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## Electrical Tools

### 3-Banana Plug Harness

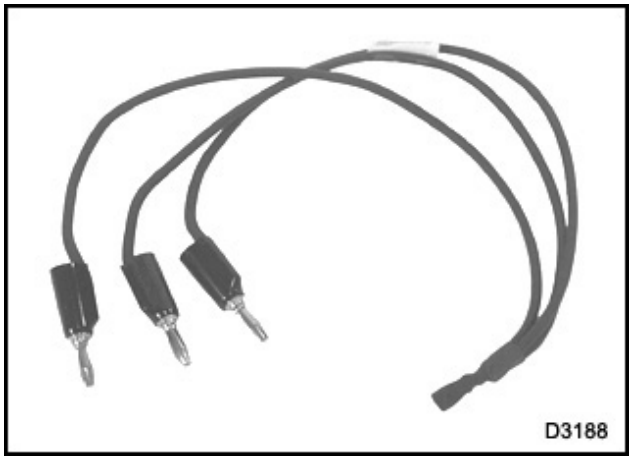


**Figure 292 ZTSE4498**

The 3-Banana Plug Harness is used for operational diagnostics of sensor circuits.

### 4-Pin Round Black Breakout Harness

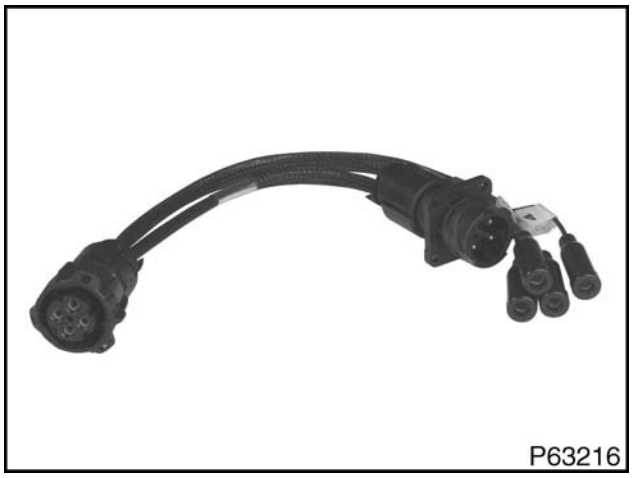


**Figure 293 ZTSE4827**

The 4-Pin Round Black Breakout Harness is used to measure voltage and resistance on circuits connected to the Exhaust Gas Recirculation (EGR) control valve, Engine Coolant Temperature (ECT) sensors, Engine Oil Temperature (EOT) sensor, and Cold Start Solenoid (CSS).

### 4-Pin Round Blue Breakout Harness

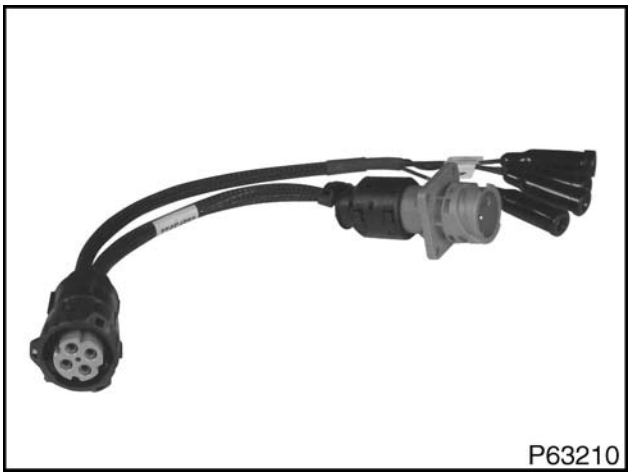


**Figure 294 ZTSE4883**

The 4-Pin Round Blue Breakout Harness is used to measure voltage and resistance on circuits connected to the Manifold Air Temperature (MAT) sensor.

### 4-Pin Round Gray Breakout Harness

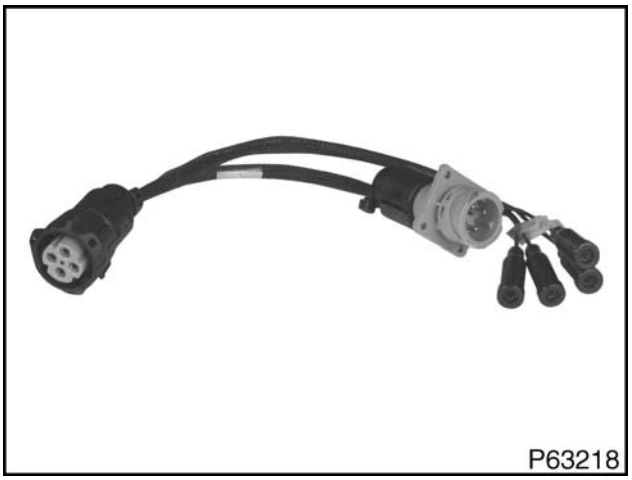


**Figure 295 ZTSE4881**

The 4-Pin Round Gray Breakout Harness is used to measure voltage and resistance on circuits connected to the Engine Fuel Pressure (EFP) sensor.

**4-Pin Round Green Breakout Harness**

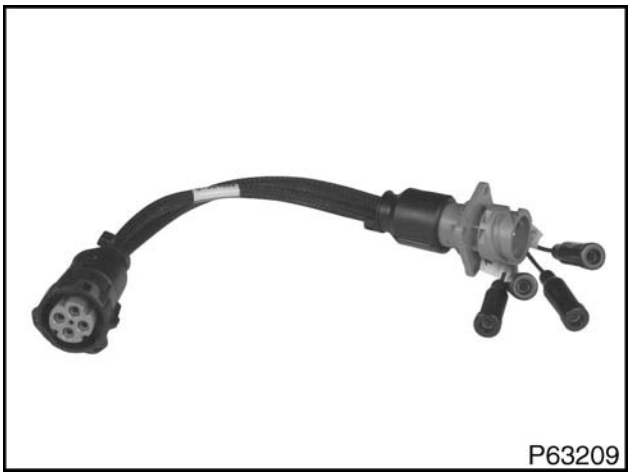


**Figure 296 ZTSE4882**

The 4-Pin Round Green Breakout Harness is used to measure voltage and resistance on circuits connected to the Engine Oil Pressure (EOP) sensor.

**96-Pin Breakout Box – DLC II**

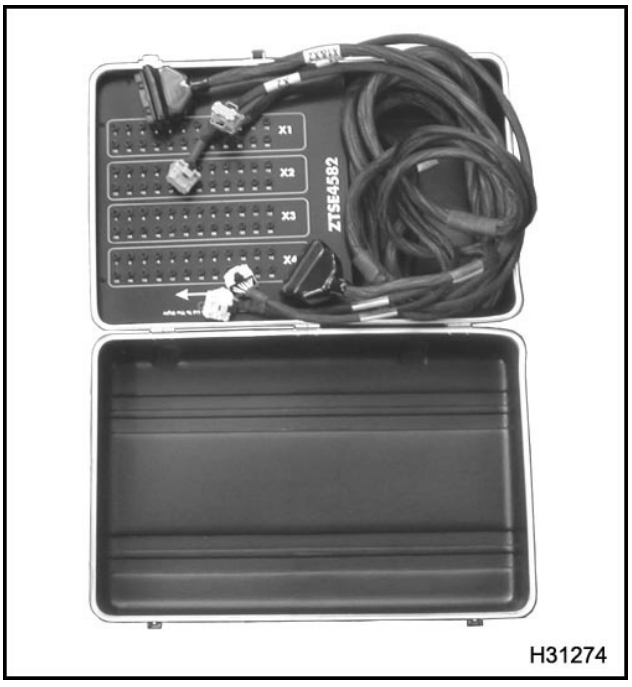


**Figure 297 ZTSE4582**

The 96-Pin Breakout Box – DLC II allows testing of the Engine Interface Module (EIM) controlled components without disturbing connections or piercing wire insulation when accessing various signal voltages in the electronic control system.

**CAUTION:** To prevent damage to the breakout box, the breakout box is used for measurement only, not to activate or control circuits. High current levels passing through the breakout box will burn out the internal circuitry.

**180-Pin Breakout Box**

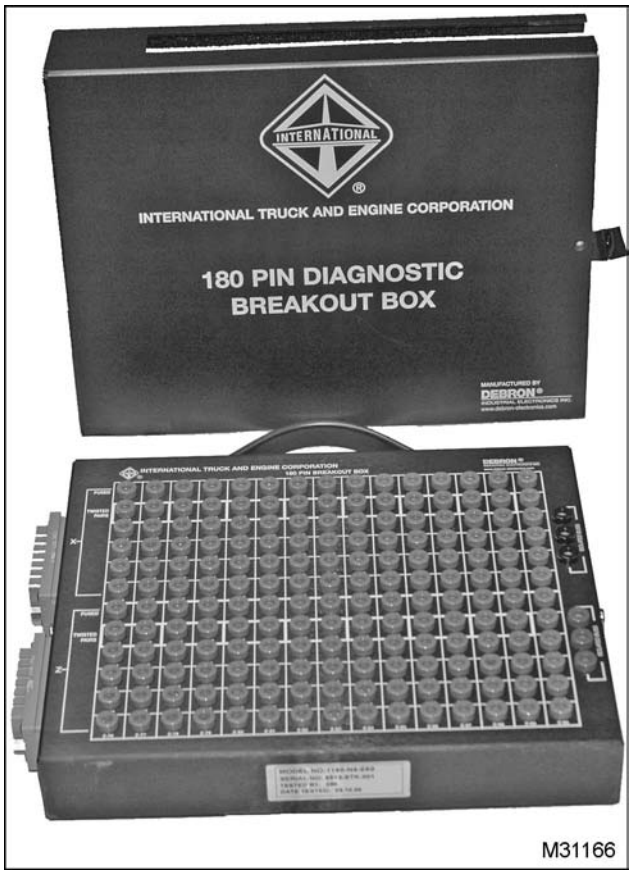


**Figure 298 1180-N4-0X0**

The 180-Pin Breakout Box allows testing of the Engine Control Module (ECM) and Aftertreatment Control Module (ACM) controlled components without disturbing connections or piercing wire insulation when accessing various signal voltages in the electronic control system.

**CAUTION:** To prevent damage to the breakout box, the breakout box is used for measurement only, not to activate or control circuits. High current levels passing through the breakout box will burn out the internal circuitry.

This box is a universal type box that can adapt to any control system by means of a unique jumper harness. Each jumper harness is a separate part, complete with a breakout box overlay (pin identifier) sheet.

The standard box layout is as follows:

- Two 90-pin connectors which feed 90 banana plug probing points.
- Each 90-pin section of the box is basically a stand alone box.
- The top row is all fuse protected circuits, the second row is all twisted pair circuits.

**500 Ohm Resistor Harness**

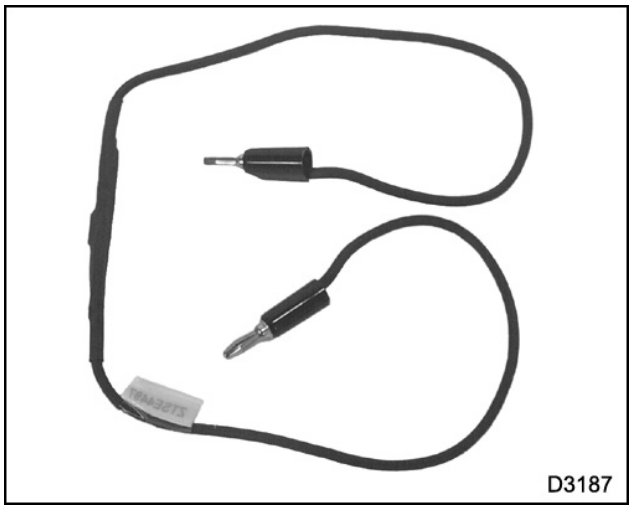


**Figure 299 ZTSE4497**

The 500 Ohm Resistor Harness is used for sensor end diagnostics of sensor circuits.

**Aftertreatment Harness**

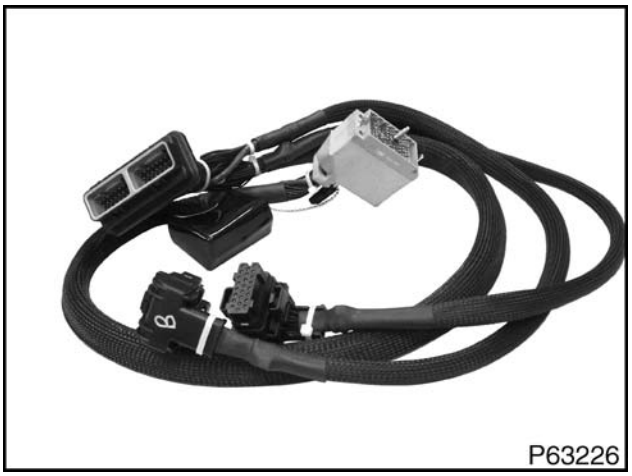


**Figure 300 00-01161-00**

The Aftertreatment Harness with breakout box overlay (pin identifier) sheet is used with the 180-pin breakout box to test circuits connected to the ACM.

**Aftertreatment 2-Pin Breakout Harness**

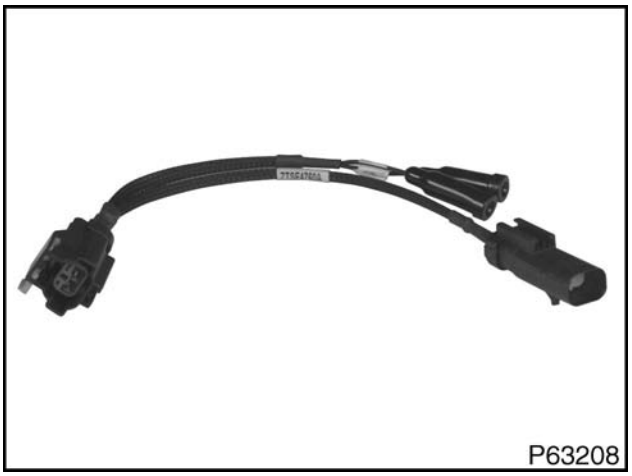


**Figure 301 ZTSE4760A**

The Aftertreatment 2-Pin Breakout Harness is used to measure voltage and resistance on circuits connected to the Exhaust Gas Temperature (EGT) sensors, Aftertreatment Fuel Supply (AFS) valve, Aftertreatment Fuel Injector (AFI), and Aftertreatment Fuel Drain (AFD) valve.

**Aftertreatment Fuel Pressure Breakout Harness**

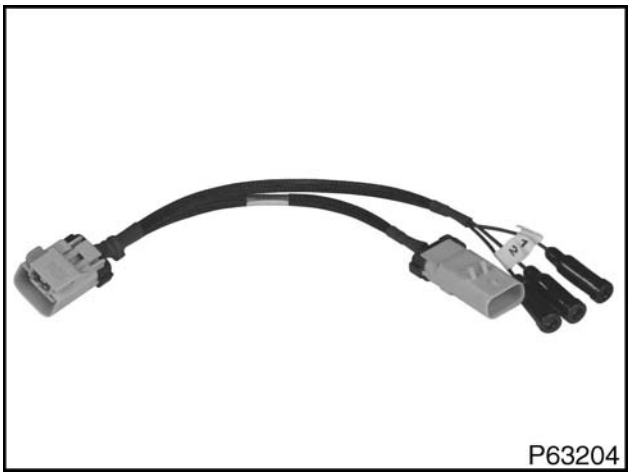


**Figure 302 ZTSE4845**

The Aftertreatment Fuel Pressure Breakout Harness is used to measure the voltage and resistance on circuits connected to the Aftertreatment Fuel Pressure (AFP) sensor.

**Amp Clamp**

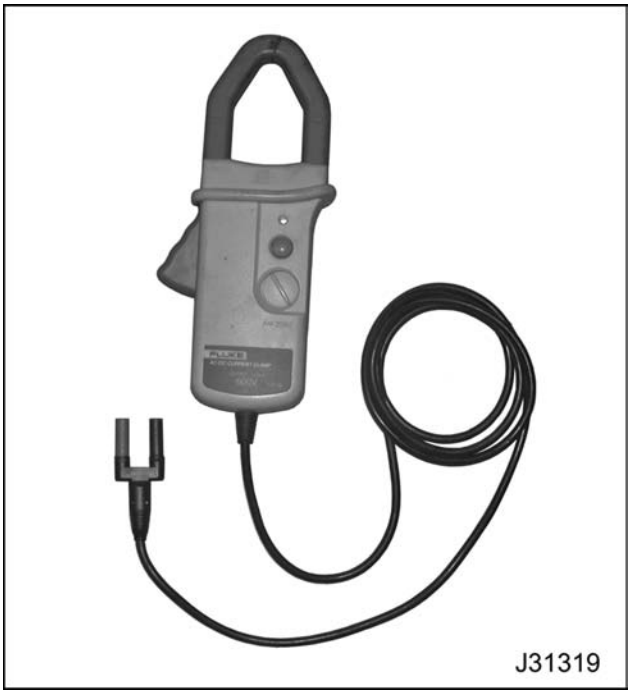


**Figure 303 ZTSE4575**

The Amp Clamp is used to measure amperage draw for the cold start assist system glow plug.

**APS/IVS Sensor Breakout Harness**

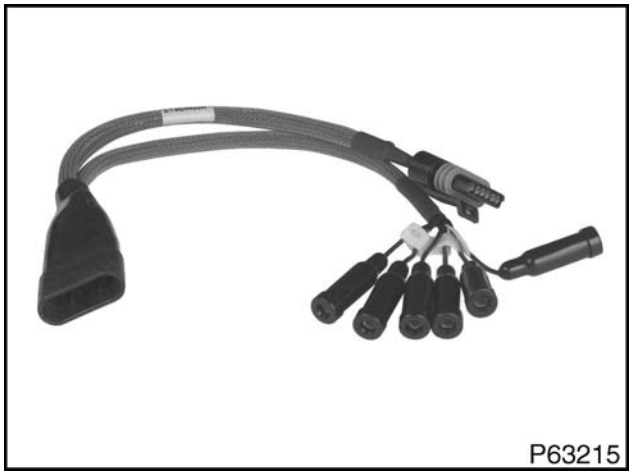


**Figure 304 ZTSE4485A**

The APS/IVS Sensor Breakout Harness is used to measure voltage and resistance on circuits connected to the APS/IVS sensor.

**Boost Control Solenoid Breakout Harness**

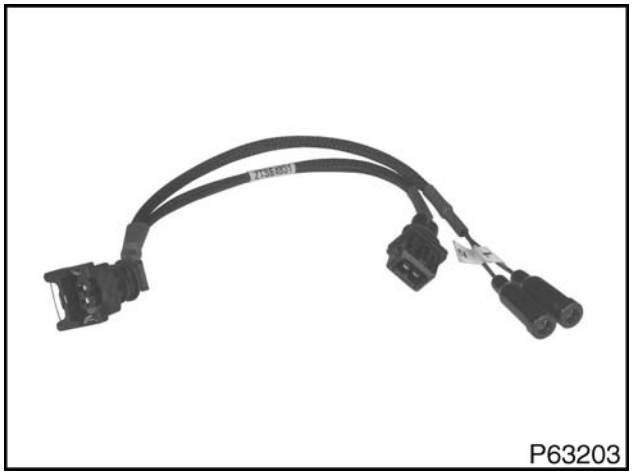


**Figure 305 ZTSE4831**

The Boost Control Solenoid Breakout Harness is used to measure voltage and resistance on circuits connected to the Boost Control Solenoid (BCS) valve.

