CONSTRUCTION OF AN ACADEMIC PURPOSE DIESEL FUEL SYSTEM

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THE AUTOMOTIVE FUEL SYSTEM IN DIESEL ENGINES

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Declaration

This is to certify the project entitled “**CONSTRUCTION OF AN ACADEMIC FUEL SYSTEM “**is supervised by ***Dr. Md. Faisal KADER.*** This project work has not been submitted anywhere for a degree or diploma.

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Dedicated

To our parents

Abstract

The key to a vehicle's overall operation is the superior, quality design of its major moving subsystems. Automotive diesel fuel delivery system in particular must be virtually malfunctioning free for all components for the entire vehicle prescribed service life. Fuel systems must be robust and precise enough to store and deliver the appropriate amount of fuel to power the engine. These stringent requirements necessitate a basic understanding of the subsystem working principles, functionalities and interrelated components.

The fuel supply system of the vehicle constitutes an important element of an engine. Its core function is to ensure the smooth and uninterrupted supply of fuel to other peripherals of an engine. An automobile fuel supply system comprises of various components and devices like fuel cells, carburetor, fuel pump, fuel tank, fuel coolers, automobile filters which are used for storing fuel and distributing it to internal combustion engine as in when needed. Today, almost every automobile has a pressurized fuel supply system equipped with a pump that is used for pushing fuel from the fuel tank to engine of the vehicle.

This thesis provides a basic yet thorough examination of technical issues involved in automotive diesel fuel delivery. After going through the thesis, you will acquire a fundamental understanding of the current technology and requirement guidelines and apply some of the principles through an in-class exercise and other lab works. Examples of frequently encountered technical issues of fuel delivery systems shall also be discussed. The thesis is designed to encourage discussion, insights, and possible solutions into the engineering problems encountered in the diesel fuel delivery system and components.

Acknowledgement

First and foremost, we are very much indebted to Almighty Allah, the most Merciful without whose patronage and blessing this project report would not have been successfully completed.

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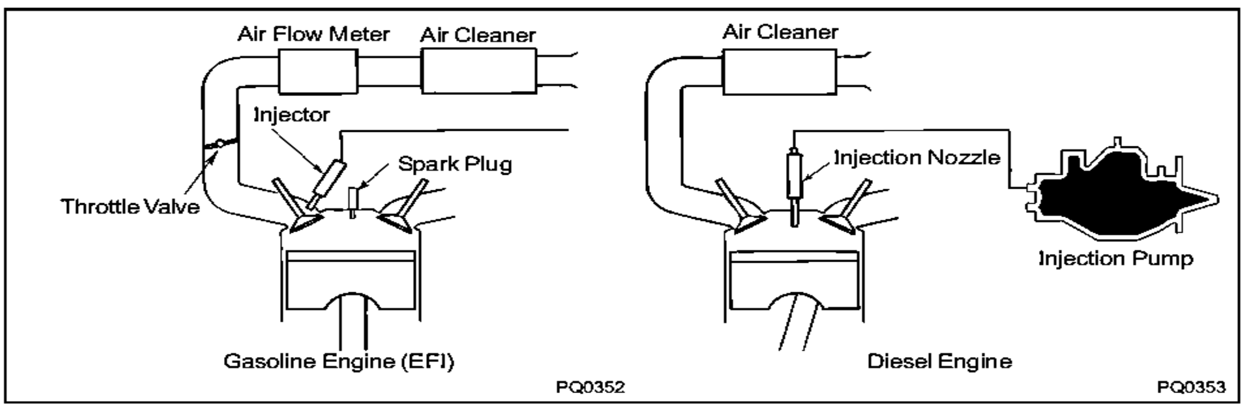
Chapter 1

THE DIESEL ENGINE

1.1 COMPARISON TO GASOLINE ENGINE

In a gasoline engine, the intake air volume is regulated by the throttle valve, which is located at the intake and linked to the accelerator pedal. Then, the volume of fuel that corresponds to the air volume is injected by the injectors. The air-fuel mixture is then drawn during the intake stoke into the cylinder, where it reaches a high temperature and becomes compressed to a high pressure. Then the injection nozzles inject the diesel fuel, which undergoes combustion and explosion through self-ignition because there is a load. For this reason, the engine output is controlled by regulating the fuel injection volume. Therefore, a diesel engine requires a fuel system that is different from a gasoline engine.



Reference: The table below compares the diesel engine to the gasoline engine.

		Diesel Engine	Gasoline Engine
Combustion Cycle		Sabathee Cycle	Auto Cycle
Compression Ratio		15~22	5~10
Thermal Efficiency	%	30~40	25~30
Fuel Consumption Rate	g/psh	140~210	200~280
Creation of Air-Fuel Mixture		Atomized, injected, and mixed after compression	Gasified and mixed before compression
Fuel		Diesel Fuel	Gasoline
Fuel Consumption Volume	%	30~40	100
Fuel Cost	%	50~60	100

Fig. comparison between the diesel and the gasoline engines

1.2 ***DIESEL ENGINE OPERATION***

An engine that completes one cycle with four strokes of the piston, or two revolutions of the crankshaft is called a four-cycle diesel engine. An engine that completes one cycle with two stokes of the piston or one revolution of the crankshaft is called a two cycle diesel engine. The operation of a four-cycle diesel engine will be described below.

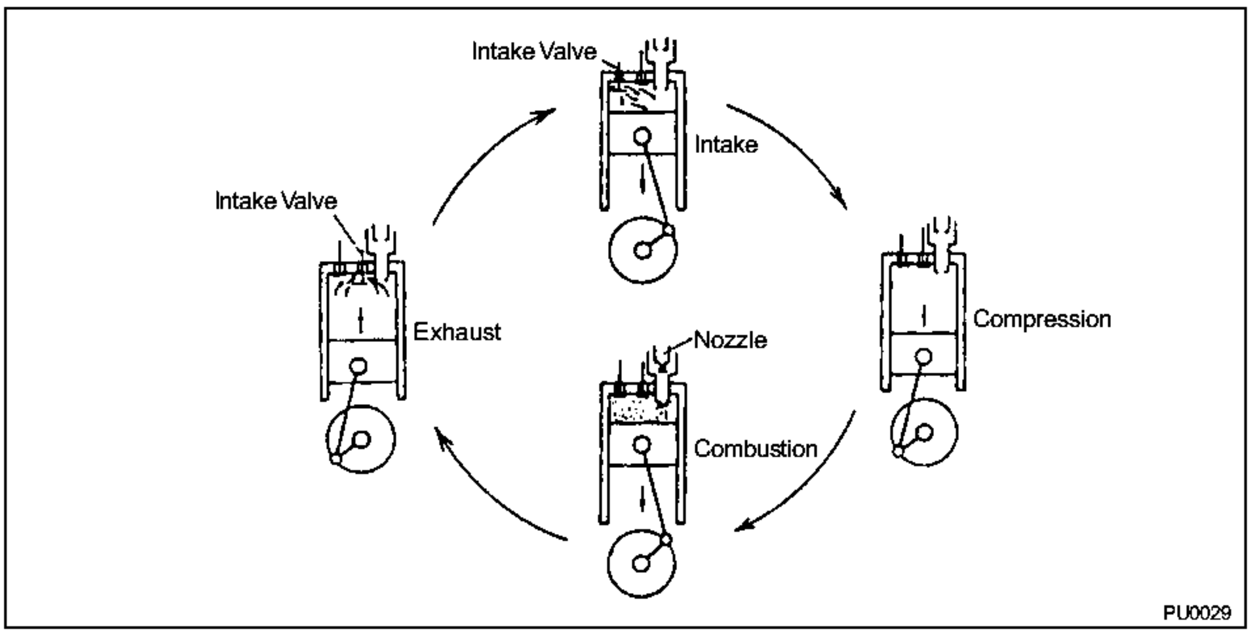


Fig. The diesel engine operation cycle

Intake stroke

Clean air is drawn into the cylinder as the piston descends from its top-dead-center. At this time, the intake valve opens slightly before the piton reaches its top-dead-center in order to facilitate the intake of air. It remains open for a while even after the piston has passed its bottom-dead-center and has started ascending again.

Compression stroke

After the piston moves past its bottom-dead-center and starts ascend, the intake valve closes, causing the air that was drawn into the cylinder to become compressed with the ascent of the piston. Because a diesel engine creates combustion by igniting the injected fuel with the heat of the compressed air, the compressive pressure is much higher than in a gasoline engine. Even when the engine speed gets low. Such as during starting, there is a compressive pressure of approximately 20 to 30 Kg/cm^2, and the compressive temperature reaches 400 to 500^0c.

Power stroke

Near the end of the compression stroke, fuel is injected in a spray form by a nozzle that is provided in the cylinder head. The compressive heat causes the mixture to self-ignite, resulting in a sudden combustion and the expansion of the combustion gas pushes the piston down.

Exhaust stroke

Slightly before the piston reaches the bottom-dead-center in the combustion stroke, the exhaust valve opens and the resulting difference in the pressures starts the discharge of the exhaust gas. Then as the piston ascends from the bottom-dead-center, the exhaust gas is pushed out of the cylinder. As described thus far, the engine effects the four strokes of intake, compression, combustion and exhaust while the piston moves in the cylinder from its top-dead-center to bottom-dead-center or vice-versa.

1.3 ***DIESEL ENGINE'S COMBUSTION PROCESS***

Here is a brief description of the combustion process of a four-cycle diesel engine. The air that is compressed in the cylinder reaches a high temperature and pressure. When the nozzle injects fuel in a spray form into this air, the fuel particles become superheated, their surface temperature rises, and they begin to evaporate. When the evaporated fuel mixes with air at an appropriate temperature, the mixture ignites and causes combustion. This process is described in further detail in the figure below. In terms of the relationship between the rotational angle of the crankshaft and the pressure in the cylinder. Thus the combustion process can be divided into the four periods shown on the next page.

