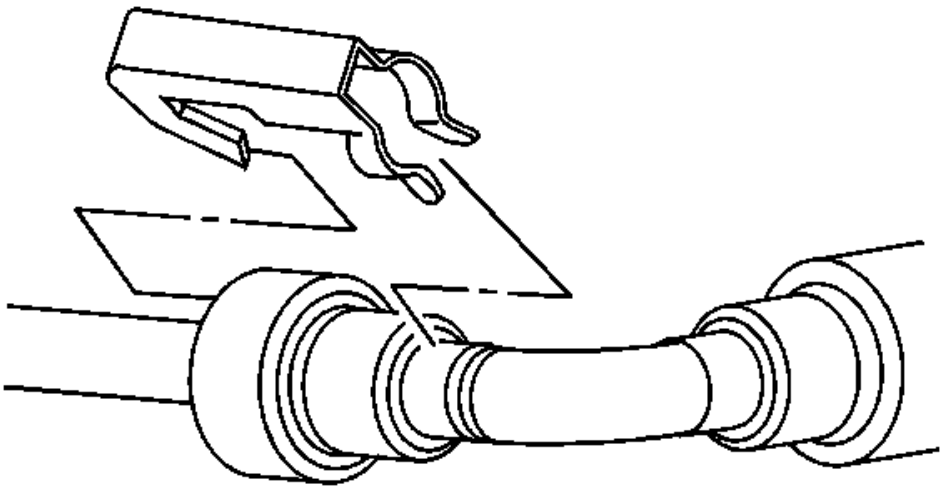


Fig. 51: View Of Quick-Connect Fitting Retainer (Metal Collar)
Courtesy of GENERAL MOTORS CORP.

4. Install the retainer to the quick-connect fitting.

PLASTIC COLLAR QUICK CONNECT FITTING SERVICE

Removal Procedure

CAUTION: Refer to Gasoline/Gasoline Vapors Caution .

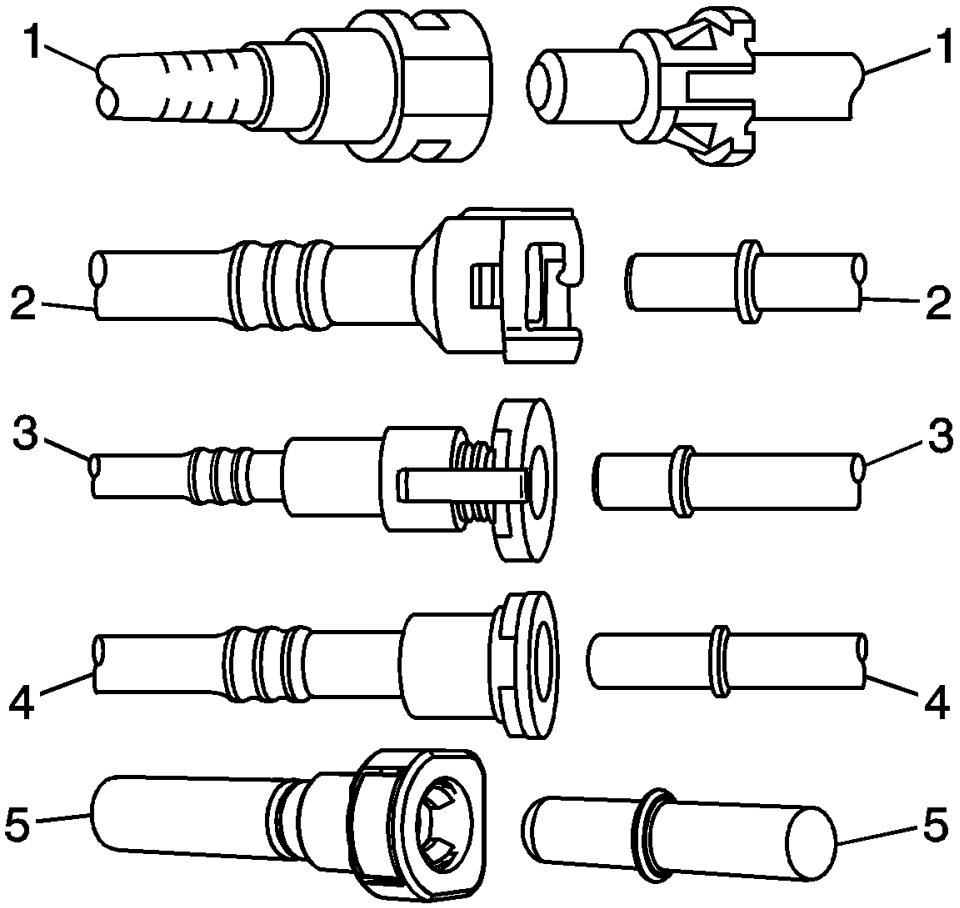


Fig. 52: Identifying Plastic Collar Fuel & Evaporative Emission Quick Connect Fittings
Courtesy of GENERAL MOTORS CORP.

IMPORTANT: There are several types of plastic collar fuel and evaporative emission quick connect fittings that may be used on this vehicle.

- **Bartholomew (1)**
- **Q release (2)**
- **Squeeze to release (3)**
- **Sliding retainer (4)**
- **Push down TI (5)**

The following instructions apply to all of these types of fittings except where indicated.

1. Relieve the fuel system pressure. Refer to **Fuel Pressure Relief (With CH 48027)** or **Fuel Pressure Relief (Without CH 48027)**.

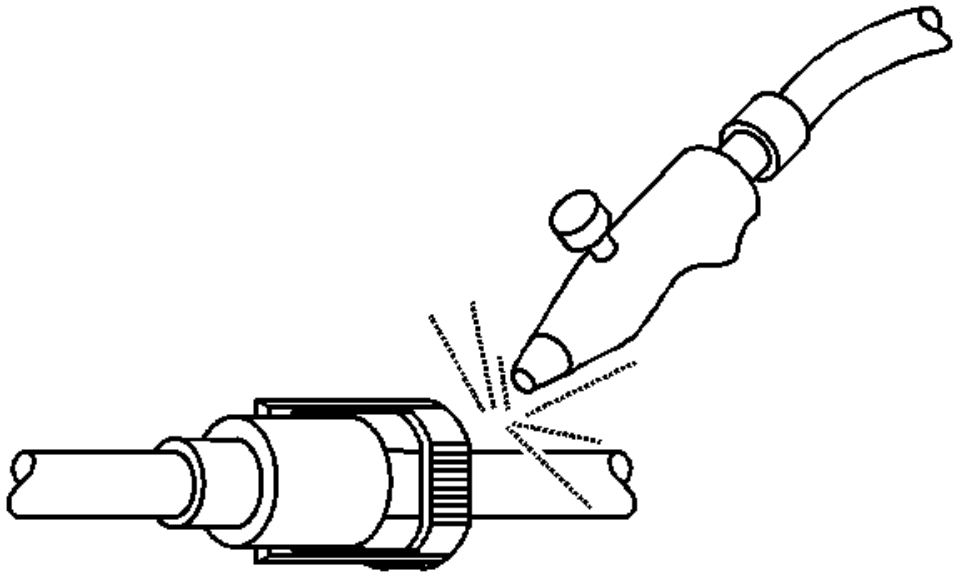


Fig. 53: Blowing Dirt Out Of Fitting (Plastic Collar)
Courtesy of GENERAL MOTORS CORP.

CAUTION: Wear safety glasses when using compressed air, as flying dirt particles may cause eye injury.

2. Using compressed air, blow any dirt out of the quick connect fitting.

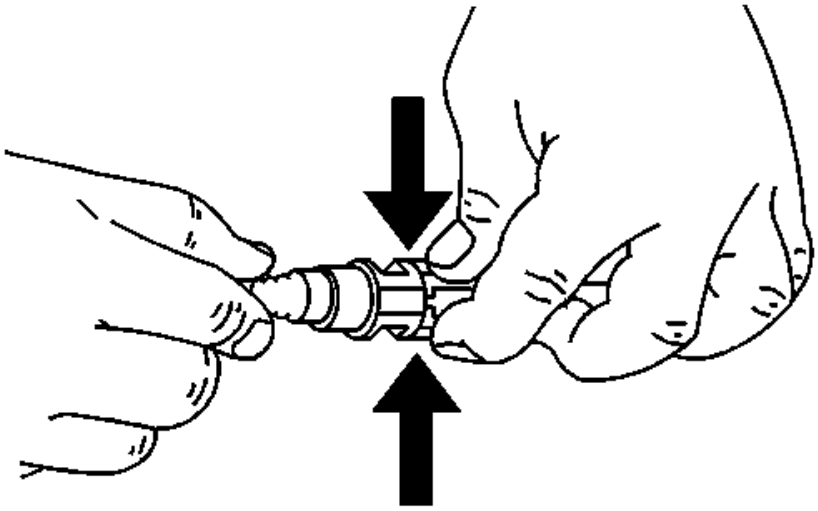


Fig. 54: Squeezing Quick Connect Fitting Release Tabs (Plastic Collar)
Courtesy of GENERAL MOTORS CORP.

3. This step applies to the Bartholomew style connectors ONLY. Squeeze the plastic quick connect fitting release tabs.

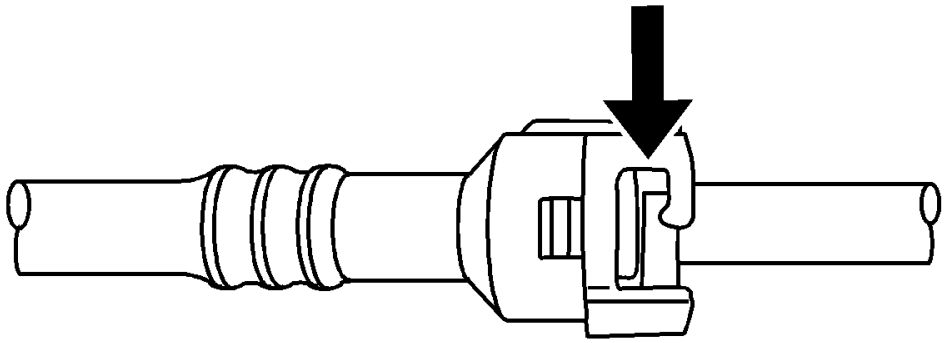


Fig. 55: Releasing Q Release Style Connectors (Plastic Collar)
Courtesy of GENERAL MOTORS CORP.

4. This step applies to the Q release type connectors ONLY. Release the fitting by pushing the tab toward the other side of the slot in the fitting.

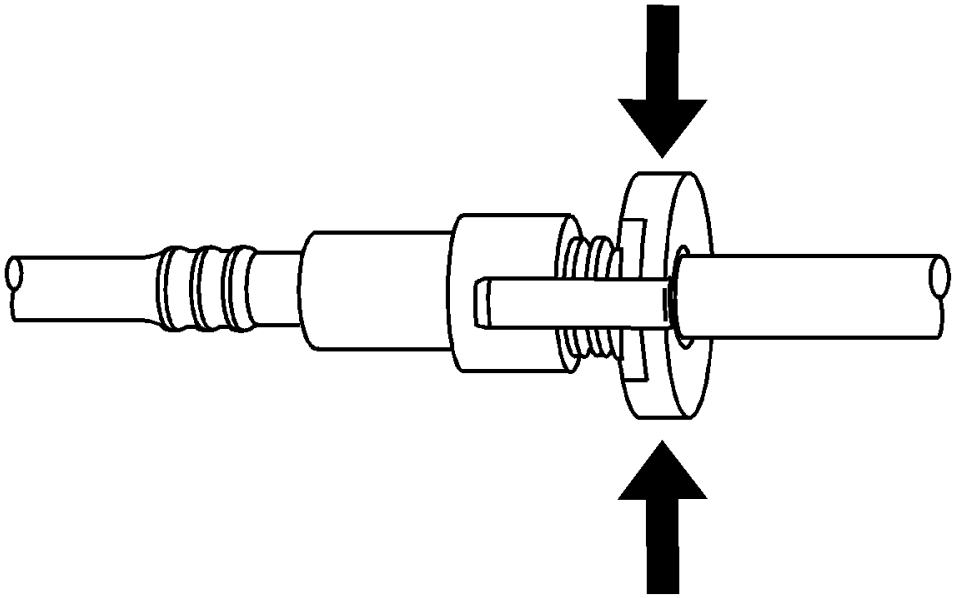


Fig. 56: Disengaging Quick Connect Fitting (Plastic Collar)
Courtesy of GENERAL MOTORS CORP.

5. This step applies to the Squeeze to release style connectors ONLY. Squeeze where indicated by arrows on both sides of the plastic ring surrounding the quick connect fitting.

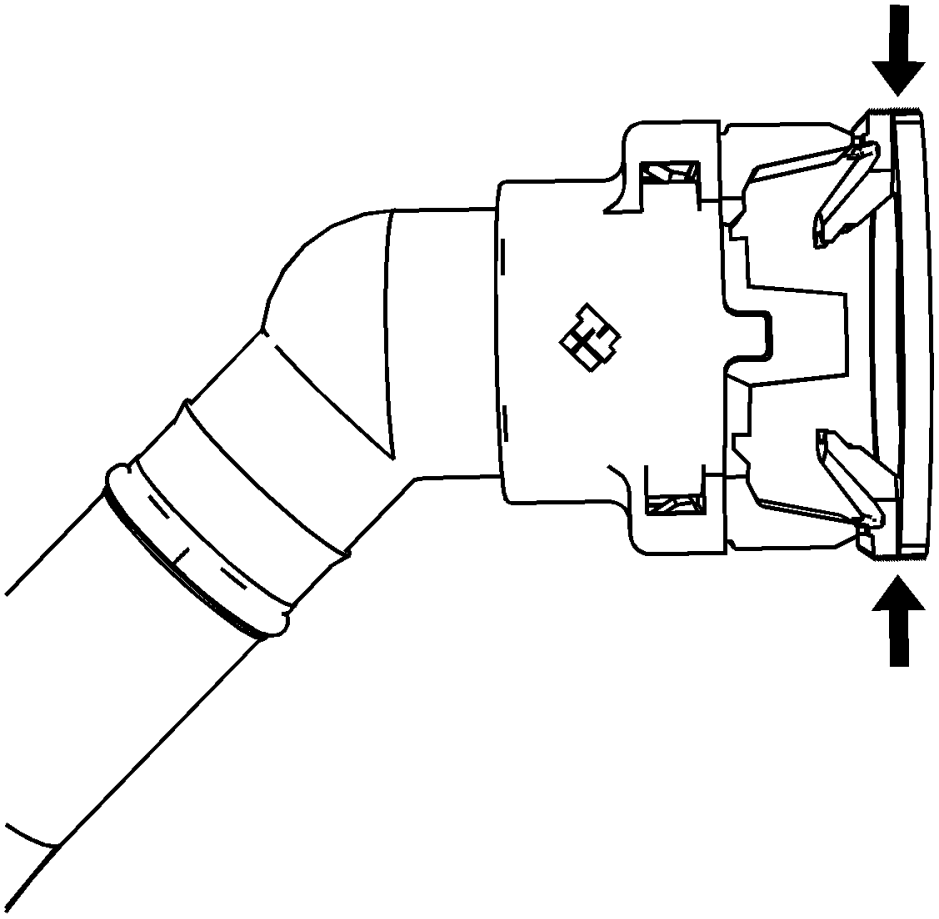


Fig. 57: Disengaging Quick Connect Fitting (Plastic Collar)
Courtesy of GENERAL MOTORS CORP.

6. This step also applies to the Squeeze to release style connectors ONLY. Squeeze where indicated by the arrows on both sides of the plastic ring surrounding the quick connect fitting.

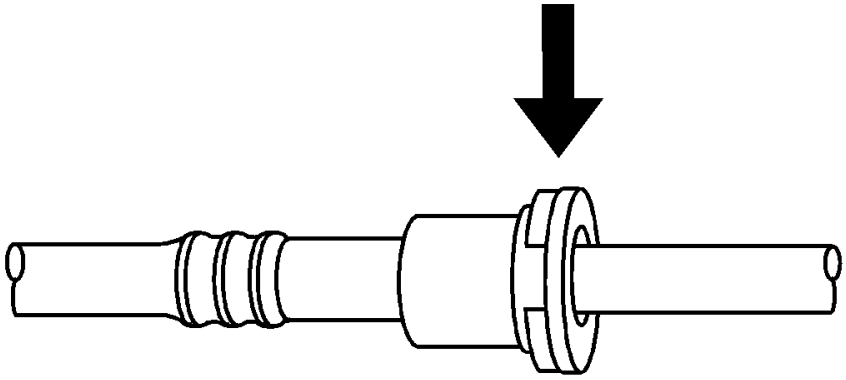


Fig. 58: View Of Sliding Retainer Style Connector
Courtesy of GENERAL MOTORS CORP.

7. This step applies to the Sliding retainer style connectors ONLY. Release the fitting by pressing on one side of the release tab causing it to push in slightly. If the tab does not move, try pressing the tab in from the opposite side. the tab will only move in one direction.

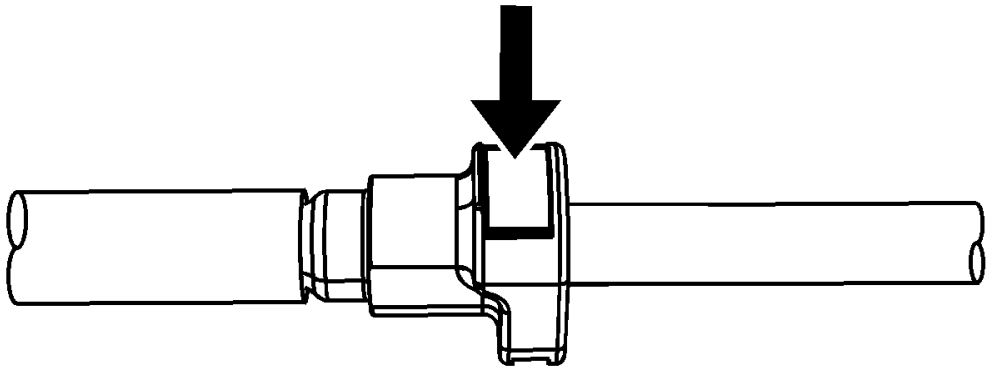


Fig. 59: View Of Push Down TI Style Connector
Courtesy of GENERAL MOTORS CORP.

8. This step applies to the Push down TI style connectors ONLY. Release the fitting by pressing on the tabs indicated by the arrow.

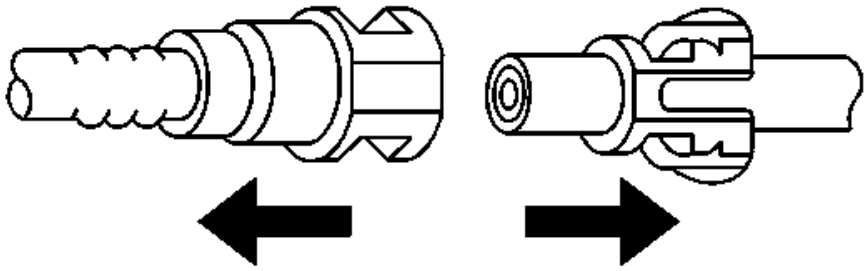


Fig. 60: Pulling Connection Apart (Plastic Collar)
Courtesy of GENERAL MOTORS CORP.

9. Pull the connection apart.
10. Wipe off the male pipe end using a clean shop towel.
11. Inspect both ends of the fitting for dirt and burrs.
12. Clean or replace the components as required.

Installation Procedure

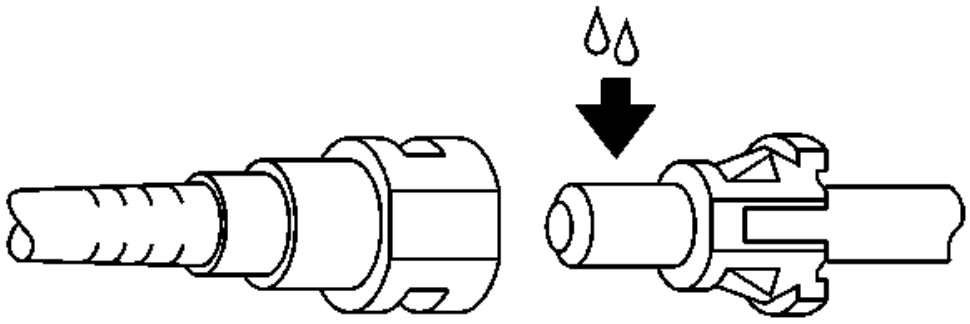


Fig. 61: Lubricating Male Pipe End
Courtesy of GENERAL MOTORS CORP.

1. Apply a few drops of clean engine oil to the male connection end.

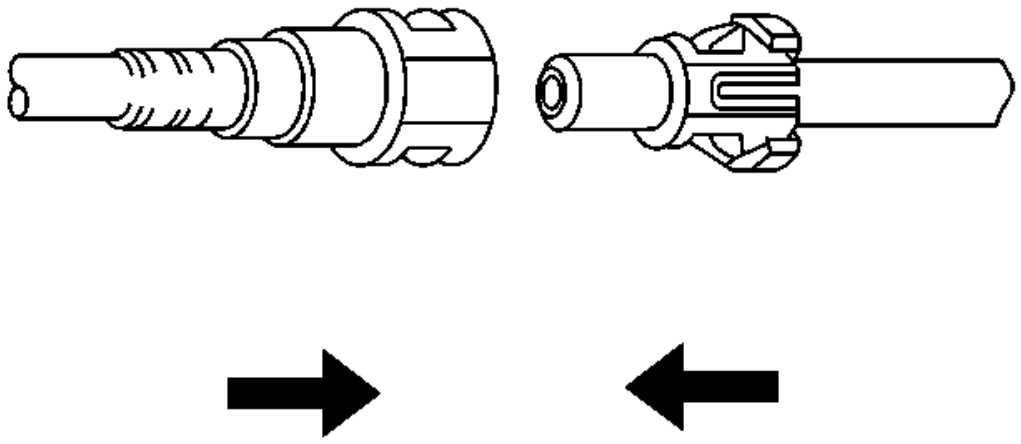


Fig. 62: Connecting Fittings (Plastic Collar)
Courtesy of GENERAL MOTORS CORP.

2. Push both sides of the quick connect fitting together in order to cause the retaining feature to snap into place.

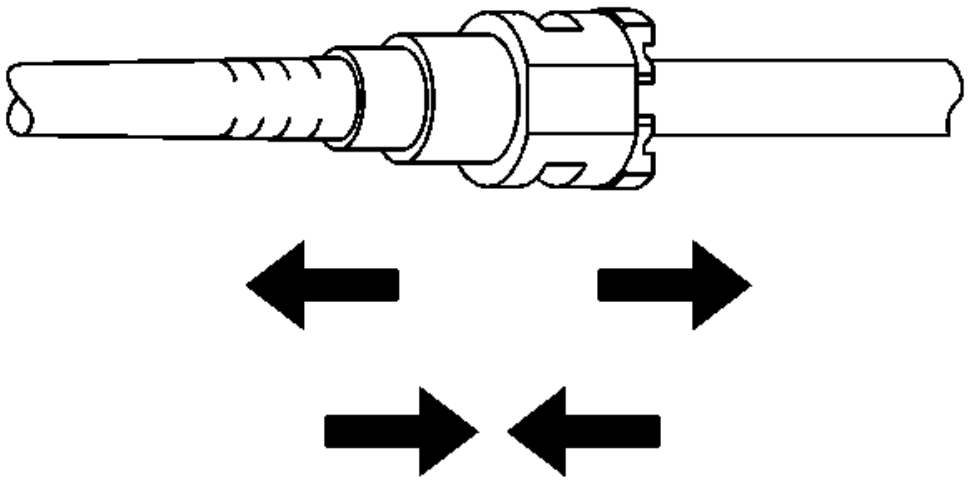


Fig. 63: Ensuring Secure Connection
Courtesy of GENERAL MOTORS CORP.

3. Once installed, pull on both sides of the quick connect fitting in order to make sure the connection is secure.

FUEL TANK DRAINING

Tools Required

- **J 43290** Fuel Tank Siphoning Hose. See **Special Tools**.
- **J 42960-2** Fuel Flapper Door Holder. See **Special Tools**.

CAUTION: Never drain or store fuel in an open container.

Always use an approved fuel storage container in order to reduce the chance of fire or explosion.

CAUTION: Place a dry chemical (Class B) fire extinguisher nearby before performing any on-vehicle service procedures. Failure to follow these precautions may result in personal injury.

1. Remove the fuel filler cap.
2. Install the **J 42960-2** , or equivalent, into the fuel fill pipe in order to hold the door open. See **Special Tools**.

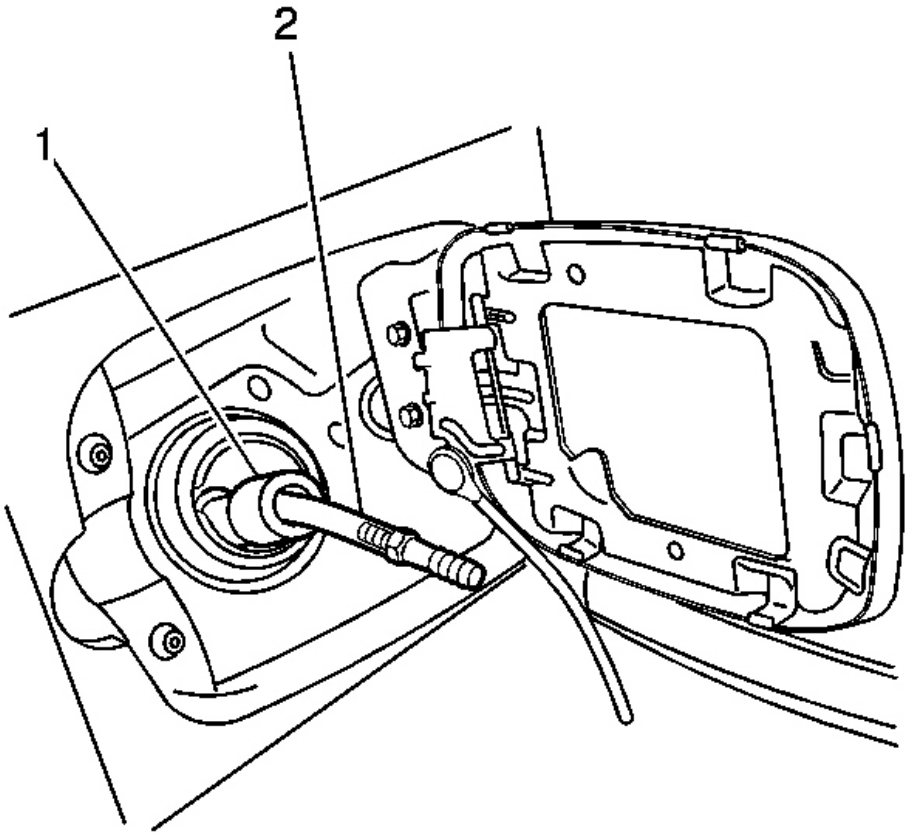


Fig. 64: View Of J 43290 & J 42960-2 Inserted Into Filler Pipe
Courtesy of GENERAL MOTORS CORP.

3. Insert the **J 43290** (2) through the **J 42960-2** (1) and into the fill pipe. See **Special Tools**.
4. Continue to insert the **J 43290** (2) into the fill pipe until the hose exits the valve (1) and reaches the bottom of the tank. See **Special Tools**.
5. Use an air operated pump device in order to drain as much fuel out through the

J 43290 (1) as possible. See **Special Tools**.

FUEL TANK REPLACEMENT

Removal Procedure

CAUTION: Refer to Gasoline/Gasoline Vapors Caution .

NOTE: Cap the fittings and plug the holes when servicing the fuel system in order to prevent dirt and other contaminants from entering the open pipes and passages.

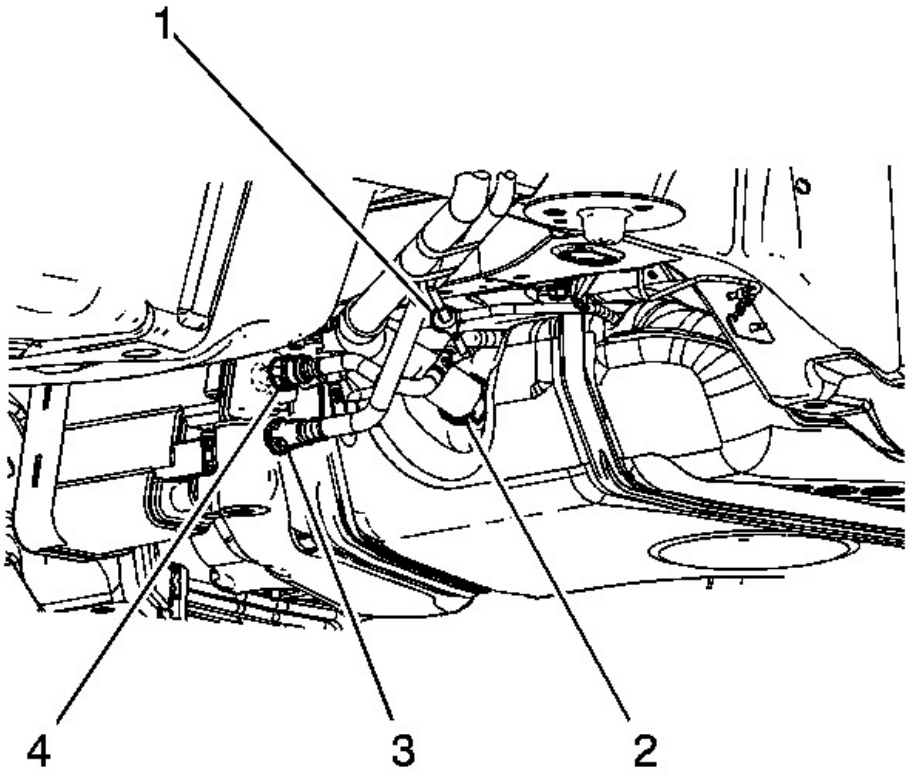


Fig. 65: Fuel Fill Pipe Hose
Courtesy of GENERAL MOTORS CORP.

1. Relieve the fuel system pressure. Refer to **Fuel Pressure Relief (With CH 48027)** or **Fuel Pressure Relief (Without CH 48027)**.
2. Drain the fuel tank. Refer to **Fuel Tank Draining**.
3. Raise and support the vehicle. Refer to **Lifting and Jacking the Vehicle** .
4. Disconnect the fuel tank vent pipe quick connect fittings (1, 4). Refer to **Plastic Collar Quick Connect Fitting Service**.

5. Loosen the fuel fill pipe hose clamp (2) at the fuel tank.
6. Remove the fuel fill pipe hose from the fuel tank.

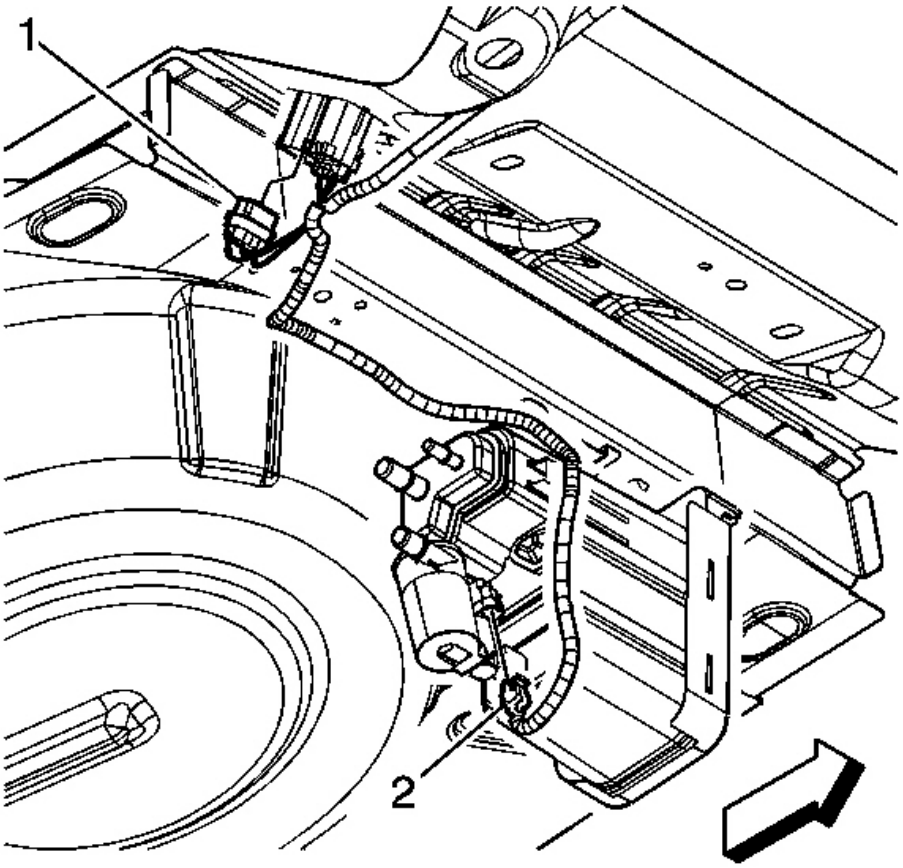


Fig. 66: Fuel Tank Electrical Connector
Courtesy of GENERAL MOTORS CORP.

7. Disconnect the fuel tank electrical connector (1) from the pass thru connector.

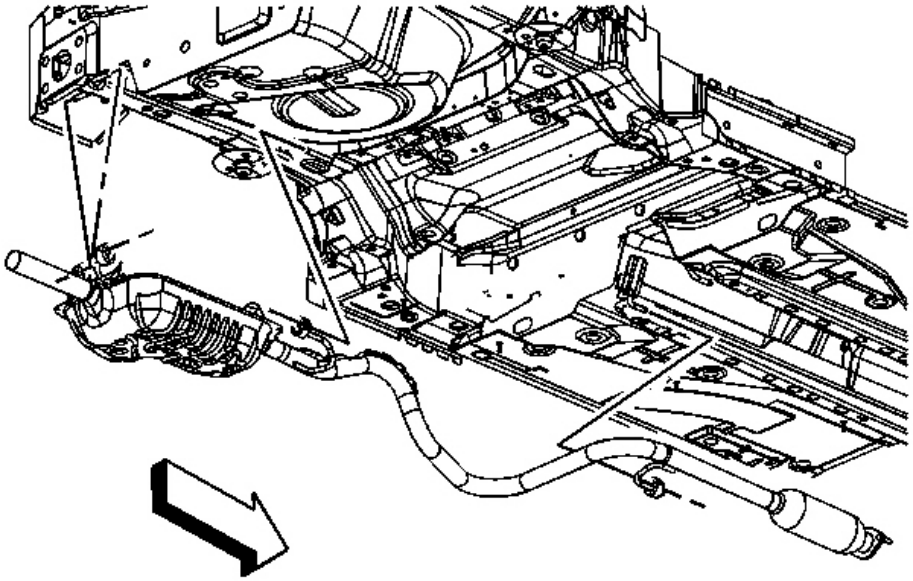


Fig. 67: Exhaust Pipe Insulators
Courtesy of GENERAL MOTORS CORP.

8. Remove the exhaust pipe insulators from the underbody hangers.
9. Remove the muffler insulators from the underbody hanger and slowly lower the exhaust in order to allow it to rest on the rear axle beam.

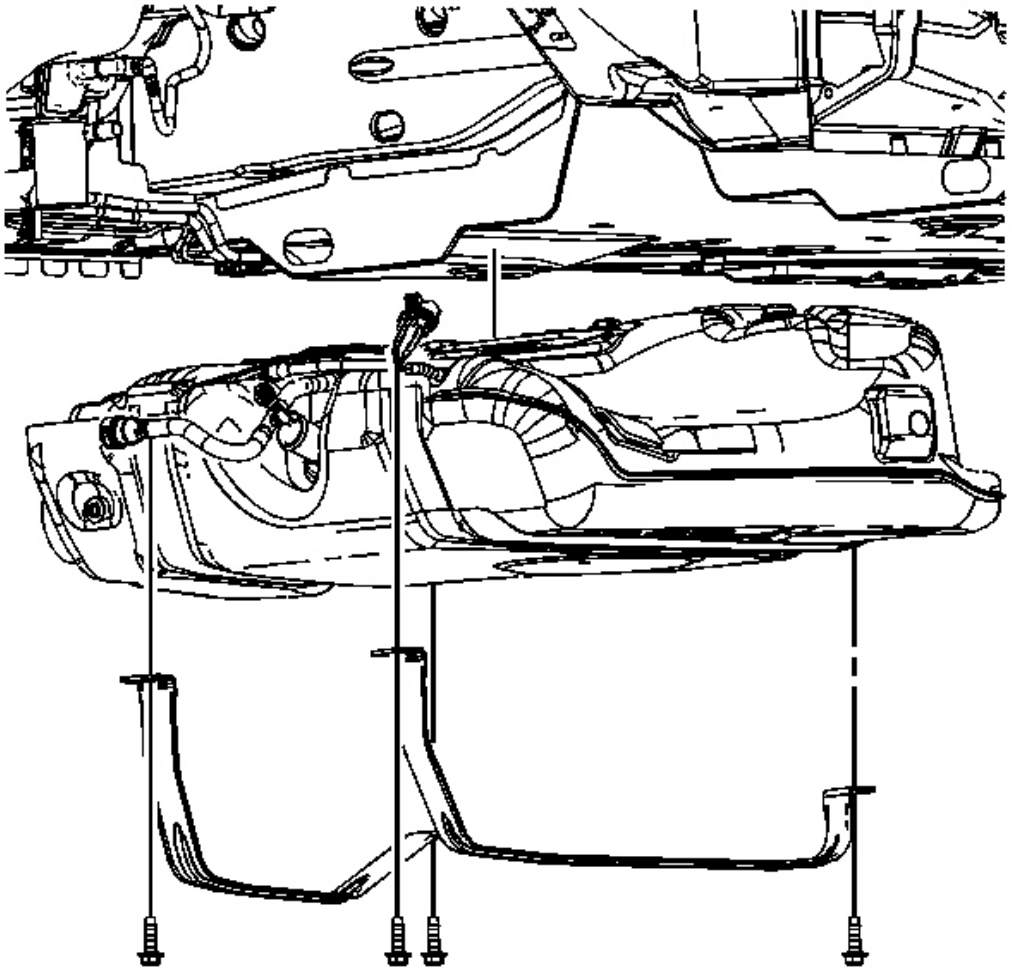


Fig. 68: Fuel Tank & Straps
Courtesy of GENERAL MOTORS CORP.

10. Place an adjustable jack under the fuel tank.
11. Remove the fuel tank strap bolts.
12. Remove the fuel tank straps.
13. Using the adjustable jack, carefully lower the fuel tank away from the vehicle.
14. With the aid of an assistant, place the fuel tank on a suitable work surface.

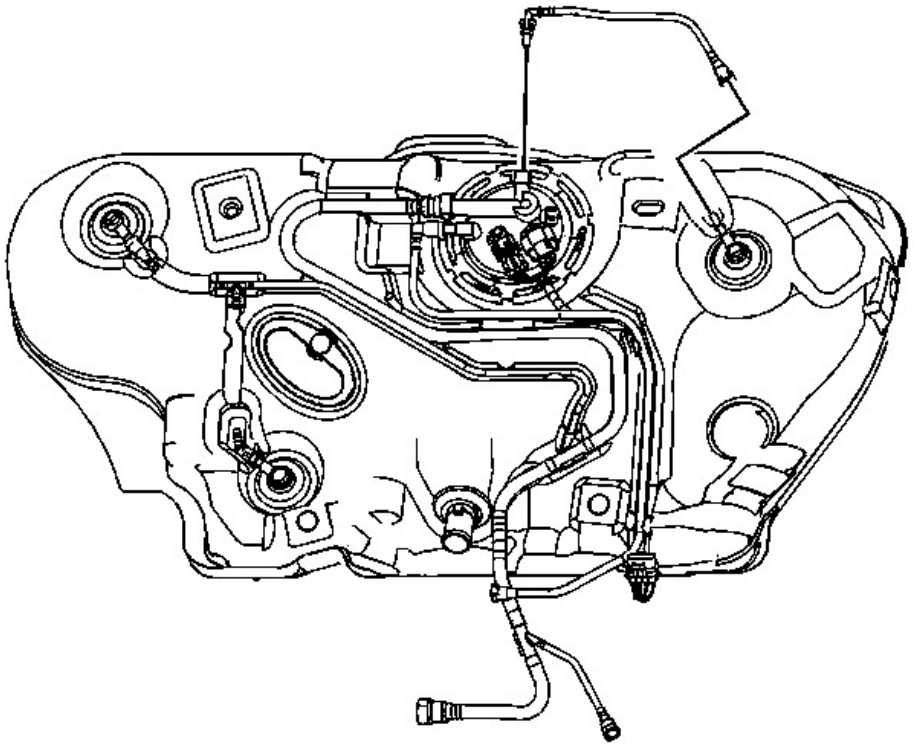


Fig. 69: Fuel Tank Vent Pipe
Courtesy of GENERAL MOTORS CORP.

15. If replacing the fuel tank perform the following steps, remove the fuel tank vent pipe. Refer to **Plastic Collar Quick Connect Fitting Service**.

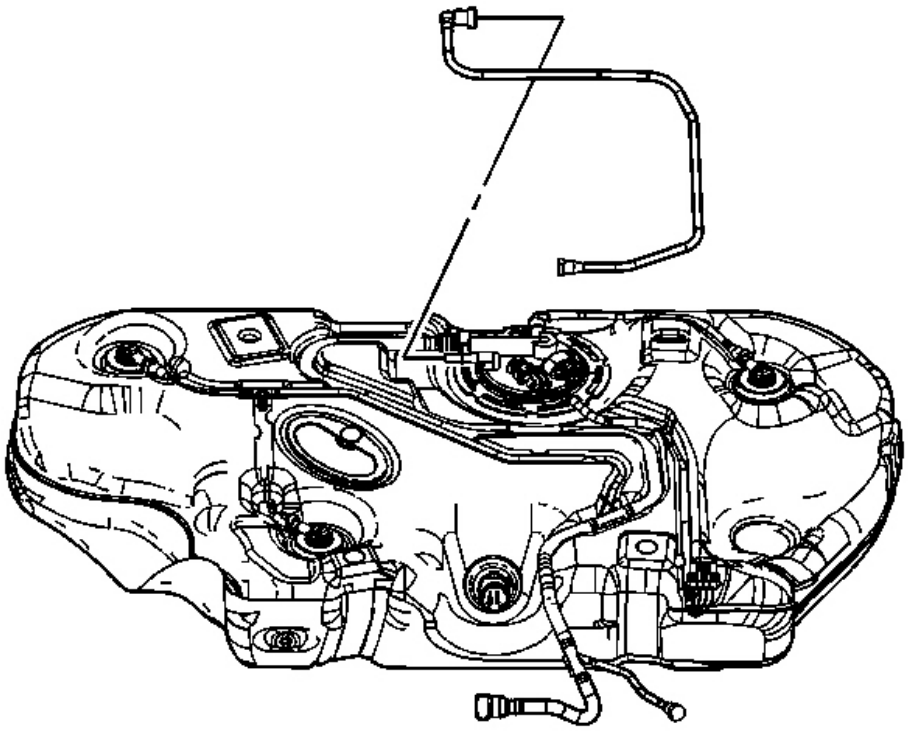


Fig. 70: Fuel Feed Intermediate Pipe
Courtesy of GENERAL MOTORS CORP.

16. Remove the fuel feed intermediate pipe. Refer to **Plastic Collar Quick Connect Fitting Service**.

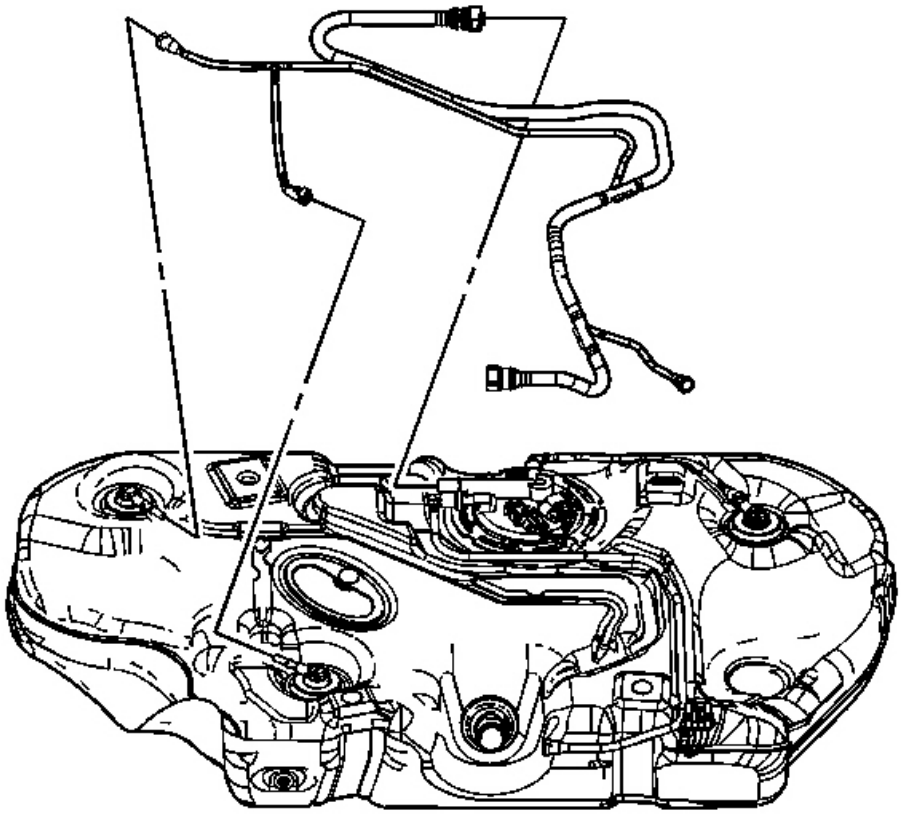


Fig. 71: Fuel Tank Vent Pipe
Courtesy of GENERAL MOTORS CORP.

17. Remove the fuel tank vent pipe. Refer to **Plastic Collar Quick Connect Fitting Service**.

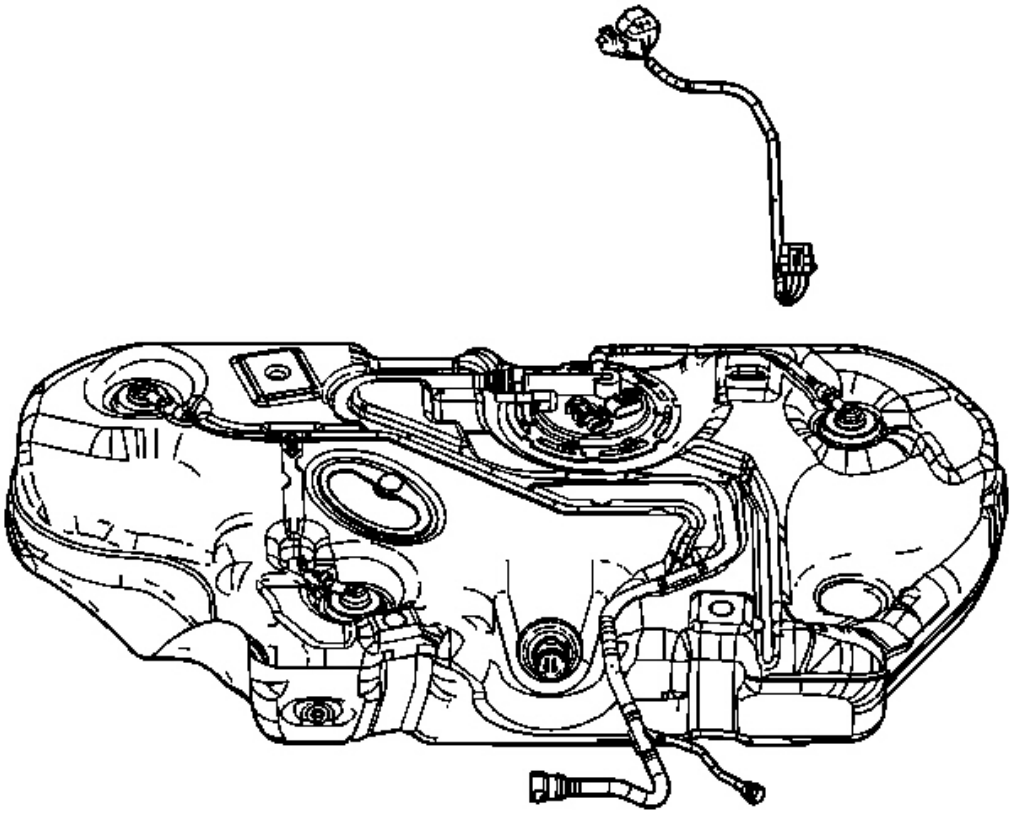


Fig. 72: Fuel Tank Electrical Harness
Courtesy of GENERAL MOTORS CORP.

18. Disconnect and remove the fuel tank electrical harness.
19. Remove the fuel tank module. Refer to **Fuel Pump Module Replacement**.

Installation Procedure

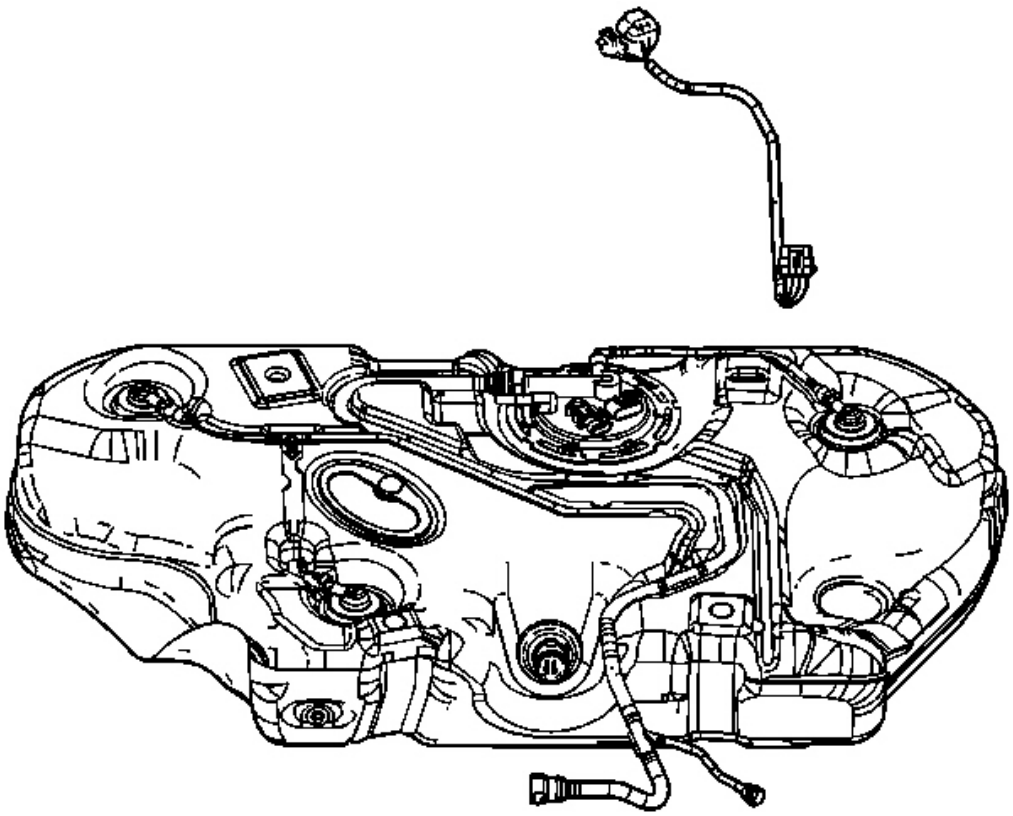


Fig. 73: Fuel Tank Electrical Harness
Courtesy of GENERAL MOTORS CORP.

1. If the fuel tank was replaced perform the following steps, install the fuel tank module. Refer to **Fuel Pump Module Replacement**.
2. Install and connect the fuel tank electrical harness.

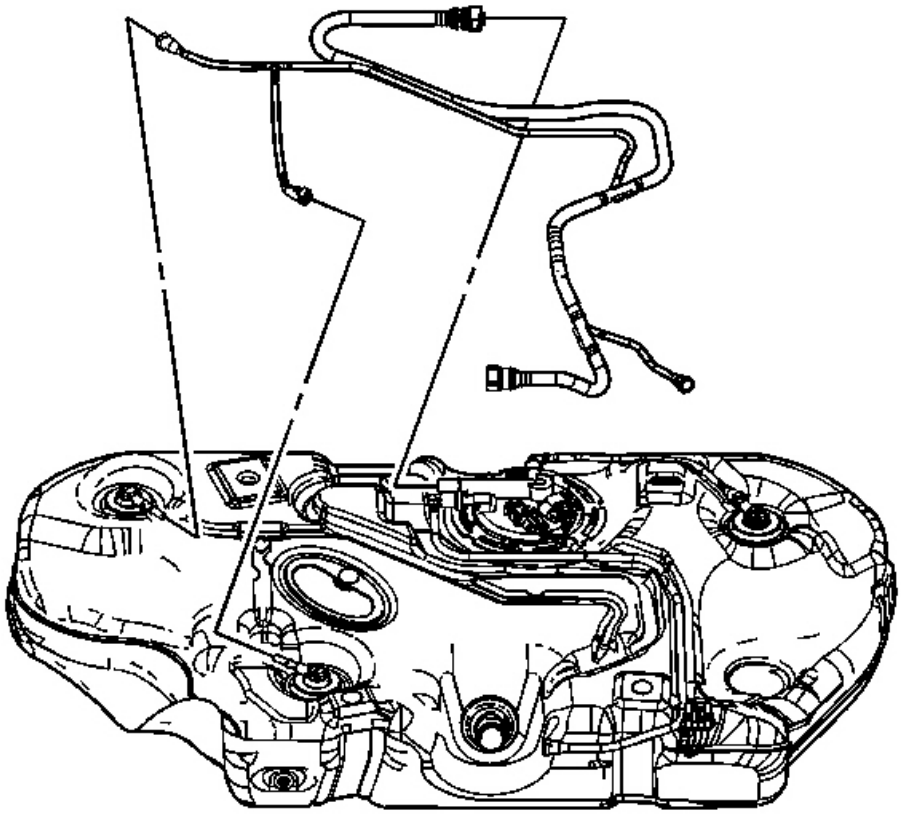


Fig. 74: Fuel Tank Vent Pipe
Courtesy of GENERAL MOTORS CORP.

3. Install the fuel tank vent pipe. Refer to **Plastic Collar Quick Connect Fitting Service**.

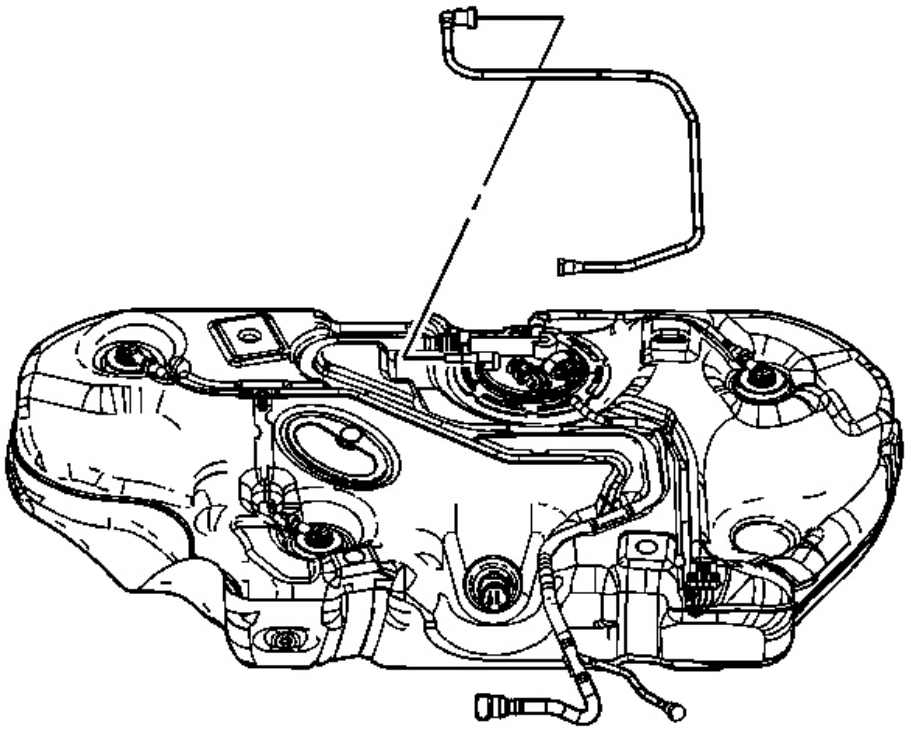


Fig. 75: Fuel Feed Intermediate Pipe
Courtesy of GENERAL MOTORS CORP.

4. Install the fuel feed intermediate pipe. Refer to **Plastic Collar Quick Connect Fitting Service**.

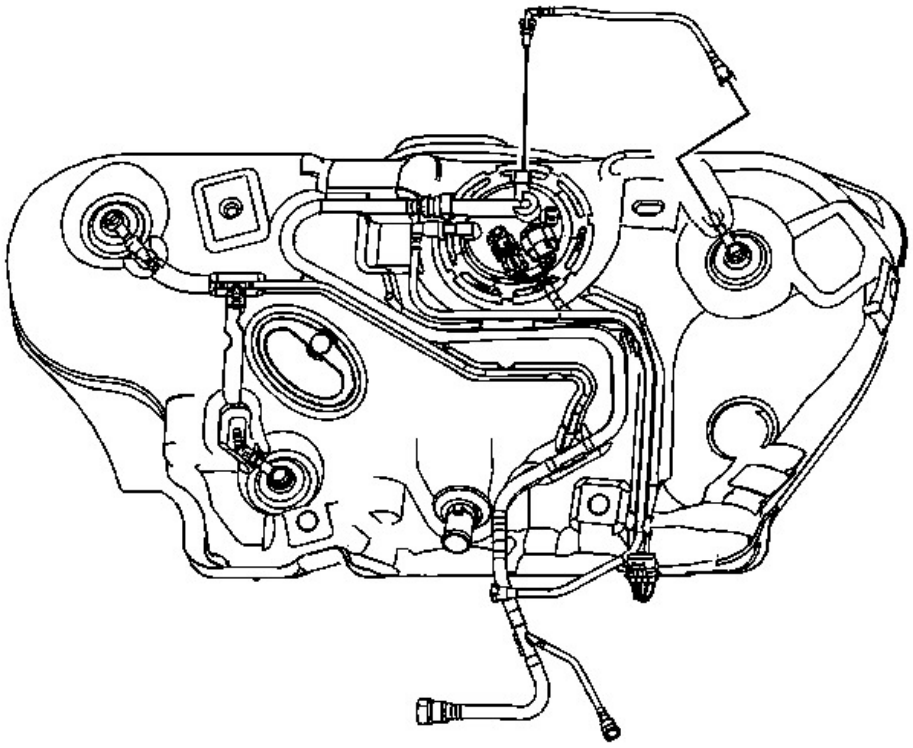


Fig. 76: Fuel Tank Vent Pipe
Courtesy of GENERAL MOTORS CORP.

5. Install the fuel tank vent pipe. Refer to **Plastic Collar Quick Connect Fitting Service**.

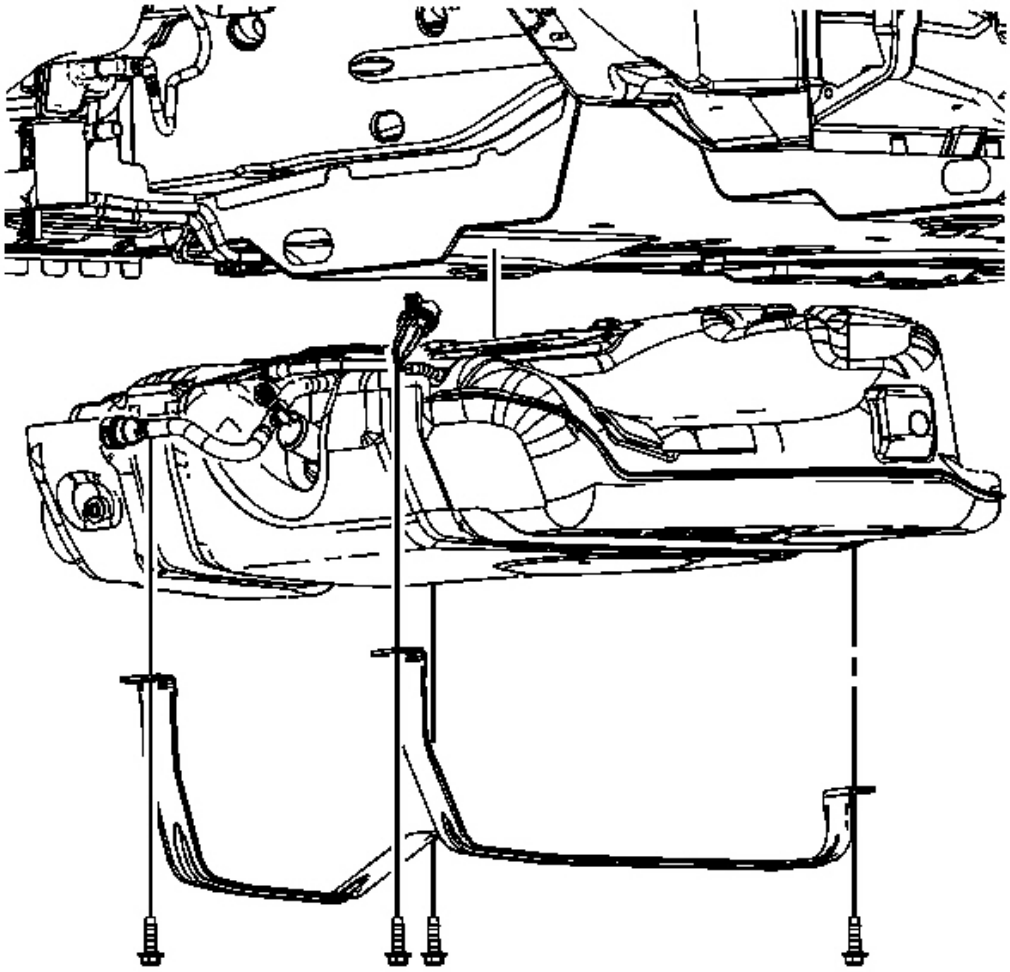


Fig. 77: Fuel Tank & Straps
Courtesy of GENERAL MOTORS CORP.

6. With the aid of an assistant, place the fuel tank on the suitable jack.
7. Using the adjustable jack, carefully raise the fuel tank into position.
8. Position the fuel tank straps.

NOTE: Refer to Fastener Notice .

9. Install the fuel tank strap bolts.

Tighten: Tighten the bolts to 45 N.m (33 lb ft).

10. Remove adjustable jack from under the fuel tank.

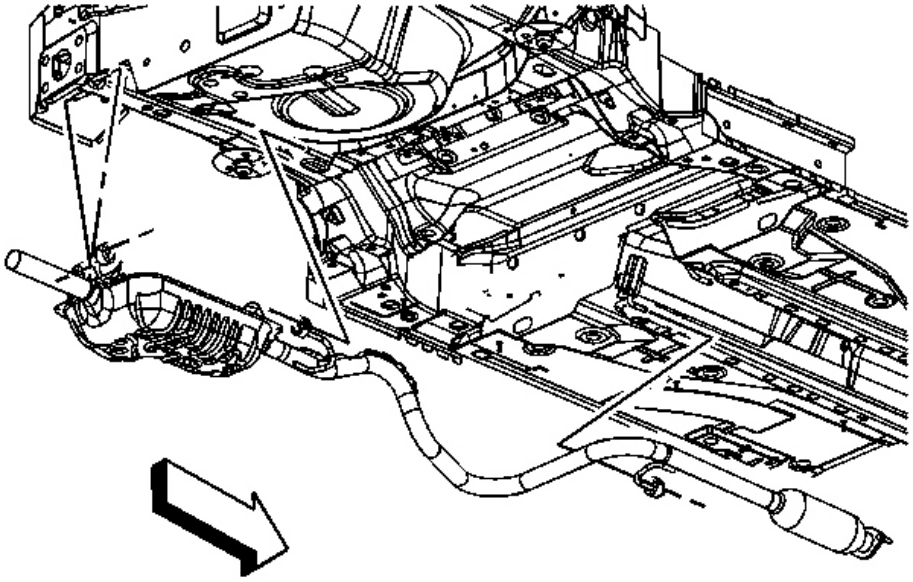


Fig. 78: Exhaust Pipe Insulators
Courtesy of GENERAL MOTORS CORP.

11. Raise the exhaust and install the muffler insulators to the underbody hangers.
12. Install the exhaust pipe insulators to the underbody hangers.

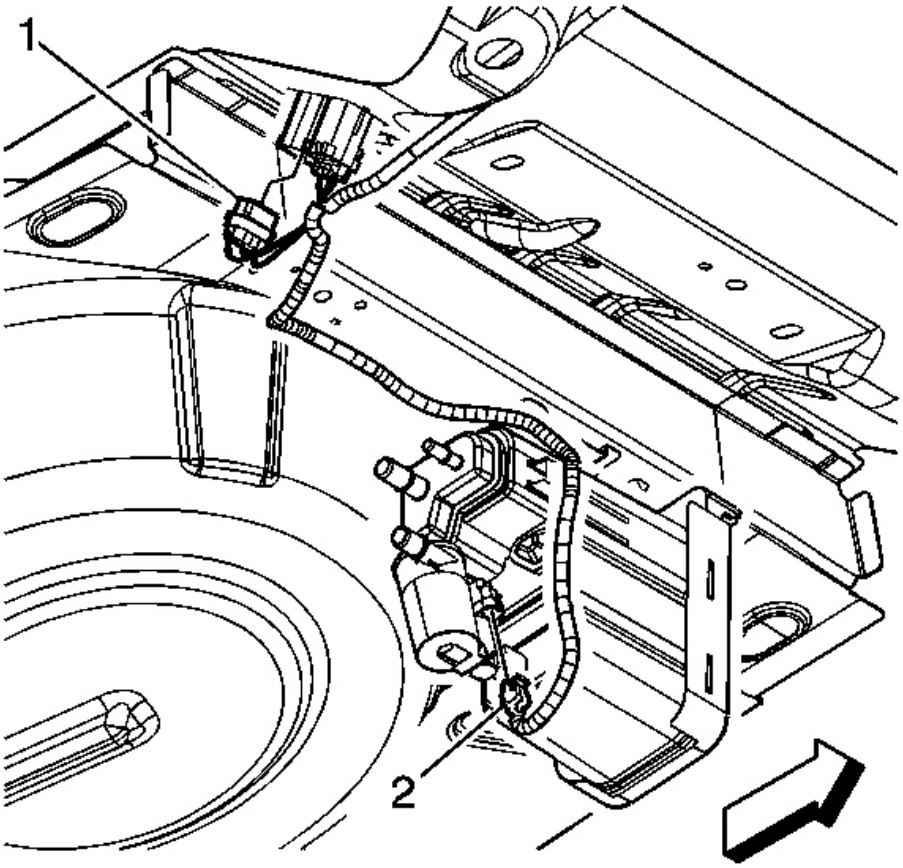


Fig. 79: Fuel Tank Electrical Connector
Courtesy of GENERAL MOTORS CORP.

13. Connect the fuel tank electrical connector (1) to the pass thru connector.

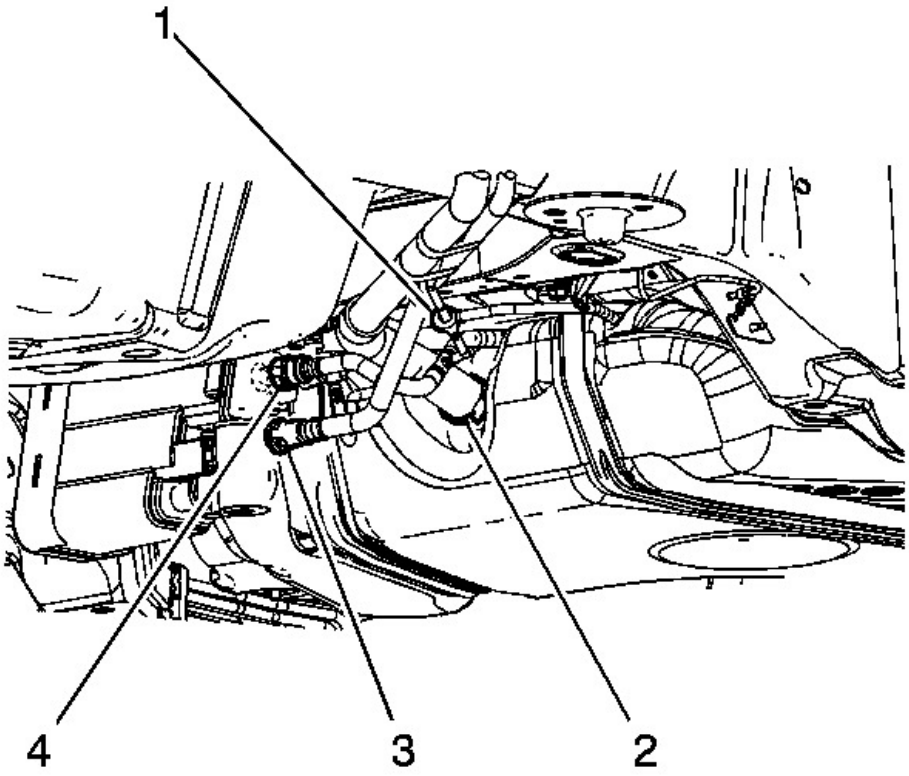


Fig. 80: Fuel Fill Pipe Hose
Courtesy of GENERAL MOTORS CORP.

14. Install the fuel fill pipe hose to the fuel tank.
15. Tighten the fuel fill pipe hose clamp (2) at the fuel tank.

    Tighten: Tighten the clamp to 4.5 N.m (40 lb in).

16. Connect the fuel tank vent pipe quick connect fittings (1, 4). Refer to **Plastic Collar Quick Connect Fitting Service**.

17. Lower the vehicle.
18. Refill the fuel tank.
19. Connect the negative battery cable. Refer to **Battery Negative Cable Disconnection and Connection** .
20. Inspect for fuel leaks using the following procedure:
    1. Turn ON the ignition, with the engine OFF for 2 seconds.
    2. Turn OFF the ignition for 10 seconds.
    3. Turn ON the ignition, with the engine OFF.
    4. Inspect for fuel leaks.

FUEL TANK PRESSURE SENSOR REPLACEMENT

Removal Procedure

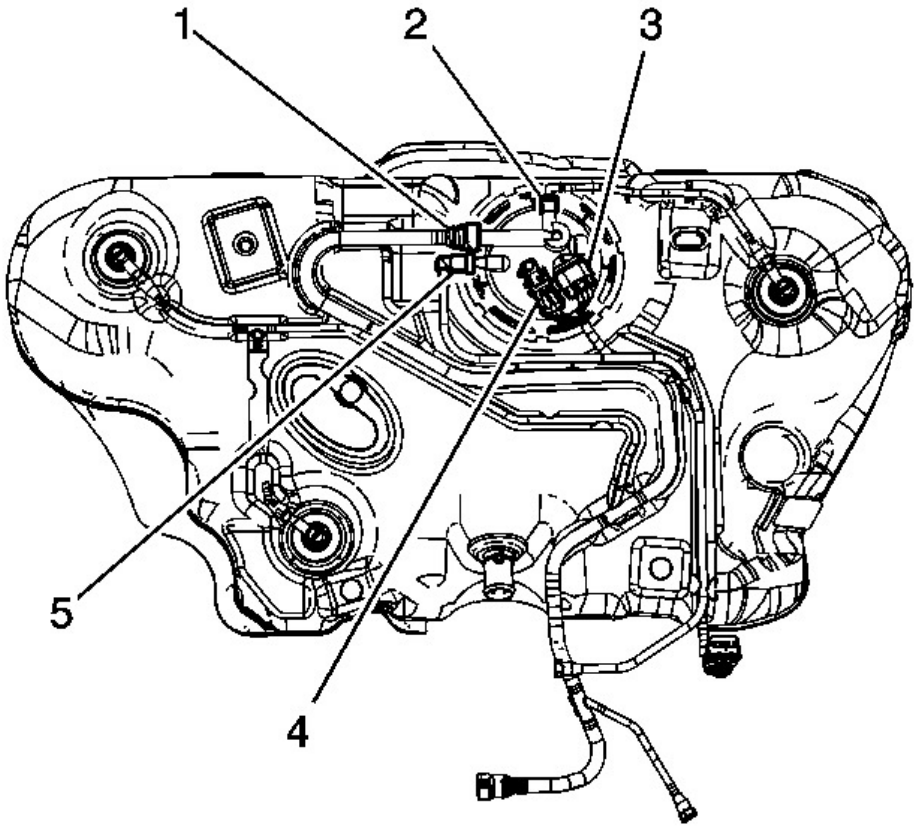


Fig. 81: Fuel Tank & Fuel Pressure Sensor Electrical Connector
Courtesy of GENERAL MOTORS CORP.

1. Remove the fuel tank. Refer to **Fuel Tank Replacement**.
2. Disconnect the fuel pressure sensor electrical connector (4).

