TRAINING
COURSE 5

PRINCIPLES OF INTERNAL COMBUSTION ENGINES

The purpose of this course is to increase the mechanic's knowledge of the principles, components, and operation of internal combustion engines.

Seven credit hours are awarded for successful completion of this subcourse.

Lesson 1: INTERNAL COMBUSTION ENGINES

Describe the principles, components, and operation of both the two stroke and four stroke diesel engines.

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LESSON 1

INTERNAL COMBUSTION ENGINES

Describe the principles, components, and operation of both the two stroke and four stroke diesel engines.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

REFERENCES

No supplementary references are needed for this task.

1. Introduction

In this task, the operation of a four stroke gasoline engine and a four stroke diesel engine will be compared. In addition, information will be provided on the two stroke diesel engine and the combustion chambers.

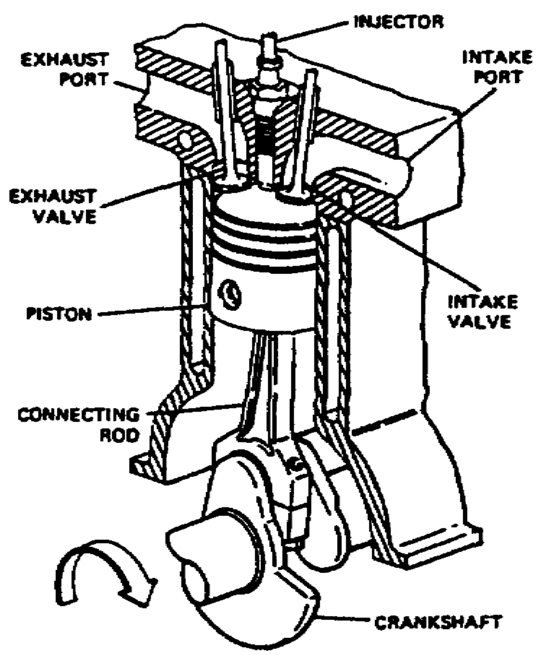
2. Gasoline Engine Versus Diesel Engine

a. *General*. In many respects, the four stroke cycle gasoline engine and the four stroke cycle diesel engine are very similar. They both follow an operating cycle consisting of intake, compression, power, and exhaust strokes. They also share the same system for intake and exhaust valves. The component parts of a diesel engine are shown in (figure 25). The main differences between gasoline engines and diesel engines follow:

(1) In a diesel engine the fuel and air mixture is ignited by the heat generated by the compression stroke, versus the use of a spark ignition system in a gasoline engine. The diesel engine therefore needs no ignition system. For this reason, the gasoline engine is referred to as a spark ignition engine and a diesel engine is referred to as a compression ignition engine.

(2) In a diesel engine the fuel and air mixture is compressed to about one-twentieth of its original volume. In contrast, the fuel and air mixture in a gasoline engine is compressed to about one-eighth of its original volume. The diesel engine must compress the mixture this tightly to generate enough heat to ignite the fuel and air mixture. The contrast between the two engines is shown in figure 26 on the following page.

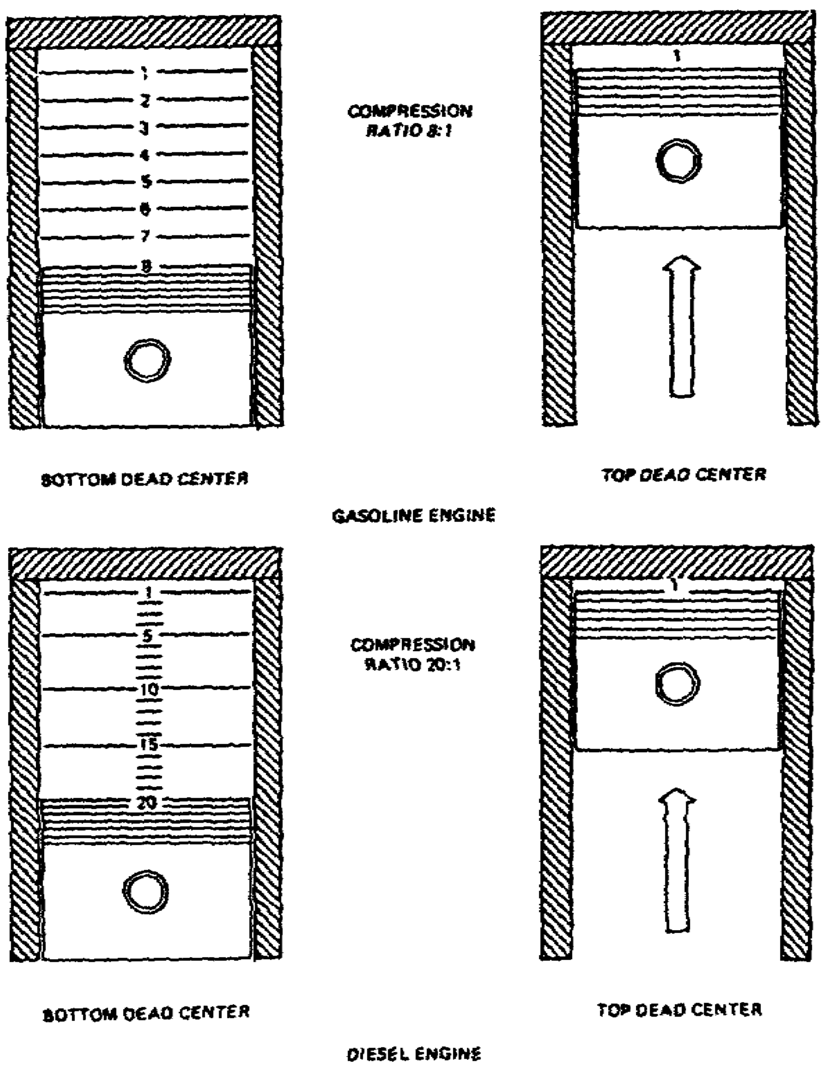
FIGURE 25. THE FOUR STROKE CYCLE DIESEL.