**Breakout Harnesses Kit**


**Figure 306 ZTSE4904**

The Breakout Harness Kit contains the following:

- 4-Pin Round Black Breakout Harness
- 4-Pin Round Blue Breakout Harness
- 4-Pin Round Gray Breakout Harness
- 4-Pin Round Green Breakout Harness
- Aftertreatment 2-Pin Breakout Harness
- Aftertreatment Fuel Pressure Breakout Harness
- APS/IVS Sensor Breakout Harness
- Boost Control Solenoid Breakout Harness
- CMP, CKP and FPCV Breakout Harness
- Coolant Flow Valve Breakout Harness
- Coolant Mixer Valve Breakout Harness
- Cold Start Relay Breakout Harness
- EGDP Breakout Harness
- EGR Position and ITV Breakout Harness
- EIM Power Relay Breakout Harness
- ELS and V8 EGR breakout Harness
- Engine Fan Control Breakout Harness
- FRP Breakout Harness
- MAP/IAT2 Breakout Harness
- Retarder Control Breakout Harness

**Cold Start Relay Breakout Harness**

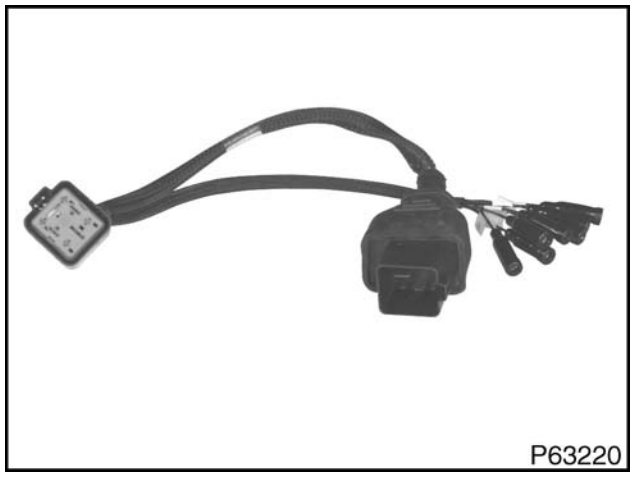


**Figure 307 ZTSE4885**

The Cold Start Relay Breakout Harness is used to measure voltage and resistance on circuits connected to the Cold Start Relay (CSR).

**Coolant Flow Valve Breakout Harness**

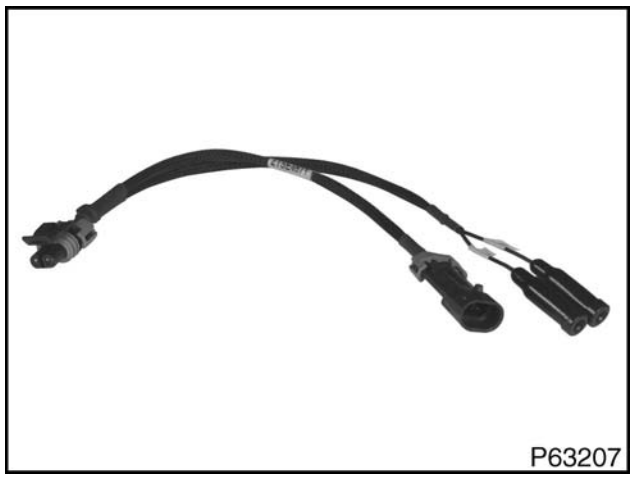


**Figure 308 ZTSE4871**

The Coolant Flow Valve Breakout Harness is used to measure voltage and resistance on circuits connected to the Coolant Flow Valve (CFV).

**Coolant Mixer Valve Breakout Harness**

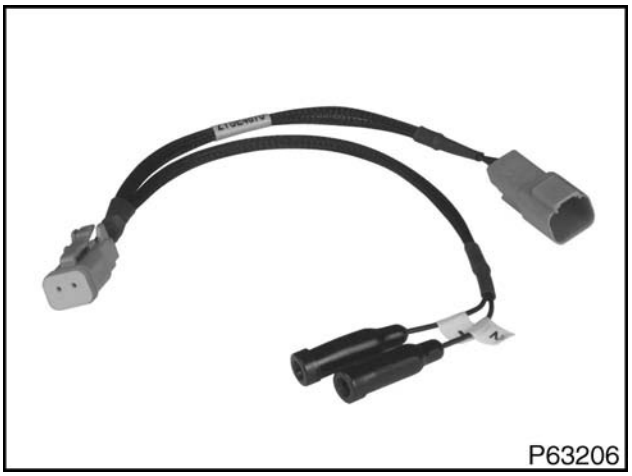


**Figure 309 ZTSE4870**

The Coolant Mixer Valve Breakout Harness is used to measure voltage and resistance on circuits connected to the Coolant Mixer Valve (CMV).

**CMP, CKP and FPCV Breakout Harness**

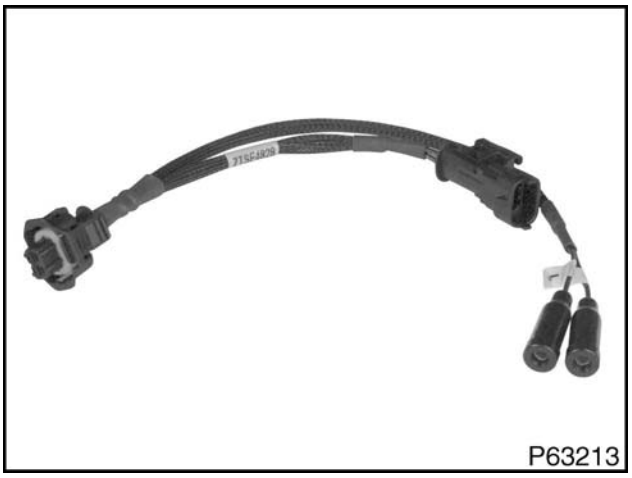


**Figure 310 ZTSE4828**

The CMP, CKP and FPCV Breakout Harness is used to measure voltage and resistance on circuits connected to the Fuel Pressure Control Valve (FPCV), Crankshaft Position (CKP) sensor and Camshaft Position (CMP) sensor.

**Digital Multimeter (DMM) (Fluke 88V)**


**Figure 311 ZTSE4357**

The Digital Multimeter (DMM) (Fluke 88V) is used to troubleshoot electrical components, sensors, injector solenoids, relays, and wiring harnesses. The DMM has a high input impedance that allows testing of sensors while the engine is running, without loading the circuit being tested. This ensures the signal voltage measurement is not affected by the voltmeter.

**E1-Engine Harness**


**Figure 312 00-01160-00**

The E1-Engine Harness with breakout box overlay (pin identifier) sheet is used with the 180-pin breakout box to test circuits connected to the ECM E1 connector.

**E2-Engine, D-Injector, C-Chassis Harness**


**Figure 313 00-01162-00**

The E2-Engine, D-Injector, C-Chassis Harness with breakout box overlay (pin identifier) sheet is used with the 180-pin breakout box to test circuits connected to the ECM E2, D, and powertrain harness connectors.

**EGDP Breakout Harness**

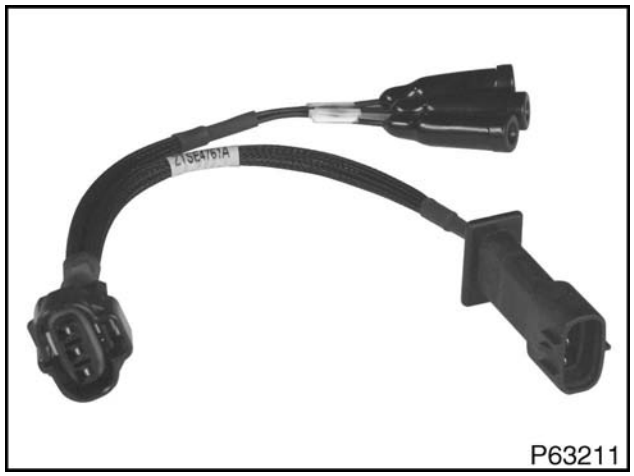


**Figure 314 ZTSE4761A**

The EGDP Breakout Harness is used to measure voltage and resistance on circuits connected to the Exhaust Gas Differential Pressure (EGDP) sensor.

**EGR Position and ITV Breakout Harness**

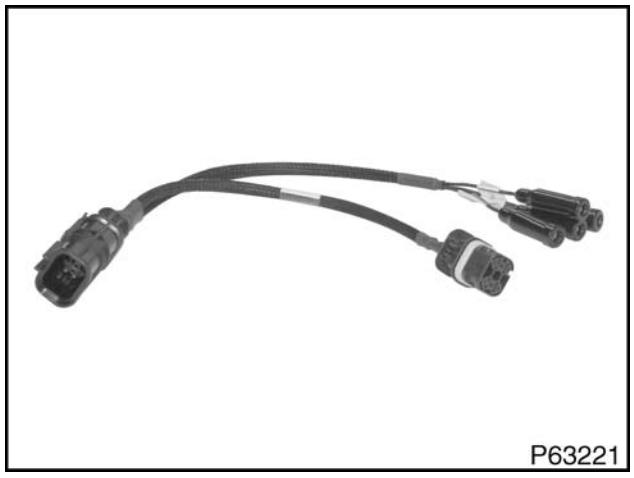


**Figure 315 ZTSE4833**

The EGR Position and ITV Breakout Harness is used to measure voltage and resistance on circuits connected to the Exhaust Gas Recirculation Position (EGRP) sensor and Intake Throttle Valve (ITV).

**EIM Power Relay Breakout Harness**

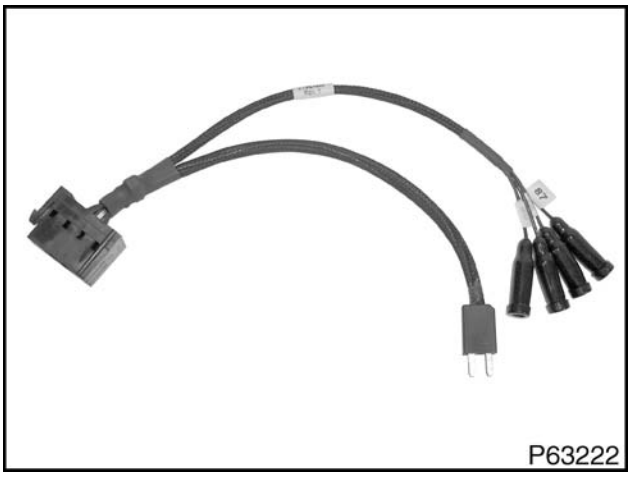


**Figure 316 ZTSE4908**

The EIM Power Relay Breakout Harness is used to measure voltage and resistance on circuits to the EIM relay.

**ELS and V8 EGR Breakout Harness**

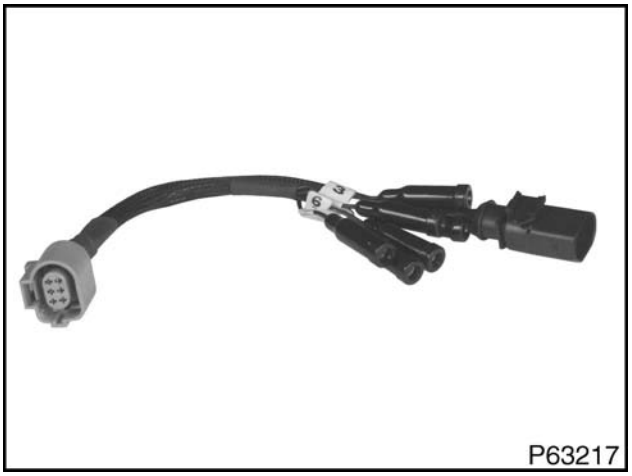


**Figure 317 ZTSE4735A**

The ELS and V8 EGR Breakout Harness is used to measure voltage and resistance on circuits connected to the Exhaust Lambda Sensor (ELS).

**Engine Fan Control Breakout Harness**

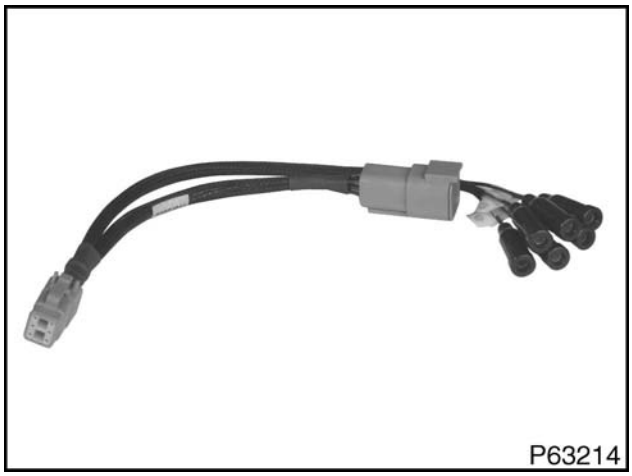


**Figure 318 ZTSE4844**

The Engine Fan Control Breakout Harness is used to measure voltage and resistance on circuits connected to the variable electronic fan control.

### EZ-Tech® Electronic Service Tool (EST)

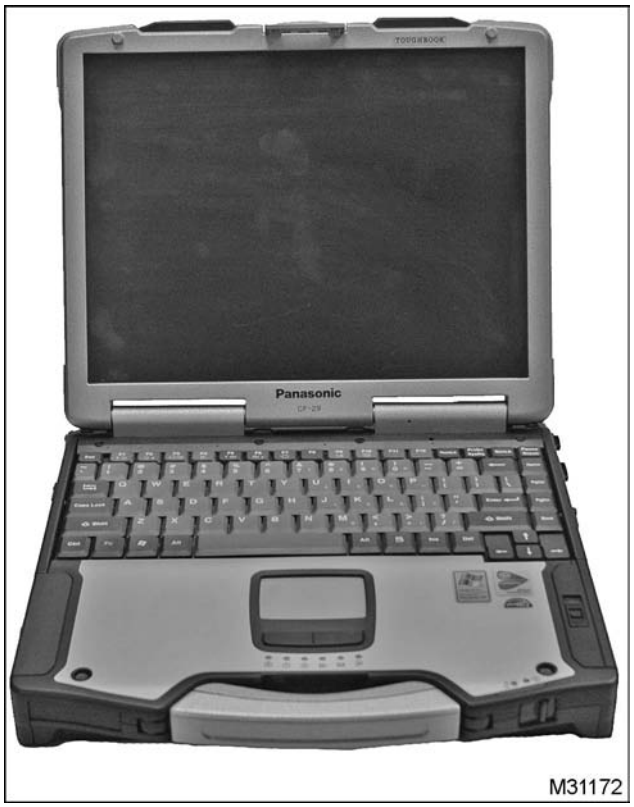


**Figure 319 J-45067**

The EZ-Tech® Electronic Service Tool (EST) is used to run the MasterDiagnostics® software for diagnosing and troubleshooting engine and vehicle problems.

### MasterDiagnostics® Software

MasterDiagnostics® software, loaded to an EST or laptop computer, is used to check performance of engine systems, diagnose engine problems, and store troubleshooting history for an engine.

### FRP Breakout Harness

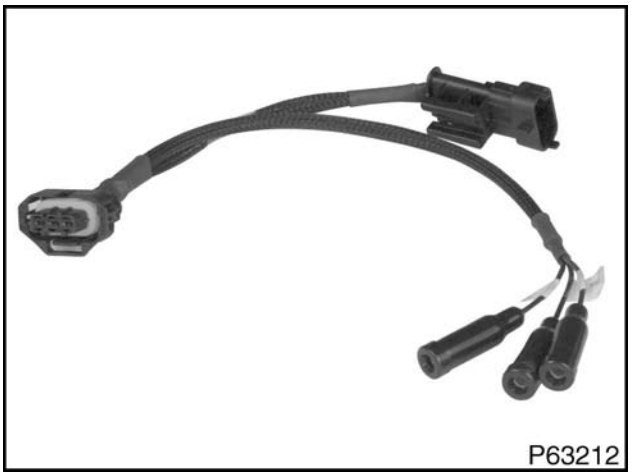


**Figure 320 ZTSE4829**

The FRP Breakout Harness is used to measure voltage and resistance on circuits connected to the Fuel Rail Pressure (FRP) sensor.

### IC4 USB Interface Cable


**Figure 321 ZTSE4632-USB**

The IC4 USB Interface Cable connects the EST to the truck Controller Area Network (CAN) through the vehicle diagnostic connector.

**MAP/IAT2 Breakout Harness**

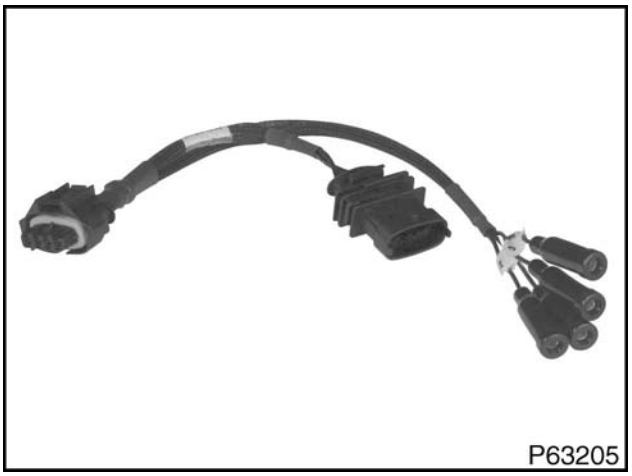


**Figure 322 ZTSE4830**

The MAP/IAT2 Breakout Harness is used to measure voltage and resistance on circuits connected to the Manifold Absolute Pressure/ Intake Air Temperature (MAP/IAT2) sensor.

**Retarder Control Breakout Harness**

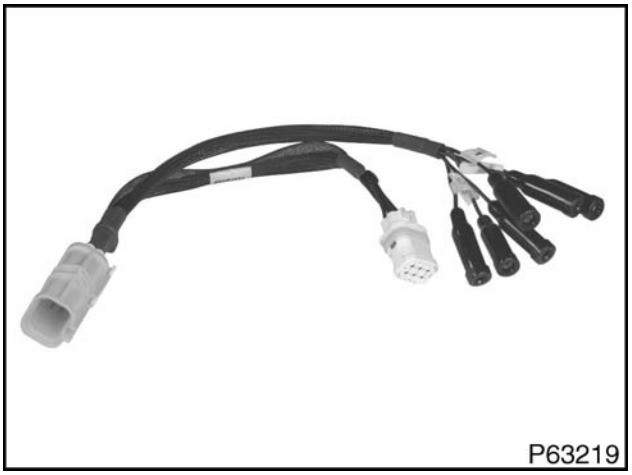


**Figure 323 ZTSE4834**

The Retarder Control Breakout Harness is used to measure voltage and resistance on circuits connected to the retarder control.

**Temperature Sensor Breakout Harness**

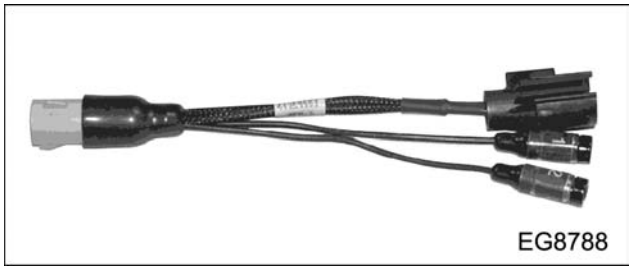


**Figure 324 ZTSE4483**

The Temperature Sensor Breakout Harness is used to measure voltage and resistance on circuits connected to the Intake Air Temperature (IAT) sensor.

**Terminal Test Adapter Kit**


**Figure 325 ZTSE4435A**

The Terminal Test Adapter Kit is used to access circuits in the connector harness and allows for the use of a DMM without damaging the harness

connectors. The probes may also be used as a guide to determine whether the harness connector is retaining correct tension on the mating terminal.

