Engine Performance

Engine Repair

Steering & Suspension

Electrical Systems

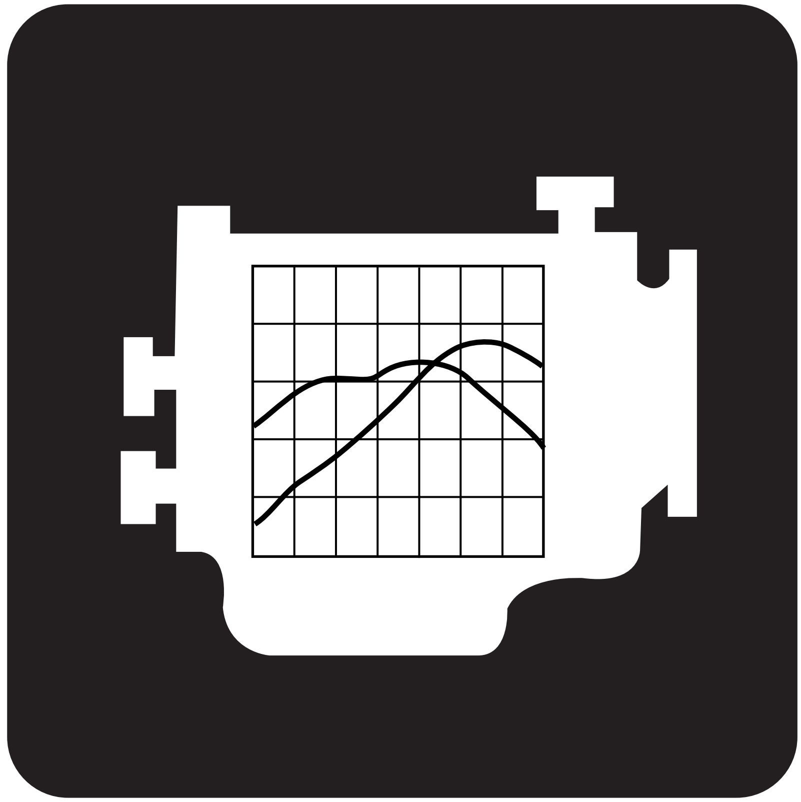
Climate Control

Manual Transmission

Automatic Transmission

Brakes

diesel engine performance



diesel engine operation fundamentals

self-study

COURSE CODE: 51S01S0
ORDER NUMBER: FCS-13004-REF

STST
Service Technician Specialty Training
Ford
Ford Customer Service Division
Technical Training

IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles, as well as the personal safety of the individual doing the work. This manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedures, techniques, tools and parts for servicing vehicles, as well as in the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from instructions provided in this manual must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools or parts.

As you read through the procedures, you will come across NOTES, CAUTIONS, and WARNINGS. Each one is there for a specific purpose. NOTES give you added information that will help you to complete a particular procedure. CAUTIONS are given to prevent you from making an error that could damage the vehicle. WARNINGS remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general WARNINGS that you should follow when you work on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires you to be under the vehicle.
- Be sure that the ignition switch is always in the OFF position, unless otherwise required by the procedure.
- Set the parking brake when working on the vehicle. If you have an automatic transmission, set it in PARK unless instructed otherwise for a specific service operation. If you have a manual transmission it should be in REVERSE (engine OFF) or NEUTRAL (engine ON) unless instructed otherwise for a specific service operation.
- Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.
- Keep yourself and your clothing away from moving parts when the engine is running, especially the fan and belts.
- To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, catalytic converter and muffler.
- Do not smoke while working on the vehicle.
- To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind your head.
- Keep hands and other objects clear of the radiator fan blades. Electric cooling fans can start to operate at any time by an increase in underhood temperatures, even though the ignition is in the OFF position. Therefore, care should be taken to ensure that the electric cooling fan is completely disconnected when working under the hood.

The recommendations and suggestions contained in this manual are made to assist the dealer in improving his dealership parts and/or service department operations. These recommendations and suggestions do not supersede or override the provisions of the Warranty and Policy Manual, and in any cases where there may be a conflict, the provisions of the Warranty and Policy Manual shall govern.

The descriptions, testing procedures, and specifications in this handbook were in effect at the time the handbook was approved for printing. Ford Motor Company reserves the right to discontinue models at any time, or change specifications, design, or testing procedures without notice and without incurring obligation. Any reference to brand names in this manual is intended merely as an example of the types of tools, lubricants, materials, etc. recommended for use. Equivalents, if available, may be used. The right is reserved to make changes at any time without notice.

WARNING: Many brake linings contain asbestos fibers. When working on brake components, avoid breathing the dust. Breathing the asbestos dust can cause asbestosis and cancer.

Breathing asbestos dust is harmful to your health.

Dust and dirt present on car wheel brake and clutch assemblies may contain asbestos fibers that are hazardous to your health when made airborne by cleaning with compressed air or by dry brushing.

Wheel brake assemblies and clutch facings should be cleaned using a vacuum cleaner recommended for use with asbestos fibers. Dust and dirt should be disposed of in a manner that prevents dust exposure, such as sealed bags. The bag must be labeled per OSHA instructions and the trash hauler notified as to the contents of the bag.

If a vacuum bag suitable for asbestos is not available, cleaning should be done wet. If dust generation is still possible, technicians should wear government approved toxic dust purifying respirators.

OSHA requires areas where asbestos dust generation is possible to be isolated and posted with warning signs. Only technicians concerned with performing brake or clutch service should be present in the area.

Produced and Coordinated by
Technical Service Support Operations
Ford Customer Service Division

October, 1999

TABLE OF CONTENTS

INTRODUCTION

The Diesel Engine Operation self-study is the first course of the Diesel Engine Curriculum. Since this course sets the building blocks for the other three courses, it is important that it be completed first. It is also important that all prerequisite courses be completed prior to taking this self-study, as this will lead to a better understanding of the material presented.

This course has two main goals. The first goal is to introduce you to the diesel engines used on Ford vehicles. The second goal is to provide an understanding of the symptom-to-system-to-component-to-cause diagnostic process. As you learn new information, try to relate the new knowledge to the diesel engine systems as a whole. Think about the cause-and-effect relationships between the subsystems and components. Understanding the cause-and-effect relationships will help you in diagnosis. This course will include information related to the diesel engine systems. Although electronic diesel engine systems may be mentioned, that information will be covered, in detail, in the Diesel Engine Electronics self-study course. Some of the topics that will be covered in this course include the following:

- Diesel Engine Concepts and Characteristics
- Diesel Engine Operation
- The Fuel Delivery System
- The Oil System
- Fuel Quality
- Oil Quality
- The Air Inlet and Exhaust Systems
- Coolant
- Maintenance Intervals
- Diesel Engine Starting Aids
- Diagnostics

Although you may be familiar with some of these topics, it is essential that you, as a professional diesel engine technician, have a thorough understanding and mastery of this information. You will find that mastery learning is necessary to diagnose and service the latest diesel engine systems.

CURRICULUM DESCRIPTION

Diesel Engine Curriculum

Each course found in the Diesel Engine Curriculum is one of the following types:

- Self-Study – This type of course is a self-paced program. The technician is responsible for learning the material on his or her own. The training material consists of a reference book and an accompanying videotape. The videotape is designed to support the material in the reference book and should not be used on its own.
- Ford Multimedia Training (FMT) – This type of course is also self-paced. The multimedia course allows the technician to interact with the training materials. The multimedia course allows the technician to utilize the knowledge attained in the self-study course. The FMT concentrates on relationships, such as the cause- and-effect relationships between symptoms and components.
- Classroom – The classroom course allows for practical, real-world application of skills and knowledge learned in the other courses.

There are four courses in the Diesel Engine Curriculum. Please refer to the Diesel Engine Curriculum Path that follows.

Course Codes

These courses may be found in the STARS planner using the following course codes:

Engine Performance

- Diesel Engine Operation – Self-Study .... Course code: 51S01S0
- Diesel Engine Electronics – Self-Study .... Course code: 51S02S0
- 7.3 DIT Diesel Engine Performance Diagnosis – FMT .... Course code: 51S03M0
- Advanced Diesel Engine Performance Diagnosis – Classroom .... Course code: 51S04T0

ENGINE PERFORMANCE CURRICULUM PATH

Diesel Engine Operation – SS

Diesel Engine Electronics – SS

7.3L DIT Diesel Engine Performance Diagnosis – FMT

Advance Diesel Engine Performance Diagnosis – Classroom

Prerequisites

- *Basic Electrical Part 1 – SS*
- *Basic Electrical Part 2 – FMT*
- *Basic Electrical Part 3 – Classroom*
- *Electronics Part 1 – SS*
- *Electronics Part 2 – FMT*
- *Electronics Part 3 – Classroom*
- *Networks + Multiplexing Part 1 – SS*
- *Networks + Multiplexing Part 2 – FMT*

Legend

- *= Self Study (SS)*
- *= Ford Multimedia Training (FMT)*
- *= Instructor Led – Classroom*

Curriculum Training Pathway

COURSE PURPOSE

Technician Course Objectives

Upon completion of this course, you will be able to:

- describe diesel engine concepts and characteristics.
- describe diesel engine operation.
- describe the fuel delivery system.
- describe the oil system.
- describe the importance of fuel quality.
- describe the importance of oil quality.
- describe the air inlet and exhaust systems.
- describe the importance of coolant in the diesel engine.
- describe the importance of maintenance intervals.
- describe the importance of diesel engine starting aids.
- describe diesel engine diagnostics.

Why Training?

1. Customers bring vehicles to the dealership because they want the best service possible. They believe that no other technician besides you, a Ford trained technician, could know their vehicle better.
2. Customers expect a dealership to "Fix It Right The First Time, On Time."

So, how do you live up to the customer's expectations? The answer is continuous training. Training allows you to gain efficiency. Efficiency makes you an asset to the customer, the dealer, and yourself. Training promotes job security and allows you to learn the "latest and greatest" technology and service procedures.

COURSE DESCRIPTION AND FORMAT

Course Description for Self-Study Learners

This Student Reference Book is designed for use as part of a self-study training course, which means you can allow yourself as much time as you need to learn the information in each section. A videotape has been developed to accompany this book. The videotape provides information that can best be presented through visual means.

Lesson Review Questions are provided throughout this book to help evaluate your individual learning needs. Answers to the Lesson Review Questions are provided with page references to help you determine your strengths and weaknesses. If you have difficulty answering certain questions, review the material until you feel confident that you understand the information.

Take as much time as you need to master the material. You may not answer the questions 100% correctly the first time around. With study, you will quickly master those areas with which you may have difficulty.

Evaluation Strategy

The final evaluation questions for this self-study course are on the 7.3L DIT Diesel Engine Performances Diagnosis FMT CD-ROM. You must pass this test and the test for the Diesel Engine Electronics Self-Study before you can begin the FMT course.

HISTORY OF DIESEL ENGINES

The initial idea for the diesel engine started shortly after the gasoline engine was built in 1876 by the German firm, Otto and Langen. Engineers at that time had determined that during the compression stroke the air/fuel mixture in a cylinder became hot due to compression, sometimes causing the fuel mixed with air to ignite before spark had occurred. It was widely felt that if air could be compressed sufficiently to provide a high amount of heat, then fuel could be injected under high-pressure, and a running engine would result.

Before such an engine could be developed, several problems had to be overcome. First, to inject fuel under high-pressure, precise components would have to be developed to raise the fuel pressure and inject it into the hot, pressurized air. Machine tools of that time were not precise enough to accomplish this. Second, the pressure generated in this type of engine would be so immense, strong engine components would be required. At that time, the science of metallurgy was not yet advanced to the point where sufficiently strong materials were available in lightweight form. For strength, engineers simply added more metal, increasing weight.

As time progressed, more and more engineering research was being done in the area of high compression and fuel injection. Finally, in 1892, a German engineer by the name of Rudolph Diesel obtained a patent for a new type of engine. This engine was similar to the gasoline engine that had already been invented, except that it did not rely on a spark to ignite the air/fuel mixture. This engine relied on the large amount of heat generated by the compression of air in a cylinder to ignite the fuel. This lack of spark to ignite the fuel mixture is the main difference between the diesel and other types of internal combustion engines.

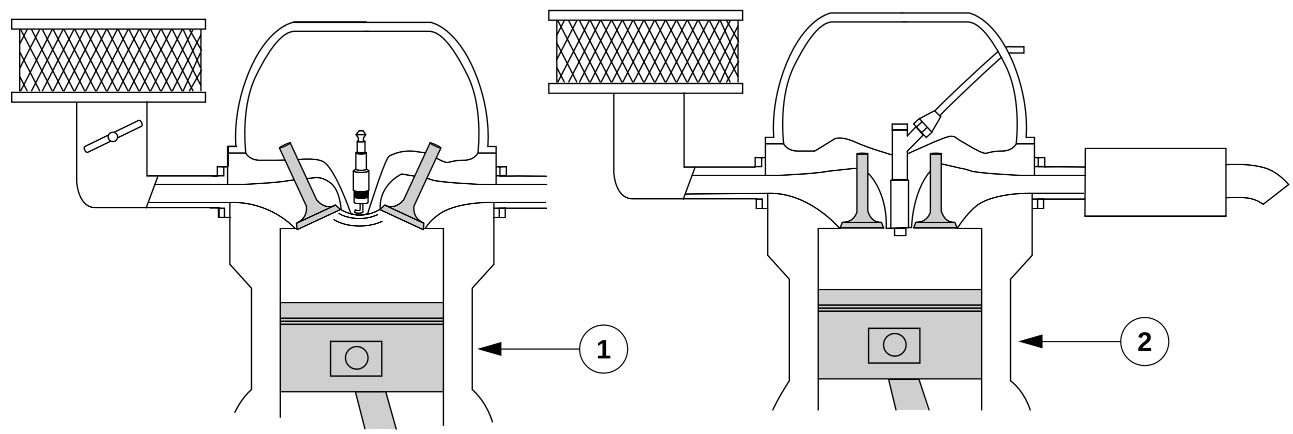
LESSON 1: DIESEL ENGINE CONCEPTS AND CHARACTERISTICS

TECHNICIAN OBJECTIVES

- Describe major operating differences between diesel engines and gasoline engines.
- Describe the operating characteristics of a diesel engine.
- Describe the advantages of the diesel engine.
- Describe the disadvantages of the diesel engine.

CONTENTS

MAJOR OPERATING DIFFERENCES BETWEEN DIESEL AND GASOLINE ENGINES

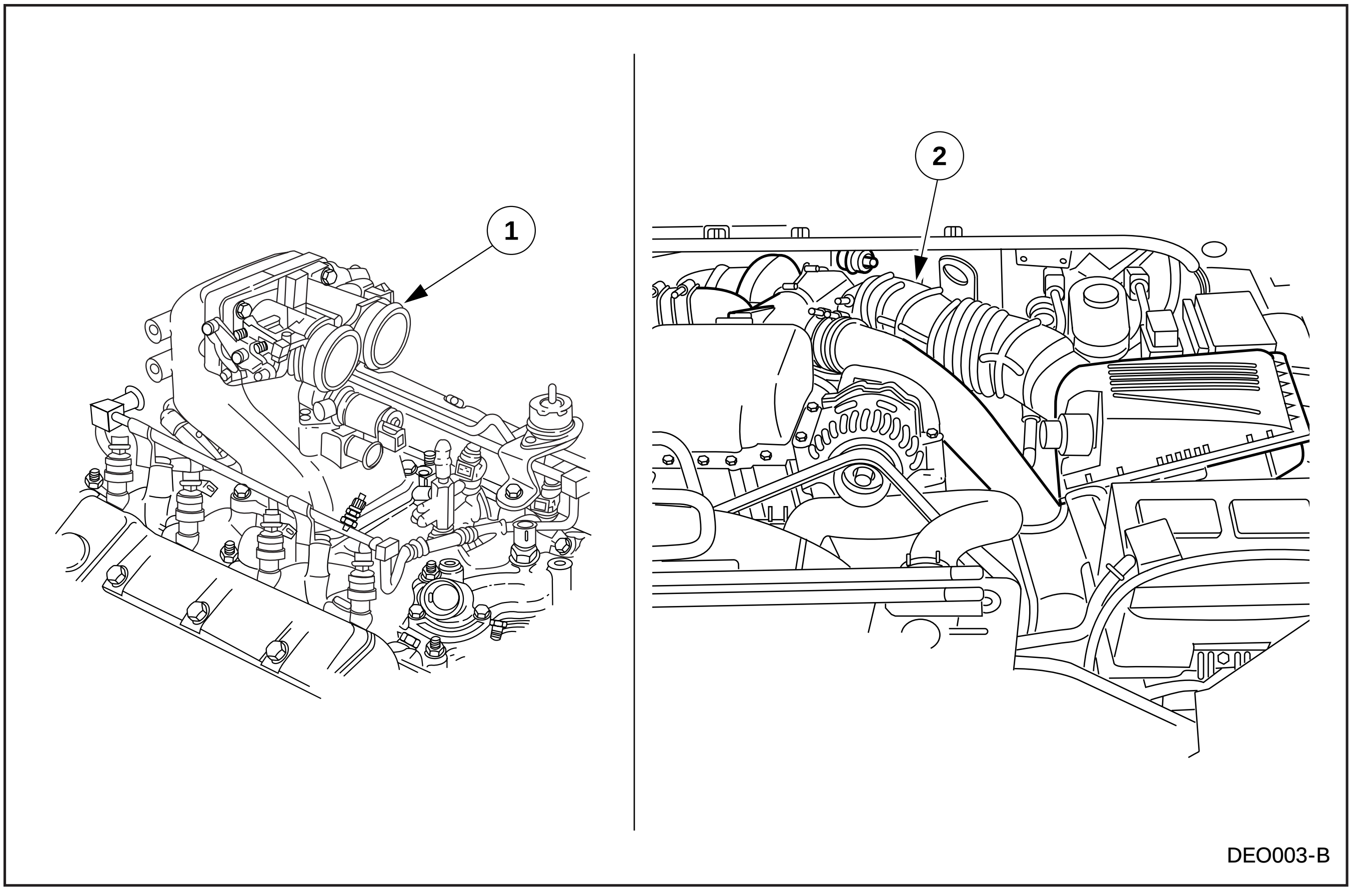


Gasoline and Diesel Ignition

Item	Description
1	Gasoline Engine
2	Diesel Engine

There are a number of items that are different between a diesel and a gasoline engine. The most obvious is the lack of an ignition system on the diesel engine. This is because the diesel is a compression-ignition type engine, as opposed to a spark-ignition type. There are no spark plugs, wires or ignition coil. Heat generated from compression is used to ignite the air/fuel mixture in the cylinders. The diesel engine has a much higher compression ratio than a gasoline engine. This means that the diesel will compress air into a tighter space in a cylinder, thus creating the higher temperatures needed to ignite the air/fuel mixture.

NOTES



Gasoline and Diesel Engine Air Intake

Item	Description
1	Throttle Body (Restriction)
2	Intake Manifold Hose (No Restriction)

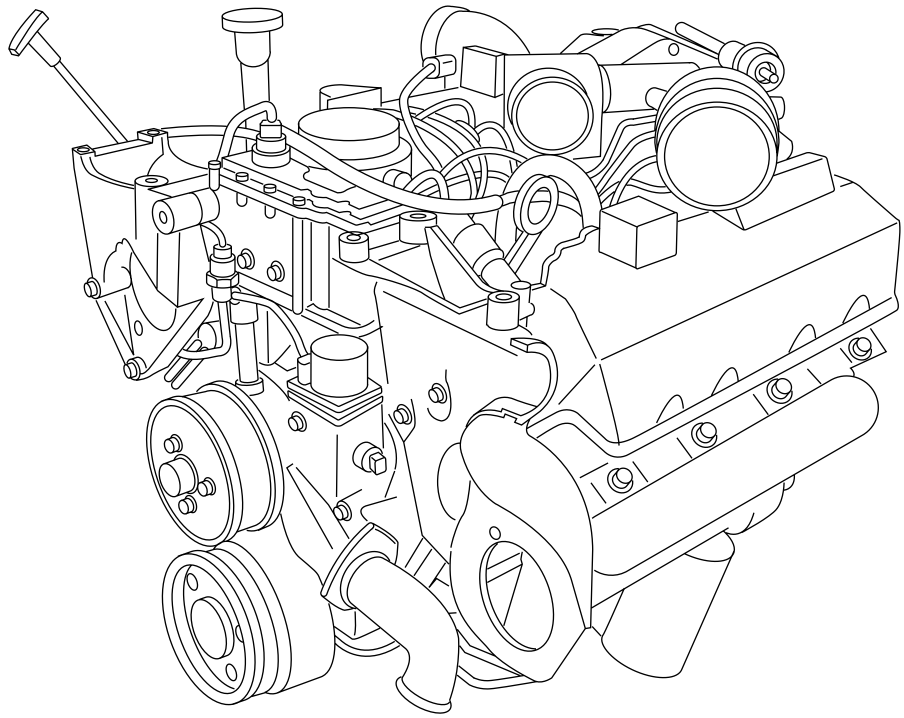
Diesel engines do not use a throttle plate to regulate the amount of air entering the intake, such as on gasoline engines. The diesel has a wide open intake that allows a large volume of air to enter the engine. The smooth operation of the diesel engine is directly proportional to the amount of air it is allowed to draw. If airflow is interrupted, driveability concerns may occur. The diesel engine also needs fuel to run (this is true of the gasoline engine as well). However, the gasoline engine design allows for the mixing of air and fuel before it enters the combustion chambers. The diesel, on the other hand, mixes fuel and air directly in the combustion chambers or precombustion chambers. Fuel must be added to the hot air in the cylinders at just the right moment for timely combustion and complete burning of the fuel. Fuel injection timing is critical to the operation of a diesel engine. The fuel must be injected into the hot compressed air, in the combustion chamber or precombustion chamber.

Fuel quality is also a big factor in diesel engine operation. Gasoline engines typically are slightly more forgiving when it comes to fuel quality. Both diesel fuel and gasoline are made from crude oil. Even though they are made from the same raw material, each has certain characteristics and differences. Such as:

- viscosity
- volatility
- gel point
- cetane (diesel) or octane (gasoline)
- specific gravity

In summary: although the gasoline and diesel engines have very similar base engine components, air/fuel delivery along with combustion characteristics are very different.

OPERATING CHARACTERISTICS OF A DIESEL ENGINE



7.3L DIT Diesel Engine

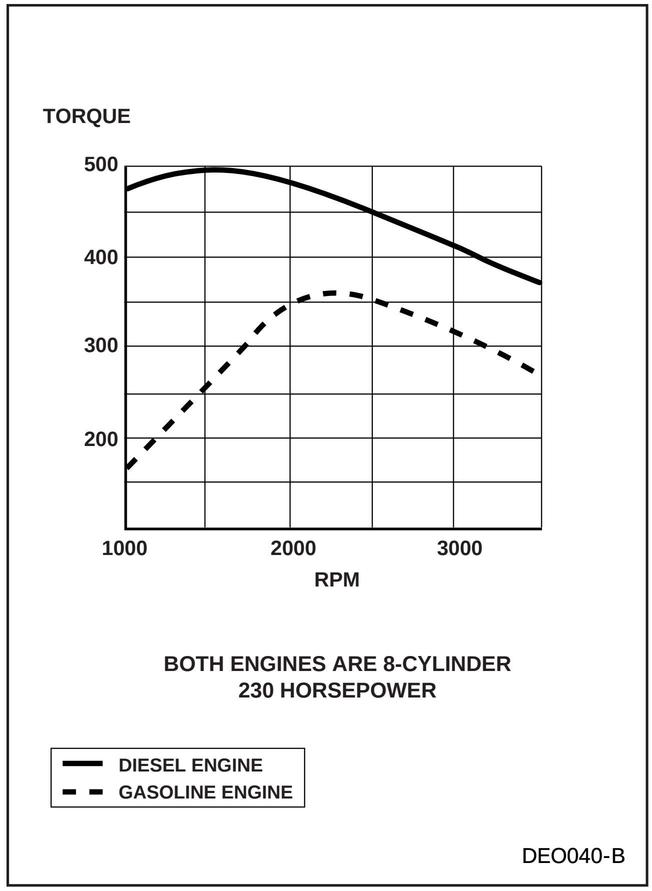
Strong, precisely timed components are required in the diesel engine to handle the high internal pressure produced by compression, combustion, and the fuel injection system. The fuel injection pump and the fuel injectors may have clearances down to six-millionths of an inch. The diesel engine is made of heavier, stronger, forged components than the gasoline engine. It tends to give better reliability if maintained well. A point to note about diesel engines is that despite their reputation for toughness and strength they are highly susceptible to dirt and water contamination. Because of the very tight tolerances in the diesel engine, the smallest amount of dirt can cause extensive damage to internal components in both the engine itself, or the fuel injection system. Water can cause corrosive damage as well as accelerate wear, because water has poor lubrication properties.

The type of fuel used in gasoline and diesel engines contributes to the power produced by the engine. Because the diesel engine is a compression ignition type engine, it generally produces very good fuel mileage. This is because compression ignition burns fuel more evenly than the spark ignition of gasoline engines. For this reason, a diesel engine produces more power than a gasoline engine for the amount of fuel used.

Gasoline typically does not have as high of a heat value as diesel fuel. The higher the heat value (measured in BTUs), the more heat and power produced by the fuel when burning. This means that diesel fuel produces more expanding gases than gasoline when it burns.

A diesel operates at a lower rpm with higher torque than a comparably sized gasoline engine. The peak horsepower and torque of a gasoline engine come at a much higher rpm than in a diesel engine.

Higher torque is produced because of the way diesel fuel burns. Diesel fuel burns over a longer period of time, as a result combustion occurs throughout almost the entire downward movement of the piston during the power stroke. This means that fuel is burning, producing heat and expanding pressures almost the entire travel distance of the piston from top dead center (TDC) to bottom dead center (BDC) of the power stroke. In contrast, because gasoline burns faster, the heat value of the fuel is used up near the beginning of the downward push of the piston. The piston then travels downward without the aid of heat and expanding combustion gasses, thus not producing power until combustion occurs again in that cylinder.



Gasoline to Diesel Torque Comparison

The engine noise (knocking) produced by diesels may sound strange to someone more familiar with the sound of a gasoline engine, but be assured that it is normal. As an automotive technician, you will have to train your ear to the sounds produced by the diesel engine. Due to such factors as compression ignition, high compression, rate of pressure increase in the cylinder, the nature of the fuel being used and nonuniform combustion, the diesel will produce a noticeable knocking sound that is very evident at idle.

Diesel exhaust has a distinct odor. Many conditions can affect or cause the odor given off by diesel exhaust. They include:

- engine speed
- engine temperature
- exhaust system design
- quantity of fuel injected
- timing of the injection
- combustion chamber design

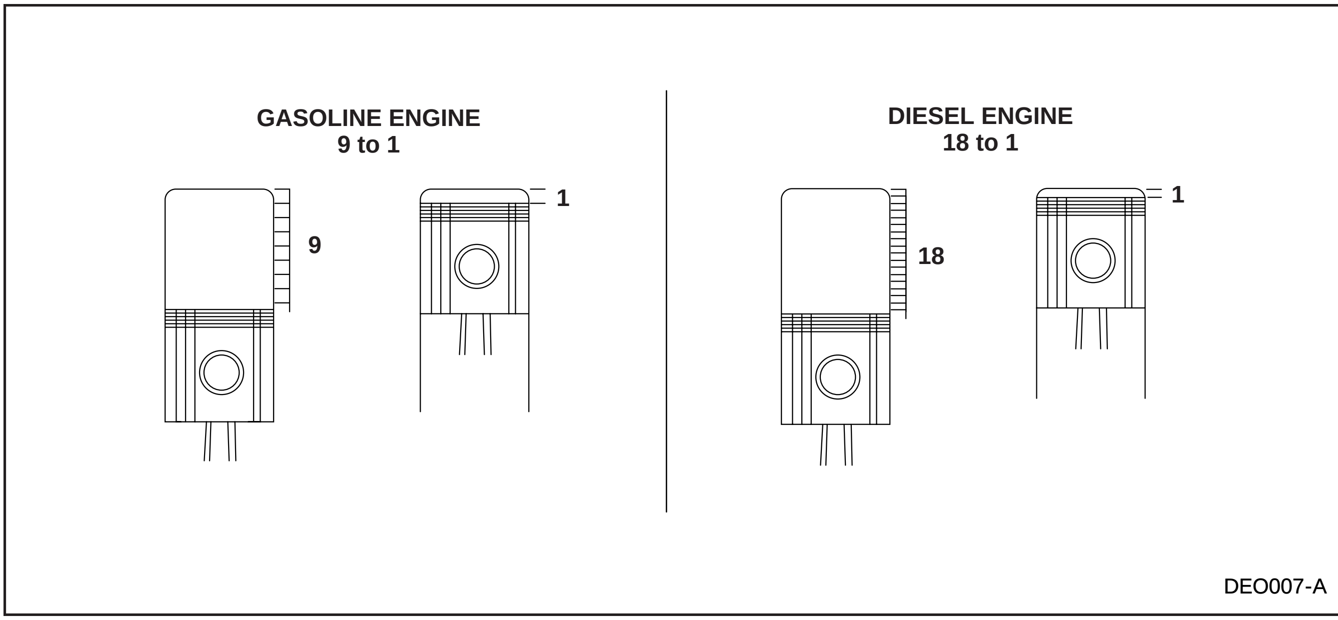
Diesel exhaust is very low in hydrocarbons (HC) and carbon monoxide (CO). The additional air present in a cylinder at the time of combustion is the reason for this.

Although the diesel engine is environmentally friendly, and has lower HC and CO emissions, it produces a higher amount of oxides of nitrogen (NO_x) emissions. Because the combustion chambers operate at much higher temperatures than gasoline engines, a natural by-product of combustion in the diesel is NO_x emissions.

Through its history, the diesel has had slower acceleration, more expensive construction and a narrower speed range due to the heavier components and high-pressure fuel injection system requirements. It is somewhat noisier than gasoline engines, especially during idle and requires longer cranking times, especially in cold weather starting conditions. Also, it requires more precise machining of some components.

In recent years, the disadvantages of diesel engines have been reduced. Through the use of special alloys, the difference in diesel and gasoline engine weight is not as great. Engineering advances have improved cold weather starting, acceleration and response, as well as widened the speed range. Also, the more expensive construction is being offset by increases in fuel savings, strengthening the demand for diesel engines. Additionally, the noise factor, although still more than gasoline engines, has been reduced.

GASOLINE AND DIESEL COMPRESSION RATIOS



Gasoline and Diesel Compression Ratios

Compression ratios in gasoline engines, are usually between 8.5:1 and 9:1. This means that the air in the cylinder is compressed to one-ninth of its normal volume. A diesel engine compression ratio is usually greater than 15:1. This is because the temperatures needed to ignite the fuel require a much higher compression ratio.

REVIEW QUESTIONS

1. Gasoline and diesel engines have similar base engine components.

   A. True

   B. False

2. List some of the differences between diesel and gasoline engines.

   ____

   ____

   ____

   ____

   ____

3. Diesel engines are highly susceptible to _______________ and ________________ damage.

4. Where does the diesel engine mix the air and fuel?

   ____

   ____

5. Why does a diesel engine have a higher compression ratio as compared to the gasoline engine?

   ____

   ____

TECHNICIAN OBJECTIVES

- Identify the four-strokes in diesel engine operation.
- Describe the intake stroke.
- Describe the compression stroke.
- Describe the combustion stroke.
- Describe the exhaust stroke.

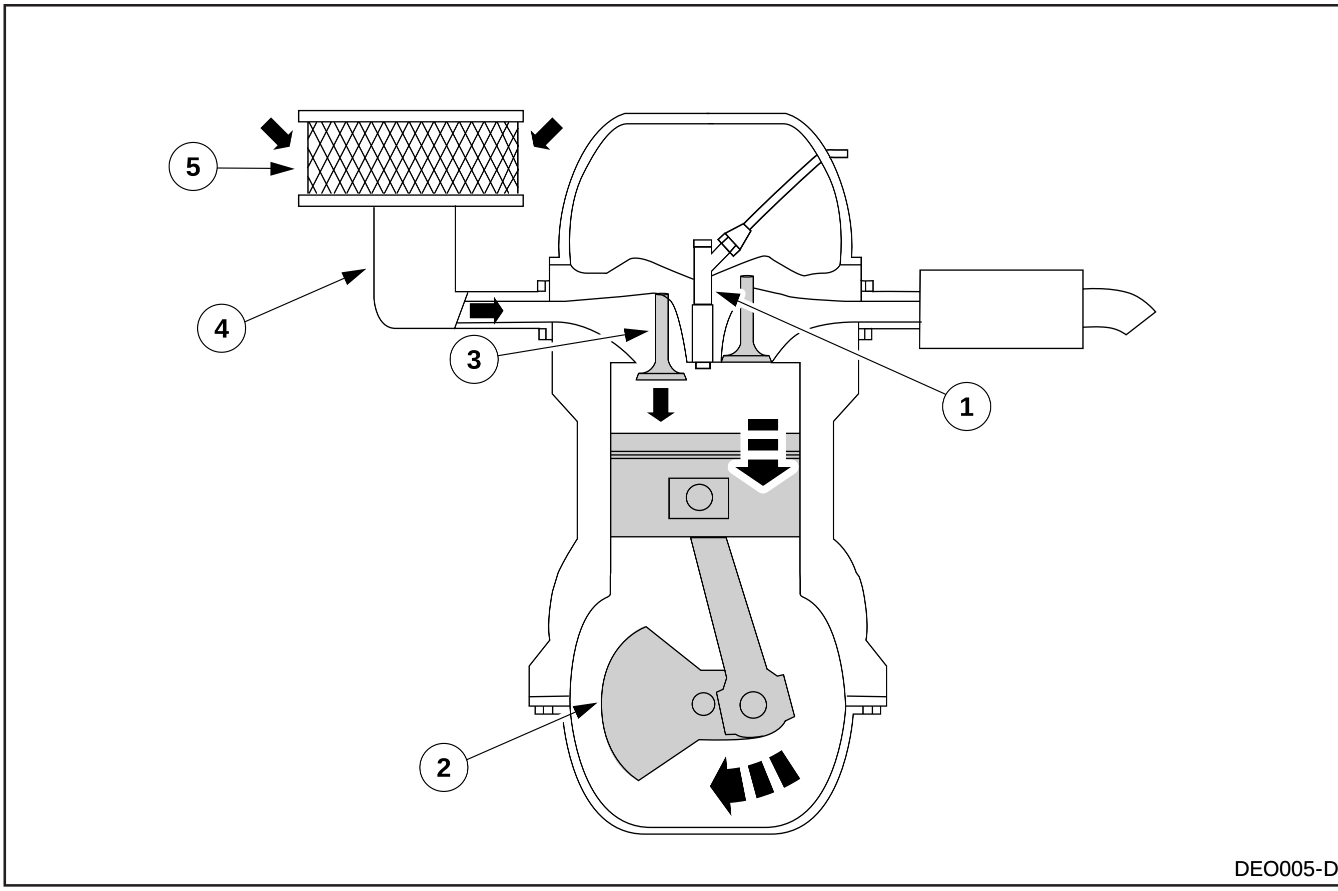
CONTENTS

OVERVIEW OF DIESEL ENGINE OPERATION

In the previous lesson you learned that diesel and gasoline engines differ. Diesel engines have higher compression ratios, different air induction systems, and use different fuels than their gasoline counterparts. In spite of the differences, the basic engine components are similar. The diesel engine uses that same four stroke system of operation, which consists of an intake stroke, compression stroke, power stroke, and exhaust stroke. In this lesson you will take a closer look at each of these four strokes.

NOTES

INTAKE STROKE



The Diesel Intake Stroke

Item	Description
1	Fuel Injector
2	Crankshaft
3	Intake Valve (Open)

Item	Description
4	Intake Manifold
5	Air Filter

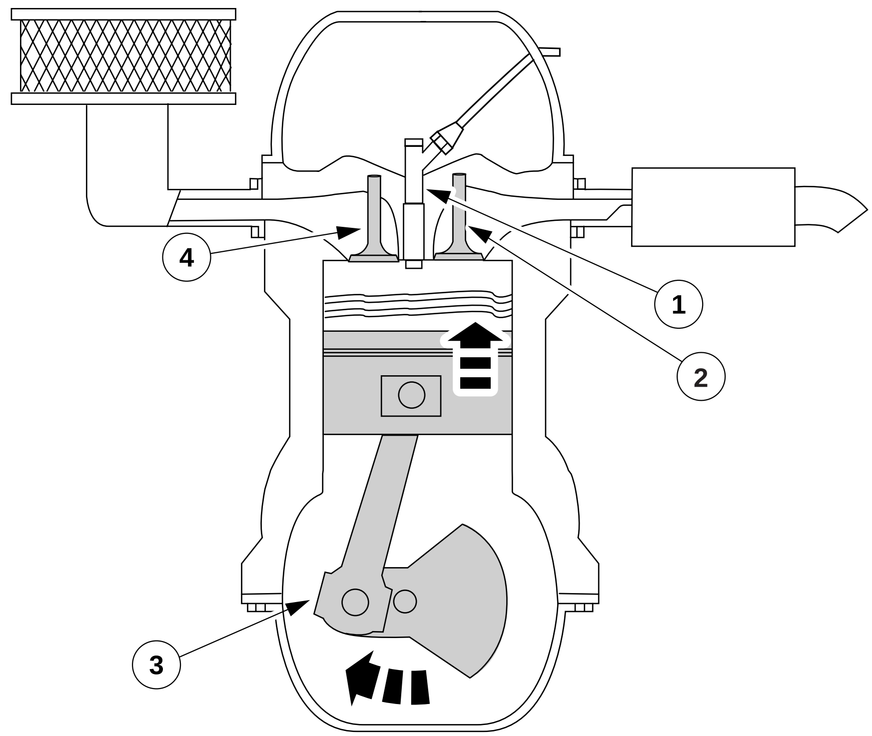
The intake stroke of the diesel engine begins with the intake valve open. The piston moves down the bore due to the rotation of the crankshaft. (The energy required to move the piston from top dead center to bottom dead center comes from either a flywheel or overlapping power strokes on a multiple-cylinder engine.) During its downward motion, the piston creates a low-pressure region in the area above the piston (as volume in the cylinder increases, the pressure decreases). Because atmospheric pressure is greater than the pressure in the cylinder, air rushes into the cylinder to fill the space left by the downward movement of the piston. Simply stated, the piston tries to inhale a volume of air equal to its own displacement.