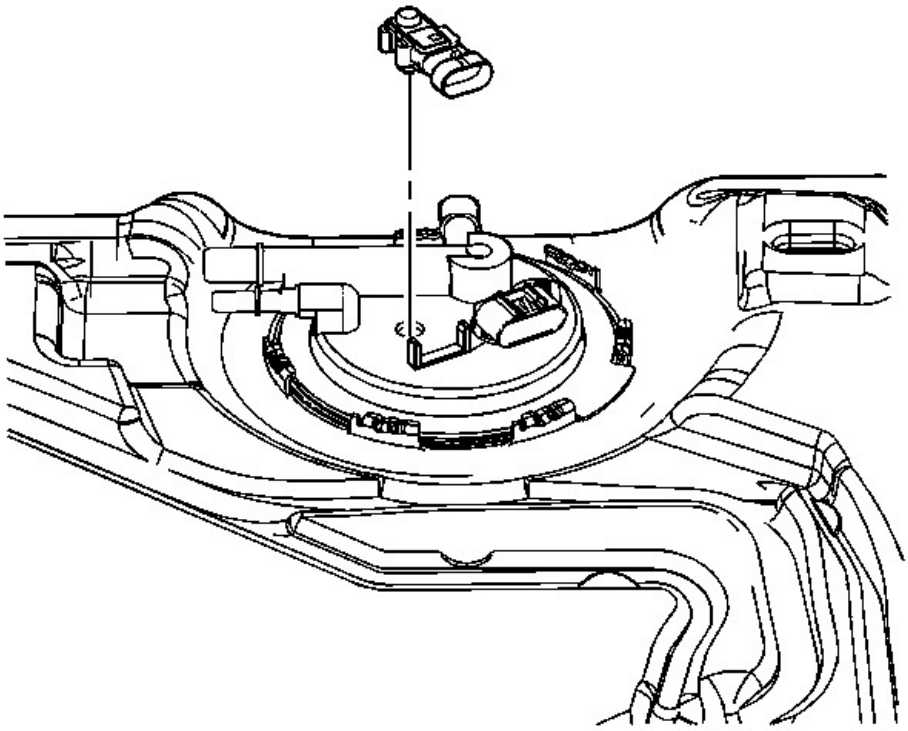


Fig. 82: Fuel Tank Pressure Sensor
Courtesy of GENERAL MOTORS CORP.

3. Position 2 flat-bladed screwdrivers, one on each side of the sensor, near the vacuum port.
4. Using the screwdrivers as leverage, carefully pry up in order to release the sensor from the module.

Installation Procedure

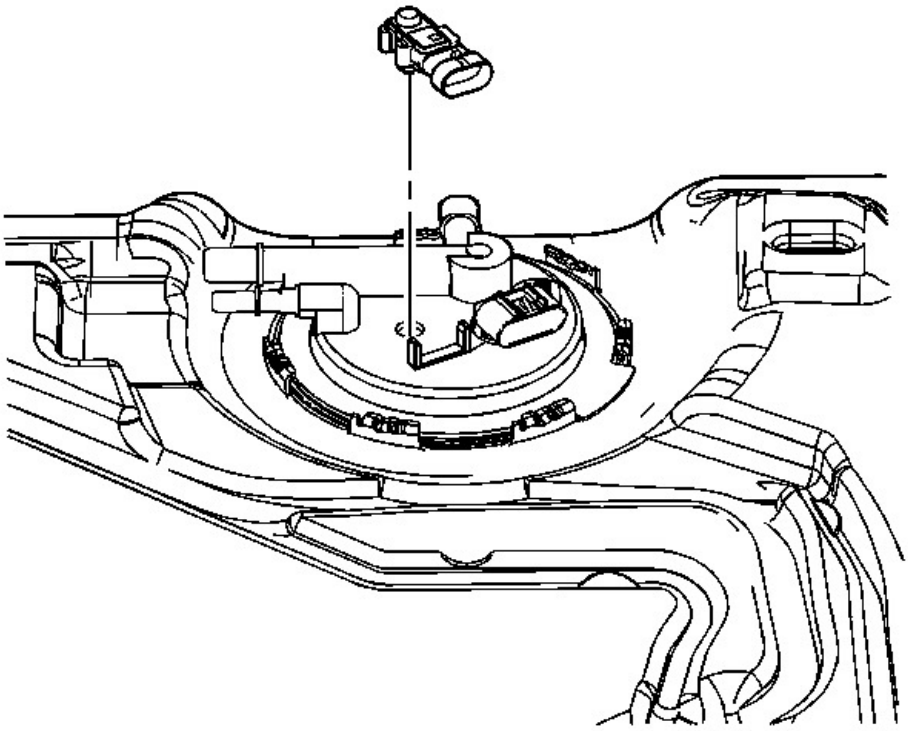


Fig. 83: Fuel Tank Pressure Sensor
Courtesy of GENERAL MOTORS CORP.

1. Install the fuel tank pressure sensor to the module. Ensure that the sensor grommet is fully seated in the module.

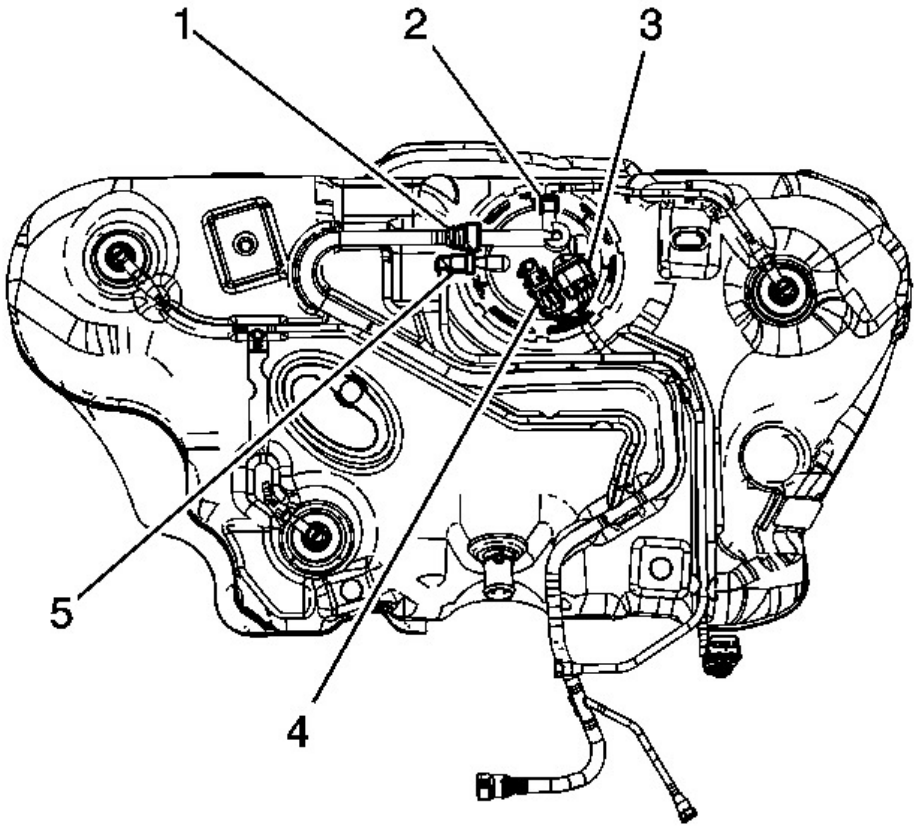


Fig. 84: Fuel Tank & Fuel Pressure Sensor Electrical Connector
Courtesy of GENERAL MOTORS CORP.

2. Connect the fuel pressure sensor electrical connector (4).
3. Install the fuel tank. Refer to **Fuel Tank Replacement**.

FUEL LEVEL SENSOR REPLACEMENT

Removal Procedure

CAUTION: Refer to Gasoline/Gasoline Vapors Caution .

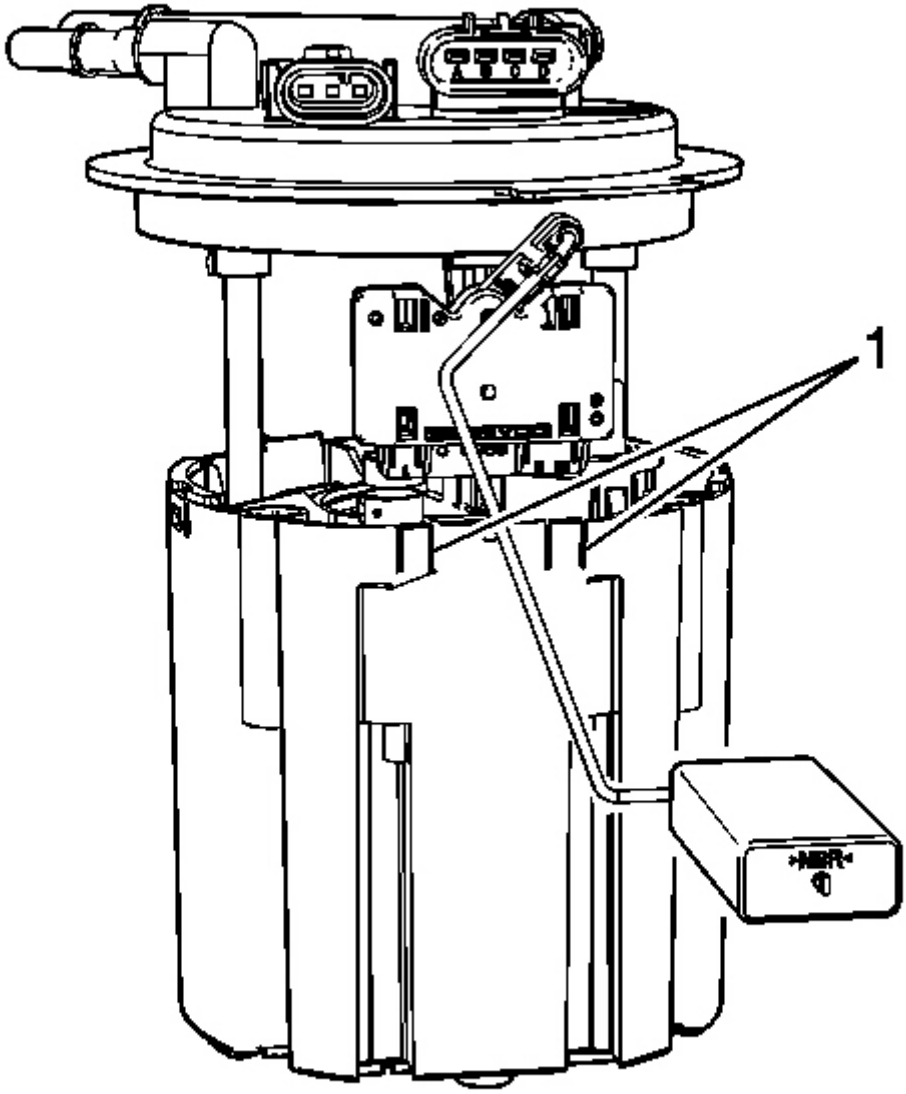


Fig. 85: Fuel Pump Module
Courtesy of GENERAL MOTORS CORP.

1. Remove the fuel pump module. Refer to **Fuel Pump Module Replacement**.

2. Release the retaining tabs (2) on the reservoir body and begin to slide the level sensor out away from the reservoir.
3. Carefully slide the level sensor the rest of the way out of the reservoir.

Installation Procedure

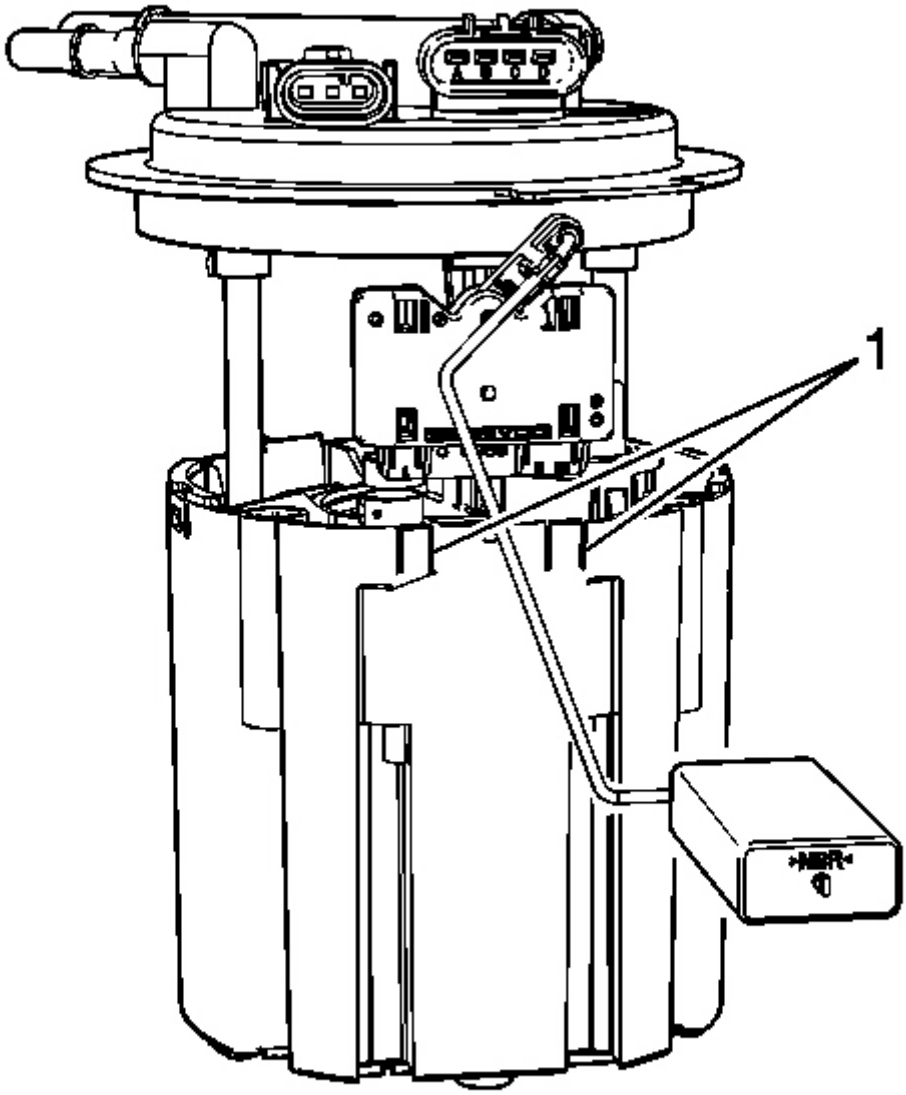


Fig. 86: Fuel Pump Module

Courtesy of GENERAL MOTORS CORP.

1. Carefully slide the fuel level sensor into the slots on the reservoir.
2. Slide the sensor down until the retaining tabs (2) engage the sensor.
3. Install the fuel pump module. Refer to **Fuel Pump Module Replacement**.

FUEL PUMP MODULE REPLACEMENT

Special Tools

J 45722 Fuel Sender Lock Ring Wrench. See **Special Tools**.

Removal Procedure

CAUTION: Refer to Gasoline/Gasoline Vapors Caution .

CAUTION: In order to reduce the risk of fire and personal injury that may result from a fuel leak, always replace the fuel sender gasket when reinstalling the fuel sender assembly.

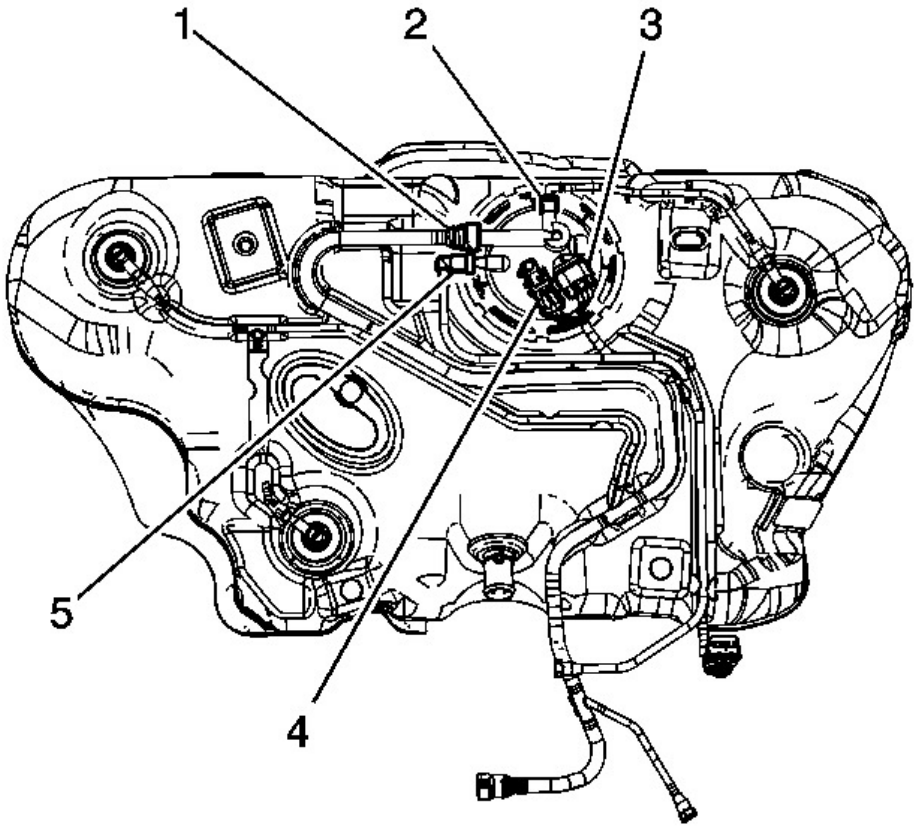


Fig. 87: Fuel Tank & Fuel Pressure Sensor Electrical Connector
Courtesy of GENERAL MOTORS CORP.

1. Remove the fuel tank. Refer to **Fuel Tank Replacement**.
2. Disconnect the fuel pressure sensor and fuel pump module electrical connectors (1, 4).
3. Disconnect the fuel tank vent pipe quick connect fittings (2, 3). Refer to **Plastic Collar Quick Connect Fitting Service**.
4. Disconnect the fuel tank feed pipe quick connect fitting (5). Refer to **Plastic**

Collar Quick Connect Fitting Service.

5. Install the **J 45722** to the lock ring. See **Special Tools**.

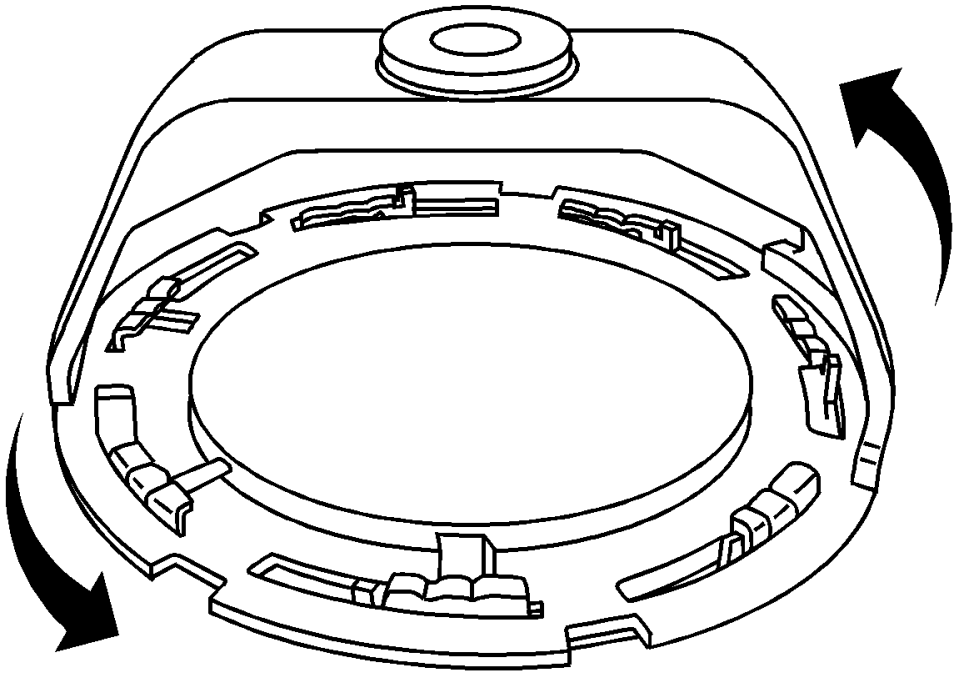


Fig. 88: Identifying Lock Ring
Courtesy of GENERAL MOTORS CORP.

NOTE: Avoid damaging the lock ring. Use only J-45722 to prevent damage to the lock ring.

NOTE: Do Not handle the fuel sender assembly by the fuel pipes. The amount of leverage generated by handling the fuel pipes could damage the joints.

IMPORTANT: Do NOT use impact tools. Significant force will be

required to release the lock ring. The use of a hammer and screwdriver is not recommended. Secure the fuel tank in order to prevent fuel tank rotation.

6. Use the **J 45722** and a long breaker-bar in order to unlock the fuel sender lock ring. See **Special Tools**. Turn the fuel sender lock ring in a counterclockwise direction.
7. Remove the module lock ring.

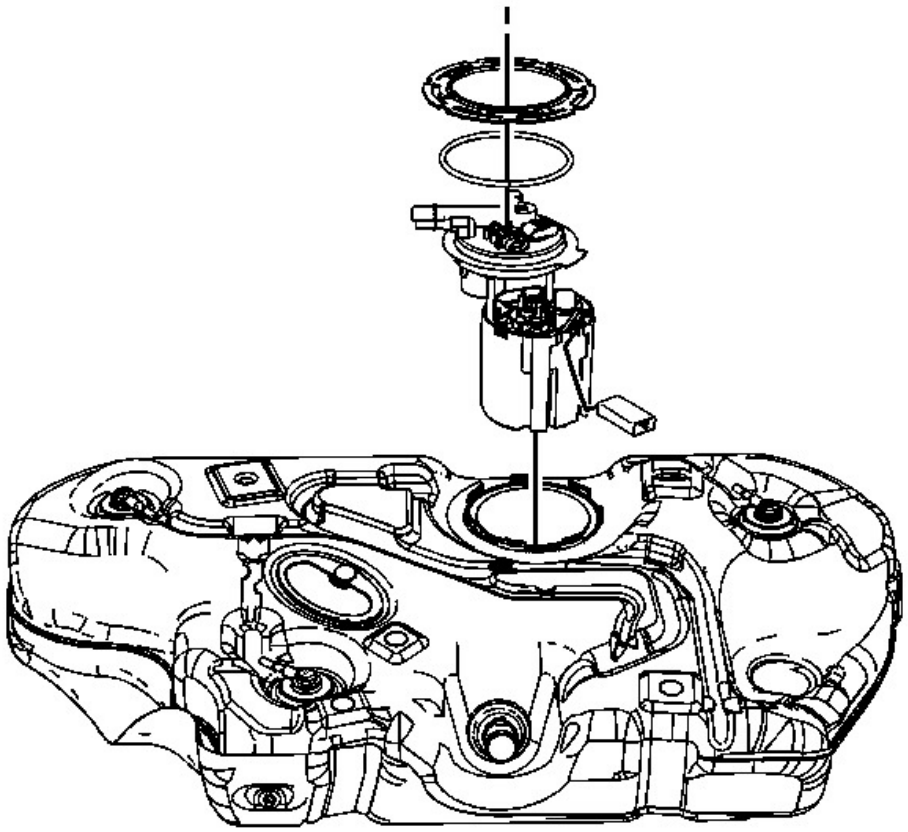


Fig. 89: Fuel Pump Module
Courtesy of GENERAL MOTORS CORP.

8. Slowly raise the module until the fuel level sensor float arm is just visible. Ensure that the fuel level sensor harness connector clears the tank opening.

IMPORTANT: When removing the module from the fuel tank, be aware that the module reservoir bowl is full of fuel. The module must be tipped slightly during removal

to avoid bending the fuel level sensor float arm.

9. Tilt the module toward the rear of the fuel tank to allow the level sensor float arm to clear the tank opening. Remove the module from the tank.
10. Carefully discard the fuel in the module reservoir bowl into an approved fuel container.

IMPORTANT: DO NOT reuse the old fuel pump module seal.

11. Remove and discard the fuel pump module seal.

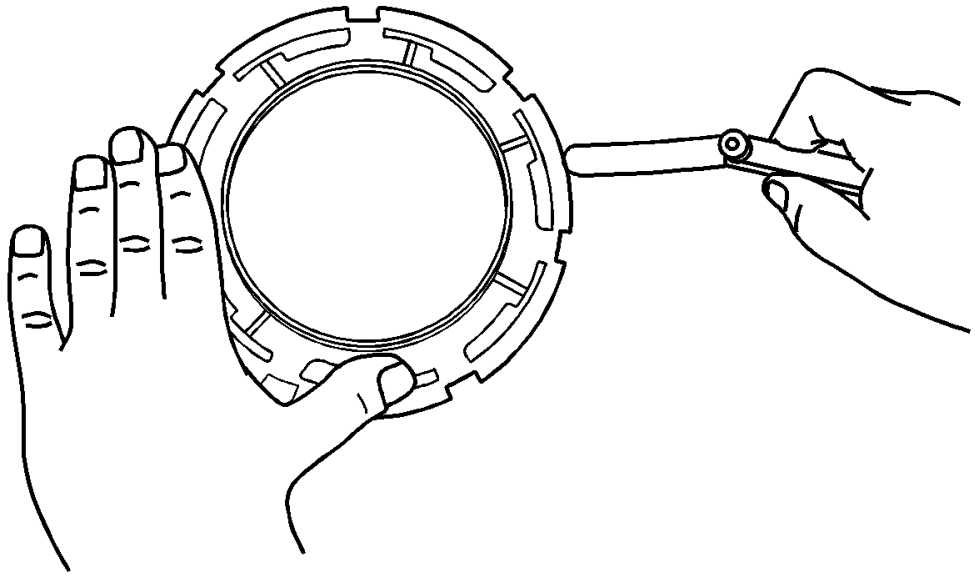


Fig. 90: Checking Lock Ring For Flatness
Courtesy of GENERAL MOTORS CORP.

IMPORTANT: Some lock ring were manufactured with DO NOT REUSE stamped into them. These lock rings may be reused if they are not damaged or warped.

IMPORTANT: Inspect the lock ring for damage due to improper removal or installation procedures. If damage is found, install a NEW lock ring.

IMPORTANT: Check the lock ring for flatness.

12. Place the lock ring on a flat surface. Measure the clearance between to lock ring and the flat surface using a feeler gage at 7 points.
13. If the warpage is less than 0.41 mm (0.016 in), the lock ring does not require replacement.
14. If the warpage is greater than 0.41 mm (0.016 in), the lock ring must be replaced.

Installation Procedure

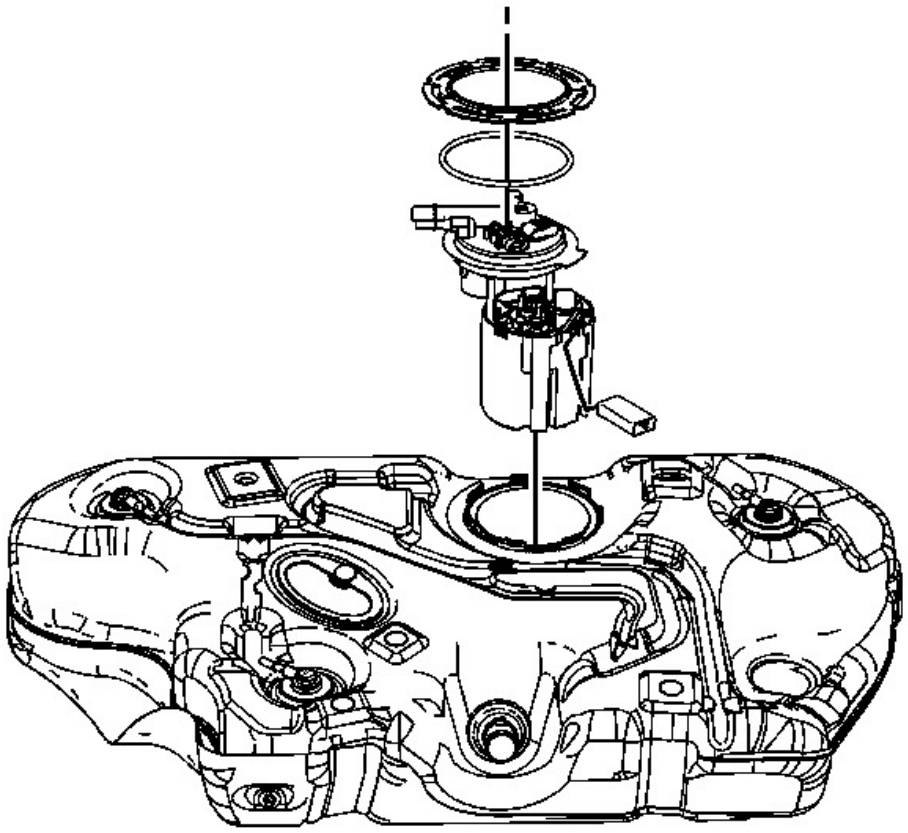


Fig. 91: Fuel Pump Module
Courtesy of GENERAL MOTORS CORP.

1. Install a NEW fuel pump module seal onto the fuel tank.

IMPORTANT: The reservoir must be tipped slightly during installation to avoid bending the fuel level sensor float arm.

2. Tilt the module toward the rear of the fuel tank to allow the fuel level sensor float arm to clear the tank opening. Install the module into the fuel tank.
3. Lower the module assembly into the tank. Ensure that the fuel level sensor harness connector is positioned properly.
4. Install the module lock ring over the module pipes and electrical harness, and into position on the top of the module.

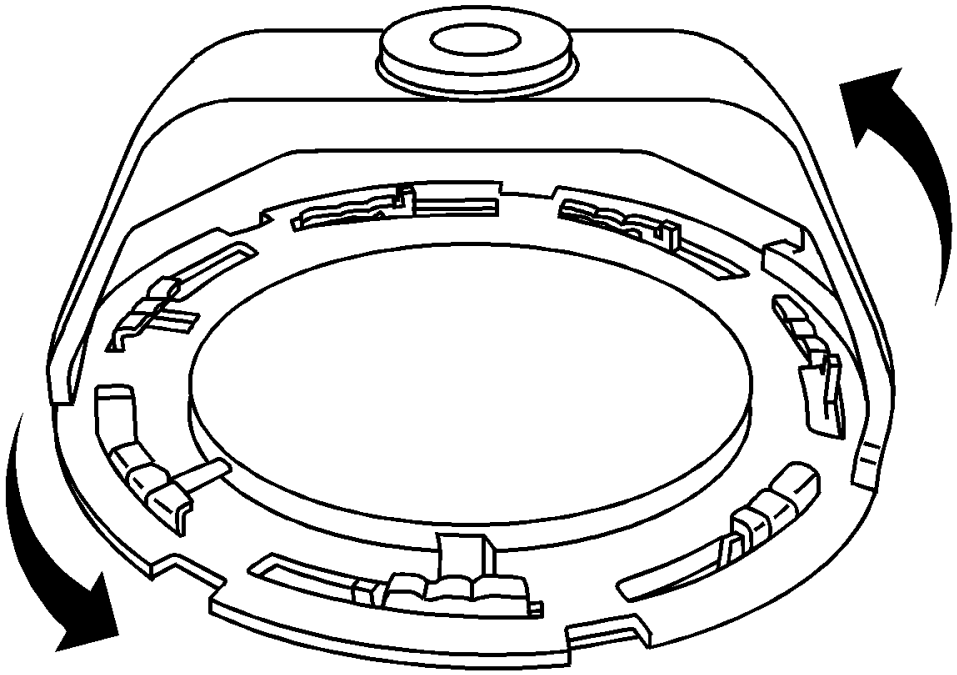


Fig. 92: Identifying Lock Ring
Courtesy of GENERAL MOTORS CORP.

IMPORTANT: Always replace the fuel sender seal when installing the fuel sender assembly. Replace the lock ring if necessary. Do not apply any type of lubrication in the seal groove.

Ensure the lock ring is installed with the correct side facing upward. A correctly installed lock ring will only turn in a clockwise direction.

5. Use the **J 45722** in order to install the fuel sender lock ring. See **Special Tools**. Turn the fuel sender lock ring in a clockwise direction.
6. Remove the **J 45722** from the lock ring. See **Special Tools**.

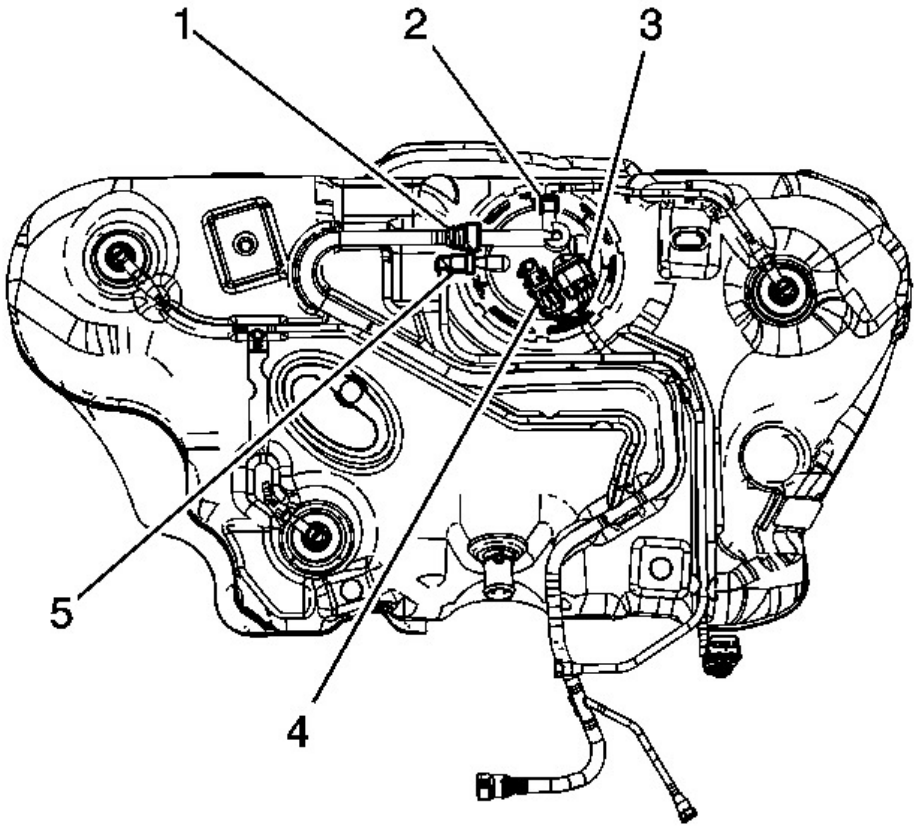


Fig. 93: Fuel Tank & Fuel Pressure Sensor Electrical Connector

Courtesy of GENERAL MOTORS CORP.

7. Connect the fuel tank feed pipe quick connect fitting (5). Refer to **Plastic Collar Quick Connect Fitting Service**.
8. Connect the fuel tank vent pipe quick connect fittings (2, 3). Refer to **Plastic Collar Quick Connect Fitting Service**.
9. Connect the fuel pressure sensor and fuel pump module electrical connectors (1, 4).
10. Install the fuel tank. Refer to **Fuel Tank Replacement**.

FUEL TANK FILLER PIPE REPLACEMENT

Removal Procedure

CAUTION: Refer to Gasoline/Gasoline Vapors Caution .

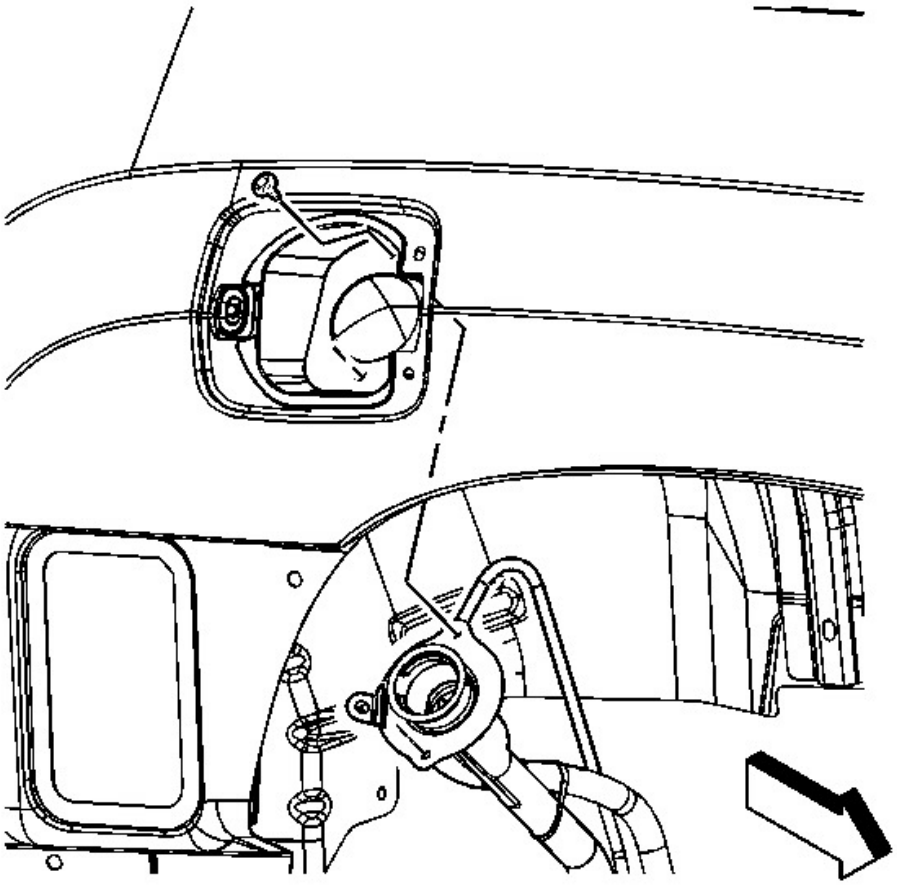


Fig. 94: Fuel Tank Filler Pipe
Courtesy of GENERAL MOTORS CORP.

1. Drain the fuel tank. Refer to **Fuel Tank Draining**.
2. Remove the fuel fill pipe to fill pipe housing bolts.
3. Remove the fuel fill pocket. Refer to **Fuel Tank Filler Pipe Housing Replacement** .

4. Raise and support the vehicle. Refer to **Lifting and Jacking the Vehicle** .

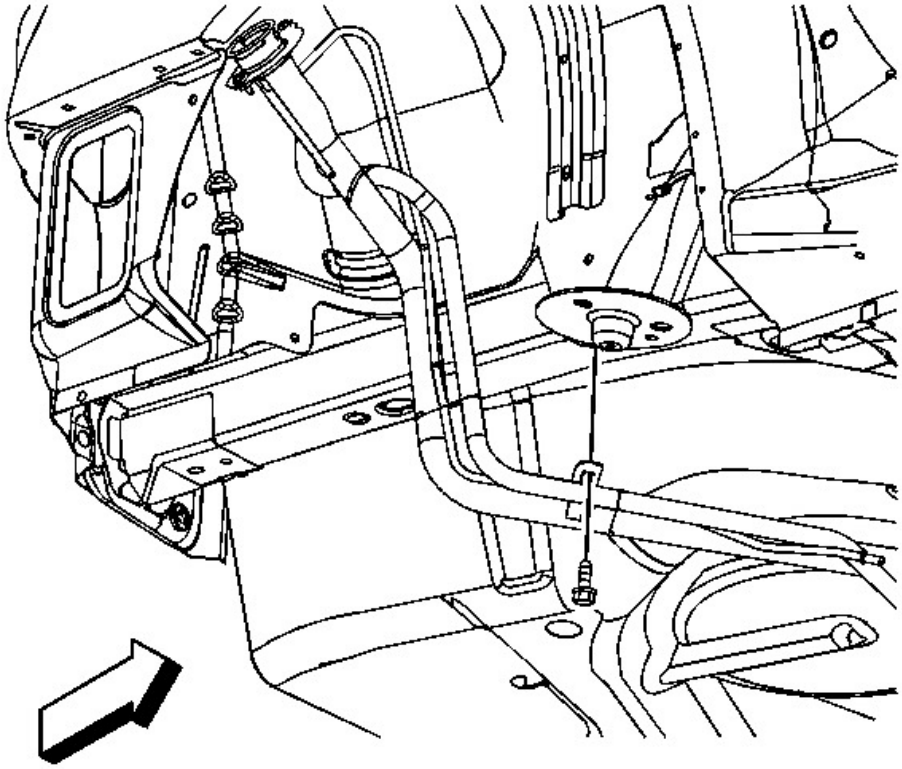


Fig. 95: Fuel Fill Pipe Lower Bolt
Courtesy of GENERAL MOTORS CORP.

5. Remove the fuel fill pipe lower bolt.

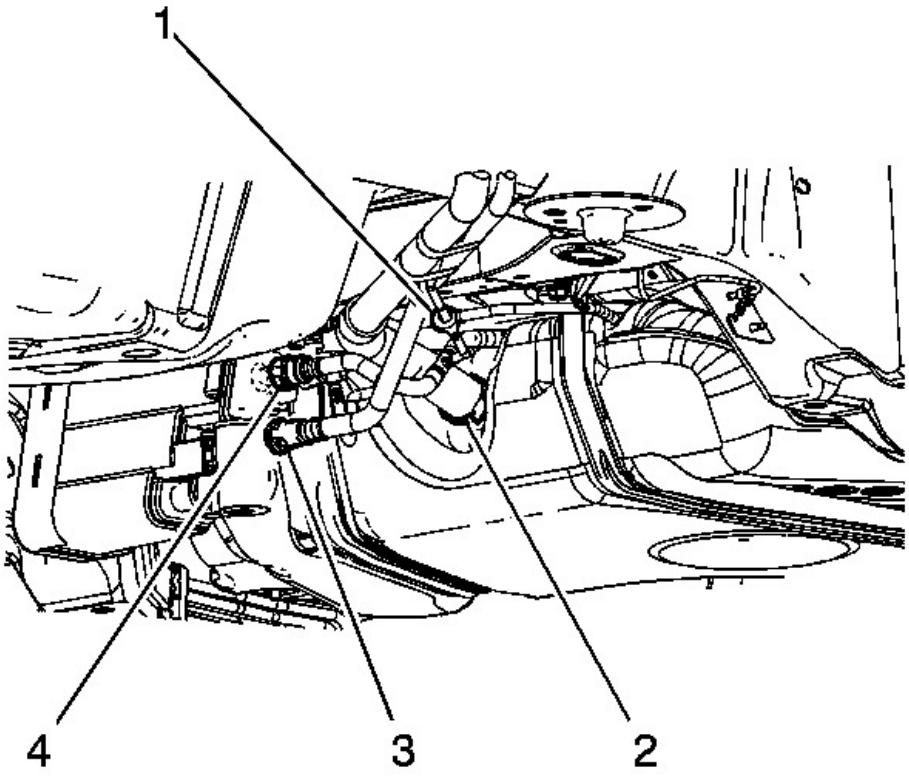


Fig. 96: Fuel Fill Pipe Hose
Courtesy of GENERAL MOTORS CORP.

6. Disconnect the fuel tank vent pipe quick connect fittings (1, 3). Refer to **Plastic Collar Quick Connect Fitting Service**.
7. Loosen the fuel fill pipe hose clamp (2) at the fuel tank.
8. Remove the fuel fill pipe hose from the fuel tank.

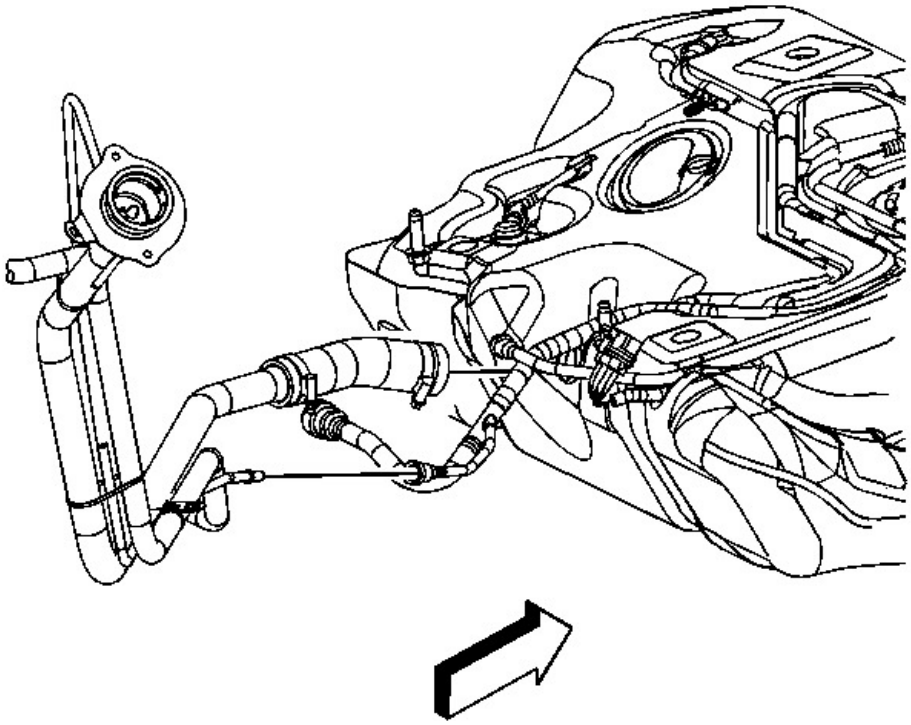


Fig. 97: Fuel Fill Pipe
Courtesy of GENERAL MOTORS CORP.

9. Remove the fuel fill pipe from the vehicle.

Installation Procedure

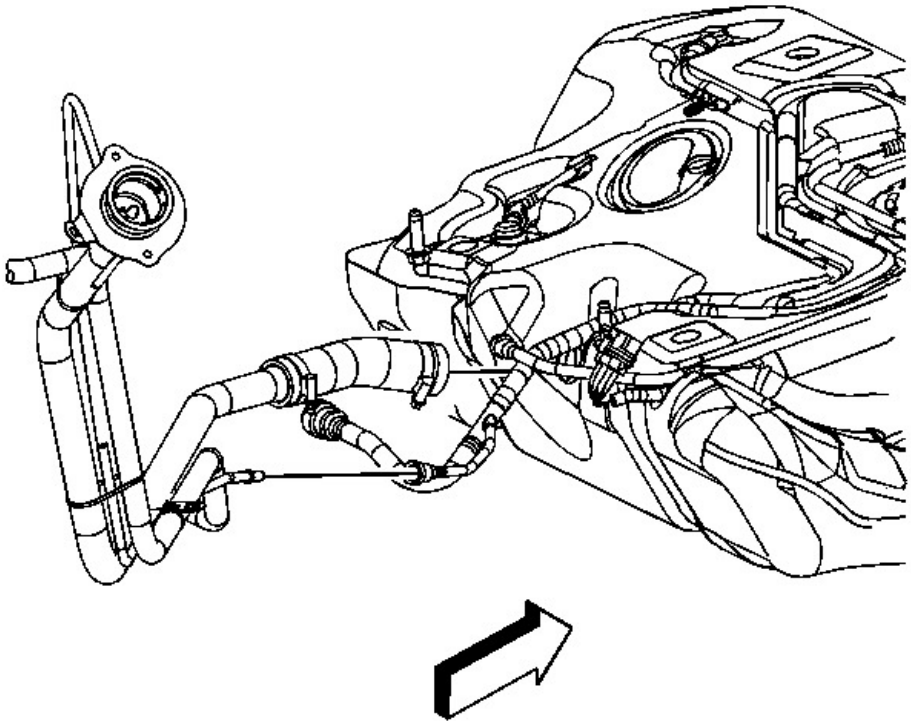


Fig. 98: Fuel Fill Pipe
Courtesy of GENERAL MOTORS CORP.

1. Install the fuel fill pipe to the vehicle.

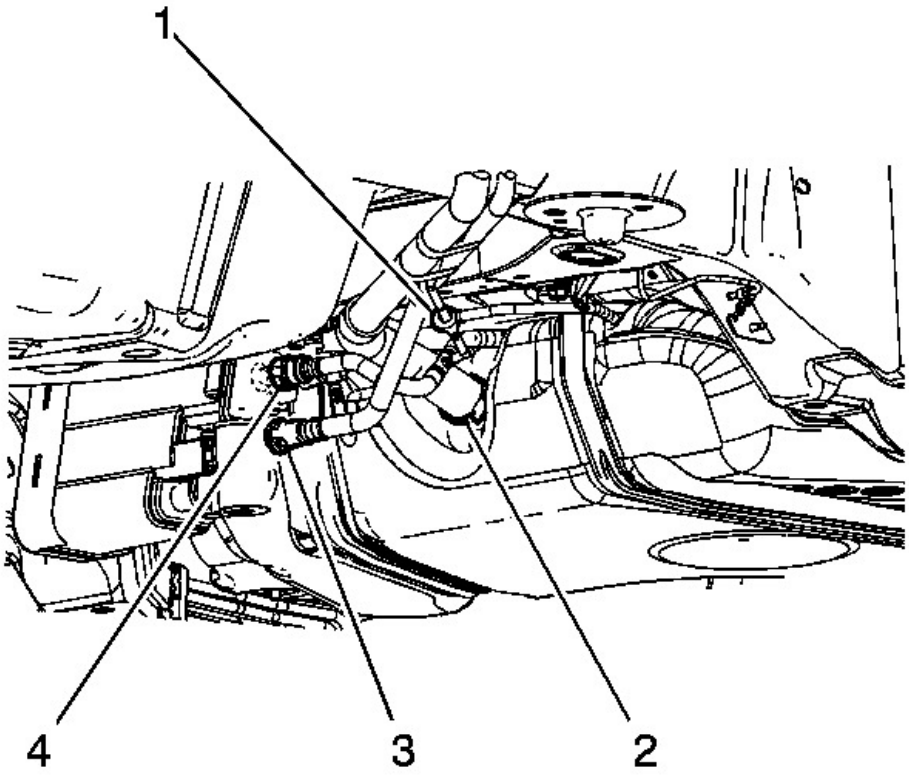


Fig. 99: Fuel Fill Pipe Hose
Courtesy of GENERAL MOTORS CORP.

2. Install the fuel fill pipe hose to the fuel tank.

NOTE: Refer to Fastener Notice .

3. Tighten the fuel fill pipe hose clamp (2) at the fuel tank.

Tighten: Tighten the clamp to 4.5 N.m (40 lb in).

4. Connect the fuel tank vent pipe quick connect fittings (1, 3). Refer to **Plastic Collar Quick Connect Fitting Service**.

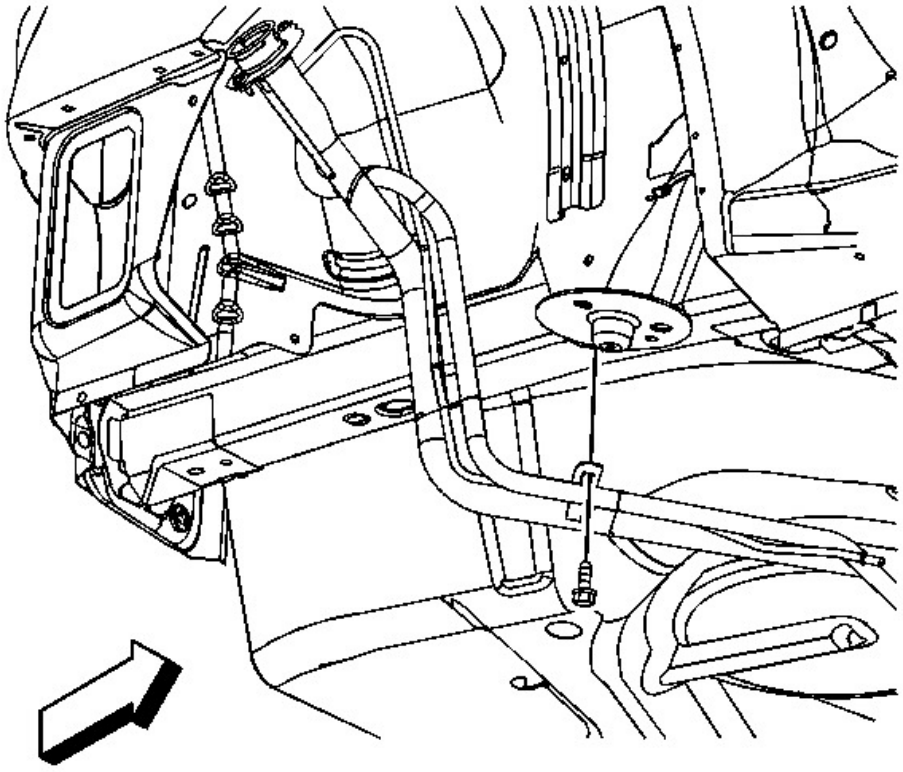


Fig. 100: Fuel Fill Pipe Lower Bolt
Courtesy of GENERAL MOTORS CORP.

5. Instal the fuel fill pipe lower bolt.

   Tighten: Tighten the bolt to 10 N.m (89 lb in).

6. Lower the vehicle.
7. Install the fuel fill pocket. Refer to **Fuel Tank Filler Pipe Housing Replacement** .

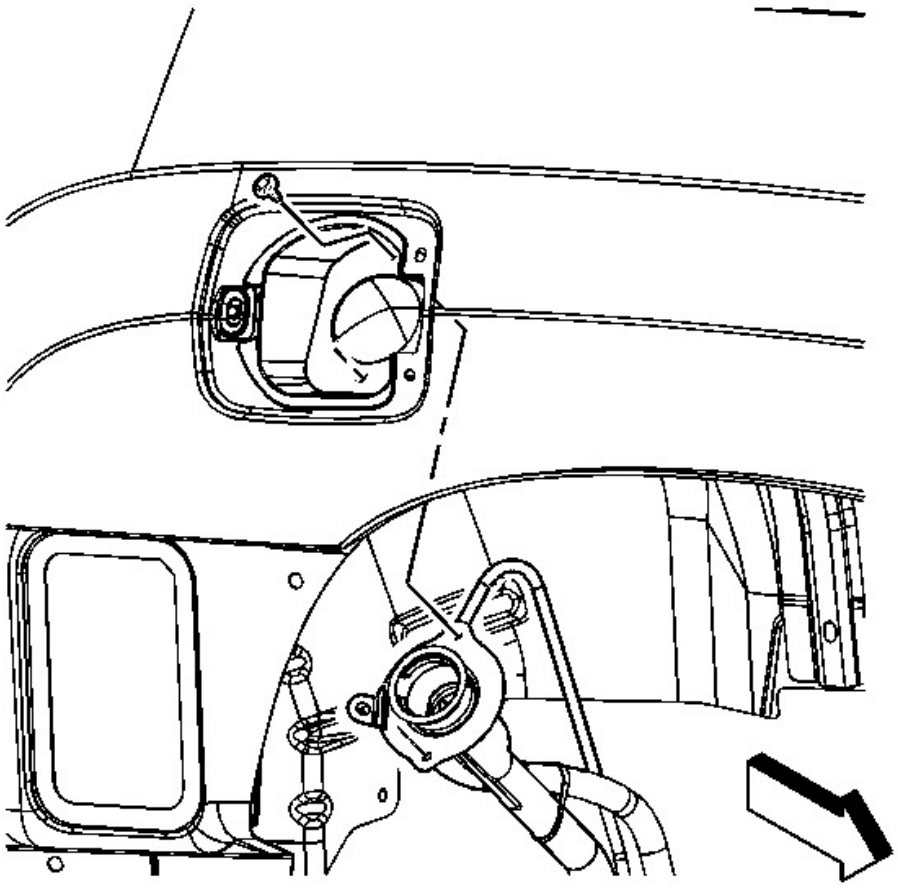


Fig. 101: Fuel Tank Filler Pipe
Courtesy of GENERAL MOTORS CORP.

8. Install the fuel fill pipe to fill pipe housing bolts.

   Tighten: Tighten the bolts to 1.5 N.m (13 lb in).

9. Refill the fuel tank.
10. Install the fuel fill cap.

FUEL HOSE/PIPES REPLACEMENT - CHASSIS

Removal Procedure

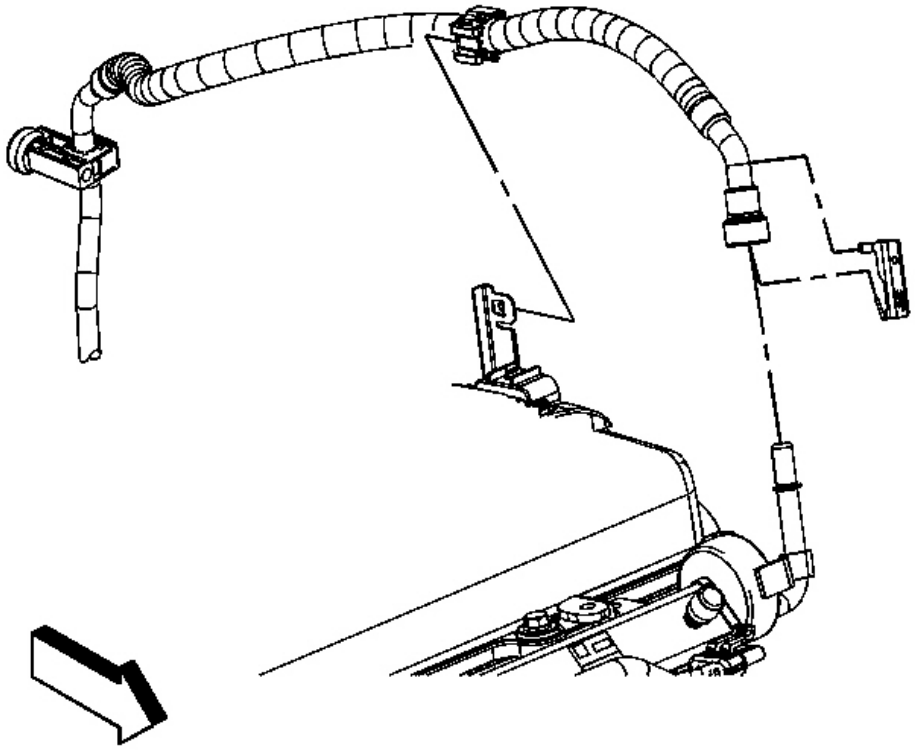


Fig. 102: Fuel Feed Line

Courtesy of GENERAL MOTORS CORP.

1. Relieve the fuel system pressure. Refer to **Fuel Pressure Relief (With CH 48027)** or **Fuel Pressure Relief (Without CH 48027)**.
2. Remove the air cleaner assembly. Refer to **Air Cleaner Assembly Replacement**.
3. Disconnect the fuel feed pipe from the fuel rail. Refer to **Metal Collar Quick Connect Fitting Service** .
4. Cap or plug the fuel pipe and the engine fuel rail to prevent contamination.

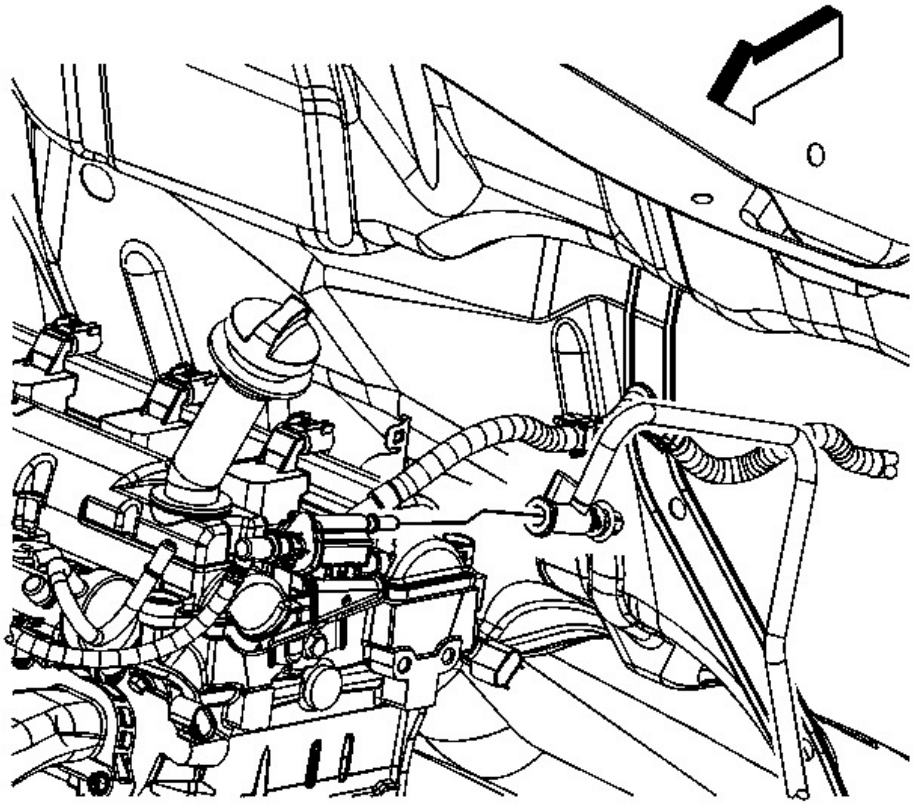


Fig. 103: EVAP Line
Courtesy of GENERAL MOTORS CORP.

5. Disconnect the evaporative emission (EVAP) pipe from the purge solenoid. Refer to **Plastic Collar Quick Connect Fitting Service**.
6. Cap or plug the EVAP pipe in order to prevent contamination.
7. Raise and support the vehicle. Refer to **Lifting and Jacking the Vehicle** .
8. Remove the evaporative emission (EVAP) canister, if necessary. Refer to **Evaporative Emission Canister Replacement**.

9. Disconnect the fuel feed pipe quick connect fitting. Refer to **Plastic Collar Quick Connect Fitting Service**.

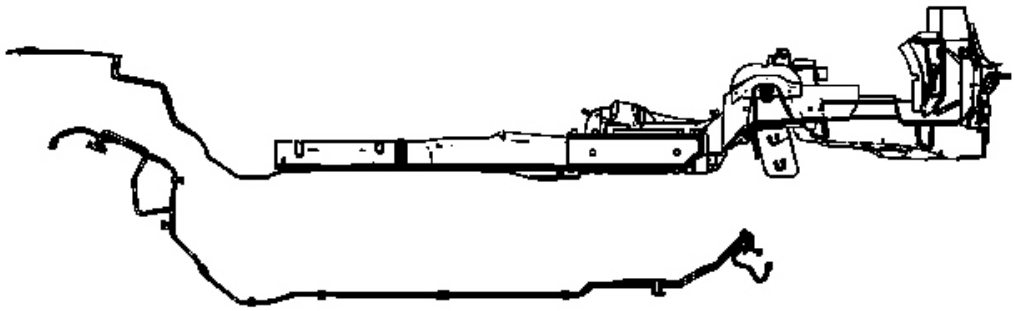


Fig. 104: Fuel/EVAP/Brake Line Brackets
Courtesy of GENERAL MOTORS CORP.

10. Remove the brake lines from the fuel/EVAP/brake line brackets.
11. Remove the fuel/EVAP/brake line bracket nuts and remove the brackets from the body studs.
12. Remove the fuel and EVAP lines from the vehicle.
13. Open the brackets and remove the fuel feed pipe.

Installation Procedure

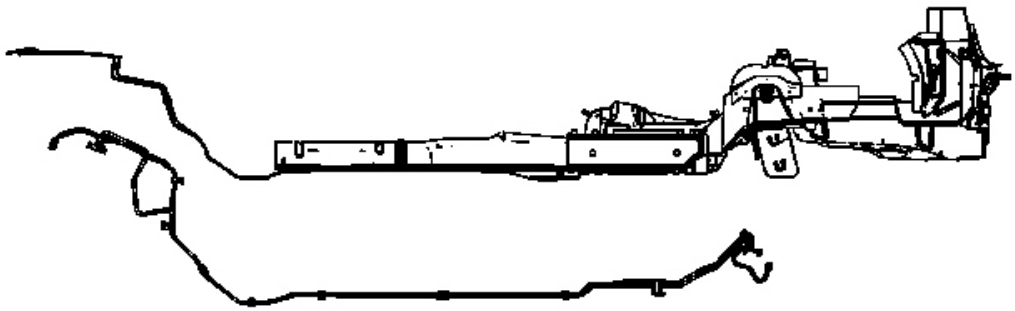


Fig. 105: Fuel/EVAP/Brake Line Brackets
Courtesy of GENERAL MOTORS CORP.

1. Install the fuel feed pipe to the brackets and close the covers.
2. Install the fuel and EVAP lines to the vehicle.
3. Install the fuel/EVAP/brake line bracket to the body studs.

NOTE: Refer to Fastener Notice .

4. Install the fuel/EVAP/brake line bracket nuts.

   Tighten: Tighten the nuts to 10 N.m (89 lb in).

5. Install the brake lines to the fuel/EVAP/brake line brackets.

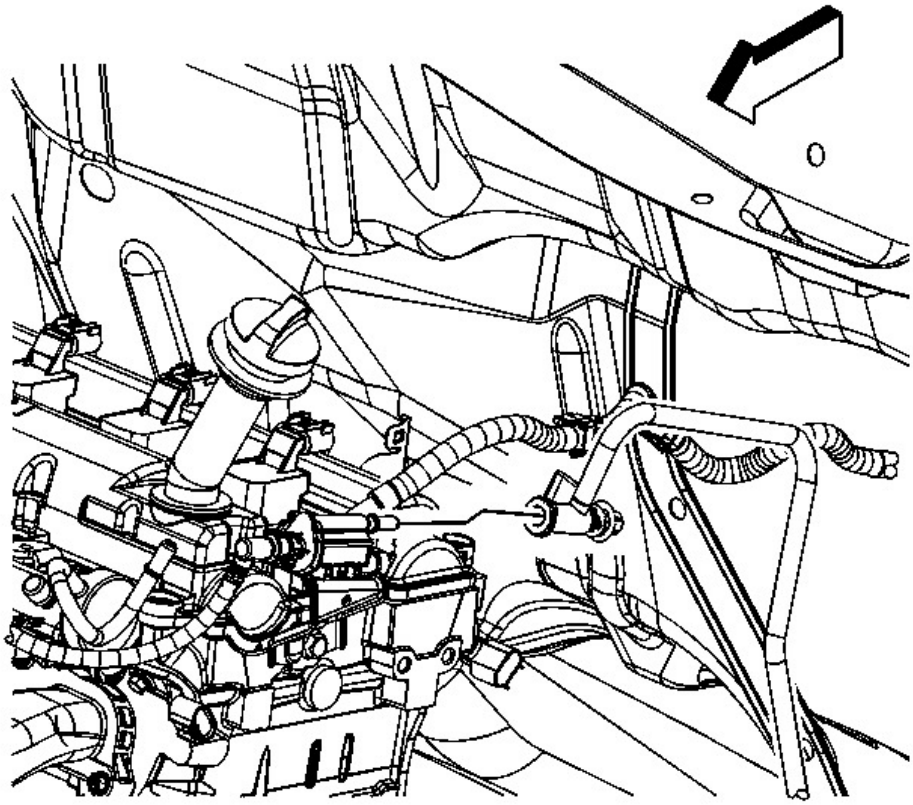


Fig. 106: EVAP Line
Courtesy of GENERAL MOTORS CORP.

6. Connect the fuel feed pipe quick connect fitting. Refer to **Plastic Collar Quick Connect Fitting Service**.
7. Install the canister, if necessary. Refer to **Evaporative Emission Canister Replacement**.
8. Lower the vehicle.
9. Remove the cap or plug from the EVAP pipe.

10. Connect the EVAP pipe to the purge solenoid. Refer to **Plastic Collar Quick Connect Fitting Service**.

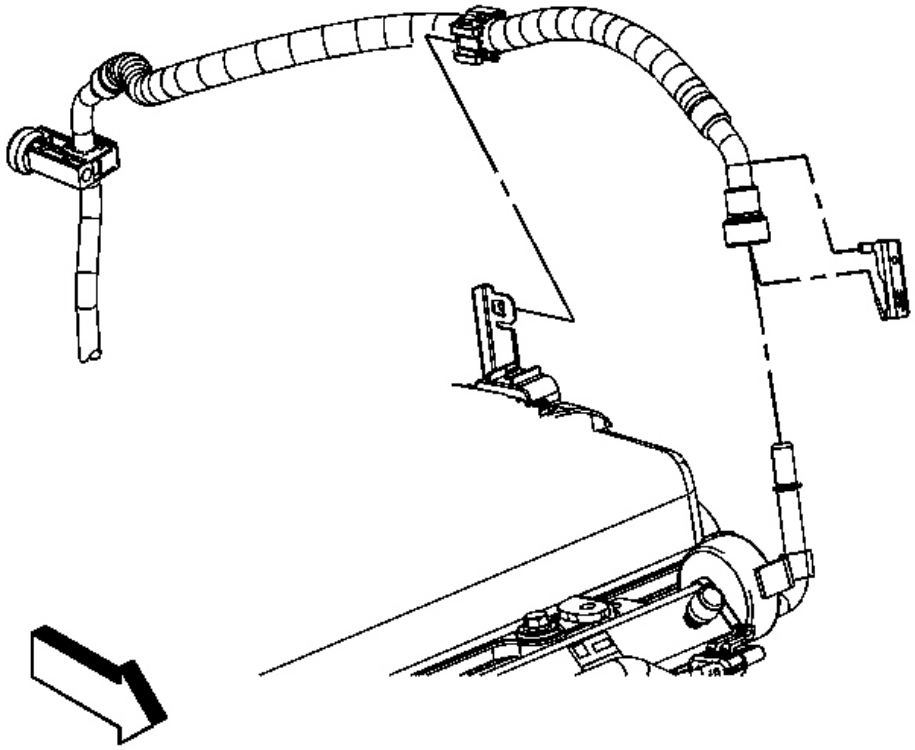


Fig. 107: Fuel Feed Line
Courtesy of GENERAL MOTORS CORP.

11. Remove the cap or plug from the fuel pipe and the engine fuel rail.
12. Connect the fuel feed pipe to the fuel rail. Refer to **Metal Collar Quick Connect Fitting Service** .
13. Install the air cleaner assembly. Refer to **Air Cleaner Assembly**

Replacement.

14. Connect the negative battery cable. Refer to **Battery Negative Cable Disconnection and Connection** .
15. Inspect for fuel leaks using the following procedure:
    1. Turn ON the ignition, with the engine OFF for 2 seconds.
    2. Turn OFF the ignition for 10 seconds.
    3. Turn ON the ignition, with the engine OFF.
    4. Inspect for fuel leaks.

FUEL PUMP FUEL FEED HOSE REPLACEMENT

Removal Procedure

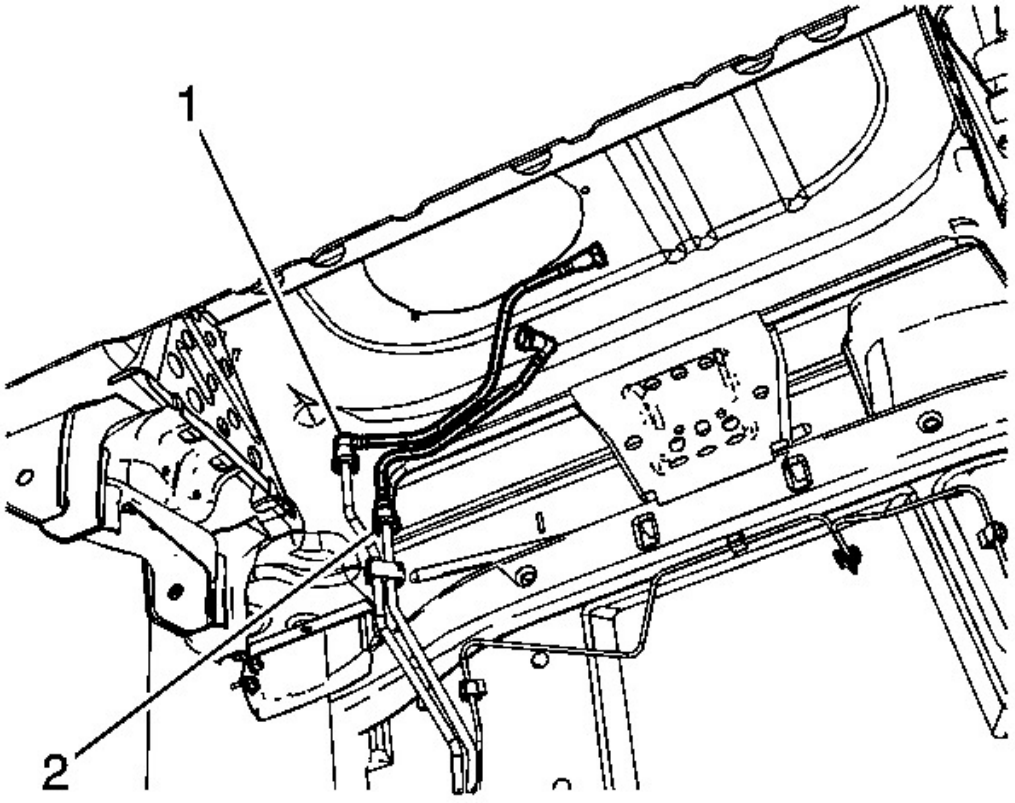


Fig. 108: Fuel Feed Line Quick Connect Fittings

Courtesy of GENERAL MOTORS CORP.

1. Remove the fuel tank. Refer to **Fuel Tank Replacement**.
2. Disconnect the fuel pump fuel feed line quick connect fitting (2) from the chassis line. Refer to **Plastic Collar Quick Connect Fitting Service**.
3. Remove the fuel pump fuel feed line.

