CHAPTER 5

Two-Cycle and Four-Cycle Engines

After studying this chapter, you will be able to:
- Describe four-stroke cycle engine operation and explain the purpose of each stroke.
- Explain the concept of valve timing.
- Compare the lubrication system in a four-cycle engine to the system in a two-cycle engine.
- Describe two-stroke cycle engine operation and explain the principles of two-cycle operation.
- List the advantages and disadvantages of two-cycle and four-cycle engines.

Small Engine Identification

A basic design feature that aids in small engine identification is the number of piston strokes required to complete one operating (power) cycle. A four-stroke cycle engine, for example, requires four strokes per cycle; a two-stroke cycle engine requires two.

A ***stroke*** of the piston is its movement in the cylinder from one end of its travel to the other. Each stroke of the piston, then, is either toward the rotating crankshaft or away from it. Each stroke is identified by the job it performs (intake, exhaust, etc.).

Four-Stroke Cycle Engine

In a ***four-stroke cycle engine*** (called a *four-cycle*), four strokes are needed to complete the operating cycle. The four strokes are as follows:
- ***intake stroke***
- ***compression stroke***
- ***power stroke***
- ***exhaust stroke***

Two strokes occur during each revolution of the crankshaft. Therefore, a four-stroke cycle requires two revolutions of the crankshaft. **Figure 5-1** illustrates each of the four strokes taking place in proper sequence.

Intake stroke

Figure 5-1A shows the piston traveling downward in the cylinder on the ***intake stroke.*** As piston moves down, the volume of space above it is increased. This creates a partial vacuum that draws the air-fuel mixture through the intake valve port and into the cylinder.

With the intake valve open during the intake stroke, atmospheric pressure outside the engine forces air through the carburetor. This gives a large boost to the air-fuel induction process. With nature balancing unequal pressures in this manner, it follows that the larger the diameter of the cylinder and the longer the stroke of the piston, the greater the volume of air entering the cylinder on the intake stroke.

Bear in mind that the intake valve, **Figure 5-2,** performs several key functions. These key functions are as follows:
1. It must open at the correct instant to permit intake of air-fuel mixture.
2. It must close at the correct time and seal during compression.
3. Its shape must be streamlined, so the flow of gases into combustion chamber will not be obstructed.

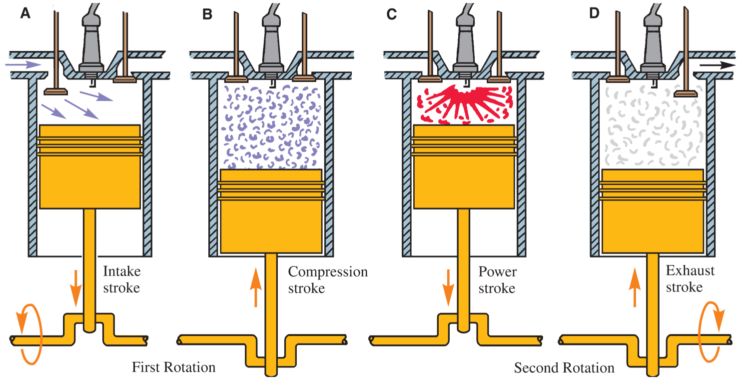

Figure 5-1. *Sequence of events in a four-stroke cycle engine, requiring two revolutions of the crankshaft and one power stroke out of four.*

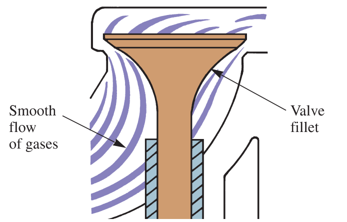

Figure 5-2. *The shape of the valve smoothes the flow of gases around it. Note how the flow follows the fillet, speeding entry or expulsion. (Cedar Rapids Engineering Co.)*

The intake valves are not subjected to as high temperatures as the exhaust valve. The incoming air-fuel mixture tends to cool the intake valve during operation.

Compression stroke

The ***compression stroke*** is created by the piston moving upward in the cylinder. See **Figure 5-1B.** Compression is a squeezing action while both valves are closed. On this stroke, the valves are tightly sealed and the piston rings prevent leakage past the piston.

As the piston moves upward, the air-fuel mixture is compressed into a smaller space. This increases the force of combustion for two reasons:
1. When atoms that make up tiny molecules of air and fuel are squeezed closer together, heat energy is created. Each molecule of fuel is heated very close to its flash point (point at which fuel will ignite spontaneously). When combustion does occur, it is practically instantaneous and complete for the entire air-fuel mixture.
2. The force of combustion is increased because tightly packed molecules are highly activated and are striving to move apart. This energy, combined with expanding energy of combustion, provides tremendous force against the piston.

It is possible to run an engine on uncompressed mixtures, but power loss produces a very inefficient engine.

