

# ***ProDiesel***<sup>®</sup>

## **Unit Fuel Injectors Technician's Guide**



## **ATTENTION**

This document is a reference tool for qualified personnel. It explains the operation of the fuel system. ProDiesel makes no representations or warranties regarding the information contained in this document. The information contained in this document may not be complete and is subject to change without notice.

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## INTRODUCTION

This technician's guide explains the fuel injection system operation and is mainly focused on the electronic unit injector.

The heart of the diesel engine is the fuel injection system. It has the vital function of communicating with the Electronic Control Module (ECM) and pumping a measured quantity of fuel into each cylinder at precisely the right moment. The unit injector does all this with simple design and few parts. The benefits are low unit cost and minimal maintenance cost. The advantage of the 30,000 psi fuel injection pressure capability is high velocity injection which translates into excellent penetration and atomization. As a result of the ability to control injection spray, exhaust emissions and fuel consumption parameters are optimized. These features help make the most efficient use of each ounce of fuel, minimizing smoke, NOx, and HC emissions.

## DIESEL FUEL SYSTEM OVERVIEW

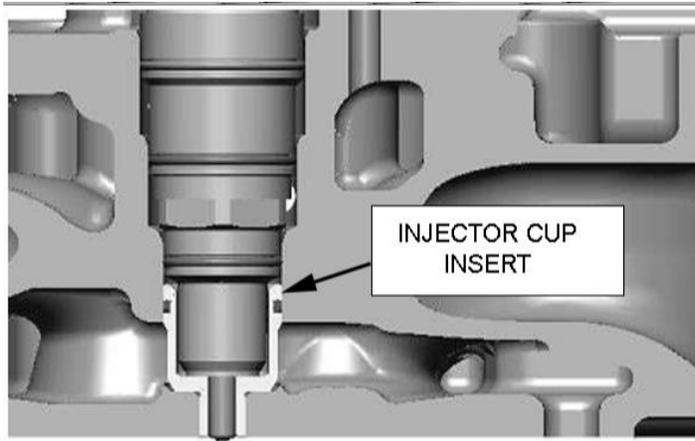
The function of the fuel system is to store and supply fuel to the combustion chamber. The major parts of the diesel fuel system are the fuel tank, fuel filters, fuel pump, electronic control module, injection nozzles or injectors, and fuel lines. The fuel pump draws filtered fuel from the tank through low-pressure fuel lines leading to the water separator (not all diesel engines have a water separator). In most diesel engines, the fuel passes through a primary fuel filter before reaching the pump. The pump circulates an excess supply of fuel through the injectors, which purges air from the fuel system and also cools and lubricates the injectors. The unused portion of fuel returns to the fuel tank by means of the fuel return line. The primary filter captures large contaminants from the fuel and acts as a water separator. Water is heavier than diesel fuel and falls to the bottom of the primary filter, where in most applications it can be drained. After passing through the pump, the fuel goes through a secondary filter before reaching the fuel injectors to keep them clean and prevent them from damage. The fuel flows to the fuel injectors where it is injected into the cylinders. The primary job of the entire fuel system is to inject a controlled amount of atomized fuel into each engine cylinder at the precise time. Excess fuel exits at the rear of the cylinder head just above the inlet, through a restrictive return fitting that maintains fuel pressure in the system. It then returns back to the tank.

The electronic unit injector injects fuel directly into the combustion chamber. The injector performs these three functions:

1. Creates the high fuel pressure required for efficient injection.
2. Meters and injects the exact amount of fuel required to handle the power requirement.
3. Atomizes the fuel for mixing with the air in the combustion chamber.

## ELECTRONIC UNIT INJECTOR (EUI)

The Electronic Unit Injector (EUI) injects fuel directly into the combustion chamber. The small size of the injector along with the trapezoidal valve placement in the cylinder head allows the EUI to be placed in the center of the combustion chamber for optimal fuel efficiency and low emissions. The EUI is placed in an injector cup insert, and O-rings are used to seal between the injector and the cylinder head as well as the injector cup insert and the cylinder head.



### **Injector Cup Insert**

The injector operates off the camshaft and ECM commands. As the piston travels about two-thirds of the way up on the compression stroke, the injector cam lobe begins to lift the injector rocker arm, in turn pushing the other side of the arm down on top of the injector. To start the fuel injection process, the ECM sends a signal to close the poppet valve, stopping the flow of fuel through the injector body and trapping fuel in the passages leading to the injector tip. As the injector arm continues the downward stroke, the trapped fuel in the injector passages comes under extremely high pressure.

The ECM controls how much fuel is injected. Injection begins soon after the poppet valve closes and the trapped fuel pressure rises to approximately 28,000 psi. The ECM, monitoring engine parameters, determines how long the valve will stay closed on the pressurized fuel and therefore how much fuel will be injected into the combustion chamber. The high-pressure fuel overcomes spring-loaded valves in the injector tip. The fine spray of atomized fuel is broken up into droplets smaller than 20 microns and mixes with the incoming charged air for combustion. When the ECM opens the poppet control valve, the trapped fuel is released, fuel pressure drops, and injection ends. This results in even fuel distribution that helps reduce black smoke, NO<sub>x</sub>, and particulate matter in exhaust gasses.

The fuel injection event is measured with injector response time (IRT), and pulse width (PW). IRT is the length of time in milliseconds (ms) from when the stator valve opens to the time the poppet control valve closes. PW is the duration of time the injectors are fueling the engine, measured in degrees of rotation of the crankshaft, which is determined by the ECU.

Once the injection event has ended and the rocker arm begins its upward travel, trapped fuel is released and begins to re-circulate through the system. By providing this constant recirculation of fuel, much of the heat is transferred from the injectors, they are cooled and the heat is returned to the fuel tank. Fuel also lubricates the precision-machined parts within the injector. (Dirty fuel will not lubricate.) Fuel not injected by the injector is returned to the fuel tank.

## SAFETY

The service procedures recommended and described in this technician's guide are effective methods of performing service and repairs. Some of these procedures require the use of tools specially designed for this purpose.

Accordingly, anyone who intends to use a replacement part, service procedure or tool which is not recommended by original equipment manufacturer must first determine that neither their safety nor the safe operation of the engine will be jeopardized by the replacement part, service procedure or tool selected.

This technician's guide contains various work procedures that must be carefully observed in order to reduce the risk of personal injury during service or repair or the possibility that improper service or repair may damage the engine or render it unsafe. It is also important to understand that these work procedures are not exhaustive, because it is impossible to warn of all the possible hazardous consequences that might result from failure to follow these instructions.

A service technician can be severely injured if caught in the pulleys, belts or rotating parts of an engine that is accidentally started. To avoid personal injury, observe the original equipment manufacturer's precautions and procedures before starting to work on the engine, no matter what task is being performed.

Disconnect the battery from the starting system by removing one or both of the battery cables (disconnect negative [ground] cable first). With the electrical circuit disrupted, accidental contact with the starter button will not produce an engine start.

It is important that when inspecting, testing, adjusting, repairing, and/or pulling maintenance on engines or equipment that fluid spills are avoided. Preparations should be made before hand having containers and procedures in place to prevent or contain such spills. Take care in meeting local requirements for disposing of waste fluids.

## FUEL

Diesel engines are designed to operate satisfactorily on a wide range of diesel fuels. Refer to the original equipment manufacturer's recommendations.

### AIR IN FUEL

Air trapped in diesel fuel systems is one of the main reasons for a hard-starting engine. Air can enter the fuel system at loose joints in the piping, leakage in seals, or through a spray nozzle that does not close properly. Letting the vehicle run out of fuel will also cause air to enter the system. Like water, air can interfere with the proper flow of fuel from the tank to the cylinder. A large amount of air in a system will prevent fuel pumps from picking up fuel and pushing it through the system. Bleeding the system can remove air. Consult the current original equipment manufacturer's service manual for the proper procedure.

### FUEL FILTRATION

**The most common cause of fuel system problems is failure to follow the manufacturer's recommended fuel filter change intervals. Preventing dirt and water from entering a precision fuel injection system is very important in obtaining the maximum life and performance of any diesel engine. If contaminants build up in the filter, it can significantly affect engine performance. The fuel delivery rate is reduced, making less fuel available for combustion. The fuel pump is forced to work harder to make the same volume of fuel. This subjects internal seals to abnormal conditions, which may lead to seal leakage. In extreme cases, air can be drawn in the system. Filters make up an integral part of the fuel system. Proper filter selection and maintenance are important to satisfactory engine operation and service life. Filters, however, should be used to maintain a clean system, not to clean up a contaminated system. Again refer to the original equipment manufacturer's recommendations.**

Filter performance and test specifications vary between manufacturers. The user is also cautioned when comparing micron ratings between filter makes. It is important to note that capacity and efficiency (micron) ratings should not be the only criteria on which to judge filter performance. Many other important factors, including media strength, resistance to impulse failures and burst strength, often differ greatly between filter makers and should enter into the filter selection process.

Finer filtration will generally provide increased engine service life, but many require shorter filter change intervals.

Primary and Secondary fuel filters are essential to removing foreign matter from the fuel, before it enters the injectors. The first is usually a strainer that removes larger particles and the second is a filter, which removes micro-particles. Primary filters are on the suction side of the fuel pump and can allow air into the systems if not installed correctly. Secondary filters are pressurized and leaks will appear if seals or gaskets are damaged or improperly installed.

## FUEL STABILITY

Diesel fuel oxidizes in the presence of air, heat, and water. The oxidation of fuel can result in the formation of undesirable gums and black sediment. Such undesirable products can cause filter plugging, combustion chamber deposit formation, and gumming or lacquering of injection system components, with resultant reduced engine performance and fuel economy. Good quality fuel is a requirement.

## FUEL TEMPERATURE

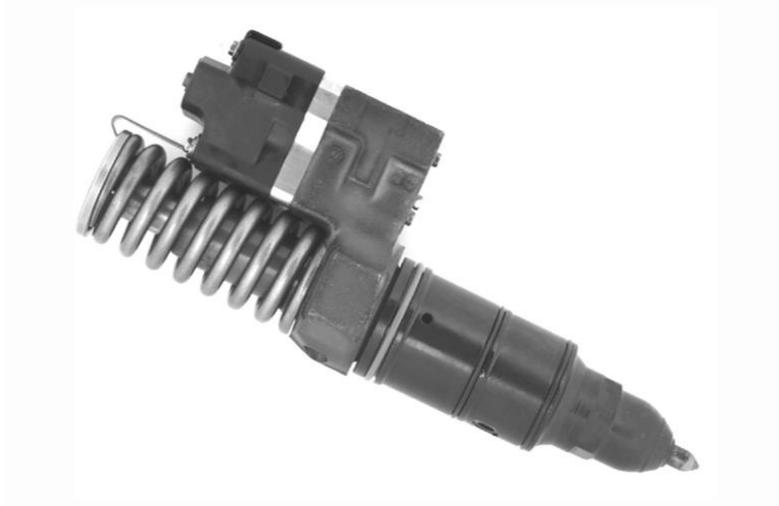
**Diesel fuel provides cooling of the injection system. However, the temperature of the fuel may vary considerably due to engine operating temperature. As fuel temperature increases, fuel viscosity decreases, along with the lubrication capabilities of the fuel. When the system is operated with elevated fuel temperatures, the injectors will operate at reduced internal clearances. As a result, dirt and smaller particulate material may cause injection durability concerns. Installing a fuel cooler or operating with fuel tanks above half full may also help eliminate concern. Maintaining proper fuel temperatures will help provide proper fuel injection system functioning.**

## FUEL WATER CONTAMINATION

The prevention of water in the fuel system is essential to optimize engine performance. Unit injector, pump, and nozzle failure can result from water entering the fuel system.

