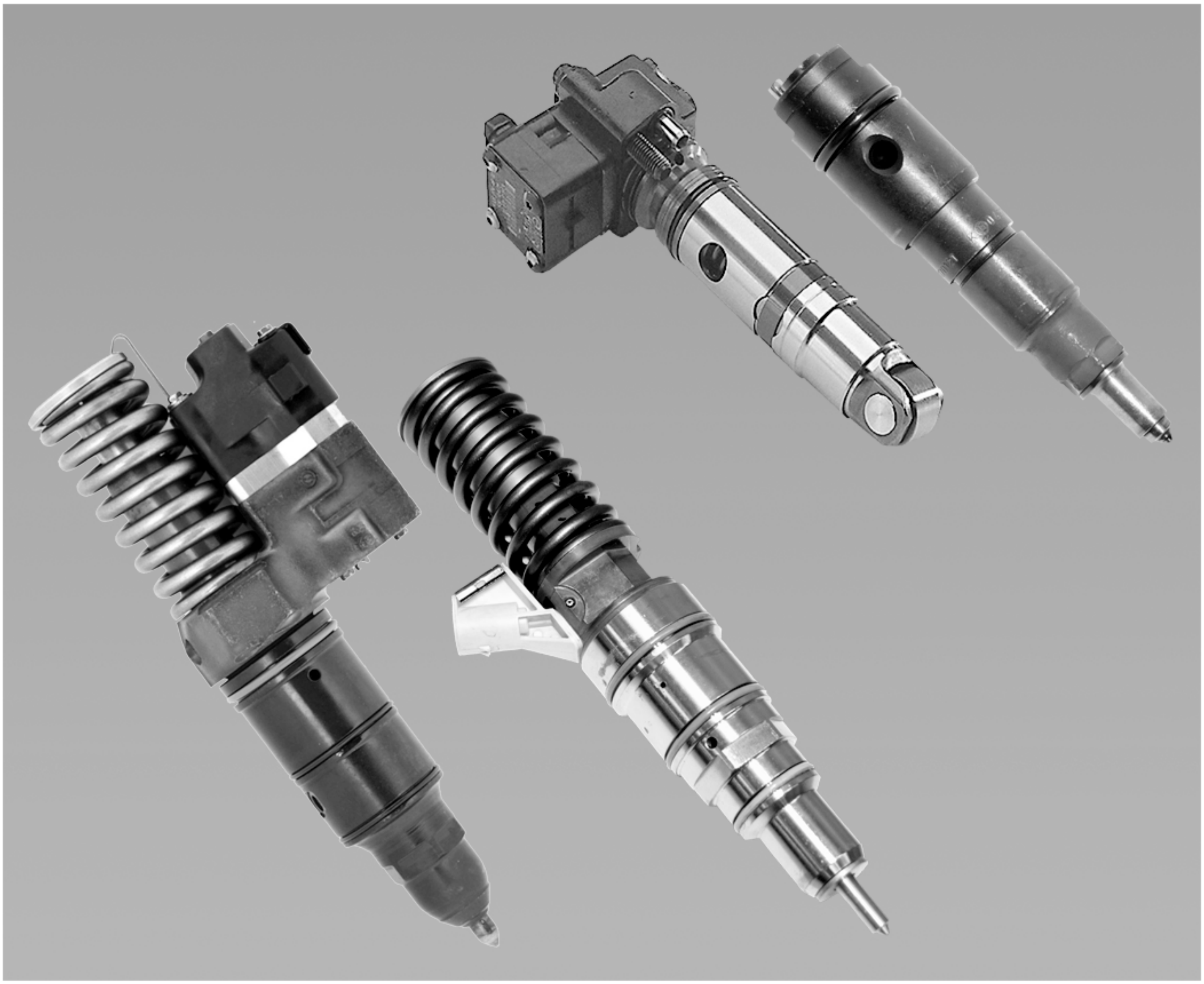
DETROIT DIESEL

Unit Fuel Injectors and Unit Pumps Technician's Guide



Inspection/Analysis *Failure Examination* *Troubleshooting*

ATTENTION

This document is a guideline for qualified personnel. It explains the operation of the fuel injections system for Detroit Diesel Corporation four-cycle engines and Mercedes Benz MBE 900 and MBE 4000 engines. Detroit Diesel Corporation 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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1 INTRODUCTION

This technicians guide explains the fuel injection system operation in current on-highway, four-cycle Detroit Diesel®Corporation engines. Series 50®, Series 60®, MBE 900, and MBE 4000 engines are the models covered in this guide. The main emphasis of this guide is on the unit injector and the unit pump.

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. This is achieved by Detroit Diesel Corporation's electronic control technology: Detroit Diesel Electronic Controls (DDEC®). 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.

1.1 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.

There are differences between the Series 50/60 and the MBE fuel injection system. In the Series 50/60 engines, the unit injectors pressurize the fuel prior to injection. See Figure 1-1. The MBE engines have a unit pump for each cylinder that produces the pressure and a high-pressure fuel line that carries fuel to the injector nozzles. See Figure 1-2.

In the Series 50/60 engines, the fuel pump draws the 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 free 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. See Figure 1-1.

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

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

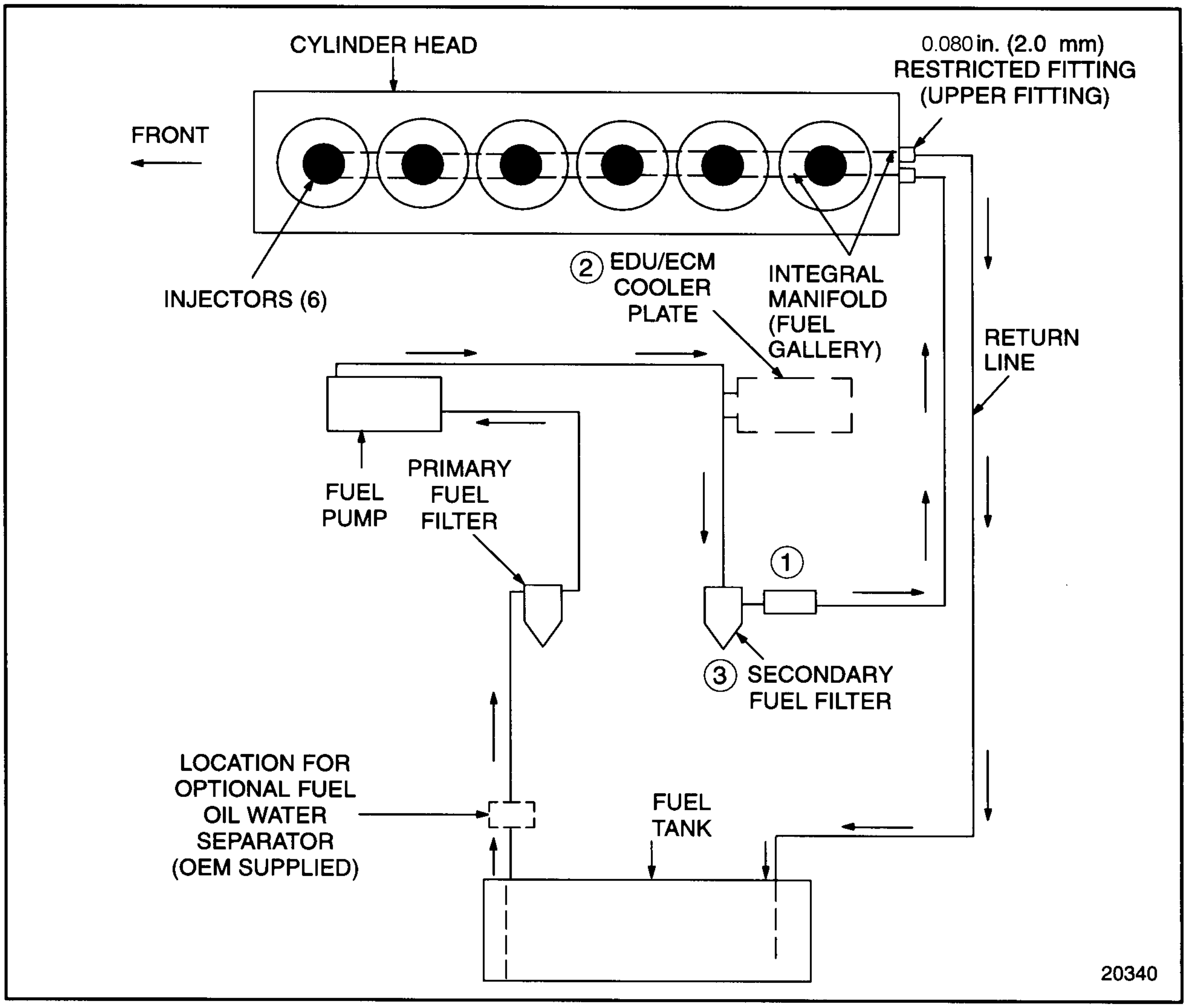

Figure 1-1 Schematic Diagram of Series 50/60 Fuel System

The following changes have been made to the fuel system:

- ☐ Effective with engine serial number 6R56762, a manually operated fuel shutoff valve replaced a check valve. A PRO-CHEK® valve may be installed at this location to remove air. See number 1 in Figure 1-1.
- ☐ Effective with engine serial number 6R8950, the ECM/EDU cooler platet was removed from all Series 50/60 engines used in on-highway applications. See number 2 Figure 1-1.
- ☐ Effective with engine serial number 6R13060, a fuel system check valve is installed in the secondary fuel filter head to prevent fuel drainback when filters are changed. See number 3 in Figure 1-1.

In the MBE system, the fuel pump draws fuel from the tank through the pre-filter up to the fuel pump. The fuel pump delivers fuel at low pressure to the main fuel filter, then to the individual fuel injection pumps. Each unit pump delivers fuel at high pressure to the fuel injectors. The leak line collects unused fuel and empties through the overflow valve. The return lines bring the fuel back to the fuel tank. See Figure 1-2.

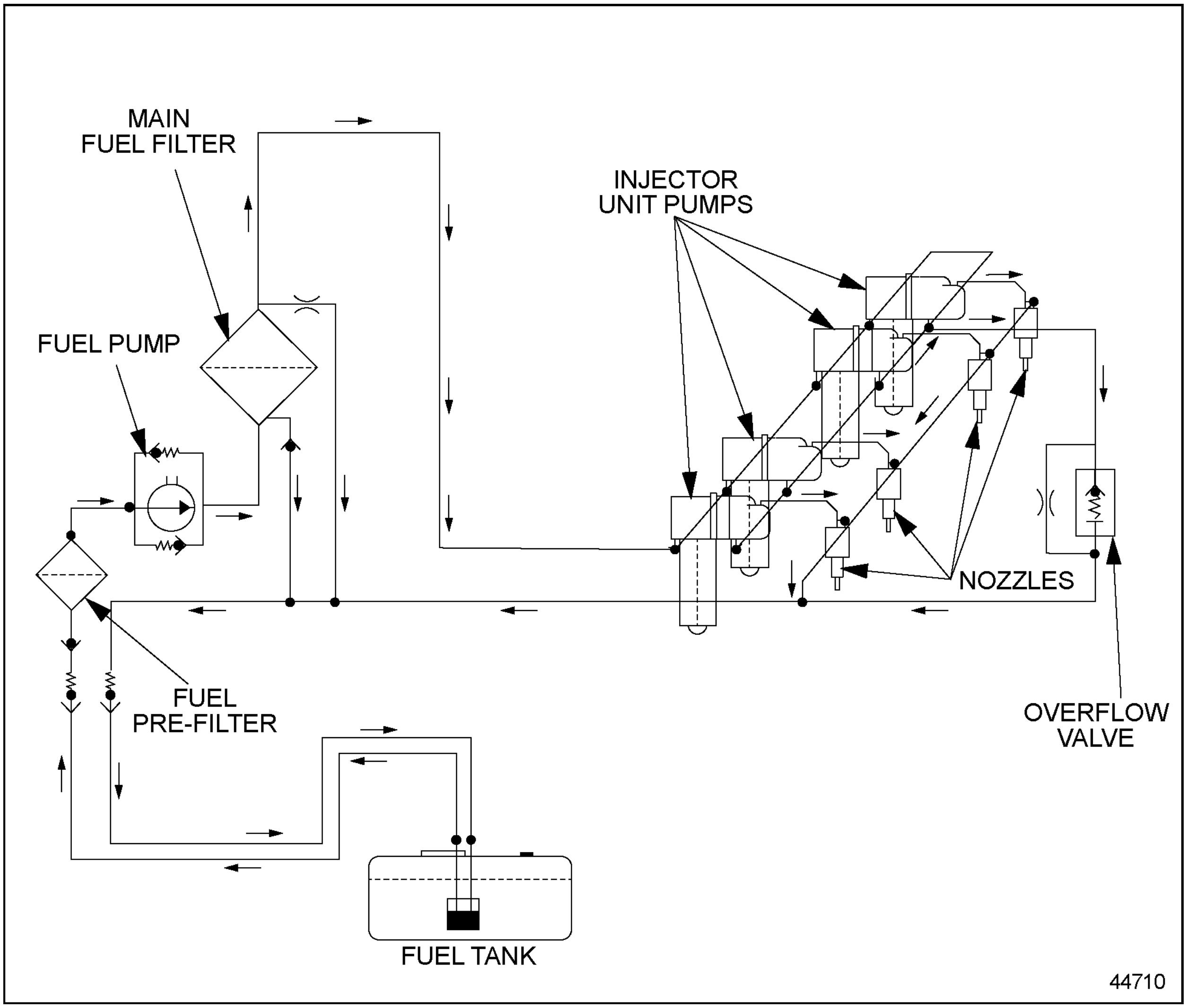

Figure 1-2 Schematic Diagram of MBE 900 and MBE 4000 Fuel System

1.1.1 SERIES 50/60 ELECTRONIC UNIT INJECTOR

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, see Figure 1-3.

