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DIAGNOSTIC ANALYSIS PROCEDURES

OIL CONSUMPTION

When investigating oil consumption:

1. Inspect for external oil leaks and correct

2. Check for air cleaner restriction, air induction system leaks, excessive crankcase pressure, and faulty air compressor

NOTE – Change the air filter element and inspect the turbocharger for damage if lube oil is drawn into the engine.

3. Verify the problem

If the above conditions are not the cause of oil consumption, continue analysis.

- Incorrect oil level (overfill)
- Incorrect API specification
- Change the oil (use the recommended API Specification and viscosity for current ambient temperature values).
- Determine initial oil consumption rate and trend at: 1000 miles/50 hours and 5000 miles/250 hours.
- Record the amount of make up oil added during the test period.

Excessive oil consumption can be caused by:

- Abnormally heavy loads pulled by the vehicle (above the specified GVW).
- Incorrect operation (i.e. allowing the engine to lug in the incorrect gear range) resulting in oil consumption.
- Faulty air compressor (if compressor piston rings are worn, oil can be forced into the air system).
- Worn engine valve guides or valve stem seals (clean and inspect).
- Worn rings or bores from normal wear or dirt passing through the air filter element (perform crankcase pressure test).
- Turbocharger compressor or turbine leak.
- Defective injector O-ring allowing oil to mix with fuel. See ICP leakage test in Section 2, Hard Start / No Start Diagnostics.
- Defective injector

FUEL CONSUMPTION

When excessive fuel consumption is suspected:

- Compare the actual rate of fuel consumption in miles per gallon or (liters per kilometers) with normal fuel usage. Fuel consumption is a factor of load and operating conditions. The greater the load or higher engine rpm, the greater the fuel consumption.

When excessive fuel consumption is confirmed:

- Check the fuel system for leaks:
    - Check for internal fuel leakage into the lubricating oil. Take an oil sample and have it analyzed for fuel in the oil.
    - Pressurize the fuel system to 30-40 psi (207-275 kPa) to isolate any leakage.
    - Do a Cylinder Contribution Test (Engine Running Injector Test) to find injectors contributing to excessive fuel consumption. See Performance Diagnostics Test (CHECK NO 24) on the Hard Start / No Start & Performance Engine Diagnostics form EGED-220.
- Check for correct engine component and performance specifications by conducting all Performance Diagnostic Tests on form EGED-220, Hard Start / No Start & Performance Engine Diagnostics.

Excessive fuel consumption can be caused by:

- Fuel leak in lube oil or cooling system
- Excessive engine speed or lugging of the engine.
- Excessive idle time
- Mismatch of engine components

HIGH COOLANT TEMPERATURE OR COOLANT LOSS

To verify high coolant temperature or coolant loss:

- Determine operating conditions when overheating occurs.
- Check fault codes for overheating or event log information. Use the Electronic Service Tool (EST).
- Check the following:
    - Filler cap (pressure cap) on deaeration tank
    - External leaks (pressurize system)
    - Coolant solution (glycol contamination)
    - Coolant solution (glycol excess concentration)
    - Serpentine belt and tensioner
    - Dash gauge and sender accuracy / calibration
    - Thermostat operation (stuck or near closed)
    - Radiator cleanliness (inside and out)
    - Shutter operation (if equipped)
    - Air flow blockage (winter front etc.)
    - Fan operation
    - Collapsed hose

Verify Operation:

- Accessory Equipment - Is the equipment approved and installed correctly?

Engine Maintenance:

- Clean. No oil leaks. No external coolant leaks.
- Condition of serpentine belt and tensioner.

Inspect cooling system for:

- Clean coolant having the correct conditioning inhibitor and concentration of ethylene glycol (green) **or** propylene (red), if used for the season.
- Deaeration tank (pressure) cap. Use Pressure Test Kit Model D200 (ZTSE2239) or Gauge Bar (PS94-831-3). Check restriction at water pump inlet. Restriction should not exceed 3 in Hg (10 kPa) without pressure cap, with thermostat open, and engine at high idle.
- Hoses - Correct type and securely clamped.
- Radiator - Clean and unobstructed by bent fins, pinched tubes, etc.
- Radiator correct. Check specifications. Check repair history. Check for evidence of stop leak.
- Fan - Correct specifications. Fit in shroud. installation.
- Fan clutch operation - Verify Manufacturer's recommendations
- Correct settings for shutter control operation (if equipped).

Inspect engine for:

- Water pump condition. Bearing seal and weep holes for leakage.
- Thermostat and seal - Correct specifications and operation.
- Oil cooler - Correct oil and coolant flow.
- Correct engine power.
- Coolant aeration from cylinder head gasket or a cracked/porous cylinder head.

EXCESSIVE EXHAUST SMOKE

Evaluating Normal Exhaust Smoke

Blue-white smoke can be observed:

- at engine start up under all ambient temperatures and engine operating temperatures.
- after the engine warm up period, after idling ten minutes or more.
- at low idle speeds after cold engine start up. The smoke will clear when normal operating temperature is achieved.

Darker smoke can be observed:

- when pulling hard, on a steep grade.
- when pulling a trailer or operating with a maximum payload.
- during acceleration.

Excessive smoke can be seen during three driving operations:

- Acceleration
- Full load
- Coasting (slowing down)

Incorrect vehicle operation will cause excessive exhaust smoke. For example, excessive exhaust smoke will occur if the driver does not keep engine rpm within the specified range for the transmission and rear axle ratio.

Critical diagnosis:

- Check restriction in the air induction system and air cleaner.
- Inspect the turbocharger for lube oil leakage in the compressor housing.
- Inspect the cooling system. Low operating temperature can cause blue smoke.
- Check oil consumption. Excessive lube oil consumption can cause blue smoke.
- Check exhaust smoke. Constant gray smoke can be caused by the air induction system.
- Check for black smoke. Determine the cause, by doing all tests on form EGED-220, Hard Start / No Start & Performance Engine Diagnostics.

FUEL DILUTION

- Fuel dilution can be caused by an internal leak in the transfer pump, damaged or eroded injector O-rings, or a leaking injector causing cylinder wash down.
- If fuel dilution is suspected, take an oil sample to an independent lab for testing.

COOLANT IN LUBRICATING OIL OR LUBRICATING OIL IN COOLANT

Oil Cooler Pressure Check

Use oil cooler test plate (ZTSE4376). See engine service manual. Possible locations of leakage include:

- Lube oil cooler bundle (cracked / loose tubes or cut O-rings).
- Cylinder sleeve cavitation.
- Blown air compressor head gasket.
- Cracked or porous cylinder head (top deck, injector sleeve, or defective head gasket).
- Porous or cracked crankcase (in main bearing crankcase webbing).

Pressure Leakage Test for Engine Crankcase

If oil cooler is okay, perform pressure test.

- Drain all lube oil and coolant from engine and radiator.
- Disconnect the radiator from the engine and cap off all engine connections (with plugs and hose clamps).
- Disconnect cab heater connections at the engine and cap engine openings.
- Disconnect air compressor coolant supply / discharge lines, then cap lines at engine.
- Disconnect oil supply return line from air compressor to crankcase and leave open (if equipped).

- Remove the intake manifold / valve cover, lube oil pan, and drain plug from the lube oil cooler.
- Fill the engine with water and attach an air line connection coupled with a regulator assembly to the water drain in cylinder block.
- Pressurize the crankcase cooling system to 30 psi (207 kPa). Maintain pressure to find leakage (overnight, if necessary) to locate porous castings or tiny cracks.
- All points of leakage must be found before tear down and repair.

NOTE – No external or internal leakage is allowable. After leaks are found and repaired, clean the contaminated engine.

EXCESSIVE CRANKCASE PRESSURE

Excessive crankcase pressure can be caused by :

- Worn piston rings due to dirt.
- Broken piston rings due to wear.
- Stuck piston rings due to incorrect specification lube oil.
- Blown air compressor head gasket or worn air compressor rings.
- Turbocharger seal failure.
- Excessive valve guide wear.

LUBE OIL IN FUEL

Possible causes for detecting lube oil in the fuel would include:

- Leaking injector O-rings
- Internal leakage of HEUI injector
- High pressure fuel / oil manifold gasket
- Cracked or porous fuel / oil manifold
- Cracked or porous cylinder head

If lube oil is suspected in the fuel, drain some fuel from the filter. If the fuel appears darker than it should be, get fuel sample from a supplier to compare with the fuel taken and check for contamination.

If a supplier sample is not available, remove the fuel filter, and use a filter cutter to cut open the housing. If the filter element is black, oil may have entered the fuel system, most likely past an injector O-ring or a missing O-ring.

DIAGNOSING SCUFFED INJECTORS

KEY-ON ENGINE-RUNNING INJECTOR TEST

The injector test is designed to detect problems with injection and combustion events. Performing a cylinder contribution test will analyze the individual contribution of each of the power cylinders. Its primary function is to detect a bad injector. The test will also detect problems that could affect the overall performance of the power cylinders (i.e.: valves, pushrods, pistons, rings, etc.).

During this test the ECM will control fuel delivery and determine each cylinder's power contribution. If a cylinder is not performing satisfactorily, a Diagnostic Trouble Code will be set.

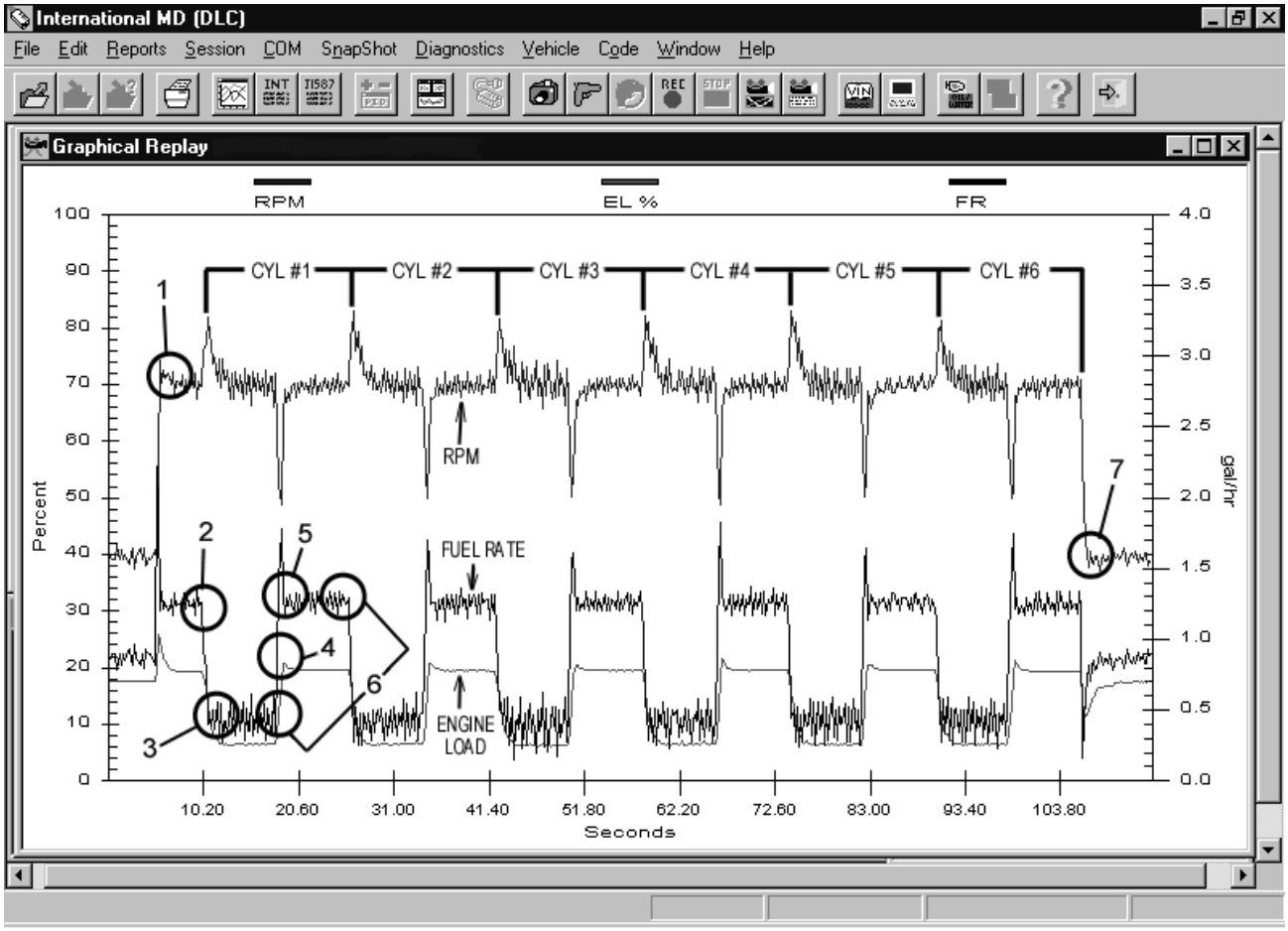

Figure 167 Good Cylinder Contribution Test Recording

Some of the key areas to examine on the graphical display of the cylinder contribution test are:

1. When the test begins, the engine speed increases in increments up to 850 rpm.

2. The ECM increases fuel delivery to cylinder #1 (over-fuels) which causes engine speed to increase.

3. Fuel is reduced to remaining cylinders to maintain 850 rpm

4. The ECM decreases fuel delivery to cylinder #1 (under-fuels) which causes engine speed to decrease.

5. Fuel is increased to the remaining cylinders to maintain 850 rpm

6. At this point 2 key observations are noted:

   - The ECM compares fuel delivery of the remaining 5 cylinders during over-fuel condition
   - The ECM compares fuel delivery of remaining 5 cylinders during under-fuel condition

   If the difference is not what the ECM expects, a DTC is set for non-contributing cylinder. The procedure will repeat for the remaining cylinders until the test is complete.

7. The engine speed returns to low idle. The test is complete

NOTE – During the cylinder contribution test, the fuel rate graph represents fuel delivery to the remaining 5 cylinders.

The cylinder contribution test begins with cylinder #1 (front cylinder) and is performed sequentially. The rpm fluctuation on engines with more than one severely scuffed injector can be enough to stop the cylinder contribution test.

TROUBLESHOOTING

A scuffed injector can be very difficult to diagnose. The best way to troubleshoot a scuffed injector is by using the EST and Master Diagnostics. Using Master Diagnostics KOER_CCT_I6.SSN:

- Visualize - use the on-line graphs to compare one cylinder trace to another. Even the slightest scuffed injectors can display a significant change in pattern from a good injector.
- Listen - watch the real-time graph and carefully listen to the sound characteristics of the engine.
- Verify - when the DTC is set, verify that there is a significant change for that cylinder.

TEST PROCEDURE - USING THE EST AND MASTER DIAGNOSTICS

NOTE – All of the following screen views are based off of MD32 Version 2.3 default settings unless otherwise stated. You may have variations of views if you are using a different version of MD. If you have customized settings you may have different view.

WARNING – To avoid personal injury, be certain that the transmission is in neutral, parking brake is applied, and drive wheels are blocked prior to starting the engine.

1. Start the engine and bring it up to its normal operating temperature above 160°F (71°C).

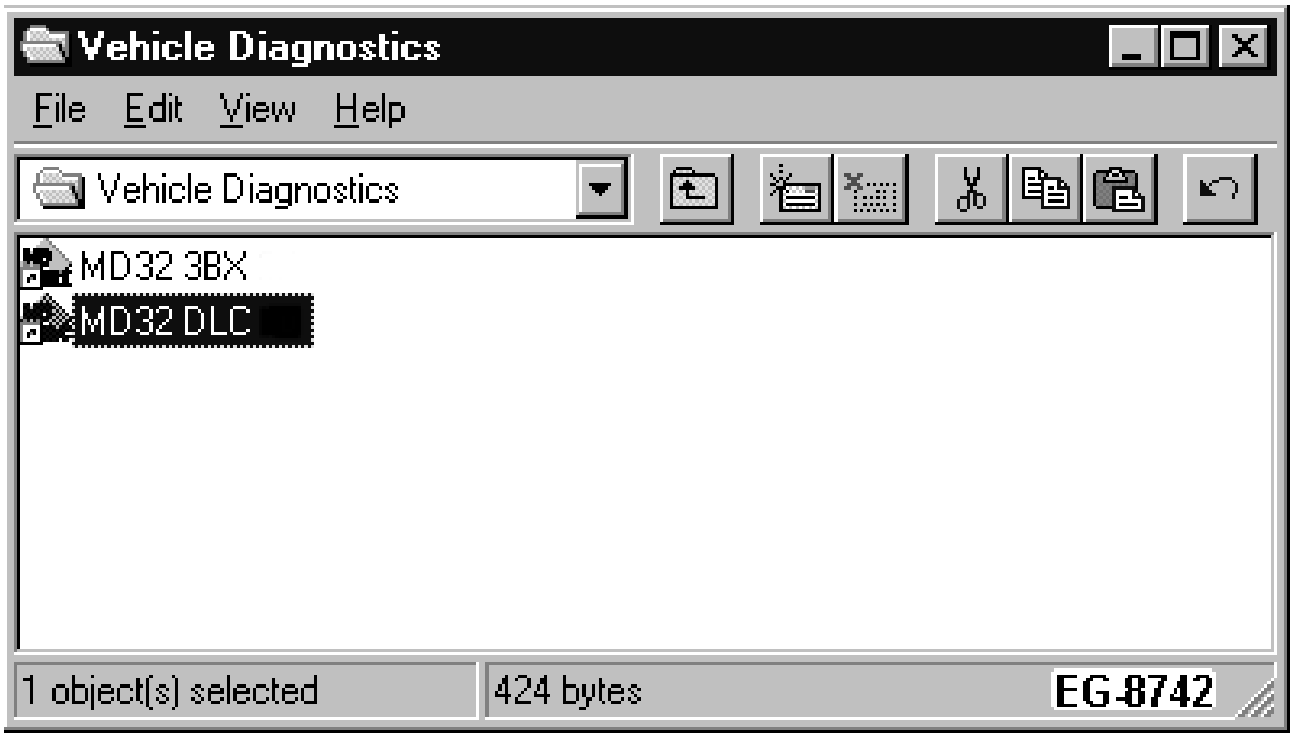

Figure 168

2. Start the Master Diagnostics. Select the single box ECM application (MD32 DLC) (See Figure 168, page 364). Selecting the wrong application will give you erroneous readings.

3. Connect the EST with the International® truck interface cable to the 6 pin ATA connector located near the left side kick panel. For 9 pin ATA connectors, use the pigtail connector (6 pin to 9 pin) adapter tool ZTSE4467.

Figure 169

4. Select the **Session** drop-down menu bar and select **Open** to begin a session (See Figure 169, page 364).

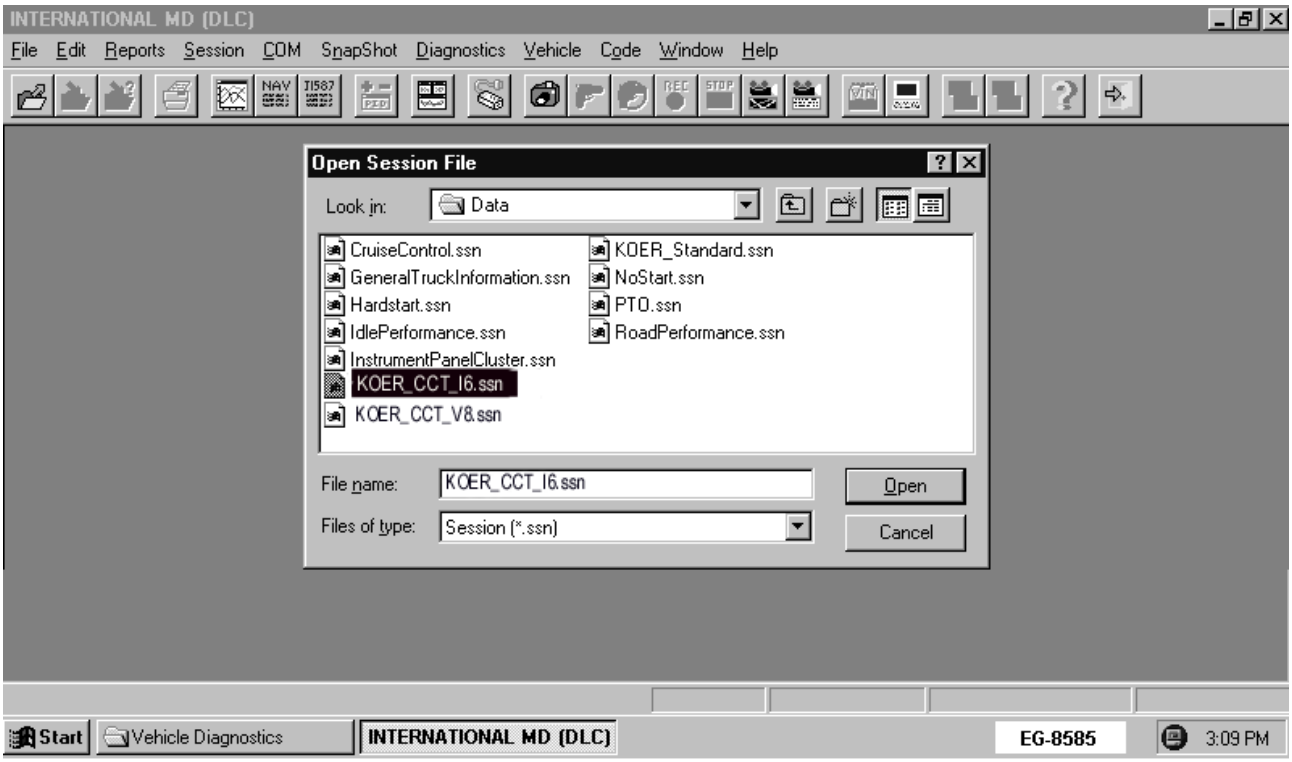

Figure 170

5. Select the file **KOER_CCT_I6.SSN** (Key-On Engine Running Cylinder Contribution Test) from the **Open Session File** dialog window. The file name should now appear in the **File Name** box (See Figure 170, page 365). Select **Open**.

6. When selecting a factory default session from International® Engine, Master Diagnostics automatically selects the correct **COM** port. Refer to the Master Diagnostics Software User's Manual for additional information.

7. Verify that the engine coolant temperature (ECT) is greater than 160°F (71°C).

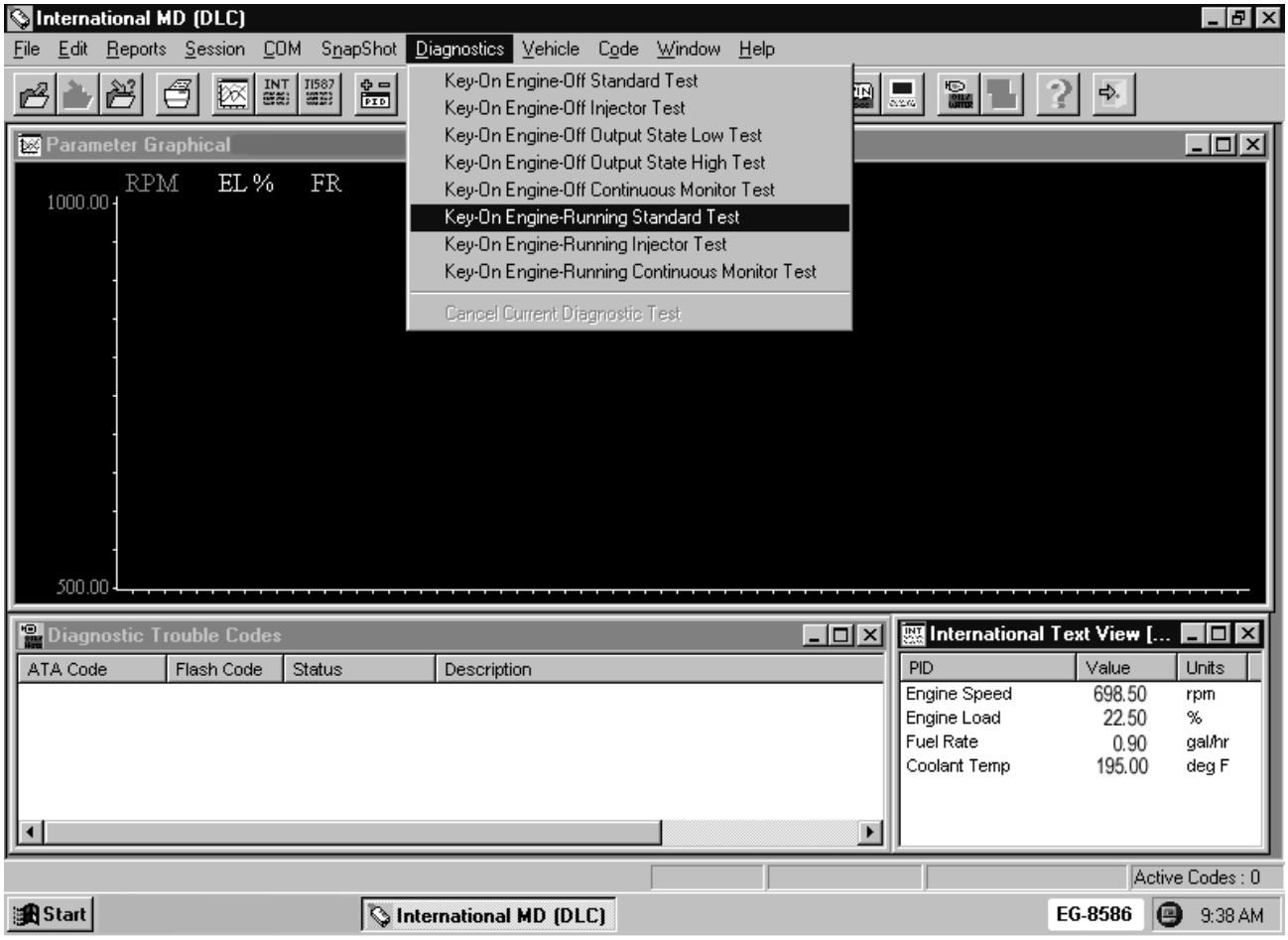

Figure 171

8. It is essential to run the **Key-On Engine-Running Standard Test** in order to gain access to cylinder contribution testing. Select the **Diagnostics** drop-down menu bar, then select the **Key-On Engine-Running Standard Test** (See Figure 171, page 366).

If a diagnostic message appears, take note of the message, select **OK** and try again. If the message reappears, refer to the Diagnostic Tests section in MD Software Users Manual.

NOTE – The status bar will display the message **DIAGNOSTICS RUNNING** at the bottom of the screen.

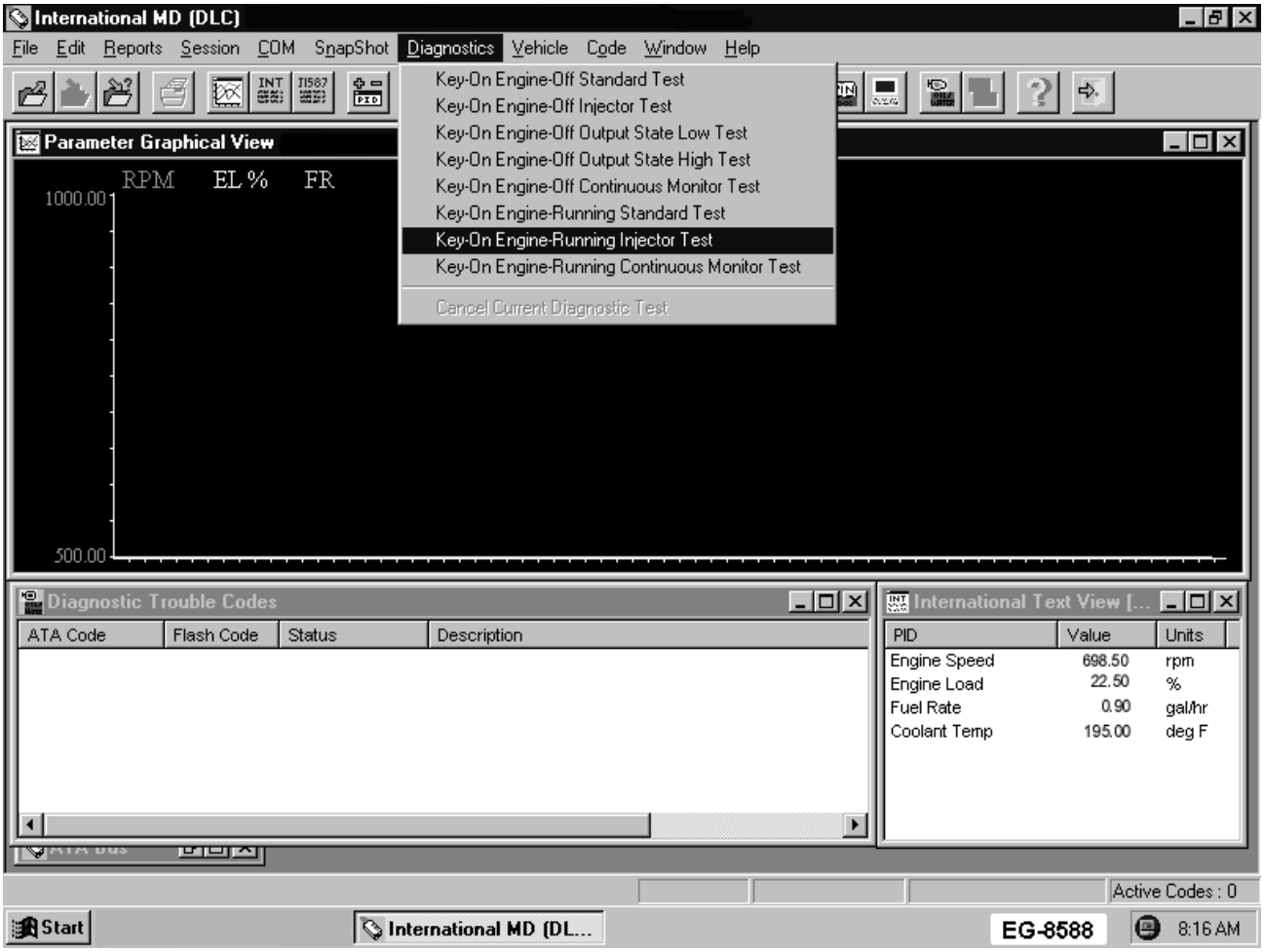

Figure 172

9. When the standard test is complete, select the **Diagnostics** drop-down menu and select the **Key-On Engine-Running Injector Test** (See Figure 172, page 367).

   If a diagnostic message appears, take note of the message, select **OK** and try again. If the message reappears, refer to the Diagnostic Tests section in MD Software Users Manual.

   NOTE – The status bar will display the message **DIAGNOSTICS RUNNING** at the bottom of the screen.