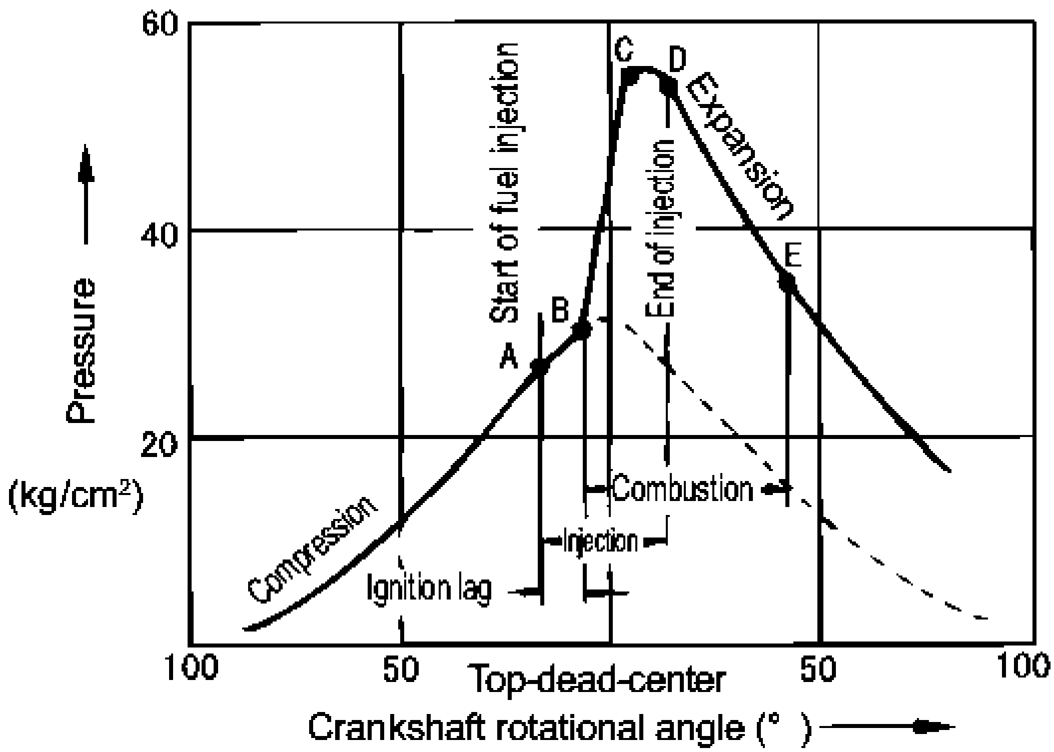


Fig. the diesel engine combustion process

i. ***ignition lag period(between and b)***

In the figure above, the period between a and b is the preparatory period during which the fuel particles that are injected into the cylinder absorb heat from the compressed air, thus creating an ignitable air-fuel mixture. Time-wise, this is an extremely short period during which no rapid rise in temperature or pressure is exhibited.

ii. ***flame propagation period(between b and c)***

from the figure, the time period between b and c is when the mixture that was prepared for combustion in the previous ignition lag ignites in one or more areas at point b. as the combustion spreads quickly in the cylinder, practically all of the mixture burns simultaneously, causing the pressure to rise rapidly to point c. the pressure rise at this time is influence by the volume of fuel that was injected during the ignition lag time as well as by its atomized state.

iii. ***direct combustion period(between c and d)***

during this period, fuel continues to be injected past point c, and burns immediately upon injection without causing any ignition lag, due to the flame that was created between points b and c. therefore, the changes in the pressure that occur during this period can be adjusted to a certain extent by appropriately regulating the fuel injection volume.

iv. ***afterburn period (between d and e)***

The injection of fuel is completed at point d given in the figure on the previous page. Any fuel that did not burn completely up to this point will burn during the expansion period between points d and e, which is called the "afterburn period". Because the exhaust temperature increases and the thermal efficiency decreases as this period becomes longer, it is necessary to keep it short.

although the combustion process can be divided into the four periods as described, in contrast to the direct combustion period, the ignition lag period and the flame propagation period can be considered a preparatory period. The outcome of this period greatly influences combustion. Therefore, the proper injection starting pressure of the nozzle, state of atomization, compressive pressure and injection timing become important factors.

1.4 ***DIESEL KNOCK***

The knocks that occur in both diesel and gasoline engines are similar in that they are associated with an abnormal rise in pressure during combustion. However, the knocks of the two engines differ fundamentally in the timing in which they occur, their causes, and situations. a diesel knock is created by the rapid rise in pressure as a result of the instantaneous explosion and combustion of the flammable air-fuel mixture that was created during the ignition lag period. Meanwhile, a gasoline engine knock occurs because the unburned air-fuel mixture susceptible to self-ignition. As the air-fuel mixture burns instantly at the end of the flame propagation, it results in a localized pressure rise and a considerable pressure imbalance in the cylinder. This generates large pressure waves that create knocking sounds.

The diesel engine knock is created as a result of the difficulty in causing self-ignition, while the gasoline line engine knock is created because of the ease with which self-ignition occurs. Thus, their causes are directly opposite to each other.

In a gasoline engine, a knock is one of the symptoms of abnormal combustion. However, in a diesel engine, it is difficult to clearly separate a normal combustion from one that is accompanied by knocks. Therefore knocks are distinguished merely by whether they are created by a rapid pressure rise or if they apply shocks to the various areas of the engine.

To prevent a diesel knock, it is important to shorten the ignition lag period, when we consider its cause. Generally speaking, nozzles are designed to minimize the volume of fuel that is injected during this period. Other preventive measures are as follows;

a) Increasing the temperature in the cylinder to help increase the compressive pressure.
b) Using diesel fuel with high cetane value.
c) Optimizing the injection timing.
d) Optimizing the coolant temperature.
e) Optimizing the fuel injection pressure and atomization.

1.5 COMBUSTION CHAMBER

i) **direct injection type**

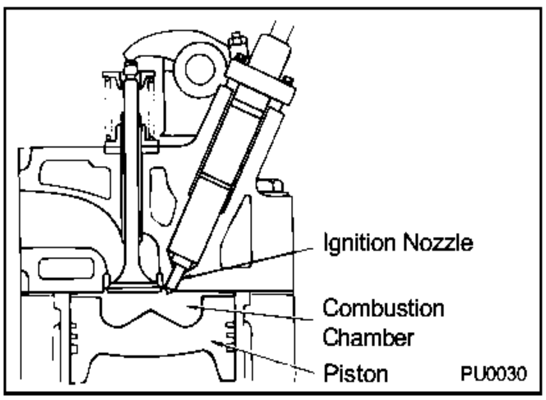
The direct injection type uses a nozzle to directly inject fuel into the combustion chamber, which is formed in the area between the cylinder and the piston head, where combustion takes place. The direct injection system has been adopted in many engines in recent years due to its low fuel consumption rate and high economy.

ii) **pre-combustion chamber type**

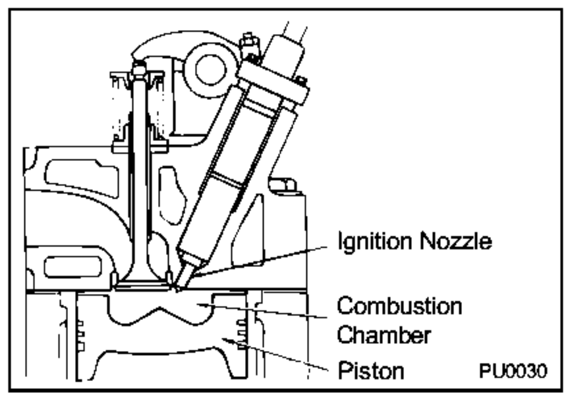
iii) The pre-combustion chamber type contains a sub-chamber that is called the "pre-combustion chamber" directly above the main combustion chamber. Fuel from the injection nozzle is injected into the pre-combustion chamber in order to burn a portion of the fuel and the resulting pressure is used to push the remaining unburned fuel into the main combustion chamber. The swirl that is created in the cylinder thoroughly mixes the fuel with air, resulting in a complete combustion.

iv) **swirl chamber type**

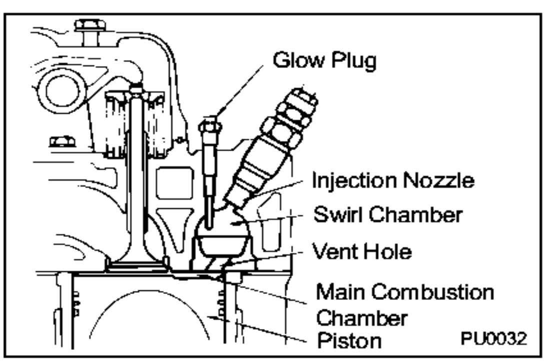
The swirl chamber type contains a spherical sub-chamber called a "swirl chamber" in the cylinder head or in the cylinder. The air that is compressed by the piston flows into the swirl chamber and constitutes to form a swirl. The injection nozzle then sprays fuel into this swirl which results in most of the unburned fuel that remains is then pushed out to the main combustion chamber where it undergoes a complete combustion.



A)



B)



C)

Fig. a) direct injection type, b) prechamber injection type, c) swirl chamber type

v) **air chamber type**

The air chamber type contains a sub-chamber called “air chamber” in the piston or in the cylinder head. The injection nozzle sprays the fuel to the mouth of the air chamber, and it is then ignited and burned in the main combustion chamber. At this time, a portion of the fuel enters the air chamber where it is burned, thus raising the pressure in the air chamber. When the piston starts to descend, the air in the chamber is pushed out to the main combustion chamber in order to help complete the combustion in the chamber. The reference table below compares the types of combustion chambers.