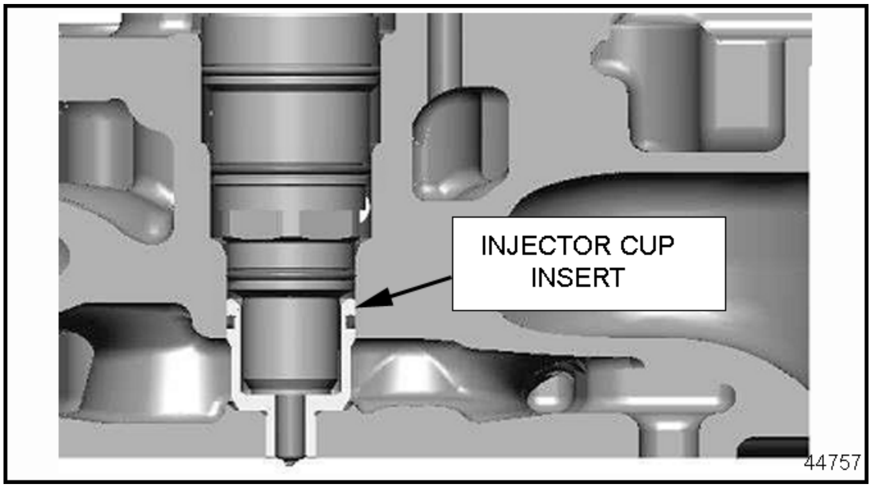

Figure 1-3 Injector Cup Insert

The injector operates off the camshaft and ECM commands. As the piston travels about two-thirds of the way up on the compression stoke, 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. See Figure 1-4. As the injector arm continues the downward stroke, the trapped fuel in the injector passages comes under extremely high pressure.

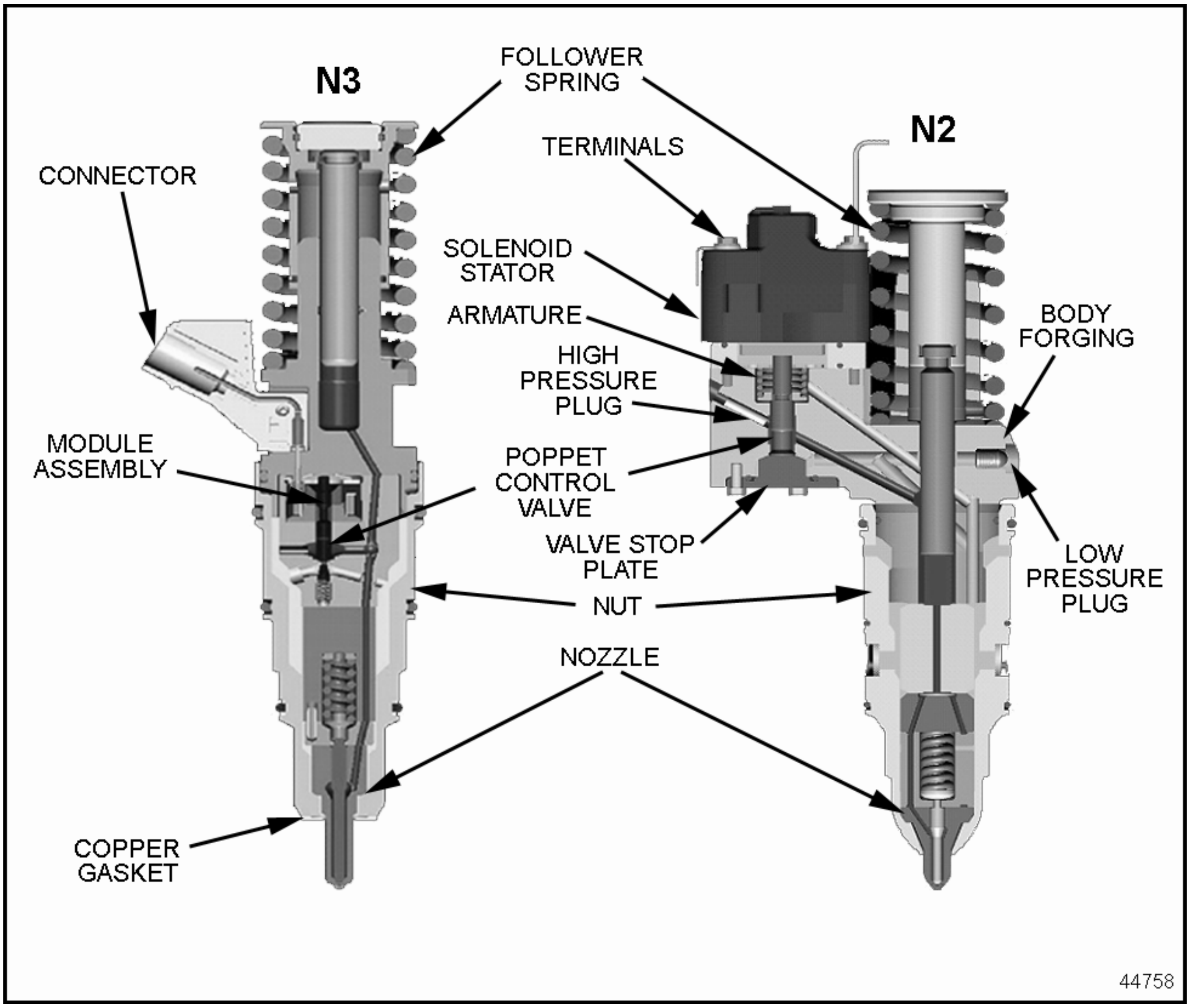

Figure 1-4 Series 50/60 Injector Components

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, NOx, 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. When the injector actually begins injection, it is referred to as Beginning of Injection (BOI). See Figure 1-5.

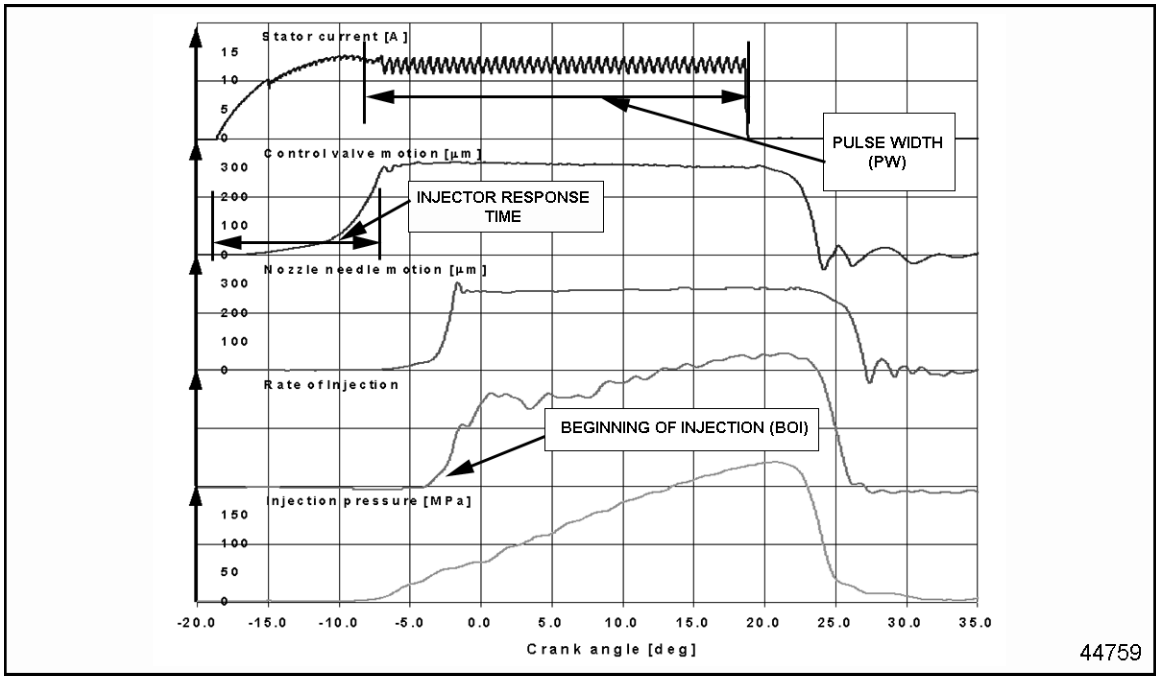

Figure 1-5 Injector Cycle Graph

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. Fuel not injected by the injector is returned to the fuel tank.

The Series 50/60 has two types of injectors: the former S60 EUI (N2), see Figure 1-6, and the current N3, see Figure 1-7. The current N3 injector offers four product improvements compared to the N2: an: internal solenoid, reduced internal fuel volume capacity, an electrical connector instead of ring terminals, and a design able to accept a stainless steel injector cup insert See Figure 1-8.

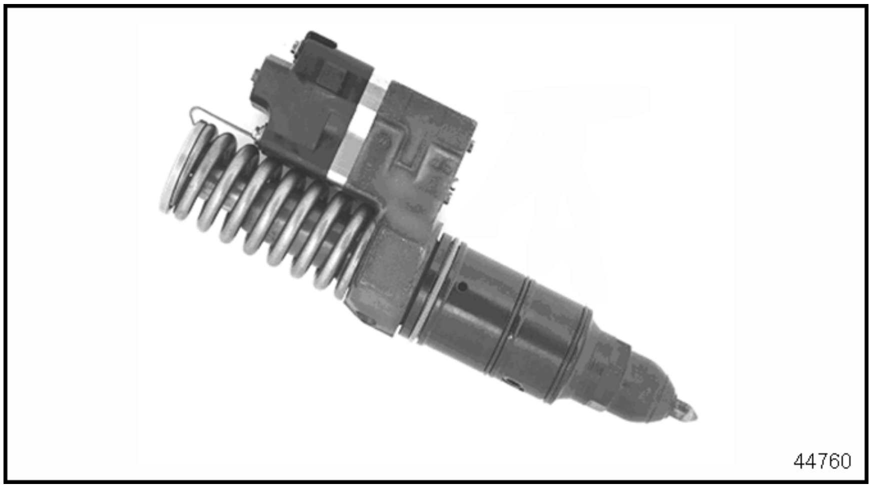

Figure 1-6 Former Injector N2

Figure 1-7 Current Injector N3

Series 50/60 injectors should not be rebuilt in the field. They must be sent back to the manufacturer and replaced with a rebuilt injector. However, the external injector body O-ring seals are serviceable. In the case of the N2, there is a solenoid O-ring kit and follower spring kit offered as serviceable parts.

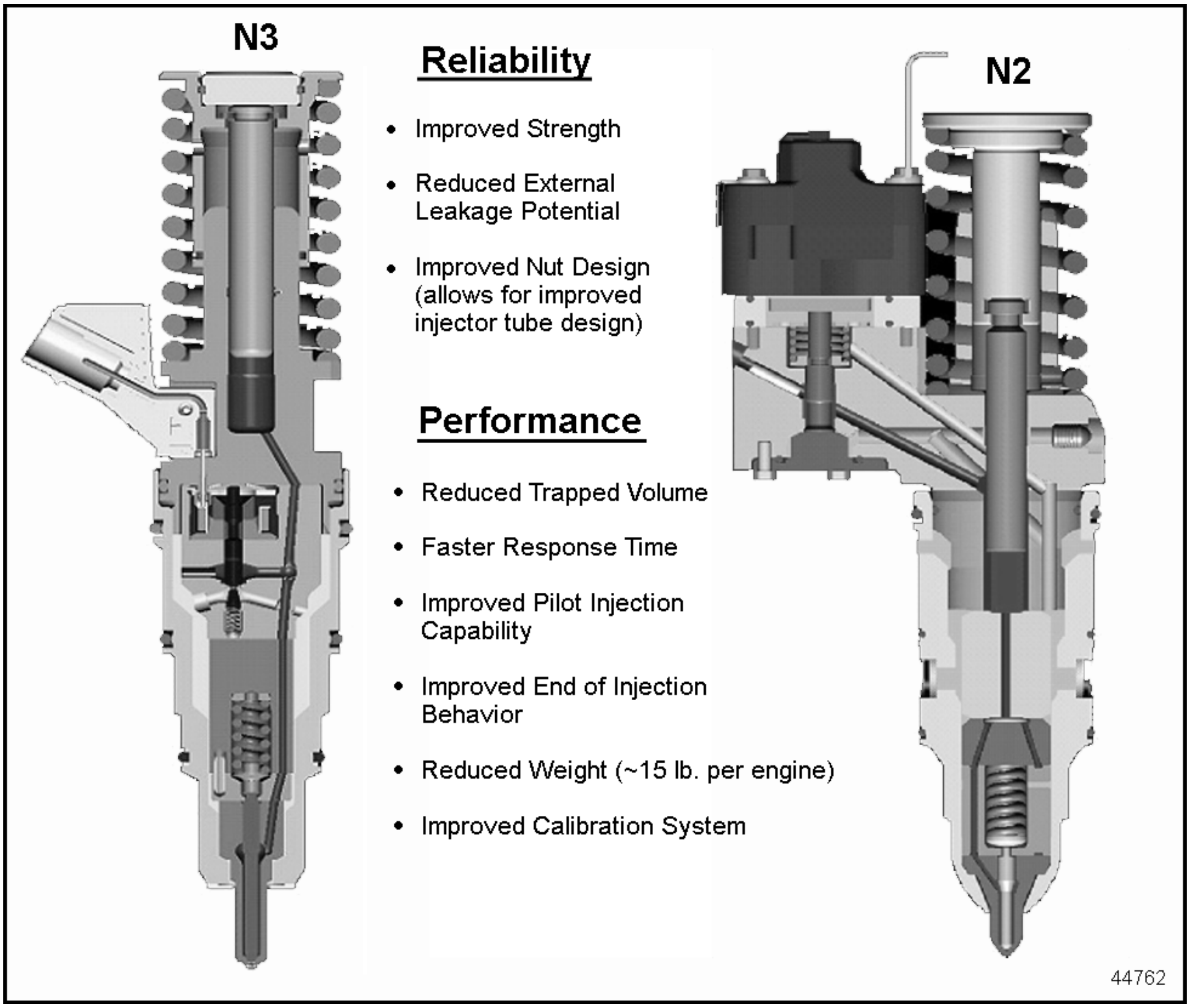

Figure 1-8 N3 Injector Advantages Over N2 Injector

1.1.2 MBE 900 AND MBE 4000 UNIT PUMP AND NOZZLE

In the MBE 900, the fuel pump draws fuel from the tank through the pre-filter up to the fuel pump. In the MBE 4000, fuel is drawn from the tank through the primary filter/water separator and PLD-MR cooler (also referred to as the Fuel Heat Exchanger), by the fuel pump. The fuel pump delivers fuel at low pressure to the fuel filter and from there to the individual fuel injection pumps. see Figure 1-9 and See Figure 1-10. Each unit pump delivers fuel at high pressure to the high-pressure line., See Figure 1-11. High-pressure lines take high-pressure fuel from the unit pumps to the injection nozzles.

