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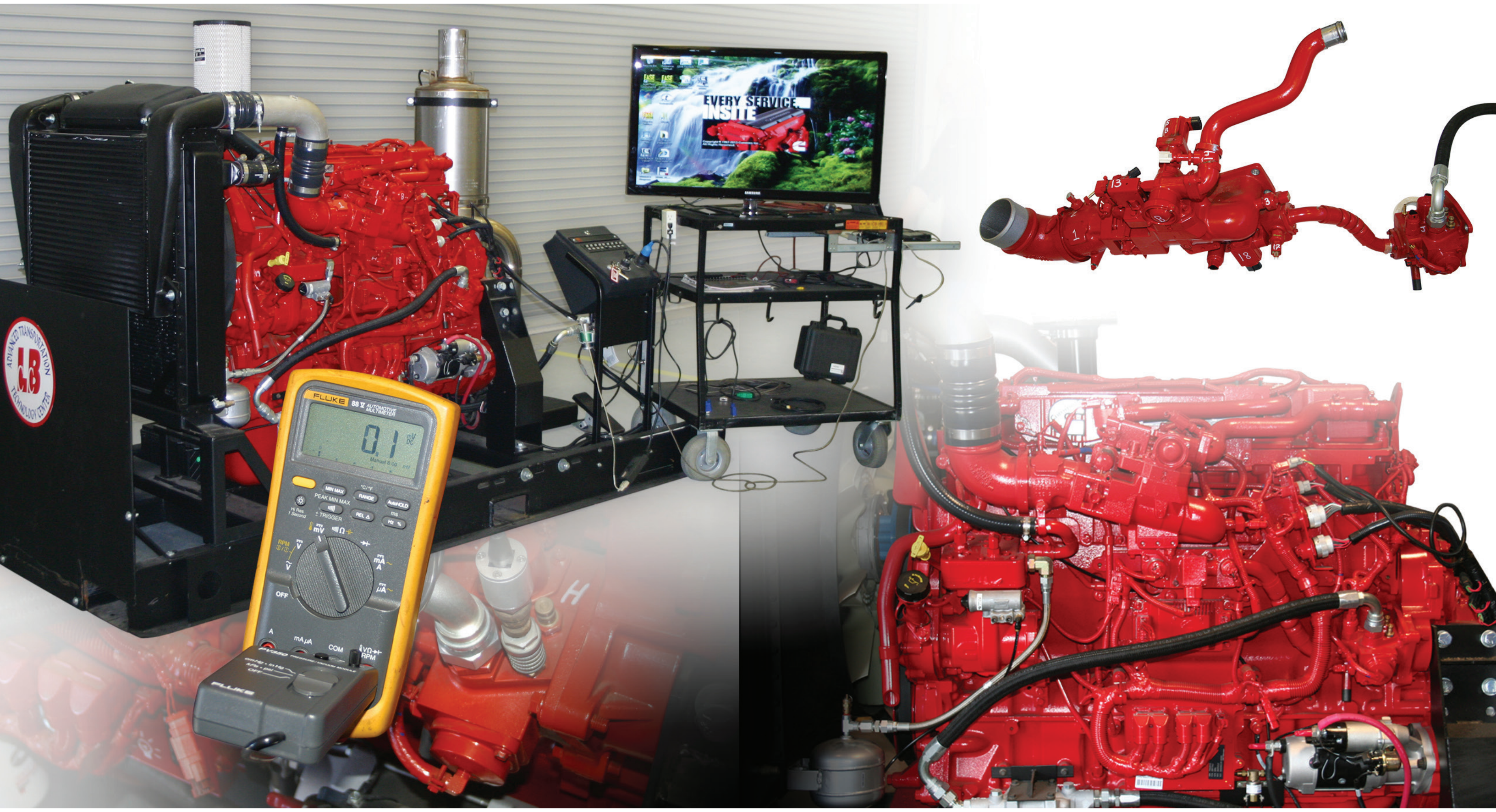

Cummins ISX12-G Fuel Systems Level Two

Technical Resource Guide

Doing what matters for jobs and the economy with funding provided by the California Energy Commission (senate bill AB118) through a partnership with the California Community Colleges, Office of Workforce Development, Advanced Transportation and Renewable Energy sector.

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COURSE INTRODUCTION

Course Title

ISX 12 G Level 2 Training

Course Length

16 hours

Description

This course is designed to give technicians the hands on skills needed to diagnose and repair the 11.9L Cummins ISX12G NG fuel system. This course covers sensors, actuators, pin-out voltage values and real world diagnostic applications using Cummins Electronic Service Tools. This course includes the discussion of:

Diagnose faults using INSITE™ for:

- Ignition Systems
- Temperature Sensors
- Pressure Sensors
- Position Sensors
- Voltage Producing Sensors
- Mass Gas & Air Flow Sensors

Diagnose common fuel system issues:

- Low Pressure Fuel Regulator Issues
- Fuel/EGR Mixer Issues
- Fuel System Contamination Issue

Course Benefits

Students receive a wealth of experience working on the system and understanding where everything is located and how it works. This class is a must for technicians involved with diagnosis and repair of natural gas engine management and fuel delivery systems. Students will learn the proper and safe methods of working with the high pressure CNG fuel systems as well as LNG cryogenic fuel using DVOMs and the laptop diagnostic software specific to the Cummins controllers.

Reference Material installed on technician-provided USB drive upon completion of levels I & II.

Prerequisites

This is a combination of the ISX12G Series. Familiarity with DVOM, Electrical I and engine fuel systems. The proper sequence is ISX12G Level 1, INSITE™, ISX12G Level 2.

Objectives

- Define Speed Density Fuel Management Systems
- Define Mass Air Flow Fuel Management Systems
- Identify and Examine the various systems
- Identify and test sensors and actuators with a DVOM
- Use INSITE™ to verify parameters

Competence

Competence will be measured by both lab demonstrations and class participation.

Course Introduction

Instructional Objectives

By the end of this course, the student will be able to:

Diagnose faults using INSITE™ for:

- Ignition Systems
- Temperature Sensors
- Pressure Sensors
- Position Sensors
- Voltage Producing Sensors
- Mass Gas & Air Flow Sensors

Diagnose common fuel system issues:

- Low Pressure Fuel Regulator Issues
- Fuel/EGR Mixer Issues
- Fuel System Contamination Issues

Important

The Material presented here is intended for instructional purposes only. Please be sure to follow manufacturer's latest bulletins and procedures as the ultimate source.

Agenda

- MSD Ignition
- INSITE™ Diagnostics
- Temperature Sensors
- Pressure Sensors
- Position Sensors
- Voltage Producing Sensors
- Mass Gas & Air Flow Sensors

Pretest

Cummins ISX 12-G Level II

1. A temperature sensor is a Thermistor Device.
   a. True b. False

2. What is the stoichiometric, A/F ratio for the Cummins ISX 12L running on CNG?
   a. 12.5:1 b. 14.7:1 c. 16.5:1 d. 18.5:1

3. What type of sensors are the crankshaft and camshaft sensors?
   a. Magnetic reluctance
   b. Hall Effect
   c. Thermistor Devices
   d. The Cummins ISX 12L does not need crankshaft and camshaft sensors

4. What is the purpose of the fuel shut-off valve?
   a. Control the fuel entering the Mixer
   b. Shut-off fuel to the engine if engine RPM is not present
   c. Takes the place of needing a shut-off valve at each cylinder
   d. Takes the place of needing a Manual Shut-Off valve

5. What is the relationship of the Camshaft to the Crankshaft?
   a. 1:1 b. 2:1 c. 3:1 d. 4:1

6. When should you reset the fuel tables in INSITE™?
   a. Only when you need to replace the ECM
   b. Every time you perform preventative maintenance
   c. Whenever any fuel system component is replaced
   d. This is a Cummins proprietary option

7. What is a Snap Throttle test used for?
   a. Check crank sensor operation
   b. Check for last O_2 Sensor
   c. Determine if the Accelerator pedal is working correctly
   d. Determine Catalytic Converter efficiency

8. Does the throttle actuator operate in the KOEO position?
   a. True b. False

9. Is the air-fuel mixture leaner or richer on cold startup?
   a. Leaner
   b. Richer

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- Catalyst Inlet Oxygen Sensors
- Catalyst Outlet Oxygen Sensor
- Combustion Knock Sensors 1 & 2
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- Snap-Throttle Test using INSITE™
- Activitity 2.8
- Mass Gas Sensor
- Mass Air Flow Sensor
- Activity 2.8b
- Pressure & Humidity Sensor
- Coolant Level Sensor
- Activity 2.

7. Diagnosing Actuators and Outputs

- Fuel Control Valve
- Wastegate Control Valve
- Throttle Actuator

Post Test

Natural Gas Safety Considerations

References

1 Module One

Instructional Objectives

In Level One, we discussed how the various systems worked and how to manually test them. Level Two will revisit these systems with an emphasis on diagnosis and repair. This advanced level will be lab dominant utilizing INSITE™ and advanced diagnostic strategies learned in the INSITE™ class.

ISX12G Ignition System

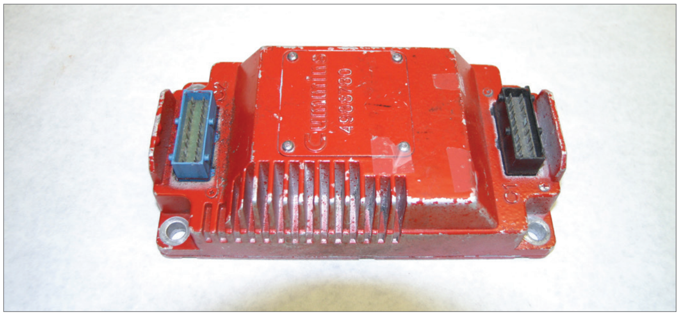
The capacitive discharge ignition stores electrons in a capacitor and shoots them off to ground through the primary of the coil. When the spark plug fires, the air around the spark plug is ionized and primed to ignite. As long as there is enough voltage stored in the capacitor and the Ignition Control Module (ICM) switch is closed, the spark plug will continue to fire until the capacitor dissipates or the circuit is broken. The additional closed switch time and stored voltage allows multiple sparks to occur as long as the switch is closed. As engine RPM increases, the possibility of multi-spark decreases as this switched-on time is shortened.

Multiple spark discharge can occur at all times on the ISX12G engines. It cannot be measured or seen with a meter. It is induced by increasing the on time spark signal from the ECM.

How Fast Does a Spark Plug Fire?

A spark plug works very hard to make the engine run. The ignition system is challenged to ignite the natural gas under very difficult circumstances, repeatedly with extreme speed. The amount of time needed for the coil to saturate and discharge has required the use of coil on plug designs. Using 600 rpm on these four stroke engines as an example, how many times would ONE coil fire per second? This would be near idle speed and doubles when cruising. At freeway speed, the coils must fire 4 times faster per second. Hint: The answer to the first question relies on four-stroke theory. Now imagine a six-cylinder engine with only one coil. It would have to fire 6 times for each four-stroke cycle, working 6 times as hard and fast. We drive thousands of miles with the coil working this hard under varying load conditions that are a challenge for the plug. When a misfire is isolated to a cylinder, the plug and coils are likely suspects that should be checked out carefully. Perform standard diagnostics by checking the resistance across the coils and inspecting the coils for cracks where sparks could arc to the engine block. When in doubt, change them out as the standard visual checks will not usually reveal issues.

Ignition Control Module



Ignition Control Module

The ICM contains a DC-to-DC converter and a separate coil driver for each spark plug. The DC-to-DC converter steps up the 12 volt battery supply voltage to 400 volts. This voltage can provide a dangerous jolt on the primary side of the coil that can cause bodily injury. It discharges when shut down but the capacitors can always provide a jolt if they become energized with the key ON.

This voltage charges the capacitor in each of the coil drivers. It is important to never disconnect the ICM harness with engine running or damage can occur.

The ICM has misfire detection and kV per cylinder tracking. kV detection is performed by watching the primary current drawn as the 400 volts is supplied to the coils as voltage is applied across spark plug gap. The spark current through the gap is then analyzed.

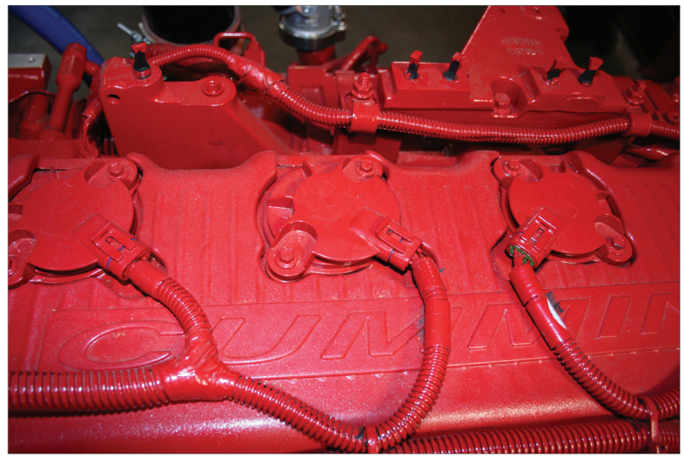
Misfire detection is performed through ion sensing of the positively charged electrons that have been disassociated from atoms during heat of combustion. Good combustion generates a current peak, misfire is indicated by low current, and a flat response or late combustion reduces and delays the current waveform. These inputs to the ECM are beneficial to diagnostics but if they malfunction, they will not usually affect engine operation.

Overheating of the Coil On Plug (COP) ignition coils is minimized by an increased primary voltage and filled coils. The higher voltage of 400v allows the current requirement to be reduced. which creates less heat.

Ignition System

The ignition system begins with the ECM sending ignition information to the ICM as it receives engine position and engine speed signals from the Camshaft and Crankshaft position sensors respectively. Then the ICM then sends the appropriate firing signals to the individual coils based upon the firing order in its memory. The ICM is both a processor and the ignition coil driver but remains dependent upon the ECM for its timing commands. It only knows the firing order.

The ECM will use the oxygen sensor information to adjust the fuel control valve and throttle plate actuator positions and provide the proper fuel delivery. This compensation deviation commanded by the ECM can be monitored using INSITE™. If the compensation deviation exceeds set limits, the system reverts to open loop operation.



Separate Coils for Each Cylinder

Coil On Plug Ignition

There is one coil per cylinder that is direct fired by the ICM. The coil can induce a total voltage to the plugs of 40 kV. The average spark is approximately 15 – 20 kV, depending upon engine load and conditions. This is the required voltage, which leaves a reserve voltage to accommodate changing engine conditions and component deterioration without a misfire.

ISX12G Ignition System

The ECM and ICM are located on the cold side of the engine with the Fuel Control Housing and Air Intake Manifold. The ECM and ICM on the ISX12 G is similar to ECMs and ICMs of previous Cummins Westport engines but they are not interchangeable. Failure to use an ICM with the correct part number for the engine will result in misfire faults and other intermittent behavior. Once load and speed are determined, the ECM commands the ICM to fire its capacitors through the grounded coils. This is different from most conventional systems as they ground the coils through the computer to charge them and break this ground to fire the plug.