		Direct Injection Type	Pre-Combustion Chamber Type	Swirl Chamber Type	Air Chamber Type
Construction		Simple	Complex	Somewhat complex	Complex
Compression Ratio		12~20	16~22	Medium	Medium
Fuel		Good quality	Poor quality	Medium	Medium
Starting		Easy	Preheating device required	←	Somewhat easy
Net Average Effective Pressure	kg/cm^2	5.6~8.0	5.2~8.0	5.5~7.5	5.5~7.5
Maximum Engine Speed	rpm	3,000	4,000	4,500	3,000
Maximum Cylinder Pressure	kg/cm^2	60~100	45~80	50~80	45~70
Net Fuel Consumption Rate	g/psh	160~200	180~250	180~230	180~230
Injection Nozzle Type		Hole type	Pin type	←	←
Injection Pressure	kg/cm^2	150~300	80~150	80~150	80~150
Minimum Excess Air Ratio	*	1.5~1.7	1.2~1.7	1.3~1.6	1.3~1.6

$$\text{*Excess air ratio} = \frac{\text{Actual supplied air volume}}{\text{Theoretical air volume required for combustion}}$$

Fig. comparison between the combustion chambers

1.6 DIESEL FUEL

The automotive diesel engines use a lighter fuel, and the low-speed diesel engines for ships use the heavier marine diesel fuel. The lighter diesel fuel, like gasoline, kerosene and heavier diesel fuel is produced during petroleum refining process. It has a boiling point of between 200 and 330^{0}C, a specific gravity of 0.82 to 0.86 and heating value of 10,000 to 11,000 KCa/Kg. very similar to kerosene, diesel fuel is slightly more yellowish and viscous.

PROPERTIES OF DIESEL FUEL

i) **Ignitability of diesel fuel**

The ignitability of fuel is determined by the self-ignition that results from raising the temperature of the fuel, without the presence of a flame nearby, in the example shown in the figure below, a few drops of diesel fuel and gasoline are squirted on top of a heated Iron plate. After a while, the diesel bursts into flames, but gasoline evaporates immediately without burning, and the temperature at which it ignites is called the "ignition point". Thus, the lower the ignition point of a fuel, the better ignitability.

In diesel engine, in which fuel is burned by the compressive heat of the air, ignitability is an important characteristic. It greatly influences the length of time after the fuel is injected into the combustion chamber until it starts to burn, which is called the "ignition lag time".

The measurement that is used to indicate the ignitability of diesel fuel is the cetane value. A fuel with a low cetane value has poor ignitability and a longer ignition lag time, which leads diesel knocks.

ii) **viscosity of diesel fuel**

Viscosity is one of the most important characteristics of the fuel that is used in diesel engines. A high viscosity results in large fuel particles when fuel is injected into the combustion chamber, which leads to sluggish dissipation and poor combustion. Conversely, a low viscosity results in a poor lubrication of the various parts of the fuel system such as the injection pump and nozzles, leading to premature wear or seizure.

iii) **sulfur content of diesel fuel**

The sulfur that is included in the fuel turns into sulfurous acid gas and sulfuric anhydride during combustion. They combine with water that results from the combustion to form sulfuric acid, which is highly corrosive. Because sulfur compounds also have poor ignitability and combustibility, they tend to create black smoke and contribute to fouling the engine oil.

iv) **Volatility of diesel fuel.**

Because diesel fuel has a high boiling point, it is practically non-volatile at room temperature. However, volatility is desirable to certain extent, considering that diesel fuel must become gasified and mixed with air, and combustion can only occur when its density enters the combustion range.

v) **Specifications for diesel fuel.**

The properties of diesel fuel used in diesel engines are specified by JIS K2204 as given in the table below.

		Diesel Fuel Type *			
		No. 1	No. 2	No. 3	Special No.
Reaction		Neutral	Neutral	Neutral	Neutral
Flash point	°C	50 minimum	50 minimum	50 minimum	50 minimum
Fractional distillation property 90%; distillation temperature	°C	350 maximum	350 maximum	350 maximum	350 maximum
Pour point	°C	–5 maximum	–10 maximum	–20 maximum	–30 maximum
Carbon residue of 10% bottom oil		0.15 maximum	0.15 maximum	0.15 maximum	0.15 maximum
Cetane value		50 minimum	45 minimum	40 minimum	42 minimum
Dynamic viscosity (30°C)	CST	2.7 minimum	2.5 minimum	2.0 minimum	1.8 minimum
Sulfur content	%	1.20 maximum	1.20 maximum	1.10 maximum	1.00 maximum

* Applications by type

No. 1: general use, No. 2: general use, No. 3: cold-weather use, Special No. 3: extreme cold-weather use Ordinarily, No. 2 diesel fuel is widely used.

Fig. diesel fuel specifications by the JIS K2204

1.7 EXHAUST SMOKE

i) White smoke.

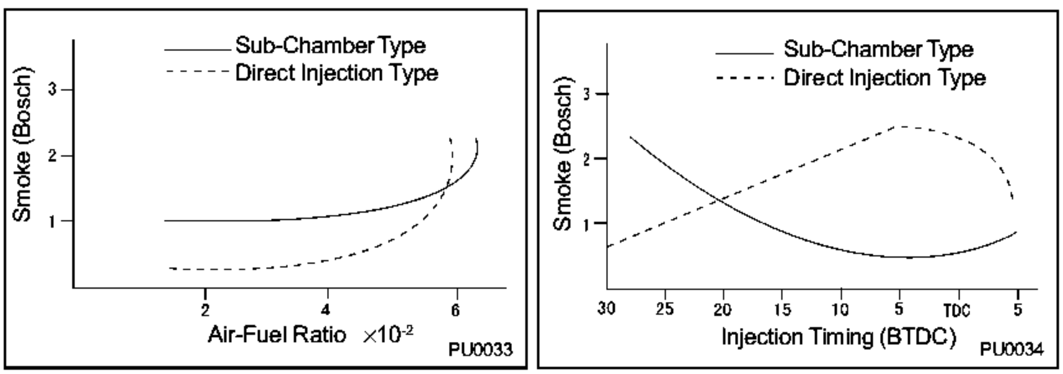
Resulting from the discharge of the minute particles of fuel or engine oil that have not been burned, this type of smoke is likely to occur when the engine is started in a cold climate.

ii) Blue smoke.

Resulting from the non-combustion, partial combustion or thermal decomposition of the fuel or engine oil, this type of smoke is the discharge of minute particles in a liquefied state. While both white and blue smokes are minute particles in a liquefied state, the particle diameter of the white smoke is microscopic and measures about 1 micron unlike 0.4 micron for the blue smoke. The difference in size is considered to create different colors.

iii) Black smoke.

- ❖ Generally, smoke refers to black smoke. When fuel becomes baked due to the lack of air, it thermally decomposes and the carbon residues are discharged in the form of black smoke. The figure below shows the relationship between the injection volume and black smoke. In a sub chamber type engine, the smoke denser than in the direct injection type when the injection volume is small. However, as the injection volume increases, the smoke of the sub-chamber type has a lower tendency to worsen, and suddenly becomes denser in the vicinity of the full load.



a) b)

fig. a) smoke Vs. air-fuel ratio characteristics, b) smoke vs. injection timing characteristic

- ❖ When the injection timing is advanced, the ignition lad becomes greater in a direct-injection type as seen in the figure below. Because the volume of fuel that becomes gasified increase before ignition, the amount of black smoke decreases. In a sub-chamber type, the ignition lad also becomes greater. However, because the ratio of combustion in the sub-chamber that contains a small volume of air is greater, the amount of black smoke increases.

- ❖ Generally speaking, the optimal injection timing for favorable black smoke conditions is later than the optional injection timing for favorable fuel conditions.

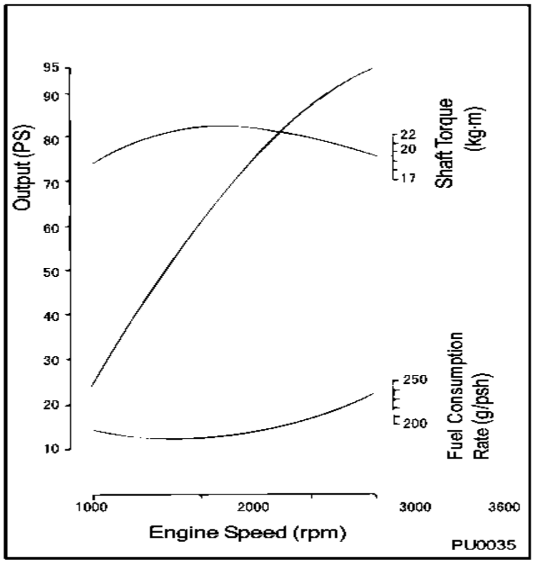
1.8 DIESEL ENGINE PERFORMANCE

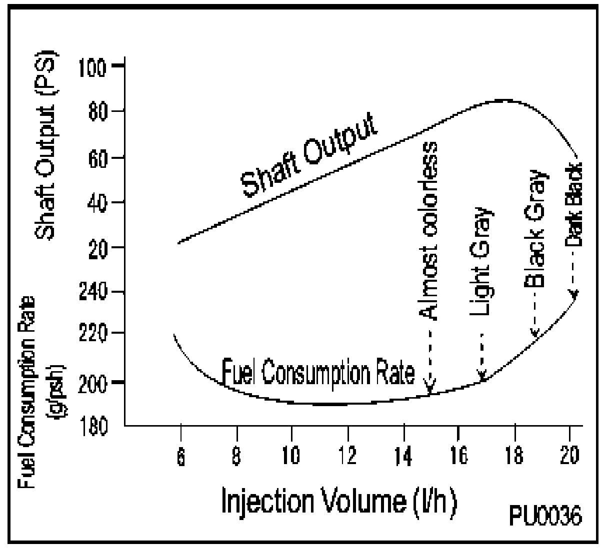
i) **The engine performance curve**

An engine performance curve shows the performance of an engine at a glance. As the figure below shows, the performance curve indicates the maximum output horsepower, shaft torque and fuel consumption rate at each engine.