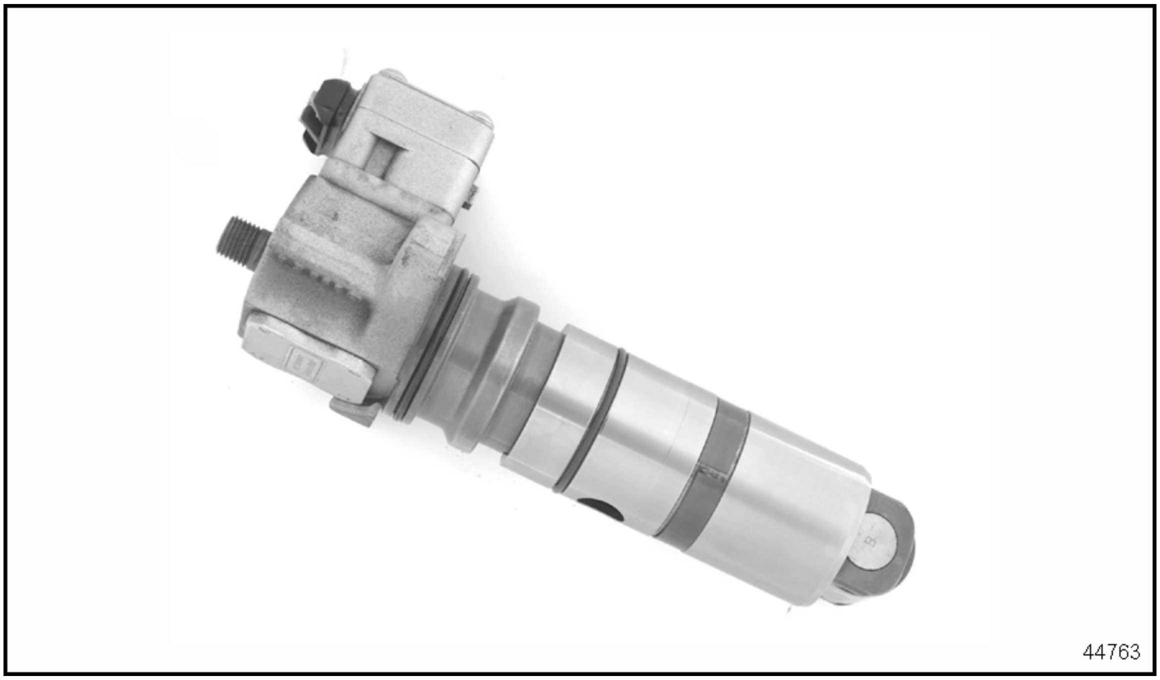

Figure 1-9 MBE Unit Pump

In the MBE 900, fuel is filtered twice, once in a pre-filter, upstream of the fuel pump and second in the main filter, downstream of the fuel pump. The main filter has a drain valve to return fuel, accumulated in the filter, to the fuel tank as well as constant ventilation to reduce and return fuel vapor to the tank. The MBE 4000 has a secondary filter mounted on the engine. The fuel filter housing contains a replaceable fuel filter and has a check valve attached at the bottom. The fuel filter is upright, which makes it easy to replace and an internal return when the filter is removed to reduce spillage during replacement.

Electronic unit pumps are integrated into the crankcase and driven directly off the camshaft in the cylinder block. The injection unit pumps, which create injection pressures of more than 1,586 Bar (23,000 psi) and up to 2,137 Bar (31,000 psi) in the Exhaust Gas Recirculation (EGR) equipped engines for the MBE 900 and 1,793 Bar (26,000 psi) for the MBE 4000, are electronically controlled, and regulate the injection timing using solenoid valves. See Figure 1-11. The control system consists of an engine-injector unit pump and nozzle control unit (DDEC-ECU/PLD-MR) and a vehicle control unit (DDEC-VCU). Metering and timing of the fuel is regulated by the control system, which actuates the solenoid poppet control valve to stop the free flow of fuel through the injector unit pump. When the solenoid poppet valve closes, fuel is trapped in the injector unit pump plunger. The continuous fuel flow through the injector unit pump prevents air pockets in the fuel system and cools those injector unit pump parts subjected to high combustion temperatures.

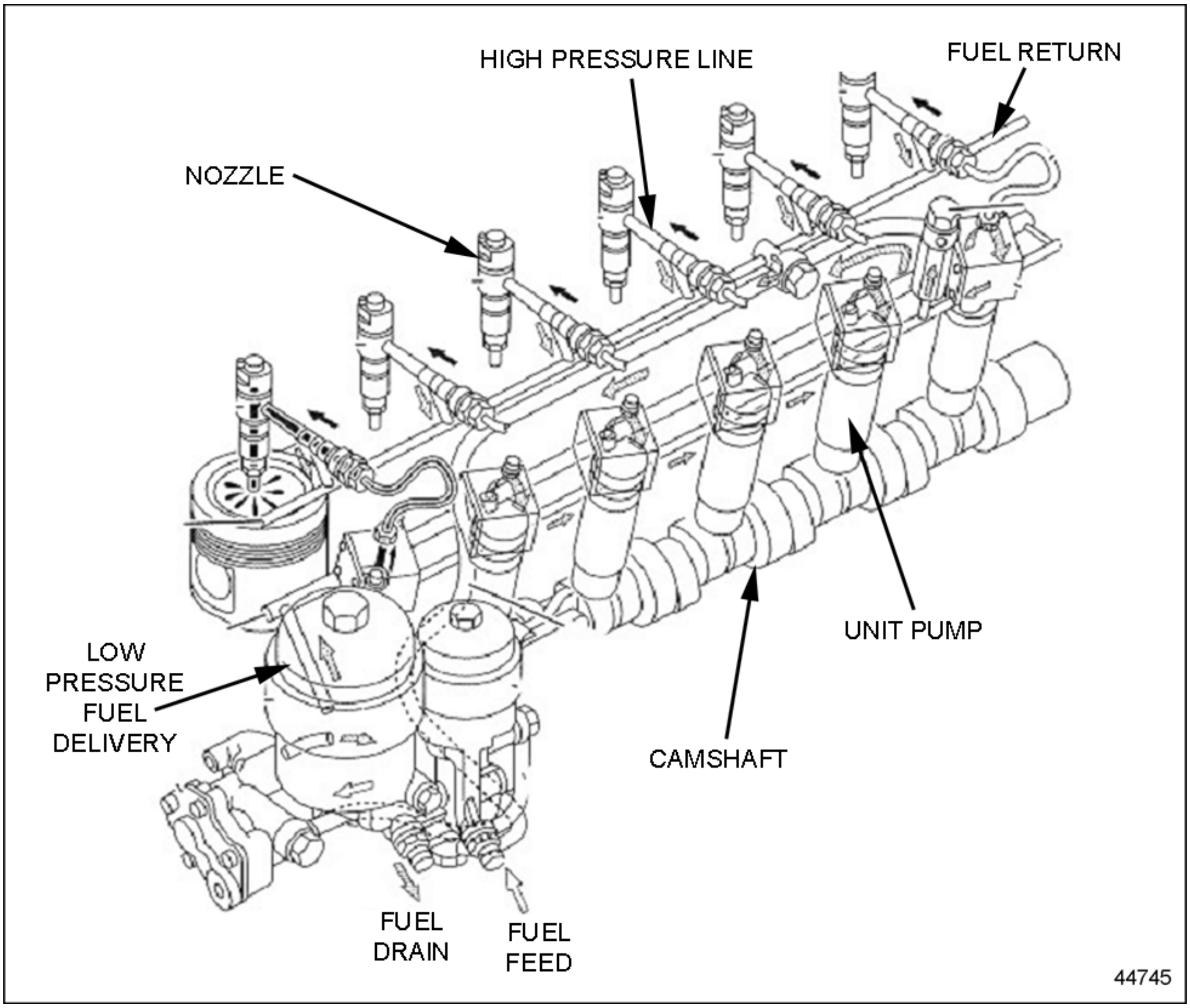

Figure 1-10 General MBE Fuel System

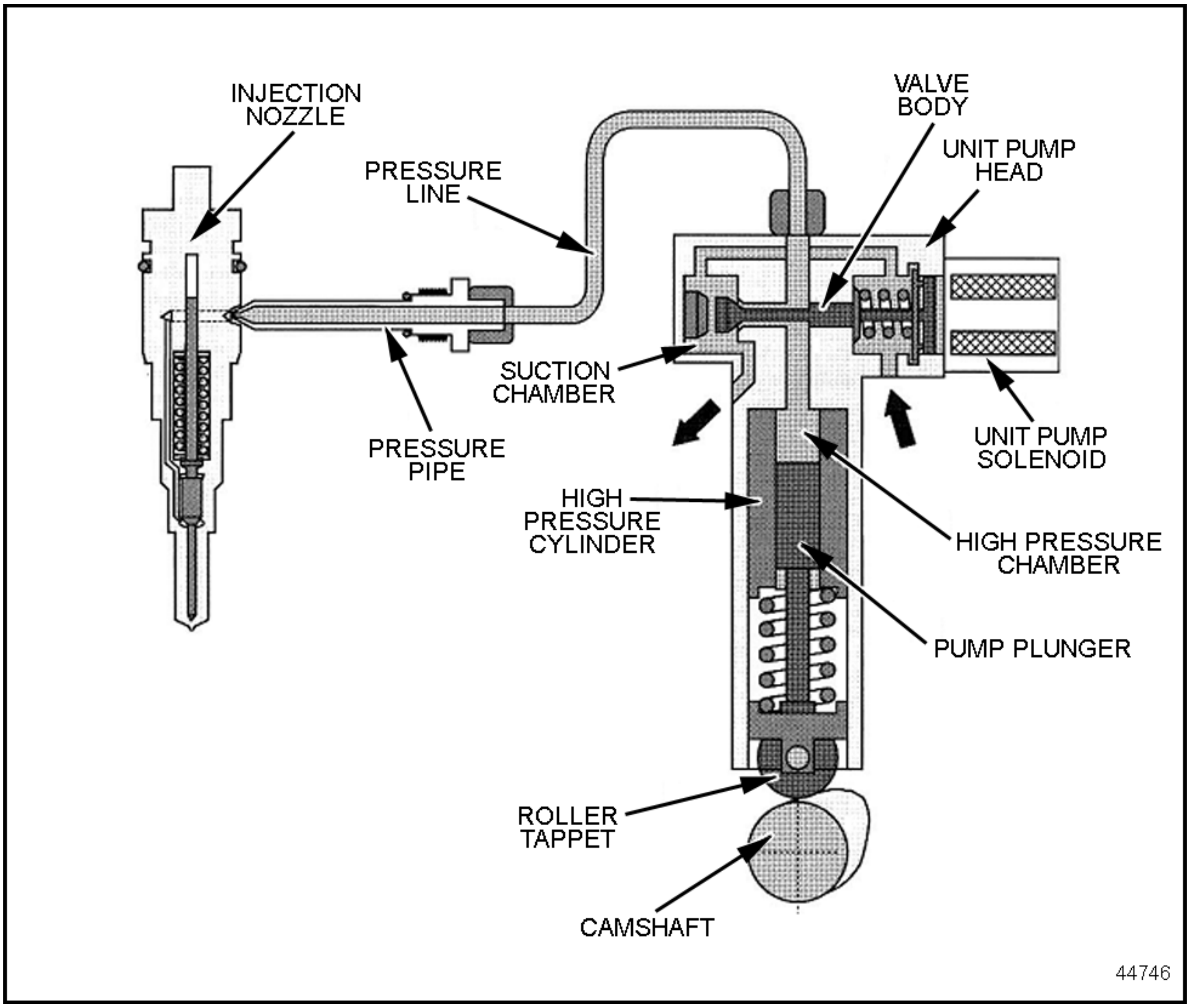

Figure 1-11 MBE 900 and MBE 4000 Unit Pump and Nozzle System

2 SAFETY

The service procedures recommended by Detroit Diesel Corporation and described in this Technicians 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 Detroit Diesel Corporation 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 for Detroit Diesel Corporation 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 following precautions 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.

2.1 GENERAL SAFETY PRECAUTIONS TO OBSERVE WHEN WORKING ON THE ENGINE

The following safety measures are essential when servicing the unit fuel injector and the unit injector pumps.

2.1.1 EXHAUST (START/RUN ENGINE)

Before starting and running the engine, adhere to the following safety precautions:

CAUTION:

EXHAUST FUMES

To avoid injury or injury to bystanders from fumes, engine or vehicle fuel system service operations should be performed in a well ventilated area.

WARNING:

PERSONAL INJURY

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

WARNING: **PERSONAL INJURY**
To avoid injury, never remove any engine component while the engine is running.

2.1.2 ITEMS UNDER TENSION

To avoid injury from an injector unit pump, do not completely loosen the mounting bolts if under tension. Before removing the unit pump, rotate the crankshaft to relieve the tension on the pump.

WARNING: **PERSONAL INJURY**
To avoid injury from an ejected injector unit pump, do not completely loosen the mounting bolts until you have tested the spring tension. If the spring tension is at maximum and you remove the mounting cap screws, the pump will be ejected from the engine crankcase.

WARNING: **EYE INJURY**
To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

2.1.3 WORK PLACE

To avoid injury from slipping and falling, organize your work area and keep it clean.

WARNING:

PERSONAL INJURY

To avoid injury from slipping and falling, immediately clean up any spilled liquids.

Eliminate the possibility of a fall by:

- Wiping up oil spills
- Keeping tools and parts off the floor

A fall could result in a serious injury.

2.1.4 FLUIDS AND PRESSURE

Be extremely careful with fluids under pressure.

WARNING:

FIRE AND TOXICITY

Some pressurized fluid may be trapped in the system. To avoid personal injury, loosen all connections slowly to avoid contact with fluid. When required, spray fluid into a proper container. The engine starting fluid used in DDEC Ether Start Systems contains extremely flammable and toxic substances.

WARNING:

PERSONAL INJURY

To avoid injury from penetrating fluids, do not put your hands in front of fluid under pressure. Fluids under pressure can penetrate skin and clothing.

Fluids under pressure can have enough force to penetrate the skin. These fluids can infect a minor cut or opening in the skin. If injured by escaping fluid, see a doctor at once. Serious infection or reaction can result without immediate medical treatment.

2.1.5 GLASSES

Select appropriate safety glasses for the job. It is especially important to wear safety glasses when using tools such as hammers, chisels, pullers or punches.