Some fuel additives provide temporary benefit when the fuel is contaminated with water. They are not intended to replace good fuel handling practices. Where water contamination is a concern, the fuel system should be equipped with a fuel/water separator that should be serviced regularly. In environments where microbe growth is a problem, a fungicide may be used. Follow the original equipment manufacturer's instructions for treatment. Avoid the use of fungicides containing chlorine, bromine, or fluorine compounds, since these may cause fuel system corrosion. When small amounts of water are present, supplemental additives containing methyl carbitol or butyl cellusolve are effective. The use of isopropyl alcohol is no longer recommended due to its negative effect on fuel lubricity. Refer to the original equipment manufacturer's recommendations.

NORMAL INJECTORS



Detroit Series 60 Electronic



Caterpillar 3406E



Cummins Celect

## INJECTOR FAILURE MODES

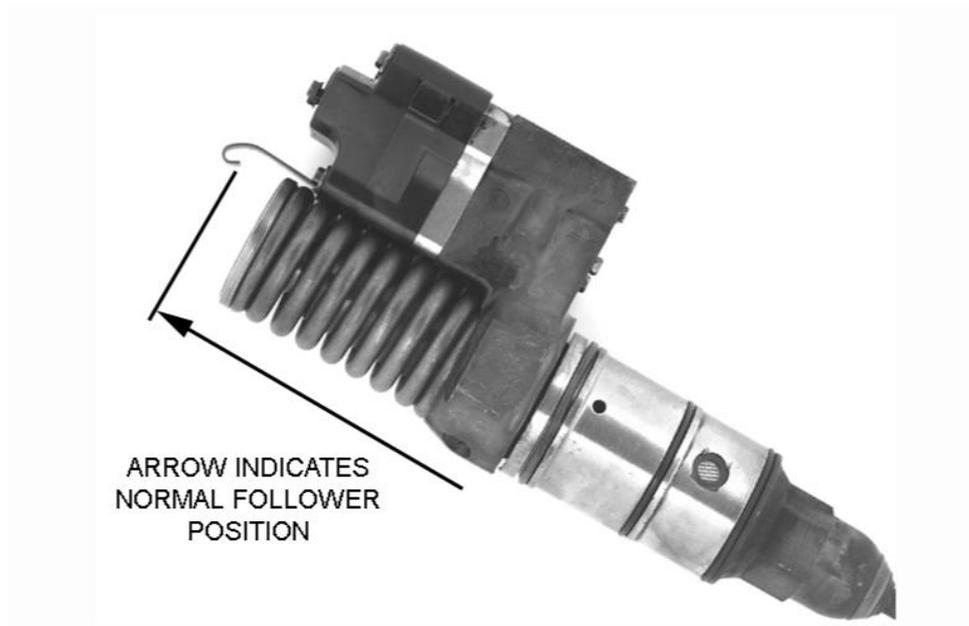
The list below identifies some of the problem issues associated with injector failures. On the pages that follow this list are photographs representing these examples.

The failures explained in this section are:

- Seized unit injector.
- Broken injector follower spring and damaged stator with broken stator screws .
- Loose stop plate screw.
- Missing stop plate screw.
- Cracked injector body.
- Broken solenoid terminal screws.
- Failed/blown spray tip.
- Low pressure plug leak.
- High pressure plug leak.
- Trim code issues.
- Misc. examples.
- Black or gray smoke condition.
- White smoke condition.

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## SEIZED INJECTOR



Seized Injector Failure Series 60 Detroit



Seized Injector Failure CAT 3406E Comparison

**PROBLEM:** Noisy, rough running, misfiring.

**REASON:** Seized plunger, plunger/body not matching.

*Note: This failure within 1,000 miles would indicate fuel contamination.*

**SOLUTION:** Replace injector

**SUGGESTION:** Check for water in fuel. Check fuel temperature.

# BROKEN INJECTOR FOLLOWER SPRING



Broken Spring Series 60 Detroit



Broken Spring Cummins Celect



Broken Spring CAT 3406E

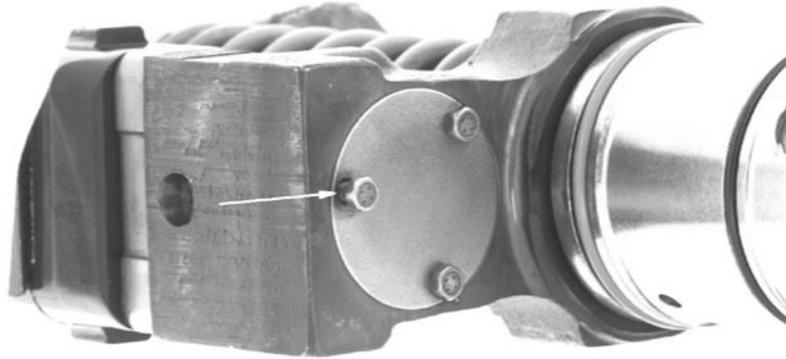
**PROBLEM:** Oil in fuel. Tapping or slapping noise.

**REASON:** Injector follower spring failure.

**SOLUTION:** Replace injector.

**SUGGESTION:** Check the springs in all of engine's injectors.

## LOOSE STOP PLATE SCREW



### Loose Stop Plate Screw Failure

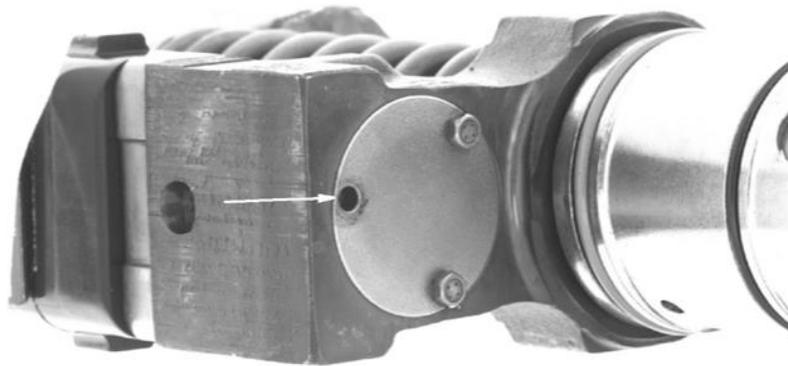
**PROBLEM:** Fuel in Oil.

**REASON:** Stop plate screw backed out. Damaged O-ring under torqued screw.

**SOLUTION:** Replace injector.

**SUGGESTION:** Check all stop plate screws in remaining injectors.

## MISSING STOP PLATE SCREW



### Missing Stop Plate Screw Failure

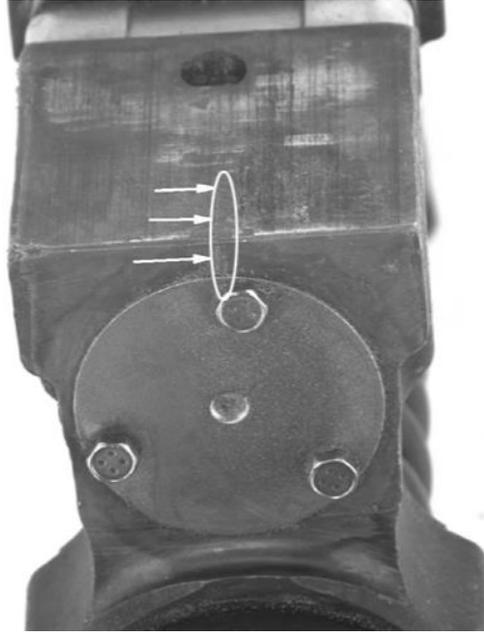
**PROBLEM:** Fuel in oil.

**REASON:** Missing stop plate screw. Damaged O-ring under torqued screw.

**SOLUTION:** Replace injector.

**SUGGESTION:** Check all stop plate screws in remaining injectors.

## CRACKED INJECTOR BODY FAILURE



Cracked Injector Body Failure

**PROBLEM:** Fuel in oil.

**REASON:** Excessive pressure. Fatigue.

**SOLUTION:** Replace Injector.

**SUGGESTION:** Check all remaining injectors for cracks.

*Cracks in the injector body, as in the above picture, are often hard to discover while on the engine. Remove the injector(s) and spray with a cleaner agent before inspecting.*

## BROKEN SOLENOID TERMINAL SCREW FAILURE



Broken Solenoid Terminal Screw Failure

**PROBLEM:** Rough running. Misfiring.

**REASON:** Over torquing screw during installation.

**SOLUTION:** Replace injector.

**SUGGESTION:** Do not bend terminals down after installation. Torque terminal screws to OEM specifications. (1.07 - 1.13 N·m (9.5 - 10.0 lb·in.)).

## FAILED OR BLOWN SPRAY TIP FAILURE



Failed or Blown Spray Tip Failure

**PROBLEM:** Rough running. Misfiring. Low horsepower. Black smoke.

**REASON:** Unit damaged before or during installation. Fatigue. Water contamination. Dropped intake or exhaust valve.

**SOLUTION:** Replace injector.

**SUGGESTION:** Check all remaining injectors for damage especially if there was water contamination.

## LOW PRESSURE PLUG LEAK



Low Pressure Plug Leak

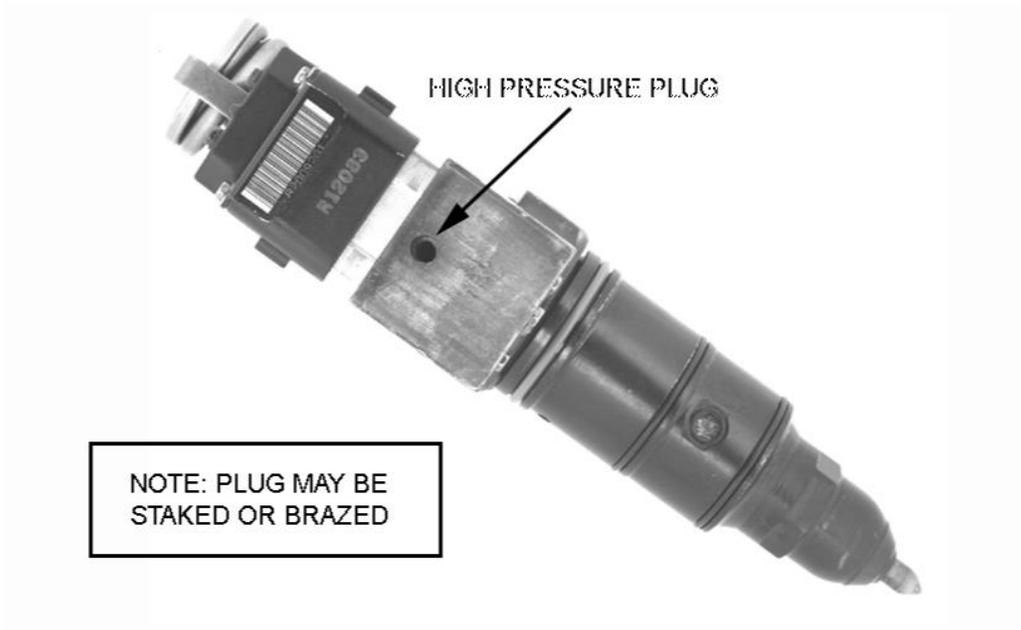
**PROBLEM:** Fuel in oil.