10. While the test is running, the following parameters are observed in the graphical view:

    - Engine Speed (RPM) (500–1000 rpm)
    - Engine Load (EL) (0–127.5%)
    - Fuel Rate (FR) (0–4 gal/hr)

Figure 173 Typical Graphical View – Good Cylinder Contribution

11. The following graphic is an example of how a low fuel delivery injector looks during the test. (See Figure 174, page 369)

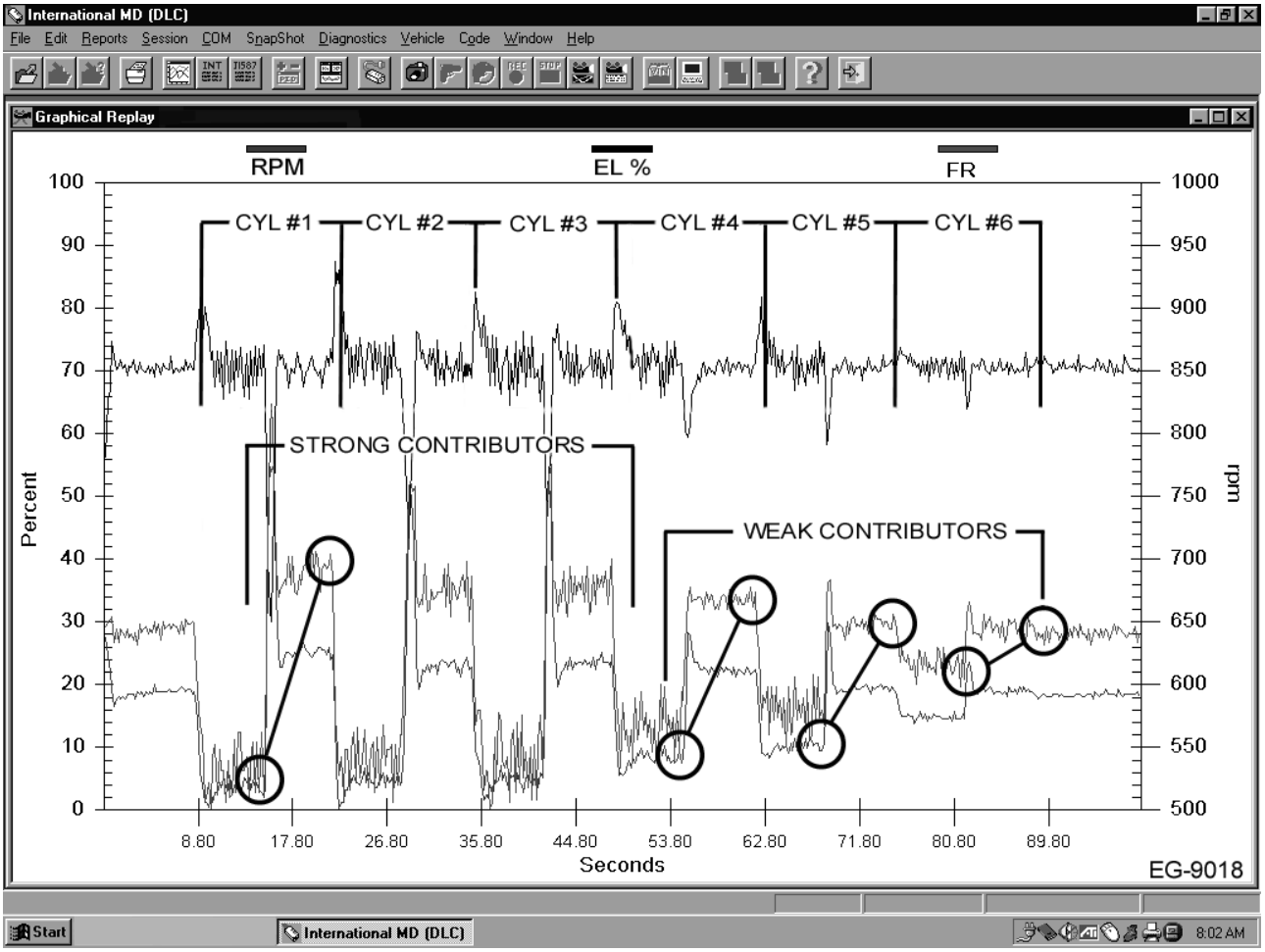

Figure 174 Interpreting Graphical Data – Poor Cylinder Contribution

When the over-fuel condition is compared to the under-fuel condition a significant difference is observed. This indicates that a cylinder is a strong contributor.

NOTE – Figure represents a graphical replay (SnapShot recording).

Strong Contributor Indicators – Cylinders 1-3

Key Observations:

- To maintain constant engine speed the ECM makes greater changes to the fuel rate than seen in weaker cylinders (cylinders 4–6).
- There is a greater impact on Engine Load (EL).

Weak Contributor Indicators– Cylinders 4-6

Key Observations:

- To maintain constant engine speed the ECM makes minimal changes to the fuel rate than seen in stronger cylinders (cylinders 1–3).
- There is a minimal impact on Engine Load (EL).

NOTE – The graphical replay provided for discussion is not severe enough to generate a fault code.

The previously described procedure allows the technician to troubleshoot and repair the engine by replacing only the scuffed or defective injector(s). In cases where rust or corrosion is present within the injectors, some additional precautions are required.

- Clean the entire fuel system of any water or other foreign contamination, including fuel tanks, fuel filter housings, strainers and fuel supply manifold.
- After cleaning the fuel system, install and run existing injectors to purge the fuel system of any remaining contamination. Installation of new injector(s) can now be made.
- It is recommended to replace all injectors that show signs of rust or corrosion.

SNAPSHOT RECORDING & REPLAY OF CYLINDER CONTRIBUTION TEST

The snapshot feature is an option that can be used to document the engine condition.

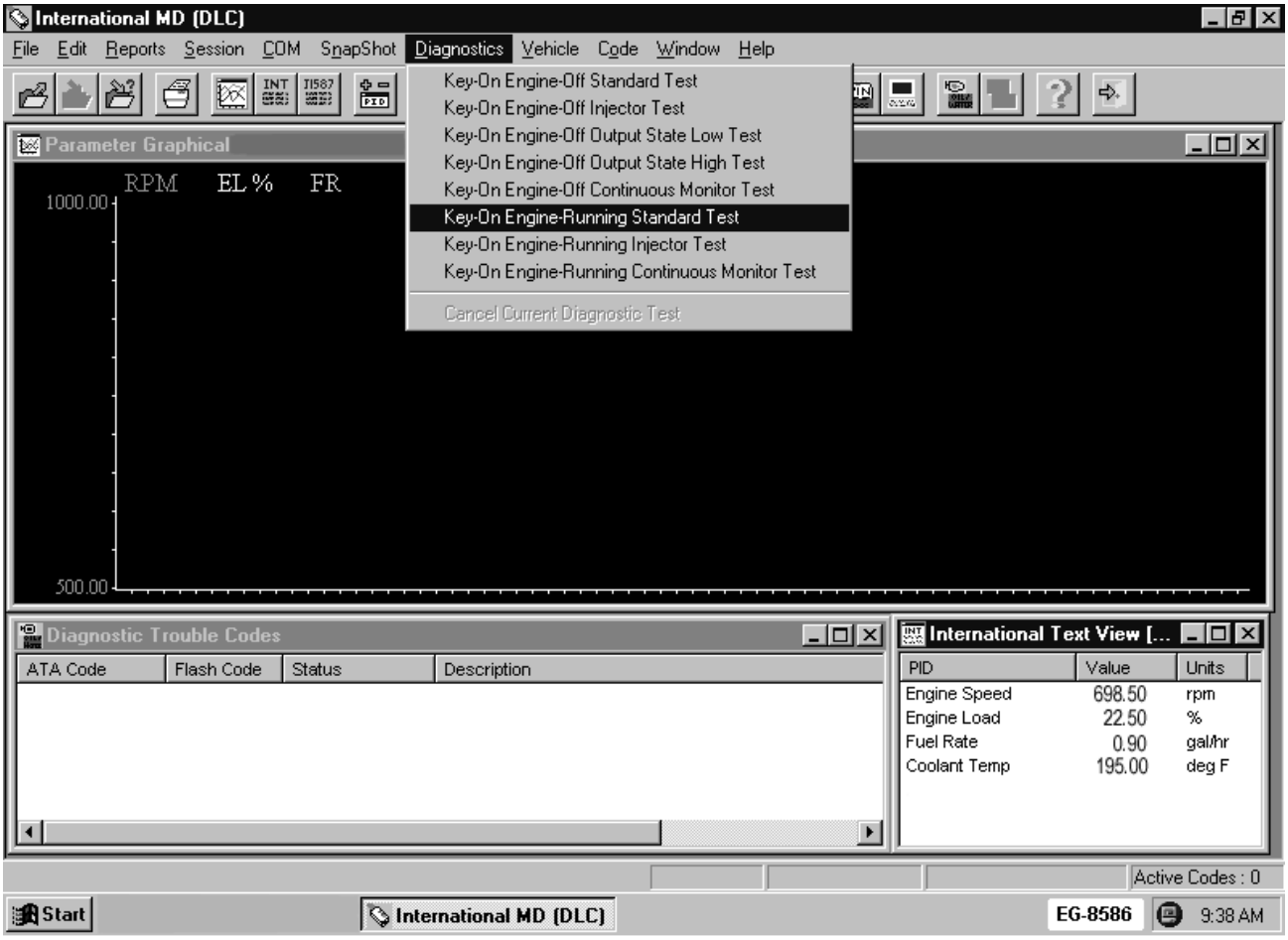

Figure 175

NOTE – Do not arm the trigger when performing **Key-On-Engine-Running Standard Test**.

1. Select the **Diagnostic** drop-down menu and then select **Key-On Engine-Running Standard Test** (See Figure 175, page 371). After the KOER_CCT_I6.SSN file is open and the Key-On Engine-Running Standard Test has been performed.

    - Select the **SnapShot** drop-down menu and select **Arm Trigger** (See Figure 176, page 372).

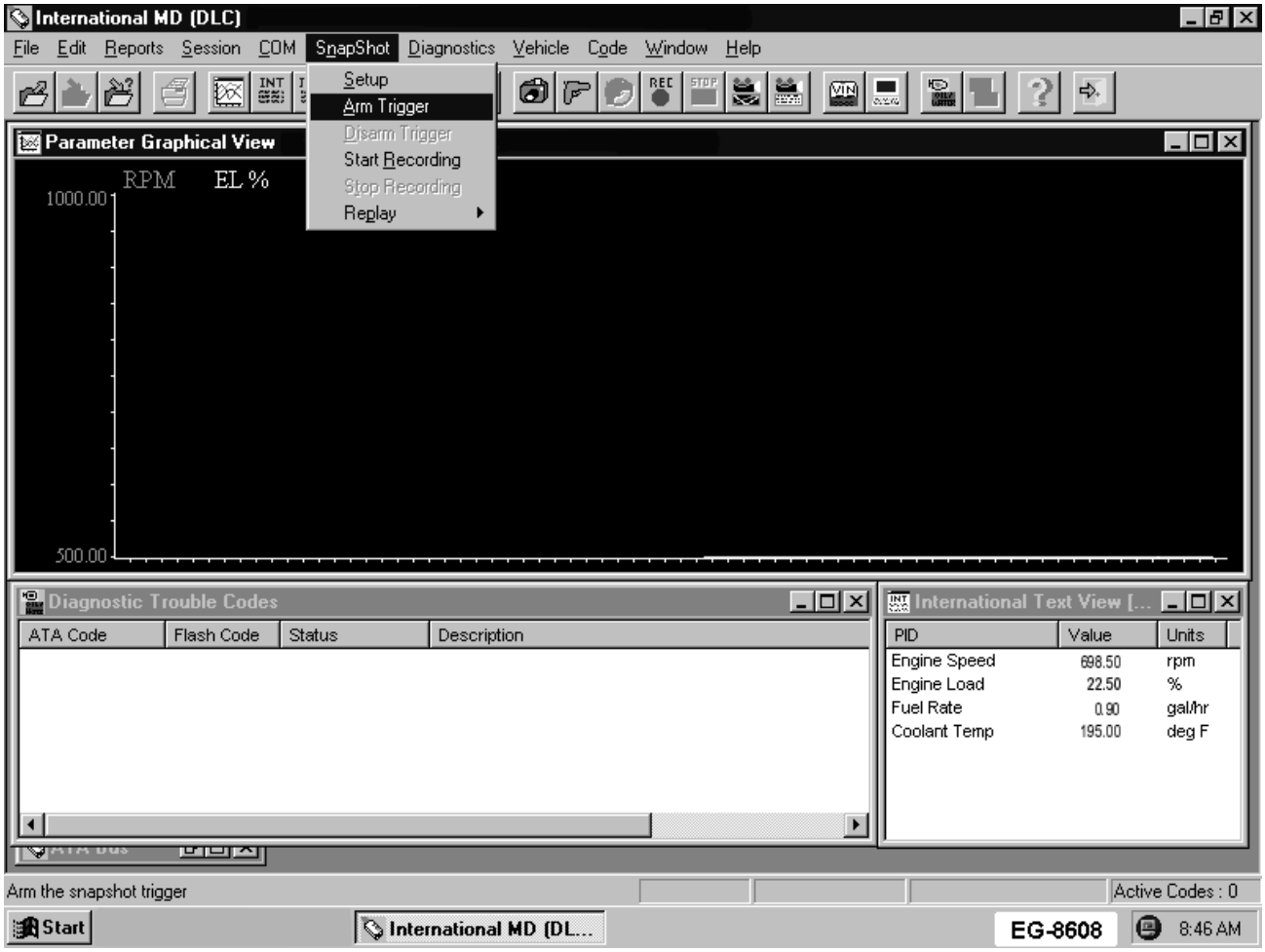

Figure 176

2. Verify the message **Trigger Armed** to be active in the status bar (See Figure 177, page 372).

Figure 177

3. Select the **Diagnostic** drop-down menu and select the **Key-On Engine-Running Injector Test** (See Figure 178, page 373).

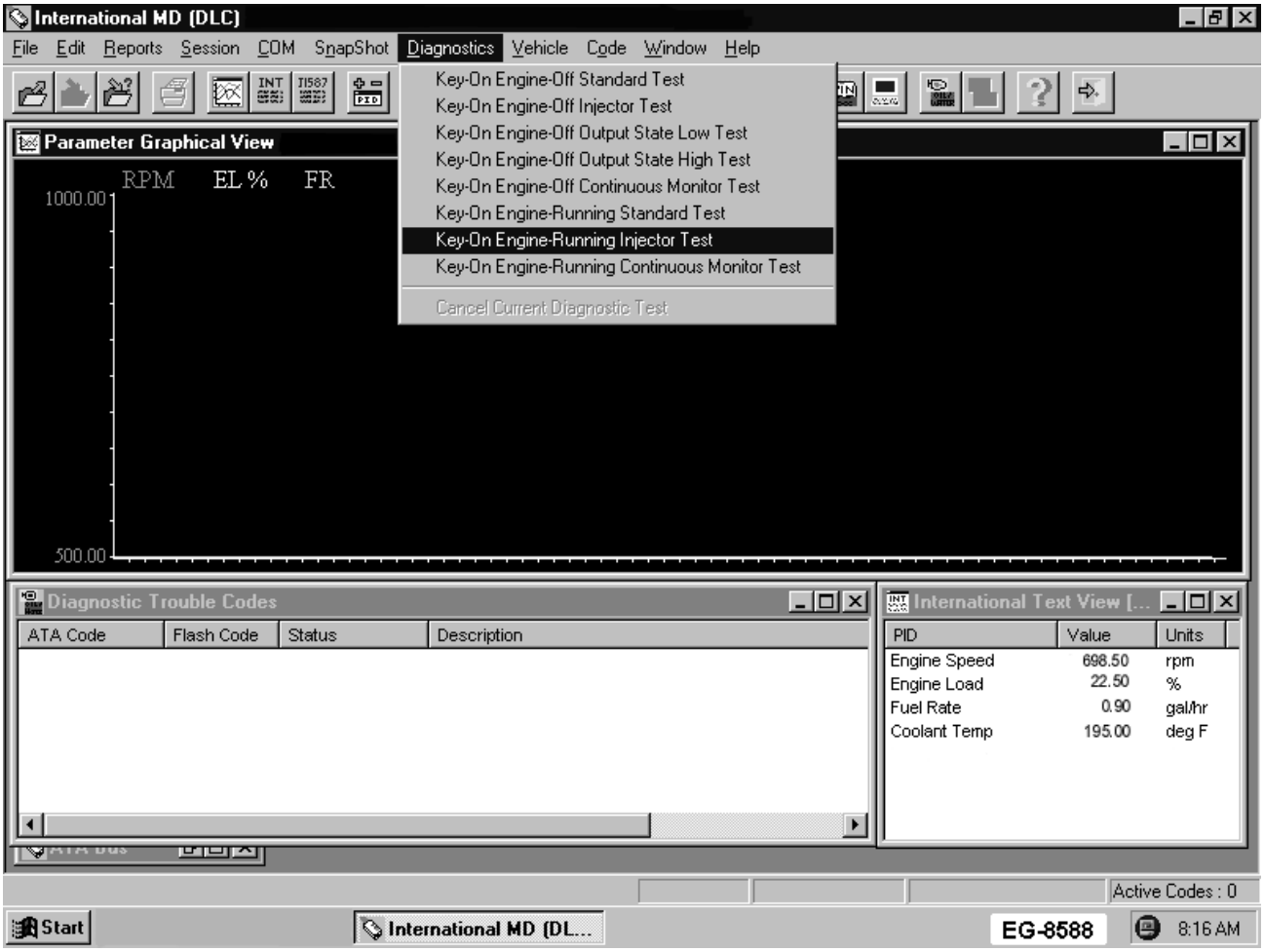

Figure 178

4. Verify that the **Trigger Armed** message changes to **Recording** as soon as the engine rpm is increased by the test (See Figure 179, page 373). You will also see the message **Diagnostic Running** message in the status bar.

Figure 179

5. When the test is complete the **Diagnostic Running** message disappears. To stop SnapShot recording select **Stop** from the setup menu (See Figure 180, page 374). When recording is complete the **Record** message disappears.

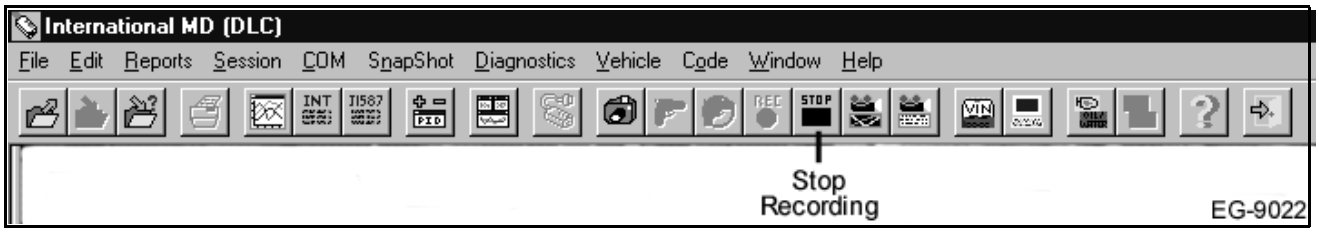

Figure 180

The following procedure provides step by step instructions to replay the recorded session.

Figure 181

6. To review SnapShot recording file, select **Graphical Replay** from toolbar (See Figure 181, page 374).

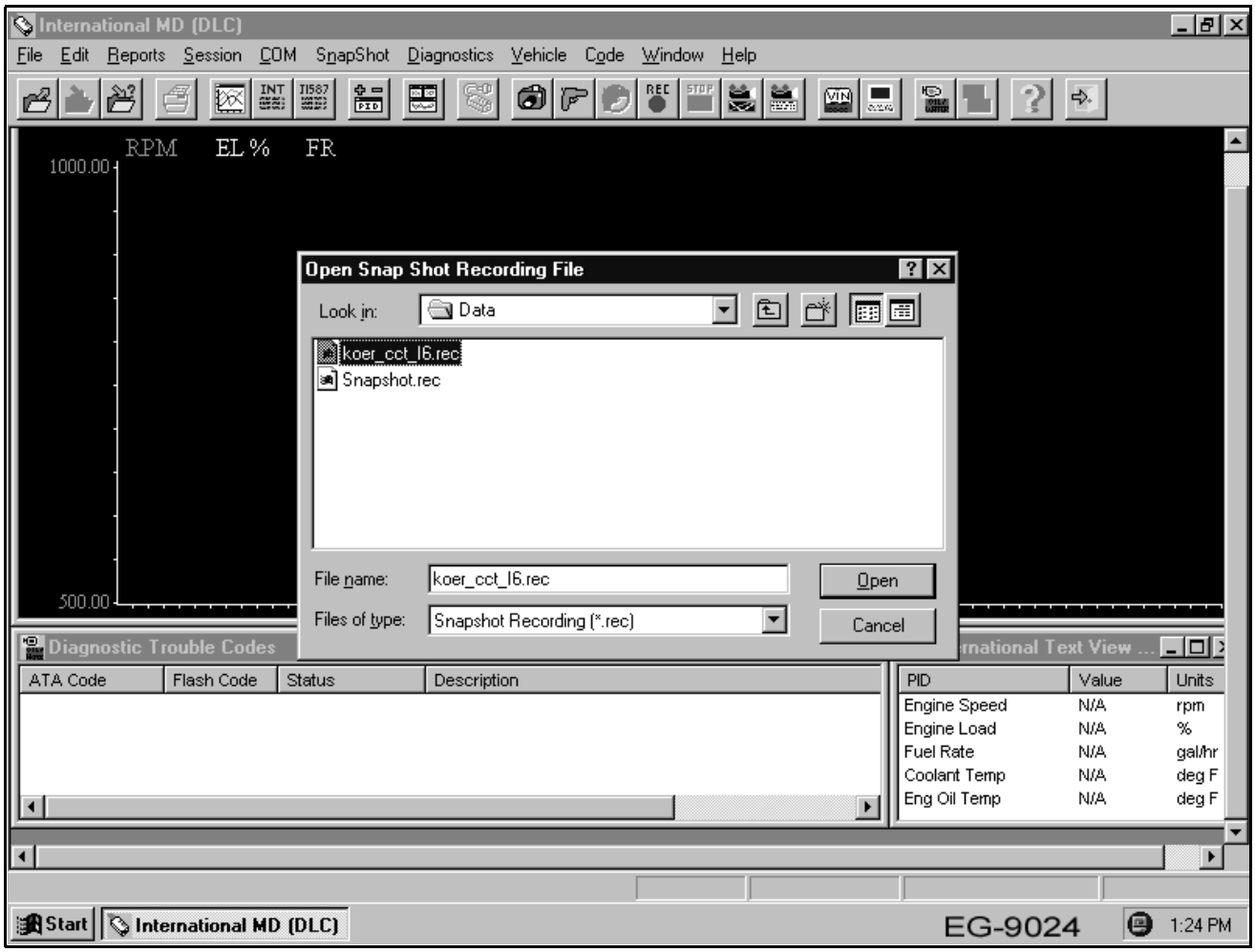

Figure 182 Opening SnapShot Recording

7. Select file **koer_cct_I6.rec** from the pop-up window (See Figure 182, page 375).

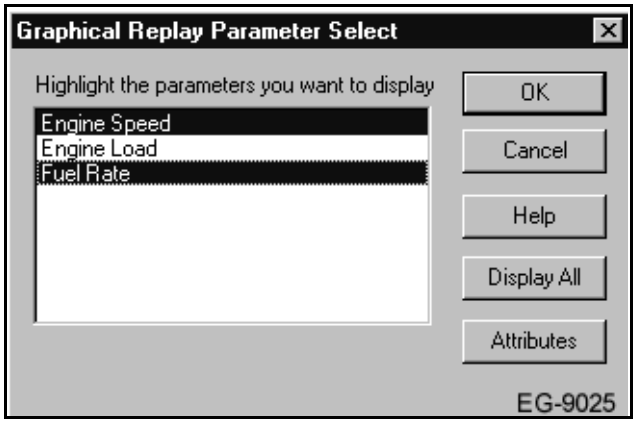

Figure 183

8. Select **Engine Speed** and **Fuel Rate** from the pop-up menu to modify default attributes. To display, select **Attributes**.

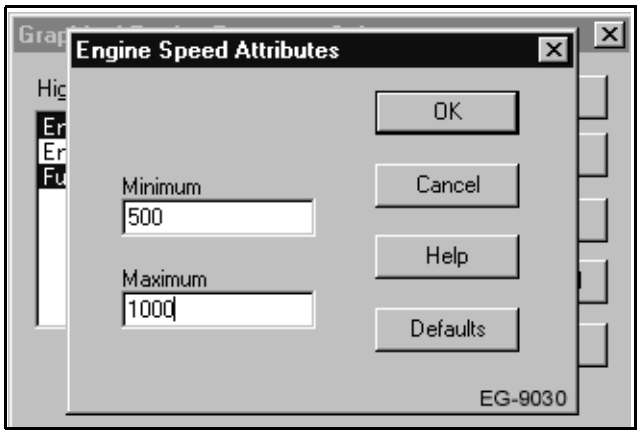

Figure 184 Modified Engine Speed Attributes

9. Modify **Engine Speed Attributes**. Enter 500 for minimum value and 1000 for maximum value. Select **OK** (See Figure 184, page 376).

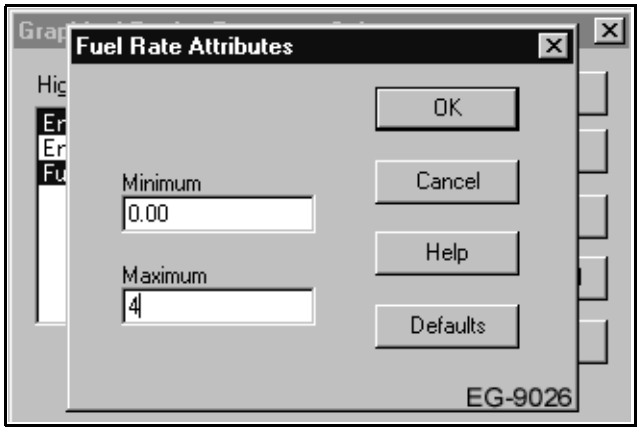

Figure 185 Modified Fuel Rate Attributes

10. Modify **Fuel Rate Attributes**. Enter 4 for maximum value (See Figure 185, page 376). Select **OK** .

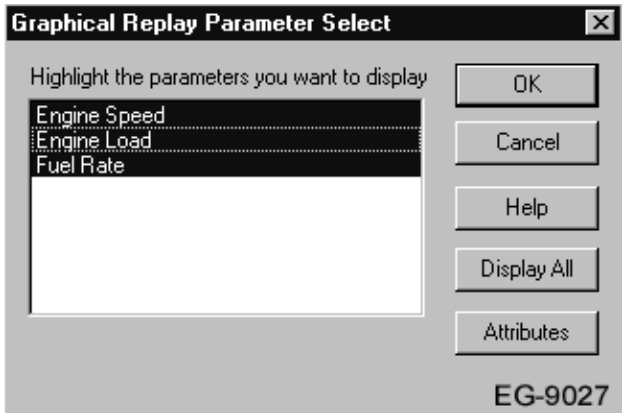

Figure 186

11. To display SnapShot recording file, select **Display All** and then select **OK**. The recorded session will open.

NOTE – To save multiple record files, the record file name must be changed for each recording. Failure to rename record file will result in file being overwritten. Refer to MD Software Users Manual.

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TOOLS

BEYERS MODEL 200 PRESSURE TEST KIT (ZTSE2239)

Description

The Pressure Test Kit (See Figure 187, page 381) can be used to measure intake manifold (boost) pressure, fuel pressure, air cleaner intake restriction, fuel restriction, exhaust restriction and crankcase pressure. It may also be used to test the accuracy of the gauges within the kit.

Figure 187 Pressure Test Kit Model D-200 (ZTSE2239)

The 0-30 psi gauge may be used to measure intake manifold (boost) pressure.

The 0-30 in Hg vacuum gauge (0-14.7 psi), is used to measure fuel system inlet restriction.

The 0-60 in of H_2O (magnehelic) gauge (0-2.16 psi), may be used to measure air cleaner restriction or crankcase pressure.

CAUTION – The quick disconnects have shut off valves in the panel connectors not in the plug. DO NOT connect or disconnect lines while under pressure.

NOTE – When using the magnehelic gauge, be sure to plug the test line into the proper (Pressure or Vacuum) port. Use the pressure port to read exhaust back pressure and crankcase pressure. Use vacuum port to read air cleaner restriction. In both cases, THE OPPOSITE CONNECTOR MUST BE VENTED TO THE ATMOSPHERE BY INSTALLING A QUICK CONNECT PLUG IN THE PORT.

The 0-160 psi gauge may be used to check fuel pressure.

The 0-300 psi gauge is not normally used for any engine diagnostic checks on International® engines.

Operating Instructions

Connect tubes between the test ports on the panel and the test points shown on the (REAR SIDE) of HARD START / NO START AND PERFORMANCE DIAGNOSTIC FORM EGED-220.

GAUGE BAR TOOL (PS94-831-3)

Description

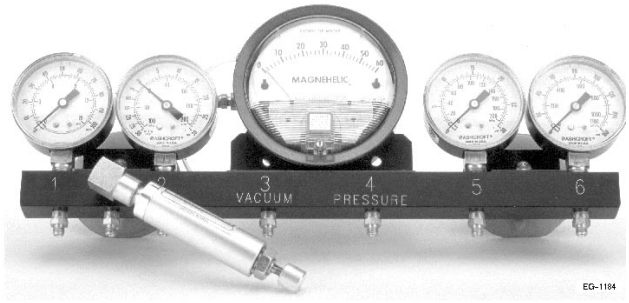


Figure 188 Gauge Bar Tool (PS94-831-3)

Gauge Bar Tool (See Figure 188, page 382) can be used to measure intake manifold (Boost) pressure, fuel pressure, air cleaner intake restriction, fuel restriction, exhaust restriction and crankcase pressure.

Gauge (1), 0-30 psi gauge, may be used to measure intake manifold (boost) pressure.

Gauge (2) (compound) (0-30 in Hg vacuum) and (0-30 psi) may be used to measure fuel system inlet restriction, fuel pressure or intake manifold (boost) pressure.

The 0-60 in H_2O (magnehelic) gauge (0-2.16 psi), may be used to measure air cleaner restriction or crankcase pressure.

NOTE – When using the magnehelic gauge, be sure to plug the test line into the proper vacuum (3) or pressure (4) ports.

Gauge (5), 0-100 psi gauge may be used to check fuel pressure.

Gauge (6), 0-30 psi gauge with a built in regulator may be used to check waste gate actuator movement.

Operating Instructions

Connect test lines between the gauge ports on the Gauge Bar and the test points shown on the (REAR SIDE) of HARD START / NO START AND PERFORMANCE DIAGNOSTIC FORM EGED-220.