## Mechanical Tools

### Air Intake Guard

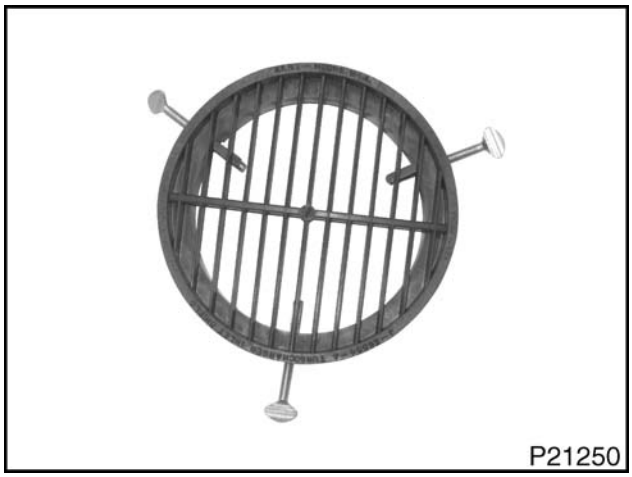


**Figure 326 ZTSE4893**

The Air Intake Guard is used to protect the turbochargers while performing diagnostics with the air cleaner disconnected.

### Crankcase Pressure Test Adapter

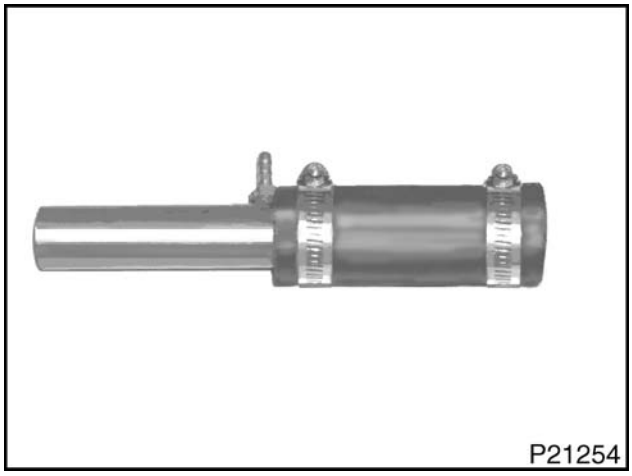


**Figure 327 ZTSE4039 (0.406 in. diameter)**

The Crankcase Pressure Test Adapter is used to measure combustion gas flow from the valve cover and may be used with the magnehelic gauge or slack tube manometer.

Use the pressure readings obtained with this adapter as the main source of engine condition. Use oil consumption trend data if the pressure readings are over the specified limits. Neither changes in oil consumption trends nor crankcase diagnostic pressure trends can establish a specific problem. These changes only indicate that a problem exists.

### Digital Manometer


**Figure 328 Locally obtained**

The digital manometer is used to measure low vacuum for intake restriction or low crankcase pressure. A variety of digital manometers are available for purchase locally.

**Disposable Air and Fuel Caps**

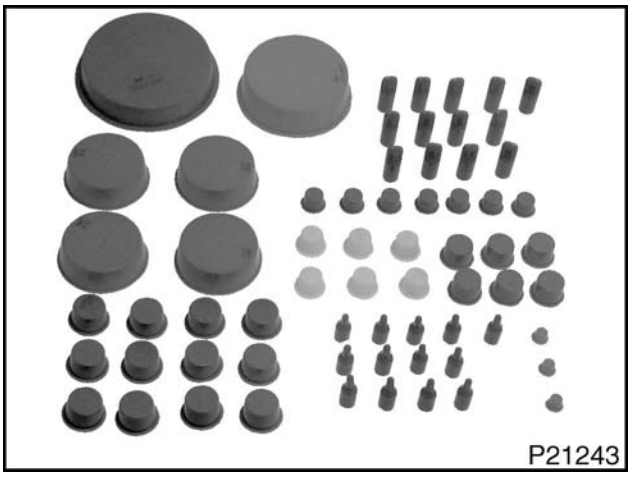


**Figure 329 ZTSE4891**

The Disposable Air and Fuel Caps are used to cap the fuel system lines and fittings when the fuel system is disconnected for diagnostics. The Disposable Air and Fuel Caps prevent dirt and foreign particles from entering and contaminating the fuel system.

**EGR Cooler Pressure Test Plates**

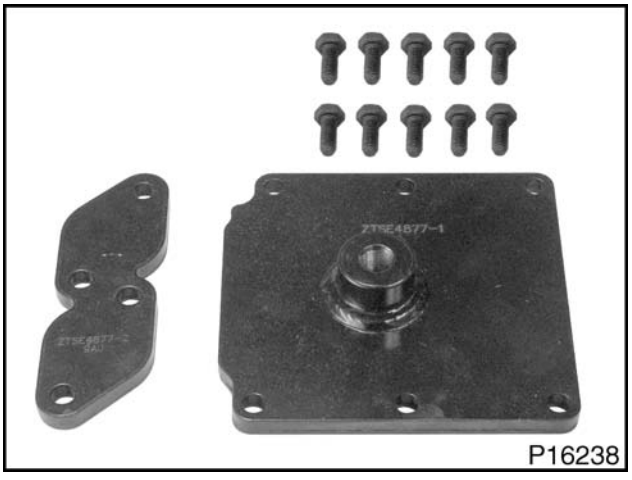


**Figure 330 ZTSE4877**

The EGR Cooler Pressure Test Plates are used to pressure test the EGR cooler.

**Fuel Block Off Tool**

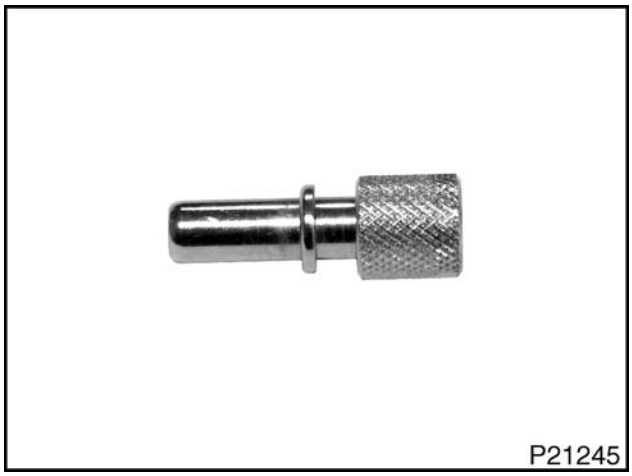


**Figure 331 ZTSE4905**

The Fuel Block Off Tool is used to block the T-connector fuel line at the high pressure pump in order to measure the low pressure pump output pressure.

**Fuel Fitting Adapter**


**Figure 332 ZTSE4906**

The Fuel Fitting Adapter is used in conjunction with the Fuel Inlet Restriction and Aeration Tool to measure the fuel pressure in the return line.

**Fuel Inlet Restriction and Aeration Tool**

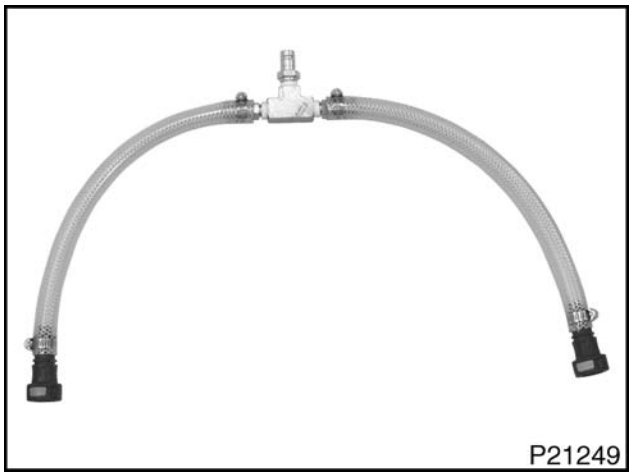


**Figure 333 ZTSE4886**

The Fuel Inlet Restriction and Aeration Tool is used to check for pressure and aerated fuel in the low fuel pressure system.

**Fuel Line Disconnect Tool 11.8 mm**

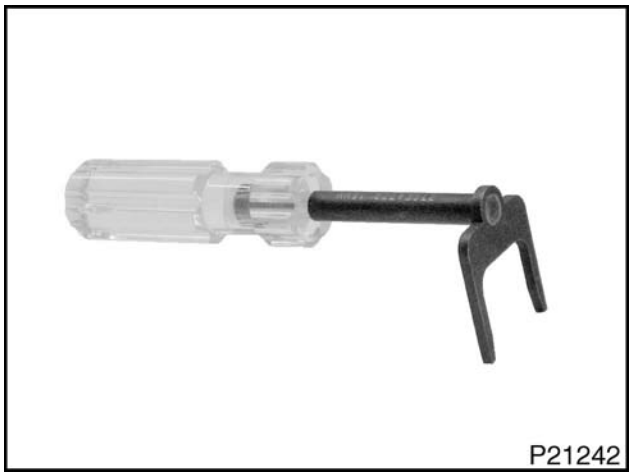


**Figure 334 ZTSE4773**

The Fuel Line Disconnect Tool 11.8 mm is used to release the locking mechanism on low pressure fuel line connectors.

**Fuel Line Disconnect Tool 16 mm**

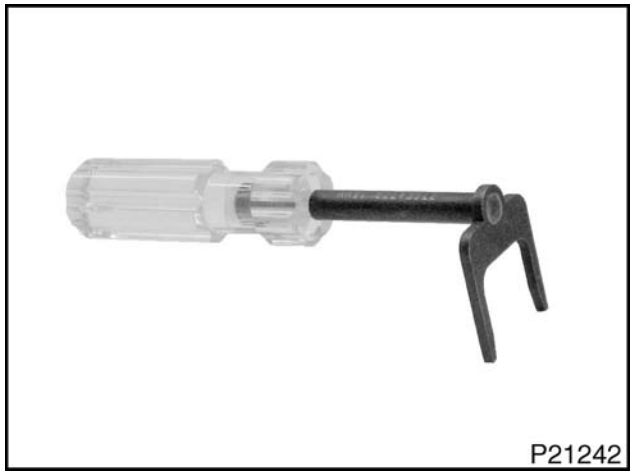


**Figure 335 ZTSE4772**

The Fuel Line Disconnect Tool 16 mm is used to release the locking mechanism on low pressure fuel line connectors.

**Fuel Pressure Gauge**

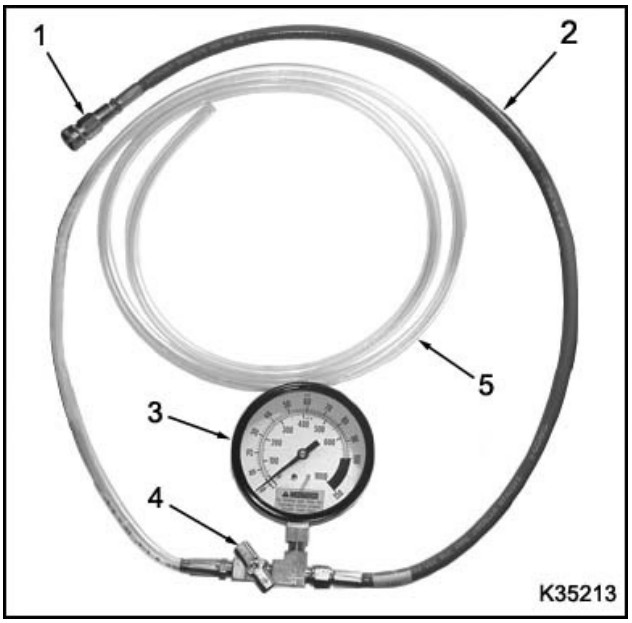


**Figure 336 ZTSE4681**

1. Quick disconnect check valve
2. Fuel test line
3. Fuel Pressure Gauge
4. Inline shut-off valve
5. Clear test line

The Fuel Pressure Gauge is used to check for fuel pressure and aerated fuel in the low fuel pressure system.

**Gauge Bar Tool**

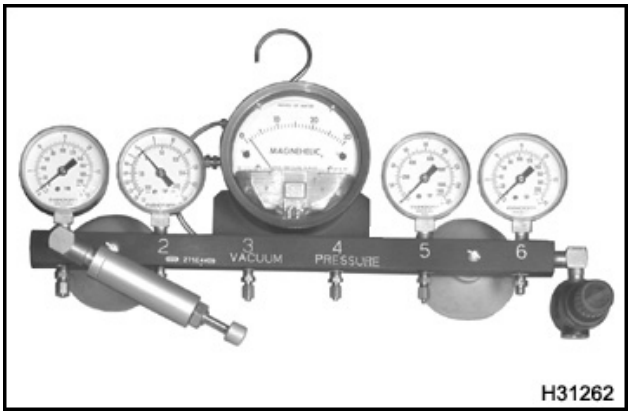


**Figure 337 ZTSE4409**

The Gauge Bar Tool is used to measure intake manifold (boost) pressure, fuel system inlet restriction, fuel pressure, oil pressure, air cleaner intake restriction, and crankcase pressure.

- 0 kPa to 200 kPa (0 psi to 30 psi) measures intake manifold pressure.
- 0-30 in-Hg vacuum /0 kPa to 200 kPa (0 psi to 30 psi) compound gauge measures fuel system inlet restriction and intake manifold pressure.

  0-30 in-$H_2O$ 0 kPa to 7.5 kPa (0 psi to 1 psi) maximum pressure magnehelic gauge measures crankcase pressure and air inlet restriction.
- 60 kPa to 1100 kPa (0 psi to 160 psi) gauge may be used to check the fuel pressure and oil pressure.

**High Pressure Rail Plugs**

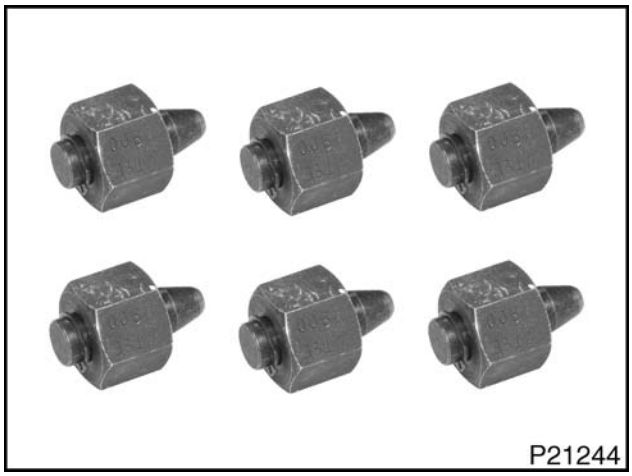


**Figure 338 ZTSE4900**

The High Pressure Rail Plugs are used to isolate individual injectors by blocking the pressure pipe rail output.

**High Pressure Return Line Tester**

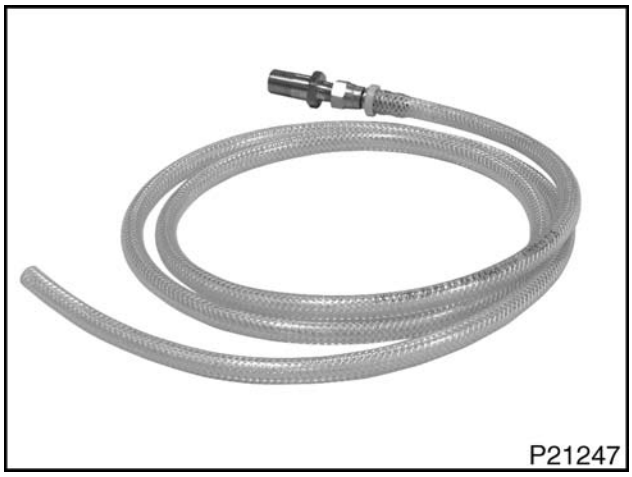


**Figure 339 ZTSE4887-1 – 17 mm**

The 17 mm High Pressure Return Line Tester is used to check for fuel returning from the pressure pipe rail.

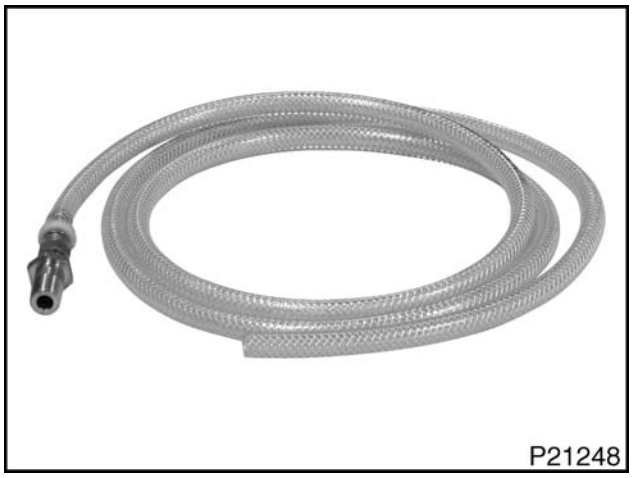


**Figure 340 ZTSE4887-2 – 19 mm**

The 19 mm High Pressure Return Line Tester is used to check for excessive fuel returning from the fuel injectors at the cylinder head fuel return port.

**Plastic Surge Tank Cap Adaptor**

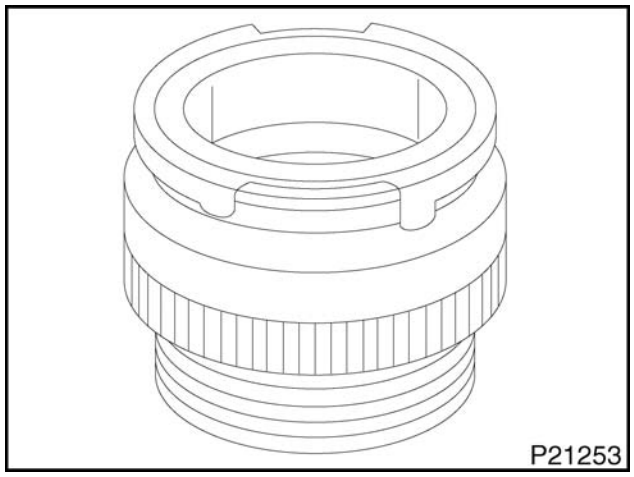


**Figure 341 ZTSE23842**

The Plastic Surge Tank Cap Adaptor is used to block off the surge tank while performing a cooling system pressure test.

**Radiator Pressure Testing Kit**

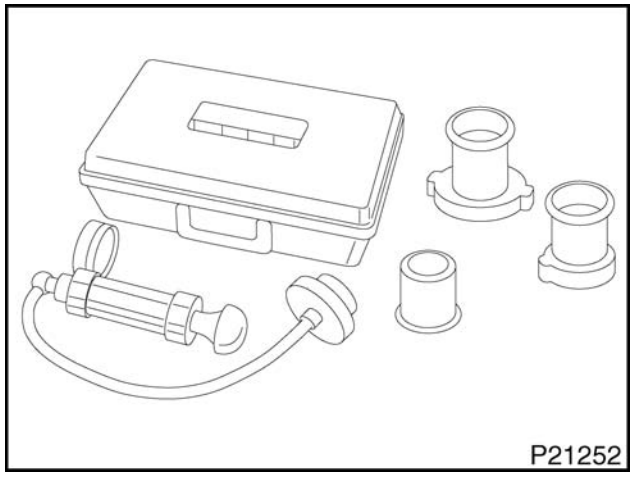


**Figure 342 ZTSE2384**

The Radiator Pressure Test Kit is used to check pressure caps and cooling systems. The easy-to-read pressure gauge indicates if the cap is in good condition and whether the cooling system leaks.