**REASON:** Fatigue. Low pressure plug leak.

**SOLUTION:** Replace Injector.

**SUGGESTION:** Check remaining injectors for leaks and/or for correct pressure.

## HIGH PRESSURE PLUG LEAK



### High Pressure Plug Leak

**COMPLAINT:** Fuel in oil.

**CAUSE:** Bad braze. Fatigue.

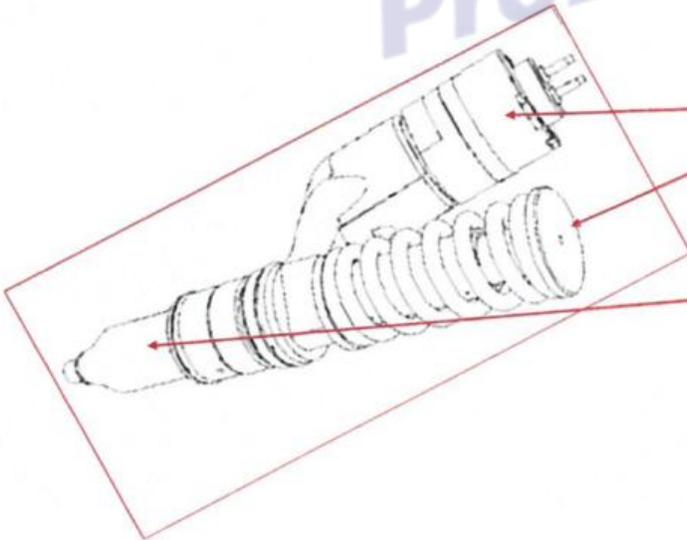
**CORRECTION:** Replace Injector.

**RECOMMENDATION:** Check remaining injectors for leaks and/or for correct pressure.

# TRIM CODE LOCATIONS



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**Serial Number**  
Either Location  
**Trim-Auth (Code)**

**Part Number**  
**Date code**

## DETROIT FAULT CODES

Below are common flash codes related to the unit injector and fuel system:

### FLASH CODE 37- FUEL PRESSURE SENSOR/FUEL RESTRICTION SENSOR VOLTAGE HIGH

Flash Code 37 indicates that the engine Fuel Pressure Sensor, or Fuel Restriction Sensor input to the ECM has exceeded 95% (normally > 4.75 volts) of the sensor supply voltage. The SAE J1587 equivalent code for Flash Code 37 is PID 94-FMI 3, Fuel Pressure Sensor, and PID 95-FMI 3, Fuel Restriction Sensor.

This diagnostic condition is typically:

- Open sensor return circuit.
- Sensor signal circuit is shorted to the sensor +5 volt supply.

### FLASH CODE 38- FUEL PRESSURE SENSOR/FUEL RESTRICTION SENSOR VOLTAGE LOW

Flash Code 38 indicates that the Engine Fuel Pressure Sensor, and/or, Fuel Restriction Sensor input to the ECM has dropped below 5% (normally < 0.25 volts) of the sensor supply voltage. The SAE J1587 equivalent code for Flash Code 38 is PID 94-FMI 4, Fuel Pressure Sensor, and PID 95-FMI 4, Fuel Restriction Sensor.

This diagnostic condition is typically:

- Open sensor signal circuit.
- Open sensor +5 volt supply circuit.
- Sensor signal is shorted to sensor return circuit or to ground.
- Sensor +5 volt supply is shorted to the sensor return circuit.

### FLASH CODE 47- AIR/FUEL PRESSURE HIGH

Flash Code 47 indicates that the ECM has detected that the turbo boost pressure has exceeded a programmed operating range. This normally occurs due to a mechanical fault in the air system or fuel system of the engine. The SAE J1587 equivalent code for Flash Code 47 is PID 94-FMI 0, fuel pressure high, PID102-FMI 0, turbo boost pressure high, PID 106-FMI 0, air inlet pressure high, and PID 1 64-FMI 0, injection control pressure high. This code indicates a mechanical fault. Check for reasons for high turbo boost pressure, e.g. Variable Nozzle Turbocharger (VNT) stuck. Refer to the original equipment manual for complete testing procedures.

### FLASH CODE 48- AIR/FUEL PRESSURE LOW

Flash Code 48 indicates that the ECM has detected that the fuel pressure has dropped below a programmed limit. This condition is normally associated with a restriction in the fuel supply system. The SAE J1587 equivalent code for Flash Code 48 is PID 094-FMI 1, fuel pressure low, PID 1 06-FMI 1, air inlet pressure low, and PID 1 64-FMI 1, injection control pressure low. Refer to the original equipment manual for complete testing procedures.

This diagnostic condition is typically:

- Plugged fuel filter
- Low fuel supply

## FLASH CODE 61 - INJECTOR RESPONSE TIME LONG

Flash Code 61 indicates that the time it takes from when the DDEC ECM requests an injector to be turned on to when the injector solenoid valve actually closes is longer than the high limit of the expected range. Engine oil temperature must be greater than 87F (30C). The SAE J1587 equivalent code for Flash Code 61 is SID 001/0, or SID 002/0, or SID 003/0, or SID 004/0, or SID 005/0, or SID 006/0.

This diagnostic condition is typically:

- Bad injector harness and or connection (high resistance)
- Poor vehicle grounds
- Sticky solenoid valve
- Injector failure
- Bad stator

### NOTE:

*The injector diagnostic SID (Subsystem Identifier) indicates which cylinder number has an injector with a long response time. The injector number describes the cylinder and or bank, which has the injector with a long response time.*

Injector response times generally increase with low battery supply voltage and decrease with high battery supply voltage. Although injector response times vary from injector to injector at a given rpm, each individual injector response time should remain relatively consistent from one firing to the next. Wide variations in response time (typically  $\pm 0.2$  msec) for one injector at a steady engine rpm may indicate an electrical problem (faulty alternator or voltage regulator, poor or broken ground cables, etc.).

## FLASH CODE 71 - INJECTOR RESPONSE TIME SHORT

Flash Code 71 indicates that the time it takes from when the DDEC ECU requests an injector be turned on, to when the injector valve actually closes, is shorter than the lower limit of the expected range. The SAE J1587 equivalent code for Flash Code 71 is SID 00 1/1, or SID 002/1, or SID 003/1, or SID 004/1, or SID 005/1, or SID 006/1.

This diagnostic condition is typically:

- Aerated fuel system.
- High system battery (+) supply voltage.
- Injector failure.
- Failed solenoid.

## FLASH CODE 77 - ISOLATED FUEL

Flash Code 77 is used for several DDEC information codes. The fuel related code descriptions are listed below:

- PID 95-FMI 1 is a fuel filter differential pressure below range. Fuel filter differential pressure sensor signal fell below calibrated limit. Not likely to show up on any DDEC IV on-highway engines.
- PID 1 74-FMI 0 is a fuel temperature above range. Indicates fuel temperature exceeded DDC limits for that particular engine. No DDEC troubleshooting is suggested. High fuel temperature should be reviewed with the OEM to determine if any additional fuel coolers need to be considered.
- PID 1 74-FMI 1 is a fuel temperature below range. Indicates the fuel temperature fell below a calibrated range. No troubleshooting is suggested.

## SERIES 50/60 CODE INFORMATION

Injector calibration and bar codes may be absent from the load plates on first-run production N2 (DDEC III/IV) injectors 5235575, 5235580, and 5235550. The correct calibration code for these units is "01". Load plates on current N2 (DDEC III/IV) injectors include the required calibration or bar code information.

Record the injector calibration code of each injector noting the cylinder number.

To find the injector calibration code location:

1. Turn vehicle ignition to the on position, but do not run engine.
2. Install Diagnostic Data Line (DDL) adaptor to the data cable and plug the adaptor into the DDL connector in the vehicle; refer to OEM guidelines.
3. From the Diagnostic Data Reader (DDR) DDEC III/IV Select Menu, scroll to select ENGINE and press the ENTER key.
4. Scroll to select FUEL INJECTOR INFO and press the ENTER key.
5. Scroll to select FUEL INJECTOR CAL and press the ENTER key.
6. Scroll to select FUEL INJECTOR VIEW and press the ENTER key.
7. Compare the calibration code(s) shown on the display with the two digit calibration code(s) on the injector(s).
  - a) If the calibration code on the display is different than the calibration code on the suspect injector for that cylinder, the injector setting must be repaired. If test codes match, look for improper valve clearance or injector height, and worn or damaged camshaft lobes and rollers. Refer to the original equipment manual for complete testing procedures.

### Improper Injector Setting Repair:

Perform the following steps to recalibrate improper injector setting:

1. Scroll to select FUNCTION to return to the FUEL INJECTOR CAL menu on the DDR.
2. Scroll to select FUEL INJECTOR CAL. Select UPDATE and press the ENTER key.
3. Type the four-digit "Update Injector Calibration" password for the DDR and press the ENTER key. If this feature is not password protected, type "0000" and press the ENTER key.
4. A message will appear telling you to use the scroll keys to select the cylinder (requiring changes) or select TYPE # (enter the numerical keys to change the CAL (calibration value).
5. Scroll to the cylinder requiring change and type in the required two-digit injector calibration code number. Press the ENTER key.

*NOTE: The ENTER key must be pressed before the DDR will allow selection of another cylinder number.*

6. Repeat step until all changes have been made.
7. Scroll to select FUNCTION and press the ENTER key.
8. Scroll to select YES and press the ENTER key to reprogram the ECM with the revised injector calibration codes.

*NOTE: Turning the ignition to the off position and waiting five seconds before starting the engine is not required.*

9. Disconnect the DDR; refer to OEM guidelines.

### Verification of Repair for Improper Injector Setting:

Perform the following steps to determine if the proper injector setting adjustment resolved the misfiring cylinder condition:

1. Install the valve rocker cover(s).
2. Start the engine.
3. Run the engine at 1000 rpm.
4. Listen for misfiring cylinder.
  - [a] If the engine is not misfiring, no further troubleshooting is required. Shut down the engine.
  - [b] If the engine is misfiring, shut down the engine. Check for improper valve clearance and injector height and damaged or worn camshaft lobes and rollers.

OTHER FAILURE EXAMPLES



Damaged Harness Cummins Select



Damaged Solenoid CAT 3406E



Tip Damaged during Installation



Cracked Tip

Damaged Tip

## SMOKE PROBLEMS

To determine if an improper grade of fuel oil is causing excessive black or gray smoke, perform the following steps:

1. Acquire a fuel oil sample from the vehicle fuel tank(s).
2. Submit fuel oil sample for testing.
3. If evidence of improper grade fuel in system, follow these steps to resolve concern:
  - [a] Drain the fuel oil tanks; refer to OEM guidelines, and dispose of properly.
  - [b] Clean fuel lines and install new filters.
  - [c] Refill the fuel oil tanks with new fuel oil.
  - [d] Test operation.

A faulty fuel injector, such as a blown or plugged nozzle, can cause black smoke. Follow procedures in testing section and in original equipment service manuals.