CAUTION:

EYE INJURY

To avoid injury from flying debris, wear a face shield or goggles.

2.1.6 FIRE

Keep a charged fire extinguisher within reach. Be sure you have the correct type of extinguisher for the situation. The correct fire extinguisher types are listed in Table 2-1.

Fire Extinguisher	Work Environment
Type A	Wood, Paper, Textile and Rubbish
Type B	Flammable Liquids
Type C	Electrical Equipment

Table 2-1 The Correct Type of Fire Extinguisher

WARNING:

FIRE

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not smoke or allow open flames when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

2.1.7 BATTERIES

Electrical storage batteries give off highly flammable hydrogen gas when charging and continue to do so for some time after receiving a steady charge.

WARNING:

Battery Explosion and Acid Burn

To avoid injury from battery explosion or contact with battery acid, work in a well ventilated area, wear protective clothing, and avoid sparks or flames near the battery. If you come in contact with battery acid:

- ☐ **Flush your skin with water.**
- ☐ **Apply baking soda or lime to help neutralize the acid.**
- ☐ **Flush your eyes with water.**
- ☐ **Get medical attention immediately.**

Always disconnect the battery cable before working the engine.

2.1.8 CLOTHING

Make sure that safe work clothing fits and it is in good condition. Use work shoes that are sturdy and rough soled. Bare feet, sandals or sneakers are not acceptable foot wear when adjusting and/or servicing an engine. Do not wear rings, wrist watches, bracelets, necklaces and loose fitting clothing that could catch on moving parts causing serious injury.

WARNING:

PERSONAL INJURY

To avoid injury when working near or on an operating engine, remove loose items of clothing and jewelry. Tie back or contain long hair that could be caught in any moving part causing injury.

WARNING:

PERSONAL INJURY

To avoid injury when working on or near an operating engine, wear protective clothing, eye protection, and hearing protection.

2.1.9 AIR

Observe the following caution when using compressed air.

WARNING:

EYE INJURY

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

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3 INSPECTION AND REMOVAL OF SYSTEMS

This section covers the inspection and removal of the EUI in the Series50/60 and the removal of the Injection Unit Pump in the MBE engines.

3.1 SERIES 50/60 UNIT INJECTOR INSPECTION/REMOVAL

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.
2. Clean EUI (See current *Series 60* service manual (6SE483) or *Series 50* service manual (6SE50) for proper procedure).
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. See Section 6.
4. The only serviceable items are the Injector Follower Spring and O-rings.
5. Replace and install new or remanufactured injector if required.

Follow the service manual procedures to remove the unit injector:

1. Clean the valve rocker cover around its seat on the head, and in the attaching bolt recesses.
2. 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.
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. Remove unit injector terminals from solenoid, or if N3 injector, disconnect the wiring connector.
5. Lift the injector from its seat in the cylinder head by inserting a pry bar under the injector body.

NOTE:
For current information on removal and installation, refer to the *MBE 900* service manual (6SE414).

3.2 MBE 900 UNIT PUMP INSPECTION/REMOVAL

To determine if the unit pump and nozzle are not functioning properly and need to be replaced, follow this procedure:

1. Drain fuel system and remove unit pump. If necessary, remove nozzle.
2. Wipe oil off unit pump.
3. Inspect unit pump and nozzle for leaks, turned O-rings, seized pump, cracked body, or failed/blown spray nozzle.

Folow the service manual procedures to remove the unit pump:

1. Remove engine trim cover.
2. Remove the end cover from the lower right side of the flywheel housing, then attach the engine barring tool (J-46392).
3. Remove the fuel injection line.
4. Disconnect the engine wiring harness from each injector unit pump to be removed.
5. Carefully loosen the injector unit pump mounting bolts.
6. Check the spring tension on the injector unit pump by pushing down on it. If you cannot push down on the injector pump manually, the spring tension is at the maximum. You must decrease the spring tension on the injector pump before removing it.
7. Using the barring tool (J-46392), rotate the crankshaft until the spring tension decreases enough to push the injector pump down manually.
8. Remove the mounting bolts from the injector unit pump.
9. Using the barring tool, rotate the crankshaft until the camshaft lifts the injector unit pump.
10. If the injector unit pump does not come out easily, use the injector/unit pump puller tool (J-46375) to remove it.
11. Thread the impact extractor (J-46393) onto the top of the injector unit pump, where the injection line was installed.
12. Pull the injector unit pump out by using the slide hammer on the impact extractor. Do not use excessive force that could damage the threads on the injector unit pump fuel line connection.

If nozzle and holder needs to be removed, follow this procedure:

NOTE:
Do not attempt to take apart the nozzle holder. If there is a problem, replace the nozzle holder.

1. Remove the engine trim panel and cylinder head cover.
2. Remove the injection line using injection line socket (J-46371).
3. Remove the transfer tube. Discard the old O-ring.

4. Remove the tensioning arm.
5. Attach the adapter tool J-46384 and impact extractor tool (J-46375). Thread the narrow end of the adaptor onto the internal threading in the head of the nozzle holder. Thread the impact extractor onto the wide end of the adaptor.
6. Using the impact extractor, pull out the nozzle holder.
7. Take the heat isolator off the nozzle holder.

NOTE:
For current information on removal and installation of unit pumps or nozzles, refer to the *MBE 900* service manual (6SE414) or *MBE 4000* service manual (6SE412).

3.3 MBE 4000 UNIT PUMP INSPECTION/REMOVAL

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

1. Drain fuel system and remove unit pump. If necessary, remove nozzle.
2. Wipe oil off unit pump.
3. Inspect unit pump and nozzle for leaks, turned O-rings, seized pump, cracked body, or failed/ blown spray nozzle.

Follow the service manual procedure to remove the unit pump:

1. Remove the engine trim cover.
2. Unscrew the fuel filter cap.
3. Disconnect the engine wiring harness from the injector unit pump.
4. Remove the high-pressure fuel injector line.
5. Disconnect the fuel line at the fuel gallery inlet. Use suitable container to catch any fuel that comes out of the cylinder block or fuel line.
6. Drain the fuel from the engine through the fuel gallery outlet on the return lines.
7. Remove the end cover from the lower right side of the flywheel housing, then attach the engine cranking tool (J-46167).
8. Carefully loosen the injector unit pump mounting bolts about 6 mm (0.25 inch), but do not remove them yet.
9. Using the cranking tool number (J-46167), rotate the crankshaft until the cam pushes the unit pump upwards.
10. Remove mounting bolts and carefully pull unit out of cylinder block. Discard O-rings.

NOTE:
If the injector unit pump is locked up, or frozen in its seat, release it using the blade of a small screwdriver on the flange where the mounting bolt attaches.

If nozzle and holder needs to be removed, follow this procedure:

NOTE:
Do not attempt to take apart the nozzle. If there is a problem, replace the nozzle.

1. Remove the engine trim cover and cylinder head cover for each cylinder head.
2. Remove the charge-air manifold.
3. Remove the injector line.
4. Remove the thrust bolt and the transfer tube. Discard the old O-ring.
5. Remove the tensioning arm.
6. Attach the impact extractor tool (J-46375) and adaptor tool (J-46384). Thread the narrow end of the adaptor onto the internal M8 threading in the head of the nozzle. Thread the impact extractor onto the wide end of the adaptor.
7. Using the impact extractor tool (J-46375), remove the nozzle from the cylinder head. Discard the O-ring and seal ring.
8. Cap off or cover the openings in the fuel lines to prevent contamination of the fuel.

NOTE:
For current information on removal and installation of unit pump or nozzle, refer to *MBE 900* service manual (6SE414) or *MBE 4000* service manual (6SE412).

4 FUEL

Detroit Diesel engines are designed to operate satisfactorily on a wide range of diesel fuels.

4.1 FUEL ADDITIVES

The use of supplemental fuel additives is not required or recommended. Some additives may be beneficial in addressing temporary fuel quality problems, but should not replace proper fuel selection and handling. It has been shown that some additives increase operating costs without providing benefit. The use of these additives does not necessarily void the engine warranty. However, repair expenses which result from fuel system or engine component malfunctions or damage attributed to their use will not be covered. Detroit Diesel Corporation will not test or verify the performance of any supplemental additives and will not accept responsibility for use, selection or hazards relating to the use of such products.

Detroit Diesel Corporation specifically prohibits the use of drained lubricating oil in diesel fuel. Used lubricating oil contains combustion acids and particulate materials, which erode injector components, resulting in loss of power and increased exhaust emissions. In addition, the use of drained lubricating oil will increase maintenance requirements due to filter plugging and combustion deposits.

4.2 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 though the system. Bleeding the system can remove air. Consult the current service manual for the proper procedure.

4.3 FUEL CETANE NUMBER

The cetane number affects the time delay between the beginning of fuel injection and the start of combustion. In a cold engine, a low cetane number of below 40 causes hard starting, visible white smoke, poor fuel economy, and lack of power in cold ambient temperatures, until the engine warms up. In engines with charge air-cooling, a low cetane number fuel may also cause white exhaust smoke during light load operation.

The minimum cetane number specified for Detroit Diesel engines is 45. The primary benefits of a high cetane number are improved starting and smooth running when the engine is cold. The higher the cetane number of a diesel fuel, the shorter the lag time from when the fuel first enters the combustion chamber until it ignites. Diesel fuel with a cetane number above 45 will provide increased power and economy.

4.4 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.

Filter performance and test specifications vary between manufacturers. These specifications are general in nature and do not reflect the actual performance of genuine DDC *Power Guard*® filters. 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. Detroit Diesel specifies filter performance based on the optimum combination of filter micron rating, filter capacity and mechanical requirements.

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.

There is an optional filter called a Fuel Pro® filter that replaces the primary fuel filter. It consists of three major components: an aluminum fuel processor, filter element and clear cover. It is permanently mounted to the truck, typically in back of the cab where it can be easily seen. As fuel is drawn into the Fuel Pro filter processor, heavier dirt and water falls to the collection chamber in the bottom of the canister, where it can be purged through a manual drain valve. Fuel rises up out of the canister and passes through the 5-micron filter element and is discharged back into the fuel system. With the clear cover enclosing the filter element, it is easy for a driver or technician to see when the filter needs changing. There are two key advantages to this. First, unnecessary filter changes are eliminated, saving downtime and maintenance expense. Second, low power complaints related to restricted filters are quickly resolved.

By replacing the standard primary filter and changing the element only when necessary, the Fuel Pro can reduce filter usage by as much as 75%, as well as the hidden costs of downtime required to change them. Some fleets also request the optional thermostatically controlled heater, which warms fuel as it enters the processor and keeps fuel flowing for cold weather starts.

4.5 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.

4.6 FUEL SULFUR CONTENT

High sulfur content in fuel, above 0.05 mass percent (500 ppm), is not recommended for DDC engines equipped with EGR. If engines are operated with fuels not meeting the 500 ppm sulfur content limit, the drain intervals must be shortened. This can be determined by oil analysis or by using a drain interval table.

4.7 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.

4.8 FUEL WATER CONTAMINATION

The prevention of water in the fuel system is essential to optimize engine performance. Unit injector, unit 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 such as Biobor®JF (or equivalent) may be used. Follow the 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.

NOTE:
Refer to DDC publication 7SE270 for complete fuel-related information.

5 ELECTRONIC CONTROL SYSTEMS

Detroit Diesel Corporation has produced electronically controlled engines since the mid 1980's. Detroit Diesel Electronic Controls (DDEC®) manages the timing and amount of fuel injected into each cylinder. The system also monitors several engine functions using sensors that send signals to the electronic control module. DDEC V, the fifth generation electronic engine controller, offers improved engine control, improved engine protection, improved diagnostics, and a more extensive range of engine and vehicle operations.

DDEC offers state-of-the-art fuel management and economy, including compensation for changing environmental conditions and user preferences. The DDEC ECU provides engine monitoring as well as a stored summary of engine performance. Data can be extracted and analyzed with PC software products such as DDEC Reports, ProDriver® Reports, and Detroit Diesel Data Summaries. These products allow printing of comprehensive reports for managing vehicle operation.

Abbreviations and terms common to all DDEC versions are listed in Table 5-1.

The differences between DDEC V and older systems are listed in Table 5-2.

5.1 DDEC ABBREVIATIONS AND TERMS

Abbreviations and terms common to all DDEC versions:

Acronyms	Descriptions/Terms
BOI	Beginning of Injection: The number of crank angle degrees, before top-dead-center (TDC), where the ECU is requesting the injectors to be turned on
CEL	Check Engine Light
DDDL	Detroit Diesel Diagnostic Link: PC software package supporting DDEC
DDEC	Detroit Diesel Electronic Controls
DDEC III	Third generation Detroit Diesel Electronic Controls
DDEC IV	Fourth generation Detroit Diesel Electronic Controls
DDEC V	Fifth generation Detroit Diesel Electronic Controls
DDL	Diagnostic Data Link: The lines (wires) over which the ECU transmits information that can be read by a Diagnostic Data Reader
DDR	Diagnostic Data Reader: The hand held tool used for troubleshooting the DDEC system
DTC	Diagnostic Trouble Code
ECU	Electronic Control Unit
SFT Sensor	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

Table 5-1 DDEC Abbreviations and Terms

Former Acronyms	DDEC V
(ECM) Electronic Control Module	(ECU) Electronic Control Unit: It reads the engine and vehicle inputs, sensors and switches, calculates injector firing and duration, and fires injectors at appropriate times
(EFPA) Electronic Foot Pedal Assembly	(AP) Accelerator Pedal: Contains the throttle position sensor
(LSG) Limiting Speed Governor	(ALSG) Automotive Limiting Speed Governor
(TPS) Throttle Position Sensor	(AP Sensor) Accelerator Pedal Sensor: Used to detect throttle request.

Table 5-2 Differences Between DDEC V and Older System Terminology

5.2 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® Diagnostic Data Reader (DDR).

5.2.1 RETRIEVING AND CLEARING CODES

Start with the Menu Selection screen, on the DDR:

1. To call up active codes, select ENGINE and ENTER three times.
2. To call up inactive codes:
   - [a] Select ENGINE and ENTER twice.
   - [b] Select INACTIVE CODES and ENTER.
3. To clear codes:
   - [a] Select ENGINE and push ENTER twice.
   - [b] Go down and select CLEAR CODES and ENTER.
   - [c] Left to YES, and ENTER.
   - [d] Wait and then push FUNC three times.

[e] Go to lines 1 and 2 of the Engine Data List, Active and Inactive Codes, and verify that both lines display NO.