**Slack Tube Manometer**

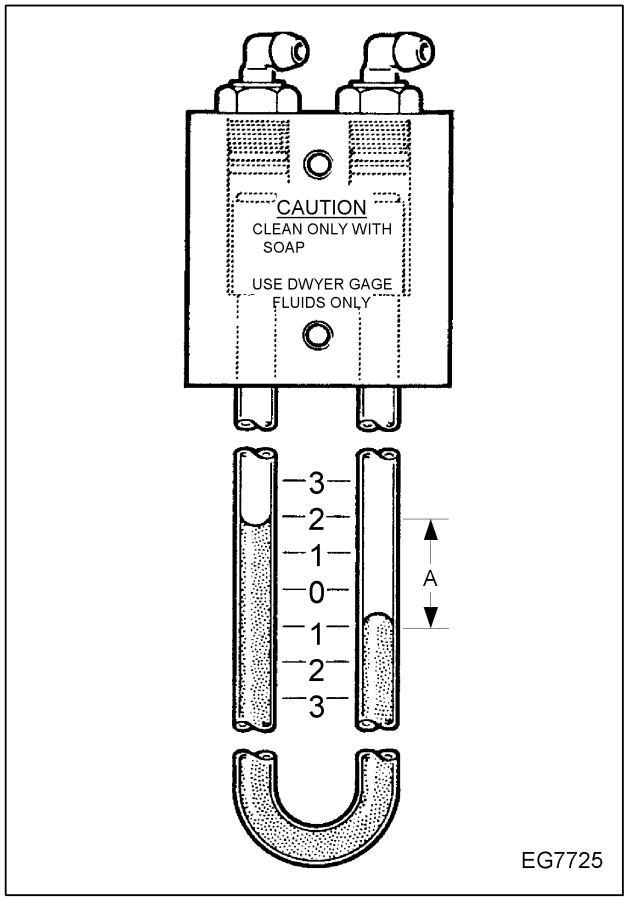


**Figure 343 ZTSE2217A**

The Slack Tube Manometer is a U-shaped tube with a scale mounted between the legs of the tube. When the portability of the gauge bar tool is not required, this manometer is used to measure low vacuum for intake restriction or low crankcase pressure.

**Filling**

Fill the manometer with water before checking pressure. Use only distilled water. Add some colored water vegetable dye so the scale can be read more easily. With both legs of the manometer open to the atmosphere, fill the tube until the top of the fluid column is near the zero mark on the scale. Shake the tube to eliminate any air bubbles.

**Installing, Reading, and Cleaning**

1. Support the manometer vertically. Make sure the fluid level is in line with the zero indicator on the graduated scale.
2. Connect one leg of the manometer to the source of the pressure or vacuum. Leave the other leg open to atmospheric pressure.
3. Start the engine and allow it to reach normal operating temperature. Then run the engine to high idle. The manometer can be read after 10 seconds.
4. Record the average position of the fluid level when it is above and below the zero indicator. Add the two figures together. The sum of the two is the total column of fluid (distance A). This represents the crankcase pressure in inches of water (in-$H_2O$).

   At times, both columns of the manometer will not travel the same distance. This is no concern if the leg not connected to the pressure or vacuum source is open to the atmosphere.
5. Compare the manometer reading with engine specifications.
6. When the test is done, clean the tube thoroughly using soap and water. Avoid liquid soaps and solvents.

**UV Leak Detection Kit**


**Figure 344 ZTSE4618**

The UV Leak Detection Kit is used with fuel dye to quickly identify leaks. The fuel dye combines with

fuel and migrates out at the leak. The ultraviolet lamp illuminates the leaking fuel dye, which appears fluorescent yellow-green in color.

## Electronic Circuit Testing

### Electrical Theory

#### Voltage

Voltage is electrical pressure or force that pushes current through a circuit. The pressure is measured in volts. The symbol V (for example, 12 V) is used in circuit diagrams to denote voltage. The letter E (Electromotive force) is also used for voltage. Voltage can be compared to the pressure necessary to push water through a metering valve.

Low voltage to a lamp causes the lamp to glow dimly. This can be caused by low source voltage (discharged battery or low alternator output) or by high circuit resistance resulting from a poor connection. Resistance from a poor connection or poor ground is an additional load in the circuit. The additional load reduces voltage available to push current through the load device. Before making any meter measurements, review Ohm's Law.

#### Ohm's Law

Ohm's Law describes the relationship between current, voltage, and resistance in an electrical circuit. Ohm's Law also provides the basic formula for calculations.

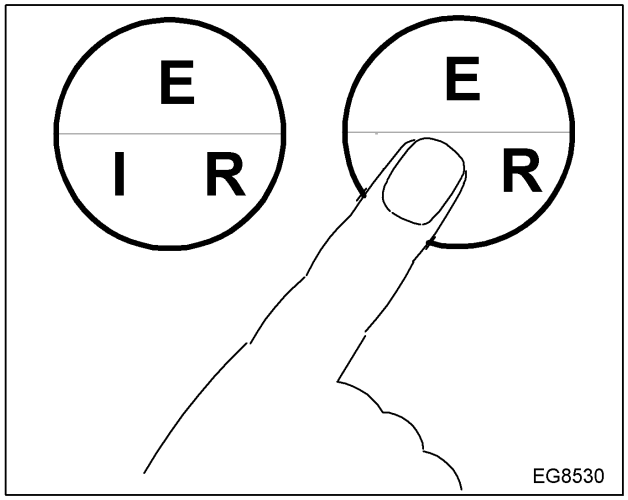


**Figure 345 Ohm's Law**

Memorize the formula in the circle. Cover the letter with a finger for the desired formula. For example, I is covered, the formula is I = E ÷ R.

If two values are known for a given circuit, the missing one can be found by substituting the values in amperes, volts, or ohms.

The three basic formulas for Ohm's Law are as follows:
I = Current (amperes)
E = Voltage (volts)
R = Resistance (ohms)

- I = E ÷ R

  This formula states that the current flow (I) in the circuit equals the voltage (E) applied to the circuit divided by the total resistance (R) in the circuit. This shows that an increase in voltage or a decrease in resistance increases the current flow.

- E = I × R

  This formula states that the voltage (E) applied to the circuit equals the current flow (I) in the circuit multiplied by the total resistance (R) in the circuit. The voltage drop is caused by resistance across a particular load device in a series of load devices.

- R = E ÷ I

  This formula states that the total resistance (R) in the circuit equals the voltage (E) applied to the circuit divided by the current flow (I) in the circuit. Resistance can be calculated for a specific current flow when a specific voltage is applied.

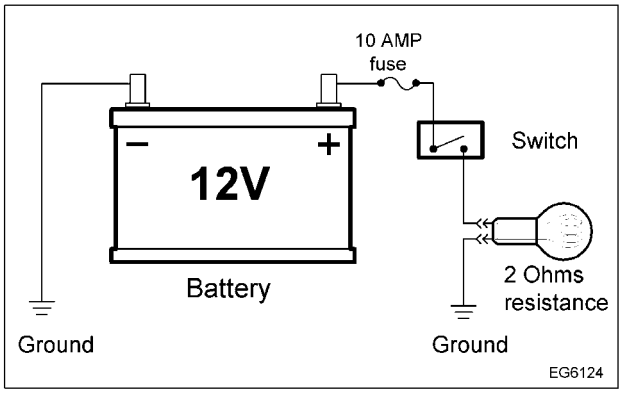


**Figure 346 Simple electrical circuit**

In a typical circuit, battery voltage is applied to a bulb through a 10 amp fuse and a switch. Closing the switch turns on the bulb.

To find the current flow, use the formula I = E ÷ R:

Fill in the numbers for the formula:

I = 12 V ÷ 2 ohms

I = 6 amps

The bulb in this circuit operates at 6 amps and is rated at 6 amps. With 12 volts applied, the bulb glows at the rated output level (candlepower rating). However,

- if the voltage applied is low (low battery), the value of E is lower, current flow is less, and the bulb glows less brightly.
- if connections are loose or the switch is corroded, the circuit resistance are greater (value of R is larger), the current flow is reduced, and the bulb glows less brightly.

Voltage drops are important for the following reasons:

- High voltage drops indicate excessive resistance. For example, if a blower motor runs too slowly or a light glows too dimly, the circuit may have excessive resistance. Voltage drop readings can isolate problems in parts of a circuit (corroded or loose terminals, for example).
- Too low of a voltage drop indicates low resistance. For example, if a blower motor runs too fast, the problem could be low resistance in a resistor pack.
- Maximum allowable voltage drop under load is critical, especially for more than one high resistance problem. All voltage drops in a circuit are cumulative. Corroded terminals, loose connections, damaged wires or other similar conditions create undesirable voltage drops that decrease the voltage available across the key components in the circuit. Increased resistance will decrease current flow in the circuit, preventing other components from operating at peak efficiency. A small drop across wires (conductors), connectors, switches, etc., is normal because all conductors have some resistance, but the total should be less than 10% of the total voltage drop in the circuit.

**Using the Digital Multimeter (DMM)**

The following electrical test equipment should be available for testing electronic circuits:

- Voltmeter
- Ohmmeter
- Ammeter
- Jumper wires
- Test lights

**Test Meters**

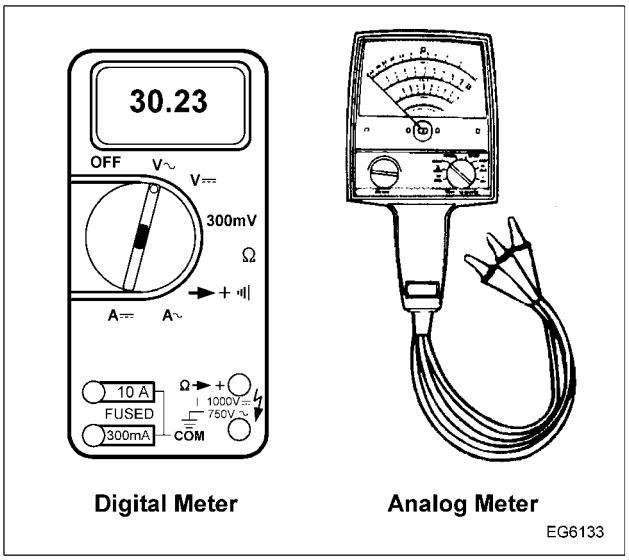


**Figure 347 Typical Test Meters**

Test meters come in a variety of models. Any working model will be adequate for simple tests. However, accurate readings are important. Make sure the test meter is of high quality. The Fluke 88 Digital Multimeter (DMM) is recommended because it has very little current and a high impedance (resistance) of 10 megaohms (10 MΩ).

**CAUTION:** Only use a high impedance digital multimeter when troubleshooting an electronic circuit. Do not use any kind of battery powered test light. Battery test lights can damage an electronic control circuit.

**NOTE:** Some devices in an electronic control system are not capable of carrying an appreciable amount of current. Therefore, test equipment must be designed to not damage any part the electronic control system. Do not use analog meters unless specified. Analog meters use too much current to test an electronic control system.

**Jumper Wires**

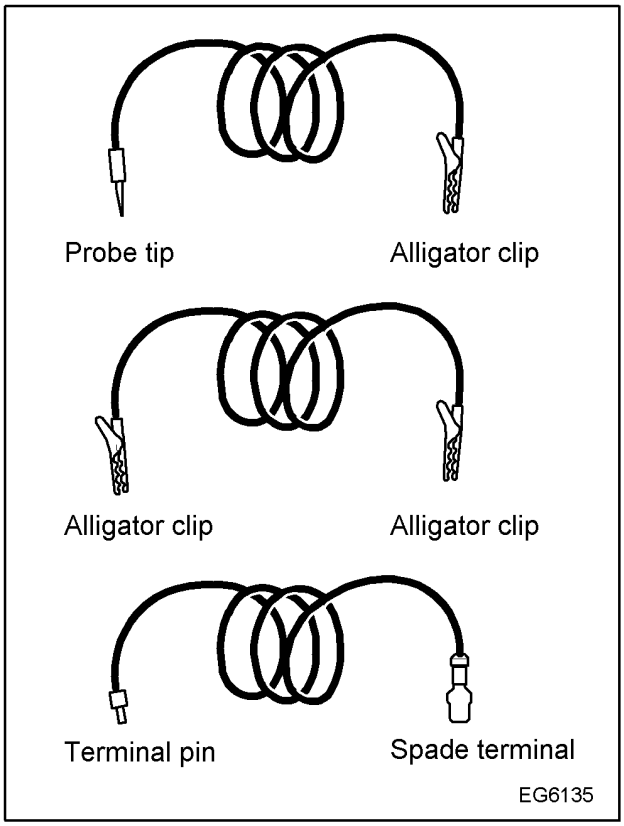


**Figure 348 Jumper wires**

Jumper wires allow a circuit to bypass a suspected opening or break in a circuit. Use a jumper wire to check for open relay contacts, wire breaks and poor ground connections. Several jumper wires with different tips should be available.

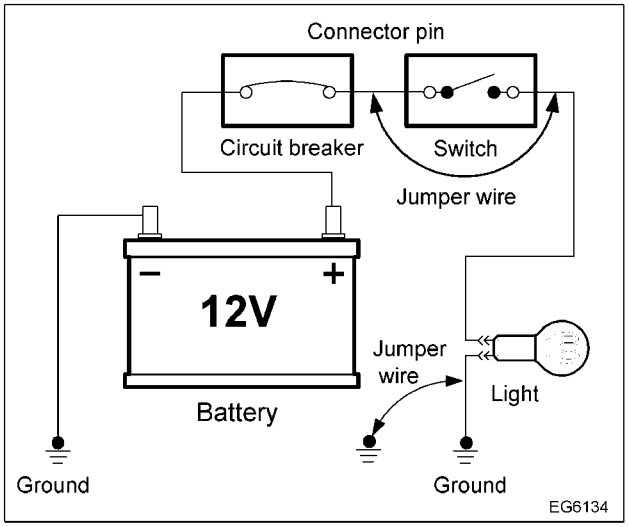


**Figure 349 Troubleshooting with jumper wires**

If the circuit works correctly with the jumper wire in place, but does not work when the jumper wire is removed, the circuit is open.

A circuit with no openings or breaks has continuity (uninterrupted current flow) and needs no further testing.

An opening in the ground circuit exists for the following:

- A switch is closed but the light does not illuminate.
- Jumping the switch does not illuminate the light.
- Jumping the light to the ground causes the light to illuminate.

### Voltmeter

Use a voltmeter to answer the following questions:

- Does the circuit have voltage?
- What is the voltage reading?
- What is the voltage drop across a load device?

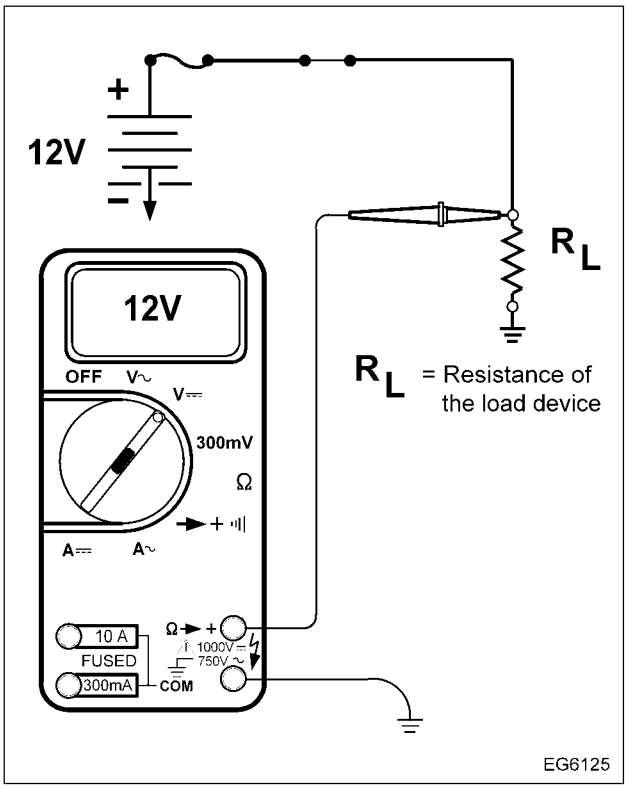


**Figure 350 Checking power to a load device**

To check for voltage to a load device, connect the positive meter lead to the input connection of the device (positive side) and connect the negative meter lead to a good vehicle ground.

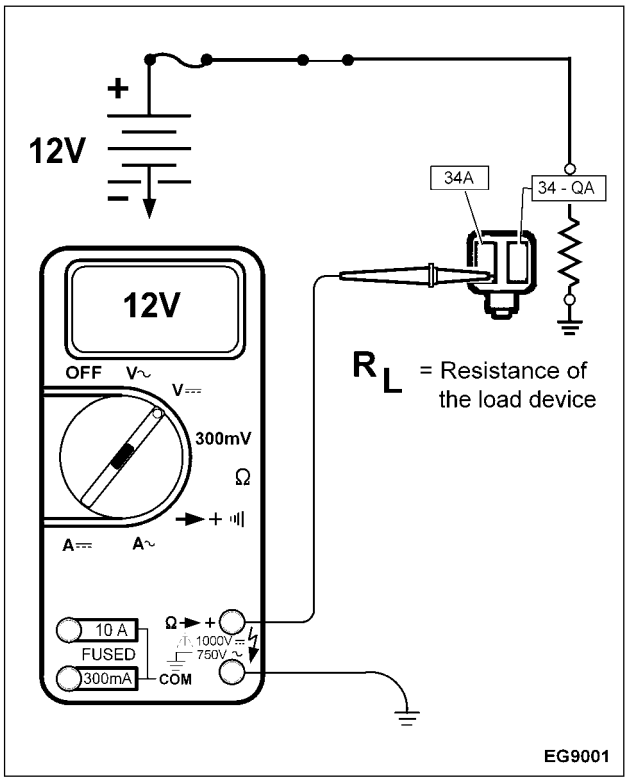


**Figure 351 Checking power to a connector**

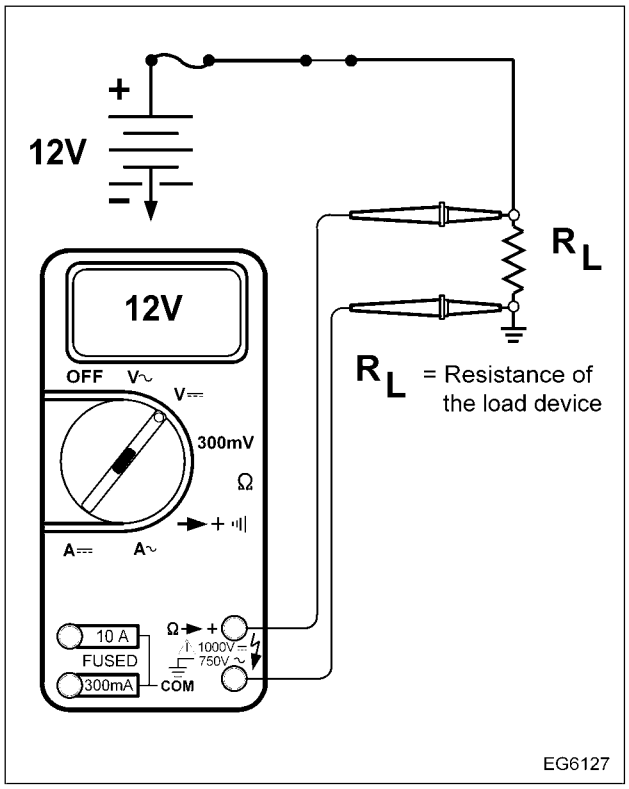


**Figure 352 Checking voltage drop**

Voltage to a device can also be measured by disconnecting the harness connector and using the correct tool in the Terminal Test Adapter Kit.