The engine generates greater torque as the gas pressure in the cylinder increases. However, when the engine speed exceeds a certain speed, the combustion conditions change due to the reduction in the intake air volume, thus causing the engine torque to decrease at high speeds. At intermediate speeds, the air intake is more favorable which leads to a better combustion condition and greater torque. At lower speeds, the intake air volume decreases due to the opening and closing timing of the intake valve, causing the torque to decrease.

Although the power output increases in production to the engine speed, it does not increase significantly in the high-speed range due to the reduction in torque. The fuel consumption rate is directly influenced by the combustion conditions, and this rate is the lowest at an engine speed in the vicinity of the maximum torque, in which the combustion condition is best.





ii) **Factors contributing to the engine performance.**

a) **Injection timing**

The engine output varies in accordance with the injection timing. Because the injection timing at the maximum output by engine speed, it is better to advance the injection timing along with the increase in the engine speed. However, care must be taken to change the injection timing because it is closely related to diesel knocks.

b) **Injection volume**

If the injection volume is changed while the engine speed and the injection timing remain constant, the power output and the fuel consumption rate will be as shown in the figure. The power output increases in proportion to the injection volume within the range where black smoke is not emitted. However, if the injection volume is increased to the extent that black smoke is emitted, the power output decreases and is uneconomical.

c) **Nozzle and nozzle valve opening pressure**

When the type of throttle nozzle is changed, even though its spray angle remains the same, the atomization performance and injection volume characteristics change. Therefore, the maximum output noise, or idle stability will be affected. When the nozzle opening pressure decreases, the injection volume increases, causing the output to increase slightly. However, the emission of black smoke also increases.

d) **Maximum engine speed**

The increase in engine speed causes the power output to also increase. However, the inertia of the moving parts also increases, causing a reduction in the durability of the engine. Furthermore, the friction between the piston or the piston rings and the cylinder surface increases, and this factor also limits the maximum speed of the engine.

e) **Altitude**

At high altitudes, the air density decreases and the emission of black smoke increases. In order to maintain the black smoke emissions within the specified value, it is necessary to decrease the injection volume in accordance with the air density. This results in a power output reduction or 10% per 1000 m or altitude. Some automobiles that are operated in an area with significant altitude differences may be equipped with an altitude compensator system, ACS that automatically decreases the injection volume. The figure below shows how density varies with altitude.

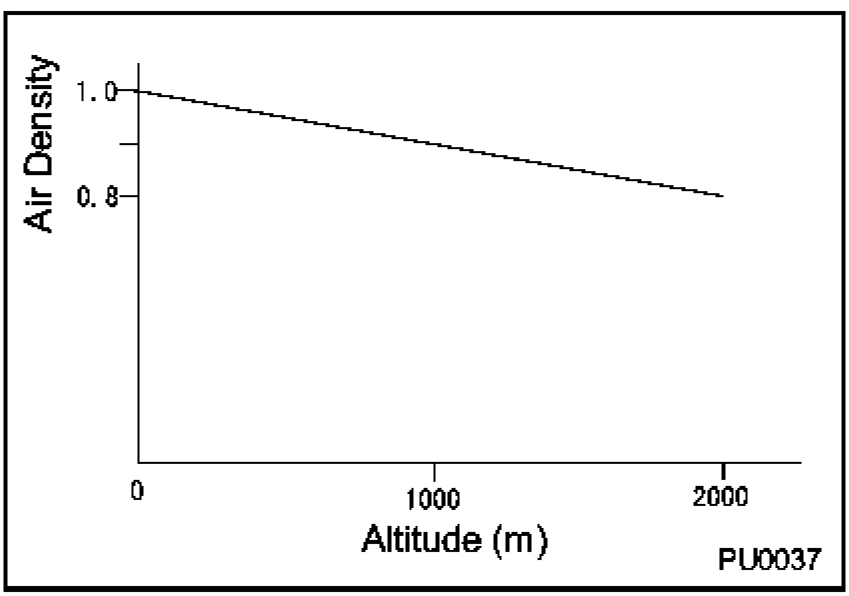


Fig. air density vs. altitude characteristic

Chapter 2

HIGH PRESSURE ELEMENTS

2.1 THE ACCUMULATOR

An accumulator fuel injector suitable for a diesel engine, having a fuel inlet connected in communication with at least one nozzle hole through a valve closing pressure chamber, a first check valve, an accumulator means and an injection valve in a body thereof, said injection valve being provided with a valve closing spring, a valve closing pressure receiving surface and a valve opening pressure receiving surface, and said injection valve being adapted to be pushed in a first direction toward a valve closing side by a net force comprising force exerted by the valve closing spring and pressure in the valve closing pressure chamber acting on the valve closing pressure receiving surface and in a second direction toward a valve opening side by a pressure within the accumulator means acting on the valve opening pressure receiving surface. The present invention relates to an accumulator fuel injector for a diesel engine, the device including first and second accumulators which are connected through a check valve and a relief valve. Fuel pressurized and delivered by a fuel injection pump is charged into the first accumulator so as to increase its pressure abruptly. When the fuel pressure in the first accumulator reaches a selected relief pressure, the fuel is charged into the second accumulator through the check valve and is accumulated therein. When fuel injection is started by opening of an injection valve, the fuel accumulated in the first accumulator is injected through the injection valve and at the same time the fuel accumulated in the second accumulator flows out to the first accumulator through the relief valve so as to also be injected through the injection valve. When the injection pressure decreases to the relief pressure at the end of the injection, the relief valve closes so that the fuel in the second accumulator is prevented from flowing into the first accumulator, and only the fuel accumulated in the first accumulator is injected.

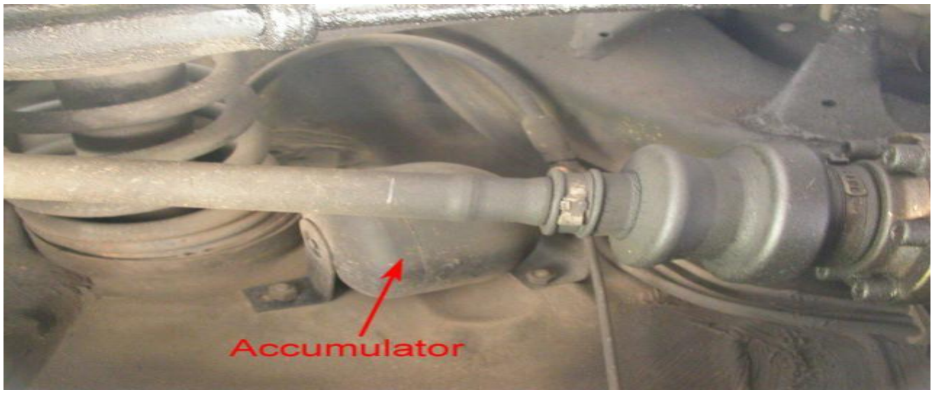


Fig.the position of the accumulator

2.2 FUEL METERING VALVE

A fuel metering device and method for metering fuel to an engine provides smooth transfer to a backup mode. A common cavity provides pressure relief, fuel metering and bypass of fuel flow. A metering valve for scheduling fuel flow to the engine and the metering valve is controlled in either a primary mode or a backup mode. A pressure relief valve limits the maximum pump discharge pressure of a fuel pump. A bypass valve maintains a constant pressure across the metering valve by redirecting non-metered fuel flow back to a pump stage inlet. An electrical clutch determines whether the metering valve function is accomplished by said primary mode or said backup mode. Smooth transfer to a backup is accomplished automatically.

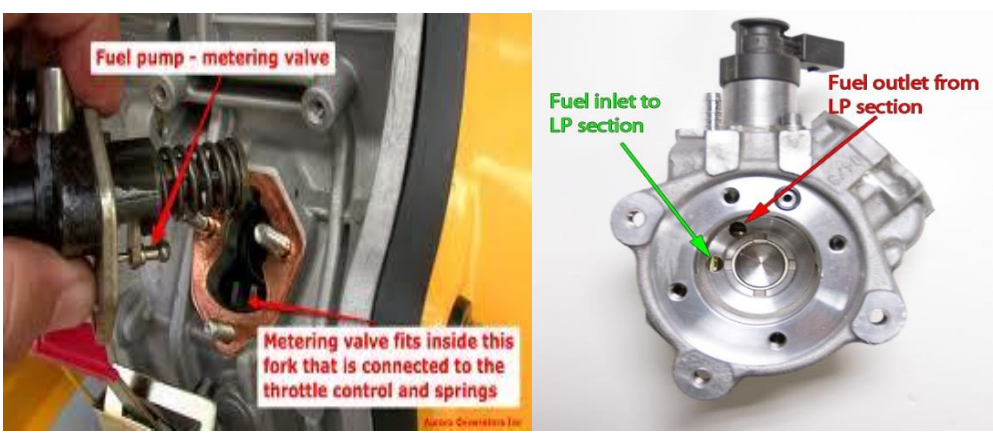


Fig. the fuel metering valve

Chapter 3

COMPONENTS OF THE FUEL SYSTEM

The fuel systme is originally desinged with making different constraints and pre-defined criteria in an aid to achieve the following; engine power, fuel efficiency, emission levels, reliability, drivability under different throttle requirements, maintenance intervals, diagnostic abilities and engine tunning. We will be discursing the following in this section.

1) Fuel injectors, 2) fuel injector pump, 3) fuel filter, 4) fuel tank, etc.

The figure below shows the basic diesel fuel system setup used in most vehicles nowadays.