5.2.2 UNIT INJECTOR CALIBRATION UPDATE

The unit injector calibration update function is a setting in the ECU that is used to improve product performance, and cylinder balancing. This is set to improve performance or whenever an injector is changed. The calibration code is located on a metal plate on top of the solenoid on the N2 unit injector and on top of the electrical connector of the N3.

To update the injector calibration, start with the Menu Selection screen:

1. Select ENGINE and ENTER.
2. Go down to FUEL INJECTOR INFO and ENTER.
3. Go down to CAL UPDATE and ENTER.
4. Select VIEW and ENTER or select UPDATE and ENTER.
5. Enter password: 0000 or xxxx and ENTER twice.
6. Enter new CAL # and ENTER. Use UP/DN arrow keys to select line.
7. When finished, select FUNC, select YES, ENTER and wait.
8. ENTER to continue.

5.2.3 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.

To generate a snapshot, start with the Menu Selection screen:

1. Select PRO-LINK and ENTER.
2. Go up to SNAPSHOT and ENTER.
3. Go down to DATA UPDATE RATE and ENTER.
4. Type in NEW RATE and ENTER (0.0 to 9.9 seconds), (90 frames will be recorded.)
5. Go up to TRIGGER SOURCE and ENTER:
   [a] Any Numeric Key
   [b] Any code
   [c] Specific PID
   [d] Specific SID
6. Select TRIGGER SOURCE and ENTER.

7. Adjust TRIGGER POINT: NO, or select YES and ENTER; change trigger point with RT/LT arrow keys and ENTER.
8. WAITING FOR TRIGGER. When ready to take SNAPSHOT, apply the trigger. ANY NUMERIC KEY overrides all other triggers.
9. PROCESSING TRIGGER; Filling remaining frames (90 frames Max). When all frames are filled, the first three lines of the TRIGGER FRAME, “T” will display.
   - [a] To do SNAPSHOT after setup is done, do items 1, 2, and 8 only, or go to QUICK TRIGGER and ENTER.
   - [b] SNAPSHOT DATA stays stored in Pro-Link memory as long as the DDR remains powered up.

5.3 DDEC FOR MBE 900 AND MBE 4000 ENGINES

The MBE system has the same functions and options as the DDEC system, but it utilizes two control systems. The control systems consist of an engine resident pump and nozzle control unit, the DDEC-ECU and the DDEC- vehicle control unit (VCU). The two are connected by a proprietary datalink. The DDEC-ECU monitors and determines all values which are required for the operation of the engine. The DDEC-VCU monitors the vehicle systems. Within the VCU, sets of data for specific applications are stored. These include idle speed, maximum running speed, and speed limitation. The VCU receives data from the operator (accelerator pedal position, switches, various sensors) and other electronic control units (for example, the anti-lock brake system, transmission controllers, etc.). From this data instructions are computed for controlling the engine and transmitted to the DDEC-ECU via the proprietary datalink.

5.4 FUEL-RELATED ELECTRONIC FAULT CODES

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

5.4.1 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. Refer to *MBE 900* service manual (6SE414) or *MBE 4000* service manual (6SE412) for complete testing procedures.

This diagnostic condition is typically:

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

5.4.2 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. Refer to *MBE 900* service manual (6SE414) or *MBE 4000* service manual (6SE412) for complete testing procedures.

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

5.4.3 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 164-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 *MBE 900* service manual (6SE414) or *MBE 4000* service manual (6SE412) for complete testing procedures.

5.4.4 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 106-FMI 1, air inlet pressure low, and PID 164-FMI 1, injection control pressure low. Refer to *MBE 900* service manual (6SE414) or *MBE 4000* service manual (6SE412) for complete testing procedures.

This diagnostic condition is typically:

- Plugged fuel filter
- Low fuel supply

5.4.5 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 87°F (30°C). 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 ± 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.).

5.4.6 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 001/1, 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

5.4.7 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 174-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 174-FMI 1 is a fuel temperature below range. Indicates the fuel temperature fell below a calibrated range. No troubleshooting is suggested.

6 FAILURE MODES

This section explains failures relating to Series 50/60 unit injectors. The failures are addressed as: a complaint, cause, correction, and recommendation. These failures are accompanied with a picture to help in diagnosing the failure.

The failures explained in this section are:

- ☐ Seized unit injector (refer to section 6.2)
- ☐ Broken injector follower spring and damaged stator with broken stator screws (refer to section 6.3)
- ☐ Loose stop plate screw (refer to section 6.4)
- ☐ Missing stop plate screw (refer to section 6.5)
- ☐ Cracked injector body (refer to section 6.6)
- ☐ Broken solenoid terminal screws (refer to section 6.7)
- ☐ Failed/brown spray tip (refer to section 6.8)
- ☐ Low pressure plug conditions (refer to section 6.9)
- ☐ High pressure plug condition (refer to section 6.10)
- ☐ Black or gray smoke condition (refer to section 6.11)
- ☐ White smoke condition (refer to section 6.12)

6.1 NORMAL INJECTOR

For a normal injector, see Figure 6-1.

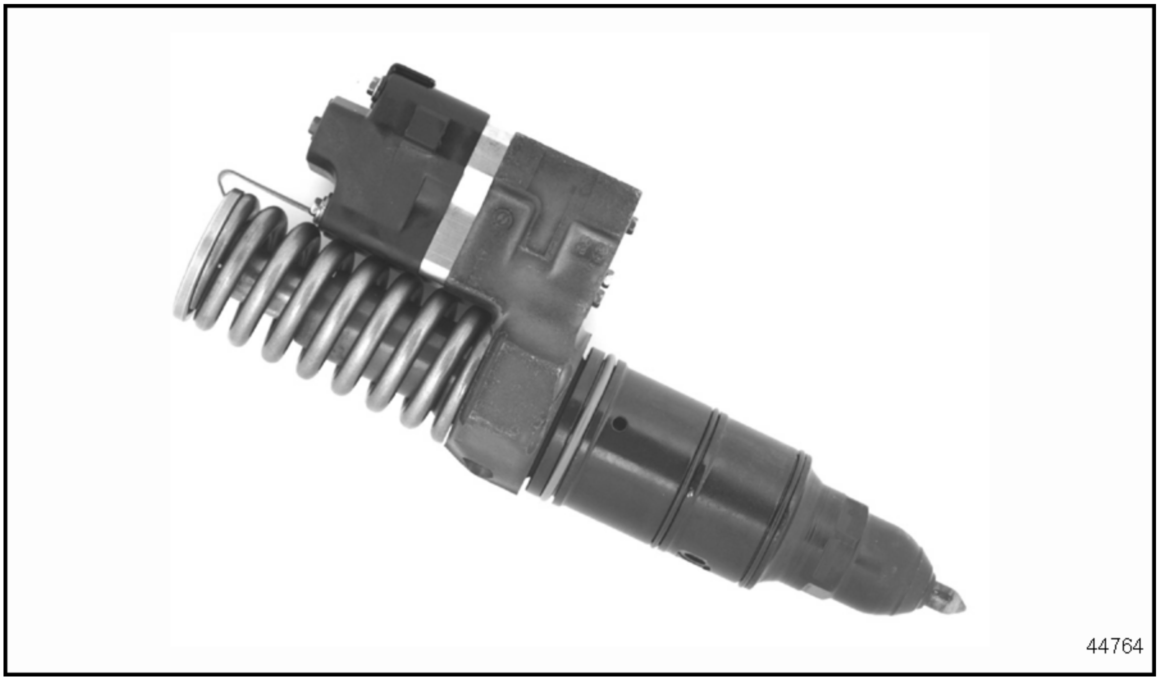

Figure 6-1 Normal Injector – No Failure

6.2 SEIZED INJECTOR

For a seized injector, see Figure 6-2.

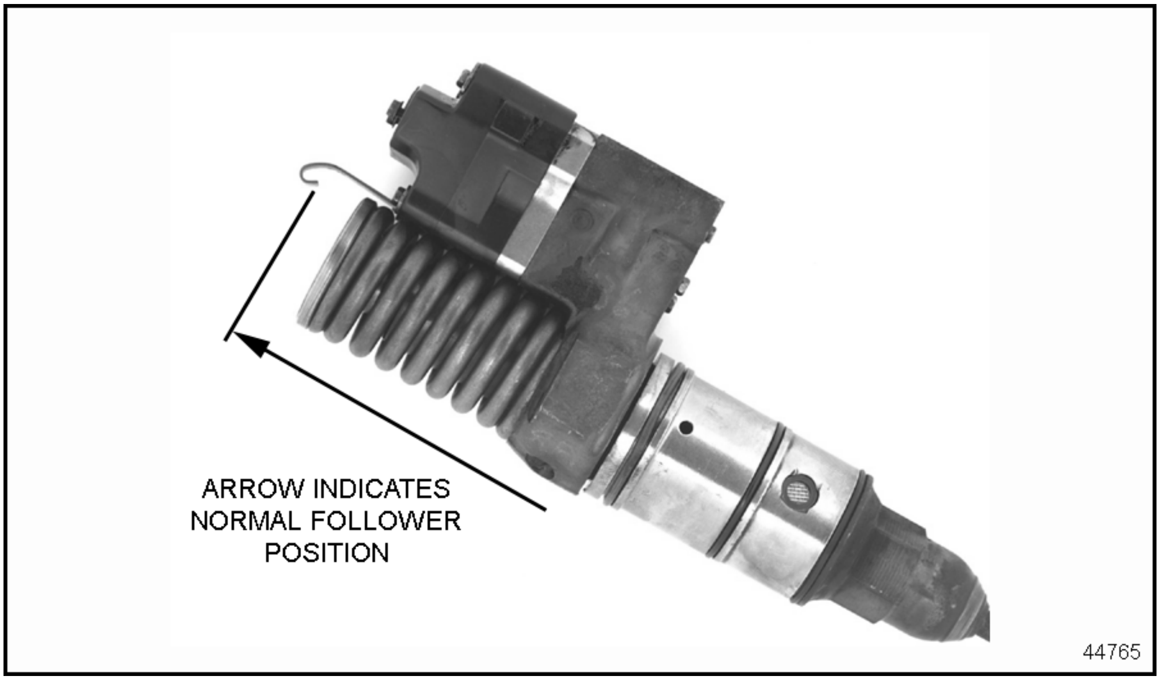

Figure 6-2 Seized Injector Failure

COMPLAINT: Misfire, Noisy (slapping), erratic running.

CAUSE: Plunger seized, incorrect plunger/body match (failure with less than 1,000 miles, suggests contamination in fuel system).

CORRECTION: Replace unit injector

RECOMMENDATION: Check fuel quality for water in fuel. Check fuel temperature.

6.3 BROKEN INJECTOR FOLLOWER SPRING AND DAMAGED STATOR WITH BROKEN STATOR SCREWS

For a broken injector follower spring and damaged stator with broken stator screws, see Figure 6-3.

Figure 6-3 Broken Injector Follower Spring And Damaged Stator With Broken Stator Screws Failure

COMPLAINT: Slapping or rapping noise and/or fuel in oil.

CAUSE: Injector follower spring failure.

CORRECTION: Replace spring, using kit number 23528939 and publication number 18SP532 (only applies to old series 60 injector, not N3). If stator is damaged, replace unit injector.

RECOMMENDATION: Check the springs in the remaining injectors.

6.4 LOOSE STOP PLATE SCREW

For a loose stop plate screw, see Figure 6-4.

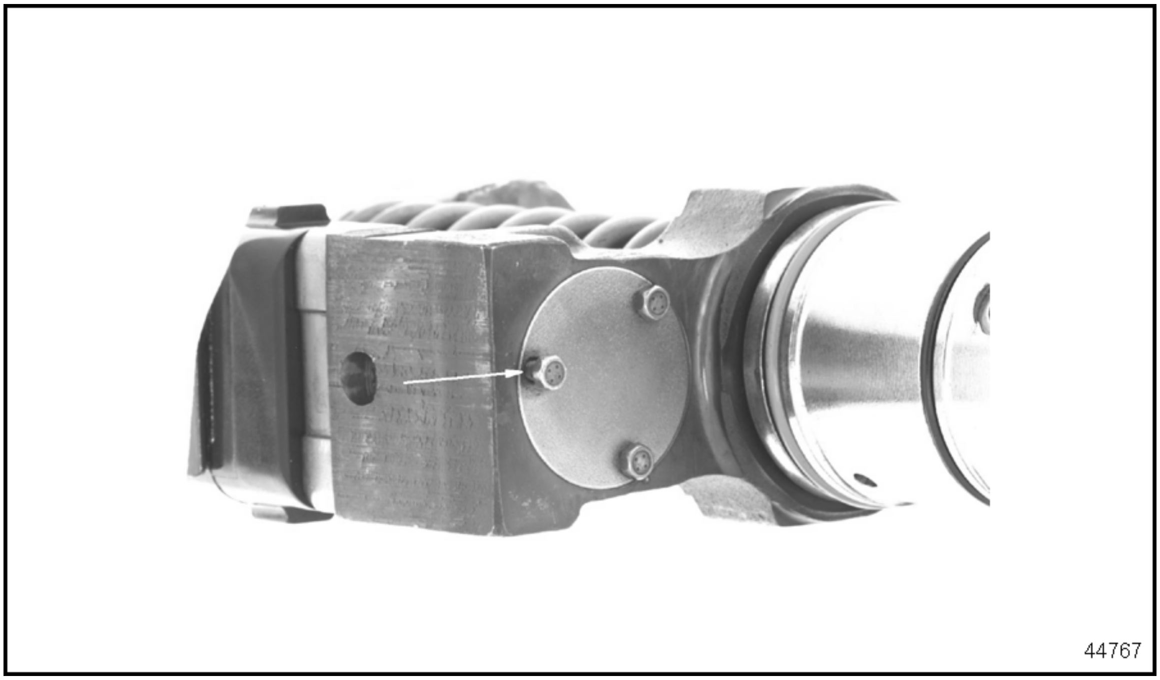

Figure 6-4 Loose Stop Plate Screw Failure

COMPLAINT: Fuel in Oil.

CAUSE: Pinched O-ring under torqued screw, backed out stop plate screw.

CORRECTION: Replace unit injector.

RECOMMENDATION: Check remaining injector stop plate screws if injectors are original installation.

6.5 MISSING STOP PLATE SCREW

For a missing stop plate screw, see Figure 6-5.

