Study Unit

# Two-Stroke Internal-Combustion Engines

By

**Ed Abdo**

# Author Acknowledgment

Edward Abdo has been actively involved in the motorcycle and ATV industry for over 25 years. He received factory training from Honda, Kawasaki, Suzuki, and Yamaha training schools. He has worked as a motorcycle technician, service manager, and Service/Parts department director.

After being a chief instructor for several years, Ed is now the Curriculum Development Manager for the Motorcycle Mechanics Institute in Phoenix, Arizona. He is also a contract instructor and administrator for American Honda's Motorcycle Service Education Department.

# Preview

From the previous study unit, you should have a good understanding of how the basic internal-combustion engine operates. You should also be able to identify the component parts and explain the theory of operation for four-stroke engines found on motorcycles and ATVs.

This study unit focuses on the two-stroke engine. We'll begin by identifying the components found in the two-stroke engine and then learn how the two-stroke engine operates. Next, we'll describe the different types of induction systems. After completing our look at the two-stroke engine, we'll discuss the differences between two-stroke engines and four-stroke engines. At the conclusion of this study unit, we'll look at the advantages and disadvantages of each of these engine designs.

When you complete this study unit, you'll be able to

- Visually identify the component parts used in a two-stroke engine including the piston, crankshaft, cylinder head, and cylinder
- Explain the theory behind the operation of the two-stroke engine
- Understand the different induction systems used on the two-stroke engine
- Describe how a two-stroke engine physically differs from a four-stroke engine
- Understand both the advantages and disadvantages of both the two- and four-stroke engines used in the modern motorcycle and ATV

# Contents

# Two-Stroke Internal-Combustion Engines

## INTRODUCTION

This study unit describes the components found in the two-stroke engine and explains how the two-stroke engine operates. The different types of induction systems (the way that the air-and-fuel mixture passes through two-stroke engines) are also described.

You've already learned that an engine is classified according to the number of strokes its piston takes to complete one full engine cycle. You've also learned that, in order for any engine to operate, it must run through four stages of operation: intake, compression, power, and exhaust. The four-stroke engine accomplishes these four stages in four piston strokes—one stroke for each stage. Now we'll learn how the two-stroke engine operates.

As you're aware, in a two-stroke engine the piston takes only two strokes to complete one full operational cycle. When the piston in a two-stroke engine moves in an upward direction, it completes the intake and compression stages. When the piston moves downward, it completes the power and the exhaust stages.

Two-stroke engines are much simpler in design than four-stroke engines. The basic two-stroke engine has only three moving parts: the piston, the connecting rod, and the crankshaft. Note that there's no camshaft used to operate valves for the flow of the air-and-fuel mixture or exhaust gases on the two-stroke engine.

Before you learn how two-stroke engines operate, we'll discuss the component parts used on two-stroke engines. You'll notice that many of the parts used on the two-stroke engine are similar, if not identical, to those used on the four-stroke engine.

## BASIC TWO-STROKE ENGINE COMPONENTS

We'll begin our coverage of two-stroke engine components with the basic parts. Illustrations and photographs are provided to help you identify the parts and their locations in the engine. As we've mentioned before, not all engines look exactly the same. The engines illustrated here are typical of many of the two-stroke engines you'll see.

# Two-Stroke Engine Cylinder Heads

The primary difference between the two-stroke engine cylinder head and the four-stroke engine cylinder head is that there are no ports (and therefore no valves) in the two-stroke cylinder head. This makes the two-stroke cylinder head much simpler to produce.

One purpose of the two-stroke cylinder head is to create a combustion chamber by sealing the area between the cylinder and the cylinder head (Figure 1). A second purpose is to hold the spark plug. The *squish area* of the combustion chamber forces the air-and-fuel mixture into a tight pocket under the spark plug to increase the combustion efficiency. This squish area, or as it's also known, *squish band*, is more critical in the two-stroke engine as compared to the four-stroke engine.

The modern two-stroke cylinder head is constructed of aluminum alloy. Like four-stroke cylinder heads, two-stroke cylinder heads also aid in the transfer of heat from the engine by the use of fins on air-cooled engines or water jackets on liquid-cooled engines.