To check the voltage drop across a load device, connect the positive lead of the voltmeter to the positive side of the device and the negative meter lead to the negative side of the device.

With the device operating, this measures the voltage drop across the device. With only one device, all of the voltage should be dropped at the device. In any circuit, the voltage applied equals the voltage dropped in the circuit. If this circuit only dropped 9 V across the load, it indicates the wires and connections dropped 3 V, indicating excessive circuit resistance.

**Ammeter**

An ammeter measures current flow (amperage) in a circuit. Amperes (or amps) are units of electron flow that indicate how many electrons are passing through the circuit. An amp is the unit of measurement for the current flow in the circuit.

Ohm's Law states that the current flow is equal to the circuit voltage divided by the total circuit resistance (I = E ÷ R). Therefore, increasing the voltage also

increases the current flow. Any decrease in resistance also increases the current flow.

At normal operating voltage, most circuits have a characteristic amount of current flow (current draw). Current draw can be measured with an ammeter. Valuable diagnostic information can be provided by referring to a specified current draw rating for a component (electrical device), measuring the current flow in the circuit, and then comparing the two measurements (the specified current draw versus the actual measurement).

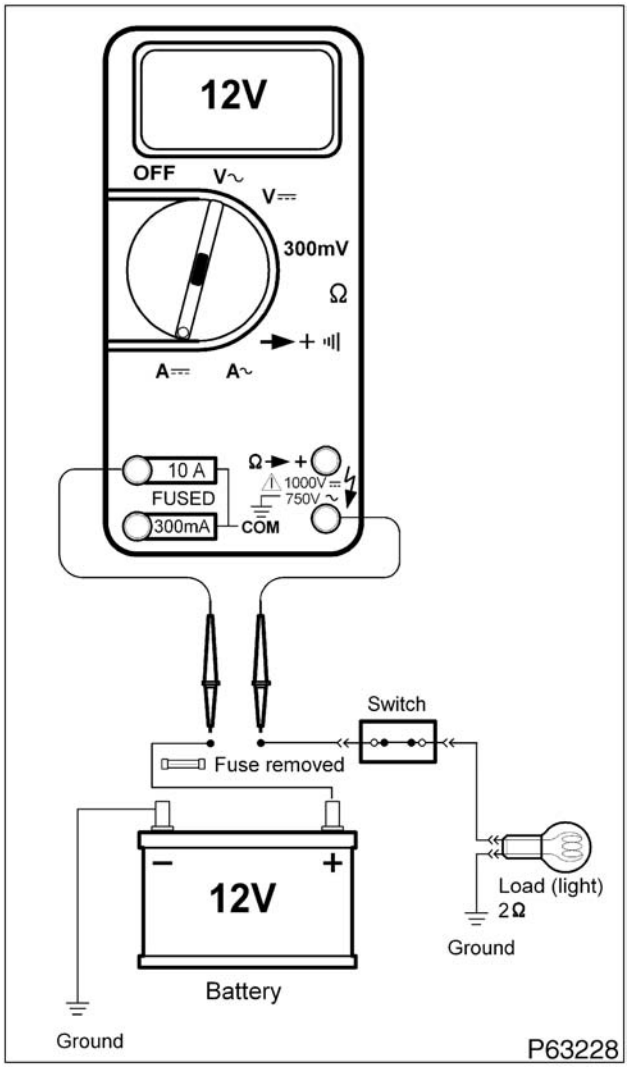


**Figure 353 Installing the ammeter**

An ammeter is connected in series with the load, so that all of the current flows through the meter. The ammeter measures current flow only when the circuit is powered up and operating. The DMM is fused to measure up to 10 amps using the 10 A connection point.

Before measuring current flow, determine approximately how many amps are in the circuit to correctly connect the ammeter. The estimate of current flow can easily be calculated. The resistance of the light bulb is 2 ohms. Applying Ohm's law, current flow will be 6 amps (6 amps = 12 V ÷ 2 ohms). If the fuse is removed and an ammeter is installed with the switch closed, 6 amps of current is measured flowing in the circuit. Notice that the ammeter is installed in series so that all the current in the circuit flows through it.

**WARNING: To avoid serious personal injury or possible death, always make sure the power is off before cutting, soldering, removing circuit components, or before inserting the digital multimeter for current measurements. Even small amounts of current can be dangerous.**

Excessive current draw means that more current is flowing in a circuit than the fuse and circuit were designed to handle. Excessive current draw opens fuses and circuit breakers, and also quickly discharges batteries. An ammeter can diagnose these conditions.

Reduced current draw causes a device (an electric window motor, for example) to operate poorly. Increased circuit resistance causes lower current flow (often due to loose or corroded connections).

### Ohmmeter

**CAUTION:** To prevent damage to the test meter, only use the ohmmeter on circuits when the power is OFF. Power from 12 V systems may damage the meter.

The ohmmeter measures resistance (ohms) in a circuit. Ohmmeters use a small battery to supply voltage and current flow through the circuit being tested. Based on Ohm's Law, the ohmmeter calculates resistance in the circuit by measuring the voltage of the meter battery and the amount of current flow in the circuit. Range selection and meter adjustment are not necessary with the DMM.

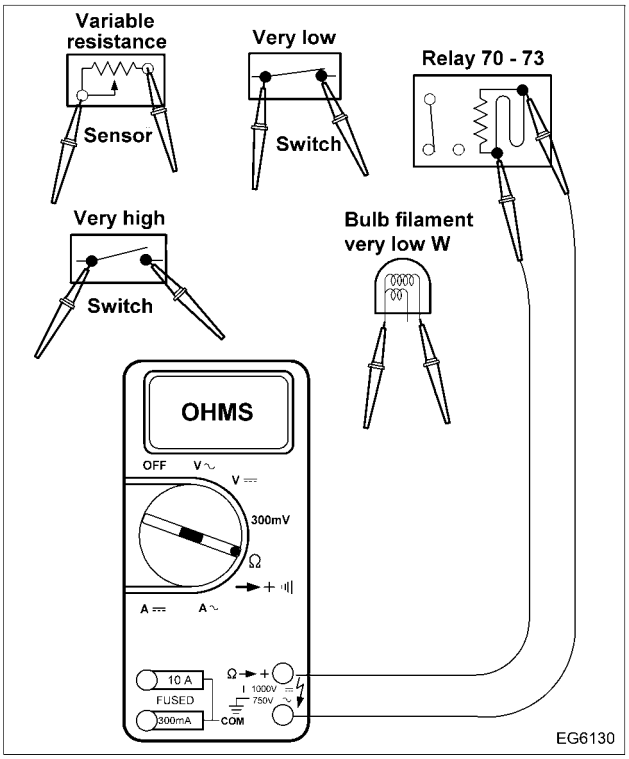


**Figure 354 Measuring resistance**

Resistance measurements are used to determine the resistance of a load or conductors, the value of resistors and the operation of variable resistors.

To measure the resistance of a component or a circuit, remove power from the circuit. Isolate the component or circuit from other components and circuits so that the meter current (from probe to probe) only flows through the selected component or circuit. When measuring the resistance of the load, most of the current flow from the meter goes through the indicator lamp because it has less resistance.

Remove one connector to the load. It is not always apparent when a component must be isolated, so it is a good practice to isolate a component or circuit by disconnecting one circuit. Place the ohmmeter leads across the component or circuit to display the resistance in ohms. When checking a sensor or variable resistor such as the fuel level gauge, heating the element or moving the arm should move the meter through a range of resistance that can be compared to a specification.

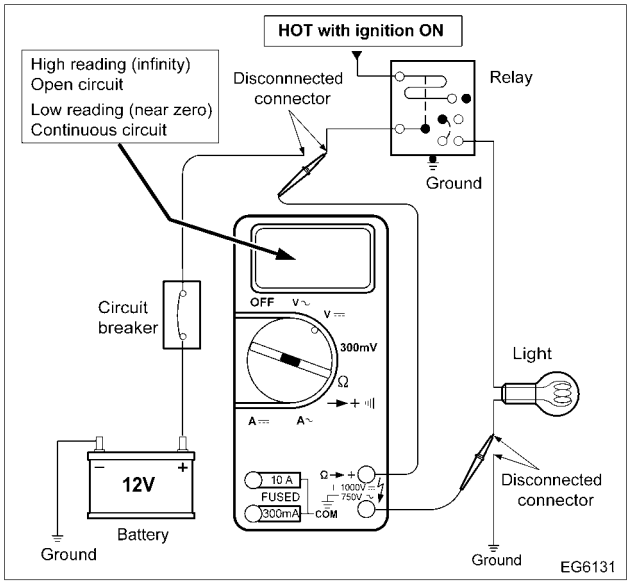


**Figure 355 Checking for open circuits**

Open electrical circuits can be diagnosed using an ohmmeter. Disconnect the power supply to the circuit and isolate the circuit from all other circuits. The circuit between the light and the ground is disconnected to prevent reading a circuit that may be shorted to ground ahead of the load device as a continuous circuit. Connect the ohmmeter to the open ends of the circuit. A high reading (infinity) indicates an open circuit. A reading near zero indicates a continuous circuit. With the Fluke 88 Digital Multimeter (DMM), an open circuit reads OL (over limit).

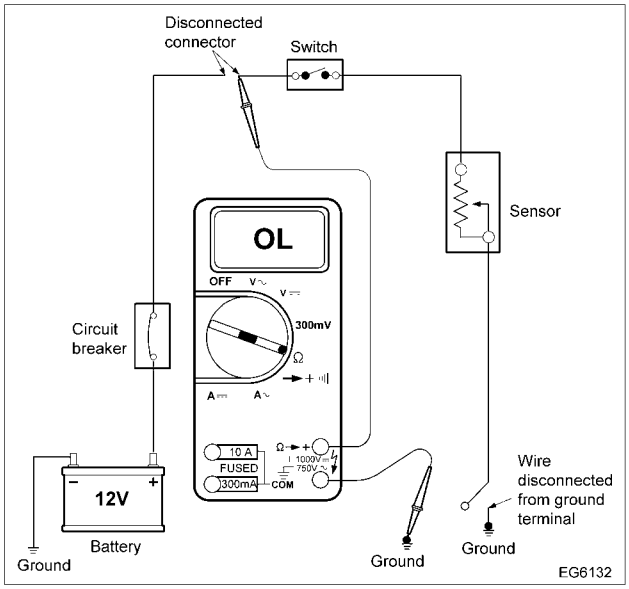


**Figure 356 Checking for short circuits**

Checks for short circuits are similar to checks for open circuits. Isolate the circuit from the power source and the ground point. Connect the ohmmeter between an isolated circuit and a good ground point to check the circuit for a short to ground. A short to ground is indicated by a reading near zero. A circuit that is not shorted to ground causes a high meter reading.

### Measuring Duty Cycle with Fluke 88

When measuring duty cycle, make sure the large dial on the meter is pointing to volts DC, the % DUTY button is set to the Duty Cycle function, and the trigger has a positive slope.

Use the following procedure to check duty cycle:

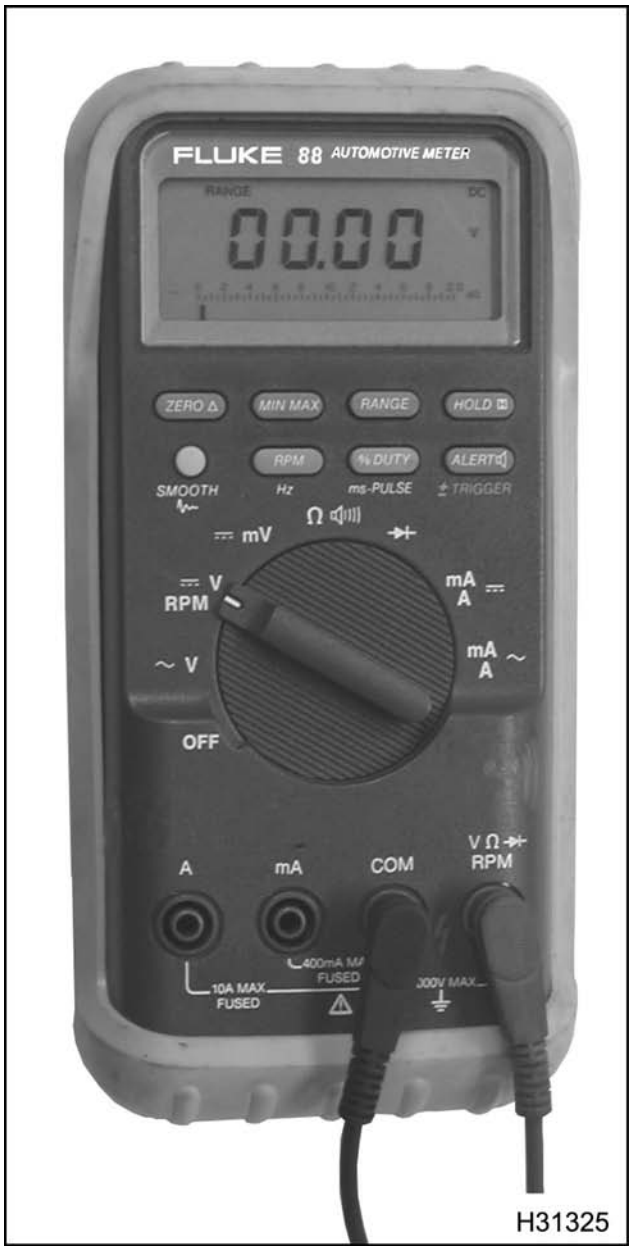


**Figure 357 Fluke 88 in volts DC mode**

1. Turn the large dial on the meter to volts DC, indicated by V RPM.


**Figure 358 Fluke 88 with negative trigger slope in duty cycle mode**

2. Press the % DUTY button to select duty cycle mode. The screen on the meter shows TRIG (with a _ under the TRIG) in the lower left hand corner of the screen. A percent sign appears on the upper right hand corner of the screen.


**Figure 359 Fluke 88 in duty cycle mode with positive trigger slope**

3. In duty cycle mode, press the ALERT button to change from negative to positive trigger slope. The slope is indicated by a plus or minus sign below TRIG in the lower left hand corner of the screen. A percent sign appears on the upper right hand corner of the screen.
4. After the meter has been set to the correct settings, connect meter as indicated in Pinpoint Diagnostics.

**Troubleshooting**

1. Verify the problem.

   Operate the complete system and list all symptoms as follows:

   - Check the accuracy and completeness of the complaint.
   - Learn more that might give a clue to the nature and location of the problem.
   - Analyze what parts of the system are working.

2. See Section 7 in this manual or the correct chassis manual.

   Read the electrical operation for the problem circuit and review the circuit diagram. Understanding electrical operation and the circuit diagram can narrow the cause of the problem to one component or certain parts of the circuit.

3. Check the circuit diagram.

   Check the circuit diagram for possible clues to the problem. Location of specific components in the circuit helps identify the source of the problem.

   Circuit diagrams are designed to make it easy to identify common points in circuits. This helps to narrow the problem to a specific area. For example, if several circuits fail at the same time, check for a common power source or common ground connection (such as $V_{REF}$, signal ground, actuator power, actuator ground).

   If part of a circuit fails, check the connections between the part that works and the part that does not work. For example, if the low beam headlights work, but both high beam headlights and the high beam indicator do not work, the power and ground paths must be good. Since the dimmer switch is the component that switches the power to the high beam headlights, it is probably the cause of failure.

4. Determine the cause of the problem and follow diagnostic procedures in Section 7.
5. Make the repair.

   Repair the problem circuit as directed in the diagnostic tables.

6. Verify the repair is complete.

   Operate the system. Make sure the repair has removed all symptoms and not caused any new symptoms.

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# Abbreviations and Acronyms

### Abbreviations and Acronyms

**A or amp –** Ampere
**ABDC –** After Bottom Dead Center
**ABS –** Antilock Brake System
**AC –** Alternating Current
**A/C –** Air Conditioner
**ACC –** Air Conditioner Control
**ACCEL –** Accelerator
**ACD –** Air Conditioner Demand
**ACM –** Aftertreatment Control Module
**ACT PWR GND –** Actuator Power Ground
**A/F –** Air to Fuel ratio
**AFD –** Aftertreatment Fuel Drain
**AFI –** Aftertreatment Fuel Injector
**AFP –** Aftertreatment Fuel Pressure
**AFS –** Aftertreatment Fuel Supply
**AFT –** Aftertreatment
**AIT –** Air Intake Temperature
**Amb –** Ambient
**amp or A –** Ampere
**AMS –** Air Management System
**API –** American Petroleum Institute
**APS –** Accelerator Position Sensor
**APS/IVS –** Accelerator Position Sensor / Idle Validation Switch
**ASTM –** American Society for Testing and Materials
**ATA –** American Trucking Association
**ATDC –** After Top Dead Center
**AWG –** American Wire Gauge

**B+ or VBAT –** Battery Voltage
**BAP or BARO –** Barometric Absolute Pressure
**BARO or BAP –** Barometric Absolute Pressure
**BBDC –** Before Bottom Dead Center
**BCP –** Brake Control Pressure
**BCS –** Boost Control Solenoid
**BDC –** Bottom Dead Center
**bhp –** Brake Horsepower
**BNO –** Brake Normally Open
**BOO –** Brake On / Off
**BPS –** Brake Pressure Switch
**BSV –** Brake Shut-off Valve
**BTDC –** Before Top Dead Center
**BTU –** British Thermal Unit

**C –** Celsius
**CAC –** Charge Air Cooler
**CAN –** Controller Area Network
**CAP –** Cold Ambient Protection
**CARB –** California Air Resources Board
**cc –** Cubic centimeter
**CCA –** Cold Cranking Ampere
**CCV –** Coolant Control Valve
**CDR –** Crankcase Depression Regulator
**CID –** Cubic Inch Displacement
**cfm –** Cubic feet per minute
**cfs –** Cubic feet per second
**CFV –** Coolant Flow Valve
**CKP –** Crankshaft Position
**CKPO –** Crankshaft Position Out
**cm –** Centimeter
**CMP –** Camshaft Position
**CMPO –** Camshaft Position Out
**CMV –** Coolant Mixer Valve
**CO –** Carbon Monoxide
**COO –** Cruise On / Off switch
**CPU –** Central Processing Unit
**CSS –** Cold Start Solenoid
**CSR –** Cold Start Relay
**CTC –** Coolant Temperature Compensation
**Cyl –** Cylinder

**DB –** Decibel
**DCA –** Diesel Coolant Additive
**DDI –** Digital Direct Fuel Injection
**DDS –** Driveline Disengagement Switch
**DLC –** Data Link Connector
**DME –** Dimethyl Ether
**DMM –** Digital Multimeter
**DOC –** Diesel Oxidation Catalyst
**DPF –** Diesel Particulate Filter
**DT –** Diesel Turbocharged
**DTC –** Diagnostic Trouble Code
**DTRM –** Diesel Thermo Recirculation Module

**EBC –** Exhaust Brake Controller
**EBP –** Exhaust Back Pressure
**EBPD –** Exhaust Back Pressure Desired
**ECI –** Engine Crank inhibit
**ECL –** Engine Coolant Level
**ECM –** Engine Control Module
**ECM PWR –** Engine Control Module Power
**ECT –** Engine Coolant Temperature
**ECT2 –** Engine Coolant Temperature 2
**EFAN –** Electronic Engine Fan
**EFANS –** Electronic Engine Fan Speed
**EFP –** Engine Fuel Pressure
**EFRC –** Engine Family Rating Code
**EFT –** Engine Fuel Temperature
**EG –** Ethylene Glycol
**EGC –** Electronic Gauge Cluster
**EGDP –** Exhaust Gas Differential Pressure