(3) The gasoline engine mixes the fuel and air before it reaches the combustion chamber. A diesel engine takes in only air through the intake port. Fuel is put into the combustion chamber directly through an injection system. The air and fuel then mix in the combustion chamber. This is illustrated in figure 27 on the following page.

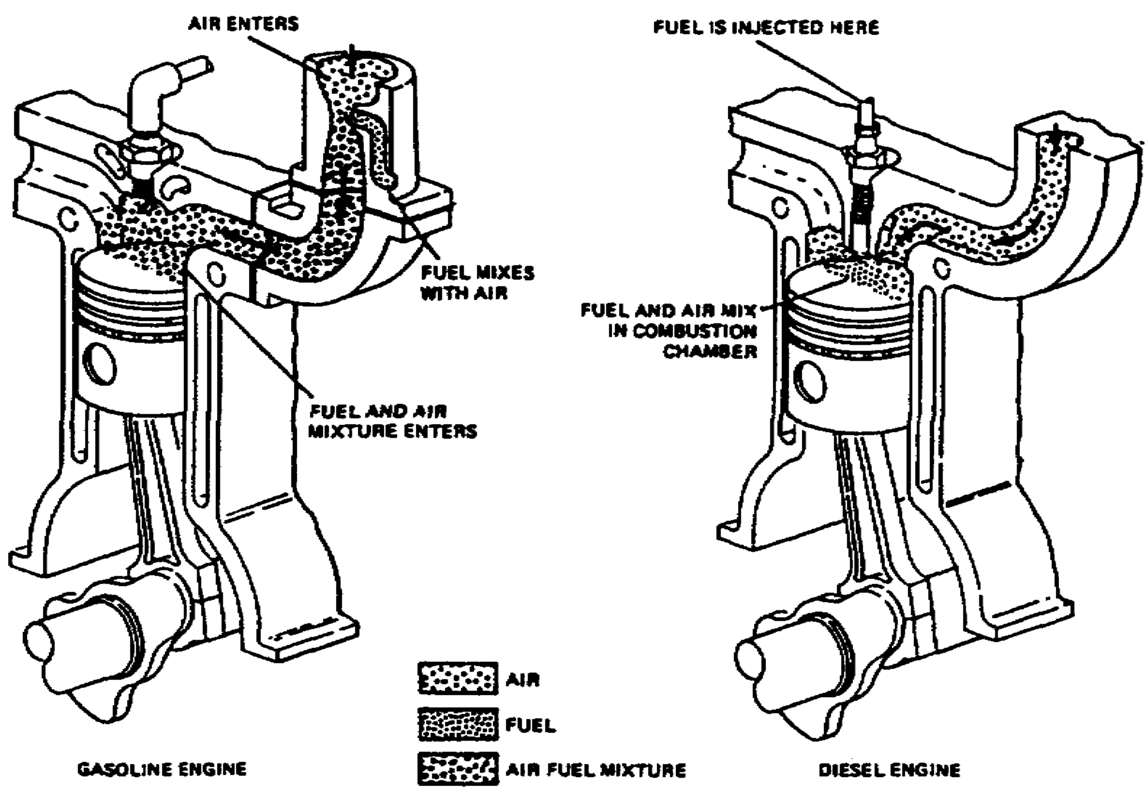
(4) The engine speed and the power output of a diesel engine are controlled by the quantity of fuel admitted to the combustion chamber. The

FIGURE 26. COMPARISON OF DIESEL AND GASOLINE ENGINE COMPRESSION STROKES.



amount of air is constant. This contrasts with the gasoline engine where the speed and power output are regulated by limiting the air entering the engine. This comparison is illustrated in figure 28 on the following page.

FIGURE 27. COMPARISON OF DIESEL AND GASOLINE ENGINE INTAKE STROKES.

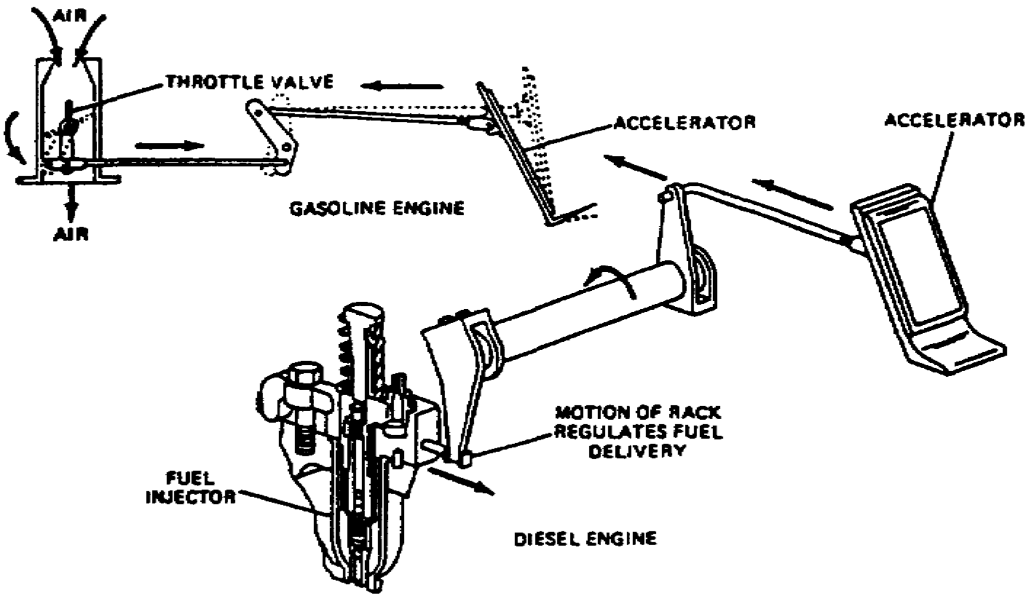


b. *Operation*.