### WHITE SMOKE PROBLEM

To determine if an improper grade of fuel is causing excessive white smoke, perform the following:

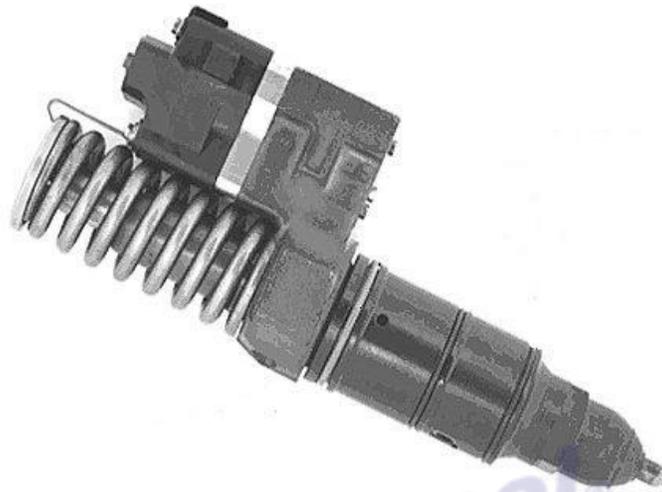
1. Acquire a fuel oil sample from the vehicle fuel tank(s).
2. Submit fuel oil sample for testing.
3. If evidence of improper grade fuel in system, follow these steps to resolve the concern:
  - [a] Drain the fuel tanks; refer to OEM guidelines, and dispose of properly.
  - [b] Refill the fuel tanks with new fuel oil.
  - [c] Test operation.

To determine if aerated fuel is causing excessive white smoke, perform the following steps:

1. Disconnect the fuel line return hose from the fitting located at the fuel tank; refer to OEM guidelines.
2. Place the open end of the fuel line into a suitable container elevated above engine.
3. Start and run the engine at 1000 rpm.
4. Visually check to see if air bubbles are rising to the surface of the fuel within the container.
5. If evidence of aerated fuel in system, follow these steps to resolve them:
  - [a] Tighten all fuel line connections between fuel tank and fuel pump; refer to OEM guidelines.
  - [b] Visually inspect all fuel lines between fuel tank and fuel pump for leaks (fuel pump problems can cause white smoke conditions, refer to original equipment service manuals for fuel pump testing).
  - [c] Repair damaged components as required; refer to OEM guidelines.
  - [d] Verify aerated fuel resolution.
  - [e] If air bubbles are not present, shut down engine, check for improper injector calibration setting.

## INJECTOR O-RINGS

The O-rings are a serviceable part on the unit injector. O-ring damage can occur from improper installation or combustion heat, which could result in return fuel leaking past the O-rings into the engine oil or compression gases entering the return fuel. O-rings should be replaced whenever the unit injector is removed. Apply a thin coat of clean ethylene glycol (petroleum jelly) to the injector O-rings and install them in the injector nut ring grooves. Make sure O-rings are properly seated, do not force them in place. On the Series 50/60 N2 injectors, the top O-ring is black and thicker; the middle and bottom O-rings are black and are the same thickness.



ProDiesel®  
O-rings



## FUEL SYSTEM TESTS

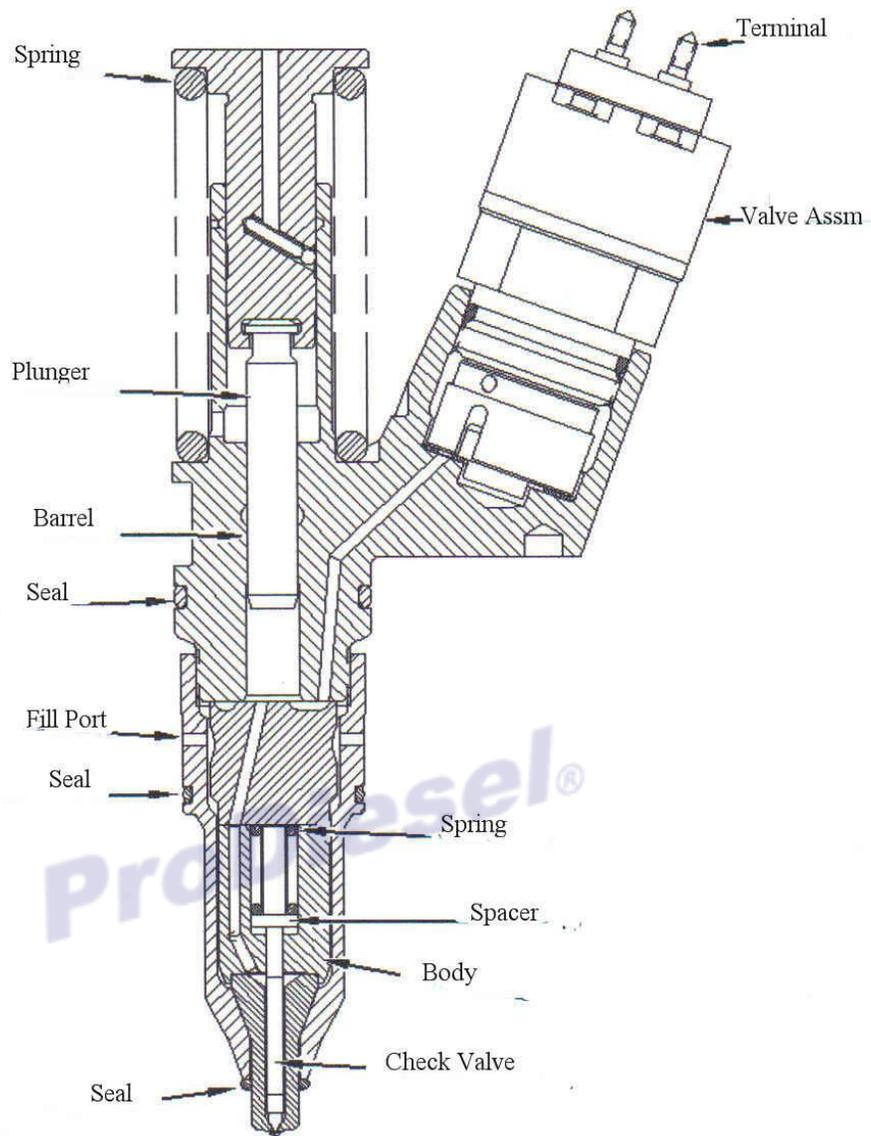
The cylinder cutout test is a valuable tool to identify a cylinder in the engine that has a suspect performance issue. This is helpful in identifying a problem with a unit injector. In order to better understand and interpret the results of this test it would be wise to review the definition of some terms associated with the test.

A cylinder cutout test measures the power contribution of each cylinder to the total engine power, based on cylinder pulse width measurements.

Pulse width represents the quantity of fuel going into a cylinder, measured in degrees of crankshaft rotation. The higher the numbers of degrees, the more fuel being injected in the cylinder.

**ProDiesel®**

# CATERPILLAR ELECTRONIC INJECTORS



Generic Caterpillar Electronic Injector

## CATERPILLAR ELECTRONIC INJECTORS

### Injector Removal and Replacement:

1. Start by disconnecting the harness assembly.
2. Mark the bridge assemblies and the injectors for reference during replacement. (Each injector must be reinstalled in the original sleeve.)
3. Remove the bridge assemblies.
4. Remove the bolt, spacer, and clamp holding the injector in place.
5. Inspect the hold-down assembly. (If the bolt is not loose during disassembly, then use tooling to pry beneath the base and free the injector.)
6. Remove the injector from the cylinder head.
7. Inspect the injector bore for debris and signs of wear.
8. Replace the clamp and spacer.
9. Be sure to replace the injector hold-down bolt with a new bolt.
10. Clean the engine internal fuel lines and injector sleeve before replacing the injector.
11. Install a new fuel filter.
12. Use the OEM Service Manual instructions for servicing or replacing the injector cylinder head sleeves.
13. Before installing the injector, apply clean engine oil on the o-ring seals to prevent possible o-ring damage.
14. Do not strike, hit, or hammer the injector before or after installation.

*(Note: Leave all protective caps on the new injector until ready to install.)*

**Refer to OEM installation manual for complete installation procedure.**

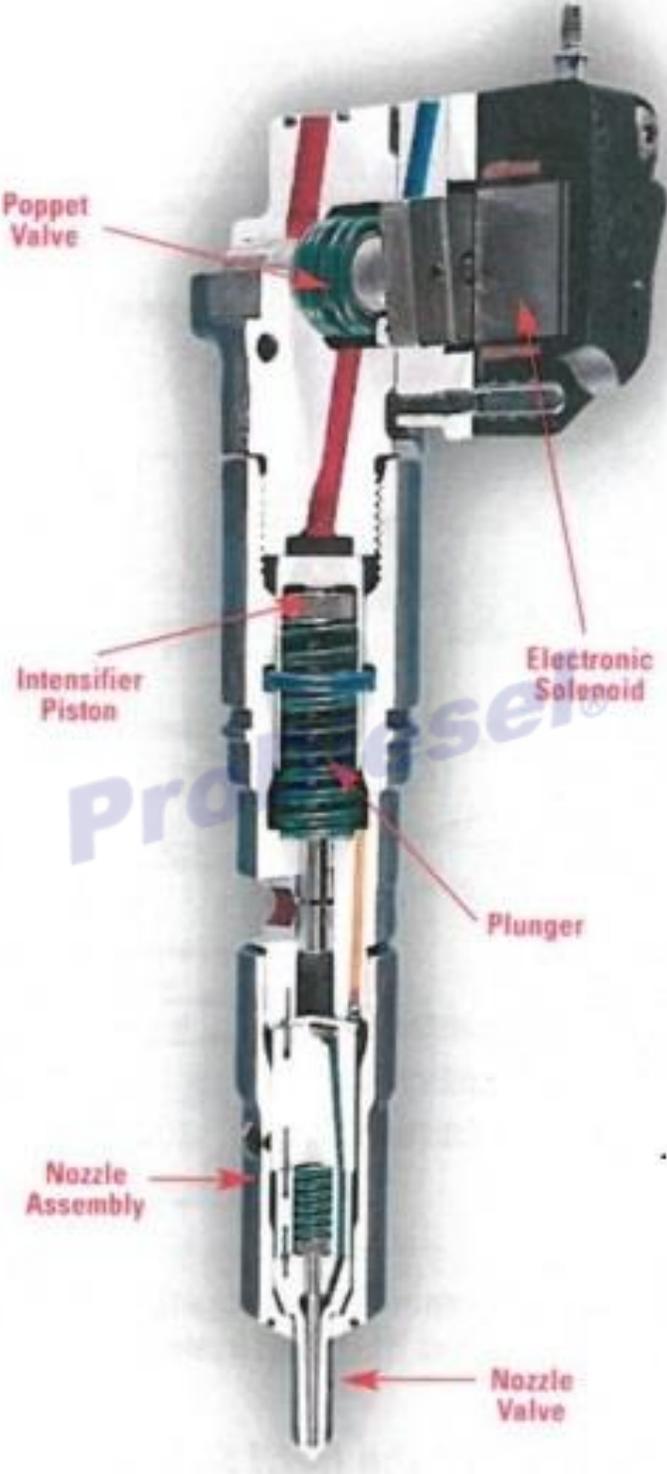


## IMPORTANT NOTICE



- Before installing replacement injectors, it is good practice to confirm the root cause of the failure.
- If the failure can be attributed to a contaminated system such as metal from a failed high pressure pump or poor fuel handling, the condition must be corrected and the system flushed before installing and running the replacement injector(s).
- Do not remove the injector from its protective packaging until you are ready to install. This will reduce the likelihood of contamination or external damage.
- To ensure proper engine performance the trim code on the CD-ROM must be entered into the engine ECM.
- To prevent injector plunger spring failure, the fuel system should be primed before starting the engine.
- Deviating from these recommendations could result in premature failure of the replacement injector(s).