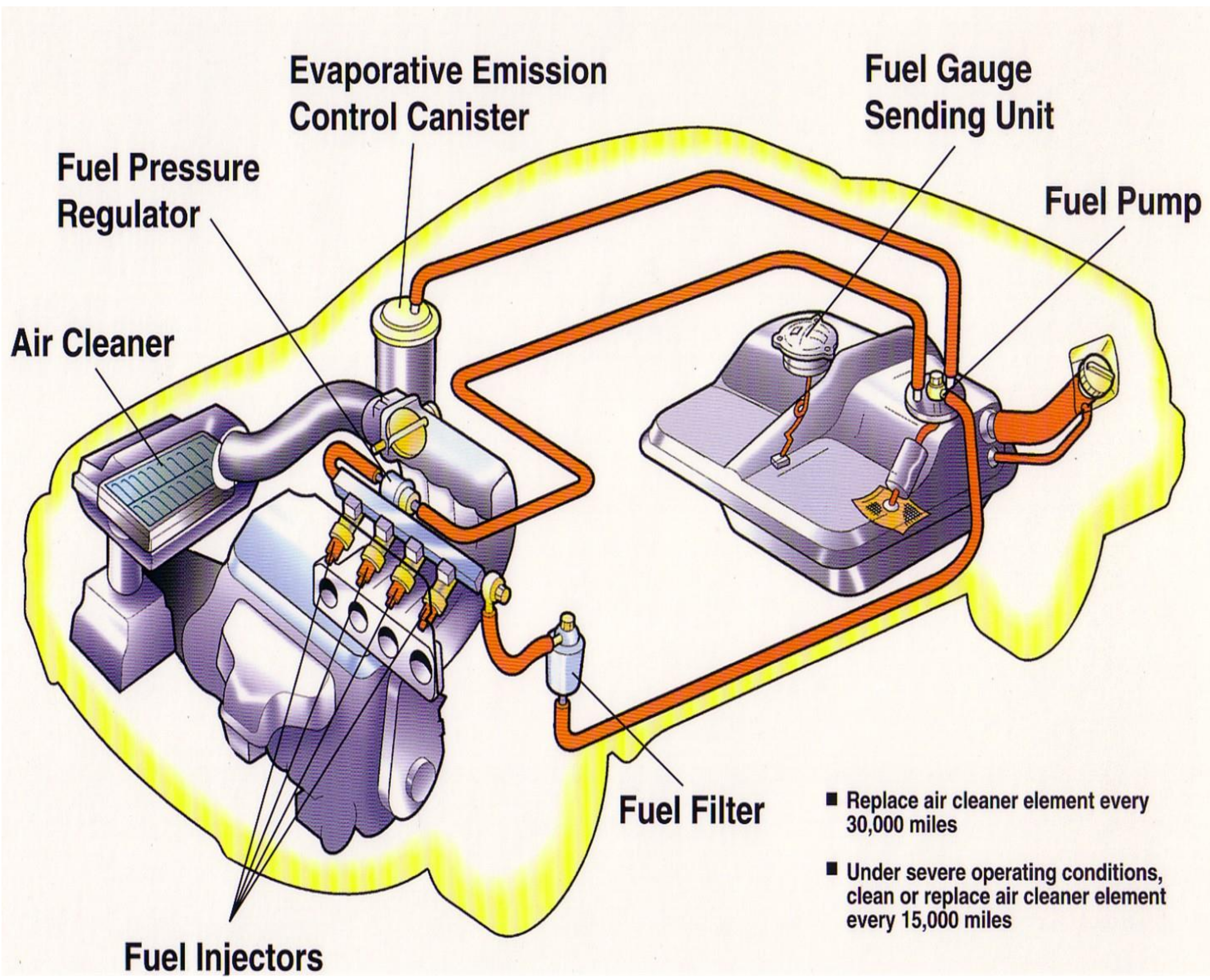


Fig. the outline of the fuel system

3.1 DIESEL FUEL TANK

Nowadays, fuel systems have a 5 gallon capacity plastic fuel tank having a vented, screw on filler cap. A 10 gallon tank is optional and usually is what most people purchase. It's readily accessible behind the driver's seat (C-1) or passenger's seat (C-2) through a hinged door. There are aftermarket plastic tanks available giving fuel capacities of 12 and 14 gallons, a fiberglass tank of 15 gallons, and some specially designed and built aluminum tanks allowing as much as 18 gallons.

Fig. fuel tank

Fuel is picked up via a copper or brass tube which extends to near the bottom of the tank in a depressed area called the sump. Water and debris are supposed to collect in this lower area of the tank but has also been seen in the four corners of the tank. A slot cut into the lower end of the pickup tube prevents any debris that might be sucked onto the open end of the tube, from blocking fuel flow up into the tube and causing an engine outage due to fuel starvation. The tube should be positioned a half inch or so off the bottom to help prevent any debris from being sucked into the system. Porous bronze filters are also available to mount on the end of the pickup tube.

The question occasionally comes up as to the advisability of installing a drain valve in the bottom of the factory-issue plastic tank. This drain would be used to empty old fuel out of the tank and to possibly drain out any water that may have collected.

The opinions on this are almost unanimously against it. This arises from the difficulty in getting a good seal between the drain valve and the thin plastic of the tank. And, the one place you don't want to get a leak is at the bottom of the tank.

Alternative methods can be used to draw the fuel from the tank or to suck out any water and debris that may have accumulated. These methods typically use a pump or siphon that incorporates a metal tube on the end of a piece of fuel line. The tube is moved around the bottom of the tank, in vacuum-cleaner fashion, to suck out any foreign material. Incidentally, an old squeeze bulb inserted in the siphon line provides an easy way to get the fuel flow started.

3.2 FUEL LINES, FITTINGS AND CONNECTIONS.

Types of fuel line available:

The most popular fuel line used on ultra-lights is the clear blue urethane. It is light, flexible, transparent, and supposedly will not harden, crack, or become brittle with age.

Other types of fuel line are available from aircraft parts suppliers that will work just fine. However, resist the temptation of just going down to the local auto parts store and getting your fuel line there. The fuel line available there is heavy, has little UV resistance, and has been found to deteriorate with age and flake off internally, contributing small, black flakes of debris to the fuel system.

Tees and hose barbs:

The number of these required will depend upon the final design of the system and may range from none to several. Filters and squeeze bulbs have their own built-in nipples for connecting the line, so no additional fittings are required for these. For the most part, you are likely to need only a few Tees. If your system includes a primer, you will need a special Tee that allows the 1/8 inch primer line to tap into the regular 1/4 inch fuel line.

We now describe ways to secure the fuel line to the hose barbs and nipples, that is, hose clamps. There are at least four different types in common use. As always, different builders have their own preferences.

The overall objective of a hose clamp is to apply a uniform pressure to the entire outer circumference of the fuel line. Here, the key word is "uniform." As we explain below, not all popular hose clamps achieve this objective.

Many reports are out there relating to connections that leak, and in general, to the difficulty of getting good, secure connections that won't leak fuel or allow air to enter the system. Our impression is that something is wrong here. Perhaps the following will help.

Safety wire:

As it turns out, the best "hose clamp" for the urethane blue line is also the cheapest. All that is required is to wrap two turns (720 degrees) of safety wire around the connection, and then twist the wire, tightening only until the wire dents the fuel line ever so slightly. Twist the safety wire for about an inch outward from the fuel line, cut it at that point, and then fold it over so the sharp edges are not exposed. And that is it!

Now for a few details. If the line is being connected to a hose barb, place the two turns of safety wire in a "valley" between the high points on the barb. Keep the two turns close together all the way around the line. For a really neat job, pay attention to the direction of the twist. Twisting in one direction will produce an obvious crossing-over of the two turns near the point of the twist. Twisting in the opposite direction will make the cross-over look natural and hardly noticeable. It's hard to explain. Try it and you will see.

Two complete turns are used in order to achieve a uniform pressure on the line all the way around. This is not the same thing as taking a doubled wire around the line only one time. If you try this shortcut, you will almost certainly have a leak.

Worm clamps:

Worm clamps are used extensively on other types of fuel line, but they don't work well on the 3/8 inch OD of the urethane. This is because it is hard, if not impossible, to find worm clamps of the proper size even though the specification for the clamps says they "are" the proper size.

Some people use a worm clamp successfully by cutting a piece of larger fuel line slightly wider than the width of the worm clamp. The inside diameter of this piece of tubing is the same size as the outside diameter of the (smaller) fuel line. It's then slipped over the end of the fuel line and put on the barbed fitting. The worm clamp is placed on the larger piece of line then tightened securely. Any distortion or cutting of the line by the worm clamp is negated by the larger piece of line absorbing the abuse. And, the fuel line is clamped tightly.

Metal clips:

These are small, circular, spring-metal rings with two tabs sticking out that are squeezed with pliars to expand the circle. To make the connection, the clip is placed on the line to a point back from the end of the line, and then the line is placed over the barb or nipple. Finally, the clip is expanded again with a pair of pliars and then slid into position over the barb or nipple.

The difficulty with these arises because they tend to get distorted during the installation process, assuming you can even find the proper size. The distortion then causes the clip to not give uniform pressure on the line, all the way around.

Plastic clips:

Small plastic clips are favored by many as a quick, easy way to get the job done. However, there is some question or concern about the long term durability of these clips, as well as the amount of pressure they actually apply to the line.

All in all, the safety wire method, if done properly, is the best. One contributor to this article has a plane with a fuel system that is somewhat complex (it grew into it), having a grand total of 24 connections, all made with safety wire. And, not a one of them has leaked yet.

3.3 DIESEL FUEL FILTER.

The Challenger kit comes with a common paper filter in a clear plastic housing. The same filters are used on Briggs & Stratton engines for lawnmowers and work well. The filter is usually next in line after the fuel tank.