(1) *Intake* (figure 29, view A, on page 32). The piston is at top dead center at the beginning of the intake stroke. As the piston moves downward, the intake valve opens. The downward movement of the piston draws air into the cylinder. As the piston reaches bottom dead center, the intake valve closes, ending the intake stroke.

(2) *Compression* (figure 29, view B). The piston is at bottom dead center at the beginning of the compression stroke. The piston moves upward,

FIGURE 28. COMPARISON OF GASOLINE AND DIESEL ENGINE REGULATION OF POWER.



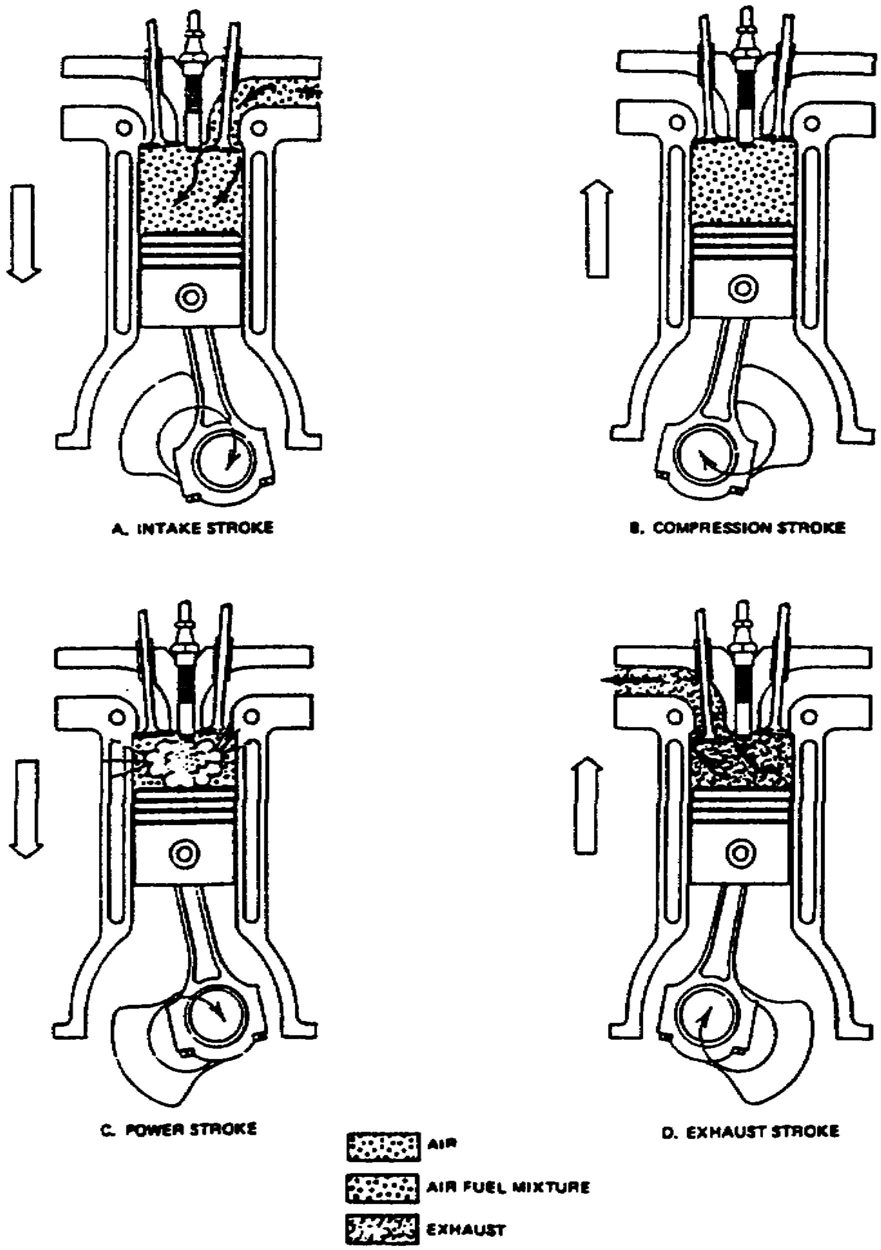
compressing the air. As the piston reaches top dead center, the compression stroke ends.

(3) *Power* (figure 29, view C, on the following page). The piston begins the power stroke at top dead center. At this time, air is compressed in the upper cylinder to as much as 500 psi (3448kPa). The tremendous pressure in the upper cylinder brings the temperature of the compressed air to approximately 1000° F (538° C). The power stroke then begins with the injection of a fuel charge into the engine. The heat of compression ignites the fuel as it is injected. The expanding force of the burning gases pushes the piston downward, providing power to the crankshaft. The power generated in a diesel engine is continuous throughout the power stroke. This contrasts with a gasoline engine, which has a power stroke with rapid combustion in the beginning and little or no combustion at the end.

(4) *Exhaust* (figure 29, view D). As the piston reaches bottom dead center on the power stroke, the power stroke ends and the exhaust stroke begins. The exhaust valve opens and the piston pushes the

burnt gas out through the exhaust port. As the piston reaches top dead center, the exhaust valve closes and the intake valve opens. The engine is then ready to begin another operating cycle.

FIGURE 29. FOUR STROKE CYCLE DIESEL.



c. *Advantages*.