CRANKCASE PRESSURE RESTRICTION TOOL (ZTSE4039)

Description

Crankcase Breather Tool (ZTSE4039) with a 0.406 in. restriction orifice (See Figure 189, page 383).

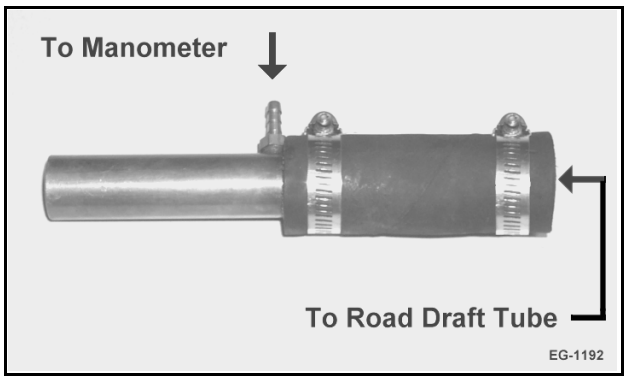


Figure 189 Crankcase Breather Tool (ZTSE4039)

The restriction tool is used to measure combustion gas flow out of the engine breather and may be used with Pressure Test Kit Model D 200 or Gauge Bar (PS94-831-3), refer to:

- Pressure Kit Model D 200 (See Figure 187, page 381)
- Gauge Bar (PS94-831-3) (See Figure 188, page 382)

IMPORTANT – PRESSURE READINGS OBTAINED WITH THIS ORIFICE RESTRICTION MUST BE USED AS THE MAIN SOURCE OF ENGINE CONDITION. OIL CONSUMPTION TREND DATA MUST ALSO BE USED IF THE PRESSURE READINGS ARE BEYOND THE SPECIFIED LIMITS. NEITHER CHANGES IN OIL CONSUMPTION TRENDS NOR CRANKCASE DIAGNOSTIC PRESSURE TRENDS CAN ESTABLISH A SPECIFIC COMPONENT PROBLEM. THESE CHANGES ONLY INDICATE THAT SOME PROBLEM EXISTS.

Operation

Refer to Crankcase Pressure Test.

DWYER SLACK TUBE MANOMETER

Description

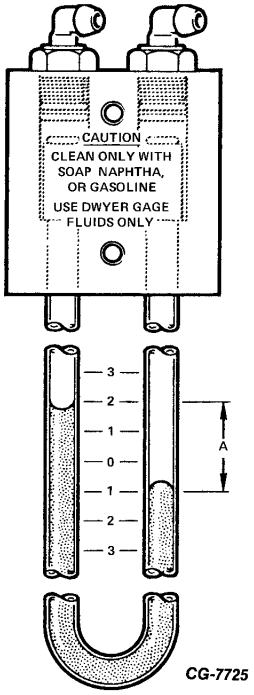


Figure 190 Slack Tube Manometer, Dwyer No. 1211-48

The manometer is a “U” shaped tube with a scale mounted between the legs of the U. Where the portability of the Model 200 Pressure Test Kit is not required, this manometer can be used to measure either low pressure or vacuum (intake restriction, crankcase pressure or exhaust back pressure) and must be filled with water. Refer to Dwyer Slack Tube Manometer (See Figure 190, page 384).

Filling

The manometer must be filled with water before checking any pressure.

When filling with water, use only good drinking water without additives, except for some colored water vegetable dye, which enables the tester to read the scale easier. 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.

IMPORTANT – NEVER USE AN ANTIFREEZE SOLUTION, SODA POP, TONIC, ETC. TO FILL MANOMETER. THE INCREASE IN DENSITY CAUSES FALSE READINGS.

Installing and Reading

1. Support the manometer in a vertical position. Be sure the fluid level line 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. The other leg is left open to atmospheric pressure.

3. After starting the engine and allowing it to reach its normal operating temperature, it can be set to **High Idle**. After approximately **10 seconds** the manometer can be observed.

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 and represents the crankcase pressure in inches of water.

5. Compare manometer reading with engine specifications.

NOTE – At times both columns of the manometer will not travel the same distance. This is of no concern to the tester as long as the leg not connected to the pressure or vacuum source is open to the atmosphere.

Cleaning

1. Wash the tube thoroughly using a little pure soap and water. Avoid liquid soaps and solvents.

TERMINAL TEST ADAPTER KIT

Description

The Terminal Test Adapter Kit (ZTSE4435) (See Figure 191, page 386) is used to gain access to individual circuits in the connector harness and allows for the use of a digital volt ohmmeter (DMM) without damaging the harness connectors. The probes may also be used as a guide to determine if the harness connector is retaining proper tension on the mating terminal.

Figure 191 Terminal Test Adapter Kit (ZTSE4435)

INJECTOR TEST HARNESS (ZTSE4401)

Description

The **Injector Test Harness (ZTSE4401)**(See Figure 192, page 387) is used to measure injector wiring harness and injector solenoid continuity (See Figure 193, page 388) without removing the intake manifold / valve cover.

Figure 192 Injector Test Harness (ZTSE4401)

The following table lists the injector number and the corresponding color coded leads.

Table 87

ZTSE4401	
Injector 1	Black
Injector 2	Blue
Injector 3	Red
Common 1–3	Brown
Injector 4	Violet
Injector 5	Green
Injector 6	Orange
Common 4–6	Yellow

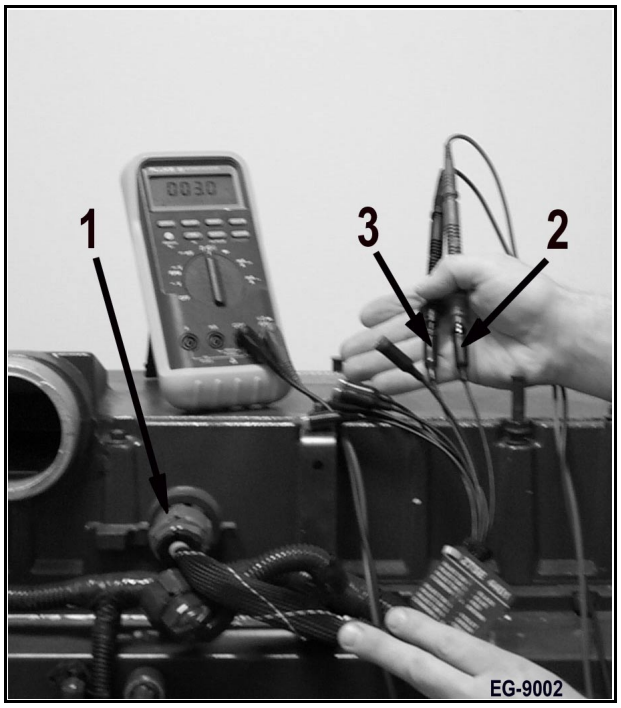


Figure 193 Continuity Check of Injector Number 1

1. Injector Test Harness Connection Point
2. Brown Lead
3. Black Lead

3-WIRE PRESSURE SENSOR BREAKOUT TEE (ZTSE4347)

Description

The **3-wire pressure sensor breakout tee (ZTSE4347)**(See Figure 194, page 389) is used to gain access to the V_{REF}, signal ground, and signal voltage circuits on the EOP, MAP, and ICP sensors.

Figure 194 ICP Breakout Tee (ZTSE4347)

2-WIRE TEMPERATURE BREAKOUT TEE (ZTSE4483)

Description

The **2-wire temperature breakout tee (ZTSE4483)** (See Figure 195, page 389) enables the technician to quickly connect a voltmeter and read voltage signals at each of the following Temperature sensing units:

- **ECT** Engine Coolant Temperature
- **EOT** Engine Oil Temperature
- **IAT** Intake Air Temperature

Use of the breakout tee to obtain the above voltage (temperature) readings is shown in the Electrical Diagnostics section of this manual.

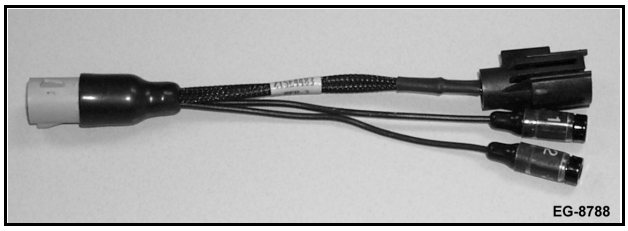


Figure 195 2-Wire Temperature Breakout Tee

IPR SENSOR BREAKOUT TEE (ZTSE4484)

Description

The **IPR sensor breakout tee (ZTSE4484)** enables the technician to measure the ECM voltage when the EST is not available (See Figure 196, page 390).

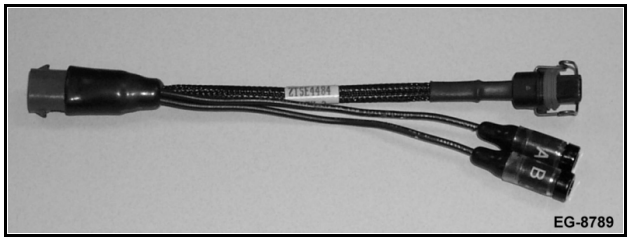


Figure 196 IPR Sensor Breakout Tee

APS / IVS SENSOR BREAKOUT TEE (ZTSE4485)

Description

The **APS / IVS sensor breakout tee (ZTSE4485)** enables the technician to measure V_{Ref} signal, ground, IVS signal, and IVS power at the APS / IVS sensor(See Figure 197, page 390).

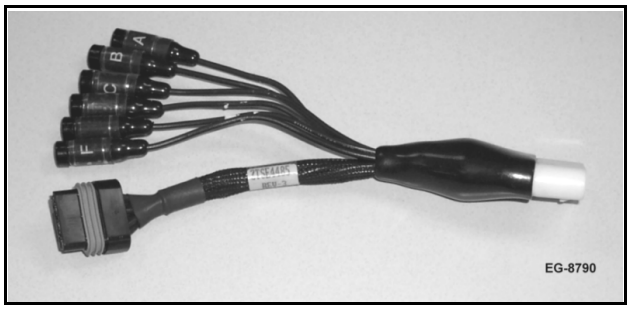


Figure 197 APS / IVS Sensor Breakout Tee

CMP SENSOR BREAKOUT TEE (ZTSE4486)

Description

The **CMP sensor breakout tee (ZTSE4486)** enables the technician to measure rpm when the EST is not available (See Figure 198, page 390).

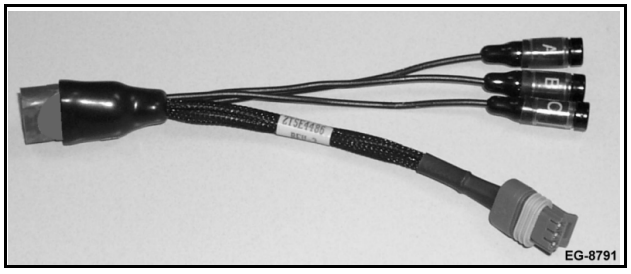


Figure 198 CMP Sensor Breakout Tee

ICP ADAPTER / PLUG KIT (ZTSE4359)

Description

Injection Control Pressure Adapter/Plug Kit (ZTSE4359) (See Figure 199, page 391).

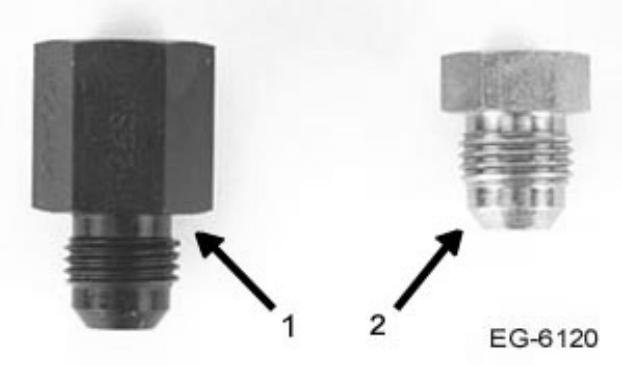


Figure 199 Injection Control Pressure Adapter/Plug Kit (ZTSE4359)

1. Adapter
2. Plug

The Injection Control Pressure Adapter/Plug Kit (ZTSE4359) (See Figure 199, page 391) is used in Injection Control Pressure diagnostic testing of the T 444E, DT 466 and DT 530 diesel engines. Diagnostic testing of the ICP system on the DT 466 and DT 530 diesel engines only require the use of the adapter within this kit. The T 444E engine requires the use of both adapter and plug to properly diagnose the ICP system. Refer to Low ICP Pressure Test and ICP Leakage Test in the Mechanical Diagnostics section of this manual for the proper use of the adapter.

FLUKE 88™ DIGITAL MULTIMETER (ZTSE4357)

Description

Fluke 88™ Digital Multimeter (DMM) (ZTSE4357) (See Figure 200, page 392).

Figure 200 Fluke 88™ Digital Multimeter (DMM) (ZTSE4357)

The Fluke 88™ (DMM) (See Figure 200, page 392) allows the technician to troubleshoot electrical components, sensors, injector solenoids, relays, and wiring harnesses. This meter has a high input impedance which allows testing of sensors while the engine is running, without loading the circuit which is being tested. This ensures the signal voltage measurement will not be affected by the voltmeter.

BREAKOUT BOX (ZTSE4445)

Breakout Box (ZTSE4445)(See Figure 201, page 393).

Figure 201 Breakout Box (ZTSE4445)

The breakout box was designed to allow testing of the electronic control system components without disturbing connections or the piercing of wire insulation to gain access to various signal voltages in the electronic control system.

IMPORTANT – The breakout box should be used for measurement only and not to activate or control circuits. High current levels passing through the breakout box will burn out the internal circuitry.

Breakout Box Installation

What the technician is trying to measure will determine how the breakout box is installed.

Measuring harness resistance:

- Disconnect the 60 pin ECM harness connector that contains the circuit that is to be tested.
- Attach the ECM harness connector to the breakout box connector.

Measurements can now be made.

Measuring operational signals:

- Disconnect the 60 pin ECM harness connector that contains the circuit that is to be tested.
- Attach the breakout box connector to the ECM using the bolts provided.
- Attach the 60 pin ECM connector to the breakout box adapter.

Measurements can now be made.

MASTER DIAGNOSTICS (MD 32)

STARTING MASTER DIAGNOSTICS FROM THE WINDOWS DESKTOP

Basics

Electronic Service Tool (EST) (See Figure 202, page 394).

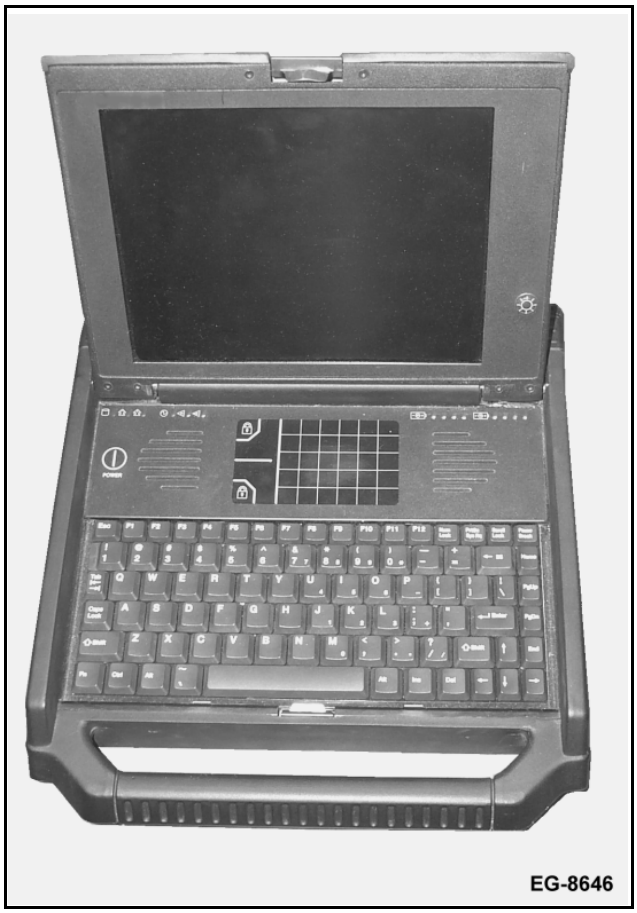


Figure 202 Electronic Service Tool (EST)

Figure 203 International® Truck Interface

The International® truck interface allows the EST to communicate with the ECM through the ATA connector.

ATA Connector, 9 Pin to 6 Pin (See Figure 204, page 395).

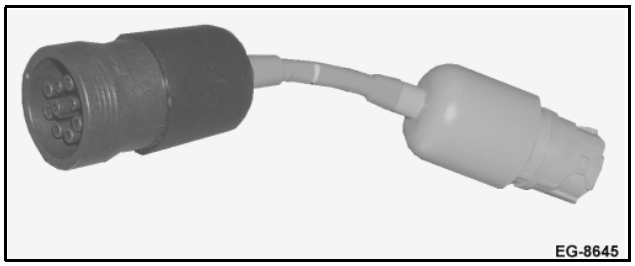


Figure 204 ATA 9 Pin to 6 Pin Adapter (ZTSE4467)

After connecting the EST to the 9 pin and 6 pin adapter:

1. Boot up your EST with Master Diagnostics software.

2. Double click on the desktop icon entitled **Vehicle Diagnostics**.

3. The **Vehicle Diagnostics** window will be displayed. Depending on your vehicle, you can open up Master Diagnostics for engines using a 3 box engine controller or for those that use the single box Diamond Logic™ controller (See Figure 205, page 395).

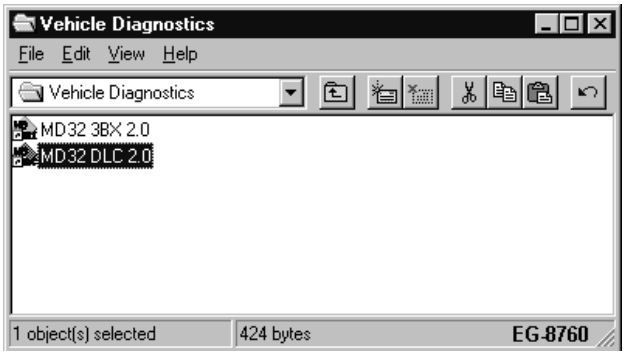


Figure 205 Vehicle Diagnostics Open Window

After starting the Master Diagnostics software, your computer should display the following main window (See Figure 206, page 395).

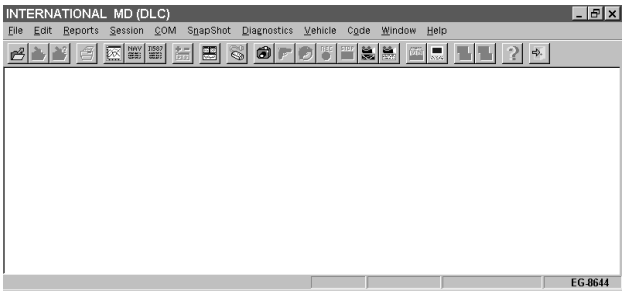


Figure 206

The software provides a menu bar that is right below the window's title bar. All available features of the software can be accessed via the drop-down menu bar (See Figure 207, page 396).

EG-8683

Figure 207

The tool bar is provided for frequently used actions. The tool bar provides a quick and easy way to access important features of this software. Each tool bar button will be described briefly below. The number below the toolbar button is associated with its description (See Figure 208, page 396).

EG-8684

Figure 208

1. File→ Open: Opens an existing graphical or text display file, snapshot setup (*.trg), or programmable parameter display file (*.ppv). Using this option allows the user to recall and view a previously saved configuration. Three display formats are available: *.ntv (a text display for International engines), *.jtv (a text display for generic J1587 ATA data link engines), *.pgv (a graphical display).
2. File→ Save: Saves the configuration of the highlighted window.
3. File→ Save As: Saves the configuration of the highlighted window and prompts the user for a file name.
4. File→ Print: Prints the highlighted window to the printer or a file. Not all windows may be printed.
5. File→ New: Opens a new graphical display window.
6. File→ New: Opens a new International® text display window.
7. File→ New: Opens a new J1587 ATA text display window.
8. Edit→ Add/Delete/Edit: Adds, deletes or edits parameters from the highlighted window.
9. Session→ Open: Retrieves a previously setup Master Diagnostics sessions.
10. COM→ Open: Begins the ATA communications via the EST COM port.
11. Snapshot→ Setup: Sets up the snapshot recording options: the trigger source, pre-trigger recording time, post-trigger recording time, which parameters to record, how often to sample data, etc.
12. Snapshot→ Arm: Arms the trigger for the snapshot.
13. Snapshot→ Disarm: Disarms the trigger for the snapshot.
14. Snapshot→ Start: Manually starts the snapshot recording. The F2 key has the same function.
15. Snapshot→ Stop: Manually stops the snapshot recording. The F3 key has the same function.
16. Snapshot→ Replay: Replays a snapshot recording file in a graphical format.
17. Snapshot→ Replay: Replays a snapshot recording file in a text format.
18. Vehicle→ View Information: Opens the electronic engine controller module identification window.
19. Vehicle→ Program: Opens an electronic engine controller module programming window.
20. Code→ View: Opens the trouble code window.
21. Code→ Clear: Clears the trouble codes contained in the ECM.
22. Help→ Contents: Opens Master Diagnostics software help.
23. File→ Exit: Exits and terminates the Master Diagnostics program.

OPENING A COM PORT

Basics

1. Prior to using the software, the settings must be configured properly. Click on **COM** on the drop-down menu bar and select **Open** (See Figure 209, page 397). Select COM 1 or COM 2. This opens up the ATA bus allowing a communication link from the ECM to Master Diagnostics.

2. Turn the key to the ON position to complete the link. Data can now begin flowing to Master Diagnostics.

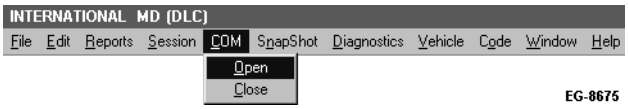


Figure 209

TEXT WINDOW & ADDING PARAMETER IDENTIFIERS (PID)

Data in Text Format

1. To monitor engine parameter data in text format you must first create a text window.

2. Select **File** and then **New** on the menu bar (See Figure 210, page 397) to open the **Select a File Type** dialog box.

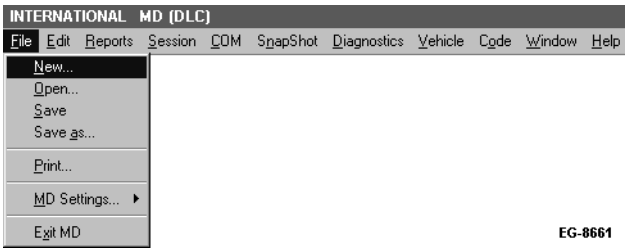


Figure 210

3. Select **International Text View (.ntv)** as the desired type and click on **OK** (See Figure 211, page 397).

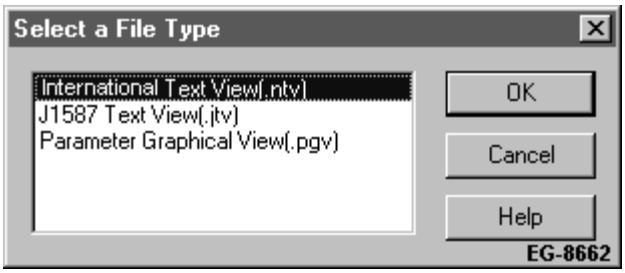


Figure 211

A generic text view display window will appear and it will have no parameters in it. Text view windows consist of three columns: **PID**, **Value**, and **Units**. The PID column shows the PID description or acronym. The Value column shows the current data value. The Units column shows the display value units, which may be in english or metric (See Figure 212, page 398).

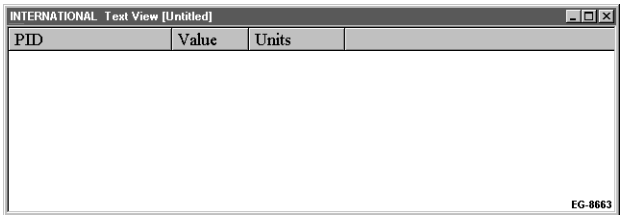


Figure 212

4. To add parameters to this window, select **Edit** and then **Add/Delete/Edit Parameters** on the menu bar, (See Figure 213, page 398).

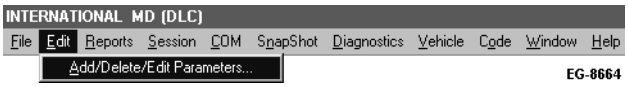


Figure 213

5. Double clicking on a parameter or clicking on all of the desired parameters in the **Available Parameter** list box and then clicking the **>>ADD>>** button adds the selected parameters to the **Selected Parameter** list box (See Figure 214, page 398).

The order in which PIDs are displayed in the text view window is dependent upon when a parameter is added to the Selected Parameter list. For example, if you double click **Fuel Rate** first and then **Fueling Pulse Width**, then **Fuel Rate** will be displayed on top of **Fueling Pulse Width** in the text view window. Use the vertical scroll bar to view additional parameters within the **Available Parameters** list box.

Double clicking a parameter from the **Selected Parameter** list will remove it from the text view window (See Figure 214, page 398).

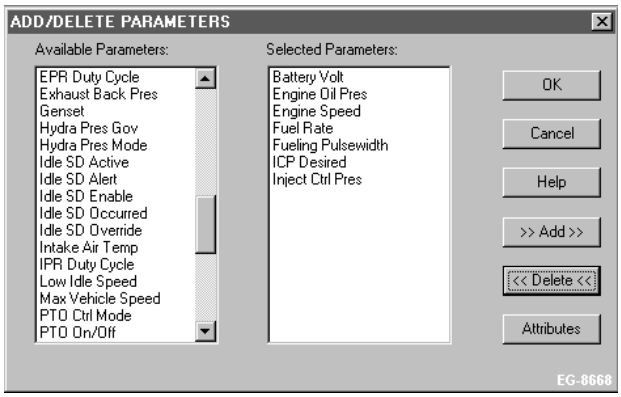


Figure 214

If you need to recall the original settings you may click on the **Defaults** button to restore the attributes to the factory defaults.

When finished with adding or deleting parameters and modifying the attributes, click the **OK** button in the **ADD/DELETE PARAMETERS** dialog box.

The text window will display the selected parameters, (See Figure 215, page 399).

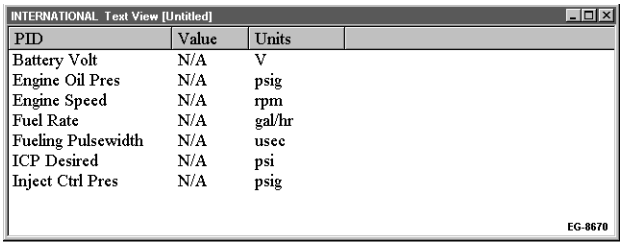


Figure 215

This text view window is configured and ready to be used. Opening the **COM** port at this time will allow the data to be displayed. The resulting window illustrates some parameter values (static data w/engine off) (See Figure 216, page 399).

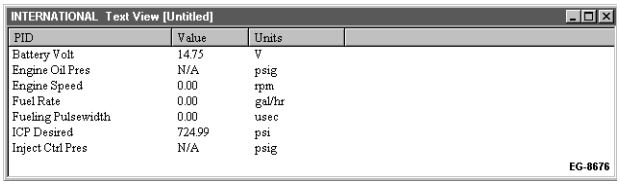


Figure 216

By clicking on **Units**, the units of all the displayed parameters can be toggled between metric or english based (See Figure 216, page 399).

The information in these text view windows may be printed by selecting **File** and then **Print** on the menu bar (See Figure 217, page 399).

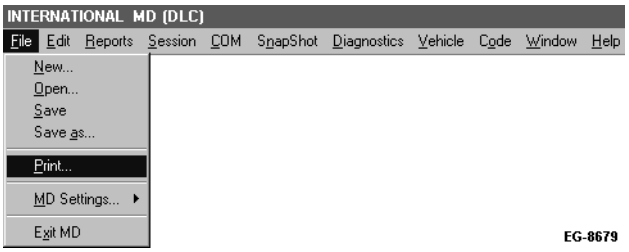


Figure 217

You may send the printout to the printer or to a file (See Figure 218, page 399).

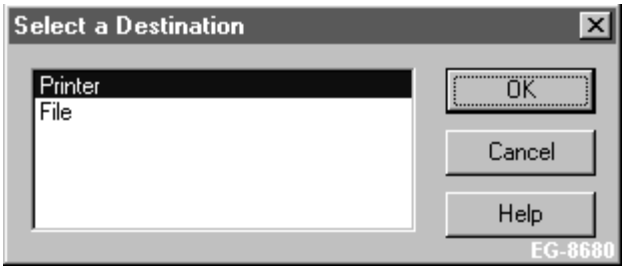


Figure 218

The configuration of these text windows may be saved for later retrieval. Please be aware that the list of displayed parameters and the font size and type information is saved. The actual parameter data is not included as part of the configuration. Click on **File** on the menu bar and then click **Save As** (See Figure 219, page 400).

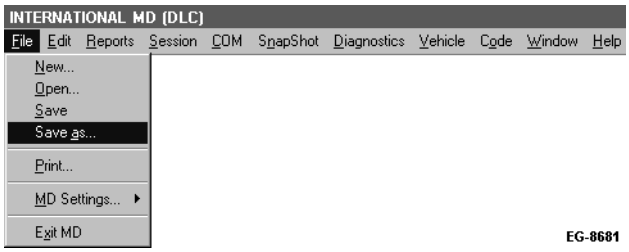


Figure 219

The **Save As** file dialog box will appear (See Figure 220, page 400).

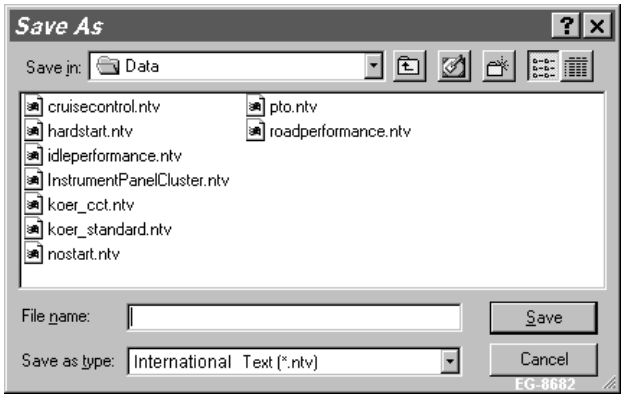


Figure 220

Simply type a file name inside the **File name** edit box and click on the **Save** button.

GRAPHIC WINDOW & ADDING PARAMETER IDENTIFIERS (PID)

Data in Graphical Format

To monitor the engine parameter data in graphical format you must first create a graphical window. This is done similar to the creation of a text view window. Select **File** and then **New** (See Figure 210, page 397) on the menu bar. Then open the **Select a File Type** dialog box.