The only material drawn into the cylinder during the diesel intake stroke is air. No throttle plate exists, so the cylinder completely fills with air at the inlet manifold pressure. On some diesel engines, pressure is high due to the use of a turbocharger for forced air induction. If there are any combustion gases left in the cylinder from the previous cycle, the air mixes with them.

Unrestricted airflow is very important for the performance of the diesel engine. To sustain the high compression needed to produce acceptable combustion temperatures, the diesel engine requires an enormous amount of air. Any restriction of airflow can be detrimental to engine performance.

As the piston reaches bottom dead center, it reverses direction. Then the intake valve closes, sealing the air-filled cylinder and the compression stroke begins.

COMPRESSION STROKE



The Diesel Compression Stroke

Item	Description
1	Fuel Injector
2	Exhaust Valve (Closed)

Item	Description
3	Crankshaft
4	Intake Valve (Closed)

The second stroke in the four-stroke cycle is the compression stroke. As the piston passes bottom dead center (its lowest point of movement) and starts up again, the compression stroke begins, the intake valve is closed and the exhaust valve remains closed. The air in the engine is now compressed into a very small volume at the top of the cylinder. Compression of the air is very important for developing high enough temperatures to ignite the air/fuel mixture and ultimately develop power.

Just before the piston reaches top dead center of the compression stroke, the fuel injector releases a fine spray of fuel into the combustion chamber. The temperature in the cylinder ignites the air/fuel so that the burning will already be in progress when the power stroke begins. The idea is to have the point of maximum pressure in the cylinder occur at a point slightly after the piston reaches top dead center, so that the piston can be pushed downward with the greatest force.

Compression Temperature Range

In the cylinders of a diesel engine compression pressures are very high. This is needed to produce high compression temperatures for the ignition of fuel. Cylinder compression temperatures in a diesel engine can reach over 556°C (1000°F).

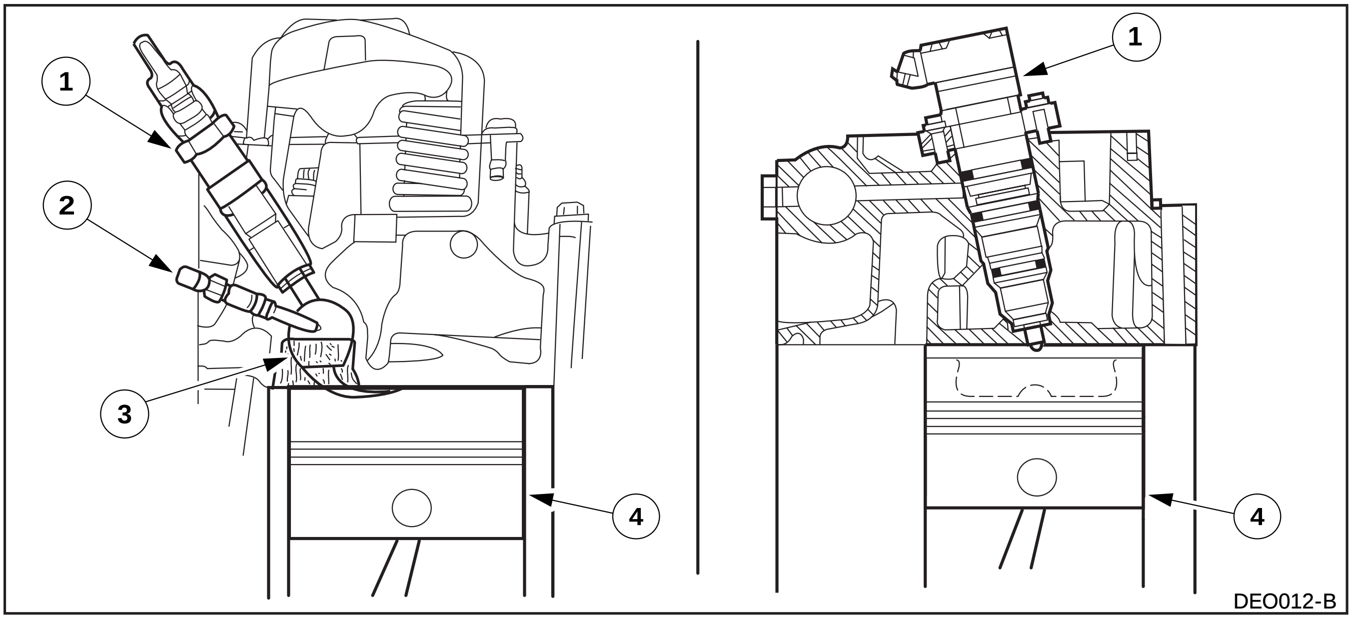
NOTES

Combustion Chamber Design

One of the primary areas of difference between diesel and gasoline engines is the combustion chamber design. The function of the combustion chamber is not just the area where fuel and air burn. It plays an important role in:

- complete combustion
- emission level
- noise level
- fuel economy
- smooth engine operation

Combustion in a diesel engine is affected to a great extent by the air turbulence created by the shape of the combustion chamber. The spray of fuel into the combustion chamber from the fuel injector is designed to take advantage of the air turbulence within the combustion chamber, so that complete burning will occur within the proper time frame. Each combustion chamber shape has its own unique pattern of air turbulence that is right for the particular design in which it functions. It may not be right for another engine or application – that is why there is so much design work that goes into a diesel combustion chamber before an engine is produced and marketed.



Indirect and Direct Injection

Item	Description
1	Fuel Injector
2	Glow Plug

Item	Description
3	Precombustion Chamber
4	Piston

There are two basic types of combustion chamber designs, although each of these designs may vary slightly depending on application.

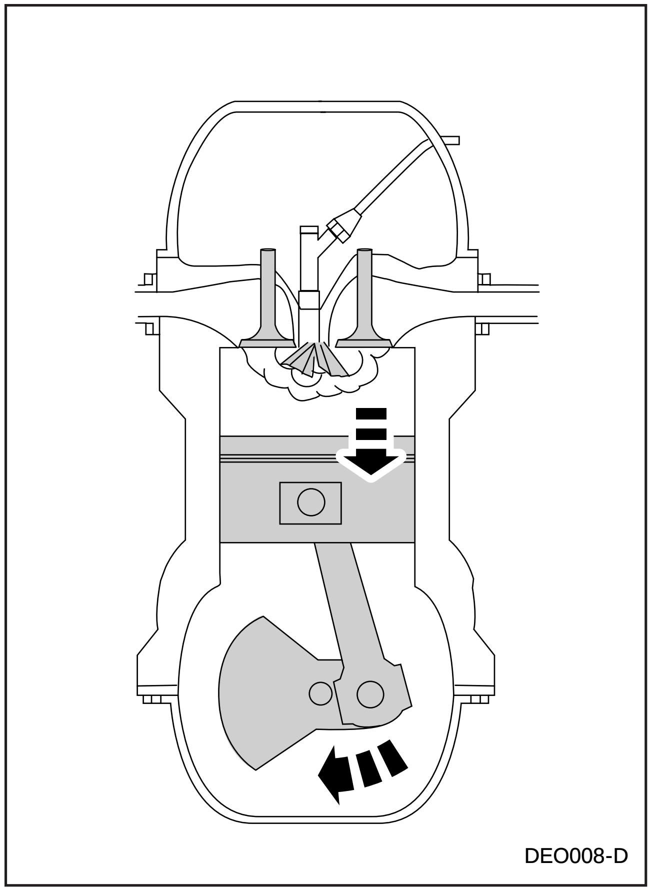
- **Indirect Injection**
  - The indirect injection design has a precombustion chamber connected by a narrow passageway to the main combustion chamber in the cylinder head. The fuel injector and glow plug are located in the precombustion chamber. When called for, fuel is sprayed into the precombustion chamber by the fuel injector. It is then ignited by combustion chamber temperatures, and burns. As the burning fuel moves into the combustion chamber, it begins a swirling motion (turbulence). The swirling effect caused by the transfer from the precombustion chamber to the combustion chamber helps to mix the fuel and air in a cylinder. This aids in complete burning of the fuel, which creates power at the piston. This design was used in most Ford light duty diesel applications prior to 1994.
- **Direct Injection**
  - A direct injection design is one in which the fuel injector is positioned so that it sprays a fuel charge directly into the combustion chamber. The direct injection combustion chamber may also be called an open chamber because there are no restrictions or obstacles for the fuel to go through within the combustion chamber.

    The creation of turbulence within the direct injection combustion chamber is primarily accomplished through the design of the piston head. This design is used on the 7.3L Direct Injection Turbo (DIT) diesel.

Fuel Delivery to the Combustion Chamber

The fuel injector sprays fuel into the combustion chamber or precombustion chamber under very high-pressure, atomizing the fuel so that it sprays evenly. The spray from the fuel nozzle occurs in a short burst. This burst of fuel forms a fuel-rich core surrounded by hot air zones.

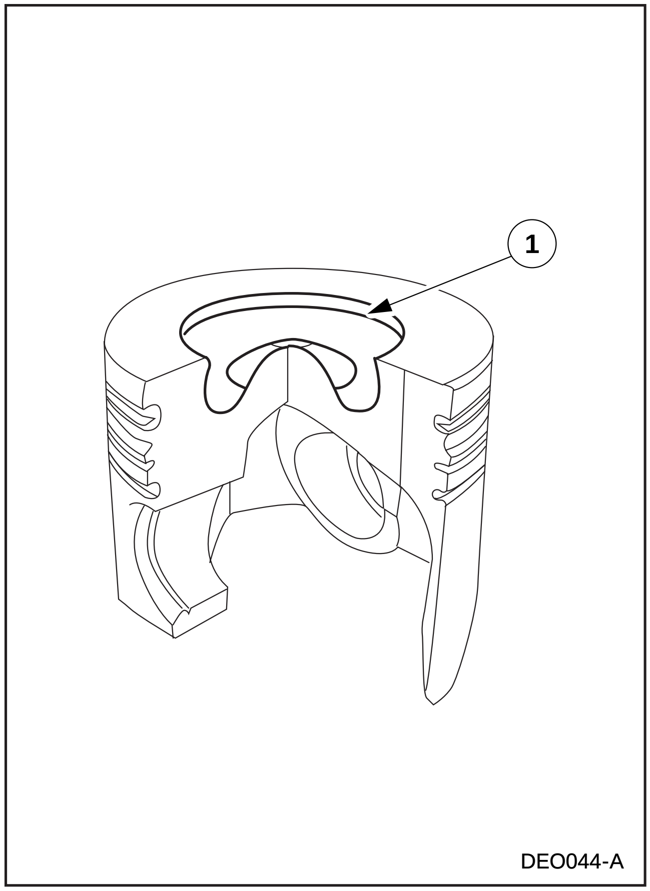
Diesel engine combustion properties rely heavily on how the fuel and air are mixed. In a gasoline engine the air and fuel are mixed prior to entering the combustion chamber. However, in the diesel engine the air and fuel are mixed directly in the chamber. How rapidly the cylinder pressure increases during combustion is directly proportional to how the fuel and air are mixed.



Fuel Delivery

7.3L DIT COMBUSTION CHAMBERS

The combustion chambers in the 7.3L DIT diesel engine are machined into the tops of the pistons. This allows the entering air and fuel to mix with a swirling motion. The 7.3L Direct Injection Turbo (DIT) diesel engine utilizes direct injection and does not have precombustion chambers.



Combustion Chamber

Item	Description
1	Combustion Chamber

Ignition of Fuel/Air Mixture

A diesel engine relies on compression ignition. It is essential that the fuel be delivered to the combustion chamber or precombustion chamber at precisely the right moment. Fuel that is delivered too soon will not mix well with the air in the cylinder. Fuel that is delivered too late will not burn completely and cause a loss of usable pressure and heat, ultimately causing a decrease in engine power and increased emissions.

In a diesel engine there are three distinct parts to combustion. They are:

1. Delay – Near the end of the compression stroke fuel injection begins. After the start of injection, the fuel does not ignite immediately. This period is termed delay.
2. Rapid Combustion – This is the sudden rise in pressure within the combustion chamber that causes diesel knock. This condition occurs when the fuel first starts to burn.
3. Controlled Combustion – After rapid combustion occurs, other fuel within the combustion chamber begins to burn and injection continues. There is a rich core of fuel at the injector along with zones of air. This core of fuel burns as it mixes with air.

During initial injection, fuel has been introduced to the combustion chamber, but has not begun to burn. The temperature of the air is much higher than the fuel, causing some of the fuel to vaporize, while some of the fuel stays in droplet form. The vaporized fuel mixes with the hot compressed air. After about 0.001 second, any zones that are hot enough and have the correct air/fuel mixture will spontaneously ignite, rapidly followed by ignition of the remaining fuel. Note that ignition takes place only where air meets fuel. In the first part of ignition, fuel burns very rapidly. This rapid burning causes a sudden rise in pressure. A fast rise in pressure within the combustion chamber can be caused by a long ignition delay time.

Since the majority of fuel is injected during this delay period, a large amount of fuel causes a rapid pressure rise. The sudden rise in pressure causes a high, localized pressure. It is this localized pressure that gives a diesel engine its characteristic knock. The severity of the knocking sound depends on the speed of the pressure rise. Also, during a long delay period, more time is available for mixing the fuel and air. If the burning is too slow, there is not sufficient time for the fuel to burn completely, resulting in lower power output and increased emissions.

The high-pressure in the cylinder pushes down on the piston. It should be noted that following the sudden rise in pressure, the remaining diesel fuel burns in a very controlled manner that is slower than that of gasoline. This causes a longer sustained push against the piston as it travels down the bore and is one of the major reasons that diesel engines have a reputation for high torque. Simply stated, the expanding gases push against the piston for a longer, more sustained period.

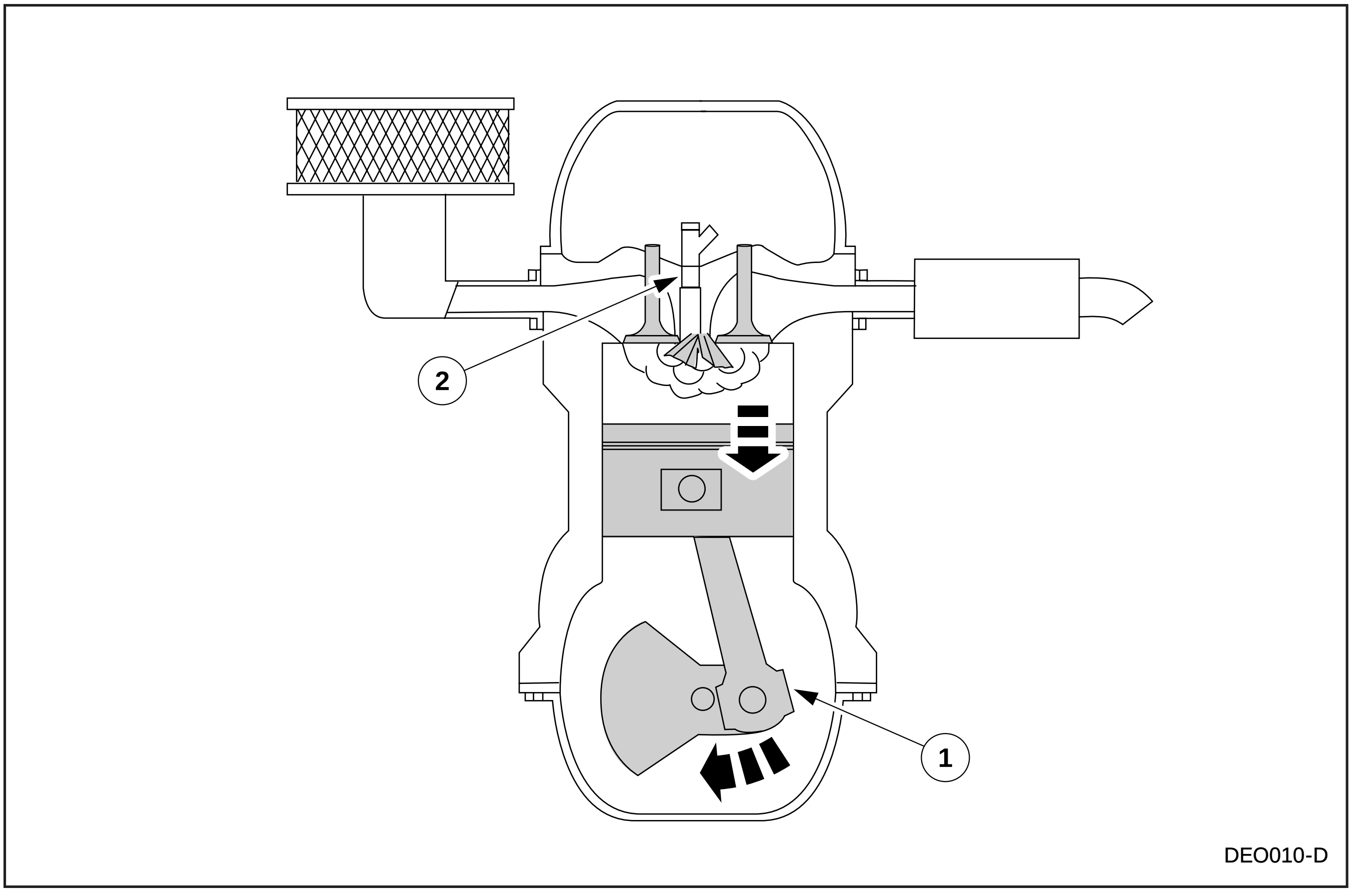
Because of its combustion characteristics, flame speed (how fast the combustion flame travels in a cylinder) is not as important in diesel engines as in gasoline engines. Instead, the rate of combustion is determined by how quickly the air and fuel are mixed. As engine speed rises, mixing increases, but not enough to compensate for the reduced time available for combustion. Due to this factor, the upper speed of the diesel engine is limited. Engine designers must be careful with air/fuel mixing. If all of the fuel could be instantly mixed with air, then the mixture would burn immediately upon ignition.

Emissions Created During Combustion

All burning fuels including wood, paper, gasoline and diesel fuel give off emissions. The level and types of emissions are dependent on a number of factors. In the case of a gasoline or diesel engine, combustion chamber design, fuel ignition, cylinder or combustion chamber temperatures all play a part in determining the level of emissions produced in the exhaust. The properties of the diesel engine and diesel combustion contribute to lower emissions than a gasoline engine. The types of significant emissions given off by diesel engines are:

- hydrocarbons (HC)
- oxides of nitrogen (NO_x)
- particulate matter (visible)
- carbon dioxide (CO_2)

POWER STROKE



The Diesel Power Stroke

Item	Description
1	Fuel Injector
2	Crankshaft

The power stroke of the diesel is very similar to that of the gasoline engine. When the fuel/air mixture is ignited during the end of the compression stroke, it begins to burn. This is not an explosion, but a slow burning process. As the fuel/air mixture burns it causes a rapid increase in pressure in the cylinder. This increase in pressure pushes down on the top of the piston. This burst of energy is transferred to the crankshaft and is measured as horsepower and torque.

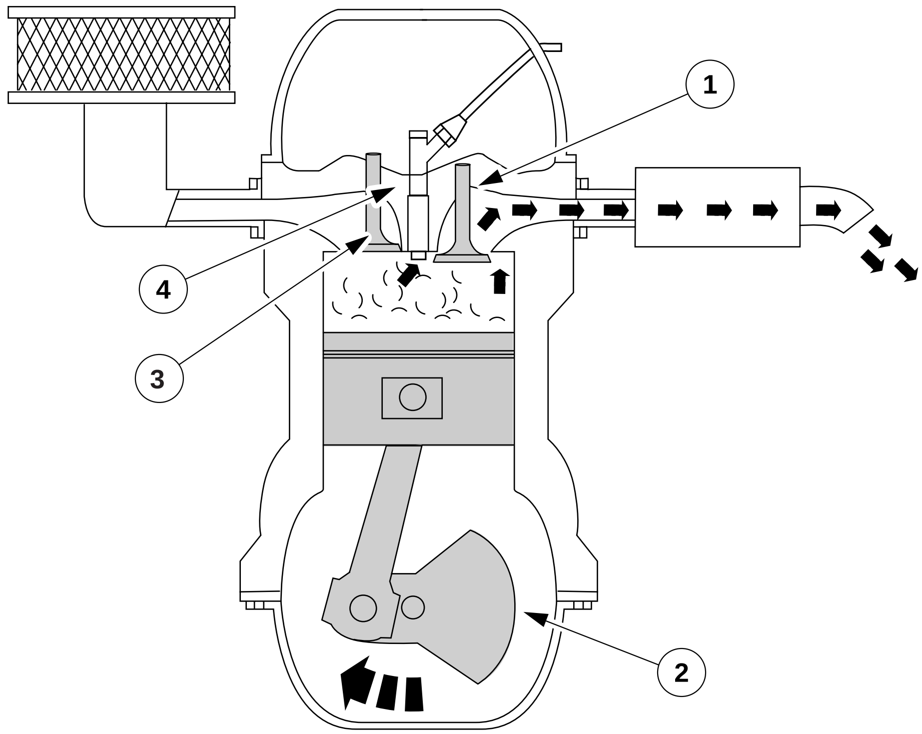
Power and Fuel Injection Relationships

The diesel engine gets its power increase from an increase of fuel. The engine has a constant flow of air. Because the air intake is not restricted, the cylinders receive the same amount of air consistently. Therefore, to increase power output of the engine, more fuel must be injected into the cylinders.

Thermal Efficiency

The internal combustion process produces heat and heat is a form of energy. Much of this heat may be wasted and dissipated through the cooling and exhaust systems. The ability of an engine to effectively use this heat energy is referred to as thermal efficiency. Since the diesel engine combustion process requires heat for ignition, its thermal efficiency is greater than a gasoline engine. Less heat energy on a diesel is wasted and dissipated through the cooling and exhaust systems, and more is recycled for use in the combustion process.

EXHAUST STROKE



The Diesel Exhaust Stroke

Item	Description
1	Exhaust Valve (Open)
2	Crankshaft

Item	Description
3	Intake Valve (Closed)
4	Fuel Injector

The exhaust stroke is the same on both gasoline and diesel engines. The exhaust valve is opened as the rotation of the crankshaft pushes the piston back up the cylinder. This forces the burned gases out through the exhaust port. As the piston nears top dead center, the intake valve is opened again and the cycle repeats itself. The exhaust valve is closed shortly after the piston begins its downward movement.

The exhaust stroke produces no work, but expends a quantity of energy to push the exhaust gases from the cylinder.

High Volume Exhaust

The diesel engine is essentially a breathing machine. It uses a very high volume of air to operate, and expends a very high volume of exhaust. There is a noticeable increase in exhaust volume in a diesel engine over a gasoline engine.

REVIEW QUESTIONS

1. The shape of the combustion chamber affects combustion in a diesel engine.
   A. True
   B. False
2. The exhaust stroke is the same on both diesel and gasoline engines.
   A. True
   B. False
3. Which part of combustion consists of a sudden rise in pressure within the combustion chamber?

   ____

   ____
4. How is the power output on a diesel engine controlled?

   ____

   ____
5. What is the main difference between direct and indirect injection?

   ____

   ____

NOTES

TECHNICIAN OBJECTIVES

- Explain the function of the fuel system.
- Identify the function of the fuel supply system.
- Describe fuel supply system components and operation.
- Explain the purpose of the fuel delivery system.
- Describe fuel delivery system operation.
- Describe the purpose and function of the fuel injectors.
- Describe 7.3L DIT specific fuel system components and operation.

CONTENTS

PURPOSE OF THE FUEL SYSTEM

The purpose of the fuel system is to move stored fuel from a fuel tank, through a filtering system to the fuel delivery system and ultimately to the cylinders for combustion. In a diesel engine proper fuel delivery is critical to engine operation. Therefore, fuel system concerns can dramatically affect engine performance.

Diesel fuel systems can be divided into two subsystems:

- The Fuel Supply System, which draws fuel from the tank and delivers it to the fuel delivery system.
- The Fuel Delivery System, which delivers fuel into the combustion chamber.

In this lesson, both systems will be explained in detail for conventional diesel engines and for the Ford 7.3L DIT engine.

NOTES

CONVENTIONAL DIESEL FUEL SUPPLY SYSTEM

The fuel supply system of a conventional diesel engine is a low-pressure system that moves the fuel from the fuel tank to a point where it is pressurized to be injected into the engine combustion chamber. The components of the fuel supply system will vary between types and makes of diesel engine, however, the following are components common to all of them.

Fuel Tank - Fuel tanks on diesel vehicles are similar to those found on gasoline vehicles. However, because diesel powered vehicles are often used for long distance driving, there are often multiple high-volume fuel tanks.

Fuel Pickup - The fuel pickup in a diesel engine draws fuel from the bottom of the tank. The pickup usually contains a screen to help reduce the amount of particle contamination drawn into the system.

Lift Pump- To transfer fuel from the fuel tank to the filtering system and then on to the fuel delivery system, a lift pump is commonly used. This pump is usually mounted in-line between the tank and fuel filter, and may be either mechanically driven by the engine or electrically driven.

Fuel Filter - Fuel filtration is extremely important to diesel engines and very fine filters are required. The reason for having such a fine filtering system is because of the tight tolerances within the fuel injectors. Any abrasive particles that get past the filter could cause severe damage.

Fuel/Water Separator - Because of the damage that may be caused by water in a diesel engine, most diesels have a fuel/water separator. Since diesel fuel is lighter than water, water will accumulate below the fuel. Water separators take advantage of this to remove the water from the fuel system. Fuel/water separators must be drained regularly as part of normal maintenance.

Fuel Heater - Because of the tendency for diesel fuel to wax and gel in cold weather, electric fuel heaters are typically used on most automotive diesel engines. Fuel heaters are used to warm the fuel entering the injection system, to minimize the effects of fuel jelling, waxing, and general cold weather fuel concerns.

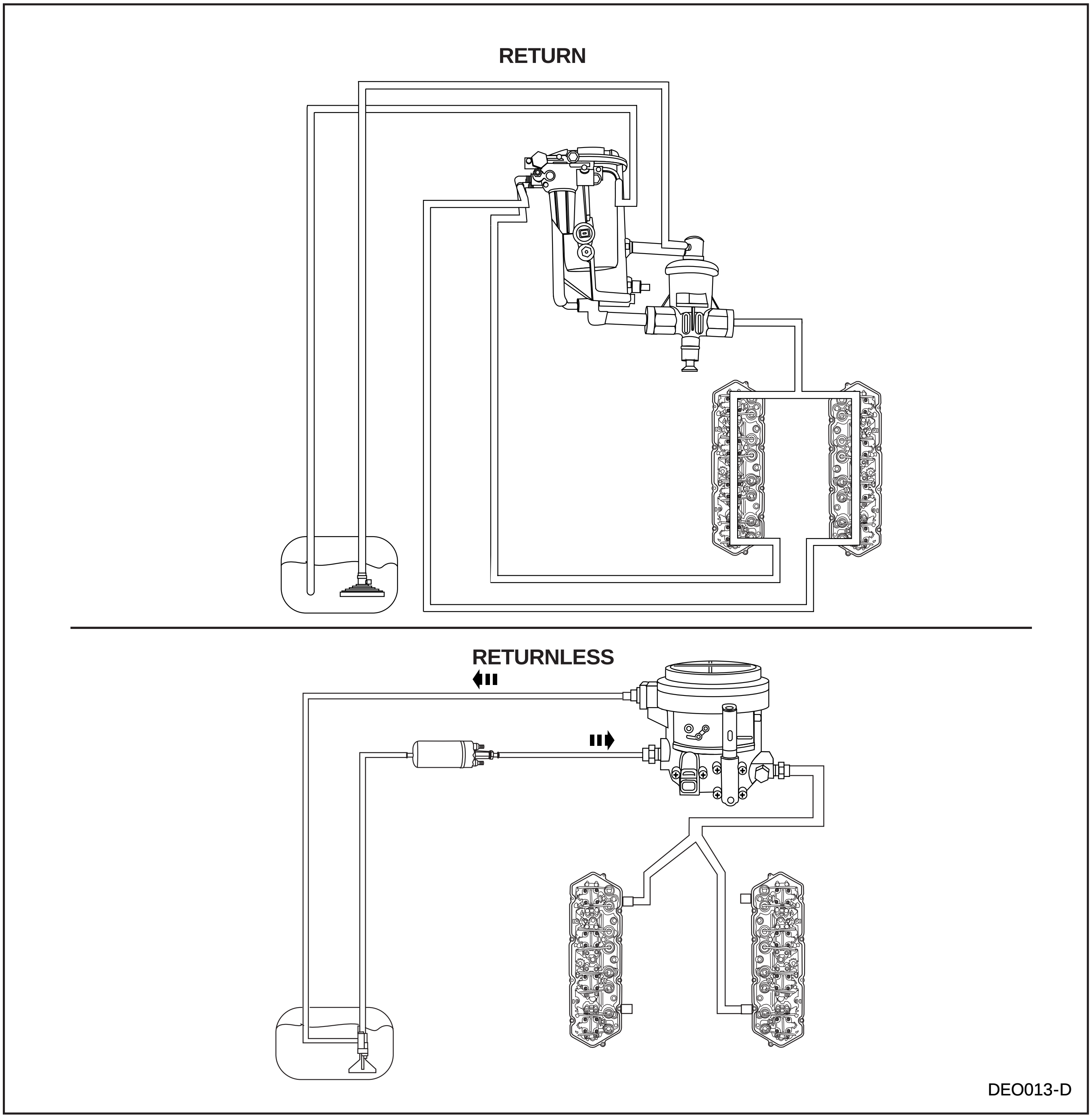
Fuel Injection Pump - Diesel engines require fuel to be injected into the engine under extremely high pressure to overcome the compression pressure in the combustion chamber. On some vehicles mechanical pumps are used to direct fuel and raise fuel pressure for injection.

NOTES

7.3L DIT FUEL SUPPLY SYSTEM

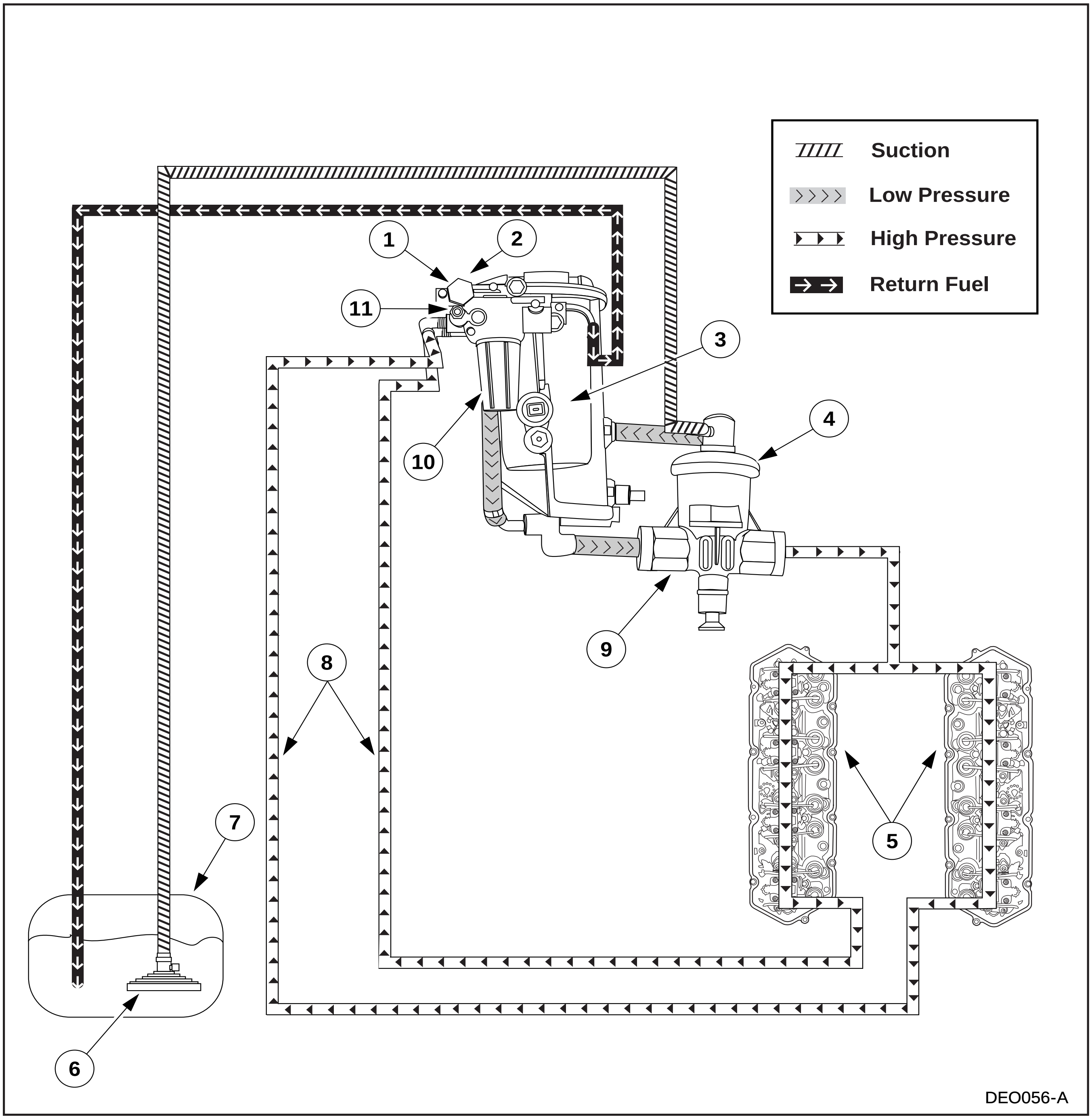
There are two distinct types of fuel systems used on the 7.3L DIT diesel engine: return and returnless. While these systems are similar, each also has some important differences. You must be aware of these differences because the diagnostic procedures are different for each system. Even though one of the systems is called returnless, both systems actually return excess system fuel to the tank. On the return type of fuel system, fuel not used by the injectors is returned from the cylinder heads to the fuel pressure regulator. On the returnless system no fuel is returned from the cylinder heads.

Return vs Returnless Fuel Supply System



Return vs Returnless Fuel Supply System

Return Fuel Supply System



Return Fuel System

Item	Description
1	.035 Orifice
2	.020 Orifice
3	Fuel Filter Housing
4	Diaphragm Stage
5	Cylinder Heads
6	Pick Up

Item	Description
7	Fuel Tank
8	Fuel Return Hoses
9	Piston Stage
10	Fuel Strainer
11	Pressure Regulator

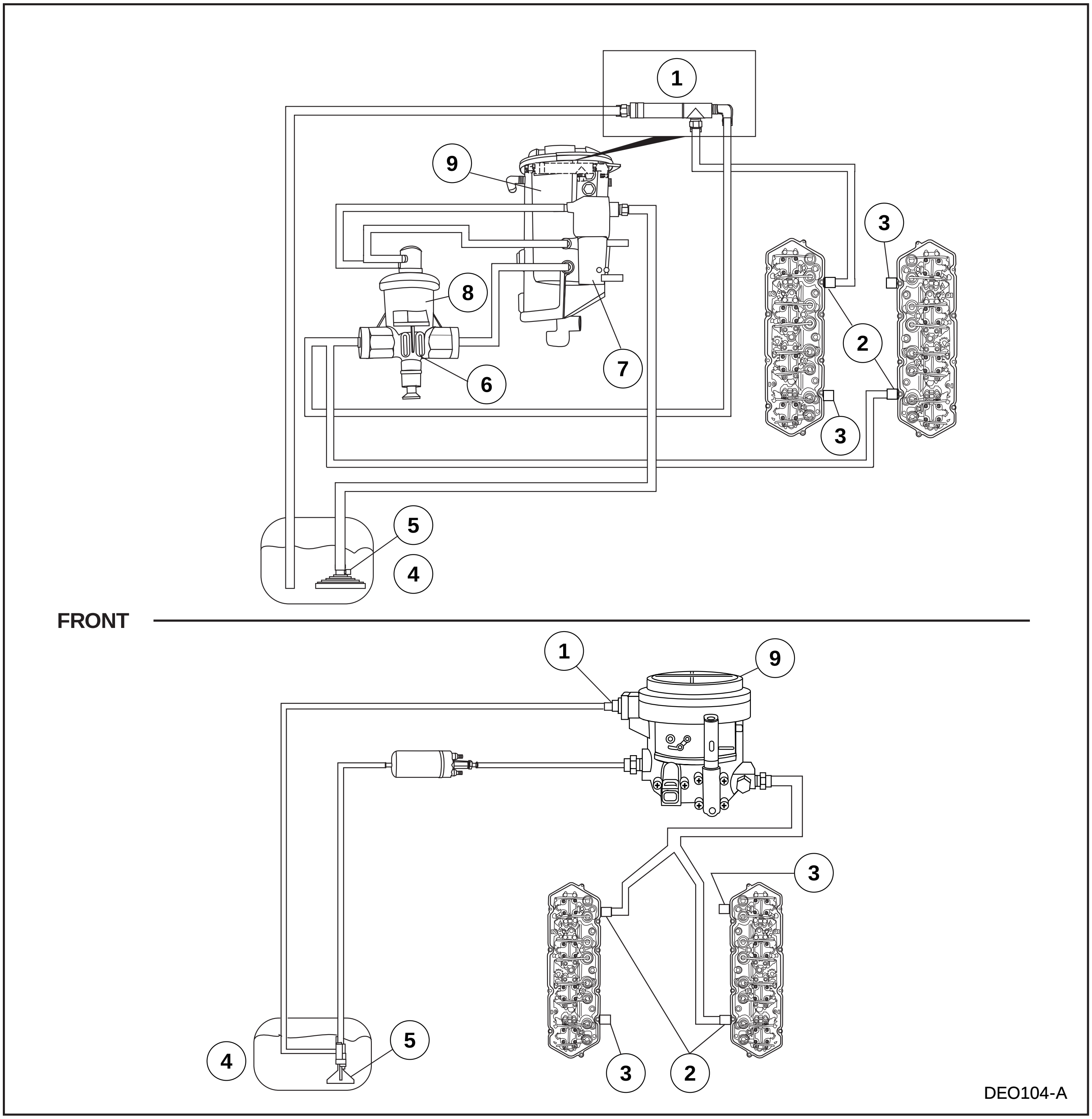
All 1998 and earlier model year vehicles using the 7.3L DIT use this system.