Fig. diesel fuel filter

There are also more expensive metal filters with replaceable elements that may be used. However, you can't readily see if the filter is dirty by looking at it like you can if a clear housing is used. Fine debris as well as moisture can usually be seen in the filter housing or on the element. This requires replacement of the filter. Many folks replace their filter annually or every 100 hours. Some replace the fuel filter at the time of each sparkplug change. Fuel filters help reduce damage and premature wear from contaminants by retaining very fine particles and water to prevent them from entering the fuel injection system. As shown in Figure 1, fuel systems can contain one or more stages of filtration. In many cases, a course screen is also located at the fuel intake located in the fuel tank.

Two stage filter system typically uses a primary filter on the inlet side of the fuel transfer pump and a secondary filter on the outlet side. The primary filter is required to remove larger particles. The secondary filter is required to withstand higher pressures and remove smaller particles that can damage the engine components. One-stage systems remove larger and smaller particles in a single filter.

Filters can be a box-type or replacement element design, as shown in Figure 2. The box-type filter is that which can be completely replaced as needed and does not require cleaning. Filters with a replaceable element have to be thoroughly cleaned when replacing elements and care must be taken to avoid any dirt residue that could migrate to the intricate parts of the fuel injection system. Filters can be constructed of metal or plastic.

3.4 DIESEL FUEL LIFT PUMP.

The fuel supply pump, often referred to as the lift pump, is responsible for drawing fuel from the tank and delivering it to the high pressure pump.

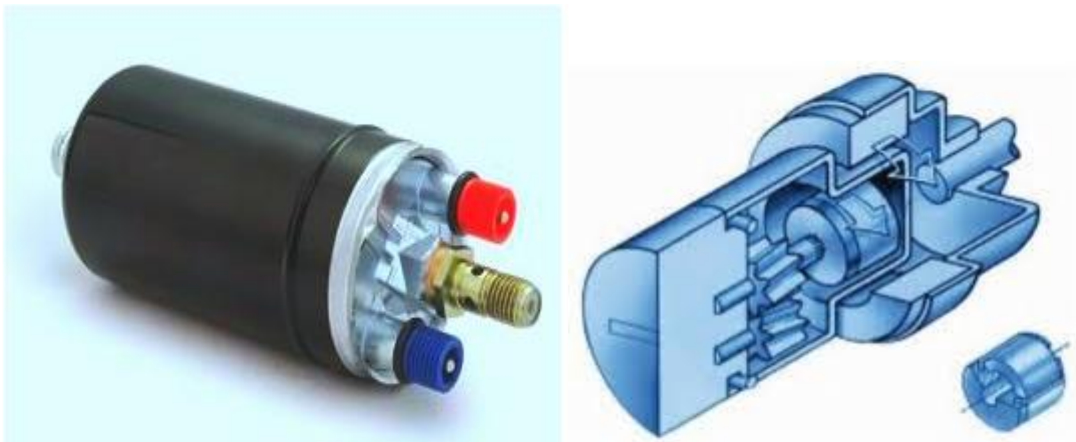


Fig. diesel fuel lift pump

Modern day fuel pumps can be electrically or mechanically driven by the engine. Using an electrically driven fuel pump allows the pump to be placed anywhere in the fuel system including inside the fuel tank. Pumps driven by the engine are attached to the engine. Some fuel pumps may be incorporated into units that serve other functions. For example, so called tandem pumps are units that incorporate a fuel pump and a vacuum pump for the brake booster. Some fuel systems, such as those based on a distributor type pump, incorporate a mechanically driven supply pump and the high pressure pump in one unit.

Fuel pumps are commonly sized to deliver more fuel than is consumed by the engine at any particular operating system. This extra fuel flow can serve a number of important functions including providing extra fuel to help to cool injectors, pumps and other engine components and maintaining a more constant temperature of the fuel in the entire fuel system. Also, the excess fuel that is heated by its contact with hot engine components can be returned to the tank or fuel filter to improve the vehicle’s low temperature operability.

3.5 MECHANICAL AND PNEUMATIC GOVERNORS

The governor is a centrifugal type unit which gives precision control of engine speeds. When speed control is not desired it should be disengaged with the twin-pin type. Never engage this clutch with the engine running. To operate it pull the cap outward and rotate it ¼ turn in either direction until you feel the two lugs drop into the recesses provided. The governor is engaged when the lugs are in the deeper recesses. The shallow recesses lock it in the disengaged position. Some governor clutches are controlled by a spring loaded lever mounted at the top of the governor housing the operation of which is obvious.

The belt tension may be adjusted by raising or lowering the governor in the slotted mounting holes. Keep the pulleys and belt free of dirt and oil. Belt slippage will effect governor operation and a tight belt may cause rapid wear of the governor shaft and bearings. Adjust it to allow 1" depression midway between the pulleys with thumb pressure.

The controlled engine speed may be varied with the hand control mounted on the dash. With this control in against the dash, the controlled engine speed is 1000 rpm. The speed is increased 200 rpm. Per notch, as the hand control is pulled out. The top speed is 2600 rpm. In the 9th notch, the hand control is released by turning the handle ¼ turn in either direction.

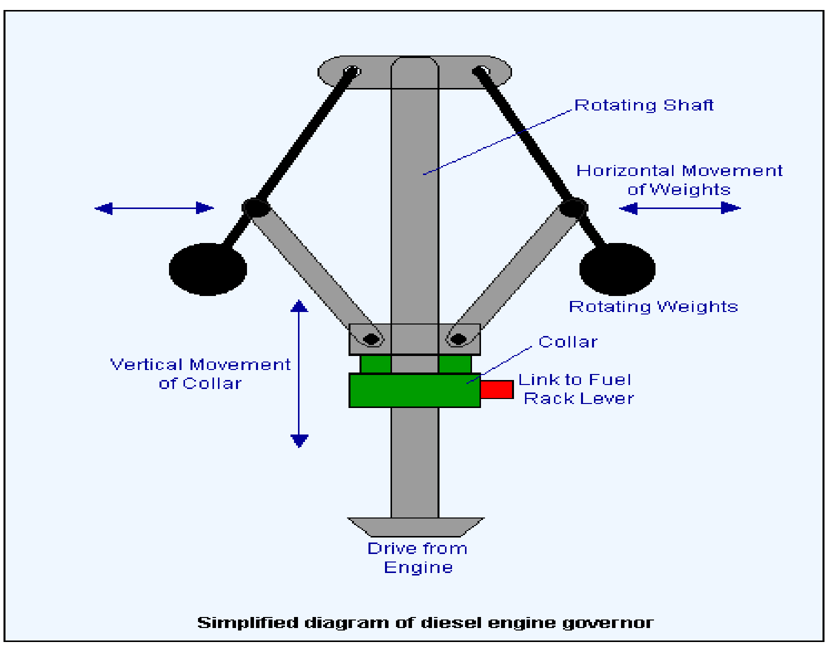


Fig. simplified diagram of a diesel engine governor

The governor consists of a rotating shaft, which is driven by the diesel engine. A pair of flyweights is linked to the shaft and they rotate as it rotates. The centrifugal force caused by the rotation causes the weights to be thrown outwards as the speed of the shaft rises. If the speed falls the weights move inwards.

The flyweights are linked to a collar fitted around the shaft by a pair of arms. As the weights move out, so the collar rises on the shaft. If the weights move inwards, the collar moves down the shaft. The movement of the collar is used to operate the fuel rack lever controlling the amount of fuel supplied to the engine by the injectors.

Types of governor:

The governors used in automobile vehicles are of the following three types:

(i) Mechanical or centrifugal governor: these types function through mechanical linkages.

(ii) Pneumatic governor: functions through the use of pressured air and control valves.

(iii) Hydraulic governor: uses hydraulic oil to achieve its actuation.

3.6 DIESEL FUEL INJECTION PUMP AND INJECTORS

The purpose of the fuel injection pump is to deliver an exact metered amount of fuel, under high pressure, at the right time to the injector. The injector, unlike in a gasoline engine, injects the fuel directly into the cylinder or a prechamber connected to the cylinder.

Fig. fuel injectors.

The VE in the name of the Bosch pump used in the VW diesels and many other small diesel engines stands for "Verteiler", which is German for distributor or divider. The other common kind of injection pump is the inline pump. The difference between them is that the "Verteiler" VE pump has one fuel metering plunger, and a mechanism (the "Verteiler"/distributor) to send the fuel to the right cylinder. The inline pump has one plunger for each cylinder.

The fuel injectors are driven by the fuel pump and their job is to spray a fuel and air mixture into the combustion chamber, ready to be ignited to produce power to the driven wheels. The fuel injectors are basically a nozzle, with a valve attached, the nozzle creates a pray of fuel and air droplets in the process of atomization. This can be viewed similar to that of a perfume dispenser or a spray of fine mist. The valves in the system controlled by the Electronic Fuel Injection system, EFI which is governed by the ECU. The whole system uses a multitude of different sensors around the engine to precisely adjust the required air to fuel ratio. This increases the engine efficiency compared to older technologies like carburetors which relied on the air to fuel mixture being sucked into the intake manifold.

The whole fuel system delivers the petrol or diesel from the fuel tanks into the combustion chamber, with a pre-defined mixed air-fuel ratio. As we upgrade other components of the engine, its ability to remain being efficient at converting this mixture to power also decreases as standard fuel injectors always have a flow rate limit design for their original specifications.

As the needs of the engine increase and power gains are obtained, larger fuel injectors to deliver more fuel flow rates are required once the engine has reached a certain level of tune. Otherwise there is a risk of the engine running lean which could lead to damage or unreliable characteristic during high throttle load periods.