Select **Parameter Graphical View (.pgv)** as the desired type to open and click **OK**(See Figure 221, page 400).

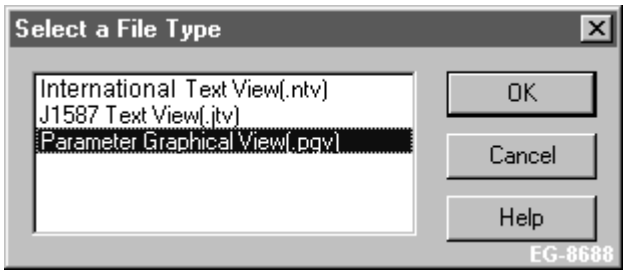


Figure 221

A generic graphical display window will appear. It will not have any parameters in it . It will display the time axis and the range axis (See Figure 222, page 401).

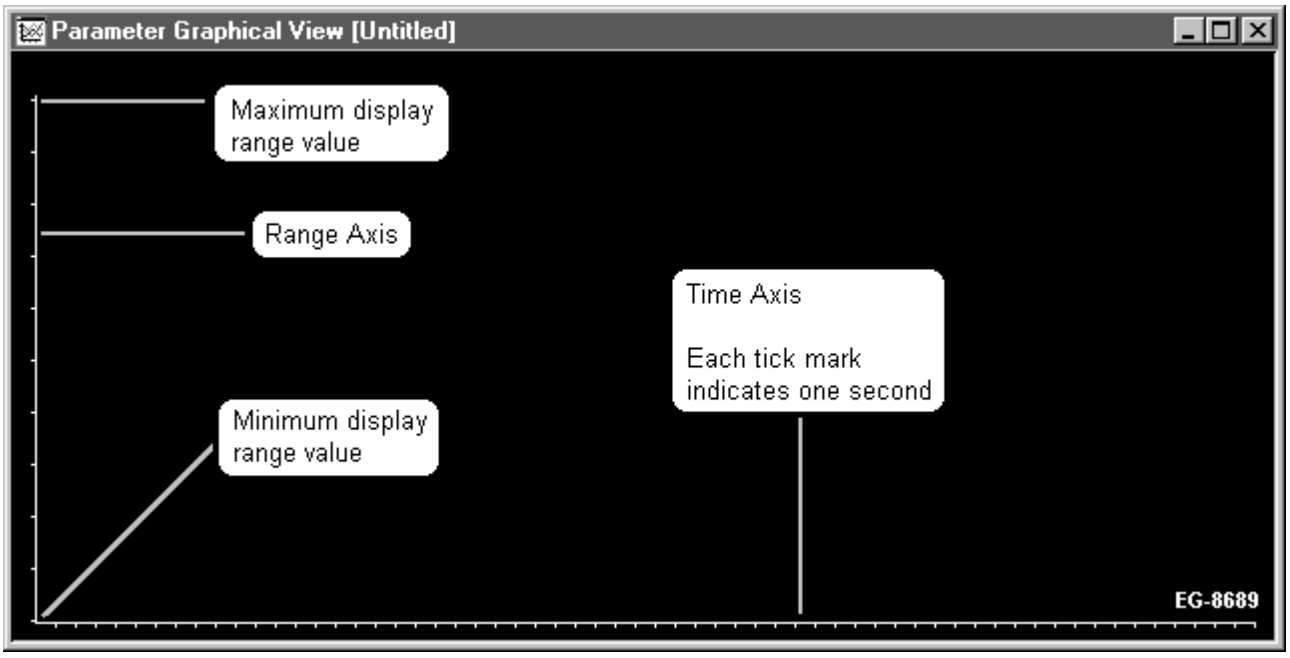


Figure 222

The procedure to add or delete a single or series of parameters is the same as the procedure found in the previous section entitled **Data in Text Format** beginning with Step 5 page 398.

The graphical window will now display the selected parameters using their acronyms. Master Diagnostics preselects different colors for each parameter in the order they are added to the window (See Figure 223, page 402).

Use a text view window to find the full description for these parameters (See Figure 216, page 399).

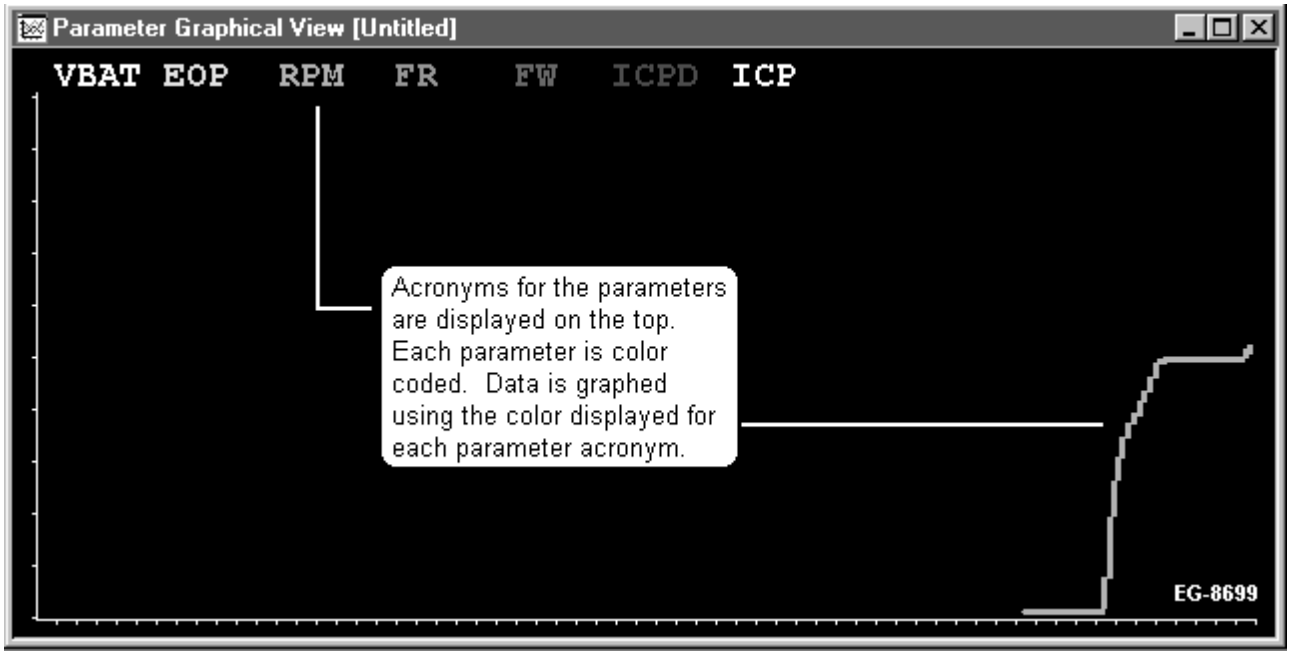


Figure 223

OPENING A SESSION FILE

Basics

The session menu allows the opening of a previously setup session. International Engine Reliability and Engineering has setup several diagnostic sessions. The desktop workspace will have all the needed text view windows, trouble code windows, ATA bus, etc., already preconfigured for your use.

Select **Session** and then **Open** from the drop-down menu bar (See Figure 224, page 402).

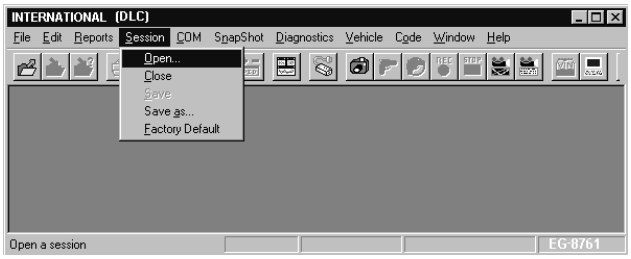


Figure 224

The **Open Session File** dialog box will appear. Click on one of the preconfigured sessions to highlight it, then select **Open** (See Figure 225, page 403).

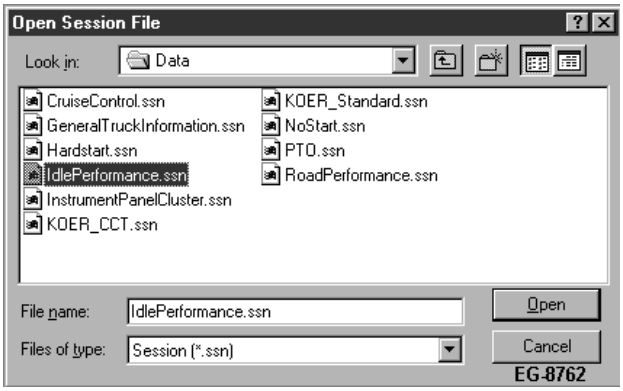


Figure 225

The session will automatically be brought up. These windows are placed in an organized manner (See Figure 226, page 403).

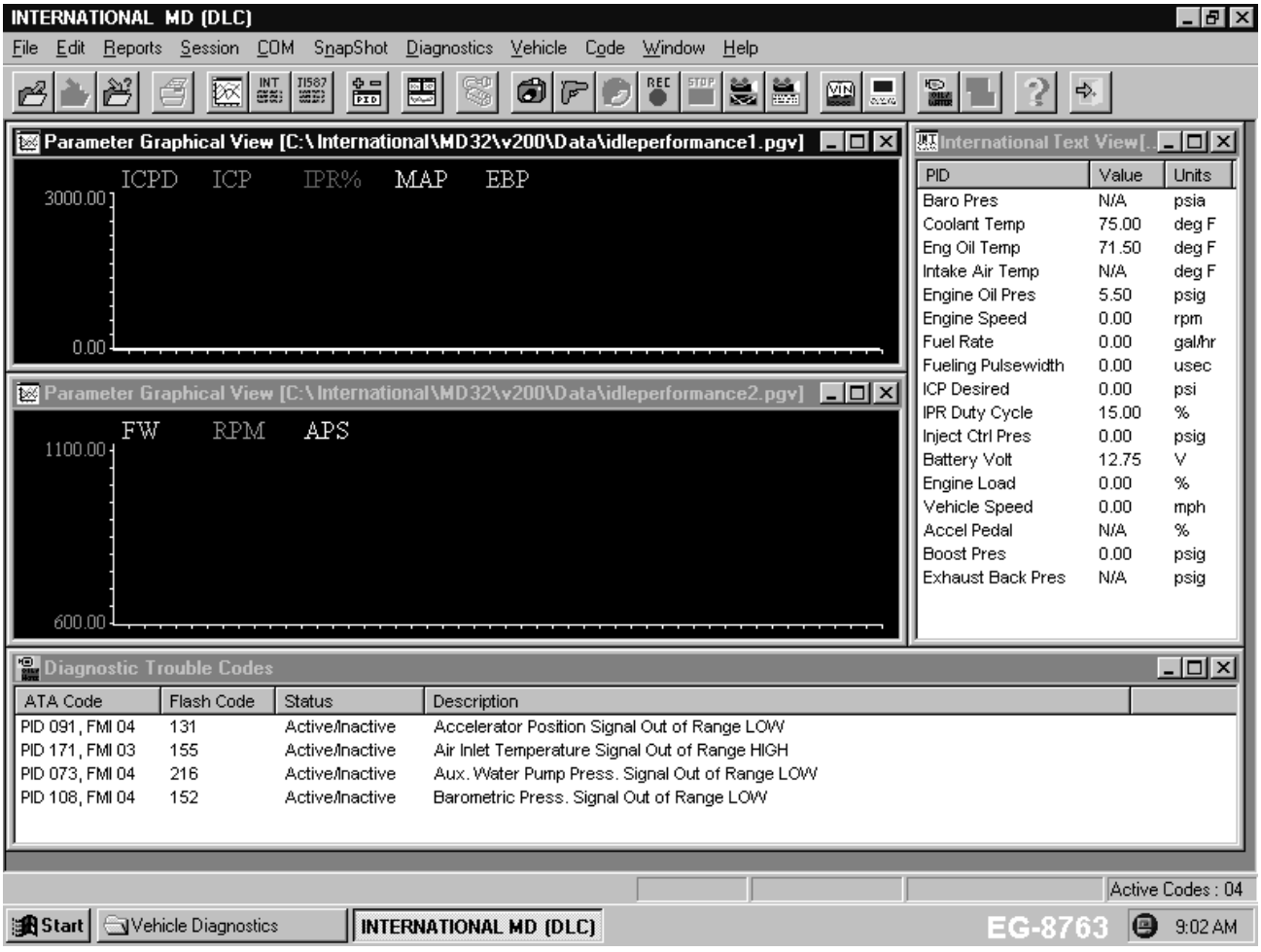


Figure 226

You may set up your own session and save it for future use. Refer to the **Master Diagnostics (MD) Software User's Manual** for detailed instructions.

DISPLAYING SENSOR VOLTAGES

NOTE – The following procedure is available only with Master Diagnostics version 2.31 or later.

1. Open Session File (Sensor Voltages)
2. Select Diagnostic drop-down menu
3. Select Continuous Monitor Test

DIAGNOSTIC TESTING

Initiating Diagnostic Tests

Select **Diagnostics** from the menu bar. These on-demand diagnostic tests may only be invoked via the menu. Refer to the diagnostic manual as to when to perform these tests and how to interpret the results.

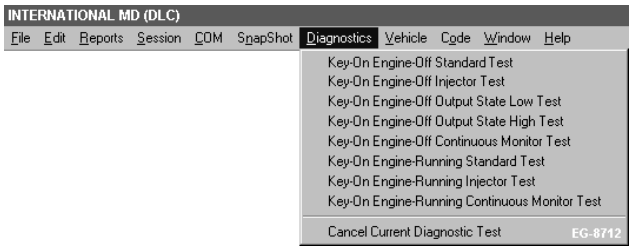


Figure 227

- **Key-On Engine-Off Standard Test**
- **Key-On Engine-Off Injector Test**
- **Key-On Engine-Off Output State Low Test** and the **Key-On Engine-Off Output State High Test**
- **Key-On Engine-Off Continuous Monitor Test**
- **Key-On Engine-Running Standard Test**
- **Key-On Engine-Running Injector Test**
- **Key-On Engine-Running Continuous Monitor Test**

Selecting **Cancel Current Diagnostic Test** cancels any of the above on-demand diagnostic tests (See Figure 227, page 404).

The ECM determines if the requested on-demand diagnostic test can be executed. Master Diagnostics will provide a warning messages as to the reason why the ECM did not execute the test. Refer to Master Diagnostic Users Manual for detailed instruction.

CHECK AND CLEAR DIAGNOSTIC TROUBLE CODES (DTC)

Select **Code** and then the **View** option on the menu bar opens the trouble code window (See Figure 228, page 405).

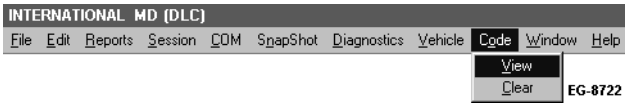


Figure 228

The **Diagnostic Trouble Codes** window will appear. If the electronic control module (ECM) has detected any Diagnostic Trouble Codes, the Diagnostic Trouble Codes will be displayed automatically. The Diagnostic Trouble Codes which have been detected on the current (ignition) Key-ON cycle will be displayed as active. Those detected on previous key cycles only, will be displayed as inactive. An up/down scroll bar will automatically appear whenever there are too many Diagnostic Trouble Codes to be displayed in the window. Slide the scroll bar up or down to view any remaining Diagnostic Trouble Codes.

To learn more about a particular Diagnostic Trouble Code simply double click on any of the parameters listed in the **ATA Code** column of the **Diagnostic Trouble Code** window. This will launch **Help** and display further details associated with a specific Diagnostic Trouble Code (See Figure 229, page 405).

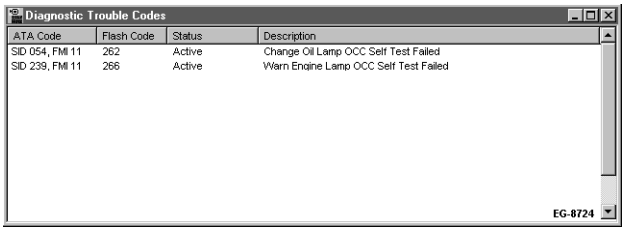


Figure 229

By selecting any of the available Diagnostic Trouble Codes, additional information can be obtained. Refer to the following images (See Figure 230, page 405), (See Figure 231, page 406), (See Figure 232, page 406).

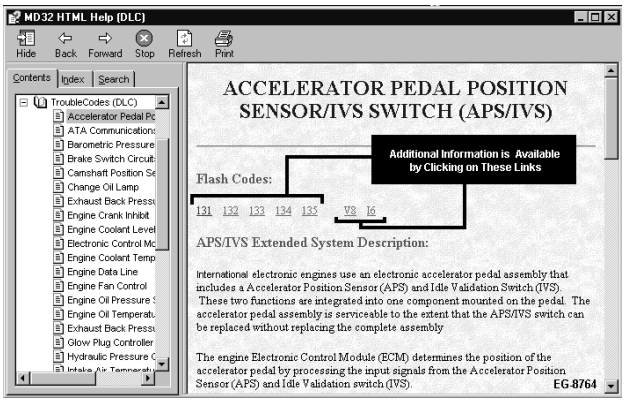


Figure 230

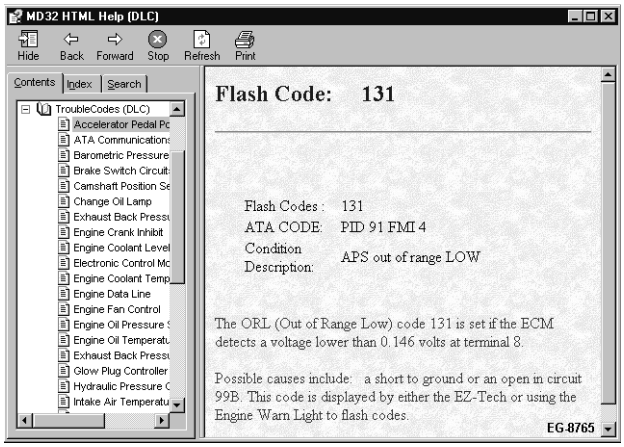


Figure 231

Selecting **V-8** or **I-6** will link you to circuit diagrams and connector checks associated with the Diagnostic Trouble Code (See Figure 232, page 406).

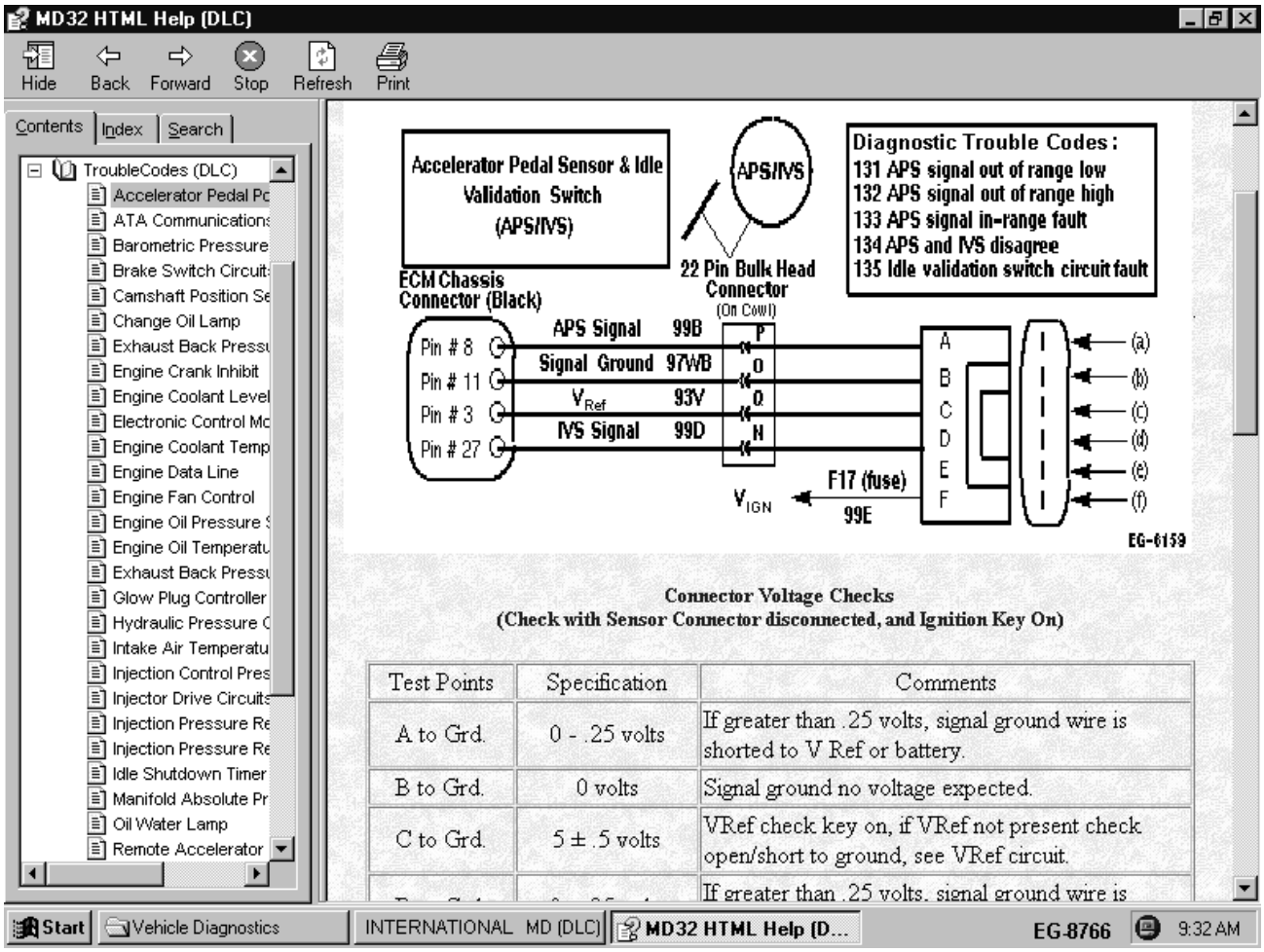


Figure 232

To clear codes, simply select **Code** then the **Clear** option from the drop-down menu bar (See Figure 233, page 407).

Figure 233

VIEW ACCUMULATORS (VEHICLE INFORMATION)

Select **Vehicle** and then **View Information** on the menu bar (See Figure 234, page 407).

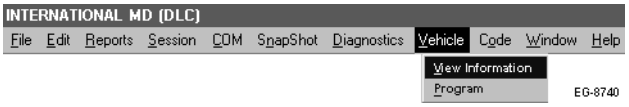


Figure 234

The **Vehicle Information** will appear (See Figure 235, page 407).

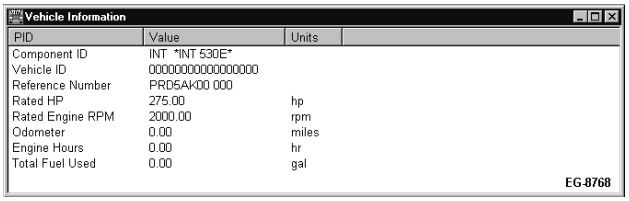


Figure 235

PROGRAMMABLE PARAMETERS, CHANGE / VIEW

Select **Vehicle** then **Program** from the drop-down menu bar.

A generic **Vehicle Programming** window will appear (See Figure 236, page 408).

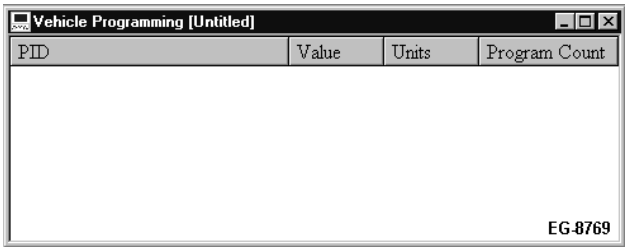


Figure 236

1. Add programmable parameters to this window by selecting **Add/Delete/Edit Parameters**.

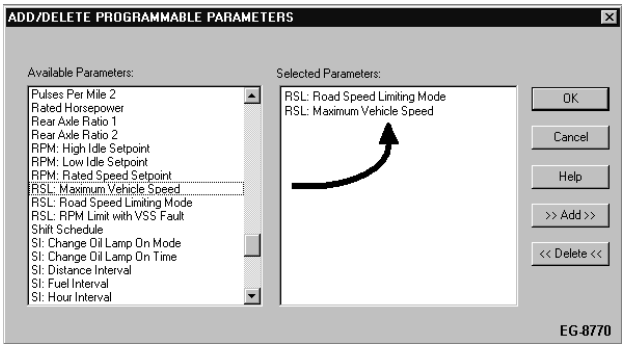


Figure 237

2. Double clicking on a parameter from the **Selected Parameters** list box will remove it from the **Vehicle Programming** view window. (See Figure 237, page 408) .

3. Placing the mouse pointer within the **Vehicle Programming** window and right clicking will bring up the advanced features.

4. Click the advanced features **Refresh** option (See Figure 238, page 408).

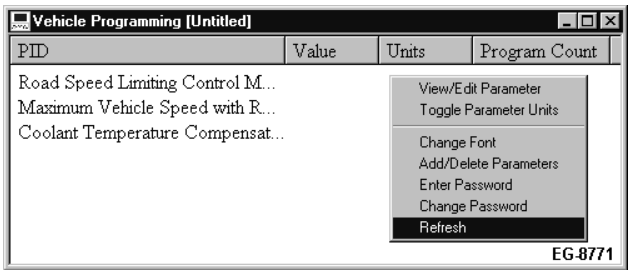


Figure 238

The current value information being supplied by the ECM will be displayed to the desired parameters. You must enter a password in order to modify any parameters.

5. Placing the mouse pointer within the **Vehicle Programming** window and right clicking will bring up the advanced features. Click on the **Enter Password** option. This allows a password to be entered and retained for use. The password must be between 4 and 8 alphanumeric characters (See Figure 239, page 409).

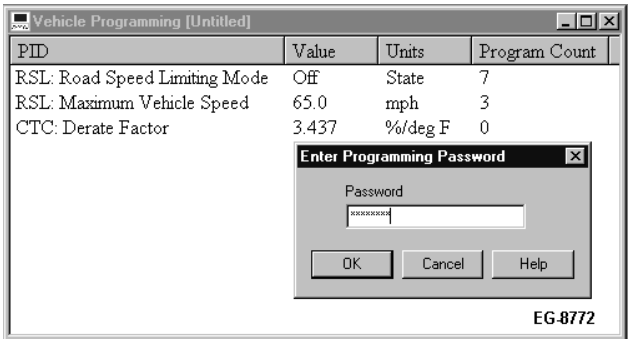


Figure 239

The following screens illustrate the three **Edit Parameter** displays that you will normally encounter. They differ on what can be changed. All parameters that can be toggled ON / OFF or changed within a numerical range will display a message stating "**The parameter was programmed successfully**" after clicking OK.

The following shows an example where the parameter value can only be turned either **ON** or **OFF** (See Figure 240, page 409). After your selection, click **OK**.

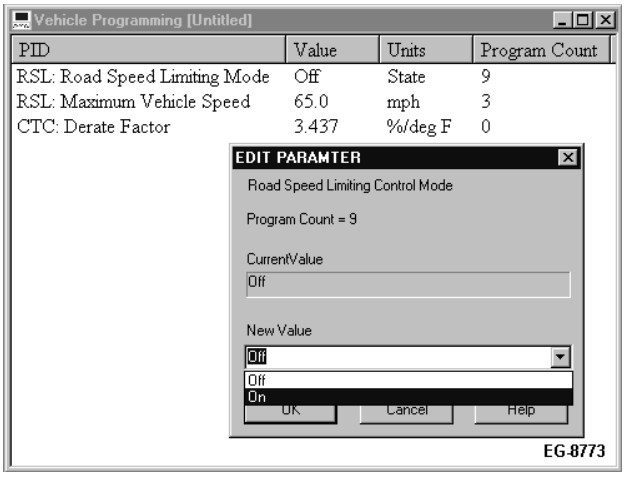


Figure 240

For those parameters that require numeric entries, enter the appropriate value in the **New Value** box, as long as it is within the required range (See Figure 241, page 410). Click **OK** when complete.

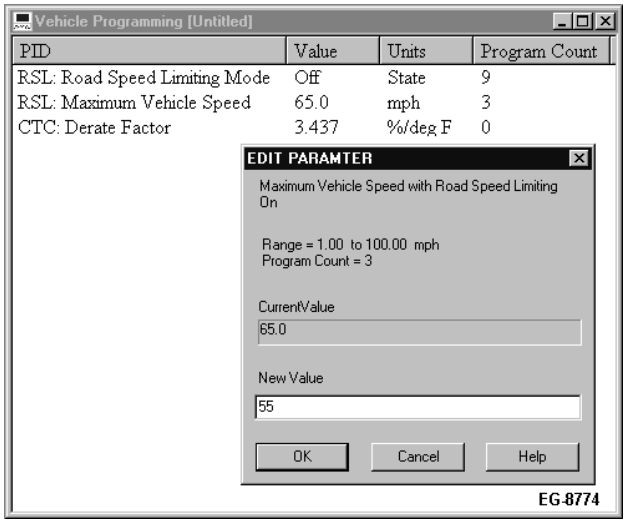


Figure 241

Some parameters can not be changed at all depending upon application. These are read only parameters and provide no means for modification (See Figure 242, page 410) . Simply click **OK** to acknowledge.

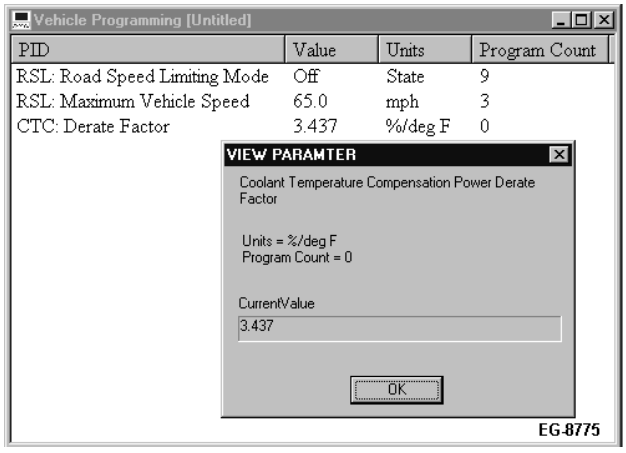


Figure 242

To verify that the parameter was changed, right click to bring up the advanced features. Click the **Refresh** option. MD will request all the programmable parameter information from the ECM.

SNAPSHOT- RECORD & REPLAY

Recording a Snapshot

To open an existing snapshot setup, select **File** from the drop-down menu, then **Open**. Select the **(*.trg)** extension in the **Files of type** box within the **Open** dialog box, then select the appropriate file from the various list (See Figure 243, page 411).