Power stroke

During the ***power stroke,*** both valves remain in the closed position. See **Figure 5-1C.** As the piston compresses the charge and reaches the top of the cylinder, an electrical spark jumps the gap between the electrodes of the spark plug. This ignites the air-fuel mixture, and the force of the explosion (violent burning action) forces the piston downward.

Actually, the full charge does not burn at once. The flame progresses outward from the spark plug, spreading combustion and providing even pressure over the piston face throughout the power stroke.

The entire fuel charge must ignite and expand in an incredibly short period of time. Most engines have the spark timed to ignite the fuel slightly before the piston reaches ***top dead center (TDC)*** of the compression stroke. This provides a little more time for the mixture to burn and accumulate its expanding force.

Basically, the amount of power produced by the power stroke depends on the volume of the air-fuel mixture in the cylinder and the compression ratio of the engine. The ***compression ratio*** is the proportionate difference in volume of cylinder and combustion chamber at bottom dead center and at top dead center. If the compression ratio is too high, the fuel may be heated to its flash point during the compression stroke and ignite too early.

Exhaust stroke

After the piston has completed the power stroke, the burned gases must be removed from the cylinder before introducing a fresh charge. This takes place during the ***exhaust stroke.*** The exhaust valve opens and the rising piston pushes the exhaust gases from the cylinder. See **Figure 5-1D.**

The exhaust valve has to function much like the intake valve. When closed, the valve must seal. When open, it must allow a streamlined flow of exhaust gases out through the port. See **Figure 5-2.** The removal of gases from the cylinder is called ***scavenging.***

The passageway that carries away exhaust gases is referred to as the exhaust manifold or exhaust port. Like the intake manifold, the exhaust manifold must be designed for smooth flow of gases.

The heat absorbed by the exhaust valve must be controlled or the valve will deteriorate rapidly. See **Figure 5-3.** Some valve heat is carried away by conduction through the valve stem to the guide. However, the hottest part of the valve, the valve head, transfers heat through the valve seat to the cylinder block. See **Figure 5-4.**

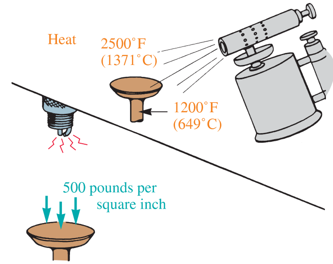

Figure 5-3. *Exhaust valve temperature may range from 1200°F (649°C) to 2500°F (1371°C) due to the hot gases surrounding it. The pressure of combustion may be as high as 500 pounds per square inch. (Briggs & Stratton Corp.)*

Valve timing

Valve timing is measured in degrees of crankshaft rotation. The point at which the valves open or close before or after the piston is at ***top dead center (TDC)*** or ***bottom dead center (BDC)*** varies

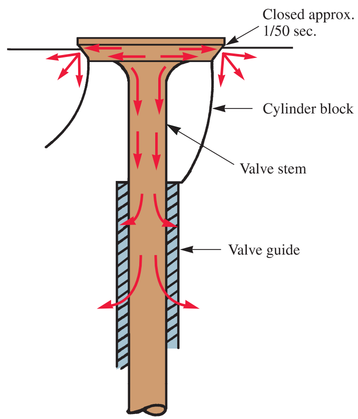

Figure 5-4. *The exhaust valve must cool during an incredibly short period (1/50 sec. at 3600 rpm). Heat is conducted from the valve through the seat to the cylinder block. Some heat travels down the stem and to the valve guide.*

with different engines. However, if the timing marks on the crankshaft and camshaft gears, sprockets, or pulleys are aligned, the valve timing will take care of itself.

Engineers also specify the point at which the spark must occur. Chapter 9 of this text explores this in more detail.

Figure 5-5 shows one complete operating cycle of a four-cycle engine. Beginning at point A, the intake valve opens 10° before TDC and stays open through 235°. The exhaust valve closes 30° after TDC. ***Valve overlap*** occurs when both valves are open at the same time.

During the compression stroke, the intake valve closes and ignition occurs 30° before TDC. The power stroke continues through 120° past TDC. The exhaust valve opens 60° before BDC and stays open through 270°. During the last 40°, the intake valve is also open and the second cycle has begun.

Lubrication

Lubrication of the four-cycle engine is provided by placing the correct quantity and grade of engine oil in the crankcase. Several methods are used to feed the oil to the correct locations. The two most common methods are the splash system and the pump system. Some engines employ one or the other; others use a combination of both.