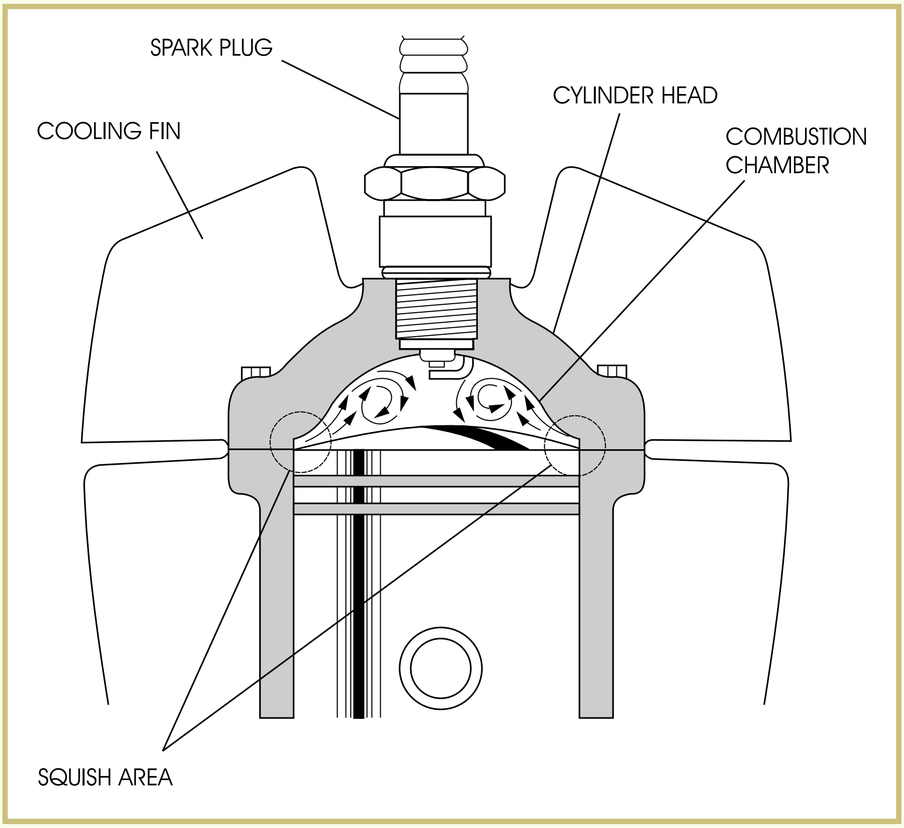



***FIGURE 1—Two-Stroke Cylinder and Cylinder Head*** (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

# Two-Stroke Engine Cylinders

The main difference between the two-stroke cylinder and the four-stroke cylinder is that the two-stroke cylinder has holes known as *ports* located in the cylinder wall (Figure 2). These ports serve the same purpose as the ports in the cylinder head of the four-stroke engine. Ports allow the air-and-fuel mixture to enter the cylinder and exhaust gases to leave the cylinder.