Coil on Plug

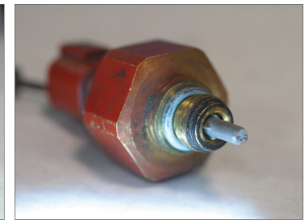
The primary resistance on the COP is measured between pins "A" and "B". This measurement should be approximately 3 Ohms.

The secondary winding measurement for the COP resistance is taken between the spark plug connection and either pins B or C of the four-pin connector.

Ignition Inputs to ECM Base Timing

The primary inputs to the ECM for spark timing are the Engine Position Sensor and the Manifold Absolute Pressure Sensor. The Manifold Absolute Pressure is the load-sensing element that the ECM uses to adjust the base timing and as an input for air mass calculation. This is equivalent to the vacuum advance systems in 1980 vintage vehicles. Because of the throttle plate, the manifold pressure before and after the throttle plate may be different due to

CAM Position Sensor



Manifold Pressure

turbocharger boost pressure. Intake Manifold vacuum leaks can reduce the reading and cause extra fueling to occur.

The Engine Camshaft Speed/Position Sensor measures the position of the engine camshaft by the use of a Hall-effects sensor and seven cast protrusions on the camshaft gear. Whenever the cam gear protrusions pass the Engine Camshaft Speed/Position Sensor, a signal is produced. These sensors produce a digital on-off signal that is used to determine engine position (#1 cylinder) and speed. The engine will not run without a tach signal but may run without a reference by the cam sensor. A Digital Storage Oscilloscope is needed to see these signals.

Ignition Inputs to ECM: Camshaft Gear

The Camshaft gear has protrusions that, when passed across the camshaft Hall-Effect sensor, send a signal to the ICM when to start the firing order. In turn, the Crankshaft sensor receives a signal from protrusions on the crankshaft for when to send commands to the respective coils to fire the spark plugs for each cylinder.

The ECM interprets the 7th signal input as the beginning of a new cycle in the firing order and generates a timing reference signal for the ICM to start the sequence over again. Any interruption of this signal can lead to the ECM starting over on the firing order causing driveability problems.

Radio Frequency Interference (RFI) and Electro-magnetic Field Interference (EFI) can cause havoc with the signal in the ECM so special protection is used. The protrusions can be damaged by prying on then or dropping during repair operations and must be avoided.

Ignition Inputs to ECM: Cam/Speed Sensor

Interruptions in the frequency of the signal would cause misfires and tach problems. If this sensor fails, you can have a no start condition and the lock-off solenoid may not open. These sensors can fail intermittently under certain conditions caused by connector resistance or winding shorts or opens that will usually show up with the heat of operation.

Combustion Knock Sensors 1&2

Knock Sensors sense engine detonation that occurs under load. Knock Sensor 1 monitors the front three cylinders and Knock Sensor 2 monitors the three rear cylinders. There are three levels of knock.

Light Knock is the lowest of the three thresholds. It is designed to guard against damage from light to mild knock. The ECM will retard ignition timing and slightly de-rate the throttle. A yellow lamp will illuminate to warn the operator that light knock has been detected. Heavy Knock warning will be activated if the light knock protection fails to eliminate the problem or a knock is detected that crosses the heavy knock threshold. The ECM will trigger a severe throttle de-rate and illuminate the red warning lamp. A Cold Knock threshold provides severe protection while the engine is reaching a stable operating temperature. Time at this threshold is a function of coolant temperature at startup. The cold knock threshold is disabled when the engine temperature reaches 160°F (71°C).

Knock Sensor #2

When testing sensors, use an ohmmeter and check for continuity. A frequency counting DVOM can also be used with the engine running providing a load can be created.

Detonation percentages can also be monitored with INSITE™ as it is hard to get it to react during an idle or stall test.

Paint on the bottom of the sensor or its mounting location (block or head) can cause a dampening of the signal. If Cummins paint is interfering, clean the areas and torque the bolt to proper spec.

ICM Outputs: Coil on Plug

External testing of the coil should be done carefully. The coil is oil filled, so they must be mounted 45 degrees to vertical if fired. If this is not done, coils will prematurely fail. Shorting or disconnecting coils to do a cylinder balance test is not recommended as the resulting misfire can damage the expensive Catalyst substrate. Swapping of coils or plugs from one cylinder to another can be time consuming but will confirm the misfire culprit if done. Swapping of connectors on the coils will cause misfires on the incorrectly driven coil.

When checking plugs, always check for cracks and wear to the electrodes. Natural Gas is a dry low-carbon gas that will not usually leave residue or wetness if fouled. It is difficult to determine a rich running engine by plug inspection alone. Coils can be easily damaged when removing and reinstalling. Install all coils and their brackets loosely before troqueing them down.

Multiple Spark Discharge

Coil and Boot Assembly

This engine incorporates multiple spark discharge at all times to fire the spark plug. The capacitor keeps discharging until the available voltage drops below required voltage far enough that the ionization trail is broken and the plug stops discharging. This is like Mallory ignition from the 1970s.

ICM Spark Voltage and Misfire Signals

Coils can be checked for output using several commercially available handheld testers or INSITE™. Disabling coils while the engine is running during a cylinder balance test can damage the catalyst so this ECM test is not available.

The ICM sends signals for spark plug voltages and misfires back to the ECM, which can be monitored in INSITE™. This is for diagnostic purposes only.

False reading for cylinder kV voltages are possible from time to time with no misfires; this is caused on the diagnostic side of the ICM. This has no effect on carrying out the basic ignition control as it is for diagnostic purposes only.

Coil Over Plug Ignition

The plugs in the 12L are single ground-electrode plugs, which are different than the 8.9L. Always use the Cummins replacement procedures when changing spark plugs to avoid Carbon tracking and premature spark plug failure. These procedures include the use of a 5/8 deep well magnetic socket to install plugs without a rubber insert. In addition, do not touch the spark plugs as fingerprints cause carbon tracking on the plug. If touched, clean plugs with denatured alcohol. Plugs should be torqued to the proper manufacturer specification to dissipate heat, which is critical to plug life.

Proper Installation is Critical

Coil On Plug Ignition Maintenance

It is imperative that the maintenance intervals are kept in regards to the ISX 12G per Cummins. These levels are based upon an average speed of 45 mph.

Coil Over Plug Ignition Testing

It is difficult to test the ignition system with an Ignition Scope due to the multiple coils. Firing of coils without proper grounding can damage a coil. INSITE™ shows ignition spark voltages and misfires but won't test a coil to prevent catalyst damage. In order to check ignition coil operation, a coil tester is recommended. The Cummins ignition coil tester part number is #3164486.

ICM Module Check

This is the Cummins procedure to check the ICM module for any shorts in the harness and confirm that the module is functioning properly. Before disconnecting this module, make sure that the ignition is OFF or damage can occur to the ECM and/or ICM modules.

Cummins Engine Wiring Harness

After checking that the Original Equipment Manufacturer (OEM) connector was providing proper power and ground, a DVOM would be used to check continuity of the wiring harness between the ECM and the ICM.

To remove this harness from its support brackets and the ECM, it is necessary to remove the connectors from several components first per Cummins test procedures. Then continuity checks can be made with a DVOM.

Cummins Engine Wiring Harness Inspection

Refer to the engine manufacturer's repair manual when servicing and troubleshooting the wiring harness. The torque on the ECM harness is very low. (27 in-lbs.)

If the harness is faulty or there is an open or shorted circuit, either repair or replace the harness. INSITE™ has an ECM diagnostic test that includes a "wiggle test" to check for intermittent connections.

Cummins Engine Wiring Harness Servicing

The ICM cannot always be removed without first disconnecting the ECM wiring. Using a DVOM to test whether the ICM harness can be done without removing the ICM. When reinstalling, make sure that the latches are in place to secure all plugs to the ECM module so that vibration does not loosen any connections.

ICM Module Check

Cummins outlines procedures for diagnosing shorts and open circuits in the wiring harness between the ICM and the ignition coils. This is a top down process where you first check the resistance between plugs to confirm continuity. The next step is to confirm that there are no shorts in the wiring. After confirming there are no short circuits, you are to attach the harness to the ICM and confirm continuity and that no shorts occur when harness is connected to the ICM.

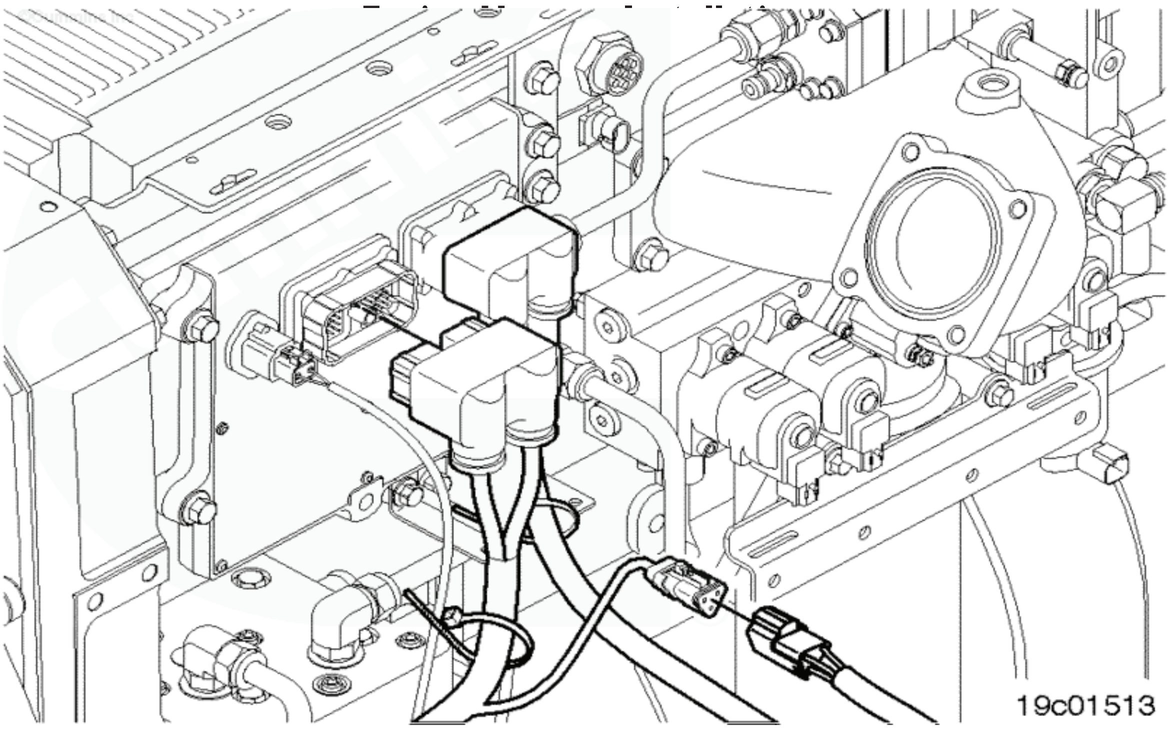
Activity 2.1:
Ignition System Harness

Tools required:

1.	Inch-pound torque wrench (only if removing ICM)	2. Sockets
3.	Pocket screwdriver	4. DVOM
5.	Spark tester	6. Jumper wire
6.	Insulated Needle-nose Pliers	

OEM Wiring Harness

The original equipment manufacturer (OEM) harness is supplied and installed by the vehicle manufacturer. Follow the vehicle manufacturer's procedures, if replacement is necessary. Refer to the vehicle manufacturer's troubleshooting and repair manual.



1. Connect the engine harness to the ECM.
2. Torque Value: 3 Nm [27 in-lb]
3. Install the harness clamps that hold the engine harness to the block.
4. Connect the sensors and switches to the engine harness.
5. Connect the battery cables.

ICM Wiring Harness

(Removal)

1. Unlatch the connectors by using a small screwdriver to open the connector.
2. Slide the latch fully to remove the connector from the ICM.
3. Remove the four cap screws and ICM.

Tech Tip: In some applications, the ICM cannot be removed without first disconnecting the ECM wiring.

Installation after Inspection

1. Install the new ICM and the four cap screws.
2. Torque Value: 24 Nm [212 in-lb]
3. Connect the two (or three) harness connectors.
4. Slide the connector lock until a click sound is heard and the slide face is flush with the connector.

ICM Harness Inspection

NOTE: NEVER disconnect a module with the ignition in the ON position or it can damage the computer.

Check the ICM outputs.

1. Turn the key switch to the OFF position and remove the key from the ignition.
2. Disconnect the harness from ignition coil #6 and momentarily ground terminal “C” for 30 seconds to dissipate the Capacitor.
3. Disconnect the ignition coil harness connector from the ICM.
4. Measure the resistance between the chassis ground pins on the ICM(pins #7 & #15 and block ground.
   What is this Resistance? ____________________ Ohms

Note: In order to proceed, this resistance must be 10 ohms or less.

5. Measure the resistance on the ICM output for each coil and block ground.
   What is this Resistance? ____________________ Ohms (should be INFINITE)
6. Disconnect all coils from the harness to isolate the harness for testing.
7. Notice that all coil pins are wired in parallel for both A and C and share a common pin for each at the ICM connector. Using the supplied Cummins documentation, what are the harness pin numbers and what is the wiring harness resistance to each coil plug, for coil pins A, B, & C (with coils disconnected)?

Note: Check resistance from ICM harness connector to each coil plug.

ICM Pin# ______ Coil Pin A _______Ohms
ICM Pin# ______ Coil (1) Pin B_____ Ohms
ICM Pin# ______ Coil (2) Pin B_____ Ohms
ICM Pin# ______ Coil (3) Pin B_____ Ohms
ICM Pin# ______ Coil (4) Pin B_____ Ohms
ICM Pin# ______ Coil (5) Pin B_____ Ohms
ICM Pin# ______ Coil (6) Pin B_____ Ohms
ICM Pin# ______ Coil Pin C_______ Ohms

Note: The resistance must be 10 ohms or less. If the resistance is incorrect, repair or replace the wiring harness.

8. To check for shorted connectors or wiring, measure the resistance of each pin on the ignition coil end of harness to ground.

Coil Pin A ________Ohms
Coil (1) Pin B______ Ohms Coil (2) Pin B_____ Ohms
Coil (3) Pin B______ Ohms Coil (4) Pin B_____ Ohms
Coil (5) Pin B______ Ohms Coil (6) Pin B_____ Ohms
Coil Pin C_________ Ohms

Note: The resistance must be infinite. If the resistance is incorrect, repair or replace the wiring harness

9. To check the ICM for an internal short, reconnect the harness and check resistance to ground.

Coil Pin A _______Ohms
Coil (1) Pin B_____ Ohms Coil (2) Pin B_____ Ohms
Coil (3) Pin B_____ Ohms Coil (4) Pin B_____ Ohms
Coil (5) Pin B_____ Ohms Coil (6) Pin B_____ Ohms
Coil Pin C_______ Ohms

Note: The resistance must show an open circuit (100k ohms or more).
If the circuit is not open there is an internal short in the ICM. Replace the ICM.