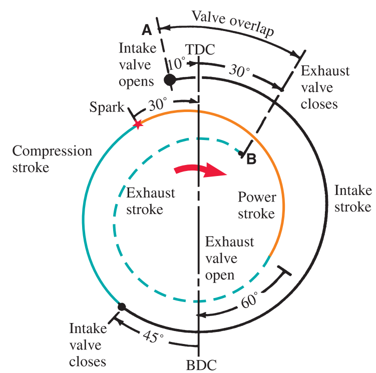

Figure 5-5. *The four-stroke cycle diagram shows the exact number of degrees each valve is open or closed and the time spark ignition occurs. Note that both valves are open (overlap) through an arc of 40°, permitting exhausting gases to create a partial vacuum in the cylinder and help draw a mixture of fuel into the cylinder.*

The multiple vee cylinder engine shown in **Figure 5-6** utilizes a combination splash and pressure lubrication system. The pump picks up the oil from the crankcase and circulates some oil through the filter and directly back to the crankcase. This keeps a clean supply available.

Oil is also pumped through a spray nozzle aimed at the crankshaft. As the shaft rotates, it deflects the oil toward other moving parts. In addition, the splash finger on the bearing cap dips into the crankcase oil and splashes it on various internal surfaces.

Part of the engine oil is pumped through a tube to lubricate the governor assembly above the engine. Oil holes are provided in the connecting rod for lubricating the bearings and piston pin.

Obviously, the oil in a four-cycle engine must be drained periodically and replaced with clean oil. Also worth noting, four-cycle engines must be operated in an upright position or the oil will flow away from the pump or splash finger, preventing lubrication.

Two-Stroke Cycle Engine

The ***two-stroke cycle engine*** (commonly called *two-cycle*) performs the same cycle of events as the four-cycle engine. The main difference is that intake, compression, power, and exhaust functions take place during only two strokes of the piston. The two strokes occur during each revolution of the crankshaft. Therefore, it takes only one revolution of the shaft to complete a two-stroke cycle.

A two-cycle engine has several advantages over a four-cycle unit. It is much simpler in design than the four-cycle engine because the conventional camshaft, valves, and tappets are unnecessary. See **Figure 5-7.**

Additionally, a two-cycle engine is smaller and lighter than a four-cycle engine of equivalent horsepower. Unlike the four-stroke cycle engine, the two-cycle engine will get adequate lubrication even when operated at extreme angles. It receives its lubrication as fuel mixed with oil is passed through the engine.

Installing the correct mixture of fuel and oil is a critical factor in maintaining a two-cycle engine in good working condition. The prescribed type and grade of engine oil must be mixed with the fuel in proper proportion before being placed in the fuel tank.

In this way, there is clean oil continuously supplied to all moving parts while the engine is

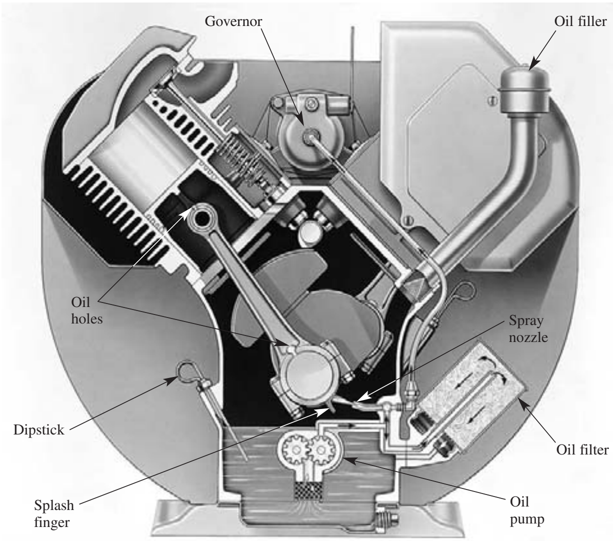

Figure 5-6. *Two common methods of supplying lubrication in four-cycle engines are the splash system and the pressurized system. The engine shown employs both methods. The splash finger churns oil into a mist that makes its way into oil holes and other parts. The gear pump directs oil to remote parts and sprays some on critical parts. (Wisconsin Motors Corp.)*

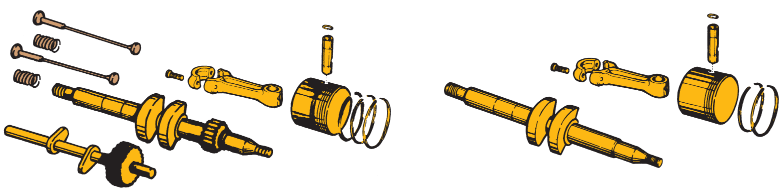

Figure 5-7. *The number of moving parts in a four-cycle engine is greater than in a two-cycle engine. Other differences are listed in the chart at the end of this chapter. (Lawn-Boy Power Equipment, Gale Products)*

running. The oil eventually burns in the combustion chamber and is exhausted with other gases.

Two-cycle engines are popular in lawn mowers, snowmobiles, chain saws, string trimmers, leaf blowers, and other high-rpm applications.