HIA450 HEUI INJECTOR

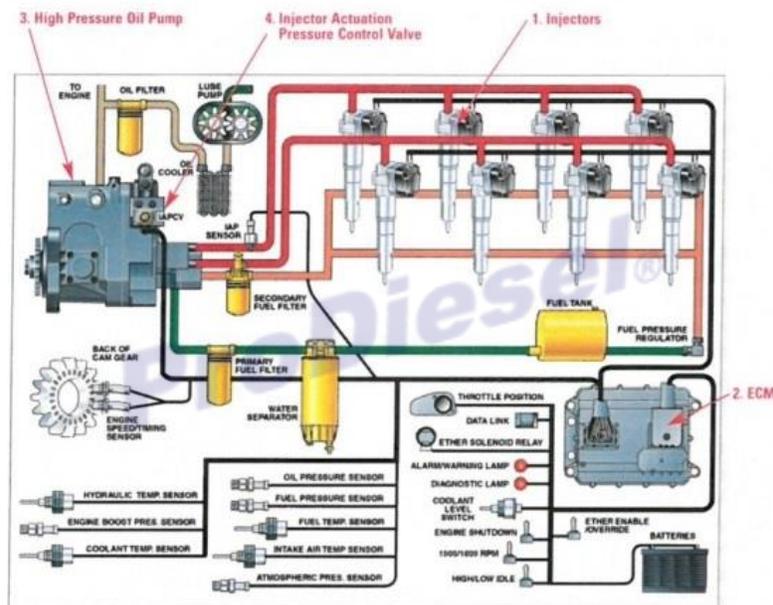


## HEUI Fuel Systems

HEUI injector technology is changing the way equipment owners, technicians and operators think about diesel engine performance. HEUI performance surpasses mechanical unit injectors and conventional electronic unit injectors meeting the demand for lower emissions, better fuel economy and higher performance.

In the traditional common rail fuel system, the entire fuel line is under high pressure. With the HEUI system, fuel remains at low pressure until it is injected into the cylinder. Injection pressure in a HEUI fuel system is independent of engine speed. Fuel pressure is created hydraulically in response to a signal from the Electronic Control Module (ECM). Injection pressure in a HEUI fuel system is independent of engine speed. HEUI controls injection pressure electronically. This unique capability means the regulation of injection pressure is completely independent of crankshaft speed. Peak injection pressure can be achieved under acceleration and lug conditions, providing better fuel economy, better response and reduced smoke.

### Four Basic Components of the HEUI System



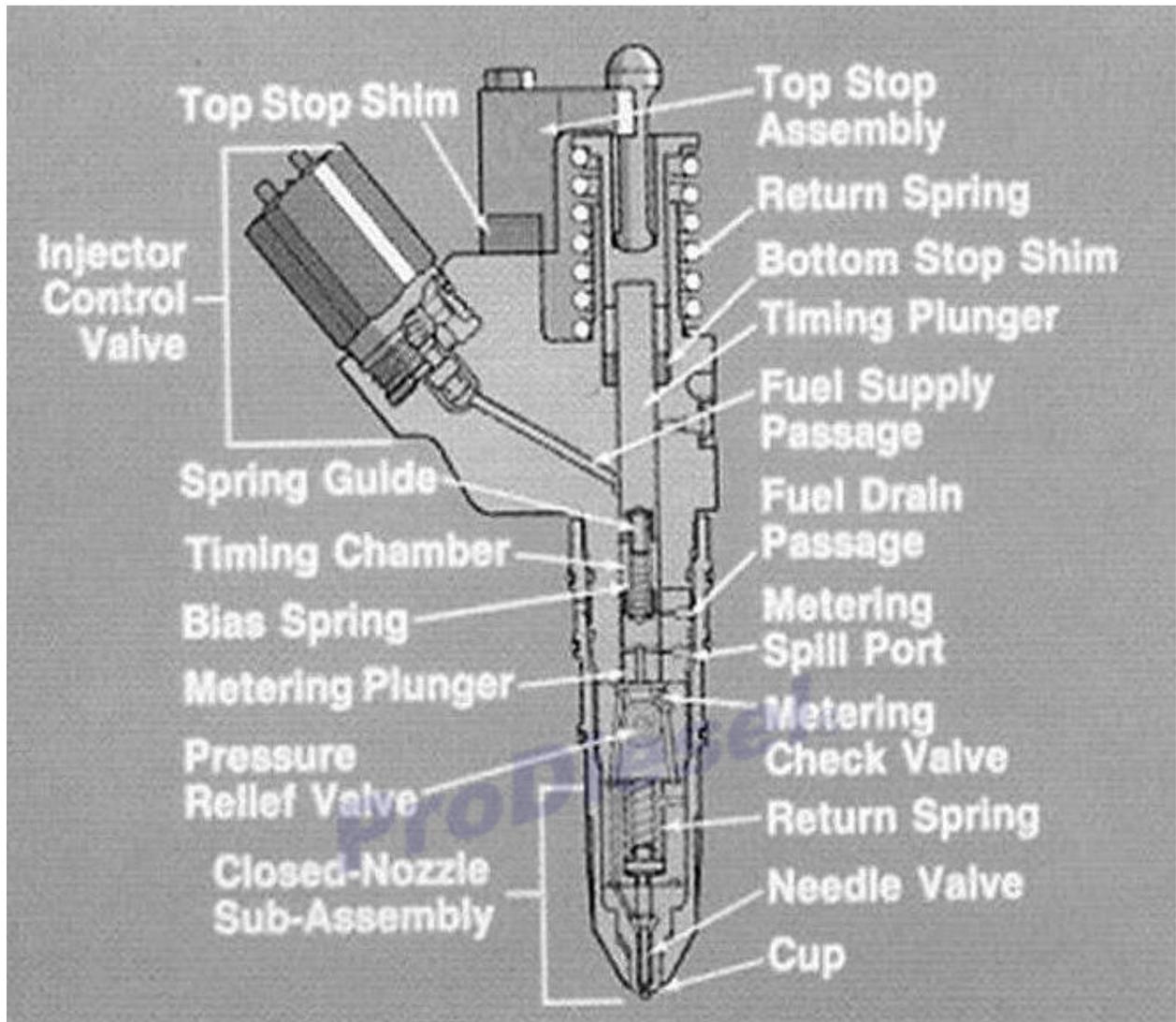
**1. HEUI Injector** - The HEUI injector uses hydraulic energy (as opposed to mechanical energy from the engine camshaft) from pressurized engine lube oil for injection. The pressure of the incoming oil (800 to 3300 psi) controls the rate of injection, while the amount of fuel injected is determined by the ECM.

**2. Electronic Control Module (ECM)** - This sophisticated on-board computer precisely manages fuel injection and other engine systems. The HEUI injector solenoid is energized by an electronic signal generated in the ECM. Using input from multiple sensors, the ECM's dual microprocessors use proprietary software and customer-supplied performance parameters to produce maximum engine performance under any conditions.

**3. High Pressure Oil Pump** -The variable displacement axial pump features a built-in reservoir to immediately supply oil at cold starts.

**4. Injector Actuation Pressure Control Valve** - This electronically operated valve controls oil pump output and injection pressure.

CUMMINS CELECT ELECTRONIC INJECTOR



Cummins Celect Injector

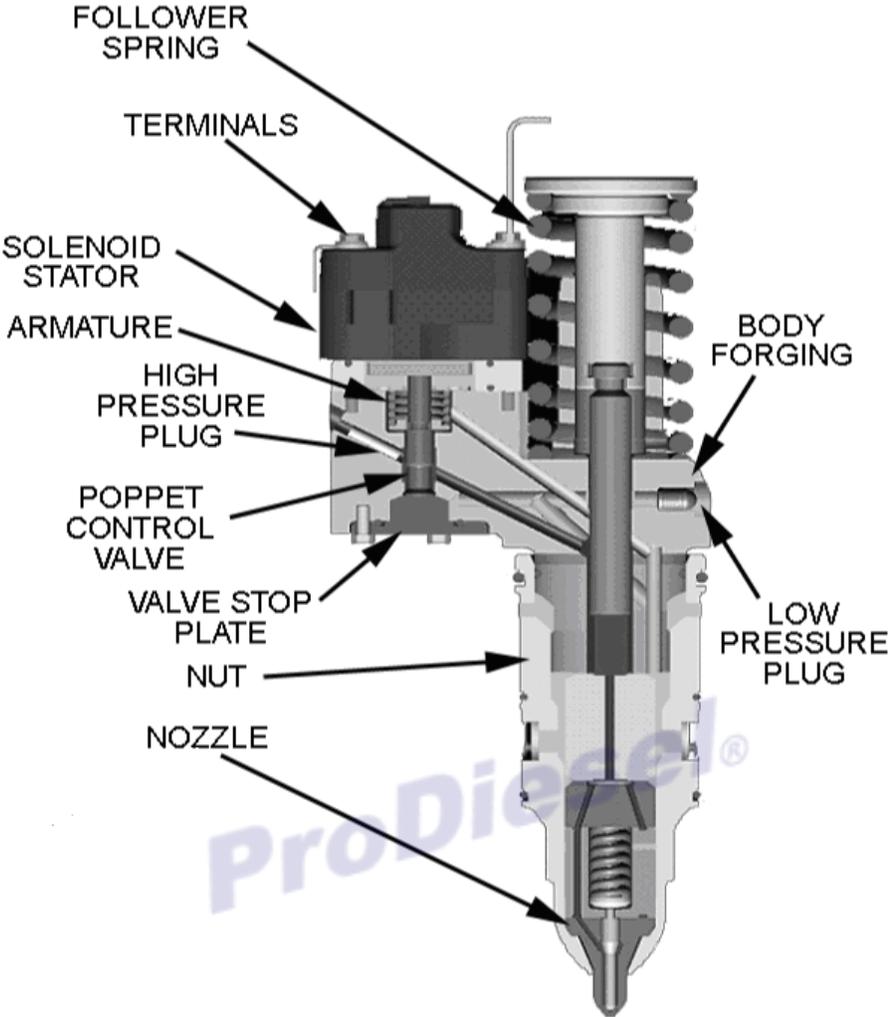
## CUMMINS CELECT ELECTRONIC INJECTOR

1. Injector hold-down clamps torque for N14 @ 30 Ft Lbs, L10 & M11 @ 55 Ft Lbs.
2. Celect injector nozzles can be easily damaged when contacted against any hard surface. Any tip damage which causes spray hole deformation may lead to cracks and/or blown nozzles.
3. When replacing Celect injectors always remove battery cables for a minimum of five minutes to allow the computer to reset.
4. After installation allow the engine to run for 50 miles to allow the computer to recalibrate to the new injector.
5. Never replace an injector for a misfire unless it fails two (2) successive Compulink Automatic Cylinder Performance Tests.
6. Never replace an injector for rough idle or a misfire complaint if there is not a low power complaint.
7. Never replace an injector without referring to the OEM Celect Troubleshooting Procedures.
8. Never replace an injector if the complaint cannot be verified.
9. Never replace injectors in full sets without a specific identified cause.
10. Check fuel inlet restriction on all low power complaints before any other diagnostic work.
11. Never replace injectors at the same time other components are replaced.
12. When it is necessary to replace 2 or more injectors to correct rough idle/misfire, always check the filters and tanks for water presence. Drain water before restarting.
13. Never replace an injector for 5% or less lube oil fuel dilution.
14. Always use fluorescent dye or the air pressure test when troubleshooting lube oil fuel dilution. Refer to OEM Service Parts Topic 91T6-12 for leakage limits and reject criteria.
15. Never replace a full set of injectors for fuel dilution of the lube oil.
16. Never replace an injector for external o-rings leaking fuel. Replace the o-rings.
17. Never replace an injector for any fault code if the injector solenoid checks ok.
18. Never replace an injector with a faulty or broken pigtail/connector. Replace the pigtail.