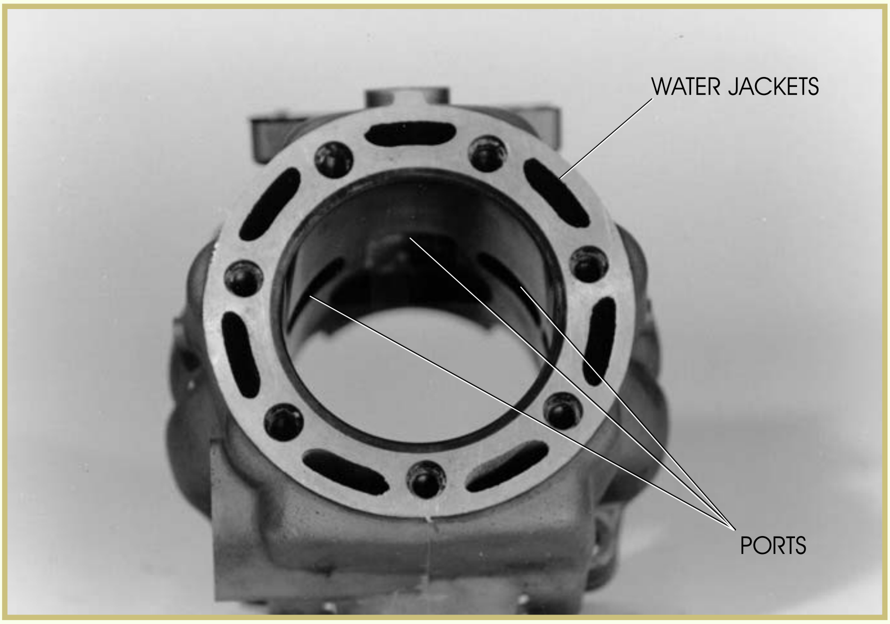



***FIGURE 2—Ports are located in the cylinder wall of the two-stroke engine. Water jackets help cool the cylinder.***

The ports in a two-stroke cylinder may be *bridged*. Bridged ports are used on very wide ports to prevent the piston ring from catching on the edge of the port. Both the upper and lower edges of the ports are *chamfered*. When ports are chamfered, the sharp edge of the port is removed to help keep the piston ring from catching as is moves up and down in the cylinder.

The ports that may be found in the two-stroke cylinder are the *exhaust port*, which is used to allow the exhaust gases to escape; *transfer ports*, which are used to transfer the intake gases from the bottom of the cylinder to the combustion chamber; and in many two-stroke cylinders, the *intake port*, which is used to allow the gases to enter the engine.

Like the four-stroke cylinder, the two-stroke engine cylinder guides the piston as it travels up and down. The cylinder also aids in transferring engine heat and may be either air cooled or liquid cooled. Also, just as with the four-stroke engine cylinder, there are different types of materials used in the construction of a two-stroke cylinder. Each material has its own advantages and disadvantages.

- Cast-iron cylinders have a one-piece design and can be fit with oversize pistons by boring to a larger size. When a cylinder is bored, material is removed from the cylinder to enlarge the hole. A larger *oversize* piston is then used in place of the previous piston. The cast-iron cylinder is inexpensive to manufacture but has poor heat transfer characteristics when compared to other materials used to construct cylinders. Cast-iron cylinders are also very heavy.

- Aluminum cylinders with cast-iron or steel sleeves have much better heat transfer abilities than cast-iron cylinders and are much lighter in weight. These cylinders can also be bored to a larger diameter. In most cases, the sleeve can be replaced if needed.

- Plated-aluminum cylinders, which are also called Nikasil or composite cylinders, have the best heat transfer characteristics of any cylinder produced today. They're the lightest-weight cylinder available and, when properly maintained, are the longest-lasting cylinders. The disadvantage of plated-aluminum cylinders is that they can't be bored to a larger diameter and therefore must be replaced when damaged. These cylinders are expensive to replace when compared to the other types of cylinders.

As with the four-stroke, two-stroke cylinders also have tiny scratches called *crosshatching* purposely installed into the cylinder wall. You'll recall that crosshatching is created by honing the cylinder wall with a cylinder hone. The purpose of honing is to help seat the piston rings and retain a very thin layer of oil on the cylinder walls to keep them properly lubricated.

## Pistons

The purpose of the two-stroke piston is to transfer the power produced in the combustion chamber to the connecting rod. The two-stroke piston has pins to prevent the piston rings from rotating around the piston (Figure 3).

The two-stroke piston is somewhat different in design from the four-stroke piston. Figure 4 illustrates the parts of the two-stroke piston.

- The *crown*, which acts as the bottom of the combustion chamber, is the top of the piston. The crown is the hottest part of the piston, due to combustion chamber temperatures. The crown area expands more than the rest of the piston because it's hotter and has more mass. The piston crown on the two-stroke engine normally has a positive dome, but may have a flat top or even a negative dome or dish. The piston crown on a two-stroke engine also controls the duration of the exhaust and transfer ports. *Duration* is the time that the ports are open and is measured in crankshaft degrees.

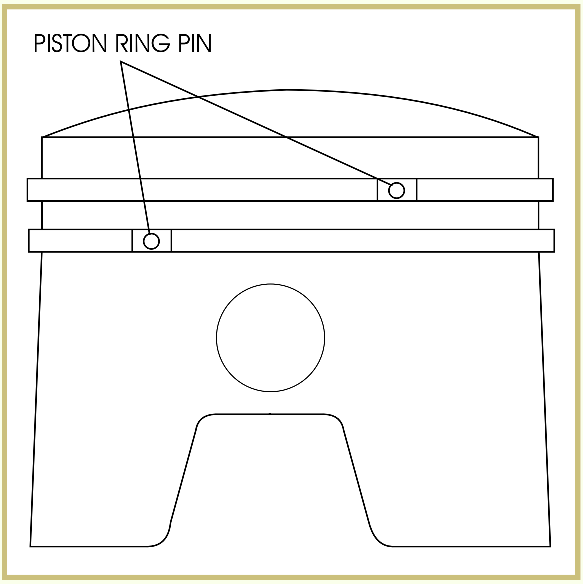



***FIGURE 3—Pins installed in the piston prevent the piston rings from rotating.*** (Courtesy of American Suzuki Motor Corporation)