Variations in design

Two basic types of two-cycle engines are in general use. They are the cross-scavenged and loop-scavenged designs. See **Figure 5-8.**

The ***cross-scavenged*** engine has a special contour on the piston head, which acts as a baffle to deflect the air-fuel charge upward in the cylinder. See **Figure 5-8A.** This prevents the charge from going straight out the exhaust port, which is located directly across from the intake port.

Cross-scavenged engines usually employ reed valves or a rotary valve, which is attached to the flywheel. See **Figure 5-8B.** These valves hold the incoming charge in the crankcase so it can be compressed while the piston moves downward in the cylinder. With this design, the piston acts as a valve in opening and closing intake, exhaust, and transfer ports. The transfer port permits passage of the fuel from the crankcase to the cylinder.

The ***loop-scavenged*** engine does not have to deflect the incoming gases, so it has a relatively flat or slightly domed piston, as shown in **Figure 5-8C.** The fuel transfer ports in loop-scavenged engines are shaped and located so that

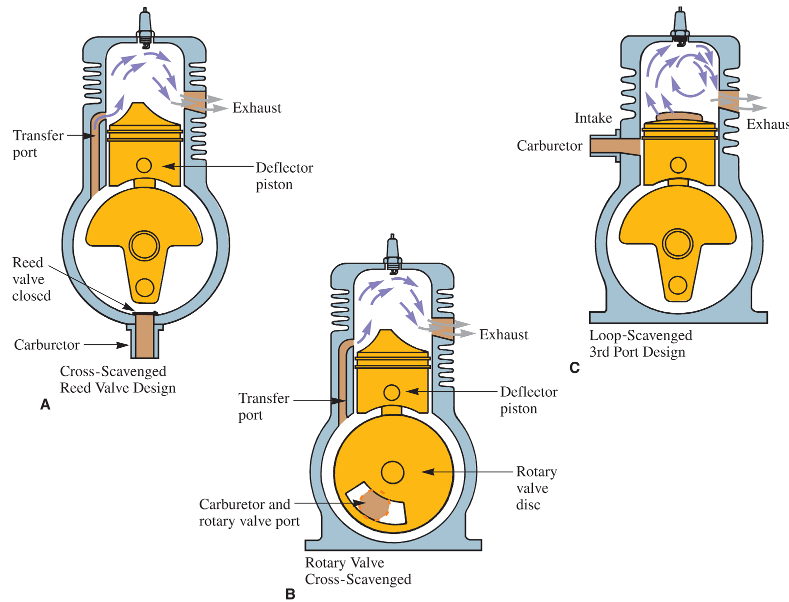

Figure 5-8. *Basically, two-cycle engines are either cross-scavenged or loop-scavenged. Cross-scavenged engines have a contoured baffle on top of the piston to direct the air-fuel mixture upward into the cylinder while exhaust gases are being expelled. Loop-scavenged engines have flat or domed pistons with more than one transfer port. Note the three styles of crankcase intake valves. (Kohler Co.)*

the incoming air-fuel mixture swirls. This controlled flow of gas helps force exhaust gases out and permits a new charge of air and fuel to enter.

Principles of operation

The location of the ports in a two-cycle engine is essential to correct timing of the intake, transfer, and exhaust functions. The cutaway cylinder in **Figure 5-9A** shows the exhaust port at the highest point, the transfer port next, and the intake port at the lowest point. Some engines, particularly loop-scavenged engines, have more than one transfer port. See **Figure 5-9B.**

Intake into crankcase

As the piston moves upward in the cylinder of a two-cycle engine, crankcase pressure drops and the intake port is exposed. Because atmospheric pressure is greater than the crankcase pressure, air rushes through the carburetor and into the crankcase to equalize the pressures. See **Figure 5-10A.**

While passing through the carburetor, the intake air pulls a charge of fuel and oil along with it. This charge remains in the crankcase to lubricate ball and needle bearings until the piston opens the transfer port on the downstroke.

Ignition-power

As the piston travels upward, it also compresses the air-fuel charge brought into the cylinder during the previous cycle to about one-tenth of its original volume. See **Figure 5-10A.** The spark is timed to ignite the air-fuel mixture when the piston reaches TDC. See **Figure 5-10B.**

On some small engines, spark occurs almost at TDC during starting, then automatically advances so that it occurs earlier. This is done to get better efficiency from the force of combustion at higher speeds.

Peak combustion pressure is applied against the piston top immediately after TDC. Driving downward with maximum force, the piston transmits straight line motion through the connecting rod to create rotary motion of the crankshaft. See **Figure 5-10C.**

Exhaust

Several things happen during the exhaust phase. See **Figure 5-10C.** As the piston moves to expose the exhaust port, most of the burned gases are expelled. Complete exhausting of gases from the cylinder and combustion chamber takes place when the transfer ports are opened and the new air-fuel charge rushes in.