*(Note: Leave all protective caps on the new injector until ready to install.)*

**Refer to OEM installation manual for complete installation procedure.**

DETROIT 60 SERIES ELECTRONIC INJECTORS



Detroit Series 60 Injector

## Series 60 Model Description Chart and Serial Number Location

Digit Position	Description
1 <sup>st</sup>	Series 60 Engine
2 <sup>nd</sup> & 3 <sup>rd</sup>	Number of Cylinders
4 <sup>th</sup>	Application Designation
5 <sup>th</sup>	Displacement
6 <sup>th</sup>	Engine Control
7 <sup>th</sup> & 8 <sup>th</sup>	Customer Designation

Application Designation

- 2 = Marine
- 3 = Industrial
- 5 = Generator
- 7 = Vehicle

Displacement

B = 12.7L Premium	M = 12.7L Standard
E = 11.1L	P = 12.7L Premium
F = 14.0L	S = 11.1L
G = 12.7 Standard	T = 12.7L
H = 14.0L	W = 11.1L
L = 11.1L	

Engine Control

- T = DDEC I
- U = DDEC II
- K = DDEC III or IV

Customer Designation

- 28 = Buses 1991 and Later
- 32 = Underground Mining
- 40 = 1991 and Earlier
- 60 = 1991 and Later On-Highway Trucks

Located on the left side of the valve cover is an option plate showing the engine serial number, model number and any option equipment used on the engine. If the option plate is missing the engine serial number is stamped on the cylinder block below the manifolds. The serial number will be required when placing part orders.

Serial Number Example: 6067WK60 would represent an 11.1L, Series 60 engine that is controlled with DDEC III or IV electronics used in a 1991 or later truck.

## DETROIT 60 SERIES CODE INFORMATION

### DDEC AND PRO-LINK OPERATIONS

Diagnostic trouble codes (DTC) are generated in the ECU when a condition exists that prevents the engine from operating at peak efficiency. They aid in helping the technician locate a problem. Three primary codes exist: Component, Logic, and Engine Protection.

A component DTC is activated when a specific component failure exists. This is most commonly seen as a high volt or low volt code for a specific device. The failure can generally be found within the component or associated wiring.

A logic DTC is activated when specific conditions occur within a given amount of time that the calibration determines is not “normal.”

An engine protection DTC is activated when an engine operating condition exists that can cause immediate damage to the engine and the engine should be shut down until the condition is corrected to prevent additional damage.

The following procedures are performed using the Pro-Link<sup>®</sup> Diagnostic Data Reader (DDR). To retrieve and clear codes refer to the owner’s manual.

#### SNAPSHOT SEQUENCE

A snapshot allows a customer to record an event in the engine. The ECU monitors many sensors that can be displayed and graphed through Pro-Link operations. The snapshot allows a technician to store and analyze the performance of the engine. The snapshot can also be forwarded electronically to aid in resolving the concern.

Generate a snapshot following the directions stated in the owner’s manual.

ProDiesel<sup>®</sup>

## DETROIT EUI HIGH PRESSURE FUEL TEST

To determine if high fuel pressure is causing lack of power, perform the following steps:

1. Remove either the fuel pressure sensor or supply fuel temperature (SFT) sensor fitting from the secondary filter, if equipped. Refer to the original equipment manual for complete testing procedures.
2. Install a tee fitting between the secondary filter and fuel outlet line.
3. Attach a calibrated gauge capable of reading 0-689 kPa (0 - 100 psi) to the tee fitting.
4. Start and run the engine to the speeds listed in table below and record the fuel pressure.

Engine Speed rpm	Fuel Pressure. kPa (psi)
600	103 - 152 (15 - 22)
1200 - 1300	207 - 310 (30 - 45)
1800 - 2100	448 - 552 (65 - 80)

5. Shut down the engine
6. Remove the tee fitting and calibrated gauge from the secondary filter.
7. Reinstall any sensors that were removed.
8. Analyze the measured fuel pressure readings.
  - [a] If the fuel oil pressure is within specification, testing is complete.
  - [b] If the fuel oil pressure is outside specifications listed in table, check fuel pressure regulator.

## SERIES 50/60 DDEC INSUFFICIENT FUEL FLOW TEST

Perform the following steps to resolve the insufficient fuel flow:

1. Replace the fuel filter(s).

*NOTE: Always fill the filter(s) with clean fuel before installing. Turn the filter(s) until they contact the gasket fully. Then, turn them an additional two-thirds by hand.*

2. Inspect the fuel lines for restrictions due to pinching, kinking or other damage. If damage is found, repair as necessary; refer to OEM guidelines.
3. Inspect the cylinder head for a correct restricted fitting. If an incorrect fitting is found, replace with a new fitting. Refer to the original equipment manual for complete testing procedures.
4. Inspect the fuel return check valve for restrictive movement. See current service manual.
5. Inspect the fuel pump drive assembly. If damage is found, repair as necessary. See current service manual.
6. Verify repairs done to correct insufficient fuel flow.

Perform the following steps to test the engine:

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately five minutes, allowing the engine coolant to reach normal operating range, 88-96C (190-210F).
  - [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut down the engine.
  - [b] If the engine is running rough or stalling, shut down the engine. Check for high fuel oil temperature return, or air in the fuel. See current service manual.

## DETROIT EUI INSPECTION AND REPLACEMENT OF SYSTEMS

This section covers the inspection and removal of the EUI in the Series50/60.

### SERIES 50/60 UNIT INJECTOR INSPECTION/REPLACEMENT

To determine if the unit injector is not functioning properly and needs to be replaced, follow this procedure:

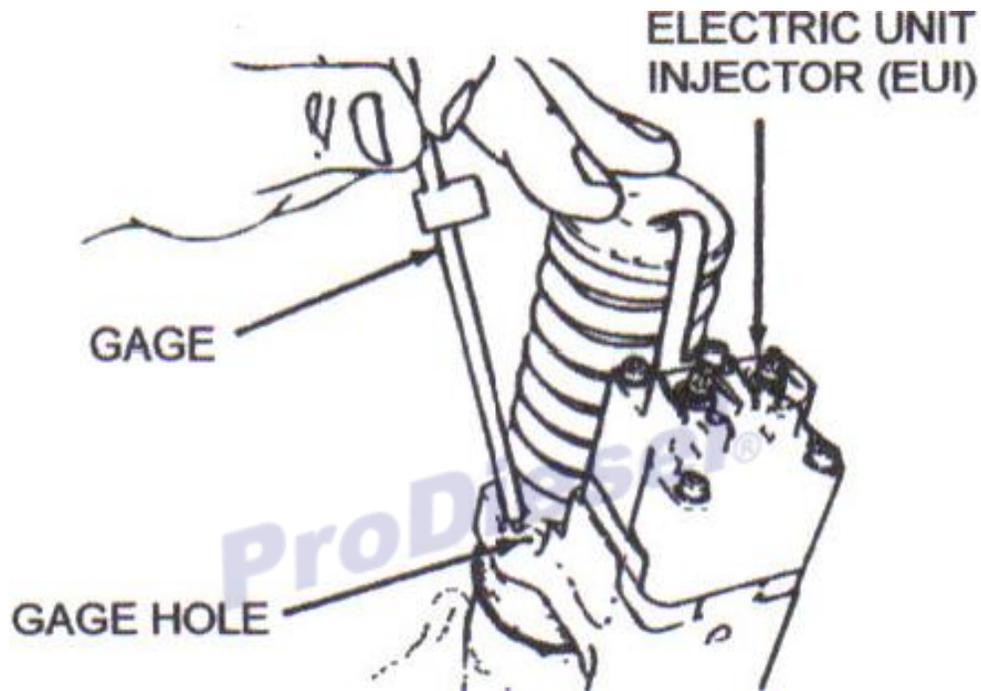
1. Drain fuel system and remove EUI.
  - [a] Clean the valve rocker cover around its seat on the head, and in the attaching bolt recesses.
  - [b] Drain the cylinder head fuel gallery by removing the inlet and outlet lines from the fittings at the rear of the cylinder head. Use caution and blow low pressure compressed air 276 kPa (40 psi) maximum, into the inlet fitting for 20 to 30 seconds or until all of the fuel is purged from the cylinder head.
  - [c] Remove the two rocker shaft through-bolts and one nut for each rocker shaft assembly, and lift the rocker shaft assembly off the engine.
  - [d] Remove unit injector terminals from solenoid.
  - [e] Lift the injector from its seat in the cylinder head by inserting a pry bar under the injector body.
2. Clean EUI (See a current original equipment manufacturer's service manual for proper procedures).
3. Inspect EUI for leaks, turned O-rings, broken injector follower spring, seized injector, cracked body, loose valve stop screws, blown pressure plug, plugged or blown spray nozzle, or broken terminal screws.
4. The only recommended serviceable items are the O-rings.
5. Replace and install a remanufactured injector if required.

*(Note: Leave all protective caps on the new injector until ready to install.)*

**Refer to OEM installation manual for complete installation procedure.**

## Series 50/60 Valve Clearance and Injector Height Settings

The fuel injector height is adjusted using the injector height gage shown below. On Engines with a Jake Brake®, move the handle on the injector height gage to the alternate position, 90° to the shank. A height gage pilot hole is provided in the injector body on the machined surface contacted by the injector clamp near the solenoid.



(Please see the Settings Charts for the correct gage part number.)

### Notice:

Make sure that the height gage seats on the machined surface with the tip in the pilot hole. Foreign material in the pilot hole or on the machined surface may prevent accurate injector height setting.