The return system uses a tandem mechanical lift pump to provide filtered fuel to drilled passages in the cylinder heads that channel fuel to the injectors. Fuel flow is as follows:

- Fuel is drawn from the tank to the engine by the diaphragm stage of the tandem lift pump.
- The diaphragm stage pressurizes the fuel to between 27 to 34 kPa (4 and 6 psi) while pushing it to the filter housing.
- Filtered fuel is then directed to the piston stage of the tandem lift pump, where its pressure is increased to between 275 and 482 kPa (30 and 80 psi).
- The fuel is then directed through flexible braided steel lines to the rear of each cylinder head where it enters the fuel galleries feeding the injectors.
- To maintain proper pressure in the fuel galleries fuel return flow is directed to the fuel pressure regulator attached to the filter housing.
- Fuel is then returned to the piston side of the tandem pump, excess fuel is returned to the tank through a 0.5mm (0.20 in) orifice to separate air from the fuel.
- A 0.889 mm (0.035 in) orifice is located in the fuel filter housing to allow air to bleed back to the fuel return line.

This system is called a “return” type system because fuel sent to the cylinder head, and injectors that is not used is returned to the piston stage of the lift pump.

Returnless System



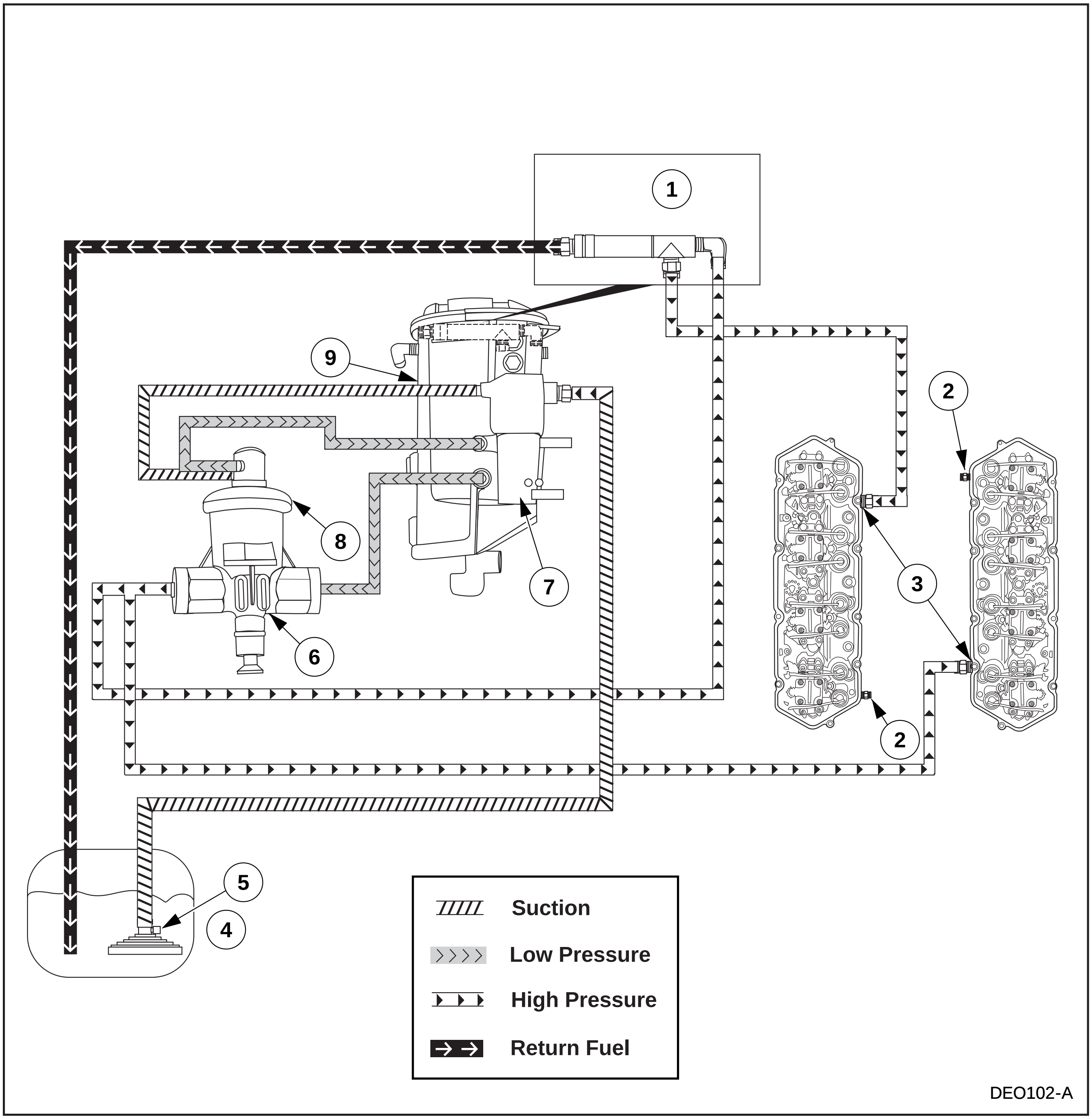
Returnless System

Item	Description
1	Pressure Regulator
2	Check Valves
3	Fuel Pressure Test Ports
4	Fuel Tank
5	Pick Up

Item	Description
6	Piston Stage of Lift Pump
7	Strainer
8	Diaphragm Stage of Lift Pump
9	Fuel Filter Housing
10	Electrical Fuel Pump

There are two types of returnless systems: mechanical pump systems, and electrical pump systems. In both types of systems, fuel that goes to the cylinder head cannot return back through the system. Electrical lift pump returnless systems are found on 1998-½ and newer Econoline trucks, and 1999 and newer F-Series vehicles. The mechanical lift pump returnless systems are found on model year 2000 and later F650 and F750 vehicles.

Mechanical Fuel System



Mechanical Fuel System

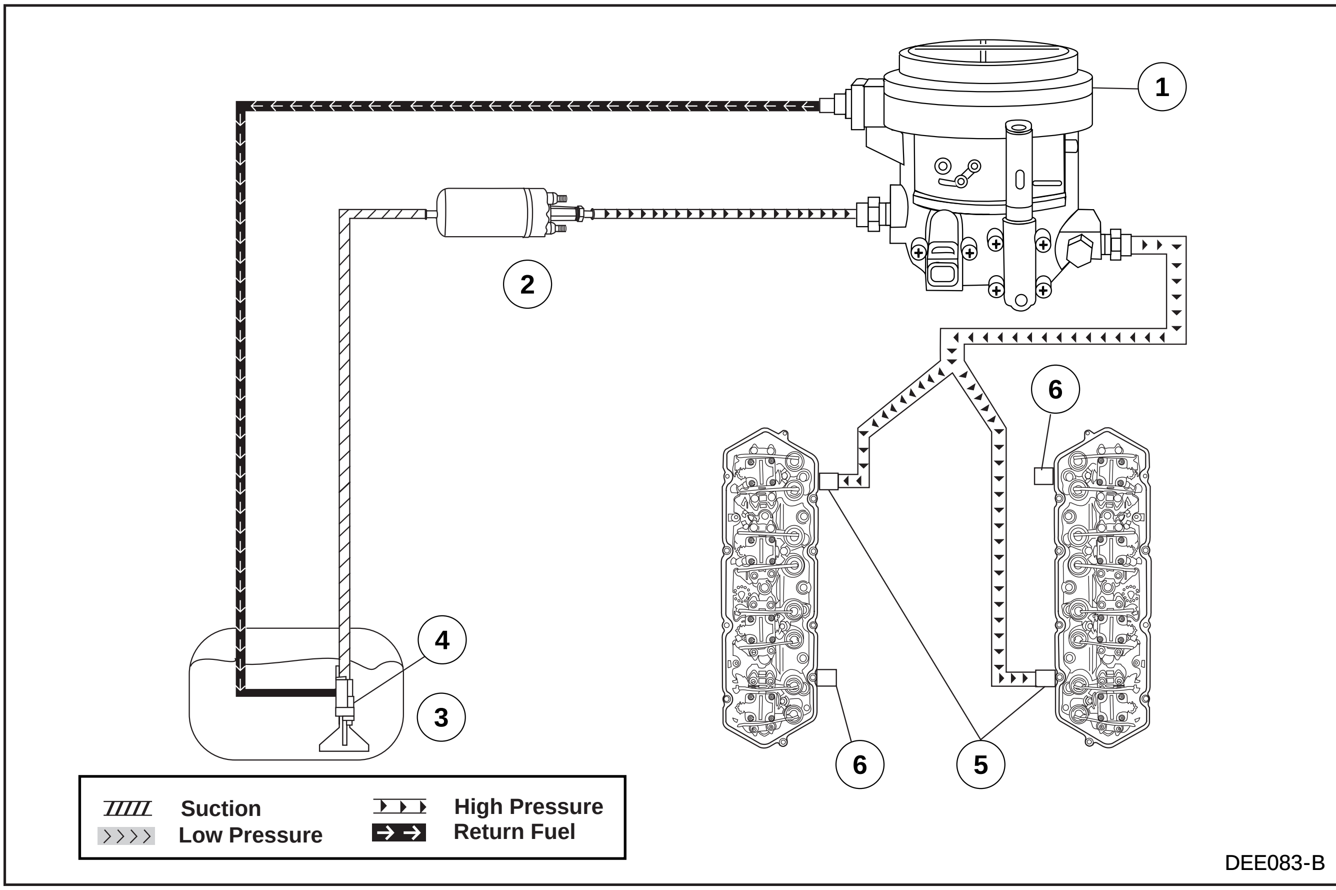
Item	Description
1	Pressure Regulator
2	Fuel Pressure Test Port
3	Check Valves
4	Fuel Tank
5	Pick Up

Item	Description
6	Piston Stage of Lift Pump
7	Strainer
8	Diaphragm Stage of Lift Pump
9	Fuel Filter Housing

- Fuel is drawn through a strainer mounted to the filter assembly by the first stage of the mechanical powered pump
- Fuel then passes through the main filter and to the second stage of the pump.
- The second stage of the pump pushes fuel through a series of lines, either to the cylinder heads or a pressure regulator.

  Fuel passes through check valves located on the cylinder heads. The check valves are used to prevent pressure spikes from the injectors from returning into the fuel supply system.
- The regulator returns excessive pressure to the tank.

Electric Fuel System



Electronic Fuel System

Item	Description
1	Fuel Filter Housing
2	Electric Fuel Pump (FP)
3	Pick Up
4	Diesel Thermal Recirculation Module (DTRM)

Item	Description
5	Check Valves
6	Fuel Pressure Test Ports

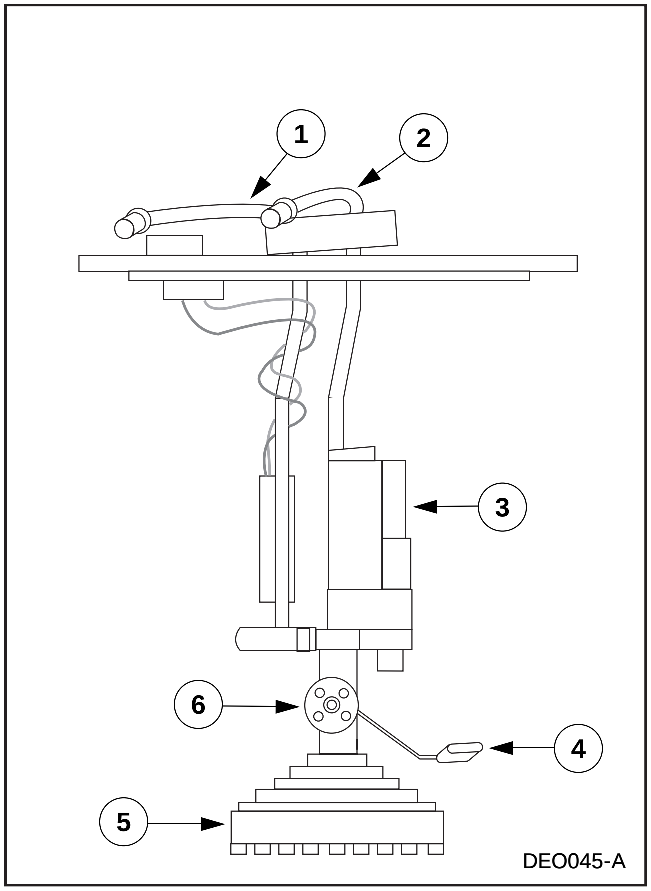
- Fuel is drawn through Diesel Thermal Recirculation Module (DTRM) by the electric pump and is delivered to the filter assembly.
- The fuel filter housing is pressurized to specification. The excessive pressure is returned to the fuel tank through the pressure regulator.
- The pressurized fuel then passes through the main filter and is delivered to each cylinder head.
- A check valve in each cylinder head is used to contain pressure spikes.

7.3L DIT FUEL SUPPLY SYSTEM COMPONENTS

Fuel Tank/Fuel Pickup

In most cases, the fuel tanks used on diesel-powered vehicles are similar to those used on gasoline-powered vehicles. The tanks, of course, must be made of a material that will not be attacked or corroded by diesel fuel. The interior components (in particular, the diesel fuel intake and sending unit) are specifically designed for diesel engine applications.

Diesel fuel pickup units are different from gasoline units, especially in the area of the inlet. Many of the applications used by Ford Motor Company vehicles use a Ford-designed diesel fuel intake that is unique. The diesel fuel intake maintains constant contact with the bottom of the fuel tank. The reason for keeping the fuel intake constantly drawing from the bottom of the tank is to prevent buildup of contaminants, such as water and microbiological organisms, in the fuel tank. The contaminants are removed by the fuel filter assembly.



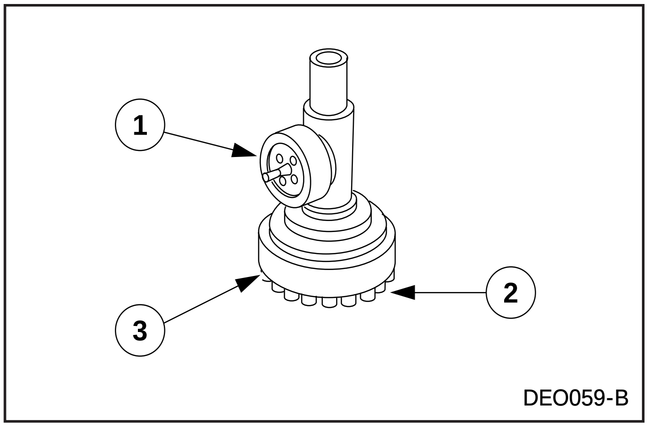
Diesel Fuel Pickup Unit

Item	Description
1	Fuel Return Line
2	Fuel Pickup Line
3	Diesel Thermal Recirculation Module (DTRM)
4	Fuel Level Sending Unit
5	Nib Assembly
6	Fuel Bypass Valve

Nib Assembly

The diesel fuel intake actually draws water to it by creating a pressure differential between itself and the fuel tank. The “nibs” restrict the fuel flow and create a type of venturi effect on the fuel. Fuel going past the nibs accelerates, and the pressure drops. This pressure drop is what attracts the water. Water contained in the fuel is drawn, along with the fuel, into the diesel fuel intake and is accelerated and forced through a nylon screen that is contained there. The screen is present to prevent any large particles from being drawn into the fuel lines. The water is removed from the fuel later in the system by the fuel/water separator.

Included on the diesel fuel intake is a bypass valve. Its purpose is to allow fuel to pass into the fuel line if the filter screen becomes clogged with waxed fuel, ice, or some other impurity. The bypass valve opens when there is an extremely high vacuum. In order for the bypass valve to work correctly, it must be covered by fuel.



Nib Assembly

Item	Description
1	Bypass Valve
2	Nibs
3	Nylon Screen

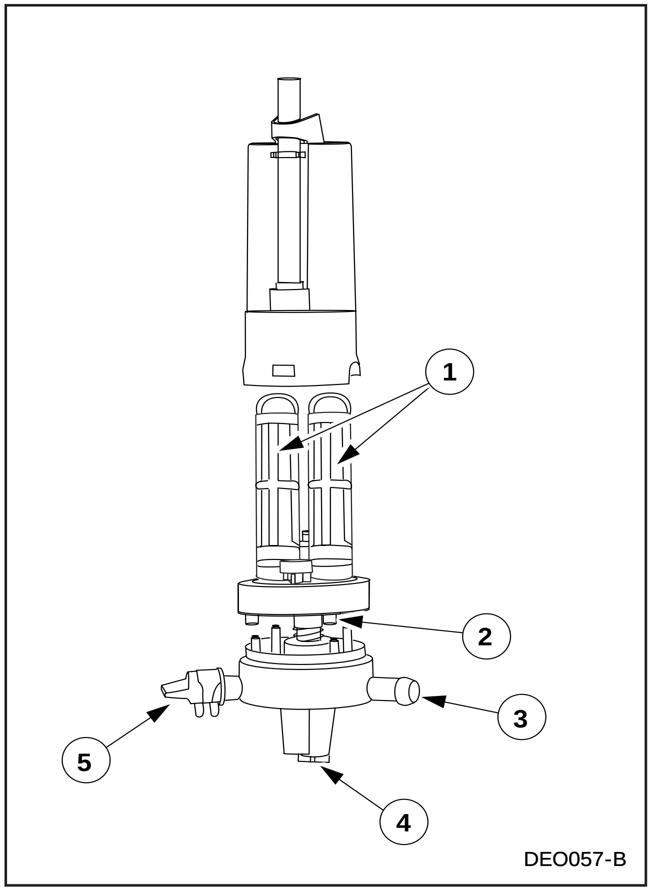
Diesel Thermal Recirculation Module (DTRM)

The DTRM is used on the 7.3L DIT equipped vehicles that incorporate an electric fuel pump. Located on the fuel pickup unit, the purpose of the DTRM is twofold. First, it is used to screen fuel before it is drawn into the fuel pump. Second, it helps to warm the fuel in the fuel system and maintain a controlled fuel temperature.

The screen located at the bottom of the fuel pickup unit, part of the Nib assembly, is too coarse to protect the electric fuel pump assembly from particle damage and wear. Two screens located in the DTRM assembly are used to stop smaller particles from reaching the fuel pump.

The thermostatically controlled spool valve in the DTRM is used to help maintain a normal fuel temperature 10 to 66ºC (50 to 150ºF) in the fuel delivery system. This is needed to prevent cold fuel from waxing and jelling, and to prevent hot fuel from overheating the fuel pump. A constant fuel temperature of 38ºC (100ºF) is best for optimal fuel pump efficiency.

Operation - The fuel pump draws the fuel from the tank through the screen assemblies. Returning fuel that has been warmed by the engine is directed by a thermostatically controlled spool valve. The thermostat is exposed to the temperature of the fuel that has already passed through the screens. If the thermostat device is cold, it contracts to allow the warm return fuel to pass through the spool valve and enter the inlet prior to the screens and mix with the cooler fuel from the tank. If the thermostat is too warm, it expands and pushes the spool valve closed, to force the fuel out the duck bill and into the tank.



Diesel Thermal Recirculation Module

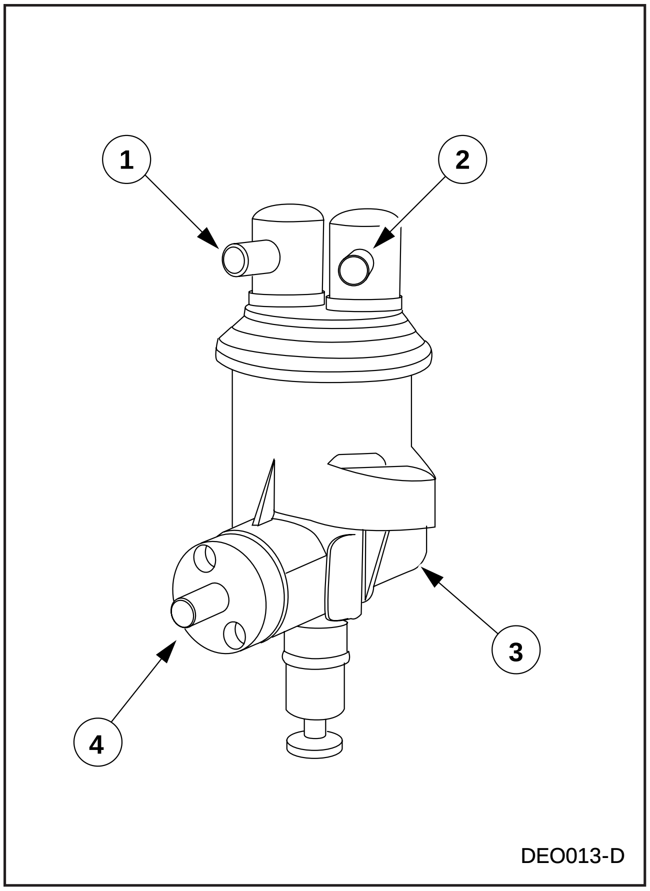
Item	Description
1	Screens
2	Spool Valve
3	Return Fuel
4	From Nib Assembly
5	Duck Bill

7.3L Fuel Pumps

Mechanical Lift Pump

The mechanical lift pump contains two separate pumps within one assembly. The pump is driven by a single lobe on the camshaft.

- The upper stage is a typical diaphragm type which creates a vacuum to draw the fuel from the tank.
- The lower stage is a piston type pump that increases pressure for use by the fuel injectors.
- Each pump has a pair of check valves that allow fuel to only go in one direction.



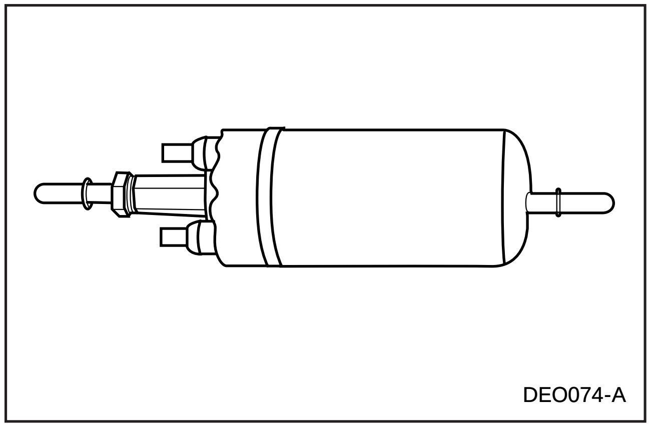
Mechanical Lift Pump

Item	Description
1	Fuel Out Low-Pressure
2	Fuel In Low-Pressure
3	Fuel Out High-Pressure
4	Fuel In High-Pressure

Electric Fuel Pump

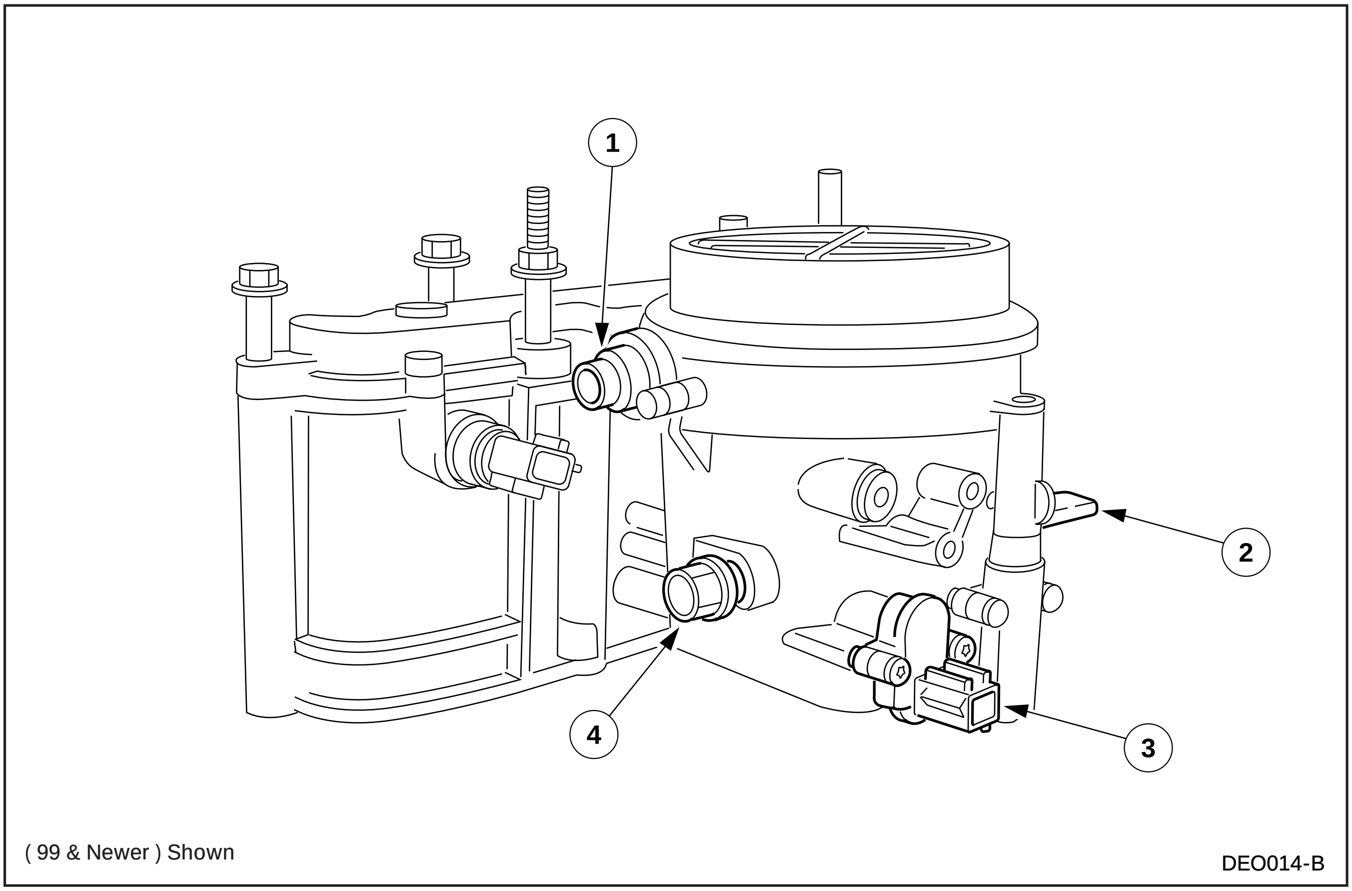
Electric fuel pumps are used on all 1998-½ model year and later 7.3L DIT vehicles, except F650/750. Although it functions the same as the mechanical fuel pump, its operation is quite different.

The pump draws fuel from the tank and creates adequate pressure for the HUEI injectors. The pump is controlled through a relay by a control module.



Electric Fuel Pump

Fuel/Water Separator/Filter/Heater Assembly



7.3L DIT Fuel/Water Separator/Filter/Heater Assembly

Item	Description
1	Fuel Pressure Regulator/Return to Tank
2	Water Drain Lever

Item	Description
3	Fuel Heater and Water in Fuel Sensor
4	Fuel Supply From Tank

This device carries out three separate functions. It is commonly called the filter assembly, and also houses the pressure regulator, fuel heater and water in fuel sensor. The following is a description of its functions.

Fuel/Water Separator - Gravity causes water, which is heavier than diesel fuel, to sink to the bottom of the fuel/water separator, where it remains until the device is emptied. The fuel/water separator must be drained regularly, otherwise, water could get to the high-pressure fuel injection components. A sensor located at the base of the filter housing detects the presence of water in the fuel. When excessive water has collected in the fuel separator, the sensor illuminates a light in the instrument cluster alerting the driver that the water must be drained.

Filter - The filter element is a replaceable type that removes particulate contaminates. It uses a cartridge type element.

CAUTION: The bevel-cut gasket on the filter housing must be oriented correctly during repair, or the assembly will leak.

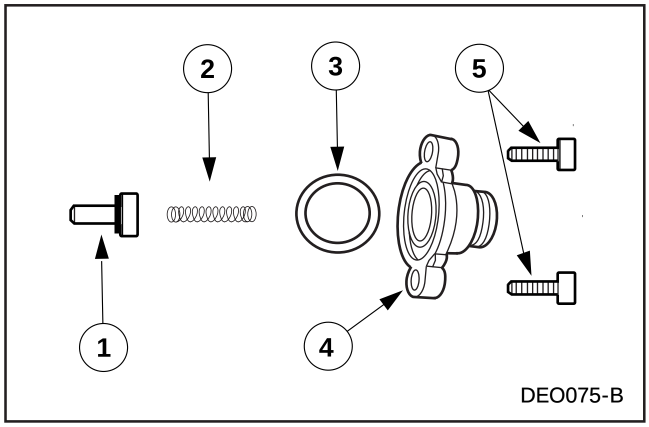
Heater - The base of the filter housing contains an electric heating element to warm the fuel, to prevent waxing during cold weather. The heater is thermostatically controlled so that it is only activated during cold temperatures.

Fuel Pressure Regulator

The fuel pressure regulator used on the 7.3L DIT engine contains a spring-loaded spool valve to control pressure in the fuel galleries to 276-483 kPa (30-80 psi). The pressure regulators on both the return and returnless systems operate in a similar way, however, each regulates the fuel at a different point in the system.

- On return systems, fuel pressure is regulated after it leaves the cylinder head.
- On returnless systems, fuel pressure is regulated before it enters the cylinder head.

On both the return and returnless systems the regulator is located on the filter housing.



Fuel Pressure Regulator

Item	Description
1	Spool Valve and O-Ring
2	Spring
3	O-Ring
4	Cap
5	Bolts

Fuel Return Lines and Hoses

The placement of the fuel return line in the fuel tank reduces fuel oxidation. Incorporated with the fuel pickup unit, the fuel return line sprays out return fuel in a mist. This spray is located near the bottom of the fuel tank, so that the return fuel is sprayed into the fuel. If this mist were exposed to large amounts of air, which would occur if it sprayed out near the top of the tank, a tar-like substance could form, eventually clogging the injectors.

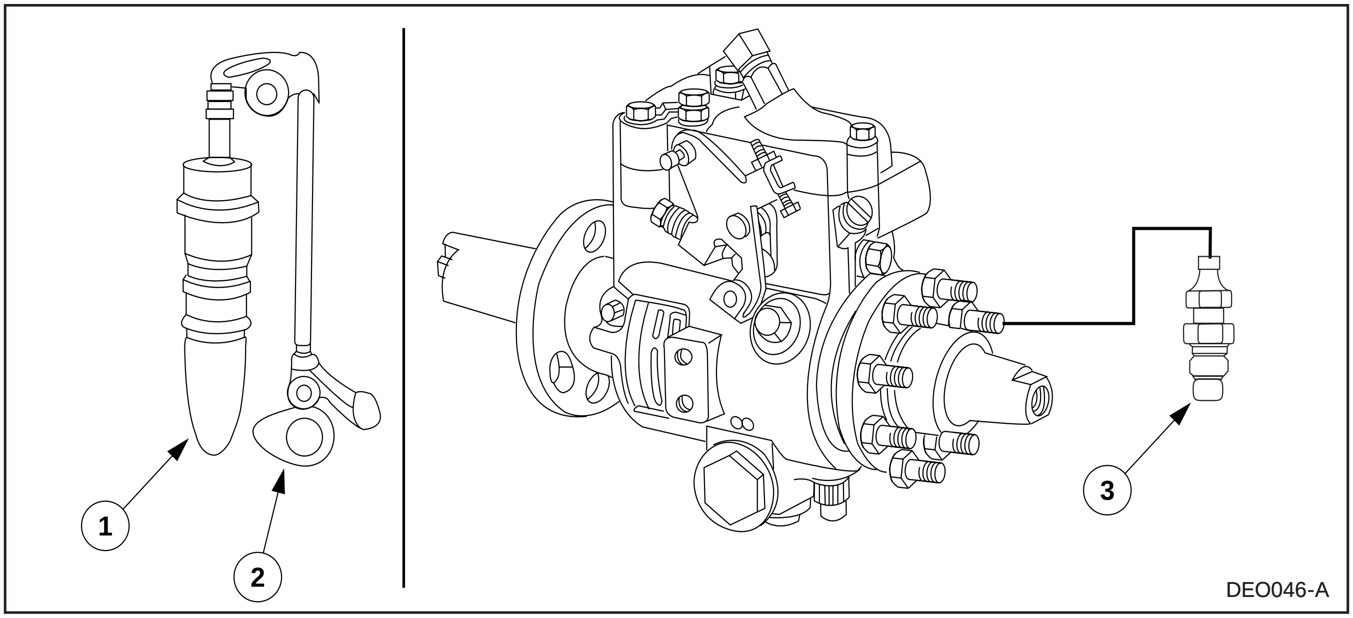
Return fuel has passed through components in the engine compartment where it picks up heat. This warm fuel is returned near the fuel pickup.

FUEL DELIVERY SYSTEM

As explained earlier, the diesel engine fuel system has two subsystems. The previous pages described the fuel supply system. The rest of this lesson will be devoted to explaining the operation of the fuel delivery system. The function of the fuel delivery system is to actually inject the fuel into the engine cylinders.

Fuel delivery into the cylinders is critical on diesel engines. Because of the high compression ratios of diesel engines, a great deal of pressure is needed to get the fuel into the diesel engine cylinders. Before we explain the specifics of the 7.3L DIT engine fuel delivery system, let's first look at how fuel delivery systems on conventional diesel engines work.

DIESEL ENGINE FUEL DELIVERY SYSTEMS



Conventional-Type Fuel Injection Systems

Item	Description
1	Unit Fuel Injector
2	Camshaft Lobe
3	Fuel Injector (Nozzle)

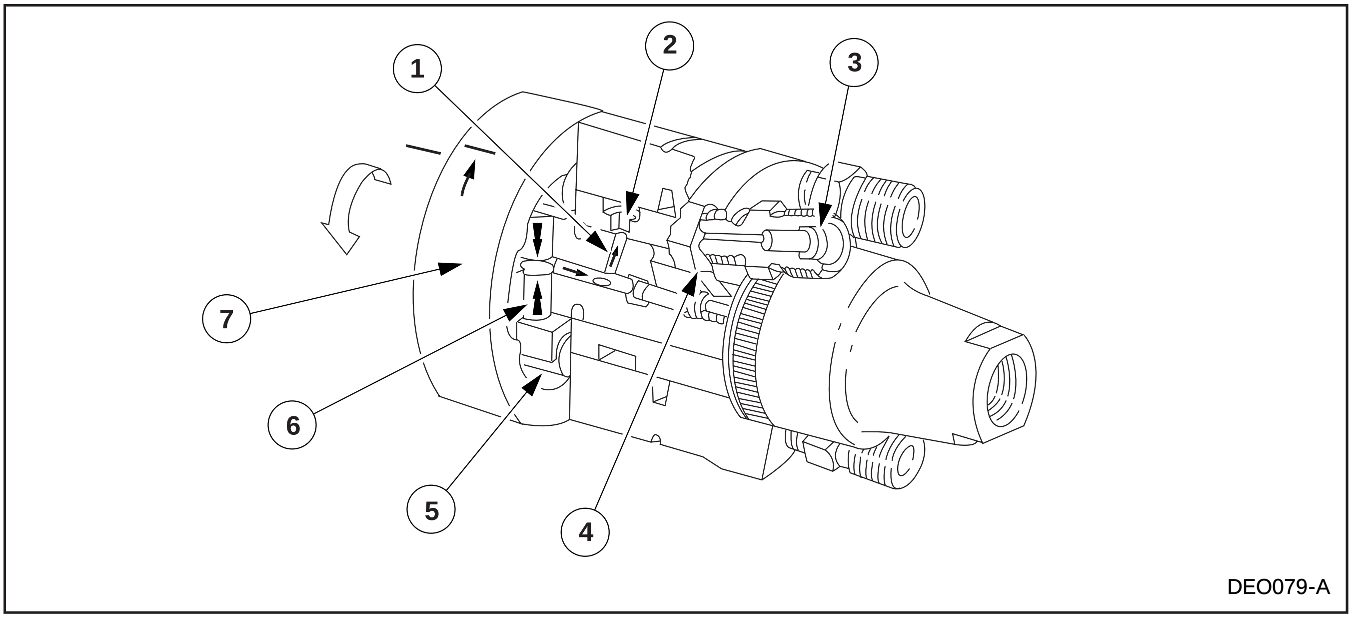
Diesel engines can use many different types of injection systems. Two of the more common ones include:

The Distributor Injection System - this type of system uses a distributor-type fuel injection pump, sometimes called a rotary pump. This pump typically uses a single pumping element, whose pressure is directed to individual fuel injectors or nozzles.

The Unit Injection System - This type of system includes the functions of the fuel injection pump and fuel injector into a single fuel injection unit. There is one unit for each cylinder.

The following are brief descriptions of the operation of these systems.