Fuel transfer

Figure 5-10C and **Figure 5-10D** show the piston moving downward, compressing the air-fuel charge in the crankcase. When the piston travels far enough on the downstroke, the transfer port is opened and the compressed air-fuel charge rushes through the port and into the cylinder. The new charge cools the combustion area and pushes (scavenges) the exhaust gases out of the cylinder. This completes one cycle of operation.

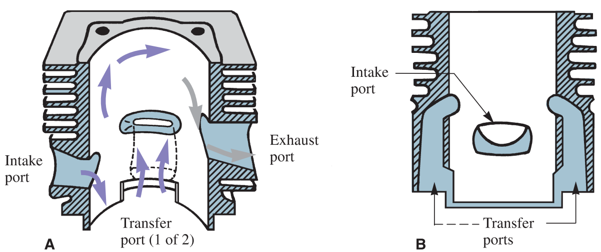

Figure 5-9. *A cutaway cylinder block shows the location of the intake, exhaust, and transfer ports of a loop-scavenged engine. A—Due to the cutaway, only one of two transfer ports is shown. B—The section is revolved 90° to show both ports.*

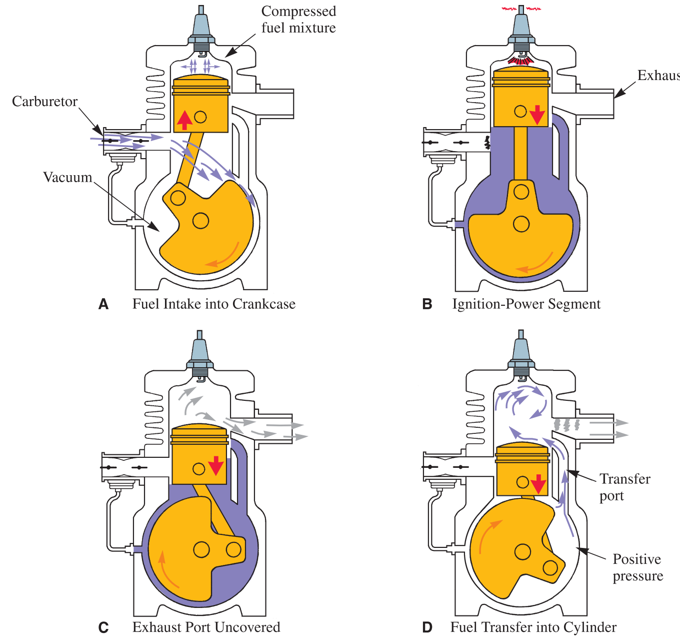

Figure 5-10. These *illustrations show the sequence of events that take place in a two-cycle engine. Compression and intake occur simultaneously, then ignition occurs. Exhaust precedes the transfer of fuel during the lower portion of the power stroke. The piston functions as the only valve in the engine. (Rupp Industries, Inc.)*

Scavenging and tuning

When properly designed, the exhaust system scavenges all exhaust gases from the combustion chamber. The system allows the new fuel charge to move in more rapidly for cleaner and more complete combustion.

For best efficiency, the fuel charge should be held in the cylinder momentarily while the exhaust port is open. This helps prevent fuel from being drawn out of the cylinder with exhaust gases.

Some well-engineered exhaust systems use the energy of sound waves from the exhaust gases for proper tuning. **Figure 5-11** shows a megaphone-like device, which amplifies the sound to speed up scavenging. The sound waves are reflected back into the megaphone to develop back pressure, which prevents the incoming air-fuel mixture from leaving with the exhaust gases. Compare this device with straight pipe operation shown in **Figure 5-12.**

Rotary disc valve engine

Figure 5-13 illustrates a two-cycle engine equipped with a ***rotary disc valve.*** The intake port is located directly in the crankcase, allowing room for additional transfer ports that promote better fuel transfer and scavenging.

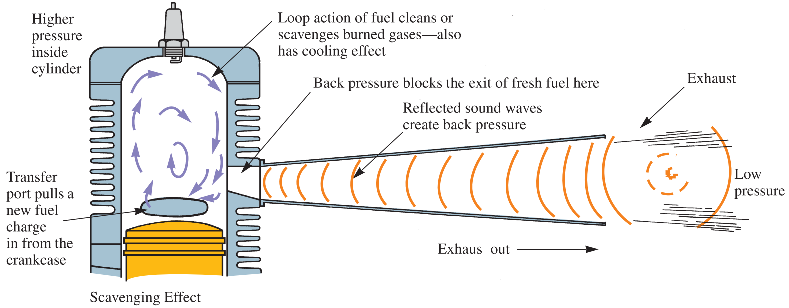

Figure 5-11. *Pressure pulse exhaust tuning is an effective way of increasing power and efficiency in two-cycle engines. Exhaust sound waves reflected back into the manifold create a back pressure that stops the fuel mixture from leaving the cylinder before the piston closes the port. This system requires precise engineering. (Kohler Co.)*