10. Are there any internal shorts? (Y / N) ___________________

Checking ICM Outputs

11. Reconnect all connectors to both coil packs and the ICM module correctly.
12. By back probing, measure the voltages on Pin A, B, & C to ground of a coil pack with key in the following positions;

KOEO Pin A: _____________ Volts Pin B: ____________ Volts Pin C: ___________ Volts
KOER Pin A: _____________ Volts Pin B: ____________ Volts Pin C: ___________ Volts

13. Which pin is the control signal from the ICM to the coil? _________________

(Optional) Instructor led demo on spark tester(s)

2

Module Two

Diagnosing Temperature Sensors

Diagnosis Utilizing INSITE™

When engine faults occur due to failed sensor/components, the ECM will attempt to keep the engine running as Engine Limp-in Mode to get the vehicle back to home base. In this mode, the ECM will either assign default values or substitute another sensor's values to keep the engine running. The failing sensor and the current engine mode will determine which method the ECM will use to attempt limp-in. When a sensor fails, the engine protection is lost through that sensor as the ECM no longer has reliable data from this failed sensor.

The ECM uses the 90/10 concept to determine whether or not a sensor is providing good data to the ECM. This concept states that if the signal voltage is within 10% and 90% of the reference voltage (5V), the ECM believes that the data is correct. If that data is less than 10% or greater than 90% of the reference voltage, the ECM considers the data to be unacceptable and out of range, which sets a fault. The 90/10 is a concept to understand what determines if a sensor is providing accurate data. It may fluctuate in actual minimum and maximum percentages depending upon the system component design.

There are three de-rate methods available that provide engine protection when faults are set.

They are Torque, RPM, and/or Shutdown Methods. Depending on the fault, INSITE™ may incorporate multiple methods sequentially if the fault continues to provide engine protection. An example of this would be an engine fault for low oil pressure.

The de-rate thresholds can be found in INSITE™ under the Advanced ECM Data section. They include time delays effect on the engine and light functions for each de-rate method.

There are 6 different voltage supplies and each has its assignments. Sources from 5-15v are assigned to these supply circuits with the Gas Mass Meter requiring 15V to operate. If multiple faults are noted in INSITE™, it may be due to sensors powered by the same Sensor Voltage Supply Line from the ECM. If this is the case, the problem may be due to wiring harness problems for the group of sensors either on the common voltage supply side or through the common return.

Inputs

The types of sensors that are on this engine are:

- Temperature
- Pressure
- Position
- Voltage Producing
- Mass Gas
- Mass Air Flow
- Switches & Misc. Signals

There are 8 temperature sensors to help maintain a Stoichiometric air/fuel ratio:

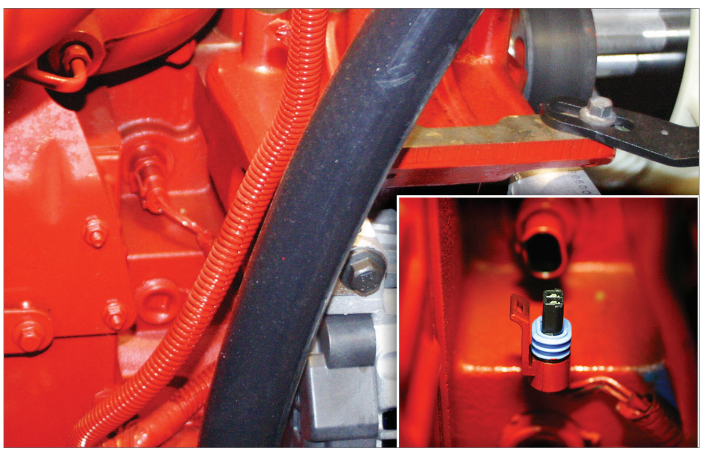
- Engine Coolant Temp Sensor
- Intake Manifold Temp Sensor
- Compressor Inlet Humidity/Temp Sensor
- Turbine Inlet Temp Sensor
- EGR Temp Sensor
- Fuel Outlet Pressure/Temp Sensor
- Catalyst Temp Sensor
- Mass Air Flow Temp Sensor

Temperature sensors of either the pyrometer or thermistor type are tested similarly.

Engine Coolant Temperature Sensor

The Engine coolant temperature sensor, a two wire sensor has signal and return. Temperature sensors are thermistor devices and change resistance with temperature changes. When testing temperature sensors and comparing their corresponding temperature with known good values, the temperature should be accurate within 5° of its base temperature or the sensor is not calibrated correctly.

If engine temperature rises over 217°, the ECM will set a torque de-rate. If the temperature rises to 233.6°, the ECM will shut down the engine.

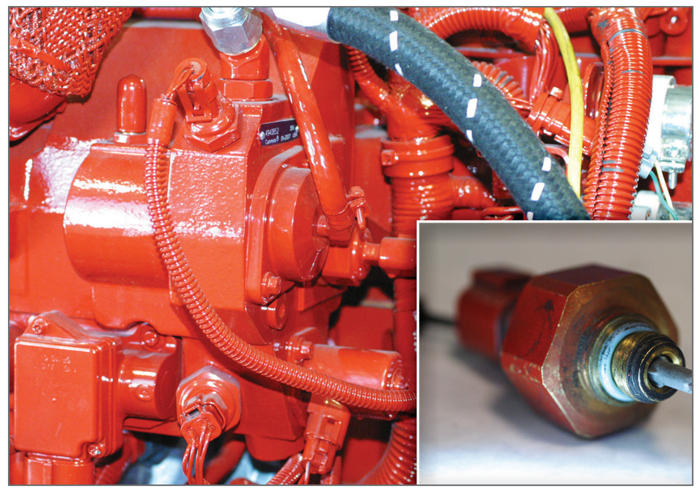


Engine Coolant Temperature Sensor Provides Choke Circuit

Intake Manifold Pressure/Temp Sensor

The combination Intake Manifold Pressure/ Temperature Sensor will torque de-rate the engine at 152.6 °F with a 5-second delay and shutdown at 192.2 °F with a 50-second delay.

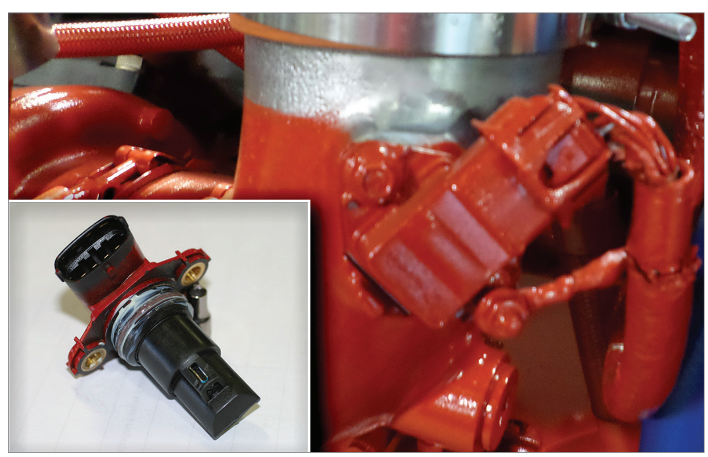
It will use both amber and then flashing red warnings. The Sensor has a four-wire plug in which the return is common for both the pressure and temperature sensors. When checking voltage drop for the temperature sensor, measure the temperature signal on pin 4 and the signal return on pin 2. The Pressure signal should be measured on pin 3 and the common signal on pin 2.



Manifold Pressure

Compressor Inlet Temperature, Pressure & Humidity Sensor

The Compressor Inlet, Temperature, Pressure & Humidity Sensor is a smart sensor that is connected to the CAN network. When testing this sensor, it is necessary to use INSITE™ to monitor the parameters.



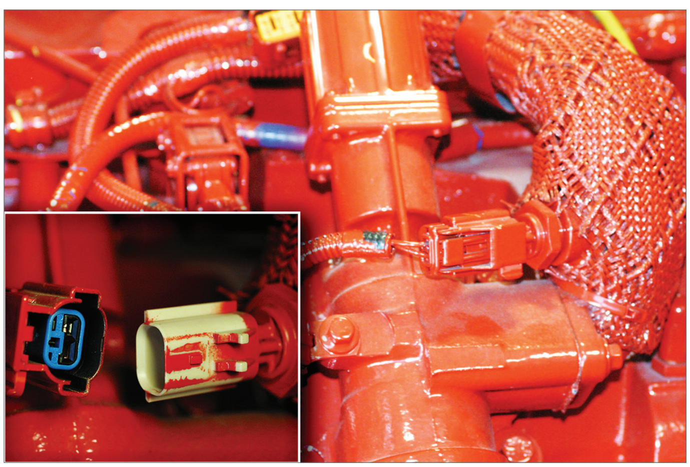
Humidity Sensor

EGR Temperature Sensor

The EGR Temperature Sensor is a thermistor that provides a torque de-rate at 266 °F and shut down at 284 °F with a red flashing lamp. This temperature sensor and the Delta Pressure Sensor, provide information for the EGR to keep EGR flow to a maximum of 30%.

If the EGR cooler is replaced, make sure that the cooling system is purged of air pockets.

Refer to TSB 110056 for the procedures on refilling coolant and bleeding system. When refilling cooling system, always fill until coolant comes out at bleeder fitting on top of the EGR cooler and/or hose to recovery tank at top of radiator. Run engine with radiator cap off and heater turned on for 10-20 minutes, depending on vehicle, to make sure cooling system is free of air pockets.

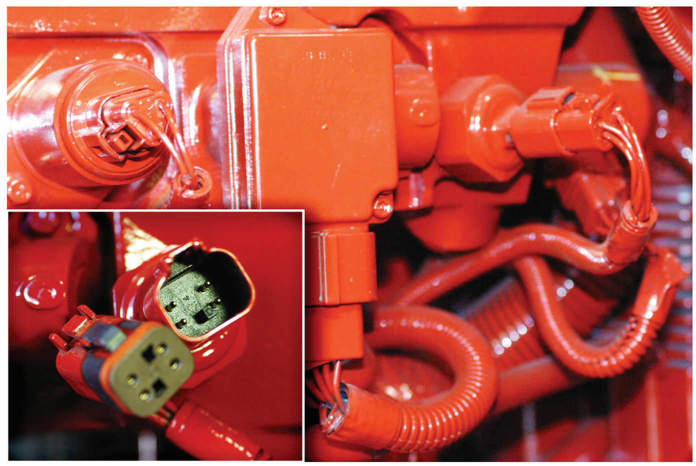


EGR Temperature Sensor

Fuel Outlet Pressure/Temp Sensor

The Fuel Outlet Pressure/Temp Sensor is before the Fuel Control Valve and just after the secondary regulator. This sensor has a common return with other sensors and can set multiple faults if the return has problems.

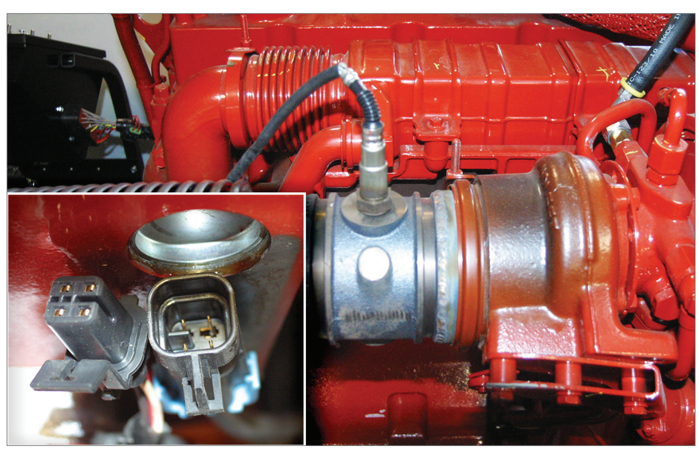
Always reset, fuel tables in INSITE™ whenever replacing any fuel system component.



Fuel Outlet Pressure/Temp Sensor

Catalyst Temperature Sensor

The Catalyst temperature is apyrometer. The ECM will provide a torque de-rate if the catalyst temperature exceeds 1247° and a RPM de-rate if the temperature exceeds 1337°.



Catalyst Temperature Sensor

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Activity 2.2:

Engine Coolant Temperature Sensor

Tools and equipment:

1. Classroom handouts   2. INSITE™

Step 1:

Using your classroom materials locate the ECT wiring diagram.

ECT – Temperature signal wire terminal __________

Sensor return wire terminal __________

Step 2:

Connect INSITE™.

CLEAR all inactive fault codes.

Start engine and view the Temperature Sensor parameters.

A. Record the Parameters with the sensor harness **connected**.

Temp ________ Volts _________ Are these default values? Yes/No

B. Record the Parameters with the sensor harness **disconnected**.

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code ________ Lamp color _________ PID/SID ________

C. Record the Parameter with the sensor signal/return **shorted.**

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status _______ Fault Code ________ Lamp color ________ PID/SID ________

STOP DO NOT GO ANY FURTHER

Step 3

Go to the classroom and look up the fault codes for steps B & C on the classroom computers using INSITE™. Answer the following questions for B & C below.

Referring to B. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ____

RED ____

When does the ECM reset the inactive fault codes? ______________

Is there any engine protection or de-rating available? ____________

Referring to C. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ____

RED ____

When does the ECM reset the inactive fault codes? ______________

Is there any engine protection or de-rating available? ____________

Are the fault codes numbered sequentially? ____________________

Are there other Fault Codes for this sensor? ___________________

Is so, which Fault Codes? ___________________________________

EGR Temperature Sensor

Tools and equipment:

1. Classroom handouts 2. INSITE™

Step 1:

Using your classroom materials locate the EGRT wiring diagram.

EGRT – Temperature signal wire terminal __________

Sensor return wire terminal __________

Step 2:

Connect INSITE™.

CLEAR all inactive fault codes.

Start engine and view the Temperature Sensor parameters.

A. Record the Parameters with the sensor harness **connected**.

Temp ________ Volts _________ Are these default values? Yes/No

B. Record the Parameters with the sensor harness **disconnected**.

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code________ Lamp color ________ PID/SID _______

C. Record the Parameter with the sensor signal/return **shorted** .

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code _______ Lamp color __________ PID/SID _________

STOP DO NOT GO ANY FURTHER

Step 3

Go to the classroom and look up the fault codes for steps B & C on the classroom computers using INSITE™. Answer the following questions for B & C below.

Referring to B. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Referring to C. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Are the fault codes numbered sequentially? ______________________________

Are there other Fault Codes for this sensor? ______________________________

Is so, which Fault Codes? ______________________________

Catalyst Outlet Temperature Sensor

Tools and equipment:

1. Classroom handouts 2. INSITE™

Step 1:

Using your classroom materials locate the CAT TEMP wiring diagram.

CAT TEMP – 5-volt supply wire terminal __________

Sensor return wire terminal __________

Step 2:

Connect INSITE™.

CLEAR all inactive fault codes.

Start engine and view the Temperature Sensor parameters.