Installation Procedure

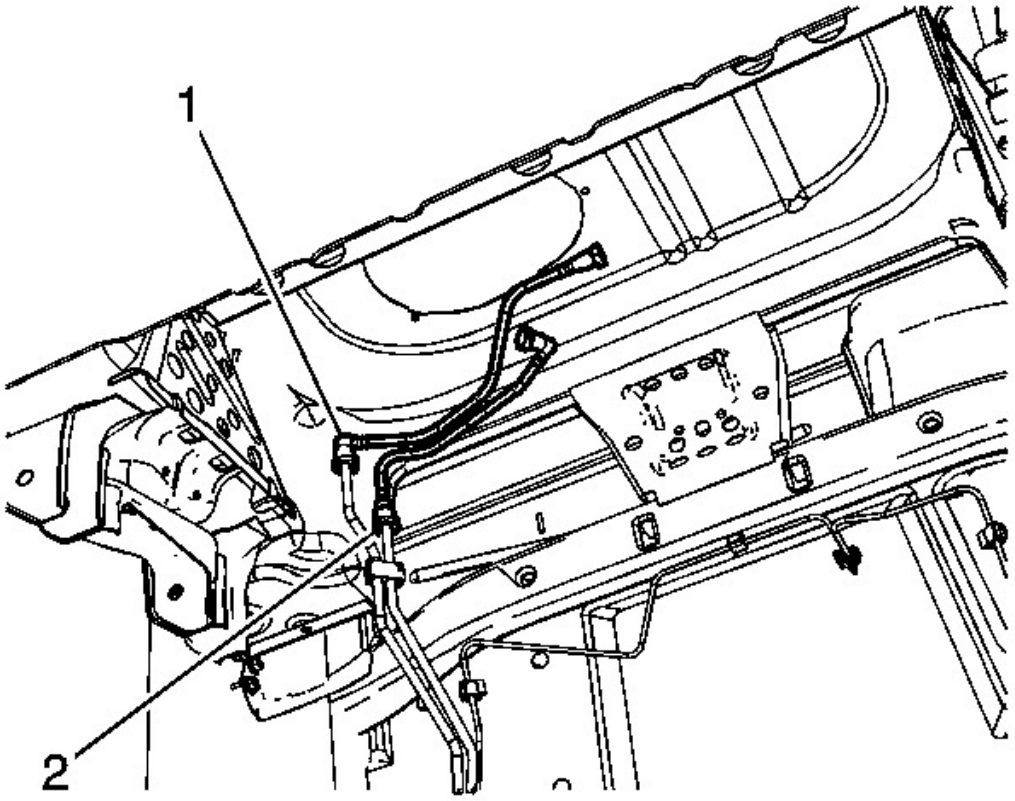


Fig. 109: Fuel Feed Line Quick Connect Fittings
Courtesy of GENERAL MOTORS CORP.

1. Install the fuel pump fuel feed line.
2. Connect the fuel pump fuel feed line quick connect fitting (2) to the chassis

line. Refer to **Plastic Collar Quick Connect Fitting Service**.

3. Install the fuel tank. Refer to **Fuel Tank Replacement**.

FUEL SYSTEM CLEANING

IMPORTANT: If the fuel filter is plugged, the fuel tank should be inspected internally and cleaned if necessary.

1. Remove the fuel pump module. Refer to **Fuel Pump Module Replacement**.
2. Inspect the fuel pump module strainer. Replace the pump module if the fuel strainer is contaminated.

IMPORTANT: When flushing the fuel tank, handle the fuel and water mixture as a hazardous material. Handle the fuel and water in accordance with all applicable local, state, and federal laws and regulations.

3. Flush the fuel tank with hot water.
4. Pour the water out of the fuel sender assembly opening in the fuel tank. Rock the fuel tank in order to be sure that the removal of the water from the fuel tank is complete.
5. Allow the tank to dry completely before reassembly.
6. Disconnect the fuel feed pipe at the engine fuel rail. Refer to **Metal Collar Quick Connect Fitting Service** .

IMPORTANT: Only use oil-free compressed air to blow out the fuel pipes.

7. Clean the fuel pipes by applying air pressure in the opposite direction of the fuel flow.
8. Connect the fuel feed pipe to the engine fuel rail. Refer to **Metal Collar Quick Connect Fitting Service** .
9. Install the fuel pump module. Refer to **Fuel Pump Module Replacement**.

FUEL FEED PIPE REPLACEMENT

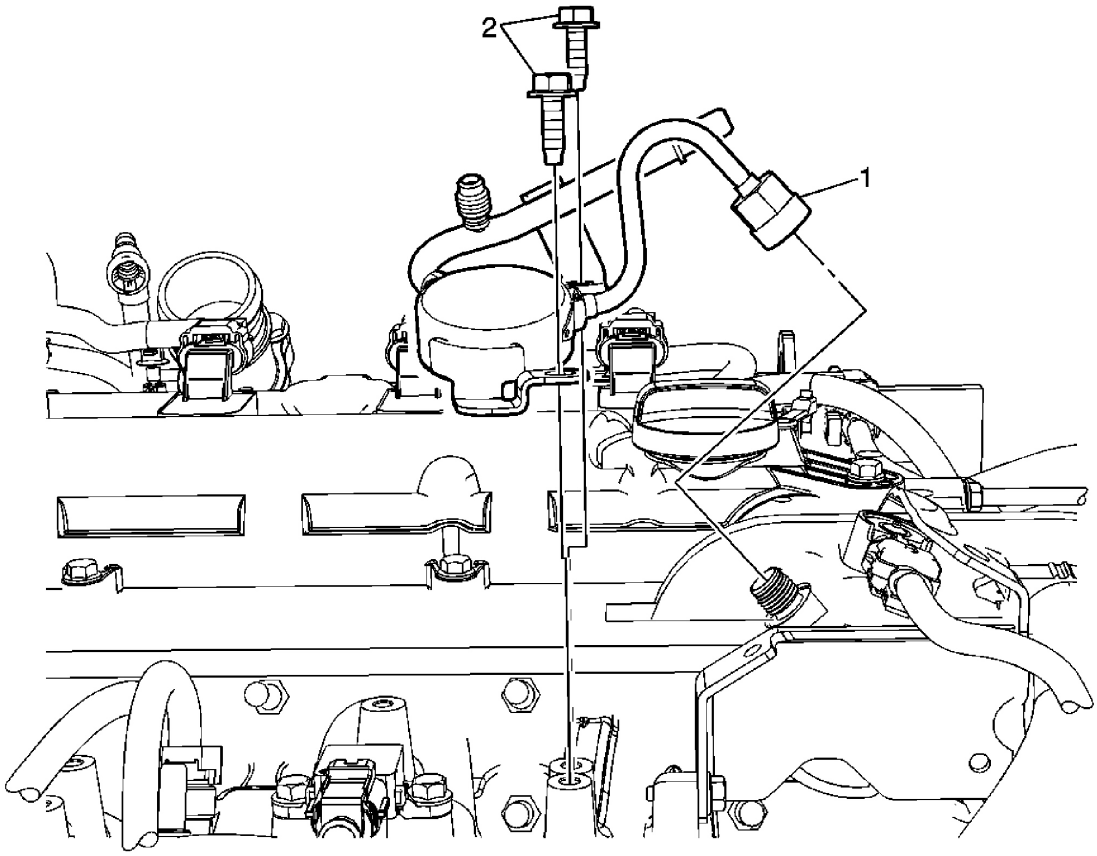


Fig. 110: Fuel Feed Pipe
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
Preliminary Procedures 1. Relieve the low side fuel system pressure. Refer to **Fuel Pressure Relief (Without CH 48027)** or **Fuel Pressure Relief (With CH 48027)**. 2. Disconnect the fuel feed line quick connect fitting from the fuel feed pipe. Refer to **Metal Collar Quick Connect Fitting Service**.	
1	High Pressure Fuel Pump Fitting **NOTE:** **Refer to Fastener Notice .** **Procedure:**

	Lubricate the fuel feed pipe and the high pressure fuel pump fitting with silicon-free engine oil GM P/N 12345610 (Canadian P/N 993193) or equivalent. **Tighten:** 32 N.m (24 lb ft)
2	Fuel Feed Pipe Bolt (Qty: 2) **Tighten:** 10 N.m (89 lb in)

FUEL FEED INTERMEDIATE PIPE REPLACEMENT

Removal Procedure

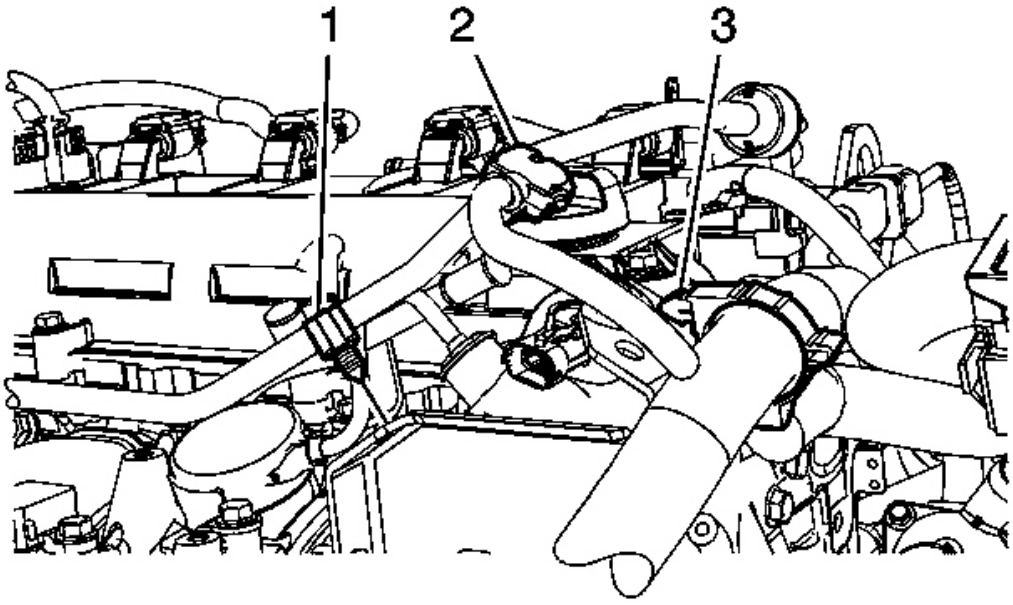


Fig. 111: Identifying High Pressure Fuel Pump Electrical Harness & Connector
Courtesy of GENERAL MOTORS CORP.

1. Relieve the high side fuel system pressure. Refer to **Fuel Pressure Relief (Without CH 48027)** or **Fuel Pressure Relief (With CH 48027)**.

2. Remove and reposition the evaporative emission retaining clip (1) from the high pressure fuel pump cover.
3. Disconnect the high pressure fuel pump electrical connector (2).
4. Remove the engine wiring harness clip (3) from the high pressure fuel pump cover and reposition the engine wire harness out of the way.

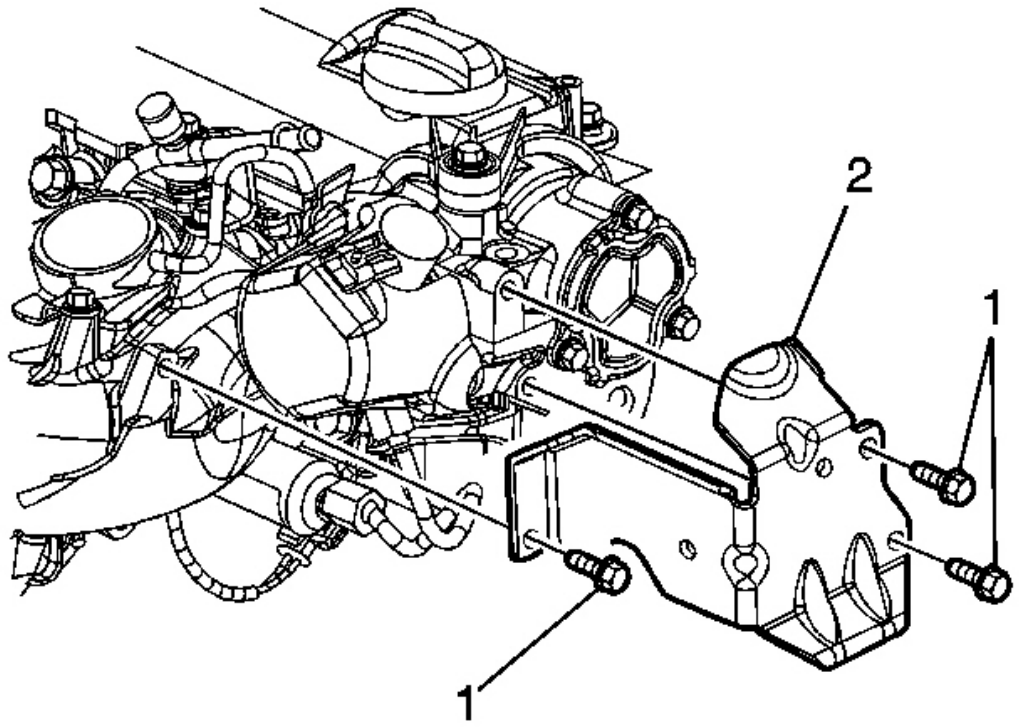


Fig. 112: View Of High Pressure Fuel Pump Cover & Bolts
Courtesy of GENERAL MOTORS CORP.

5. Remove the high pressure fuel pump cover bolts (1) and cover (2).

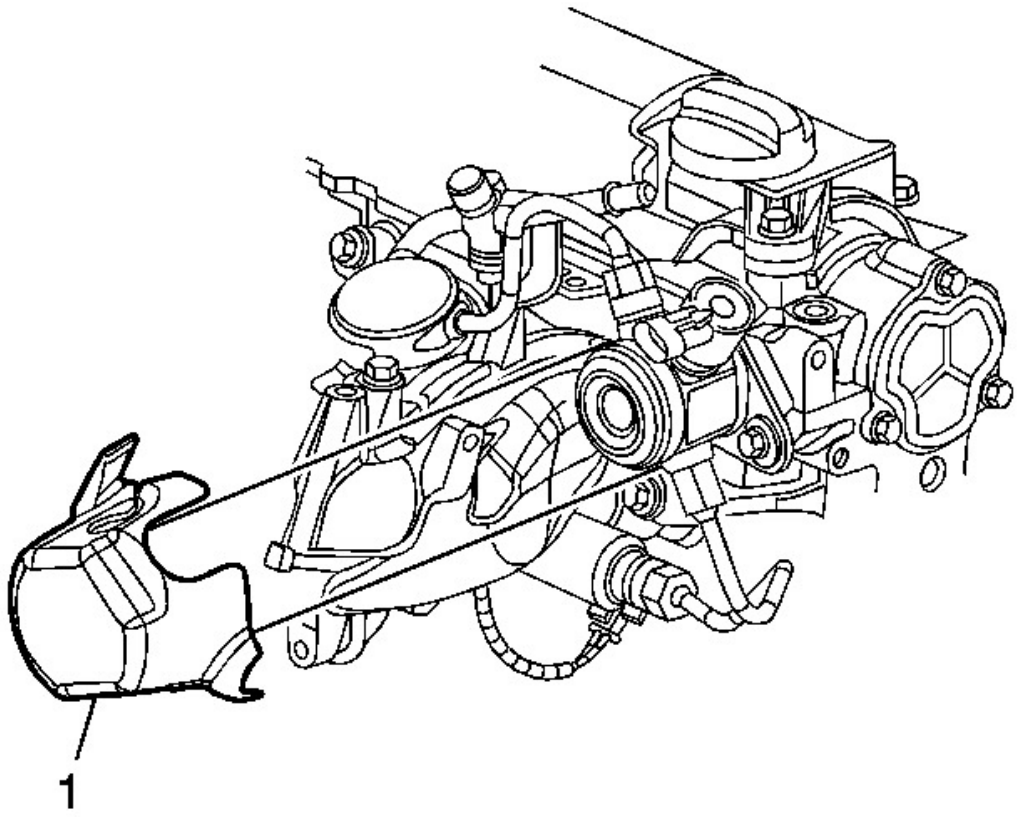


Fig. 113: View Of High Pressure Fuel Pump Insulator
Courtesy of GENERAL MOTORS CORP.

6. Remove the high pressure fuel pump insulator (1).

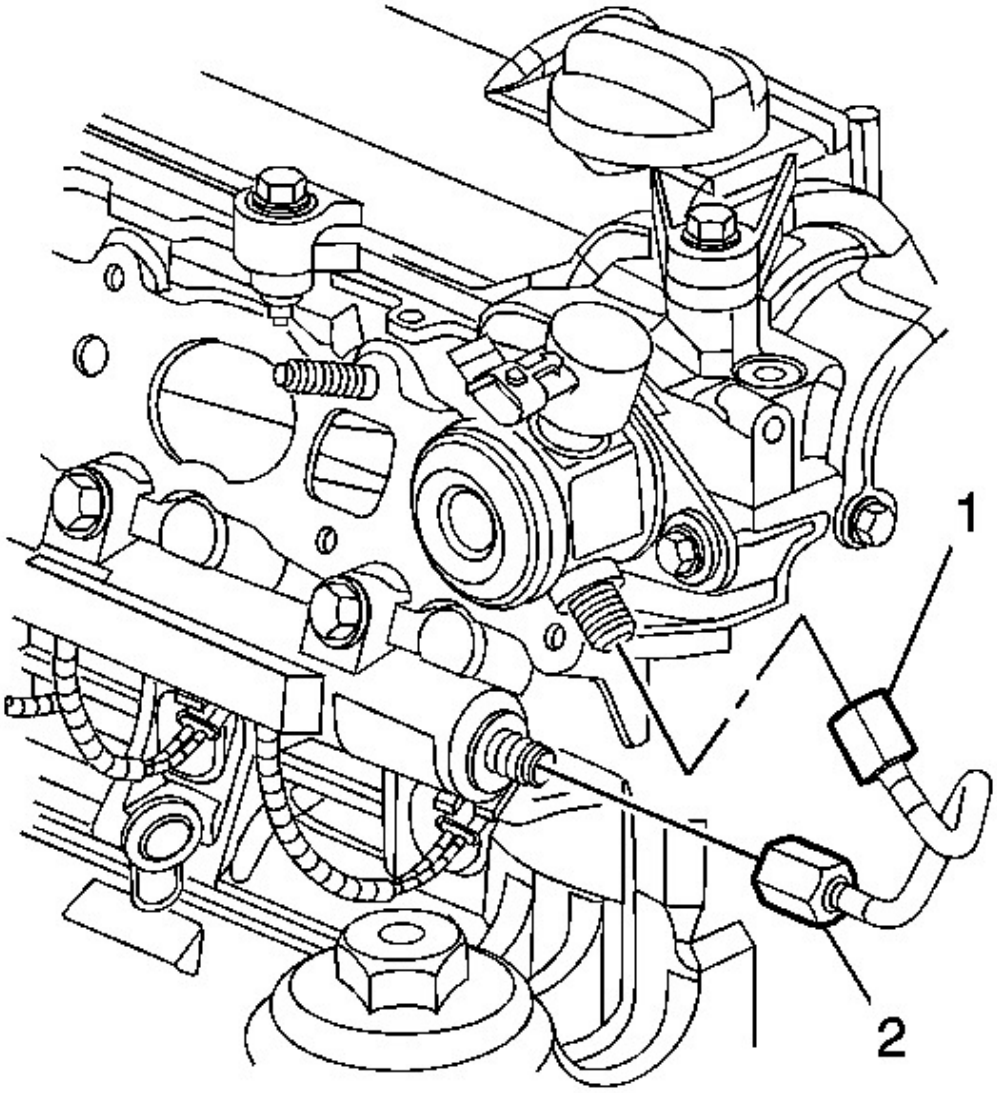


Fig. 114: View Of Fuel Feed Intermediate Pipe Fittings
Courtesy of GENERAL MOTORS CORP.

7. Loosen the fuel feed intermediate pipe fittings at the fuel pump (1) and the fuel rail (2).
8. Remove and discard the fuel feed intermediate pipe.

Installation Procedure

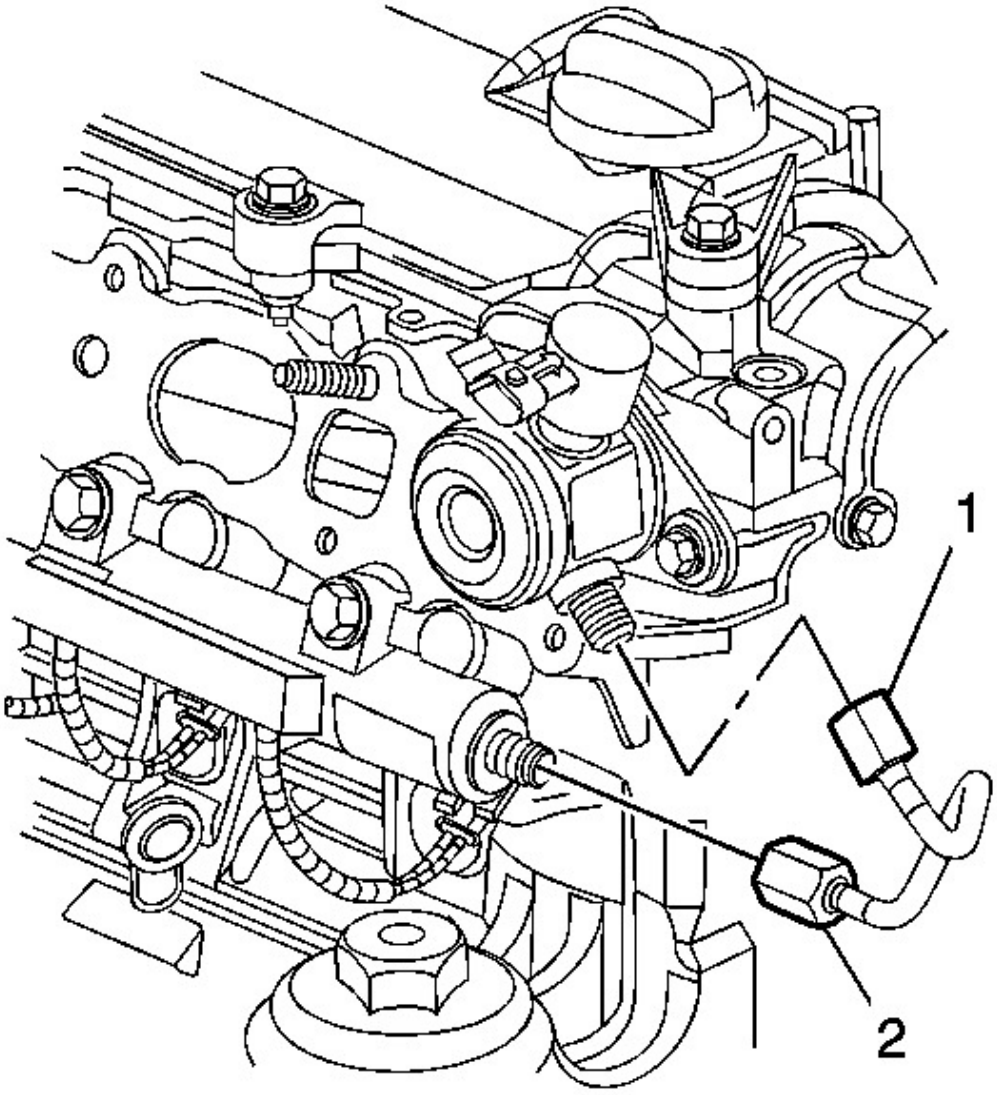


Fig. 115: View Of Fuel Feed Intermediate Pipe Fittings
Courtesy of GENERAL MOTORS CORP.

1. Ensure that the high pressure fuel pump, and fuel rail fittings are clean prior to assembly.

2. Install the NEW fuel feed intermediate pipe and start the fittings hand tight.
3. Tighten the fuel feed intermediate pipe fittings at the fuel pump (1) and the fuel rail (2).

NOTE: Refer to Fastener Notice .

4. **Tighten:** Tighten the fittings to 32 N.m (24 lb ft).

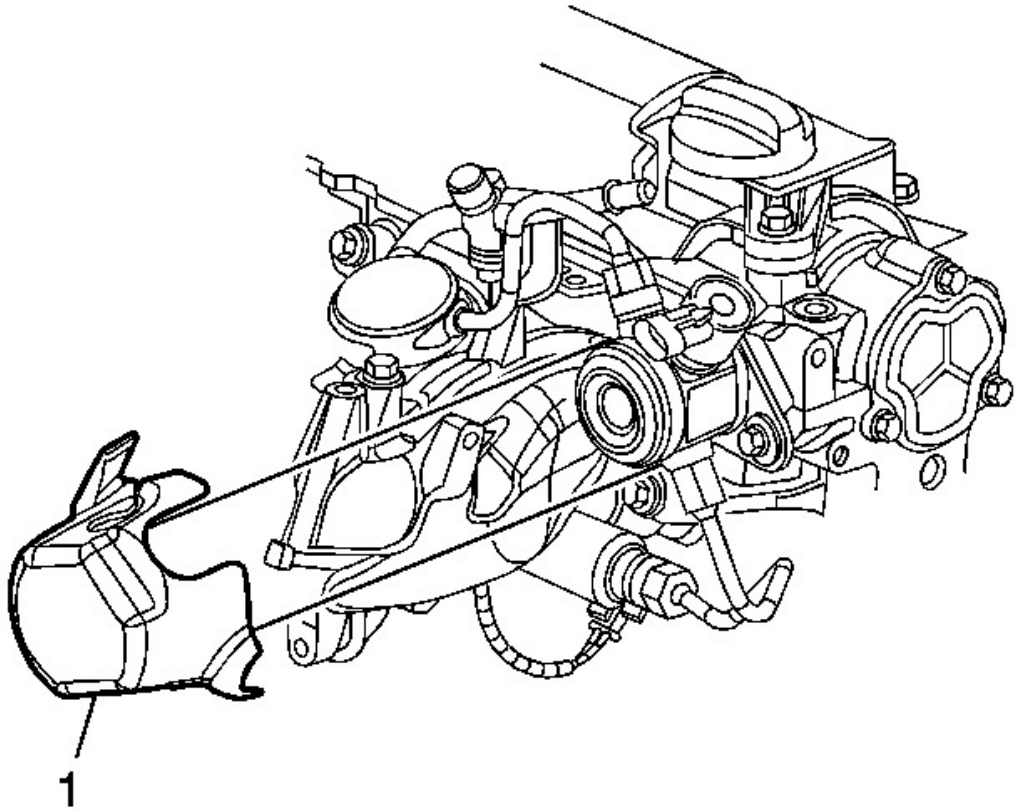


Fig. 116: View Of High Pressure Fuel Pump Insulator
Courtesy of GENERAL MOTORS CORP.

5. Install the high pressure fuel pump insulator (1).

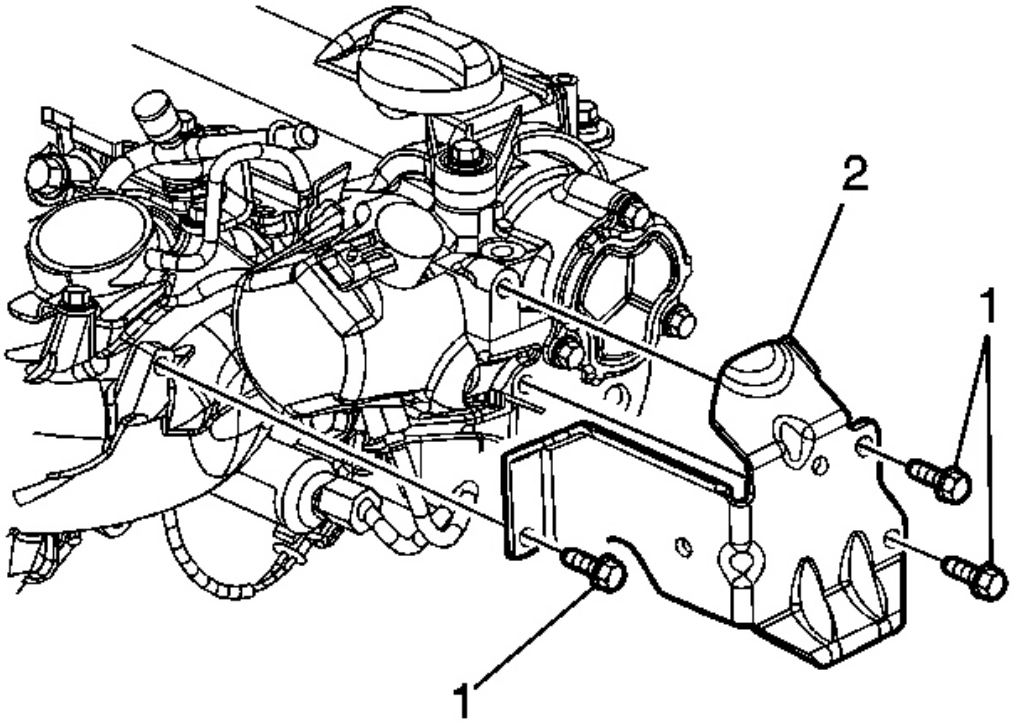


Fig. 117: View Of High Pressure Fuel Pump Cover & Bolts
Courtesy of GENERAL MOTORS CORP.

6. Install the high pressure fuel pump cover bolts (1) and cover (2).

   Tighten: Tighten the cover bolts to 10 N.m (89 lb in).

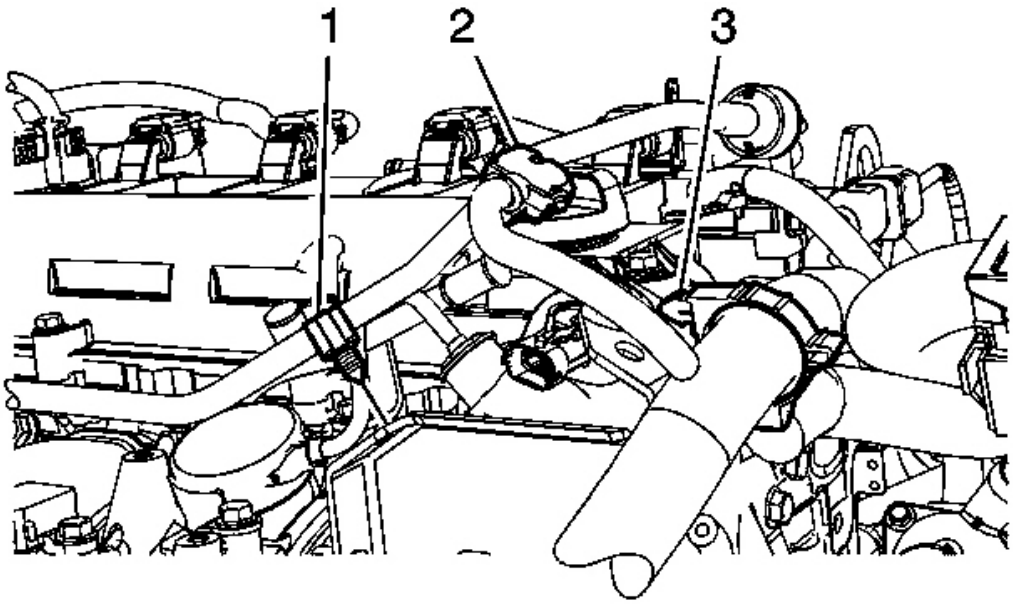


Fig. 118: Identifying High Pressure Fuel Pump Electrical Harness & Connector
Courtesy of GENERAL MOTORS CORP.

7. Install the evaporative emission retaining clip (1) to the high pressure fuel pump cover.
8. Install the engine wiring harness clip (3) to the high pressure fuel pump cover.
9. Connect the high pressure fuel pump electrical connector (2).
10. Install the engine wiring harness clip (3) to the high pressure fuel pump cover and reposition the engine wire harness.
11. Inspect for leaks using the following procedure:
    1. Turn ON the ignition, with the engine OFF for 2 seconds.
    2. Turn OFF the ignition, for 10 seconds.
    3. Turn ON the ignition, with the engine OFF.
    4. Inspect for fuel leaks.
12. Install the low side fuel pressure service port cap.

13. Tighten the fuel fill cap.

FUEL INJECTION FUEL RAIL ASSEMBLY REPLACEMENT

Removal Procedure

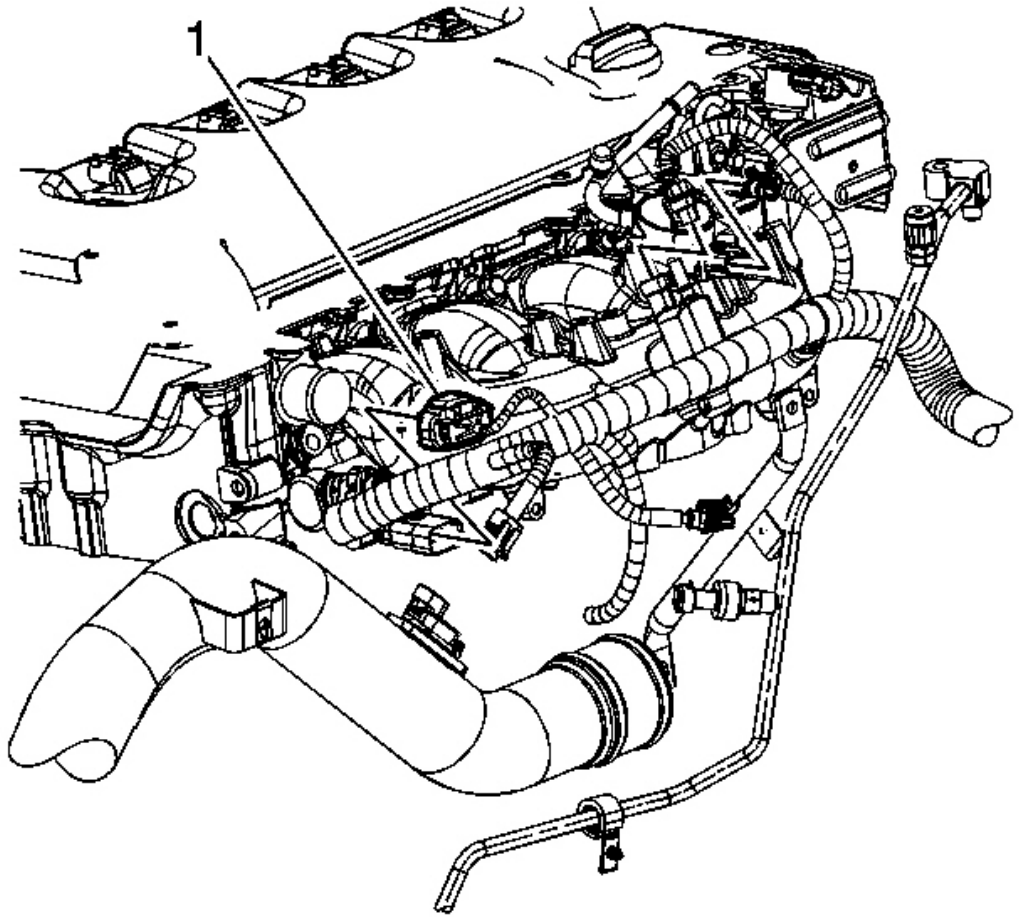


Fig. 119: Identifying Engine Wiring Harness Connector & Fuel Injector Wiring Harness Connector
Courtesy of GENERAL MOTORS CORP.

1. Disconnect the engine wiring harness electrical connector (1) from the fuel injector wiring harness electrical connector.

2. Remove the intake manifold. Refer to **Intake Manifold Replacement** .

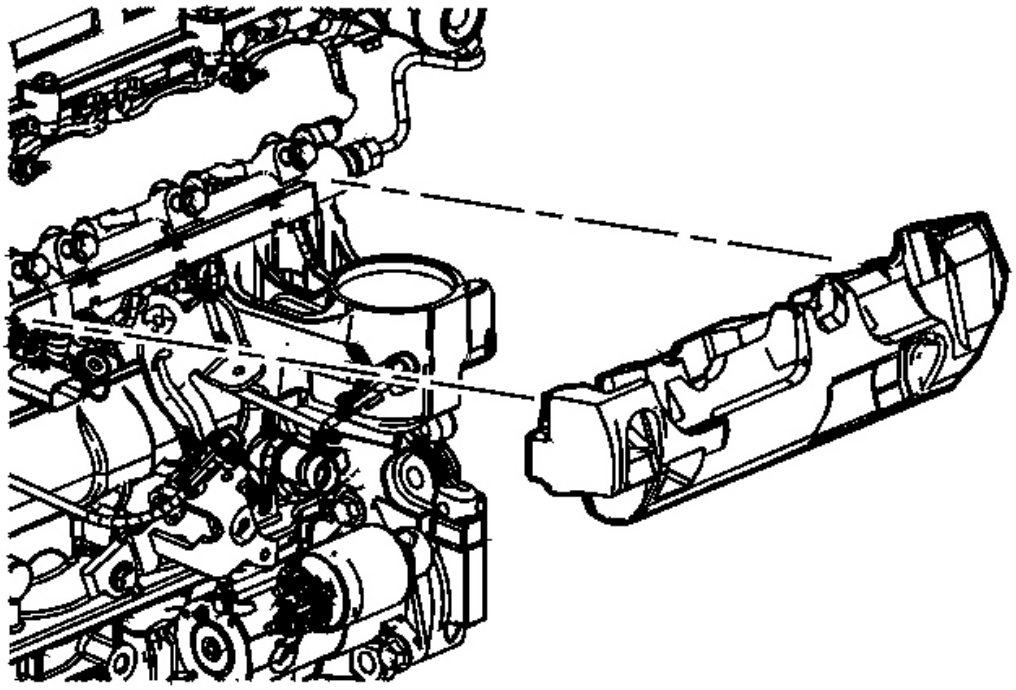


Fig. 120: Fuel Injector Insulator
Courtesy of GENERAL MOTORS CORP.

3. Remove the fuel injector insulator.

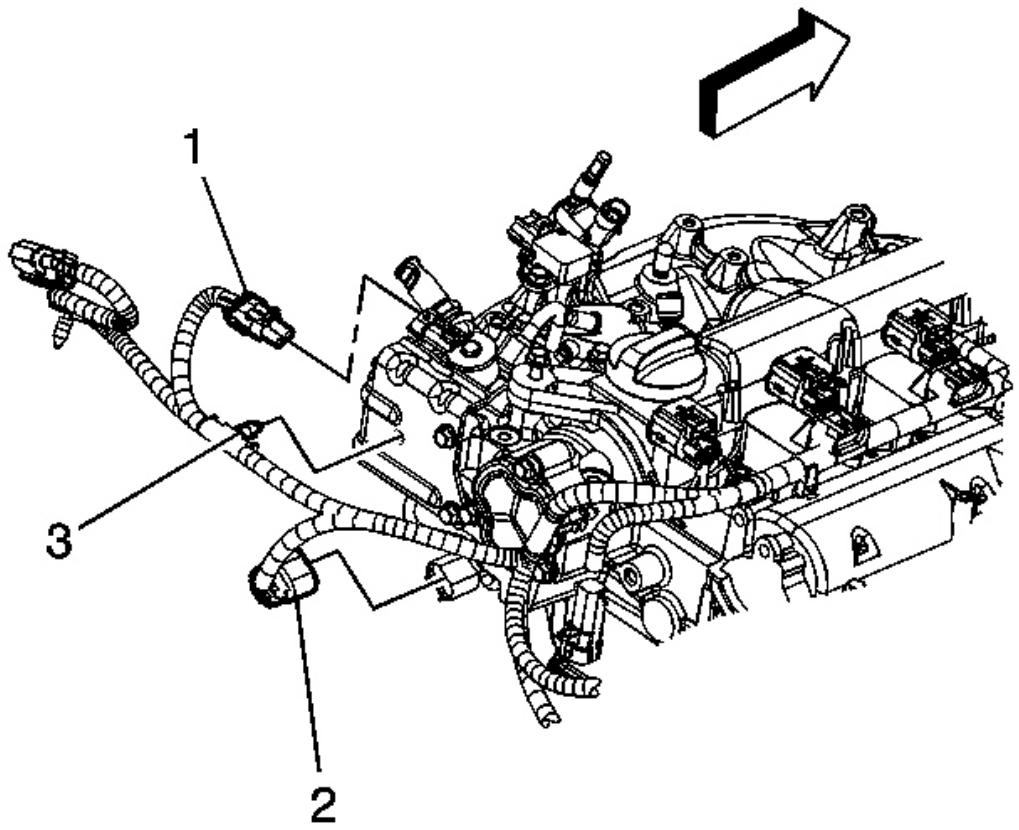


Fig. 121: High Pressure Fuel Pump Connector & Clip
Courtesy of GENERAL MOTORS CORP.

4. Relieve the high side fuel system pressure. Refer to **Fuel Pressure Relief (Without CH 48027)** or **Fuel Pressure Relief (With CH 48027)**.
5. Disconnect the engine wiring harness electrical connector (1) from the high pressure fuel pump.
6. Remove the intermediate fuel pipe. Refer to **Fuel Feed Intermediate Pipe Replacement**.

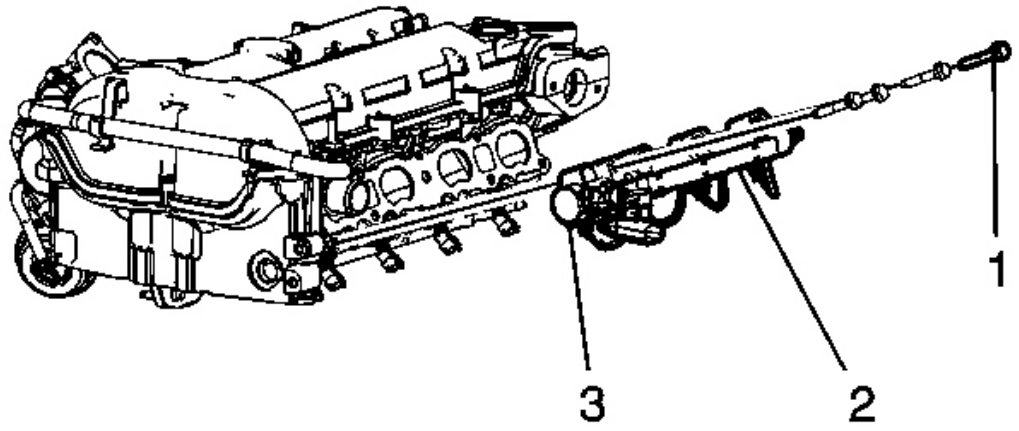


Fig. 122: Fuel Rail Bolts
Courtesy of GENERAL MOTORS CORP.

7. Disconnect the fuel injector wiring harness electrical connectors from the fuel injectors.
8. Remove the fuel rail bolts (1).

IMPORTANT: Carefully remove the fuel rail. The fuel injectors may come out of the cylinder head with the fuel rail.

9. Carefully remove the fuel rail (2).
10. If the fuel injectors have been removed with the fuel rail, reinstall the injectors. Refer to **Direct Fuel Injector Replacement**.

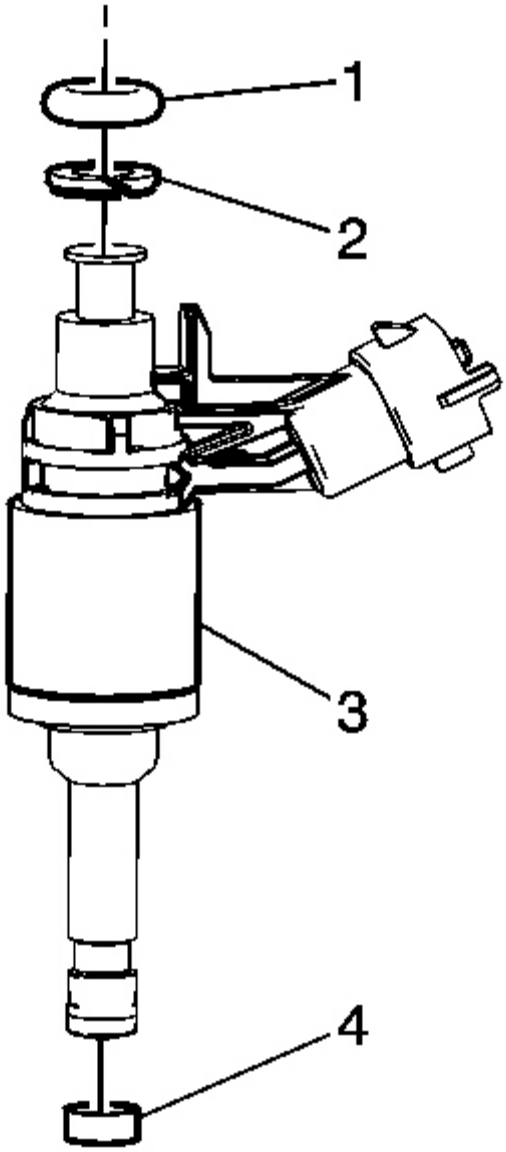


Fig. 123: Fuel Injector
Courtesy of GENERAL MOTORS CORP.

11. Remove and discard the fuel injector upper O-ring seal (1).
12. Inspect the plastic spacer (2) for damage, remove if damaged.

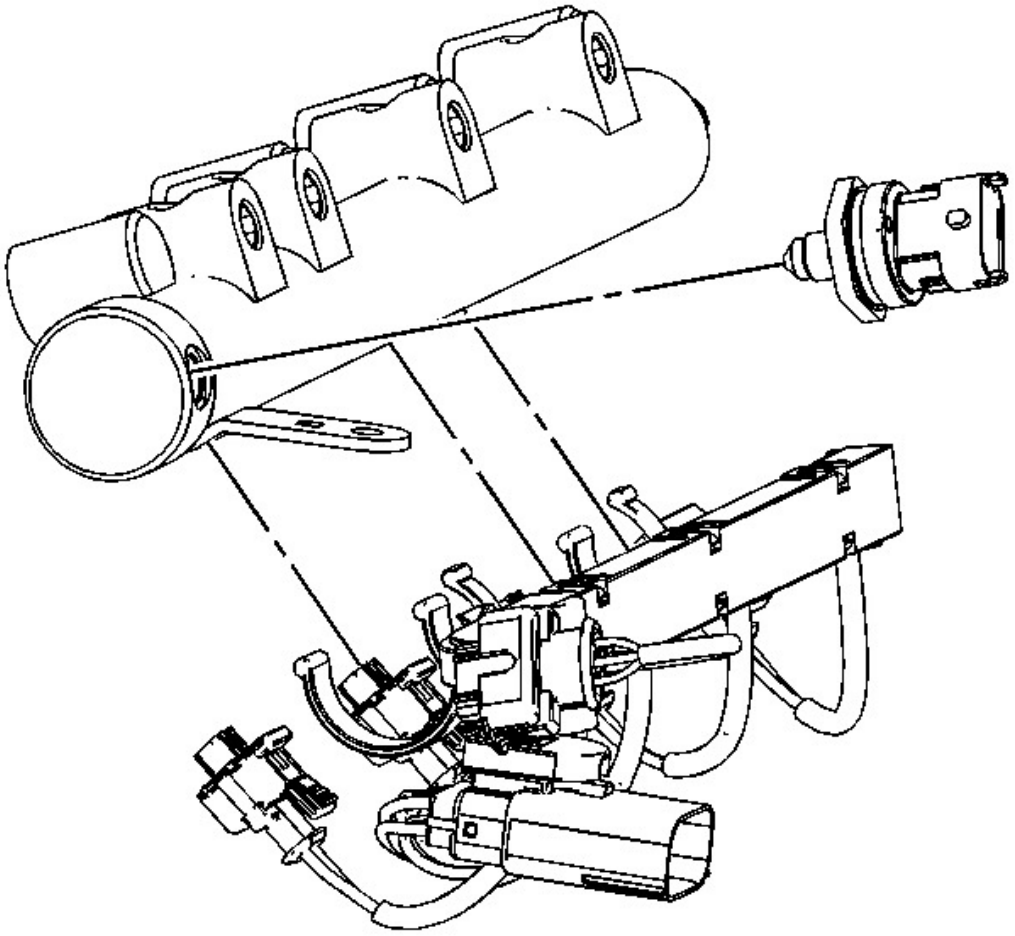


Fig. 124: Fuel Rail Fuel Pressure Sensor
Courtesy of GENERAL MOTORS CORP.

IMPORTANT: Applying force to the plastic housing of the sensor will destroy the sensor. To tighten or loosen, only apply force to the attached hexagon.

13. If replacing the fuel rail, remove the fuel injection fuel rail fuel pressure sensor.
14. Remove the fuel injector wiring harness.

Installation Procedure

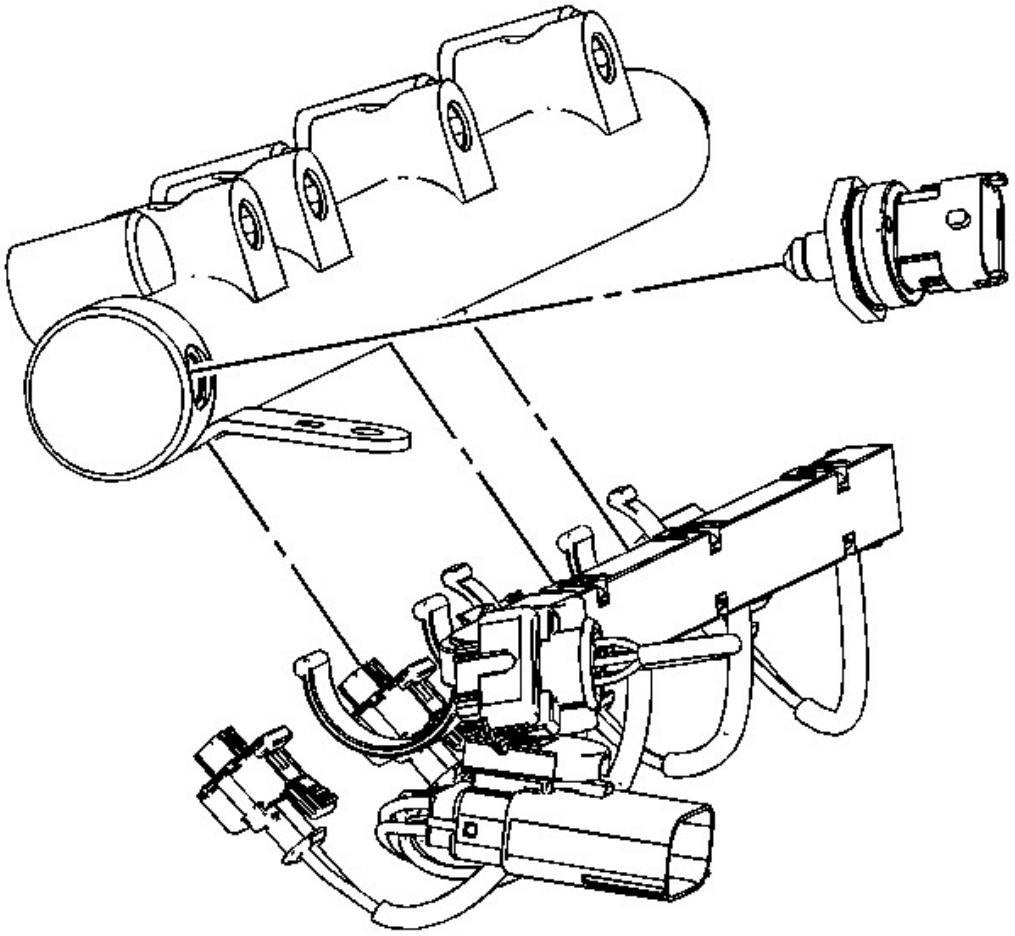


Fig. 125: Fuel Rail Fuel Pressure Sensor
Courtesy of GENERAL MOTORS CORP.

1. If the fuel rail was replaced, Lubricate the threads and sealing cone of the NEW fuel rail with silicon free engine oil GM P/N 12345610 (Canadian P/N 993193) or equivalent.
2. Lubricate the threads and sealing cone of the sensor with silicon free engine oil GM P/N 12345610 (Canadian P/N 993193) or equivalent.

IMPORTANT: Applying force to the plastic housing of the sensor will destroy the sensor. To tighten or loosen, only

apply force to the attached hexagon.

NOTE: Refer to Fastener Notice .

3. Install the fuel injection fuel rail fuel pressure sensor.

   Tighten: Tighten the sensor to 33 N.m (25 lb ft).

4. Install the fuel injector wiring harness.

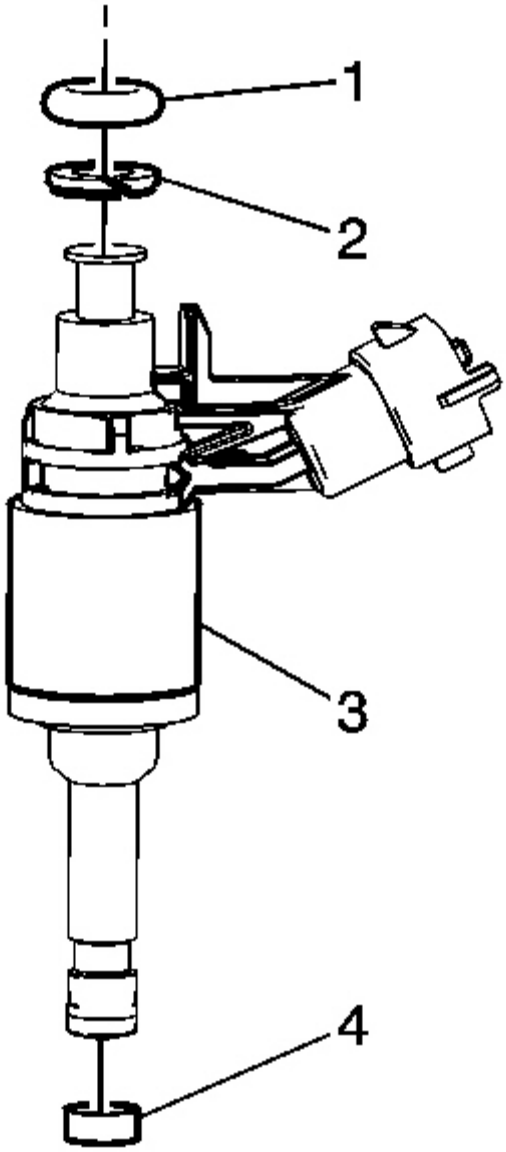


Fig. 126: Fuel Injector
Courtesy of GENERAL MOTORS CORP.

5. Install a NEW plastic spacer (2) if the old one was damaged.
6. Lubricate a NEW fuel injector upper O-ring seal (1) with silicon free engine oil

GM P/N 12345610 (Canadian P/N 993193) or equivalent.

7. Install the NEW fuel injector upper O-ring seal (1).

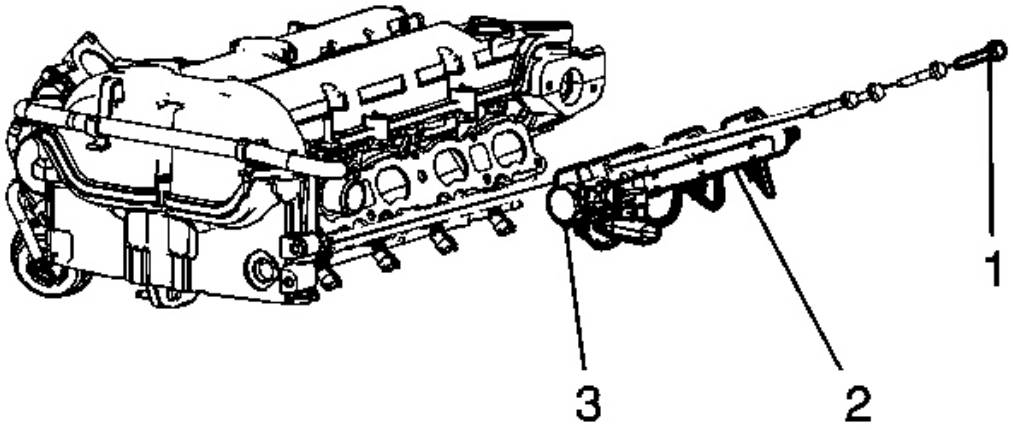


Fig. 127: Fuel Rail Bolts
Courtesy of GENERAL MOTORS CORP.

8. Place the fuel rail (2) into position.
9. Install the 2 outer fuel rail bolts (1) first hand tight, and then install the remaining 2 bolts, hand tight.
10. Connect the fuel injector wiring harness electrical connectors to the fuel injectors.

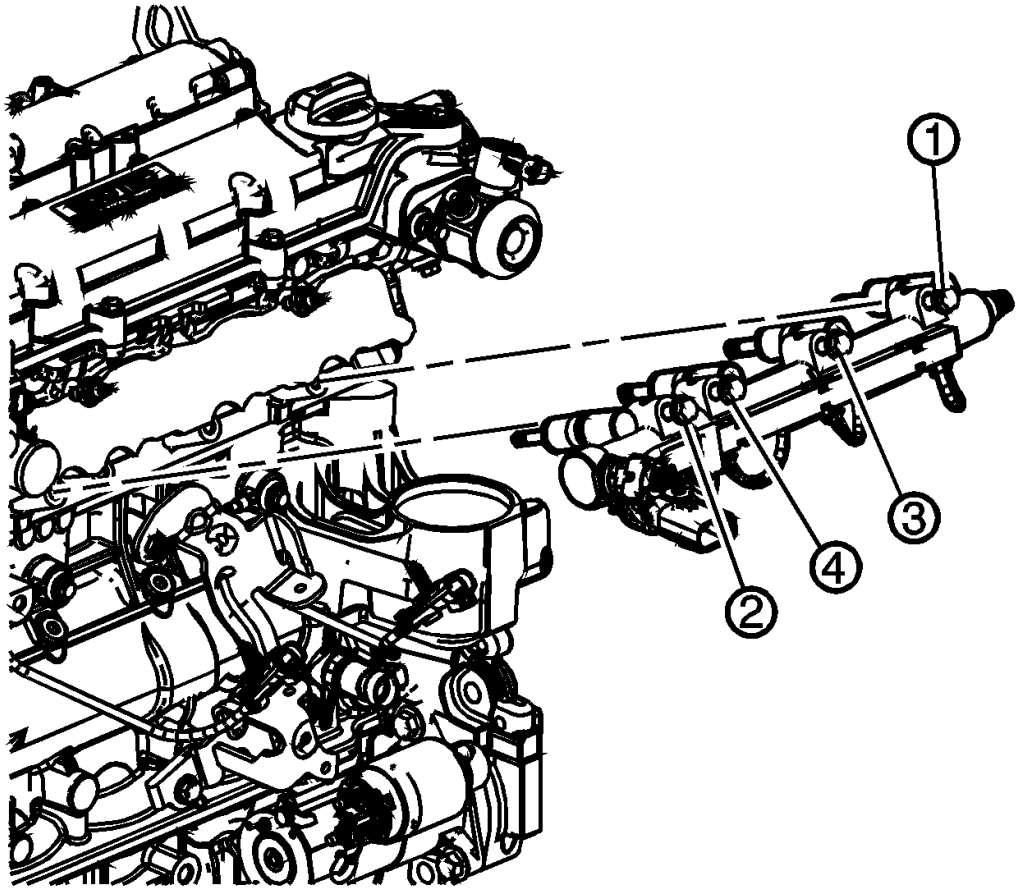


Fig. 128: Fuel Rail Bolt Tightening Sequence
Courtesy of GENERAL MOTORS CORP.

11. Tighten the fuel rail bolts in the sequence shown.

    Tighten:

    - Tighten the bolts a first pass to 22 N.m (16 lb ft).
    - Tighten the bolts a final pass to 22 N.m (16 lb ft).

12. Install the intermediate fuel pipe. Refer to **Fuel Feed Intermediate Pipe Replacement**.

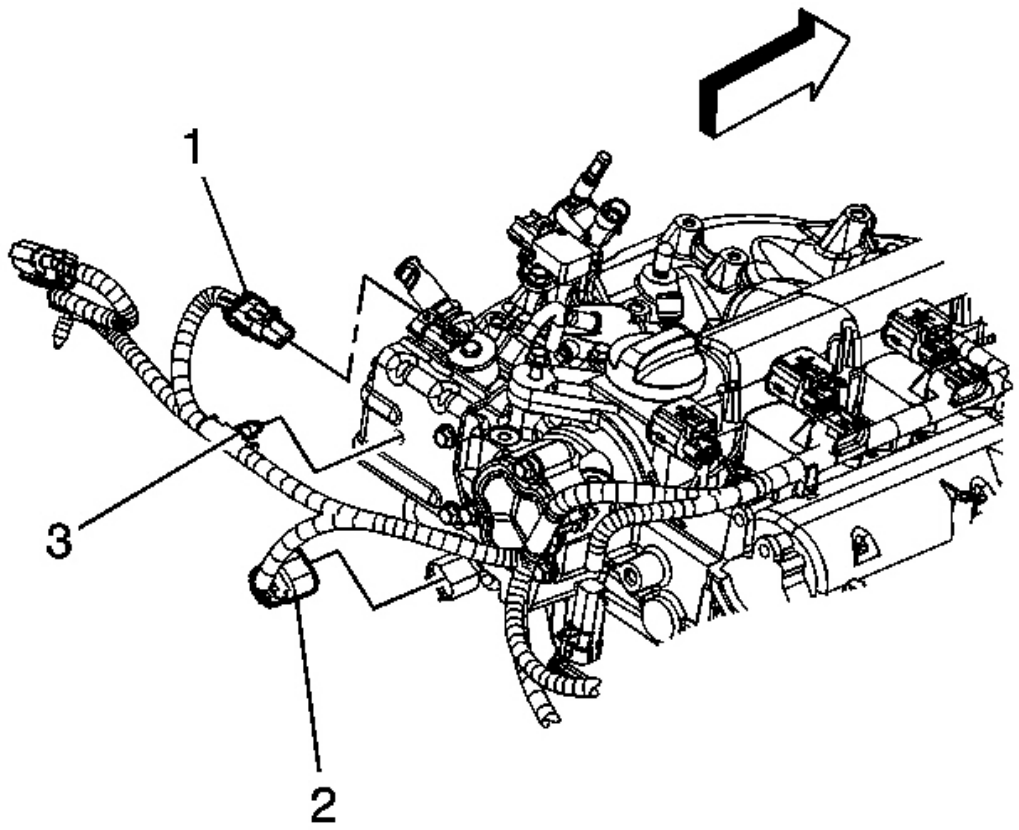


Fig. 129: High Pressure Fuel Pump Connector & Clip
Courtesy of GENERAL MOTORS CORP.

13. Connect the engine wiring harness electrical connector (1) to the high pressure fuel pump.

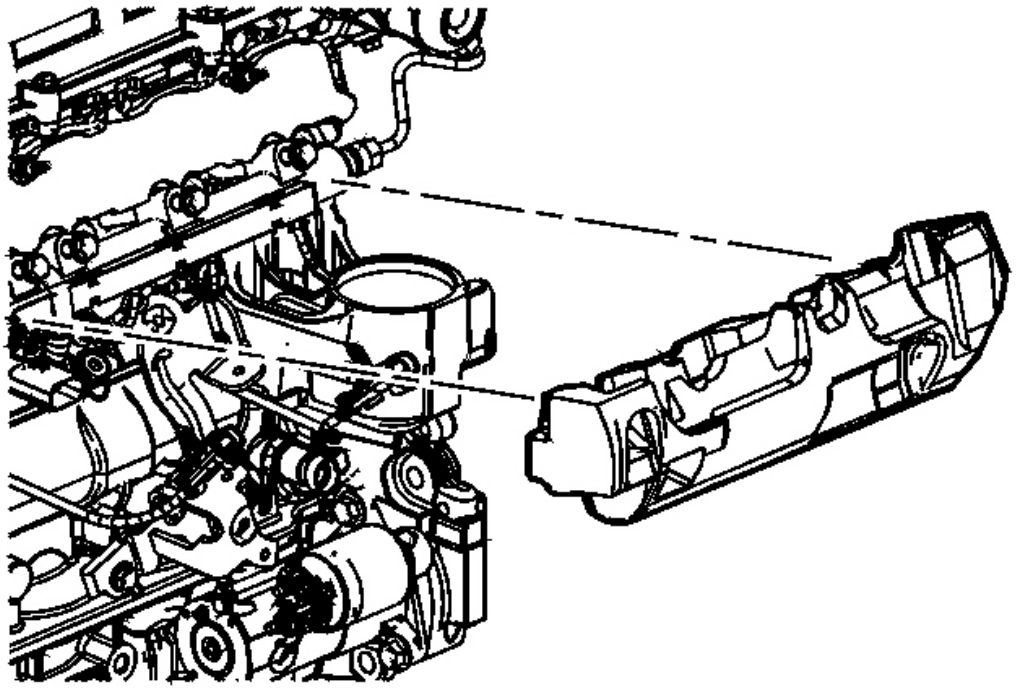


Fig. 130: Fuel Injector Insulator
Courtesy of GENERAL MOTORS CORP.

14. Install the fuel injector insulator.
15. Install the intake manifold. Refer to **Intake Manifold Replacement** .

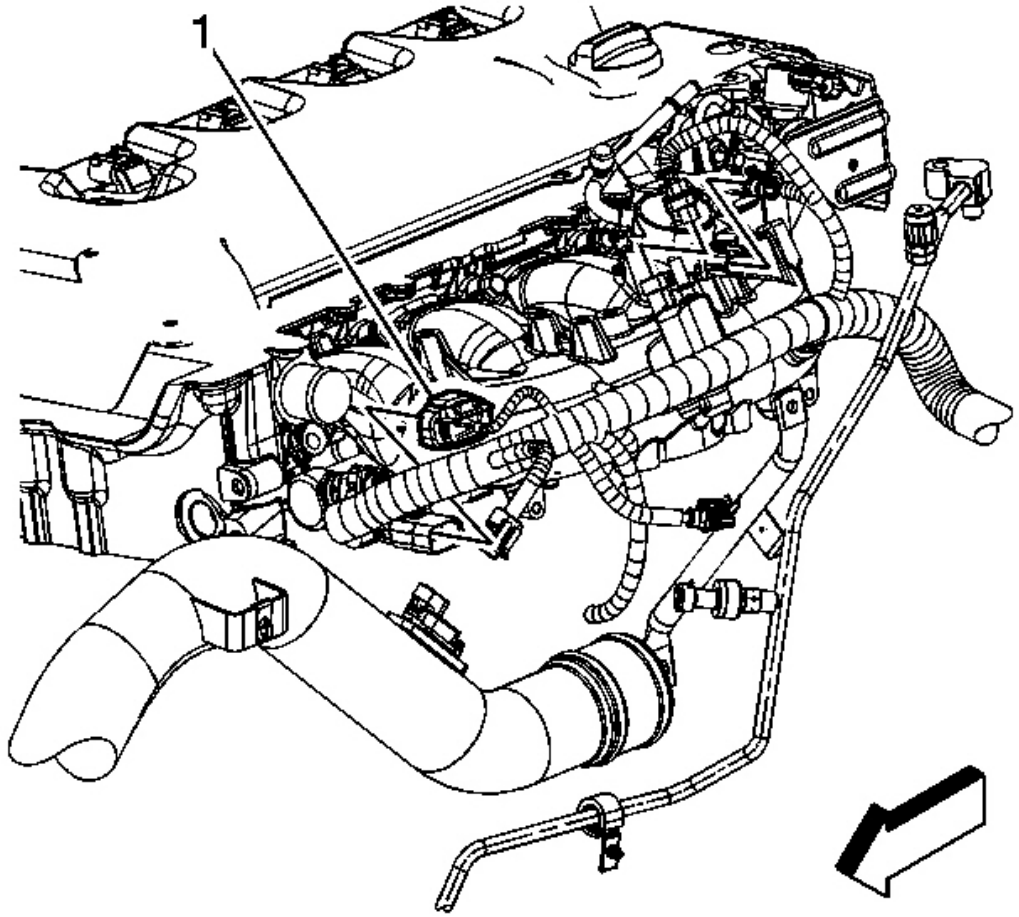


Fig. 131: Fuel Injector Wiring Harness Electrical Connector
Courtesy of GENERAL MOTORS CORP.

16. Connect the engine wiring harness electrical connector (1) to the fuel injector wiring harness electrical connector.
17. Inspect for leaks using the following procedure:
    1. Turn ON the ignition, with the engine OFF for 2 seconds.
    2. Turn OFF the ignition, for 10 seconds.
    3. Turn ON the ignition, with the engine OFF.
    4. Inspect for fuel leaks.

18. Install the low side fuel pressure service port cap.
19. Tighten the fuel fill cap.
20. Install the air cleaner assembly. Refer to **Air Cleaner Assembly Replacement**.

FUEL INJECTION FUEL RAIL FUEL PRESSURE SENSOR REPLACEMENT

Removal Procedure

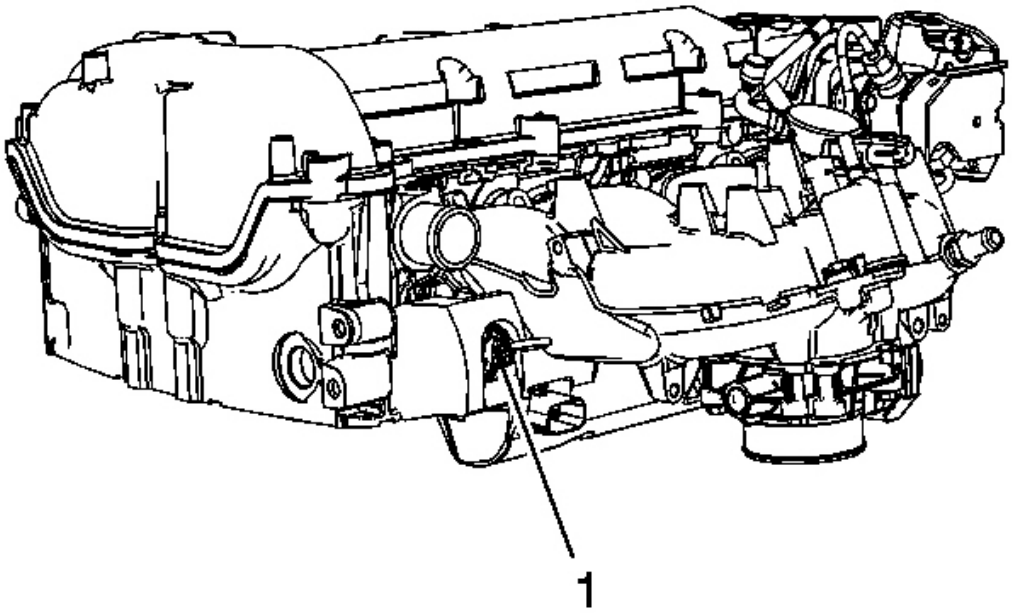


Fig. 132: Fuel Rail Fuel Pressure Sensor
Courtesy of GENERAL MOTORS CORP.

1. Relieve the high side fuel system pressure. Refer to **Fuel Pressure Relief (Without CH 48027)** or **Fuel Pressure Relief (With CH 48027)**.
2. Disconnect the fuel injector wiring harness electrical connector (1) from the fuel injection fuel rail fuel pressure sensor.

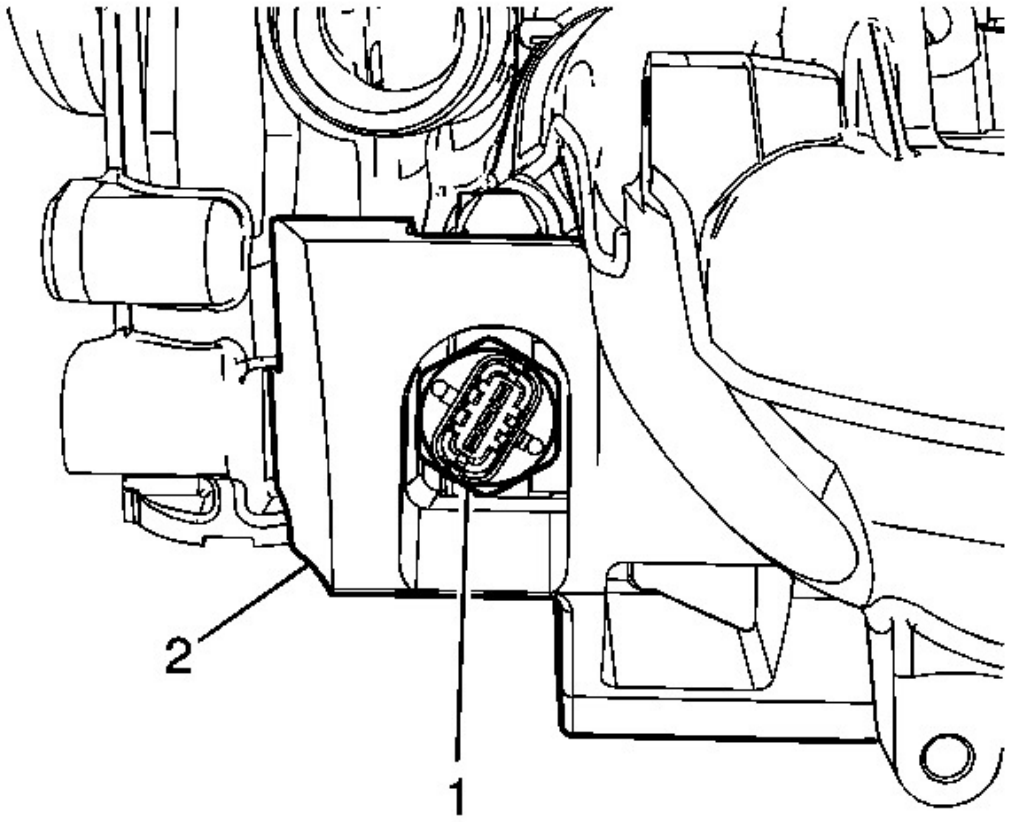


Fig. 133: Fuel Rail Fuel Pressure Sensor And Foam Insulator
Courtesy of GENERAL MOTORS CORP.