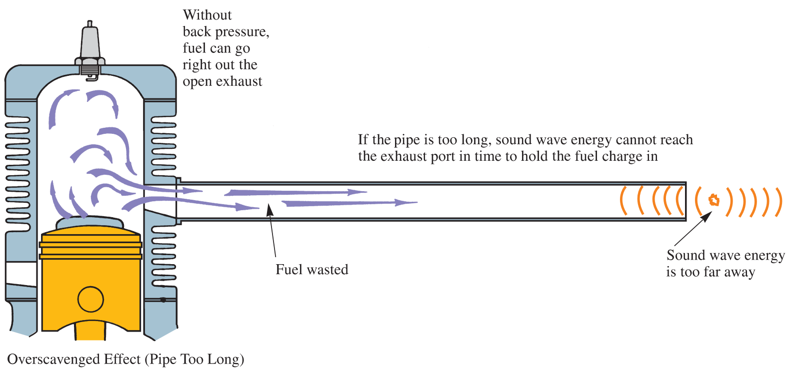

Figure 5-12. *A straight pipe may sound louder and more powerful than tuned exhaust, but actually is far less efficient. In this illustration, center of sound is too far and lacks amplification to have any beneficial effect on engine.*

Reed valve engine

The ***reed valve engine*** permits fuel intake directly into the crankcase. See **Figure 5-14.** The reed is made of thin, flexible spring steel, which is fastened at one end. See **Figure 5-15.** The opposite end covers the intake port. The ***reed stop*** is thick and inflexible. It prevents the reed from opening too far and becoming permanently bent.

In operation, the reed is opened by atmospheric pressure during the intake stroke. It is closed by the springiness of the metal and the compression in the crankcase on the power stroke. **Figure 5-16A** illustrates the air-fuel mixture entering the crankcase. **Figure 5-16B** shows how the reed valve is closed by crankcase pressure.

There are many reed valve designs. Some typical configurations are illustrated in **Figure 5-17.**

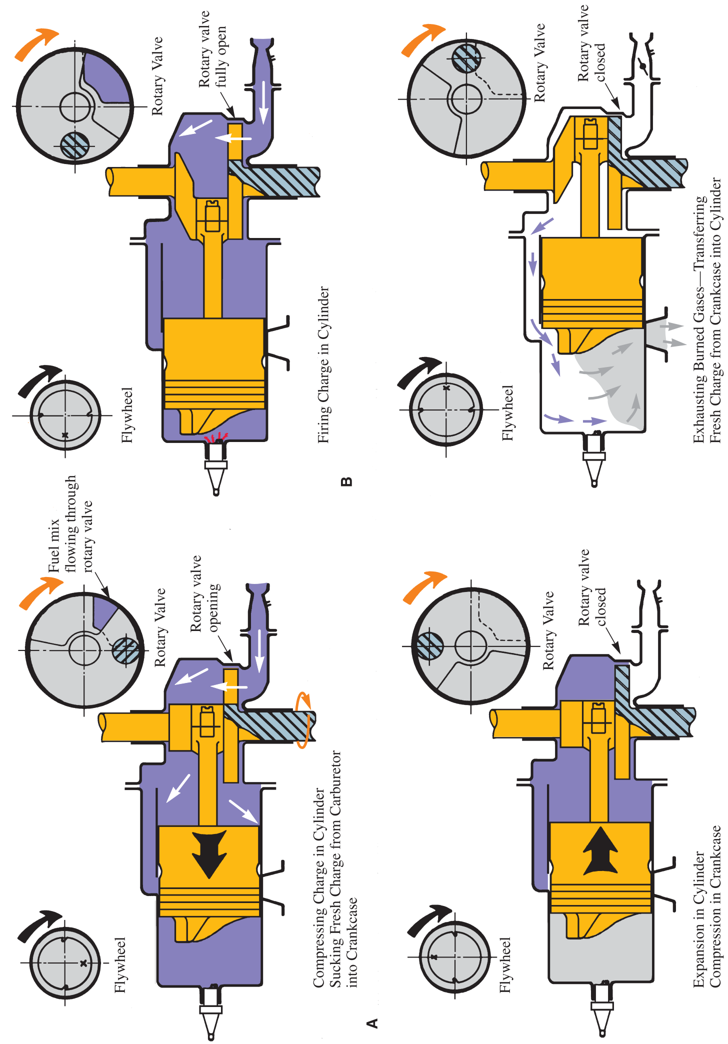

Figure 5-13. *These diagrams show how a rotary valve operates in a two-cycle engine. Since the rotary disc is part of the crankshaft, the port is open only when the hole in the disc and the crankcase port are in alignment. (Evinrude Motors)*