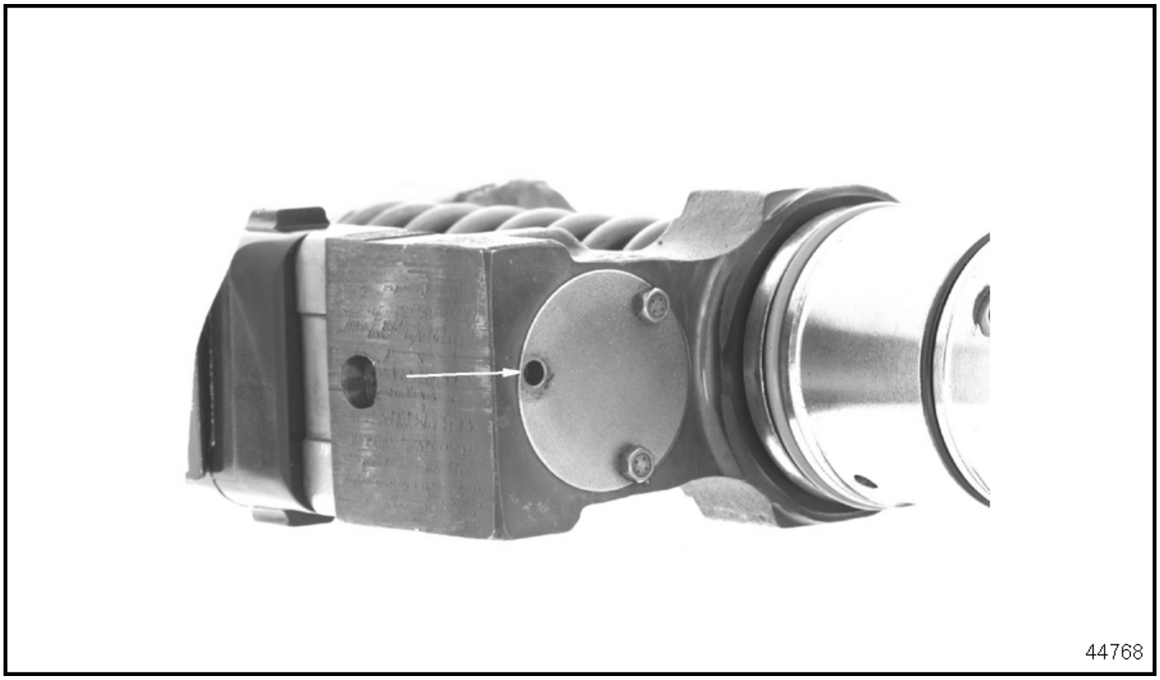

Figure 6-5 Missing Stop Plate Screw Failure

COMPLAINT: Fuel in oil.

CAUSE: Pinched O-ring under torqued screw, stop plate screw missing.

CORRECTION: Replace unit injector.

RECOMMENDATION: Check remaining injector stop plate screws if injectors are original installation.

6.6 CRACKED INJECTOR BODY FAILURE

For a cracked injector body failure, see Figure 6-6.

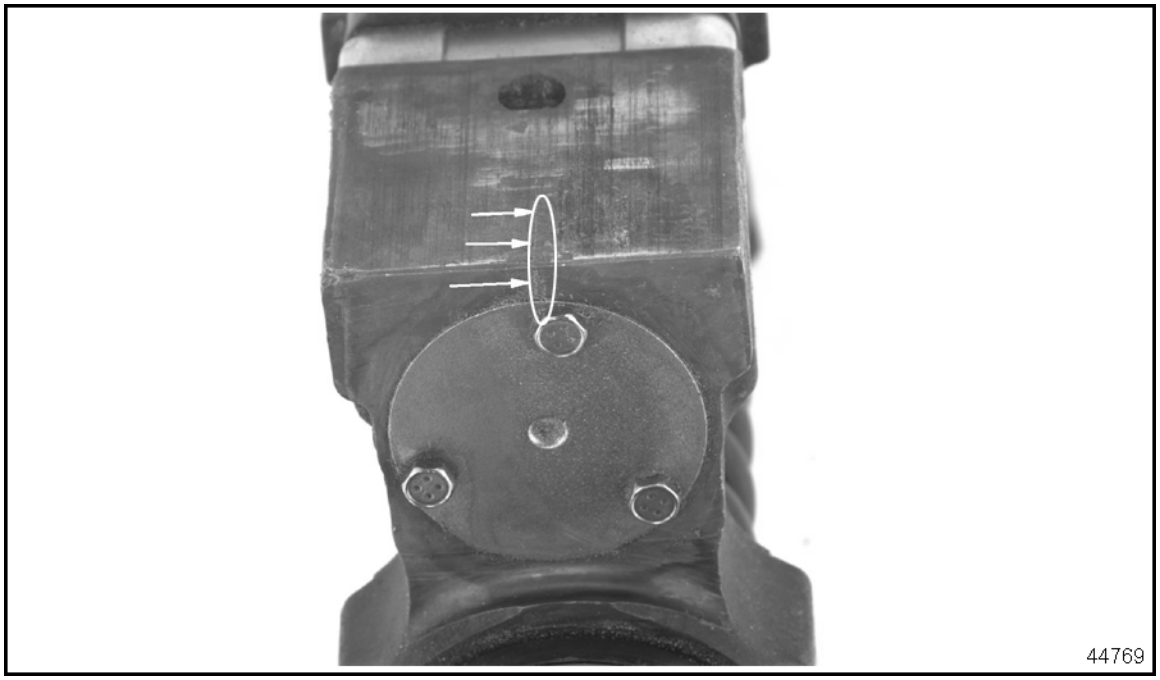

Figure 6-6 Cracked Injector Body Failure

COMPLAINT: Fuel in oil.

CAUSE: Fatigue, excessive pressure.

CORRECTION: Replace Unit Injector.

RECOMMENDATION: Check remaining injectors for cracks, if injectors are original installation.

NOTE:
Body cracks are difficult to detect in the field. They normally occur as shown in photograph above. If body crack is suspected, **REMOVE** injector and use brake or contact cleaner to aid in the detection of this condition.

6.7 BROKEN SOLENOID TERMINAL SCREW FAILURE

For a broken solenoid terminal screw failure, see Figure 6-7.

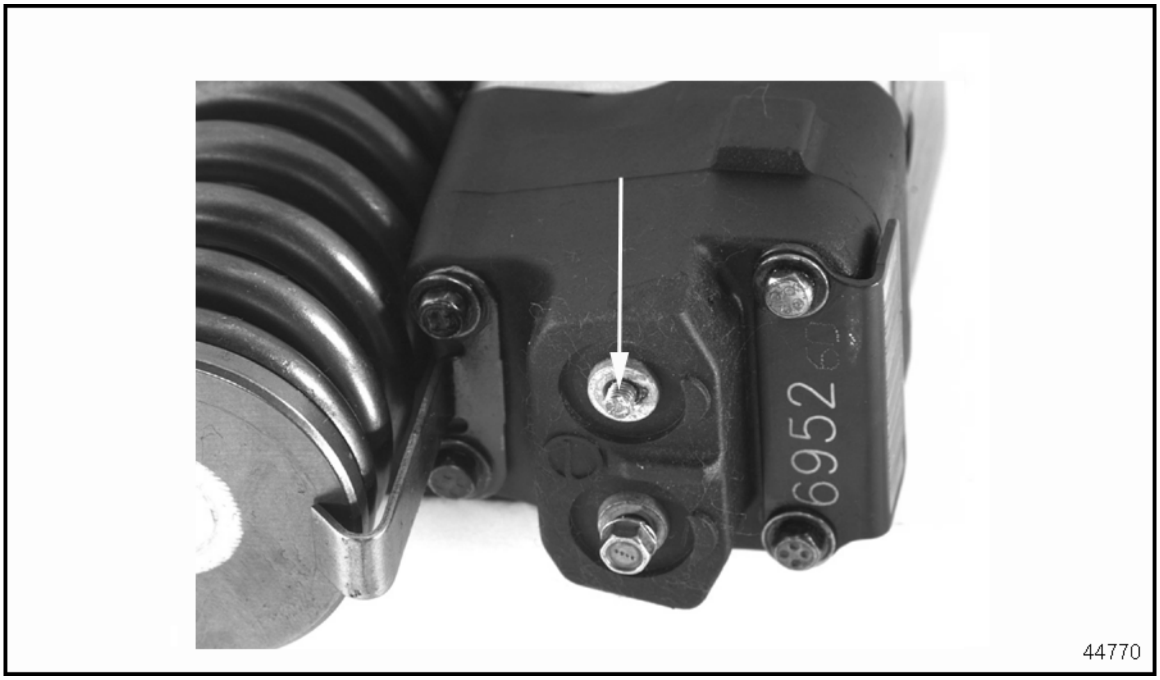

Figure 6-7 Broken Solenoid Terminal Screw Failure

COMPLAINT: Misfire, erratic running.

CAUSE: Over-torquing screw at installation.

CORRECTION: Replace unit injector.

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

6.8 FAILED OR BLOWN SPRAY TIP FAILURE

For a failed or blown tip failure, see Figure 6-8.

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Figure 6-8 Failed or Blown Spray Tip Failure

COMPLAINT: Black smoke, low horsepower, misfire, erratic running.

CAUSE: Handling damage, water in fuel, dropped intake or exhaust valve, fatigue.

CORRECTION: Replace unit injector.

RECOMMENDATION: If fuel is contaminated with water, check remaining injectors for damage.

6.9 LOW PRESSURE PLUG LEAK

For a low pressure plug failure, see Figure 6-9.

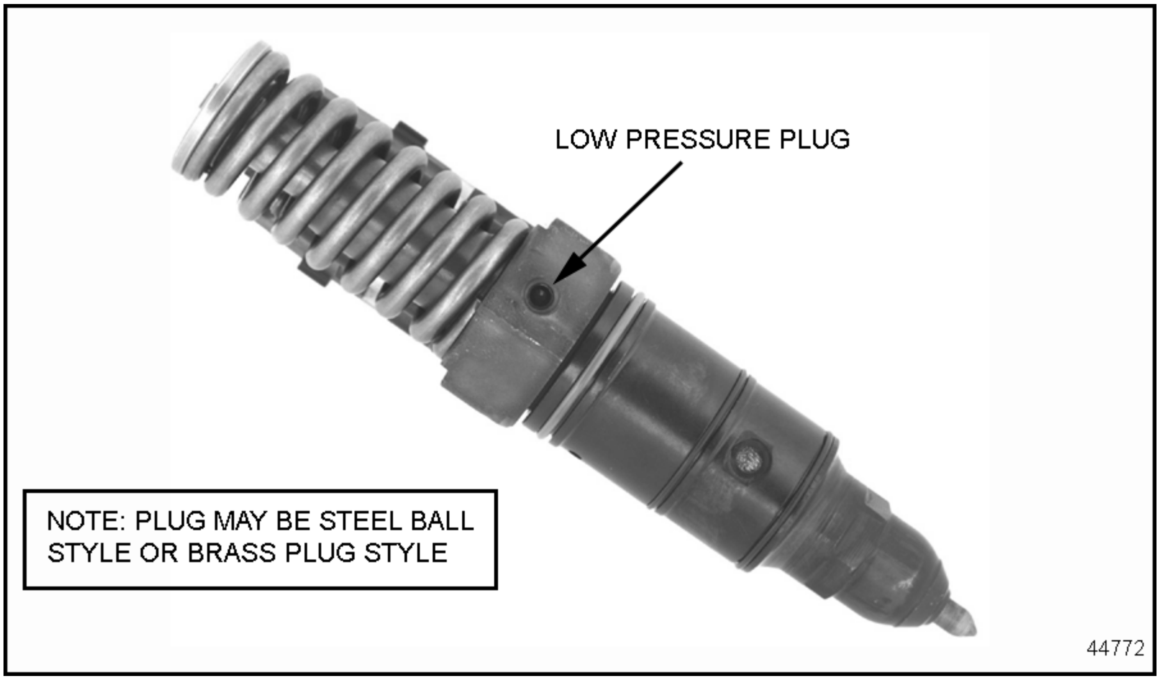

Figure 6-9 Low Pressure Plug Leak

COMPLAINT: Fuel in oil.

CAUSE: Fatigue, bad braze.

CORRECTION: Replace Unit Injector.

RECOMMENDATION: Check remaining injectors for correct pressure and leaking at plugs using a pop ‘n’ fixture, tool number J-34760-A.

6.10 HIGH PRESSURE PLUG LEAK

For a high pressure plug failure, see Figure 6-10.

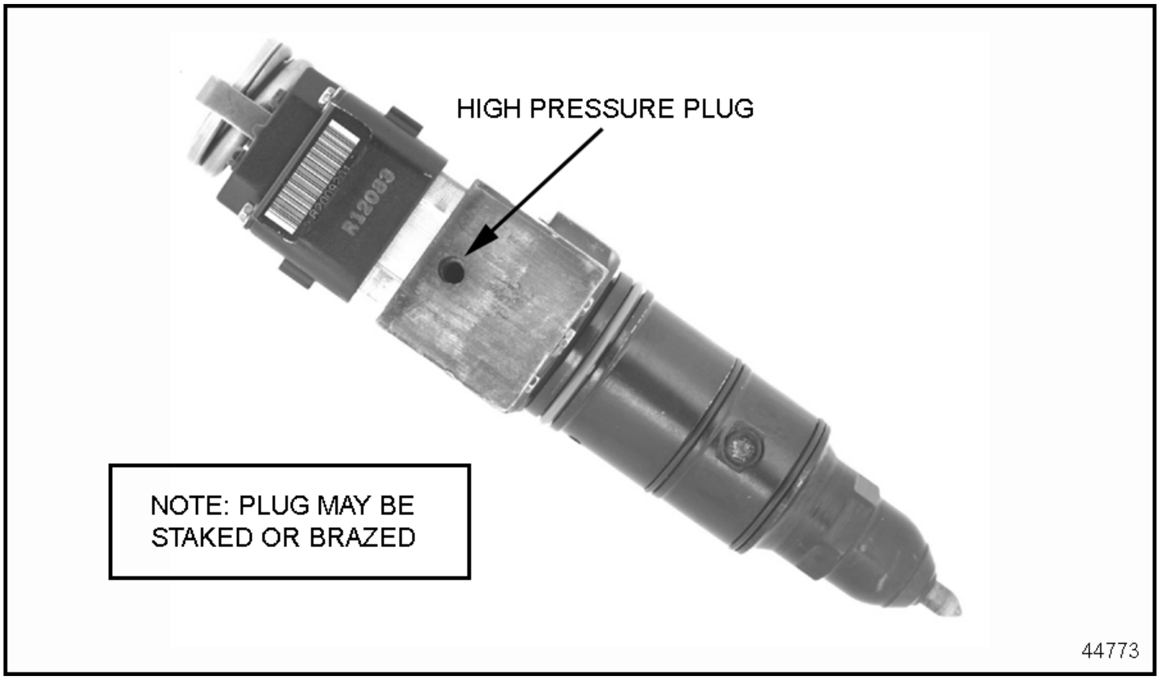

Figure 6-10 High Pressure Plug Leak

COMPLAINT: Fuel in oil.