A. Record the Parameters with the sensor harness **connected**.

Temp ________ Volts _________ Are these default values? Yes/No

B. Record the Parameters with the sensor harness **disconnected**.

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code________ Lamp color ________ PID/SID _______

C. Record the Parameter with the sensor signal/return **shorted**.

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code _______ Lamp color __________ PID/SID _________

STOP DO NOT GO ANY FURTHER

Step 3

Go to the classroom and look up the fault codes for steps B & C on the classroom computers using INSITE™. Answer the following questions for B & C below.

Referring to B. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Referring to C. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Are the fault codes numbered sequentially? ______________________________

Are there other Fault Codes for this sensor? ______________________________

Is so, which Fault Codes? ______________________________

Turbine Intake Temperature Sensor

Tools and equipment:

1. Classroom handouts 2. INSITE™

Step 1:

Using your classroom materials locate the Turbine Inlet Temp Senor wiring diagram.

Turbine Inlet Temp sensor – 5-volt supply wire terminal __________

Sensor return wire terminal __________

Step 2:

Connect INSITE™.

CLEAR all inactive fault codes.

Start engine and view the Temperature Sensor parameters.

A. Record the Parameters with the sensor harness **connected.**

Temp ________ Volts _________ Are these default values? Yes/No

B. Record the Parameters with the sensor harness **disconnected.**

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code________ Lamp color ________ PID/SID _______

C. Record the Parameter with the sensor signal/return **shorted.**

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code _______ Lamp color __________ PID/SID _________

STOP DO NOT GO ANY FURTHER

Step 3

Go to the classroom and look up the fault codes for steps B & C on the classroom computers using INSITE™. Answer the following questions for B & C below.

Referring to B. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Referring to C. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Are the fault codes numbered sequentially? ______________________________

Are there other Fault Codes for this sensor? ______________________________

Is so, which Fault Codes? ______________________________

Intake Manifold (Air) Temperature Sensor

Tools and equipment:

1. Classroom handouts 2. INSITE™

Step 1:

Locate the IMT sensor

IMT –5-volt supply wire terminal __________

Sensor signal wire terminal __________

Sensor return wire terminal __________

Step 2:

Connect INSITE™.

CLEAR all inactive fault codes.

Start engine and view the Temperature Sensor parameters.

A. Record the Parameters with the sensor harness **connected**.

Temp ________ Volts _________ Are these default values? Yes/No

B. Record the Parameters with the sensor harness **disconnected**.

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code________ Lamp color ________ PID/SID _______

C. Record the Parameter with the sensor signal/return **shorted**.

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code _______ Lamp color __________ PID/SID __________

STOP DO NOT GO ANY FURTHER

Step 3

Go to the classroom and look up the fault codes for steps B & C on the classroom computers using INSITE™. Answer the following questions for B & C below.

Referring to B. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ____________________________________

RED ______________________________________

When does the ECM reset the inactive fault codes? ______________________

Is there any engine protection or de-rating available? ______________________

Referring to C. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ____________________________________

RED ______________________________________

When does the ECM reset the inactive fault codes? ______________________

Is there any engine protection or de-rating available? ______________________

Are the fault codes numbered sequentially? ________________________

Are there other Fault Codes for this sensor? ________________________

Is so, which Fault Codes? _______________________________

Oil Temperature Sensor

Tools and equipment:

1. Classroom handouts 2. INSITE™

Step 1:

Locate the IMT sensor

IMT –5-volt supply wire terminal __________

Sensor signal wire terminal __________

Sensor return wire terminal __________

Step 2: Default Values

Connect INSITE™.

CLEAR all inactive fault codes.

Start engine and view the Temperature Sensor parameters.

A. Record the Parameters with the sensor harness **connected.**

Temp ________ Volts _________ Are these default values? Yes/No

B. Record the Parameters with the sensor harness **disconnected.**

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code________ Lamp color ________ PID/SID _______

C. Record the Parameter with the sensor signal/return **shorted.**

Temp ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code _______ Lamp color __________ PID/SID __________

STOP DO NOT GO ANY FURTHER

Step 3

Go to the classroom and look up the fault codes for steps B & C on the classroom computers using INSITE™. Answer the following questions for B & C below.

Referring to B. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Referring to C. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Are the fault codes numbered sequentially? ______________________________

Are there other Fault Codes for this sensor? ______________________________

Is so, which Fault Codes? ______________________________

Module Activity 2.2.5:
Cummins ISL-G Pressure Sensors

Oil Pressure Sensor

Tools and equipment:

1. Classroom handouts
2. INSITE™

Step 1:

Using your classroom materials locate the pressure sensor on the wiring diagram.

5 Volt Supply_____________

Pressure signal wire terminal _________

Sensor return wire terminal _________

Step 2:

Connect INSITE™.

CLEAR all inactive fault codes.

Start engine and View the Pressure Sensor parameters.

A. Record the Parameters with the sensor harness **connected** .

Pressure ________ Volts _________ Are these default values? Yes/No

B. Record the Parameters with the sensor harness **disconnected**.

Pressure ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code________ Lamp color ________ PID/SID _______

C. Record the Parameter with the sensor signal/return **shorted.**

Pressure ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code _______ Lamp color __________ PID/SID __________

STOP DO NOT GO ANY FURTHER

Step 3

Go to the classroom and look up the fault codes for steps B & C on the classroom computers using INSITE™. Answer the following questions for B & C below.

Referring to B. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Referring to C. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Are the fault codes numbered sequentially? ______________________________

Are there other Fault Codes for this sensor? ______________________________

Is so, which Fault Codes? ______________________________

EGR Delta Pressure Sensor

Tools and equipment:

1. Classroom handouts
2. INSITE™

Step 1:

Using your classroom materials locate the pressure sensor on the wiring diagram.

5 Volt Supply______________
Pressure signal wire terminal __________
Sensor return wire terminal __________

Step 2:

Connect INSITE™.

CLEAR all inactive fault codes.

Start engine and view the Pressure Sensor parameters.

A. Record the Parameters with the sensor harness **connected** .

Pressure ________ Volts _________ Are these default values? Yes/No

B. Record the Parameters with the sensor harness **disconnected.**

Pressure ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code________ Lamp color ________ PID/SID _______

C. Record the Parameter with the sensor signal/return **shorted** .

Pressure ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code _______ Lamp color __________ PID/SID __________

STOP DO NOT GO ANY FURTHER

Step 3

Go to the classroom and look up the fault codes for steps B & C on the classroom computers using INSITE™. Answer the following questions for B & C below.

Referring to B. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Referring to C. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Are the fault codes numbered sequentially? ______________________________

Are there other Fault Codes for this sensor? ______________________________

Is so, which Fault Codes? ______________________________

Manifold Pressure Sensor

Tools and equipment:

1. Classroom handouts
2. INSITE™

Step 1:

Using your classroom materials locate the pressure sensor on the wiring diagram.

5 Volt Supply______________
Pressure signal wire terminal __________
Sensor return wire terminal __________

Step 2:

Connect INSITE™.

CLEAR all inactive fault codes.

Start engine and view the Pressure Sensor parameters.

A. Record the Parameters with the sensor harness **connected.**

Pressure ________ Volts _________ Are these default values? Yes/No

B. Record the Parameters with the sensor harness **disconnected**.

Pressure ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code________ Lamp color ________ PID/SID _______

C. Record the Parameter with the sensor signal/return **shorted**.

Pressure ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code _______ Lamp color __________ PID/SID __________

STOP DO NOT GO ANY FURTHER

Step 3

Go to the classroom and look up the fault codes for steps B & C on the classroom computers using INSITE™. Answer the following questions for B & C below.

Referring to B. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Referring to C. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Are the fault codes numbered sequentially? ______________________________

Are there other Fault Codes for this sensor? ______________________________

Is so, which Fault Codes? ______________________________

Crankcase Pressure Sensor

Tools and equipment:

1. Classroom handouts
2. INSITE™

Step 1:

Using your classroom materials locate the pressure sensor on the wiring diagram.

5 Volt Supply______________
Pressure signal wire terminal __________
Sensor return wire terminal __________

Step 2:

Connect INSITE™.

CLEAR all inactive fault codes.

Start engine and view the Pressure Sensor parameters.

A. Record the Parameters with the sensor harness **connected.**

Pressure ________ Volts _________ Are these default values? Yes/No

B. Record the Parameters with the sensor harness **disconnected.**

Pressure ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code________ Lamp color ________ PID/SID _______

C. Record the Parameter with the sensor signal/return **shorted.**

Pressure ________ Volts _________ Are these default values? Yes/No

View Fault codes and record the Fault Code information.

MIL light status ________ Fault Code _______ Lamp color __________ PID/SID __________

STOP DO NOT GO ANY FURTHER

Step 3

Go to the classroom and look up the fault codes for steps B & C on the classroom computers using INSITE™. Answer the following questions for B & C below.

Referring to B. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Referring to C. What conditions must be present to run the diagnostics and set this code?

____

How do you validate the repair? ______________________________

What conditions must be present for the ECM to turn off the check engine/MIL light?

AMBER ______________________________

RED ______________________________

When does the ECM reset the inactive fault codes? ______________________________

Is there any engine protection or de-rating available? ______________________________

Are the fault codes numbered sequentially? ______________________________

Are there other Fault Codes for this sensor? ______________________________

Is so, which Fault Codes? ______________________________

ISX12-G Electronics

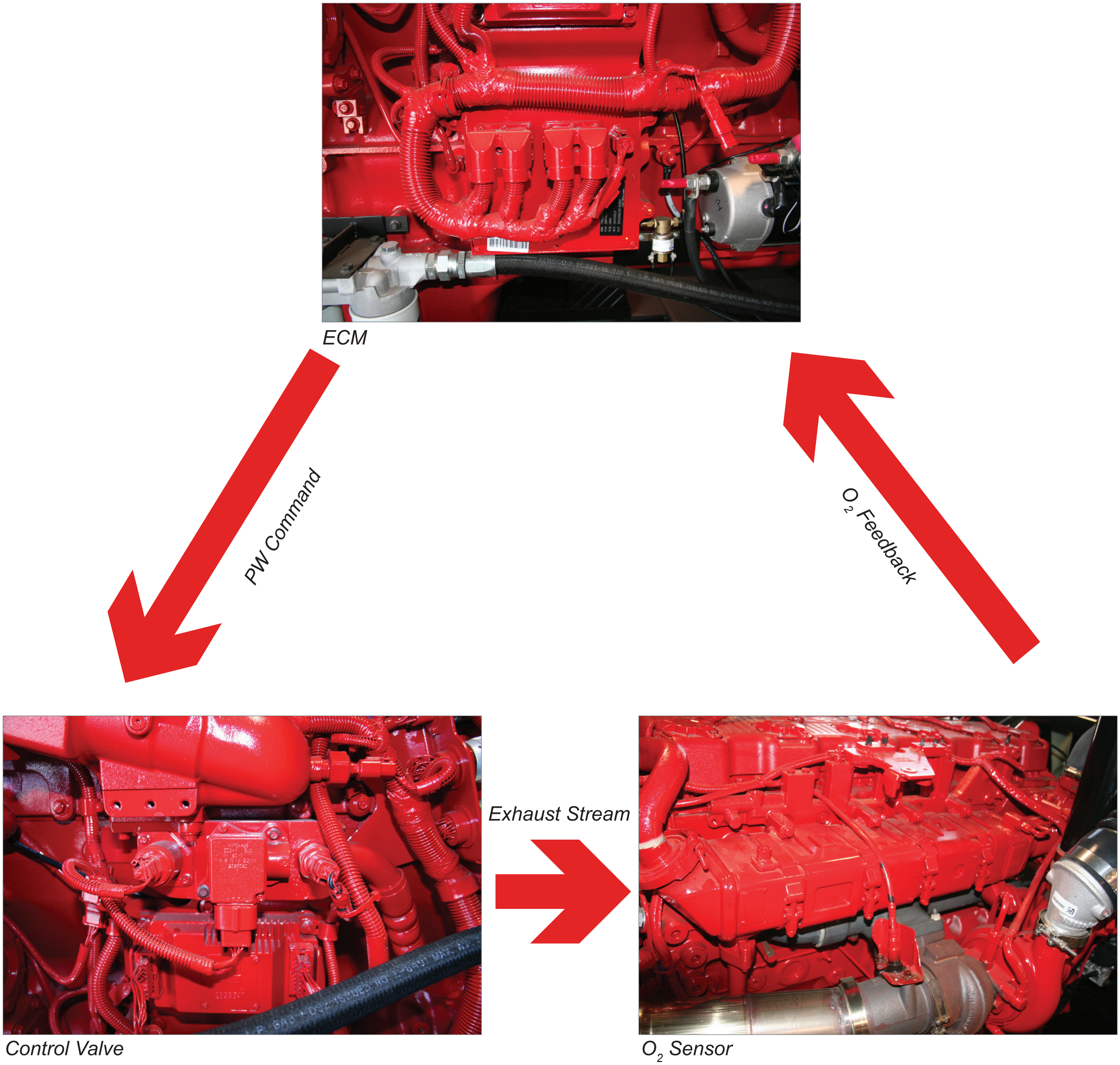
The ECM is the brains behind the system. The calibration for each engine is installed and compliant with EPA and CARB regulations to meet the emission requirements in effect. There are 27 sensor inputs and eight switched inputs to the ECM that drive 9 Outputs. The slightest variance in the components can cause an engine to have driveability issues. In some cases, issues can be caused by calibrations that need to be changed by downloading from the factory. Always look in QuickServ for possible bulletins and updates that may need to be applied to resolve symptoms. The system has two communication protocalls J1587 & J1939, to network the computer with its inputs and outputs as well as to allow calibration changes. J1939 is preferred as it is the fastest and contains the most data available.

Emissions & Operation Modes

When an engine is not up to operating temperature, fuel enrichment is necessary. It takes about 1½ minutes to go from open loop to closed loop each time the ISX is started. The system can enter closed loop during this cold enrichment mode.

In closed loop, the Catalytic Converter reduces Oxides of Nitrogen (NOx), Hydrocarbons (HC) and Carbon Monoxide (CO). Misfires result in no combustion which allows HC and oxygen O_2 to pass to the catalyst unburned. Both gasses re-burn in the three way catalyst (TWC) causing excessive heat which can drastically shorten its life. During closed loop the system must vary between rich and lean evenly for proper catalyst operation. During the rich cycle the Carbon Monoxide (CO) reacts with the Rhodium to reduce NOx in the front bed or reduction section. During the lean cycle The rear bed absorbs oxygen in the platinum and palladium which oxidizes the HC & CO’s. An engine that is biased excessively rich will overheat the catalytic converter just like misfires.

Because of the BTU and density of natural gas the stoichiometric A/F ratio is adjusted to around 16.5: 1, which is leaner than gasoline or diesel. This varies with operating conditions and is calculated using Mass Air Flow and Gas Mass flow calculations along with the input sensors.


ECM
PW Command
O_2 Feedback
Exhaust Stream
Control Valve
O_2 Sensor

Activity 2.3

Fuel Control Valve & Closed Loop Analysis

Tools and Equipment:

1. Cummins Troubleshooting and Repair Manual
2. Tool Set
3. INSITE™
4. Propane Enrichment
5. Classroom handouts
5. Lab Scope

Step 1: Closed Loop Analysis

Note: Every time engine is started a timer is set for approx. 1½ mins before engine goes into closed loop operation.