(1) The diesel engine is much more efficient than a gasoline engine due to the much tighter compression of the fuel and air mixture. The diesel engine produces tremendous low-speed power, and gets much greater fuel mileage than its gasoline counterpart. This makes the engine very suitable for large trucks.

(2) The diesel engine requires no ignition tune-ups because there is no ignition system.

(3) Because diesel fuel is of an oily consistency and is less volatile than gasoline, it is not as likely to explode in a collision.

d. *Disadvantages*.

(1) The diesel engine must be made very heavy to have enough strength to withstand the tighter compression of the fuel and air mixture.

(2) The diesel engine is very noisy.

(3) Diesel fuel creates a large amount of fumes.

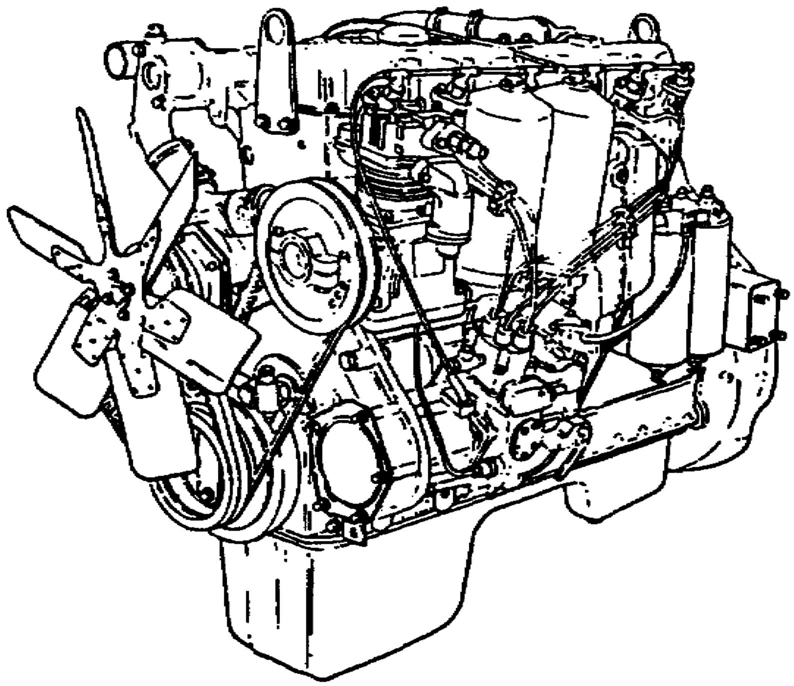
(4) Because diesel fuel is not very volatile, cold weather starting is difficult.

(5) A diesel engine operates well only in low-speed ranges in relation to gasoline engines. This creates problems when using them in passenger cars, which require a wide speed range.

e. *Usage*. Diesel engines are widely used in all types of heavy trucks, trains, and boats. In recent years, more attention has been focused on using diesels in passenger cars.

f. *Multifuel Engine* (figure 30 on the following page). The multifuel engine is basically a four stroke cycle diesel engine with the capability of operating on a wide variety of fuel oils without adjustment or modification. The fuel injection system is equipped with a device called a fuel density compensator. Its job is to vary the amount of fuel, keeping the power output constant regardless of the fuel being used. The multifuel engine uses a spherical combustion chamber to aid in thorough mixing, complete combustion, and minimized knocks.

FIGURE 30. MULTIFUEL ENGINE.



3. Two Stroke Cycle Diesel

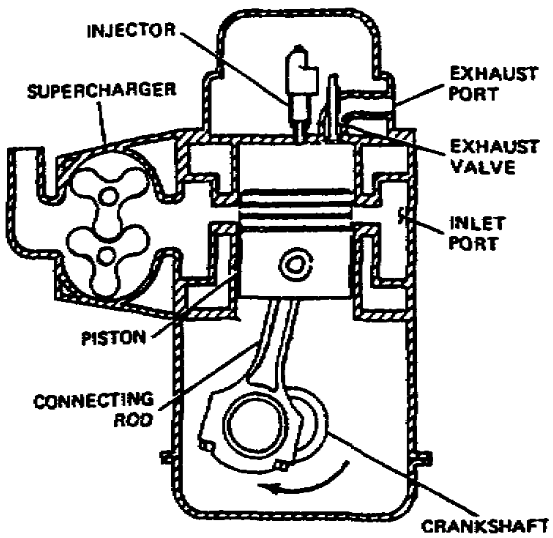
a. *General*. The two stroke cycle diesel (figure 31 on the following page) is a hybrid engine sharing operating principles of both a two stroke cycle gasoline engine and a four stroke cycle diesel engine. The major features of the engine are as follows:

(1) It completes an operating cycle every two piston strokes or every crankshaft revolution. Like a two stroke cycle gasoline engine, it provides a power stroke every time the piston moves downward.

(2) It is a compression ignition engine, making it a true diesel engine.

(3) It uses an exhaust valve on top of the combustion chamber as in a four stroke cycle diesel engine. Intake ports are cut into the cylinder wall as in a two stroke cycle gasoline engine.

FIGURE 31. THE TWO STROKE CYCLE DIESEL ENGINE.



(4) It mixes its fuel and air in the combustion chamber as in a four stroke cycle diesel engine. The air enters through the intake ports and the fuel is injected into the combustion chamber by the fuel injection system.