Distributor-Type Fuel Injection System



Distributor Injection Pump

Item	Description
1	Spill Passage
2	Charging Port
3	Discharge Port
4	Discharge Passage

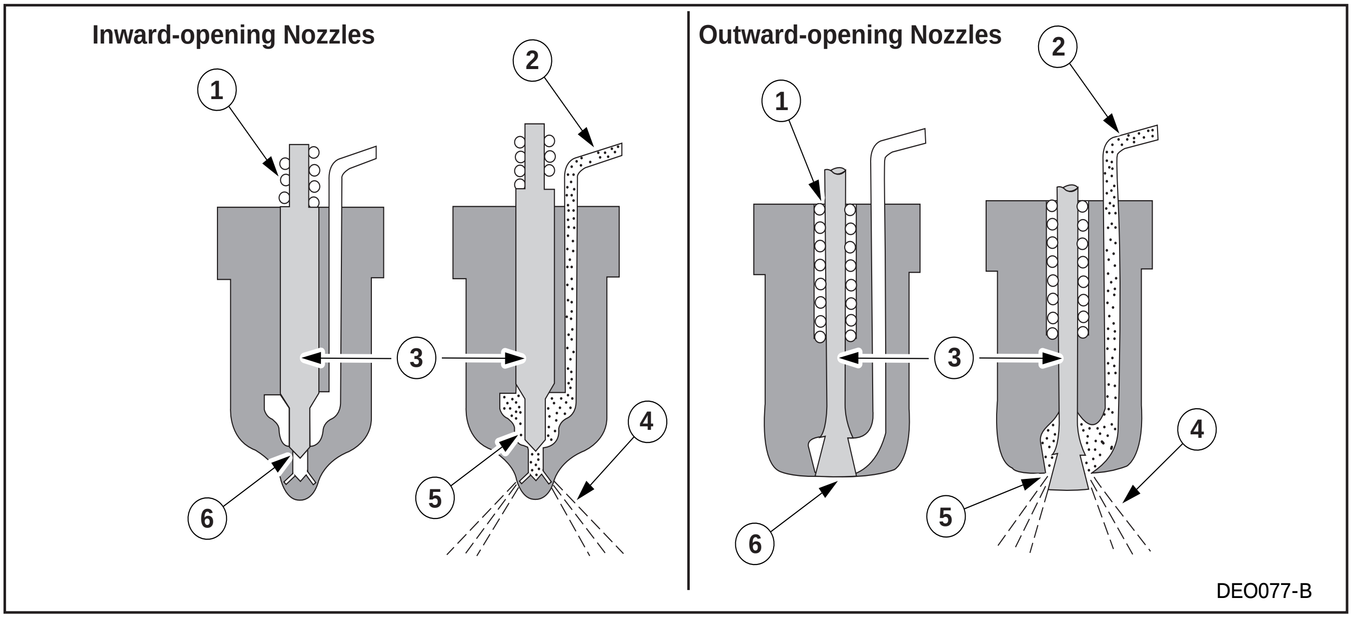
Item	Description
5	Roller
6	Plunger
7	Cam

There are a variety of distributor-type fuel injection pumps currently in use on diesel powered vehicles. This type of fuel injection pump is a precise piece of equipment capable of delivering an exact amount of fuel under very high-pressure to each fuel injector at exactly the right moment. The action of the fuel injection pump is similar to an automotive distributor, which must direct a high-voltage electrical charge to each spark plug at exactly the right time.

The distributor-type fuel injection pump is driven at camshaft speed by a belt or gear. It consists of a pump barrel and plunger that supplies the total amount of high-pressure fuel and makes sure that the engine receives the correctly metered fuel in the specified firing order.

During operation, fuel is admitted to the area in front of the pump plunger. The turning plunger is actuated by a cam disc and roller ring. When the roller and cam come in contact, the plunger is pushed forward, pressurizing the fuel to over 17,238 kPa (2,500 psi). The pressurized fuel is then sent to the correct cylinder (whatever cylinder outlet is aligned with the discharge passage of the plunger) according to the firing order.

Fuel Injection Nozzles



Types of Fuel Injector Nozzles

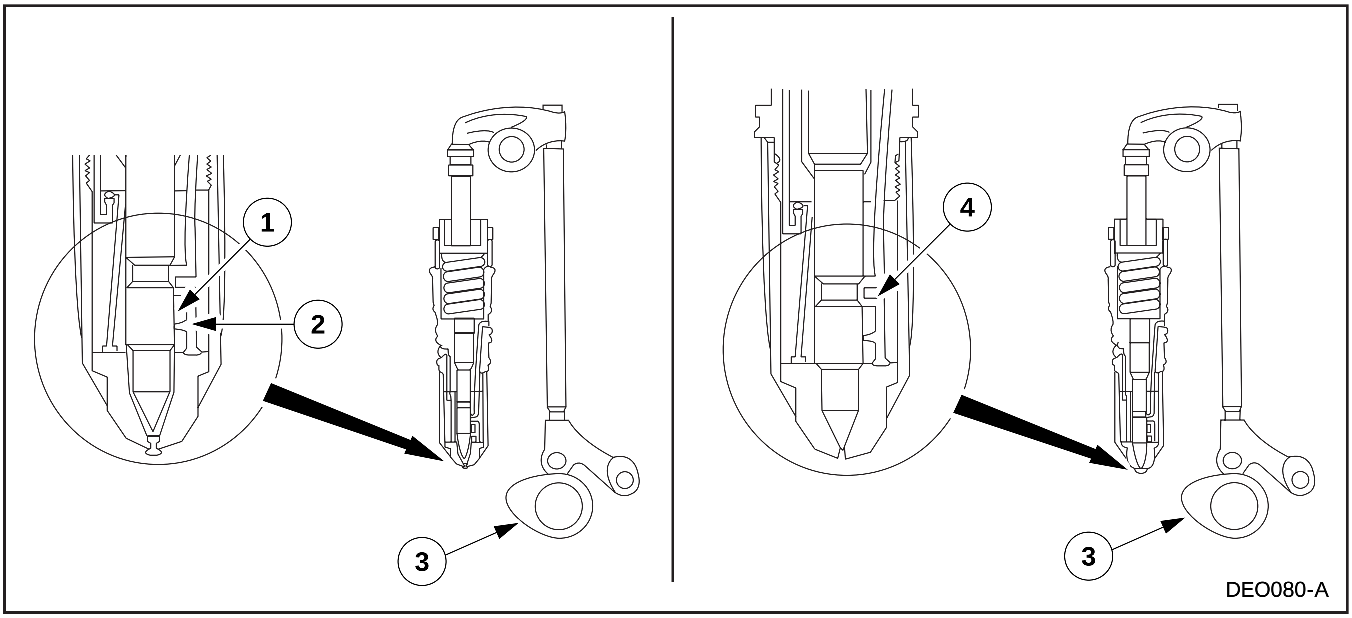
Item	Description
1	Spring
2	Fuel Line
3	Pintle

Item	Description
4	Fuel Spray
5	Valve Open
6	Valve Closed

Once high-pressure fuel is delivered from the injection pump it must be delivered into the combustion or precombustion chamber. This is the job of the fuel injector or nozzle.

There are two types of nozzles, an inward opening or outward opening. They both function primarily the same. A high tension spring is used to keep a pintle closed against a seat. When high-pressure fuel is presented to the nozzle, spring pressure is overcome and the pintle moves to allow fuel to be injected into the combustion chamber.

Unit Injectors



Injector Actuating Device

Item	Description
1	Injector Plunger
2	Metering Orifice

Item	Description
3	Camshaft Lobe
4	Drainport

Unit injectors are placed on individual cylinders in a diesel engine. In this type of system, the unit injector functions as both fuel injection pump and injector nozzle. Each injector is driven by a separate lobe on the camshaft.

During operation, low-pressure fuel is fed into the unit injector from a lift pump through the filler cap. This fuel fills the chamber between the bushing and deflector. Here the fuel is exposed to a plunger that is pushed down by a rocker arm that is driven through linkage by the engine cam. This plunger pressurizes the fuel until it is forced past a check valve to the discharge valve. When pressure is high enough, the discharge valve is lifted off its seat by the fuel trying to get past it, and injection occurs.

Plunger travel within the injector never varies, and the amount of fuel injected is based strictly on the fuel pressure supplied by pump and engine speed, which determines the time of injector spray.

7.3L DIT FUEL DELIVERY SYSTEM

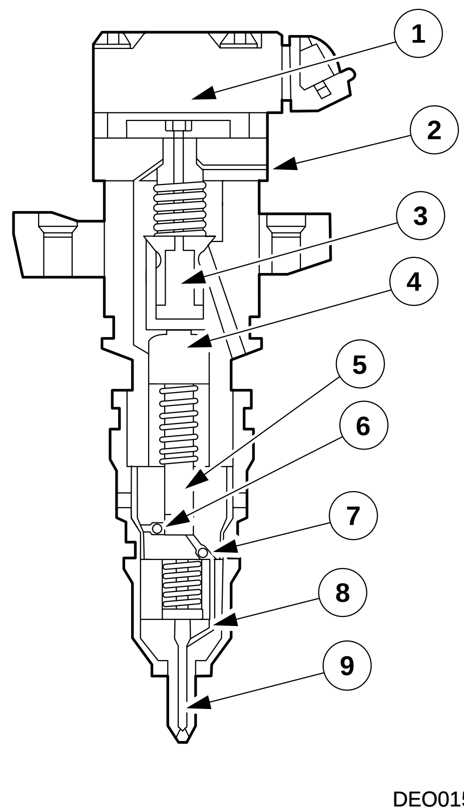
As you have learned, the trick to getting fuel into the cylinder of a diesel engine is to use a pump to create high enough fuel pressure to overcome engine compression, and to inject the fuel at the right time. The Ford 7.3L DIT engine uses a unique system to accomplish this task.

The Hydraulic Electronic Unit Injectors (HEUI)

The HEUI injector does this hydraulically using high-pressure oil supplied by a high-pressure oil pump. These injectors are PCM controlled by high voltage signals sent by the injector driver module (IDM).

The injector has four major components which contribute to higher injection pressure, improve fuel economy and help to meet emissions regulations. The components are:

- Solenoid (controls poppet valve)
  - These are high-voltage injectors, requiring about 115 v D/C and 7-15 amps of current to actuate.
- Poppet valve
  - Controls oil flow in and out.
- Intensifier piston and plunger
  - The intensifier piston is seven times larger in surface area than the plunger, causing a multiplication of force or injection pressure.
- Nozzle assembly
  - Delivers and atomizes fuel into combustion chamber.



7.3L DIT Fuel Injector

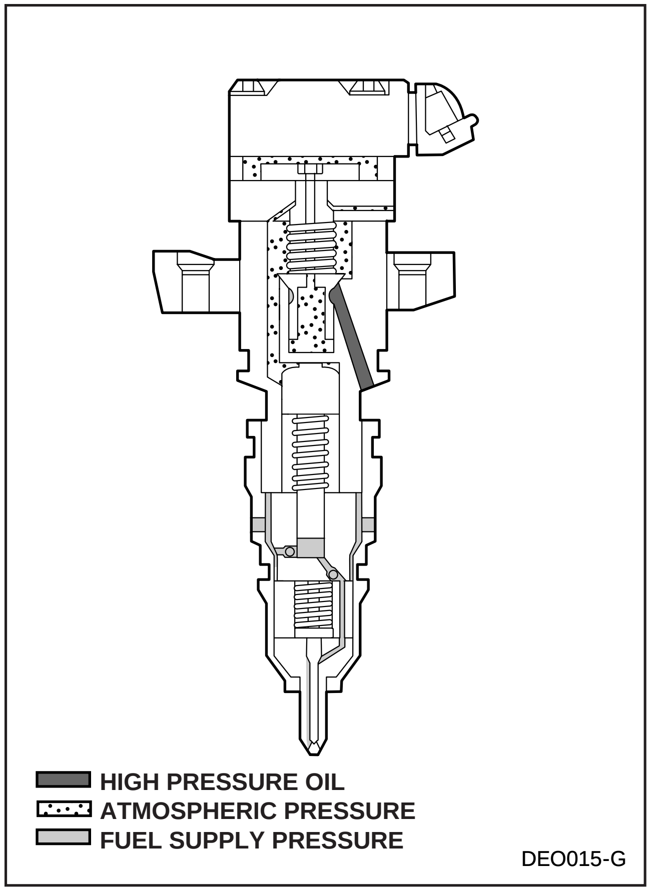
Item	Description
1	Electronic Solenoid
2	Spill Spout
3	Poppet Valve
4	Intensifier Piston
5	Plunger
6	Check Ball
7	Check Valve
8	Nozzle Assembly
9	Pintle Valve

Three stages of injection

The three stages of injection are:

- fill cycle
- injection
- end of injection

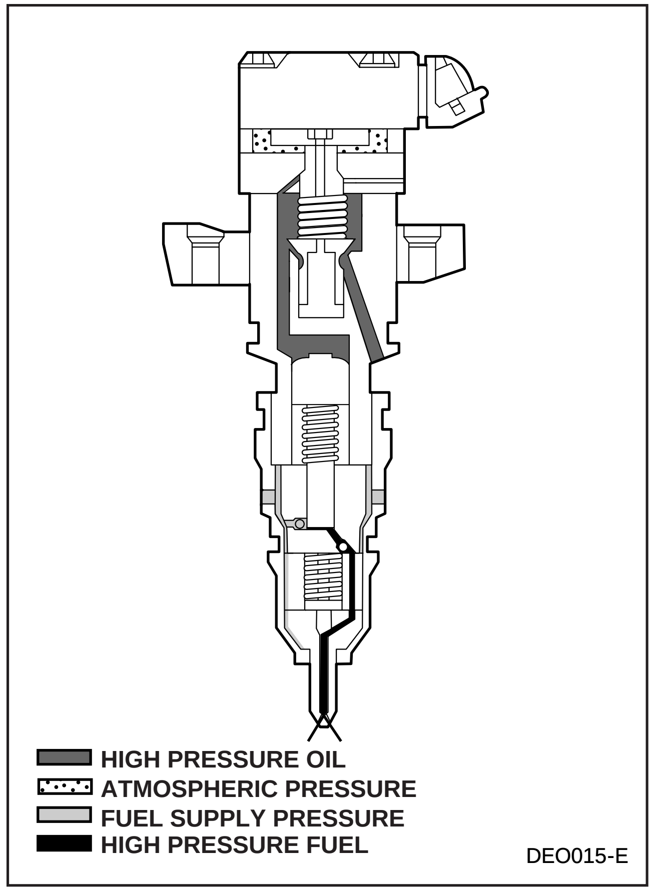
Fill cycle – During the fill cycle internal components are returning to their spring-loaded positions. The poppet valve is blocking high-pressure oil from entering the injector. The plunger and intensifier have returned to the top of their bore. The fuel fill check valve unseats and allows the plunger cavity to fill with fuel. Fuel pressure in the cavity is the same as fuel supply pressure 207-552 kPa (30-80 psi).



Fill Cycle

Injection – During the injection cycle, the following sequence of events occur:

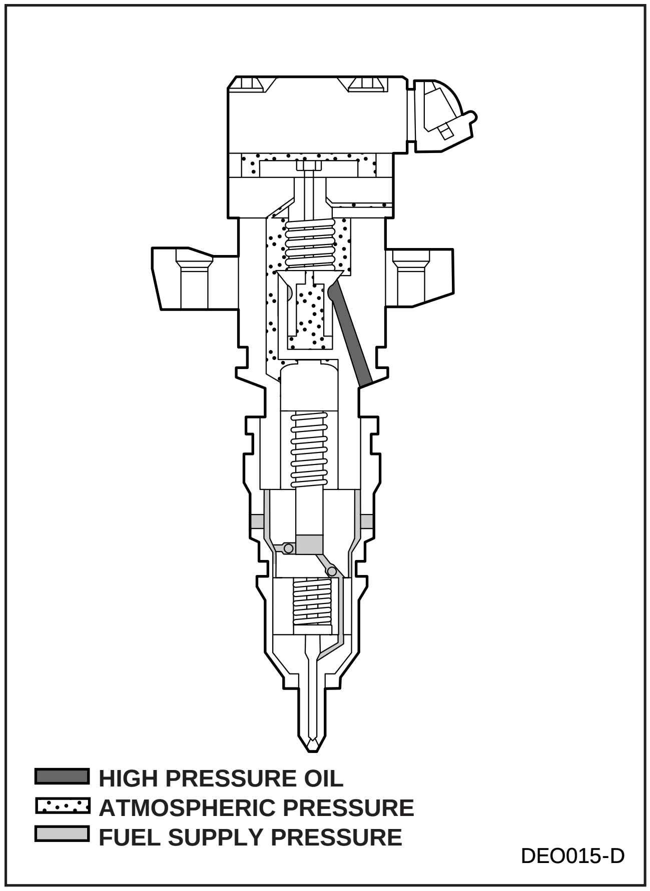
- The solenoid is energized, creating a strong magnetic pull on the armature.
- Magnetic pull of the solenoid overcomes spring tension and the poppet is quickly raised to the top of the bore.
- The upper poppet land closes off the path to drain.
- The lower land opens the poppet chamber to incoming high-pressure oil.
- The high-pressure oil pushes past the poppet to the top of the intensifier piston.
- Pressure on the plunger pressurizes the fuel in the fuel cavity.
- The pressurized fuel unseats the fuel delivery check valve.
- When the fuel pressure reaches valve opening pressure (VOP) of about 18,616 kPa (2,700 psi), the pintle inside the injector nozzle assembly lifts off its seat and injection begins.
- Injection pressures may be as high as 144,790 kPa (21,000 psi) depending on engine requirements.
- The amount of plunger travel determines fuel quantity.



Injection

End of injection – At the end of the injection cycle the following sequence of events occur:

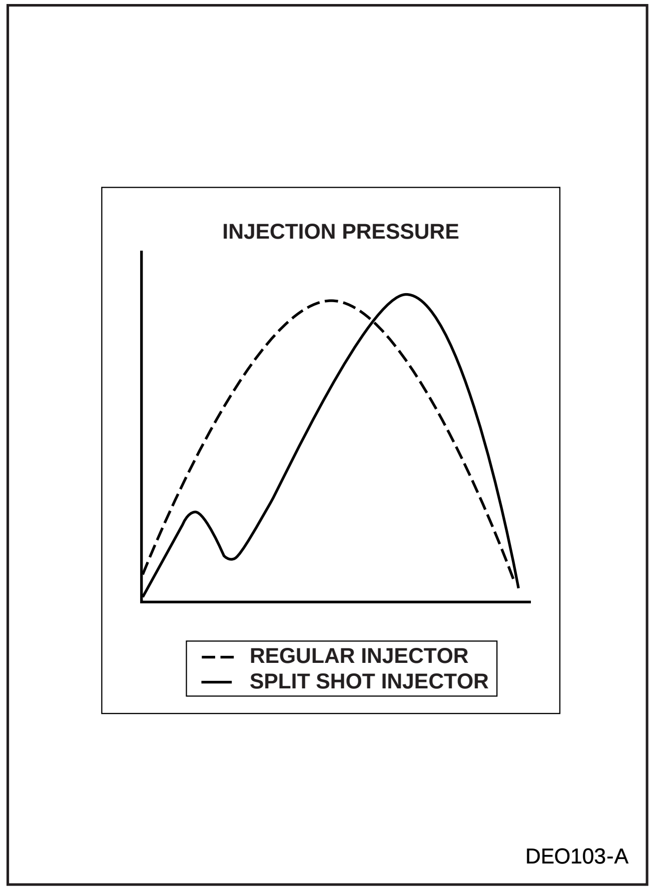
- The solenoid is de-energized.
- The magnetic field of the solenoid collapses and is no longer able to overcome poppet spring tension to hold the poppet at the top of its bore.
- The poppet is forced down by spring pressure, shutting off high-pressure oil from entering the injector.
- The upper land of the poppet opens, allowing oil to drain at the spill spout.
- The spring pressure and fuel pressure exerts an upward force on the plunger and intensifier.
- Oil in the intensifier chamber flows upward around the poppet seat, and out the spill spout.
- The fuel delivery check valve seats, maintaining residual pressure in the nozzle assembly and allowing a quick pressure drop in the fuel cavity.



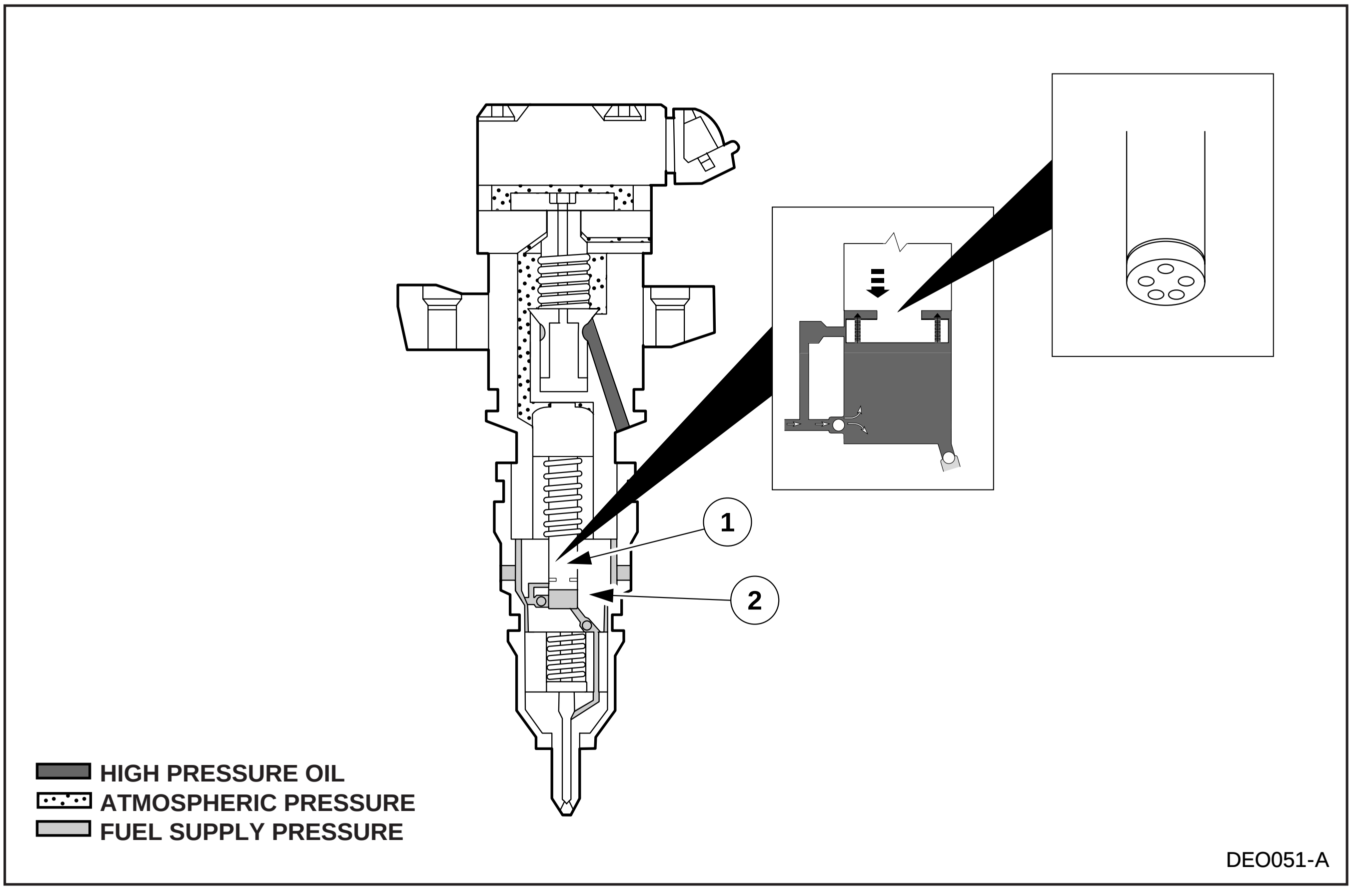
End of Injection

HEUI Split-Shot Injectors

All 1999 and newer, and selected older DIT equipped vehicles use HUEI injectors with an updated design feature know as split-shot. Split-shot injectors are HEUI type injectors that function similarly to conventional HEUI injectors, however, they use a unique barrel and plunger. Split-shot injectors provide improved exhaust emissions and quieter engine operation, particularly at idle. They tailor delivery of the fuel, without a decrease in engine performance. The split-shot injectors supply a small amount of fuel to the combustion chambers just before the piston reaches TDC. As combustion begins, the injectors spray a larger amount of fuel to continue combustion. The purpose of this is to help the fuel burn more completely, aiding in more dispersed power in the cylinder and lower emissions in the exhaust. This process also helps to reduce the knocking sound heard when initial combustion begins in the diesel engine.



Injection Pressure



Split-Shot Injector

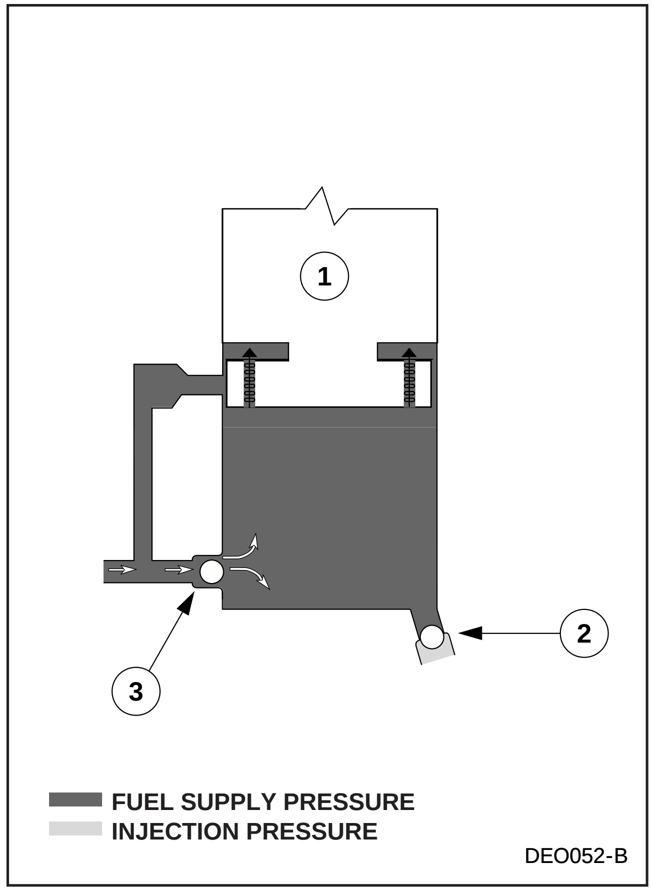
Item	Description
1	Plunger
2	Barrel

The split-shot injectors use a unique barrel and plunger. The barrel contains a relief port which allows injection pressure to be bled into the fuel supply rails. The plunger has two modifications. It has passages through the bottom that allow injection pressure to travel up to a groove cut into the outer edge of the plunger. When the groove in the plunger aligns with the relief part in the barrel, injection is temporarily stopped. The split-shot injectors have four steps to the injection process:

- Fill Stage
- First Injection
- End of First Injection
- Second Injection

Fill Stage – Step One

- Fuel pressure fills the plunger cavity with incoming fuel from the fuel rail in the cylinder head.

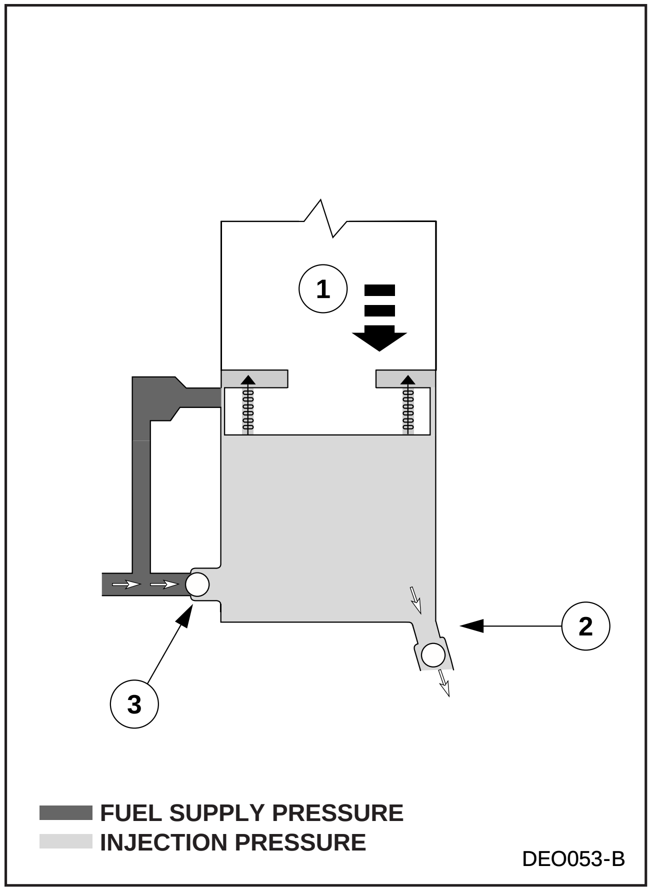


Fill Stage

Item	Description
1	Plunger
2	Check Valve Closed
3	Check Valve Open

First Injection – Step Two

- While the lower land of the plunger covers the relief port in the barrel, plunger movement increases pressure and the delivery check valve is unseated. Fuel delivery begins.

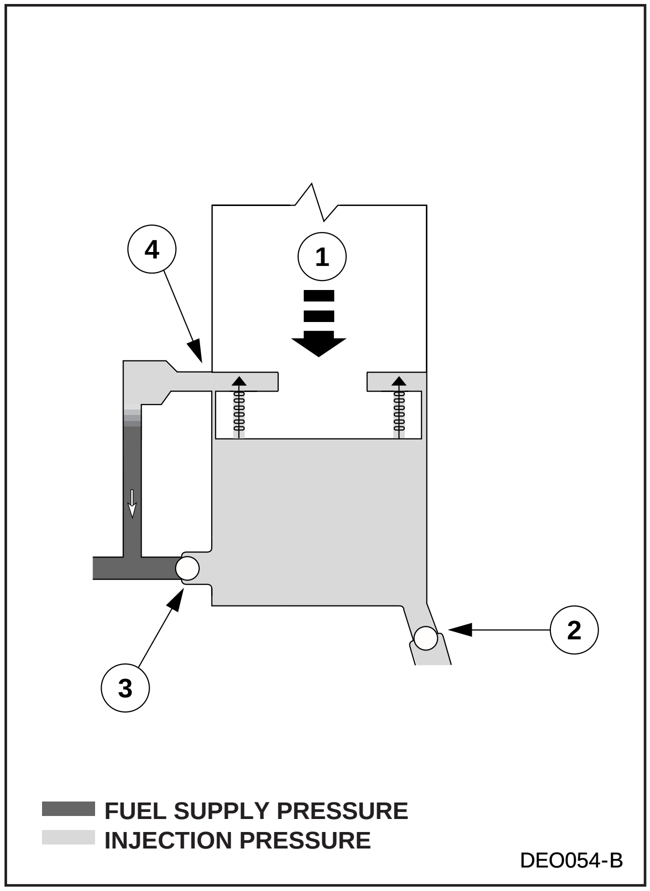


First Injection

Item	Description
1	Plunger
2	Check Valve Open
3	Check Valve Closed

End of First Injection – Step Three

- When the lower land travels past the relief port in the barrel, pressure is released into the fuel supply system and fuel delivery is stopped.



End of First Injection

Item	Description
1	Plunger
2	Check Valve Closed
3	Check Valve Closed
4	Relief Port

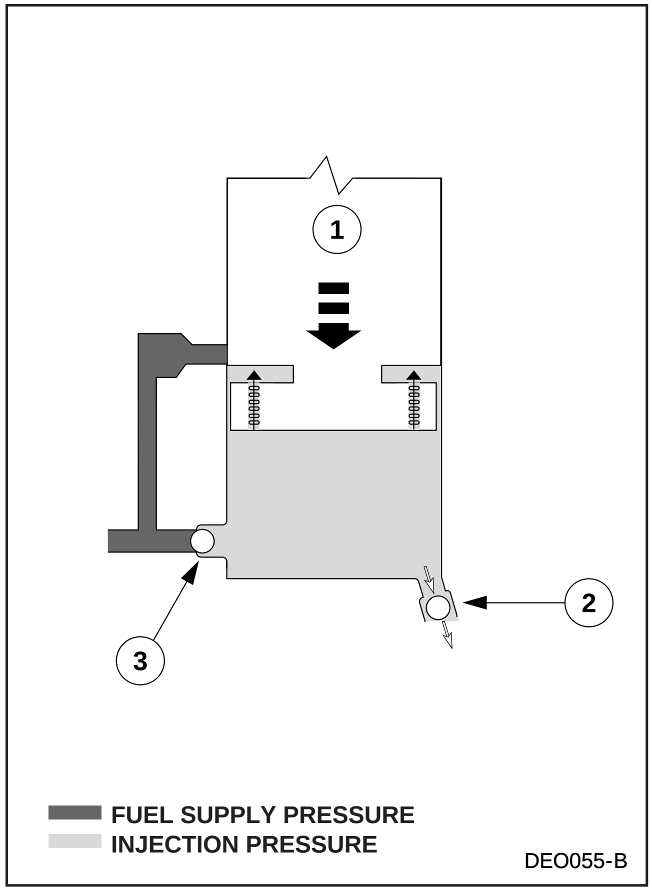
Second Injection – Step Four

- When the upper land seals the relief port in the barrel, the plunger continues to move down, delivering fuel until the end of injection.

Split-Shot Injectors

Split-shot injectors have been used in:

- 1996 and later California 7.3L DIT
- 1997 and later 7.3L DIT Econoline
- 1999 and later 7.3L DIT F-Series truck



Second Injection

Item	Description
1	Plunger
2	Check Valve Open
3	Check Valve Closed

REVIEW QUESTIONS

1. The split shot injectors supply a small amount of fuel to the combustion chambers just after the piston reaches top dead center.

   A. True

   B. False

2. What are the two types of fuel systems for the diesel engine?

   ____

   ____

   ____

3 There is no fuel returned to the fuel tank after it has been drawn through the fuel pump in a 7.3L DIT returnless system.

   A. True

   B. False

4. Which component in the returnless fuel system with an electric fuel pump strains large particles from the fuel before it reaches the fuel pump?

   ____

   ____

   ____

   ____

5. What are the three functions of the fuel filter assembly?

   ____

   ____

   ____

6. What happens during the fill stage of the HEUI Split Shot injector?

   ____

   ____

   ____

   ____

   ____

NOTES

TECHNICIAN OBJECTIVES

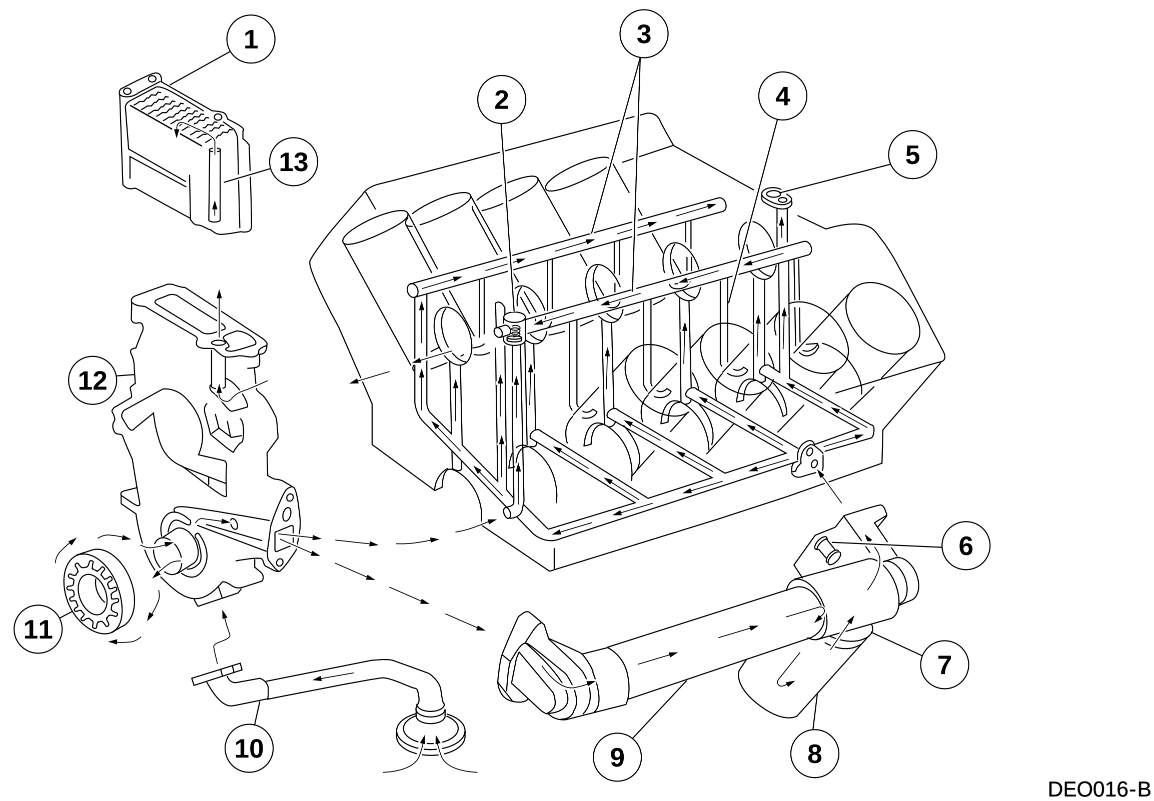
- Describe the purpose and operation of the low-pressure oil system.
- Describe the purpose and operation of the high-pressure oil system.

CONTENTS

PURPOSE AND OPERATION OF THE LOW-PRESSURE OIL SYSTEM

Understanding low-pressure oil system operation on the 7.3L DIT engine can help with understanding how some driveability concerns associated with this engine may come about. The lube-oil or low-pressure system is directly tied to the high-pressure oil system that helps to operate the fuel injection system. Some concerns involving the low-pressure oil system may affect vehicle performance and driveability.