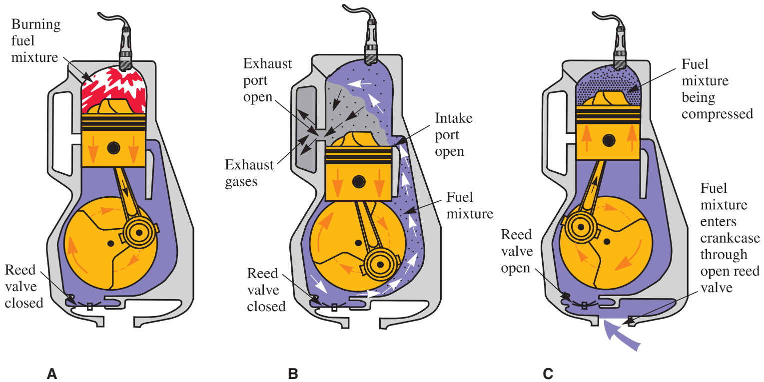

Figure 5-14. *A popular method of crankcase valving is a reed valve designed to fit into the crankcase wall. It relies upon the difference between atmospheric pressure and crankcase pressure to be opened. The default position of the reed valve is the closed position.*

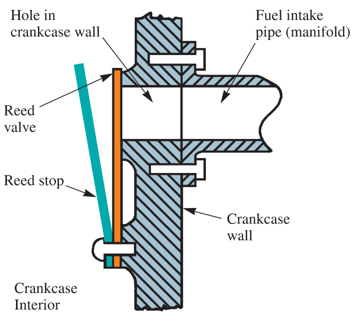

Figure 5-15. *This side view of a reed valve shows the spring steel reed covering the entry hole. The reed stop controls the distance the reed may open. This prevents permanent distortion and failure of the reed to return snugly against the port during crankcase compression.*

Four-Cycle Engine vs. Two-Cycle Engine

The advantages and disadvantages of any engine are directly related to the purpose for which the engine is intended. It cannot be said that one type of engine is better than another without considering every aspect of its application.

The chart in **Figure 5-18** lists the differences between two- and four-cycle engines.

Summary

The stroke of a piston is its movement in the cylinder from one end of its travel to another. Four-stroke cycle engines need four strokes to complete the operating cycle: intake, compression, power, and exhaust. Lubrication of four-cycle engines is generally provided by a splash system or a pump system.

In a two-stroke cycle engine, the intake, compression, power, and exhaust functions take place during two strokes of the piston. Two-cycle engines have many advantages over four-cycle units. They do not have conventional valves, tappets, or a camshaft, so they are simpler in design. Two-cycle engines are also smaller and lighter than four-cycle engines of equivalent horsepower.

The two-cycle engine receives its lubrication as a fuel-oil mixture is passed through the engine. Therefore, it will receive adequate lubrication even when operated at extreme angles.

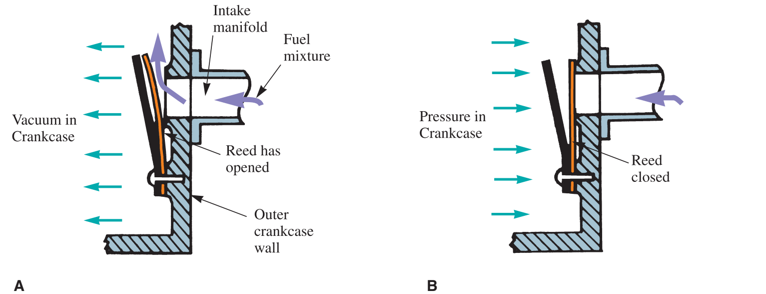

Figure 5-16. *Reed valve action. A—Vacuum in the crankcase, formed by the upward moving piston, causes atmospheric pressure to force air-fuel mixture through the port opening. B—Downward piston movement compresses the fuel mixture in the crankcase to a pressure greater than atmospheric pressure. The springiness of the reed and crankcase pressure act together to close the port.*

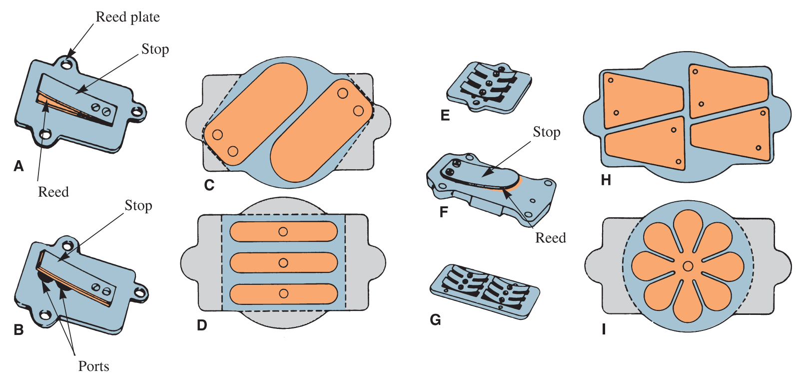

Figure 5-17. *Several forms of reed valves. A—Single reed, closed position. B—Single reed, open position. Note how the reed opening distance is controlled by the stop. C—Twin reed. D—Triple reed. E—Another form of triple reed. F—Single reed. G—Multiple reed. H—Four reed. I—Multiple reed.*