Procedure: In the following steps, we are going to record the values from INSITE™ (at 30 second intervals) as the engine warms up and goes from "Open Loop" mode of operation to "Closed Loop" operation. We will also estimate how long it takes for the engine to go into "Closed Loop" mode.

a) Turn Cummins engine ignition to the ON position (do not start).

b) Connect INSITE™ and establish communication with engine.

c) Configure INSITE™ to view, engine coolant temperature (ECT), Gas Mass Sensor, and all O_2 sensor outputs.

d) Add the following parameters to INSITE™:
   - Mass Gas Sensor
   - Fuel Control Valve
   - Input & Output O_2 Sensor voltages
   - Engine Coolant Temperature

e) Connect DVOM to O_2 and monitor when sensor starts cross-counting (approx.1 ½ min.).

Step 2: INSITE™ Parameter Readings

Start engine and run @ 1200 RPM while recording the following information at 60 second intervals:

Time	ECT Temp	Mass Gas Flow	Mass Gas Voltage	Fuel Control Valve Cmd	Input O^2 Sensor	Output O^2 Sensor
________	________	________	________	________	________	________
________	________	________	________	________	________	________
________	________	________	________	________	________	________
________	________	________	________	________	________	________
________	________	________	________	________	________	________

a) Are there any of indicators of closed loop operation? ___________________________________

b) Disconnect one coil pack momentarily and compare to the readings for a normal idle. (closed loop)

Mass Gas Flow	Mass Gas Voltage	Fuel Control Valve Cmd	Input O_2 Sensor	Output O_2 Sensor
________	________	________	________	________
________	________	________	________	________

c) How did the Mass Gas & O_2 readings change and why? ____________________________________

d) Reconnect the coil packs.

Step 3: Locate the Fuel Control Valve

Visually locate the Fuel Control Valve and identify the power and ground wires:

#1 ground Wire terminal ___________________________

#1 power Wire terminal ___________________________

Step 4:

Connect the laptop to the diagnostic connector and view the Fuel Control Valve data parameters.

Run the engine at the following speeds and record the appropriate data:

	INSITE™ Lowest Value	INSITE™ Highest Value
KOEO	_______________	________________
KOER @ Idle	_______________	________________
Snap the throttle and observe any changes	_______________	________________

Step 5:

Using a Lab-scope, connect the FCV to Channel 1.
Draw the wave-form in the space provided: **KEY ON ENGINE RUNNING (KOER)**

Depress the throttle pedal slowly increasing the RPM to 1500 and watch the signal change

Why does the wave-form change with RPM?

____

____

Step 6:

Note the Mass Gas Flow Compensation and Fuel Control Valve parameters in INSITE™ prior to propane enrichment and record the value.

KOER @ 1000 RPM Compensation + / - _________ FCV _______________

Note the HO^2S PID ________________

Step 7:

Note the Mass Gas Flow Compensation and Fuel Control Valve while performing the propane enrichment and record the value.

KOER @ 1000 RPM Compensation +/- _________ FCV________________

(w/ propane enrichment)

Note the HO^2S PID ________________

Step 8:

a) With KOER, disconnect Fuel Control Valve.
b) Note if a code is set and what fault code through INSITE™. Fault Code ______________
   Fault Description:____
c) According to INSITE™, what are the effects of this set fault?:
   ____
d) What are the conditions to set? ____
e) When do the conditions for setting this code take place?_____________________________________
f) What are the possible causes for setting this code?____
g) What are the conditions for clearing this fault? ____
h) What is the action taken when the fault is active? ____
i) Is there an "Engine De-rate" for this sensor? (y / n) What is the de-rate? __________________________
j) In Step 6, we have forced the Gas Mass Sensor (high, low)
k) What happens to the FCV output on deceleration? ____

Reconnect Sensor and clear fault codes.

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Activity 2.3
(Supplement)
4-Gas Analyzer

If a 4-Gas Analyzer is available, record the following reading simultaneously during step 2.

Time	HC (ppm)	CO (%)	CO_2(%)	O_2 (%)	ECT Temp	O_2 Sensor
________	________	________	________	________	________	________
________	________	________	________	________	________	________
________	________	________	________	________	________	________
________	________	________	________	________	________	________
________	________	________	________	________	________	________

a) Are there any of indicators of closed loop operation? ________________________________

b) Disconnect one coil pack momentarily and compare to the readings for a normal idle. (closed-loop)

HC	CO	CO_2	O_2	O_2 Sensor
________	________	________	________	________

c) How did the HC & O_2 readings change and why? ____________________________________

d) Reconnect the coil packs.

4

Module Four

Diagnosing Pressure Sensors

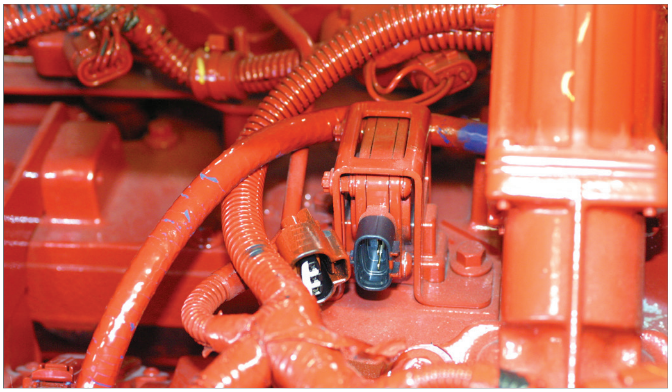
There are 8 pressure sensors to help maintain a Stoichiometric air/fuel ratio:

- Intake Manifold Pressure/Temp
- EGR Differential Pressure
- Mixer Inlet (Boost Pressure)
- Fuel Inlet Pressure
- Fuel Outlet Pressure
- Engine Oil Pressure

These are pressure transducers that are three-wire components with a 5v source voltage that increases corresponding to pressure increases.

EGR Differential Pressure Sensor

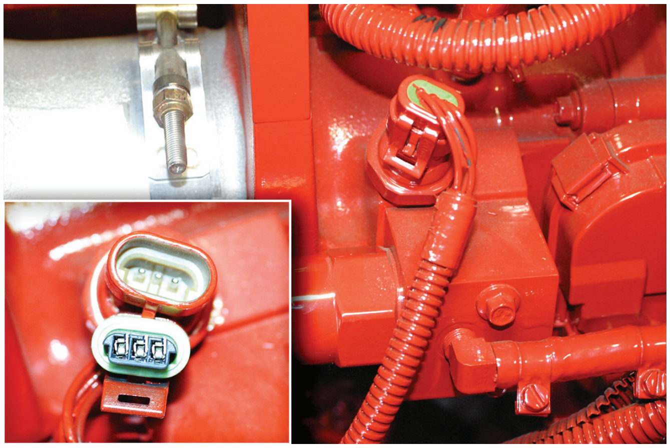
The EGR Delta Pressure Sensor (DPS) is a three-wire pressure sensor that compares the pressure differential between the exhaust and intake manifold while keeping flow to a maximum of 30%. Multiple EGR related fault codes are set from water in DPS circuit feeds. Having water or moisture in the feed ports under the DPS can be resolved sometimes by removing the DPS and blowing it out with low pressure shop air. If there has been an EGR cooler leak/replacement, the EGR DPS may have become ethylyne glycol coated, which creates additional issues.



EGR Differential Pressure Sensor

To check the calibration of this sensor with the EGR valve, the engine needs to be under load or in a stall. Back probe the sensor plug and measure voltage with a DVOM on the signal (Pin C) and return pins (Pin B). Also confirm that there is 5 volts at Pin A. To confirm calibration, compare voltage drop measurements with known good values for actual pressure.

Mixer Inlet (Boost) Pressure Sensor



Boost Pressure

The Mixer Inlet (Boost) Pressure Sensor has had several name changes and is listed in INSITE™ as the Engine Turbocharger Boost Pressure Sensor and other Cummins documentation as throttle or mixer inlet pressure. Terminology differences can exist. This is a three-wire transducer sensor. When taking DVOM measurements for this pressure sensor, compare to known good values using the signal (Pin A) and return (Pin B) pins. You will also want to confirm that the sensor has the appropriate 5 volts to operate properly.

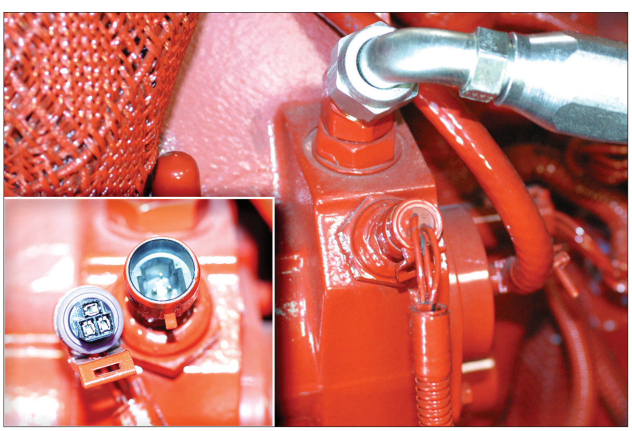
If secondary fault codes are being set for low secondary pressure, check for blocked boost signal line.

To test this sensor, back probe the sensor plug with Key On Engine Running (KOER) and measure voltage with a DVOM on the signal (Pin C) and return pins (Pin B), and confirm that there is 5 volts at Pin A. To confirm calibration, compare voltage drop measurements with known good values for actual pressure.

Fuel Inlet Pressure Sensor

The Fuel Inlet Pressure Sensor is a three-wire sensor. The pressure from the chassis to this sensor is in the 110 to 120 PSIA range as required by Cummins. Low pressures on the chassis side can cause secondary fault codes to be set as the fuel supplied from the chassis will not be able to keep up under load. Check the primary regulator for sticking. Contaminated filters can a cause this low volume, resulting in a pressure drop. The mixer inlet fitting at the mixer housing and in front of the Mass Air flow sensor can have debris blocking the boost signal pressure to the secondary regulator.

When checking the sensor calibration, measure voltage across signal and return, compare to known good values, and then measure voltage to pressure gauge. To test this sensor, at KOER back probe sensor plug and measure voltage with a DVOM on the signal (Pin C) and return pins (Pin B), and confirm that there is 5 volts at Pin A. To confirm calibration, compare voltage drop measurements with known good values for actual pressure.

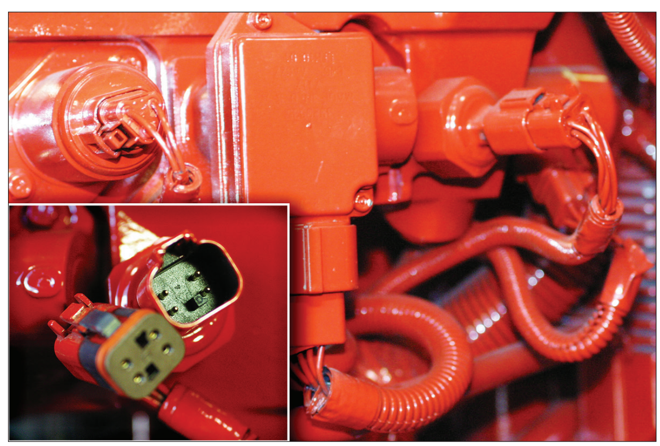


Fuel Inlet Pressure Sensor

Fuel Outlet Pressure/Temp Sensor

The Fuel Outlet Pressure Sensor is a four-wire combination sensor. This sensor monitors the fuel temperature and pressure. The pressure from the secondary regulator must be 65 - 73 PSIA under load or the engine will run lean and lack power. Check secondary and primary regulators for sticking and contaminated filters if fault codes are being set and/or low on power.

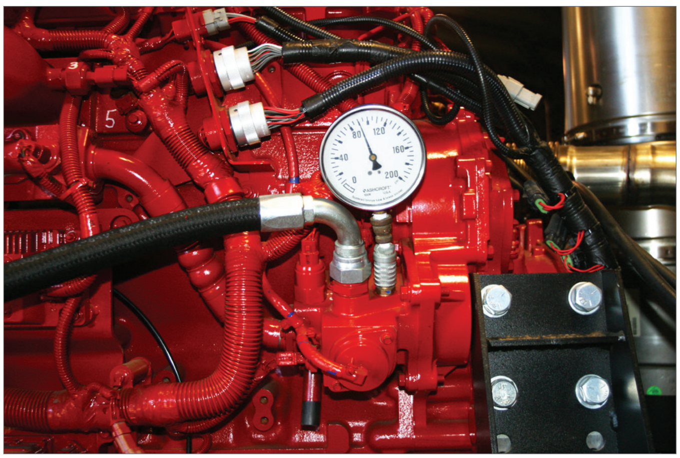
When checking sensor calibration, measure voltage across signal and return, compare to known good values, and then measure voltage to pressure gauge. To test this sensor, at KOER back probe Fuel Outlet Pressure/Temp sensor plug and measure voltage with a DVOM on the signal (Pin 3) and return pins (Pin 2), and confirm that there is 5 volts at Pin 1. To confirm calibration, compare voltage drop measurements with known good values for actual pressure.



Fuel Outlet Pressure/Temp Sensor

ISX12-G System Pressures

Fuel pressure readings should be taken when the engine is under load to ensure enough volume to keep the engine running. Either use a mechanical or electric gauge on the port to see absolute readings. Gauge readings will be 14.7 PSI different from INSITE™ at sea level. Cummins uses Quick Disconnect couplings and Nipples on the engine for this purpose. Part numbers are Quick Disconnect #3376859 and Coupling Nipple # 3042619.

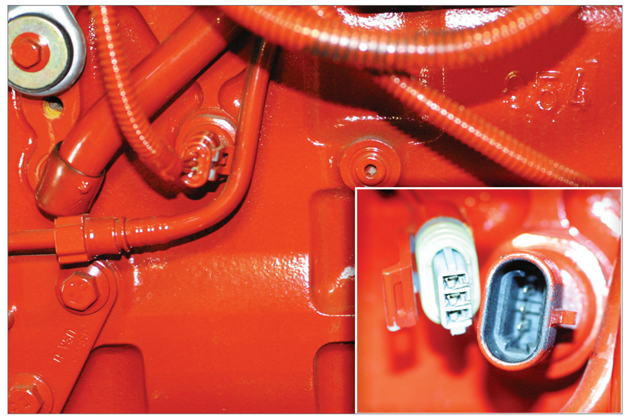


Secondary Pressure Guage

Engine Oil Pressure Sensor

The oil pressure sensor is a three-wire pressure sensor/transducer device. The ECM uses input from the oil pressure sensor for engine protection. If the oil pressure is too low engine de-rate and possible shutdown will occur.