Purpose of the Conventional Low-Pressure Oil System



The Low-Pressure Oil System

Item	Description
1	Oil Reservoir
2	Short Circuit Device
3	Valve Lifter Oil Galley
4	Cooling Jets (8)
5	Turbo Oil Supply
6	Pressure Relief/Regulator Valve
7	Oil Filter Bypass Valve Location

Item	Description
8	Oil Filter
9	Oil Cooler
10	Oil Pickup Tube
11	Gerotor Oil Pump
12	Front Cover
13	Stand Pipe

The low-pressure oil or lubrication system is absolutely essential to correct engine operation. The components that make up the lubrication system on a diesel engine are similar to those found on gasoline engines. The basic flow of oil is the same on both gasoline and diesel engines. That is: from oil pan to filter, from filter to main oil gallery, from the gallery to the bearings, from the bearings to the pistons, upper engine components, and gear trains. However, diesel engines have jets that spray oil on the bottom of the pistons for cooling. The low-pressure oil system of the 7.3L DIT also feeds the high-pressure oil reservoir.

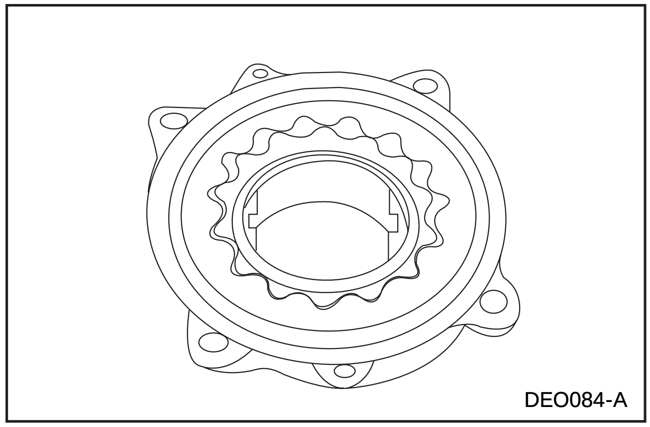
Operation of the 7.3L DIT Low-Pressure Oil System

Gerotor Oil Pump

The engine oil pump is a gerotor-type pump driven by the crankshaft. On the nose of the crankshaft there are two flats used to drive the gerotor pump inner gear. The inner rotor has 14 teeth and the outer rotor has 15 spaces. When the pump rotates, the rotors unmesh, increasing the area inside the pump, and oil is drawn into the pump. As the pump continues to rotate, the rotors on the side of the pump mesh, decreasing the area inside the pump, and oil is forced out of the pump.

NOTE: It is important to note that when installing the gear assembly, the gears are marked for placement. Be sure to follow the workshop manual direction on gear placement.

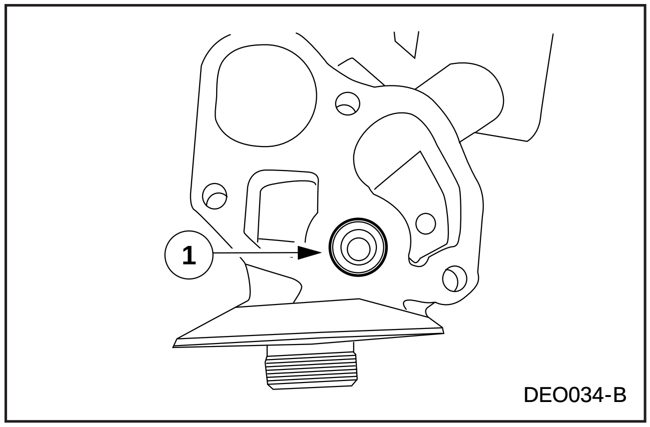
The oil pump housing is doweled to the front cover for correct alignment and is sealed with an O-ring seal.



Gerotor Oil Pump

Oil Pressure Regulator

The oil pressure regulator is located in the filter housing. The regulator valve starts to open to the sump above 345 kPa (50 psi). This protects the engine components from damage caused by high engine oil pressure.



Oil Pressure Regulator

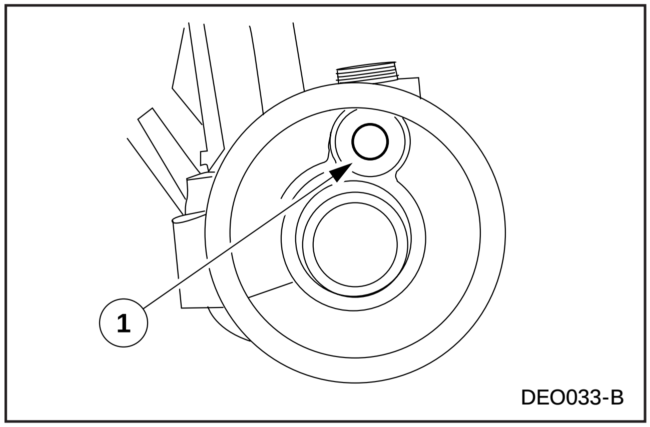
Item	Description
1	Oil Pressure Regulator

Oil Filter Bypass Valve

To prevent damage caused by lack of lubrication in the event of a plugged oil filter, a bypass valve is provided to bypass the oil filter if the filter becomes restricted. This bypass valve is located in the filter housing.

Always check security of the bypass valve during oil filter repair service. A missing bypass valve can result in engine damage.

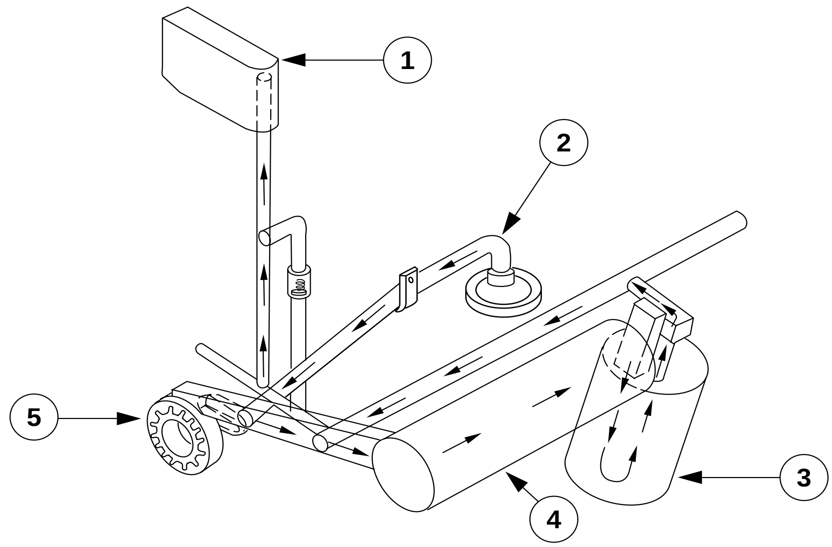
Always make sure that the recommended filter and oil products are used.



Oil Filter Bypass Valve

Item	Description
1	Oil Filter Bypass Valve

Oil Cooler



Short Circuit Device

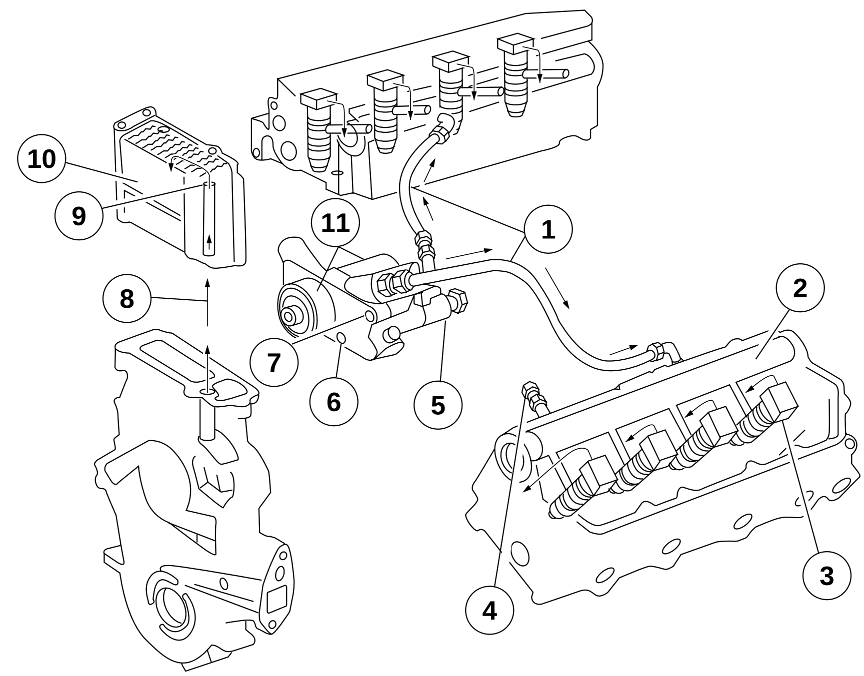
Item	Description
1	High Pressure Oil Reservoir
2	Pick-Up Tube
3	Oil Filter

Item	Description
4	Oil Cooler
5	Engine Oil Pump (Gerotor-Type)

The oil cooler is a cylinder with a set of tubes that carry engine oil submerged in engine coolant It is mounted on the left side of the block. The oil cooler moderates engine oil temperature by transferring heat to, or from the engine cooling system. This means that cold oil can warm sooner, and hot oil can be cooled as it is exposed to coolant temperatures. It consists of a long cylindrical-shaped set of tubes that coolant flows through, indirectly exposing the engine coolant temperature to the oil that surrounds them. The coolant carries out two functions here:

1. To help bring the oil up to operating temperature sooner.
2. To help cool the oil and keep it a constant temperature.

PURPOSE AND OPERATION OF THE HIGH-PRESSURE OIL SYSTEM



The High-Pressure Oil System

Item	Description
1	High-Pressure Hoses
2	High-Pressure Oil Rail
3	HEUI Injector
4	Injector Control Pressure Sensor (ICP)
5	Injector Pressure Regulator (IPR)
6	Oil Supply to Pump

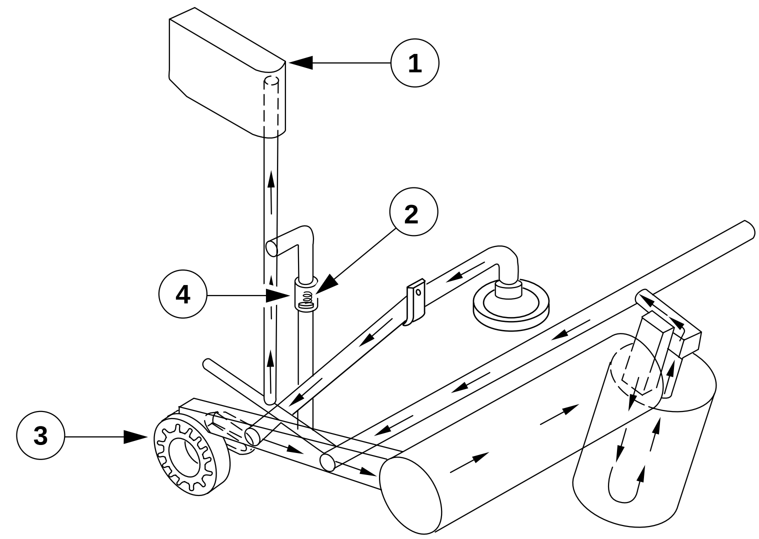
Item	Description
7	Injector Pressure Regulator (IPR) Drain
8	Oil Supply to Reservoir
9	Stand Pipe
10	Reservoir
11	High-Pressure Oil Pump

Purpose of the High-Pressure Oil System

The purpose of the high-pressure oil system is to deliver engine oil under high pressure to the fuel injectors. This high-pressure oil is used to actuate the hydraulic portion of the injectors. The fuel injectors are electronically controlled and hydraulically actuated. The high-pressure oil system is also known as the injection control system.

Understanding the operation of the high-pressure oil system will aid you in diagnosing possible driveability concerns associated with this system.

Short Circuit Device



Short Circuit Device

Item	Description
1	High Pressure Oil Reservoir
2	Spring

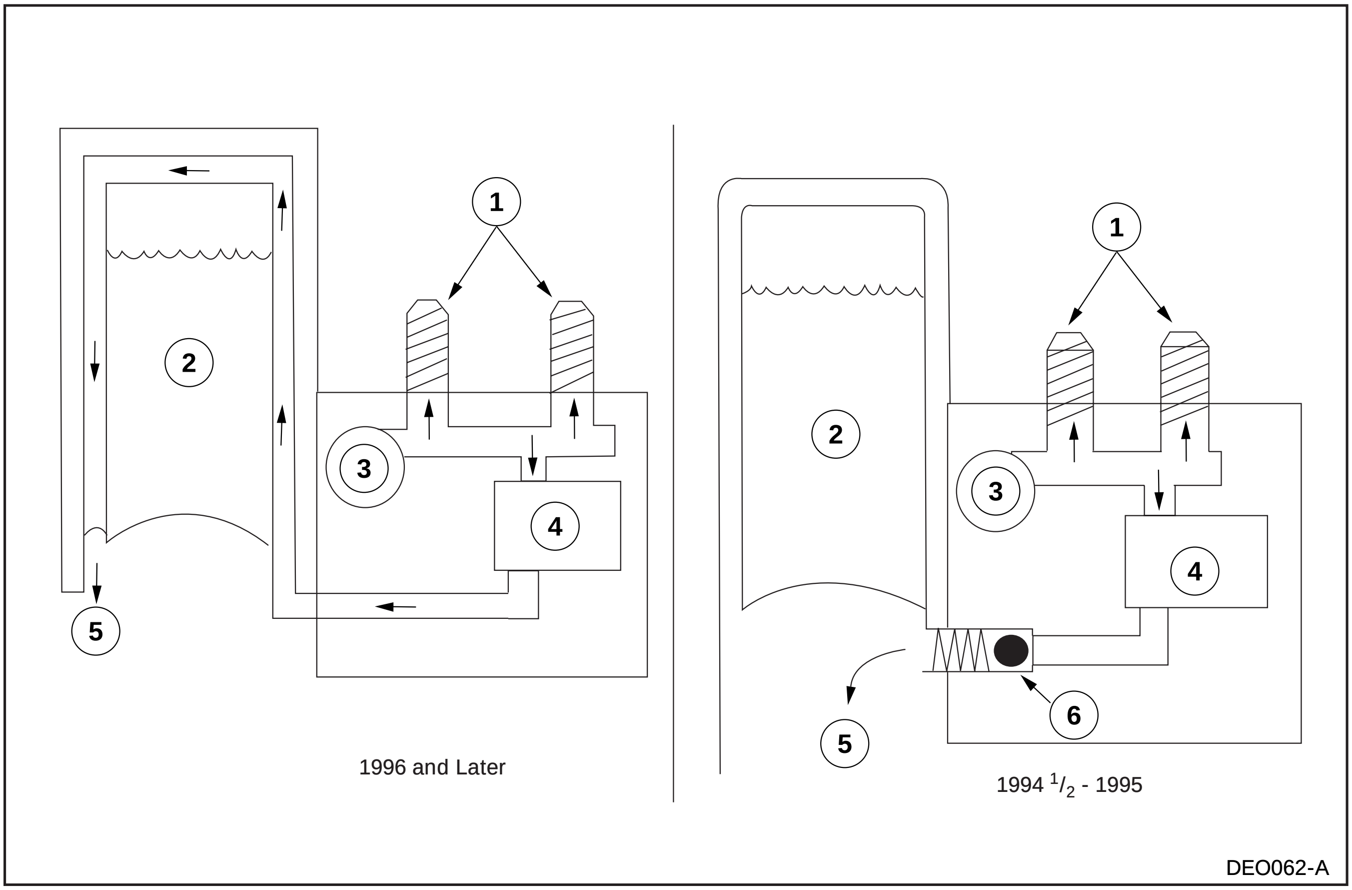
Item	Description
3	Engine Oil Pump (Gerotor-Type)
4	Check Valve

On 7.3L (DIT) diesel engines a high pressure oil system is used in tandem with the low pressure oil to control the fuel delivery system. Oil from the low pressure oil system is used to supply oil to the high pressure oil reservoir.

The short circuit oil gallery is connected directly to the gerotor pump discharge. This provides a quick fill of the high-pressure reservoir for fast cold starting. The check valve unseats momentarily during cold cranking until engine oil pressure is equalized on both sides of the check ball. When the ball seats, it prevents unfiltered oil from entering the reservoir during engine operation.

NOTES

Operation of the 7.3L DIT High-Pressure Oil System



Injector Pressure Regulator (IPR) Drainback

Item	Description
1	Pump Outlet to Cylinder Heads
2	Oil Level in Reservoir
3	Pump

Item	Description
4	Injection Control Pressure Regulator (IPR)
5	To Sump
6	Check Ball

The high-pressure oil system includes the following components:

- Oil reservoir
  - The reservoir holds about 0.946 L (1 qt) of oil for use by the high-pressure oil system. It is fed by the low-pressure oil system. The oil reservoir (depending on application) may have an anti-drainback check ball located in the high-pressure pump, or a standpipe located in the reservoir, depending upon model year. Both of these designs are incorporated to maintain oil in the reservoir in engine OFF situations.
- High-pressure oil pump
  - The high-pressure oil pump is a gear-driven, seven plunger, swash plate pump. High-pressure oil is delivered by the high-pressure pump to oil rails machined into the cylinder heads.
  - The high-pressure pump is mounted to the front cover with a reusable gasket and two bolts. The high-pressure oil pump drive gear is not timed to the engine. The gear is attached to the pump shaft by a bolt requiring correct torque, as this gear has no locator or keyway. Removing a plate on the front cover can access the retaining bolt.

- High-pressure braided hoses
  - The high-pressure braided hoses deliver oil from the pump to the cylinder heads.
  - These are special hoses capable of withstanding extreme pressures. Do not attempt to install any other types of hoses in their place.

WARNING: WHEN REPLACING HIGH-PRESSURE OIL HOSES USE ONLY FORD-APPROVED HOSES. OTHER TYPES OF HOSES MAY NOT HAVE THE SAME PRESSURE WITHSTANDING CAPABILITIES. USE OF THE INCORRECT HOSES FOR THIS APPLICATION COULD CAUSE PERSONAL INJURY AND/OR ENGINE DAMAGE.

- Injection Control Pressure Regulator (IPR)
  - The injection control pressure regulator (IPR) is an electronically controlled valve. The IPR controls a drain path out of the pump and is controlled by the PCM to regulate injection control pressure.

    The IPR controls pump outlet pressure in a range between 3,102-20,685 kPa (500-3,000 psi). An electrical signal to the solenoid creates a magnetic field which applies a variable force on the regulator to control pressure to the injectors.

    Operation – Engine Off

    - With the engine off, the valve spool is pushed on by the return spring and the drain ports are open.

    Operation – Engine Cranking

    - During cranking, with an oil temperature of more than 42°C (75°F), oil pressure will normally be approximately 10,342 kPa (1,500 psi). However, the vehicle will start with oil pressure as low as 3,448 kPa (500 psi). Additionally, under cold operating conditions oil pressure may be as high as 18,615 kPa (2,700 psi).

    Operation – Engine Running

    - Once the engine starts, the PCM sends a signal to the IPR to give the gallery pressure desired. The injection control pressure sensor monitors actual gallery pressure. The PCM compares the actual gallery pressure to the desired pressure and adjusts the signals to the IPR accordingly.
- Injection Control Pressure Sensor (ICP)
  - The injection control pressure (ICP) sensor provides a signal to the PCM indicating actual oil rail pressure. The PCM compares the actual rail pressure to the desired rail pressure and adjusts the signal sent to the IPR to obtain the desired rail pressure.
- Oil rails
  - The oil rails are machined into each cylinder head, and are used to supply high-pressure oil to the injectors. Threaded cap plugs seal the oil rails at the ends of each cylinder head. The plugs in each end of the high-pressure oil rails in the cylinder heads have O-ring seals and Loctite #277 sealant applied. The double seal is intended to reduce the possibility of leakage. Plug removal is generally not required for normal repair and plugs are best left undisturbed. Removal is required only when cleaning of the rails is necessary (typically at the time of major overhaul). Make sure to follow correct workshop manual procedures.
- Injectors
  - As you have already learned, high-pressure oil enters the injector and acts upon the intensifier piston to inject high-pressure fuel into the engine. During cranking, a minimum of 3,102 kPa (500 psi) of oil pressure is required for the injectors to operate.

REVIEW QUESTIONS

1. Some concerns involving the low-pressure oil system may affect vehicle performance and driveability.
   A. True
   B. False
2. What component in the low pressure oil system prevents damage caused by a plugged oil filter?
3. What is the minimum oil pressure required for the injectors to operate?
4. What is the function of the oil cooler?
5. The high-pressure oil system is also known as:
6. What is the function of the ICP sensor?

NOTES

TECHNICIAN OBJECTIVES

- Describe the properties of diesel fuel.
- Describe characteristics of various grades of diesel fuel.
- Describe the effects of poor fuel quality/contamination on diesel engine operation.

CONTENTS

PROPERTIES OF DIESEL FUEL

Cetane Rating

The temperature at which fuel begins to burn is referred to as the ignition point. Diesel fuel, which has a low ignition point, is said to have good ignition quality. Fuels that have good ignition qualities will burn soon after being injected into the combustion chamber.

The cetane rating is a measure of the ignition quality of a diesel fuel. To get a cetane number rating, a fuel is compared with cetane, a colorless, liquid hydrocarbon that has excellent ignition qualities. Cetane is rated at 100. 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. The exact rating is determined by mixing cetane with a chemical called methylnaphthalene to produce a similar ignition quality of the fuel being tested. The percentage of cetane used determines the cetane number rating.

As you probably know, the quality of gasoline is measured by octane. Octane numbers indicate the resistance of a fuel to knock. Premium gasoline burns slower than regular, and has more resistance to preignition and detonation. The higher an octane number, the more resistance a fuel will have to knocking. Diesel fuel cetane ratings are the opposite of gasoline octane ratings. A high quality diesel fuel with a high cetane rating will ignite the moment it enters the combustion chamber. If there is delay in ignition of the fuel, performance of the engine will suffer.

One of the primary benefits of a high cetane number is easy starting and smooth running when the engine is cold. Generally an increase of 10 in the cetane number will lower the equivalent start temperature 7-9ºC (12-15°F). However, the performance differences between a 40 cetane and 50 cetane fuel are noticeable once the engine has reached operating temperature. Another point is that the starting characteristics are not generally noticeable at most summer ambient temperatures with fuels that have a cetane number above 40. It is also true that engines that are warm, either because of indoor storage or because of heaters in the cooling system (block heaters), are less sensitive to cetane numbers.

Checking Cetane Rating

To check the cetane rating, a Rotunda Cetane Tester (078-0012-1) and conversion chart is needed. To operate the tester, draw a sample of diesel fuel into the tube and note the position of the float along the scale. This tool works on the same principle as a hydrometer. The minimum recommended cetane rating for Ford diesel engines is 40. Anything below this is considered inadequate and the customer should be told to change fuel sources.

Specific Gravity

Specific gravity of a fuel is a measurement of the fuel’s weight as compared to water. Diesel fuel is heavier than gasoline, so it will have a higher specific gravity. The importance of specific gravity to diesel fuel is that it must be heavy enough to achieve adequate spray penetration into the combustion chamber. If the specific gravity is too low, all the fuel will burn immediately upon entering the combustion chamber. This would put all the force of combustion on one small area of the piston, rather than having an equal force across the piston head. As a result, performance would suffer, engine noise would increase, and the piston could eventually be damaged.

Heat Value

The heat value of any fuel is measured in British Thermal Units, or BTUs. One BTU is the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit. Converting the fuel to heat creates power from an engine. The more heat produced by a fuel, the more energy available to be changed into usable power.

Diesel fuel to gasoline comparison:

Fuel	Average Weight per Gallon (lbs)	Average BTU per Gallon
Diesel	3.2 kg (7.1 lbs)	(138,000 btu)
Gasoline	2.72 kg (6.0 lbs)	(124,000 btu)

Volatility

Volatility is the ability of a liquid to change into a vapor. Gasoline is extremely volatile compared to diesel fuel. To illustrate this, if both diesel fuel and gasoline are dripped onto a heated steel plate, the gasoline will evaporate without igniting, whereas the diesel fuel will not immediately evaporate, but will burn with a flame when it reaches a certain temperature. Of course, if the gasoline vapors are exposed to a flame they will immediately ignite.

Lubricity

Lubricity refers to the capability of the fuel to reduce friction. High lubricity means that the fuel has a better ability to prevent metal-to-metal contact between moving components. High lubricity is important for diesel fuels because of the tight tolerances in the injectors and injection system. If a fuel with low lubricity is used, more friction and wear may occur between moving parts within the injection system.

Viscosity

Viscosity is the property of a fluid that resists the force which causes fluid to flow. Fluid viscosity can be affected by temperature. The warmer the fluid, the less resistance there will be to flow. Fluid viscosity can also be affected by contaminants and oxidation. The viscosity of diesel fuel directly affects the spray pattern of the fuel into the combustion chamber. Fuel with high viscosity results in a fuel dispersion that contains large droplets that are hard to burn. Fuel with a low viscosity sprays in a fine, easily burned mist. However, if the viscosity of the fuel is too low, it will not adequately lubricate and cool the injection pump and injectors, possibly causing parts to seize.

Cloud and Pour Points

Diesel fuel is affected by temperature much more than gasoline. This is due to the fact that diesel fuels contain paraffin, a wax substance. As temperatures drop past a certain point, wax crystals will begin to form in the fuel. This gives the fuel a cloudy appearance, referred to as the cloud point. Not all fuels have the same cloud point – winter blended diesel fuel is able to withstand a much lower temperature, even below -18ºC (0º F).
As temperatures drop further, the fuel will actually begin clotting, as the wax crystals grow larger. When the fuel reaches this point it will have difficulty flowing through the filters and the fuel system. As the fuel gets even colder, it will reach a point where it is insoluble and will no longer flow; this is the pour point. A high pour point rating for fuel indicates that in cold weather the diesel fuel will not flow easily through the fuel system.

Gel Point

The gel point of diesel fuel is just past the pour point. This is when the fuel becomes so insoluble that it gels. The fuel coagulates to the point that it becomes a solid rather than a liquid. This usually occurs, in very cold temperatures, with fuel that does not have adequate additives to inhibit gelling.

Sulfur Content

Sulfur content is common in fuels made from crude oil. Although refining processes can remove much of the sulfur content, some will remain behind. Excessive sulfur increases ring and cylinder wear, causes formation of varnish on piston skirts, and is a prime cause of sludge in the oil pan, and plugged converters.

Low sulphur fuel has been mandated by the Environmental Protection Agency (EPA) for highway use to reduce exhaust emissions.

Marked Fuel

Marked fuel is industrial fuel used in industries such as farming or construction. It is usually colored red or blue. Marked fuel has a tendency to be stored for longer periods of time than on-highway fuel. This type of fuel may also contain more sulfur than commercial fuels.

Carbon Residue

Carbon residue is a byproduct of combustion left in the combustion chamber of any engine that burns a hydrocarbon fuel.

The amount of carbon residue produced by diesel fuel depends on the quality of the fuel used, and the volatility of that fuel. Fuel that has a low volatility is much more prone to leaving carbon residue.

CHARACTERISTICS OF VARIOUS GRADES OF DIESEL FUEL

There are two grades of diesel fuel for automotive use: D2, and D1.

The fuel typically recommended for automotive diesel use is D2. This fuel is formulated with sufficient viscosity and energy content to make it applicable to most diesel engines. Grade D1 is sometimes used in winter when a lower viscosity grade of fuel is needed, but usually in cold weather a fuel called “winterized” or “blended” is used. This usually indicates a blend between D1 and D2 diesel fuels to provide improved low temperature characteristics.

EFFECTS OF POOR FUEL QUALITY/CONTAMINATION ON DIESEL ENGINE OPERATION

Effects of Water and Oxidation in Diesel Fuel

Fuel may contain free and dispersed water from tank bottoms agitated at the time of dispensing or at the time of fuel fills. This free and dispersed water can contribute to an ice problem, but unlike totally dissolved water, it can also contribute to other filter malfunctions at any temperature. The water from agitation often carries other contaminants such as rust and dirt into the fuel and forms a pasty, dirty fuel/water mixture that is capable of blocking filters. Moisture in fuel can contribute to filter malfunctions at any time, more so with low-temperature operation.

Water entering the precise fuel system components (specifically the fuel injection pump and fuel injectors) can cause extreme damage because water does not provide the required lubrication and also causes corrosion. These components have very tight tolerances that are easily destroyed by lack of lubrication and/or corrosion.

Effects of Gasoline in Diesel Fuel

Gasoline is much more volatile than diesel fuel and it burns at a faster rate. Therefore, gasoline in a diesel system could cause preignition concerns along with engine damage from excessive cylinder pressures. Gasoline also does not have the lubrication properties that diesel fuel has, and could cause severe damage to the injectors. These symptoms may be present if gasoline is introduced to a tank of diesel fuel:

- rough running
- excessive white smoke
- low power output
- knocking

Effects of Prolonged Fuel Storage

A diesel engine requires clean fuel for peak performance. Adequate containers must be used to store fuel until it is used. Technicians who keep a small supply of diesel fuel on hand should be aware of these facts.

1. Diesel fuel ages and will go stale. It is a good idea to keep a fresh supply on hand.
2. Variations in heat and humidity tend to form condensation in fuel storage containers. Keep fuel storage containers out of direct sunlight.
3. Fuel that is stored for long periods of time has a tendency to form algae that could harm the fuel system.
4. All diesel fuels contain some amounts of an asphaltic substance called asphaltene. During long periods of storage this substance can separate from the fuel and be more likely to be picked up and possibly clog the fuel filter(s).

Storage Containers

A dedicated container, specifically for diesel fuel, should be utilized. Do not use the same container to hold gasoline and diesel fuel. Never store diesel fuel in galvanized containers. Diesel fuel will cause the galvanizing to flake off, contaminating the fuel and clogging filters when the fuel is used. Containers should always be correctly labeled or identified as containing diesel fuel.

Performance Concerns

Fuel that is not stored correctly could have an adverse affect on engine performance. A technician should keep in mind, while diagnosing driveability concerns, where the customer may have procured their fuel. If the fuel was not stored correctly, chances are that this is the cause of the concern. When dealing with a possible fuel storage concern causing driveability concerns, the technician should empty the fuel supply and refill from a known good storage container.

REVIEW QUESTIONS

1. What is the measurement of the ignition quality of fuel?

2. What is the measurement of the fuel's weight as compared to water?

3. Water entering the precise fuel system components can cause extreme damage because:

4. Gasoline in a diesel engine may cause:

5. What are some of the effects of prolonged fuel storage?

TECHNICIAN OBJECTIVES

- Describe the purpose and properties of oil in a diesel engine.
- Describe diesel oil additives.
- Describe the characteristics of contaminated oil.

CONTENTS

PURPOSE AND PROPERTIES OF OIL IN A DIESEL ENGINE

Today’s diesel motor oils are made either from naturally occurring crude oil (petroleum) or from man-made organic compounds (synthetics). Some motor oils are made from both and are called semi-synthetics.

Most of the motor oils used today utilize the petroleum base stocks, which are made from crude oil. Crude oil is a mixture of thousands of different chemical compounds. Most of the compounds are composed of hydrogen and carbon and are therefore referred to as hydrocarbons. In its natural state, crude oil has no common use and must be extensively processed in a petroleum refinery before it can be converted into its many desirable end products.

Motor oil is a liquid product primarily formulated for the lubrication of internal combustion engines. The internal rubbing speeds of metal parts in an engine are so high and pressure so great that without proper lubrication, friction would generate enough heat to melt some of the parts. Therefore, motor oils are absolutely essential for internal combustion engines.

Viscosity Grade

The viscosity rating is found in the center area of the API Service Symbol.

Viscosity is a measurement of the oil’s resistance to flow as temperatures change. In cold ambient temperatures oil thickens and is said to be highly viscous. Heat, on the other hand, thins oil and makes it flow more freely.

The Society of Automotive Engineers (SAE) devised a system for classifying the viscosity of motor oil to enable motorists to choose the right grade of oil for different temperature ranges and driving conditions.

The familiar SAE designations for grades of oil, such as 5W, 10W, 15W, 30, 40, and 50, simply refer to the viscosity of oil at a specific temperature. High viscosity (thicker, heavier) oils are identified by higher numbers than low viscosity (thinner, lighter) oils. The higher the number, the thicker or more viscous the oil. The “W” that is often seen in the viscosity rating originally stood for “winter.” Today this indicates the cold start capabilities of the oil. The lower the “W” numbers, the easier the engine will crank in cold ambient temperatures. For instance, 5W-30 oil will allow an engine to crank much easier when the temperatures are -18°C (0°F) than 10W-30 oil would. The “W” number provides an indication of how easily the oil will flow, which is of extreme importance at cold ambient temperatures.

To earn a “W” rating, motor oil must work within prescribed limits at one of six subzero temperatures, depending on the grade. Oils without the “W” rating have been tested to work within prescribed limits at 100°C (212°F), which approximates the normal operating temperature of an automobile engine.

Typically, most single weight oils will become thick enough at low temperatures to make cranking a concern. They can also become so thin at elevated temperatures that they lose their capacity for carrying loads or maintaining correct compression sealing. These characteristics force vehicle owners who use single grade products to practice seasonal changes.

Multigrade oils, unlike single viscosity oils, show relatively small change in viscosity over a wide range of temperatures. This difference is accomplished by using the viscosity-index improving additives. The cost of this extra additive causes multi-viscosity oils to be more expensive than single grades.

Lubrication Property

Motor oil has excellent lubrication properties. If clean, it will significantly reduce friction between moving parts within an engine. However, when contaminated with dirt and soot particles its lubrication effectiveness diminishes.

Cooling Property

Motor oil is primarily used in engines for lubrication purposes. However, the chemicals in motor oil that allow it to cling to moving parts allow for heat dissipation as well. The motor oil will transfer heat away from the engine components and carry it to the sump area for dissipation.

Stress Load Bearing Property

Motor oil is designed to form a film between moving components and create an oil surface for the components to ride on. This helps to lessen the contact between these components, thus reducing friction. Many of the components, such as bearings, have very tight tolerances between them and the contacting surfaces of the moving components. The motor oil that comes between them is put under extreme pressures, in some cases. Because of this, it is very important that the correct weight oil be used for a particular application.

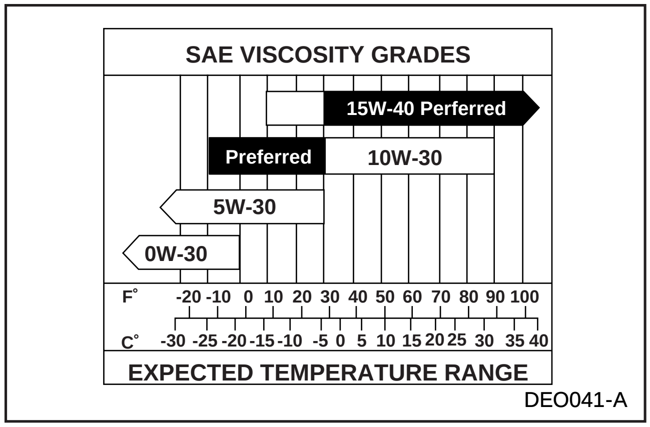
Contaminate Suspension Property

Motor oil is designed to help suspend particles of contamination, keeping them from gathering around the oil intake tube and blocking it. Because motor oil has a thicker than water consistency, it can float or suspend particles, keeping them from sinking to the bottom of the oil sump area.

Importance of Using Oil Specially Formulated for Diesel Engines

It is vitally important that the correct motor oil be used for a particular application. Oil is formulated, and additives are used, to blend oils to exhibit peak performance when used in the correct application. Using motor oil that is formulated specifically for diesel engines makes sure that the correct additives are present. Using the correct weight oil makes sure that the lubrication and stress load properties are present.

Using the wrong weight (viscosity) oil can have an adverse effect on engine performance with the 7.3L DIT diesel engine, because the engine oil is used under very high-pressure to operate the fuel injectors. The correct oil for a particular application is dictated by the ambient temperatures that the engine is used in. A lower viscosity oil should be used in areas that consistently have lower ambient temperatures. A higher viscosity oil should be used in areas that consistently have higher ambient temperatures. An expected temperature range chart can be consulted for the appropriate grade oil to be used.



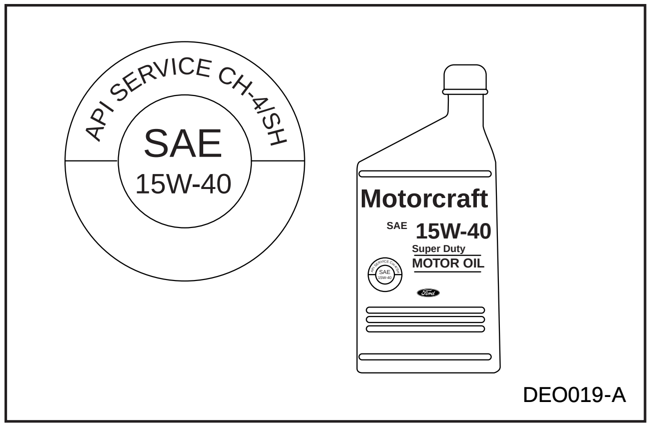
0:1 Viscosity Grades

Diesel Engine Oil API Rating

There are a number of important ways in which the oil industry and the automotive manufacturers voluntarily work together to assure certain standards. One of the most obvious examples is the cooperation shown in the development of the American Petroleum Institute (API) Service Symbol. This is the Institute's registered trademark for "Engine Oil Classification." This symbol was developed to give automotive technicians and their customers a reliable source of information about the quality of motor oil.

A container of motor oil bearing this symbol conforms to the high standards and specifications of the API and the Society of Automotive Engineers (SAE). Only use motor oils that have this API symbol on the container. Note that all Motorcraft quality oils bear this symbol.