CAUSE: Fatigue, bad braze.

CORRECTION: Replace Unit Injector.

RECOMMENDATION: Check remaining injectors for correct pressure using a pop ‘n’ fixture, tool number J-34760-A and for leaking or absence of plugs.

6.11 BLACK OR GRAY SMOKE PROBLEM

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] Refill the fuel oil tanks with new fuel oil having a cetane number greater than 45.
   - [c] Test operation.

A faulty fuel injector, such as a blown or plugged nozzle, can cause black smoke. Follow procedures in testing section and in *Series 60* service manual (6SE483) or *Series 50* service manual (6SE50) to check.

6.12 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 having a cetane number greater than 45.
   - [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.
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, see *Series 60* service manual (6SE483) or *Series 50* service manual (6SE50) 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.

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7 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 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 thicker and has a bright orange color; the middle and bottom O-rings are black and are the same thickness. See Figure 7-1.

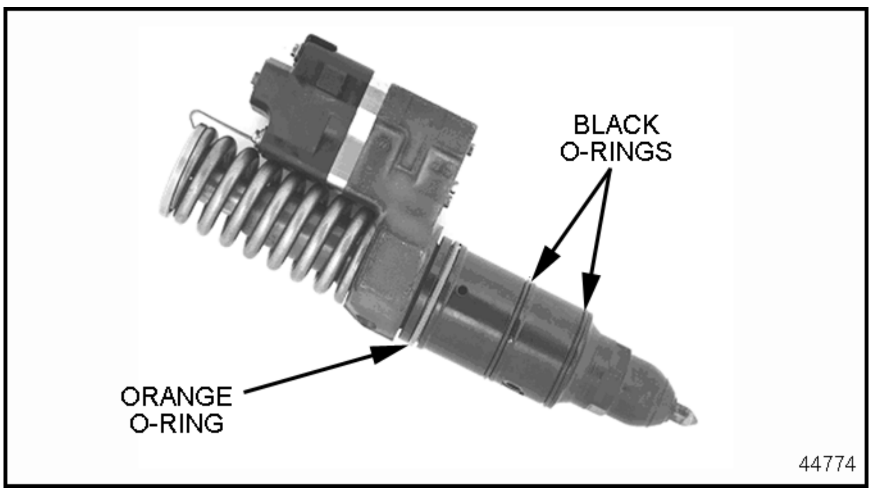

Figure 7-1 O-rings – N2 Injector

On the Series 50/60 N3, the top O-ring is orange, the middle O-ring is purple, and the bottom O-ring is blue. See Figure 7-2.

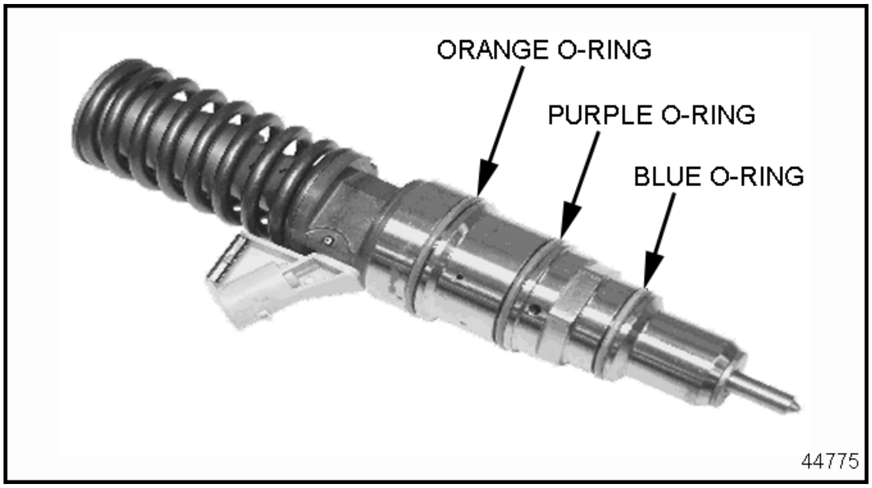

Figure 7-2 O-rings – N3 Injector

8 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.

8.1 SERIES 50/60 DDEC CYLINDER CUTOUT TEST

If a driver complains about cylinder miss and low power on a Series 50 or Series 60 engine, run a cylinder cutout test to identify the suspect injector. A cylinder cutout test may be run with either a Pro-Link reader or the Detroit Diesel Diagnostic Link (DDDL) PC software program. For current test steps, please refer to *Series 60* service manual (6SE483) or *Series 50* service manual (6SE50). Test options include an automatic test (all cylinders are automatically cutout in sequence) or a manual test (you can identify and cutout specific cylinders manually). This option is very helpful with a suspected injector. If the technician sees that there is a concern with #2 cylinder for example, swap injectors with a non-suspect injector. If the readings also change, then the injector is faulty. If it does not, then the injector is working properly. You may also choose to run the test at idle (1000 rpm recommended), or at free idle (manual setting via the cruise control switch or foot pedal). In this example, the automatic test at 1000 rpm is selected. After selecting the test parameters, start the test using DDDL. As the test begins you will see this screen, shown in figure 8-1.

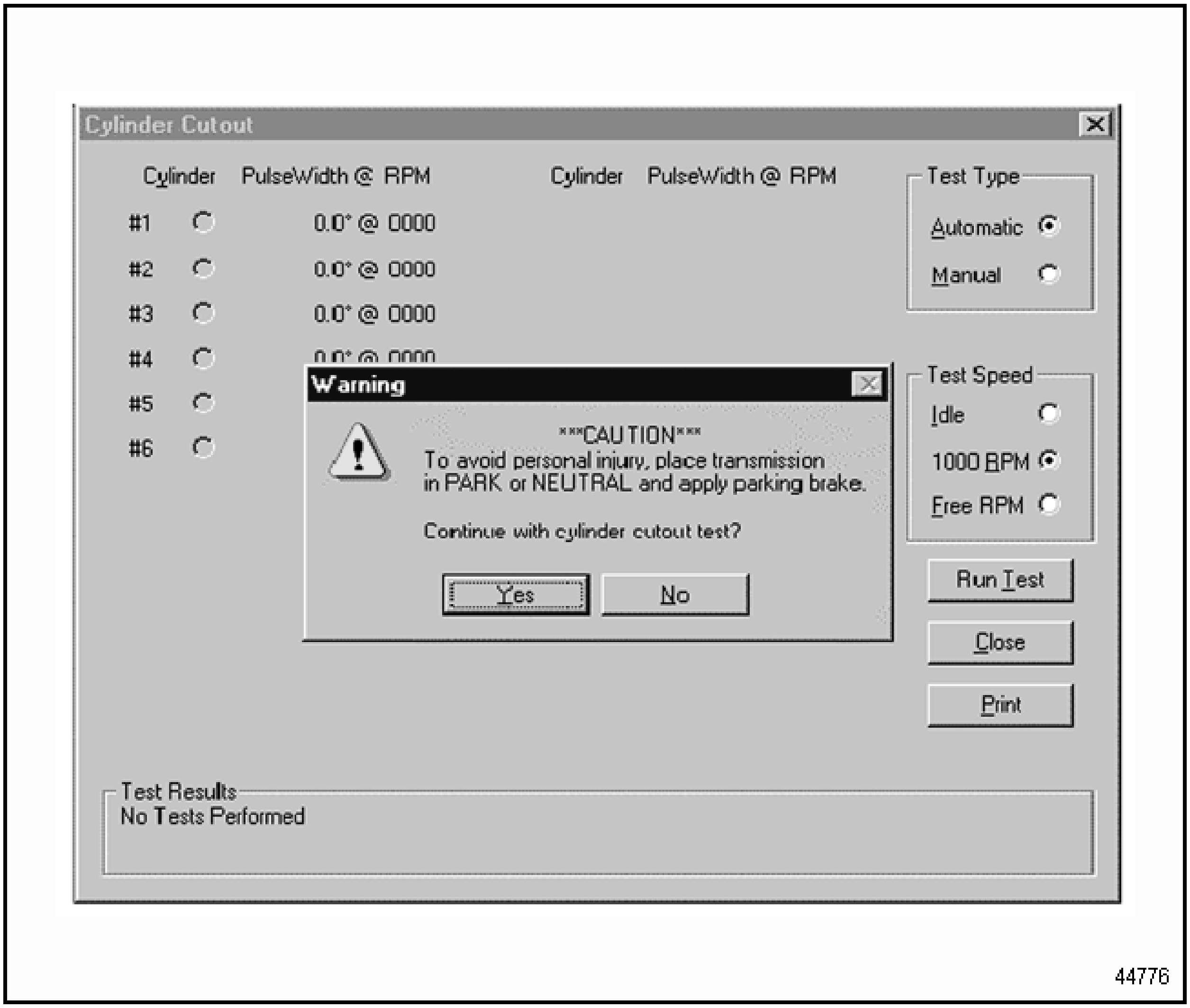

Figure 8-1 Cylinder Cutout Start-Up Display

The engine should be at operating temperature before any cylinder cutout test is run. The first operation of this test will establish a baseline pulse width. The baseline pulse width is the pulse width being reported under the assumption all cylinders in the engine are firing. The program now begins to cut out each cylinder sequentially and record the new pulse width value with the engine performing on one less than the full number of cylinders. Because the engine is trying to maintain the same level of power output with one less cylinder active, the active cylinders will each get more fuel and a higher pulse width value will be recorded. The DDDL screen, shown in figure 8-2, shows the results.

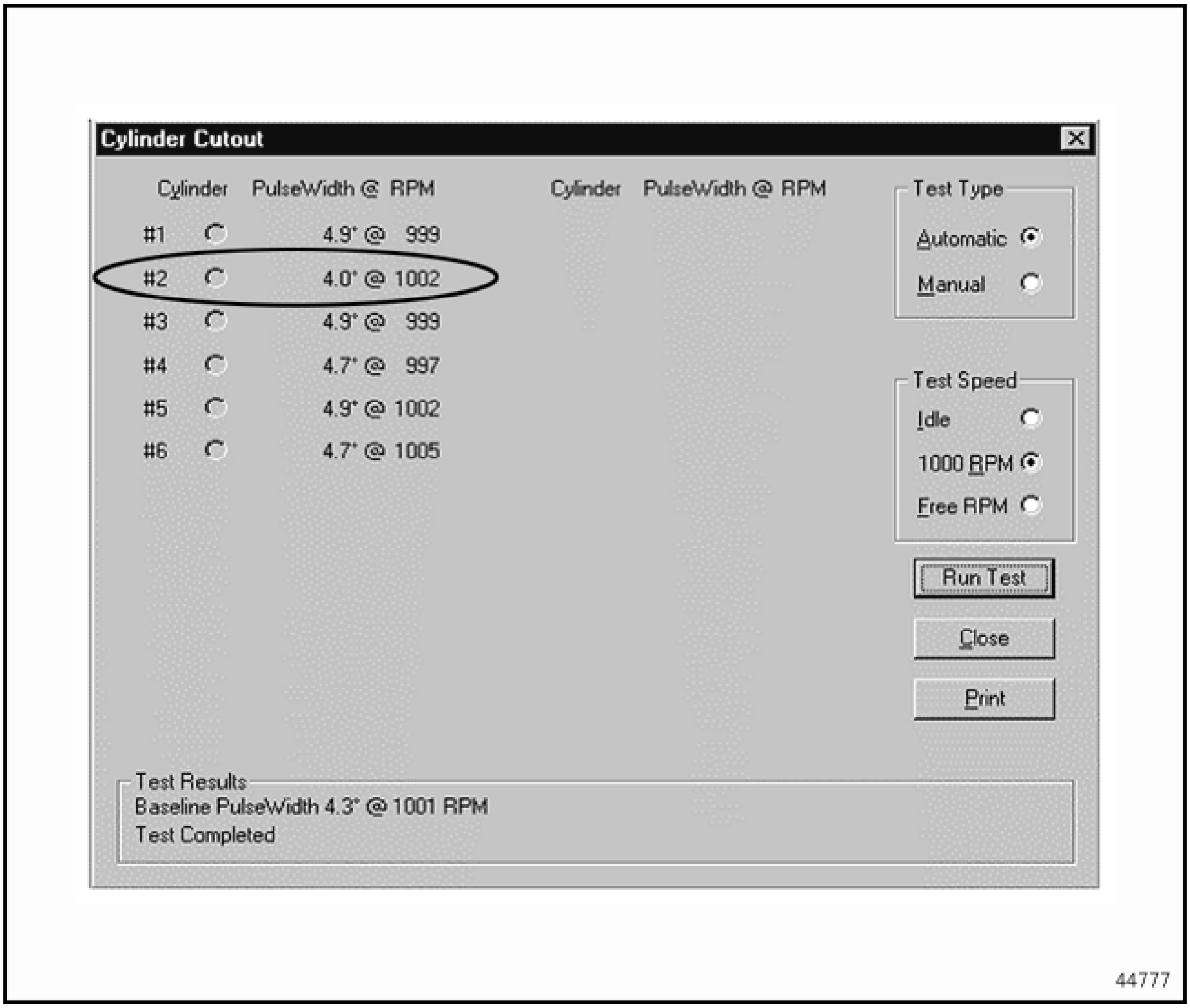

Figure 8-2 Results of a Cylinder Cutout Test

You will notice that there has been a significant jump in the pulse width values of each cylinder except cylinder #2. This suggests that the baseline pulse width was actually measuring the pulse width of the engine when it was performing with five cylinders operating correctly. When each of the cylinders was cut out, the new pulse width recorded was actually reflecting the data with four cylinders running. The pulse width recorded when cylinder two was cut out remained essentially the same or even slightly below the baseline because this cylinder has a problem and was not contributing to engine output at the base line.