The Oil pressure should read ZERO with the Key On Engine Off (KOEO). If the transducer sticks, it could be reporting that there is oil pressure when there is none and an engine failure could occur due to lack of registered oil pressure. If the pressure is above 0, then replace sensor. Cummins Engineering is working to change software to recognize whatever pressure is at startup to be zero baseline and read from there as a sensor check. If the pressure does not increase from baseline, engine shut down should occur.



Engine Oil Pressure Sensor

To test this sensor, at KOER back probe sensor plug and measure voltage with a DVOM on the signal (Pin C) and return pins (Pin B), and confirm that there is 5 volts at Pin A. To confirm calibration, compare voltage drop measurements with known good values for actual pressure.

Checking Secondary Pressure with Electronic Guage

Activity 2.4
INSITE™ Diagnostics

Tools and equipment:

1. INSITE™

Condition: Driver states bus doesn't run as well as the others he drives.

The Service Technician confirmed and performed the following;

When taken out for test drive, Service Tech noticed that bus lacks power on hills

After - Treatment System was checked for blockage - Good

EGR Checked - Good

Accelerator Pedal (App1 & App2) Checked Good

Throttle Plate and Accelerator Pedal- In-sync & No Glitches

Turbo Boost & Waste Gate Operation- Normal

For the purposes of analyzing a log file, we want to limit our parameter list to only the possible areas of concern. Use the following parameters and generate a log file through INSITE™?

Amber Warning Lamp Status
Red Stop Lamp Status
Engine Speed (RPM)
Fuel Control Valve Int. Pressure (psi)
Fuel Control Valve Int. Pressure Sensor Signal Volt
Fuel Supply Pressure Sensor (In Hg)
Fuel Supply Pressure Sensor Voltage (V)
Intake Manifold Pressure (In Hg)
Mass Gas Flow Compensation (Percent)
Throttle Plate Position 1 (Percent)

Procedure:

Step 1: Start engine and launch INSITE™. Consider the above parameters in determining your parameter list for the INSITE™ log file. You may want to view the above parameters before the actual recording of your log file.

Step 2: Warm-up engine and then follow procedure below to diagnose possible causes.

Run a diagnostic sequence by recording a snapshot to determine if there are any drivability concerns. Record a drive cycle data log of the following sequence of events:

1. Idle for 30 seconds,
2. 1000 rpm for 10 seconds
3. Snap the throttle once
4. Idle for 10 seconds
5. 1500 rpm for 10 seconds
6. Back to idle - Drive Cycle Complete

Save the drive cycle data log to a file and print it in an Excel format for use in the classroom.

Step 3: Use your data log info to diagnose the symptoms. Look at the drive cycle parameters, referencing the specific frames, to determine if a condition exists and what symptoms are present. Record your findings below.

Symptomatic analysis of snapshot:

Time Seq:_____________ symptom____

Time Seq:_____________ symptom____

Time Seq:_____________ symptom____

Time Seq:_____________ symptom____

Time Seq:_____________ symptom____

Time Seq:_____________ symptom____

Time Seq:_____________ symptom____

Time Seq:_____________ symptom____

Time Seq:_____________ symptom____

Time Seq:_____________ symptom____

Cause:

Correction:

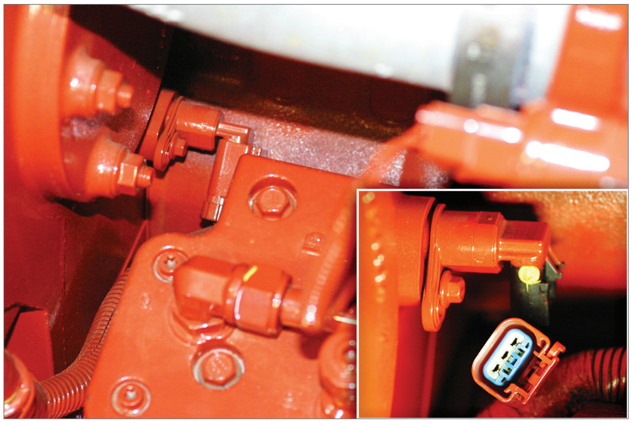
5

Module Five

Diagnosing Speed/Position Sensors

Camshaft Speed/Position Sensor

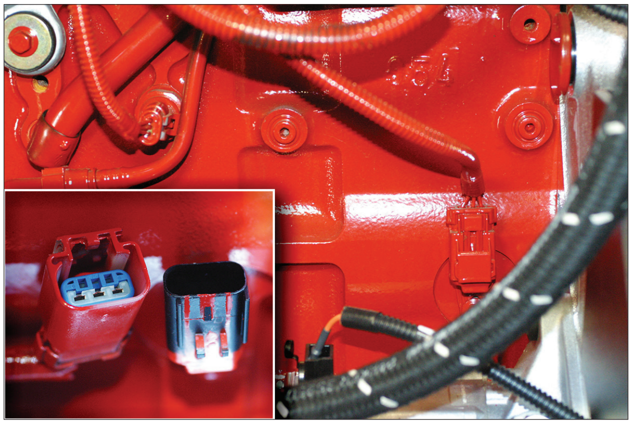
The camshaft speed sensor is a three-wire Hall-effect sensor. Crank and cam sensors are not interchangeable, as the reach and mount is different between them. When testing this sensor, check the output across the signal and return pins. These Hall-Effect sensors can be intermittent or fail completely. If this senor fails, the ECM will switch to the crank sensor as needed to limp-in. When testing, check for signal on pins B and C along with 5 volt reference on Pin A. Testing can be performed using a DVOM to measure both voltage and frequency. The preferred method is to use an Automotive Oscilloscope.



Camshaft Speed/Position Sensor

Crankshaft Position/Speed Sensor

The crankshaft speed sensor is also a three-wire Hall-effect sensor. Cam and crank sensors are not interchangeable, however testing is identical. These hall-effect sensors can be intermittent or fail completely. If this senor fails, the ECM will switch to the cam sensor as needed to limp-in. When testing, check for signal on pins B and C along with 5 volt reference on Pin A. Testing can be performed using a DVOM to measure both voltage and frequency. The preferred method is to use an Automotive Oscilloscope.



Crankshaft Position/Speed Sensor

Speed Sensor Rationale

Speed Sensor Rationale if a sensor fails:

On Startup:

- Camshaft Speed Position Sensor – must be functional in order for engine to start
- Crankshaft Speed Position Sensor – engine will start without a signal

While Running:

- Camshaft Speed Sensor Signal - loss of signal will have no impact to engine operation until the engine is turned OFF
- Crankshaft Speed Position Sensor – signal loss will result in a severe knock condition de-rate
- If sensors disagree by a pre-determined threshold, engine will use the sensor outputting the faster speed

Vehicle Speed Sensor

The vehicle speed sensor is a two-wire sensor and is composed of a coil that has a magnet pass through it inducing an A/C voltage that changes in frequency. This sensor is similar to most ABS wheels sensors. When testing this sensor, check for resistance, and check the AC output noticing a frequency change as output shaft speed changes.

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Activity 2.5

Camshaft & Crankshaft Speed/Position Sensors

Tools and equipment:
1. Cummins Troubleshooting and Repair Manual   2. DSO - Lab Scope

Step 1: Using the repair manual, locate the Cam and Crank Speed/Position sensor wiring diagram:

CS/P 5 volt supply (Cam) Wire terminal ___________________________
CS/P Signal Return Wire terminal ___________________________
CS/P Sensor Signal Wire terminal ___________________________

CS/P 5 volt supply (Crank) Wire terminal ___________________________
CS/P Signal Return Wire terminal ___________________________
CS/P Sensor Signal Wire terminal ___________________________

Step 2: Using a Lab-scope, connect the positive lead to Cam Speed/Position Signal wire to Channel 1. Draw the wave-form in the space provided: KEY ON ENGINE RUNNING (KOER).

Depress the throttle pedal slowly increasing the RPM to 1500 and watch the signal change

Time base setting ______________

Voltage setting ________________

Step 3: Disconnect the Camshaft sensor. Does the engine continue to run? (Y / N)
Shut off engine and restart. Will engine start with the Cam sensor disconnected? (Y / N)
Reconnect the Camshaft Sensor.

Step 4: Using a Lab-scope, connect the positive lead to Crank Speed/Position Signal wire to Channel 1. Draw the wave-form in the space provided below: **KEY ON ENGINE RUNNING (KOER)**

Depress the throttle pedal slowly increasing the RPM to 1500 and watch the signal change.

Time base setting _____________

Voltage setting _______________

Step 5: Disconnect the Crankshaft sensor. Does the engine continue to run? (Y / N)
Shut off engine and restart. Will engine start with the Crankshaft sensor disconnected? (Y / N)

Step 6: Using a Lab-scope, reconnect the positive lead to Cam Speed/Position Signal wire this time to Channel 2. Draw the wave-forms and relationship of the camshaft and crankshaft sensors in the space provided: **KEY ON ENGINE RUNNING (KOER)**

Time base setting _____________

Voltage setting _______________

Inputs

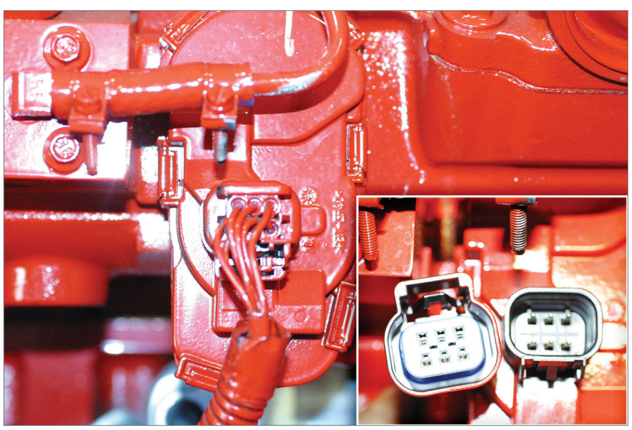
Position sensors are three-wire Potentiometers sensing movement of a mechanical device.

Throttle Plate Position Sensors 1&2

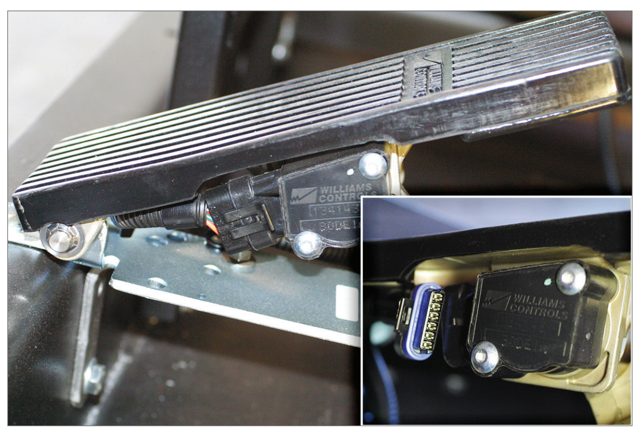
The Throttle housing has two throttle position sensors to determine throttle position and the throttle actuator. Older throttle pedals used a single throttle position sensor and an idle validation switch. If fault codes 132 and 1241 are active when the accelerator pedal is in the idle position and fault code 132 goes inactive and fault code 1239 goes active when the accelerator is depressed, the incorrect accelerator pedal has been installed in the vehicle. A throttle pedal with two accelerator position sensors should be installed.

Accelerator Pedal Sensor

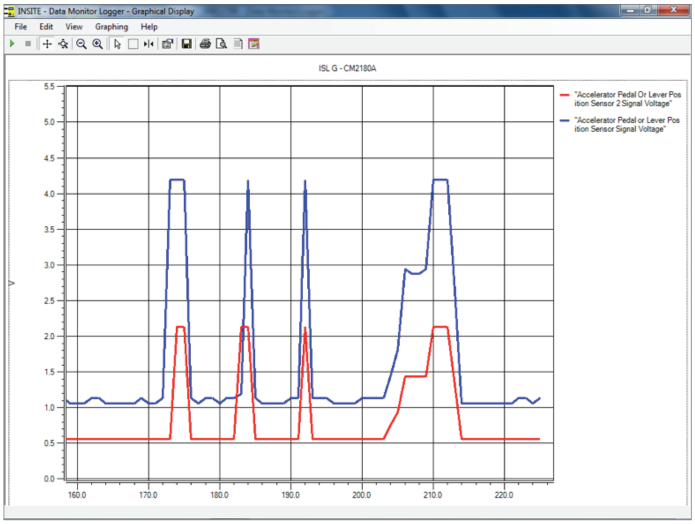
The Accelerator Pedal (APP) has two pedal position sensors connected to ECM via a three wire connector for each sensor. The purpose for two sensors is to provide a degree of redundancy and safety. Each APP sensor can tested with INSITE™ graphing or an oscilloscope while doing a sweep on the pedal at KOEO. This sweep test will detect opens, or glitches, that may not be detectable with the DVOM. Normally the APP will return approximately 10% of the supply voltage at idle, and approximately 90% at wide open throttle. As the accelerator pedal is slowly pushed down, the signal return voltage at terminal B of the sensor will gradually increase from .5v to 4.0V. If the accelerator position voltage is determined to be out of range by the ECM, a code 18 will be set and the engine will idle only. The override switch will provide limp-in operation of the system.

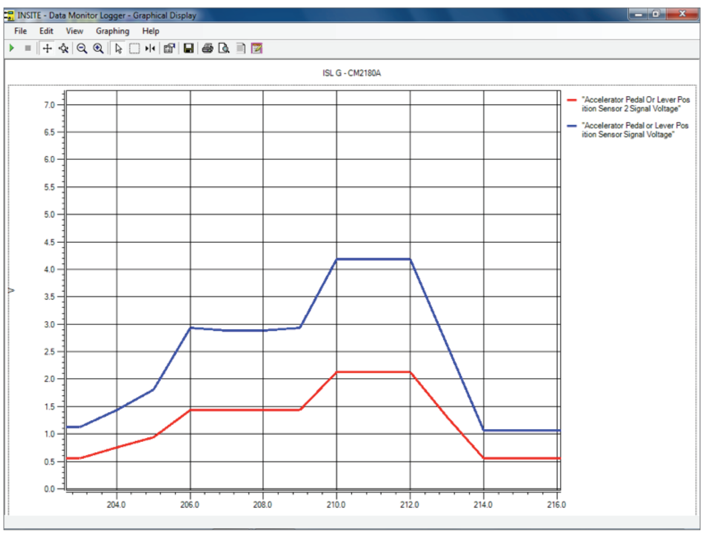


Throttle Plate Position Sensors 1 & 2



Accelerator Pedal Sensor

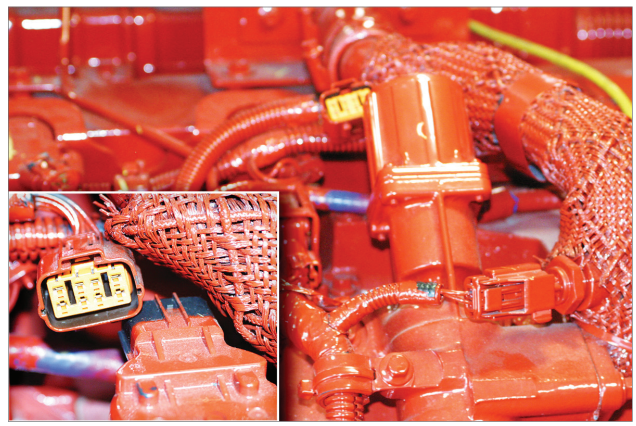




Remote Accelerator Pedal Assembly

The remote throttle is switched by the ECM to control the main or remote accelerator pedal sensors. This is performed by switching the wiper from the main accelerator pedal to the wiper on the remote.