3.7 DIESEL ENGINE GLOW PLUGS

A glow plug (alternatively spelled as glow plug or glow-plug) is a heating device used to aid starting diesel engines. The glow plug is a pencil-shaped piece of metal with a heating element at the tip. This heating element, when electrified, heats due to its electrical resistance and begins to emit light in the visible spectrum, hence the term "glow" plug. The effect is very similar to that of a toaster. Heat generated by the glow plugs is directed into the cylinders, and serves to warm the engine block immediately surrounding the cylinders.

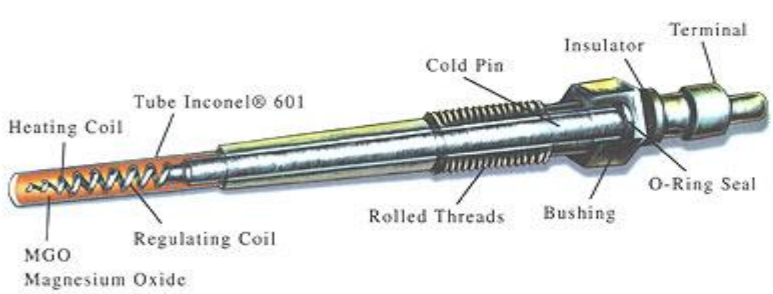


Fig. simplified figure of the glow plug.

This aids in reducing the amount of thermal diffusion which will occur when the engine attempts to start.

- Construction

During the cold season, diesel engines do not always start as desired. The arising heat is often insufficient for starting the engine on its own. Therefore, the necessary heat in the combustion chambers is missing. Heat losses through the cold cylinders and the air intake impede the self-ignition. The diesel engine does not reach the necessary temperatures without the addition of heat.

- The function of glow plugs

The central function of glow plugs is to provide additional energy for the start. Glow plugs from NGK are the required energy source. Before the start of the engine, the glow plug is energized and the glow tube heats up to more than 800 °C.

This heat improves the engine's ability to cold-start considerably. The glow plug's heat development also optimizes the combustion, so that the development of smoke and other emissions is reduced.

- Installation position in the engine

Glow plugs are installed in the cylinder head. The glow rod extends into the hot zone and/or the precombustion chambers. However, the glow rod should be positioned exactly at the edge of the mixture. In this way it can provide the heat exactly where it is needed. However, it may in no case extend too far into the combustion chamber, because the preparation of the fuel and thus the formation of an ignitable fuel-air mixture would not be guaranteed.

Chapter 4

SERVICING THE FUEL SYSTEM

4.1 INTRODUCTION

Diesel engines can go for long periods without major repairs. Since a diesel engine does not have an ignition system, certain normal gasoline engine maintenance like replacing ignition wires, spark plugs, distributor caps or rotors is not required. There is no need for ignition tune-ups either.

However for smooth functioning they do require the following regular maintenance.

4.2 DIRT IN FUEL SYSTEM

Many diesel engine operating troubles result directly or indirectly from dirt in the fuel system. That is why proper fuel storage and handling are so important. One of the most important aspects of and injector troubles will occur. Diesel fuel, because it is more viscous than gasoline, will hold dirt in suspension for longer periods. Therefore, every precaution should be made to keep the fuel clean. If the engine starts missing, running irregularly, rapping, or puffing black smoke from the exhaust manifold, look for trouble at the spray nozzle valves. In this event, it is almost a sure bet that dirt is responsible for improper diesel fuel is cleanliness. The fuel should not contain more than a trace of foreign substance; otherwise, fuel pumps fuel inject into the cylinder. A valve held open or scratched by particles of dirt so that it cannot seat properly will allow fuel to pass into the exhaust without being completely burned, causing black smoke. Too much fuel may cause a cylinder to miss entirely. If dirt prevents the proper amount of fuel from entering the cylinders by restricting spray nozzle holes, the engine may skip or stop entirely. In most cases, injector or valve troubles are easily identified. Improper injection pump operation, however, is not easily recognized it is more likely caused by excessive wear than by an accumulation of dirt or carbon, such as the spray nozzle is subjected to it in the cylinder combustion chambers. If considerable abrasive dirt gets by the filters to increase (by wear) the small clearance between the injector pump plunger and barrel, fuel will leak by the plunger instead of being forced into the injector nozzle in the cylinder. This gradual decrease in fuel delivery at the spray nozzle may remain unnoticed for some time or until the operator complains of sluggish engine performance. Although worn injector pumps will result in loss of engine power and hard starting, worn piston rings, cylinder liners, and valves (intake and exhaust) can be responsible for the same conditions. However, with worn cylinder parts or valves, poor compression, a smoky exhaust, and excessive blow-by will accompany the hard starting and loss of power from the crankcase breather.

4.3 WATER IN FUEL SYSTEM

It requires only a little WATER in a fuel system to cause an engine to miss, and if present in large enough quantities, the engine will stop entirely. Many fuel filters are designed to clog completely when exposed to water, thereby stopping all fuel flow. Water that enters a tank with the fuel or that is formed by condensation in a partially empty tank or line usually settles to the lowest part of the fuel system. This water should be drained off daily.

4.4 AIR IN FUEL SYSTEM

Air trapped in diesel fuel systems is one of the main reasons for a hard starting engine. Air can enter the fuel system at loose joints in the piping or through a spray nozzle that does not close properly. Letting the vehicle run out of fuel will also cause air to enter the system. Like water, air can interfere with the unbroken flow of fuel from the tank to the cylinder. A great deal of air in a system will prevent fuel pumps from picking up fuel and pushing it through the piping system. Air can be removed by bleeding the system as set forth in the procedures described in the manufacturer’s maintenance manual.

4.5 CLEANING INJECTORS

Unless special servicing equipment and repair instructions are available, defective nozzles and pumps are exchanged for new ones. However, in an emergency, and if spray valves or pumps are not too badly worn, they may be returned to a serviceable condition, with minor adjustment, after a thorough cleaning. Injector spray nozzles or pumps should be disassembled in the field only when no other recourse is available. Whenever possible, they should be removed from the equipment and brought to the shop for repair. The first requirement for the cleaning job is a clean working area.

4.6 BASIC SERVICING TIPS FOR IMPORTANT COMPONENTS

- Changing the lubricating oil - This is usually necessary on a more frequent basis than gasoline engines - generally every 3000 miles
- Changing the air filter - Since diesel engines experience high intake pressures, the air filtering system is important to not only filter media but also to cool the air.
- Changing the oil filter - while a gasoline engine may give less mileage or performance with a dirty fuel filter, this can be more serious in the case of a diesel engine where dirty fuel can damage a diesel engine's fuel injection system. The filter should meet or exceed the standards suggested by manufacturer so that sulfur and carbon residues are removed. Synthetic oil is also recommended.
- Early warning system - The early warning system that warns of engine overheating should be checked for functionality. A gasoline engine if overheated can be shut off, cooled down and restarted. However if a diesel engine gets overheated, it will be damaged.
- Changing the fuel filter - It is important the change the fuel filter as recommended by the manufacturer in order to prevent condensation from building up and getting into the fuel injectors. The fuel tank should also be kept full to avoid moisture forming.
- Gaskets should be checked and replaced on all critical areas especially in the combustion mounting areas and coolant hoses.
- Bleeding the fuel system - While some diesel engines have self-bleeding systems, others which do not, need to have the fuel system bled to get a steady air free flow of fuel. This becomes necessary after any of the following situations have occurred
  1. Running out of fuel.
  2. If fuel shut off valve is left closed and engine runs out of fuel.
  3. Replacing fuel filter.
  4. Fuel injector nozzle or injector pump repair.
  5. After repairing or replacing any fuel line.
  6. Before putting engine back into service in the spring, if fuel system has

been drained.

7. Replacement of electric or mechanical fuel pump.

8. Any time air is permitted to enter the fuel system.

- Draining the water separators - Since diesel fuel absorbs water more than gasoline, it can get contaminated very easily. Therefore most diesel engine vehicles have a water separator that collects water from fuel. This water needs to be drained regularly from the separator using a drain valve called a petcock. Some water separators are self-draining.
- Glow plugs - Glow plugs enable a diesel engine to get heated for combustion to take place. After prolonged use, these can wear out and may need to be replaced.
- Installing an engine heating kit for diesel engines are especially useful in winter when diesel engines are hard to start. This saves fuel and prolongs the life of the diesel engine while cutting down on exhaust emissions. It also eliminates the need for idling which cause wear and tear on the internal parts of a diesel engine not to mention unnecessary fuel consumption.

Chapter 5

CONCLUSION

5.1 INTRODUCTION

The fuel system supply, transfers, cleans and delivers fuel to the engines' cylinders to facilitate combustion, thereby producing power. Although fuel systems vary from engine to engine, all systems are the same in that they must supply fuel to the combustion chamber and control the amount of fuel supplied in relation to the amount of air.

The fuel system should meter the exact amount of fuel and deliver the fuel to the injector assembly with precise timing. As the fuel is delivered, the final conditions for providing complete combustion are atomization and the spray pattern of the fuel. Atomization is accomplished as a result of the injection pressure, due in part to the diameter of the holes in the injector. The spacing, angle and number of holes in the injector tip determine the spray pattern.

In modern diesel engines, fuel system pressures are extremely high, ranging in the 20,000 to 30,000 psi range. These high pressures are necessary to ensure optimum fuel economy, as well as providing exhaust emissions that comply with more stringent Environmental Protection Agency regulations.

Supply, timing and the precision of fuel delivery are all critical elements in the efficient operation of a diesel engine. High system pressures relate directly to the strict tolerances found in the fuel system components. Contaminants can have various adverse effects on these components, affecting overall efficiency. These contaminants are generally introduced through refining, mixing, storage or through transferring of the diesel fuel. Regardless of where the fuel is purchased, or how high the quality, if you don't do what is necessary to prevent contamination, trouble will result. It is the function of fuel filters, as well as proper maintenance practices, to ensure the most economical and efficient fuel system life.