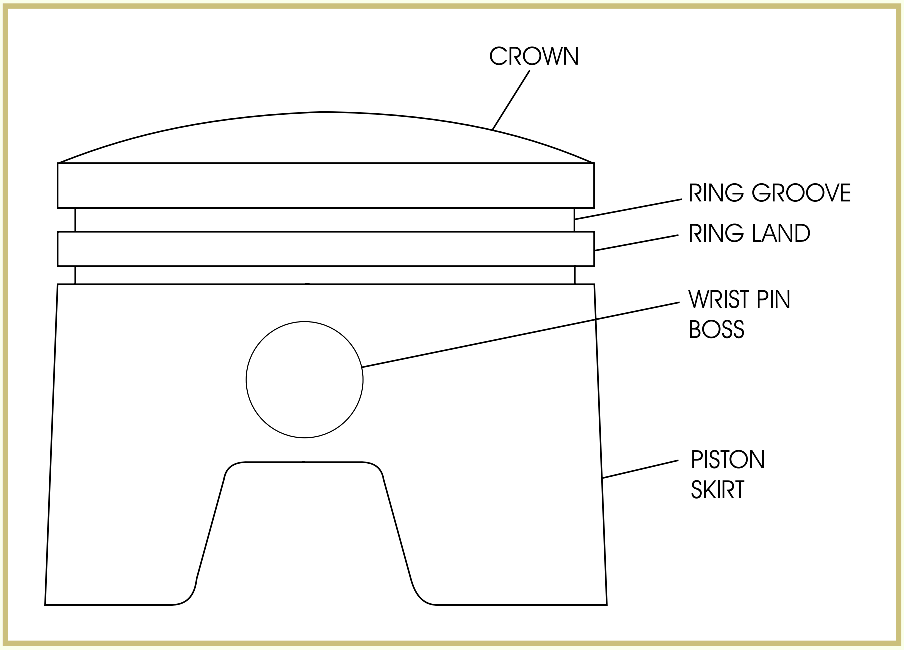



***FIGURE 4—The Parts of a Typical Two-Stroke Piston*** (Courtesy of American Suzuki Motor Corporation)

- The *ring grooves* have pins installed in them to prevent the piston rings from rotating. The two-stroke piston normally has no more than two piston ring grooves. *Piston ring lands* support the piston rings.

- The *wrist pin boss* is where the piston attaches to the small end of the connecting rod. A hardened tool-steel wrist pin attaches the piston to the rod. The wrist pin is normally held in place with retaining clips to prevent the wrist pin from contacting the cylinder wall.

- The *piston skirt* is the load-bearing surface of the piston. The piston skirt contacts the cylinder wall and is the primary wiping surface for the cylinder wall. The largest diameter of the piston is usually at or close to the bottom of the skirt, 90 degrees from the wrist pin. This is where the piston is normally measured. Two-stroke engines that use a reed valve induction system have a cutaway, or holes, machined on the intake side of the piston skirt. (Induction systems will be discussed later in this study unit.)

## Piston Rings

The purpose of the two-stroke piston ring is to aid in heat transfer from the piston to the cylinder wall and to seal in the combustion gases. There are three different types of piston rings used on the two-stroke piston (Figure 5).