## Series 50 Valve Clearance and Injector Height Settings

Component	Setting Dimensions	Tolerance
Fuel Injector Height: DDEC II Models 6047 GUXX	78.2 mm (3.078 in.) Use Detroit Diesel Tool J 35837-A	77.95-78.45 mm (3.068-3.088 in.)
Fuel injector Height: DDEC III Models 6047 GKXX	78.8 mm (3.103 in.) Use Detroit Diesel Tool J 39697	77.55-79.05 mm (3.053-3.112 in.)
Fuel Injector Height: DDEC IV Model 6047 TKXX	80.3 n (3.161 in.) Use Detroit Diesel Tool J 42665	80.05-80.55 mm (3.151-3.171 in.)
Fuel Injector Height: DDEC IV Model 6047 MKXX	81.0 mm (3.190 in.)	
Intake Valve Clearance	0.203 mm (0.008 in.)	0.127-0.280 mm (0.005-0.011 in.)
Intake Valve Clearance: Natural Gas Models 604X GKGX	0.279 mm (0.011 in.)	0.203-0.356 mm (0.008-0.014 in.)
Intake Valve Clearance: Model 604X MKGX	0.267 mm (0.010 in.)	0.253-0.281 mm (0.009-0.011 in.)
Exhaust Valve Clearance: "U" Valve Model 604X GUXX	0.508 mm (0.020 in.)	0.432-0.584 mm (0.017-0.023 in.)
Exhaust Valve Clearance: "H" Valve Model 604X GKXX	0.660 mm (0.025)	0.584-0.736 mm (0.023-0.029 in.)
Exhaust Valve Clearance: "J" All Natural Gas Models 604X XXGX	0.914 mm (0.036 in.)	
Exhaust Valve Clearance: Nickel-Alloy Valves Models 604X MKXX, 604X TK7CX	0.508 mm (0.020 in.)	0.432-0.584 mm (0.017-0.023 in.)

## Series 60 Valve Clearance and Injector Height Settings

Components	Setting Dimensions	Tolerance
FUEL INJECTOR HEIGHTS Models: 6067GT40, 6067WT40, 6067WU40, 6067GU40, 6063WU00, 6063GU00, 6067WU60, 6067GU60, 6067GU91 (All DDECI and DDECII 1986-1993)	78.2 mm (3.078 in.)  Use Tool J 35637-A	77.95 - 78.45 mm  (3.068 - 3.088 in.)
FUEL INJECTOR HEIGHTS Models: 6064TKXX, 6063EKXX, 6063TKXX, 606XGKXX, 606XWKXX, 606XSKXX (All DDEC III 1994-1997)	78.8 mm (3.102 in.)  Use Tool J 39697 32J Cam	77.55 - 79.05 mm  (3.092 - 3.112 in.)
FUEL INJECTOR HEIGHTS Models: 6067TKXX, 606XPKXX, 606XGKXX (1997-98 DDEC IV and Later 1997 DDEC III)	80.3 mm (3.161 in.)  Use Tool J 42665 47J Cam	80.05 - 80.55 mm  (3.151 - 3.171 in.)
FUEL INJECTOR HEIGHTS Models: 606XBKXX, 6067EKXX, 606XMKXX 606XLKXX, 606XHKXX, 606XFKXX (1998 & 1999 DDEC IV)	81.0 mm (3.189 in.)  Use Tool J 42749 65J Cam 92J Cam	80.75 - 81.25 mm  (3.179 - 3.199 in.)
FUEL INJECTOR HEIGHTS Models: § 6067BKXX, MKXX, HKXX  6067MKXX  606XBKXX  606XMKXX	82.1 mm (3.23 in.) Use Tool J 45002 w/101J Cam 81.0 mm (3.189 in.) Use Tool J42749 w/92J Cam 82.1 mm (3.23 in.) Use Tool J 45002 w/107J Cam On Off-highway Units Only  82.1 mm (3.23 in.) Use Tool J 45002 w1107J Cam On Off-highway Units Only	0.8128 mm (0.032 in.)
INTAKE VALVE CLEARANCE	0.203 mm (0.008 in.)	0.127 - 0.280 mm (0.005 - 0.011 in.)
EXHAUST VALVE CLEARANCE - "U" Models: 6067GT40, 6067WT40, 6067WU40, 6067GU40, 6063XX00 (1986-1990 All DDEC I & Early DDEC II)	0.508 mm (0.020 in.)	0.432 - 0.584 mm (0.017 - 0.023 in.)
EXHAUST VALVE CLEARANCE - "H" Models: 606XWUXX, 606XGUXX, 606XXKXX, (1991-1999 w/DDEC IV, III and later DDEC II)	0.660 mm (0.026 in.)	0.584 - 0.736 mm (0.023 - 0.029 in.)

# DETROIT N3 ELECTRONIC INJECTOR



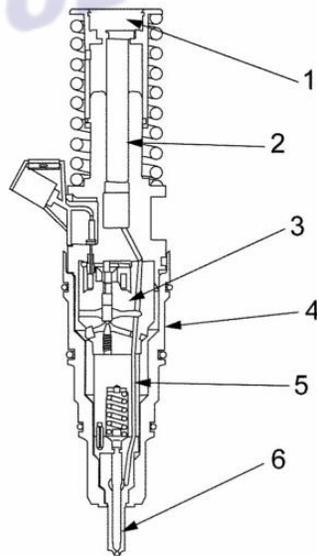
# Detroit N3 Electronic Injector

The N3 injector is designed as an inline concept. The fuel metering unit or module is positioned under the plunger, so the overall envelope of the N3 is smaller than previous injectors. The N3 has an inwardly opening of solenoid valve which controls beginning of injection and end of injection. The solenoid valve closing point defines the beginning of injection (BOI) and the solenoid valve opening point defines the end of injection (EOI). Pressure is generated by the downward movement of the plunger in combination with the closed solenoid valve. Fuel quantity is metered by the length of time the solenoid valve remains closed. A magnetic core is incorporated into the module. The electrical leads from the core are brought to an external position on the injector through a modular two-pin connector socket.

The advantages of the N3 injector are:

- (1) Improved strength.
- (2) Reduced external leakage potential.
- (3) Compact design.
- (4) Reduced weight.

N3 Electronic Unit Injector Cross-Section



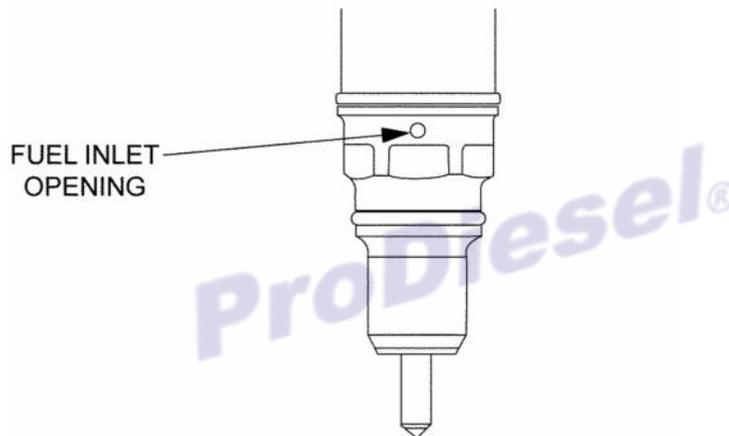
- |                      |                         |
|----------------------|-------------------------|
| 1. Injector Follower | 4. Injector Nut         |
| 2. Plunger           | 5. Injector Spring Cage |
| 3. Module            | 6. Nozzle               |

The amount of fuel injected and the beginning of injection timing is determined by the Electronic Control Unit (ECU). The ECU sends a command pulse which activates the injector solenoid. The N3 EUI performs four functions:

- (1) Creates the high-fuel pressure required for efficient injection.
- (2) Meters and injects the exact amount of fuel to handle the load.
- (3) Atomizes the fuel for mixing with the air in the combustion chamber.
- (4) Permits continuous fuel flow for component cooling.

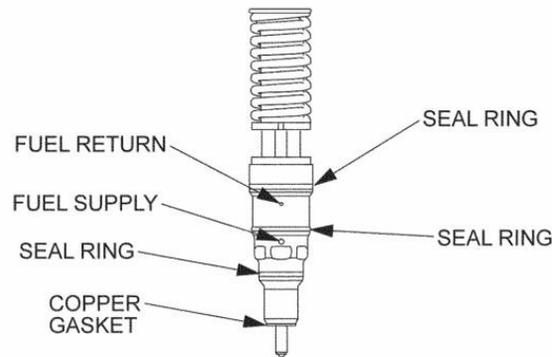
Engine combustion is obtained by injecting, under pressure, a small quantity of accurately metered and finely atomized fuel oil into the cylinder. Metering and timing of the fuel is accomplished by the ECU which actuates the solenoid control valve to stop the free flow of fuel through the injector. When the solenoid control valve closes, fuel is trapped in the injector body and under the plunger. The continuous fuel flow through the injector prevents air pockets in the fuel system and cools those injector parts subjected to high combustion temperatures.

Fuel enters the injector through the fuel inlet opening located around the injector body.



N3 Fuel Injector Body

Outlet openings through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, are located around the injector nut.



After entering the nut cavity, the fuel passes through a drilled passage into the module and plunger area. See Figure 2-1.

The plunger operates up and down in the body bore of the injector. The motion of the injector rocker arm is transmitted to the plunger and follower that bears against the follower spring.

As the piston moves approximately two-thirds of the way up in the cylinder on the compression stroke, the injector cam lobe begins to lift causing the injector rocker arm to push down on the follower and the plunger. Just before injection begins, the ECU sends an electronic pulse which turns on the injector solenoid. The energized solenoid creates a magnetic force which closes the control valve and traps fuel under the plunger and passages leading down to the needle valve. The fuel pressure increases as the plunger continues its downward stroke.

This fuel pressure acts on the needle valve. When it creates a force high enough to overcome the valve spring force holding the needle on its seat, the needle valve moves up, allowing the high pressure fuel to spray into the combustion chamber. The high pressure of the fuel passing through the small holes in the nozzle creates a finely atomized spray for combustion within the cylinder.

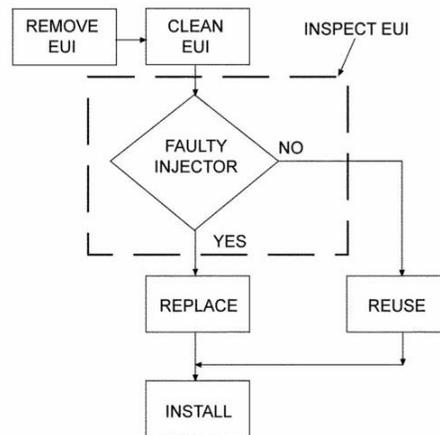
After the pulse width time has passed, the ECU turns off the current to the injector solenoid. The de-energized solenoid allows a spring to open the control valve, permitting the trapped fuel to spill down, dropping the pressure within the injector. When the pressure is low enough the needle valve closes and ends injection.

The beginning of injection and metering of the fuel in relation to the crankshaft position are controlled by the ECU. Injection begins soon after the control valve is closed. The valve closing point known as the injector response time is returned to the ECU. This information is used to monitor and adjust injection timing, thus removing injector-to-injector variation influences on timing. The amount of fuel injected depends on the pulse width stored in the calibration which determines how long the control valve remains closed; the larger the pulse width the longer the valve is closed and the more fuel is injected.

When the injector rocker arm has completed its downward travel the injector follower spring returns it to the starting position. As the plunger moves up fuel enters the injector pumping cavity for another injection cycle. The constant circulation of fuel through the injector renews the fuel supply in the chamber and aids the cooling of the injector.

# Replacement of N3 Electronic Unit Injector

## Flowchart for Replacement of N3 Electronic Unit Injector



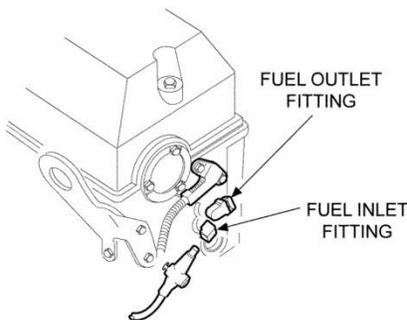
- (1) Clean the valve rocker cover around its seat on the head, and in the attaching bolt recesses.