IMPORTANT: Do NOT reposition the foam insulator as damage to the insulator may occur.

3. Insert a 27 mm socket through the opening in the foam insulator (2) onto the fuel injection fuel rail fuel pressure sensor (1).

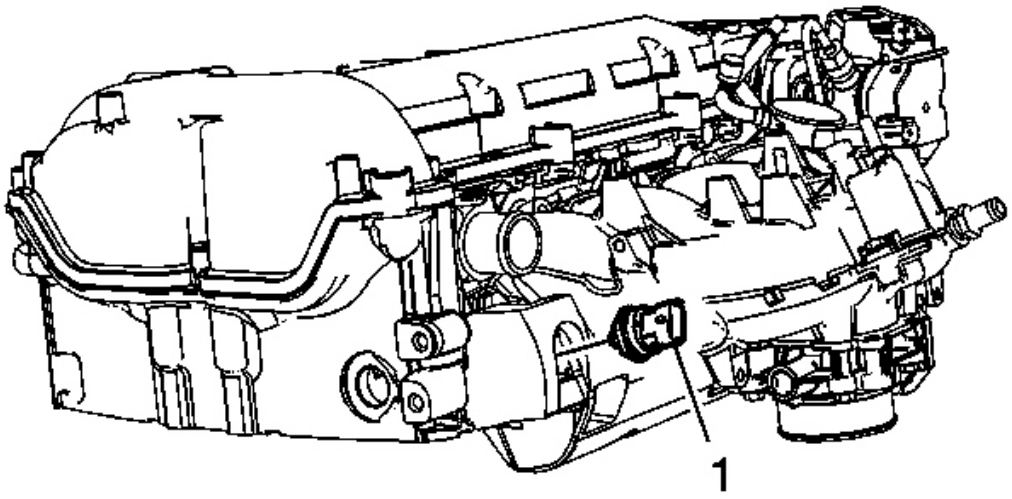


Fig. 134: Fuel Rail Fuel Pressure Sensor
Courtesy of GENERAL MOTORS CORP.

IMPORTANT: Applying force to the plastic housing of the sensor will destroy the sensor. To tighten or loosen, only apply force to the attached hexagon.

4. Place a clean shop towel under the fuel injection fuel rail pressure sensor to fuel rail location.
5. Remove and discard the fuel injection fuel rail fuel pressure sensor (1).
6. Allow any fuel to drain from the fuel rail and pressure sensor location.
7. Dry the sealing cone in the fuel rail and the area around the sensor joint with a lint free cloth.
8. Inspect the sealing cone in the fuel rail. The surface should be free of fuel, debris, and burrs.

Installation Procedure

IMPORTANT: Applying force to the plastic housing of the sensor will destroy the sensor. To tighten or loosen, only apply

force to the attached hexagon.

IMPORTANT: Ensure that the fuel rail threads have been cleaned of any excess fuel, or the NEW fuel injection fuel rail fuel pressure sensor will NOT seal properly.

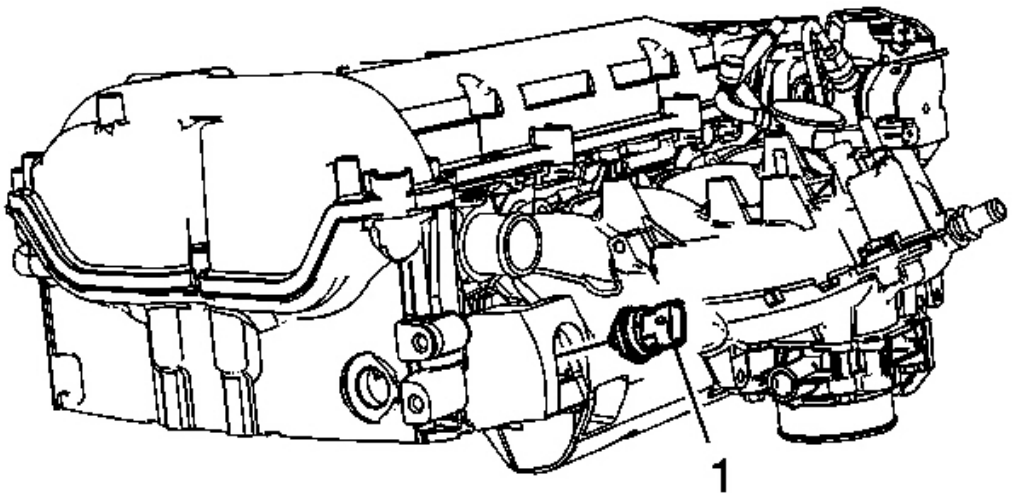


Fig. 135: Fuel Rail Fuel Pressure Sensor
Courtesy of GENERAL MOTORS CORP.

1. Lubricate the threads and the sealing cone in the fuel rail with silicon free engine oil GM P/N 12345610 (Canadian P/N 993193) or equivalent.
2. Lubricate the threads and sealing cone on the NEW fuel injection fuel rail fuel pressure sensor with silicon free engine oil GM P/N 12345610 (Canadian P/N 993193) or equivalent.
3. Install the NEW fuel injection fuel rail fuel pressure sensor hand tight.
4. Remove the NEW fuel injection fuel rail fuel pressure sensor, re-lubricate following steps 1 and 2 above.

NOTE: Refer to Fastener Notice .

5. Install the NEW fuel injection fuel rail fuel pressure sensor (1).

   Tighten: Tighten the sensor to 33 N.m (25 lb ft).

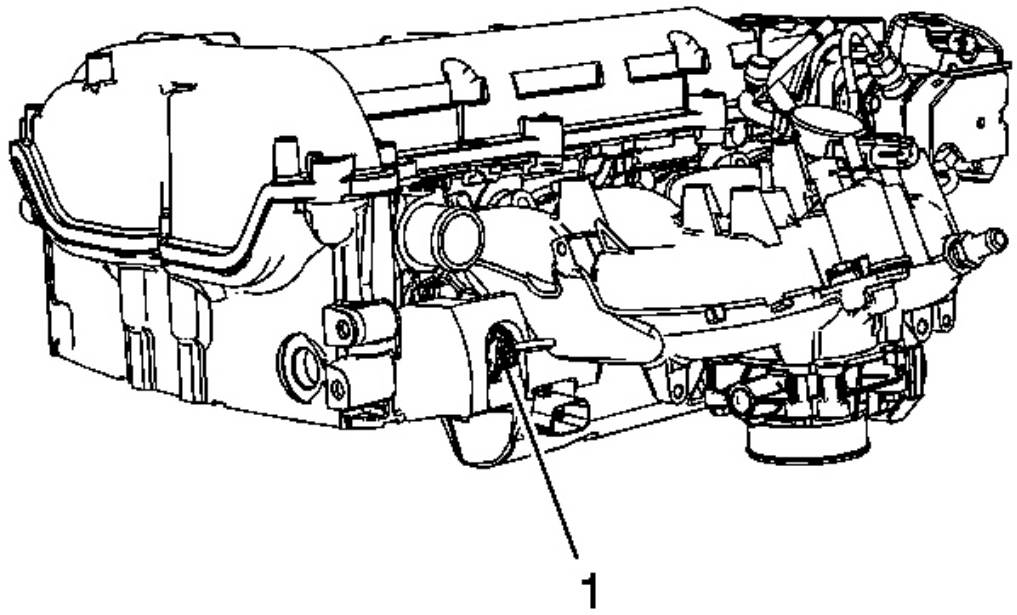


Fig. 136: Fuel Rail Fuel Pressure Sensor
Courtesy of GENERAL MOTORS CORP.

6. Connect the fuel injector wiring harness electrical connector (1) to the fuel injection fuel rail fuel pressure sensor.
7. Install a NEW high pressure fuel line. Refer to **Fuel Feed Intermediate Pipe Replacement**.
8. Install the low side fuel pressure service port cap.
9. Tighten the fuel fill cap.
10. Inspect for fuel leaks using the following procedure:
    1. Place a sheet of paper towel in between the bottom of the sensor and the top of the generator.
    2. Start the vehicle and allow the vehicle to idle for approximately 5 minutes.

3. Shut the vehicle off.
4. Remove the paper towel and inspect the towel for wetting. If wetting is noted repeat steps 1 through 5.

HIGH PRESSURE FUEL PUMP REPLACEMENT

Removal Procedure

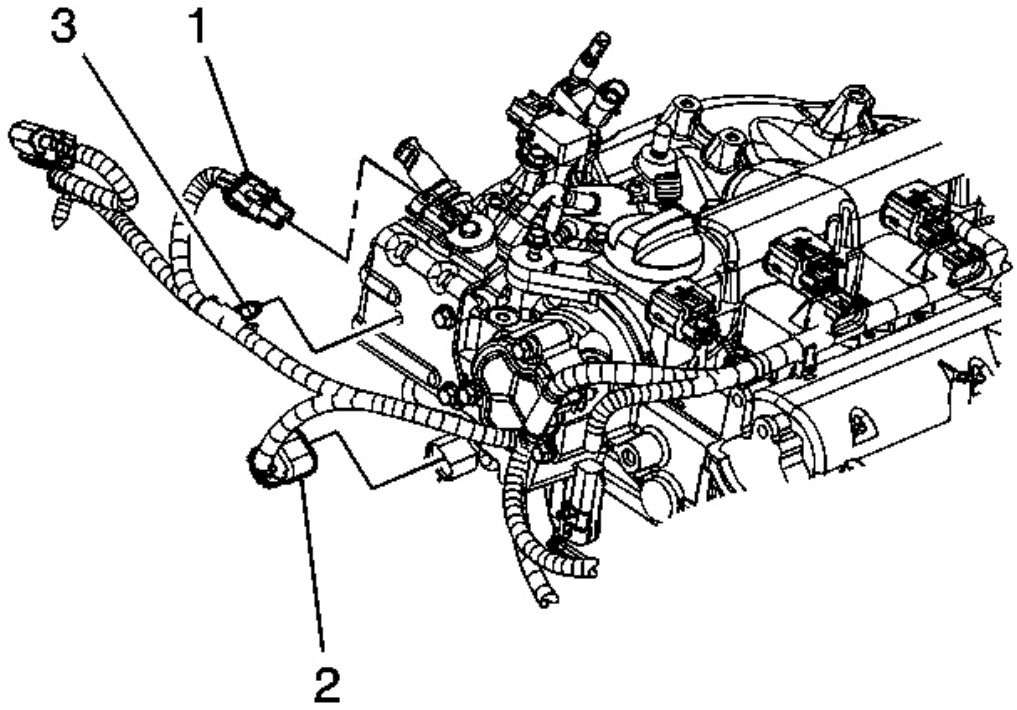


Fig. 137: View Of Engine Wiring Harness & High Pressure Fuel Pump
Courtesy of GENERAL MOTORS CORP.

1. Relieve the low and high side fuel system pressure. Refer to **Fuel Pressure Relief (Without CH 48027)** or **Fuel Pressure Relief (With CH 48027)**.
2. Disconnect the engine wiring harness electrical connector (1) from the high pressure fuel pump.
3. Remove the engine wiring harness clip (3) from the high pressure fuel pump

cover.

4. Remove the fuel feed intermediate pipe. Refer to **Fuel Feed Intermediate Pipe Replacement**.
5. Remove the fuel feed pipe. Refer to **Fuel Feed Pipe Replacement**.

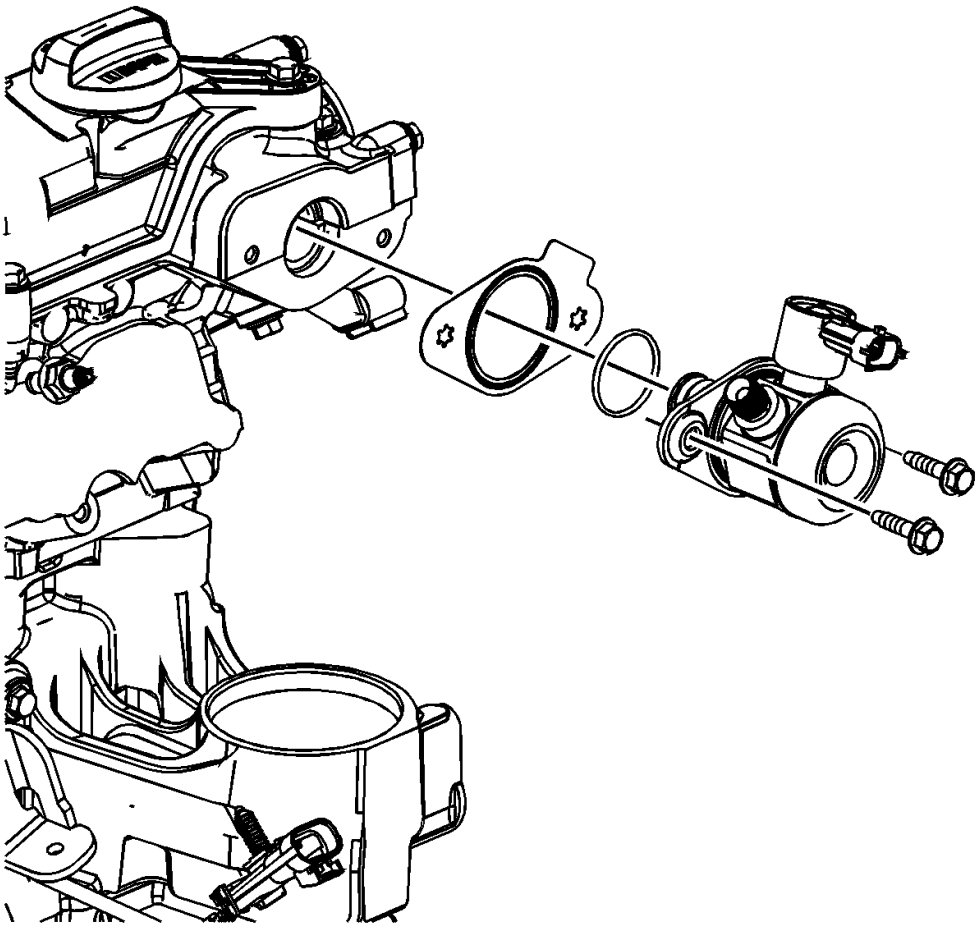


Fig. 138: High Pressure Fuel Pump & Bolts
Courtesy of GENERAL MOTORS CORP.

6. Remove and discard the high pressure fuel pump bolts.
7. Remove the high pressure fuel pump.
8. Remove and discard the high pressure fuel pump gasket.
9. Remove and discard the high pressure fuel pump O-ring.

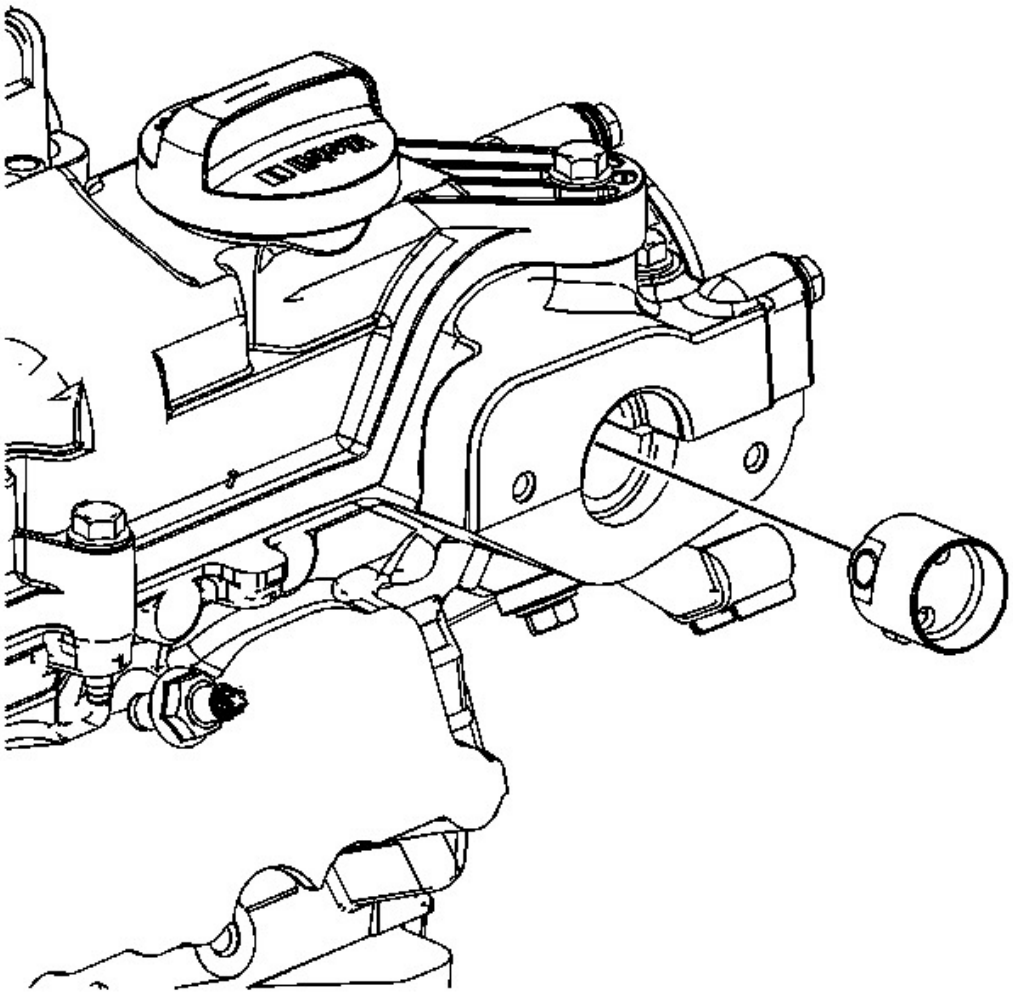


Fig. 139: Fuel Pump Roller Lifter
Courtesy of GENERAL MOTORS CORP.

10. Remove the high pressure fuel pump roller lifter, if necessary.

Installation Procedure

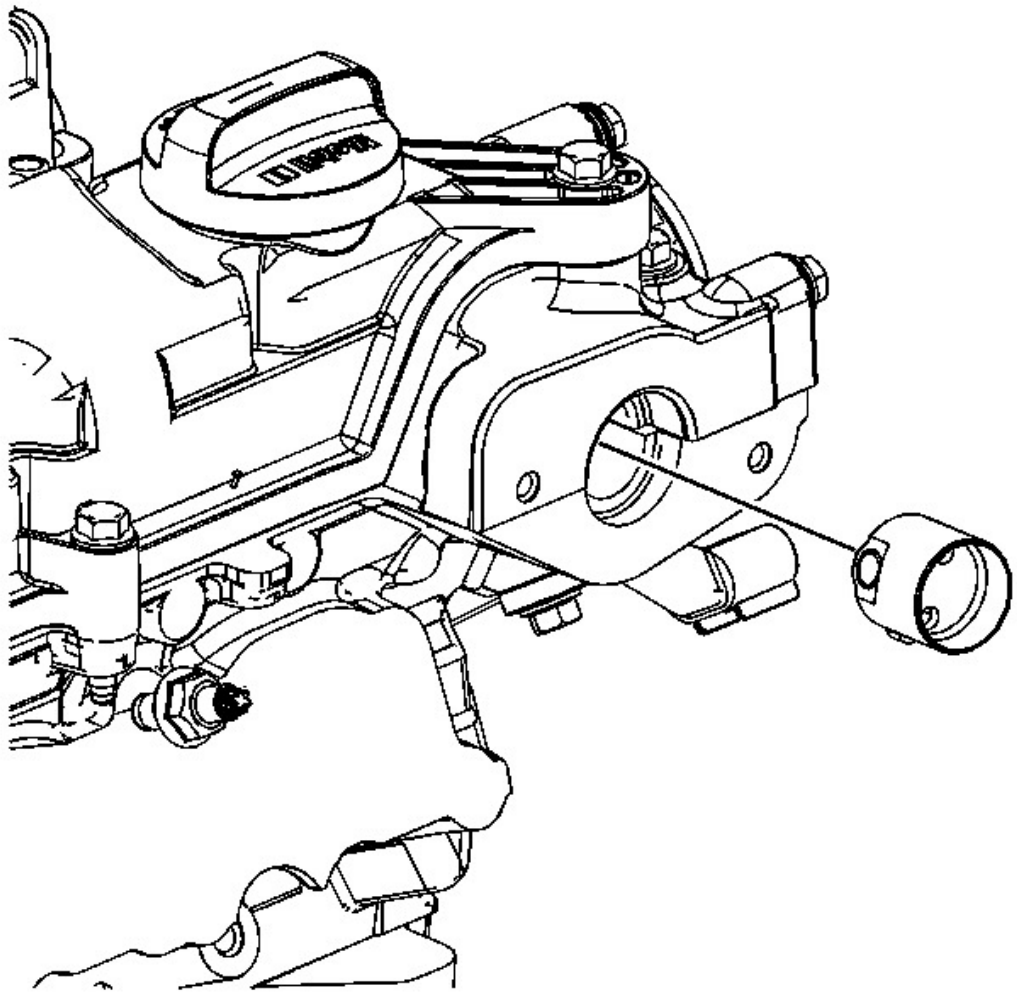


Fig. 140: Fuel Pump Roller Lifter
Courtesy of GENERAL MOTORS CORP.

1. Lubricate the high pressure fuel pump cylinder head bore and roller lifter with silicon free engine oil GM P/N 12345610 (Canadian P/N 993193) or equivalent, if necessary.
2. Install the high pressure fuel pump roller lifter, if necessary.

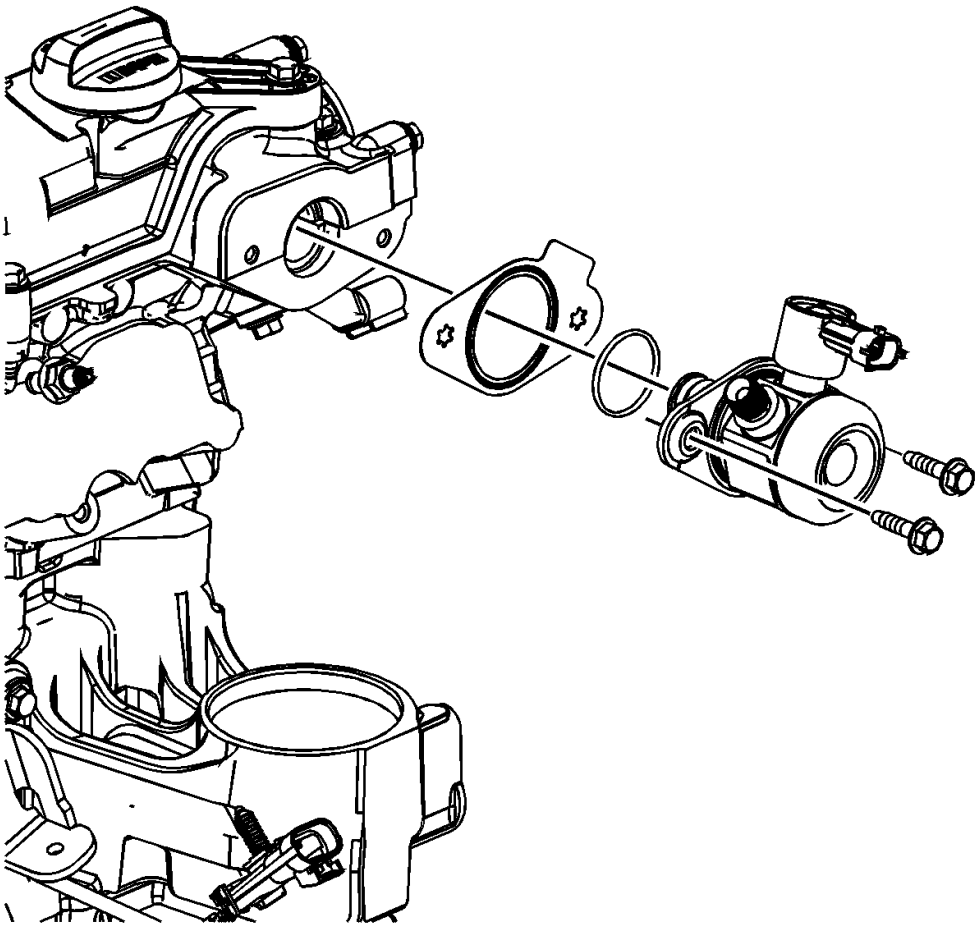


Fig. 141: High Pressure Fuel Pump & Bolts
Courtesy of GENERAL MOTORS CORP.

3. Install a NEW high pressure fuel pump O-ring.
4. Position the NEW high pressure fuel pump gasket to the cylinder head.

IMPORTANT: Ensure the plastic bolt retainers are installed in the high pressure fuel pump mounting holes prior to installing.

5. Install the high pressure fuel pump. Push the pump into the cylinder head bore by hand, applying force to the top of the pump.
6. Install the NEW high pressure fuel pump bolts hand tight.
7. Ensure that the high pressure fuel pump, and fuel rail fittings are clean prior to

assembly.

8. Lubricate the high pressure fuel pump, and the fuel rail fittings with silicon free engine oil GM P/N 12345610 (Canadian P/N 993193) or equivalent.

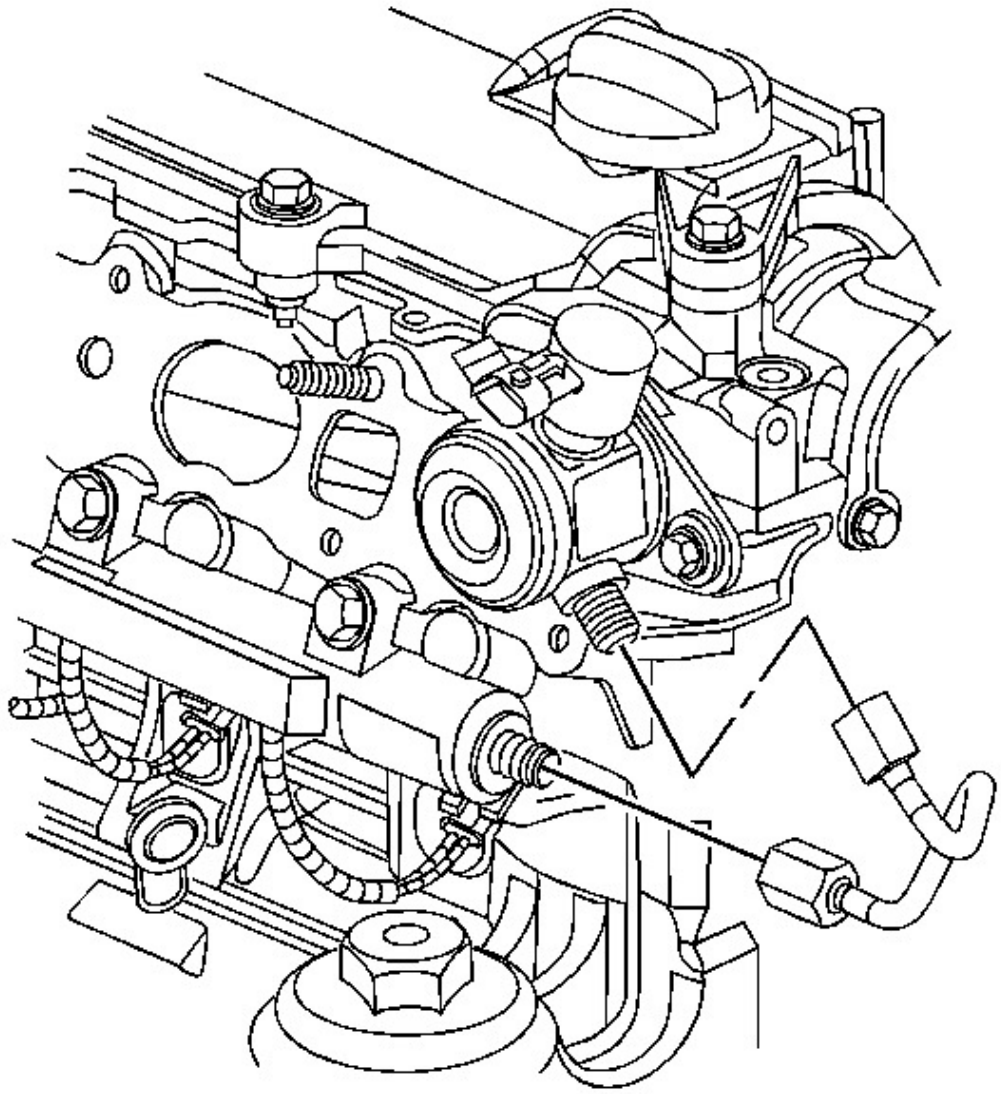


Fig. 142: View Of High Pressure Fuel Pipe
Courtesy of GENERAL MOTORS CORP.

9. Install the NEW high pressure fuel pipe.
10. Tighten the high pressure fuel pipe fitting to the fuel rail hand tight.
11. Tighten the high pressure fuel pipe fitting to the fuel pump hand tight.

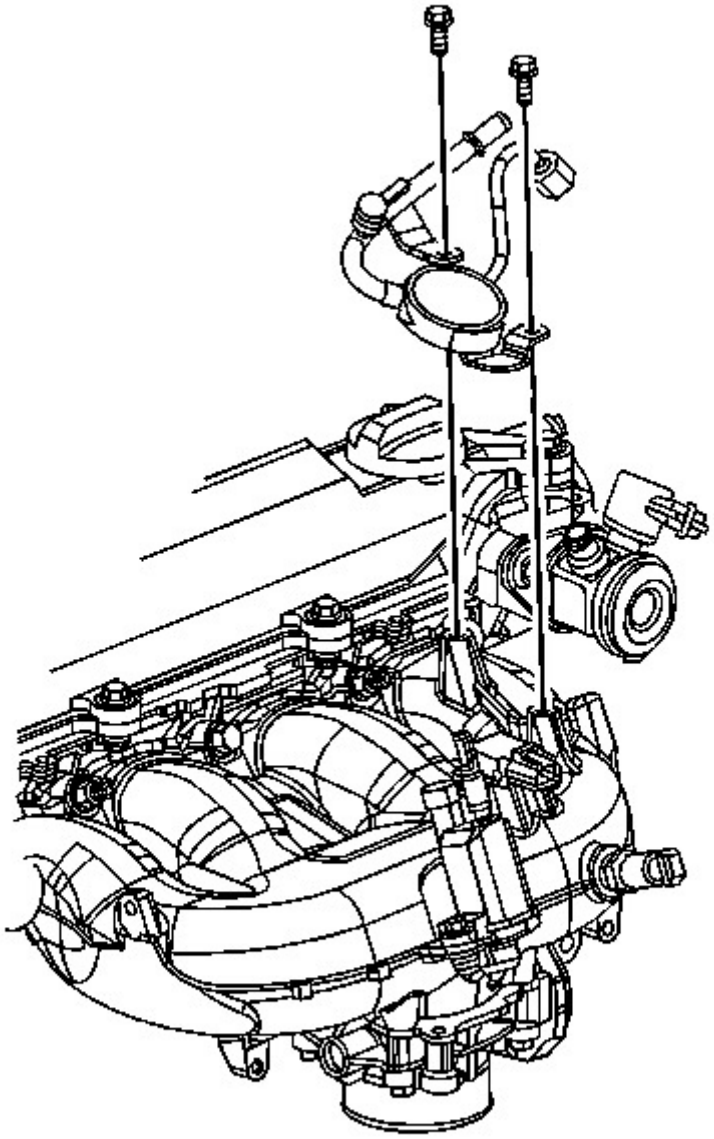


Fig. 143: View Of High Pressure Fuel Pipe & Intake Manifold

Courtesy of GENERAL MOTORS CORP.

12. Place the fuel feed pipe onto the intake manifold.
13. Install the fuel feed pipe bolts hand tight.

NOTE: Refer to Fastener Notice .

14. Tighten the fuel feed pipe to fuel pump fitting hand tight.

Tighten:

1. Tighten the fuel feed pipe bolts to 10 N.m (89 lb in).
2. Tighten the fuel feed pipe to fuel pump fitting to 30 N.m (22 lb ft).
3. Tighten the high pressure fuel pipe fittings to 32 N.m (24 lb ft).
4. Tighten the high pressure fuel pump bolts evenly to 15 N.m (11 lb ft).

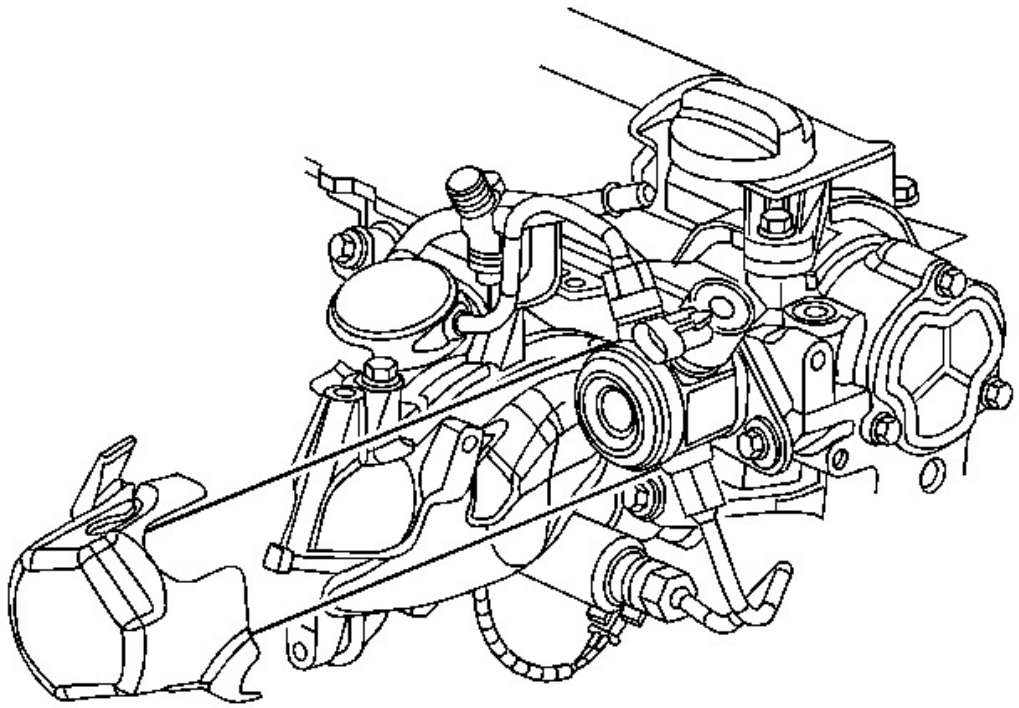


Fig. 144: Identifying High Pressure Fuel Pump Insulator

Courtesy of GENERAL MOTORS CORP.

15. Install the high pressure fuel pump insulator.

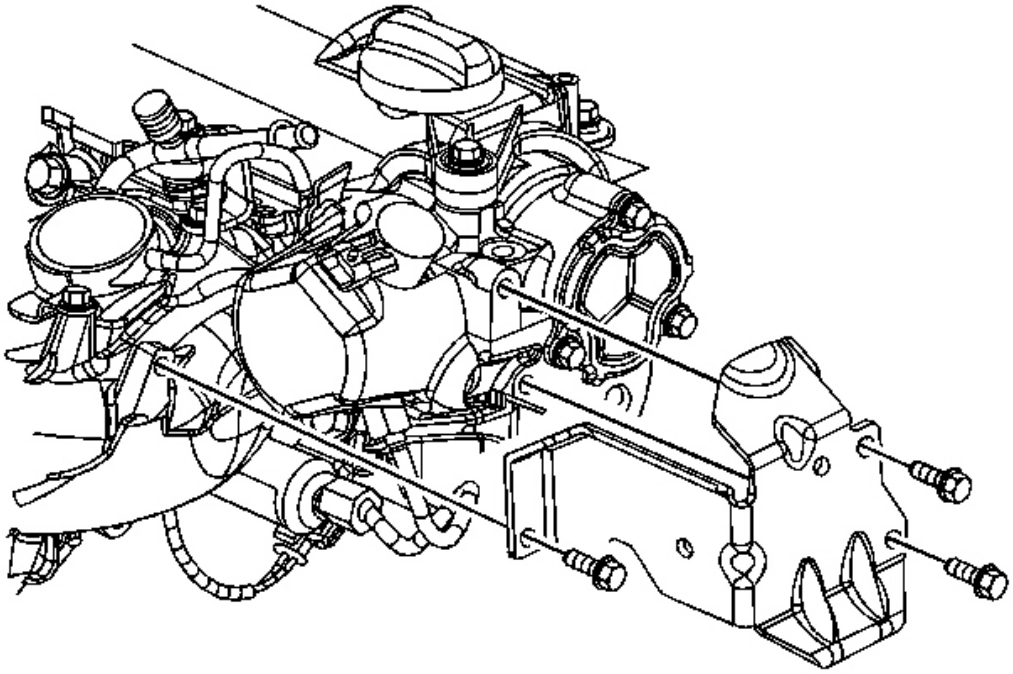


Fig. 145: View Of High Pressure Fuel Pump Cover
Courtesy of GENERAL MOTORS CORP.

16. Position the high pressure fuel pump cover.
17. Install the high pressure fuel pump cover bolts.

Tighten: Tighten the bolts to 10 N.m (89 lb in).

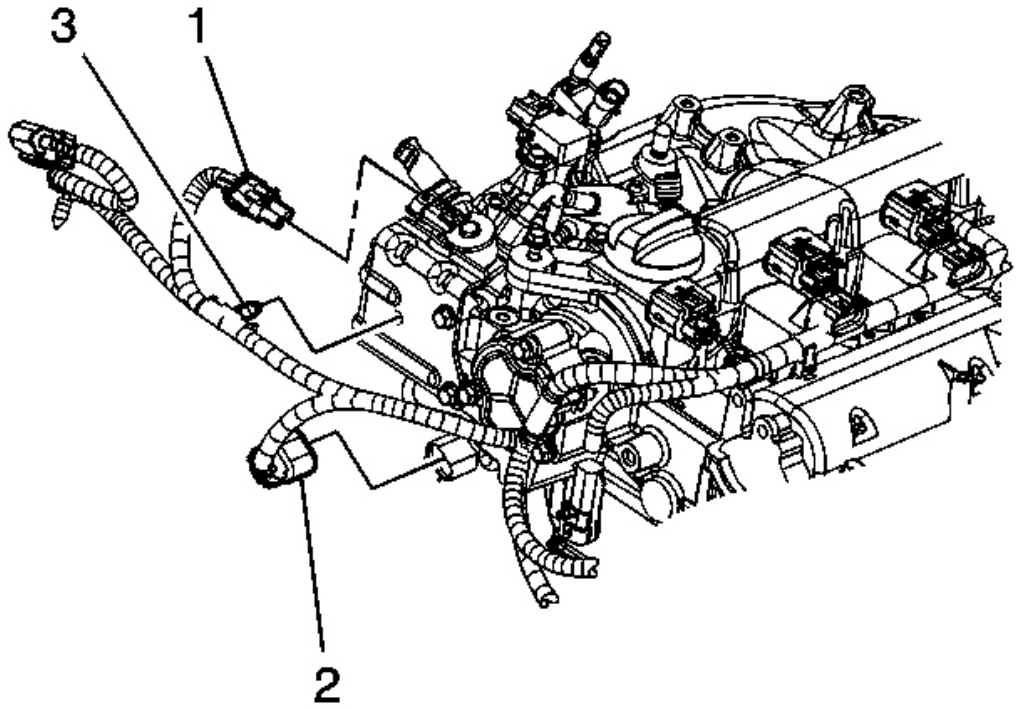


Fig. 146: View Of Engine Wiring Harness & High Pressure Fuel Pump
Courtesy of GENERAL MOTORS CORP.

18. Connect the engine wiring harness electrical connector (1) to the high pressure fuel pump.
19. Install the engine wiring harness clip (3) to the fuel pump cover.
20. Inspect for leaks using the following procedure:
    1. Turn ON the ignition, with the engine OFF for 2 seconds.
    2. Turn OFF the ignition, for 10 seconds.
    3. Turn ON the ignition, with the engine OFF.
    4. Inspect for fuel leaks.
21. Install the low side fuel pressure service port cap.
22. Tighten the fuel fill cap.

DIRECT FUEL INJECTOR REPLACEMENT

Special Tools

- **EN-47909** Injector Bore and Sleeve Cleaning Kit. See **Special Tools**.
- **EN-48266** Injector Seal Installer and Sizer. See **Special Tools**.
- **J 2619-01** Slide Hammer. See **Special Tools**.
- **J-37281-A** Injector Remover. See **Special Tools**.

Removal Procedure

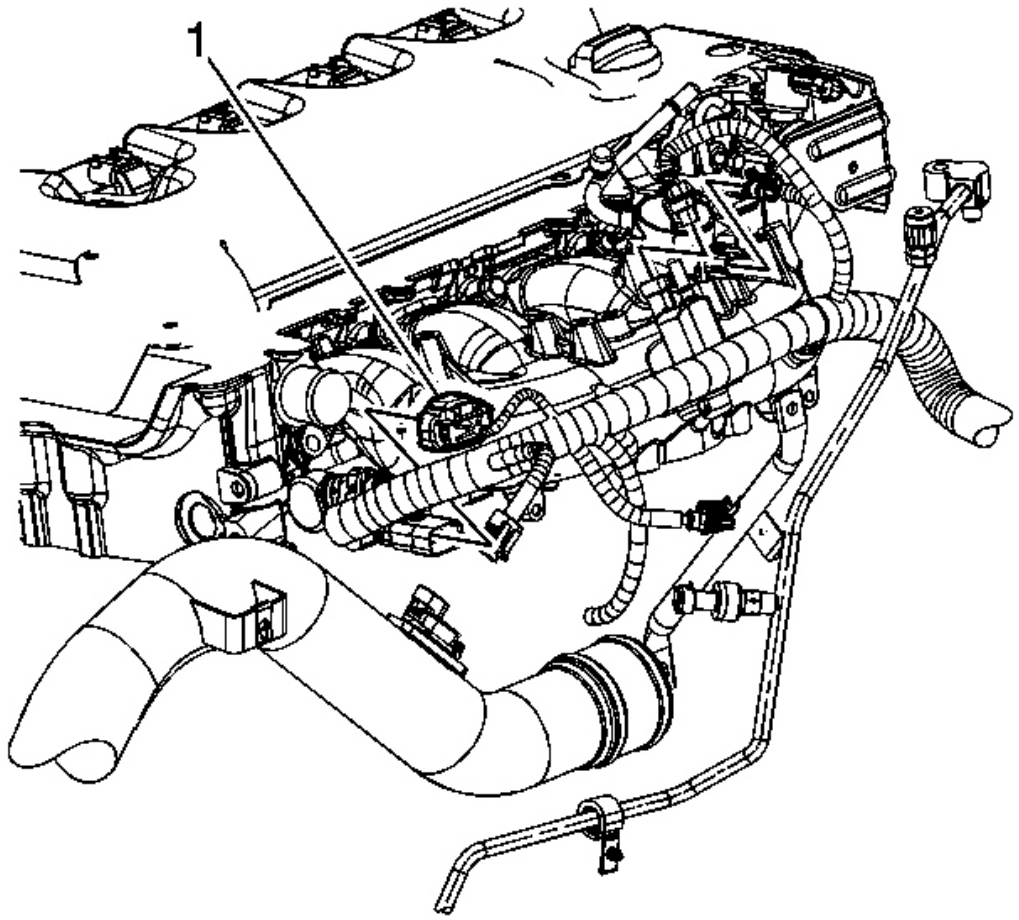


Fig. 147: Identifying Engine Wiring Harness Connector & Fuel Injector Wiring Harness Connector
Courtesy of GENERAL MOTORS CORP.

1. Disconnect the engine wiring harness electrical connector (1) from the fuel injector wiring harness electrical connector.
2. Remove the intake manifold assembly. Refer to **Intake Manifold Replacement** .

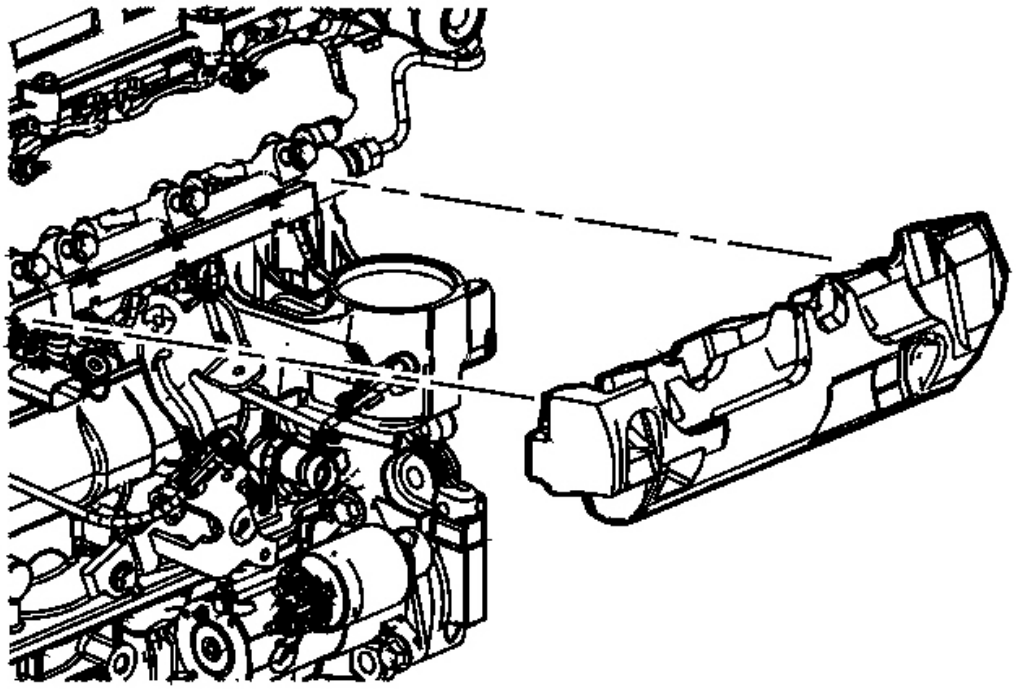


Fig. 148: Fuel Injector Insulator
Courtesy of GENERAL MOTORS CORP.

3. Remove the fuel injector insulator.

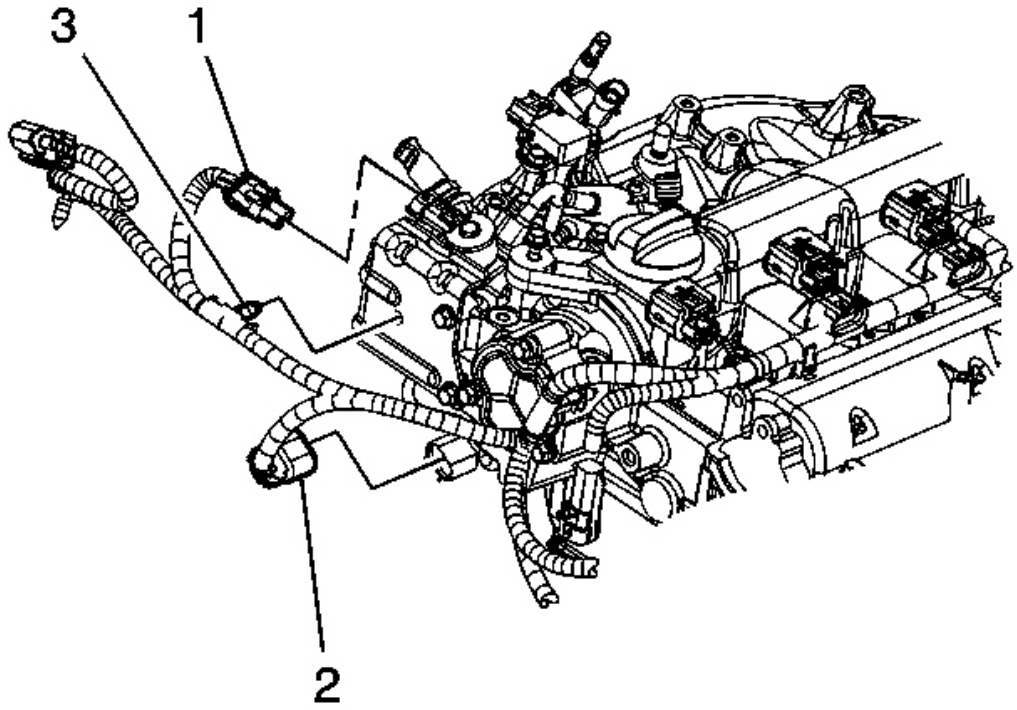


Fig. 149: View Of Engine Wiring Harness & High Pressure Fuel Pump
Courtesy of GENERAL MOTORS CORP.

4. Relieve the high side fuel system pressure. Refer to **Fuel Pressure Relief (Without CH 48027)** or **Fuel Pressure Relief (With CH 48027)**.
5. Disconnect the engine wiring harness electrical connector (1) from the high pressure fuel pump.
6. Remove the engine wiring harness clip (3) from the high pressure fuel pump cover.
7. Remove the fuel feed intermediate pipe. Refer to **Fuel Feed Intermediate Pipe Replacement**.

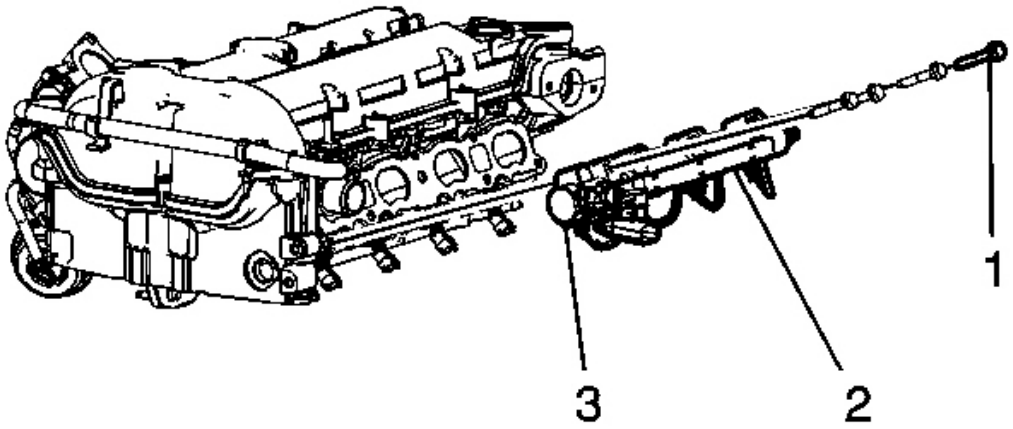


Fig. 150: Fuel Rail Bolts
Courtesy of GENERAL MOTORS CORP.

8. Disconnect the fuel injector wiring harness electrical connectors from the fuel injectors.
9. Remove the fuel rail bolts (1).

IMPORTANT: Carefully remove the fuel rail. The fuel injectors may come out of the cylinder head with the fuel rail.

10. Carefully remove the fuel rail (2).

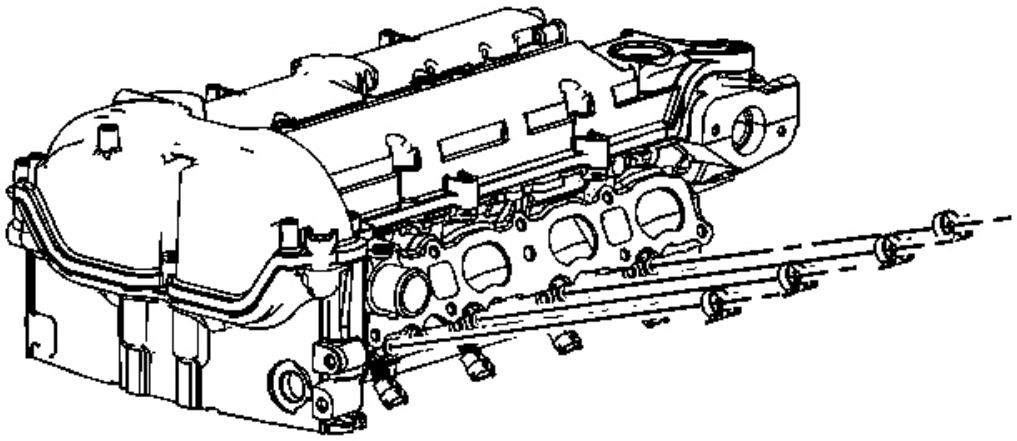


Fig. 151: Direct Fuel Injector Hold Down Clamps
Courtesy of GENERAL MOTORS CORP.

11. Remove and discard the direct fuel injector hold down clamps.

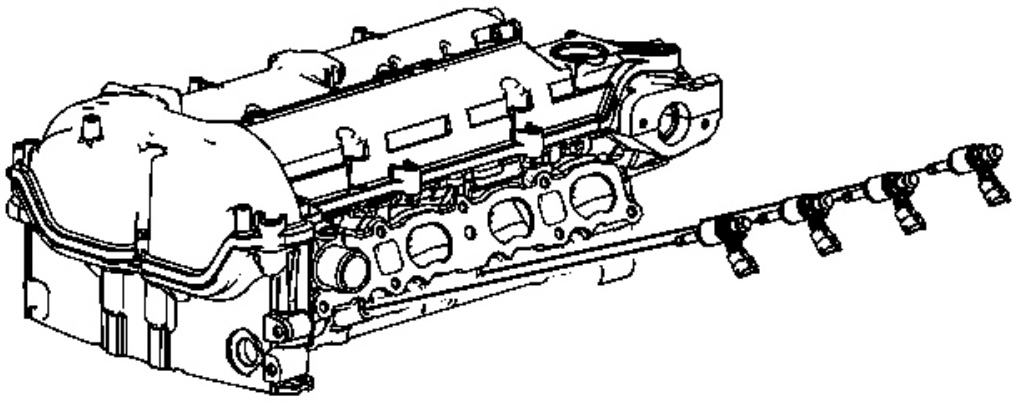


Fig. 152: Direct Fuel Injectors
Courtesy of GENERAL MOTORS CORP.

12. Remove the direct fuel injectors.

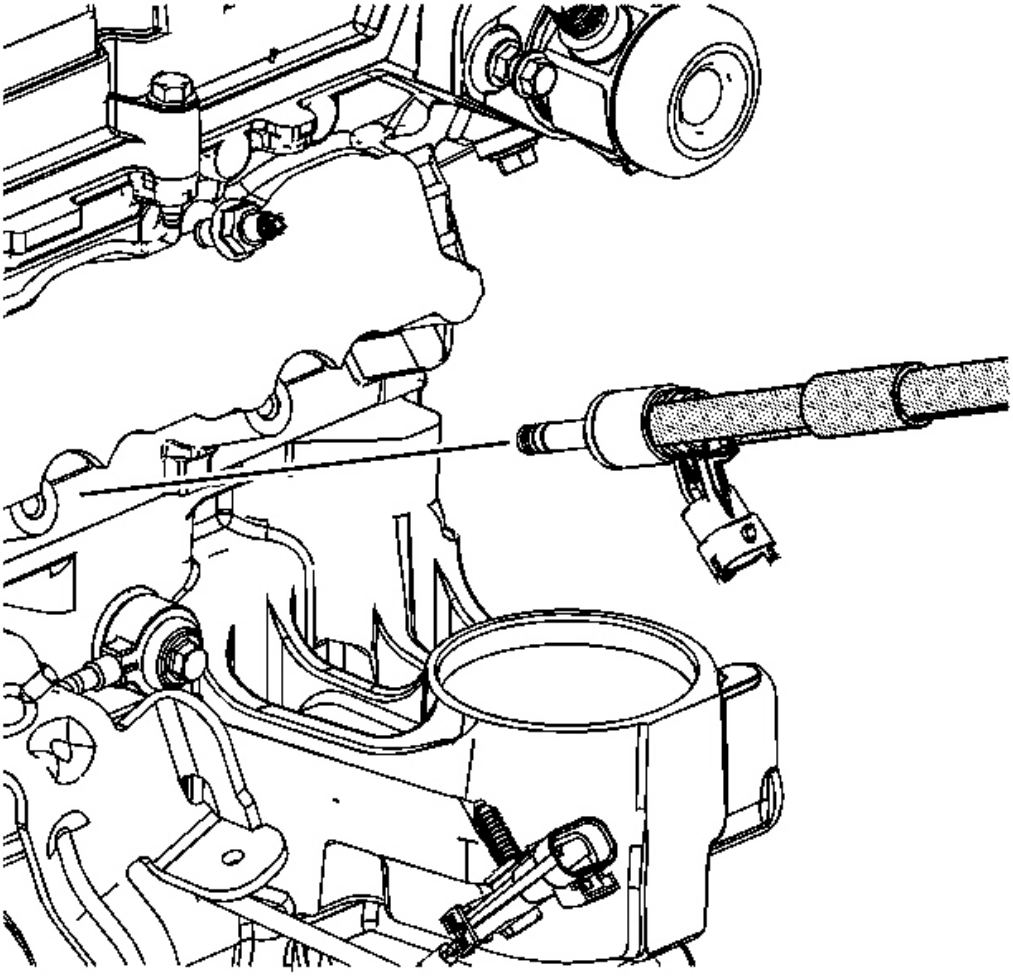


Fig. 153: Using J 2619-01 & J-37281-A
Courtesy of GENERAL MOTORS CORP.

13. If necessary, use the **J 2619-01** and the **J-37281-A** in order to remove the direct fuel injector(s). See **Special Tools**.

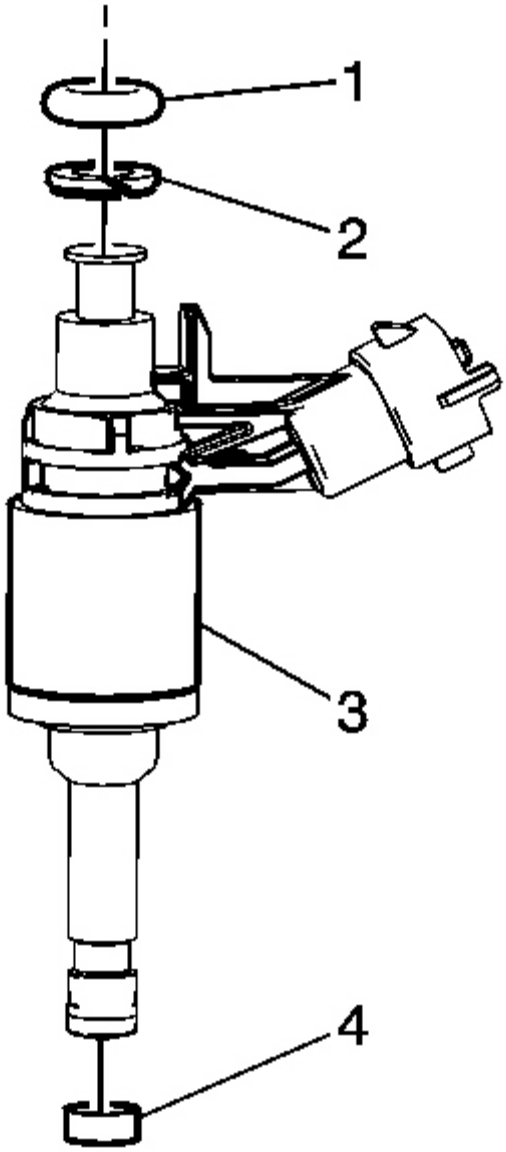


Fig. 154: Fuel Injector
Courtesy of GENERAL MOTORS CORP.

14. Remove and discard the upper O-ring seal (1) and plastic spacer (2) from the injector(s).

15. Carefully remove and discard the lower nylon seal (4) from the injector(s).

Installation Procedure

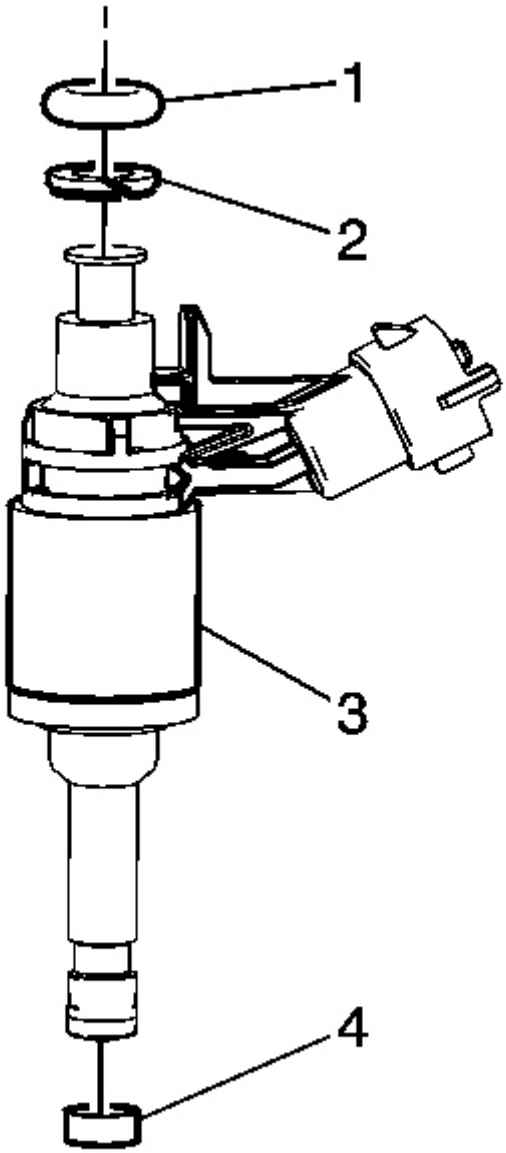


Fig. 155: Fuel Injector
Courtesy of GENERAL MOTORS CORP.

1. Install a NEW plastic spacer (2) onto the fuel injector(s).
2. Lubricate a NEW O-ring seal (1) with silicon free engine oil GM P/N 12345610 (Canadian P/N 993193) or equivalent.
3. Install the NEW O-ring seal (1) onto the fuel injector(s).

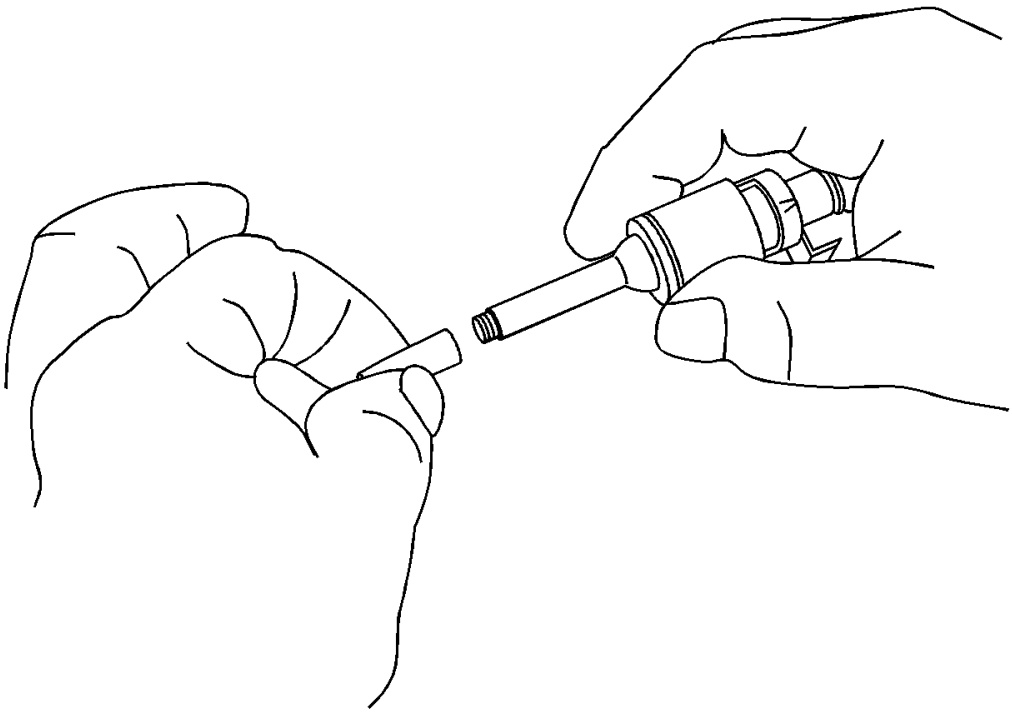


Fig. 156: Identifying Injector Tip & EN 48266-1
Courtesy of GENERAL MOTORS CORP.

4. From the **EN-48266** , position the EN 48266-1 to the injector tip. See **Special Tools**.

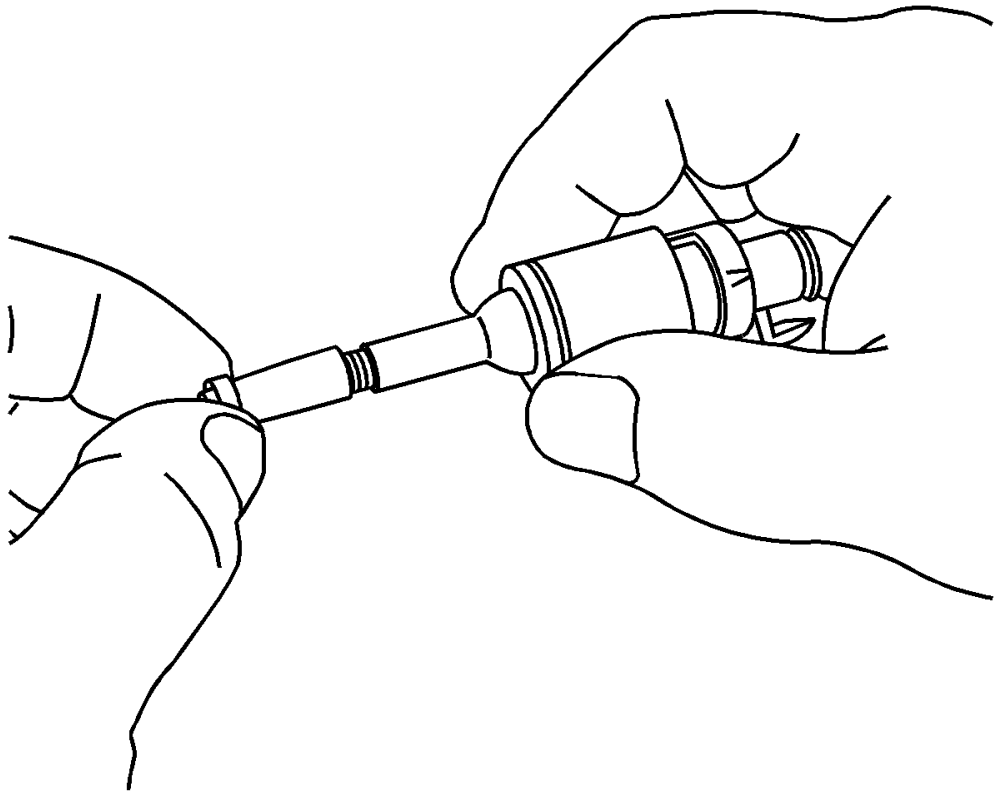


Fig. 157: Using EN 48266-1
Courtesy of GENERAL MOTORS CORP.

IMPORTANT: DO NOT lubricate the NEW seal.

5. Install a NEW seal onto the EN 48266-1.

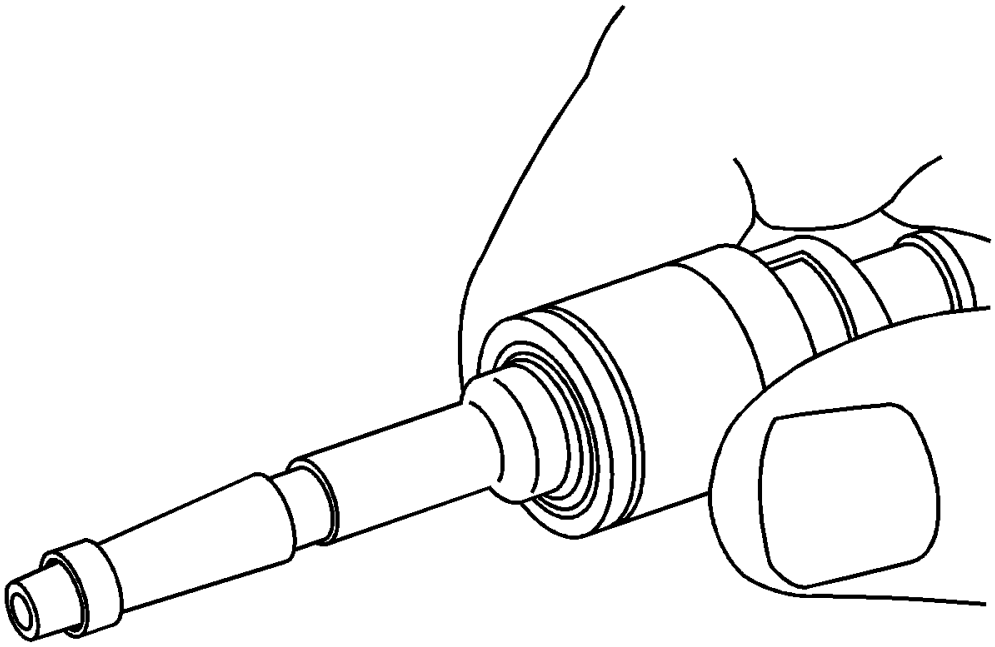


Fig. 158: EN 48266-1 Installed
Courtesy of GENERAL MOTORS CORP.

6. Pull the NEW seal by hand over the EN 48266-1 and into the groove in the injector.
7. Remove the EN 48266-1 from the injector tip.

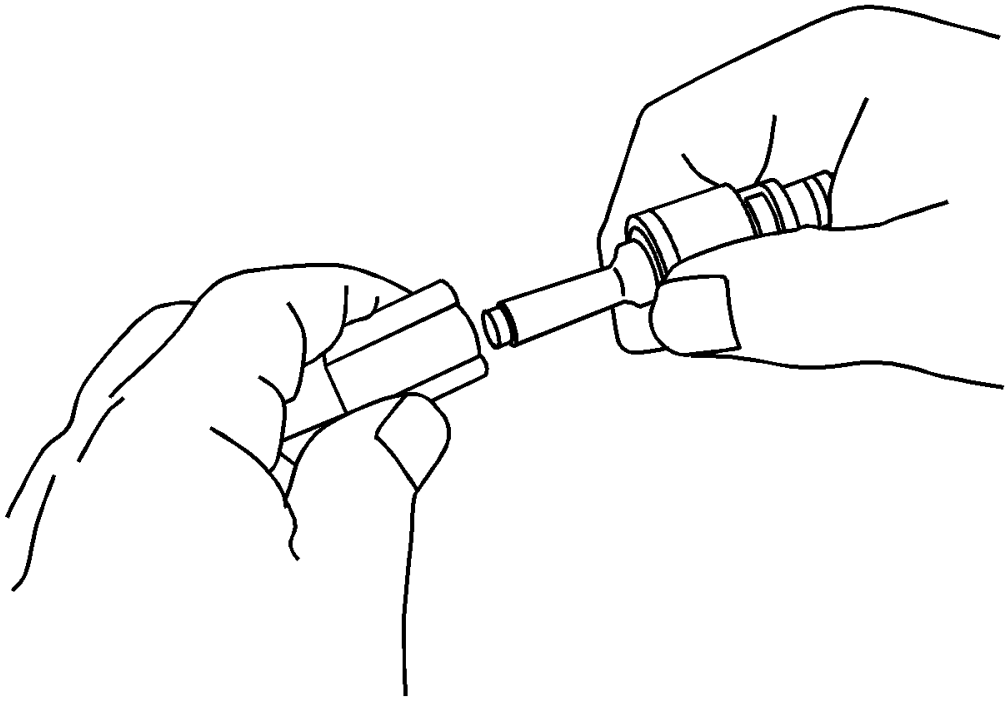


Fig. 159: View Of Injector Tip & EN 48266-2
Courtesy of GENERAL MOTORS CORP.

8. From the **EN-48266** , install the EN 48266-2 to the injector tip. See **Special Tools**.

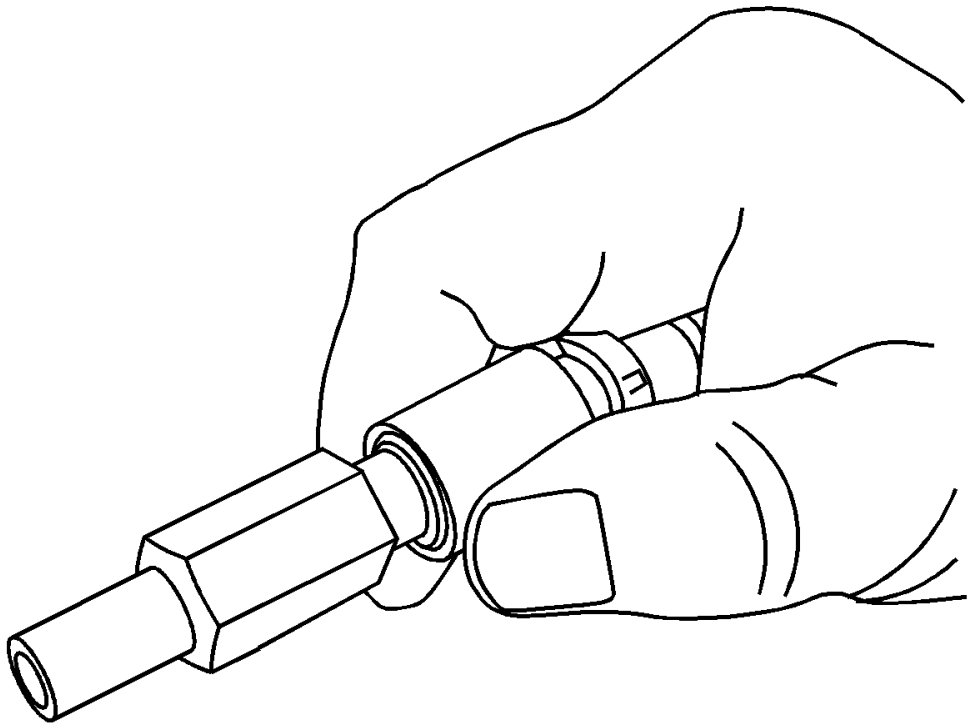


Fig. 160: View Of EN 48266-2 Installed
Courtesy of GENERAL MOTORS CORP.