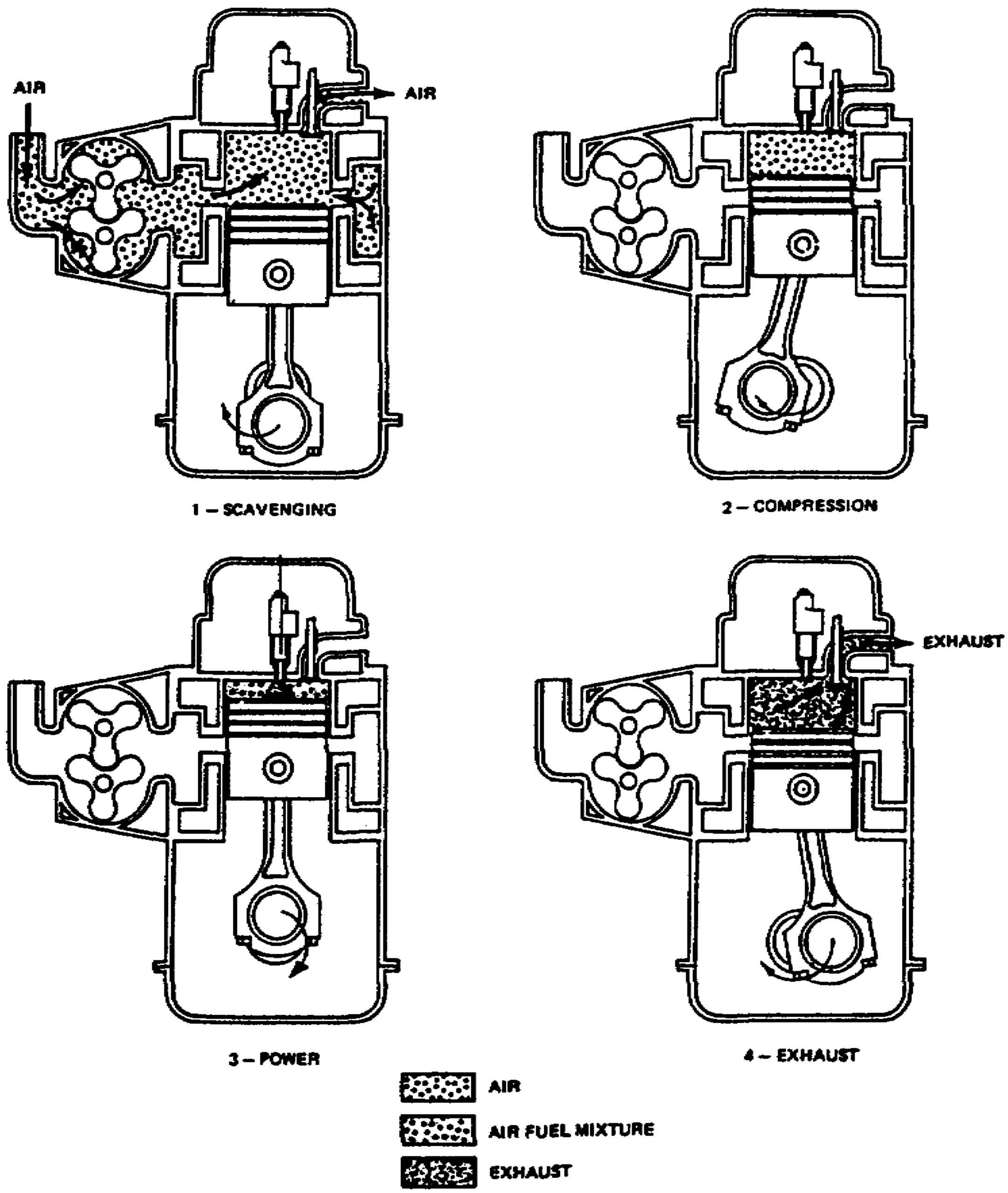
(5) The air supply to the engine is constant while the speed and power output of the engine is regulated by controlling the quantity of fuel injected into the combustion chamber.

(6) Unlike any of the other engine types, the two stroke cycle diesel engine must have a supercharger to force the intake air into the upper cylinder. The most common type used is the Rootes.

b. *Operation* (figure 32 on the following page).

(1) *Scavenging*. Scavenging begins with the piston at bottom dead center. The intake ports are uncovered in the cylinder wall and the exhaust valve opens. Air is forced into the upper cylinder by the supercharger. As the air is forced in, the burnt gases from the previous operating cycle are forced out.

FIGURE 32. THE TWO STROKE DIESEL CYCLE.



(2) *Compression*. As the piston moves toward top dead center, it covers the intake ports. The exhaust valve closes at this point sealing the upper cylinder. As the piston continues upward, the air in the cylinder is tightly compressed. As in the four stroke cycle diesel, a tremendous amount of heat is generated by the compression.

(3) *Power*. As the piston reaches top dead center, the compression stroke ends. Fuel is injected at this point. The intense heat of compression causes the fuel to ignite. The burning fuel pushes the piston down, giving power to the crankshaft. The power stroke ends when the piston gets down to the point where the intake ports are uncovered. At about this point, the exhaust valve opens and scavenging begins again.

c. *Advantages*. The two stroke cycle diesel engine has all of the advantages that a four stroke cycle engine has over a gasoline engine, plus the following:

(1) Because it is a two stroke cycle engine, it will run smoother than its four stroke cycle counterpart. This is because there is a power stroke generated for every crankshaft revolution.

(2) The two stroke cycle diesel has a less complicated valve train because it does not use intake valves.

d. *Disadvantages*.