Figure 243

Replaying a Snapshot via Graphical Windows

The replay feature will only playback recorded files that were created by Master Diagnostics software. The replay feature allows two different display types, graphical and text.

Select **Snapshot** then **Replay** and finally **Graphical**.

The **Open Snap Shot Recording File** dialog box will appear. Click on a filename to select it, then click **Open**. The **Graphical Replay** window opens (See Figure 244, page 412). To modify this window for viewing data, see the Master Diagnostics (MD) Software User's Manual.

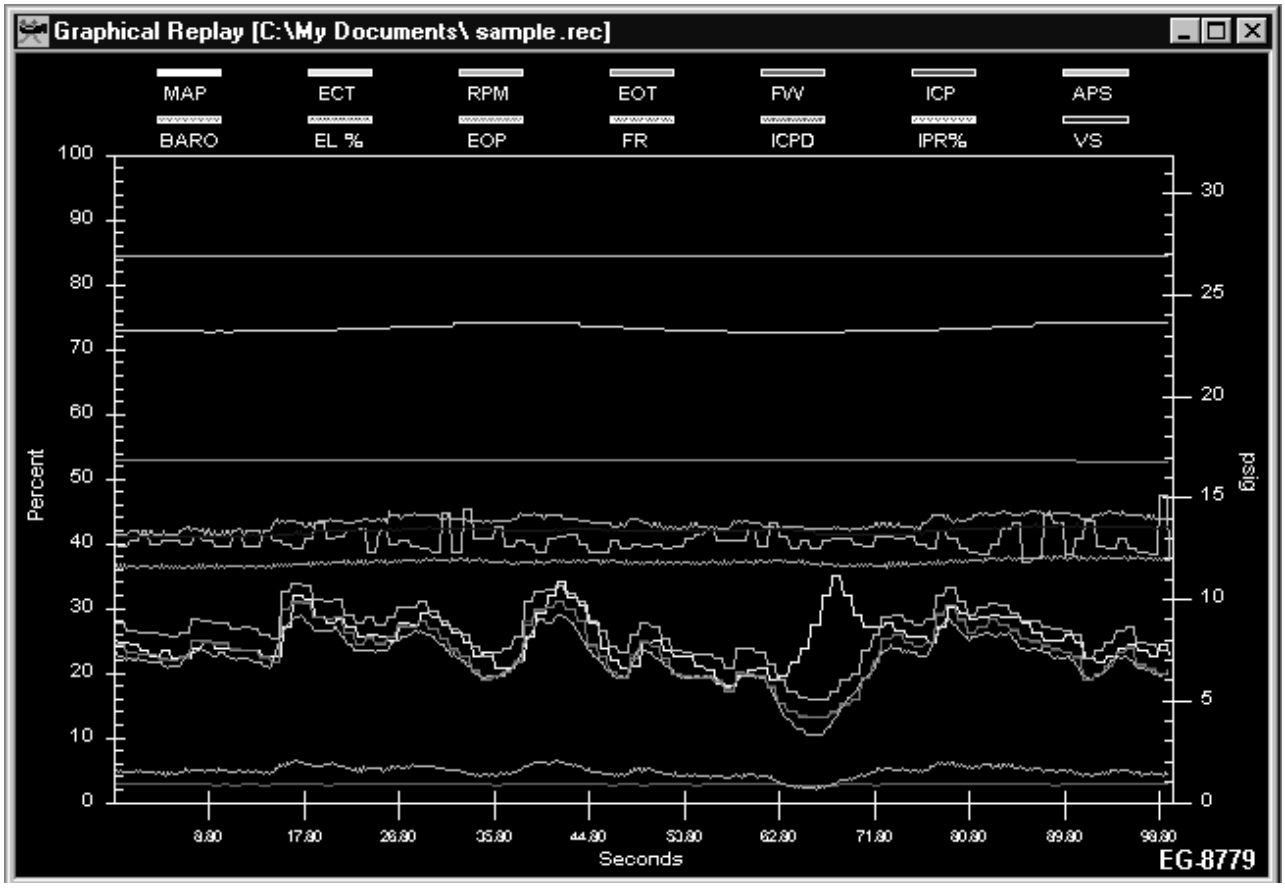
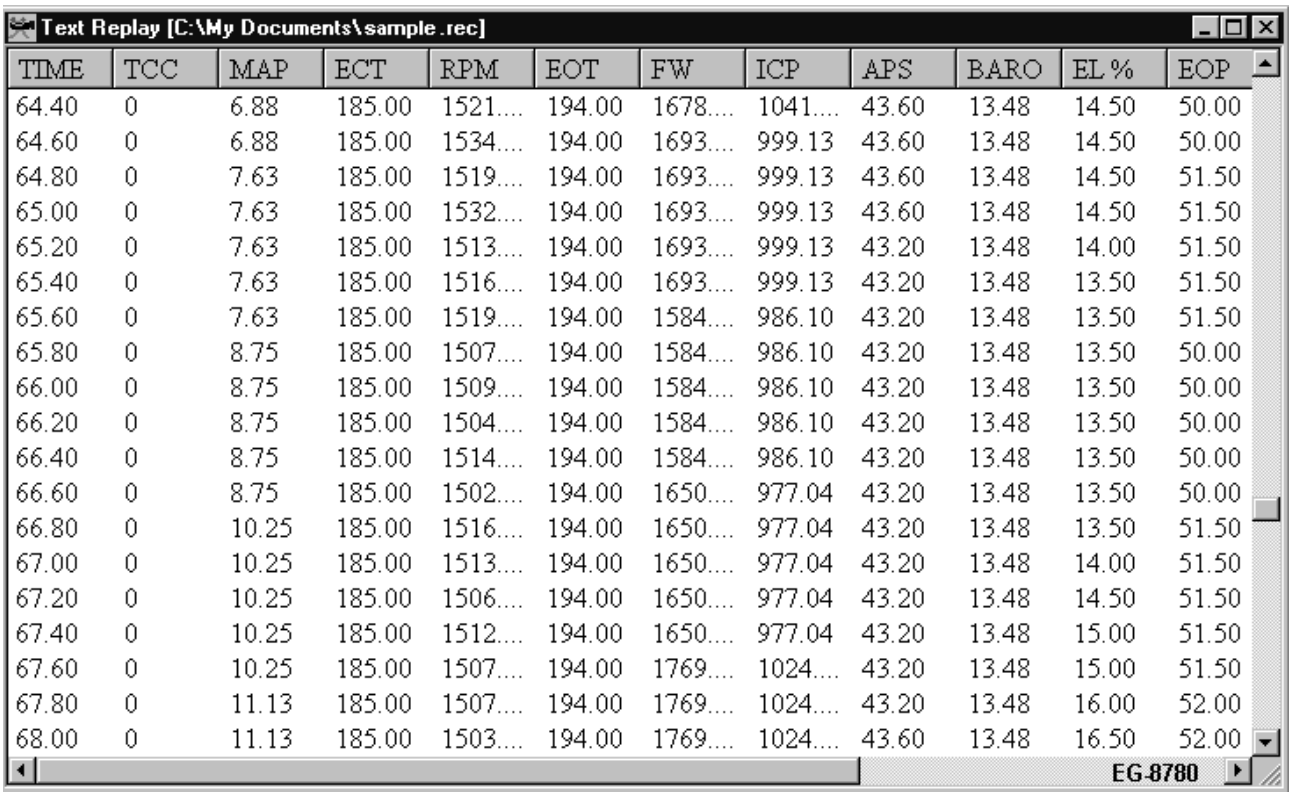


Figure 244 Replaying a Snapshot via Graphical Window

Replaying a Snapshot via Text Windows

Select **SnapShot**, then **Replay** and finally **Text**.

The **Open Snap Shot Recording File** dialog box appears. Click on a filename to select it and then click **Open**. The **Text Replay** window opens (See Figure 245, page 413).



Text Replay [C:\My Documents\sample.rec]

TIME	TCC	MAP	ECT	RPM	EOT	FW	ICP	APS	BARO	EL %	EOP
64.40	0	6.88	185.00	1521....	194.00	1678....	1041....	43.60	13.48	14.50	50.00
64.60	0	6.88	185.00	1534....	194.00	1693....	999.13	43.60	13.48	14.50	50.00
64.80	0	7.63	185.00	1519....	194.00	1693....	999.13	43.60	13.48	14.50	51.50
65.00	0	7.63	185.00	1532....	194.00	1693....	999.13	43.60	13.48	14.50	51.50
65.20	0	7.63	185.00	1513....	194.00	1693....	999.13	43.20	13.48	14.00	51.50
65.40	0	7.63	185.00	1516....	194.00	1693....	999.13	43.20	13.48	13.50	51.50
65.60	0	7.63	185.00	1519....	194.00	1584....	986.10	43.20	13.48	13.50	51.50
65.80	0	8.75	185.00	1507....	194.00	1584....	986.10	43.20	13.48	13.50	50.00
66.00	0	8.75	185.00	1509....	194.00	1584....	986.10	43.20	13.48	13.50	50.00
66.20	0	8.75	185.00	1504....	194.00	1584....	986.10	43.20	13.48	13.50	50.00
66.40	0	8.75	185.00	1514....	194.00	1584....	986.10	43.20	13.48	13.50	50.00
66.60	0	8.75	185.00	1502....	194.00	1650....	977.04	43.20	13.48	13.50	50.00
66.80	0	10.25	185.00	1516....	194.00	1650....	977.04	43.20	13.48	13.50	51.50
67.00	0	10.25	185.00	1513....	194.00	1650....	977.04	43.20	13.48	14.00	51.50
67.20	0	10.25	185.00	1506....	194.00	1650....	977.04	43.20	13.48	14.50	51.50
67.40	0	10.25	185.00	1512....	194.00	1650....	977.04	43.20	13.48	15.00	51.50
67.60	0	10.25	185.00	1507....	194.00	1769....	1024....	43.20	13.48	15.00	51.50
67.80	0	11.13	185.00	1507....	194.00	1769....	1024....	43.20	13.48	16.00	52.00
68.00	0	11.13	185.00	1503....	194.00	1769....	1024....	43.60	13.48	16.50	52.00

EG-8780

Figure 245 Replaying a Snapshot via Text Window

EST HELP

This software release of Master Diagnostics has an extensive set of documentation loaded into the electronic help file. This section describes the organization and the layout of **Help** file.

Select **Help** and then **Contents** (See Figure 246, page 414).

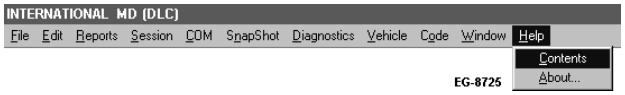


Figure 246

The **Help** section will appear (See Figure 247, page 414).

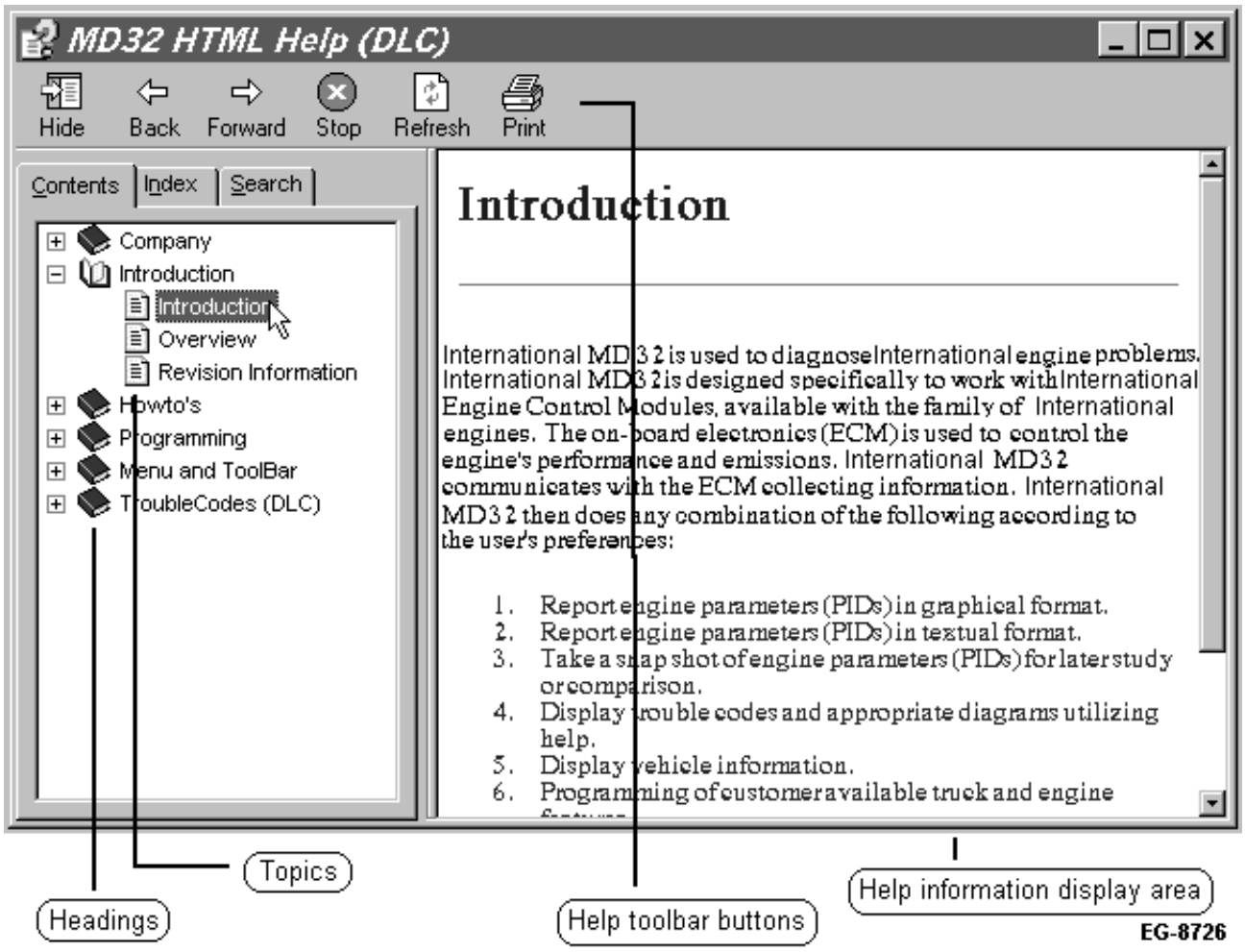


Figure 247

The **Help** file is arranged under the following headings: **Company, Introduction, How to's, Programming, Menus Toolbar**, and **Trouble Codes (DLC)**.

The **Introduction** topic contains the software revision information. This topic documents the changes to individual software releases. Click on the topic titled **Revision Information**. It will display the software revision contained in this release.

The **How to's** topic describes the features of this software's usage, access, and examples. Double clicking on the heading labeled **How to's** will display more help functions.

The **Trouble Codes (DLC)** topic contains service procedures and technical information on the International family of engines. Placing the mouse pointer over a Diagnostic Trouble Code number or the circuit index causes the pointer to change from the shape of an arrow to the shape of a hand indicating these topics can be hot linked (See Figure 248, page 415).

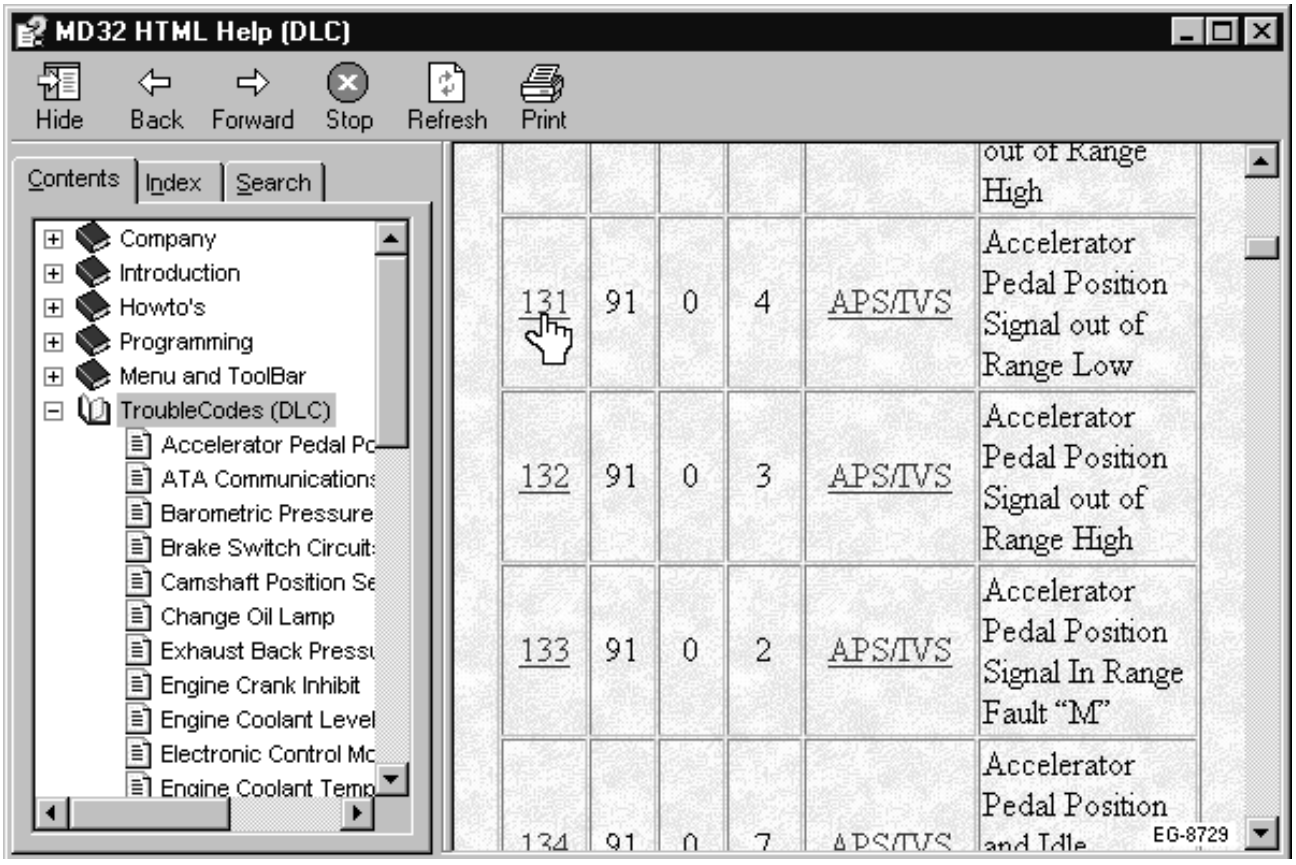


Figure 248

Example: Double clicking on the Diagnostic Trouble Code brings up a detailed description of possible causes. This is normally displayed when double clicking the **DTC** in the **Diagnostic Trouble Code** window (See Figure 229, page 405).

Clicking on a hot link in the circuit index will bring up a detailed description of the circuit involved with this Diagnostic Trouble Code as well as others. The circuit index is also organized under individual topics corresponding to their related Diagnostic Trouble Codes. Related circuit diagrams can be reviewed as well by clicking on the appropriate engine family hot link (V-8 or I-6) (See Figure 230, page 405).

Example: Clicking on Diagnostic Trouble Code 131, results in a window detailing more information about that particular diagnostic code (See Figure 231, page 406). Clicking on the I-6 hot link opens up an electrical diagram and voltage / resistance checks for harnesses and connectors (See Figure 232, page 406).

Click on the tab label **Index**. This displays all EST HELP topic indexes. Double clicking on an index item causes the help information to be displayed.

Click on the tab labeled **Search**. You can search help by using specific words or phrases. You can use the advanced search features by making conditional searches. Type in the words or phrases in the search box and click on the **List Topics** button. Select the topic and then click on the **Display** button to display the help information.

Please check the Master Diagnostic software users manual for questions and additional information.

DIGITAL MULTIMETER USE

VOLTAGE

Voltage is an electrical pressure or force that pushes current through a circuit. The pressure is measured in Volts and the symbol V (ex., 12V) is used in circuit diagrams. The letter “E” is also used for voltage and stands for Electromotive Force. Voltage can be compared to the pressure necessary to push water through a metering valve.

Low voltage to a lamp will cause 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 the relationship between voltage, current, and resistance (Ohm’s law).

OHM’S LAW REVIEW

Ohm’s law describes the relationship of current, voltage, and resistance in an electrical circuit. Ohm’s law also provides the basic formula for simple calculations (See Figure 249, page 418).

Basic formula for Ohm’s law

- I = Current (amperes)
- E = Voltage (volts)
- R = Resistance (ohms)

A. I = E / R

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

B. R = E / I

This formula states that resistance (R) = voltage (E) applied to a circuit divided by current flow (I) in the circuit. Resistance can be calculated for a specific current flow when a specific voltage is applied, e.g. 12V.

C. E = IR

(I multiplied by R)

IR gives the voltage drop (resistance) across a particular load device that is part of a series of load devices.

Memorize the formula in the circle. Cover the letter with your finger for the desired formula. For example, if you cover the I, the formula is I = E / R. (See Figure 249, page 418)

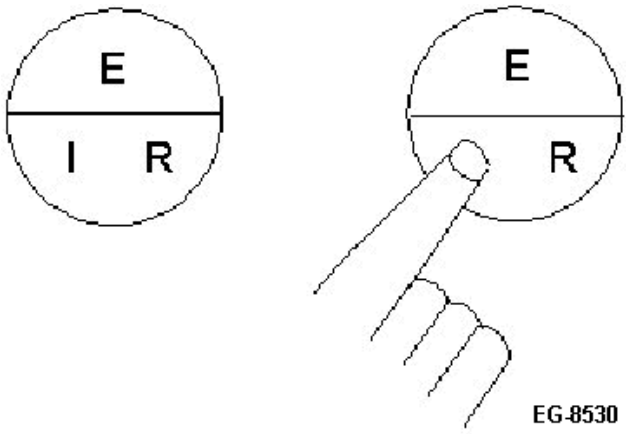


Figure 249 Ohm's Law

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

In a typical circuit, battery voltage is applied to a bulb through a 10-amp fuse and a switch (See Figure 250, page 418). Closing the switch turns on the bulb.

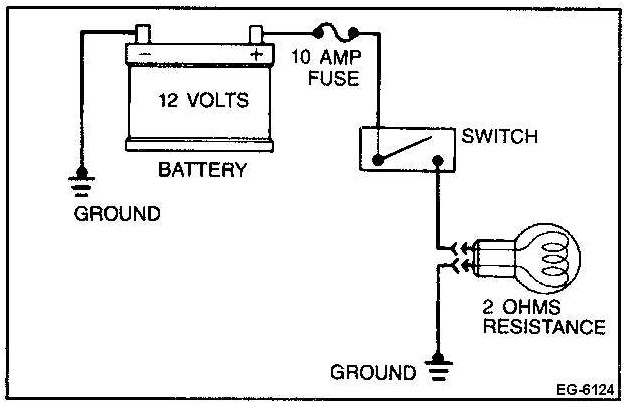


Figure 250 Simple Electrical Circuit

To find the current flow use formula:

I = E / R

Fill in the numbers for the formula.

I = 12V / 2 ohms **or** I = 12 divided by 2 = 6 amperes of current flow.

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

- if the voltage applied is low (low battery), then the value of "E" is lower and current flow will be less and the bulb will glow less brightly.
- if the connections are loose, or the switch corroded, the circuit resistance will be greater (value of R will be larger) and the current flow will be reduced and the bulb will glow 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 will 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 ran too fast, the problem could be isolated to a low resistance in a resistor pack by taking voltage drop readings.
- Maximum allowable voltage drop under load is critical, especially if there is more than one high resistance problem in a circuit. It is important because 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 circuit components. Remember our earlier discussion, the increased resistance from the undesirable conditions will also decrease the current flow in the circuit and all the affected components will operate at less than peak efficiency. A small drop across wires (conductors), connectors, switches, etc. is normal. This is because all conductors have some resistance, but the total should be less than 10 percent of the total voltage drop in the circuit.

Using the Voltmeter

In electrical diagnosis, the voltmeter is used to answer:

- Is voltage present?
- What is the voltage reading?
- What is the voltage drop across a load device?

When using a voltmeter to determine if voltage is present to power a device, connect the positive meter lead to input connection of the device (positive side) and connect the negative meter lead to a good vehicle ground (See Figure 251, page 420). This shows how much of the source voltage is available to the device. Note that the meter is connected in parallel to the device.

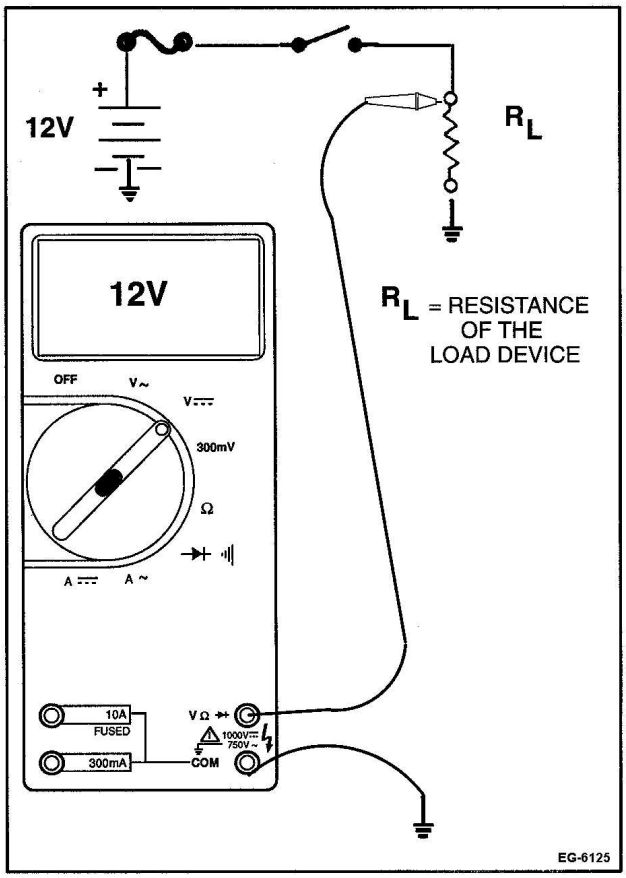


Figure 251 Checking Power to a Load Device

Voltage to a device can also be measured by disconnecting the harness connector and using the appropriate tool from the Terminal Test Adapter Kit (ZTSE 4435)(See Figure 252, page 421).

To check the voltage drop across a load device (See Figure 253, page 422), 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.

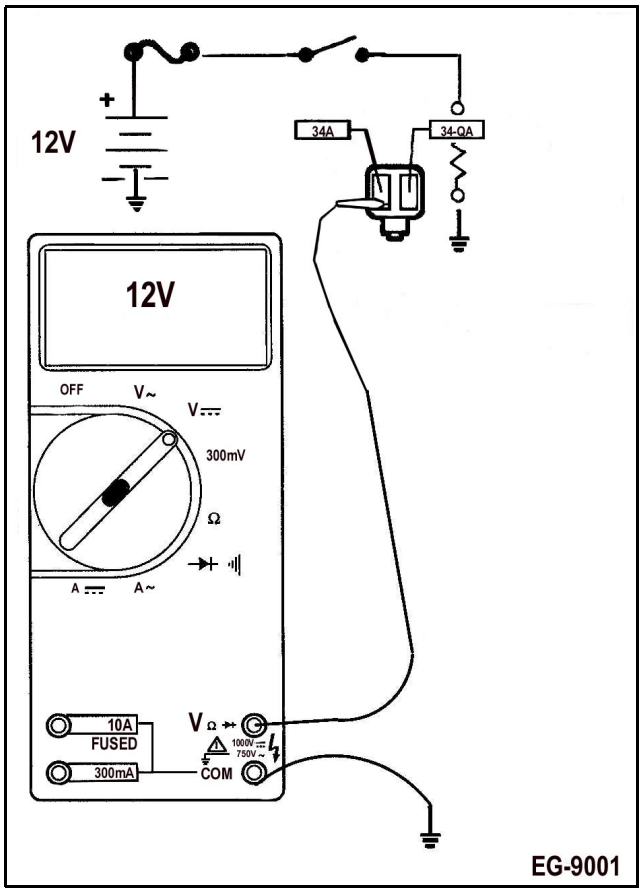


Figure 252 Checking Power to a Connector

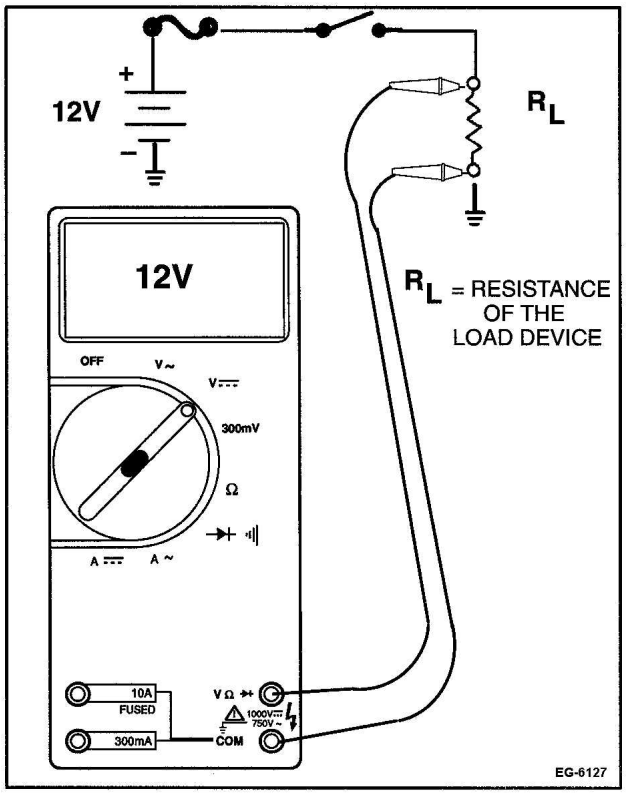


Figure 253 Checking Voltage Loss

With the device operating, this will measure the voltage drop across the device. With only one device, all of the voltage should be dropped at the device (See Figure 253, page 422). In any circuit, the voltage applied will equal the voltage dropped in the circuit. If this circuit only dropped 9V across the load, it indicates the wires and connections dropped 3V and suggests excessive circuit resistance.

AMMETER

An ammeter is used to measure current flow (amperage) in a circuit. Amperes are units of electron flow, which indicate how many electrons are passing through the circuit. Ohm's Law indicates that current flow in a circuit is equal to the circuit voltage divided by total circuit resistance. Since amps (I) is the current in the circuit, increasing voltage also increases the current level (amps). Also, any decrease in resistance (ohms) will increase current flow (amps).

At normal operating voltage, most circuits have a characteristic amount of current flow, referred to as current draw. Current draw can be measured with an ammeter. Referring to a specified current draw rating for a component (electrical device), measuring the current flow in the circuit, and comparing the two (the rating versus the actual measured) can provide valuable diagnostic information.