Under MISFIRING CYLINDER SECTION (faulty fuel injector) of the *Series 60* service manual (6SE483) or *Series 50* service manual (6SE50), the results of a cylinder cutout test state:

Scroll the list to review the results of the cylinder cutout test. To find suspect injector, look for a cylinder with a value that is within 0.2 degrees of the NO CUTOUT PULSE WIDTH, by comparing the CUTOUT PULSE WIDTH values to the NO CUTOUT PULSE WIDTH values.

1. If the CUTOUT PULSE WIDTH values are within 0.2 degrees of the NO CUTOUT PULSE WIDTH, shut down the engine and refer to "Faulty Fuel Injector Repair."

2. If the CUTOUT PULSE WIDTH values are not within 0.2 degrees of the NO CUTOUT PULSE WIDTH, shut down the engine and refer to " Faulty Electronic Control Module."

The following tips will help run successful Cylinder Cutout Tests:

1. Please be aware that the cylinder cutout test results will be invalid if the engine load changes in the middle of a cylinder cutout test. This could result from such things as the engine fan or the air compressor turning on or off at any time during the cutout test.
2. While a load change in the middle of a test will invalidate the results, increasing the parasitic load on the engine prior to beginning the test will generally make test results easier to interpret. One way to increase the parasitic load is to turn on the air conditioning and set the blower to "High".
3. Test results are generally easier to interpret when the test is run at 1,000 rpm rather than 600 rpm.
4. Pulse width readings for different engine types may vary widely. Pulse width readings also vary between different power ratings for the same engine. For detailed information on your particular engine model, please consult the service staff at your local Detroit Diesel service center.

8.2 SERIES 50/60 FAULTY FUEL INJECTOR TEST

Perform the following steps for servicing faulty fuel injector assembly(s):

1. Remove and replace injector assembly(s) whose pulse width values are within 0.2 degrees of the NO CUTOUT PULSE WIDTH.
2. Verify replaced injector assembly(s).

Perform the following steps to verify if the replaced fuel injector(s) resolved the misfiring cylinder condition:

1. Start the engine.
2. Run the engine speed up to the occurrence of the misfiring.
3. Listen for misfiring cylinder.
4. If the engine is not misfiring, shut down the engine. No further troubleshooting is required.
5. If the engine is misfiring, shut down the engine and check for a faulty electronic control module.

8.3 SERIES 50/60 DDEC IMPROPER INJECTOR CALIBRATION TEST

To determine if an improper injector calibration setting is causing the cylinder to misfire, perform the following steps:

1. Remove the valve rocker cover(s).

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

NOTE:
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. On N3 (DDEC IV & DDEC V) injectors the calibration code is found on the name plate.

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 then the calibration code on the suspect injector for that cylinder, the injector setting must be repaired.
   [b] If test codes match, look for improper valve clearance or injector height, and worn or damaged camshaft lobes and rollers. See current *Series 60* service manual (6SE483) or *Series 50* service manual (6SE50).

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).

NOTE:
Note: An asterisk (*) will highlight the first cylinder number on the list.

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.

8.4 SERIES 50/60 DDEC 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. See current *Series 60* service manual (6SE483) or *Series 50* service manual (6SE50).
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 8-1 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)

Table 8-1 Engine Speed and Fuel Pressure

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.

8.5 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. See Additional Information (Shop Notes) of Section 2 of current *Series 60* service manual (6SE483) or *Series 50* service manual (6SE50).
4. Inspect the fuel return check valve for restrictive movement, (see Section 2.1 of 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, 88-96°C (190-210°F).
   [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.

8.6 MBE CYLINDER CUTOUT TEST

This test continually measures the torque of the engine. When a designated cylinder is switched off, the injector is disabled causing the engine speed to decrease. The remaining cylinders will correct for the missing cylinder and return to the correct idle speed. The change in engine torque will indicate the power loss of a particular cylinder. A low change in engine torque may indicate a faulty cylinder.

To start a Cylinder Cutout Diagnostic Test:

1. The engine must be on.
2. The engine must be at idle (no other option is available).

Notes on MBE cylinder cutout test:

- ☐ This test will check the baseline torque prior to each cylinder being cutout, unlike DDEC test that only makes an initial baseline measurement. Because of this, the test will take longer to run than a DDEC cutout test.
- ☐ The results of this test should be evaluated by the relative torque value of each cylinder. A significantly lower value indicates this cylinder may have a problem.
- ☐ In Automatic mode, the test runs through each cylinder one at a time and measures the torque as each one is switched on and off.
- ☐ In Manual mode, the user may switch the selected cylinder on or off as desired. The torque will be measured in the same manner for both types of tests.
- ☐ Upon exiting the test, all cylinders are automatically turned back on.

8.7 MBE 900 DOWNSTREAM (AFTER SECONDARY FILTER) PRESSURE TEST

Perform the following, MBE Downstream (after secondary filter) Pressure Test, to determine the downstream pressure:

1. Remove the engine trim panel. See current *MBE 900* service manual (6SE414).
2. Disconnect the fuel temperature sensor.
3. Plug the disconnected fuel temperature sensor into the engine wiring harness and tie it up out of the way.
4. Install the adaptor and seal from the fuel adapter parts kit (J-46377).
5. Attach a banjo fitting to the adaptor, and use that to connect the high-pressure fuel line (J-46372) and gauge (J-46378) to the adaptor.
6. Open the fuel fill cap to release pressure in the fuel tank.
7. Start the engine and run at a slow idle, 600-650 rpm.

8. Read off the fuel pressure on the high-pressure gage. The gauge should read at least 430 kPa (62 psi). If the fuel pressure is too low, perform a fuel flow test.
9. Increase the engine speed to 2500 rpm.
10. Read off the fuel pressure on the high-pressure gage. The gauge should read from 400 to 650 kPa (58 to 94 psi). If the fuel pressure is within limits, and concern remains, do fuel flow test at nozzle holder, to try and resolve the issue. If the fuel pressure is too high, see troubleshooting table in current *MBE 900* service manual (6SE414).
11. Remove all test equipment. Reconnect fuel temperature sensor.
12. Make sure the fuel cap is tightly closed and the vehicle has been restored to operating condition.

8.8 MBE 900 FLOW TEST AT NOZZLE HOLDER

Perform the following test set-up and test to determine the fuel flow at the nozzle holder:

1. Remove the engine trim panel. See current *MBE 900* service manual (6SE414).
2. Using the injector line socket (J-46371), remove the injector line at cylinder #4 on the 6-cylinder engine, and at cylinder #2 on the 4-cylinder engine.
3. Remove the fuel return line from the cylinder head at the same cylinder from which the injection line was removed.
4. Install an adaptor and seal ring from the fuel adaptor parts kit (J-46377). Use the adaptor to install the fuel return line back onto the cylinder head.
5. Install the injection line, as removed.
6. Place a clean cloth below the opening in the adaptor to catch any fuel which leaks out of the return line during the test.
7. Open the fuel fill cap to release pressure in the fuel tank.
8. Start the engine and run it at slow idle, 600 to 650 rpm, until the adaptor opening appears moist. If fuel or coolant flows out of the return line, see troubleshooting table in current *MBE900* service manual *(6SE414)*.
9. Increase the engine speed to 2500 rpm. At most, drops of fuel should appear at the adaptor opening. If fuel or coolant flows out of return line, see troubleshooting table in current service manual.
10. Remove the adaptor and seal ring (J-46377). Restore the fuel return line to the original installation, as removed.
11. Make sure the fuel fill cap is tightly closed and the vehicle has been restored to operating condition.

8.9 MBE 900 FLOW TEST AT FUEL FILTER

Perform the following test set-up and test to determine the flow at the fuel filter:

1. Remove the engine trim panel. See current *MBE 900* service manual *(6SE414)*.
2. Disconnect the fuel return line at the overflow valve. When loosening the banjo bolt, hold a second wrench on the overflow to avoid loosening the valve.
3. Using a banjo bolt, nut, and washer from the fuel adaptor parts kit (J-46377), seal off the fuel return line.
4. In place of the fuel return line, attach the hose with a banjo fitting from the fuel adaptor parts kit (J46377) to the overflow valve. When tightening the union, hold a second wrench on the overflow valve to avoid over-tightening the valve.
5. At the main fuel filter, detach the fuel drain line and its fitting from the main filter housing.
6. In place of the fuel drain line, attach a union from the fuel adaptor parts kit to the main filter housing.
7. At the union, attach a hose and run the other end of the hose into another clean container.
8. Open the fuel fill cap to release pressure in the fuel tank.
9. Start the engine and run it at a slow idle, 600 to 650 rpm, until the fuel flows into the container with little or no bubbling.
10. Check the fuel flow at the fuel filter. When beginning the timed portion of this test, take the transparent hose out of the clean container and insert it into a calibrated container or measuring cup.
    - [a] Measure the quantity of fuel that flows out of the hose in one minute (60 seconds). If more than 300 ml (10.1 fluid ounces) flow out, fuel flow at the filter is too high (at idle).
    - [b] Increase the engine speed to 2500 rpm.
    - [c] Measure the quantity of fuel that flows out of the hose in one minute. If more than 300 ml (10.1 fluid ounces) flow out, fuel flow at the filter is too high (at rated speed). If the fuel flow on either test is too high, correct the problem. Fuel flow is OK if the system passes both tests.
11. Check the fuel flow at the overflow valve.
    - [a] Reduce engine speed back to slow idle, 600 to 650 rpm.
    - [b] Measure the quantity of fuel that flows out of the hose in one minute (60 seconds). If more than 1.7 Liters (1.8 qt) flows out, the overflow valve fuel flow is too high. If less than 0.9 Liter (.95 qt) flows out, the overflow valve fuel flow is too low. If between 0.9 Liter (.95 qt) and 1.7 Liters (1.8 qt) flows out, the overflow valve fuel flow is within range.
    - [c] Increase the engine speed to 2500 rpm.
    - [d] Measure the quantity of fuel that flowed out of the hose in one minute. If more than 7.5 Liters (7.9 qt) flows out, the over flow fuel flow is too high. If less than 2.7 Liters (2.9 qt) flows out, the overflow fuel flow is too low. If between 2.7 Liters (2.9 qt) and 7.5 Liters (7.9 qt) flows out, the overflow fuel flow is within range.

12. If overflow valve fuel flow is too low and filter fuel flow is too high, or if fuel flow is too low and fuel flow is OK, see the causes in troubleshooting table in current service manual. If the overflow valve fuel flow is too low and the fuel flow is also too low at the filter, do upstream pressure test. If overflow valve fuel flow is OK and no fuel flows out at the filter, the continuous ventilation port in the fuel filter is blocked by impurities. Open the fuel filter and clean or replace the blocked port.

NOTE:
Do not attempt to disassemble the overflow valve. The overflow valve cannot be repaired.

13. Remove the union, transparent hose, banjo bolt, and nut. Restore the fuel return and drain lines to the original installation, as removed.
14. Make sure the fuel fill cap is tightly closed and the vehicle has been restored to operating condition.

8.10 MBE 900 UPSTREAM PRESSURE TEST

Perform the following test set-up and test to determine the upstream pressure:

1. At the main filter housing, disconnect the fuel feed line and feed line fitting. This fitting is after the fuel return line and connects to the fuel pre-filter.
2. Install the pressure tester (J-46380). Connect one end of the transparent test hose to the fuel pre-filter, using a union from the fuel adaptor parts kit (J-46377). Connect the other end of the transparent test hose to the disconnected fuel feed line, using a barbed adaptor to the proper sized fuel line fitting.

NOTE:
The opening arm of the union at the pre-filter should press open the check valve.

3. Inspect the seals at the fitting on the fuel pre-filter for damage and replace if necessary.
4. Bleed the fuel system.
   [a] If equipped with a hand pump on the fuel/water separator, work the hand pump 50 times.
   [b] Crank the engine for 30 seconds at a time, but no longer. Before cranking the engine again, wait at least two minutes. The engine should start within four 30-second attempts. The fuel system is bled automatically. Stand the pressure tester on a level spot, such as the frame rail.

NOTE:
The pressure tester must be level to indicate correctly.

5. Open the fuel fill cap to release pressure in the fuel tank.

6. Start the engine and run it at a slow idle.

NOTE:
The pressure tester reads in bar. 1 bar = 14.5 psi or 100 kPa. The test measures suction at the fuel inlet. All pressure values are negative.

7. Read off the fuel pressure on the pressure tester. The gauge should read from – 0.09 bar to – 0.12 bar (– 1.3 to – 1.7 psi [– 9 to – 12 kPa]). If the fuel pressure is too low (less suction) or if fuel pressure is too high (more suction), see the causes listed in troubleshooting table in current *MBE 900* service manual (6SE414).
8. Increase the engine speed to 2500 rpm.
9. Read off the fuel pressure on the pressure tester. The gauge should read from – 0.4 to – 0.5 bar (– 5.8 to – 7.3 psi [– 40 to – 50 kPa]).
10. Remove all test equipment. Reconnect the fuel feed line.

8.11 MBE 900 INJECTOR LEAK TEST

Remove the engine trim panel. See current *MBE 900* service manual (6SE414).

1. Disconnect the fuel temperature sensor.
2. Plug the disconnected fuel temperature sensor into the engine wiring harness and tie it up out of the way.
3. Install the adaptor and seal from the fuel adaptor parts kit (J-46377).
4. Attach a banjo fitting to the adaptor, and use that to connect the high-pressure fuel line (J-46372) and gauge (J-46378).
5. Disconnect the fuel return line at the main filter housing. Seal the opening with a cap.
6. Disconnect the fuel feed line and feed line fitting at the main filter housing. In their place, attach the hose with a banjo fitting and the shut-off lever from the fuel adaptor parts kit (J-46377).
7. Open the fuel fill cap to release pressure in the fuel tank.
8. Fill the low-pressure fuel circuit with compressed air until the fuel pressure on the high-pressure gauge reads 1000 kPa (145 psi).
9. Turn the shut-off lever to the OFF position and wait five minutes.
10. At the end of five minutes, read the pressure on the gauge again. The gauge should read at least 975 kPa (141 psi). If the gauge pressure is too low, see the causes listed in troubleshooting table in current service manual.
11. Check the engine oil for presence of fuel. If there is fuel in the engine oil, see the causes in troubleshooting table in current service manual.
12. Open the shut-off valve and remove all the test equipment. Connect the fuel feed and return lines, as removed. Reconnect the fuel temperature sensor.

13. Make sure the fuel fill cap is tightly closed and the vehicle has been restored to operating condition.

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GLOSSARY

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.