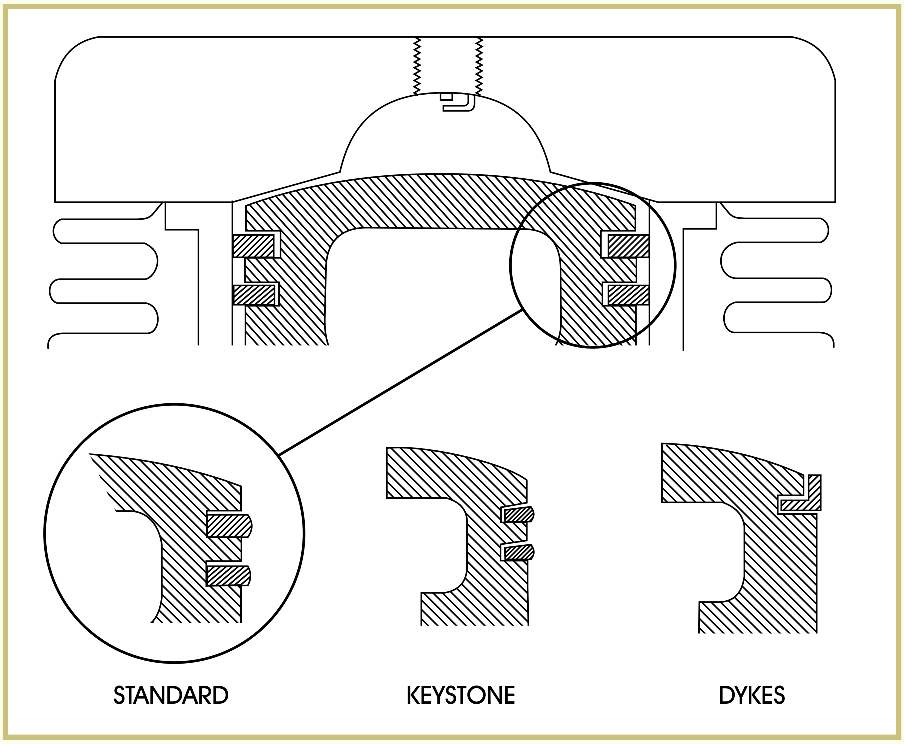



***FIGURE 5—Types of Two-Stroke Piston Rings*** (Courtesy of American Suzuki Motor Corporation)

- The *standard* piston ring is rectangular in shape and is the most popular ring found in the two-stroke engine. Standard rings are usually made of cast iron and are chrome plated.
- The *keystone* piston ring is a wedged-shaped ring that seals better than the standard piston ring. However, the keystone ring is more expensive to manufacture and requires a special wedge-shaped piston groove.
- The *Dykes* piston ring is an L-shaped ring that's only used as a top ring on the piston. This type of piston ring expands outward when the combustion gases force the piston downward. Al-

though the Dykes ring is the most expensive piston ring to produce, it's also the best-sealing ring found on a two-stroke piston.

All piston rings must have an end gap to allow for heat expansion. As we discussed in the previous study unit, the piston ring end gap is measured using a feeler gauge (blade) after fitting the ring squarely in the cylinder. In the two-stroke engine, the ring end gap fits around the piston pin that prevents the ring from rotating around the piston.

## Crankshafts

The two-stroke engine normally uses a multipiece crankshaft similar to that used on the four-stroke engine. The crankshaft halves are cast or forged. The connecting rod journal is a pin (crankpin) that's press-fit into the crankshaft halves. A one-piece connecting rod uses a roller bearing at the connecting-rod journal. The multipiece crankshaft generally uses ball bearings on the main journals. Most multipiece crankshafts can be rebuilt.

## Multicylinder Crankshafts

As with four-stroke engine designs, two-stroke multicylinder crankshafts use different offset positions for each cylinder, depending on the design. However, a major difference between the four-stroke multicylinder crankshaft design and the two-stroke multicylinder crankshaft design is that in a two-stroke engine, the areas below the cylinders are sealed from each other. This is done by using a *labyrinth seal* (Figure 6). The labyrinth seal is stationary and doesn't touch the crankshaft journal, although it has an extremely close tolerance. When the engine is running, the labyrinth area fills with fluid which forms a seal to separate the cylinders.