An ammeter is connected in series with the load, switches, resistors, etc. (See Figure 254, page 423) so that all of the current flows through the meter. The meter will measure current flow only when the circuit is powered and operating. Before measuring current flow, we need to know approximately how much current will be present to properly connect the meter. The DMM is fused to measure up to 10 amps using the 10A connection point.

The estimate of current flow can easily be calculated. In the following image Installing The Ammeter (See Figure 254, page 423), the resistance of the light bulb is 2 ohms. Applying Ohm's law, we can calculate that current flow will be 6 amps (6A = 12V / 2 ohms). If we remove the fuse, and install the ammeter as shown,

with the switch closed we will measure 6 amperes of current flowing in the circuit. Notice that the ammeter is installed so that all the current in the circuit flows through it. The ammeter is installed in series.

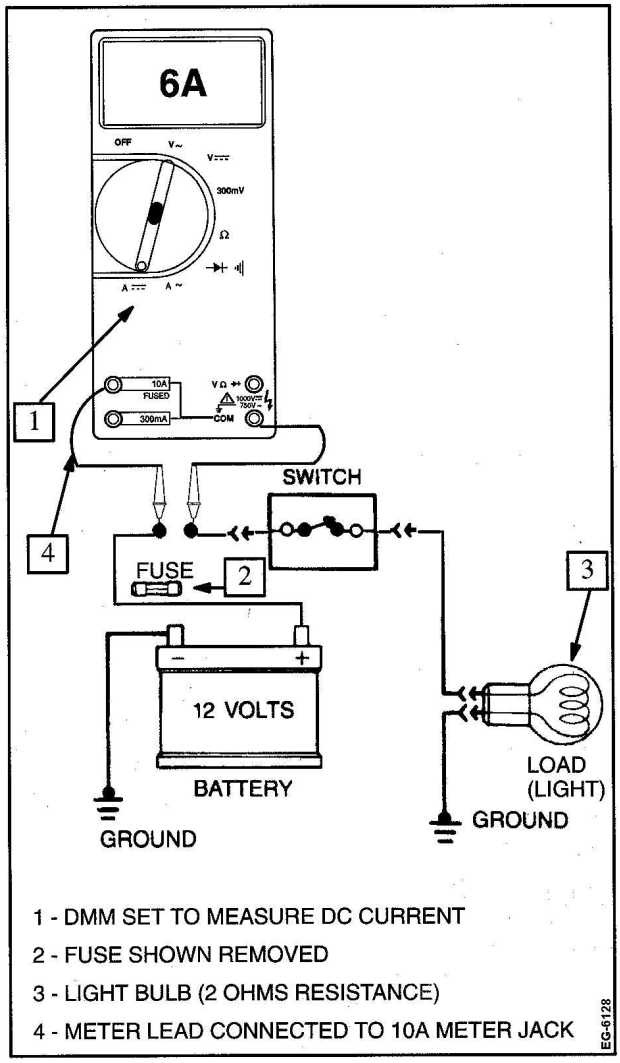


Figure 254 Installing the Ammeter

WARNING – To avoid personal injury, always make sure the power is off before cutting, soldering or removing circuit components prior to inserting the DMM 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 for. Excessive current will open fuses and circuit breakers. Excessive current draw can also quickly discharge batteries. An ammeter is useful to help diagnose these conditions. On the other hand, there are times reduced current draw will cause a device (electric window motor for example) to operate poorly. Remember increased circuit resistance causes lower current to be available to the device. Loose or corroded connections can frequently cause this problem.

OHMMETER

The ohmmeter is used to measure resistance (ohms) in a circuit. Like the ammeter and voltmeter, there are both analog and digital meters available. It is recommended that the Fluke 88™ (DMM) be used. See ELECTRONIC CIRCUIT TESTING in this section.

CAUTION – The ohmmeter can only be used on circuits when the power has been removed. The meter contains its own low voltage power supply and the power from 12-volt systems may damage the meter.

Ohmmeters use a small battery to supply the voltage and current which flow through the circuit being tested. The voltage of the meter battery and the amount of current flow in the circuit are used with Ohm's law and the meter calculates the circuit resistance which is displayed by the meter. With the Fluke 88™ (DMM), range selection and meter adjustment are not necessary.

Measuring Resistance

Resistance measurements determine:

- Resistance of a load
- Resistance of conductors
- Value of resistors
- Operation of variable resistors

To measure the resistance of a component or a circuit, power must first be removed from the circuit.

The component or circuit that is to be measured must be isolated from all other components or circuits so that meter current (from probe to probe) only flows through the desired circuit or component or the reading will not be accurate. If we wanted to measure the resistance of the load, most of the current flow from the meter would flow through the indicator lamp because it has less resistance. To measure the load, one connector to the load should be removed. It is not always apparent when a component must be isolated in such a manner, so it is a good practice to isolate the circuit or component by physically disconnecting one circuit.

The ohmmeter leads are then placed across the component or circuit and the resistance will be displayed in ohms (Ω) (See Figure 255, page 425). When checking a sensor or variable resistor such as 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.

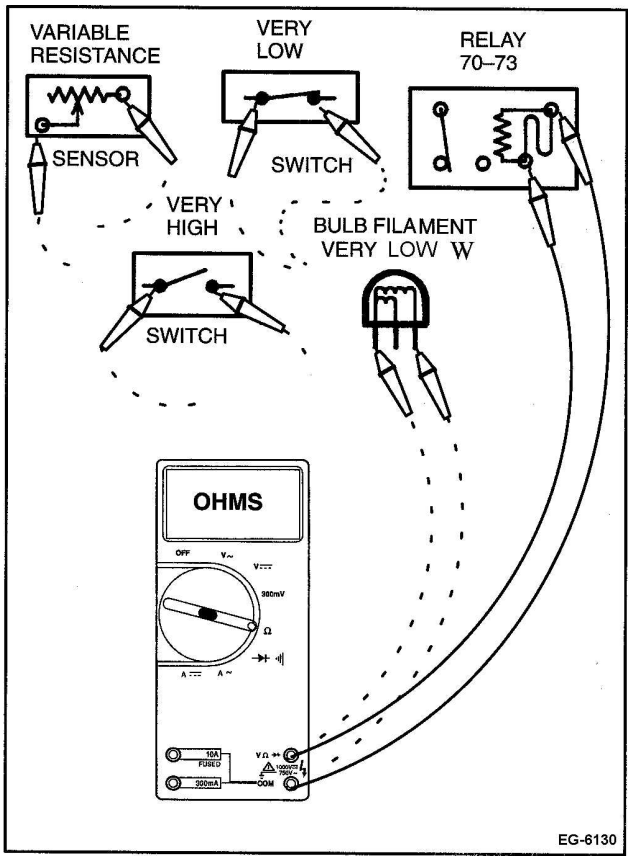


Figure 255 Measuring Resistance

Checking for Open Circuits

Electrical circuits can be checked for opens using an ohmmeter. The circuit must first be disconnected from the power supply. The circuit to be checked must also be isolated from other circuits. Connect the meter to the open ends of the circuit as shown (See Figure 256, page 426). A high reading (infinity) indicates there is an open in the circuit. A near zero reading is an indication of a continuous circuit. Notice in the same illustration the circuit between the light and the ground is disconnected. This precaution prevents reading a circuit as complete that may be shorted to ground ahead of the load device.

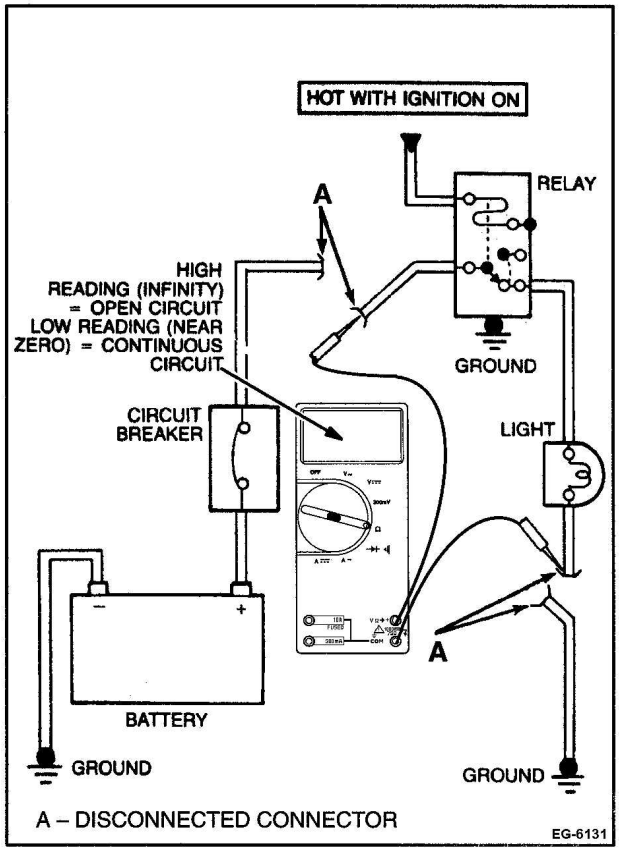


Figure 256 Open Circuit Check Using an Ohmmeter

Checking for Short Circuits

Checks for short circuits are made similarly to checks for open circuits. However, the circuit to be checked must be isolated from both the power source and the ground point.

Connecting the ohmmeter as shown in (See Figure 257, page 427) between an isolated circuit and a good ground point will allow checking the circuit for a short to ground. A short to ground will be indicated by a near zero reading, while a circuit not shorted to ground will cause the meter to read very high. With the Fluke 88™ (DMM), an open circuit will read **OL** (over limit) on the meter display.

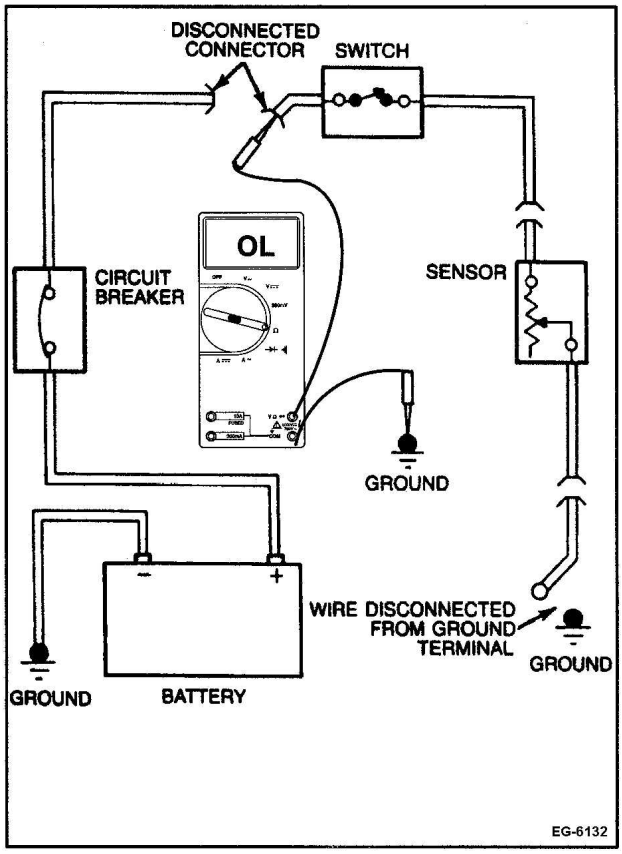


Figure 257 Short Circuit Check Using an Ohmmeter

TROUBLESHOOTING

Before beginning any troubleshooting, there are several important steps to be taken:

Verify the Problem

Operate the complete system and list all symptoms in order to:

- 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.

Read Electrical Operation

Read the electrical operation for the problem circuit while referring to the circuit diagram. By studying the circuit diagram and the electrical operation, enough information about circuit operation can be learned to narrow the cause of the problem to one component or portion of the circuit.

Check the Circuit Diagram

Refer to the circuit diagram for possible clues to the problem. Locating and identifying the components in the circuit provides some idea of where the problem could be.

The circuit diagrams are designed to make it easy to identify common points in circuits. This knowledge can help 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 (see POWER DISTRIBUTION AND GROUNDS). 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 lights and the high-beam indicator do not work, then 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.

Check for Cause of the Problem

Diagnosis charts are provided for many of the common faults that may occur. Refer to these charts in each section. Follow the procedures in the chart until the cause of the problem is located.

If the particular symptom found in the problem circuit is not covered by a diagnosis chart, refer to the general electrical troubleshooting information provided under Electrical Test Equipment in this section.

Make the Repair

Repair the problem circuit as directed in the diagnostic charts.

Verify that the Repair is Complete

Operate the system and check that the repair has removed all symptoms, and also that the repair has not caused any new symptoms.

Electrical Test Equipment

Various electrical testers have been developed over the years. A few of these are basic but necessary to perform an electrical diagnosis. These include:

- Jumper Wires
- Test Lights
- Voltmeter
- Ohmmeter
- Ammeter

All of these testers come in a variety of models and any working model will be adequate for simple tests. However, when the value of a reading obtained using a meter is critical to the diagnostic procedure, accuracy becomes important. Make sure any electrical test meter used is of sufficient quality and accuracy to make the measurements required in the electrical testing. The Fluke 88™ (DMM) is the International® recommended meter and discussions of meter use in this manual will refer to that meter.

The Fluke 88™ (DMM) is recommended because it uses very little current to do its measuring. The digital meter has a high impedance (resistance) of 10 megaohms (10 MΩ).

ELECTRONIC CIRCUIT TESTING

Some of the devices in an electronic control system are not capable of carrying any appreciable amount of current. Therefore the test equipment used to troubleshoot an electronic system must be designed not to damage any part of it. Because most analog meters (See Figure 258, page 429) use too much current to test an electronic control system, it is recommended that they not be used, unless specified.

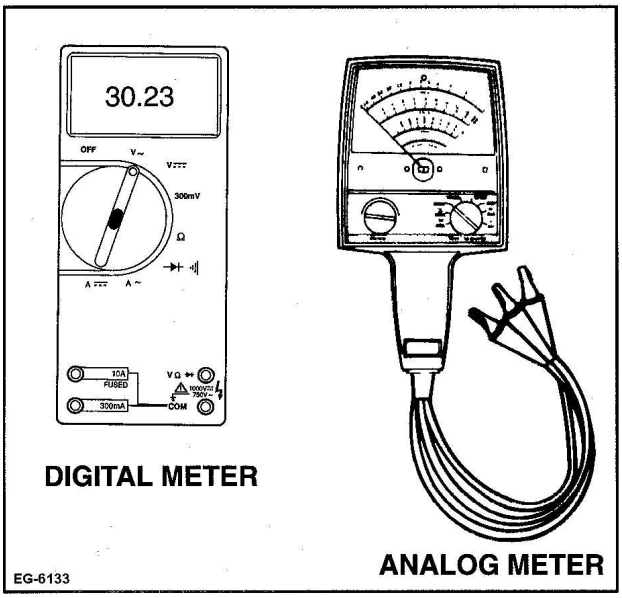


Figure 258 Typical Meters, Digital and Analog

Only high impedance DMMs should be used when troubleshooting an electronic circuit. The use of any kind of battery powered test light is not recommended when troubleshooting an electronic circuit. This can damage an electronic control circuit.

Jumper Wires

Jumper wires (See Figure 259, page 429) allow jumping across a suspected open or break in a circuit.

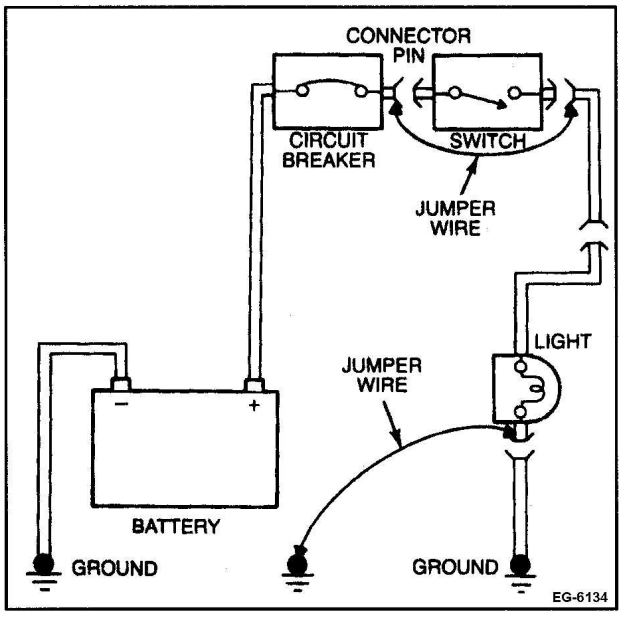


Figure 259 Troubleshooting Using Jumper Wires

- If the circuit (See Figure 259, page 429) works properly with the jumper wire in place, but does not work when the jumper wire is removed, the circuit is open.

- A circuit without any opens or breaks has continuity (which means continuous) and needs no further testing.

Jumper wires are fitted with several types of wire tips. It will be helpful to have several jumper wires available with different tips (See Figure 260, page 430).

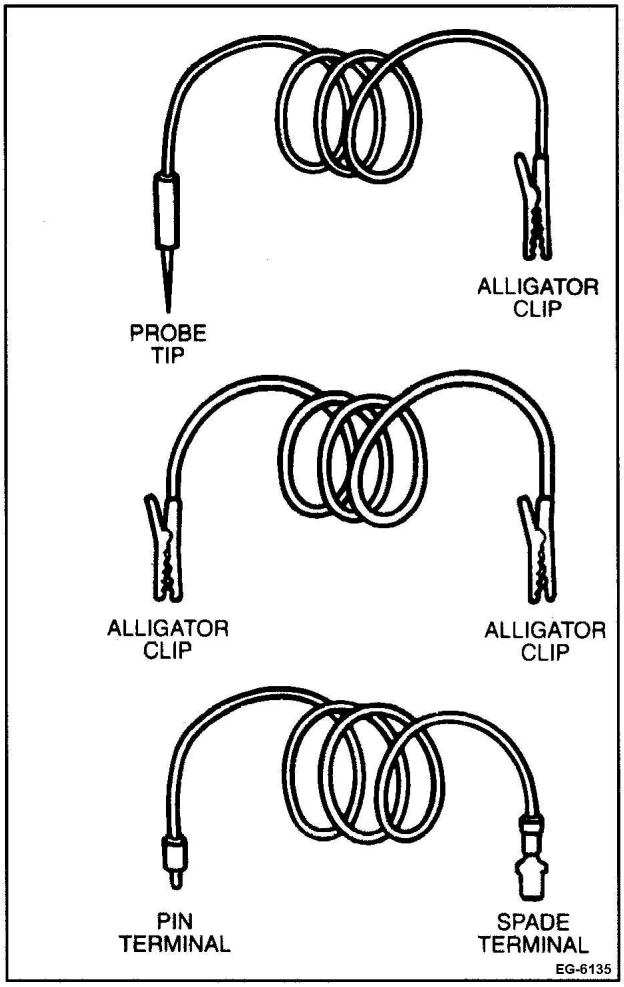


Figure 260 Jumper Wires

In the illustration Troubleshooting Using Jumper Wires (See Figure 259, page 429), an open in the ground circuit exists when:

- Switch is closed and light does not illuminate.
- Jumping the switch does not illuminate the light.
- Jumping the light to the ground causes the light to illuminate.

The jumper wire can be used to check for open relay contacts, wire breaks, and poor ground connections.

Table of Contents

CONTACT INSERTION

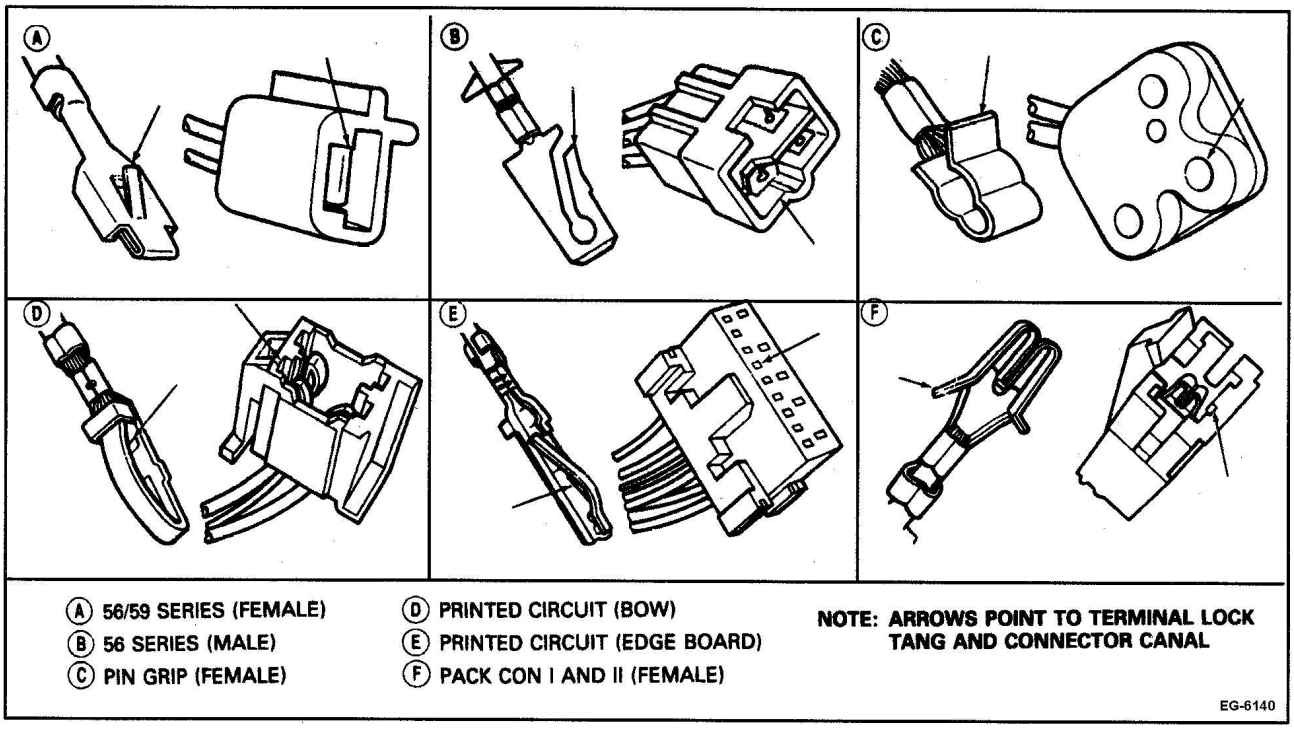


Figure 261 Connector Details

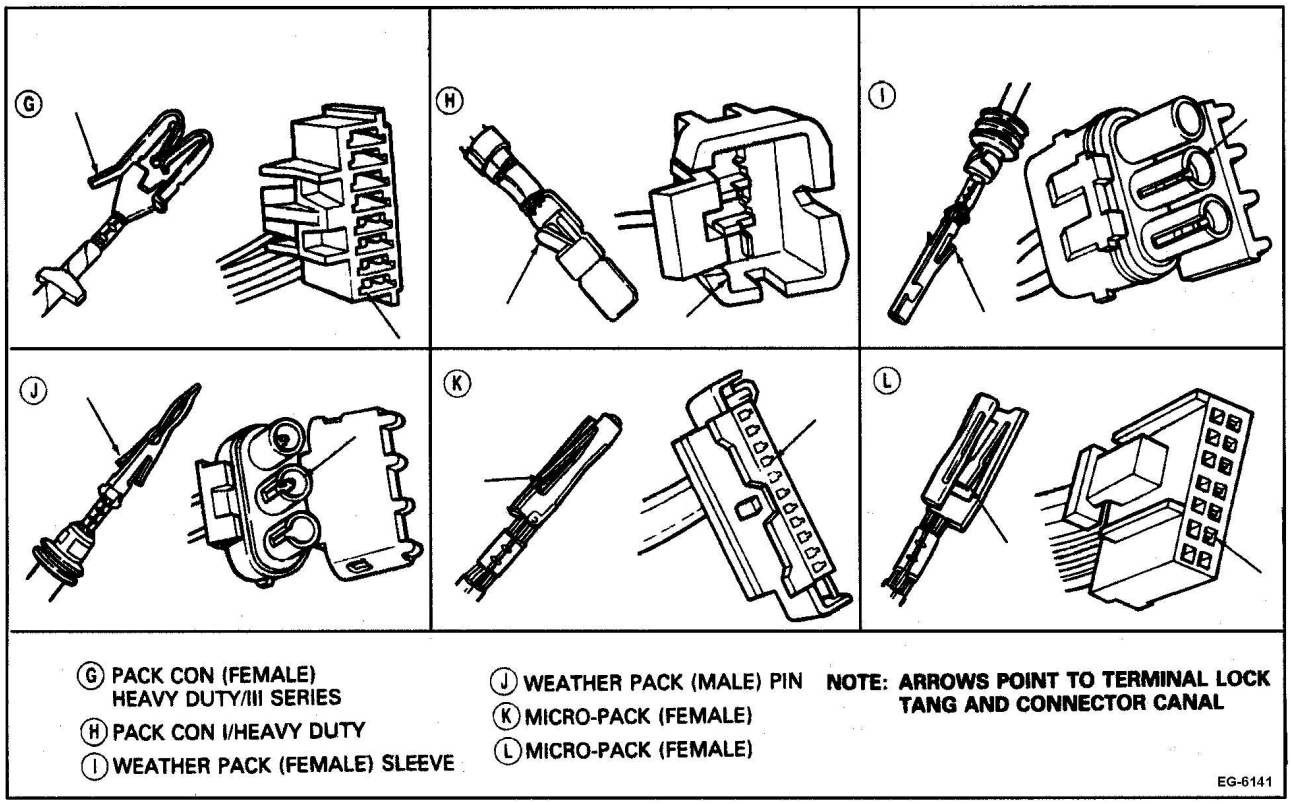


Figure 262 Connector Details

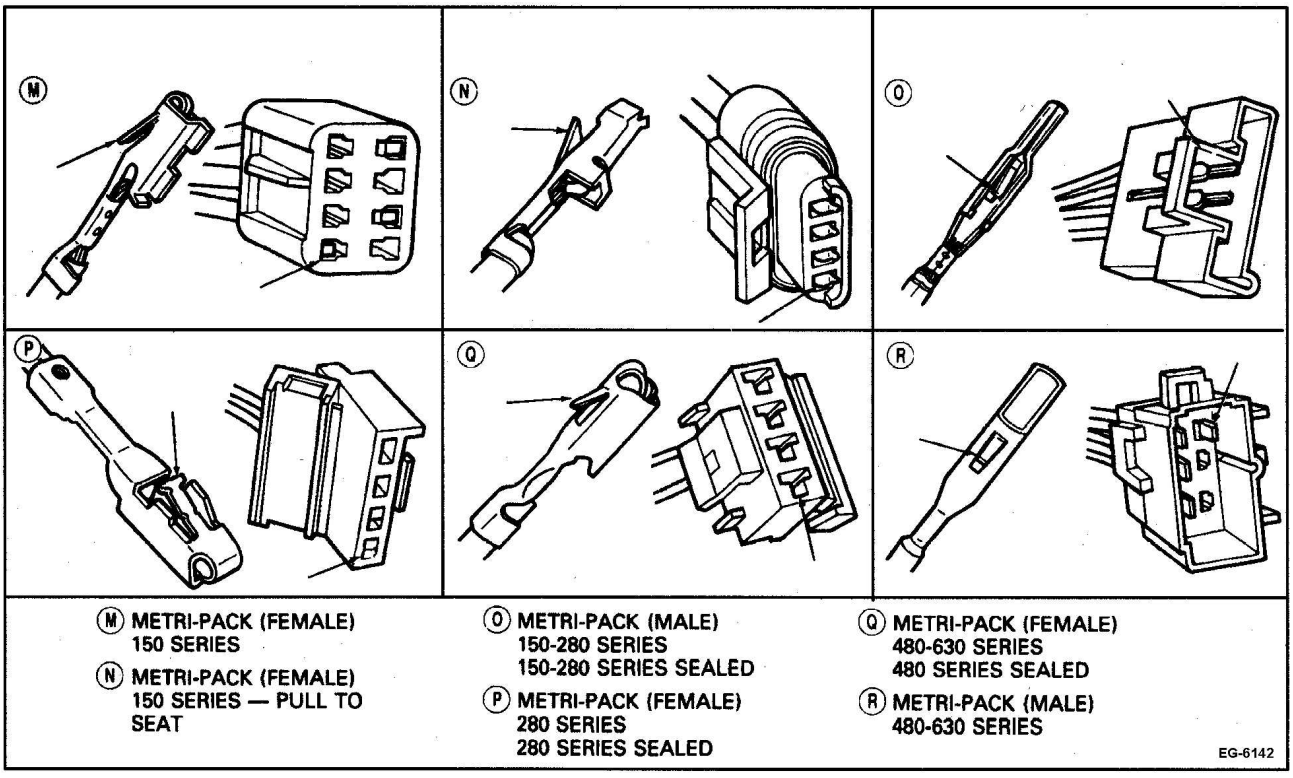


Figure 263 Connector Details

INSPECTION

Refer to the following illustration for details associated with satisfactory wire connections, Inspecting Terminal, Solder, Crimp and Seal Heat Applications (See Figure 264, page 435).

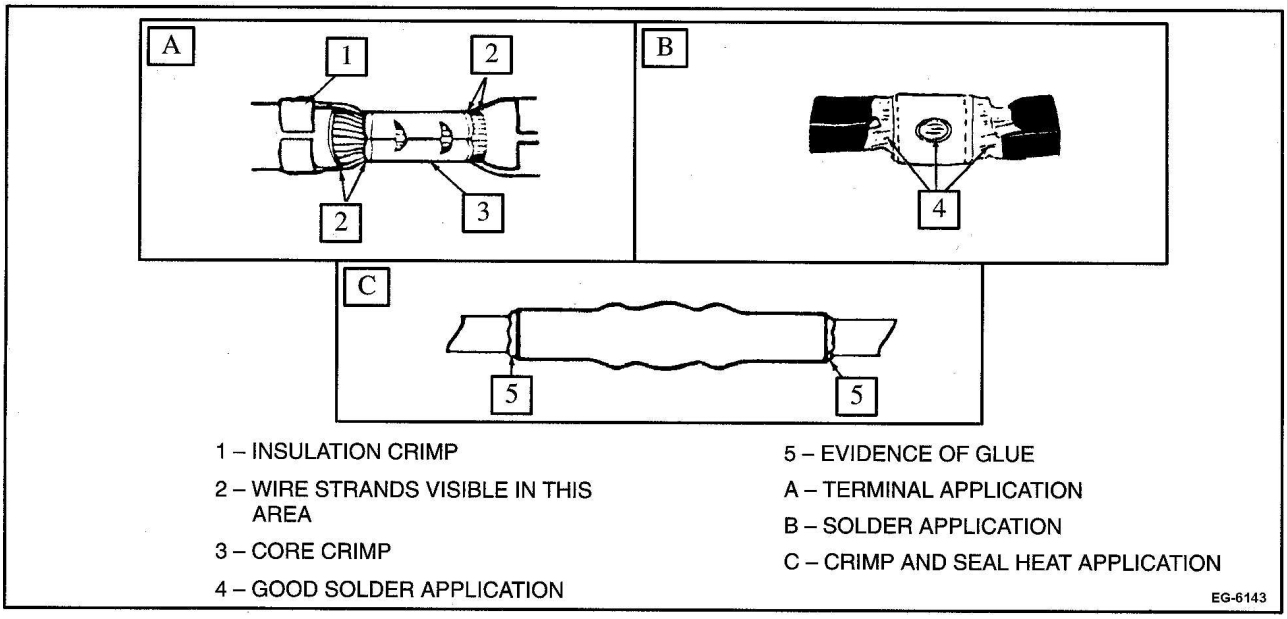


Figure 264 Inspecting Terminal, Solder, Crimp and Seal Heat Applications

STANDARD TERMINAL REPLACEMENT

Refer to Standard Terminal Replacement (See Figure 265, page 436).