9. Using the EN 48266-2, re-size the seal. Install the EN 48266-2, until it bottoms out against the injector body, and rotate the EN 48266-2 while applying only moderate force 180 degrees in one direction and then 180 degrees back in the other direction.
10. Remove the EN 48266-2.

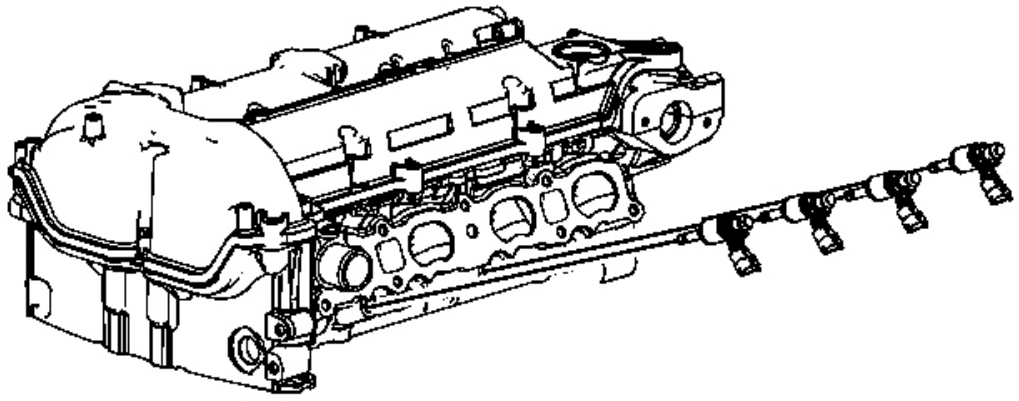


Fig. 161: Direct Fuel Injectors
Courtesy of GENERAL MOTORS CORP.

11. Install the direct fuel injectors to the cylinder head.

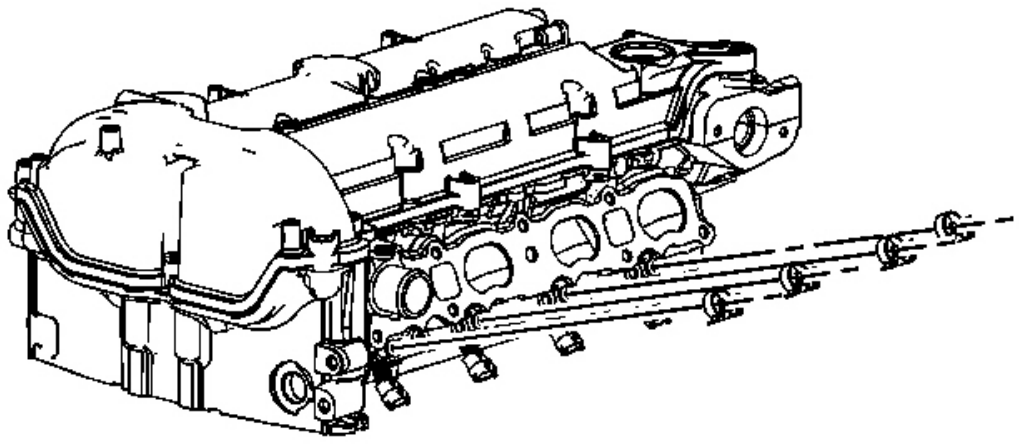


Fig. 162: Direct Fuel Injector Hold Down Clamps
Courtesy of GENERAL MOTORS CORP.

12. Install the NEW direct fuel injector hold down clamps.

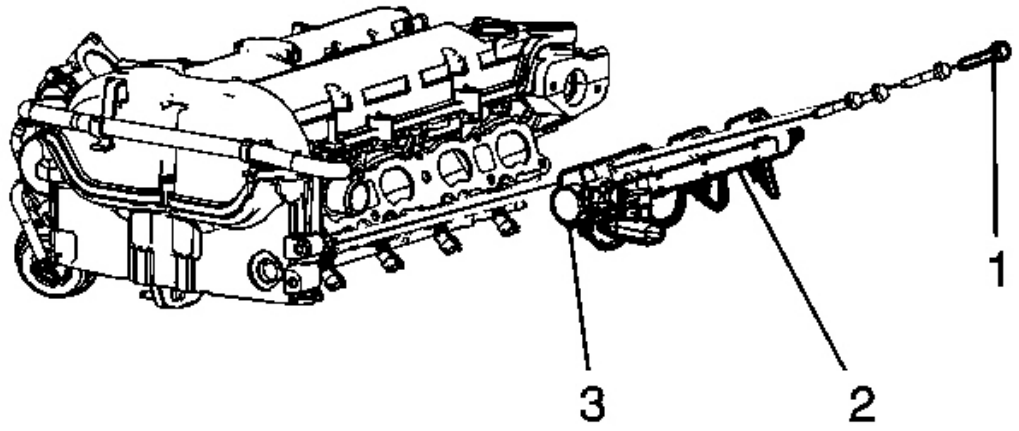


Fig. 163: Fuel Rail Bolts
Courtesy of GENERAL MOTORS CORP.

13. Place the fuel rail (2) into position.
14. Install the 2 outer fuel rail bolts (1) first, hand tight and install the remaining 2 bolts, hand tight.
15. Connect the fuel injector wiring harness electrical connectors to the fuel injectors.

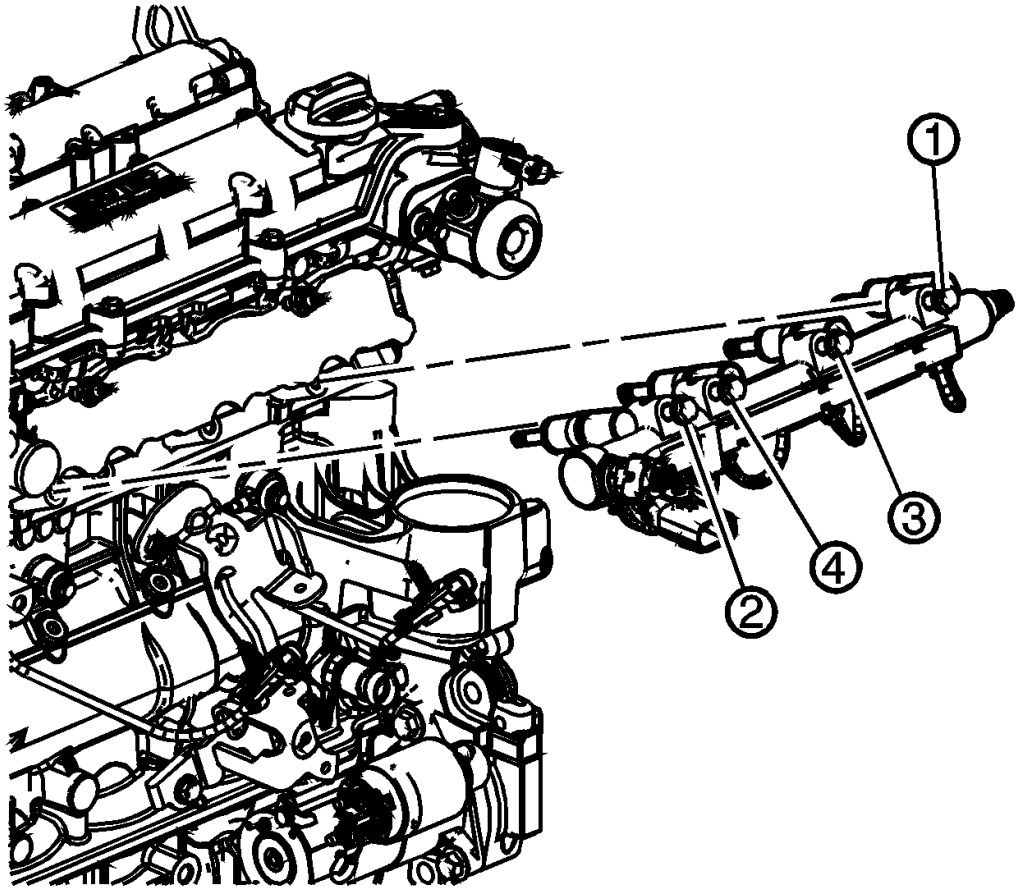


Fig. 164: Fuel Rail Bolt Tightening Sequence
Courtesy of GENERAL MOTORS CORP.

NOTE: Refer to Fastener Notice .

16. Tighten the fuel rail bolts in the sequence shown.

    Tighten:
    - Tighten the bolts a first pass to 22 N.m (16 lb ft).
    - Tighten the bolts a final pass to 22 N.m (16 lb ft).

17. Install the fuel feed intermediate pipe. Refer to **Fuel Feed Intermediate Pipe Replacement**.

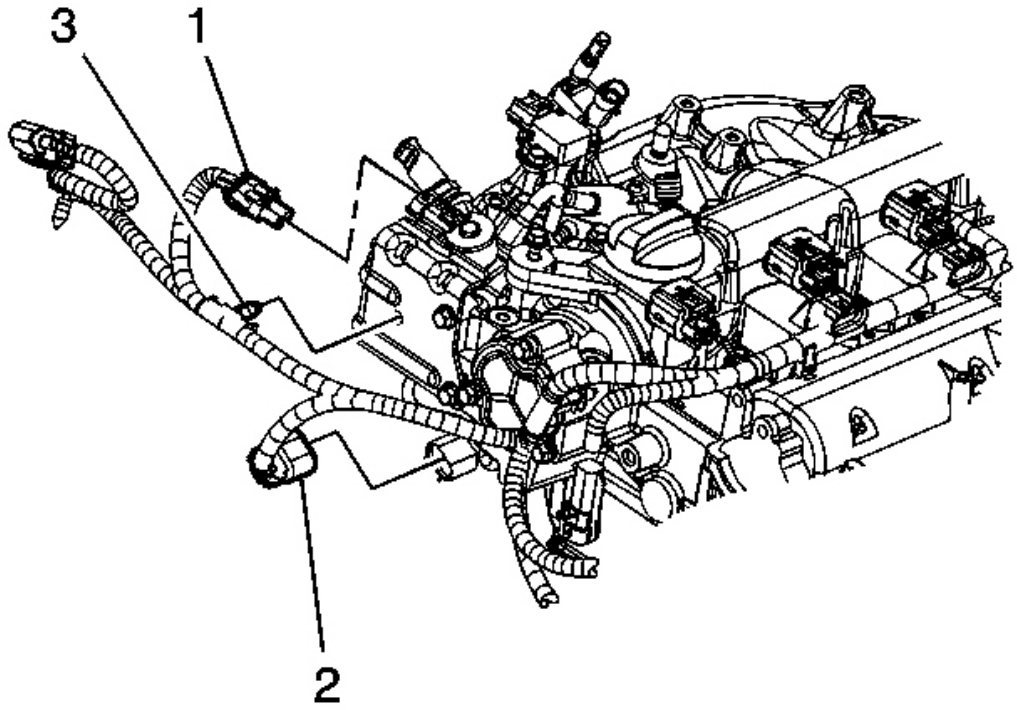


Fig. 165: View Of Engine Wiring Harness & High Pressure Fuel Pump
Courtesy of GENERAL MOTORS CORP.

18. Connect the engine wiring harness electrical connector (1) to the high pressure fuel pump.
19. Install the engine wiring harness clip (3) to the high pressure fuel pump cover.

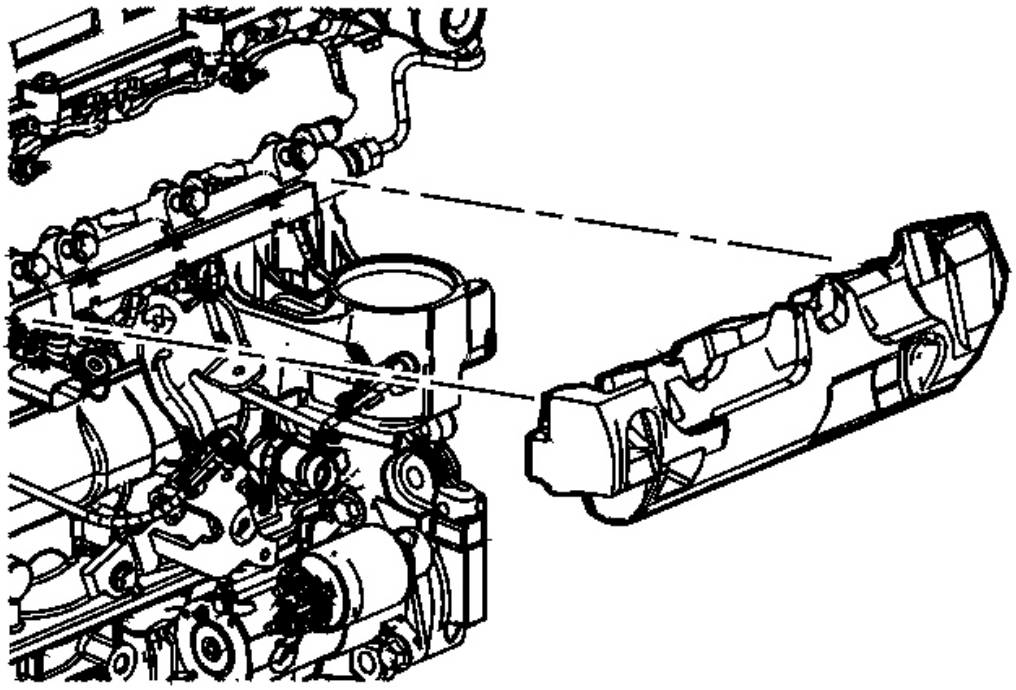


Fig. 166: Fuel Injector Insulator
Courtesy of GENERAL MOTORS CORP.

20. Install the fuel injector insulator.

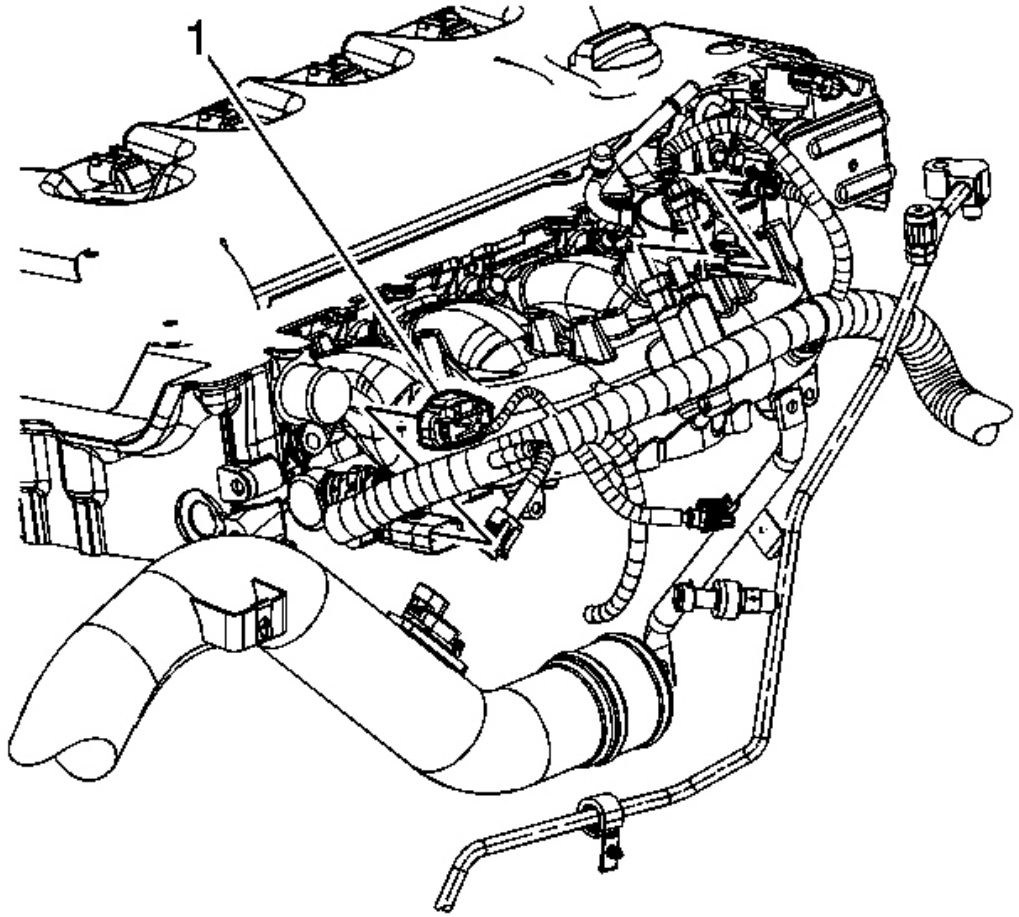


Fig. 167: Identifying Engine Wiring Harness Connector & Fuel Injector Wiring Harness Connector
Courtesy of GENERAL MOTORS CORP.

21. Connect the engine wiring harness electrical connector (1) to the fuel injector wiring harness electrical connector.
22. Inspect for leaks using the following procedure:
    1. Turn ON the ignition, with the engine OFF for 2 seconds.
    2. Turn OFF the ignition, for 10 seconds.
    3. Turn ON the ignition, with the engine OFF.
    4. Inspect for fuel leaks.

23. Install the low side fuel pressure service port cap.
24. Tighten the fuel fill cap.
25. Install the intake manifold assembly. Refer to **Intake Manifold Replacement** .

EVAPORATIVE EMISSION HOSES/PIPES REPLACEMENT - ENGINE/CHASSIS

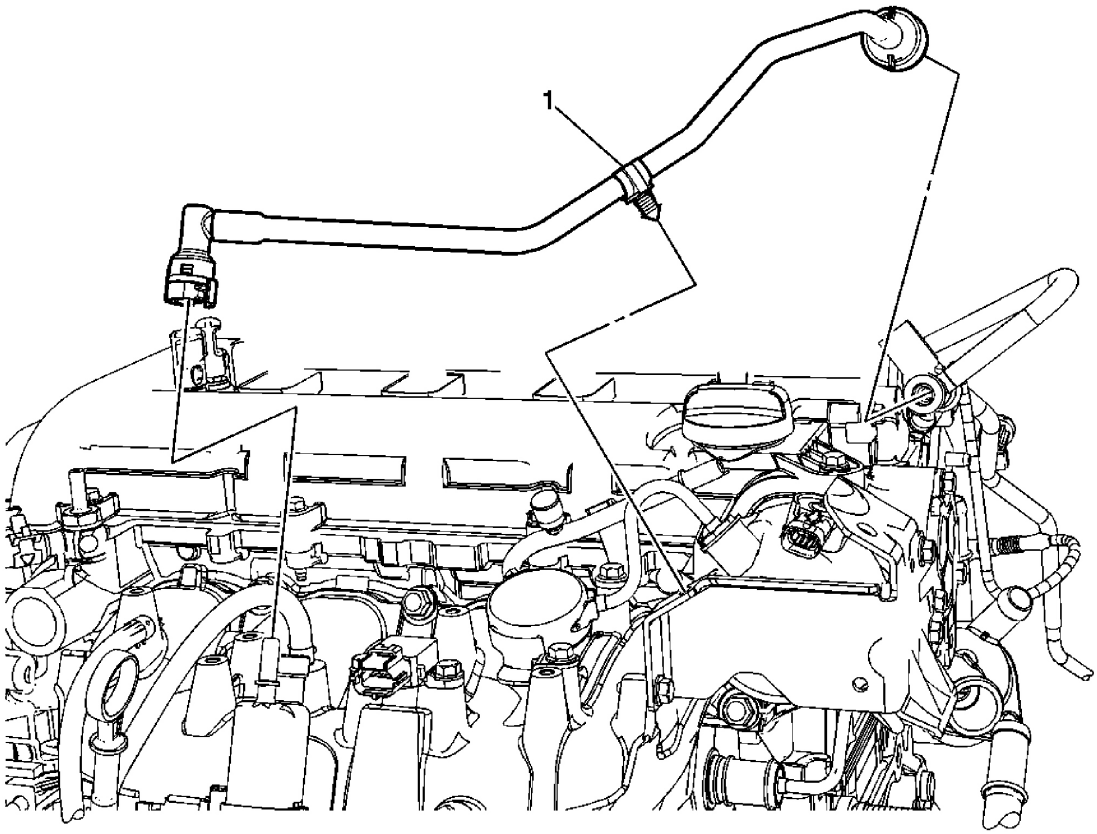


Fig. 168: Evaporative Emission Hoses/Pipes
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
Preliminary Procedures: Relieve the fuel system pressure. Refer to **Fuel Pressure Relief (Without CH 48027)** or **Fuel Pressure Relief (With CH 48027)**.	
1	Evaporative Emission Hoses/Pipe - Engine/Chassis **Procedure:** Disconnect the plastic collar quick connect fittings. Refer to **Plastic**

Collar Quick Connect Fitting Service.

EVAPORATIVE EMISSION HOSES/PIPES REPLACEMENT - CANISTER/FUEL TANK

Removal Procedure

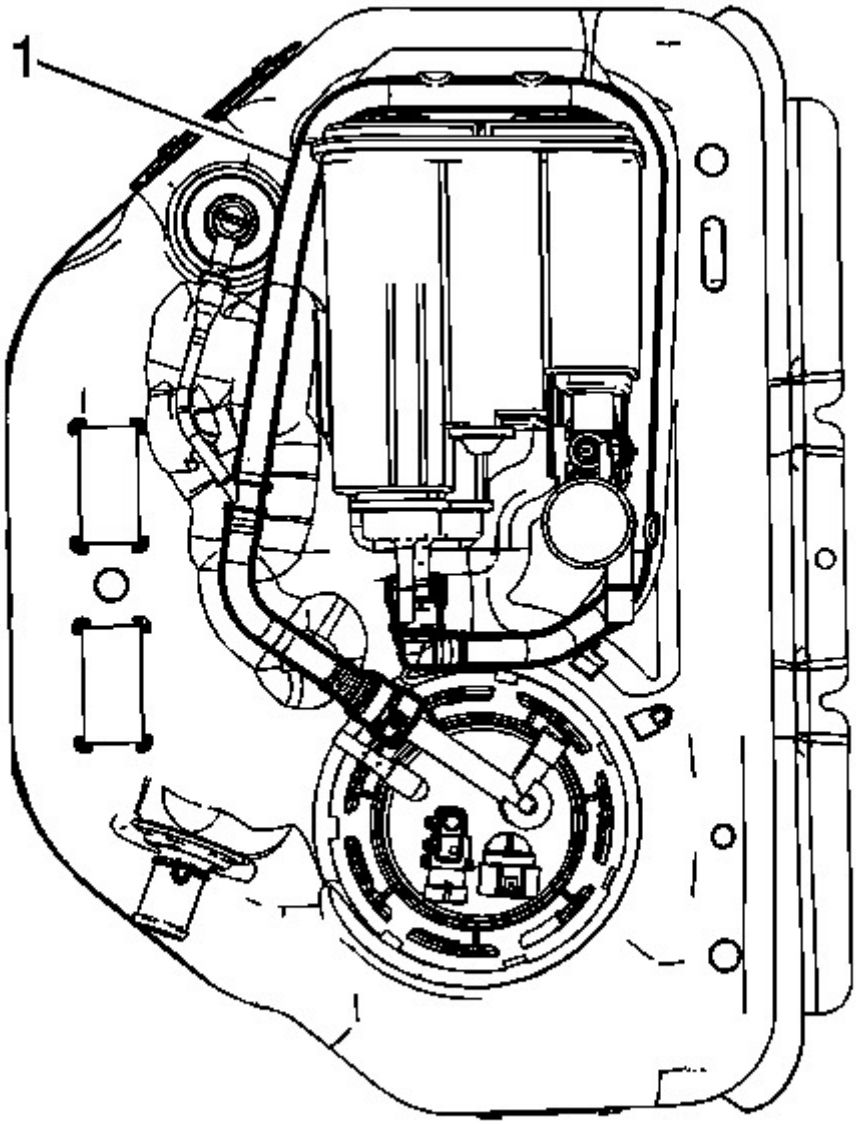


Fig. 169: EVAP Line Quick Connect Fitting

Courtesy of GENERAL MOTORS CORP.

1. Remove the fuel tank. Refer to **Fuel Tank Replacement**.
2. Disconnect the evaporative emission (EVAP) line quick connect fitting from the fuel pump module. Refer to **Plastic Collar Quick Connect Fitting Service**.
3. Disconnect the EVAP line quick connect fitting at the EVAP canister. Refer to **Plastic Collar Quick Connect Fitting Service**.
4. Disconnect the EVAP line from the roll over valve. Refer to **Plastic Collar Quick Connect Fitting Service**.
5. Cap or plug the EVAP connections, fuel pump module, and canister in order to prevent system contamination.
6. Disengage the EVAP line from the fuel tank retaining features.
7. Remove the EVAP line (1) from the fuel tank.

Installation Procedure

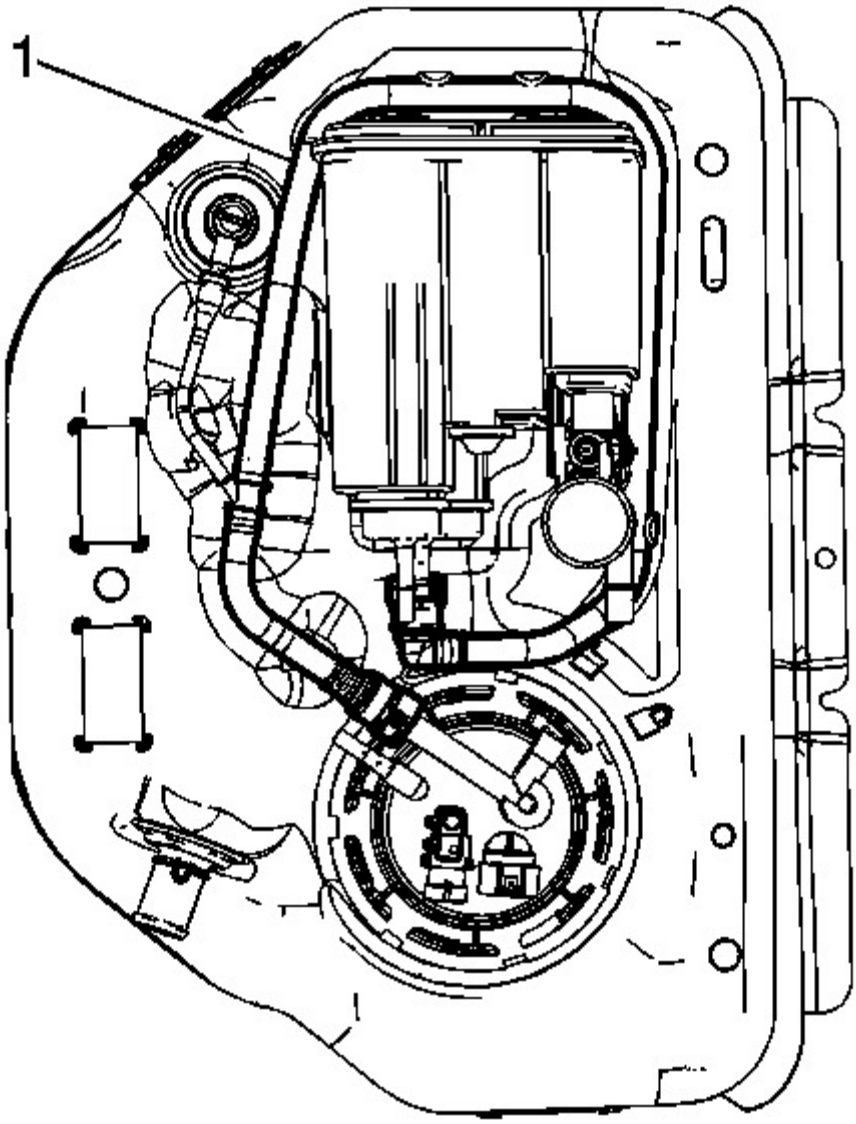


Fig. 170: EVAP Line Quick Connect Fitting
Courtesy of GENERAL MOTORS CORP.

1. Install the EVAP line (1) to the fuel tank.
2. Engage the EVAP vapor line to the fuel tank retaining features.
3. Remove the caps or plugs from the EVAP line connections, fuel pump module,

and canister.

4. Connect the EVAP line quick connect fitting to the roll over valve. Refer to **Plastic Collar Quick Connect Fitting Service**.
5. Connect the EVAP line quick connect fitting at the fuel sender. Refer to **Plastic Collar Quick Connect Fitting Service**.
6. Connect the EVAP line quick connect fitting at the EVAP canister. Refer to **Plastic Collar Quick Connect Fitting Service**.
7. Install the fuel tank. Refer to **Fuel Tank Replacement**.

EVAPORATIVE EMISSION HOSES/PIPES REPLACEMENT - CHASSIS/CANISTER

Removal Procedure

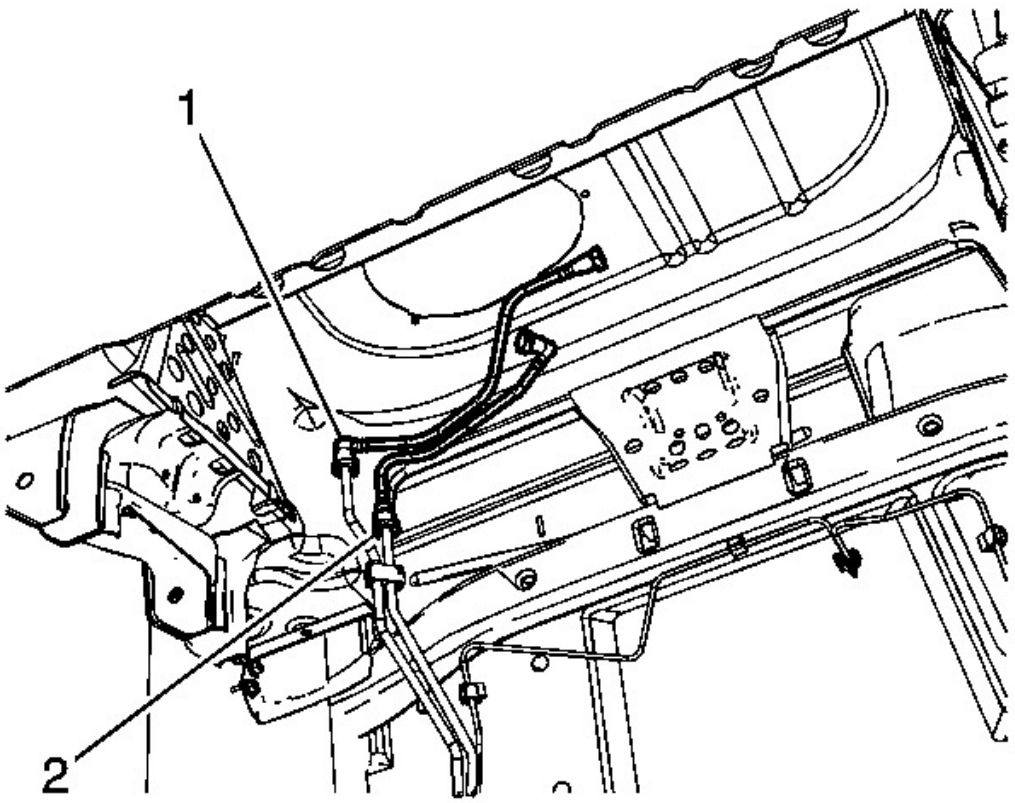


Fig. 171: Fuel Feed Line Quick Connect Fittings

Courtesy of GENERAL MOTORS CORP.

1. Remove the fuel tank. Refer to **Fuel Tank Replacement**.
2. Disconnect the evaporative emission (EVAP) canister purge line quick connect fitting (1) at the chassis line. Refer to **Plastic Collar Quick Connect Fitting Service**.
3. Remove the EVAP canister purge line.

Installation Procedure

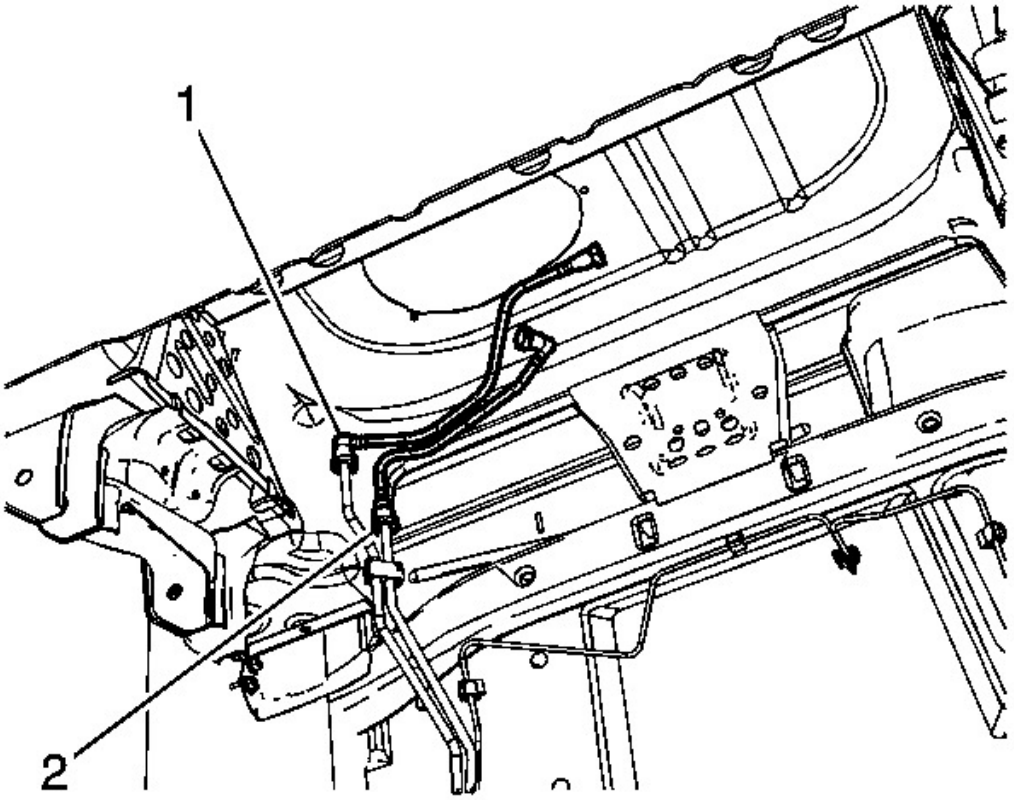


Fig. 172: Fuel Feed Line Quick Connect Fittings
Courtesy of GENERAL MOTORS CORP.

1. Install the EVAP canister purge line.

2. Connect the EVAP canister purge line quick connect fitting (1) to the chassis. Refer to **Plastic Collar Quick Connect Fitting Service**.
3. Install the fuel tank. Refer to **Fuel Tank Replacement**.

FUEL TANK FILLER EVAPORATIVE EMISSION PIPE REPLACEMENT

Removal Procedure

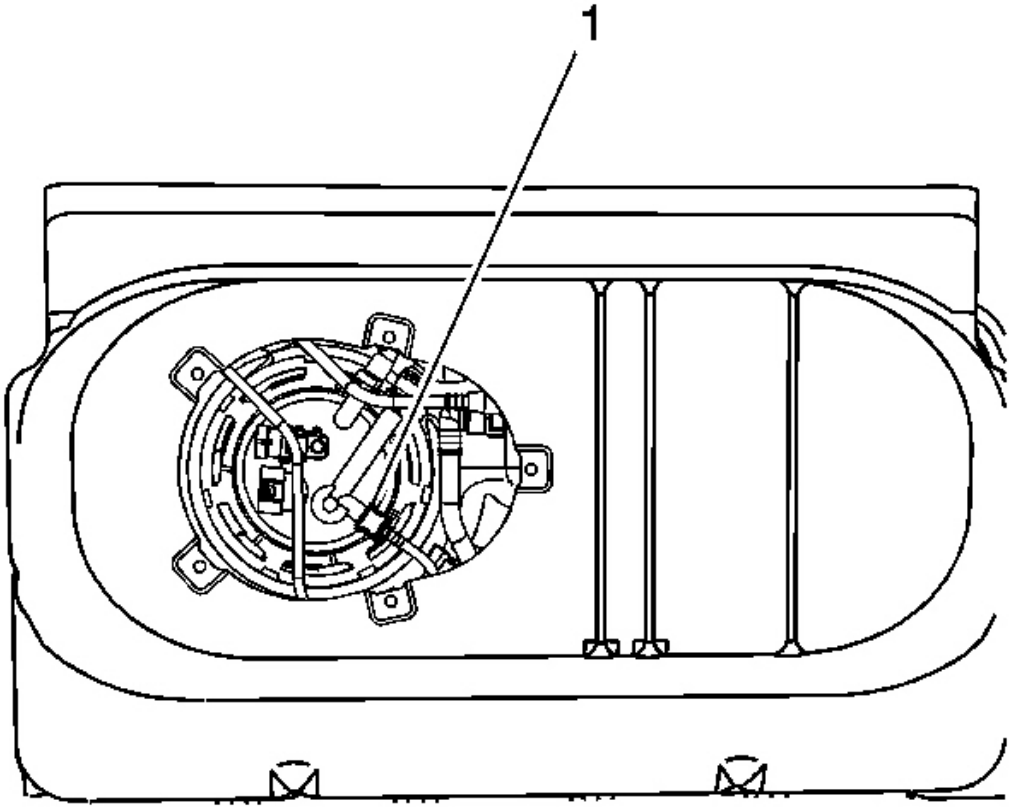


Fig. 173: EVAP Line Quick Connect Fitting
Courtesy of GENERAL MOTORS CORP.

1. Remove the fuel fill pipe. Refer to **Fuel Tank Filler Pipe Replacement**.
2. Disconnect the fuel tank fill evaporative emission (EVAP) pipe quick connect fitting (1) at the fuel pump module. Refer to **Plastic Collar Quick Connect**

Fitting Service.

3. Remove the fuel tank fill EVAP pipe.

Installation Procedure

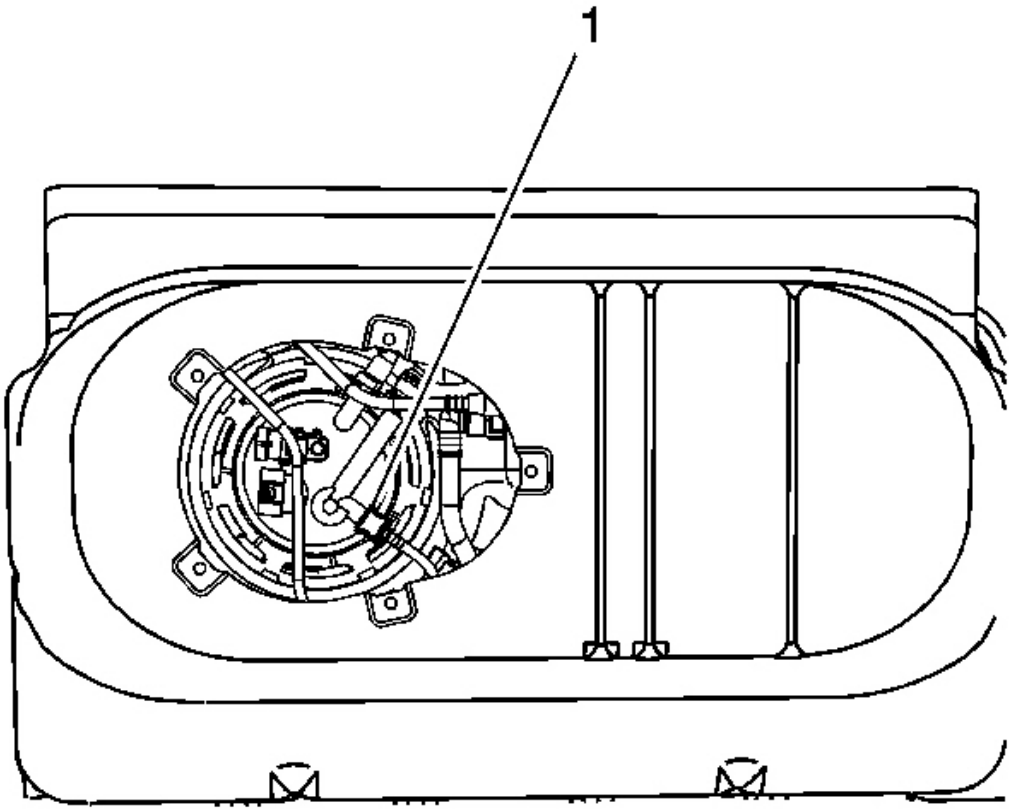


Fig. 174: EVAP Line Quick Connect Fitting
Courtesy of GENERAL MOTORS CORP.

1. Install the fuel tank fill EVAP pipe.
2. Connect the fuel tank fill EVAP pipe quick connect fitting (1) to the fuel pump module. Refer to **Plastic Collar Quick Connect Fitting Service**.
3. Install the fuel fill pipe. Refer to **Fuel Tank Filler Pipe Replacement**.

EVAPORATIVE EMISSION CANISTER PURGE SOLENOID VALVE REPLACEMENT

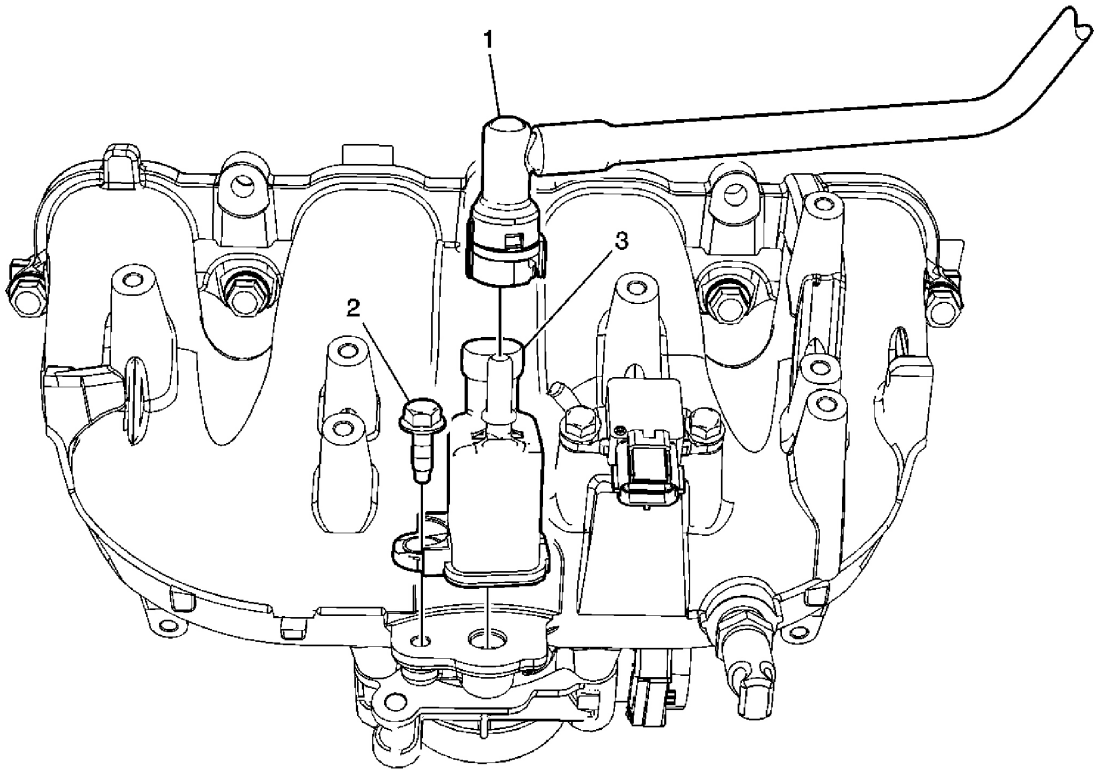


Fig. 175: Evaporative Emission Canister Purge Solenoid Valve
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
1	Evaporative Emission Canister Purge Tube Refer to **Plastic Collar Quick Connect Fitting Service**.
2	Evaporative Emission Canister Purge Solenoid Valve Bolt **NOTE:** **Refer to Fastener Notice .** **Tighten:** 10 N.m (89 lb in)
3	Evaporative Emission Canister Purge Solenoid Valve **Procedure:** Disconnect the electrical connector.

EVAPORATIVE EMISSION CANISTER VENT SOLENOID VALVE REPLACEMENT

Removal Procedure

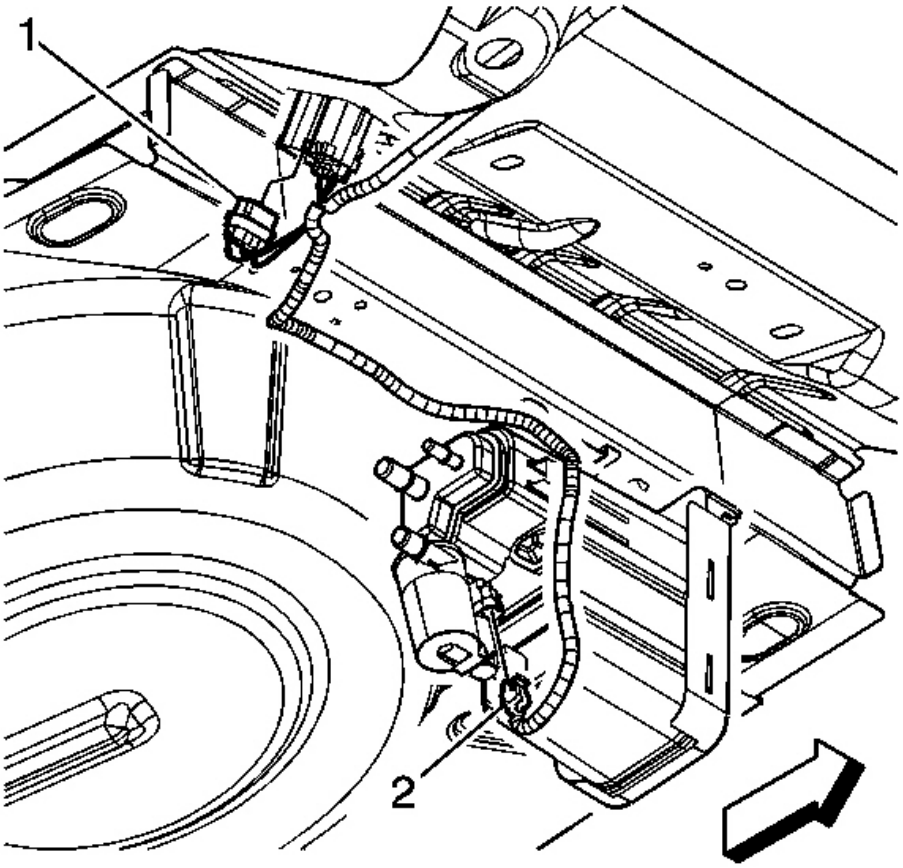


Fig. 176: Fuel Tank Electrical Connector
Courtesy of GENERAL MOTORS CORP.

1. Raise and support the vehicle. Refer to **Lifting and Jacking the Vehicle** .
2. Disconnect the evaporative emission (EVAP) canister vent solenoid valve electrical connector (2).
3. Clean any dirt or debris that may be present around the EVAP canister vent

valve.

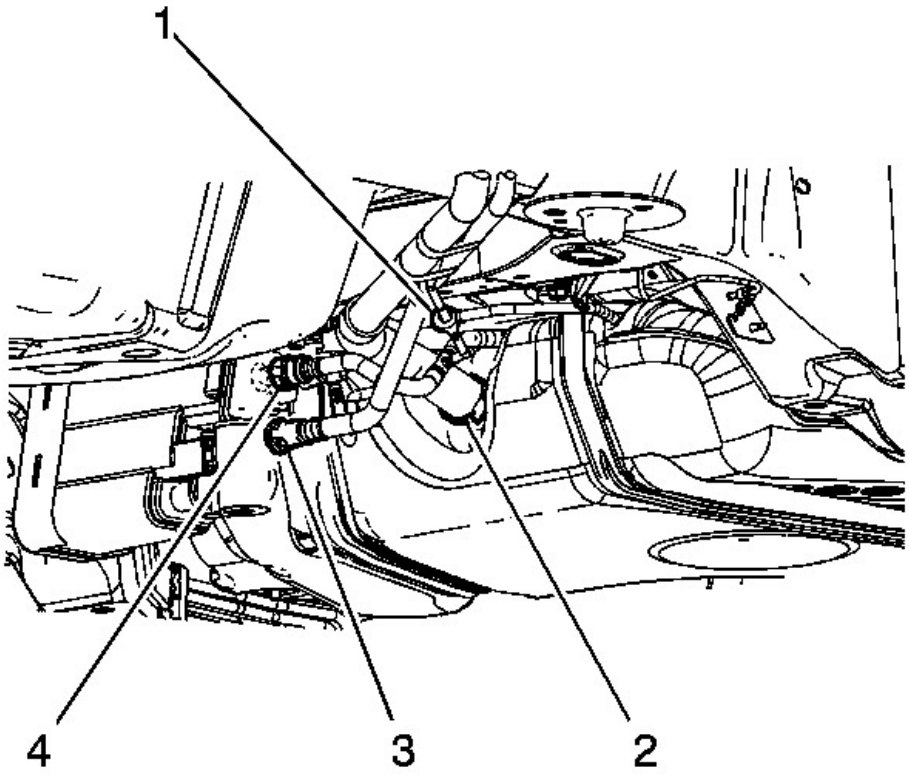


Fig. 177: Fuel Fill Pipe Hose
Courtesy of GENERAL MOTORS CORP.

4. Disconnect the fresh air tube quick connect fitting (3) from the EVAP vent solenoid valve. Refer to **Plastic Collar Quick Connect Fitting Service**.

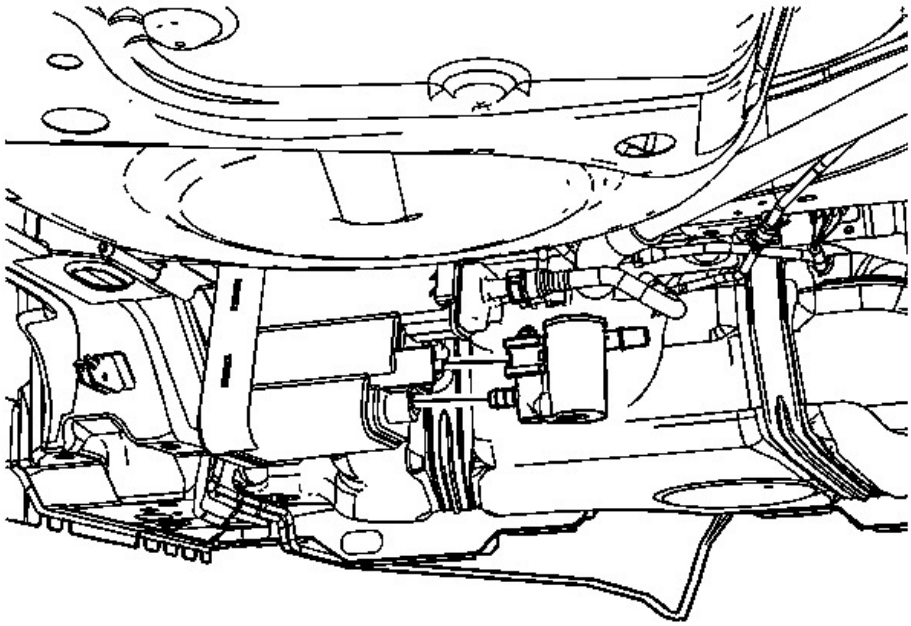


Fig. 178: EVAP Vent Solenoid Valve
Courtesy of GENERAL MOTORS CORP.

5. Disengage the retainer attaching the EVAP vent solenoid valve to the canister.
6. Remove the vent solenoid valve from the EVAP canister.

Installation Procedure

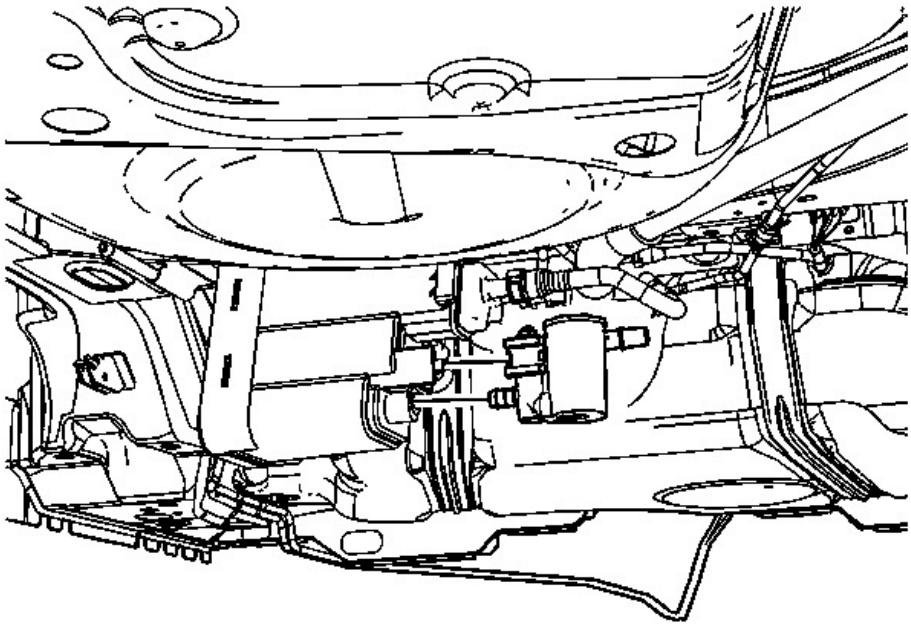


Fig. 179: EVAP Vent Solenoid Valve
Courtesy of GENERAL MOTORS CORP.

1. Install the vent solenoid valve to the EVAP canister.
2. Ensure that the retainer attaching the EVAP vent solenoid valve to the canister is engaged.

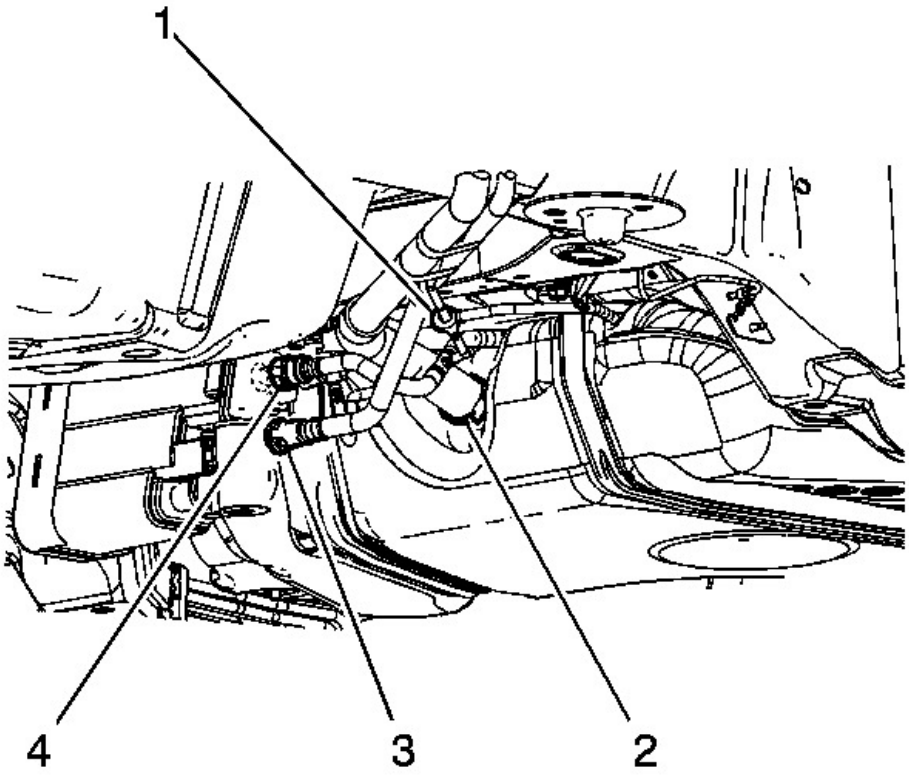


Fig. 180: Fuel Fill Pipe Hose
Courtesy of GENERAL MOTORS CORP.

3. Connect the fresh air tube quick connect fitting (3) to the EVAP vent solenoid valve. Refer to **Plastic Collar Quick Connect Fitting Service**.

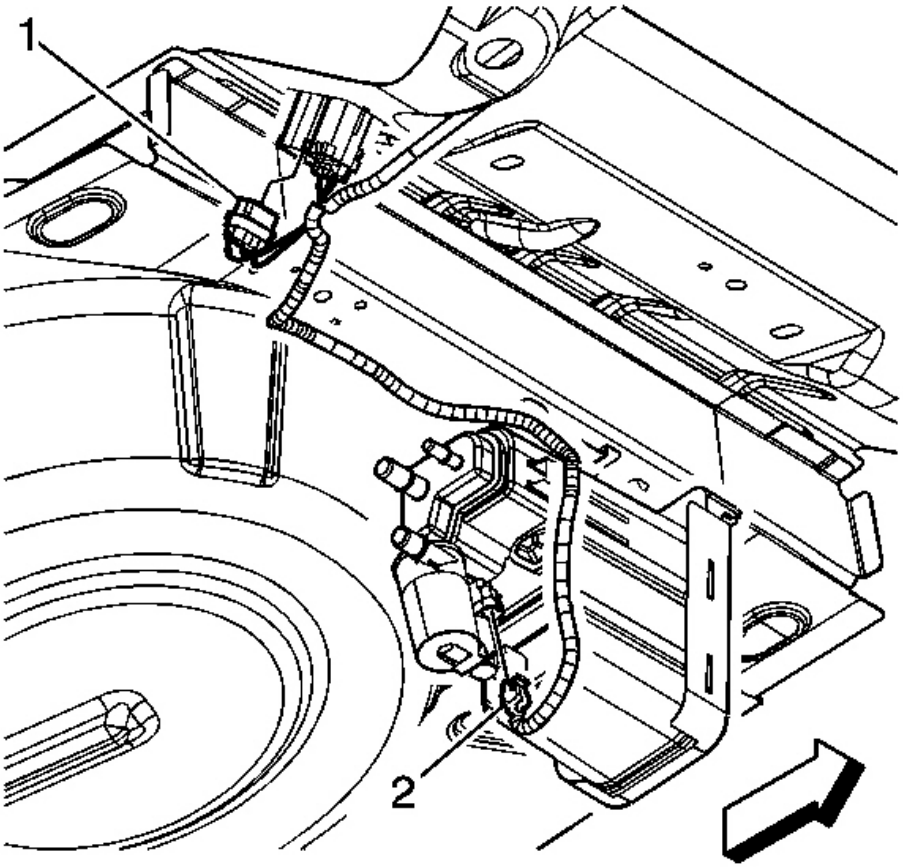


Fig. 181: Fuel Tank Electrical Connector
Courtesy of GENERAL MOTORS CORP.

4. Connect the EVAP canister vent solenoid valve electrical connector (2).
5. Lower the vehicle.

EVAPORATIVE EMISSION CANISTER REPLACEMENT

Removal Procedure

NOTE: The EVAP canister may have released carbon particles which caused this part to fail and may cause damage to other components. Check the EVAP canister for loose carbon before returning the vehicle to service.

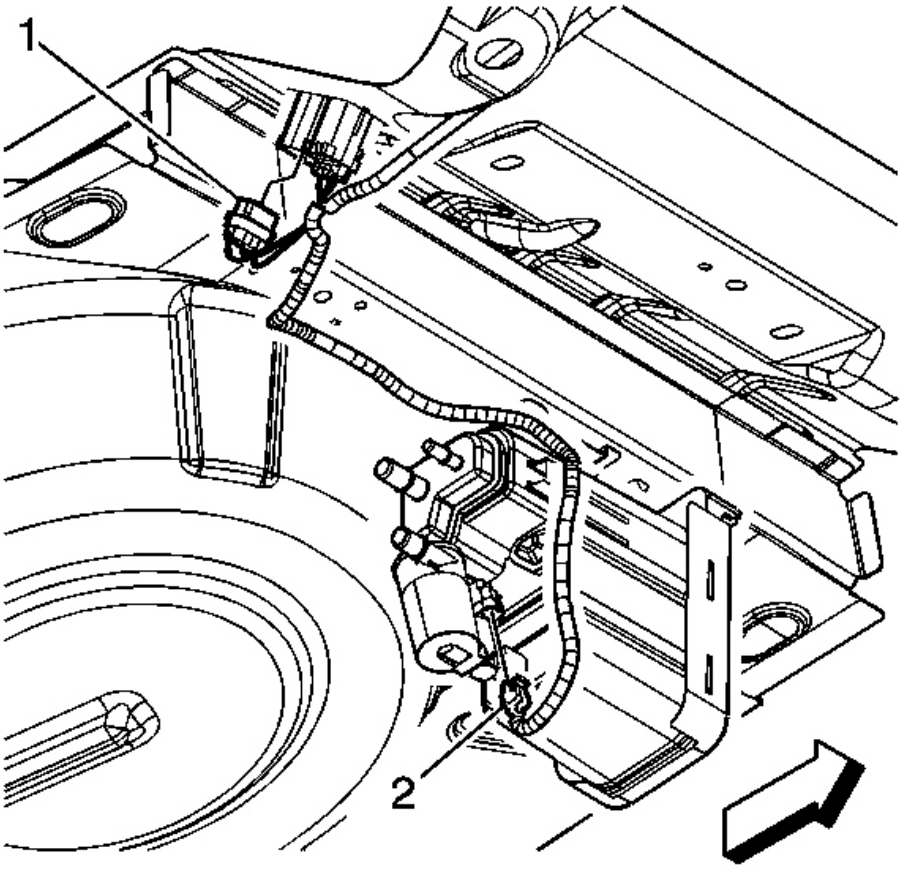


Fig. 182: Fuel Tank Electrical Connector
Courtesy of GENERAL MOTORS CORP.

1. Raise and support the vehicle. Refer to **Lifting and Jacking the Vehicle** .
2. Disconnect the evaporative emission (EVAP) canister vent solenoid valve electrical connector (2).
3. Remove the harness clip from the canister.
4. Clean any dirt or debris that may be present around the EVAP canister.

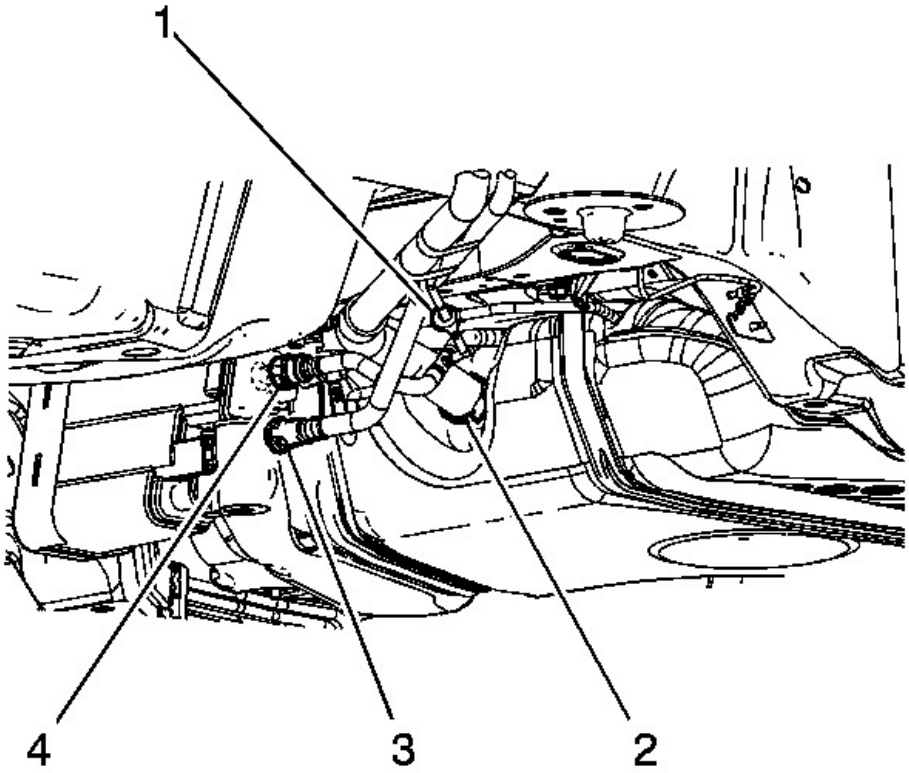


Fig. 183: Fuel Fill Pipe Hose
Courtesy of GENERAL MOTORS CORP.

5. Disconnect the fresh air tube quick connect fitting (3) from the vent solenoid

valve. Refer to **Plastic Collar Quick Connect Fitting Service**.

6. Disconnect the fuel vent pipe quick connect fitting (4) from the canister. Refer to **Plastic Collar Quick Connect Fitting Service**.

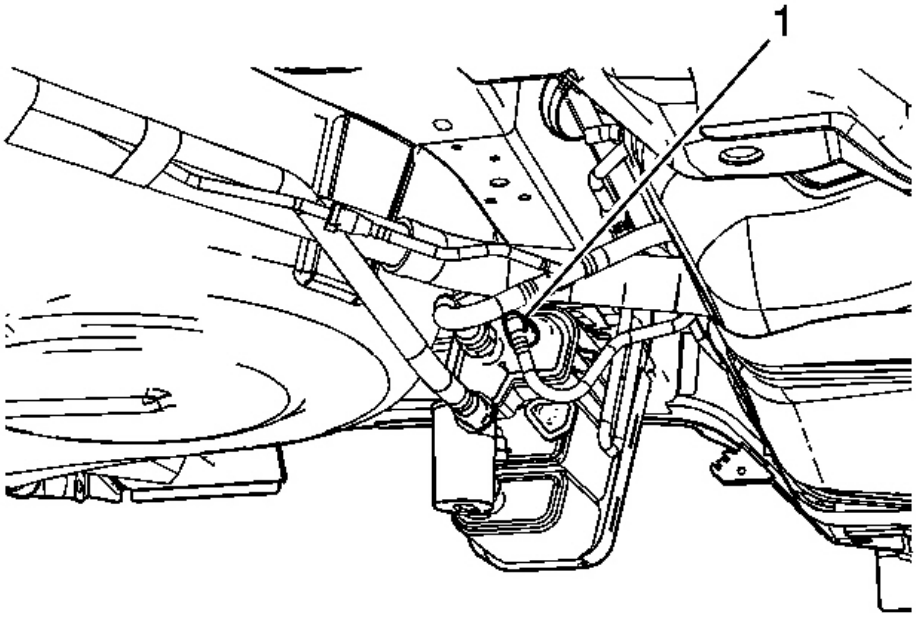


Fig. 184: EVAP Chassis Pipe Quick Connect Fitting
Courtesy of GENERAL MOTORS CORP.

7. Disconnect the EVAP chassis pipe quick connect fitting (1) from the canister. Refer to **Plastic Collar Quick Connect Fitting Service**.

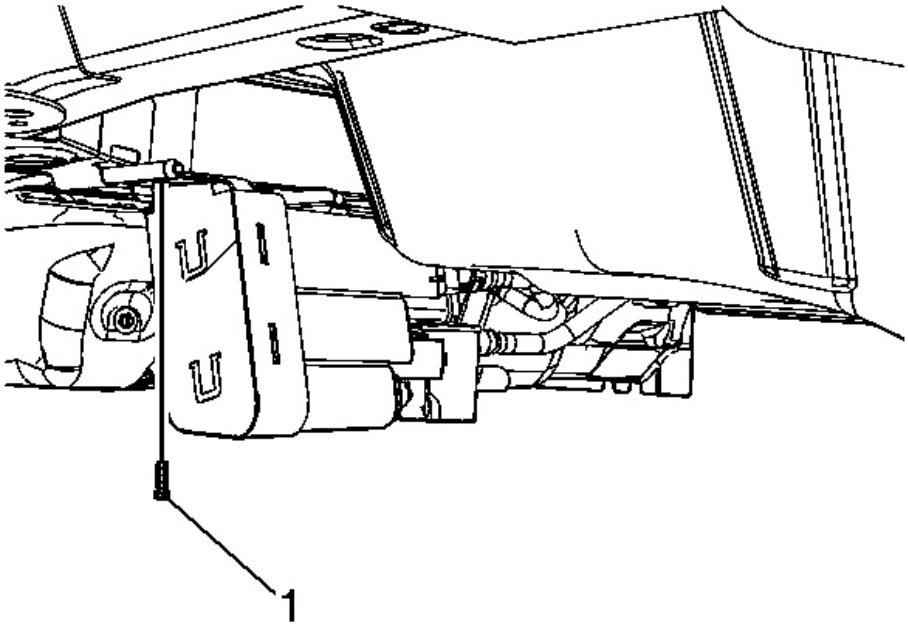


Fig. 185: EVAP Canister Bolt
Courtesy of GENERAL MOTORS CORP.

8. Remove the EVAP canister bolt (1).

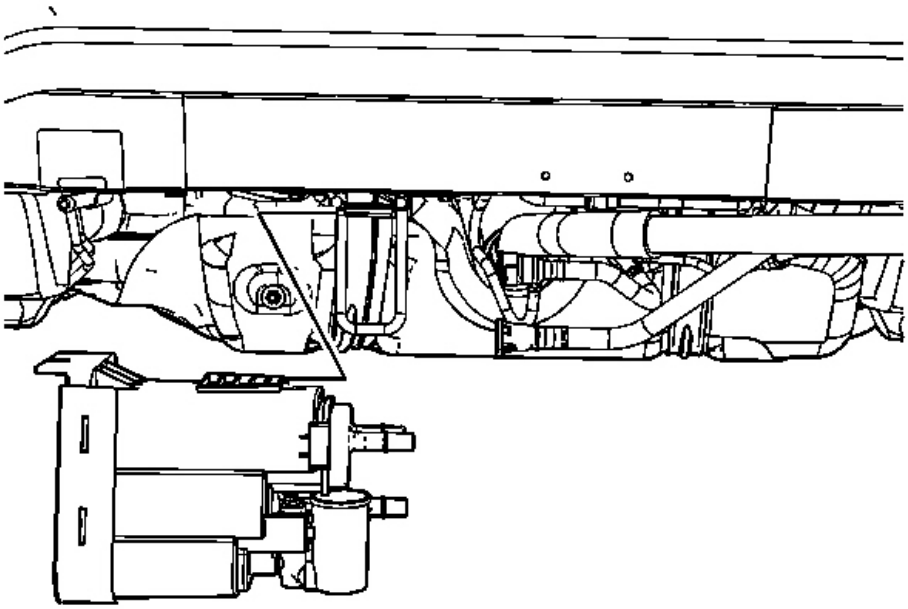


Fig. 186: EVAP Canister
Courtesy of GENERAL MOTORS CORP.

9. Remove the EVAP canister by sliding the canister towards the driver side of the vehicle.

Installation Procedure

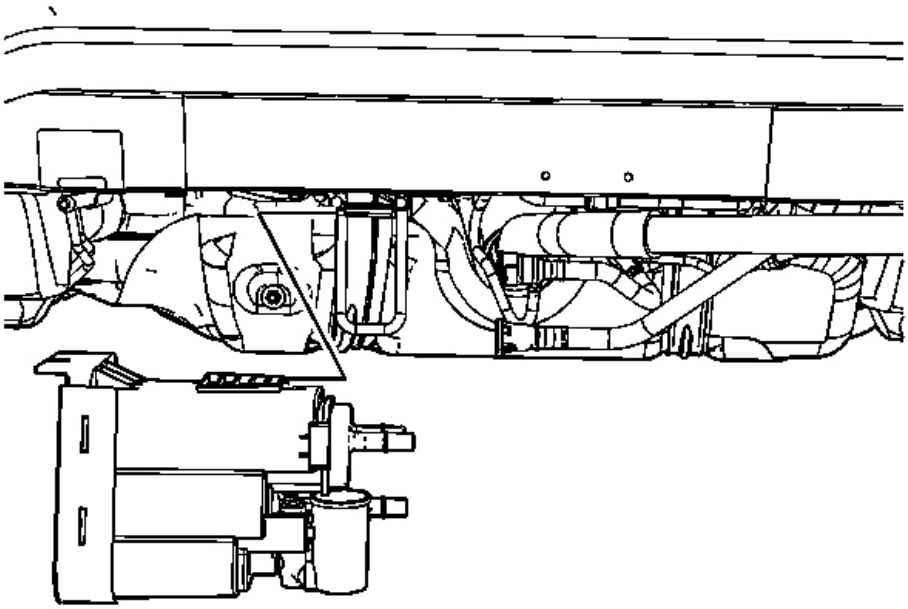


Fig. 187: EVAP Canister
Courtesy of GENERAL MOTORS CORP.

1. Align the EVAP canister retaining feature to the canister bracket.
2. Install the EVAP canister by sliding the canister towards the passenger side of the vehicle.