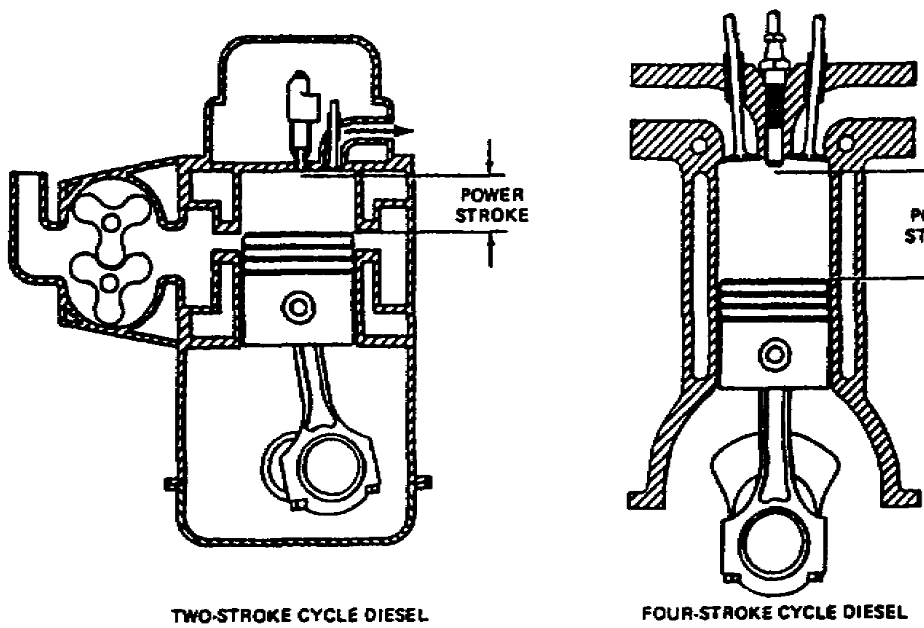
(1) The two stroke cycle engine must use a supercharger to force in the intake air and push out the burnt exhaust gases. This is because the movement of the piston is not such that it will accomplish this naturally. The supercharger uses engine power to operate.

(2) The two stroke cycle diesel uses either two or four exhaust valves per cylinder, which complicates the valve mechanism.

(3) As with the two stroke cycle gasoline engine, the diesel counterpart will not produce twice as much power as a four stroke cycle engine, even though it produces twice as many power strokes. By studying figure 33 on the following page, it can be seen that the power stroke occupies only a portion of the downstroke of the piston in a two stroke cycle diesel. In a four stroke cycle diesel, the power stroke lasts from top dead center to bottom dead center.

e. *Usage*. The two stroke cycle diesel is used in most of the same applications as the four stroke cycle diesel.

FIGURE 33. COMPARISON OF TWO AND FOUR STROKE CYCLE DIESEL POWER STROKE LENGTHS.



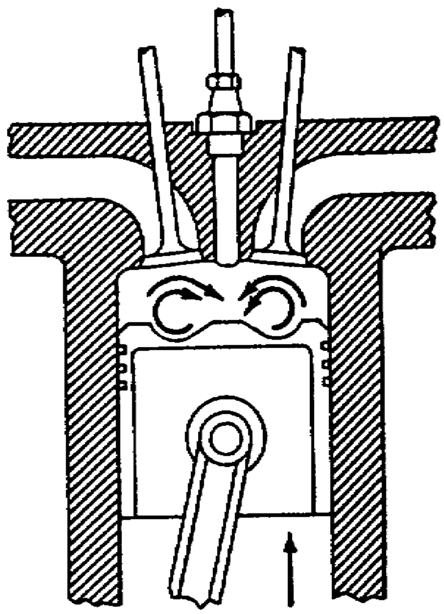
4. Combustion Chamber Design

a. *General*. The fuel injected into the combustion chamber must be mixed thoroughly with the compressed air and be distributed as evenly as possible throughout the chamber if the engine is to function at maximum driveability. The well-designed diesel engine uses a combustion chamber that is designed for the engine's intended usage. The injectors used in the engine should compliment the combustion chamber. The combustion chambers described in the following subparagraphs are the most common and cover virtually all of the designs that are used in current automotive applications.

b. *Open Chamber* (figure 34 on the following page). The open chamber is the simplest form of chamber. It is suitable for slow-speed, four stroke cycle engines, and is used widely in two stroke cycle diesel engines. In the open chamber, the fuel is injected directly into the space at the top of the cylinder. The combustion space, formed by the top of the piston and the cylinder head, is usually shaped to provide a swirling action of the air as the piston comes up on the compression stroke.

There are no special pockets, cells, or passages to aid the mixing of the fuel and air. This type of chamber requires a higher injection pressure and a greater degree of fuel atomization than is required by other combustion chambers to obtain an acceptable level of fuel mixing. This chamber design is very susceptible to ignition lag.

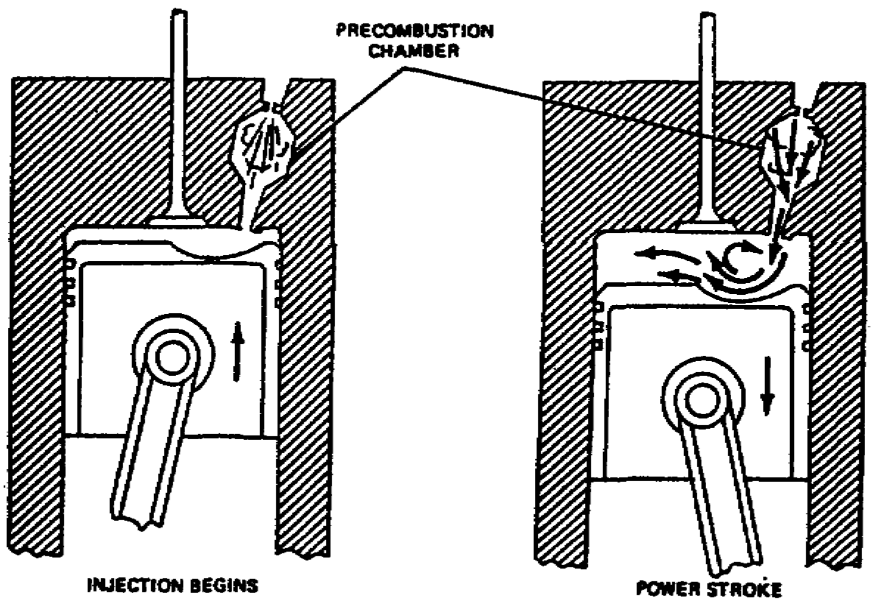
FIGURE 34. OPEN COMBUSTION CHAMBER.



c. *Precombustion Chamber* (figure 35 on the following page). The precombustion chamber is an auxiliary chamber at the top of the cylinder. It is connected to the main combustion chamber by a restricted throat or passage. The precombustion chamber conditions the fuel for final combustion in the cylinder. A hollowed-out portion of the piston top causes turbulence in the main combustion chamber as the fuel enters from the precombustion chamber to aid in mixing with air. The following steps occur during the combustion process:

(1) During the compression stroke of the engine, air is forced into the precompression chamber and, because the air is compressed, it is hot. At the beginning of injection, the precombustion chamber contains a definite volume of air.