**EGR –** Exhaust Gas Recirculation
**EGRH –** Exhaust Gas Recirculation High control
**EGRL –** Exhaust Gas Recirculation Low control
**EGRP –** Exhaust Gas Recirculation Position
**EGT1 –** Exhaust Gas Temperature 1
**EGT2 –** Exhaust Gas Temperature 2
**EGT3 –** Exhaust Gas Temperature 3
**EIM –** Engine Interface Module
**ELS –** Exhaust Lambda Sensor
**EMI –** Electromagnetic Interference
**EOP –** Engine Oil Pressure
**EOT –** Engine Oil Temperature
**EPA –** Environmental Protection Agency
**EPR –** Engine Pressure Regulator
**ESC –** Electronic System Controller
**ESN –** Engine Serial Number
**EST –** Electronic Service Tool
**EVB –** Exhaust Valve Brake
**EWPS –** Engine Warning Protection System

**F –** Fahrenheit
**FCV –** Fuel Coolant Valve
**FEL –** Family Emissions Limit
**fhp –** Friction horsepower
**FMI –** Failure Mode Indicator
**FPC –** Fuel Pump Control
**FPCV –** Fuel Pressure Control Valve
**fpm –** Feet per minute
**fps –** Feet per second
**FRP –** Fuel Rail Pressure
**ft –** Foot
**FVCV –** Fuel Volume Control Valve

**GND –** Ground (electrical)
**gal –** Gallon
**gal/h –** U.S. Gallons per hour
**gal/min –** U. S. Gallons per minute
**GCW –** Gross Combined Weight
**GCWR –** Gross Combined Weight Rating
**GPC –** Glow Plug Control
**GPD –** Glow Plug Diagnostic
**GPR –** Glow Plug Relay
**GVW –** Gross Vehicle Weight

**$H_2O$ –** Water
**HC –** Hydrocarbon
**HCI –** Hydrocarbon Injection
**HFCM –** Horizontal Fuel Conditioning Module
**Hg –** Mercury
**hp –** Horsepower
**HPCAC –** High Pressure Charge Air Cooler
**hr –** Hour
**Hyd –** Hydraulic

**IAT –** Intake Air Temperature
**IAHC –** Inlet Air Heater Control
**IAHD –** Inlet Air Heater Diagnostic
**IAHR –** Inlet Air heater Relay
**IC –** Integrated Circuit
**ICP –** Injector Control Pressure
**ID –** Inside Diameter
**IDM –** Injector Drive Module
**IGN –** Ignition
**ILO –** Injector Leak Off
**in –** Inch
**inHg –** Inch of mercury
**in$H_2O$ –** Inch of water
**INJ –** Injector
**IPR –** Injection Pressure Regulator
**ISIS® –** International® Service Information System
**IST –** Idle Shutdown Timer
**ITP –** Internal Transfer Pump
**ITV –** Intake Throttle Valve
**ITVH –** Intake Throttle Valve High control
**ITVL –** Intake Throttle Valve Low control
**ITVP –** Intake Throttle Valve Position
**IVS –** Idle Validation Switch

**JCT –** Junction (electrical)

**kg –** Kilogram
**km –** Kilometer
**km/h –** Kilometers per hour
**km/l –** Kilometers per liter
**KOEO –** Key-On Engine-Off
**KOER –** Key-On Engine-Running
**kPa –** Kilopascal

**L –** Liter
**L/h –** Liters per hour
**L/m –** Liters per minute
**L/s –** Liters per second
**lb –** Pound
**lbf –** Pound-force
**lb/s –** Pounds per second
**lbf·ft –** Pound-force foot
**lbf·in –** Pound-force inch
**lbm –** Pounds of mass
**LPCAC –** Low Pressure Charge Air Cooler
**LSD –** Low Sulfur Diesel

**m –** Meter
**m/s –** Meters per second
**MAF –** Mass Air Flow
**MAG –** Magnetic
**MAP –** Manifold Absolute Pressure

**MAP/IAT –** Manifold Absolute Pressure/Intake Air Temperature Sensor
**MAT –** Manifold Air Temperature
**mep –** Mean effective pressure
**mi –** Mile
**mm –** Millimeter
**mpg –** Miles per gallon
**mph –** Miles per hour
**MPR –** Main Power Relay
**MSDS –** Material Safety Data Sheet
**MSG –** Micro Strain Gauge
**MSM –** Multiplex System Module
**MY –** Model Year

**NC –** Normally closed (electrical)
**NETS –** Navistar Electronics Technical Support
**Nm –** Newton meter
**NO –** Normally Open (electrical)
**$NO_x$ –** Nitrogen Oxides

**OAT –** Organic Acid Technology
**OCC –** Output Circuit Check
**OCP –** Overcrank Protection
**OD –** Outside Diameter
**OL –** Over Limit
**ORH –** Out-of-Range High
**ORL –** Out-of-Range Low
**OSHA –** Occupational Safety and Health Administration
**OWL –** Oil/Water Lamp

**PID –** Parameter Identifier
**PN –** Part Number
**ppm –** Parts per million
**PROM –** Programmable Read Only Memory
**psi –** Pounds per square inch
**psia –** Pounds per square inch absolute
**psig –** Pounds per square inch gauge
**pt –** Pint
**PTO –** Power Take-off
**PWM –** Pulse Width Modulate
**PWR –** Power (voltage)

**qt –** Quart

**RAM –** Random Access Memory
**RAS –** Resume / Accel Switch (speed control)
**REPTO –** Rear Engine Power Takeoff
**RFI –** Radio Frequency Interference
**rev –** Revolution
**rpm –** Revolutions per minute
**RPRE –** Remote Preset
**RSE –** Radiator Shutter Enable
**RVAR –** Remote Variable

**SAE –** Society of Automotive Engineers®
**SCA –** Supplemental Coolant Additive
**SCCS –** Speed Control Command Switches
**SCS –** Speed Control Switch
**SHD –** Shield (electrical)
**SID –** Subsystem Identifier
**SIG GRD –** Signal Ground
**S/N –** Serial Number
**SW –** Switch (electrical)
**SYNC –** Synchronizer

**TACH –** Tachometer output signal
**TBD –** To Be Determined
**TCAPE –** Truck Computer Analysis of Performance and Economy
**TDC –** Top Dead Center
**TCM –** Transmission Control Module
**TTS –** Transmission Tailshaft Speed

**ULSD –** Ultra Low Sulfur Diesel
**UVC –** Under Valve Cover

**V –** Volt
**VBAT or B+ –** Battery Voltage
**VC –** Volume Control
**VEPS –** Vehicle Electronics Programming System
**VGT –** Variable Geometry Turbocharger
**VIGN –** Ignition Voltage
**VIN –** Vehicle Identification Number
**VOP –** Valve Opening Pressure
**VRE –** Vehicle Retarder Enable
**VREF –** Reference Voltage
**VSO or VSS_CAL –** Vehicle Speed Output
**VSS –** Vehicle Speed Sensor
**VSS_CAL or VSO –** Vehicle Speed Output

**WEL –** Warn Engine Lamp
**WIF –** Water In Fuel
**WTEC –** World Transmission Electronically Controlled automatic transmissions (Allison)

**XMNS –** Transmission

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# Terminology

### Terms

**Accessory work –** The work per cycle required to drive engine accessories (normally, only those essential to engine operation).

**Actuator –** A device that performs work in response to an input signal.

**Aeration –** The entrainment of air or combustion gas in coolant, lubricant, or fuel.

**Aftercooler (Charge Air Cooler) –** A heat exchanger mounted in the charge air path between the turbocharger and engine intake manifold. The aftercooler reduces the charge air temperature by transferring heat from the charge air to a cooling medium (usually air).

**Ambient temperature –** The environmental air temperature in which a unit is operating. In general, the temperature is measured in the shade (no solar radiation) and represents the air temperature for other engine cooling performance measurement purposes. Air entering the radiator may or may not be the same ambient due to possible heating from other sources or recirculation. (SAE J1004 SEP81)

**Ampere (amp) –** The standard unit for measuring the strength of an electrical current. The flow rate of a charge in a conductor or conducting medium of one coulomb per second. (SAE J1213 NOV82)

**Analog –** A continuously variable voltage.

**Analog to digital converter (A/D) –** A circuit in the ECM processing section that converts an analog signal (DC or AC) to a usable digital signal for the microprocessor.

**American Trucking Association (ATA) Datalink –** A serial datalink specified by the American Trucking Association and the SAE.

**Boost pressure –** 1. The pressure of the charge air leaving the turbocharger.

2. Inlet manifold pressure that is greater than atmospheric pressure. Obtained by turbocharging.

**Bottom Dead Center (BDC) –** The lowest position of the piston during the stroke.

**Brake Horsepower (bhp) –** The power output from an engine, not the indicated horsepower. The power output of an engine, sometimes-called flywheel horsepower is less than the indicated horsepower by the amount of friction horsepower consumed in the engine.

**Brake Horsepower (bhp) net –** Net brake horsepower is measured with all engine components. The power of an engine when configured as a fully equipped engine. (SAE J1349 JUN90)

**Calibration –** The data values used by the strategy to solve equations and make decisions. Calibration values are stored in ROM and put into the processor during programming to allow the engine to operate within certain parameters.

**Catalyst –** A substance that produces a chemical reaction without undergoing a chemical change itself.

**Catalytic converter –** An antipollution device in the exhaust system that contains a catalyst for chemically converting some pollutants in the exhaust gases (carbon monoxide, unburned hydrocarbons, and oxides of nitrogen) into harmless compounds.

**Cavitation –** A dynamic condition in a fluid system that forms gas-filled bubbles (cavities) in the fluid.

**Cetane number –** 1. The auto-ignition quality of diesel fuel.

2. A rating applied to diesel fuel similar to octane rating for gasoline.

3. A measure of how readily diesel fuel starts to burn (self-ignites) at high compression temperature.

Diesel fuel with a high cetane number self-ignites shortly after injection into the combustion chamber. Therefore, it has a short ignition delay time. Diesel fuel with a low cetane number resists self-ignition. Therefore, it has a longer ignition delay time.

**Charge air –** Dense, pressurized, heated air discharged from the turbocharger.

**Charge Air Cooler (CAC) –** See **Aftercooler**.

**Closed crankcase –** A crankcase ventilation that recycles crankcase gases through a breather, then back to the clean air intake.

**Closed loop operation –** A system that uses a sensor to provide feedback to the ECM. The ECM uses the sensor to continuously monitor variables and adjust to match engine requirements.

**Cloud point –** The point when wax crystals occur in fuel, making fuel cloudy or hazy. Usually below -12 °C (10 °F).

**Cold cranking ampere rating (battery rating) –** The sustained constant current (in amperes) needed to produce a minimum terminal voltage under a load of 7.2 volts per battery after 30 seconds.

**Continuous Monitor Test –** An ECM function that continuously monitors the inputs and outputs to ensure that readings are within set limits.

**Coolant –** A fluid used to transport heat from one point to another.

**Coolant level switch –** A switch sensor used to indicate low coolant level.

**Crankcase –** The housing that encloses the crankshaft, connecting rods, and allied parts.

**Crankcase breather –** A vent for the crankcase to release excess interior air pressure.

**Crankcase pressure –** The force of air inside the crankcase against the crankcase housing.

**Current –** The flow of electrons passing through a conductor. Measured in amperes.

**Damper –** A device that reduces the amplitude of torsional vibration. (SAE J1479 JAN85)

**Deaeration –** The removal or purging of gases (air or combustion gas) entrained in coolant or lubricating oil.

**Deaeration tank –** A separate tank in the cooling system used for one or more of the following functions:

- Deaeration
- Coolant reservoir (fluid expansion and afterboil)
- Coolant retention
- Filling
- Fluid level indication (visible)

**Diagnostic Trouble Code (DTC) –** Formerly called a Fault Code or Flash Code. A DTC is a three digit numeric code used for troubleshooting.

**Digital Multimeter (DMM) –** An electronic meter that uses a digital display to indicate a measured value. Preferred for use on microprocessor systems because it has a very high internal impedance and will not load down the circuit being measured.

**Disable –** A computer decision that deactivates a system and prevents operation of the system.

**Displacement –** The stroke of the piston multiplied by the area of the cylinder bore multiplied by the number of cylinders in the engine.

**Driver (high side) –** A transistor within an electronic module that controls the power to an actuator circuit.

**Driver (low side) –** A transistor within an electronic module that controls the ground to an actuator circuit.

**Duty cycle –** A control signal that has a controlled on/off time measurement from 0 to 100%. Normally used to control solenoids.

**Engine lamp –** An instrument panel lamp that comes on when DTCs are set. DTCs can be read as flash codes (red and amber instrument panel lamps).

**Engine OFF tests –** Tests that are done with the ignition switch ON and the engine OFF.

**Engine rating –** Engine rating includes **Rated hp** and **Rated rpm**.

**Engine RUNNING tests –** Tests done with the engine running.

**Exhaust brake –** A brake device using engine exhaust back pressure as a retarding medium.

**Exhaust manifold –** Exhaust gases flow through the exhaust manifold to the turbocharger exhaust inlet and are directed to the EGR cooler.

**Fault detection/management –** An alternate control strategy that reduces adverse effects that can be caused by a system failure. If a sensor fails, the ECM substitutes a good sensor signal or assumed sensor value in its place. A lit amber instrument panel lamp signals that the vehicle needs service.

**Filter restriction –** A blockage, usually from contaminants, that prevents the flow of fluid through a filter.

**Flash code –** See **Diagnostic Trouble Code (DTC)**.

**Fuel inlet restriction –** A blockage, usually from contaminants, that prevents the flow of fluid through the fuel inlet line.

**Fuel pressure –** The force that the fuel exerts on the fuel system as it is pumped through the fuel system.

**Fuel strainer –** A pre-filter in the fuel system that keeps larger contaminants from entering the fuel system.

**Fully equipped engine –** A fully equipped engine is an engine equipped with only those accessories necessary to perform its intended service. A fully equipped engine does not include components that are used to power auxiliary systems. If these components are integral with the engine or for any reason are included on the test engine, the power absorbed may be determined and added to the net brake power. (SAE J1995 JUN90)

**Fusible link (fuse link) –** A fusible link is a special section of low tension cable designed to open the circuit when subjected to an extreme current overload. (SAE J1156 APR86)

**Gradeability –** The maximum percent grade which the vehicle can transverse for a specified time at a specified speed. The gradeability limit is the grade upon which the vehicle can just move forward. (SAE J227a)

**Gross Combined Weight Rating (GCWR) –** Maximum combined weight of towing vehicle (including passengers and cargo) and the trailer. The GCWR indicates the maximum loaded weight that the vehicle is allowed to tow.

**Gross brake horsepower –** The power of a complete basic engine, with air cleaner, without fan, and alternator and air compressor not charging.

**Hall effect –** The development of a transverse electric potential gradient in a current-carrying conductor or semiconductor when a magnetic field is applied.

**Hall effect sensor –** Generates a digital on/off signal that indicates speed and timing.

**High speed digital inputs –** Inputs to the ECM from a sensor that generates varying frequencies (engine speed and vehicle speed sensors).

**Horsepower (hp) –** Horsepower is the unit of work done in a given period of time, equal to 33,000 pounds multiplied by one foot per minute. **1hp = 33,000 lb x 1 ft /1 min**.

**Hydrocarbons –** Unburned or partially burned fuel molecules.

**Idle speed –**

- Low idle is minimum rpm at no load.
- High idle is maximum rpm at no load.

**Intake manifold –** A collection of tubes through which the fuel-air mixture flows from the fuel injector to the intake valves of the cylinders.

**International NGV Tool Utilized for Next Generation Electronics (INTUNE) –** The diagnostics software for chassis related components and systems.

**Low speed digital inputs –** Switched sensor inputs that generate an on/off (high/low) signal to the ECM. The input to the ECM from the sensor could be from a high input source switch (usually 5 or 12 volts) or from a grounding switch that grounds the signal from a current limiting resistor in the ECM that creates a low signal (0 volts).

**Lubricity –** Lubricity is the ability of a substance to reduce friction between solid surfaces in relative motion under loaded conditions.

**Lug (engine) –** A condition when the engine is operating at or below maximum torque speed.

**Manometer –** A double-leg liquid-column gauge, or a single inclined gauge, used to measure the difference between two fluid pressures. Typically, a manometer records in inches of water.

**MasterDiagnostics® (MD) –** The diagnostics software for engine related components and systems.

**Microprocessor –** An integrated circuit in a microcomputer that controls information flow.

**Nitrogen Oxides ($NO_x$) –** Nitrogen oxides form by a reaction between nitrogen and oxygen at high temperatures and pressures in the combustion chamber.

**Normally closed –** Refers to a switch that remains closed when no control force is acting on it.

**Normally open –** Refers to a switch that remains open when no control force is acting on it.

**Ohm (Ω) –** The unit of resistance. One ohm is the value of resistance through which a potential of one volt will maintain a current of one ampere. (SAE J1213 NOV82)

**On demand test –** A self test that the technician initiates using the EST and is run from a program in the processor.

**Output Circuit Check (OCC) –** An On demand test done during an Engine OFF self test to check the continuity of selected actuators.

**pH –** A measure of the acidity or alkalinity of a solution.

**Particulate matter –** Particulate matter includes mostly burned particles of fuel and engine oil.

**Piezometer –** An instrument for measuring fluid pressure.

**Power –** Power is a measure of the rate at which work is done. Compare with **Torque**.

**Power TakeOff (PTO) –** Accessory output, usually from the transmission, used to power a hydraulic pump for a special auxiliary feature (garbage packing, lift equipment, etc).

**Pulse Width Modulate (PWM) –** The time that an actuator, such as an injector, remains energized.

**Random Access Memory (RAM) –** Computer memory that stores information. Information can be written to and read from RAM. Input information (current engine speed or temperature) can be stored in RAM to be compared to values stored in Read Only Memory (ROM). All memory in RAM is lost when the ignition switch is turned off.

**Rated gross horsepower –** Engine gross horsepower at rated speed as declared by the manufacturer. (SAE J1995 JUN90)

**Rated horsepower –** Maximum brake horsepower output of an engine as certified by the engine manufacturer. The power of an engine when configured as a basic engine. (SAE J1995 JUN90)

**Rated net horsepower –** Engine net horsepower at rated speed as declared by the manufacturer. (SAE J1349 JUN90)

**Rated speed –** The speed, as determined by the manufacturer, at which the engine is rated. (SAE J1995 JUN90)

**Rated torque –** Maximum torque produced by an engine as certified by the manufacturer.

**Ratiometric Voltage –** In a Micro Strain Gauge (MSG) sensor pressure to be measured exerts force on a pressure vessel that stretches and compresses to change resistance of strain gauges bonded to the surface of the pressure vessel. Internal sensor electronics convert the changes in resistance to a ratiometric voltage output.

**Reference voltage ($V_{REF}$) –** A 5 volt reference supplied by the ECM to operate the engine sensors.

**Reserve capacity –** Time in minutes that a fully charged battery can be discharged to 10.5 volts at 25 amperes.

**Signal ground –** The common ground wire to the ECM for the sensors.

**Speed Control Command Switches (SCCS) –** A set of switches used for cruise control, Power TakeOff (PTO), and remote hand throttle system.

**Steady state condition –** An engine operating at a constant speed and load and at stabilized temperatures and pressures. (SAE J215 JAN80)

**Strategy –** A plan or set of operating instructions that the microprocessor follows for a desired goal. Strategy is the computer program itself, including all equations and decision making logic. Strategy is always stored in ROM and cannot be changed during calibration.