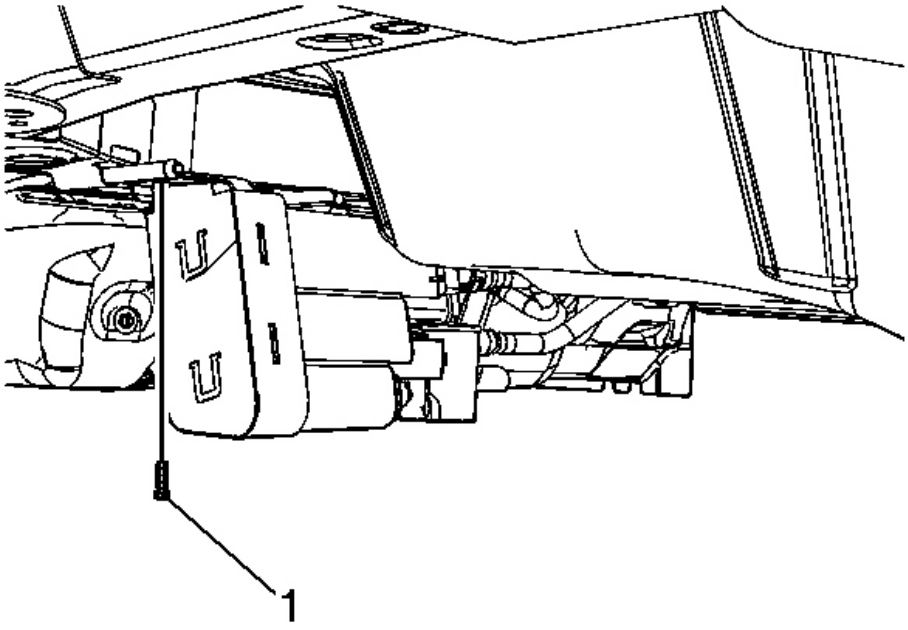


Fig. 188: EVAP Canister Bolt
Courtesy of GENERAL MOTORS CORP.

NOTE: Refer to Fastener Notice .

3. Install the EVAP canister bolt (1).

   Tighten: Tighten the bolt to 10 N.m (89 lb in).

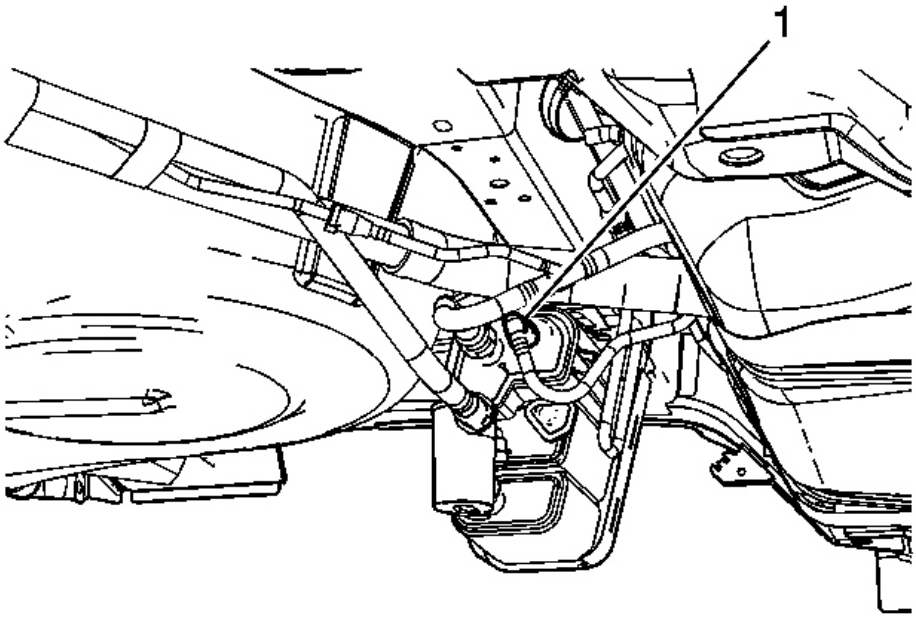


Fig. 189: EVAP Chassis Pipe Quick Connect Fitting
Courtesy of GENERAL MOTORS CORP.

4. Connect the EVAP chassis pipe quick connect fitting (1) to the canister. Refer to **Plastic Collar Quick Connect Fitting Service**.

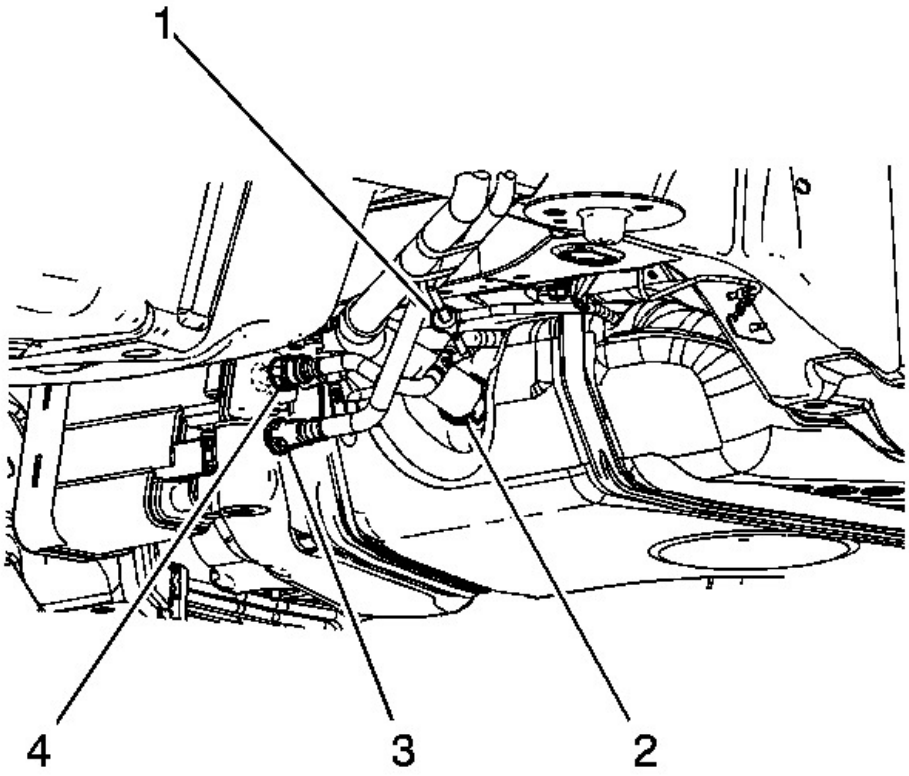


Fig. 190: Fuel Fill Pipe Hose
Courtesy of GENERAL MOTORS CORP.

5. Connect the fuel vent pipe quick connect fitting (4) to the canister. Refer to **Plastic Collar Quick Connect Fitting Service**.
6. Connect the fresh air tube quick connect fitting (3) to the vent solenoid valve. Refer to **Plastic Collar Quick Connect Fitting Service**.

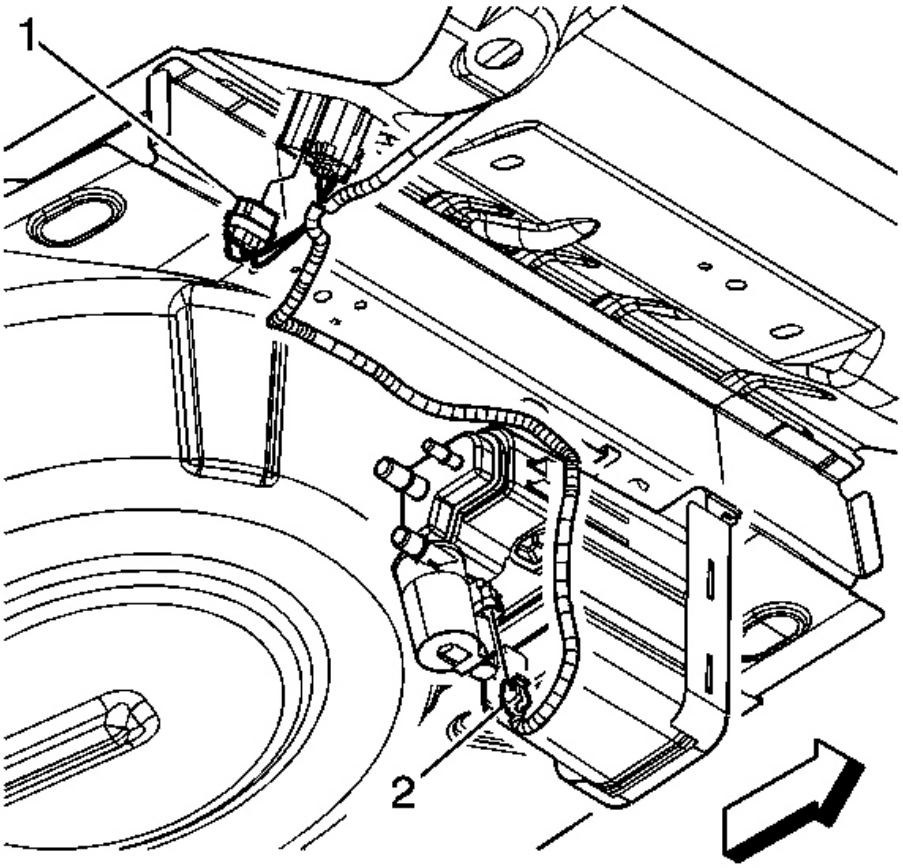


Fig. 191: Fuel Tank Electrical Connector
Courtesy of GENERAL MOTORS CORP.

7. Connect the EVAP canister vent solenoid valve electrical connector (2).
8. Install the harness clip to the canister.
9. Lower the vehicle.

EVAPORATIVE EMISSION SYSTEM CLEANING

Tools Required

J 41413 EVAP Pressure and Purge Station. See **Special Tools**.

Inspection Procedure

NOTE: Use the EVAP Pressure/Purge Diagnostic Station J 41413 in order to provide a clean, dry, low pressure gas source. Do not substitute any other pressurized gas source. Damage may result to the EVAP system.

IMPORTANT: Proceed with the following procedure only if referenced by an evaporative emission (EVAP) diagnostic or repair procedure.

1. Turn OFF the ignition.
2. Remove the EVAP canister purge valve. Refer to **Evaporative Emission Canister Purge Solenoid Valve Replacement** .
3. Lightly tap the EVAP canister purge valve on a hard surface.
4. Inspect for carbon particles exiting either of the vacuum ports.
   - If no carbon particles were detected, but a blockage was detected during a diagnostic procedure, install the original EVAP canister purge valve. Continue with the cleaning procedure.
   - If carbon particles are found during the inspection procedure, continue with the cleaning procedure.
   - If a diagnostic procedure directed you to replace the EVAP canister purge valve and no carbon particles were detected, replace the EVAP canister purge valve. Return to the published service procedure.

Cleaning Procedure

1. Remove the EVAP canister. Refer to **Evaporative Emission Canister Replacement**.
2. Turn OFF the main valve on the **J 41413** . See **Special Tools**.
3. Disconnect the hose from the diagnostic station pressure regulator.
4. Using a section of vacuum hose, connect one end onto the EVAP

pressure/purge diagnostic station pressure regulator.

5. Connect the other end of the vacuum hose to the canister side of the purge pipe.
6. Turn ON the main nitrogen cylinder valve and continue to discharge nitrogen for 15 seconds.
7. If the nitrogen does not clear the blockage, replace the purge pipe.
8. Return the EVAP pressure/purge diagnostic station to the stations original condition.
9. Install a NEW EVAP canister. Refer to **Evaporative Emission Canister Replacement**.
10. Lower the vehicle.
11. Install a new EVAP canister purge valve. Refer to **Evaporative Emission Canister Purge Solenoid Valve Replacement** .
12. Return to the diagnostic table that sent you here.

IGNITION COIL REPLACEMENT

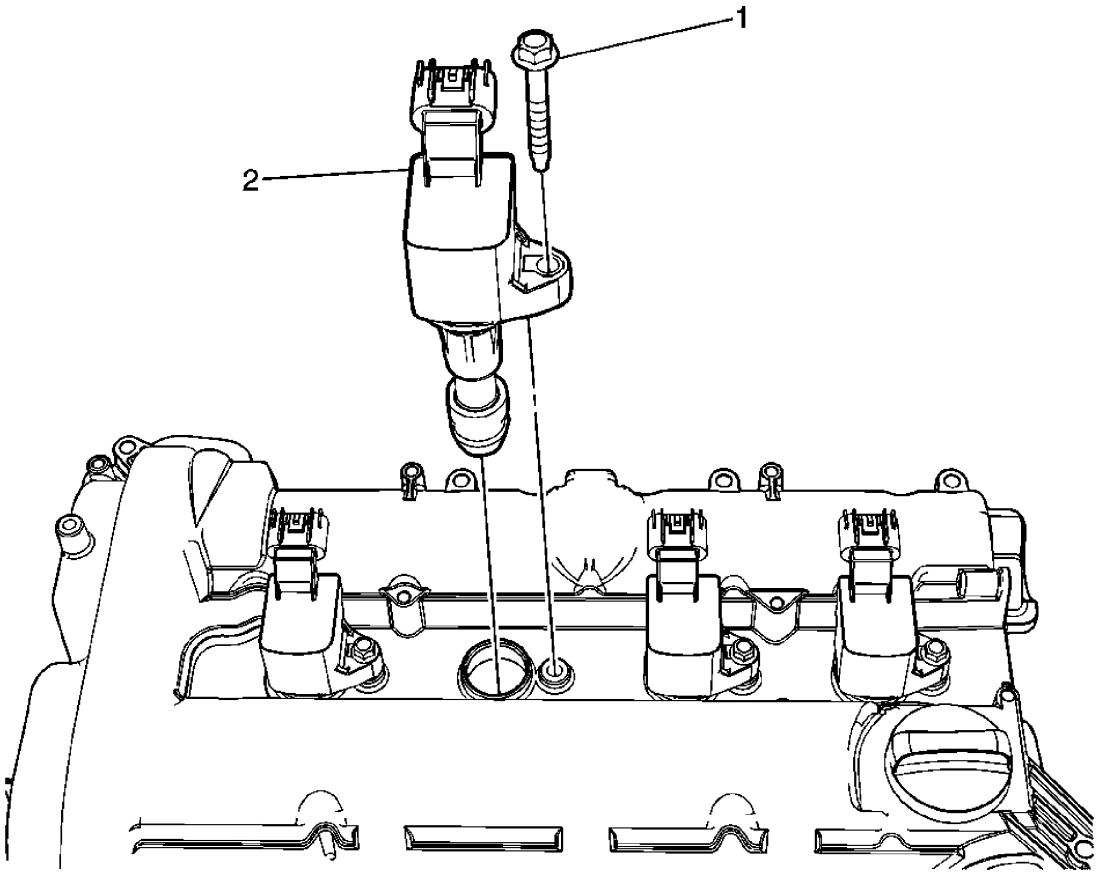


Fig. 192: Ignition Coil
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
1	Ignition Coil Bolt **NOTE:** **Refer to Fastener Notice .** **Tighten:** 10 N.m (89 lb in)
2	Ignition Coil **Procedure:** Disconnect the electrical connector.

SPARK PLUG INSPECTION

Spark Plug Usage

- Ensure that the correct spark plug is installed. An incorrect spark plug causes driveability conditions. Refer to **Ignition System Specifications** for the correct spark plug.
- Ensure that the spark plug has the correct heat range. An incorrect heat range causes the following conditions:
  - Spark plug fouling-Colder plug
  - Pre-ignition causing spark plug and/or engine damage-Hotter plug

Spark Plug Inspection

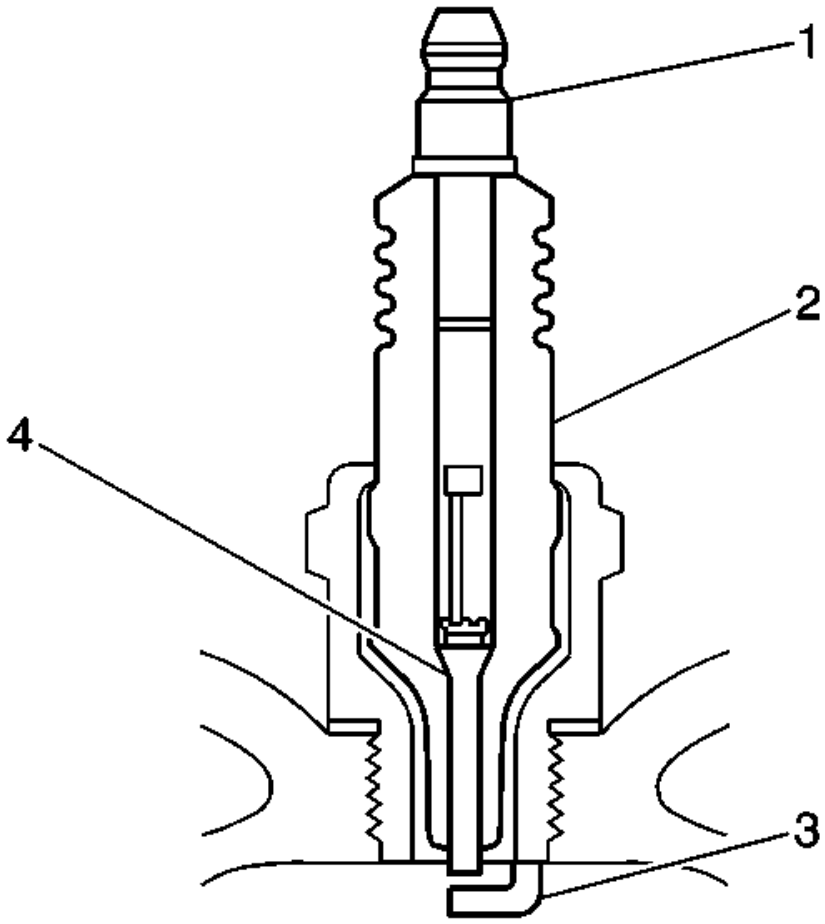


Fig. 193: Cross Sectional View Of Spark Plug
Courtesy of GENERAL MOTORS CORP.

- Inspect the terminal post (1) for damage.

- Inspect for a bent or broken terminal post (1).
- Test for a loose terminal post (1) by twisting and pulling the post. The terminal post (1) should NOT move.

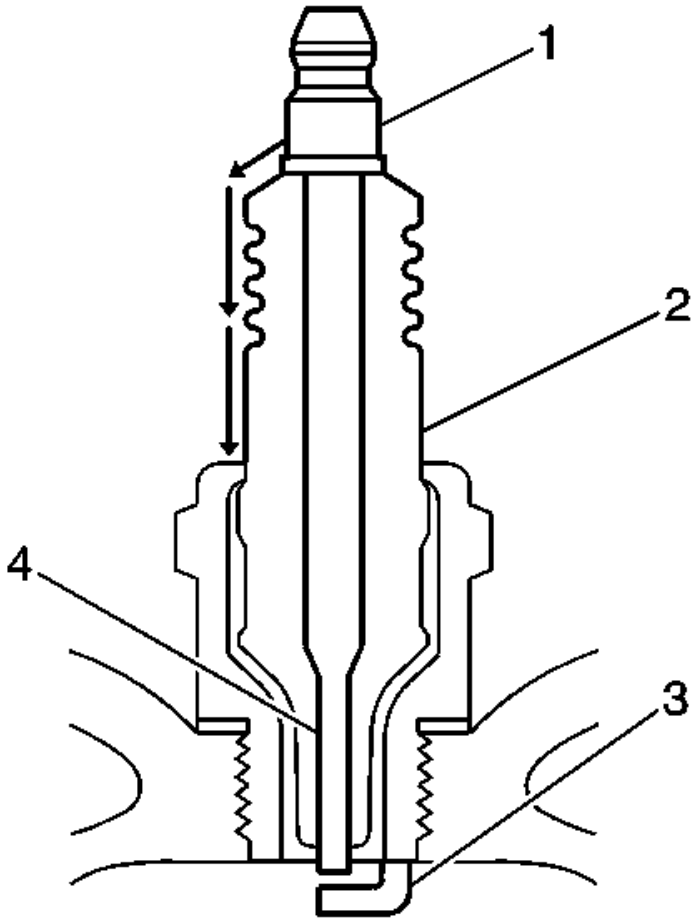


Fig. 194: Identifying Points For Inspecting Spark Plug For Flashover Or Carbon Tracking Soot
Courtesy of GENERAL MOTORS CORP.

- Inspect the insulator (2) for flashover or carbon tracking, soot. This is caused by the electrical charge traveling across the insulator (2) between the terminal post (1) and ground. Inspect for the following conditions:
  - Inspect the spark plug boot for damage.
  - Inspect the spark plug recess area of the cylinder head for moisture, such

as oil, coolant, or water. A spark plug boot that is saturated causes arcing to ground.

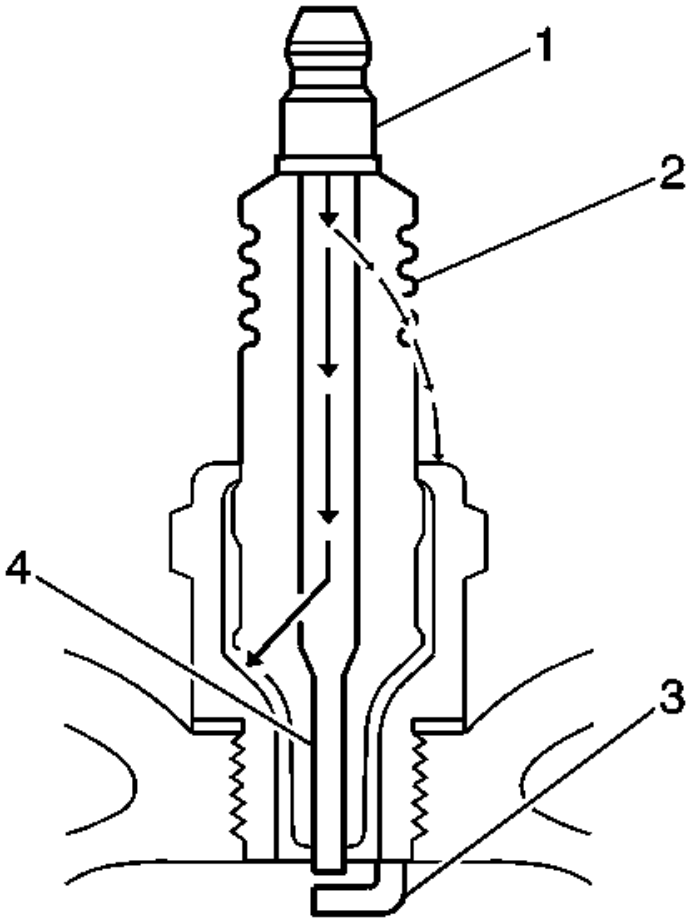


Fig. 195: Inspecting Spark Plug Insulator
Courtesy of GENERAL MOTORS CORP.

- Inspect the insulator (2) for cracks. All or part of the electrical charge may arc through the crack instead of the electrodes (3, 4).

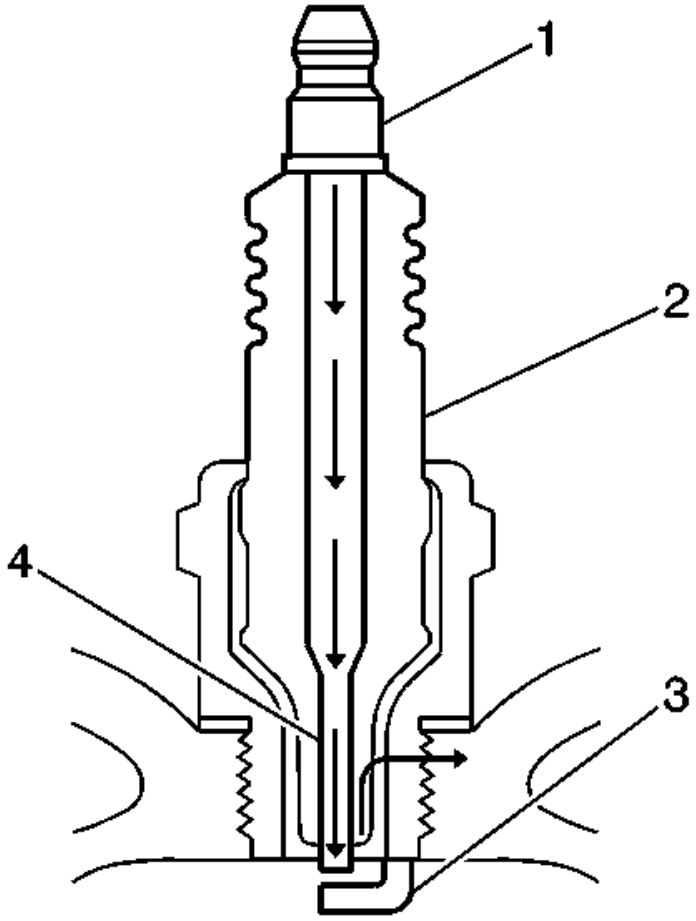


Fig. 196: Cutaway/Description View Of Spark Plug
Courtesy of GENERAL MOTORS CORP.

- Inspect for evidence of improper arcing.
  - Measure the gap between the center electrode (4) and the side electrode (3) terminals. Refer to **Ignition System Specifications**. An excessively wide electrode gap can prevent correct spark plug operation.
  - Inspect for the correct spark plug torque. Refer to **Ignition System Specifications**. Insufficient torque can prevent correct spark plug operation. An over torqued spark plug, causes the insulator (2) to crack.
  - Inspect for signs of tracking that occurred near the insulator tip instead of the center electrode (4).
  - Inspect for a broken or worn side electrode (3).

- Inspect for a broken, worn, or loose center electrode (4) by shaking the spark plug.
  - A rattling sound indicates internal damage.
  - A loose center electrode (4) reduces the spark intensity.
- Inspect for bridged electrodes (3, 4). Deposits on the electrodes (3, 4) reduce or eliminates the gap.
- Inspect for worn or missing platinum pads on the electrodes (3, 4) If equipped.
- Inspect for excessive fouling.

- Inspect the spark plug recess area of the cylinder head for debris. Dirty or damaged threads can cause the spark plug not to seat correctly during installation.

Spark Plug Visual Inspection

- Normal operation-Brown to grayish-tan with small amounts of white powdery deposits are normal combustion by-products from fuels with additives.
- Carbon Fouled-Dry, fluffy black carbon, or soot caused by the following conditions:
  - Rich fuel mixtures
    - Leaking fuel injectors
    - Excessive fuel pressure
    - Restricted air filter element
    - Incorrect combustion
  - Reduced ignition system voltage output
    - Weak coils
    - Worn ignition wires
    - Incorrect spark plug gap
  - Excessive idling or slow speeds under light loads can keep spark plug temperatures so low that normal combustion deposits may not burn off.
- Deposit Fouling-Oil, coolant, or additives that include substances such as silicone, very white coating, reduces the spark intensity. Most powdery deposits will not effect spark intensity unless they form into a glazing over the

electrode.

SPARK PLUG REPLACEMENT

Removal Procedure

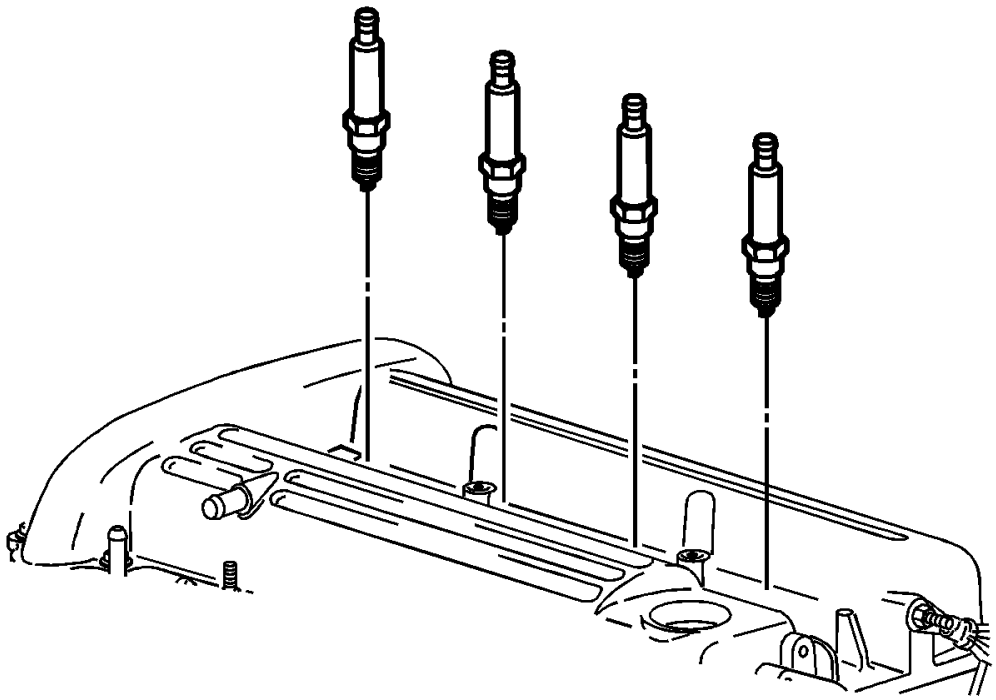


Fig. 197: View Of Spark Plugs
Courtesy of GENERAL MOTORS CORP.

1. Remove the ignition coil(s). Refer to **Ignition Coil Replacement**.

IMPORTANT: Make sure that any water and/or debris is blown out of the spark plug holes prior to removing the spark plugs.

2. Remove the spark plugs using a 5/8 inch spark plug socket.

Installation Procedure

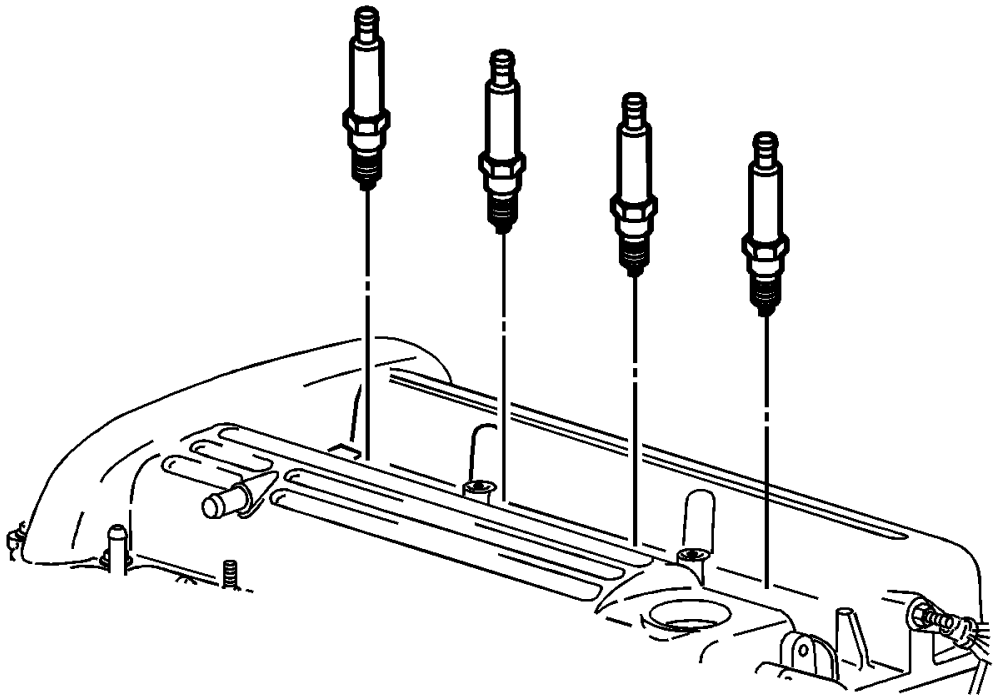


Fig. 198: View Of Spark Plugs
Courtesy of GENERAL MOTORS CORP.

NOTE: Refer to Fastener Notice .

NOTE: Do not coat spark plug threads with anti-seize compound. If anti-seize compound is used and spark plugs are over-torqued, damage to the cylinder head threads may result.

1. Install the spark plugs.

   Tighten: Tighten the plugs to 20 N.m (15 lb ft).

Specification: The spark plug gap is 1.1 mm (0.45 in).

2. Apply dielectric compound to the spark plug boots and make sure no corrosion is present.
3. Install the ignition coil(s). Refer to **Ignition Coil Replacement**.

CRANKSHAFT POSITION SENSOR REPLACEMENT

Removal Procedure

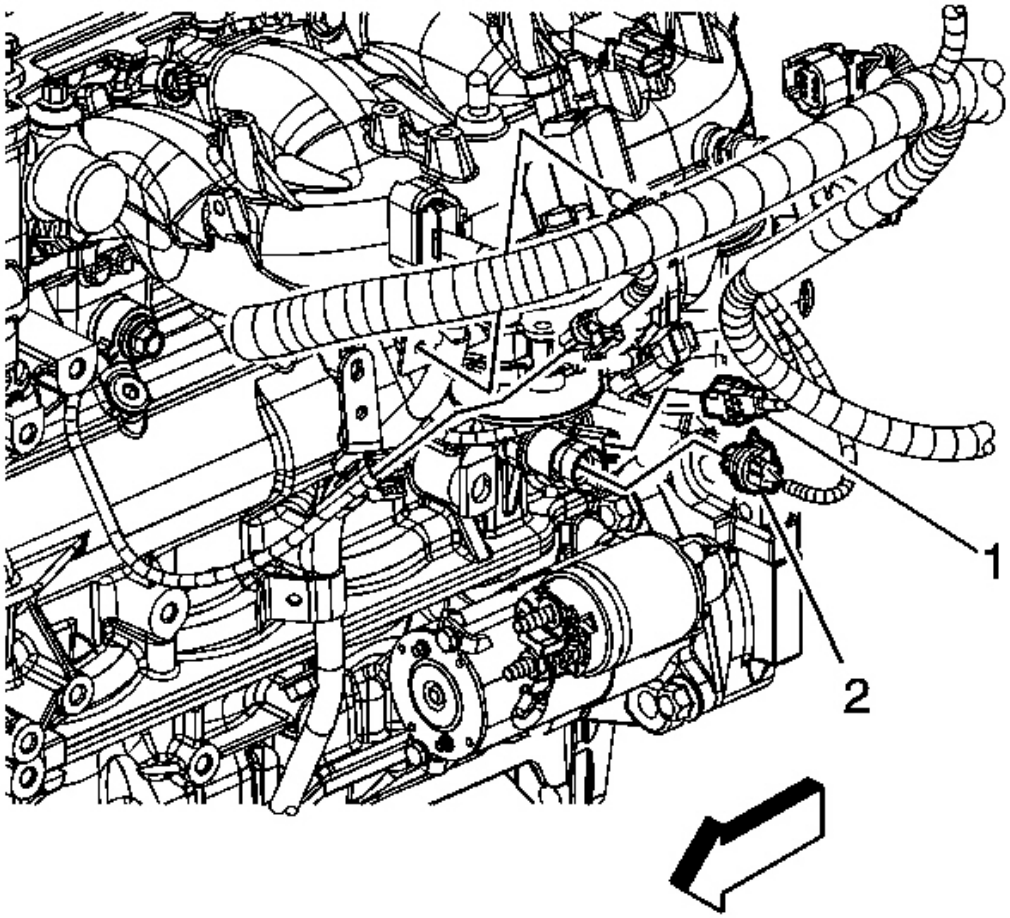


Fig. 199: CKP Sensor Electrical Connector
Courtesy of GENERAL MOTORS CORP.

1. Remove the starter. Refer to **Starter Motor Replacement** .
2. Disconnect the engine wiring harness electrical connector (1) from the crankshaft position (CKP) sensor.

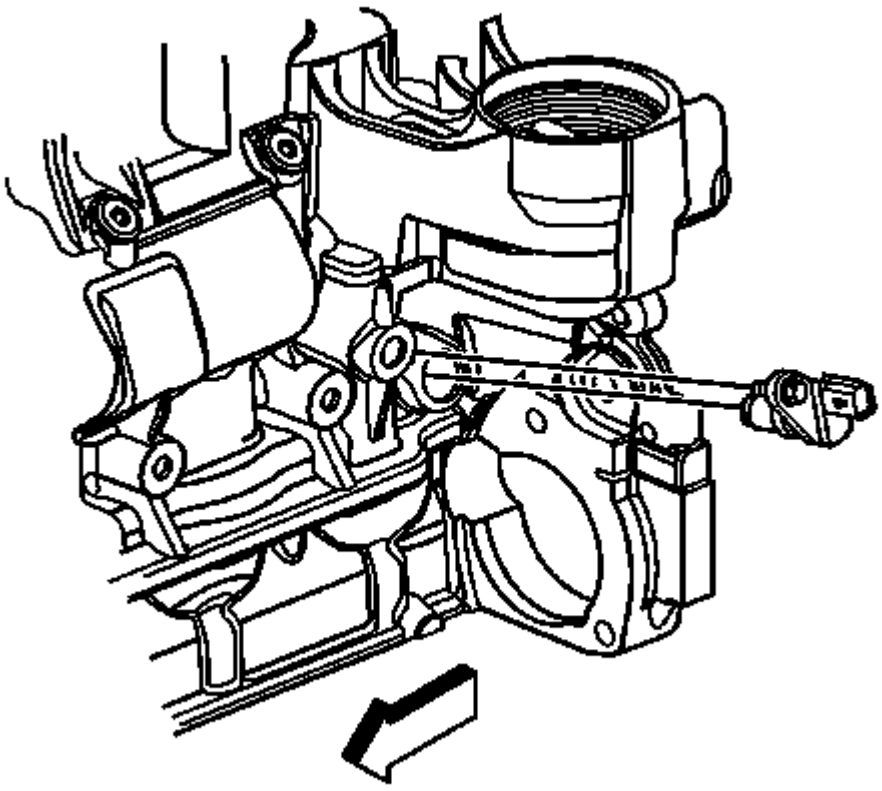


Fig. 200: Identifying CKP Sensor
Courtesy of GENERAL MOTORS CORP.

3. Remove the CKP sensor bolt.
4. Remove the CKP sensor.

Installation Procedure

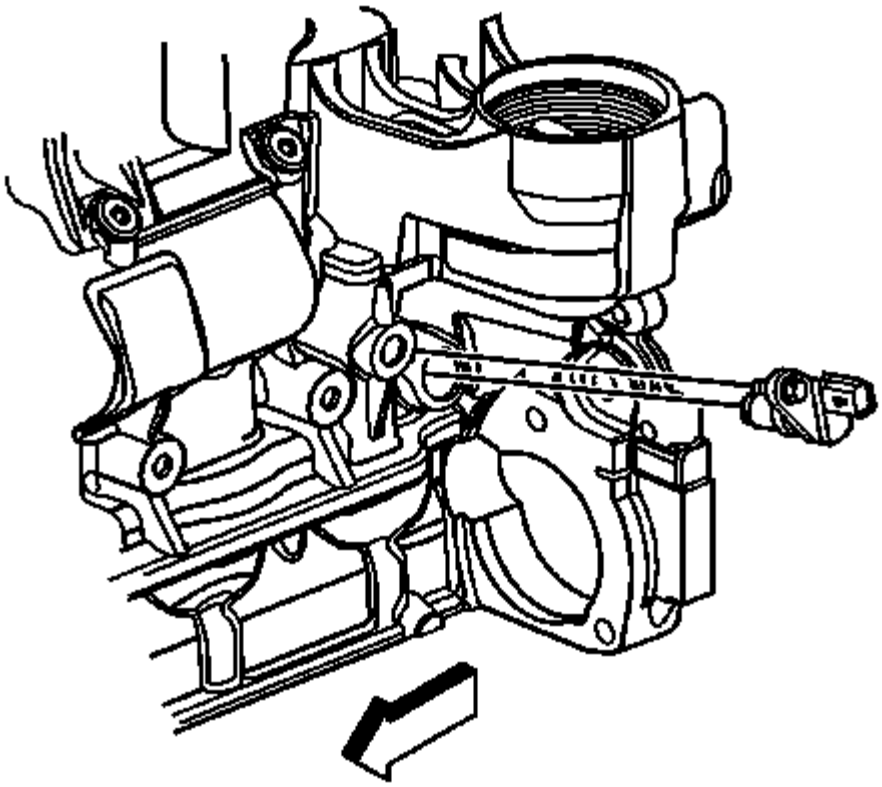


Fig. 201: Identifying CKP Sensor
Courtesy of GENERAL MOTORS CORP.

1. Lubricate the CKP sensor O-ring seal with clean engine oil.
2. Install the CKP sensor.

NOTE: Refer to Fastener Notice .

3. Install the CKP sensor bolt.

   Tighten: Tighten the sensor bolt to 10 N.m (89 lb in).

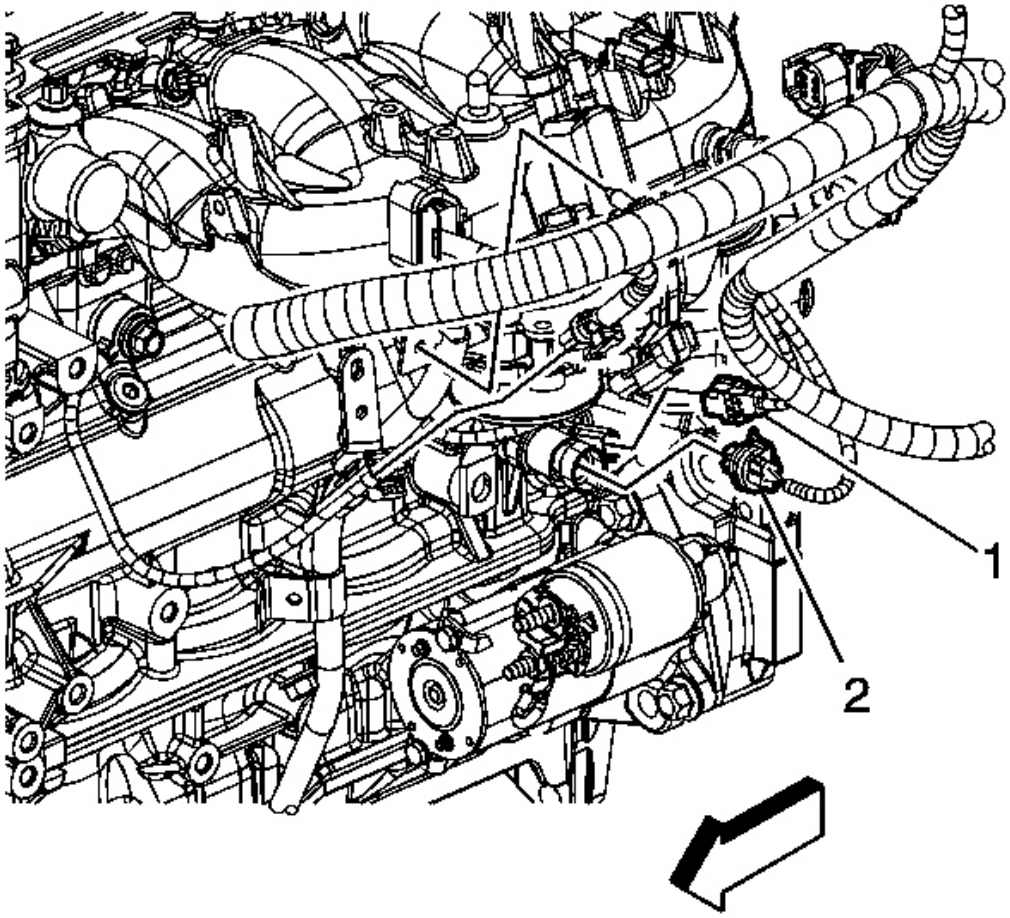


Fig. 202: CKP Sensor Electrical Connector
Courtesy of GENERAL MOTORS CORP.

4. Connect the engine wiring harness electrical connector (1) to the CKP sensor.
5. Install the starter. Refer to **Starter Motor Replacement** .

CAMSHAFT POSITION SENSOR REPLACEMENT - INTAKE

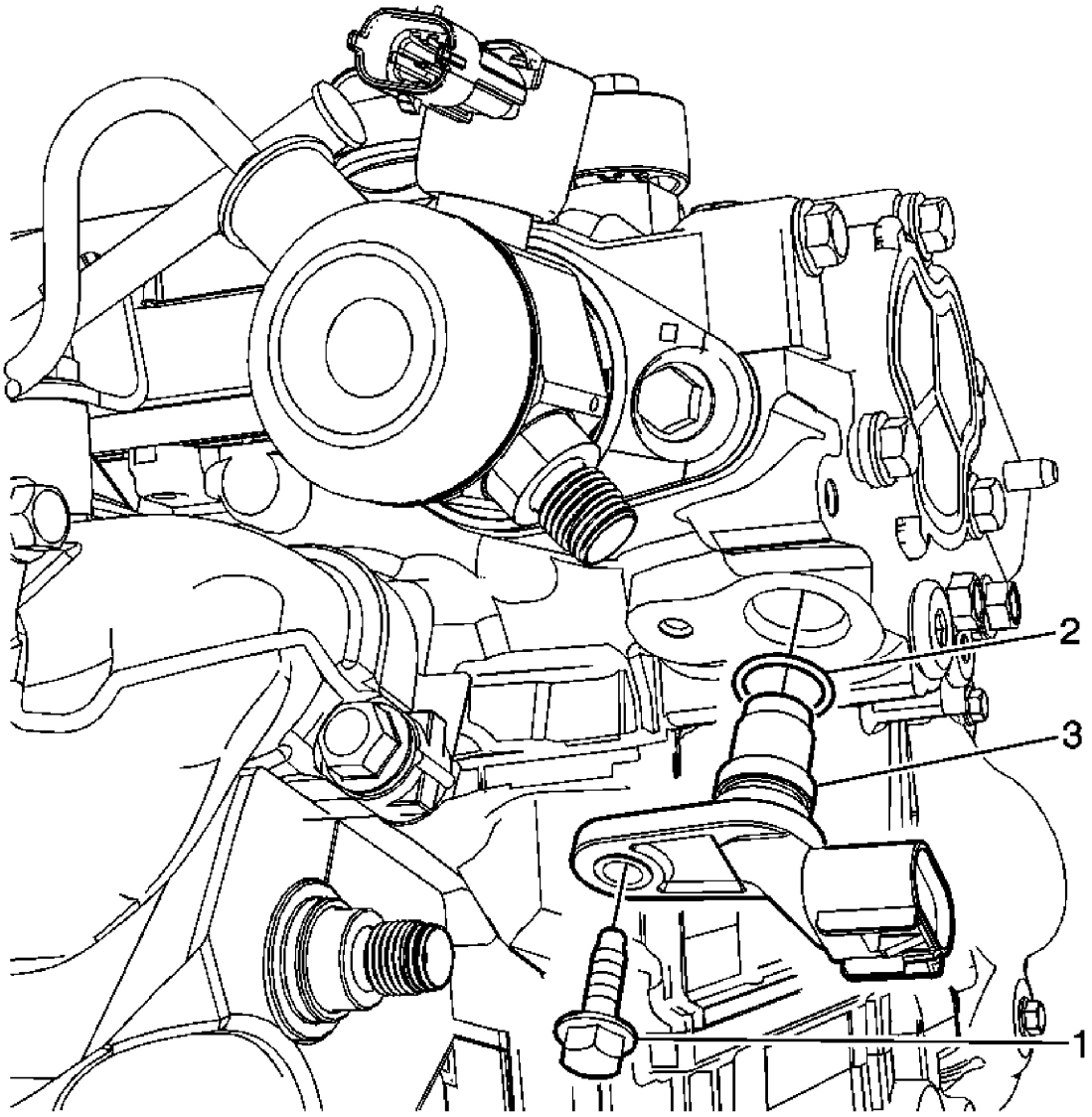


Fig. 203: View Of Intake Camshaft Position Sensor
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
Preliminary Procedure: Remove the fuel feed intermediate pipe. Refer to **Fuel Feed Intermediate Pipe Replacement**.	
1	Camshaft Position Sensor Bolt **NOTE:** **Refer to Fastener Notice .**

	Tighten: 10 N.m (89 lb in)
2	Camshaft Position Sensor O-ring **Procedure:** Lubricate the camshaft position sensor O-ring seal with clean engine oil.
3	Camshaft Position Sensor **Procedure** 1. Disconnect the sensor harness connector. 2. Inspect the camshaft position sensor for damage, replace as necessary.

CAMSHAFT POSITION SENSOR REPLACEMENT - EXHAUST

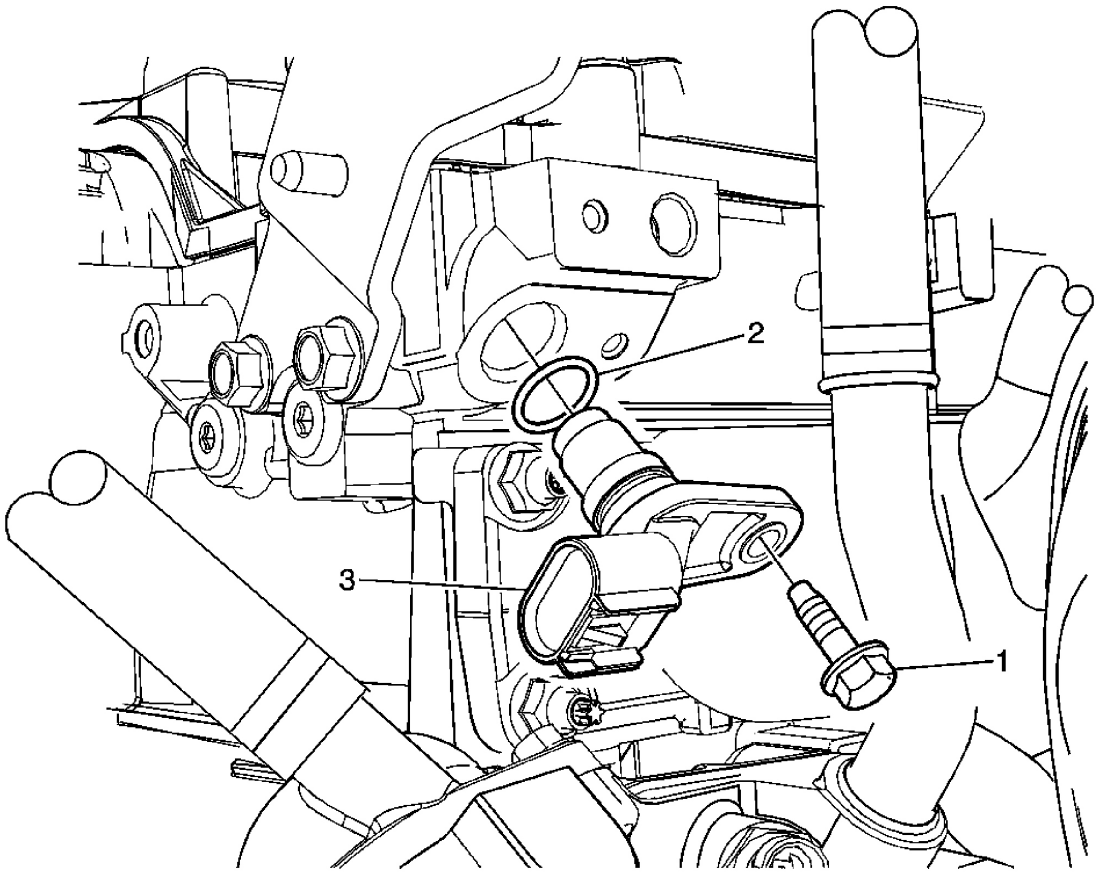


Fig. 204: Camshaft Position Sensor

Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
1	Camshaft Position Sensor Bolt **NOTE:** **Refer to Fastener Notice .** **Tighten:** 10 N.m (89 lb in)
2	Camshaft Position Sensor O-ring **Procedure:** Lubricate the camshaft position sensor O-ring seal with clean engine oil.
3	Camshaft Position Sensor (Intake CMP shown, exhaust CMP similar) **Procedure** 1. Disconnect the sensor harness connector. 2. Inspect the camshaft position sensor for damage, replace as necessary.

CAMSHAFT POSITION ACTUATOR SOLENOID VALVE REPLACEMENT

Removal Procedure

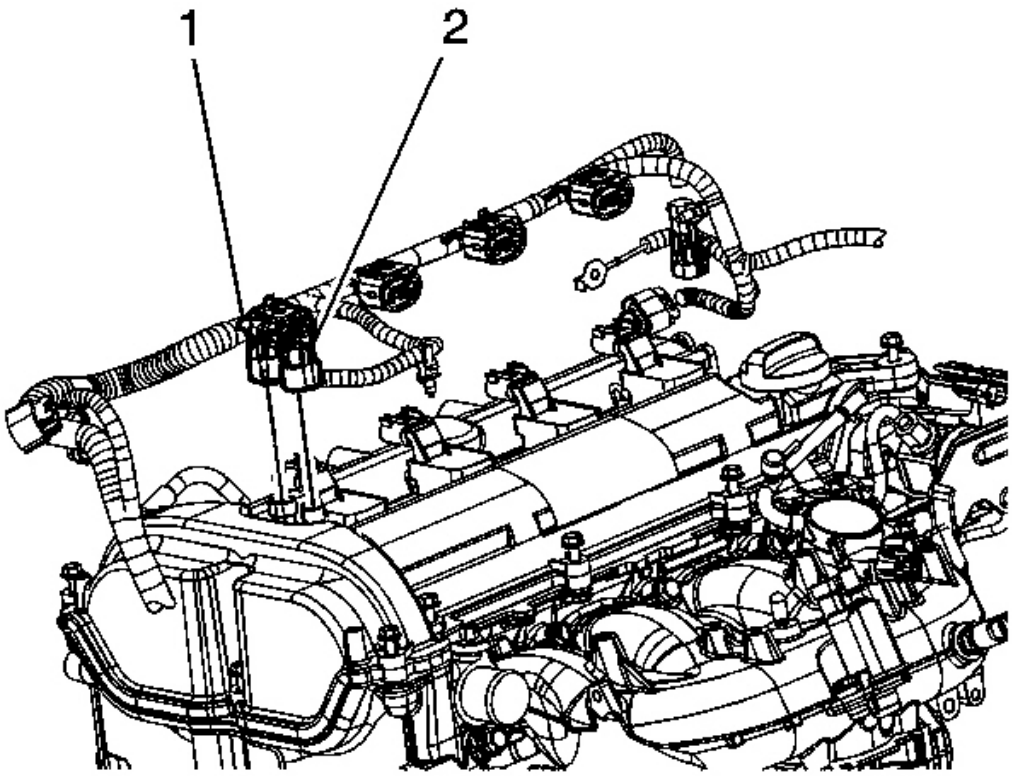


Fig. 205: View Of Intake & Exhaust Camshaft Position Actuator Solenoid Valve
Courtesy of GENERAL MOTORS CORP.

1. Remove the air cleaner assembly. Refer to **Air Cleaner Assembly Replacement**.
2. Disconnect the engine wiring harness electrical connector from either the intake (2) or exhaust (1) camshaft position actuator solenoid valve, as required.

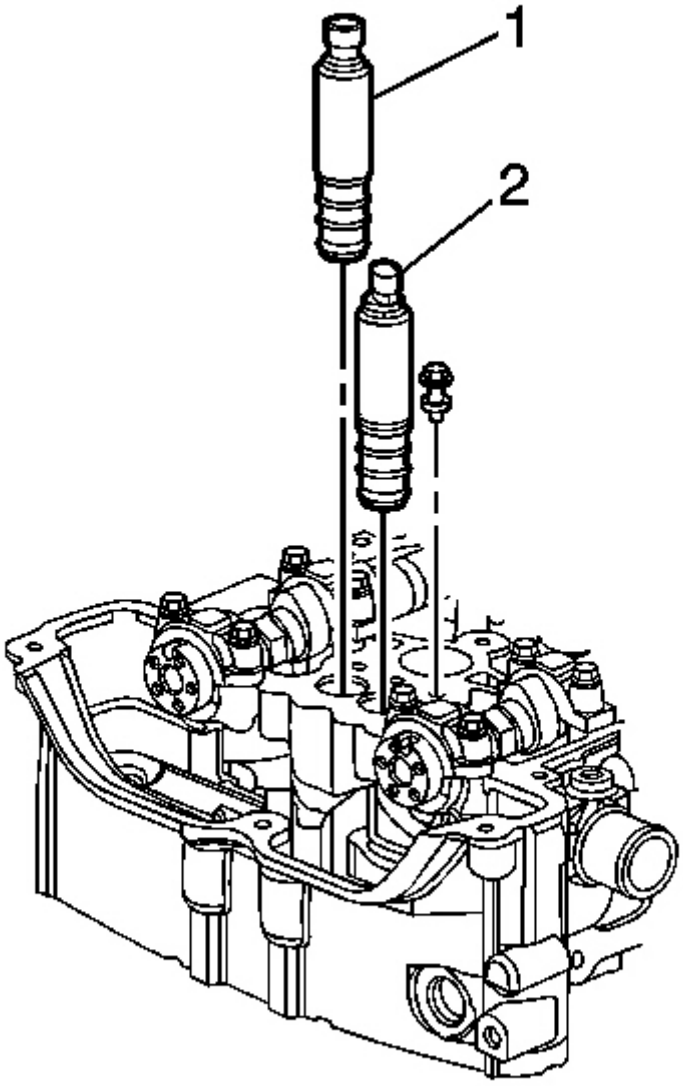


Fig. 206: View Of Intake & Exhaust Camshaft Position Actuators
Courtesy of GENERAL MOTORS CORP.

3. Remove the exhaust (1) camshaft position actuator solenoid valve bolt and valve, as required.
4. Remove the intake (2) camshaft position (CMP) actuator solenoid valve bolt and valve, as required.

5. Inspect the solenoid valve O-ring seals from damage, replace as necessary.

Installation Procedure

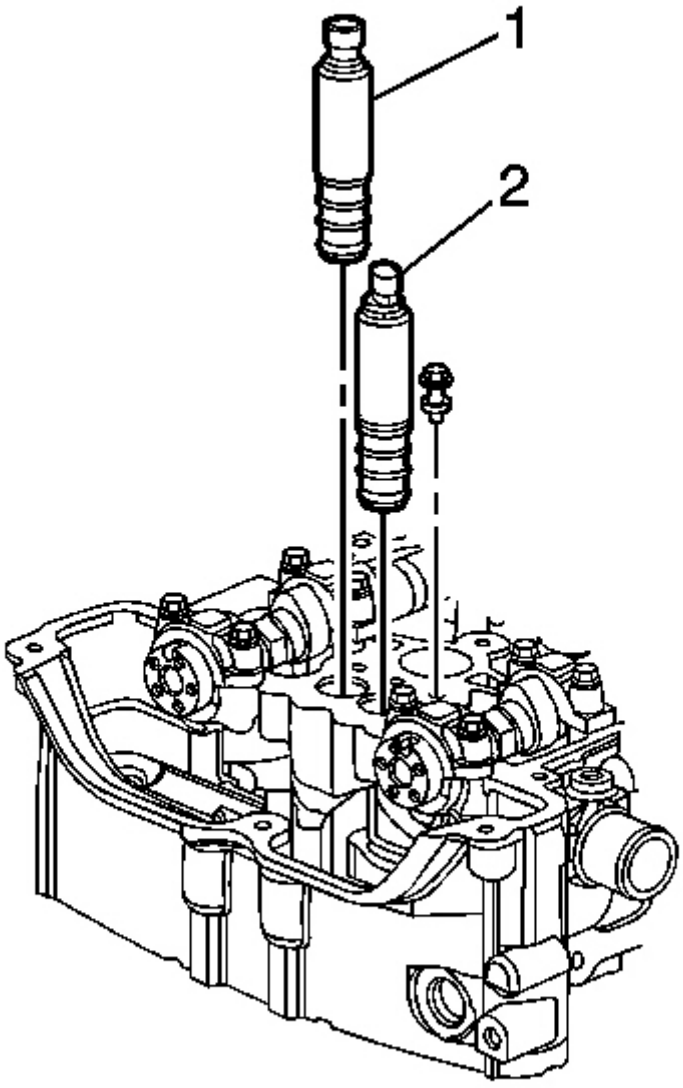


Fig. 207: View Of Intake & Exhaust Camshaft Position Actuators
Courtesy of GENERAL MOTORS CORP.

NOTE: Refer to Fastener Notice .

1. Lubricate the solenoid valve O-ring seals with clean engine oil.
2. Install the intake (2) CMP actuator solenoid valve and bolt, as required.

   Tighten: Tighten the bolt to 10 N.m (89 lb in).

3. Install the exhaust (1) CMP actuator solenoid valve and bolt, as required.

   Tighten: Tighten the bolt to 10 N.m (89 lb in).

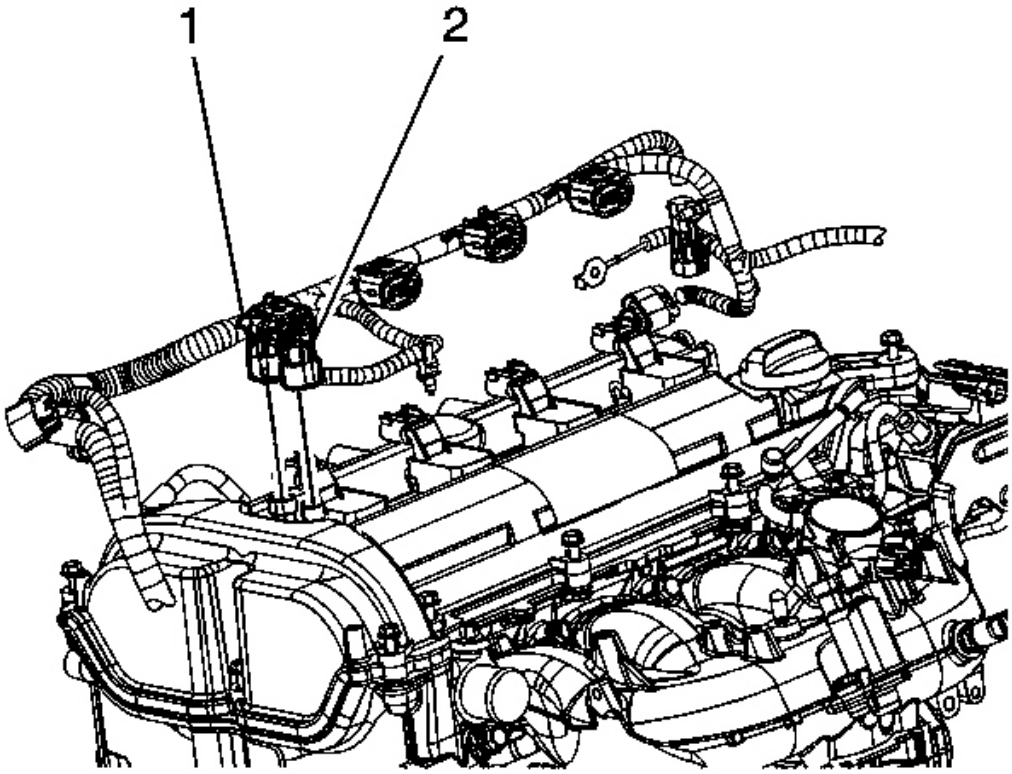


Fig. 208: View Of Intake & Exhaust Camshaft Position Actuator Solenoid Valve
Courtesy of GENERAL MOTORS CORP.

4. Connect the engine wiring harness electrical connector to the intake (1) or exhaust (2) camshaft position actuator solenoid valve, as required.
5. Install the air cleaner assembly. Refer to **Air Cleaner Assembly Replacement**.

KNOCK SENSOR REPLACEMENT

Removal Procedure

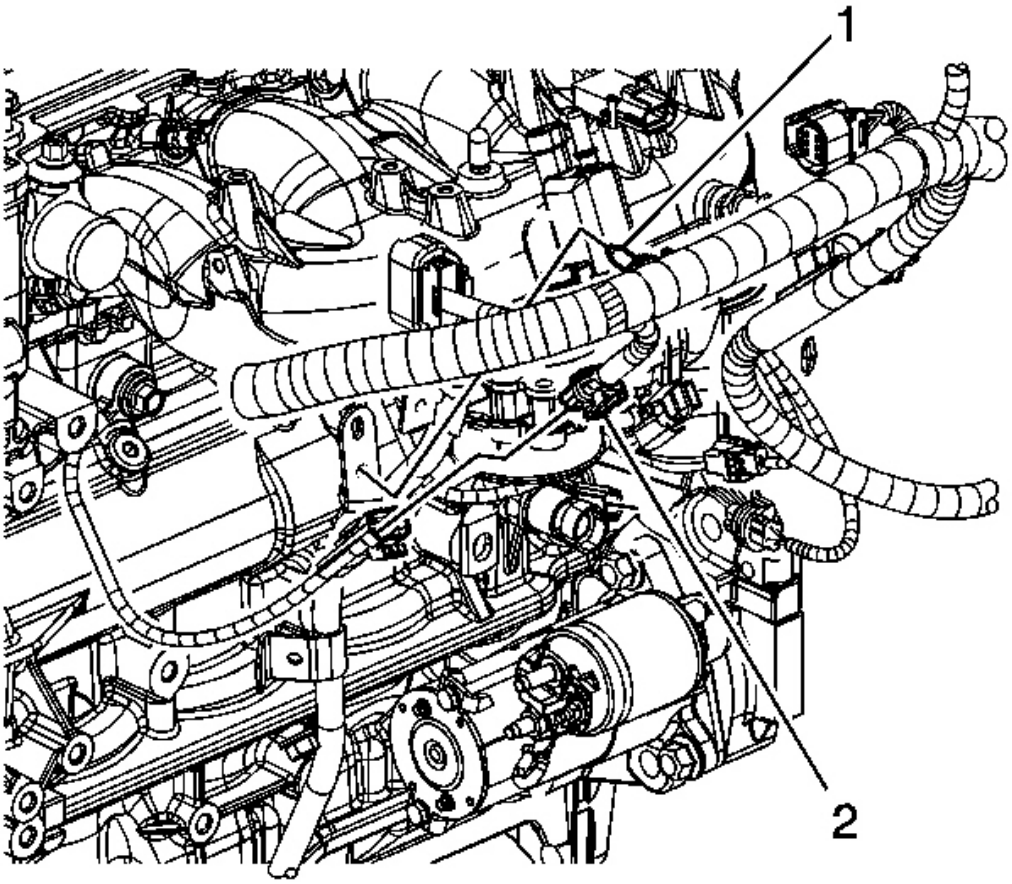


Fig. 209: Front Knock Sensor Electrical Connectors
Courtesy of GENERAL MOTORS CORP.

1. Disconnect the engine wiring harness electrical connector (2) from the front

knock sensor, if required.

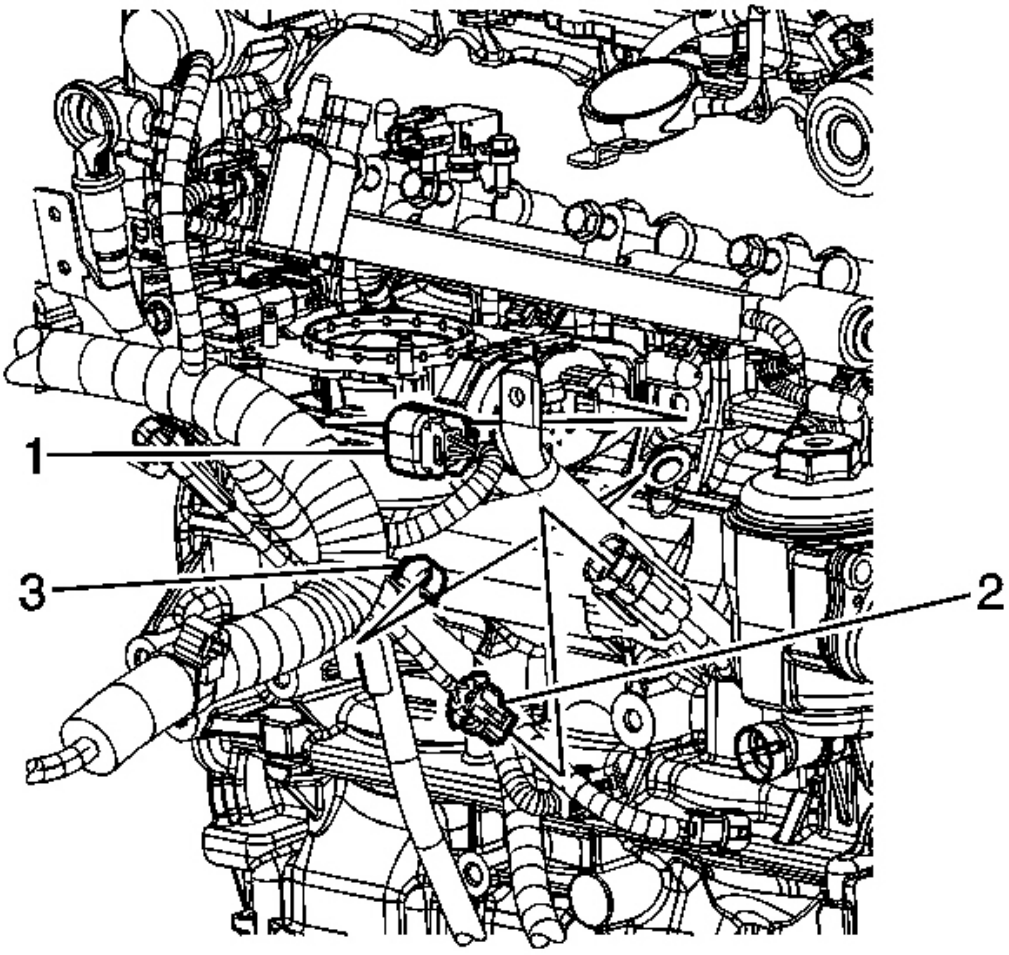


Fig. 210: ETC Connector
Courtesy of GENERAL MOTORS CORP.

2. Disconnect the engine wiring harness electrical connector (2) from the rear knock sensor, if required.

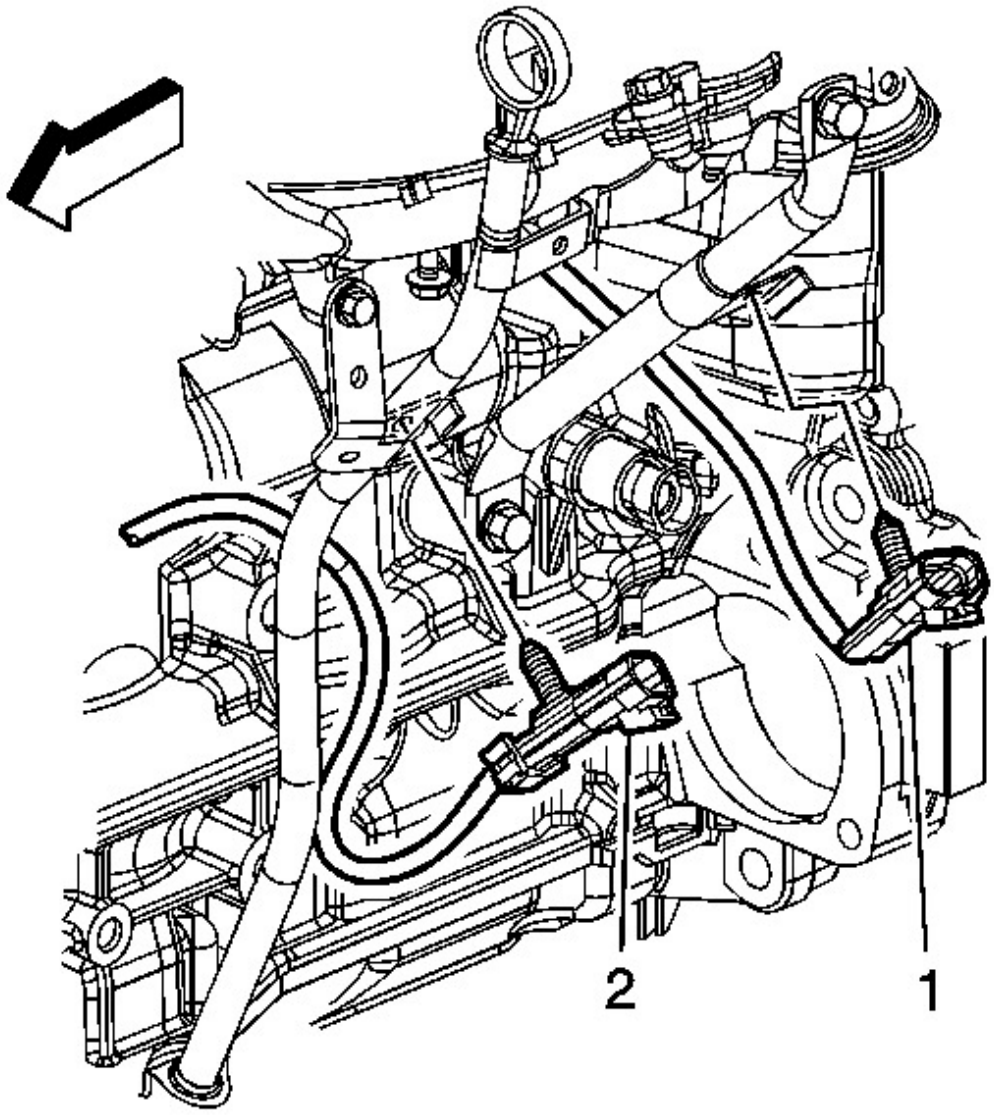


Fig. 211: Front & Rear Knock Sensor Clips
Courtesy of GENERAL MOTORS CORP.

3. Remove the front knock sensor clip (1) from the oil level indicator tube, if required.
4. Remove the rear knock sensor clip (2) from the intake manifold brace, if

required.