Characteristics	Four-Cycle Engine (equal hp) One Cylinder	Two-Cycle Engine (equal hp) One Cylinder
1. Number of major moving parts	Nine	Three
2. Power strokes	One every two revolutions of crankshaft	One every revolution of crankshaft
3. Running temperature	Cooler running	Hotter running
4. Overall engine size	Larger	Smaller
5. Engine weight	Heavier construction	Lighter in weight
6. Bore size equal hp	Larger	Smaller
7. Fuel and oil	No mixture required	Must be premixed
8. Fuel consumption	Fewer gallons per hour	More gallons per hour
9. Oil consumption	Oil recirculates and stays in engine	Oil is burned with fuel
10. Sound	Generally quiet	Louder in operation
11. Operation	Smoother	More erratic
12. Acceleration	Slower	Very quick
13. General maintenance	Greater	Less
14. Initial cost	Greater	Less
15. Versatility of operation	Limited slope operation (Receives less lubrication when tilted)	Lubrication not affected at any angle of operation
16. General operating efficiency (hp/wt. ratio)	Less efficient	More efficient
17. Pull starting	Two crankshaft rotations required to produce one ignition phase	One revolution produces an ignition phase
18. Flywheel	Requires heavier flywheel to carry engine through three nonpower strokes	Lighter flywheel

Figure 5-18. *This chart lists the differences between two-stroke and four-stroke cycle engines.*

Know These Terms

stroke
four-stroke cycle
intake stroke
compression stroke
power stroke
top dead center
exhaust stroke
scavenging
valve timing
bottom dead center
valve overlap
two-stroke engine
cross-scavenged
loop-scavenged
rotary disc valve
reed valve engine
reed stop

Chapter 5 Review Questions

Answer the following questions on a separate sheet of paper.

1. Name the four strokes of a four-cycle engine in proper order.
2. Name three important intake valve functions.
3. Explain why a four-cycle engine runs cooler than a two-cycle engine.
4. Why is there a difference in temperature between the intake and exhaust valves?
5. The exhaust valve is cooled mainly by __________.
   a. radiation
   b. conduction
   c. convection
   d. air-fuel circulation
6. How does compression increase engine power?
7. The compression ratio must be limited in gasoline spark ignition engines, because ________.
   a. there is no power advantage after compressing the fuel to a certain point
   b. the engine becomes too difficult to start
   c. mechanically it is not possible to increase the compression ratio
   d. the heat of compression will ignite the air-fuel mixture too soon
8. What are the two methods employed for lubricating four-cycle engines?
9. What are the two types of scavenging systems used in two-cycle engines?
10. Why can two-cycle engines be run in any position?
11. The baffle on a contoured piston is for __________.
    a. creating turbulent flow of gases
    b. slowing the air-fuel mixture entering the combustion chamber
    c. directing the flow of air-fuel mixture upward in the cylinder
    d. directing oil evenly to the cylinder walls
12. The __________ __________ type of two-cycle engine requires a contoured piston.
13. In a properly tuned exhaust system, ________ ________ prevent the air-fuel mixture from leaving with the exhaust.
14. What advantage is there in having the intake port lead directly into the crankcase?
15. Time during the four-stroke cycle when both valves are open is called ________ ________.
16. A four-cycle engine accelerates slower than a two-cycle engine, because __________.
    a. there is only one power stroke in four
    b. the flywheel is heavier to carry the engine through three nonpower strokes
    c. there are more moving parts to be driven by the engine
    d. All of the above.

Suggested Activities

1. Look up additional information about internal combustion engine development. Names to look up: Christian Huygens, Philip Lebon, Samuel Brown, William Barnett, Pierre Lenoir, Beau DeRochas, Dr. N. A. Otto, Atkinson, Gottlieb Daimler, Priestman and Hall, Herbert Akroyd Stuart, Rudolph Diesel.
2. Begin a collection of engine repair and service manuals.
3. Using a worn out engine, cut away portions that will make the working parts visible while still enabling them to move. Report on the operation and timing of each part. After further study, replace the spark plug of the cutaway engine with a small lightbulb switched on and off by the ignition switching system to simulate ignition.
4. Make a bulletin board display that illustrates the principles of two- and four-cycle engines.