EGR Position Sensors



EGR Position Sensors

The EGR valve position sensors sense the position of the EGR valve. The sensor confirms that the valve is in one of three positions and updates this information to the ECM which keeps flow to a maximum of 30% under load. This valve cannot be tested unless the vehicle is under load or in a stall.

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Activity 2.6
Accelerator Pedal Position Sensor

Tools and equipment:

1. Classroom materials
2. INSITE™
3. Hand tool Set
4. DVOM

Step 1: Locate terminals on the APPS wiring diagram.

APPS Sensor 1 Return — Wire terminal ________________
APPS Sensor 1 Signal — Wire terminal ________________
APPS Sensor 1 5-volt Supply — Wire terminal ________________
APPS Sensor 2 Return — Wire terminal ________________
APPS Sensor 2 Signal — Wire terminal ________________
APPS Sensor 2 5-volt Supply — Wire terminal ________________

Using the wiring diagram locate the APP wiring diagram.

Step 2:

Back probe the throttle actuator APPS2 signal wire with DVOM
Make sure the ignition is turned off
Turn ignition on (KOEO)
Turn on INSITE™ and monitor APP2 in graph mode
Press "FREEZE" when the pattern appears full screen
Draw the wave-form in the space provided
Have the instructor demonstrate open and short issues

6 Module Six

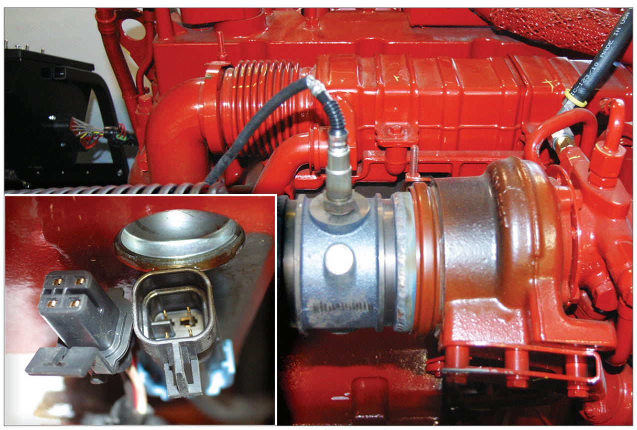
Diagnosing Signal Producing Sensors

Diagnosing Signal Producing Sensors

Signal producing sensors can be tested for signal output using INSITE™ graphing, a DVOM or Digital Storage Oscilloscope (DSO).

Catalyst Inlet Oxygen Sensors

The catalyst inlet oxygen sensor zirconia element is sensitive to contamination. The element can become coated by contaminants such as silicone so care must be taken to use only O_2 sensor safe products.

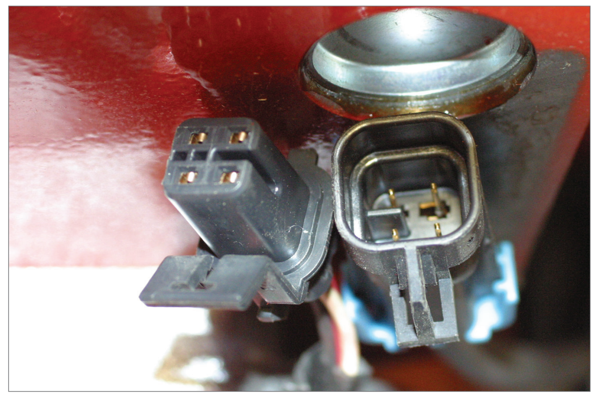


Catalyst Inlet Oxygen Sensor

The oxygen sensing portion of the sensor should never be tested with an ohmmeter the way a heater is checked. The voltage output of the sensor is read using an electronic service tool such as INSITE™. If this sensor becomes coated with a substance such as ethylene glycol from an EGR cooler leak, it can provide false readings. This sensor should also be tested for slow response (lazy O_2 response) as it can cause poor mileage and performance. To test for this perform a “Snap Throttle Test” using propane and INSITE™.

Catalyst Outlet Oxygen Sensor

Cummins has removed the blue seal to prevent gases traveling up between the wire and insulation upstream of the sensor plug and passing through the plug and to the O_2 sensor giving false readings.



Catalyst Outlet Oxygen Sensor

Combustion Knock Sensors 1&2

Use an ohmmeter to check continuity. Detonation can be monitored with INSITE™ or you can create a simulated knock and monitor with an oscilloscope. When replacing knock sensors, clean all paint from bottom of sensor and mounting location (block or head).

Torque bolt to proper spec. Make sure when air compressor is replaced, make sure the timing marks are checked and aligned. See Timing of air compressor per QuickServ #012-014.

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Activity 2.7
Knock Sensor

Tools and equipment:

1. Cummins Troubleshooting and Repair Manual   2. DSO - Lab Scope

Step 1: Locate the knock sensor wiring diagram:

Knock 2 signal Wire terminal _________________________

Knock 2 Signal return Wire terminal _________________________

Step 2: Using a Lab-scope, connect the positive lead to Knock Signal wire and the negative to the return. Draw the wave-form in the space provided: KEY ON ENGINE RUNNING (KOER) Watch knock signal in INSITE™ using graph mode if available.

Increase the RPM to 1000 and tap on a head bolt with a rattling wrench.

Time base setting _____________

Voltage setting ________________

Snap-Throttle Test using INSITE™

To perform Snap-Throttle Test, you will need to connect the vehicle to INSITE™ and use propane enrichment to force the engine rich. To start the test, add propane to intake while engine is running noting the Inlet O_2 sensor voltage. When this voltage exceeds 800 mV, remove propane (forcing the engine lean because the FCV has cut back). O_2 sensor will now report a lean mixture. Next, snap the throttle and pause INSITE™. Note the readings on INSITE™ when O_2 sensor trace went from Lean to Rich.

If sensor response is greater than 800 mV, change with less than 100ms response time when forced rich, O_2 sensor is OK. If sensor does not meet either or both requirements, sensor is lazy.

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Activity 2.8

O_2 Sensor Testing

Tools and equipment:

1. Cummins Troubleshooting and Repair Manual 2. INSITE™
3. Propane Enrichment Tool

Step 1: Using the Classroom manual, locate the Catalyst Inlet & Outlet Oxygen Sensor wiring diagram:

		Inlet	Outlet
HO^2S signal	Wire terminal	____________	_____________
HO^2S signal return	Wire terminal	____________	_____________
12v heater supply	Wire terminal	____________	_____________
12v heater return	Wire terminal	____________	_____________

If the oxygen sensor is working properly, it must be able to:

Rise to at least 800 millivolts

Drop to at least 175 millivolts

Rise from a minimum to maximum voltage in less than 100 milliseconds

What is the Catalytic Converter outlet temperature? ________________________

Set INSITE™ to graph output voltages of Inlet Oxygen Sensor @ 20 ms sample rate:

Step 2: Let the engine idle, in closed loop – remember not all vehicles will maintain closed loop at idle. For those vehicles you may have to hold just above idle. Use INSITE™ to monitor the oxygen sensor waveform.

What are the O_2 sensors Min and Max voltages?

Min Voltage:__________ Max Voltage:___________

Step 3: Put the hose from the propane enrichment tool into the air intake or intake manifold vacuum port and slowly begin adding propane.

Step 4: Keep adding propane in small increments until the computer can no longer compensate for the extra fuel enrichment. The oxygen sensor voltage should be at its highest voltage output and at least 800 millivolts.
What was the highest voltage? __________mV

Step 5: Quickly shut the propane off. The oxygen sensor voltage should drop to its minimum output; below 175 millivolts.
What was the lowest voltage? ______________________ mV

Step 6: While the oxygen sensor is at minimum voltage, snap the throttle all the way open. The mixture should jump full rich and the oxygen sensor voltage should also jump. The rise time should be less than 100 milliseconds. Use the freeze feature of INSITE™ to freeze the display during this test. Then measure the rise time in milliseconds.
What was the actual rise time in milliseconds? ________________________

Step 7: What is the average O_2 sensor voltage? ____________
What is the Catalytic Converter outlet temperature? _________________________

Step 8: Repeat step 1-4 with the Catalyst Outlet Oxygen Sensor

Step 9: View the Inlet and Outlet O_2 sensor data parameters

Run the engine at the following speeds and record the appropriate data for the Inlet Sensor.

	INSITE™ Low Voltage	INSITE™ High Voltage
KOEO	________	________
KOER @ Idle	________	________
KOER @ 1000 RPM	________	________
KOER @ 1500 RPM	________	________
KOER @ Idle (w/ propane enrichment)	________	________

Run the engine at the following speeds and record the appropriate data for the Outlet Sensor:

	INSITE™ Low Voltage	INSITE™ High Voltage
KOEO	________	________
KOER @ Idle	________	________
KOER @ 1000 RPM	________	________
KOER @ 1500 RPM	________	________
KOER @ Idle (w/ propane enrichment)	________	________

Snap the throttle and observe any changes ____

What is the Catalytic Converter outlet temperature? ____________________________________

Step 9: With KOER, disconnect the O_2 Sensor and note if a fault code is set through INSITE™.

a) Fault Code and Fault Description:____

b) According to INSITE™, what are the effects of this set fault?: ____________________________

c) When do the conditions for setting this code take place?________________________________

d) What are the conditions for clearing this fault? ______________________________________

e) What is the action taken when the fault is active? ____________________________________

_

f) Is there an "Engine De-rate" for this sensor? (y / n) What is the de-rate? ____________________

g) Reconnect Sensor and clear fault codes.

Step 10: With KOER, disconnect and short the O_2 Sensor connector signal to return.
Note what fault code is set through INSITE™.

a) Fault Code and Fault Description:____

b) What are the conditions to set this fault? ____

c) When do the conditions for setting this code take place?________________________________

d) What are the possible causes for setting this code? ____________________________________

e) What is the action taken when the fault is active? ____________________________________

f) In Step 4, we have forced the O_2 Mass Sensor (high, low)

Remove the short from connector; reconnect the sensor and clear fault codes.

Step 11: Using INSITE™, set the parameters to monitor the following:

Fuel Control Valve(FCV)

Mass Air Sensor (AMS)

Mass Gas Sensor (GMS)

Catalyst Inlet & Outlet Oxygen Sensors

What is the Catalytic Converter outlet temperature? ______________________

Run the engine at the following speeds and record the appropriate data for the Inlet Sensor:

	HOS Input Low/High Volts	HOS Output Low/HighVolts	Mass Gas Low/High Volts	Mass Air Low/High lbs/hr	Fuel Control Valve Low/High Command
KOEO	______/______	______/______	______/______	______/_______	______%/______%
KOER @ Idle	______/______	______/______	______/______	______/_______	______%/______%
KOER @ Idle w/ Coil-Pack #6 disconnected	______/______	______/______	______/______	______/_______	______%/______%
Reconnect Coil Pack #6					
KOER @ 1000 RPM	______/______	______/______	______/______	______/_______	______%/______%
KOER @ 1500 RPM	______/______	______/______	______/______	______/_______	______%/______%
KOER @ Idle (w/ propane enrichment)	______/______	______/______	______/______	______/_______	______%/______%

What is the Catalytic Converter outlet temperature? ______________________

Has the Catalytic Converter temperature changed due to the propane that has been added? (Y/N)
How? ____

Step 12: What happens to each sensor voltage when the system is made rich?

Fuel Control Valve (FCV) _________________________________%

Mass Gas Sensor (MGS) __________________________________

Mass Air Sensor (MAS)_______ ________________________lbs/hr

Catalyst Inlet Oxygen Sensor (HO^2S)________________________

Outlet Oxygen Sensor (HO_2S) ______________________________

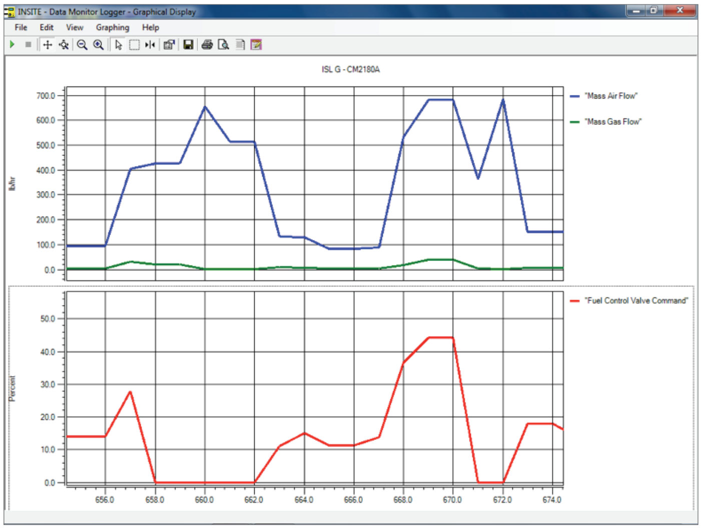
What is the reading of the FUEL CONTROL VALVE while performing the propane enrichment test?

____

What is the reading of the FUEL CONTROL VALVE @ idle. Write the value in the space provided

____

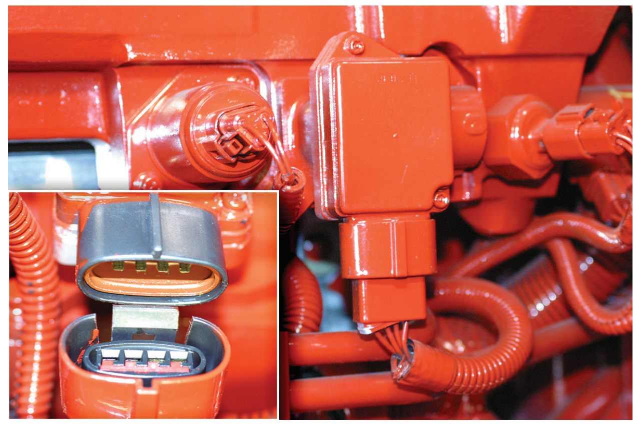
Mass Gas Sensor



INSITE™ graphing is used to show the relationship between the Fuel Control Valve, Mass Air and Mass Gas Sensors as engine demand increases and decreases. Notice that when engine RPM drops the fuel delivery decreases. Otherwise, as the demand for load increases, both the demand for air and fuel increase although at different levels. In INSITE™, the units of measure for Mass Air and Mass Gas are in Lbs/Hr.

Mass Air Flow Sensor

The Mass Air Flow (MAF) sensor is used to determine the rate of incoming air. It is only present on some ISX 12L engines, otherwise, the airflow rate is calculated using the other sensors.