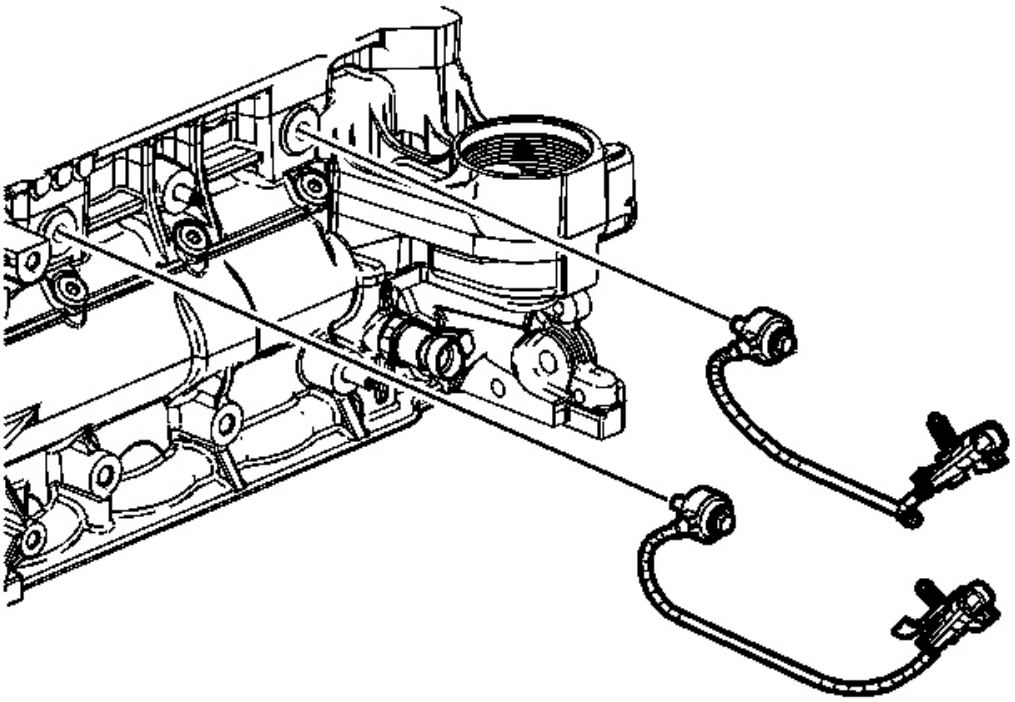


Fig. 212: Knock Sensors
Courtesy of GENERAL MOTORS CORP.

5. Loosen the appropriate knock bolt.
6. Remove the appropriate knock sensor.

Installation Procedure

IMPORTANT: Rotate the pigtail 90 degrees from vertical before securing the fastener.

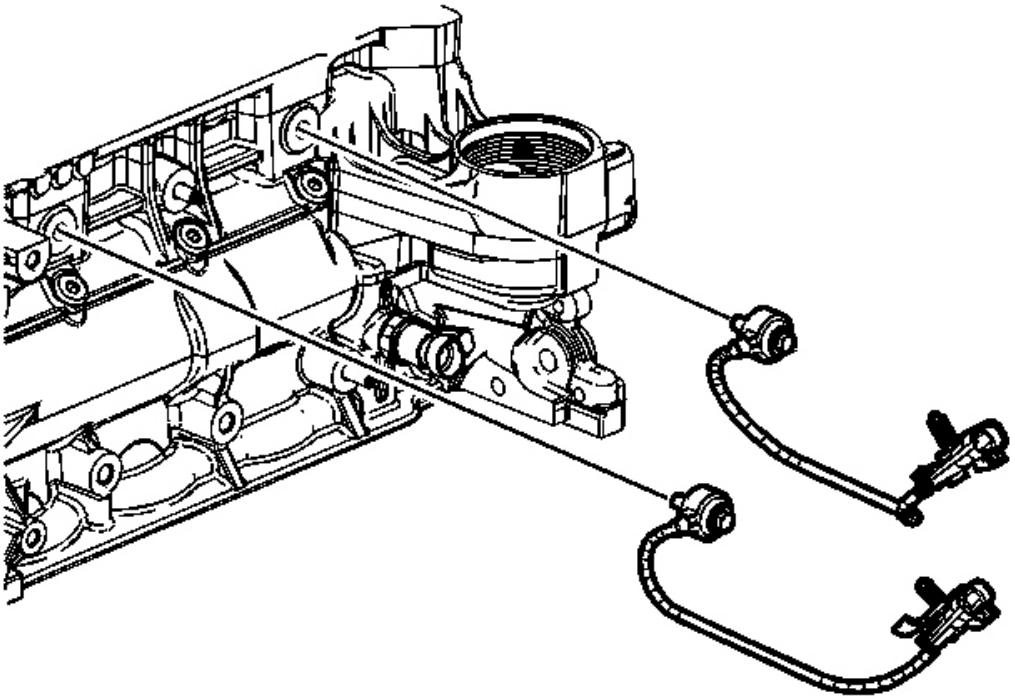


Fig. 213: Knock Sensors
Courtesy of GENERAL MOTORS CORP.

1. Position the appropriate knock sensor to the engine block.

   NOTE: Refer to Fastener Notice .

2. Tighten the appropriate knock bolt.

   Tighten: Tighten the bolt to 25 N.m (18 lb ft).

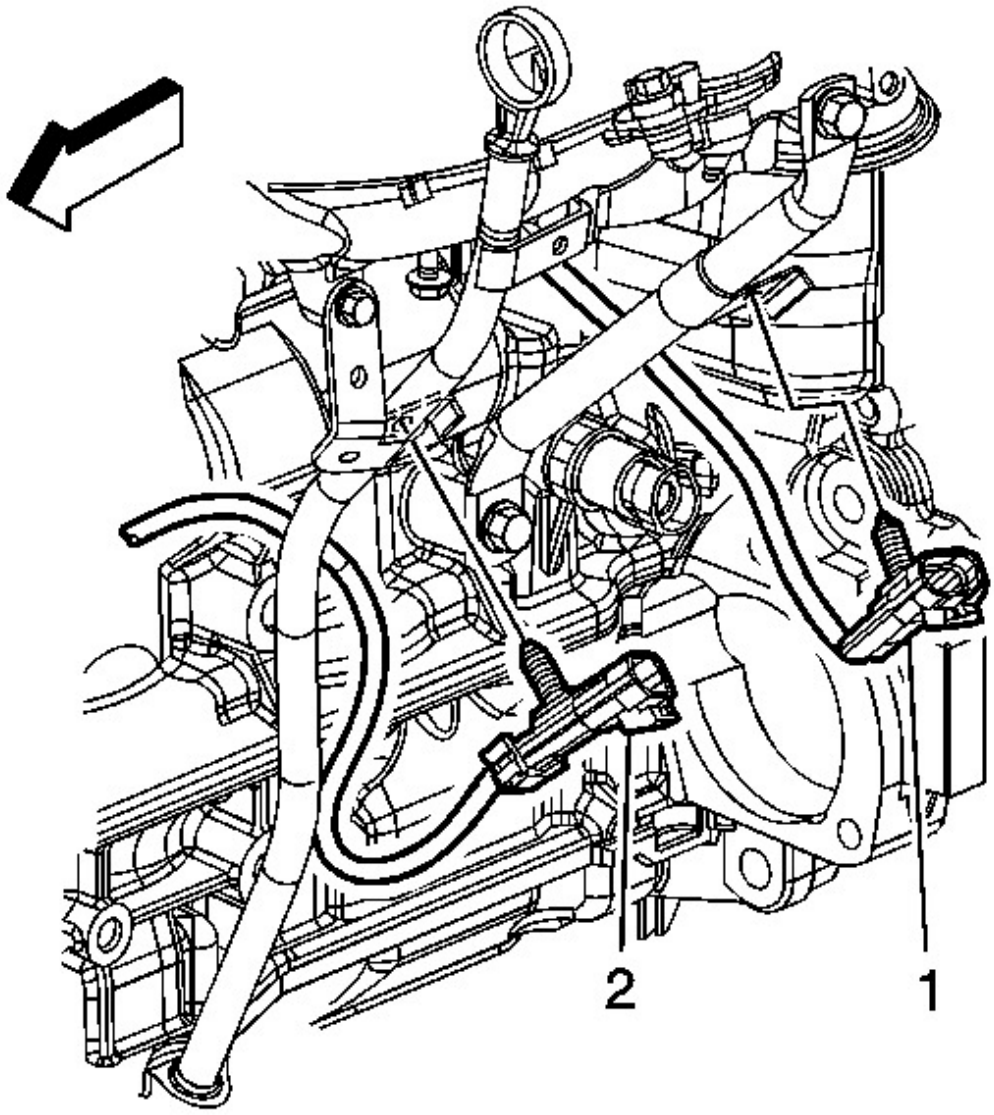


Fig. 214: Front & Rear Knock Sensor Clips
Courtesy of GENERAL MOTORS CORP.

3. Install the front knock sensor clip (1) to the oil level indicator tube, if required.
4. Install the rear knock sensor clip (2) to the intake manifold brace, if required.

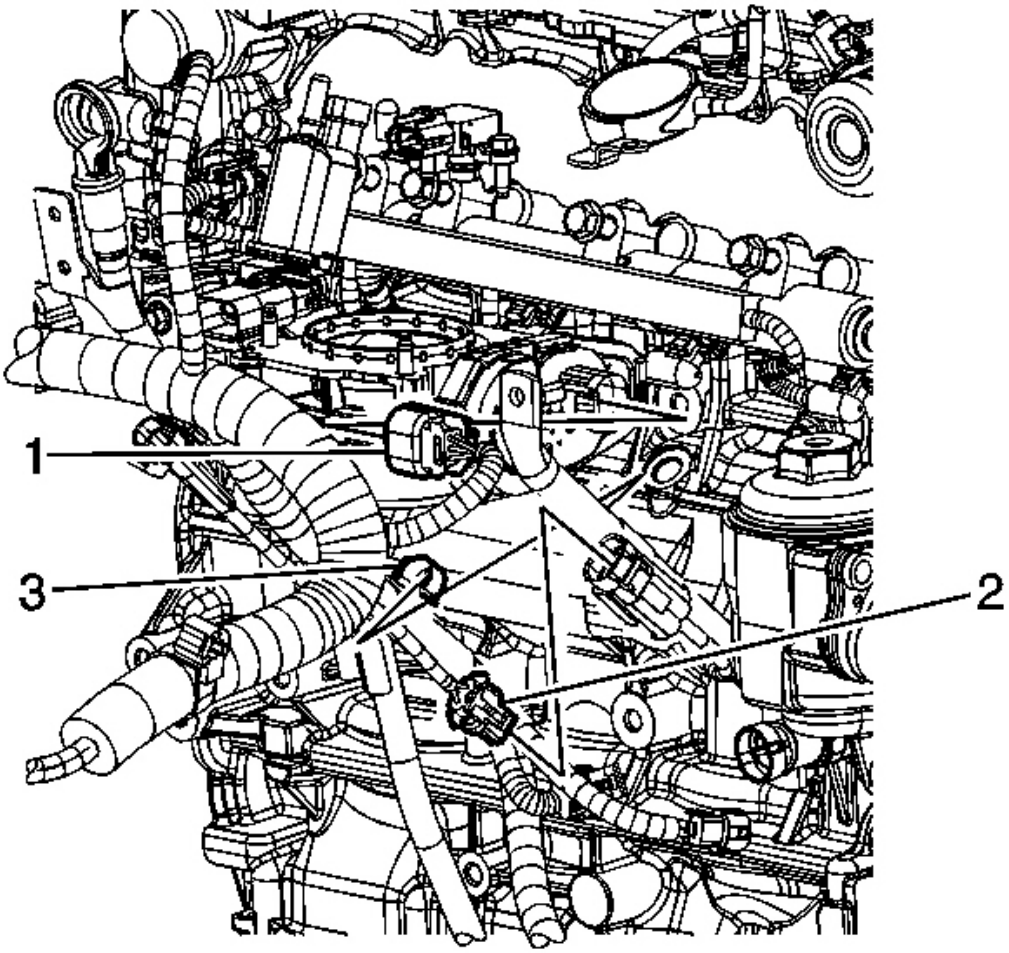


Fig. 215: ETC Connector
Courtesy of GENERAL MOTORS CORP.

5. Connect the engine wiring harness electrical connector (2) to the rear knock sensor.

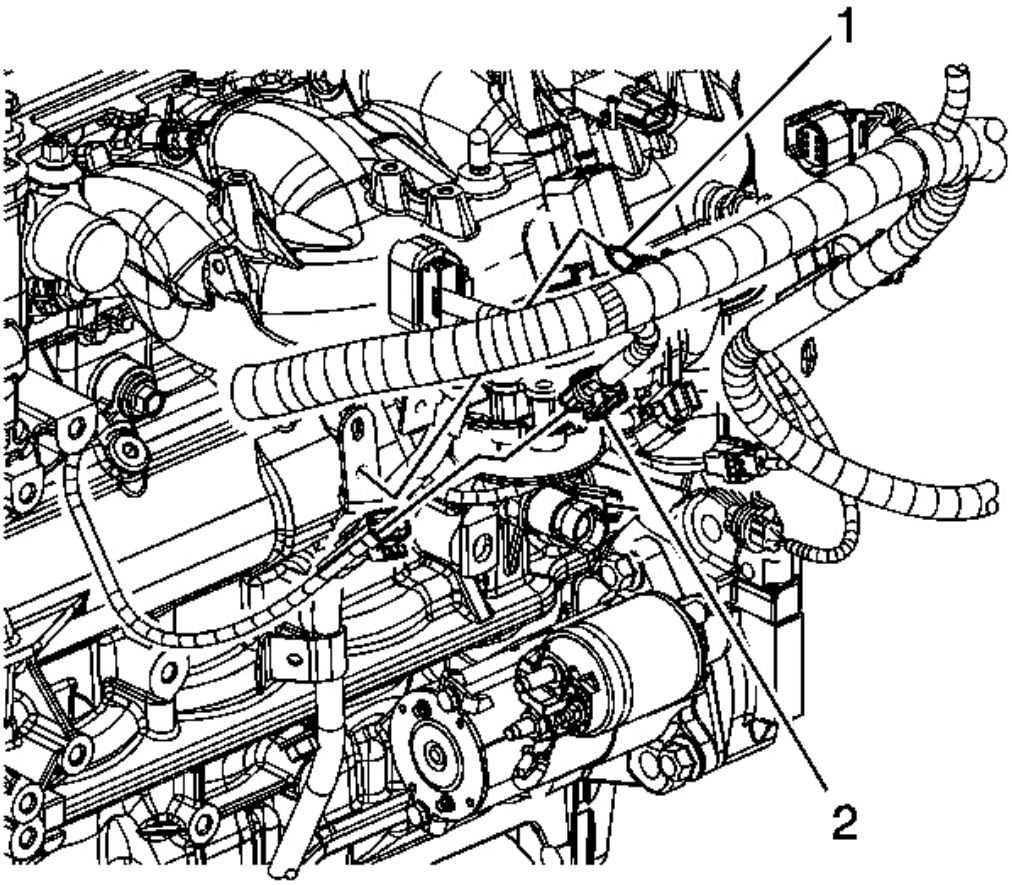


Fig. 216: Front Knock Sensor Electrical Connectors
Courtesy of GENERAL MOTORS CORP.

6. Connect the engine wiring harness electrical connector (2) to the front knock sensor.

INTAKE AIR PRESSURE AND TEMPERATURE SENSOR REPLACEMENT

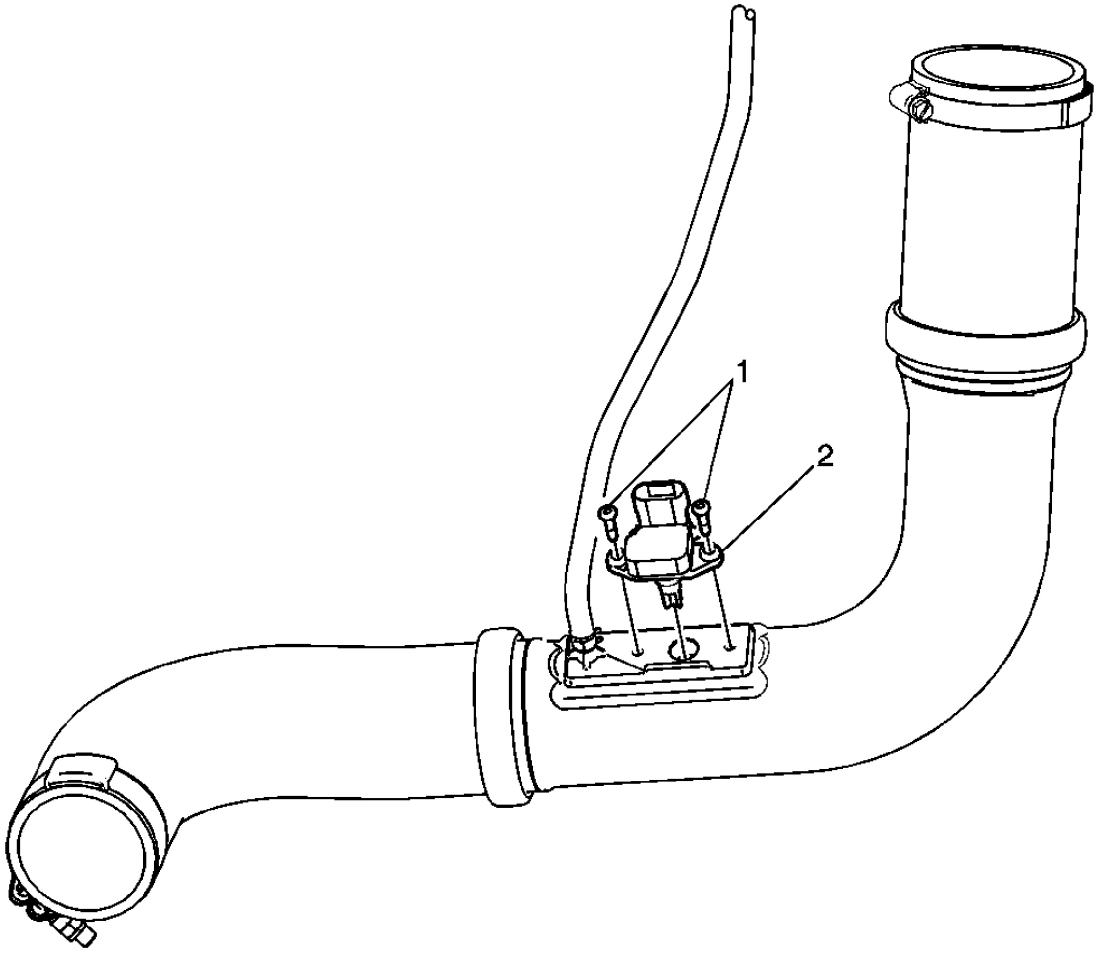


Fig. 217: Intake Air Pressure and Temperature Sensor
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
1	Sensor Screw (Qty: 2) **NOTE:** **Refer to Fastener Notice .** **Tighten:** 9 N.m (80 lb in)
2	Intake Air Pressure and Temperature Sensor **Procedure:** Disconnect the electrical connector.

CHARGE AIR BYPASS VALVE SOLENOID REPLACEMENT

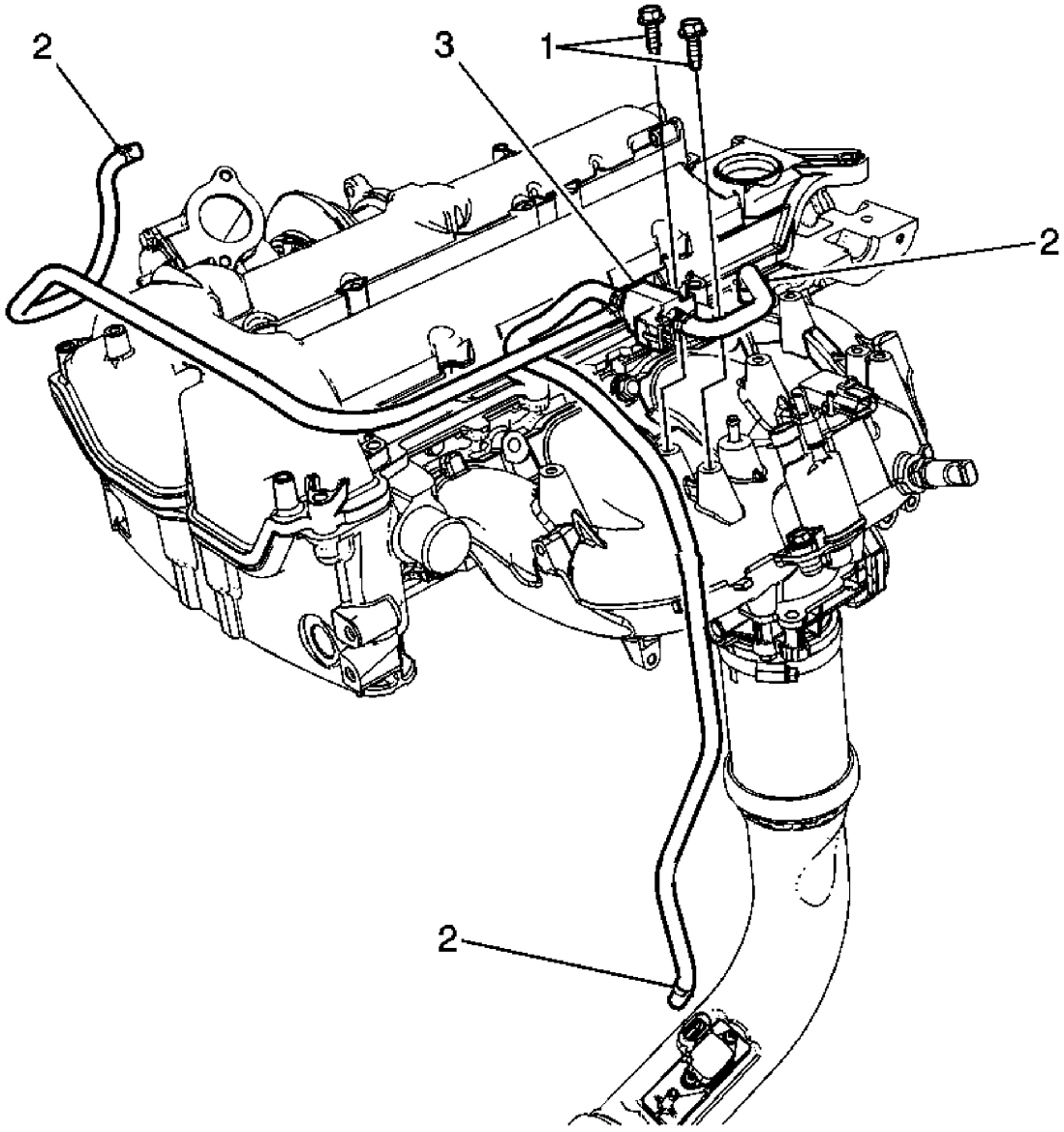


Fig. 218: Charge Air Bypass Valve Solenoid
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
Preliminary Procedure: Remove the air cleaner assembly. Refer to **Air Cleaner Assembly Replacement**.	
	Charge Air Bypass Valve Solenoid Bolt (Qty: 2) **NOTE:**

1	**Refer to Fastener Notice .** **Tighten:** 10 N.m (89 lb in)
2	Charge Air Bypass Solenoid Vacuum Hose Clamp (Qty: 3) **Procedure:** Reposition the clamps in order to remove the hoses.
3	Charge Air Bypass Valve Solenoid **Procedure:** Disconnect the electrical connector.

CHARGE AIR BYPASS VALVE VACUUM TANK REPLACEMENT

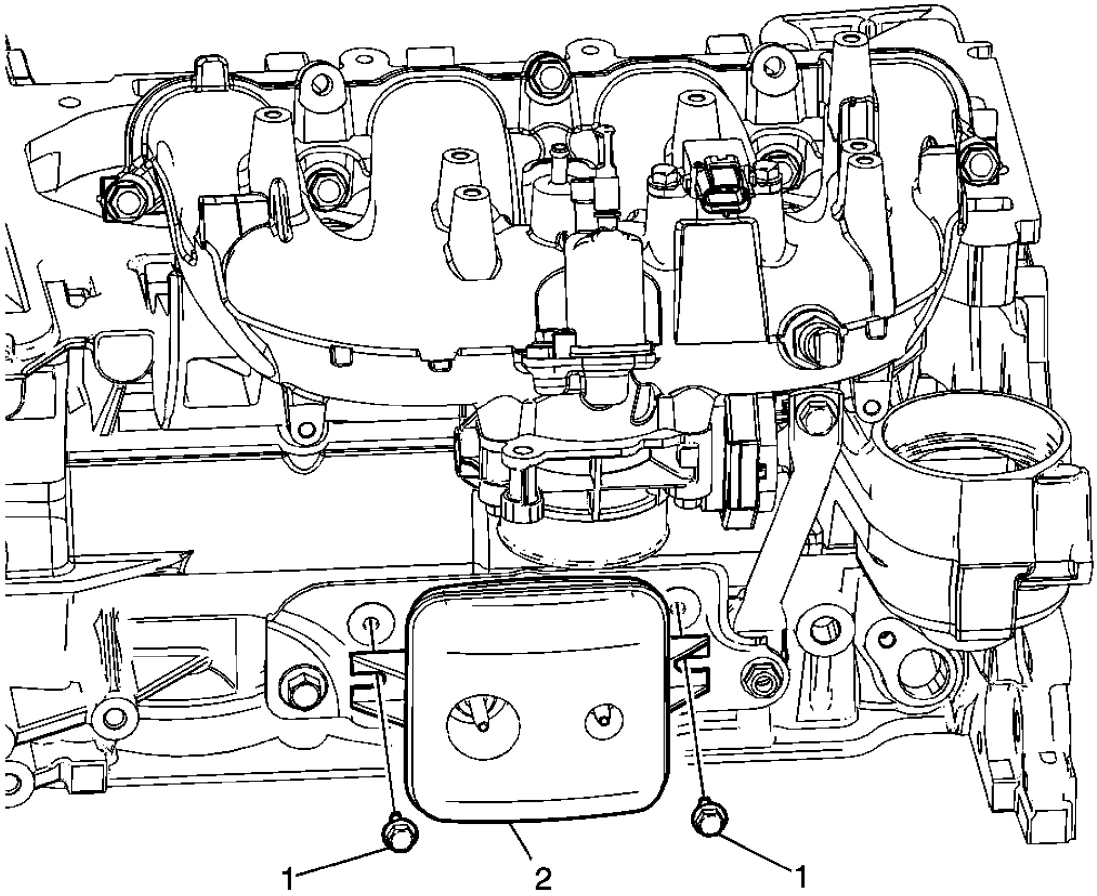


Fig. 219: Charge Air Bypass Valve Vacuum Tank
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name

Preliminary Procedure: Disconnect the charge air cooler outlet pipe from the intake manifold. Refer to **Charge Air Cooler Outlet Pipe Replacement**.	
1	Charge Air Bypass Valve Vacuum Tank Bolt (Qty: 2) **NOTE:** **Refer to Fastener Notice .** **Procedure:** Disconnect the vacuum hoses. **Tighten:** 10 N.m (89 lb in)
2	Charge Air Bypass Valve Vacuum Tank

AIR CLEANER ELEMENT REPLACEMENT

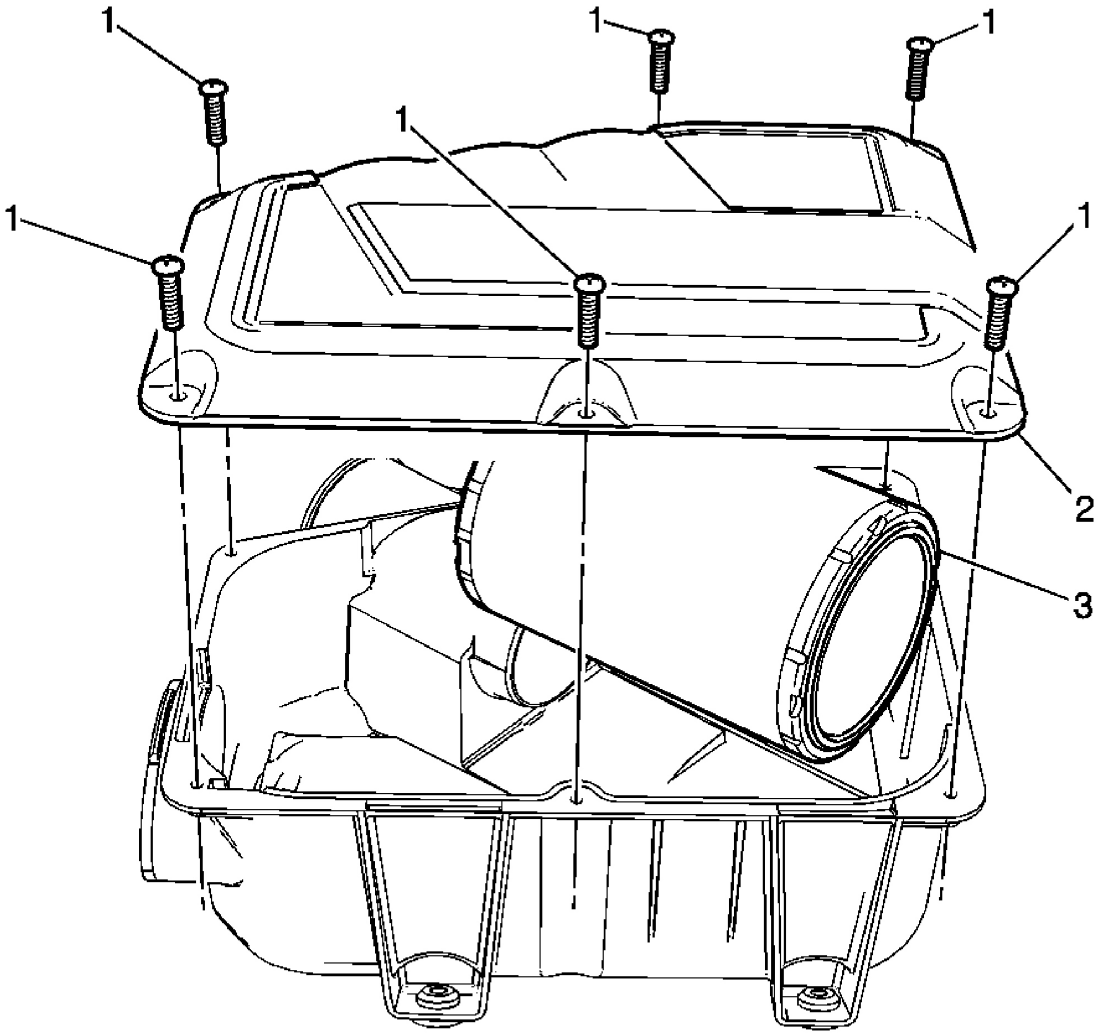


Fig. 220: Air Cleaner Element
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
1	Air Cleaner Assembly Screw (Qty: 6) **NOTE:** **Refer to Fastener Notice .** **Tighten:** 10 N.m (89 lb in)
2	Air Cleaner Assembly Cover
3	Air Cleaner Filter

AIR CLEANER ASSEMBLY REPLACEMENT

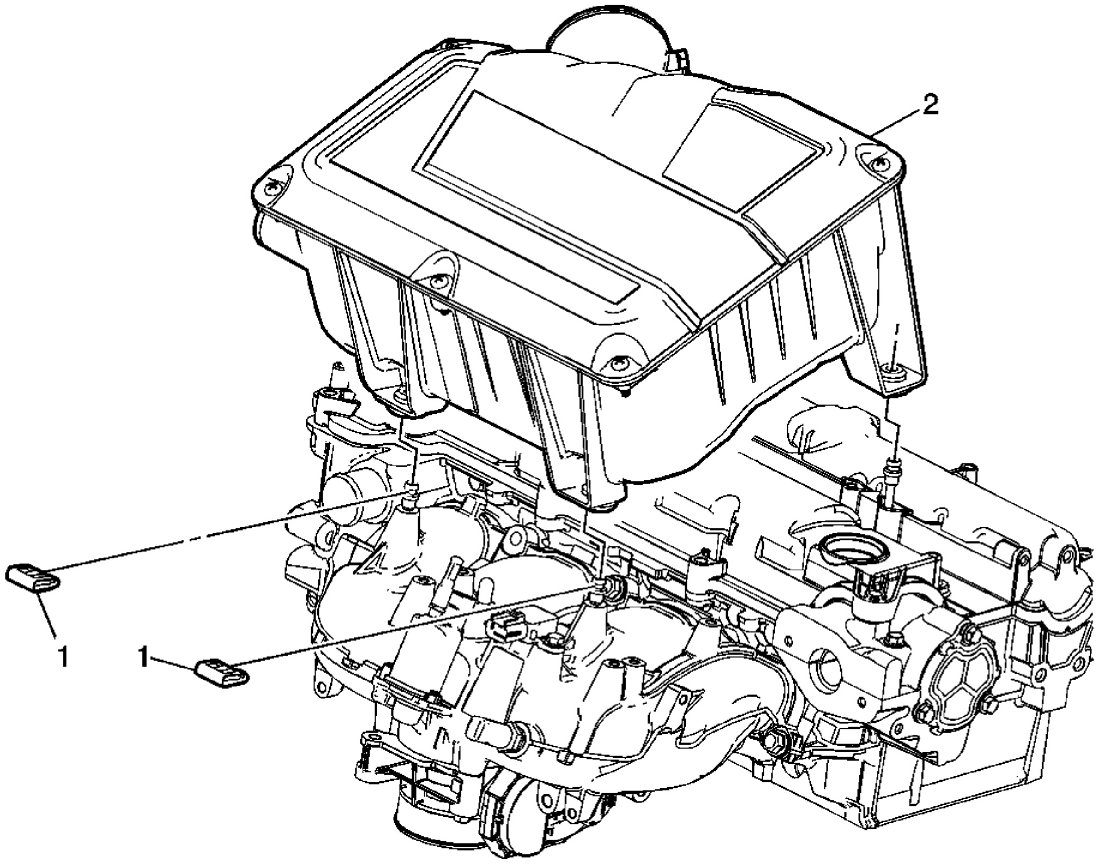


Fig. 221: Air Cleaner Assembly
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
Preliminary Procedures 1. Remove the mass air flow (MAF) sensor. Refer to **Mass Airflow Sensor Replacement**. 2. Remove the air cleaner outlet duct. Refer to **Air Cleaner Outlet Duct Replacement**.	
1	Air Cleaner Assembly Retainer (Qty: 2)
2	Air Cleaner Assembly

AIR CLEANER OUTLET DUCT REPLACEMENT

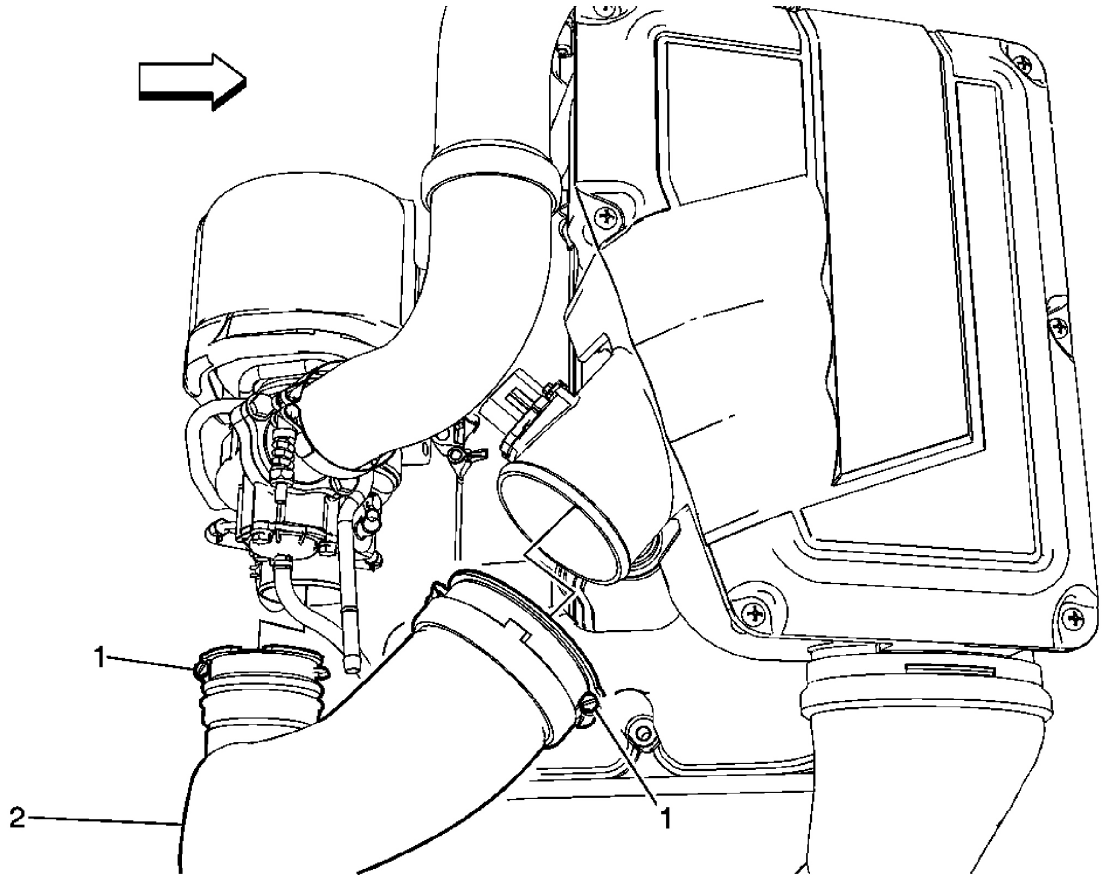


Fig. 222: Air Cleaner Outlet Duct
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
1	Air Cleaner Outlet Duct Clamp (Qty: 2) **NOTE:** **Refer to Fastener Notice .** **Tighten:** 5 N.m (44 lb in)
2	Air Cleaner Outlet Duct

CHARGE AIR COOLER INLET PIPE REPLACEMENT

Removal Procedure

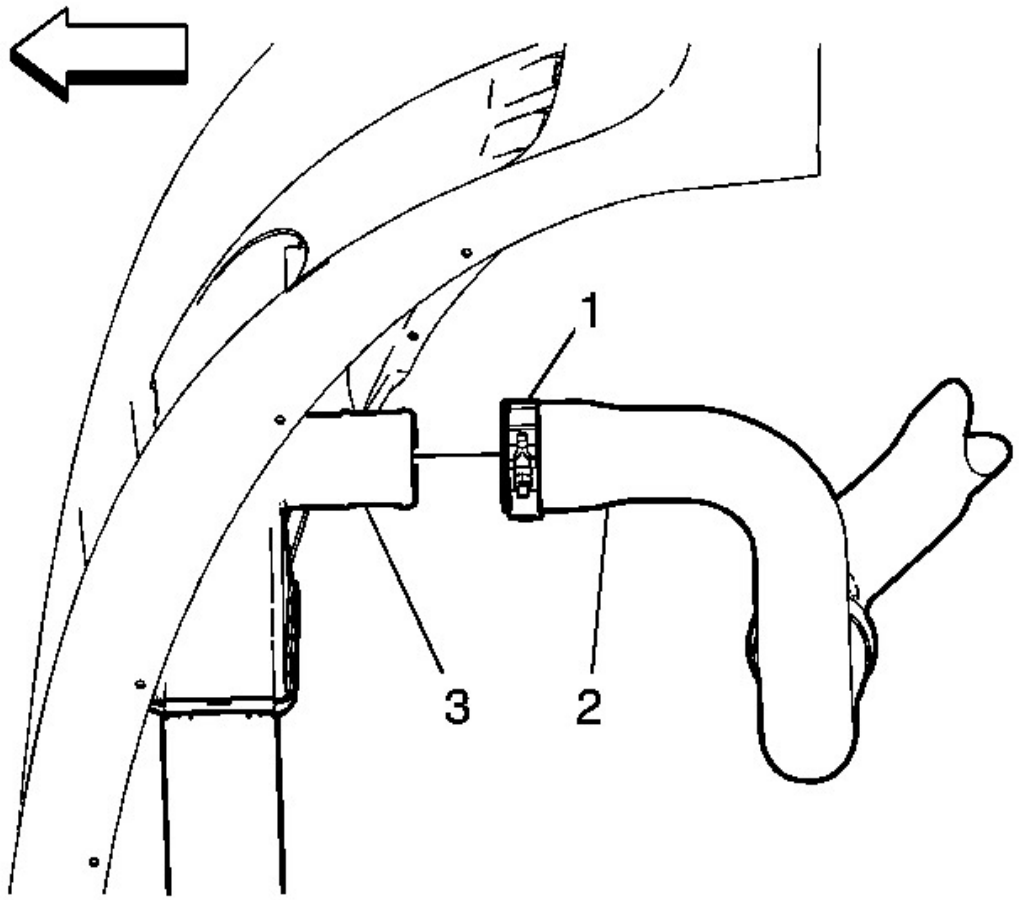


Fig. 223: View Of Charge Air Cooler Inlet Pipe
Courtesy of GENERAL MOTORS CORP.

1. Raise and support the vehicle. Refer to **Lifting and Jacking the Vehicle** .
2. Remove the front bumper fascia extension. Refer to **Front Bumper Fascia Extension Replacement** .
3. Loosen the charge air cooler inlet pipe clamp (1).
4. Remove the charge air cooler inlet pipe (2) from the charge air cooler (3).

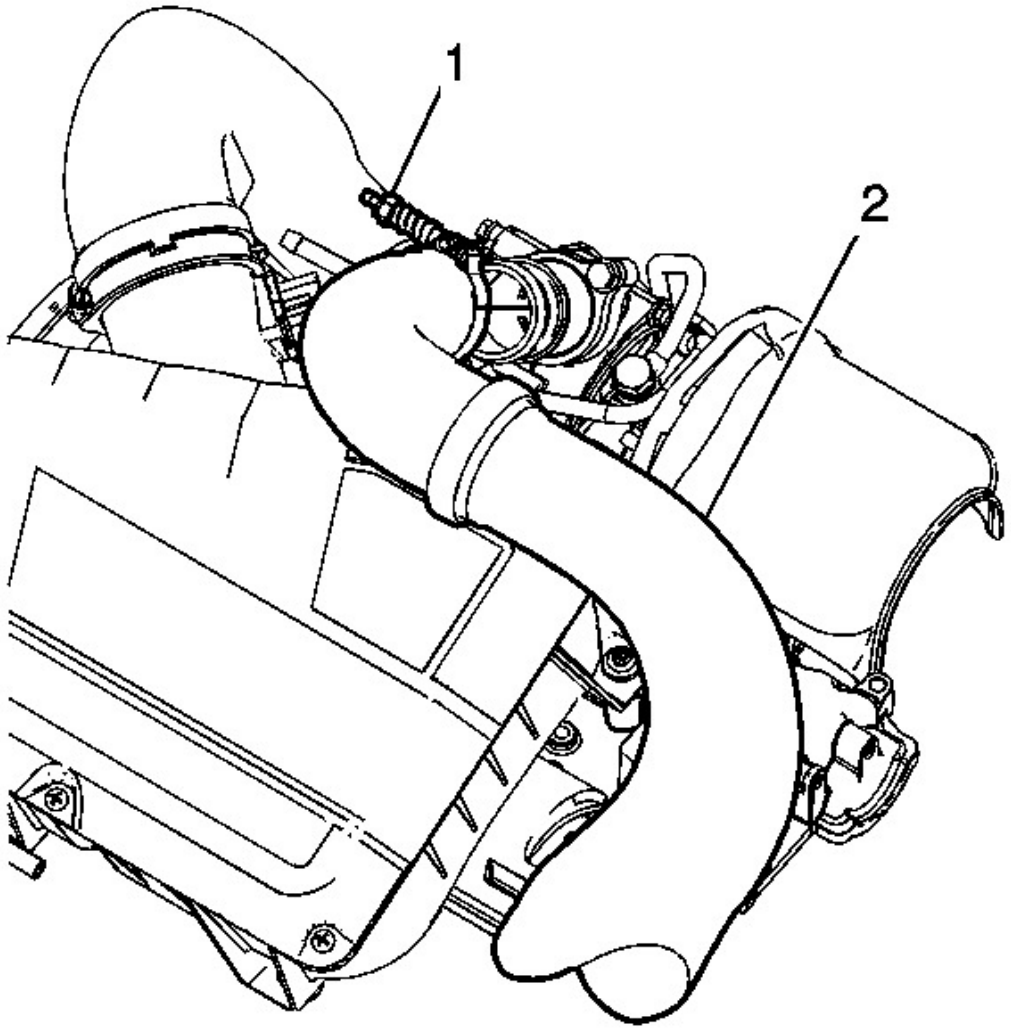


Fig. 224: Charge Air Cooler Clamp
Courtesy of GENERAL MOTORS CORP.

5. Loosen the charge air cooler clamp (1).
6. Loosen the charge air cooler inlet pipe (2) from the vehicle.

Installation Procedure

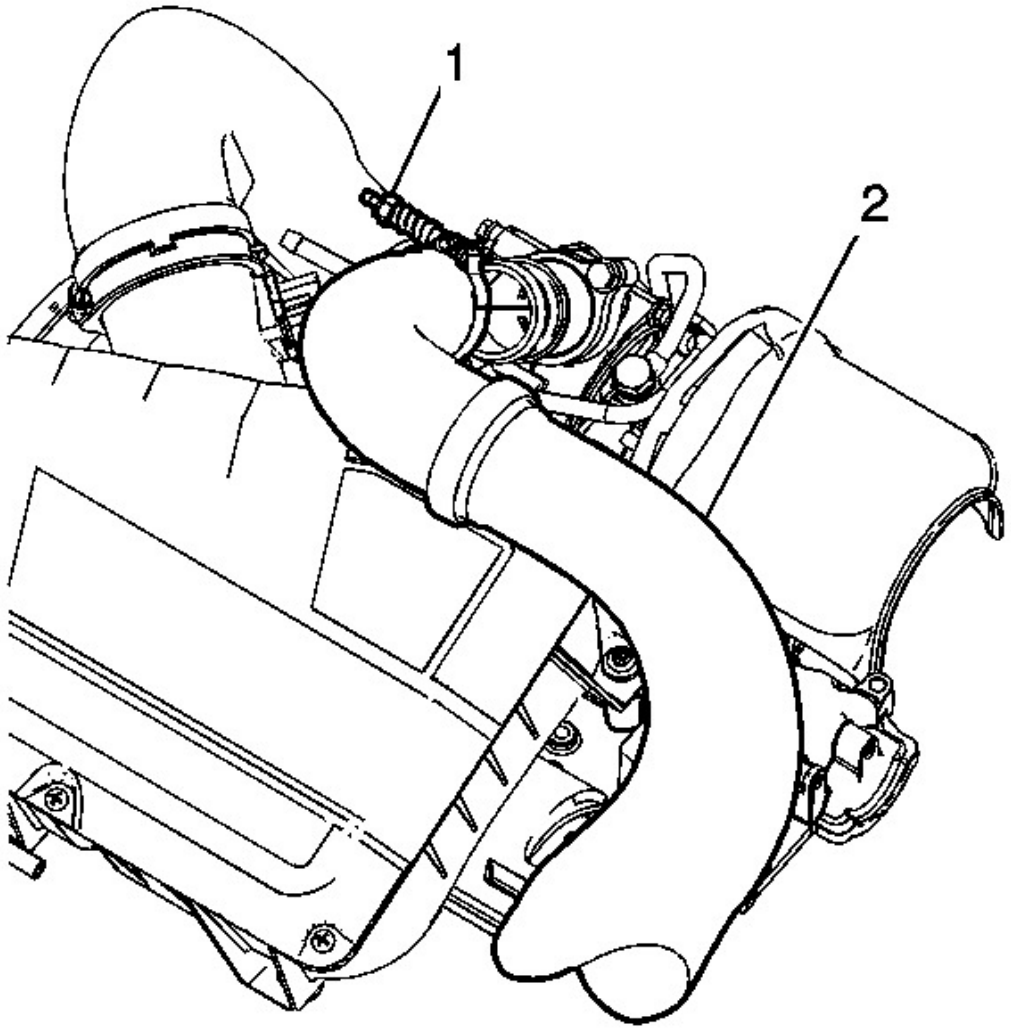


Fig. 225: Charge Air Cooler Clamp
Courtesy of GENERAL MOTORS CORP.

IMPORTANT: Remove any oil film from inside the pipes.

1. Install the charge air cooler pipe (2) and tighten the charge air cooler inlet pipe clamp.

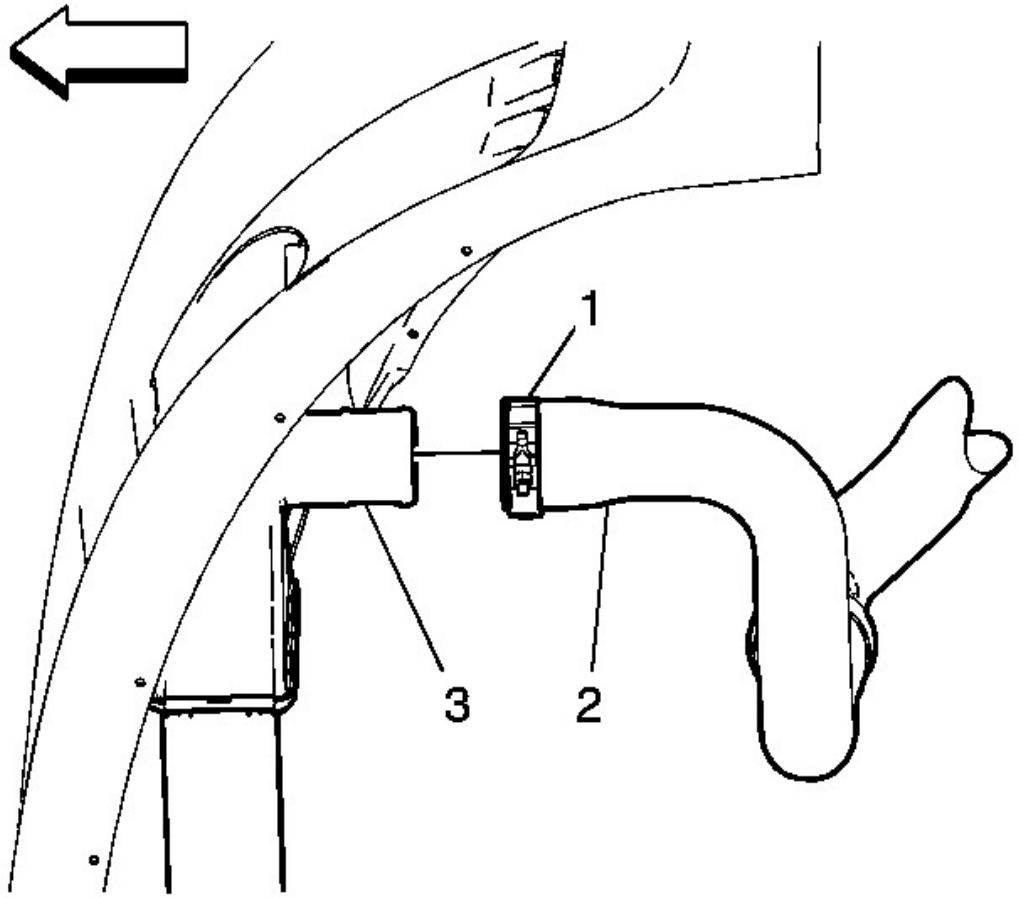


Fig. 226: View Of Charge Air Cooler Inlet Pipe
Courtesy of GENERAL MOTORS CORP.

NOTE: Refer to Fastener Notice .

2. Install the charge air cooler inlet pipe (2) to the charge air cooler (3).

   Tighten: Tighten the clamp to 5 N.m (44 lb in).

3. Install the front bumper fascia extension. Refer to **Front Bumper Fascia Extension Replacement** .

CHARGE AIR COOLER OUTLET PIPE REPLACEMENT

Removal Procedure

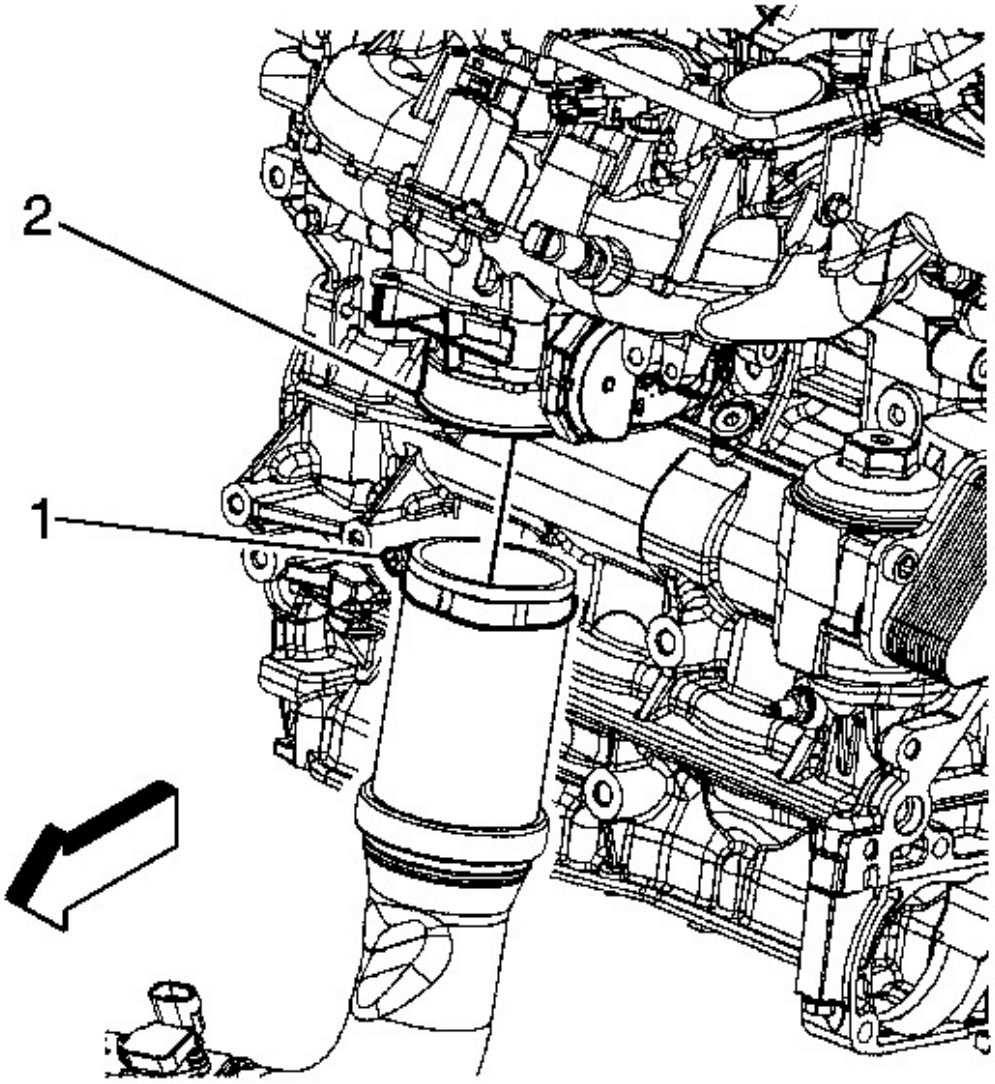


Fig. 227: View Of Charge Air Cooler Outlet Pipe
Courtesy of GENERAL MOTORS CORP.

1. Loosen the charge air cooler outlet pipe clamp (1) at the intake manifold (2).
2. Disconnect the engine wiring harness electrical connector from the intake air pressure and temperature sensor.

3. Remove the front bumper fascia extension. Refer to **Front Bumper Fascia Extension Replacement** .

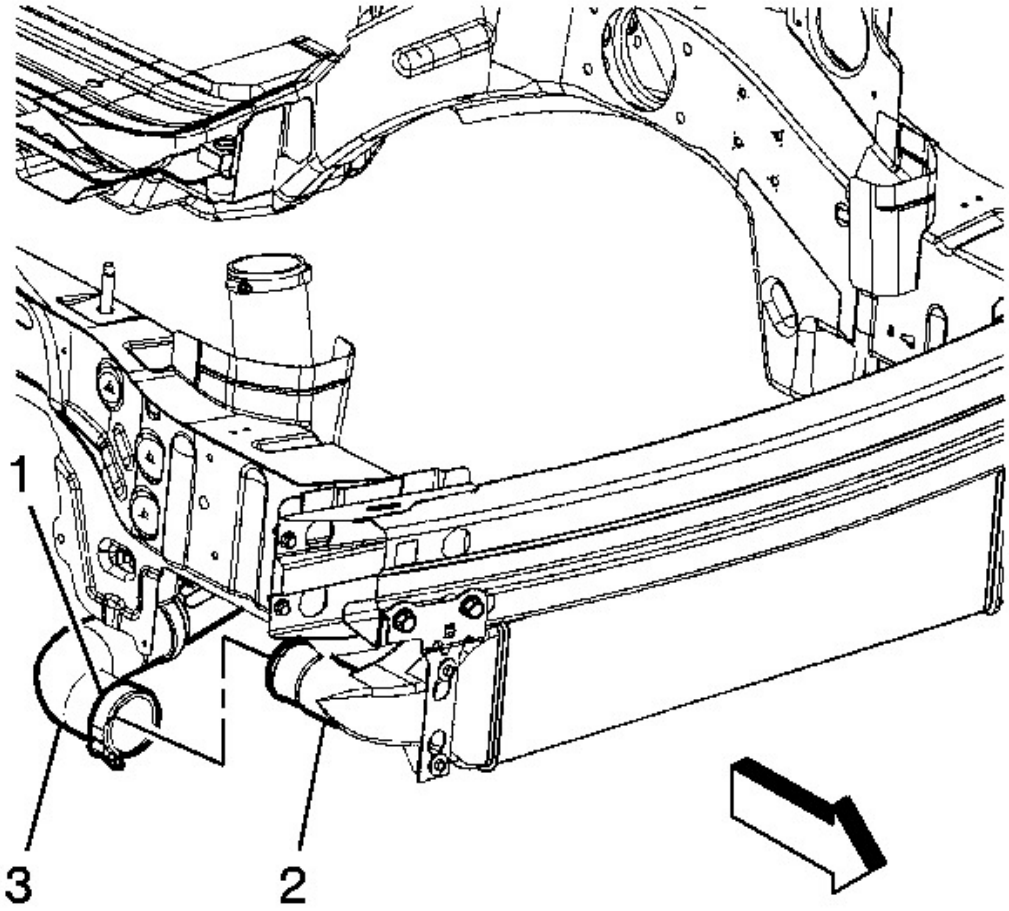


Fig. 228: View Of Charge Air Cooler Outlet Pipe Clamp & Charge Air Cooler Assembly
Courtesy of GENERAL MOTORS CORP.

4. Loosen the charge air cooler outlet pipe clamp (1) at the charge air cooler assembly (2).
5. Remove the charge air cooler outlet pipe (3).

Installation Procedure

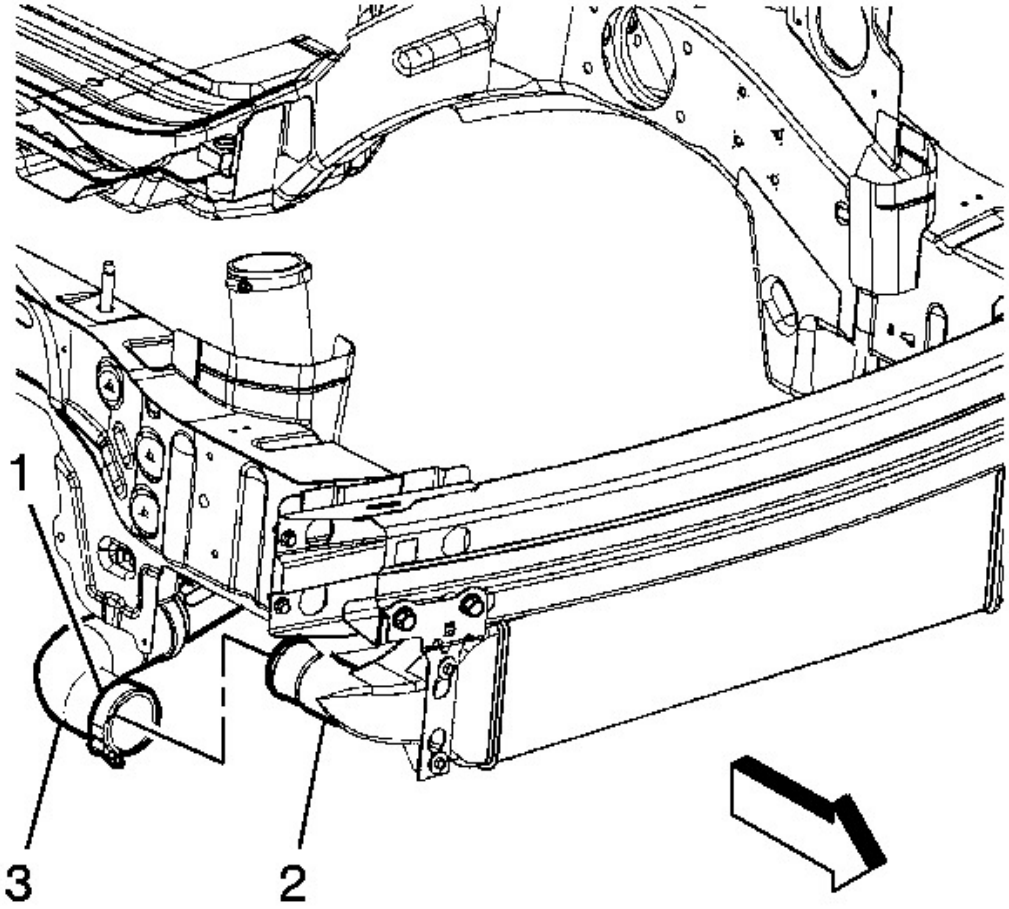


Fig. 229: View Of Charge Air Cooler Outlet Pipe Clamp & Charge Air Cooler Assembly
Courtesy of GENERAL MOTORS CORP.

NOTE: Refer to Fastener Notice .

1. Install the charge air cooler outlet pipe (3) to the charge air cooler assembly (2).

   Tighten: Tighten the clamp to 5 N.m (44 lb in).

2. Install the front bumper fascia extension. Refer to **Front Bumper Fascia**

Extension Replacement .

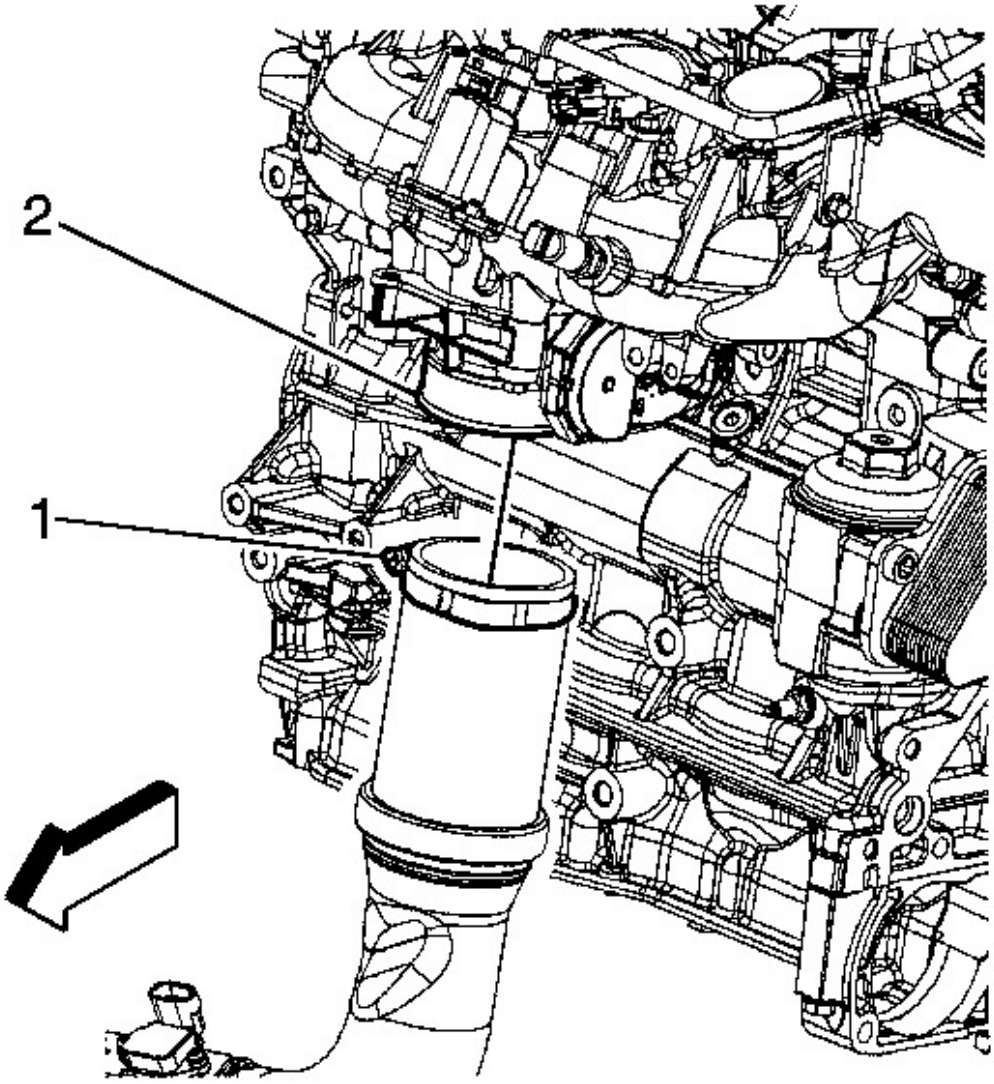


Fig. 230: View Of Charge Air Cooler Outlet Pipe
Courtesy of GENERAL MOTORS CORP.

3. Connect the engine wiring harness electrical connector to the intake air pressure and temperature sensor.

4. Install the charge air cooler outlet pipe to the intake manifold (2) and tighten the charge air cooler outlet pipe clamp (1).

   Tighten: Tighten the clamp to 5 N.m (44 lb in).

CHARGE AIR COOLER REPLACEMENT

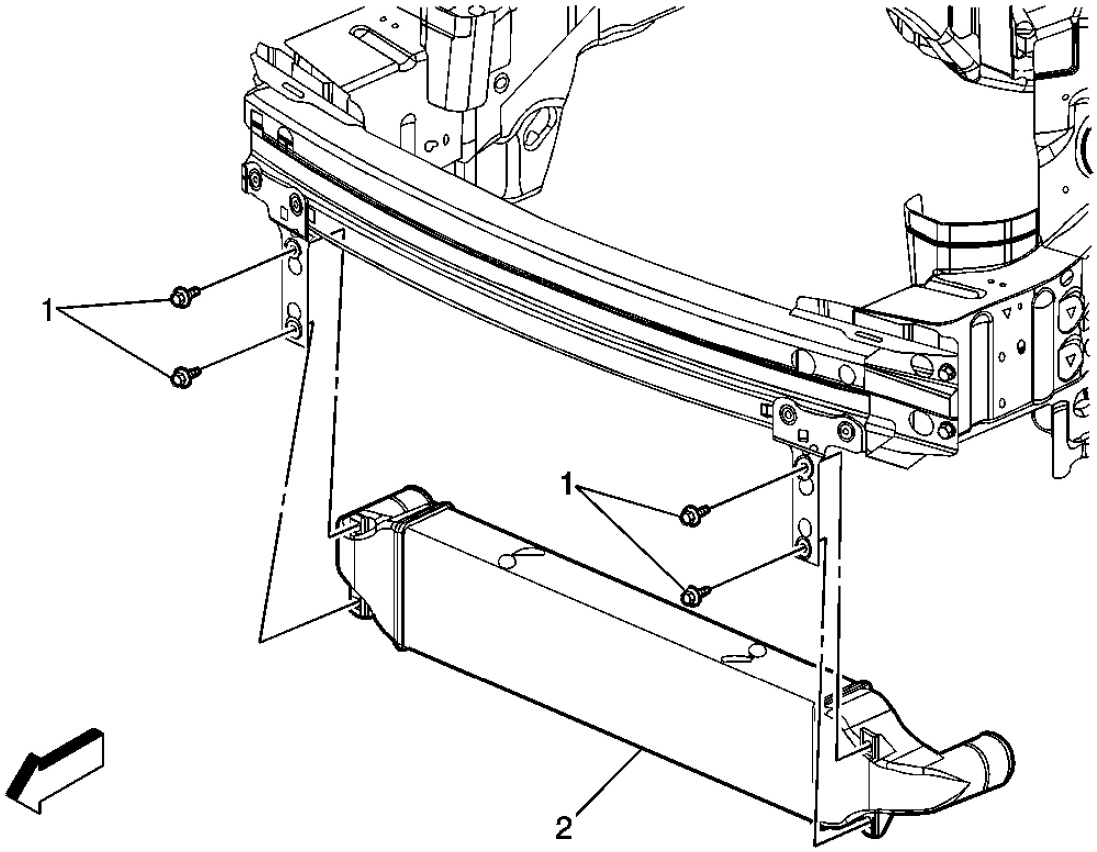


Fig. 231: View Of Charge Air Cooler
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
Preliminary Procedure	
1. Remove the front bumper fascia. Refer to **Front Bumper Fascia Replacement (Standard)** or **Front Bumper Fascia Replacement (SS)** . 2. Disconnect the inlet and outlet pipes to the charge air cooler. Refer to **Charge Air Cooler Inlet Pipe Replacement** and **Charge Air Cooler**	

	Outlet Pipe Replacement.
1	Charge Air Cooler Bolt (Qty:4) **NOTE:** **Refer to Fastener Notice .** **Tighten:** 9 N.m (80 lb in)
2	Charge Air Cooler

DESCRIPTION AND OPERATION

ENGINE CONTROL MODULE DESCRIPTION

The engine control module (ECM) interacts with many emission related components and systems, and monitors the emission related components and systems for deterioration. OBD II diagnostics monitor the system performance and a diagnostic trouble code (DTC) sets if the system performance degrades.

The malfunction indicator lamp (MIL) operation and the DTC storage are dictated by the DTC type. A DTC is ranked as a Type A or Type B if the DTC is emissions related. Type C is a non-emissions related DTC.

The ECM is in the engine compartment. The ECM is the control center of the engine controls system. The ECM controls the following components:

- The fuel injection system
- The ignition system
- The emission control systems
- The on-board diagnostics
- The A/C and fan systems
- The throttle actuation control (TAC) system

The ECM constantly monitors the information from various sensors and other inputs, and controls the systems that affect the vehicle performance and the emissions. The ECM also performs diagnostic tests on various parts of the system. The ECM can recognize operational problems and alert the driver via the MIL. When the ECM detects a malfunction, the ECM stores a DTC. The condition area is

identified by the particular DTC that is set. This aids the technician in making repairs.

ECM Function

The engine control module (ECM) can supply 5 volts or 12 volts to the various sensors or switches. This is done through pull-up resistors to the regulated power supplies within the ECM. In some cases, even an ordinary shop voltmeter will not give an accurate reading because the resistance is too low. Therefore, a DMM with at least 10 megohms input impedance is required in order to ensure accurate voltage readings.

The ECM controls the output circuits by controlling the ground or the power feed circuit through the transistors or a device called an output driver module.

EEPROM

The electronically erasable programmable read only memory (EEPROM) is a permanent memory that is physically part of the engine control module (ECM). The EEPROM contains program and calibration information that the ECM needs in order to control the powertrain operation.

Special equipment, as well as the correct program and calibration for the vehicle, are required in order to reprogram the ECM.

Data Link Connector (DLC)

The data link connector (DLC) is a 16-pin connector that provides the technician a means of accessing serial data for aid in the diagnosis. This connector allows the technician to use a scan tool in order to monitor the various serial data parameters, and display the DTC information. The DLC is located inside of the drivers compartment, underneath the dash.

Malfunction Indicator Lamp (MIL)

The malfunction indicator lamp (MIL) is inside of the instrument panel cluster (IPC). The MIL is controlled by the engine control module (ECM) and illuminates when the ECM detects a condition that affects the vehicle emissions.

ECM Service Precautions

The engine control module (ECM), by design, can withstand the normal current draws that are associated with the vehicle operations. However, care must be used in order to avoid overloading any of these circuits. When testing for opens or shorts, do not ground or apply voltage to any of the ECM circuits unless the diagnostic procedure instructs you to do so. These circuits should only be tested with a DMM.

Emissions Diagnosis For State I/M Programs

This OBD II equipped vehicle is designed to diagnose any conditions that could lead to excessive levels of the following emissions:

- Hydrocarbons (HC)
- Carbon monoxide (CO)
- Oxides of nitrogen (NOx)
- Evaporative emission (EVAP) system losses

Should this vehicles on-board diagnostic system (ECM) detect a condition that could result in excessive emissions, the ECM turns ON the malfunction indicator lamp (MIL) and stores a DTC that is associated with the condition.

Aftermarket (Add-On) Electrical And Vacuum Equipment

NOTE: Do not attach add-on vacuum operated equipment to this vehicle. The use of add-on vacuum equipment may result in damage to vehicle components or systems.

NOTE: Connect any add-on electrically operated equipment to the vehicle's electrical system at the battery (power and ground) in order to prevent damage to the vehicle.

Aftermarket, add-on, electrical and vacuum equipment is defined as any equipment installed on a vehicle after leaving the factory that connects to the vehicles electrical or vacuum systems. No allowances have been made in the vehicle design for this type of equipment.