The API symbol contains information about each of the areas previously highlighted that are important when selecting motor oil: oil performance classification, viscosity grade, and energy conservation rating.



Engine Oil API Rating

Oil Performance Classification

The oil performance classification section of the symbol defines the oil quality. The “S” (spark ignition) designates a quality suitable for gasoline engines. The “C” (compression ignition) designates a quality suitable for diesel engines.

The quality of each oil category (CH for example) is determined in carefully controlled engine tests to measure an oil’s ability to work under a variety of circumstances, while maintaining protection from rust, sludge and other factors affecting engine and oil performance.

SG and CE rated oils were introduced in 1988 and are designed to meet new vehicle warranty requirements. SH is the highest quality rating for oils meant to be used in gasoline engines. SH oils can be used in older engines requiring SA, SB, SC, SD, SD, SE, SF, or SG quality ratings. However, these lower quality oils should not be used in engines that require the SH rating. CH is the highest quality rating for oils meant to be used in diesel engines. CH oils can be used in older engines requiring CB, CC, CD, CE, CF, and CG quality ratings.

The CH rated oil is formulated to exceed the CB, CC, CD, CE, CF, and CG rated oil in a number of areas including:

- greater ability to disperse and hold soot particles
- greater ability to maintain alkalinity in the face of acids generated by fuels containing excessive amounts of sulfur
- greater ability to offset oxidation
- anti-foaming

The minimum oil rating that should be used in the 7.3L DIT engine is CF-4/SH.

Oil Filtration

Correct oil filtration is key to oil longevity. The dirtier oil becomes, the faster it begins to lose its effectiveness to carry out all of its functions. A good quality oil filter should always be used in diesel applications, as the particle contamination is greater than with gasoline engines. Soot (from cylinder blow-by) is a big factor in diesel oil contamination, and a good quality oil filter can help to minimize the problems associated with it. It is crucial to engine life that scheduled oil change intervals be followed, more so with a diesel engine because of particle contamination.

⚠ **CAUTION: Be sure when installing a new oil filter that the correct size filter is being applied. Some oil filters may have the same thread size, however, the canister itself may be smaller than the original filter. This could cause the filter to plug rapidly causing the engine oil to bypass the filter and lead to possible engine operation concerns. A smaller filter also lowers the engine oil volume, leading to faster oxidation and aeration.**

DIESEL OIL ADDITIVES

The base stock oil produced in the refining process is far from adequate to meet the needs of today's sophisticated automotive engines. Many chemicals must be added to support a wide variety of functions both in the engine and in the oil itself.

In general, today's high quality Motorcraft diesel oil is made up of approximately 80% base lube stocks and 20% additives. There are many commonly used additive packages that a diesel technician should be familiar with.

Anti-Wear Additives

Anti-wear additives have been in use since the 1930s. They are very important when the oil film between parts with extremely close clearance "breaks." When this occurs, these agents react chemically with the metal surfaces and immediately form a protective coating to reduce wear. The anti-wear additives usually contain sulfur, phosphorous and fatty materials. Anti-wear additives may also be referred to as extreme pressure (EP) additives.

Viscosity Index Improvers

Viscosity index improvers are viscous chemical compounds called "polymers" which decrease the rate at which oil changes viscosity with temperature. They enable the oil to maintain a comparatively stable flow rate over a wide range of temperatures. Viscosity index improvers are a key ingredient in multigrade or "all season" motor oils.

Foam Inhibitors

Foam inhibitors are important additives in that they weaken the surface tension of the oil. This is necessary so that any air bubbles that form in the oil break rapidly. If this does not occur, the moving parts in the engine could whip the oil into a foam that could lead to a loss of oil flow, hydraulic lifter noise and damage, and incorrect lubrication and cooling of critical parts.

This is even more crucial to the performance of the 7.3L DIT engine, as foam or aeration in the oil will adversely affect the operation of the high-pressure oil system. This will ultimately affect the operation of the fuel injectors, creating a poor running or no-start condition.

Pour Point Depressants

Pour point depressants are additives that are most important in cold weather. This additive group functions like an antifreeze for the oil by preventing wax deposits contained in the base oil from dispersing.

The pour point depressants coat the wax crystals as they form to prevent their growth. If wax crystals are allowed to grow, the oil will become too thick for use. Essentially, the chemicals used as pour point depressants effectively lower the temperature at which the oil will pour or flow.

Friction Modifiers

Friction modifiers are the additives which lend the name “ENERGY CONSERVING” to the oil identification symbol. Friction modifiers lower the friction between moving parts of the engine, increasing the potential for improved fuel economy.

Purpose and Use of Oil Additives

Oil defoamer additive may be needed when carrying out a repair that requires the use of RTV, such as resealing the oil pan. RTV sealers tend to break down the foam inhibitors in the engine oil. To minimize this, use Motorcraft RTV Silicone Sealant F5TZ-196204-AB. Also, adding defoamer additives will make sure that there will still be an adequate amount of defoamer after the RTV has completely cured.

CHARACTERISTICS OF CONTAMINATED OIL

Oxidation Contamination

When oil gets hot, it can react with oxygen and get thicker. When oxygen combines with hydrocarbon molecules in the oil this process takes place. Oxidation contamination can have adverse effects on engine oil.

- Can cause the engine oil to thicken.
- Can cause corrosive compounds to form, which may cause damage to bearing metals such as lead, cadmium and copper.

Water Contamination

Water contamination can have several adverse effects on engine oil:

- Can cause increased sludge build up.
- Can cause accelerated breakdown of oil additives.
- Water has no lubricity properties, and may cause moving components to wear.
- Can infiltrate the fuel injectors and cause them to malfunction, affecting engine performance.

Fuel Contamination

Fuel contamination can have several adverse effects on engine oil:

- Can cause accelerated breakdown of oil additives.
- Diesel fuel has less lubricity properties than motor oil and may cause the accelerated wear of components.
- Can thin out motor oil, lowering its stress load capabilities.

Oil Particulate Contamination

Particulates can have several adverse effects on engine oil:

- Particles of dirt or soot can become lodged between moving components and cause scoring and accelerated wear.
- Can clog the oil filter causing it to bypass and decrease its filtering capabilities, ultimately causing component wear.
- Can infiltrate the fuel injectors and cause them to malfunction, affecting engine performance.

Aeration

Aeration or oil foaming can have several adverse effects on engine oil and engine performance:

- Decreases the oil's stress load capabilities, and its ability to lubricate correctly.
- Can affect fuel injector operation dramatically.
- May affect the oil pump's ability to pressurize the oil and move it effectively through the engine.

Aeration can occur at high engine rpm, when the amount of oil traveling through the engine is greatest.

Crankcase Ventilation and Effects on Oil Contamination

Adequate crankcase ventilation is essential for removal of airborne particles and moisture from the crankcase. Without ventilation, these contaminants could settle in the engine oil. Condensation that forms during engine cool-down is removed when the engine is restarted and the ventilation system is operable.

Effects of Dirty Air on Oil Contamination

If dirt is allowed to enter the air intake and ultimately the cylinders, it may mix with pressure and blow-by gasses, and make its way to the crankcase and the engine oil. A clean and correct air filter is essential for helping to keep the oil filter from plugging prematurely.

REVIEW QUESTIONS

1. It is acceptable to replace an oil filter that has a different canister size as long as the threading is the same.
   A. True
   B. False
2. The correct oil for a particular application is dictated by __________________ in which the engine is used.

   ____

3. Which additive contained in the oil weakens the surface tension of the oil?

   ____

   ____

4. What are the types of oil contamination?

   ____

   ____

   ____

   ____

NOTES

LESSON 7: THE AIR INLET AND EXHAUST SYSTEMS

TECHNICIAN OBJECTIVES

- Describe the purpose and operation of the air inlet system.
- Describe the purpose and operation of the exhaust system.
- Describe the purpose and operation of the turbocharger.

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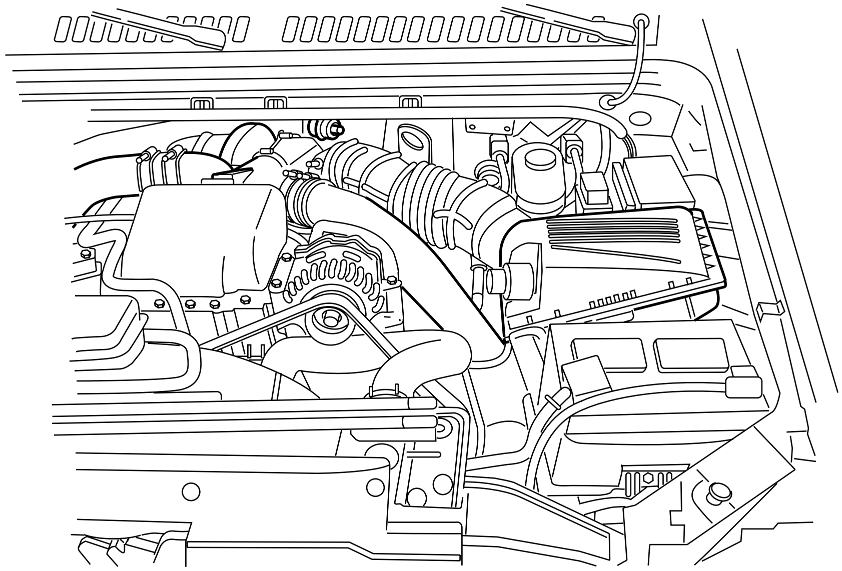
PURPOSE AND OPERATION OF THE AIR INLET SYSTEM



Air Inlet System

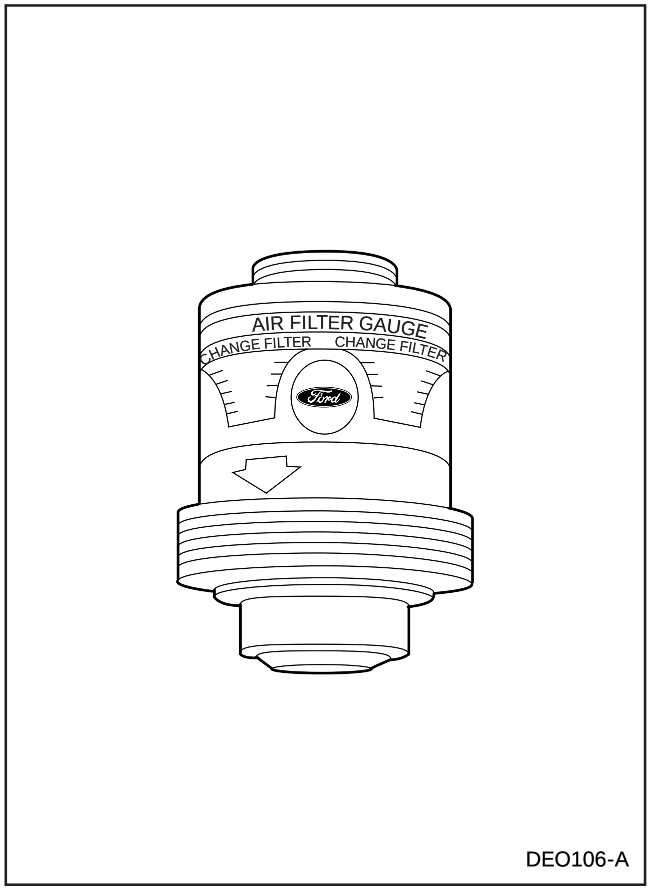
The 7.3L DIT engine requires an enormous amount of air to run at peak efficiency. The air inlet system is designed to supply the engine with all of the clean air that it needs. Lack of air intake can be detrimental to engine performance and starting capabilities.

Because of the high compression ratios in the diesel engine, a certain amount of blow-by and crankcase pressure is to be expected. If the air entering the cylinders is not filtered correctly, dirt particles could lodge around the piston rings and the cylinder walls and cause scoring. This would increase the amount of blow-by and would eventually raise crankcase pressure to undesirable amounts. Also, the dirt that passes by the pistons will settle in the oil sump area and cause the oil to become dirty faster. Once the oil becomes infested with dirt, it may plug the oil filter and cause it to bypass sooner.

It is also important that the air entering a turbocharger be filtered. Dirt particles entering the turbocharger can cause a rapid deterioration of the compressor wheel within the turbocharger, possibly making it lose effectiveness.

On dry-type air cleaners, the pressure drop across the air filter can accurately measure restriction. Restriction may be measured by tapping into the air inlet tubing or housing between the air cleaner and engine using a device that measures inches of water. This device may be permanently mounted and referred to as the filter minder, or a vacuum gauge may be used.

Particles adhere to the outside of the filtering element, and as they build up tend to stop even more dirt than the original element. Some restriction is good for the correct operation of the air filter. However, excessive restriction will hamper air flow to the engine and possibly cause driveability concerns.



Filter Minder

PURPOSE AND OPERATION OF THE EXHAUST SYSTEM

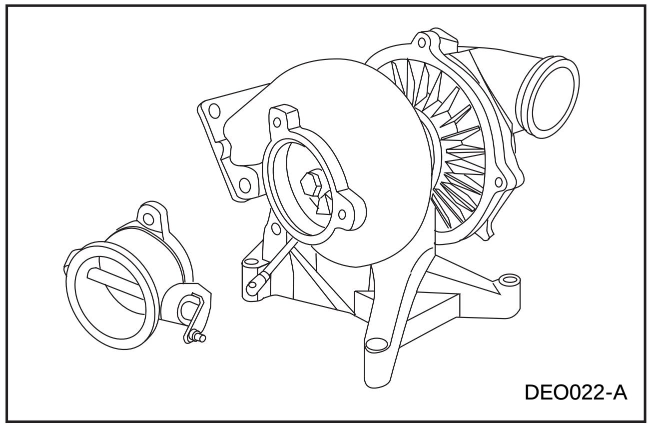
On the 7.3L DIT engine the exhaust system has a dual purpose:

1. Allows the removal of exhaust gases from the cylinders.
2. Uses the escaping exhaust gases to drive the turbocharger, supplying boost pressure to the air intake.

Exhaust Backpressure System

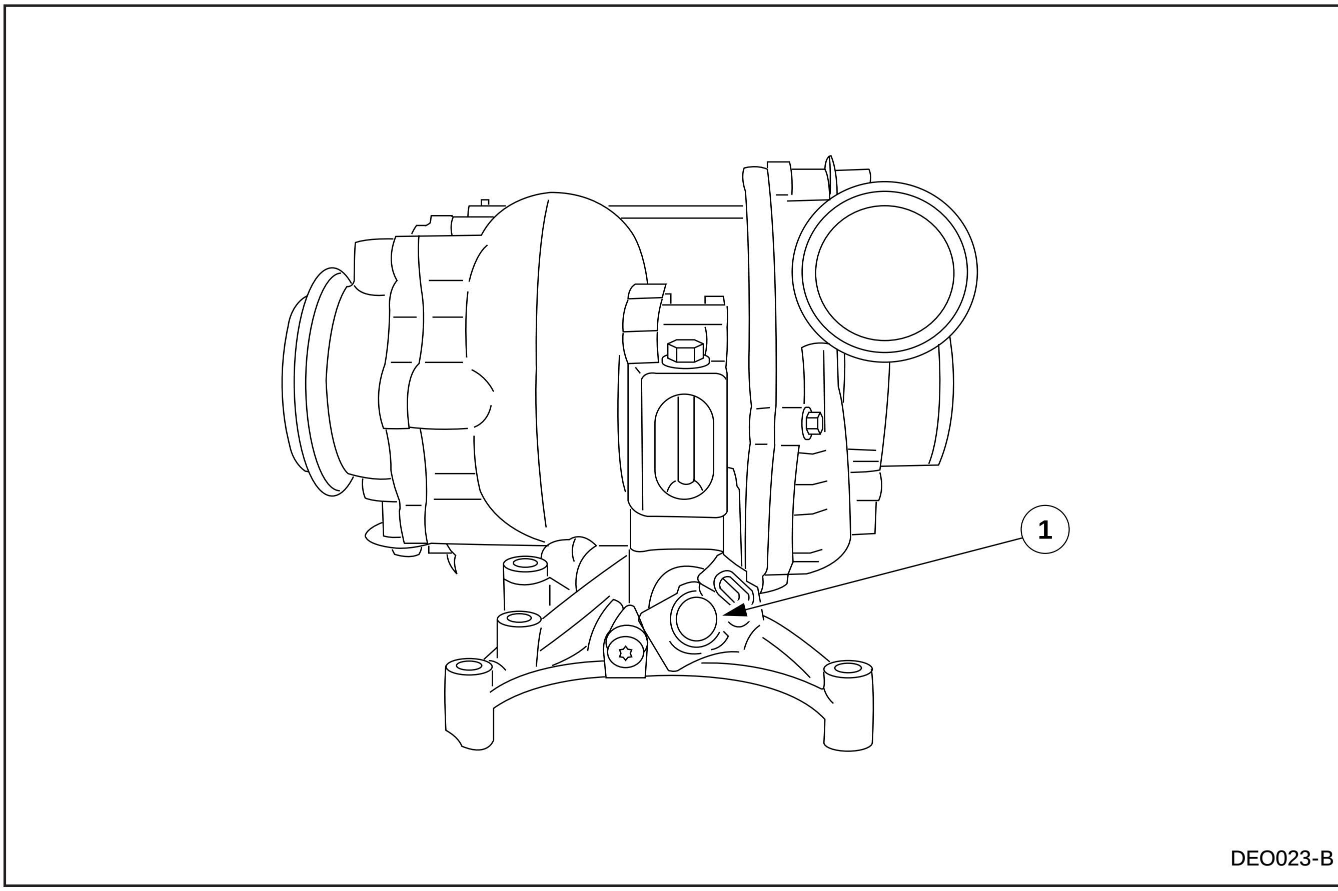
The exhaust backpressure system is controlled to provide more heat to the coolant for cab heating. This system is used primarily to help initiate higher defroster temperatures faster. The system operates during low-load, low-rpm operating conditions. At high-load, high-rpm conditions, the backpressure system is disabled to allow better exhaust flow from the engine.

The backpressure device is a butterfly-type valve located at the turbocharger outlet that is controlled by oil pressure and a solenoid. This valve closes to restrict the exhaust flow from the engine, thus, raising cylinder wall temperatures and transferring heat to the engine coolant that encompasses them.



Exhaust Backpressure System

Exhaust Backpressure Regulator (EPR)



Exhaust Backpressure Regulator

Item	Description
1	Exhaust Backpressure Regulator

The EPR regulator solenoid and EPR piston are contained in the turbocharger mounting pedestal. Pressurized lube oil in the pedestal is used to overcome spring pressure in order to close the backpressure valve. The EPR solenoid is pulse-width modulated by the PCM in order to regulate the amount of closure of the backpressure valve.

Exhaust Brake

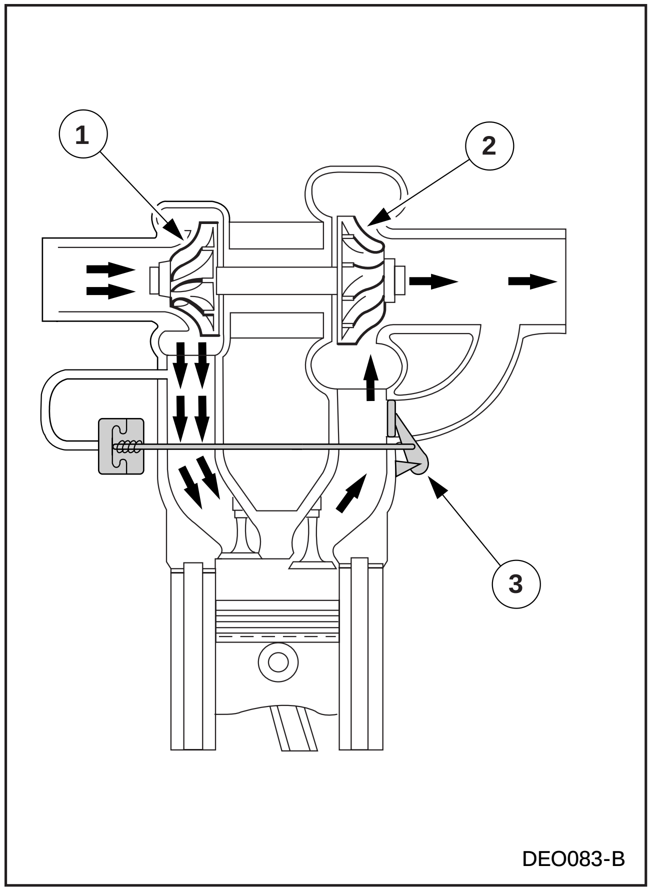
Ford Motor Company does not recommend the use of an exhaust brake on the 7.3L DIT engine.

An exhaust brake is designed to restrict exhaust flow when the vehicle is slowing. By restricting the exhaust flow, greater backpressure is presented to the cylinders and pistons. This causes resistance to crankshaft rotation and helps to reduce vehicle speed. The 7.3L DIT engine and turbocharger are not designed to withstand the increase in exhaust temperatures or pressure that an exhaust brake can cause. If an exhaust brake is used on this engine, turbocharger and/or engine valvetrain and/or transmission damage could occur.

PURPOSE AND OPERATION OF THE TURBOCHARGER

The operation of a turbocharger is quite simple. The turbocharger is a centrifugal air compressor that is powered by expanding exhaust gases from the heat produced in the cylinders. The turbocharger consists of a turbine wheel and a compressor wheel that are separately encased, but mounted on and rotating with a common shaft. The turbine side of the turbocharger is placed in the exhaust stream where it can be exposed to the exhaust gases coming from the engine. The compressor wheel side is placed in the air inlet system. The power to drive the turbine comes from the hot expanding gasses within the exhaust. The higher the engine load, the more heat is created and the faster the turbine will turn. The compressor, which is turning at the same speed as the turbine, will take in fresh air from the air inlet and compress it into the intake manifold. This is referred to as boost pressure. By pressurizing the air intake a steady flow of air is always ready for induction into the cylinders. However, because the air in the intake system is being pressurized, it is also being heated. For the best performance of the engine and combustion, the air entering the intake system from the turbocharger must be cooled as well.

The amount of time that the exhaust gases take to get the turbine wheel up to speed and produce more boost is called turbo lag. The smaller the turbocharger turbine and compressor wheels, the less turbo lag that is present.



7.3L DIT Turbocharger

Item	Description
1	Compressor Wheel
2	Turbine Wheel
3	Wastegate

It is not only exhaust flow that operates the turbocharger, but also the heat and expanding gasses within the exhaust. Therefore, it is possible to have an engine that is running at higher rpm, yet not producing the correct amount of boost because of conditions such as lowered cylinder temperatures and/or lowered exhaust temperatures. A cylinder that is not firing correctly could cause this.

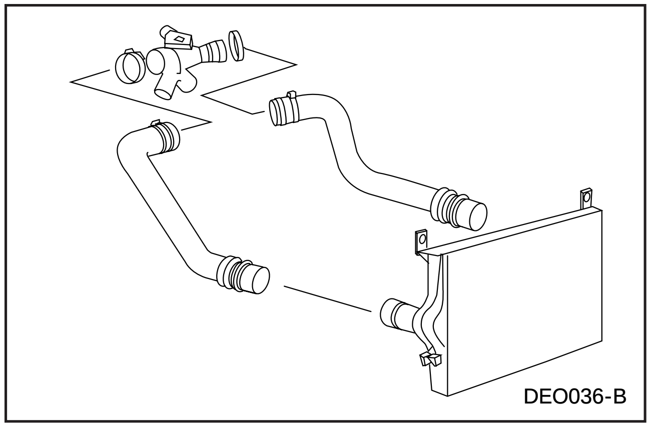
The rotating speed of the turbocharger is very high, it is capable of speeds in excess of 100,000 rpm. With such extremely high rotational speeds, lubrication and cooling are essential. These functions are accomplished by pumping oil from the engine to the turbocharger bearings and other components that require lubrication and cooling.

Running the Engine for Heat Dissipation

When a vehicle equipped with a turbocharger is run under load for a long period of time, it should never be shut off immediately after use. The temperatures in the turbocharger unit are very high after prolonged use. By not allowing oil to continue to flow through the turbocharger and aid in cooling it, the high temperatures will encompass the entire unit and possibly lead to premature malfunctions of the components. Bearings inside of the turbocharger unit are prone to damage from sustained high temperatures. A cool-down period is needed after long periods of turbocharger use, before shut-down. Allow the engine to idle for a short time before shutting it off. This will allow oil to continue to flow through the turbocharger and dissipate heat from it.

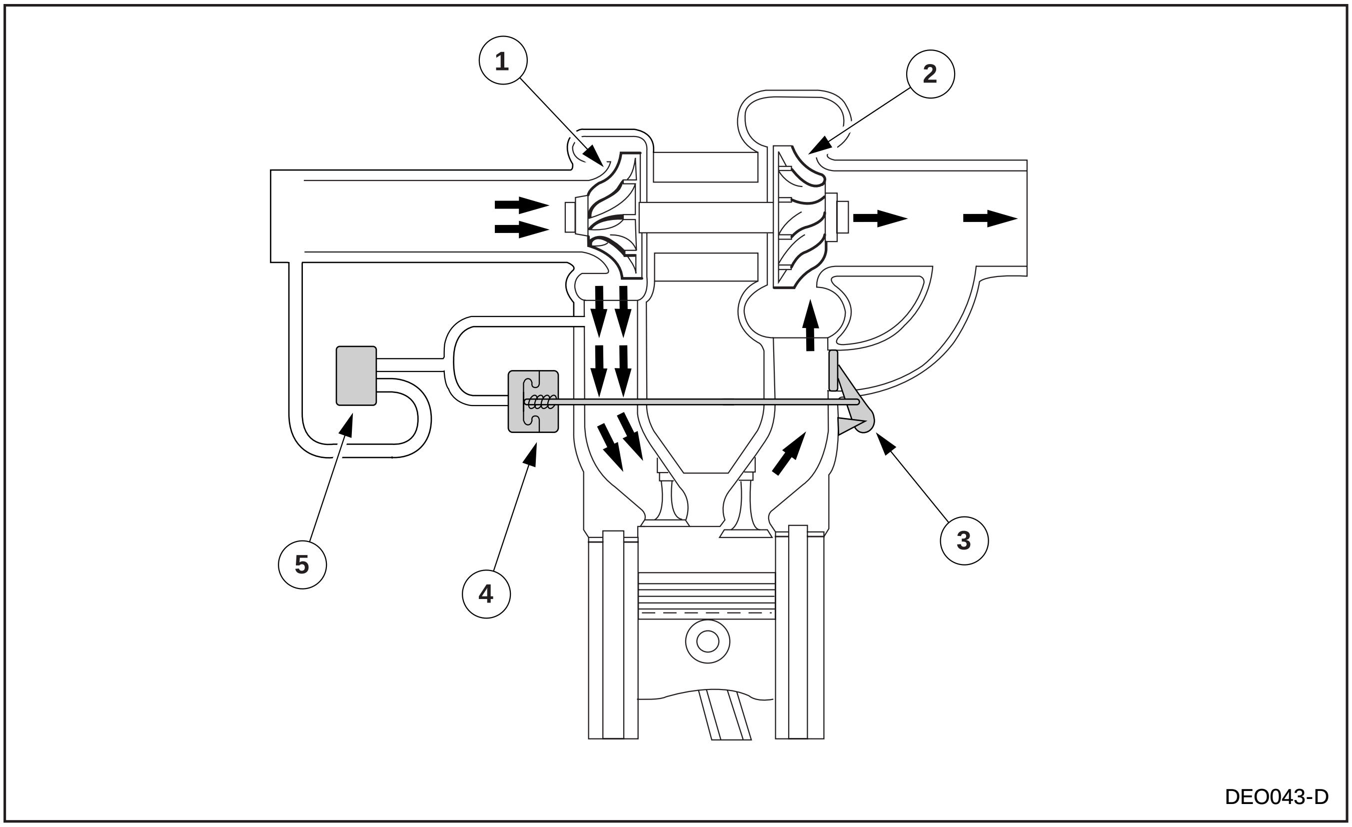
Charge Air Cooling System (CAC)

The charge air cooling system routes intake air that is transferred from the turbocharger, through a cooler assembly mounted near the radiator. After intake air leaves the turbocharger and before it enters the cylinders, it is desirable to remove excess heat created by the compression of air created by the turbocharger. The hotter the air the less dense the air is, and the less oxygen it carries. Since oxygen is a principle ingredient in the combustion process, starving the cylinders would be detrimental to overall engine performance. The CAC system can reduce intake air temperature by as much as 37.7°C (100°F).



Charge Air Cooling System (CAC)

Purpose and Operation of the Wastegate



Wastegate Control

Item	Description
1	Compressor Wheel
2	Turbine Wheel
3	Wastegate

Item	Description
4	Wastegate Actuator
5	Wastegate Solenoid

A wastegate performs two functions. First, it is designed to alleviate restriction created by the turbine wheel once it has reached its peak speed. Second, the wastegate is designed to control boost pressure created by the turbocharger.

When the accelerator in the vehicle is depressed, the PCM delivers more fuel to create horsepower and accelerate. As the exhaust gases leaving the engine increase, the turbocharger begins to spin faster and create more boost pressure in the air intake. The smaller the turbocharger turbine and compressor wheels, the less turbo lag is present.

The wastegate is a small valve in the turbine housing that is pulled closed by a spring and pushed open by boost pressure. When boost pressure reaches the desired level, boost pressure is applied to a wastegate actuator which opens the wastegate enough to maintain boost and divert the excess exhaust gases away from the turbine wheel, reducing exhaust backpressure. Some vehicles may not have a wastegate to control boost pressure.

Wastegate Control Solenoid

Wastegate operation on the 7.3L DIT with charge air cooling is controlled electronically by the wastegate control solenoid, and is used to regulate boost pressure.

Oil Buildup/Film on the Compressor Wheel

A slight oil buildup or film found on the compressor wheel is normal. This does not indicate a faulty turbocharger or seals, it is carryover from the crankcase breather system. However, a noticeable oil leak at the turbocharger should be inspected and repaired.

The charge air cooling (CAC) housing may have a light coating of oil internally. This, too, is normal and develops because of the closed crankcase ventilation system.

REVIEW QUESTIONS

1. Some restriction is good for the correct operation of the air filter.
   A. True
   B. False
2. Because of the __________________ in the diesel engine, a certain amount of blow-by and crankcase pressure is to be expected.

   ____
3. The filter minder measures:

   ____

   ____

   ____
4. What is the dual purpose of the 7.3L DIT engine exhaust system?

   ____

   ____

   ____

   ____
5. The ________________ system is controlled to provide more heat to the coolant for cab heating.

   ____

   ____
6. A _______________ is designed to alleviate restriction created by the turbine wheel once it has reached its peak speed.

   ____

   ____

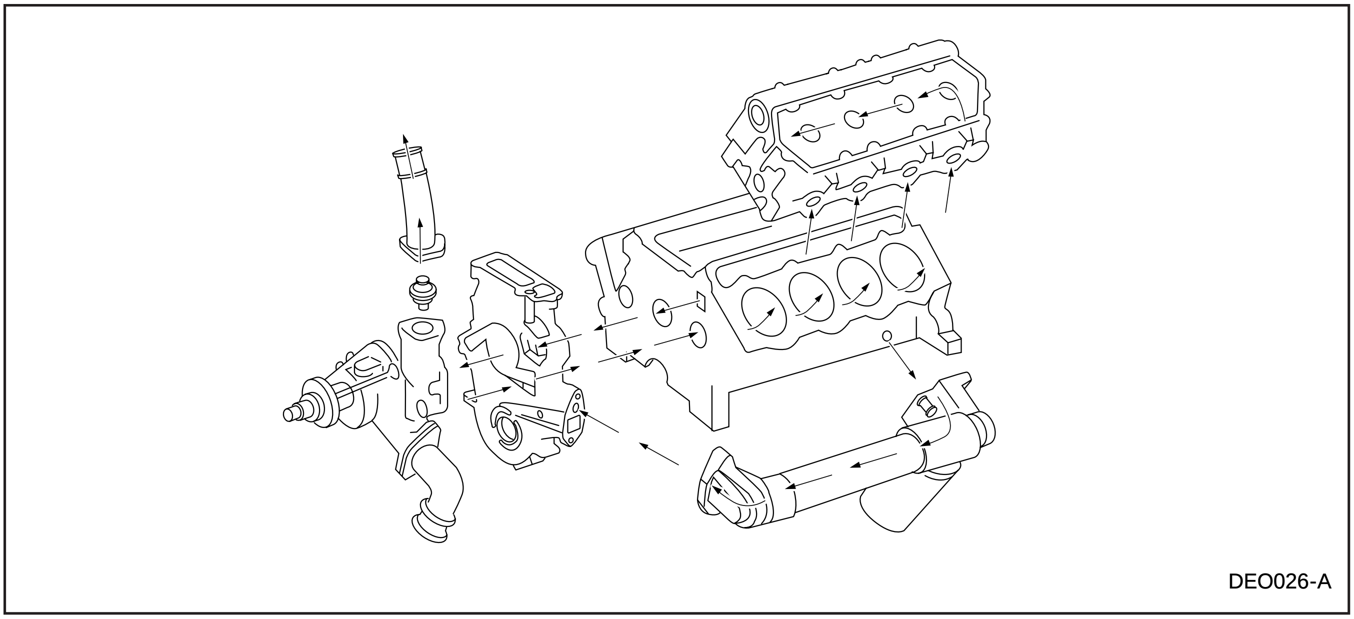
NOTES

TECHNICIAN OBJECTIVES

- Describe the purpose of coolant in diesel engines.
- Describe coolant properties.
- Describe the types and purpose of coolant additives.
- Describe the effects of cavitation in the cooling system.

CONTENTS

PURPOSE OF COOLANT IN DIESEL ENGINES



Engine Cooling System

The cooling system is extremely important to the operation of a diesel engine. If heat was not absorbed by the cooling system, it would cause cylinder overheating and engine damage. The cooling system, by circulating coolant throughout the cylinder block and heads, dissipates heat from vital components such as pistons, valves, bearings, etc. Heat dissipation occurs when heat is drawn into the moving coolant and carried to the radiator through hoses. The radiator allows excess heat to transfer to moving air currents passing through the radiator.

Coolant temperature inside a diesel engine must be closely controlled because the engine relies on heat to ignite its fuel. An engine that runs too cold will not be as efficient as an engine that runs at a steady, warm, operating temperature. A thermostat is used to control the temperature of the coolant. The thermostat controls coolant flow from the engine to the radiator or bypass circuit. When the engine is at operating temperature, the thermostat is open to the radiator and blocks the bypass. When the engine is below operating temperature, the thermostat blocks the path to the radiator and opens the bypass to allow coolant to flow through the engine.

NOTE: This system requires the use of a special type of thermostat in order to prevent engine damage.

COOLANT PROPERTIES

Coolant provides:

- freeze protection
- boil over protection
- general corrosion protection
- buffer-control pH to neutralize acids
- anti-foam
- cavitation corrosion protection
- scale inhibitors (prevents deposits on hot surfaces)
- antifouling (limits oil and dirt buildup on metal surfaces)

NOTE: For best protection it is recommended to use a 50/50 mix of coolant and water.

There are four basic types of antifreeze available:

1. Propylene glycol (PG)-based antifreeze has better cavitation corrosion protection than EG and **is recommended** for diesel engines. However, the limited availability of low silicate PG antifreeze prevents widespread use in diesel engines at this time.
2. Ethylene glycol (EG)-based antifreeze is the most readily available and suitable for freeze and boil-over protection.
3. Methyl alcohol or methoxy proponal-based antifreeze is not acceptable.
4. Organic Acid Technology (OAT-type) coolant is not approved for use in Ford diesel engines at this time.

Silicates

Silicate levels are marked on the antifreeze/coolant container. Low silicate antifreeze (with less than 0.10% silicate) is recommended for diesel engines. Higher levels of silicate are prevalent in antifreeze for passenger cars. Using high silicate antifreeze in diesel engines may result in silicate gelation – the formation of green slime that plugs coolant passages in the engine and radiator. Over-addition of coolant additive can also cause silicate gelation.

EFFECTS OF CAVITATION IN THE COOLING SYSTEM

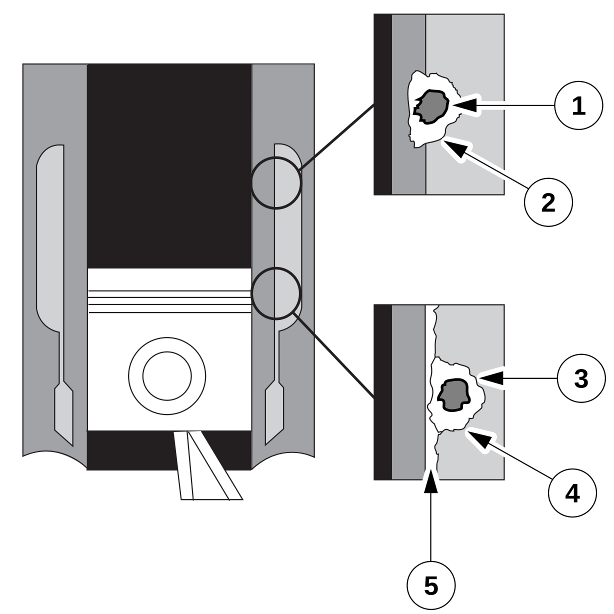
Cavitation Corrosion

Cavitation is a localized low-pressure zone. This low-pressure zone is caused by vibration of the cylinder wall due to the high cylinder pressure in a diesel engine. The cylinder walls vibrate due to irregular and sharp pressure increases during ignition. This fast cylinder wall movement causes a low-pressure zone to be created at the cylinder wall.

When this pressure zone drops below the vapor pressure point (temperature, coolant ratio, and additive dependant) a vapor bubble is formed. When this low-pressure zone returns to a high-pressure zone, the vapor bubble collapses, causing an implosion, or pitting phenomena on the cylinder wall (like hitting the surface with a microscopic ball-peen hammer). If left unchecked, it will eventually eat all the way through the cylinder wall.