1. Cut the cable just before the insulation wings on the terminal.
2. Remove the insulation, being careful not to cut any of the wire strands.
3. Position cable in the new terminal.
4. Hand crimp the core wings first, then the insulation wings.

NOTE – Always use the recommended crimp tool for each terminal. A detailed crimp chart is included in the repair kit.

5. Solder all hand crimped terminals and electrically check for continuity.

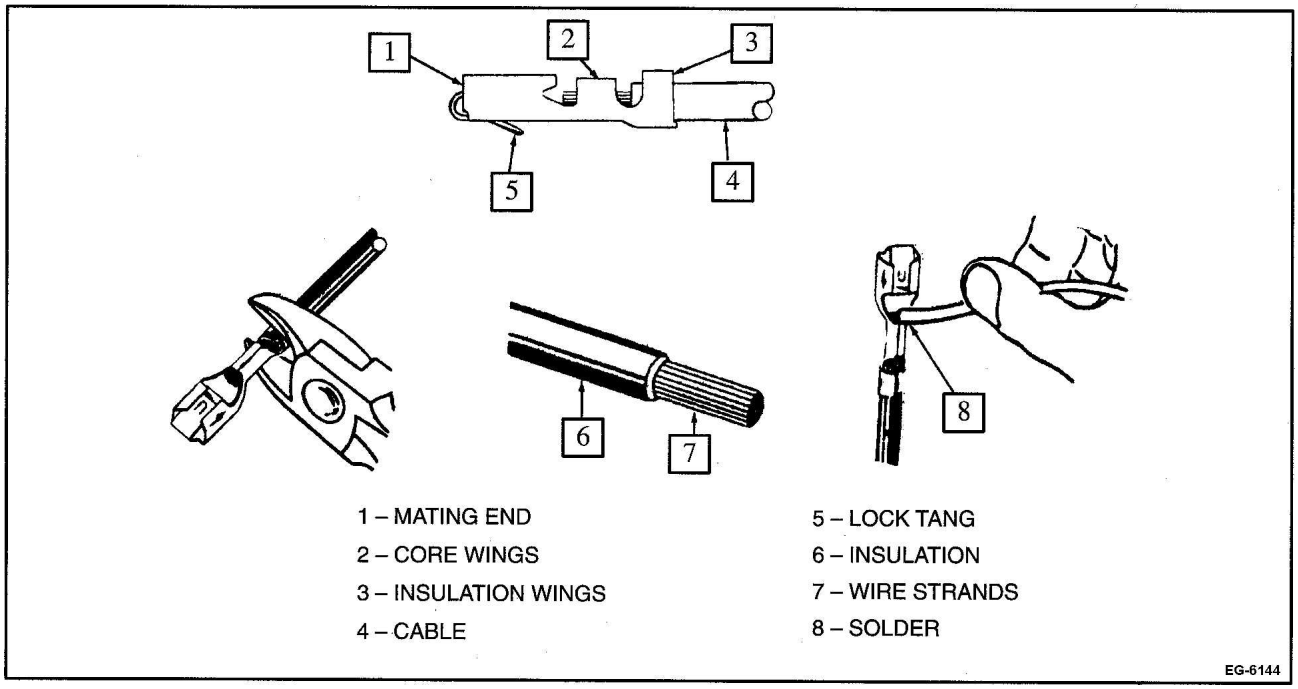


Figure 265 Standard Terminal Replacement

TERMINAL REPLACEMENT–SEALED WEATHER PACK AND METRI-PACK

Refer to Terminal Replacement–Sealed Weather Pack And Metri-Pack (See Figure 266, page 437).

1. Cut the cable just before the insulation wings on the terminal.
2. Replace the seal and remove the insulation being careful not to cut any of the wire strands.
3. Align the seal with the cable insulation.
4. Position the cable in the new terminal.
5. Hand crimp the core wings first, then the insulation wings.

NOTE – Always use the recommended crimp tool for each terminal. A detailed crimp chart is included in the repair kit.

6. Solder all hand crimped terminals and electrically check for continuity.
7. Replace the terminal in correct connector cavity.

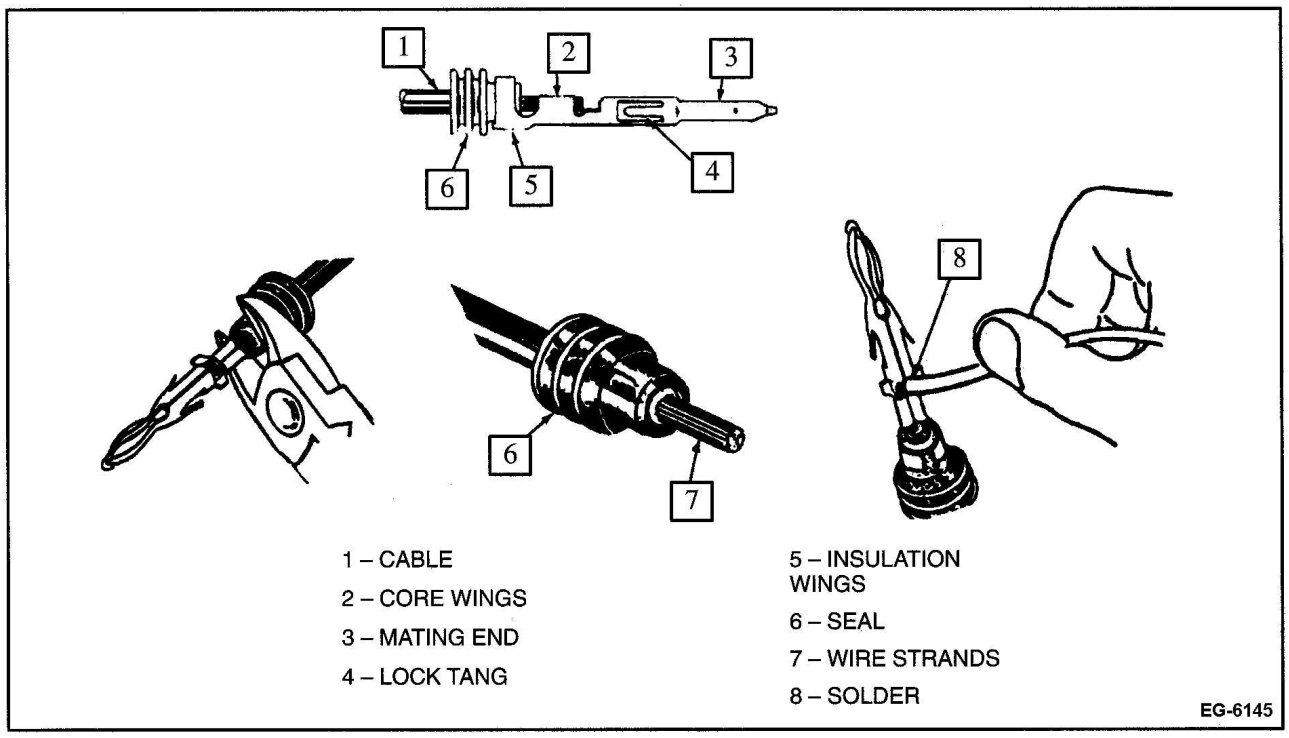


Figure 266 Terminal Replacement–Sealed Weather Pack And Metri-Pack

SPLICE CLIP INSTALLATION

Refer to Splice Clip Replacement (See Figure 267, page 438).

NOTE – A new clip must be located a minimum of 1.5 in (40 mm) from a connector, sleeve or another clip.

1. Cut off the old clip or bad section of wire.
2. Remove the insulation being careful not to cut any of the wire strands.
3. Install the proper clip on the wire strands.
4. Hand crimp the clip until securely fastened.
5. Solder the clip and electrically check for continuity.
6. Cover the entire splice with splice tape. Extend the tape onto the insulation on both sides of the splice(s).

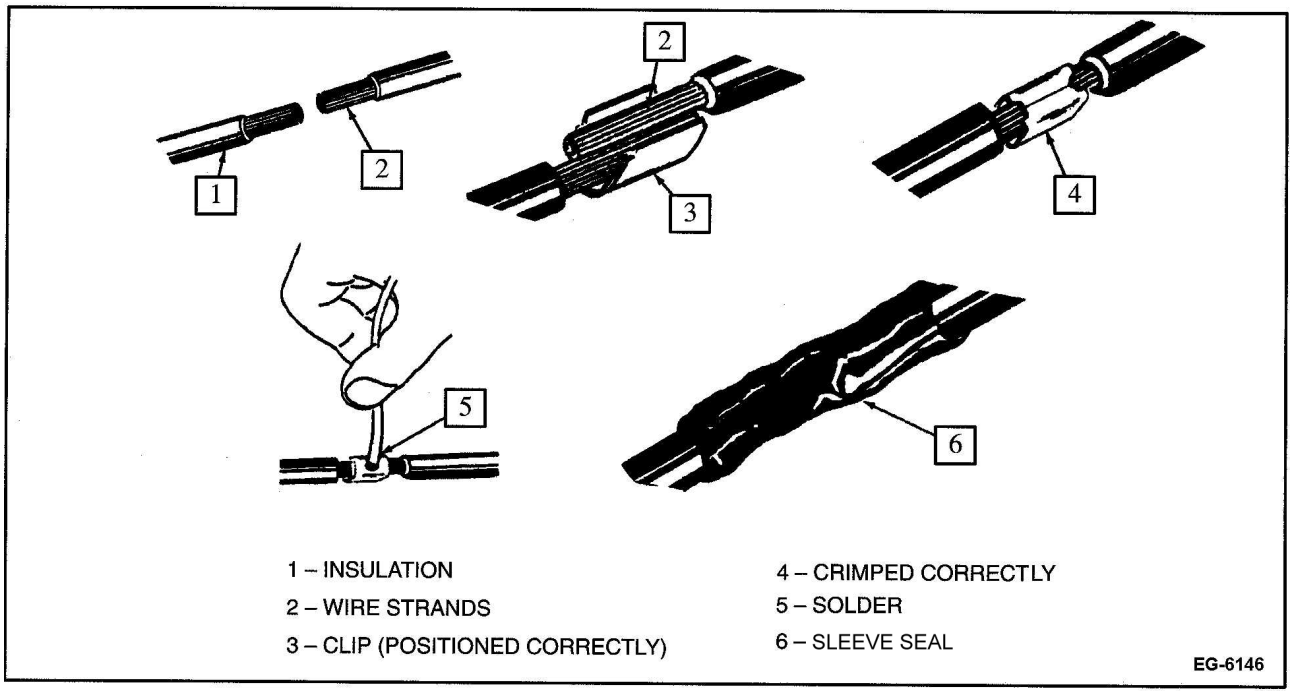


Figure 267 Splice Clip Replacement

CRIMP AND SEAL SPLICE SLEEVE INSTALLATION

Refer to Seal Splice Sleeve Replacement (See Figure 268, page 439).

NOTE – A new sleeve must be located a minimum of 1.5 in (40 mm) from a connector, clip or another sleeve.

1. Cut off the old sleeve or bad section of the wire.
2. Remove insulation being careful not to cut any of the wire strands.
3. Install the proper sleeve on the wire strands making sure the ends of the wire, hit the stop.
4. Hand crimp to the sleeve. Gently tug on the wire to make sure that they are secure.

NOTE – Always use the recommended crimp tool for each sleeve. A detailed crimp chart is included in the Repair Kit.

CAUTION – Do not use a match or open flame to heat the sleeve seal.

5. Electrically check the sleeve and wire cable for continuity.

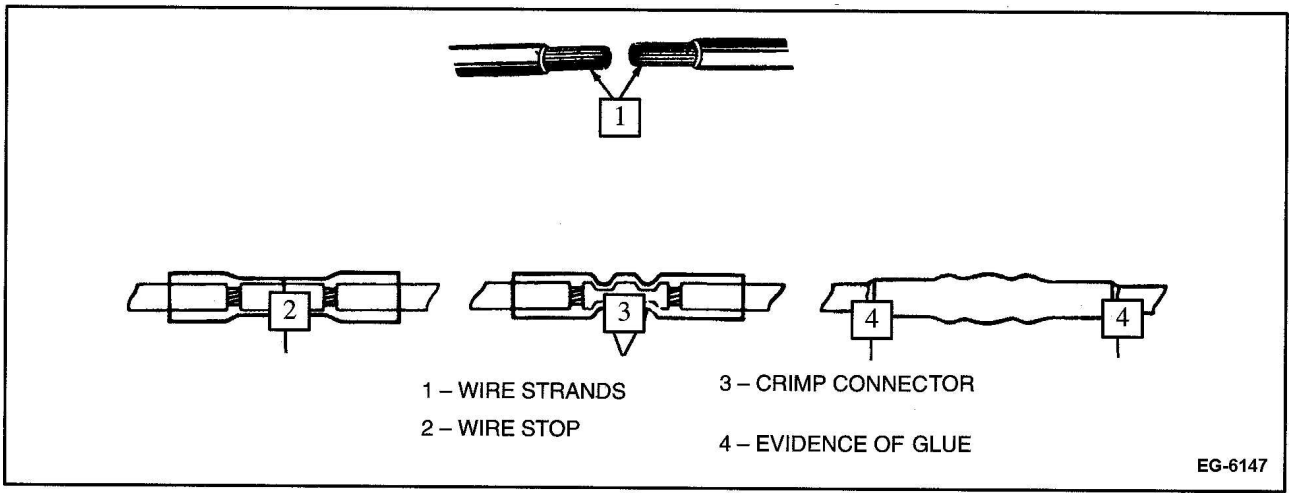


Figure 268 Seal Splice Sleeve Replacement

LOCKING WEDGE CONNECTORS

Procedure for removal of wire terminals from ECT, EOT, IAT and MAP.

The terminals are held in place by plastic retaining fingers which are part of the connector. The fingers snap into the shoulder of the terminal and are held in place by the locking wedge.

TO REMOVE THE TERMINAL FROM THE CONNECTOR

1. Using the appropriate tool, pry the connector lock out of the connector body from the mating end and remove the lock from the connector, (See Figure 269, page 440).

Figure 269 Remove Lock Wedge

2. Insert a narrow blade into the connector to lift the retaining finger away from the terminal, (See Figure 270, page 440).

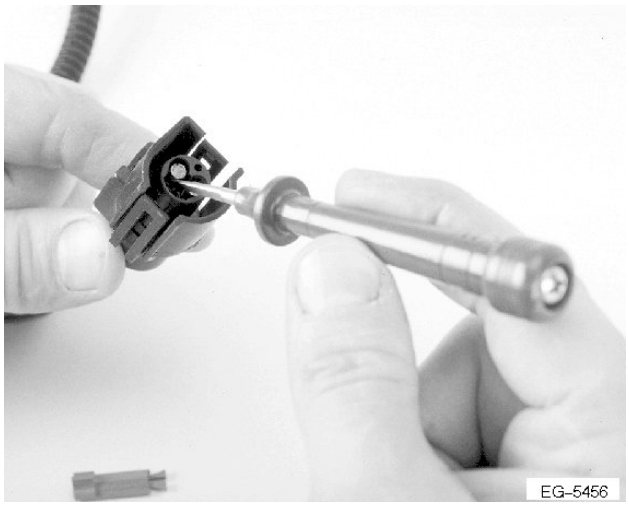


Figure 270 Release Retaining Finger

3. Pull the wire and terminal out of the connector body (See Figure 271, page 441).

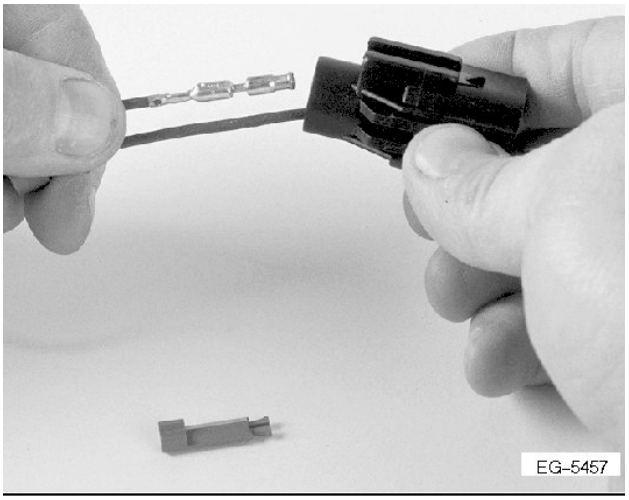


Figure 271 Remove Terminal From Connector

TO REPLACE THE TERMINAL

1. Remove the insulation, being careful not to cut any of the wire strands.
2. Position the wire in the new terminal (See Figure 272, page 441).

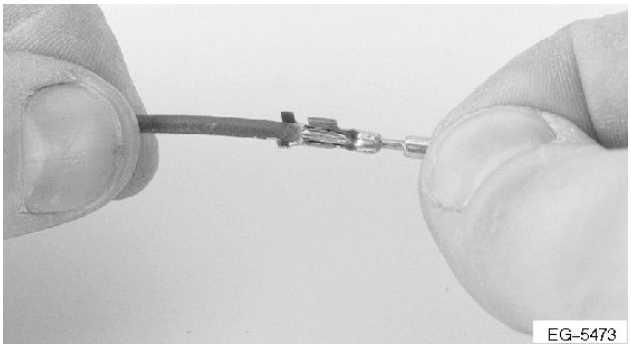


Figure 272 Place Terminal Over Wire

3. Hand crimp the core wings first and then the insulation wings (See Figure 273, page 442).

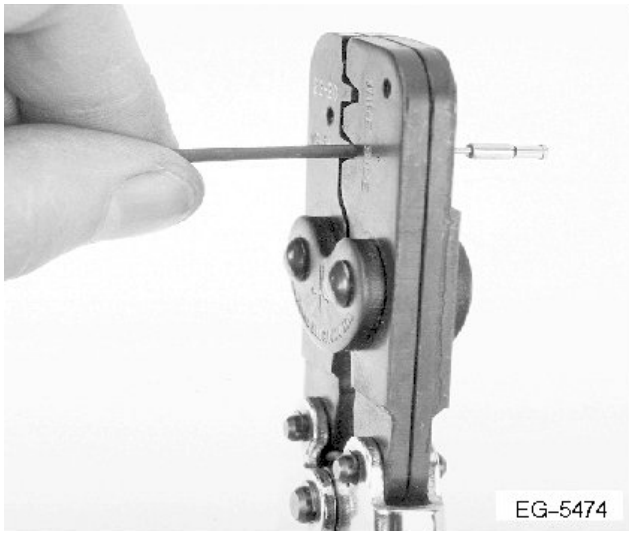


Figure 273 Terminal Over Wire

4. Contact crimping complete (See Figure 274, page 442).

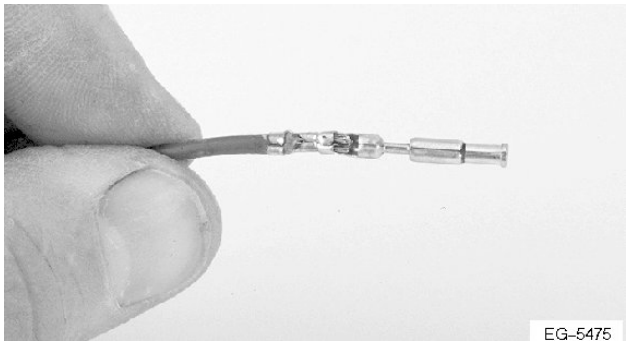


Figure 274 Contact Crimping Complete

TO INSTALL THE TERMINAL IN THE CONNECTOR

1. Push the terminal into the connector body, deep enough so that the retaining finger snaps over the terminal shoulder (See Figure 275, page 443).

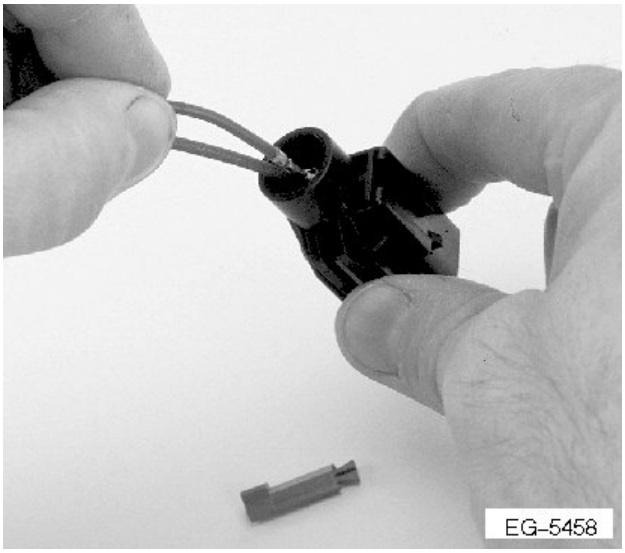


Figure 275 Insert Terminal

2. Push the insulator over the wires into the connector body (if equipped) (See Figure 276, page 443).

Figure 276 Insert Insulation

3. Insert the locking wedge and push in until flush with the face of the connector body (See Figure 277, page 444).

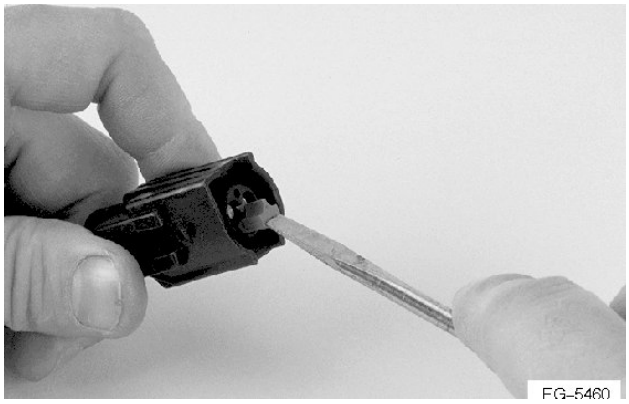


Figure 277 Insert Terminal Lock

REPLACING VALVE COVER CONNECTOR TERMINALS

Procedure for replacement of valve cover connector terminals.

To remove the terminal:

1. Using a small screwdriver pry the terminal lock out of the connector body (See Figure 278, page 445).

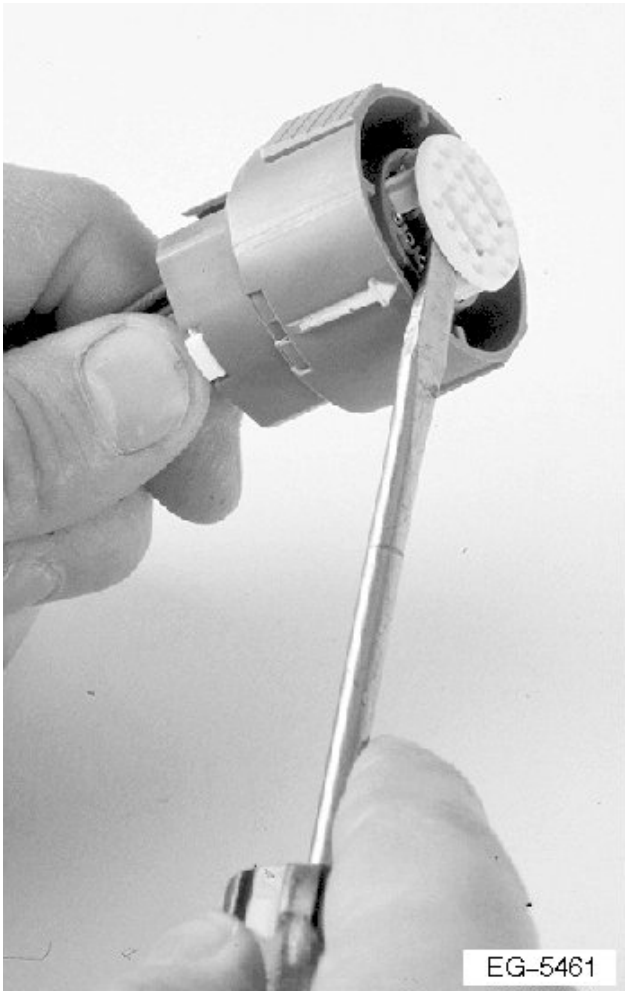


Figure 278 Remove Terminal Lock

2. Insert a narrow blade into the connector to lift the retaining finger away from the terminal (See Figure 279, page 446).

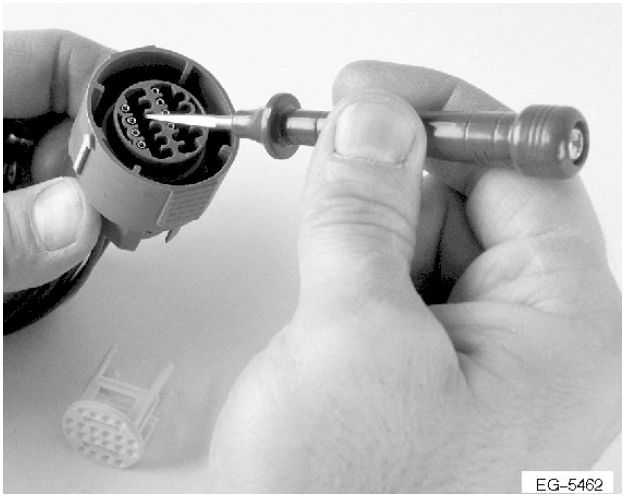


Figure 279 Release Locking Finger

3. Pull the wire and terminal out of the connector body and through the insulator on the rear of the connector (See Figure 280, page 446).

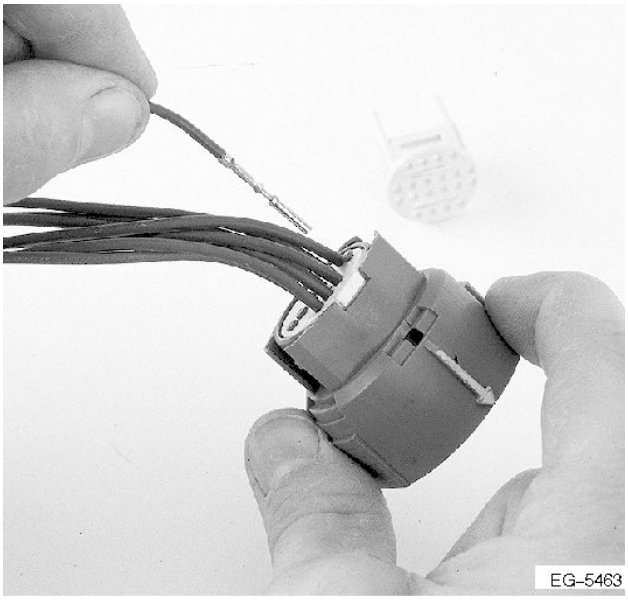


Figure 280 Remove Wire From Rear of Connector

TO INSTALL THE TERMINAL IN THE CONNECTOR

1. Insert the terminal through the insulator and the connector body and push the terminal in until the locking finger snaps over the shoulder of the terminal.

2. Insert the locking wedge into the connector body and push in until seated in the connector (See Figure 281, page 447)

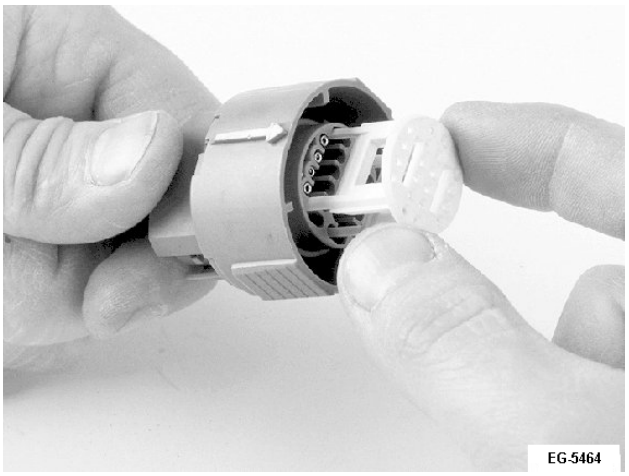


Figure 281 Install Terminal Lock

PACKARD CONNECTORS

Procedure for removal of wire terminals from CMP, ICP, IPR, EOP and injector connectors.

The terminals are held in place by locking tabs that are part of the terminal. To remove the terminal the locking tab must be released from the wire side of the connector body and the terminal is removed toward the mating end of the connector body.