Mass Air Flow Sensor

LONG BEACH CITY COLLEGE

Activity 2.8b
Mass Gas Sensors

Step 1: Using the Classroom manual, locate the Catalyst Inlet & Outlet Oxygen Sensor wiring diagram:

		Inlet	Outlet
HO^2S signal	Wire terminal	____________	_____________
HO^2S signal return	Wire terminal	____________	_____________
12v heater supply	Wire terminal	____________	_____________
12v heater return	Wire terminal	____________	_____________

If the oxygen sensor is working properly, it must be able to:

Rise to at least 800 millivolts

Drop to at least 175 millivolts

Rise from a minimum to maximum voltage in less than 100 milliseconds

What is the Catalytic Converter outlet temperature? _______________________

Set INSITE™ to graph output voltages of Inlet Oxygen Sensor @ 20 ms sample rate:

Step 2: Locate the Gas Mass Sensors

Connect INSITE™ and view the MASS sensor data parameters

Run the engine at the following speeds and record the appropriate data:

	Calculated Mass Air Low Volume	Calculated Mass Air High Volume	Mass Gas Low Voltage	Mass Gas High Voltage
KOEO	________	________	________	________
KOER @ Idle	________	________	________	________
KOER @ 1000 RPM	________	________	________	________
KOER @ 1000 RPM (with propane enrichment)	________	________	________	________
KOER @ 1500 RPM	________	________	________	________

Snap the throttle and observe any changes ____

Step 3: With KOER, disconnect the Mass Gas Sensor, and note is a fault code is set through INSITE™.

a) Fault Code and Fault Description:____
b) According to INSITE™, what are the effects of this set fault? __________________________
c) What are the conditions to set? ____
d) What are the possible causes for setting this code? _________________________________
e) What are the conditions for clearing this fault? ____________________________________
f) Reconnect the Gas Mass Sensor

Step 4: With KOER, disconnect the Mass Air Sensor, and note if there is a fault code through INSITE™.

a) Fault Code and Description:____
b) According to INSITE™, what are the effects of this set fault?__________________________
c) What are the conditions to set? ____
d) What are the conditions for clearing this fault? ____________________________________
e) Is there an "Engine De-rate" for this sensor? (y / n) What is the De-rate?__________________
f) Reconnect the Sensor

Step 5: With KOER, disconnect and short the Mass Gas Sensor connector signal to return. Note if a code is set through INSITE™.

a) Fault Code and Fault Description:____
b) According to INSITE™, what are the effects of this Set Fault? __________________________
c) What are the conditions for clearing this fault? ____________________________________
d) Is there an "Engine Derate" for this sensor? (y / n) What is the Derate? __________________
e) What is the action taken when the fault is active? ___________________________________
f) In Step 4, we have forced the Gas Mass Sensor (high, low)

Remove the short from connector; reconnect the sensor.

Step 6: Does this engine have a Mass Air Flow Sensor or is the air flow calculated? ______________

Step 7: Does INSITE™ have parameters for the Mass Air Flow Sensor? ______________________

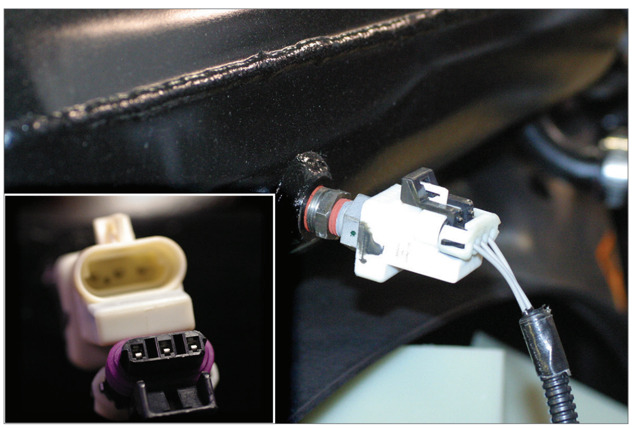
Step 8: Does INSITE™ have error codes for the Mass Air Flow Sensor? ______________________

If fault codes are available, answer the following questions.
a) Fault Code and Description:____
b) What are the conditions to set? ____
c) When do the conditions for setting this code take place?______________________________
d) What are the possible causes for setting this code?__________________________________
e) What is the action taken when the fault is active? ___________________________________
f) Is there any these faults can be set if the Air Flow is calculated? _______________________

Compressor Inlet Temperature, Pressure & Humidity Sensor

The Compressor Inlet Temperature, Pressure & Humidity Sensor is a "Smart" Sensor. This means that it contains a microprocessor that generates a CAN signal. In this signal, the temperature, pressure and humidity of ambient air is broadcast over the CAN bus to the ECM which is then interpreted. These values are used in fuel trim and timing calculations.

Coolant Level Sensor



Coolant Level Sensor

The engine coolant level sensor is a three-wire capacitance type sensor. When the coolant level drops below a certain level, the ECM will de-rate and/or shutdown the engine. The level of de-rate becomes greater with time if the problem is not corrected. This sensor is prone to leaking as the plastic becomes fatigued and cracks.

This sensor can have the signal lead shorted high, which will prevent shutdown and limp-in if it fails. Never continually drive a vehicle in this condition as there is no critical engine protection for coolant.

Activity 2.9
Natural Gas Engines
Symptoms and Possible Causes

Complete the following. You may use INSITE™, QuickServ and your notes as needed.

Symptom	1	2	3	4
Low Fuel Pressure/Restricted Fuel Flow				
Low or Restricted Air Flow				
Misfire				
Oxygen Sensor Issues				
Turbine Intake Temperature				

Activity 2.9 (part two)

Natural Gas Engines

Symptoms and Possible Causes

What parameters would be helpful to monitor when the engine is experiencing the following symptoms.
Use INSITE™ and QuickServ if necessary to determine the monitored parameters.

Low Fuel Pressure/Restricted Fuel Flow	Low or Restricted Air Flow	Misfire	Oxygen Sensor Issues	Turbine Inlet Temperature

7

Module Seven

Outputs

The work producing outputs from the ECM are electromagnets with the exceptions of the communication to and from the ECM and the fault lamps:

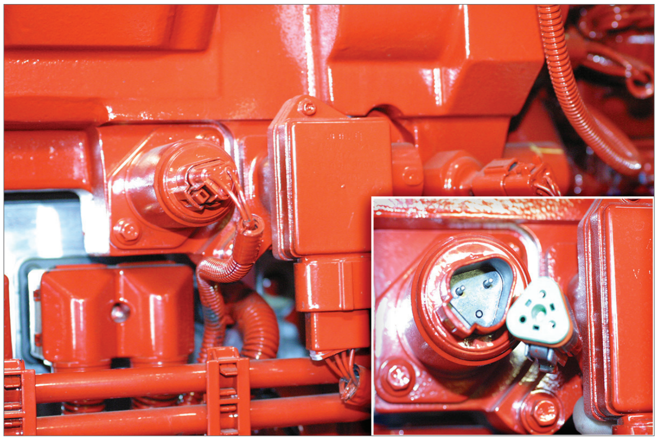
- Fuel Control Valve
- Wastegate Control Valve
- Throttle Actuator
- Fuel Shut-off valve
- Ignition Timing Control
- Ignition Control Module Reference
- Warning and Fault Lamps
- EGR Valve
- Starter Lockout Signal
- Cooling Fan Control
- CAN Communication Bus

Fuel Control Valve

This is a two-wire normally closed (n/c) valve that delivers fuel to the mixer like an injector. The DSO lab scope is the preferred method to view the Pulse-Width Modulated (PWM) signal as INSITE™ will only provide the duty-cycle as a parameter. The ECM controls the on time and assumes the pressure will be constant. Be sure to check both pressure and volume of gas if a fuel trim issue arises.

The resistance of this valve is between 3 to 5 Ohms. Check resistance both hot and cold and confirm that the resistance does not vary more than 10%. This valve is known to stick, or the coil failing open. Remember that the ECM commands this valve and does not confirm that the valve is functioning properly other than by getting feedback through the Mass Gas Sensor.

After the fuel is released by the Fuel Control valve, it enters the intake manifold where it becomes mixed with charged air and is distributed to each cylinder.

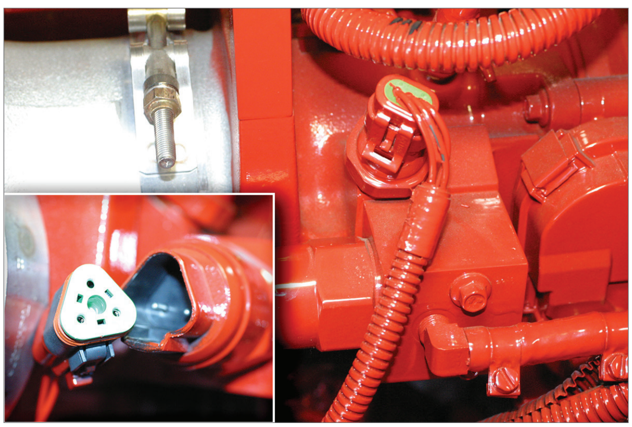


Fuel Control Valve

Wastegate Control Valve

This valve is what we call “high-side” controlled as the ECM powers up the valve to actuate it instead of grounding it. This is done for a safety factor to prevent accidental grounding of the solenoid valve and unwanted actuation. To test this valve, use an ohmmeter to test the solenoid coil. In addition, the signal to this valve is PWM so the duty cycle can be tested for this valve. Higher duty cycle will equal more boost.

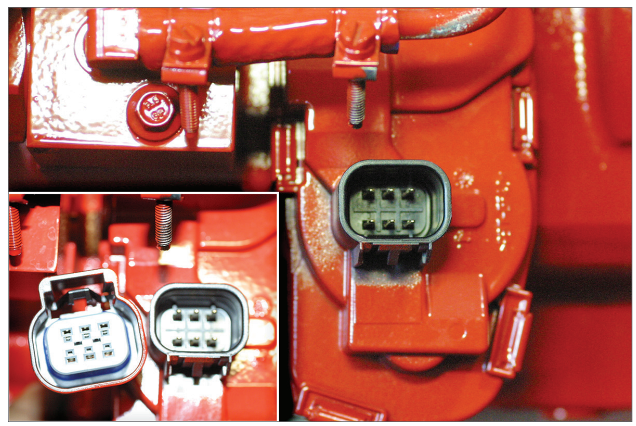
A sticking wastegate, caused by coolant leaks, can cause power problems and unwanted boost.



Wastegate Control Valve

Throttle Actuator

The Throttle Actuator controls the actual throttle position (drive-by wire). If this actuator fails or there is an intermittent connection in the harness for the drive-by wire circuit, the system will idle only and set a fault. Contamination or blockage in the fuel-air mixer can set fault codes or low RPM surging. See QuickServ. for latest TSB# 101120.



Throttle Actuator

Post Test

Cummins ISX 12-G Level II

1. A temperature sensor is a Thermistor Device?
   a. True b. False

2. What is the stoichiometric, A/F ratio for the Cummins ISX 12L running on CNG?
   a. 12.5:1 b. 14.7:1 c. 16.5:1 d. 18.5:1

3. What type of sensors are the crankshaft and camshaft sensors?
   a. Magnetic reluctance
   b. Hall Effect
   c. Thermistor Devices
   d. The Cummins ISX 12L does not need crankshaft and camshaft sensors

4. What is the purpose of the fuel shut-off valve used?
   a. Control the fuel entering the Mixer
   b. Shut-off fuel to the engine if engine RPM is not present
   c. Takes the place of needing a shut-off valve at each cylinder
   d. Takes the place of needing a Manual Shut-off valve

5. What is the relationship of the Camshaft to the Crankshaft?
   a. 1:1 b. 2:1 c. 3:1 d. 4:1

6. When should you reset the fuel tables in INSITE™?
   a. Only if you need to replace the ECM
   b. Every time you perform preventative maintenance
   c. Whenever any fuel system component is replaced
   d. This is a Cummins proprietary option

7. What is a Snap Throttle test used for?
   a. Check crank sensor operation
   b. Check for last O_2 Sensor
   c. Determine if the Accelerator pedal is working correctly
   d. Determine Catalytic Converter efficiency

8. Will the throttle actuator operate in the KOEO position?
   a. True b. False

9. Is the Air-fuel mixture leaner or richer on cold startup?
   a. Leaner
   b. Richer

Natural Gas Safety Considerations

TOXICITY: Nontoxic, it is not a poison like Carbon Monoxide but it does displace Oxygen

FLAMMABILITY: Flammability range is narrow 5-15% - below 5 is too lean to burn, above 15 too rich. Edges of a cloud could be right mixture. Heaters and other spark producing items must be relocated.

VENTILATION: Must be trapped vertically to be dangerous--- look up for traps at ceiling/false ceilings, etc. Lighter than air so most shops are equipped with auto vents on the methane detection circuit.

LEAK DETECTION: Mercaptin NOT present in LNG unless infused so it will have no odor. Methane detectors and hand held combustible gas detectors available along with commercial bubble style leak detectors. CG detectors will go off on many substances such as glycol, silicone, diesel, hyd. fluid so it is just a gross indicator.

COLLISION: Cylinders must have a Detailed Visual Inspection and hardware should be carefully inspected for damage. Cylinders should be closed and ¼ turn valve closed if vehicle is involved in an accident.

STORAGE: LNG vehicles should be stored outside due to venting of tank. CNG system is sealed and will not leak to atmosphere

SHOP SAFETY/EQUIPMENT: Methane detectors and ceiling ventilation should be reviewed by engineering. Special tools kit being provided to perform defueling, etc.

References

Sources:

Compressed Gas Association
1725 Jefferson Davis Highway,
#1004 Arlington, VA 22202-4102
Telephone: 703-412-0900

Gas Research Institute
8600 W. Bryn Mawr Avenue
Chicago, IL 60631-3652
Telephone: 773-399-8352

American National Standards Institute
11 W. 42nd Street
New York, NY 10036
Telephone: 212-642-4900

National Fire Protection Association
11 Tracy Drive
Avon, MA 02322
Telephone: 800-593-6372

Natural Gas Vehicle Coalition
1515 Wilson Blvd. Suite 1030
Arlington, VA 22209
Telephone: 703-527-3022

Department of Transportation
400 Seventh Street, SW
Washington, DC 20590
Telephone: 202-366-4000

Publications:

CGA C-6.4, "Methods for External Visual Inspection of Natural Gas Vehicle Fuel Containers and Their Installations," 1st Edition (1997)

NFPA 52, "Standards for Compressed Natural Gas Vehicular Fuel Systems" National Fire Protection Association, 1 Batterymarch Park, Box 9101, Quincy, MA 02269-9101

ANSI/AGA-NGV2, " Basic Requirements for Compressed Natural Gas Vehicle Fuel Containers," American Gas Association Laboratories, 8501 East Pleasant Valley Road, Cleveland, OH 44131

FMVSS304, "Compressed Natural Gas Fuel Container Integrity," Federal Motor Vehicle Safety Standards, US DOT, NHTSA

Gas Research Institute, " Natural Gas Vehicle Cylinder Care and Maintenance Handbook" (1997)

CHP Title 13

Notes

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