FIGURE 35. PRECOMBUSTION CHAMBER.

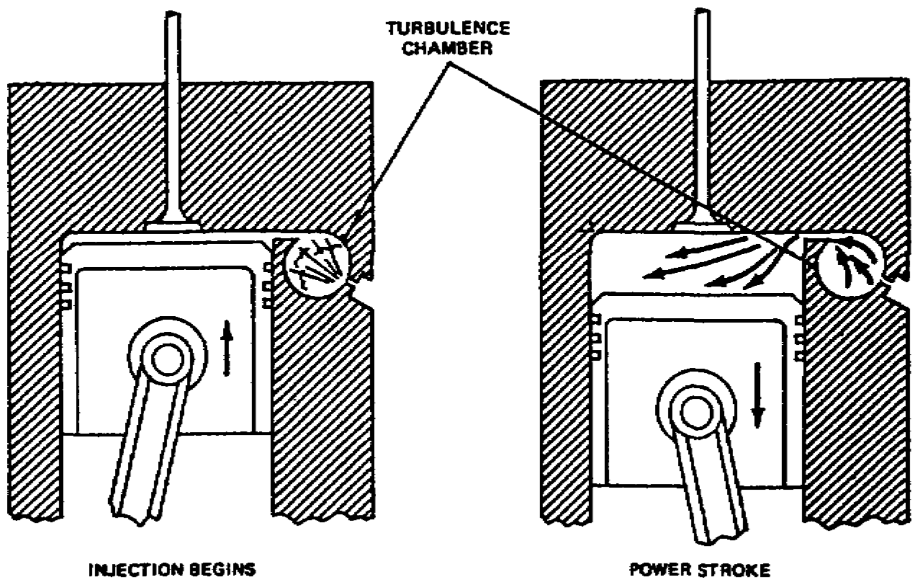


(2) As the injection begins, combustion begins in the precombustion chamber. The burning of the fuel, combined with the restricted passage to the main combustion chamber, creates a tremendous amount of pressure in the chamber. The pressure and the initial combustion cause a superheated fuel charge to enter the main combustion chamber at a tremendous velocity.

(3) The entering mixture hits the hollowed-out piston top, creating turbulence in the chamber to ensure complete mixing of the fuel charge with the air. This mixing ensures even and complete combustion. This chamber design will provide satisfactory performance with low fuel injector pressures and coarse spray patterns, because a large amount of vaporization takes place in the combustion chamber. This chamber also is not very susceptible to ignition lag, making it more suitable for high-speed applications.

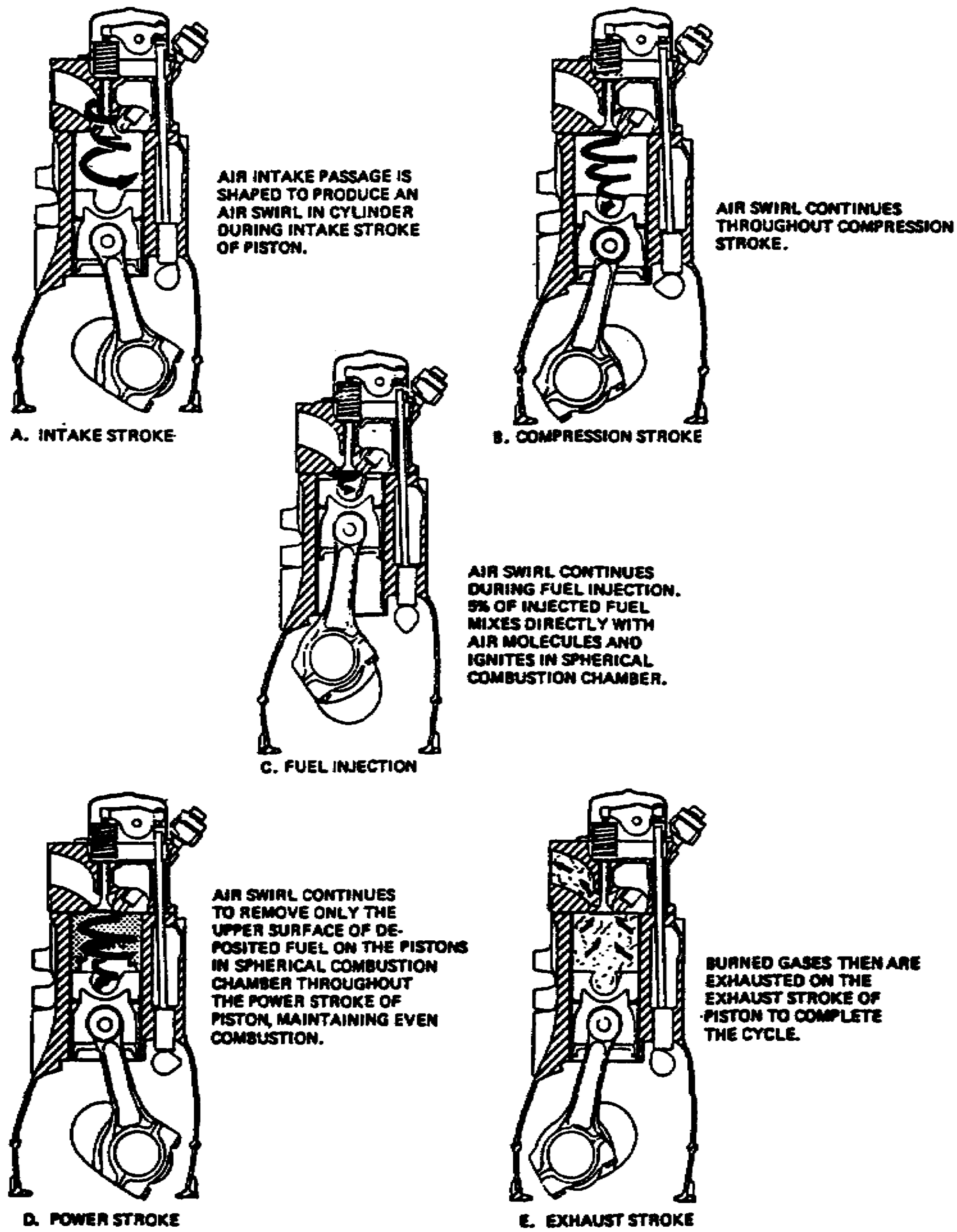
d. *Turbulence Chamber* (figure 36 on the following page). The turbulence chamber is similar in appearance to the precombustion chamber, but its function is different. There is very little clearance between the top of the piston and the head, so that a high percentage of the air between the piston and the cylinder head is forced into the turbulence chamber during the compression stroke. The chamber usually is spherical, and the opening through which the air must pass becomes smaller as the piston reaches the top of the stroke, thereby increasing the velocity of the air in the chamber. This turbulence speed is approximately 60 times crankshaft speed. The fuel injection is timed to occur when the turbulence in the chamber is the greatest. This ensures a thorough mixing of the fuel and the air, with the result that the greater part of combustion takes place in the turbulence chamber itself. The pressure created by the expansion of the burning gases is the force that drives the piston downward on the power stroke.