TO REMOVE THE TERMINAL FROM THE CONNECTOR

1. Pry the insulator from the rear of the connector body (See Figure 282, page 447).

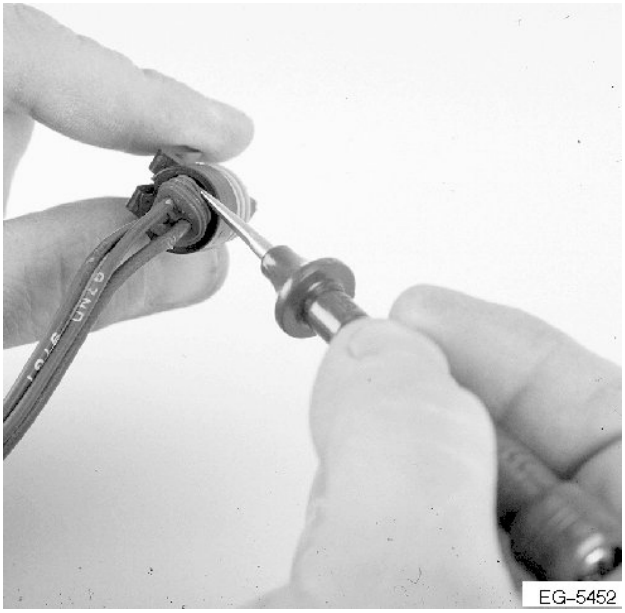


Figure 282 Move The Insulation Back

2. Slide the insulator down the wires away from the connector body (See Figure 283, page 448).

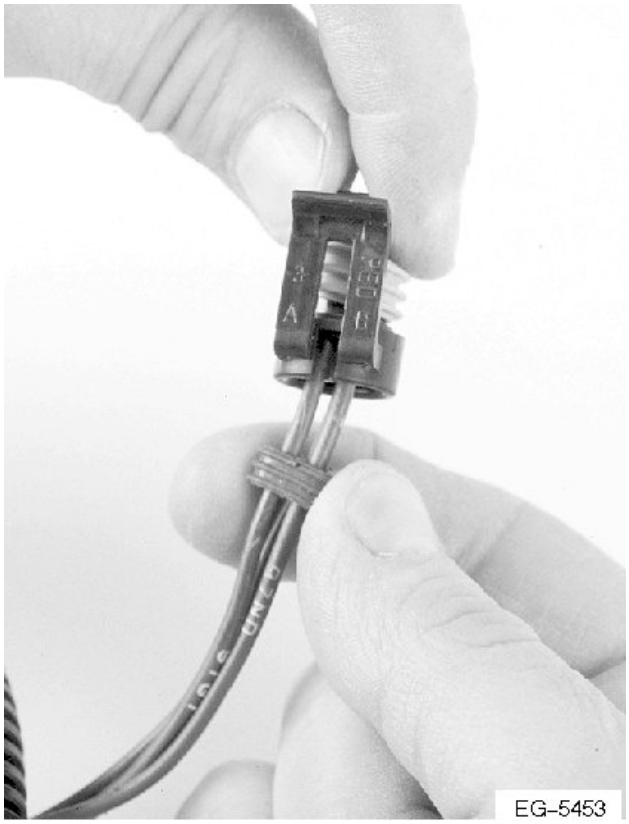


Figure 283 Slide The Insulator Away From the Connector Body

3. Insert the narrow blade tool into the rear of the connector body on the locking tab side of the wire terminal (See Figure 284, page 448).

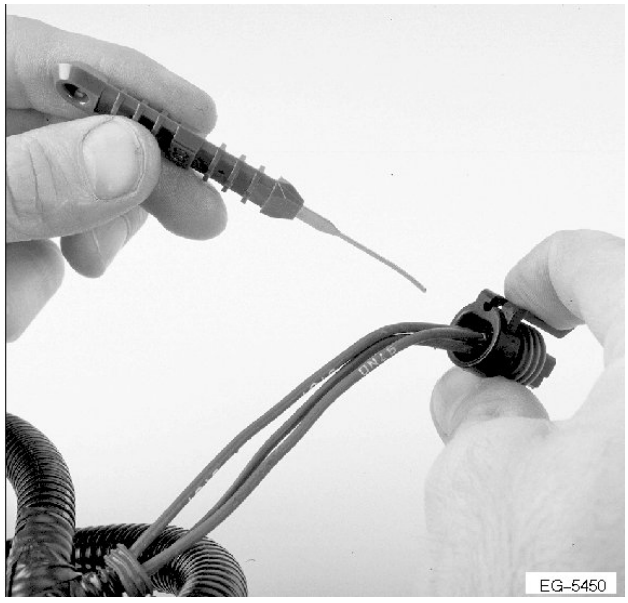


Figure 284 Release Terminal Lock Tab

4. Push the blade forward until the lock tab is depressed (See Figure 285, page 449).

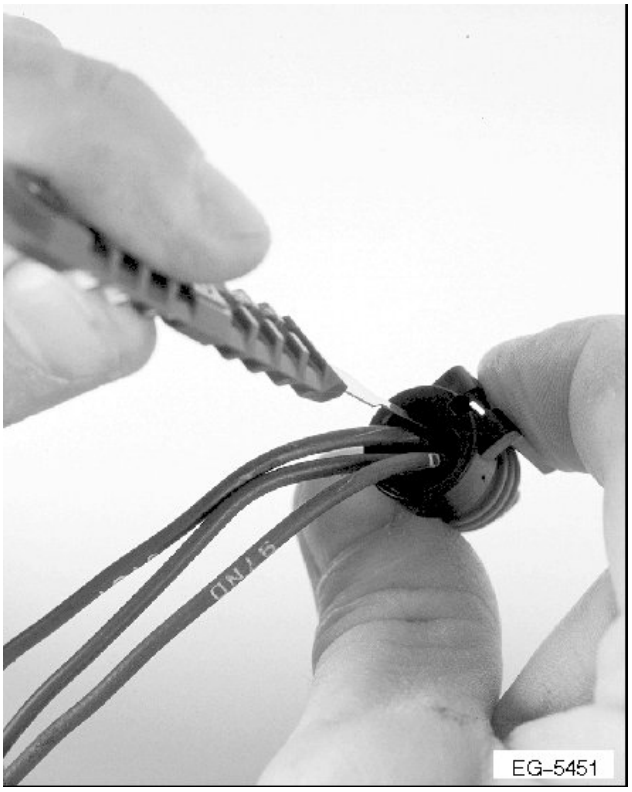


Figure 285 Release Terminal

5. Additional pressure will force the wire terminal out the end of the connector body.

   If the terminal is to be replaced, use the standard repair procedure (instructions above). Make certain that the wire is through the insulator and wire before the terminal is crimped onto the wire (See Figure 286, page 450)

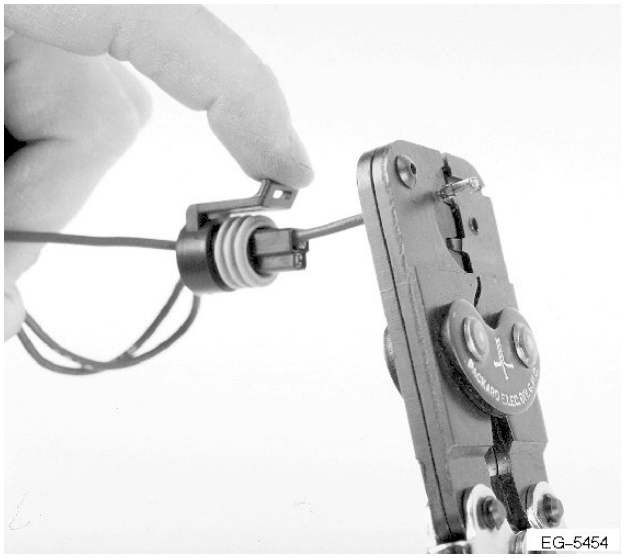


Figure 286 Contact Crimping

TO INSTALL THE TERMINAL IN THE CONNECTOR

1. Align the wing on the terminal with the slot in the connector body. Pull the wire insulator into place at the rear of the connector body until the locking tab snaps into the connector.

2. Push the wire insulator into place at the rear of the connector body (See Figure 287, page 451).

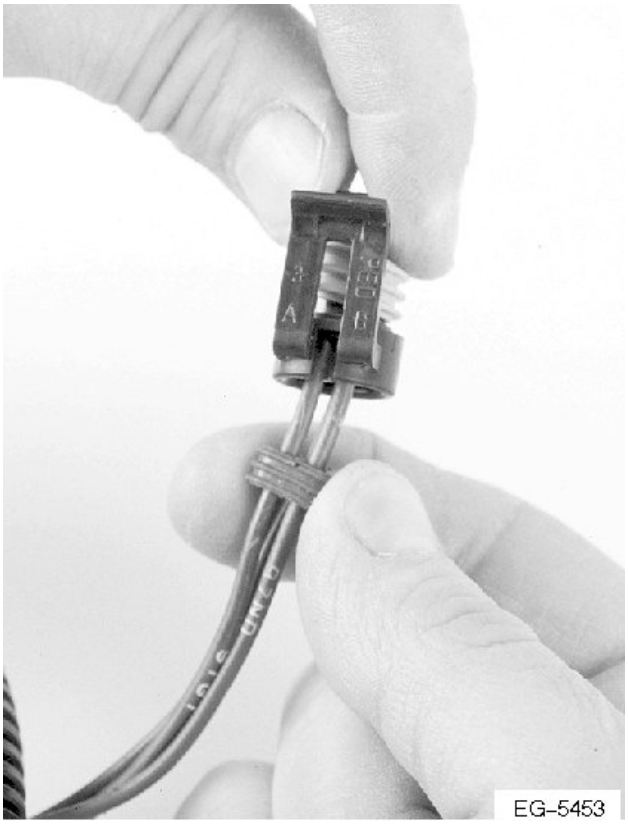


Figure 287 Reinstall Insulator

3. Make certain the connector insulator is in place prior to reinstalling the connector.

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GLOSSARY OF TECHNICAL TERMS

Actuator- A device which performs work in response to an input signal.

Analog - A continuously variable voltage.

Analog to Digital Converter (A/D) - A circuit within the processing section of the ECM that takes an analog signal (either DC or AC) and converts it into a usable digital signal for the microprocessor.

Analog Multimeter - A meter that uses a needle to point to a number on a scale of numbers to indicate a measured value (volts, ohms, amperes). Not recommended for use on microprocessor systems because of the possibility of excessive current due to the low impedance of the meter.

APS, Accelerator Position Sensor - A potentiometer style sensor that indicates the operator's throttle pedal position.

ATA Data Link - A serial data link specified by the American Trucking Association and the SAE.

Background Manager - The portion of the computer that performs "housekeeping duties." Typically the Background Manager controls low priority items or items that occur at a slower rate.

BAP, Barometric Absolute Pressure - A variable capacitance sensor which, when supplied with a 5 volt reference signal from the ECM, produces a linear analog voltage signal indicating atmospheric pressure.

BNO, Brake Normally Open - An on/off switch style sensor used to indicate if the brake is applied. Normal primary function is to disengage cruise control (normally open).

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

CLS, Coolant Level Switch - A switch style sensor used to indicate low coolant level.

CMP, Camshaft Position Sensor - A Hall effect sensor used to indicate engine speed and camshaft position. Speed is indicated by the number of vanes counted per revolution. Camshaft position is indicated by a single narrow vane which indicates #1 cylinder position.

Continuous Test - A function of the ECM in which the inputs and outputs of the ECM are continuously monitored to assure that the readings are within set limits.

DDS, Driveline Disengagement Switch - A switch indicating when the driveline is disengaged from the engine.

Disable - A type of computer decision which results in a system being deactivated and not allowed to operate.

Driver - A transistor in the output section of the ECM that is used to turn on or off various actuators in the system.

Drive Train Data Link J1939 - Drive Train Data Link J1939 is the primary communication link for ECM, ESC, and the instrument cluster.

DTC, Diagnostic Trouble Code - formerly referred to as Fault Code or Flash Code. The DTC is a 3 digit numeric code.

Duty Cycle Signal - A type of control signal that has a controlled on/off time measure from 0% to 100%. Normally used to control solenoids.

DMM, Digital Multimeter- An Electronic meter that uses a digital display to indicate a measured value. Preferred for use on microprocessor systems, because a DMM has a very high internal impedance and will not load down the circuit being measured.

ECI, Engine Crank Inhibit - An output on the ECM that controls the ECI relay and controls when the starter motor is allowed to operate and crank the engine over.

ECM, Electronic Control Module - The housing which contains the micro computer, V_{REF} regulator, input conditioners and output drivers.

ECM Power Relay - ECM controlled relay which supplies or removes power to the ECM.

ECT, Engine Coolant Temperature Sensor - A thermistor type sensor which indicates engine coolant temperature.

EFRC, Engine Family Rating Code - A code readable in the calibration list of the electronic service tool (EST) that identifies the horsepower and emission calibration of the engine.

ENGINE LIGHT- Light in the dash that comes on when selected fault codes are set. DTC can be read as flash codes through the red and amber dash lights.

Engine Off Tests - Tests that are performed with the ignition switch in the "ON" position with the engine off. See KOEO (Key ON Engine OFF)

Engine Running Tests - Tests that are performed with the engine running. See KOER (Key ON Engine RUNNING)

EOP, Engine Oil Pressure Sensor - A variable capacitance type sensor used to indicate low oil pressure.

EOT, Engine Oil Temperature Sensor- A thermistor type sensor which senses engine oil temperature.

ESC, Electronic System Controller-The ESC is an electronic module that provides multiple analog and switched input interfaces to monitor vehicle functions through solid state switches, relay driver outputs and serial data communication.

EST, Electronic Service Tool - A computer diagnostic and programming tool for the ECM. The hardware is typically a laptop or notebook computer. The diagnostic and programming software consists of the International Master Diagnostics program, ISIS on-line documentation, and NETS for factory programming.

Fault Detection / Management - An alternate control strategy devised to reduce the adverse effects that can be caused by a system failure. Should a sensor fail, the ECM substitutes a good sensor signal or assumed sensor value in its place. The amber light is then lit to alert the driver to take the vehicle in for service.

Foreground Manager - That portion of the computer that controls the primary engine control functions. The foreground manager responds to external events quickly to maintain correct engine performance under a variety of conditions. Typically the foreground manager controls high priority items.

Hall Effect Sensor - A Hall Effect sensor generates a digital on/off signal that indicates engine speed and timing.

HEUI - Hydraulically actuated Electronically controlled Unit Injector - The electronically controlled high pressure fuel injector used in INTERNATIONAL™ diesel engines. This injector uses high pressure oil acting on an amplifier piston to achieve fuel injection pressures of up to 21,000 psi.

High Speed Digital Inputs - Inputs to the ECM that are from a sensor that generates varying frequencies. Examples of high speed digital input sensors are engine speed and vehicle speed sensors.

IAT, Intake Air Temperature Sensor - A thermistor style sensor used to indicate intake air temperature.

ICP, Injector Control Pressure Sensor - A variable capacitance style sensor used to indicate Injection Control Pressure.

Impedance - A form of opposition to AC current flow measured in Ohms (Ω).

Injection Control Pressure - High lube oil pressure generated by a high pressure pump/pressure regulator used to hydraulically actuate the fuel injectors.

Input Conditioner - A device or circuit that conditions or prepares an input signal for use by the microprocessor.

IPR, Injection Control Pressure Regulator - An ECM controlled pulse width modulated regulator valve which regulates injection control oil pressure.

IVS, Idle Validation Switch - An on/off switch sensor that indicates when the accelerator pedal is in the idle position.

KOEO- Key ON Engine OFF

KOER- Key ON Engine RUNNING

Low Speed Digital Inputs - Are switched sensor inputs that generate an on/off (high/low) signal to the ECM. The input supplied to the ECM from the sensor could be from a high input source switch (usually 12 or 5 volts) or could be from a grounding type switch which grounds the signal from a current limiting resistor internal to the ECM and creating a low signal (0 volts).

MAP, Manifold Absolute Pressure - A MAP sensor is a variable capacitance sensor used to indicate low oil pressure.

Microprocessor- An integrated circuit within a microcomputer that controls information flow within that computer.

Normally Closed - Refers to a switch solenoid 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.

On Demand Test - A self test which the technician initiates, and is run from a program in the processor.

OCC, Output Circuit Check - An "On Demand" test performed during an "Engine Off" self test that tests the continuity of selected actuators.

Output State Check - An "On Demand" test selected by the technician which forces the processor to activate actuators "High or Low" for additional diagnostics.

PID - Parameter Identifier

Potentiometer - Is an electro-mechanical device (variable voltage divider) which senses the position of a mechanical component. Mechanical motion connected to the wiper causes it to move along the resistance material in a rotary fashion. The voltage on the wiper changes at each point along the resistive material and is proportional to the amount of mechanical movement. Potentiometers have three connections; V_{REF}, signal out (wiper), and ground.

PROM - Programmable Read Only Memory

PTO, Power Takeoff - Accessory output, usually from the transmission that is used to power a hydraulic pump for garbage packing, lift equipment, etc.

Pulse Width - The length of time an actuator, such as an injector remains energized.

RAM, Random Access Memory - A type of memory that is used to store information. Information can be written to and read from the RAM. Input information such as current engine speed or temperature would be stored here to be compared to values stored in the ROM. All memory in the RAM is lost when the ignition switch is turned off.

Read - A computer operation where information is retrieved from the memory.

RFI - Radio Frequency Interference

ROM, Read Only Memory - A type of memory that is used to store information permanently. Information cannot be written to the ROM memory. Operating strategies and calibration tables are the type of information most commonly stored in the ROM.

SCCS, Speed Control Command Switches - A set of switches used for cruise control, PTO and remote hand throttle system.

SID -Sub-System Identifier

SIG GRD, Signal Ground - The common ground wire to the ECM for the sensors.

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

Switch Sensors - Switch sensors are used to indicate position, levels or pressures. The signal of a switch sensor is a digital signal created by either the opening or closing a switch. The on or off signal can indicate position as in the case of a clutch switch, level as in the case of a coolant level switch, or pressure as in the case of a low oil pressure switch. A switch sensor normally has two connectors; signal return (grd), and the signal. A switch sensor is considered a low speed digital signal input.

TAC, Tachometer Output Signal - Engine speed signal used for remote tachometers.

Thermistor - Sensor used to determine temperature. A thermistor changes its resistance value in relation to temperature change. Increasing temperature results in decreasing resistance, decreasing temperature results in increasing resistance. The thermistor in conjunction with a current limiting resistor in the ECM forms a voltage divider that provides a voltage signal that indicates temperature. Since the top half of the voltage divider is the current limiting resistor and is internal to the ECM a thermistor sensor only has two connections; signal return, and ground.

Transition - Changing from one value or condition to another, such as from positive to negative in an electronic circuit.

TTS - Transmission Tailshaft Speed

VEPS, Vehicle Electronic System Programming System - The computer system used to program electronically controlled vehicles.

V_{IGN}, Voltage Ignition - Voltage supplied by the ignition switch when the key is in the "ON" position.

VRE, Vehicle Retarder Enable - Output from the ECM to a vehicle retarder.

V_{REF}, Reference Voltage - A five volt reference supplied by the ECM to operate the engine sensors.

V_{BAT} - Battery voltage

VSS, Vehicle Speed Sensor - Normally a magnetic pickup style sensor that is mounted in the tailshaft housing of the transmission to indicate ground speed.

WTEC- World Transmission, electronically controlled automatic transmissions (Allison).

MASTER DIAGNOSTICS PROGRAMMABLE PARAMETER DESCRIPTIONS

The following programmable parameters are grouped according to control system features. Please refer to other engine service manuals for additional details.

AUDIT (AUD) (ECM software): This group of parameters allows the factory and engine engineering to trace the origin and the date of programming changes throughout the life of the engine electronics.

- **AUD: Calibration Download Date**
- **AUD: Calibration Tool ID**
- **AUD: Last Service Tool ID I**
- **AUD: Last Service Tool ID 2**
- **AUD: Strategy Download Date**
- **AUD: Strategy Tool ID**

CRUISE CONTROL (CC): This group of parameters customizes the cruise control feature. The purpose of the cruise control feature is to provide electronic controlled vehicle speed regulation when the vehicle is under highway driving conditions. This feature also has the "bump up" and "bump down" functions. Wherein, the operator may "bump up" the vehicle speed in 1.0 mph increments when the Resume/Accel button is momentarily pressed. The operator may "bump down" the vehicle speed in 1.0 mph decrements when the Set/Cruise button is momentarily pressed.

- **CC: Cruise Control High VS Limit**
- **CC: Cruise Control Low RPM Limit**
- **CC: Cruise Control Low VS Limit**
- **CC: Cruise Control Mode**
- **CC: Cruise Control VS Ramp Rate**

COLD AMBIENT PROTECTION MODE: This parameter customizes the cold ambient protection feature. Cold ambient protection (CAP) allows the engine to idle at an elevated RPM when the coolant temperature falls below a certain point and the ambient temperature is cold. This allows the engine to warm up to the normal operating temperature.

COOLANT SURGE TANK TYPE: This parameter describes the type of coolant tank installed in the vehicle.

COOLANT TEMPERATURE COMPENSATION: This group of parameters customizes the coolant temperature compensation. The purpose of Coolant Temperature Compensation is to reduce the amount of fuel delivered to the engine when the engine is running near its maximum torque fuel delivery and coolant temperature is above a programmed value. This fuel reduction has two effects: First, the heat generated by the engine is reduced thereby reducing the burden on the engine cooling system. Second, the vehicle speed will decrease. In order to maintain the vehicle speed the operator is encouraged to downshift, which will result in increased efficiency of the engine cooling system.

- **CTC: Begin Derate Temperature**
- **CTC: Coolant Temp Compensation Mode**
- **CTC: Derate Factor**
- **CTC: Modify Derate Temperature**

ENGINE CRANK INHIBIT (ECI): This group of parameters customizes the crank inhibit feature. The purpose of ECI is to prevent the operator from cranking the engine while the engine is running or the driveline is engaged. A programmable time (1-5 seconds) allows the on-board electronics to inhibit cranking for a short duration until engine speed reaches idle speed.

- **ECI: Engine Crank Inhibit Mode**
- **ECI: Engine Crank Inhibit Run Mode Time**

ENGINE FAN CONTROL (EFC): This group of parameters customizes the engine fan control feature. The purpose of EFC is to provide the proper logic to determine when the fan should be turned on or off by energizing/de-energizing the fan drive solenoid. The purpose of the engine fan is to allow more air flow for heat exchange between the radiator and the ambient air when needed.

- **EFC: Air Conditioner**
- **EFC: Engine Fan Mode**
- **EFC: Fan Off Temperature**
- **EFC: Fan On Temperature**

ENGINE FAN CONTROL (EFC) FOR RADIATOR SHUTTER: The purpose of Radiator Shutter Enable is to provide the proper logic to open or close the radiator shutters (energize or de-energize a solenoid). The purpose of this device is to keep the engine warm during cold weather operation. This will enable faster warm up of the passenger cab thereby enabling faster defrost of the windshield. Fuel economy will also be improved when the radiator shutters are closed.

- **EFC: Radiator Shutter Mode**
- **EFC: Shutter Close Temperature**
- **EFC: Shutter Open Temperature**

ENGINE FAMILY RATING CODE: This group of parameters allows the on-board electronics to precisely control the fueling requirements based on the particular engine configuration. The on-board electronics has what is known as the Multiple Engine Rating Map. This allows a single on-board electronic controller to provide different engine configurations. Optimal control is provided for vehicles with various engine configuration and ratings: engine model, rated engine speed, rated engine power, and transmission type.

- **EFRC: Engine Family Extension**
- **EFRC: Engine Family Rating Code**

EVENT LOGGER (EL): This group of parameters indicates the electronic automatic engine event logging feature. The purpose of this feature is to record the accumulated engine hours and odometer readings when certain excessive engine operating conditions have occurred.

- **EL: Low Coolant Hour I**
- **EL: Low Coolant Hour 2**
- **EL: Low Coolant Odometer I**
- **EL: Low Coolant Odometer 2**
- **EL: Low Oil Pressure Hour I**
- **EL: Low Oil Pressure Hour 2**

- **EL: Low Oil Pressure Odometer I**
- **EL: Low Oil Pressure Odometer 2**
- **EL: Overheat Hour I**
- **EL: Overheat Hour 2**
- **EL: Overheat Odometer I**
- **EL: Overheat Odometer 2**
- **EL: RPM Overspeed Hour I**
- **EL: RPM Overspeed Hour 2**
- **EL: RPM Overspeed Odometer I**
- **EL: RPM Overspeed Odometer 2**

ECM MANUFACTURING DATA: This group of parameters provides the manufacturing data feature. The date and the serial number of the on-board electronics are indicated, along with the level of hardware and software.

- **EMD: S/W Strategy Checksum**
- **EMD: ECM H/W Version**
- **EMD: ECM Manufacturing Date**
- **EMD: ECM S/W Calibration Version**
- **EMD: ECM S/W Strategy Version**
- **EMD: ECM Serial Number**
- **EMD: PP List Checksum**
- **EMD: PP List Level**
- **EMD: S/W Calibration Checksum**

ENGINE SERIAL NUMBER (ESN): This parameter is the factory programmed engine serial number.

ENGINE WARNING AND PROTECTION SYSTEM (EWPS): This group of parameters customizes the engine warning and protection feature. The Engine Warning and Protection System safeguards the engine from undesirable operating conditions in order to prevent engine damage and to prolong engine life. When a warning condition is detected, the on-board electronics will light up the OIL / WATER lamp and the warning buzzer is activated. When a critical condition is detected, the on-board electronics will shut down the engine if the engine warning and protection system has the protection feature enabled. After an engine shut down, the operator may restart the engine for a thirty second run time if desired. The event-logging feature will also record when an excessive (i.e., critical) engine event has occurred in both engine hours and odometer readings. Currently there are four states of electronic operation: STANDARD, 3-WAY WARNING, 3-WAY PROTECTION, and 2- WAY WARNING.

- **EWPS: ECT Critical Temperature**
- **EWPS: ECT Warning Temperature**
- **EWPS: EOP Critical Level I**
- **EWPS: EOP Critical Level 2**
- **EWPS: EOP Critical Level 3**

- **EWPS: EOP RPM Boundary I**
- **EWPS: EOP RPM Boundary 2**
- **EWPS: EOP RPM Boundary 3**
- **EWPS: EOP Warning Level I**
- **EWPS: EOP Warning Level 2**
- **EWPS: EOP Warning Level 3**

ELECTRO-HYDRAULIC PRESSURE GOVERNOR (EPG): This group of parameters customizes the hydraulic pressure governor feature. The purpose of the Electro-Hydraulic Pressure Governor is to provide closed loop control over an external pressure input. This feature is targeted for fluid delivery pumps, especially fire truck applications. The EPG feature also provides a loss of pressure detection. This is achieved by monitoring the hydraulic pressure, the engine speed, and the status of the EPG select switch. Once the loss of pressure is detected the EPG feature is disabled and a corresponding DTC is set.

- **EPG: Driveline Mode**
- **EPG: Hydraulic Pressure Governor Mode**
- **EPG: Hydraulic Pressure Governor Mode**
- **EPG: Integral Gain Adjust**
- **EPG: Mode Indicator**
- **EPG: Proportional Gain Adjust**
- **EPG: Cavitation Operation Time**

ENGINE IDLE SHUTDOWN CONTROL (IST): This group of parameters customizes the prolonged engine idle automatic shutdown feature. The purpose of this feature is to shut the engine down after a programmable idle time has been exceeded. This allows the reduction of fuel usage, engine wear, and emissions. Thirty (30.0) seconds before an automatic engine shutdown, the operator will be warned via the red Oil/Water Lamp. This lamp will begin flashing until the engine is shutdown. The operator may override the electronics at any time. After an engine shutdown occurs, the Oil/Water Lamp will stop flashing and a diagnostic code will be recorded. The diagnostic code is recorded to assist in diagnosing possible service complaints of the engine shutting down. Currently there are four states of electronic operation: OFF, PTO AVAILABLE, NO ENGINE LOAD, and TAMPER PROOF.

- **IST: Idle Shutdown Time**
- **IST: Idle Shutdown Timer Mode**
- **IST: Max IAT for Idle Shutdown**
- **IST: Min IAT for Idle Shutdown**

IVPWR: Expected Vbat – Expected operating battery voltage on the vehicle.

POWER TAKE OFF SPEED CONTROL (PTO): This group of parameters customizes the power take off speed control feature. Power Take Off (PTO) Speed Control provides a method for the operator to set and maintain a regulated engine speed, without using the accelerator pedal, for the purpose of operating auxiliary equipment. The power take off feature has an in-cab and a remote operator interfaces. Depending on configuration, the operator may turn on and activate PTO speed control while in the comfort of the cab or at the convenience of a remote interface. If both in-cab and remote operations are enabled, the on-board electronics senses which interface is active depending on operator actions. No active mobile PTO operation is possible when the PTO

speed control is turned on using the remote interface. This feature also has the "bump up" and "bump down" functions. Wherein, the operator may "bump up" the RPM in 25 RPM increments when the Resume/Accel button is momentarily pressed or “bump down” when the set/coast button is momentarily pressed.

- **PTO: In-Cab Control**
- **PTO: In-Cab Mode**
- **PTO: Max RPM**
- **PTO: Max VS**
- **PTO: Power Take Off Mode**
- **PTO: Preset RPM I (Set)**
- **PTO: Preset RPM 2 (Resume)**
- **PTO: Remote Pedal**
- **PTO: RPM Ramp Rate**

TWO SPEED AXLE: This group of parameters is used by the ECM to determine vehicle speed calculations.

- **Two speed axle**
- **Pulses Per Mile I**
- **Pulses Per Mile 2**
- **Rear Axle Ratio I**
- **Rear Axle Ratio 2**
- **Tire Revolutions**
- **Transmission Gear Teeth**
- **Transmission Top Gear Ratio**

ROAD SPEED LIMITING (RSL): This group of parameters customizes the road speed-limiting feature. Road Speed Limiting is used by the ECM for maximum road speed governing. If the vehicle’s maximum road speed exceeds the programmed maximum vehicle speed limit, the ECM will reduce or cut-off fueling. This feature is primarily for improving fuel economy.

- **RSL: Maximum Vehicle Speed**
- **RSL: Road Speed Limiting Mode**
- **RSL: RFM Limit with VSS Fault**

SHIFT SCHEDULE: This parameter determines how and when the ECM will request the electronic transmission controller for up-shifts and downshifts.

SERVICE INTERVAL (SI): This group of parameters customizes the Service Interval feature. Service Interval allows the truck owner to customize when a truck requires servicing, such as changing the oil. When the programmed distance or engine hour has been reached the Change Oil Lamp will be lit to indicate its time for maintenance and service.

- **SI: Change Oil Lamp On Mode**

- **SI: Change Oil Lamp On Time**
- **SI: Distance Interval**
- **SI: Fuel Interval**
- **SI: Hour Interval**
- **SI: Service Interval Mode**
- **SI: Service Interval Reset**
- **SI: Service Soon Percent**
- **SI: Starting Fuel Reading**
- **SI: Starting Hour Reading**
- **SI: Starting Odometer Reading**

TRACTION CONTROL (TC): This parameter determines how and when the ECM will activate its electronic traction control.

- **TC: Traction Control Mode**

TORQUE LEVEL TAILORING (TLT): This group of parameters customizes the torque level-tailoring feature. The torque level-tailoring feature allows the on-board electronics to control the engine based on the possible driving situation. A typical application for this feature is a vehicle with an on-highway and an off-highway torque curves.

- **TLT: Lower N/VS Ratio**
- **TLT: Torque Level Tailoring Mode**
- **TLT: Upper N/VS Ratio**

TOTAL MILES: This group of parameters indicates the vehicle accumulator data. The purpose of the Accumulators feature is to record the total engine hours, the total fuel used, and the total vehicle miles. This system requirement is intended to track engine operation for scheduled preventive maintenance and as an aid to warranty administration.

- **Total Engine On Time**
- **Total Fuel Used**

TOTAL TATTLETALE: This is an internal ECM programming tracking mechanism.

VEHICLE RETARDER MODE: This parameter indicates the vehicle retarder type and its mode of operation.

VEHICLE SPEED SIGNAL SELECTION: This parameter customizes the vehicle speed signal feature.

VEHICLE IDENTIFICATION NUMBER (VIN): This parameter is the factory programmed vehicle identification number.

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