**Stroke –** Stroke is the movement of the piston from Top Dead Center (TDC) to Bottom Dead Center (BDC).

**Substrate –** Material that supports the washcoating or catalytic materials.

**System restriction (air) –** The static pressure differential that occurs at a given air flow from air entrance through air exit in a system. Usually measured in inches (millimeters) of water. (SAE J1004 SEP81)

**Tachometer output signal –** Engine speed signal for remote tachometers.

**Thermistor –** A semiconductor device. A sensing element that changes resistance as the temperature changes.

**Thrust load –** A thrust load pushes or reacts through a bearing in a direction parallel to the shaft.

**Top Dead Center (TDC) –** The uppermost position of the piston during the stroke.

**Torque –** A force having a twisting or turning effect. For a single force, the cross product of a vector from some reference point to the point of application of the force within the force itself. Also known as moment of force or rotation moment. Torque is a measure of the ability of an engine to do work.

**Truck Computer Analysis of Performance and Economy (TCAPE) –** Truck Computer Analysis of Performance and Economy is a computer program that simulates the performance and fuel economy of trucks.

**Turbocharger –** A turbine driven compressor mounted to the exhaust manifold. The turbocharger increases the pressure, temperature and density of intake air to charge air.

**Variable capacitance sensor –** A variable capacitance sensor measures pressure. The pressure forces a ceramic material closer to a thin metal disc in the sensor, changing the capacitance of the sensor.

**Vehicle Electronic System Programming System –** The computer system used to program electronically controlled vehicles.

**Vehicle Retarder Enable/Engage –** Output from the ECM to a vehicle retarder.

**Vehicle Speed Sensor (VSS) –** Normally a magnetic pickup sensor mounted in the tailshaft housing of the transmission, used to indicate ground speed.

**Viscosity –** The internal resistance to the flow of any fluid.

**Viscous fan –** A fan drive that is activated when a thermostat, sensing high air temperature, forces fluid through a special coupling. The fluid activates the fan.

**Volt (v) –** A unit of electromotive force that will move a current of one ampere through a resistance of one Ohm.

**Voltage –** Electrical potential expressed in volts.

**Voltage drop –** Reduction in applied voltage from the current flowing through a circuit or portion of the circuit current multiplied by resistance.

**Voltage ignition –** Voltage supplied by the ignition switch when the key is ON.

**Washcoat –** A layer of alumina applied to the substrate in a monolith-type converter.

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## All Ratings

### Key-On Engine-Off

| | |
|---|---|
| Barometric pressure (500 ft above sea level) | 99.01 kPa (14.36 psi) / 3.91 V |
| Engine fuel pressure | 0 kPa (0 psi) / 0.5 V |
| Engine oil pressure | 0 kPa (0 psi) / 0.5 V |
| Exhaust gas differential pressure | 0.83 kPa (0.12 psi) / 0.5 V |
| Fuel rail pressure | 0 MPa (0 psi) / 0.5 V |
| Manifold boost pressure (gauge) | 0 kPa (0 psi) / 1.06 V |
| Accelerator position sensor (at idle) | 0.7 V / 0 % |
| Accelerator position sensor (depressed to floor) | 3.75 V / 99.6 % |
| Exhaust gas recirculation (EGR) control valve position | 0.47 V / 0 % |
| Intake throttle valve position | 4.5 % |

### Engine Cranking

| | |
|---|---|
| Cranking rpm (min)<br>20 seconds minimum crank time per attempt. Wait 2 to 3 minutes before repeating. | 100 rpm |
| Battery voltage (min based on ECM drop out) | 7.5 V |
| Fuel rail pressure (min before DTC is set) | + or - 20 Mpa (2900 psi) from set point |
| Fuel rail pressure (min to start engine) | 26 MPa (3771 psi) / 1 V |
| Exhaust gas recirculation (EGR) control valve | 0 % |
| Engine fuel pressure (min) | 48 kPa (7 psi) / 0.6 V |

### Low Idle, no load, stabilized engine operating temperature

| | |
|---|---|
| Engine coolant temperature (at thermostat opening) | 83 °C (181 °F) / 1.41 V |
| Engine coolant temperature (max before DTC is set) | 120 °C (248 °F) / 0.64 V |
| Engine coolant temperature 2 (at thermostat opening) | 70 °C (157 °F) / 1.84 V |
| Engine coolant temperature 2 (max before DTC is set) | 120 °C (248 °F) / 0.64 V |
| Engine oil temperature | 89 °C (192 °F) / 1.26 V |

**Low Idle, no load, stabilized engine operating temperature (cont.)**

| | |
|---|---|
| Intake air temperature 2 (boost) | 47 °C (117 °F) / 2.68 V |
| Intake air temperature 2 (boost) (max before DTC is set) | 95 °C (203 °F) / 1.11 V |
| Manifold air temperature | 61 °C (141 °F) / 2.14 V |
| Manifold air temperature (max before DTC is set) | 135 °C (275 °F) / 0.47 V |
| Fuel rail pressure | 49 kPa (7176 psi) / 1.49 V |
| Manifold boost pressure (gauge) | 0 MPa (0 psi) / 1.06 V |
| Engine fuel pressure (min) | 300 kPa (43.5 psi) / 1.3 V |
| Engine fuel pressure (max) | 1000 kPa (145 psi) / 3.2 V |
| Fuel pump inlet restriction (max) | 374 mm Hg (14.7 in Hg) |
| Engine oil pressure (min with gauge) | 172 kPa (25 psi) / 0.93 V |
| Actuator supply pressure (min) | 655 kPa (95 psi) |
| Boost control solenoid supply pressure (min) | 358 kPa (52 psi) |

**High Idle, no load, stabilized engine operating temperature**

| | |
|---|---|
| Air cleaner restriction (max) | 3.7 kPa (15 in $H_2O$) |
| Fuel rail pressure | 148 MPa (21425 psi) / 3.46 V |
| Engine fuel pressure (min) | 300 kPa (43.5 psi) / 1.3 V |
| Engine fuel pressure (max) | 1000 kPa (145 psi) / 3.2 V |
| Fuel pump inlet restriction (max with gauge) | 374 mm Hg (14.7 in Hg) |
| Engine oil pressure (min with gauge) | 172 kPa (25 psi) / 0.93 V |
| Exhaust gas differential pressure (max before DTC is set) | 35 kPa (5 psi) / 1.9 V |
| Manifold boost pressure (min with gauge) | 69 kPa (10 psi) / 1.85 V |

**Full load, rated speed on chassis dynamometer or highway, stabilized engine operating temperature**

| | |
|---|---|
| Air cleaner restriction (max) | 6.2 kPa (25 in $H_2O$) |
| Fuel rail pressure | 180 MPa (26,000 psi) / 4.1 V |
| Engine fuel pressure (min) | 450 kPa (65 psi) / 1.7 V |
| Engine fuel pressure (max) | 1000 kPa (145 psi) / 0.31 V |
| Fuel pump inlet restriction (max with gauge) | 374 mm Hg (14.7 in Hg) |
| Engine oil pressure (min with gauge) | 372 kPa (54 psi) / 1.49 V |
| Engine oil temperature (max) | 115 °C (240 °F) / 0.73 V |
| Exhaust gas differential pressure (max before DTC is set) | 35 kPa (5 psi) / 1.9 V |
| Exhaust back pressure (max) | 35 kPa (5 psi) |
| Water temperature differential across radiator (top and bottom) | 9 °C (16 °F) |

**Component Specifications**

| | |
|---|---|
| **Temperature Sensors (Engine Coolant Temperature [ECT], Engine Coolant Temperature 2 [ECT2], Engine Oil Temperature [EOT], Manifold Air Temperature [MAT])** | |
| Temperature at -18 °C (0 °F) | 4.6 V / 15410 Ω |
| Temperature at 0 °C (32 °F) | 4.3 V / 5876 Ω |
| Temperature at 21 °C (70 °F) | 3.7 V / 2492 Ω |
| Temperature at 65 °C (150 °F) | 2.1 V / 5.6 Ω |
| Temperature at 93 °C (200 °F) | 0.7 V / 212 Ω |
| **Temperature Sensors (Intake Air Temperature [IAT])** | |
| Temperature at -18 °C (0 °F) | 4.3 V / 276959 Ω |
| Temperature at 0 °C (32 °F) | 3.85 V / 95851 Ω |
| Temperature at 21 °C (70 °F) | 3.07 V / 37340 Ω |
| Temperature at 65 °C (150 °F) | 1.34 V / 7548 Ω |
| **Temperature Sensors (Exhaust Gas Temperature 1 [EGT1], Exhaust Gas Temperature 2 [EGT2], Exhaust Gas Temperature 3 [EGT3])** | |
| Temperature at 21 °C (70 °F) | 5 V / 28100000 Ω |
| Temperature at 65 °C (150 °F) | 4.6 V / 64493 Ω |
| Temperature at 93 °C (200 °F) | 4.35 V / 37258 Ω |
| Temperature at 204 °C (400 °F) | 2.7 V / 6612 Ω |
| Temperature at 482 °C (900 °F) | 0.6 V / 761 Ω |
| **Other Components** | |
| Camshaft Position (CMP) sensor | 860 Ω ± 88 Ω |
| Crankshaft Position (CKP) sensor | 860 Ω ± 86 Ω |
| Coolant Mixer Valve (CMV) | 5.7 Ω ± 0.3 Ω |
| Coolant Flow Valve (CFV) | 5.7 Ω ± 0.3 Ω |
| Cold Start Solenoid (CSS) | 8 Ω ± 1 Ω |
| Boost Control Solenoid (BCS) valve | 23 Ω ± 1.2 Ω |
| Exhaust Gas Recirculation (EGR) control valve | 6 Ω + 0.6 Ω, -0.3 Ω |
| Injector coil | 240 Ω ± 5% @ 20 °C |

**Component Specifications (cont.)**

| | |
|---|---|
| Cold start assist glow plug | 0.17 Ω ± 0.015 Ω |
| Retarder control | 2.60 - 3.15 Ω @ 20 °C |
| | 2.19 - 2.65 Ω @ -20 °C |
| Fuel Pressure Control Valve (FPCV) | 2.80 - 3.34 Ω @ 40 °C |
| | 3.29 - 3.99 Ω @ 90 °C |

**Actuator Output State**

| | |
|---|---|
| Exhaust Gas Recirculation (EGR) control valve | Output state low – 9.6 % |
| | Output state high – 83.6 % |
| Exhaust Gas Recirculation Position (EGRP) | Output state low – 0.75 V |
| | Output state high – 3.9 V |
| Coolant Mixer Valve (CMV) | Output state low – 11 % |
| | Output state high – 93.5 % |
| Coolant Flow Valve (CFV) | Output state low – 11 % |
| | Output state high – 93.5 % |
| Cold Start Solenoid (CSS) | Output state low – 0 |
| | Output state high – 1 |
| Intake Throttle Valve (ITV) | Output state low – 9.5 % |
| | Output state high – 83.5 % |
| Retarder control | Output state low – 9.5 % |
| | Output state high – 83.5 % |
| Boost Control Solenoid (BCS) valve | Output state low – 9.5 % |
| | Output state high – 83.5 % |
| Retarder actuator linkage (full travel) | 36 mm |
| Boost control actuator (full travel) | 10 mm at 60 psi supplied to valve |

**Crankcase Pressure**

| | |
|---|---|
| Crankcase pressure (max) using ZTSE4039 with engine cooling fan off | 374 Pa (1.5 in$H_2O$) @ 2200 rpm |
| Crankcase pressure (max) using ZTSE4039 with engine cooling fan on | 498 Pa (2.0 in$H_2O$) @ 2200 rpm |

**Cold Start Assist Glow Plug (measurements taken with amp clamp)**

| | |
|---|---|
| Amperage draw | 30 amps within 2 seconds |

## MaxxForce™ 11 (10.5L)

**330 hp @ 1700 rpm**

| | |
|---|---|
| International® MaxxForce™ 11 330 hp @ 1700 rpm / 1250 ft•lb @ 1000 rpm | |
| 50 state 2008 Model Year (MY) | |
| Engine model | GDT330 |
| Engine Family Rating Code (EFRC) | 2232 and 1132 |
| Injector part number, original equipment | 62.10100-6107 |
| Turbocharger part number | 62.09100-7793 |
| Injection timing | Nonadjustable |
| High idle speed - manual transmission | 2200 rpm |
| High idle speed - automatic transmission | 2200 rpm |
| Low idle speed | 600 rpm |
| **Full load on chassis dynamometer or highway, stabilized engine operating temperature** | |
| Manifold boost pressure (gauge) | Peak torque – 203 kPa (30 psi) / 2.25 V |
| | Rated speed – 288 kPa (42 psi) / 3.22 V |

**370 hp @ 1700 rpm**

| | |
|---|---|
| International® MaxxForce™ 11 370 hp @ 1700 rpm / 1350 ft•lb @ 1000 rpm | |
| 50 state 2008 Model Year (MY) | |
| Engine model | GDT370 |
| Engine Family Rating Code (EFRC) | 2222 and 1122 |
| Injector part number, original equipment | 62.10100-6107 |
| Turbocharger part number | 62.09100-7793 |
| Injection timing | Nonadjustable |
| High idle speed - manual transmission | 2200 rpm |
| High idle speed - automatic transmission | 2200 rpm |
| Low idle speed | 600 rpm |
| **Full load on chassis dynamometer or highway, stabilized engine operating temperature** | |
| Manifold boost pressure (gauge) | Peak torque – 227 kPa (33 psi) / 2.52 V |
| | Rated speed – 288 kPa (42 psi) / 3.22 V |

**390 hp @ 1700 rpm**

| | |
|---|---|
| International® MaxxForce™ 11 390 hp @ 1700 rpm / 1400 ft•lb @ 1000 rpm | |
| 50 state 2008 Model Year (MY) | |
| Engine model | GDT390 |
| Engine Family Rating Code (EFRC) | 2212 and 1112 |
| Injector part number, original equipment | 62.10100-6107 |
| Turbocharger part number | 62.09100-7793 |
| Injection timing | Nonadjustable |
| High idle speed - manual transmission | 2200 rpm |
| High idle speed - automatic transmission | 2200 rpm |
| Low idle speed | 600 rpm |
| **Full load on chassis dynamometer or highway, stabilized engine operating temperature** | |
| Manifold boost pressure (gauge) | Peak torque – 257 kPa (37 psi) / 2.87 V |
| | Rated speed – 295 kPa (43 psi) / 3.30 V |

## MaxxForce™ 13 (12.4L)

**410 hp @ 1700 rpm**

| | |
|---|---|
| International® MaxxForce™ 13 410 hp @ 1700 rpm / 1450 ft•lb @ 1000 rpm | |
| 50 state 2008 Model Year (MY) | |
| Engine model | GDT410 |
| Engine Family Rating Code (EFRC) | 2231 and 1131 |
| Injector part number, original equipment | 62.10100-6106 |
| Turbocharger part number | 62.09100-7791 |
| Injection timing | Nonadjustable |
| High idle speed - manual transmission | 2200 rpm |
| High idle speed - automatic transmission | 2200 rpm |
| Low idle speed | 600 rpm |
| **Full load on chassis dynamometer or highway, stabilized engine operating temperature** | |
| Manifold boost pressure (gauge) | Peak torque – 196 kPa (29 psi) / 2.17 V |
| | Rated speed – 295 kPa (43 psi) / 3.30 V |

**430 hp @ 1700 rpm**

| | |
|---|---|
| International® MaxxForce™ 13 430 hp @ 1700 rpm / 1550 ft•lb @ 1000 rpm | |
| 50 state 2008 Model Year (MY) | |
| Engine model | GDT430 |
| Engine Family Rating Code (EFRC) | 2221 and 1121 |
| Injector part number, original equipment | 62.10100-6106 |
| Turbocharger part number | 62.09100-7791 |
| Injection timing | Nonadjustable |
| High idle speed - manual transmission | 2200 rpm |
| High idle speed - automatic transmission | 2200 rpm |
| Low idle speed | 600 rpm |
| **Full load on chassis dynamometer or highway, stabilized engine operating temperature** | |
| Manifold boost pressure (gauge) | Peak torque – 213 kPa (31 psi) / 2.36 V |
| | Rated speed – 298 kPa (43 psi) / 3.33 V |

**475 hp @ 1700 rpm**

| | |
|---|---|
| International® MaxxForce™ 13 475 hp @ 1700 rpm / 1700 ft•lb @ 1000 rpm | |
| 50 state 2008 Model Year (MY) | |
| Engine model | GDT475 |
| Engine Family Rating Code (EFRC) | 2211 and 1111 |
| Injector part number, original equipment | 62.10100-6106 |
| Turbocharger part number | 62.09100-7791 |
| Injection timing | Nonadjustable |
| High idle speed - manual transmission | 2200 rpm |
| High idle speed - automatic transmission | 2200 rpm |
| Low idle speed | 600 rpm |
| **Full load on chassis dynamometer or highway, stabilized engine operating temperature** | |
| Manifold boost pressure (gauge) | Peak torque – 254 kPa (36 psi) / 2.73 V |
| | Rated speed – 298 kPa (43 psi) / 3.33 V |

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**Diagnostic Trouble Codes.....495**