Add-on electrical equipment, even when installed to these strict guidelines, may still cause the powertrain system to malfunction. This may also include equipment

not connected to the vehicle electrical system, such as portable telephones and radios. Therefore, the first step in diagnosing any powertrain condition is to eliminate all of the aftermarket electrical equipment from the vehicle. After this is done, if the problem still exists, the problem may be diagnosed in the normal manner.

Electrostatic Discharge (ESD) Damage

IMPORTANT: In order to prevent possible electrostatic discharge damage to the engine control module (ECM), DO NOT touch the connector pins on the ECM.

The electronic components that are used in the control systems are often designed to carry very low voltage. The electronic components are susceptible to damage caused by electrostatic discharge. Less than 100 volts of static electricity can cause damage to some electronic components.

There are several ways for a person to become statically charged. The most common methods of charging are by friction and by induction. An example of charging by friction is a person sliding across a car seat.

Charging by induction occurs when a person with well insulated shoes stands near a highly charged object and momentarily touches ground. Charges of the same polarity are drained off leaving the person highly charged with the opposite polarity. Static charges can cause damage, therefore, it is important to use care when handling and testing electronic components.

Emissions Control Information Label

The underhood Vehicle Emissions Control Information Label contains important emission specifications and setting procedures. In the upper right corner is the exhaust emission information. This identifies the year, the manufacturing division of the engine, the displacement of the engine in liters, the class of the vehicle, and type of fuel metering system. There is also an illustrated emission components and vacuum hose schematic.

This label is located in the engine compartment of every General Motors vehicle. If the label has been removed, it can be ordered from GM service parts operations

(GMSPO).

Underhood Inspection

IMPORTANT: This inspection is very important and must be done carefully and thoroughly.

Perform a careful underhood inspection when performing any diagnostic procedure or diagnosing the cause of an emission test failure. This can often lead to repairing a condition without further steps. Use the following guidelines when performing an inspection:

- Inspect all of the vacuum hoses for correct routing, pinches, cuts, or disconnects.
- Inspect any hoses that are difficult to see.
- Inspect all of the wires in the engine compartment for the following conditions:
  - Burned or chafed spots
  - Pinched wires
  - Contact with sharp edges
  - Contact with hot exhaust manifolds

TURBOCHARGER SYSTEM DESCRIPTION

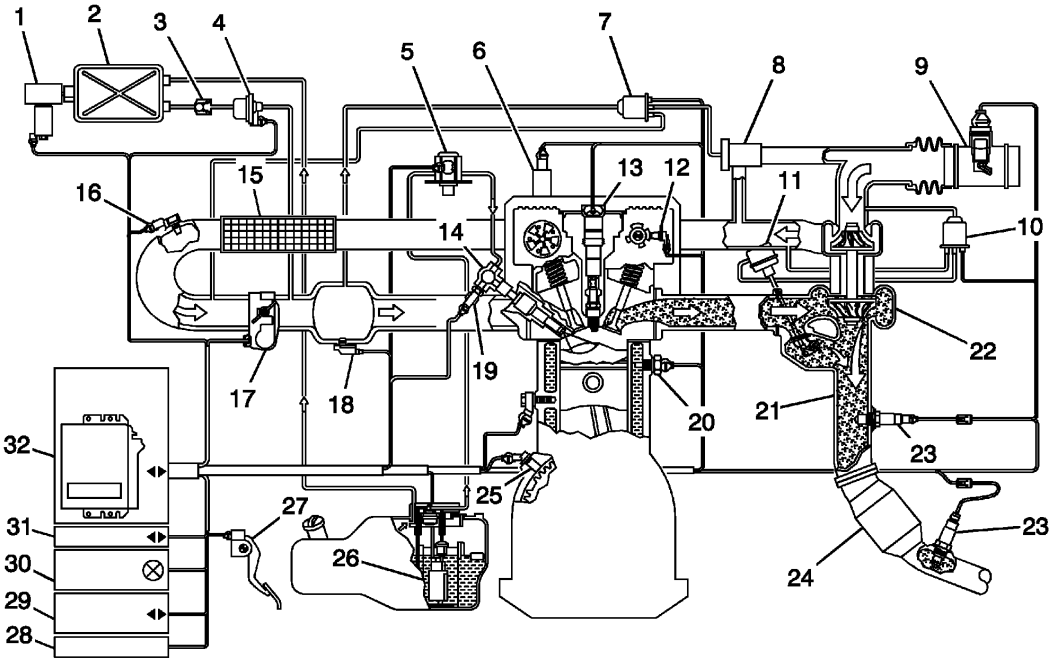


Fig. 232: Turbocharger System Diagram
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
1	Evaporative Emission (EVAP) Canister Vent Solenoid Valve
2	EVAP Canister
3	Non-Return Valve
4	EVAP Canister Purge Solenoid Valve
5	High Pressure Fuel Pump
6	Camshaft Position (CMP) Actuator Solenoid
7	Charge Air Bypass Valve Solenoid
8	Charge Air Bypass Valve
9	Mass Air Flow (MAF)/Intake Air Temperature (IAT) Sensor
10	Turbocharger Wastegate Solenoid Valve
11	Turbocharger Wastegate Actuator
12	Camshaft Position (CMP) Sensor
13	Ignition Coil/Module and Spark Plug
14	Fuel Injector

15	Charge Air Cooler (CAC)
16	Turbocharger Boost Pressure Sensor
17	Throttle Body (TB)
18	Manifold Absolute Pressure (MAP) Sensor
19	Fuel Rail Pressure (FRP) Sensor
20	Engine Coolant Temperature (ECT) Sensor
21	Engine Exhaust Manifold
22	Turbocharger
23	Heated Oxygen Sensor (HO2S) 1 and 2
24	Catalyst
25	Crankshaft Position (CKP) Sensor
26	Fuel Pump Module
27	Accelerator Pedal
28	Theft Deterrent
29	Data Link Connector (DLC)
30	Malfunction Indicator Lamp (MIL)
31	GMLAN Serial Data
32	Engine Control Module (ECM)

Turbocharger Description and Operation

A turbocharger is a compressor that is used to increase the power output of an engine by increasing the mass of the oxygen and therefore the fuel entering the engine. This BorgWarner™ dual-scroll turbocharger is mounted on the exhaust manifold and the lightweight turbine is driven by the waste energy generated by the flow of the exhaust gases. The turbine is connected by a shaft to the compressor which is mounted in the induction system of the engine. The compressor vanes compress the intake air above atmospheric pressure, thereby greatly increasing the density of the air entering the engine. The turbocharger is capable of producing up to 20 psi or 1.40 bar, of power-enhancing boost.

The turbocharger incorporates a wastegate that is controlled by a pressure differential, that is determined by the engine control module (ECM) by means of a PWM solenoid, in order to regulate the pressure ratio of the compressor. A compressor bypass valve also controlled by the ECM by utilizing a remotely

mounted solenoid is integrated into the unit to prevent compressor surging and damage from vibrations by opening during abrupt closed throttle conditions. When the valve is open during closed throttle deceleration conditions, the bypass valve allows the air to recirculate in the turbocharger and maintain compressor speed. Within a calibrated range during the closed throttle event, or upon a wide open throttle command the valve will then close to optimize turbo response.

The turbocharger is connected to the engine oiling system by a supply and drain tube and Mobile 1™ synthetic oil is installed at the factory. Synthetic oil is required for its friction-reducing capabilities and high-temperature performance. There is a cooling system circuit in the turbocharger that utilizes the engine coolant to further reduce operating temperatures.

Charge Air Cooler Description

The turbocharger is supported by an air-to-air charge air cooler (CAC) system, which uses fresh air drawn through a heat exchanger to reduce the temperature of the warmer compressed air forced through the intake system. Inlet air temperature can be reduced by up to 100°C (180°F), enhancing performance because cooler air is denser in oxygen and promotes optimal combustion. The CAC is connected to the turbocharger and to the throttle body by flexible ductwork that requires the use of special high torque fastening clamps. In order to prevent any type of air leak when servicing the ductwork, the tightening specifications and proper positioning of the clamps is critical, and must be strictly adhered to.

Benefits of Dual Cam Phasing

The camshafts of the Ecotec 2.0 liter turbocharged engine have camshaft position (CMP) sensors and CMP actuators that the ECM uses to accurately control the continuously variable intake and exhaust valve timing. This allows the combustion process to be optimized by the ECM to increase the response of the turbocharger, providing a more immediate feeling of power to the driver.

Benefits of Gasoline Direct Injection

In the Ecotec 2.0 liter turbocharged engine, the fuel is introduced directly into the combustion chamber during the intake stroke. As the piston approaches top-dead center, the mixture is ignited by the spark plug, thereby giving the name spark

ignition direct injection (SIDI). SIDI allows the mixture to be leaner, with less fuel and more air at full power. SIDI also allows a slightly higher compression ratio, resulting in improved fuel consumption at part and full throttle.

The fact that the fuel is injected after the exhaust valve closes allows particularly high valve overlap values in certain engine operating ranges. This enhances the turbocharger response time. This would not be possible in a port fuel injection (PFI) engine due to the fact that unburned fuel would escape through the open exhaust valve.

Direct injection's precise fuel delivery enables more complete combustion which reduces emissions particularly on cold starts.

Electronic Vacuum Pump

The purpose of the electronic vacuum pump is to keep the vacuum in the brake booster at an acceptable level under various operating conditions. The ECM monitors the input signal from the brake booster pressure sensor. When the vacuum in the brake booster is not in an acceptable range the ECM will command the relay ON that controls the vacuum pump.

Recommendations for Service

The turbocharger is designed so that it does not require any special maintenance, and inspection is limited to a few periodic procedures. To ensure that the turbocharger's lifetime corresponds to that of the engine, the following engine manufacturer's service instructions must be strictly adhered to:

- Oil and filter change intervals
- Maintaining the proper oil pressure
- Air filter change intervals
- Engine coolant change intervals
- Ignition system maintenance
- Injection system maintenance

The following causes are responsible for 90 percent of all turbocharger failures:

- Penetration of foreign bodies into the turbine or the compressor
- Dirt or contaminants in the oil
- Inadequate oil supply and/or pressure
- Higher than normal exhaust gas temperatures due to improper operation of the following:
  - The ignition system
  - The fuel injection system
  - The exhaust system

These failures can be avoided by regular maintenance.

FUEL SYSTEM DESCRIPTION

Fuel System Overview

The fuel system is a returnless on-demand design. The fuel pressure regulator is a part of the fuel pump module, eliminating the need for a return pipe from the engine. A returnless fuel system reduces the internal temperature of the fuel tank by not returning hot fuel from the engine to the fuel tank. Reducing the internal temperature of the fuel tank results in lower evaporative emissions.

An electric turbine style fuel pump attaches to the fuel pump module inside the fuel tank. The fuel pump supplies fuel through the fuel feed pipe to the high pressure fuel pump. The high pressure fuel pump supplies fuel to a variable-pressure fuel rail. Fuel enters the combustion chamber through precision multi-hole fuel injectors. The high pressure fuel pump, fuel rail pressure, fuel injection timing, and injection duration are controlled by the engine control module (ECM).

Fuel Tank

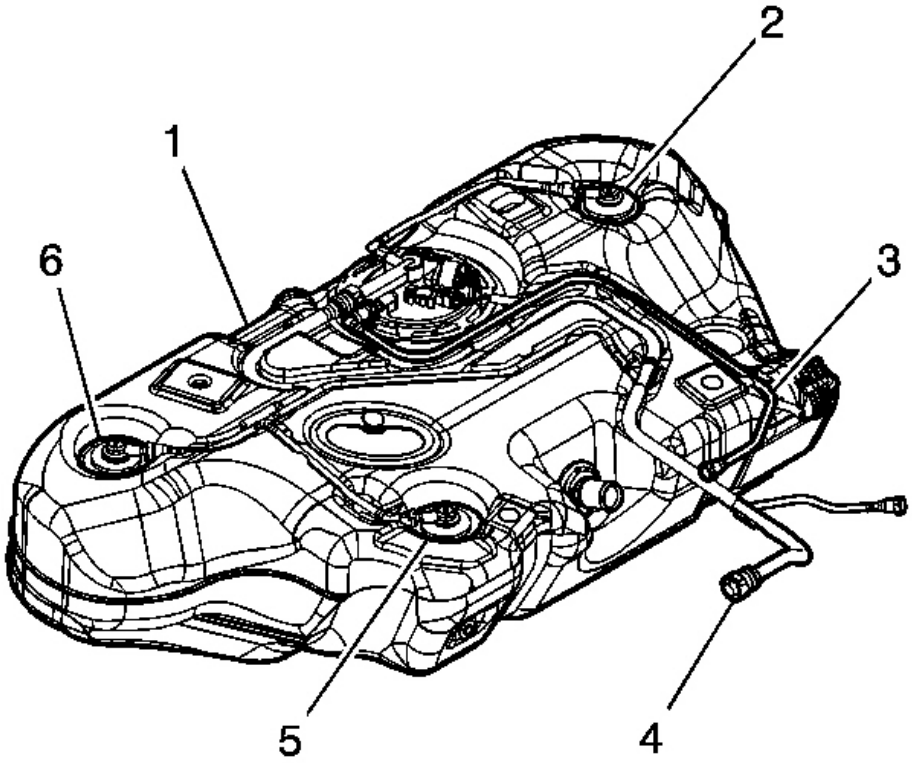


Fig. 233: Fuel Tank
Courtesy of GENERAL MOTORS CORP.

The fuel tank (1) stores the fuel supply. The fuel tank is located in the rear of the vehicle. The fuel tank is held in place by 2 metal straps that attach to the frame. The fuel tank is molded from high-density polyethylene.

Fuel Fill Pipe

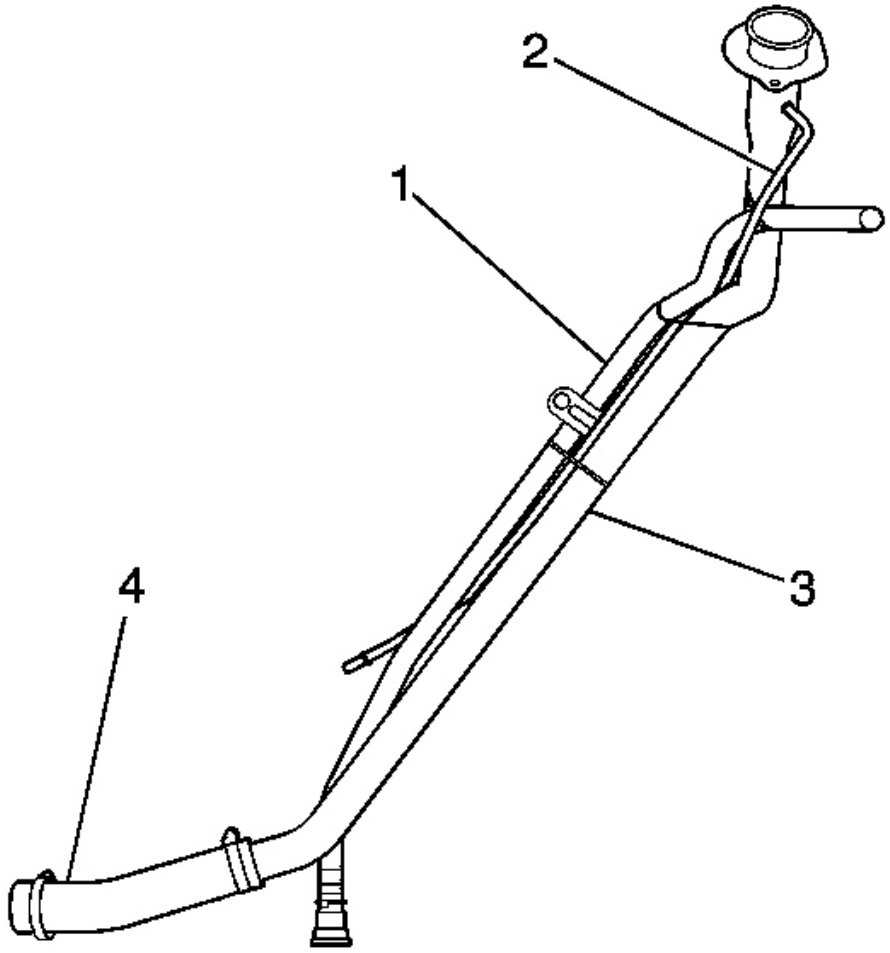


Fig. 234: Fuel Fill Pipe
Courtesy of GENERAL MOTORS CORP.

The fuel fill pipe (3) has a built-in restrictor in order to prevent refueling with leaded fuel.

Fuel Filler Cap

NOTE: If a fuel tank filler cap requires replacement, use only a fuel tank filler cap with the same features. Failure to use the correct fuel tank filler cap can result in a serious malfunction of the fuel and EVAP system.

The fuel fill pipe has a tethered fuel filler cap. A torque-limiting device prevents the cap from being over-tightened. To install the cap, turn the cap clockwise until you hear audible clicks. This indicates that the cap is correctly torqued and fully seated. A fuel filler cap that is not fully seated may cause a malfunction in the emission system.

Fuel Pump Module

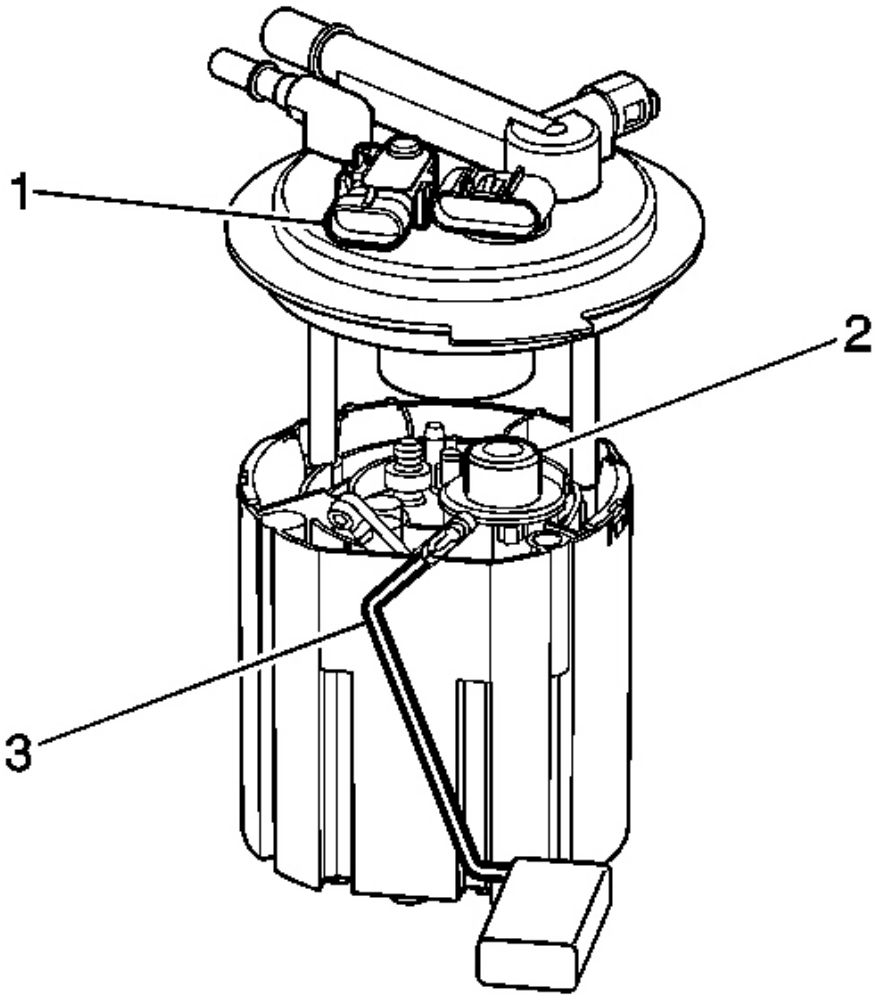


Fig. 235: Fuel Pump Module
Courtesy of GENERAL MOTORS CORP.

An electric turbine style fuel pump attaches to the fuel pump module inside the fuel

tank. The fuel pump supplies fuel through the fuel feed pipe to the high pressure fuel pump. The fuel pump provides fuel at a higher rate of flow than is needed by the high pressure fuel pump. The fuel pressure regulator, a part of the fuel pump module, maintains the correct fuel pressure to the high pressure fuel pump. The fuel pump module contains a reverse flow check valve. The check valve and the fuel pressure regulator maintain fuel pressure in the fuel feed pipe in order to prevent long cranking times.

The fuel pump module consists of the following major components:

- The fill limit vent valve
- The fuel level sensor (3)
- The fuel tank pressure (FTP) sensor (1)
- The fuel pump
- The fuel strainer
- The fuel pressure regulator (2)

Fuel Level Sensor

The fuel level sensor consists of a float, a wire float arm, and a ceramic resistor card. The position of the float arm indicates the fuel level. The fuel level sensor contains a variable resistor which changes resistance in correspondence with the position of the float arm. The control module sends the fuel level information via the serial data circuit to the instrument panel cluster (IPC). This information is used for the IPC fuel gage and the low fuel warning indicator, if applicable. The control module also monitors the fuel level input for various diagnostics.

Fuel Pump

The fuel pump is mounted in the fuel pump module reservoir. The fuel pump is an electric pump. Fuel is pumped to the high pressure fuel pump at a specified flow and pressure. The fuel pump delivers a constant flow of fuel even during low fuel conditions and aggressive vehicle maneuvers. The control module controls the electric fuel pump operation through a fuel pump relay. The fuel pump flex pipe acts to dampen the fuel pulses and noise generated by the fuel pump.

Fuel Strainer

The fuel strainer attaches to the lower end of the fuel pump module. The fuel strainer is made of woven plastic. The functions of the fuel strainer are to filter contaminants and to wick fuel. The fuel strainer normally requires no maintenance. Fuel stoppage at this point indicates that the fuel tank contains an abnormal amount of sediment or contamination.

Fuel Pressure Regulator

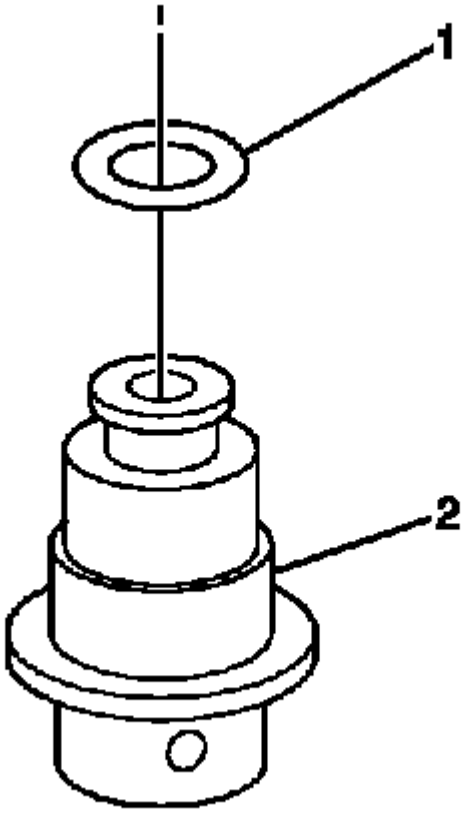


Fig. 236: View Of Fuel Pressure Regulator
Courtesy of GENERAL MOTORS CORP.

The fuel pressure regulator (2) is contained in the fuel pump module near the fuel pump outlet. The fuel pressure regulator is a diaphragm relief valve. The diaphragm has fuel pressure on one side and regulator spring pressure on the other side. The fuel pressure regulator is not vacuum biased. Fuel pressure is controlled by a pressure balance across the regulator. The fuel system pressure is constant.

Fuel Feed Pipes

The low pressure fuel feed pipe carries fuel from the fuel tank to the high pressure fuel pump. The fuel pipe consists of 3 sections:

- The fuel pump fuel feed pipe is located from the top of the fuel tank to the chassis fuel pipe. The fuel pump fuel feed pipe is constructed of nylon.
- The chassis fuel pipe is located under the vehicle and connects the fuel pump fuel feed pipe to the fuel feed pipe. The chassis fuel pipe is constructed of galvanized aluminum with a section of flexible hose protected by a braided covering.
- The fuel feed pipe assembly located in the engine compartment connects the chassis fuel pipe to the high pressure fuel pump. This pipe contains the fuel pulse dampener and the fuel pressure service valve, and is constructed of stainless steel.

The fuel feed intermediate pipe is a high pressure pipe that carries fuel from the high pressure fuel pump to the fuel rail. The fuel feed intermediate pipe is constructed of stainless steel.

Nylon Fuel Pipes

CAUTION: In order to reduce the risk of fire and personal injury observe the following items:

- **Replace all nylon fuel pipes that are nicked, scratched or damaged during installation, do not attempt to repair the sections of the nylon fuel pipes**
- **Do not hammer directly on the fuel harness body clips when installing new fuel pipes. Damage to the nylon pipes may result in a fuel leak.**
- **Always cover nylon vapor pipes with a wet towel before using a torch near them. Also, never expose the vehicle to temperatures higher than 115°C (239°F) for more than one hour, or more than 90°C (194°F) for any extended period.**
- **Apply a few drops of clean engine oil to the male**

pipe ends before connecting fuel pipe fittings. This will ensure proper reconnection and prevent a possible fuel leak. (During normal operation, the O-rings located in the female connector will swell and may prevent proper reconnection if not lubricated.)

Nylon pipes are constructed to withstand maximum fuel system pressure, exposure to fuel additives, and changes in temperature.

Heat resistant rubber hose or corrugated plastic conduit protect the sections of the pipes that are exposed to chafing, high temperature, or vibration.

Nylon fuel pipes are somewhat flexible and can be formed around gradual turns under the vehicle. However, if nylon fuel pipes are forced into sharp bends, the pipes kink and restrict the fuel flow. Also, once exposed to fuel, nylon pipes may become stiffer and are more likely to kink if bent too far. Take special care when working on a vehicle with nylon fuel pipes.

Quick-Connect Fittings

Quick-connect fittings provide a simplified means of installing and connecting fuel system components. The fittings consist of a unique female connector and a compatible male pipe end. O-rings, located inside the female connector, provide the fuel seal. Integral locking tabs inside the female connector hold the fittings together.

High Pressure Fuel Pump

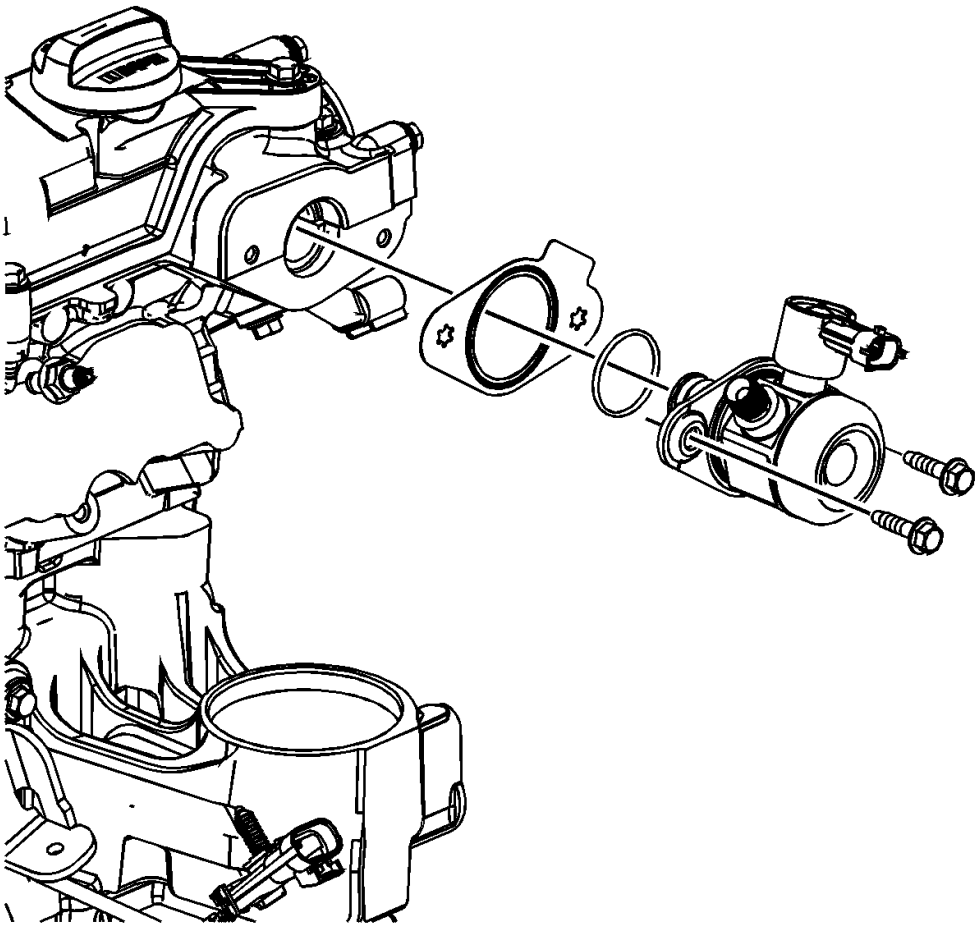


Fig. 237: High Pressure Fuel Pump & Bolts
Courtesy of GENERAL MOTORS CORP.

The high pressure fuel pump is a mechanical one-cylinder design driven by an additional three lobe cam on the camshaft. High pressure fuel is regulated by the fuel rail pressure (FRP) regulator, which is a part of the high pressure fuel pump. The FRP regulator is a magnetic actuator which controls the inlet valve of the high pressure pump. The ECM provides battery voltage on the actuator high circuit and ground on the actuator low circuit. Both circuits are controlled through output drivers within the ECM. When deactivated, both drivers are disabled and the inlet valve is held open with spring pressure. When activated, the actuator low circuit driver connects the low circuit to ground, and the actuator high circuit driver pulse-width modulates the high circuit. The ECM uses the camshaft and the crankshaft position sensor inputs to synchronize the FRP regulator with the position of each of the three camshaft lobes. The ECM regulates fuel pressure by adjusting the portion

of each pump stroke that provides fuel to the rail. The high pressure fuel pump also contains an integrated pressure relief valve.

Fuel Rail Assembly

The fuel rail assembly attaches to the cylinder head. The fuel rail distributes high pressure fuel to the fuel injectors. The fuel rail assembly consists of the following components:

- The direct fuel injectors
- The fuel rail pressure (FRP) sensor

Fuel Injectors

The fuel injection system is a high pressure, direct injection, returnless on-demand design. The fuel injectors are mounted in the cylinder head beneath the intake ports and spray fuel directly into the combustion chamber. Direct injection requires high fuel pressure due to the fuel injector's location in the combustion chamber. Fuel pressure must be higher than compression pressure requiring a high pressure fuel pump. The fuel injectors also require more electrical power due to the high fuel pressure. The ECM supplies a separate high voltage supply circuit and a high voltage control circuit for each fuel injector. The injector high voltage supply circuit and the high voltage control circuit are both controlled by the ECM. The ECM energizes each fuel injector by grounding the control circuit. The ECM controls each fuel injector with 65 volts. This is controlled by a boost capacitor in the ECM. During the 65 volt boost phase, the capacitor is discharged through an injector, allowing for initial injector opening. The injector is then held open with 12 volts.

The fuel injector assembly is an inside opening electrical magnetic injector. The injector has six precision machined holes that generate a cone shaped oval spray pattern. The fuel injector has a slim extended tip in order to allow a sufficient cooling jacket in the cylinder head.

Fuel Injection Fuel Rail Fuel Pressure Sensor

The fuel rail pressure sensor detects fuel pressure within the fuel rail. The engine control module (ECM) provides a 5-volt reference voltage on the 5-volt reference circuit and ground on the reference ground circuit. The ECM receives a varying

signal voltage on the signal circuit. The ECM monitors the voltage on the FRP sensor circuits. When the fuel pressure is high, the signal voltage is high. When the fuel pressure is low, the signal voltage is low.

Fuel Pulse Dampener

The fuel pulse dampener is a part of the low pressure fuel feed pipe assembly. The fuel pulse dampener is diaphragm-operated, with fuel pump pressure on one side and with spring pressure on the other side. The function of the dampener is to dampen the fuel pump pressure pulsations.

Fuel Metering Modes of Operation

The control module monitors voltages from several sensors in order to determine how much fuel to give the engine. The control module controls the amount of fuel delivered to the engine by changing the fuel injector pulse width. The fuel is delivered under one of several modes.

Starting Mode

When the ignition is first turned ON, the control module energizes the fuel pump relay for 2 seconds. This allows the fuel pump to build pressure in the fuel system. The control module calculates the air/fuel ratio based on inputs from the engine coolant temperature (ECT), manifold absolute pressure (MAP), mass air flow (MAF), and throttle position (TP) sensors. The system stays in starting mode until the engine speed reaches a predetermined RPM.

Clear Flood Mode

If the engine floods, clear the engine by pressing the accelerator pedal down to the floor and then crank the engine. When the throttle position (TP) sensor is at wide open throttle (WOT), the control module reduces the fuel injector pulse width in order to increase the air to fuel ratio. The control module holds this injector rate as long as the throttle stays wide open and the engine speed is below a predetermined RPM. If the throttle is not held wide open, the control module returns to the starting mode.

Run Mode

The run mode has 2 conditions called Open Loop and Closed Loop. When the

engine is first started and the engine speed is above a predetermined RPM, the system begins Open Loop operation. The control module ignores the signal from the heated oxygen sensor (HO2S). The control module calculates the air/fuel ratio based on inputs from the engine coolant temperature (ECT), manifold absolute pressure (MAP), mass air flow (MAF), and throttle position (TP) sensors. The system stays in Open Loop until meeting the following conditions:

- The HO2S has varying voltage output, showing that the HO2S is hot enough to operate properly.
- The ECT sensor is above a specified temperature.
- A specific amount of time has elapsed after starting the engine.

Specific values for the above conditions exist for each different engine, and are stored in the electrically erasable programmable read-only memory (EEPROM). The system begins Closed Loop operation after reaching these values. In Closed Loop, the control module calculates the air/fuel ratio, injector ON time, based upon the signal from various sensors, but mainly from the HO2S. This allows the air/fuel ratio to stay very close to 14.7:1.

Acceleration Mode

When the driver pushes on the accelerator pedal, air flow into the cylinders increases rapidly. To prevent possible hesitation, the control module increases the pulse width to the injectors to provide extra fuel during acceleration. This is also known as power enrichment. The control module determines the amount of fuel required based upon the throttle position (TP), the engine coolant temperature (ECT), the manifold absolute pressure (MAP), the mass air flow (MAF), and the engine speed.

Deceleration Mode

When the driver releases the accelerator pedal, air flow into the engine is reduced. The control module monitors the corresponding changes in the throttle position (TP), the mass air flow (MAF), and the manifold absolute pressure (MAP). The control module shuts OFF fuel completely if the deceleration is very rapid, or for long periods, such as long, closed-throttle coast-down. The fuel shuts OFF in order to prevent damage to the catalytic converters.

Battery Voltage Correction Mode

When the battery voltage is low, the control module compensates for the weak spark delivered by the ignition system in the following ways:

- Increasing the amount of fuel delivered
- Increasing the idle RPM
- Increasing the ignition dwell time

Fuel Cutoff Mode

The control module cuts OFF fuel from the fuel injectors when the following conditions are met in order to protect the powertrain from damage and improve driveability:

- The ignition is OFF. This prevents engine run-on.
- The ignition is ON but there is no ignition reference signal. This prevents flooding or backfiring.
- The engine speed is too high, above red line.
- The vehicle speed is too high, above rated tire speed.
- During an extended, high speed, closed throttle coast down-This reduces emissions and increases engine braking.
- During extended deceleration, in order to prevent damage to the catalytic converters

Fuel Trim

The control module controls the air/fuel metering system in order to provide the best possible combination of driveability, fuel economy, and emission control. The control module monitors the heated oxygen sensor (HO2S) signal voltage while in Closed Loop and regulates the fuel delivery by adjusting the pulse width of the injectors based on this signal. The ideal fuel trim values are around 0 percent for both short and long term fuel trim. A positive fuel trim value indicates the control module is adding fuel in order to compensate for a lean condition by increasing the pulse width. A negative fuel trim value indicates that the control module is reducing the amount of fuel in order to compensate for a rich condition by decreasing the pulse width. A change made to the fuel delivery changes the long and short term

fuel trim values. The short term fuel trim values change rapidly in response to the HO2S signal voltage. These changes fine tune the engine fueling. The long term fuel trim makes coarse adjustments to fueling in order to re-center and restore control to short term fuel trim. A scan tool can be used to monitor the short and long term fuel trim values. The long term fuel trim diagnostic is based on an average of several of the long term speed load learn cells. The control module selects the cells based on the engine speed and engine load. If the control module detects an excessively lean or rich condition, the control module will set a fuel trim diagnostic trouble code (DTC).

CAMSHAFT ACTUATOR SYSTEM DESCRIPTION

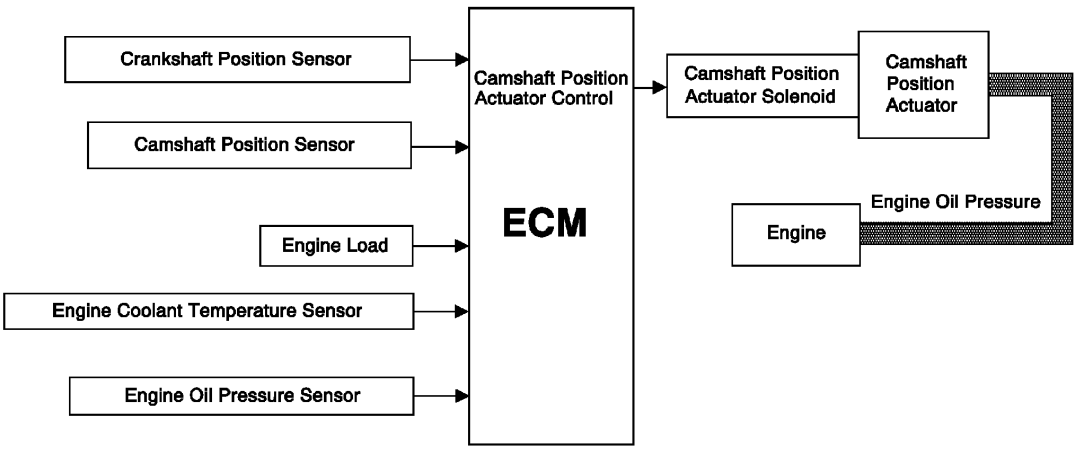


Fig. 238: Camshaft Actuator System Description
Courtesy of GENERAL MOTORS CORP.

Camshaft Position (CMP) Actuator System

The camshaft position (CMP) actuator system is an electro-hydraulic operated device used for a variety of engine performance and operational enhancements. These enhancements include lower emission output through exhaust gas dilution of the intake charge in the combustion chamber, a broader engine torque range, and

improved fuel economy. The CMP actuator system accomplishes this by changing the angle or timing of the camshaft relative to the crankshaft position. The CMP actuator simply allows earlier or later intake and exhaust valve opening during the four stroke engine cycle. The CMP actuator cannot vary the duration of valve opening, or the valve lift.

During engine OFF, engine idling conditions, and engine shutdown, the camshaft actuator is held in the Park position. Internal to the CMP actuator assembly is a return spring and a locking pin. During non-phasing modes of the camshaft, the return spring rotates the camshaft back to the Park position, and the locking pin retains the CMP actuator sprocket to the camshaft.

CMP Actuator System Operation

The camshaft position (CMP) actuator system is controlled by the engine control module (ECM). The ECM sends a signal to a CMP actuator solenoid in order to control the amount of engine oil flow to a Cam Actuator passage. The pressurized engine oil is sent to unseat the locking pin, and to the vane and rotor assembly of the CMP actuator. There are 2 different passages for oil to flow through, a passage for cam advance and a passage for cam retard. The Cam Actuator is attached to a camshaft and is hydraulically operated in order to change the angle of the camshaft relative to crankshaft position (CKP). Engine oil pressure (EOP), viscosity, temperature and engine oil level can have an adverse affect on Cam Actuator performance.

EVAPORATIVE EMISSION CONTROL SYSTEM DESCRIPTION

EVAP System Operation

The evaporative emission (EVAP) control system limits fuel vapors from escaping into the atmosphere. Fuel tank vapors are allowed to move from the fuel tank, due to pressure in the tank, through the vapor pipe, into the EVAP canister. Carbon in the canister absorbs and stores the fuel vapors. Excess pressure is vented through the vent line and EVAP vent solenoid valve to the atmosphere. The EVAP canister stores the fuel vapors until the engine is able to use them. At an appropriate time, the control module will command the EVAP purge solenoid valve ON, allowing engine vacuum to be applied to the EVAP canister. With the EVAP vent solenoid valve OFF, fresh air is drawn through the vent solenoid valve and the vent line to

the EVAP canister. Fresh air is drawn through the canister, pulling fuel vapors from the carbon. The air/fuel vapor mixture continues through the EVAP purge pipe and EVAP purge solenoid valve into the intake manifold to be consumed during normal combustion. The control module uses several tests to determine if the EVAP system is leaking.

Large Leak Test

This tests for large leaks and restrictions to the purge path in the evaporative emission (EVAP) system. When the enabling criteria has been met, the control module commands the EVAP vent solenoid valve ON and the EVAP purge solenoid valve ON, allowing vacuum into the EVAP system. The control module monitors the fuel tank pressure (FTP) sensor voltage to verify that the system is able to reach a predetermined level of vacuum within a set amount of time.

Small Leak Test

The engine off natural vacuum (EONV) diagnostic is the small-leak detection diagnostic for the evaporative emission (EVAP) system. While previous leak detection methods were performed with the engine running, the EONV diagnostic monitors the EVAP system pressure or vacuum with the ignition OFF. Because of this, it may be normal for the control module to remain active for up to 40 minutes after the ignition is turned OFF. This is important to remember when performing a parasitic draw test on vehicles equipped with EONV.

The EONV utilizes the temperature changes in the fuel tank immediately following a drive cycle to use the naturally occurring vacuum or pressure in the fuel tank. When the vehicle is driven, the temperature rises in the tank. After the vehicle is parked, the temperature in the tank continues to rise for a period of time, then starts to drop. The EONV diagnostic relies on this temperature change and the corresponding pressure change in a sealed system, to determine if an EVAP system leak is present.

The EONV diagnostic is designed to detect leaks as small as 0.51 mm (0.020 in). The diagnostic can determine if a small leak is present based on vacuum or pressure readings in the EVAP system. When the system is sealed, a finite amount of pressure or vacuum will be observed. When a 0.51 mm (0.020 in) leak is present, often little or no pressure or vacuum is observed. If the test reports a failing value,

DTC P0442 will set.

Canister Vent Restriction Test

If the evaporative emission (EVAP) vent system is restricted, fuel vapors will not be properly purged from the EVAP canister. The control module tests this by commanding the EVAP purge solenoid valve ON, commanding the EVAP vent solenoid valve OFF, and monitoring the fuel tank pressure (FTP) sensor for an increase in vacuum. If the vacuum increases more than a calibrated value, DTC P0446 will set.

Purge Solenoid Valve Leak Test

If the evaporative emission (EVAP) purge solenoid valve does not seal properly fuel vapors could enter the engine at an undesired time, causing driveability concerns. The control module tests for this by commanding the EVAP purge solenoid valve OFF and the vent solenoid valve ON, sealing the system, and monitors the fuel tank pressure (FTP) for an increase in vacuum. If the control module detects that the EVAP system vacuum increases above a calibrated value, DTC P0496 will set.

Check Gas Cap Message

The control module sends a class 2 message to the driver information center (DIC) illuminating the Check Gas Cap message when a malfunction in the evaporative emission (EVAP) system and a large leak test fails.

EVAP System Components

The evaporative emission (EVAP) system consists of the following components:

EVAP Canister

The canister is filled with carbon pellets used to absorb and store fuel vapors. Fuel vapor is stored in the canister until the control module determines that the vapor can be consumed in the normal combustion process.

EVAP Purge Solenoid Valve

The EVAP purge solenoid valve controls the flow of vapors from the EVAP system to the intake manifold. The purge solenoid valve opens when commanded ON by

the control module. This normally closed valve is pulse width modulated (PWM) by the control module to precisely control the flow of fuel vapor to the engine. The valve will also be opened during some portions of the EVAP testing, allowing engine vacuum to enter the EVAP system.

EVAP Vent Solenoid Valve

The EVAP vent solenoid valve controls fresh airflow into the EVAP canister. The valve is normally open. The control module commands the valve ON, closing the valve during some EVAP tests, allowing the system to be tested for leaks.

Fuel Tank Pressure Sensor

The fuel tank pressure (FTP) sensor measures the difference between the pressure or vacuum in the fuel tank and outside air pressure. The control module provides a 5-volt reference and a ground to the FTP sensor. The FTP sensor provides a signal voltage back to the control module that can vary between 0.1-4.9 volts. A high FTP sensor voltage indicates a low fuel tank pressure or vacuum. A low FTP sensor voltage indicates a high fuel tank pressure.

ELECTRONIC IGNITION (EI) SYSTEM DESCRIPTION

Electronic Ignition (EI) System Operation

The electronic ignition (EI) system produces and controls the high energy spark. This spark ignites the compressed air/fuel mixture at precisely the correct time, providing optimal performance, fuel economy, and control of exhaust emissions. The engine control module (ECM) primarily collects information from the crankshaft position (CKP) and camshaft position (CMP) sensors to control the sequence, dwell, and timing of the spark.

Crankshaft Position (CKP) Sensor

The CKP sensor is connected to the ECM by the following circuits:

- A 5-volt reference circuit
- A low reference circuit
- A signal circuit

The CKP sensor is an internally magnetic biased digital output integrated circuit

sensing device. The sensor detects magnetic flux changes of the teeth and slots of a 58-tooth reluctor wheel on the crankshaft. Each tooth on the reluctor wheel is spaced at 60-tooth spacing, with 2 missing teeth for the reference gap. The CKP sensor produces an ON/OFF DC voltage of varying frequency, with 58 output pulses per crankshaft revolution. The frequency of the CKP sensor output depends on the rotational velocity of the crankshaft. The CKP sensor sends a digital signal, which represents an image of the crankshaft reluctor wheel, to the ECM as each tooth on the wheel rotates past the CKP sensor. The ECM uses each CKP signal pulse to determine crankshaft speed and decodes the crankshaft reluctor wheel reference gap to identify crankshaft position. This information, along with information from the CMP sensors is then used to determine the optimum ignition and fuel injection points of the engine. The ECM also uses CKP sensor output information to determine the camshaft relative position to the crankshaft, to control camshaft phasing, and to detect cylinder misfire.

Crankshaft Reluctor Wheel

The crankshaft reluctor wheel is part of the crankshaft. The reluctor wheel consists of 58 teeth and a reference gap. Each tooth on the reluctor wheel is spaced 6 degrees apart with a 12-degree space for the reference gap. The pulse from the reference gap is known as the sync pulse. The sync pulse is used to synchronize the coil firing sequence with the crankshaft position, while the other teeth provide cylinder location during a revolution.

Camshaft Position (CMP) Sensor

The CMP sensors are triggered by a notched reluctor wheels built onto the intake and the exhaust camshaft sprockets. Both of the CMP sensors provide four signal pulses every camshaft revolution. Each notch, or feature of the reluctor wheel is of a different size which is used to identify the compression stroke of each cylinder and to enable sequential fuel injection. Both of the CMP sensors are connected to the ECM by the following circuits:

- A 5-volt reference circuit
- A low reference circuit
- A signal circuit

Ignition Coil/Module

Each ignition coil/module has the following circuits:

- An ignition voltage circuit
- A ground
- An ignition control (IC) circuit
- A low reference circuit

The ECM controls the individual ignition coil/modules by transmitting timing pulses on the IC circuit of each ignition coil/module to enable a spark event.

The spark plugs are connected to each coil by a short boot. The boot contains a spring that conducts the spark energy from the coil to the spark plug. The spark plug electrode is tipped with platinum for long wear and higher efficiency.

Engine Control Module (ECM)

The ECM controls all of the ignition system functions, and constantly corrects the spark timing. The ECM monitors information from various sensor inputs that include the following:

- The throttle position (TP) sensor
- The engine coolant temperature (ECT) sensor
- The mass air flow (MAF) sensor
- The intake air temperature (IAT) sensor
- The vehicle speed sensor (VSS)
- The engine knock sensor (KS)
- The manifold absolute pressure (MAP) sensor
- The boost pressure sensor

Modes of Operation

During normal operation the ECM controls all of the ignition system functions. If the CKP or either CMP sensor signals are lost, the engine will continue to run because the ECM will default to a limp home mode using the remaining sensor input. Each of the ignition coil/modules are internally protected against damage from excessive voltage. If one or more ignition coil/modules were to fail, a

misfiring condition would result. Diagnostic trouble codes are available to accurately diagnose the ignition system with a scan tool.

BOOST CONTROL SYSTEM DESCRIPTION

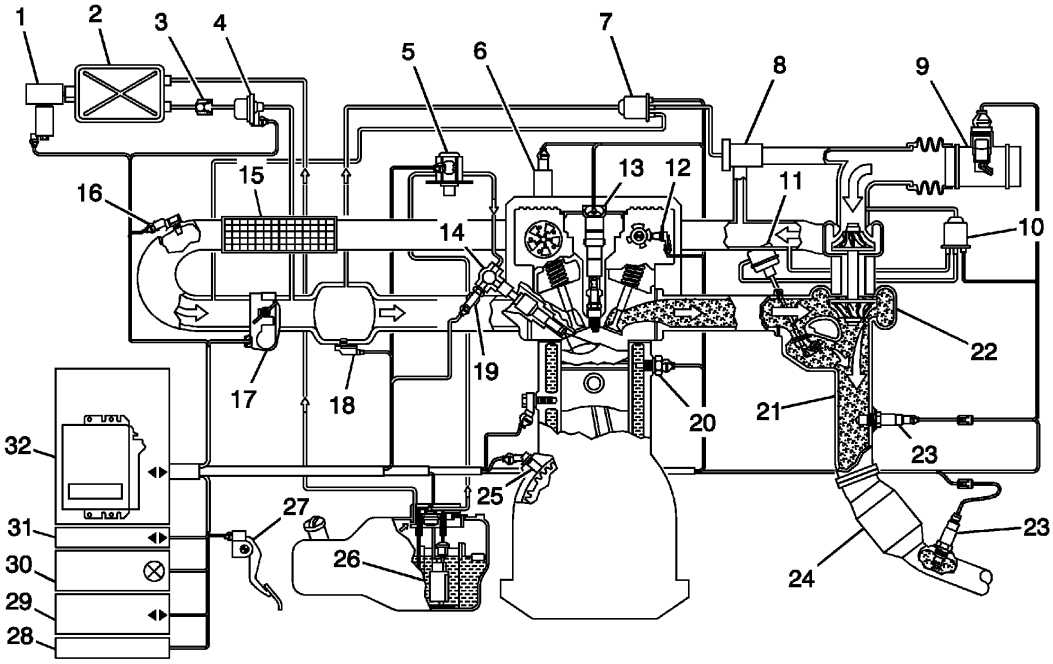


Fig. 239: Boost Control System Description
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
1	Evaporative Emission (EVAP) Canister Vent Solenoid Valve
2	EVAP Canister
3	Non-Return Valve
4	EVAP Canister Purge Solenoid Valve
5	High Pressure Fuel Pump
6	Camshaft Position (CMP) Actuator Solenoid
7	Charge Air Bypass Valve Solenoid
8	Charge Air Bypass Valve
9	Mass Air Flow (MAF)/Intake Air Temperature (IAT) Sensor
10	Turbocharger Wastegate Solenoid Valve

11	Turbocharger Wastegate Actuator
12	Camshaft Position (CMP) Sensor
13	Ignition Coil/Module and Spark Plug
14	Fuel Injector
15	Charge Air Cooler (CAC)
16	Turbocharger Boost Pressure Sensor
17	Throttle Body (TB)
18	Manifold Absolute Pressure (MAP) Sensor
19	Fuel Rail Pressure (FRP) Sensor
20	Engine Coolant Temperature (ECT) Sensor
21	Engine Exhaust Manifold
22	Turbocharger
23	Heated Oxygen Sensor (HO2S) 1 and 2
24	Catalyst
25	Crankshaft Position (CKP) Sensor
26	Fuel Pump Module
27	Accelerator Pedal
28	Theft Deterrent
29	Data Link Connector (DLC)
30	Malfunction Indicator Lamp (MIL)
31	GMLAN Serial Data
32	Engine Control Module (ECM)

Boost Control Description and Operation

A turbocharger (TC) is a compressor that is used to increase the power output of an engine by increasing the mass of the oxygen and therefore the fuel entering the engine. This BorgWarner™ dual-scroll TC is mounted on the exhaust manifold and the lightweight turbine is driven by the waste energy generated by the flow of the exhaust gases. The turbine is connected by a shaft to the compressor which is mounted in the induction system of the engine. The compressor vanes compress the intake air above atmospheric pressure, thereby greatly increasing the density of the air entering the engine. The TC is capable of producing up to 20 psi, or 1.40 bar, of power-enhancing boost.

The TC incorporates a wastegate that is controlled by a pressure differential, that is determined by the engine control module (ECM) by means of a PWM solenoid, in order to regulate the pressure ratio of the compressor. A TC bypass valve is integrated within the unit, and is also controlled by the ECM by utilizing a remotely mounted solenoid to prevent compressor surging and damage from vibrations by opening during abrupt closed throttle conditions. When the valve is commanded open during closed throttle deceleration conditions, the bypass valve allows the air to recirculate in the TC and maintain compressor speed. Within a calibrated range during the closed throttle event, or upon a wide open throttle command the valve will then close to optimize turbo response.

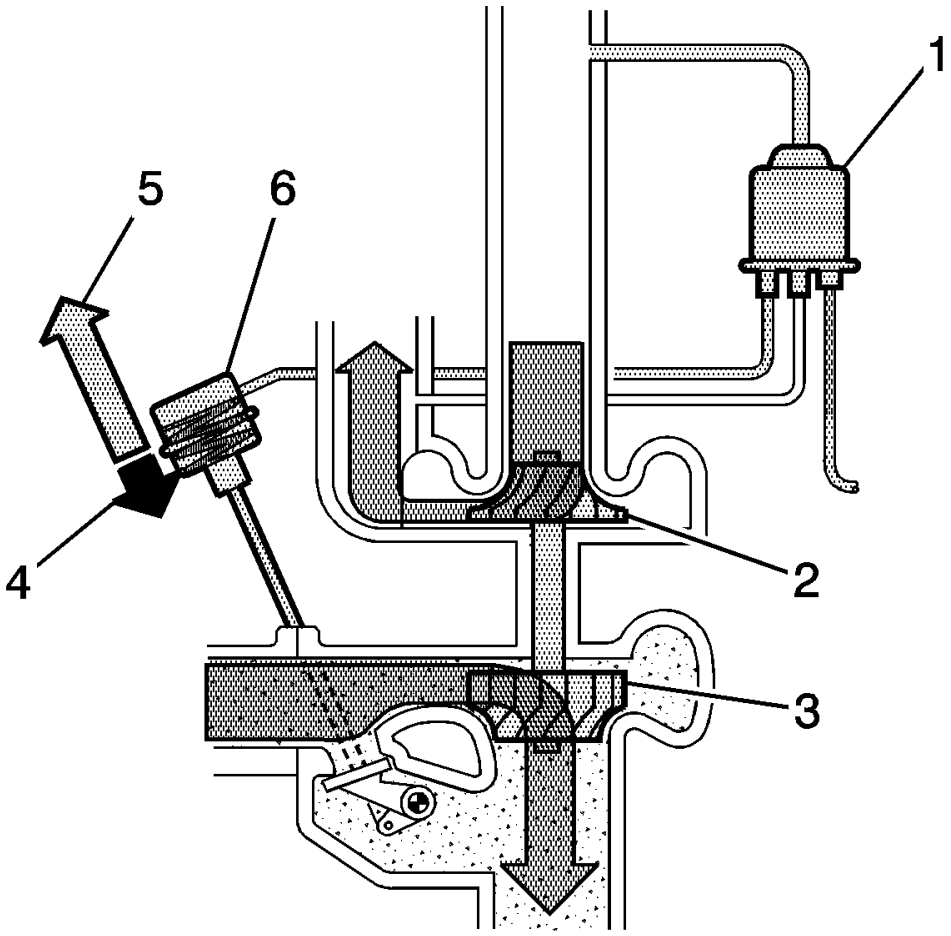


Fig. 240: TC Wastegate Closed
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name

1	Turbocharger Wastegate Solenoid with Duty Cycle at 100 percent
2	Compressor
3	Turbine
4	Exhaust Gas Pressure
5	Spring Force
6	Turbocharger Wastegate Actuator

The wastegate is completely closed at idle. All of the exhaust energy is passing through the turbine. There are three reasons that the wastegate remains closed:

- There is a lack of compressor outlet pressure. Lower compressor outlet pressures tend to close the wastegate via the pneumatic connection to the actuator.
- The return spring within the actuator is helping to keep the wastegate closed.
- The low energy of the exhaust gas flow is not enough to overcome the return spring force.

During normal operation, if a wide open throttle were to be requested at lower engine speeds, the ECM will command the boost control solenoid with a duty cycle of 100 percent to minimize any turbo lag. During engine loads in the middle and upper RPM ranges, the ECM will command the boost control solenoid, with a duty cycle of 65-80 percent. Manifold pressures of up to 240 kPa are possible.

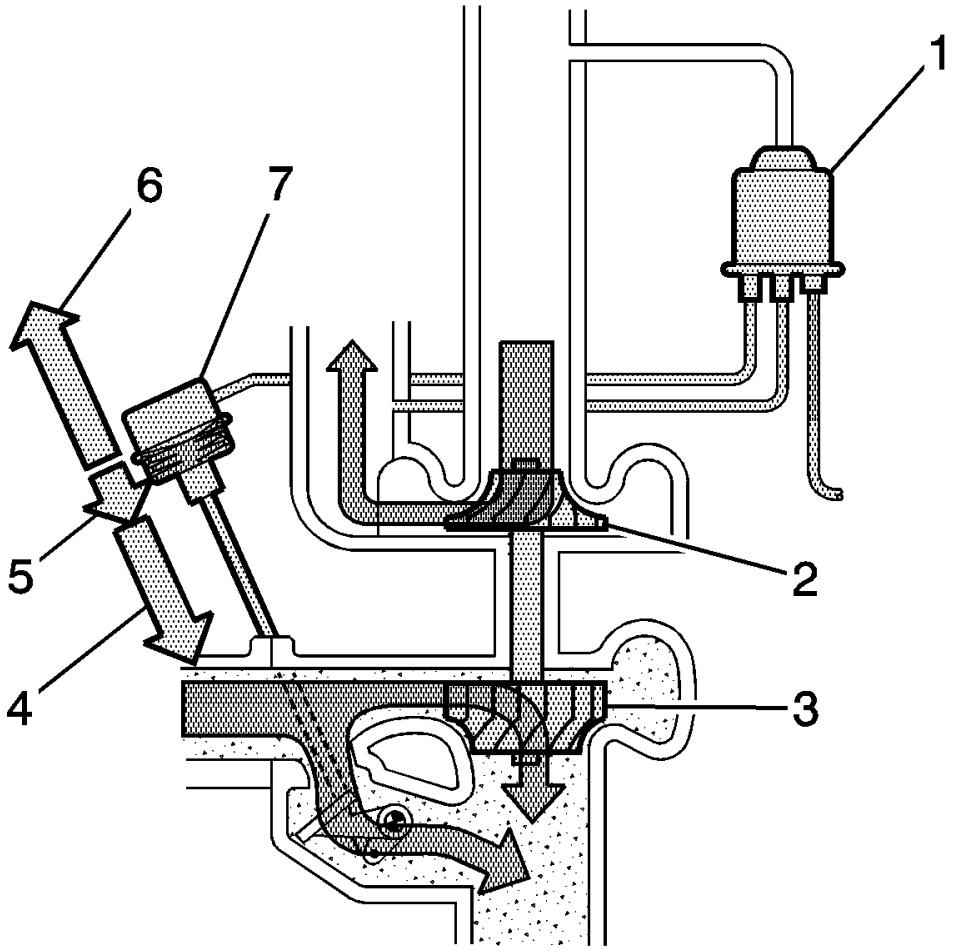


Fig. 241: TC Wastegate Open
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
1	Turbocharger Wastegate Solenoid with Duty Cycle at 0 percent
2	Compressor
3	Turbine
4	Regulating Pressure
5	Exhaust Gas Pressure
6	Spring Force
7	Turbocharger Wastegate Actuator

When certain DTCs are set the ECM will limit the amount of available boost

pressure. Limiting boost pressure is accomplished by the ECM controlling the TC wastegate solenoid and maintaining the duty cycle at 0 percent. This means that the ECM will not actively close the wastegate during greater engine loads. The system at this point is limited to mechanical boost. Mechanical boost means that the wastegate will still move, but the amount of motion is limited by the mechanical properties of the return spring within the actuator, the pneumatic properties of the actuator, and the physics of the exhaust gas flow in the exhaust system. In this mode of operation the manifold pressure will attain a maximum pressure of 140 kPa.

The TC wastegate actuator assembly has a threaded rod and nut that connects the diaphragm of the actuator to the wastegate. This rod is adjusted to BorgWarner™ factory specifications and is not adjustable.

THROTTLE ACTUATOR CONTROL (TAC) SYSTEM DESCRIPTION

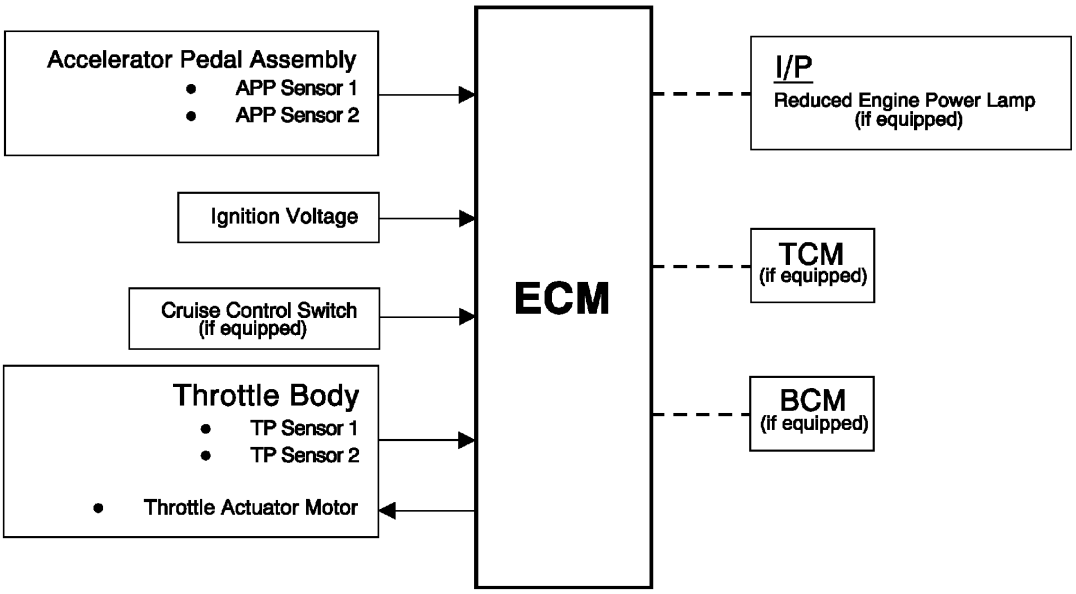


Fig. 242: Throttle Actuator Control (TAC) System Description
Courtesy of GENERAL MOTORS CORP.

The engine control module (ECM) is the control center for the throttle actuator control (TAC) system. The ECM determines the driver's intent based on input form the accelerator pedal position sensors, then calculates the appropriate throttle

response based on the throttle position sensors. The ECM achieves throttle positioning by providing a pulse width modulated voltage to the throttle actuator motor. The throttle blade is spring loaded in both directions, and the default position is slightly open.

Modes Of Operation

Normal Mode

During the operation of the TAC system, several modes, or functions, are considered normal. The following modes may be entered during normal operations:

- Minimum pedal value-At key-up, the ECM updates the learned minimum pedal value.
- Minimum throttle position values-At key-up, the ECM updates the learned minimum throttle position value. In order to learn the minimum throttle position value, the throttle blade is moved to the Closed position.
- Ice break mode-If the throttle blade is not able to reach a predetermined minimum throttle position, the ice break mode is entered. During the ice break mode, the ECM commands the maximum pulse width several times to the throttle actuator motor in the closing direction.
- Minimum pedal value-At key-up, the ECM updates the learned minimum pedal value.
- Battery saver mode-After a predetermined time without engine RPM, the ECM commands the battery saver mode. During the battery saver mode, the TAC module removes the voltage from the motor control circuits, which removes the current draw used to maintain the idle position and allows the throttle to return to the spring loaded default position.

Reduced Engine Power Mode

When the ECM detects a condition with the TAC system, the ECM may enter a reduced engine power mode. Reduced engine power may cause one or more of the following conditions:

- Acceleration limiting-The ECM will continue to use the accelerator pedal for throttle control, however, the vehicle acceleration is limited.
- Limited throttle mode-The ECM will continue to use the accelerator pedal for

throttle control, however, the maximum throttle opening is limited.

- Throttle default mode-The ECM will turn OFF the throttle actuator motor, and the throttle will return to the spring loaded default position.
- Forced idle mode-The ECM will perform the following actions:
  - Limit engine speed to idle positioning the throttle position, or by controlling the fuel and spark if the throttle is turned OFF.
  - Ignore the accelerator pedal input.
- Engine shutdown mode-The ECM will disable fuel and de-energize the throttle actuator.

KNOCK SENSOR (KS) SYSTEM DESCRIPTION

Purpose

The knock sensor (KS) system enables the control module to control the ignition timing for the best possible performance while protecting the engine from potentially damaging levels of detonation. The control module uses the KS system to test for abnormal engine noise that may indicate detonation, also known as spark knock.

Sensor Description

This KS system uses one or two flat response two-wire sensors. The sensor uses piezo-electric crystal technology that produces an AC voltage signal of varying amplitude and frequency based on the engine vibration or noise level. The amplitude and frequency are dependent upon the level of knock that the KS detects. The control module receives the KS signal through 2 isolated signal circuits.

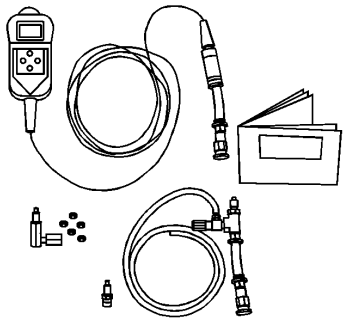
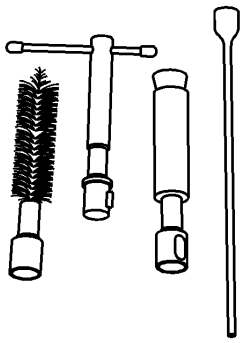
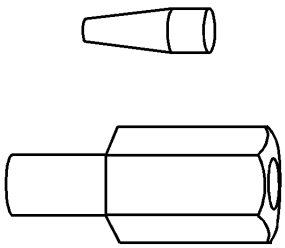
If the control module has determined that knock is present, it will retard the ignition timing to attempt to eliminate the knock. The control module is capable of controlling spark retard on an individual cylinder basis. The control module will always try to work back to a zero compensation level, or no spark retard. KS diagnostics are calibrated to detect faults with the KS circuitry inside the control module, the KS wiring, or the KS voltage output. Some diagnostics are also calibrated to detect constant noise from an outside influence such as a loose/damaged component or excessive engine mechanical noise.

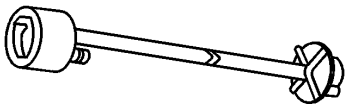
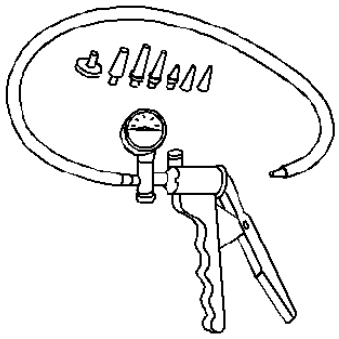
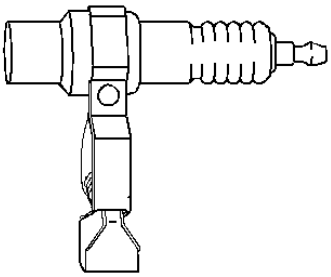
AIR INTAKE SYSTEM DESCRIPTION

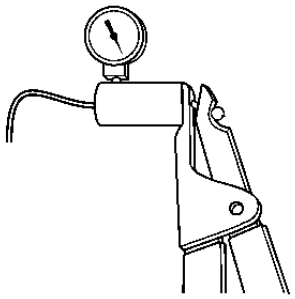
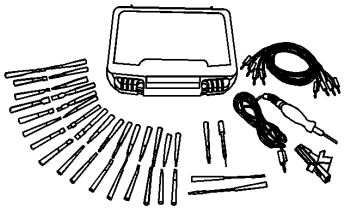
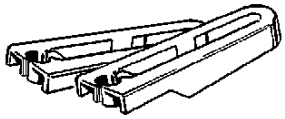
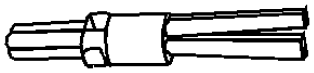
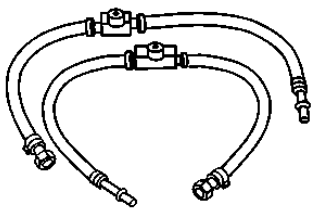
The primary function of the Air Intake System is to provide filtered air to the engine. The system uses a cleaner element mounted in a housing. The cleaner housing is remotely mounted and uses intake ducts to route the incoming air into the throttle body. The secondary function of the Air Intake System is to muffle air induction noise. This is achieved through the use of resonators attached to the air intake ducts. The resonators are tuned to the specific powertrain. The mass air flow (MAF)/intake air temperature (IAT) sensor is used to measure the temperature and the volume of the air entering the engine.

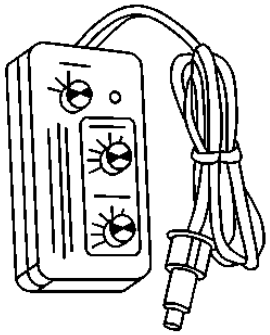
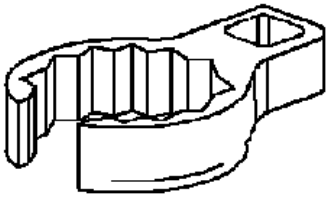
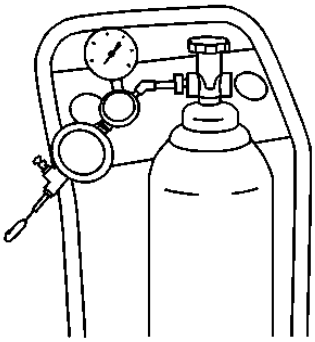
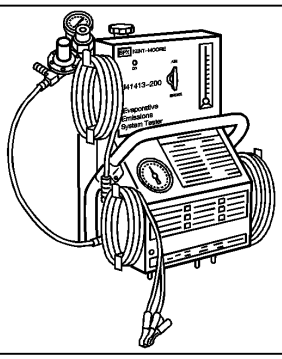
SPECIAL TOOLS AND EQUIPMENT

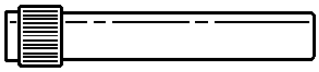
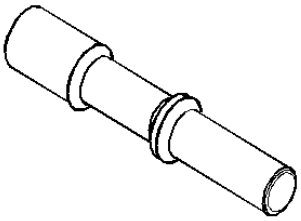
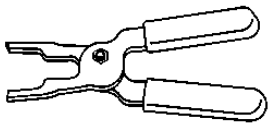
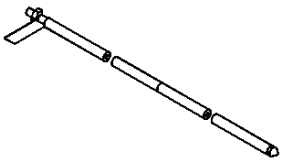
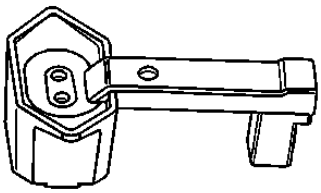
SPECIAL TOOLS

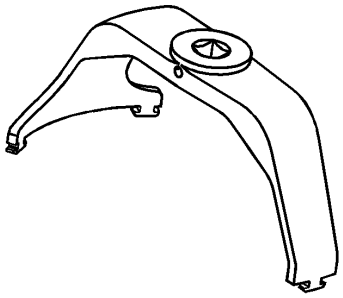
Illustration	Tool Number/ Description
	CH-48027 Digital Pressure Gage
	EN-47909 Injector Bore and Sleeve Cleaning Kit
	EN-48266 Injector Seal Installer and Sizer

	GE-41415-50 Fuel Tank Cap Adapter
	J-23738-A Mityac
	J-2619-01 Slide Hammer
	J-26792 HEI Spark Tester
	J-35555 Metal Mityvac

	
	J-35616 GM-Approved Terminal Test Kit
	J-37088-A Fuel Line Disconnect Tool Set
	J-37281-A Injector Remover
	J-37287 Fuel Line Shut-Off Adapter

	J-38522 Variable Signal Generator
	J-39194 Oxygen Sensor Wrench
	J-41413 EVAP Pressure and Purge Station
	J-41413-200 Evaporative Emissions System Tester (EEST)
	J-41413-VLV EVAP Service Port Vent Fitting

	
	J-42960-2 Fuel Flapper Door Holder
	J-43244 Relay Puller Pliers
	J-43290 Fuel Tank Siphoning Hose
	J-44175 Fuel Composition Tester

	J-45722 Fuel Sender Lock Ring Wrench