Conditions Under Which Cavitation Occurs

When the coolant additives and properties diminish over time, cavitation may begin to occur. Diesel engines that have excessive turbocharger boost or severe duty use usually incur higher cylinder pressures and are more susceptible to cavitation concerns. Vehicles that incur short drive cycles (the vehicle is driven without time to warm up) can also be prone to cavitation concerns.



Cavitation

Item	Description
1	Vacuous Pocket
2	Vapor Bubble
3	Vapor Bubble
4	Vacuous Pocket
5	Coolant Conditioner Protective Coating

Effects of Cavitation on Engine Operation

Cavitation can erode through a cylinder wall. This could cause a decrease in cylinder compression, leakage of coolant into the cylinder, leakage of coolant into the lube oil system, or combustion gases leaking into the coolant. If combustion gases leak into the coolant, a noticeable rise in pH level in the coolant may be evident. This occurs because the combustion gases are very acidic. The raised acid level in the coolant could cause corrosion concerns in the cooling system as well.

How to Prevent Cavitation

To prevent cavitation, add the appropriate coolant additive and carry out a complete coolant change at prescribed maintenance intervals. FW-16 (replacement for the older FW-15), is Ford Motor Company's recommended additive for the 7.3L DIT engine.

CAUTION: Coolant additives will deplete over time and use. It is very important for engine longevity to restore coolant additive when directed by the prescribed maintenance interval. Using only approved Ford additive is highly recommended. Use of coolant testing kits is also recommended.

REVIEW QUESTIONS

1. A ______________ is used to control the temperature of the coolant.

    ____

2. The best coolant for diesel engines is:

    ____

    ____

3. Under what conditions does cavitation occur?

    ____

    ____

    ____

TECHNICIAN OBJECTIVES

- Describe the methods for determining maintenance intervals for diesel engines.
- Describe the importance of adhering to appropriate maintenance intervals.

CONTENTS

METHODS FOR DETERMINING MAINTENANCE INTERVALS FOR DIESEL ENGINES

Ford Motor Company recommends schedules for maintenance intervals. These intervals are calculated to give the best possible use of filters and fluids, and also keep the vehicle in top running condition. However, it is up to the owner of the vehicle to determine his/her driving conditions and habits and adjust the maintenance interval timing accordingly.

Vehicles that require a great deal of idle time such as police, fire, ambulance, delivery trucks etc. should have an hour meter installed to determine maintenance intervals for some systems. Although the vehicle is not being driven, and miles are not being recorded on the odometer, the engine is still working.

Another figure that may be used to determine maintenance intervals is the amount of fuel consumed. For instance; the oil in the 7.3L DIT engine should be changed at 200 hours of operation or every 702 L (180 gal) of fuel.

Normal vs. Severe Driving Conditions and Vehicle Maintenance

Vehicles that are used under severe conditions, including dusty areas, constant cold ambient temperatures, very hot climates, very heavy loads, etc. require more frequent maintenance intervals. Normal driving conditions are considered normal everyday city or highway use. The owner of a vehicle equipped with a 7.3L DIT engine must determine what conditions the vehicle is being used under, and adjust the maintenance schedule accordingly.

Maintenance Intervals for Engine Oil and Filter

It is recommended for the 7.3L DIT engine that the engine oil and filter be replaced every 8,000 km (5,000 mi) or six months, whichever comes first. Under severe driving conditions or dusty conditions it is recommended that the engine oil and filter be replaced every 5,000 km (3,000 mi).

These intervals for engine oil and filter are maximum intervals.

Maintenance Intervals for Engine Coolant

The engine coolant strength should be checked every 24,000 km (15,000 mi) or 12 months and additive restored. Engine coolant should be changed every 48,000 km (30,000 mi) or 36 months. Cooling system additive should be included in the coolant change.

Maintenance Intervals for Water Separator/Filter in the Fuel System

The water separator should be drained every 8,000 km (5,000 mi), and must be emptied when the water in fuel light illuminates on the instrument panel (IP). The light indicates that the water reservoir at the bottom of the fuel filter housing is full.

The fuel filter should be changed every 48,000 km (30,000 mi).

NOTE: Always refer to the owner literature for the appropriate maintenance schedule when repairing diesel engines.

IMPORTANCE OF ADHERING TO APPROPRIATE MAINTENANCE INTERVALS

Failure to Adhere to Recommended Maintenance Intervals

Failure to adhere to maintenance intervals concerning the 7.3L DIT engine could shorten engine life. The diesel engine, although sturdily built, is very delicate when it comes to dirt and contaminates in the fluids. The tolerances in some areas of the engine are very tight; even microscopic particles can cause damage and accelerated wear. For uninterrupted use of the diesel engine, it is very important to maintain the fluids and filters.

REVIEW QUESTIONS

1. What should be considered when determining maintenance intervals?

____

____

____

____

2 Engine coolant should be changed every ______________.

____

____

TECHNICIAN OBJECTIVES

- Describe techniques for cold weather starting.
- Describe the purpose of starting aids.

CONTENTS

TECHNIQUES FOR COLD WEATHER STARTING

Purpose of Starting Aids

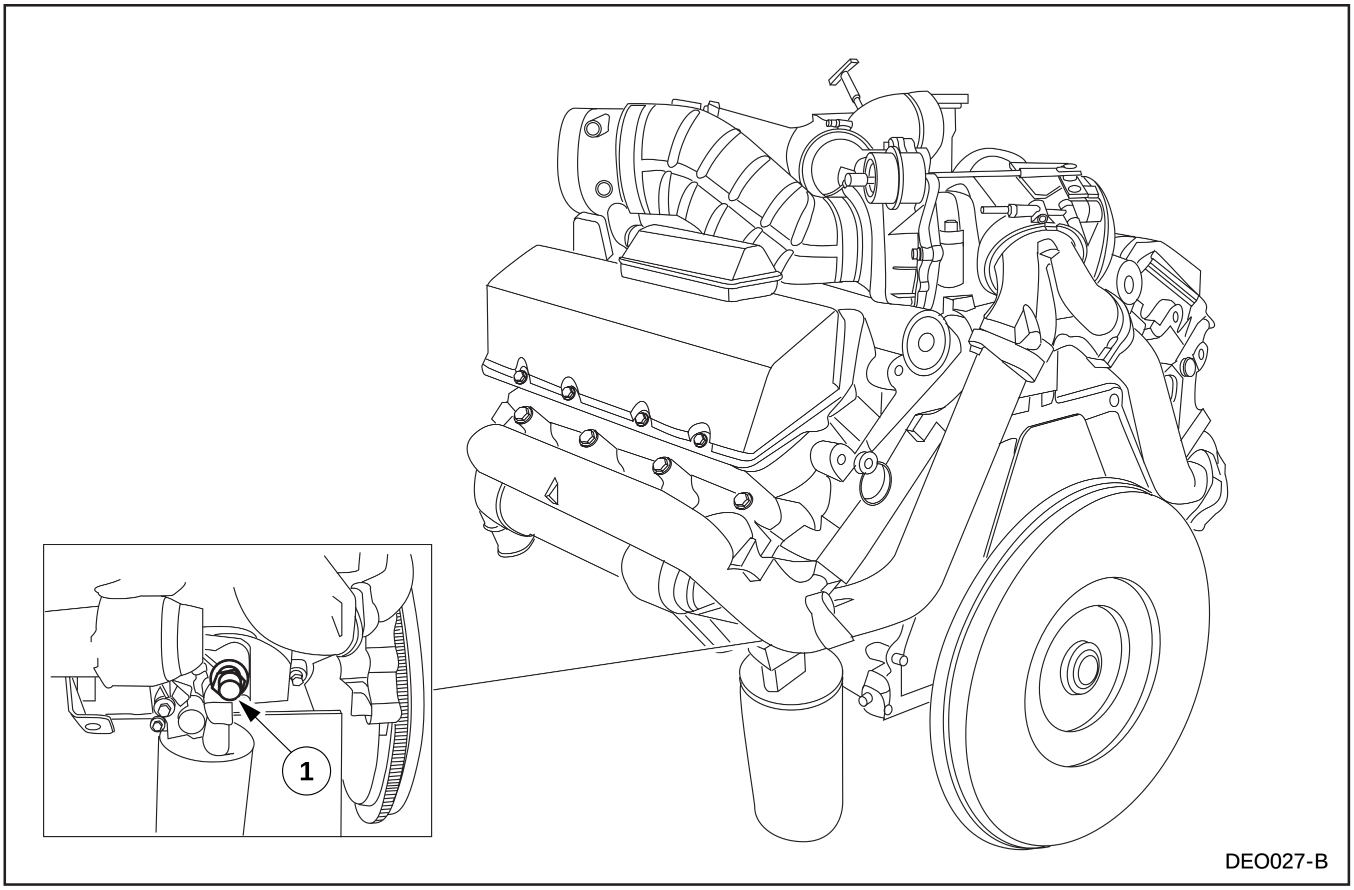
Starting aids are used on the diesel engine to help raise the temperature of the combustion or precombustion chambers. When ambient temperatures are too low, compression temperatures cannot rise enough to allow the engine to run efficiently. Once the cylinders have warmed by combustion, the engine can run smoothly.

Types of Starting Aids

There are two types of starting aids used by Ford Motor Company on diesel equipped vehicles:

1. Block heater
2. Glow plugs

Purpose and Operation of Block Heaters



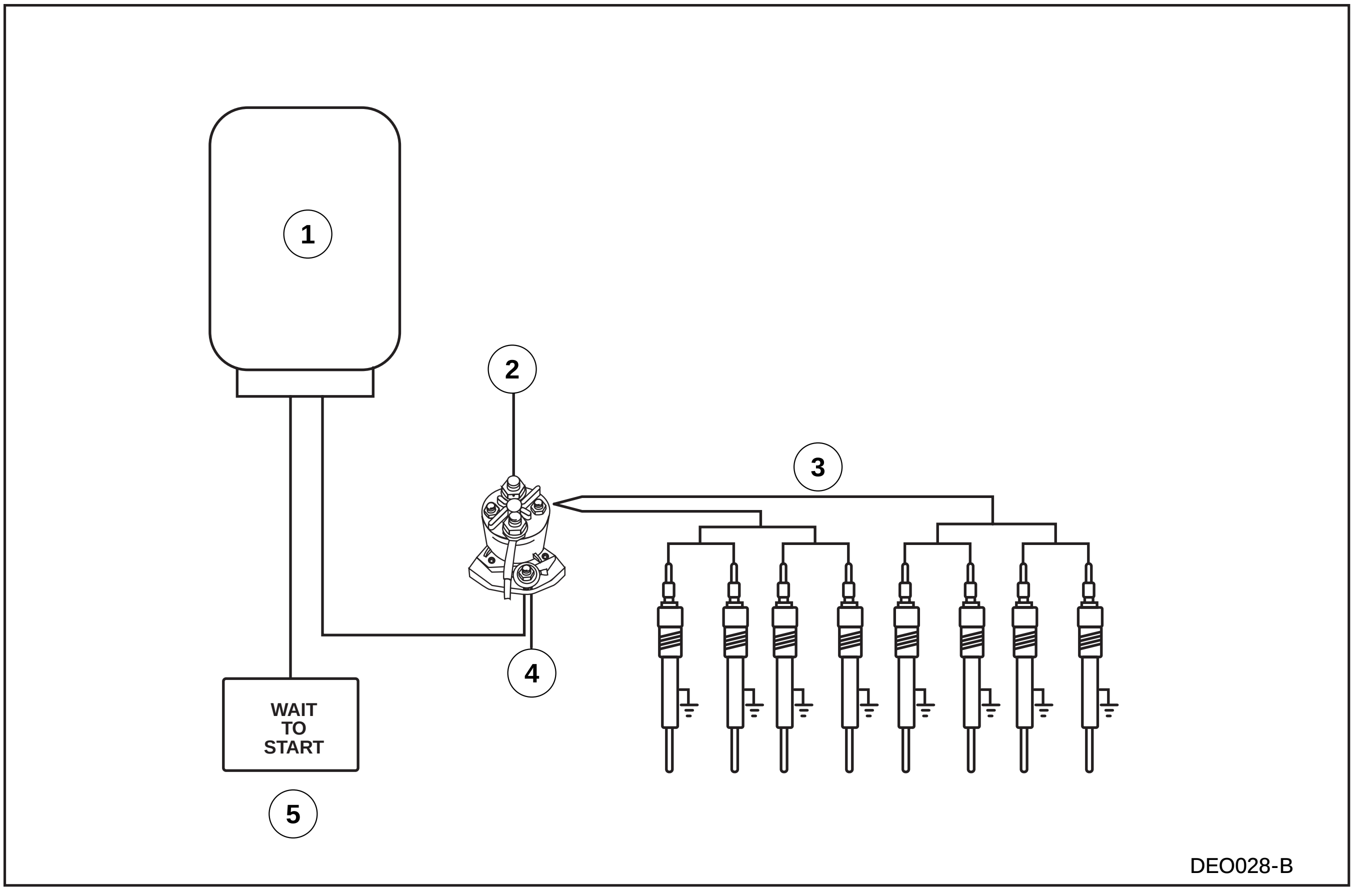
Block Heater

Item	Description
1	Engine Block Heater

A block heater is used to warm the coolant in the cylinder block.

The block heater consists of a heating element and a power cord. The heating element is mounted in the side of the rear oil cooler header, in the coolant passage. When the power cord is plugged into a standard 115v outlet, low resistance in the heating element causes the element to get warm. This in turn warms the coolant in the cylinder block that encompasses the cylinders. Heat is transferred to the cylinders and helps to increase initial compression temperatures and warms the oil, allowing the engine to start more easily in colder ambient temperatures.

Purpose and Operation of Glow Plugs



The Glow Plug System

Item	Description
1	Powertrain Control Module (PCM)
2	Battery Voltage
3	Glow Plugs

Item	Description
4	Power from EEC Relay
5	WAIT TO START Lamp

The glow plugs are used to heat the air in the combustion or precombustion chambers prior to starting the diesel engine. They help the engine to start and run smoothly during warmup. The glow plugs also help to reduce white smoke during cold temperature engine operation.

Operation

When the key switch is turned on, and the engine is cold, the glow plugs are activated. The indicator lamp, located on the instrument panel, is turned on. This informs the driver that the glow plug system is in operation. The glow plug relay is activated and allows a high amount of current to be applied to the glow plugs. When the glow plugs are sufficiently hot, the indicator light on the instrument panel goes out. This informs the driver that the engine can now be started. After the engine is started, current to the glow plugs may still be applied to reduce white smoke during warmup.

7.3L DIT vehicles use self-regulating glow plugs. This type of glow plug contains a resistor that reduces current when the plug temperature is excessive, thus preventing damage from overheating.

Effects of Ether on Diesel Engines Equipped with Glow Plugs

Ether should never be used when starting a Ford diesel-equipped vehicle, or any diesel equipped with glow plugs. Using ether to start this type of diesel engine can be hazardous to the operator as well as the engine itself. Because ether burns at a much faster rate than diesel fuel, it can ignite violently in the cylinders. In a cylinder that has the intake valve open and the glow plug hot, ether could ignite and burn all the way through the intake system, possibly injuring the person administering the ether. Also, when ether ignites it causes a very rapid increase in pressure in the cylinders. This could be harmful to the engine components, including the glow plugs.

REVEIW QUESTIONS

1. A ________________ is used to heat up the coolant in the cylinder block.

2. Ether should never be used when starting any diesel equipped with glow plugs because it may:

3. Which starting aid is used to reduce white smoke during cold engine operation?

TECHNICIAN OBJECTIVES

- Describe the diagnostic process for diesel engine performance diagnosis.
- Describe the importance of engine serial number.
- Describe low-pressure oil system diagnostics.
- Describe high-pressure oil system diagnostics.
- Describe fuel system mechanical tests.
- Describe air inlet and exhaust systems diagnostics.

CONTENTS

- The Diagnostic Process for Diesel Engine Performance Diagnosis
- Importance of Engine Serial Number
- Base Engine Diagnostics
- Low-Pressure Oil System Diagnostics
- High-Pressure Oil System Diagnostics
- Fuel System Tests
- Air Inlet and Exhaust Systems

THE DIAGNOSTIC PROCESS FOR DIESEL ENGINE PERFORMANCE DIAGNOSIS

Symptom-to-system-to-component-to-cause (S-S-C-C) is the diagnostic process used by Ford Motor Company technicians to locate the cause of a customer concern. This process uses a systematic approach to diagnosing a concern. Following this process allows the technician to lock-step through a diagnosis and rule out possibilities to arrive at an end result, which is the system or component that is causing the customer concern. The S-S-C-C process aids the technician in his/her quest to "Fix It Right The First Time On Time."

Symptom-to-System-to-Component-to-Cause (S-S-C-C) Diagnostic Process

1. Understand the repair order
2. Verify the customer concern
   - Road test
     - Safety check (visual) vehicle before road test.
     - May be necessary to have customer ride along to help point out concern.
   - Visual/Audible inspection
3. Check TSBs, OASIS, and vehicle history
   - Follow instructions in TSB or OASIS.
4. Carry out vehicle preliminary checks
   - Part of the symptom/index chart
     - Look for obviously failed components or systems.
5. Diagnostic tests
   - Diagnostic routines
     - Pinpoint Tests
     - Hard start/no start, performance diagnostic procedures
6. Carry out Repairs
   - Carry out the cause of the concern.
7. Verify the repair
   - Make sure that the original concern is gone and no new concerns have been created.

Reference Material Available for Diesel Engine Diagnostics

Reference materials available to the technician concerning diesel engine diagnostics are:

- the work history of the vehicle.
- OASIS reports, special reports and broadcasts.
- Technical Service Bulletins (TSBs).
- Hard Start/No Start Diagnostics Sheet (for warranty claims).
- Performance Diagnostics Sheet (for warranty claims).
- the Powertrain Controls/Emission Diagnostics Manual or PC/ED.
- the workshop manual.
- the Electrical/Vacuum Troubleshooting Manual (EVTM) or the Wiring Diagrams Manual.
  - As of the 1999 model year the EVTM is referred to as the Wiring Diagrams Manual. This book will no longer house vacuum diagrams.

NOTE: The Diagnostic Sheets for both Hard Start/No Start and Performance must be returned with selected parts for warranty. The parts included are listed at the bottom of each diagnostic sheet for reference. This parts list includes:

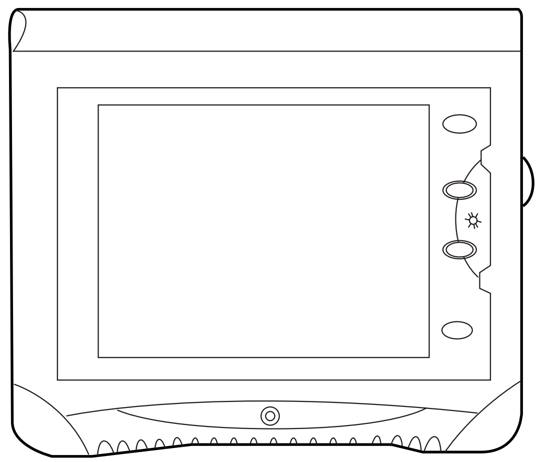
- Fuel/water separators
- IPR
- High-pressure oil pump assembly
- Turbocharger assembly w/pedestal
- IDM
- PCM
- Fuel pump

Preliminary Checks/Inspections

Preliminary checks and inspections include visual checks of systems and components to find obviously failed items. In some cases the visual inspection can find the cause of a customer concern, before any test equipment is connected to the vehicle. Preliminary checks and inspections may also include an audio check as well. In the case of a diesel engine, knowing the sounds of a known good engine as opposed to one with a defect can be an asset to the technician.

General Tools and Equipment for Diesel Engine Performance Testing and Diagnosis

Diagnostic Scan Tool



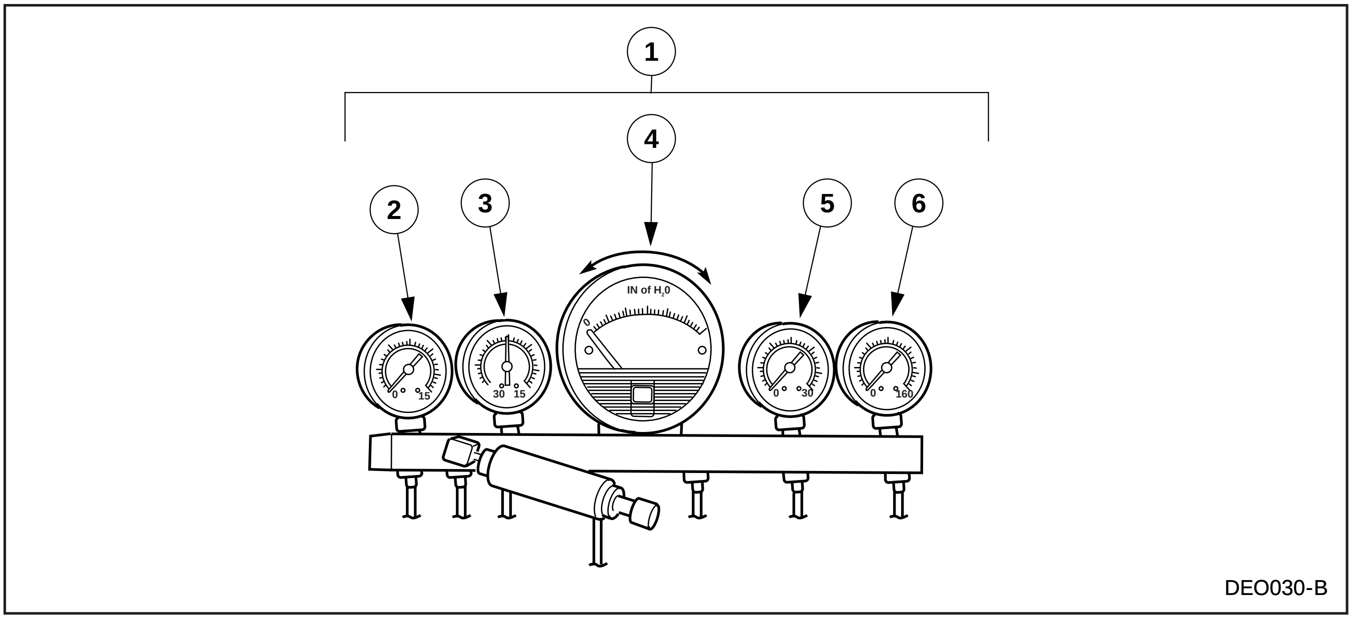
DEC065-A

Worldwide Diagnostic Scan Tool (WDS)

Ford diagnostic scan tools are used in diagnosis of the electronic engine systems in conjunction with the 7.3L DIT engine. Scan tool capabilities include:

- PID data monitor and record (Parameter ID)
- Self-test capabilities
- DVOM Digital Volt Meter
- Module Reprogramming
- Dual Channel Oscilloscope
- Guided Diagnostics

Gauge Bar Set



The Gauge Bar Set

Item	Description
1	Gauge Bar Tool (014-00761)
2	Pressure Gauge
3	Vacuum/Pressure Gauge

Item	Description
4	Magnahelic Gauge
5	Pressure Gauge
6	Pressure Gauge

Gauge Bar Tool (014-00761) is a set of five gauges mounted on a common bar with a suspension hook for easy underhood mounting. These gauges are used when carrying out vacuum/pressure tests on diesel engines such as:

- Fuel pressure tests
- Low oil pressure system tests
- Crankcase pressure test

The five gauges included on the bar are:

- A magnahelic gauge designed for a maximum pressure of 13 kPa (2 psi), using a 0-387 cm (0-60 in) water scale in 13 cm (2 in) increments. The gauge can be used to check both pressure and vacuum.

- A combination vacuum/pressure gauge with the following ranges/resolutions:

Range:	Resolution:
0-101 kPa (0-30 in-Hg)	6 kPa (2 in-Hg)
0-103 kPa (0-15 psi)	6 kPa (1 psi)

- Three pressure gauges with the following ranges/resolutions:

Range:	Resolution:
0-103 kPa (0-15 psi)	6 kPa (1 psi)
0-206 kPa (0-30 psi)	3 kPa ($^1/_2$ psi)
0-1103 kPa (0-160 psi)	34 kPa (5 psi)

In addition to these gauges, there is a hand pump to supply up to 103 kPa (15 psi) pressure to test for fuel system leaks.

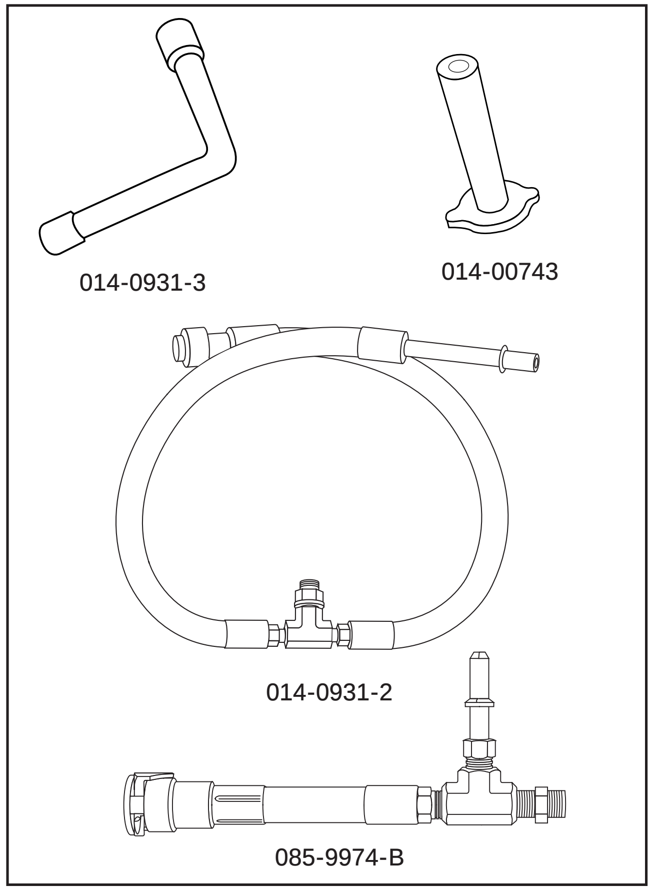
NOTE: The use of the correct gauge in diagnostic procedures is essential for accurate readings.

Adapter

Fuel Pressure Adapter Kits should be used in conjunction with the Gauge Bar Tool for checking fuel pressure on the 7.3L DIT engine. Refer to the workshop manual to identify the correct tool for the year and model vehicle you are working on.

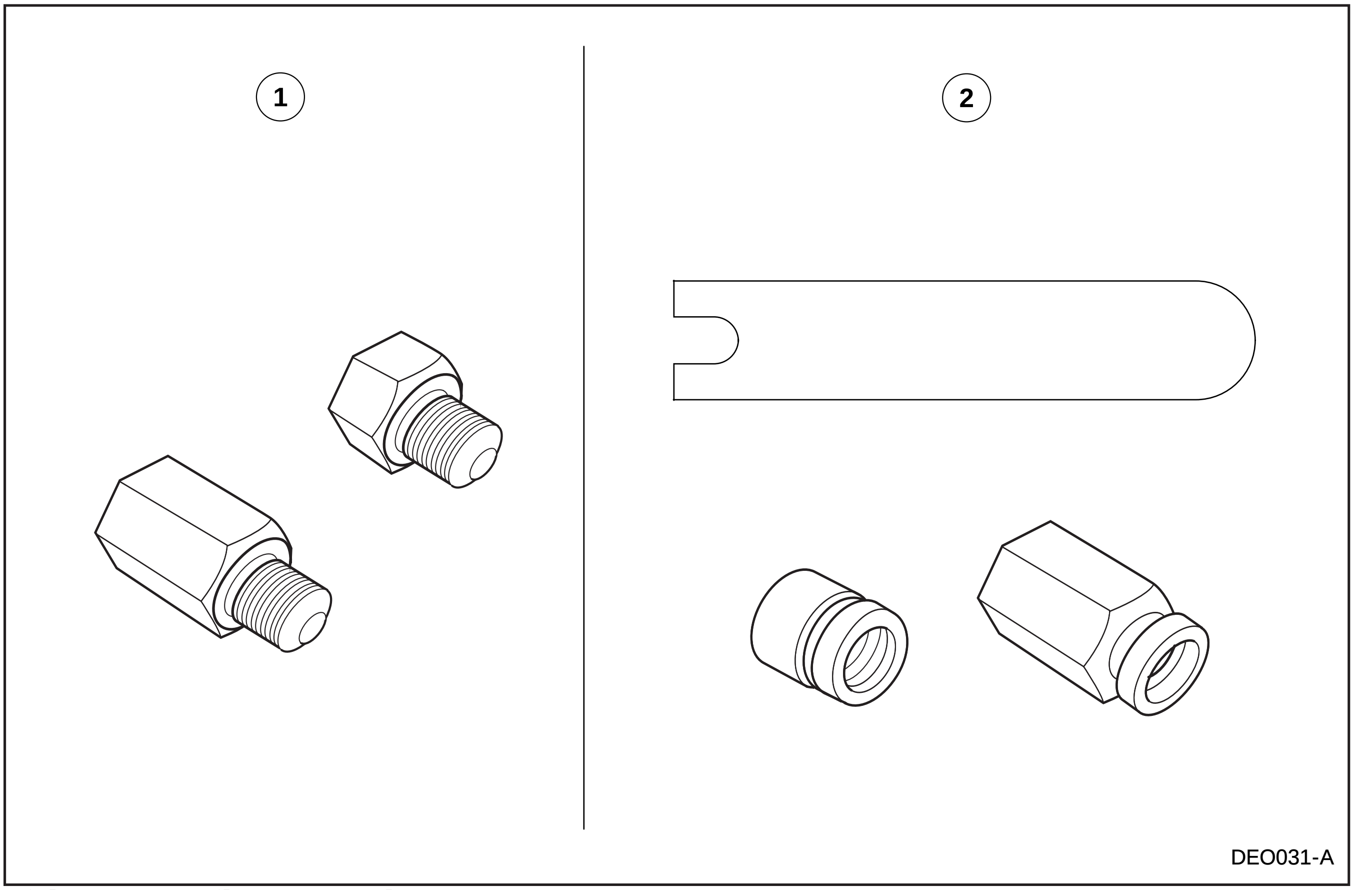
Additional adapters for gauge bar include:

- 014-00743 Crankcase Adapter used for crankcase pressure test
- 1998-1/2 and later vehicles:
  - 014-0931-2 used for fuel pump outlet test
  - 085-9974-B used for fuel inlet restriction test
- 1994-1998 model year vehicles:
  - 014-0931-2 used for fuel inlet restriction test
  - 014-0931-3 90° Schrader adapter used for fuel pressure test



Adapters

High-Pressure Plugs



High-Pressure Oil System Tools

Item	Description
1	Oil Pressure Tester Plug Tool D94T-6600-A
2	High Pressure Leakage Test Adapter Set 303-S626

Oil pressure test plugs are necessary to accurately diagnose the high-pressure oil system during a hard start/no start performance diagnosis.

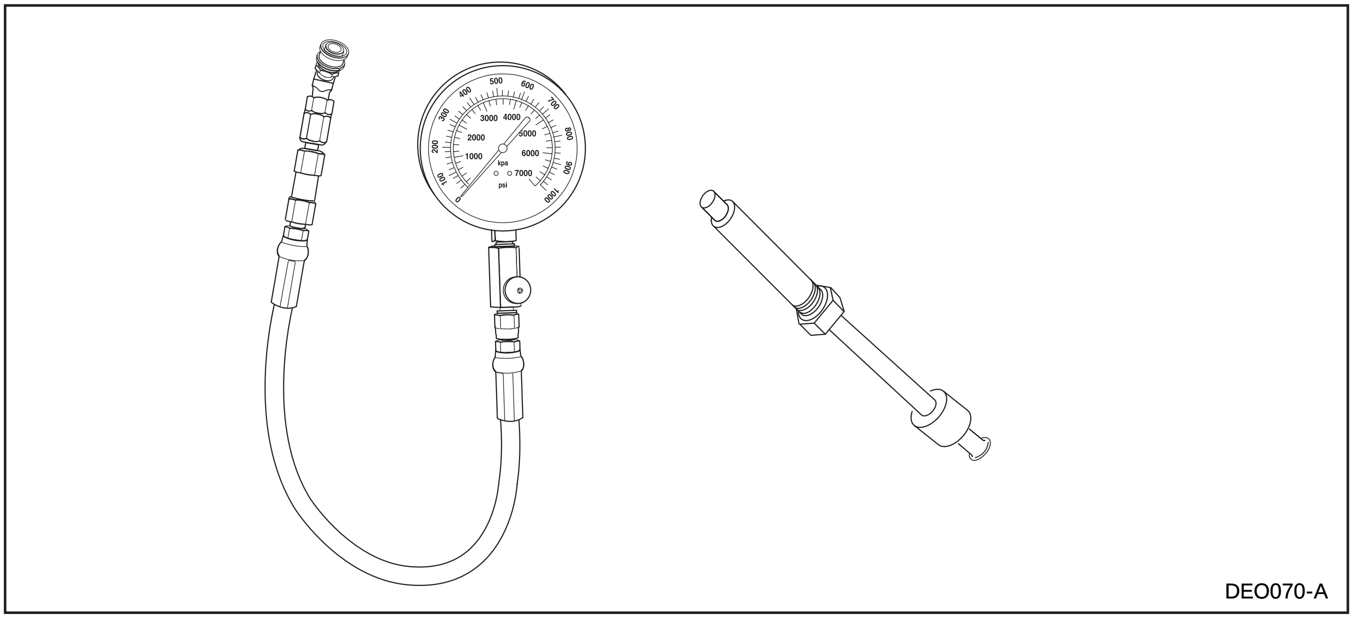
There are two different sets available:

- Threaded (1994-1998 model year vehicles)
- Quick connect (1998-1/2 and later vehicles) (requires disconnect tool)

Each set has a plug to block the right cylinder head hydraulic hose.

Each set has a straight-through adapter for connection of the ICP sensor to the left cylinder hydraulic hose.

Compression Gauge (014-00701)

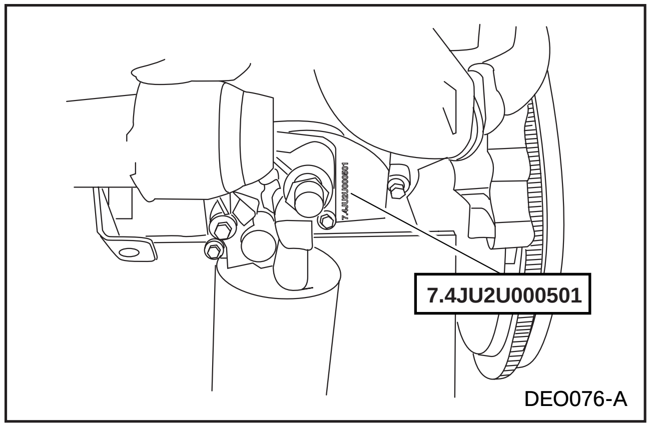


Diesel Compression Gauge and Adapter

A diesel engine compression gauge can be used to check cylinder compression pressure. There is an adapter (014-00931-1) that is inserted into an opening in the cylinder head that is made when a glow plug is removed.

IMPORTANCE OF ENGINE SERIAL NUMBER

Due to design changes, it is important to know the 7.3L DIT engine serial number when carrying out diagnostic or repair procedures. The permanent engine serial number is stamped on the lower rear LH side of the crankcase. On post-1998 engines the serial number can be located on the valve cover as well.



Location of the Engine Serial Number

BASE ENGINE DIAGNOSTICS

A rough running engine may set a cylinder contribution DTC that will lead you to carry out Base Engine Diagnostic tests. These tests can provide valuable information on the mechanical condition of the engine, and direct you to the repair required. There are three tests that are used for base engine diagnostics. These tests are usually carried out in the following order:

1. Cylinder contribution test
2. Crankcase pressure test
3. Compression test

Cylinder Contribution Test

The cylinder contribution test can easily be carried out using the scan tool. For this reason, it is recommended that it be the first test carried out, when diagnosing a base engine concern. It can be used to help determine whether or not all cylinders and injectors, are contributing equally to engine performance. When a cylinder contribution problem is detected, a DTC will be generated, identifying one or more weak cylinders.

NOTE: Be aware that earlier versions of the 7.3L DIT engine carried out this test by changing fuel quantity through the injectors one by one, and looking for fuel demand changes. On 1998 and newer engines, this is done by looking at the camshaft position sensor, and noting that there is no change in engine speed during the test.

Failing the KOER cylinder contribution self-test could indicate mechanical engine problems, or fuel delivery problems such as:

- Broken piston compression rings.
- Bent connector rods.
- Faulty injector assembly.

Crankcase Pressure Test

The purpose of the crankcase pressure test is to determine how well piston rings are sealing against the cylinder walls. You should carry out a crankcase pressure test to see if the concern relates to the seal between the piston rings and the cylinder walls. If this is the case, excessive compression pressure will enter the crankcase.

One of the likely causes of excessive crankcase pressure is dirt entering the cylinders through an incorrectly maintained air inlet system. This will quickly wear out the piston rings, and cylinder walls, and lead to serious engine performance concerns.