## Diagnostic Trouble Codes

| DTC | SPN | FMI | Circuit | Condition Description |
|---|---|---|---|---|
| 1112 | 168 | 3 | EIM PWR (page 352) | B+ to EIM out-of-range HIGH |
| 1113 | 168 | 4 | EIM PWR (page 352) | B+ to EIM out-of-range LOW |
| 1114 | 110 | 4 | ECT (page 310) | ECT signal out-of-range LOW |
| 1115 | 110 | 3 | ECT (page 310) | ECT signal out-of-range HIGH |
| 1119 | 110 | 12 | EWPS (page 373) | ECT temperature above maximum |
| 1121 | 102 | 3 | MAP (page 416) | MAP signal out-of-range HIGH |
| 1122 | 102 | 4 | MAP (page 416) | MAP signal out-of-range LOW |
| 1124 | 164 | 4 | FRP (page 383) | FRP signal out-of-range LOW |
| 1125 | 164 | 3 | FRP (page 383) | FRP signal out-of-range HIGH |
| 1129 | 91 | 0 | APS/IVS (page 243) | APS VREF out-of-range HIGH |
| 1130 | 91 | 1 | APS/IVS (page 243) | APS VREF out-of-range LOW |
| 1131 | 91 | 4 | APS/IVS (page 243) | APS signal out-of-range LOW |
| 1132 | 91 | 3 | APS/IVS (page 243) | APS signal out-of-range HIGH |
| 1133 | 91 | 2 | APS/IVS (page 243) | APS in-range fault |
| 1134 | 91 | 7 | APS/IVS (page 243) | APS and IVS disagree |
| 1135 | 558 | 11 | APS/IVS (page 243) | IVS signal fault |
| 1136 | 94 | 4 | EFP (page 318) | EFP signal out-of-range LOW |
| 1137 | 94 | 3 | EFP (page 318) | EFP signal out-of-range HIGH |
| 1141 | 84 | 4 | Truck | VSS signal out-of-range LOW |
| 1142 | 84 | 3 | Truck | VSS signal out-of-range HIGH |
| 1148 | 84 | 8 | Truck | VSS circuit frequency out-of-range HIGH |
| 1149 | 84 | 2 | Truck | VSS anti-tampering fault |
| 1151 | 108 | 3 | ECM Self (page 281) | BAP signal out-of-range HIGH |
| 1152 | 108 | 4 | ECM Self (page 281) | BAP signal out-of-range LOW |
| 1153 | 108 | 10 | ECM Self (page 281) | BAP signal abnormal rate of change |
| 1154 | 171 | 4 | IAT (page 394) | IAT signal out-of-range LOW |
| 1155 | 171 | 3 | IAT (page 394) | IAT signal out-of-range HIGH |
| 1158 | 1131 | 0 | IAT2 (page 416) | IAT2 Temp above maximum |
| 1159 | 1131 | 3 | IAT2 (page 416) | IAT2 signal out-of-range HIGH |
| 1160 | 1131 | 4 | IAT2 (page 416) | IAT2 signal out-of-range LOW |
| 1161 | 105 | 4 | MAT (page 421) | MAT signal out-of-range LOW |
| 1162 | 105 | 3 | MAT (page 421) | MAT signal out-of-range HIGH |
| 1163 | 2791 | 4 | EGRP (page 331) | EGRP signal out-of-range LOW |

| DTC | SPN | FMI | Circuit | Condition Description |
|---|---|---|---|---|
| 1164 | 2791 | 3 | EGRP (page 331) | EGRP signal out-of-range HIGH |
| 1166 | 105 | 0 | AMS (page 238) | MAT temperature above maximum |
| 1211 | 100 | 4 | EOP (page 365) | EOP signal out-of-range LOW |
| 1212 | 100 | 3 | EOP (page 365) | EOP signal out-of-range HIGH |
| 1214 | 8029 | 3 | Truck | Remote throttle signal out-of-range HIGH |
| 1221 | 536 | 2 | Truck | SCCS switch circuit fault |
| 1222 | 597 | 2 | Truck | Brake switch disagreement |
| 1236 | 111 | 2 | ECL (page 304) | ECL switch circuit fault |
| 1245 | 7272 | 0 | EFAN (variable speed) (page 433) | Fan speed above desired |
| 1246 | 7272 | 11 | EFAN (two speed) (page 430) | EFAN control circuit fault |
| 1246 | 7272 | 11 | EFAN (variable speed) (page 433) | EFAN control circuit fault |
| 1256 | 7312 | 5 | BCS (page 253) | Boost Control Solenoid open circuit |
| 1257 | 7312 | 11 | BCS (page 253) | Boost Control Solenoid short circuit |
| 1258 | 7320 | 5 | CMV (page 277) | Coolant Mixer Valve open circuit |
| 1259 | 7320 | 11 | CMV (page 277) | Coolant Mixer Valve short circuit |
| 1260 | 7321 | 5 | CFV (page 266) | Coolant Flow Valve open circuit |
| 1261 | 7321 | 11 | CFV (page 266) | Coolant Flow Valve short circuit |
| 1286 | 51 | 7 | ITV (page 410) | ITV unable to achieve commanded position |
| 1289 | 51 | 0 | ITV (page 410) | ITV overtemperature |
| 1295 | 3464 | 5 | ITV (page 410) | Intake Throttle Valve open circuit |
| 1296 | 3464 | 11 | ITV (page 410) | Intake Throttle Valve short circuit |
| 1297 | 51 | 5 | ITV (page 410) | ITV no input signal |
| 1298 | 51 | 2 | ITV (page 410) | ITV operation fault – under V, over amp, over temp |
| 1311 | 175 | 4 | EOT (page 369) | EOT signal out-of-range LOW |
| 1312 | 175 | 3 | EOT (page 369) | EOT signal out-of-range HIGH |
| 1371 | 676 | 18 | CSS (page 293) | Cold Start Solenoid fault |
| 1372 | 676 | 17 | CSR (page 287) | Cold Start Relay control fault |
| 1373 | 7263 | 11 | CSR (page 287) | Cold Start Relay fault |
| 1375 | 7264 | 7 | CSR (page 287) | Cold Start Relay circuit fault |
| 1377 | 1136 | 3 | ECM Self (page 281) | ECM Temp above maximum |
| 1378 | 1136 | 4 | ECM Self (page 281) | ECM Temp below minimum |
| 1379 | 158 | 0 | ECM Self (page 281) | B+ to ECM out-of-range HIGH |

| DTC | SPN | FMI | Circuit | Condition Description |
|---|---|---|---|---|
| 1380 | 158 | 1 | ECM PWR (page 307) | B+ to ECM out-of-range LOW |
| 1381 | 158 | 3 | ECM PWR (page 307) | B+ to ECM out-of-range spiked HIGH |
| 1382 | 158 | 4 | ECM PWR (page 307) | B+ to ECM out-of-range spiked LOW |
| 1607 | 8021 | 5 | CMP (page 273) | CMP - No signal |
| 1608 | 8021 | 7 | CMP (page 273) | CMP sensor angle based phase system error disagreement |
| 1609 | 8021 | 8 | CMP (page 273) | CMP sensor time based phase system disagreement |
| 1610 | 8021 | 14 | CMP (page 273) | CMP circuits reversed |
| 1611 | 8021 | 3 | CMP (page 273) | CMP signal out-of-range HIGH |
| 1612 | 8021 | 4 | CMP (page 273) | CMP signal out-of-range LOW |
| 1614 | 8064 | 3 | CKP (page 270) | CKP signal out-of-range HIGH |
| 1615 | 8064 | 4 | CKP (page 270) | CKP signal out-of-range LOW |
| 1616 | 1442 | 5 | FPCV (page 379) | Fuel Pressure Control Valve open circuit |
| 1617 | 1442 | 11 | FPCV (page 379) | Fuel Pressure Control Valve short circuit |
| 1618 | 1119 | 0 | ELS (page 358) | Lambda Sensor correction value above normal |
| 1619 | 1119 | 1 | ELS (page 358) | Lambda Sensor not plausible |
| 1620 | 1119 | 2 | ELS (page 358) | Lambda Sensor circuit intermittent contact |
| 1621 | 1119 | 5 | ELS (page 358) | Lambda Sensor monitoring below lower limit |
| 1622 | 1119 | 7 | ELS (page 358) | Lambda Sensor circuit fault |
| 1623 | 1119 | 11 | ELS (page 358) | Lambda heater circuit fault |
| 1624 | 7319 | 16 | ELS (page 358) | Lambda Temp calculation above normal |
| 1625 | 7319 | 17 | ELS (page 358) | Lambda Temp calculation below normal |
| 1626 | 7319 | 18 | ELS (page 358) | Lambda Temp calibration calculation value above normal |
| 1627 | 7319 | 19 | ELS (page 358) | Lambda Temp calibration calculation value below normal |
| 1628 | 1119 | 22 | ELS (page 358) | Lambda Sensor Temp above maximum |
| 1629 | 1119 | 12 | ELS (page 358) | Lambda Sensor not detected in exhaust system |
| 1630 | 1119 | 15 | ELS (page 358) | Lambda Sensor SPI communication error status |
| 1635 | 7311 | 4 | ECT2 (page 314) | ECT2 signal out-of-range LOW |
| 1636 | 7311 | 3 | ECT2 (page 314) | ECT2 signal out-of-range HIGH |
| 1729 | 3251 | 4 | EGDP (page 322) | EGDP signal out-of-range LOW |
| 1731 | 3251 | 3 | EGDP (page 322) | EGDP signal out-of-range HIGH |
| 1737 | 3241 | 4 | EGT1 (page 338) | EGT1 signal out-of-range LOW |
| 1738 | 3241 | 3 | EGT1 (page 338) | EGT1 signal out-of-range HIGH |

| DTC | SPN | FMI | Circuit | Condition Description |
|---|---|---|---|---|
| 1741 | 3242 | 4 | EGT2 (page 343) | EGT2 signal out-of-range LOW |
| 1742 | 3242 | 3 | EGT2 (page 343) | EGT2 signal out-of-range HIGH |
| 1744 | 3245 | 4 | EGT3 (page 347) | EGT3 signal out-of-range LOW |
| 1745 | 3245 | 3 | EGT3 (page 347) | EGT3 signal out-of-range HIGH |
| 2212 | 175 | 0 | EWPS (page 373) | EOT Temp above maximum |
| 2235 | 8354 | 1 | FRP SYS (page 387) | FRP unable to build during engine cranking |
| 2243 | 8351 | 7 | FRP SYS (page 387) | FRP above pressure relieve valve limitation |
| 2244 | 8351 | 0 | FRP SYS (page 387) | Fuel Rail Pressure Relief Valve opened (pressure was too high) |
| 2245 | 8352 | 1 | FRP SYS (page 387) | Fuel Pressure Controller output high at low idle |
| 2246 | 8352 | 0 | FRP SYS (page 387) | FRP above or below desired |
| 2247 | 8353 | 7 | FRP SYS (page 387) | HP fuel pump erratic fuel quantity balancing |
| 2248 | 8354 | 0 | FRP SYS (page 387) | Fuel Rail pressure above maximum |
| 2310 | 100 | 10 | EOP (page 365) | EOP abnormal rate of change |
| 2311 | 100 | 0 | EOP (page 365) | EOP above maximum |
| 2312 | 100 | 11 | EWPS (page 373) | EOP below minimum |
| 2313 | 100 | 1 | EWPS (page 373) | EOP below warning level |
| 2314 | 100 | 7 | EWPS (page 373) | EOP below critical level |
| 2315 | 190 | 0 | EWPS (page 373) | Engine speed above warning level |
| 2316 | 190 | 16 | EWPS (page 373) | Engine speed above maximum at ECM |
| 2317 | 84 | 0 | Truck | VSS value above programmable limit 1 |
| 2318 | 84 | 14 | Truck | VSS value above programmable limit 2 |
| 2321 | 110 | 0 | EWPS (page 373) | ECT above warning level |
| 2322 | 110 | 7 | EWPS (page 373) | ECT above critical level |
| 2323 | 111 | 1 | EWPS (page 373) | ECL below warning/critical level |
| 2324 | 593 | 14 | IST (California - Standard) (page 406) | Engine stopped by IST |
| 2324 | 593 | 14 | IST (Federal - Optional) (page 408) | Engine stopped by IST |
| 2325 | 110 | 14 | EWPS (page 373) | ECT value reached de-rate temperature |
| 2351 | 7129 | 1 | AMS (page 238) | EBP below desired level |
| 2352 | 7129 | 0 | AMS (page 238) | EBP above desired level |
| 2357 | 7129 | 7 | AMS (page 238) | Retarder control valve unable to achieve desired EBP |
| 2369 | 1378 | 2 | Service (page 429) | Engine oil service required |
| 2370 | 94 | 17 | Service (page 429) | Fuel filter change reminder |

| DTC | SPN | FMI | Circuit | Condition Description |
|---|---|---|---|---|
| 2371 | 94 | 0 | EFP (page 318) | Fuel pressure above normal |
| 2372 | 94 | 1 | EFP (page 318) | Fuel pressure below normal |
| 2391 | 2791 | 11 | EGR (page 327) | EGR valve internal circuit failure |
| 2674 | 3242 | 2 | EGT2 (page 343) | EGT2 signal in-range fault |
| 2675 | 3241 | 2 | EGT1 (page 338) | EGT1 signal in-range fault |
| 2676 | 3245 | 2 | EGT3 (page 347) | EGT3 signal in-range fault |
| 2687 | 8302 | 1 | AFT SYS (page 227) | DPF low flow resistance |
| 2698 | 3251 | 0 | AFT SYS (page 227) | DPF high restriction |
| 2732 | 3251 | 2 | EGDP (page 322) | EGDP stuck in-range fault |
| 2773 | 8303 | 10 | AFT SYS (page 227) | DOC unable to reach regen temp |
| 2774 | 8303 | 1 | AFT SYS (page 227) | DOC efficiency - AFI low flow |
| 3333 | 164 | 0 | FRP SYS (page 387) | Fuel Rail Pressure above maximum |
| 3341 | 7129 | 4 | EBP (page 300) | EBP signal out-of-range LOW |
| 3342 | 7129 | 3 | EBP (page 300) | EBP signal out-of-range HIGH |
| 3787 | 8326 | 2 | AFT SYS (page 227) | DPF cleanliness test - soot level too high |
| 4421 | 8001 | 5 | INJ (page 398) | Cyl 1 open coil: open circuit |
| 4422 | 8002 | 5 | INJ (page 398) | Cyl 2 open coil: open circuit |
| 4423 | 8003 | 5 | INJ (page 398) | Cyl 3 open coil: open circuit |
| 4424 | 8004 | 5 | INJ (page 398) | Cyl 4 open coil: open circuit |
| 4425 | 8005 | 5 | INJ (page 398) | Cyl 5 open coil: open circuit |
| 4426 | 8006 | 5 | INJ (page 398) | Cyl 6 open coil: open circuit |
| 4511 | 8358 | 2 | ECM Self (page 281) | Bank A Injector driver over voltage |
| 4512 | 8358 | 3 | ECM Self (page 281) | Bank A Injector driver under voltage |
| 4513 | 8358 | 4 | ECM Self (page 281) | Bank A Injector driver under current |
| 4514 | 8358 | 5 | ECM Self (page 281) | Bank A Injector driver over current |
| 4515 | 8358 | 6 | ECM Self (page 281) | Bank A Injector low driver over current |
| 4516 | 8358 | 8 | ECM Self (page 281) | Bank A Injector on phase time-out |
| 4517 | 8358 | 10 | ECM Self (page 281) | Bank A Injector time-out |
| 4521 | 8359 | 2 | ECM Self (page 281) | Bank B Injector driver over voltage |
| 4522 | 8359 | 3 | ECM Self (page 281) | Bank B Injector driver under voltage |
| 4523 | 8359 | 4 | ECM Self (page 281) | Bank B Injector driver under current |
| 4524 | 8359 | 5 | ECM Self (page 281) | Bank B Injector driver over current |
| 4525 | 8359 | 6 | ECM Self (page 281) | Bank B Injector low driver over current |
| 4526 | 8359 | 8 | ECM Self (page 281) | Bank B Injector on phase time-out |

| DTC | SPN | FMI | Circuit | Condition Description |
|---|---|---|---|---|
| 4527 | 8359 | 10 | ECM Self (page 281) | Bank B Injector time-out |
| 4528 | 7253 | 14 | ECM Self (page 281) | ECM Error - Injector control out of normal operating range |
| 4553 | 8064 | 5 | CKP (page 270) | CKP - No signal, open circuit |
| 4554 | 8064 | 7 | CKP (page 270) | CKP missing gap detection error |
| 4555 | 8064 | 8 | CKP (page 270) | CKP excessive pulses |
| 4556 | 8064 | 14 | CKP (page 270) | CKP circuits reversed |
| 4571 | 8001 | 0 | CYL BAL (page 297) | Cyl 1 cyl balance max limit exceeded |
| 4572 | 8002 | 0 | CYL BAL (page 297) | Cyl 2 cyl balance max limit exceeded |
| 4573 | 8003 | 0 | CYL BAL (page 297) | Cyl 3 cyl balance max limit exceeded |
| 4574 | 8004 | 0 | CYL BAL (page 297) | Cyl 4 cyl balance max limit exceeded |
| 4575 | 8005 | 0 | CYL BAL (page 297) | Cyl 5 cyl balance max limit exceeded |
| 4576 | 8006 | 0 | CYL BAL (page 297) | Cyl 6 cyl balance max limit exceeded |
| 5536 | 8253 | 1 | EIM Self (page 281) | EIM Error - Manufacturing defaults were selected |
| 5541 | 8254 | 8 | EIM Self (page 281) | EIM Error - Unexpected reset fault |
| 5549 | 8240 | 11 | EIM Self (page 281) | EIM Error - RAM programmable parameter list corrupted |
| 5558 | 7314 | 4 | AFP (page 218) | AFP VREF out-of-range |
| 5559 | 7310 | 2 | AFT (page 227) | AFP sensor failed ambient pressure test |
| 5560 | 7310 | 4 | AFP (page 218) | AFP signal out-of-range LOW |
| 5561 | 7310 | 3 | AFP (page 218) | AFP signal out-of-range HIGH |
| 5565 | 7313 | 5 | Retarder Control (page 425) | Retarder control valve open circuit |
| 5566 | 7313 | 11 | Retarder Control (page 425) | Retarder control valve short circuit |
| 5632 | 8254 | 12 | EIM Self (page 281) | EIM Error - RAM/CPU self-test fault |
| 5637 | 3511 | 5 | ECM Self (page 281) | ECM Error - Fuel Rail Pressure error |
| 6233 | 3511 | 3 | FRP (page 383) | FRP VREF out-of-range HIGH |
| 6234 | 3511 | 4 | FRP (page 383) | FRP VREF out-of-range LOW |
| 6258 | 102 | 7 | AMS (page 238) | Boost below desired |
| 6259 | 2791 | 7 | EGRP (page 331) | EGR control valve unable to achieve commanded position |
| 6260 | 2791 | 0 | EGRP (page 331) | EGRP unable to detect close position |
| 6262 | 2791 | 5 | EGR (page 327) | EGR control valve open circuit |
| 6270 | 2791 | 14 | EGRP (page 331) | EGRP valve stuck open |
| 6271 | 2791 | 12 | EGRP (page 331) | EGRP valve stuck closed |

| DTC | SPN | FMI | Circuit | Condition Description |
|---|---|---|---|---|
| 6314 | 8342 | 7 | CAN Private (page 262) | ECM CAN message not received from EIM |
| 6315 | 8309 | 2 | CAN Private (page 262) | ACM CAN message not received from ECM |
| 6316 | 8311 | 2 | CAN Private (page 262) | ACM CAN message not received from EIM |
| 6317 | 8316 | 2 | CAN Private (page 262) | EIM CAN message not received from ACM |
| 6318 | 8342 | 14 | CAN Private (page 262) | EIM CAN message not received from ECM |
| 6319 | 8487 | 19 | EIM Self (page 281) | EFRC information not received by ECM |
| 6320 | 8484 | 19 | EIM Self (page 281) | EFRC invalid value or time-out by ECM |
| 6321 | 7311 | 0 | EWPS (page 373) | ECT2 above warning level |
| 6322 | 7311 | 7 | EWPS (page 373) | ECT2 above critical level |
| 6813 | 3241 | 0 | EGT1(page 338) | EGT1 or EGT2 high temp without regen |
| | | | EGT2 (page 343) | |
| 6814 | 3242 | 7 | AFT SYS (page 227) | EGT2 Temp above maximum severe |
| 6817 | 3245 | 7 | AFT SYS (page 227) | EGT3 Temp above maximum severe |
| 6823 | 7311 | 14 | EWPS (page 373) | ECT2 Temp above maximum |
| 6835 | 8491 | 14 | Truck | Auxiliary engine shutdown input circuit out-of-range |
| 6840 | 51 | 12 | ITV (page 410) | ITV broken spring or linkage |
| 6841 | 51 | 8 | ITV (page 410) | ITV feedback outside duty cycle range |
| 6842 | 51 | 19 | ITV (page 410) | ITV feedback signal not plausible |
| 6900 | 8305 | 12 | AFI (page 214) | AFI circuit fault |
| 6901 | 8306 | 5 | AFS (page 223) | AFS Valve circuit fault |
| 6902 | 8307 | 5 | AFD (page 210) | AFD Valve circuit fault |
| 6905 | 8306 | 7 | AFT SYS (page 227) | Aftertreatment fuel leak: fuel line, AFD, or AFI |
| 6906 | 8306 | 14 | AFS (page 223) | AFS valve and AFD valve connections reversed |
| | | | AFD (page 210) | |
| 6910 | 8307 | 12 | AFT SYS (page 227) | AFD valve fail to open |
| 6912 | 8308 | 7 | AFT SYS (page 227) | AFP above normal with AFS closed |
| 6913 | 7310 | 7 | AFT SYS (page 227) | AFP above normal with AFD open |
| 6914 | 7310 | 1 | AFT SYS (page 227) | AFP below normal during DPF regen |

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## Description

Technical Service Information (TSI) letters are periodically published to inform service technicians of product enhancements and field service issues. File TSIs in this section for supplemental reference.

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