FIGURE 36. TURBULENCE CHAMBER.



e. *Spherical Combustion Chamber* (figure 37 on the following page). The spherical combustion chamber is principally designed for use in the multifuel engine. The chamber consists of a basic open-type chamber with a spherical-shaped relief in the top of the piston head. The chamber works in conjunction with a strategically positioned injector and an intake port that produces a swirling effect on the intake air as it enters the chamber. Operation of the chamber is as follows:

FIGURE 37. SPHERICAL CHAMBER.



(1) As the air enters the combustion chamber, a swirl effect is introduced to it by the shape of the intake port (figure 37, view A).

(2) During the compression stroke, the swirling motion of the air continues as the temperature in the chamber increases (figure 37, view B, on the previous page).

(3) As the fuel is injected, approximately 95 percent of it is deposited on the head of the piston; the remainder mixes with the air in the spherical combustion chamber (figure 37, view C).

(4) As combustion begins, the main portion of the fuel is swept off the piston head by the high-velocity swirl that was created by the intake and the compression strokes. As the fuel is swept off the head, it burns through the power stroke, maintaining even combustion and eliminating detonation (figure 37, view D and E).

6. Conclusion

This concludes the explanation of the gasoline and diesel internal combustion engines. In the next lesson, operational information on the subsystems of internal combustion engines will be discussed.

PRACTICAL EXERCISE

1. Instructions

Read the scenario and respond to the requirements that follow the scenario.

2. Scenario

SSG Fredrick has been attending an Army NCO development course for four weeks. This week the subject has been internal combustion engines, which he understands completely. One of his classmates, SSG Olson, is not very sure about this subject and is nervous about the exam which is coming up in two days.

SSG Olson asks SSG Fredrick if he would mind helping him study for the exam. SSG Fredrick agrees to help and decides that the best way to prepare SSG Olson for the exam is to give him a pretest.

3. Requirement

Below is a list of questions that SSG Fredrick feels will give SSG Olson a general understanding of internal combustion engines.

a. If the engine is going to operate, the fuel and air mixture must be fed into the ___________________________.

b. What component opens and closes the intake and exhaust valves in a timed sequence?

c. How many revolutions does the crankshaft rotate when the piston moves from top dead center to bottom dead center?

d. What are the four strokes of operation in a piston engine?

e. What system ignites the fuel and air mixture in the combustion chamber at the precise moment needed to make the engine run?

f. What type of engine is used almost exclusively in very small equipment because it is lightweight and able to run at very high speeds due to the absence of a mechanical valve train?

g. What piston ring keeps the engine's lubrication oil from getting into the combustion chamber?

h. Why is a diesel engine referred to as a compression ignition engine?

i. Why is the diesel engine much more efficient than the gasoline engine?

j. The two stroke cycle engine must use a supercharger to force in the intake air and push out the burnt exhaust gases because ____ ____.

k. What type of combustion chamber is designed principally for use in the multifuel engine?

LESSON 1. PRACTICAL EXERCISE – ANSWERS

1. Requirement

a. combustion chamber.

b. The valve train.

c. Exactly one-half.

d. Intake, compression, power, and exhaust.

e. The ignition system.

f. The two stroke cycle engine.

g. The oil control ring.

h. The fuel and air mixture is ignited by the heat generated by the compression stroke.

i. The diesel engine is much more efficient than the gasoline engine due to the much tighter compression of the fuel and air mixture.

j. the movement of the piston is not such that it will accomplish this naturally and the supercharger uses engine power to run it.

k. The spherical combustion chamber.