- Before starting the crankcase pressure test, it is important to run the engine to normal operating temperature. A cold engine will produce an abnormally high pressure reading.
- Install the crankcase orifice restrictor tool and crankcase pressure test adapter in the oil fill hole.
- Next, remove the ducting to the turbocharger inlet pipe.
- Install a protective screen over the turbocharger inlet. The screen will prevent foreign objects from entering the turbocharger.
- Block the outlet at the crankcase breather box with a suitable cap. This will cause all the pressure in the crankcase to be forced out the orifice restrictor tool during the test. Make sure the dipstick is fully seated.
- Make sure the gauge tubing is connected from the orifice restrictor tool and the pressure port of the magnahelic gauge.
- Make sure the gauge tubing is clean and dry, so that the gauge does not become damaged. It is good practice to blow through the tubing with clean, dry, compressed air, before each use.
- Also, verify that the magnahelic gauge has been zeroed.
- Block the wheels and shift the transmission to PARK, if you are working on a vehicle with an automatic transmission, or to NEUTRAL, if the vehicle has a manual transmission.
- Start the engine and run it at wide open throttle, under no load.
- Maintain this engine speed for at least 30 seconds and take a stabilized reading, taking care not to block the hole in the top of the crankcase orifice restrictor tool.
- If you obtain a reading greater than 102 mm (4 in) of water, on the crankcase pressure test, base engine mechanical concerns exist and you should refer to the workshop manual for further instructions.

Compression Test

The compression test checks cylinder compression and can be used to narrow down the possible causes for a failed cylinder contribution test. It can provide clues to mechanical component damage not detected by the crankcase pressure test. For example, it is quite possible to have a loss of compression due to valve concerns, with no pressure leakage into the crankcase. For this reason, it is a good idea to run a compression test on a vehicle that has a low contributing cylinder identified during the cylinder contribution test, even if a crankcase pressure test is passed. Before running the compression test, run the engine to normal operating temperature, and verify that the vehicle batteries are fully charged.

When carrying out a compression test:

- Remove the IDM fuse or relay. This will prevent the injectors from being actuated. More importantly, it will disable high voltage to the injectors, to eliminate the risk of electrical shock when working with the valve covers removed.
- The next step is to install the compression test adapter in a glow plug hole, and then connect the compression gauge to the adapter.
- Now, crank the engine a minimum of five compression strokes, and record the highest reading.
- Note the approximate number of compression strokes it took to generate this reading.
- Compare the code generating cylinder to the one next to it. Their compressions should be within 348 kPa (50 psi) of each other. If one or more cylinders vary by more than 348 kPa (50 psi), they are considered malfunctioning cylinders and would need to be inspected for the cause of the low compression. If low compression is found in the code generating cylinder, base engine concerns exist.

Possible causes could be:

- Stuck or damaged piston rings.
- Leaking valves, leaking cylinder head gasket.
- Bent connecting rod.

If low compression is present, refer to the workshop manual for further diagnosis.

NOTE: Under no condition should a "wet" compression test be carried out on any diesel engine.

LOW-PRESSURE OIL SYSTEM DIAGNOSTICS

Purpose and Test Equipment for Low-Pressure Oil System Checks

Oil pressure should be checked under specified conditions to assure an accurate reading. The test conditions are found in the engine specifications provided in the workshop manual. These are the typical conditions:

- engine hot (operating temperature)
- 2,000 rpm

When checking for low oil pressure, the sending unit should always be checked first by checking oil pressure with a gauge. This will eliminate the possibility of false readings from the sender being the "cause" of the concern. In addition, oil pressure can be checked at both the upper and lower sections of the engine. The sending unit passage, located on top of the reservoir, can be utilized to install a gauge on the upper half of the engine. The lower half can be checked at the main bearing cross-drilled passage located on the left side of the engine block, about 6.5 cm (1 in) above the oil pan.

Test Equipment

A mechanical oil pressure gauge should be installed in place of the oil pressure sending unit. Do not use the IP mounted gauge as a reference, as this could be the "cause" of low oil pressure readings.

Reasons for Low Oil Pressure

There are several reasons why low oil pressure can be present. The following table lists these reasons and identifies what pressure indications would be found at the sender and block test points.

Cause	Sender	Block
Insufficient or excessively thin oil	Low	Low
High fuel dilution (causes oil to thin out)	Low	Low
Weak relief valve spring	Low	Low
Worn oil pump	Low	Low
Excessive bearing clearance	Low	Normal
Broken or cracked oil line, such as the one going from the pickup screen to the oil pump	Low	Low
Obstruction in the oil line going from the pickup screen to the oil pump	Low	Low
Oil pan baffle blocking the pickup screen (this also affects injection control pressure)	Low	Low
Tappet gallery plug (at rear of engine) leaking or missing	Low	Normal
Inoperative oil pressure sending unit	Normal	Normal

Low Oil Pressure Caused by Obstructions

Obstructions were mentioned in the list of reasons for low oil pressure. Typically, an obstruction is anything that prevents the flow of oil through the engine. The most common obstruction found in engines is caused by sludge. Heavy incidences of sludge can be caused by a failure to follow maintenance schedules or failure to use the recommended engine oil.

Filter plugging indicates that the filter itself is usually doing its intended job - removing particulate matter from the oil. Filter replacement schedules take into account normal operating conditions, and the use of lubricating oils of a quality specified by the vehicle manufacturer. Under those conditions, the motor oil disperses carbon, partially burned fuel, lacquers, and varnishes in a finely divided manner that passes them through the filter. They are discarded when the oil is replaced.

NOTE: Oil filters come in many different sizes. Some may have the same thread size, but a different canister size. Be sure that the filter being installed is the correct filter for the application. If a filter of smaller canister size is used, it may plug prematurely. This would cause the oil to bypass the filter, and unfiltered oil to enter the engine. Engine longevity may be greatly reduced because of this action.

Reasons For Excessively High Oil Pressure

Too high oil pressure is not a typical lubrication system complaint, but it can occur. Excessively high oil pressure can cause damage to the oil filter element and also to seals and gaskets. A high oil pressure condition can be caused by:

- Stuck closed oil pressure relief valve.
- Cold operating engine.
- Excessively heavy oil.

HIGH-PRESSURE OIL SYSTEM DIAGNOSTICS

Purpose and Test Equipment for High-Pressure Oil System Checks

High-Pressure Oil Reservoir Check

The high-pressure oil reservoir level is checked through a fill plug located on the top of the reservoir. The oil level should be within an 6.5 cm (1 in) of the top of the reservoir. An empty reservoir could cause a normal crank/ no start condition.

The reservoir level may be low as a result of an internal leak causing a drainback problem or a low-pressure supply problem. Extended cranking time due to a no-start condition can also cause the reservoir level to be low.

Injection Control Pressure Tests

There are four injection control pressure tests that may be carried out to help diagnose driveability concerns:

1. Oil aeration test
2. Low idle stability test
3. Balance test
4. Leakage test

Oil aeration test

The oil aeration test is used to determine if the high-pressure oil is aerated to the point of causing driveability concerns. Aerated or foamed oil may cause driveability concerns associated with high-pressure oil system inability to operate the fuel injectors to their full potential. Poor idle quality can be associated with extreme oil aeration. High-pressure oil is used to drive the plunger in the injectors. Hydraulic principles show that oil (hydraulic fluid) is not compressible. Therefore, it can be used to transfer pressure and motion. However, air is compressible. If the oil in the high-pressure oil system is saturated with air, the air will compress in the plunger cavity of the injectors, and a lack of pressure and motion will be present. This causes the injectors to produce less effective delivery of the fuel entering the cylinders.

Because the aerated oil cannot deliver as much fuel through the injectors, the PCM will command more ICP to maintain the same fuel delivery.

This test is done by connecting the scan tool to the vehicles data link connector and using the PID data monitor function. Monitor the ICP PID and watch for a pressure increase from the start of the test to the end of the test, while holding engine rpm at 3,400 (not governor speed) for three minutes. Holding rpm for the entire three minutes is very important to the outcome of the test. Do not lower the rpm until the entire three minutes have elapsed. If the oil starts to aerate, the ICP will gradually increase to compensate for the gradual rise in aeration. If the ICP pressure exceeds specifications, the oil is aerating too much.

Some possible causes of oil aeration are:

- Incorrect API service rating on engine oil
- Extended oil change intervals (anti-foaming additives in the oil may have depleted)
- Low engine oil level
- Air present due to recent engine repair on the injection control pressure system
- Recent repairs using silicone sealers (Silicone sealers can cause a depletion of the anti-foaming additives in the oil.)

⚠ **CAUTION: Use only Ford Motor Company approved sealer (F5TZ-196204-AV) when resealing the 7.3L DIT engine.**

- air leaks to inlet side of low pressure oil pump (damaged or cracked pickup tube, or missing, damaged gasket)

The engine oil should be replaced and this test run again to be sure the concern has been addressed.

NOTE: Because of the PCM's ability to compensate for an unstable rpm condition, there are many concerns that could cause you to receive erroneous test results during the oil aeration test. These concerns include:

- Low fuel psi
- Base engine concerns
- Injector concerns

Low idle stability test (ICP pressure)

This test determines ICP pressure at low idle. It is used to evaluate the functionality of the IPR and ICP. The oil aeration test is used to determine the quality of the engine oil, then the ICP pressure test is used to determine the capability of the IPR and its circuit. These two tests help the technician to isolate high-pressure oil system concerns that may cause driveability concerns with the 7.3L DIT engine.

This test is done by monitoring the ICP PID with the scan tool while running the engine at idle (approximately 650 rpm).

If the ICP PID value is within range and idle is steady there is no need to continue with this test.

- If engine rpm is unstable, disconnect the ICP sensor.

NOTE: ICP will default to 4,998 kPa (725 psi) when disconnected.

- If rpm smooths out, the ICP signal may be at fault.
- If rpm is still unstable, change the IPR with a known good one, and retest to eliminate the IPR as a possible cause.

Injection Control Pressure Balance

The injection control pressure balance test is used to compare the ICP pressure of the right and left cylinder heads. Pressure differences between the heads have been found to cause poor idle and performance concerns. There are several ways to carry out the injection control balance test. One method is as follows:

Install an additional ICP sensor in the right cylinder head, connect the EBP sensor connector to the additional sensor (an extension harness may be required, part number D94T-50-A), install a breakout box and monitor the ICP signal on the right and left head. Use the pins in the breakout box that correspond to the EBP signal for the right cylinder head. Monitor the signals with two DVOMs. Compare the measured signal of the right and left cylinder heads at low idle, high idle and under a load. The difference between each head should not exceed 0.2 volt.

To isolate if the pressure difference is caused by internal leakage in the cylinder head or by the high-pressure pump, block the line feeding the right cylinder head and operate on the left bank only. Then route the line feeding the left cylinder head to the right cylinder head. The left high-pressure line will reach the right head. This will allow the isolation of both cylinder heads and give an indication as to which one may be leaking.

When performing this test it is advised that the IPR duty cycle be monitored. This will allow the technician to know how hard the pump is working to generate enough pressure to run the engine.

High-Pressure Leakage Test

This test is carried out to isolate a high-pressure oil system leak. The vehicle may be experiencing a no start/hard start symptom. If a leak within the high-pressure oil system develops, it could be located in either cylinder head or internal in the pump. This test will help to pinpoint the location of a leak.

Disconnect the high-pressure oil line from the right cylinder head and plug the hose using the closed plug provided in the tool kit. Install the a scan tool to monitor the ICP PID, and with the right cylinder head high-pressure hose plugged, make a start attempt.

NOTE: The engine may start and run on the left four cylinders.

If at least 3,447 kPa (500 psi) of ICP pressure is achieved the injectors may be enabled and the engine may start with the right cylinder head eliminated from the system. This is an indication that the right head is where the high-pressure oil system leak is.

Possible causes could be:

- Fuel injector leaking high-pressure oil through the poppet and seat and out the spill port.
- Fuel injector O-ring seal is cavitated, bypassing high-pressure oil to the fuel rail in the cylinder head, or to the rocker arm area. If the engine has under 1,609 km (1,000 mi) on it, suspect a damaged or missing O-ring seal.
- Porosity or crack in the cylinder head oil gallery (extremely rare).

If the engine does not start and still fails to generate 3,447 kPa (500 psi) after plugging the right cylinder head, test the left cylinder head.

Remove the plug from the right cylinder head and reconnect the high-pressure hose. Once the right head is reconnected, disconnect the hose from the left cylinder head. Install the straight-through adapter from the test kit.

Remove the ICP sensor from the left head and screw it into the end of the straight through adapter to monitor the ICP generated in the right cylinder head. Attempt to start the engine.

If the engine starts and runs on the right four cylinders, the leak is in the left cylinder head that was eliminated from the system.

If the engine fails to start and fails to generate 3,447 kPa (500 psi) of ICP after testing both cylinder heads individually, the next step is to determine if the high-pressure oil pump and Injection pressure regulator (IPR) have the ability to generate the needed 3,447 kPa (500 psi).

Disconnect the right high-pressure hose from the cylinder head and plug it with the appropriate tool (leave left hose plugged from previous step). The oil supply system is now “dead-headed” and isolated down to the high-pressure pump and the IPR. Check the high-pressure reservoir oil level and fill, if necessary. Monitor the ICP pressure PID with a scan:

- If the pressure goes over 3,447 kPa (500 psi), leakage is present in both cylinder heads.
- If the ICP pressure still does not reach at least 3,447 kPa (500 psi), double check the oil level in the reservoir.
- If the reservoir is full, the problem is either the injection pressure regulator (IPR) or the high-pressure pump.

The first step is to inspect/replace the injection pressure regulator. If a known good IPR does not solve the concern, process of elimination warrants pump replacement.

NOTE: High-pressure oil pump failure is rare. All other high-pressure oil system diagnostics must be completed before the high-pressure oil pump is found to be at fault.

FUEL SYSTEM TESTS

Correct fuel system pressure is critical for getting fuel to, and filling the injectors during engine operation. Lowered fuel pressure may cause driveability concerns and decreased engine performance. Carrying out the tests that follow will help to isolate the cause of a lack of fuel pressure.

Return Fuel System Tests

Fuel Pressure Test

Fuel pressure readings should be taken at the pressure regulator. If fuel pressure is within specifications, the fuel system can be eliminated as a possible cause of a driveability concern.

- For performance concerns, the test must be carried out under a full load during a road test.
- For no-start concerns, the test must be carried out while cranking.
- For vehicles with dual tanks, the test must be carried out on each tank.

Possible causes for low pressure concerns are:

- Restricted fuel filter
- Failed fuel pump
- Failed pressure regulator
- Restricted fuel pump inlet

Inlet Restriction Test

This test determines if there is excessive restriction of fuel flow in the fuel supply line from the fuel tank or tanks. It is carried out to narrow down the possible causes of a failed fuel pressure test.

Carry out the test as follows:

- Install Rotunda Low Fuel Pressure Adapter 014-00931-2 or equivalent to the fuel inlet line.
- Connect a 0-30 in-Hg vacuum gauge to the adapter.
- Start and run the vehicle at wide open throttle and no load with the brakes applied and the wheels chocked.

If the gauge registers more than 6 in-Hg at wide open throttle, there is a blockage between the test adapter and the fuel tank.

Possible causes for a fuel inlet restriction:

- Kinked or pinched fuel inlet line
- Blockage at the fuel tank pickup
- Fuel tank selector valve damaged or inoperative
- Fuel gelled in the fuel lines in cold ambient temperatures

Air in the Fuel Test

This test is carried out to check for air being drawn into the fuel system even if the fuel pressure tested is within specification.

Carry out the test as follows:

- Remove the rubber hose from the return line at the fuel pressure regulator block.
- Install a clear hose in between the return line and regulator block.
- Run the engine at idle for five minutes and look for air returning to the tank.

Air or foamy fuel indicates that air is being drawn into the fuel system.

Possible causes for air in the fuel system:

- Loose or leaky supply line at the fuel tank
- Loose or leaky supply lines at the fuel tank selector valve
- Loose or leaky supply line at the fuel pump
- Leak in the fuel supply line itself

Possible causes of no return fuel flow:

- Restricted air bleed holes
- Plugged pressure regulator
- No fuel pressure

Returnless Fuel System Tests

Fuel Pressure Test at the Cylinder heads

Fuel pressure readings should be taken at the cylinder heads. If the pressure is within specification at both cylinder heads, the fuel system can be eliminated as a possible cause of a driveability concern.

- For performance concerns, the test must be carried out under a full load during a road test.
- For no-start concerns, the test must be carried out with the key on and engine off.
- For vehicles with dual tanks, the test must be carried out on each tank.

Possible causes for low pressure concerns are:

- Restricted fuel filter
- Failed fuel pump
- Failed pressure regulator
- Restricted fuel pump inlet
- Restricted cylinder head check valve(s)

Fuel Pressure Test at the Pump Outlet

This test determines if there is enough fuel pressure at the pump outlet. It is carried out to narrow down the possible causes of a failed fuel pressure test at the cylinder heads.

Carry out the test as follows:

- Install Rotunda Low Fuel Pressure Adapter 014-00931-2 or equivalent to the fuel pump outlet.
- Connect a 0 to 1,103 kPa (0-160 psi) pressure gauge to the adapter.
- For performance concerns, the test must be carried out under a full load during a road test.
- For no-start concerns, the test must be carried out with the key on and engine off.
- For vehicles with dual tanks, the test must be performed on each tank.

Possible causes for low fuel pressure at the pump outlet:

- Failed fuel pump
- Failed pressure regulator
- Restricted fuel pump supply line

Inlet Restriction Test

This test determines if there is excessive restriction of fuel flow in the fuel supply line from the fuel tank or tanks. It is carried out to narrow down the possible causes of a failed fuel pressure test.

Carried out the test as follows:

- Install Rotunda Adapter D85L-9974-B or equivalent to the fuel inlet line at the fuel pump.
- Connect a 0-30 in-Hg vacuum gauge to the adapter.
- Start and run the vehicle at wide open throttle and no load with the brakes applied and the wheels chocked.

If the gauge registers more than 6 in-Hg at wide open throttle, there is a blockage between the test adapter and the fuel tank.

Possible causes for a fuel inlet restriction:

- Kinked or pinched fuel inlet line
- Blockage at the fuel tank pickup
- Restricted DTRM
- Fuel tank selector valve damaged or inoperative
- Fuel gelled in the fuel lines in cold ambient temperatures

Procedure and Equipment for Testing the Air Inlet System

Procedure for Visual Inspection of the Air Inlet System

Black smoke, lowered fuel economy, or lack of power can all be caused by an air inlet restriction. The diesel engine requires a very large volume of air intake to run efficiently. Any reduction in air volume can produce driveability concerns. When inspecting the air intake system for restrictions, the entire system should be checked, from the air filter forward to the beginning of the air intake tube. Debris may lodge anywhere within the air intake tube itself, or the air filter assembly.

Use of Magnahelic Gauge to Test for Vacuum

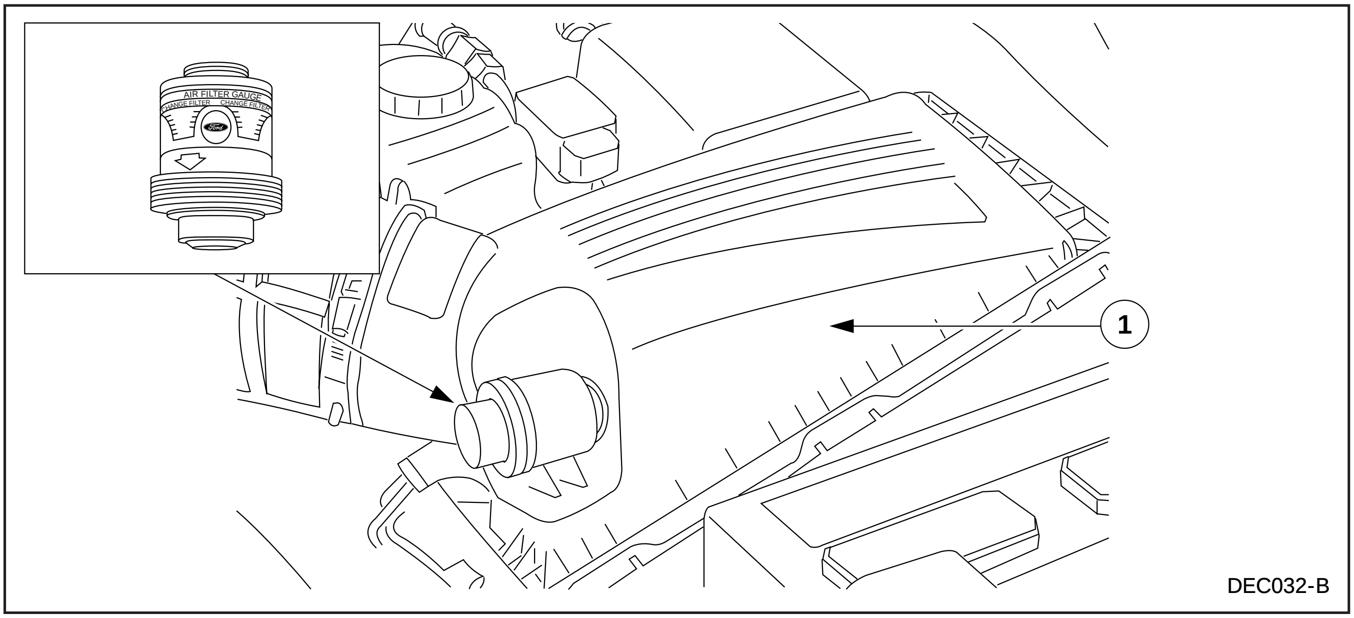
The magnahelic gauge, which is the center gauge on the Gauge Bar Tool, can be used to check for an intake restriction. The gauge is plumbed into the air filter assembly where the filter minder has been removed. The magnahelic gauge can be used to measure vacuum or pressure in inches of water. In this case the vacuum portion of the gauge is used, and the engine is run at WOT. If the gauge records an excessive amount of vacuum in the air intake system, a restriction is indicated. Expected value is 2-25 in-H_2O.

Loss of Pressure From Air Inlet System

Air leaks at the compressor manifold, intake manifold hoses or intake manifold covers could cause excessive smoke, loss of engine power and excessive engine noise.

Air intake hoses and connections need to be checked for loose connections or damage.

Purpose of the Filter Minder



7.3L DIT Air Filter Restriction Gauge (Filter Minder)

Item	Description
1	Air Cleaner Housing

The filter minder is essentially a vacuum gauge. It is a sealed unit threaded into the side of the air intake housing. Inside the filter minder is a spring loaded disc that is drawn against spring tension by the vacuum in the air intake system. If vacuum becomes excessive, the disc will shift inside the filter minder housing and register a high vacuum condition. This is an indication of an air inlet system blockage.

NOTE: Even a new air filter may register some movement of the filter minder disc. Be sure that the filter minder is not registering in the high vacuum area.

Procedure and Equipment for Exhaust System Checks

Exhaust Restriction Test

This test checks for restriction in the exhaust system. A restriction could be located at the exhaust back-pressure valve, or the catalytic converter, or anywhere in the system from the exhaust manifold back.

Carry out this test as follows:

- Visually inspect exhaust system for damage.
- Visually inspect the EBP bellcrank to be sure it is in the valve open position.
- Verify EBP device is open at WOT in PARK or NEUTRAL.
- Monitor the EBP PID with the scan tool.
  - Be sure that the engine temperature is at least 76°C (170°F) and engine speed at 3,400 rpm.
- Refer to the PC/ED for the expected value.

If the EBP PID exceeds specifications, there is a restriction somewhere in the system. Disconnecting portions of the exhaust system will help find the cause through a process of elimination.

Exhaust Color Diagnostics

There are three basic colors given off by visible exhaust. They are:

- Black smoke
  - Indicates a lack of air in the cylinders, or disturbance in the air to fuel ratio within the cylinders (excessive fuel). May be caused by:
    - air inlet restriction
    - exhaust restriction
    - faulty injector(s)
    - faulty turbocharger
    - electronic engine control concern
- White smoke
  - Indicates cold combustion chamber temperatures, low cetane rating in fuel, or coolant leak. Some white smoke on cold starts is normal until the engine warms up. May be caused by:
    - cold engine
    - inoperative glow plug
    - injector malfunction
    - low compression
    - coolant leaking into the cylinder(s)
    - electronic engine control concern
    - poor fuel quality

The cetane level of the fuel being used can lead to white smoke concerns. A fuel that has too low of a cetane rating will take longer to heat the cylinders to operating temperatures, because a fuel with lower cetane will burn much slower and not create as much temperature rise in the cylinders.

- Bluish/grey smoke
  - Indicates oil leaking into the engine. May be caused by:
    - injector leakage
    - worn intake/exhaust valve guide/seal
    - oil leak in the turbocharger on the turbine side

Procedure and Equipment for Testing the Turbocharger

Procedure and Equipment Required for the Boost Pressure Test

The boost pressure test is designed to make sure the engine develops sufficient turbocharger boost to obtain specified power output. If the engine obtains the specified turbo boost, there is no engine power problem. There may be chassis or specific application concerns.

To effectively carry out the turbo boost pressure test, the vehicle MUST be road tested because:

- Turbocharger will not build correct boost while in the service bay.
- Vehicle must be put under a load by driving it to produce turbo boost.
- Vehicle must be at correct operating temperature before testing.

Carry out the turbocharger boost test as follows:

- Verifications
  - Verify that the MAP sensor hose is not open, plugged or pinched. Verify that the intercooler hoses or intake are not leaking. On wastegate equipped vehicles, verify that the green wastegate hose is not plugged.
- Monitor manifold gauge pressure (MGP) and rpm with the scan tool.
- Road test
  - Accelerate the vehicle between 2,500 and 3,000 rpm in the appropriate gear as traffic allows.
    - Should be done climbing a hill or with the vehicle fully loaded.
- Measure and record the highest boost rating while accelerating between 2,500 and 3,000 rpm.
  - Compare to applicable specifications. Specifications for this test vary per model year.

The turbocharger depends on the heat generated by the engine to spin the turbine/compressor assembly and produce boost. If the engine is not operating correctly, the turbocharger will not build boost.

Do not replace the turbocharger in cases of low boost pressure before diagnosing engine performance as the possible cause of low boost pressure.

Failure to achieve minimum boost pressure could be caused by:

- Stuck open wastegate
- Aerated engine oil
- Restricted intake or exhaust
- Low fuel pressure
- Poor fuel quality
- IDM faults
- Injector malfunction
- Base engine failure
- Inoperative turbocharger
- Faulty MAP or BARO sensor
- Leaking intake system between the turbocharger and the intake manifold

Procedure for Turbocharger Failure Analysis

The turbocharger should be visually and physically inspected for damage. Turbocharger failure analysis comes down to this basic premise:

If the turbine and compressor wheels turn freely and there are no visible signs of damage with either, the turbocharger is NOT at fault. However, the wastegate and the EBP valve should be inspected as well.

REVIEW QUESTIONS

1. On the vehicle equipped with a returnless fuel system, if fuel pressure readings at both heads are within specification, the fuel system is eliminated as the cause of an engine performance concern.

   A. True

   B. False

2. The magnahelic gauge on the gauge bar is used to perform the ____________________ test.

   ____

   ____

3. The _______________ help(s) to determine if oil in the high-pressure system is aerated.

   ____

   ____

   ____

4. What is a possible cause of a fuel inlet restriction?

   ____

LESSON 1: DIESEL ENGINE CONCEPTS AND CHARACTERISTICS

1. Gasoline and diesel engines have similar base engine component.

   A. True

   B. False

2. List some of the differences between diesel and gasoline engines.

   Diesel has compression ignition

   Diesel has a higher compression ratio

   Diesel engines do not use a throttle plate

   Diesel engines require unrestricted air flow

3. Diesel engines are highly susceptible to ______________ and _______________ damage.

   Dirt and water

4. Where does the diesel engine mix the air and fuel?

   Directly in the combustion or pre-combustion chamber.

5. Why does a diesel engine have a higher compression ratio as compared to the gasoline engine?

   It needs higher temperatures to ignite the air/fuel mixture.

NOTES

LESSON 2: DIESEL ENGINE OPERATION

1. The shape of the combustion chamber affects combustion in a diesel engine.

   A. True

   B. False

2. The exhaust stroke is the same on both diesel and gasoline engines.

   A. True

   B. False

3. Which part of combustion consists of a sudden rise in pressure within the combustion chamber?

   Rapid combustion

4. How is the power output on a diesel engine controlled?

   By controlling the amount of fuel in the cylinder.

5. What is the main difference between direct and indirect injection?

   Combustion chamber design

NOTES

LESSON 3: THE FUEL SYSTEM

1. The split shot injectors supply a small amount of fuel to the combustion chambers just after the piston reaches top dead center.

   A. True

   B. False

2. What are the two types of fuel systems for the diesel engine?

   Return and returnless

3 There is no fuel returned to the fuel tank after it has been drawn through the fuel pump in a 7.3L DIT returnless system.

   A. True

   B. False

4. Which component in the returnless fuel system with an electric fuel pump strains large particles from the fuel before it reaches the fuel pump?

   The DTRM

5. What are the three functions of the fuel filter assembly?

   Separates water out of the fuel

   Removes particulate contaminates from the fuel

   Warms the fuel

6. What happens during the fill stage of the HEUI Split Shot injector?

   Fuel pressure and flow fill the plunger cavity with incoming fuel from the fuel rail in the cylinder head.

NOTES

LESSON 4: THE OIL SYSTEM

1. Some concerns involving the low-pressure oil system may affect vehicle performance and driveability.

   A. True

   B. False

2. What component in the low pressure oil system prevents damage caused by a plugged oil filter?

   The bypass valve

3. What is the minimum oil pressure required for the injectors to operate?

   500 PSI (3102 kPa)

4. What is the function of the oil cooler?

   Helps to bring the oil up to operating temperature sooner

   Helps to cool the oil and keep it at a constant temperature

5. The high-pressure oil system is also known as:

   The injection control system

6. What is the function of the ICP sensor?

   It provides a signal to the PCM indicating actual oil rail pressure

NOTES

LESSON 5: FUEL QUALITY

1. What is the measurement of the ignition quality of fuel?

   Cetane rating

2. What is the measurement of the fuel's weight as compared to water?

   Specific gravity

3. Water entering the precise fuel system components can cause extreme damage because:

   Water does not provide the required lubrication and also causes corrosion.

4. Gasoline in a diesel engine may cause:

   Preignition concerns

   Excessive cylinder pressures

   Severe damage to the injectors

5. What are some of the effects of prolonged fuel storage?

   It will go stale

   Heat and humidity will cause condensation in the containers

   It has a tendency to form algae

NOTES

LESSON 6: OIL QUALITY

1. It is acceptable to replace an oil filter that has a different canister size as long as the threading is the same.

   A. True

   B. False

2. The correct oil for a particular application is dictated by __________________ in which the engine is used.

   Ambient temperature

3. Which additive contained in the oil weakens the surface tension of the oil?

   Foam inhibitors

4. What are the types of oil contamination?

   Oxidation contamination

   Water contamination

   Fuel contamination

   Particulate contamination

NOTES

LESSON 7: THE AIR INLET AND EXHAUST SYSTEMS

1. Some restriction is good for the correct operation of the air filter.

   A. True

   B. False

2. Because of the __________________ in the diesel engine, a certain amount of blow-by and crankcase pressure is to be expected.

   High compression ratios

3. The filter minder measures:

   The restriction between the air filter and the engine.

4. What is the dual purpose of the 7.3L DIT engine exhaust system?

   Allows the removal of exhaust gases from the cylinders.

   Uses the escaping exhaust gases to drive the turbocharger.

5. The ________________ system is controlled to provide more heat to the coolant for cab heating.

   Exhaust backpressure

6. A _______________ is designed to alleviate restriction created by the turbine wheel once it has reached its peak speed.

   Wastegate

NOTES

LESSON 8: COOLANT

1. A ______________ is used to control the temperature of the coolant.

   Thermostat

2. The best coolant for diesel engines is:

   Propylene glycol (PG) based

3. Under what conditions does cavitation occur?

   When additives and properties of coolant diminish

   Excessive turbo boost

   Severe duty use

NOTES

LESSON 9: MAINTENANCE INTERVALS

1. What should be considered when determining maintenance intervals?

   hours driven

   miles/kilometers driven

   driving conditions

2 Engine coolant should be changed every ______________.

   30,000 miles (48,000 km)

NOTES

LESSON 10: DIESEL ENGINE STARTING AIDS

1. A ________________ is used to heat up the coolant in the cylinder block.

   Block heater

2. Ether should never be used when starting any diesel equipped with glow plugs because it may:

   Ignite violently in the cylinders

   Burn all the way through the intake system

   Cause a very rapid increase in pressure in the cylinders

3. Which starting aid is used to reduce white smoke during cold engine operation?

   Glow plugs

NOTES

LESSON 11: DIAGNOSTICS

1. On the vehicle equipped with a returnless fuel system, if fuel pressure readings at both heads are within specification, the fuel system is eliminated as the cause of an engine performance concern.

   A. True

   B. False

2. The magnahelic gauge on the gauge bar is used to perform the ____________________ test.

   Gauge pressure

3. The _______________ help(s) to determine if oil in the high-pressure system is aerated.

   Injection control pressure tests

4. What is a possible cause of a fuel inlet restriction?

   A blocked fuel tank pick up tube

NOTES

DIESEL ENGINE OPERATION TERMINOLOGY

AFTERGLOW – Glow plug operation after the engine has started. This reduces white smoke and smooths engine operation.

BLOWBY – Compression pressure and/or expanding combustion gasses that push past the piston rings into the crankcase.

CETANE RATING – A method of rating diesel fuel according to its ignition quality. A high cetane number (such as 50) indicates a fuel that more readily ignites than, a lower rating (such as 30).

CLOUD POINT – The temperature at which paraffin, contained in diesel fuel, begins to come out of solution and cause the fuel to appear cloudy. Fuel begins to cloud as temperatures drop.

COMPRESSION IGNITION – A method of igniting a fuel and air mixture in a diesel engine. Air is compressed to raise its temperature to the point where fuel being injected into the air begins to burn.

CRANKCASE PRESSURE – Pressure within the crankcase that is directly caused by blowby gasses. Excessive buildup of crankcase pressure can indicate worn base engine components.

DIESEL ENGINE – An engine that achieves ignition from the heat generated by extreme compression of the air/fuel mixture and without an electrical spark.

DIESEL, RUDOLPH (1858-1913) – German engineer who invented the diesel engine.

DIRECT INJECTION – Combustion chamber design where fuel is injected directly into the combustion chamber, as opposed to being routed through a precombustion chamber.

DISTRIBUTOR FUEL INJECTION PUMP – A fuel injection pump which raises pressure and distributes the fuel to the fuel injectors through the use of a rotating pumping element.

DRIBBLE – The undesirable leakage of fuel from a nozzle before and after injection, which can cause excessive engine knock and smoke.

DIESEL THERMAL RECIRCULATION MODULE (DTRM) – Located on the fuel Pick-Up unit, the purpose is two fold. First, it screens fuel before it is drawn into the fuel pump. Second, it helps to warm the fuel in the fuel system and maintain a controlled fuel temperature.

FUEL INJECTION PUMP – A high pressure component of the diesel fuel system designed to raise the pressure of the fuel for injection into the engine. The pump must time the injection and meter a precise amount of fuel to each injection nozzle.

GLOW PLUG – An electrical device used to heat combustion chamber air to aid in starting.

GLOW PLUG LAMP (Wait to Start) – Instrument panel lamp which illuminates until the glow plugs are up to temperature.

GLOW PLUG RELAY – Relay which directs current to the glow plug circuit.

GOVERNOR – A device used on a diesel engine to control the idling and maximum speed of the engine.

HIGH IDLE – Maximum rpm of a diesel engine.

HIGH PRESSURE FUEL LINES (Mechanical Pump System) – Matched set of high-pressure lines that route the fuel from the injection pump to the fuel injectors.

INDIRECT INJECTION – A combustion chamber design that utilizes a small precombustion chamber attached to the main combustion chamber via a tube or passage. Fuel is injected into the precombustion chamber where it begins to burn in the heated turbulent air contained there. The burning fuel and air mixture then expands into the main combustion chamber, where it completes burning.

INJECTOR NOZZLE – A device for injecting diesel fuel into the combustion chamber or precombustion chamber of an engine against the pressure of air within the chamber.

LIFT PUMP – Low-pressure fuel pump that supplies the high-pressure fuel injection pump.

LOW IDLE – Minimum idle speed of a diesel engine.

PRECOMBUSTION CHAMBER – A small combustion chamber attached to the main combustion chamber that imparts turbulence to the air and fuel for more efficient combustion.

RATED SPEED – rpm where peak horsepower occurs.

SPRAY PATTERN – The pattern displayed by fuel leaving an injection nozzle. The shape of this pattern is very important to the correct operation of some diesel engines, especially those using direct injection.

TORQUE SPEED – Speed at which the greatest amount of torque is generated in a diesel engine.

VISCOSITY GRADE – A measurement of oil resistance to flow as temperature changes.

WASTEGATE – A device used to regulate the boost pressure created by a turbocharger.

FUEL/WATER SEPARATOR – A device used to separate water from diesel fuel, preventing damage to the fuel system and engine.

DIESEL ENGINE OPERATION ACRONYM LIST

AP – Accelerator pedal

CAC – Charge air cooler

DIT – Direct injection turbocharged

DLC – Data link connector

DTC – Diagnostic trouble code

DTRM – Diesel Thermal Recirculation Module

E-Series – Econoline

EEC – Electronic engine control

EOT – Engine oil temperature

EBP – Exhaust backpressure

EPC – Electronic pressure control

EPR – Exhaust pressure regulator

F-Series – Truck

FP – Fuel pump

GPC – Glow plug circuit

GPL – Glow plug lamp

GPM – Glow plug monitor

GPR – Glow plug relay

HEUI – Hydraulically actuated, electronic controlled unit injector

ICP – Injection control pressure

IDM – Injector drive module

INJ – Injector

IPR – Injector pressure regulator

IVS – Idle validation switch

KOEO – Key on engine off

KOER – Key on engine running

MAP – Manifold absolute pressure

MAT – Manifold air temperature

MIL – Malfunction indictor lamp

NGS – New Generation STAR Tester

OBD – On board diagnostics

PCM – Powertrain control module

PID – Parameter identification

RPM – Revolutions per minute

TAC – Tachometer

UVC Harness – Under valve cover harness

WGC – Wastegate control

WG – Wastegate

WIF – Water in fuel

WOT – Wide open throttle

NOTES