**Warning: To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.**

Note:

All the fuel must be removed from the cylinder head before removing an injector to prevent the fuel from entering the cylinder and causing hydrostatic lock or washdown. If the head is not thoroughly purged of fuel before an injector is removed, fuel remaining in the fuel manifold will drain into the cylinder filling the piston dome recess. It cannot drain from the dome and, if not removed, can cause hydrostatic lock and bend the connecting rod.

- (2) Drain the cylinder head fuel gallery by removing the inlet and outlet lines and fuel regulator from the fittings at the rear of the cylinder head. Blow low pressure compressed air into the inlet fitting for 20 to 30 seconds or until all of the fuel is purged from the cylinder head.



Cylinder Head Fuel Fitting Locations

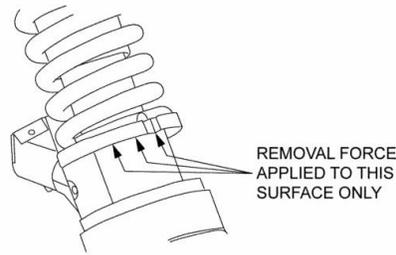
- (3) Remove the two rocker shaft through-bolts and one nut for each rocker shaft assembly, and lift the rocker shaft assembly off the engine.
- (4) Disconnect the vehicle battery power before servicing the N3 EUI to prevent failure of the DDEC V ECU.
- (5) Using injector harness remover J-47383 disengage the locking tang on the harness plug connector. Grasp the connector and gently pull it from the socket.
- (6) Remove injector hold down bolt and spherical washer. Discard the bolt and spherical washer.

**Note:**

Extreme care should be used when handling an N3 EUI to avoid costly damage by dropping or otherwise mishandling the N3 EUI.

**Note:**

The N3 EUI must be removed from the cylinder head by applying force on the body surface. Removal force must not be applied to any other area on the N3 injector.



N3 Injector Removal Surface

- (7) Lift the injector from its seat in the cylinder head using the proper injector remover tool. Note the cylinder position for each injector removed.

**Note:**

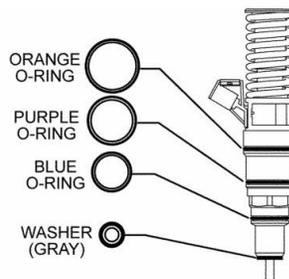
Avoid cleaning the spray holes to prevent damage and plugging. Do not wire brush.

- (8) Cover the injector hole in the cylinder head to keep out foreign material. Carefully remove carbon from the injector exterior in the area where the tip joins the nut, using a clean rag with clean diesel fuel.

On a Series 60 engine that uses the N3 EUI, only the injector seal rings and injector washer are serviceable. The injector must not be disassembled.

Inspect the N3 Electronic Unit Injector as follows:

- (1) Inspect the N3 injector body for visible damage. Replace the injector if damaged.
- (2) Discard the three injector O-rings.
- (3) Discard the injector washer on the bottom of the injector.



## Installation of the N3 Electronic Unit Injector

(1) If the fuel system is contaminated:

- (A) Drain the fuel tanks and refill with clean fuel.
- (B) Replace both filters and clean the fuel/water separator, if equipped.
- (C) Inspect the fuel injectors for damage and replace as required.

(2) If the oil system is contaminated change the engine oil and filters.

(3) If the coolant system is contaminated with fuel, flush and reverse flush the system.

Note: Leftover fuel must be removed from the injector bore before injector installation. If fuel is trapped between the top of the injector hole tube and the lower injector O-ring seal, it may seep down to the injector hole tube seal ring, causing swelling and possible seal leakage.

(4) Using a clean lint free rag, wipe up any fuel remaining in the injector tube bore.

Note: Injector O-ring seals, injector washers and the injector hold down crab bolt are considered one-use items and cannot be reused. Any time an injector is removed, all three injector O-ring seals, injector washers and the injector hold down crab bolt must be replaced with new parts. Failure to replace O-ring seals, injector washer and the injector hold down crab bolt can result in leakage.

(5) Check to make sure the injector bore is thoroughly clean.

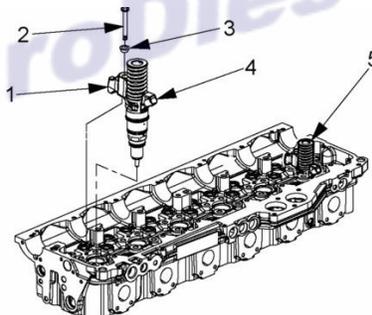
Note: The injector tube bore should be cleaned and inspected for damage before installation of the N3 Electronic Unit Injector.

(6) Install a new washer on the injector, ensure the smooth side of the washer faces down into the cylinder head. The stepped side of the washer must face up to the injector.

Note: All external O-rings must be lubricated prior to installation into the cylinder head.

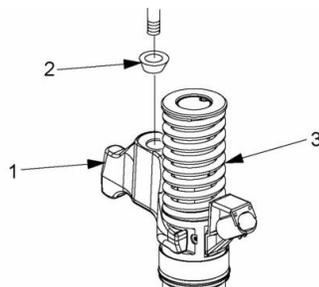
(7) Apply a thin coat of clean fuel to the injector seal rings and install them in the injector nut ring grooves. Make sure the seals are properly seated.

(8) Install the injector and hold down clamp as an assembly into its respective injector tube bore, taking care not to damage the injector O-rings.



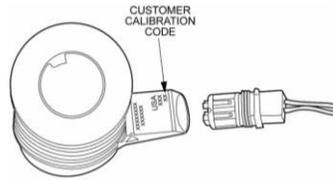
- (1) Injector Clamp
- (2) Bolt
- (3) Washer
- (4) N3 Injector
- (5) N3 Injector Installed

(9) Install a new injector hold down clamp spherical washer. The curved side of the washer fits into a corresponding curved cup in the injector hold down clamp.



- (1) Clamp
- (2) Washer
- (3) E3 Injector

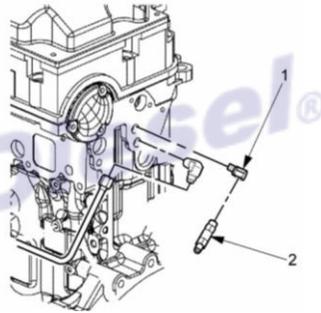
- (10) Install injector assembly with a new bolt. Torque injector assembly using the following procedure:
  - (A) Torque the bolt to 50 N·m (37 lb·ft).
  - (B) Loosen the bolt 60° (1/6 of a turn, or one bolt flat). Do not fully loosen the bolt.
  - (C) Torque the bolt to 35 N·m (26 lb·ft).
  - (D) Tighten the bolt 90° (1/4 of a turn).
- (11) Install the N3 EUI harness plug into the injector connector making sure the locking tang clicks into place.



### N3 Injector and Harness Connection

- (12) Install the rocker arm shafts, with rocker arms in place.
- (13) Adjust the intake and exhaust valve clearances and injector height.
- (14) Install the inlet fuel line to the fitting at the rear of the cylinder head
- (15) Record the injector calibration code from the name plate with the proper cylinder location.
- (16) Install the rocker cover.
- (17) Flush the injectors and cylinder head fuel passages by removing the pressure regulator/check valve from the 90° elbow in the cylinder head fuel return port.

- (1) 90° Elbow
- (2) Pressure Regulator/Check Valve



- (18) Connect a fuel line to the 90° elbow and route it to a separate container.
- (19) Disconnect the engine sensor harness 68 pin connector from the Electronic Control Unit (ECU), or remove the fuse breaker in the vehicle that powers the ECU.
- (20) Reconnect the battery power.
- (21) Using the starter, crank the engine three times for 15 seconds each time. Allow sufficient time between cranking periods to allow the starter to cool. Fuel should be flowing out of the return line into the container.
- (22) Remove the fuel line from the 90° elbow in the cylinder head fuel return port.
- (23) Install the pressure regulator/check valve and torque to 23 N·m (17 ft·lb).
- (24) Connect the engine sensor harness to the ECU, or install the fuse breaker in the vehicle to power the ECU.
- (25) Use DDDL to enter the injector calibration codes. For instructions on entering calibration codes use the DDDL help function.
- (26) Verify installation of N3 Electronic Unit Injector.

AcronymsDescriptions

BOI	Beginning of Injection
CEL	Check Engine Light
DDDL	Detroit Diesel Diagnostic Link
DDL	Diagnostic Data Link
DDR	Diagnostic Data Reader
DTC	Diagnostic Trouble Code
ECU	Electronic Control Unit
SFT	Supply Fuel Temperature Sensor
EUI	Electronic Unit Injector
FMI	Failure Mode Identifier
INJ	Injector (fuel)
IRT	Injector Response Time
kPa	Kilopascals
MPG	Miles Per Gallon
PID	Parameter Identification
PSI	Pounds per Square Inch
PW	Pulse Width
RPM	Revolutions Per Minute
RSL	Red Stop Light
SID	System Identification
VCU	Vehicle Control Unit
ECM	Electronic Control Module
EFPA	Electronic Foot Pedal Assembly
LSG	Limiting Speed Governor
TPS	Throttle Position Sensor
ECU	Electronic Control Unit
AP	Accelerator Pedal
ALSG	Automotive Limiting Speed Governor
APS	Accelerator Pedal Sensor

## GLOSSARY

ITEM	DESCRIPTION
Atomized Fuel	Fuel broken up in a very fine mist.
Check Valve	A mechanism to insure flow in one direction only.
Corrosion	The chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties.
Erode	To eat away gradually any type of material.
Failure	A general term used to imply that a part in service has become completely inoperable, or is still operable but is incapable of satisfactorily performing its intended function, or has deteriorated seriously to the point that it has become unreliable or unsafe for continued use.
Fuel Cooler	A devise used to reduce the temperature of the fuel returned to the fuel tank.
Fuel Filter	Used to remove impurities from the engine fuel supply.
Fuel Return Line	A hose or pipe used to return heated fuel to the tank.
Fuel Temperature Sensor	Monitors fuel temperatures prior to entering the cylinders
Injector Body	Main injector component to which the injector parts are assembled.
Injector Follower Spring	A spring designed to return the follower and plunger to its up position on the injector.
Injector Nut	A tube shaped part used to contain all the internal pieces of the injector, also the main seal surface in the head.
Injector Response Time	Is the length of time in milliseconds (ms) from when the stator valve opens to the time the poppet control valve closes.
Metering (Fuel)	Amount of fuel that is injected, or metered, as determined by the ECM and fuel requirements.
Nitrogen Oxide (NOx)	Any of several oxides of nitrogen most of which are produced in combustion and are considered to be atmospheric pollutants.
Proprietary	Something that is privately owned and specific to a manufacturer or operation, like a company software system.
Pulse Width	The duration of time the injectors are fueling the engine, measured in degrees of rotation of the crankshaft, which is determined by the ECU.
Purge	To eliminate air in the fuel system by flushing with clean fuel.
Rocker Arm	A device used to transmit upward motion from the camshaft to downward motion of either intake, exhaust valves, or injectors.
SAE J1587	Communication link used for DDR, Data Hub, ABS, etc.
Solenoid	Device that holds an iron armature within its air core as long as there is power applied to it. When de-energized, the armature is released.