The major components of the fuel system involved in the fuel delivery process are the fuel tank, the fuel transfer pump, the injection pump assembly and injectors, and the fuel system filtration products.

Fuel system contamination is a fact of life. The most common contaminants found in diesel fuel are organic elements, micro-organisms such as algae, water and inorganic elements.

Organic contaminants such as aspheltenes are natural occurring contaminants in fuels that form from oxidation or degradation of the fuel, thermal stability (ability to handle heat), cold temperature reactions (waxing), and unstable reaction to additive mixing (lube additive mixed with fuel additive).

If you cut open a used fuel filter and discover a shiny black material coating the media or a gel buildup, this is evidence of organic contamination. Typically, 80 percent of the material in a plugged fuel filter will be organic contaminant, which greatly affects filter life. Fuel additives, along with increased filter capacity and proper fuel sourcing, can minimize the negative effects of organic contamination.

Algae growth can occur when a mixture of water and diesel fuel sits idle for an extended period of time. These microorganisms live in the water, feed off the diesel fuel, and can thrive at any fuel/water/air interface. Diesel fuel with algae will have a definite sour odor, and this contamination can lead to premature fuel filter plugging. A slimy, smelly, greenish-brown material coating the media of a cut open fuel filter is evidence of algae contamination.

Water in fuel comes in two forms: free and emulsified. Free water, or, coarse water, is water that is not entrained in the fuel and will settle out over a short period of time. Emulsified water is actually entrained or bonded in diesel fuel.

Now, more importantly, how does this water get into the fuel? Water is introduced into the fuel system through the vented fuel filler cap. The vented cap intentionally allows air to enter the tank to equalize pressure, as fuel is removed. This air naturally contains moisture. As a machine sits, and is subjected to changes in temperature, this moisture in the air condenses into water inside the tank. This is how free water gets into the fuel. As this free water and fuel mixture goes through the injection pump, it is vigorously churned, and the water becomes thoroughly mixed with the fuel, resulting in emulsified water. It then flows to the injectors, or returns to the tank, ready to cause problems later.

In addition to water, inorganic contaminants can cause the most damage to fuel system components because of their hard and abrasive nature. This type of contamination typically comprises 10 to 20 percent of the material trapped in the fuel filter. Inorganic materials include component wear-metals, rust, scale and dirt.

Of these, wear metals are the toughest to deal with because they occur through normal system operation and quite often occur downstream of the filter. In the diesel industry, small holes in injector tips, tight spaces and precision fitting components are described in terms of strict tolerances. To best meet the varying demands of the combustion process, fuel system components are designed and built to very strict tolerances. As a result, contaminants can have highly adverse effects on these components, and it doesn't take very large or very many particles to damage strict tolerance components such as injector tips, thus reducing overall engine efficiency.

Other effects of contamination include wear and corrosion in the transfer pump and injection pump causing reduced pressures and flows, usually indicated by hard starting and unnecessary wear of the injector tips causing inefficient spray patterns and poor fuel economy. The main point is this: trouble results when contamination is neither prevented nor controlled.

5.2 MAINTENANCE

It is the goal of proper maintenance practices, which includes effective filtration, to keep the system clean and help ensure the most economical and efficient fuel system life. Some of the ways contaminants can be kept out of the system from the onset are by keeping fuel transfer equipment like nozzles, tanks and hoses free from surface dirt and out of the rain, and by using filtration at the pump. Proper storage techniques, such as keeping storage tanks covered to minimize temperature fluctuations, also reduce the impact of contamination.

The keys to maintaining the fuel tank are periodically check for free water in the tank, visually inspect the tank exterior and connections for rust and inspect the interior for signs of corrosion or algae growth. If contamination is present, the tank must be drained and cleaned. If algae are found, a commercially available biocide can be used to kill it, and then the tank must be drained, rinsed and refilled with clean fuel.

5.3 FILTRATION

Suitable filtration includes using a fuel filter and/or fuel/water separator and changing them at recommended intervals. The purpose of the fuel filter is to remove unwanted contamination before it reaches the other components of the fuel system.

There are two types of fuel filters, primary and secondary. Typically, the primary filter is considered the suction side filter and the secondary filter, the pressure side. The primary filter is upstream of the fuel pump and the fuel is pulled (suction) through the filter. Its function is to catch contaminant before the fuel flows through the fuel pump. The secondary filter is downstream of the fuel pump and fuel is pushed (pressure) through the filter. Its main function is to capture contaminant in the fuel before it flows into the injection pump assembly.

Some engines require a primary filter, some require only a secondary filter and some require both. In some cases, in place of a primary and secondary filter setup, a more efficient fuel/water separator is used, as is the case on Cummins engines. The primary filter, or fuel/water separator, will be found on the suction side or before the fuel pump.

As mentioned before, water gets into the fuel as a result of natural condensation, leaking fuel storage tanks and so on. It can be in the form of large droplets, or it can be emulsified in the fuel. The water must be removed to achieve maximum performance and maximum life from the engine. Fuel/water separators are designed to provide both filtration and water removal. Use a fuel/water separator in place of a fuel filter or in conjunction with a fuel filter to remove water as well as contaminants from the fuel system.

Fuel additives are intended to disperse contaminants, clean components, increase fuel lubricity and decrease extreme temperature effects — all impacting filter and component life. Competitive products have varying degrees of success in relation to their claims, depending on the formulation.

Some products provide a gauge that tells you when to change the primary or suction side fuel filter. Service intervals of fuel filters vary due to factors such as fuel quality, temperature and filter size. The fuel filter restriction indicator gives the operator an easy-to-read gauge that gives feedback on the remaining life of the fuel filter.

Finally, use diesel fuel analysis for troubleshooting a fuel-related problem. Fleet guard offers different test packages that include testing for calculating the cetane number, gravity, distillation, viscosity, cloud point, flash point, sulfur, carbon residue, water & sediment, fuel stability and more, and that give specific recommendations based on the results. Remember that the fuel system is the heart of a diesel engine. Keep it functioning properly through proper maintenance practices, and you will be assured of long, trouble-free life.

5.4 THE THESIS OVERALL SUMMARY

Table: the thesis overall summery.

Diesel fuel systems	Diesel fuel injection	Diesel engines draw air only, past the intake valve into the cylinder. Fuel is injected into the cylinder at high pressure. The amount of fuel injected varies to suit load, and control engine speed.
	High pressure components	For all diesel engines, at a fixed fuel setting, the amount of fuel delivered to the engine will increase as engine and pump speed increases. It must be controlled, or over-speeding of the engine will occur.
	Diesel fuel	The cetane rating of a diesel fuel defines how easily the fuel will ignite when it is injected into the cylinder. The lower a fuel's cetane rating, the longer it takes to reach ignition point.
	Diesel fuel characteristics	The primary factors that affect the performance of diesel fuel are: the cetane rating, viscosity, its cloud point, the extent to which the fuel is contaminated.

	Quiet diesel technology	The annoying rattle of a diesel engine has largely been subdued by a combination of engineering and fuel improvements, leading to quieter engines more suitable for use in passenger vehicles.
	Clean diesel technology	Clean diesel technology is a combination of better fuel delivery and control systems, better combustion chamber design, turbo charging, and other improvements including lower sulfur fuels and dual-fuel systems.
Diesel fuel system components	Diesel tanks & lines	The fuel tank stores fuel away from the engine. Baffles ensure the pickup tube is always submerged in fuel. This stops air entering the system.
	Diesel fuel filters	Fuel filters remove abrasive particles and water.
	Lift pump	A diaphragm-type lift pump can be mounted on the engine, or the injection pump. An eccentric on a camshaft pushes on a rocker arm. It acts on a diaphragm to create a pressure difference, which lifts fuel from the tank to the injection system.

Plunger pump	A plunger-type lift pump is mounted on the in-line injection pump, and driven by a cam inside the in-line injection pump housing.
Priming pump	Light vehicle diesel engines use a priming pump to remove air from the fuel system. Otherwise, the engine would have to be cranked over with the starter motor, to bleed and prime the system.
Inline injection pump	An in-line injection pump meters the fuel and raises its pressure. The basic principle is for a plunger to act on a column of fuel, to lift an injector needle off its seat.
Mechanical or pneumatic governors	A mechanical governor uses rotating fly weights to control movement of a rack against a spring. A pneumatic governor has a venturi unit, linked to a diaphragm assembly, on the in-line injection pump housing.
Distributor-type injection pump	The distributor-type pump uses a vane-type transfer pump to fill the single pumping element. This then raises fuel pressure to injection pressure. A distribution system then

		distributes fuel to each cylinder, in the firing order of the engine.
	Diesel injectors	The injection pump delivers fuel to the injector. As fuel pressure rises, it acts on the needle valve, eventually lifting it from its seat. Highly-pressurized fuel enters the engine in an atomized spray at a high velocity.
	Glow plugs	Glow plugs pre-heat the incoming air so that ignition can more easily occur. This assists a cold engine to start more reliably, and once the engine is running, the glow plugs are no longer required.
	Cummins & Detroit Diesel injection	Unit injectors have been available for many years in heavy commercial diesel engines. These include the 'Cummins Pressure Time System' and the 'Detroit Diesel System'. For both systems actuation is a result of an extra lobe on the engine camshaft for each cylinder.
Diesel electronic control	Diesel electronic control systems	Electronic controlled diesel systems give very precise control of the fuel injection and combustion process.

Common rail diesel injection system	The Common Rail Diesel Injection System delivers a more controlled quantity of atomized fuel, which leads to better fuel economy; a reduction in exhaust emissions; and a significant decrease in engine noise during operation.
HEUI diesel injection system	The Hydraulically actuated, Electronically controlled Unit Injector or HEUI system of diesel fuel injection operates by drawing fuel from the tank using a tandem high and low pressure fuel pump.

END

Note; our project has been mostly written based on research grounds and the required experience from the IUT automotive lab.

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