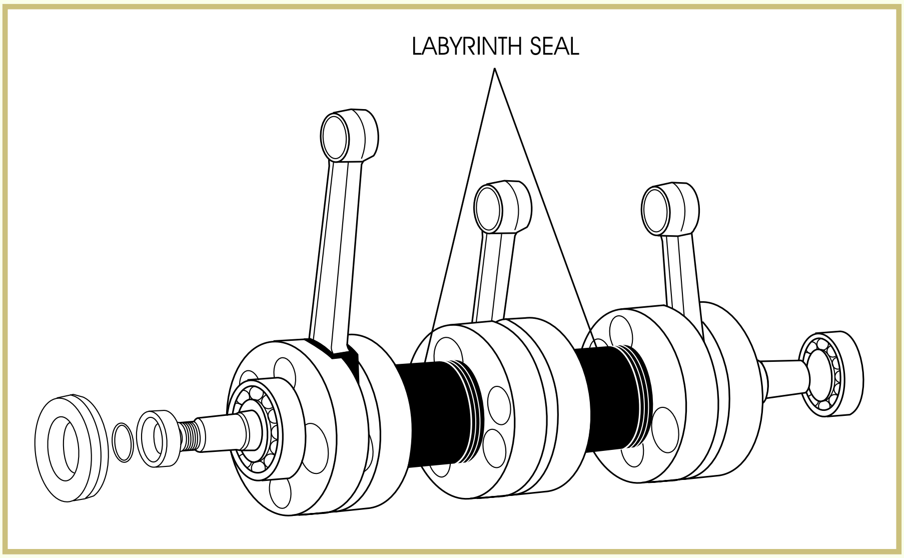



***FIGURE 6—This illustration shows a three-cylinder two-stroke crankshaft with two labyrinth seals.*** (Courtesy Kawasaki Motor Corp., U.S.A.)

- In the 360° design, both pistons move up and down together. This design requires more counterweight and tends to vibrate at higher engine speeds.
- In the 180° design, the pistons move in opposite directions. This design requires less counterweight and has less vibration at higher engine speeds. On an in-line four-cylinder engine, a pair of 180° crankshafts are used.
- In the 120° design, the pistons move 120° apart from each other. This design is used on three-cylinder two-stroke engines.

## Connecting Rods

The connecting rod is a lever that transfers power from the piston to the crankshaft. Connecting rods are usually made of forged steel or aluminum and use an I-beam construction. The connecting rods found on two-stroke engines are normally a one-piece design. This design uses a roller bearing at the big end and a needle bearing at the small end of the rod. The one-piece connecting rod normally has holes or slots on both the small and large ends for added lubrication.

## Crankcases

The purpose of the two-stroke crankcase is the same as that of the four-stroke crankcase—to contain and support the major engine components. These components can include the crankshaft, cylinder, primary drive, and transmission. Unlike the four-stroke engine, which requires ventilation, the two-stroke crankcase must be sealed from the atmosphere and from the transmission area to allow pressure to build up inside the engine. The two-stroke crankcase assembly is very similar in design to the four-stroke crankcases that you've already learned about. The two-stroke engine crankcase is assembled in one of the following fashions.

- The vertically split crankcase consists of two case halves that separate vertically. This design requires the removal of the cylinders before the case halves can be split.
- The horizontally split crankcase consists of two case halves that separate horizontally. This design allows the bottom half to be removed with the cylinders still attached to the top half.

## Exhaust Port Power Valves

The basic two-stroke engine has a limited *power band*. This means that the engine makes usable power within only a very small rpm range, especially when compared to the four-stroke engine. Motorcycle and ATV manufacturers of two-stroke engines have developed variations of components known as *exhaust power valves* to help increase the power band and improve engine performance. These two-stroke exhaust valve designs help to use the engine's speed to change the port timing and therefore change the power characteristics of the engine as it's running. There are many different designs of power ports used on motorcycles and ATVs. We'll briefly discuss some of the most popular systems.

One design uses a cylindrical valve that's incorporated into the exhaust port. This valve matches the shape of the port and rotates to increase or reduce the exhaust port height, which changes the exhaust port timing. By changing the exhaust port timing, we can change where the engine makes the most power.

Another design uses two sliding guillotine valves activated by rocker arms. The rocker arms are controlled by centrifugal force, which allows the valves to open and close at a predetermined engine speed.

Still another power port system changes the actual volume of the exhaust system using a subchamber. By changing the volume of the exhaust system's expansion chamber, we can also change where the engine makes the most power and therefore change the effective power band.

Finally, there's a system that uses both a valve to alter the exhaust port height and a device to change the exhaust chamber volume. This system obtains optimum performance at all engine speeds and creates a very wide power band.

## Exhaust System Expansion Chambers

The two-stroke exhaust system is a tuned chamber that operates from sonic (sound) waves created by the engine. The shape of the chamber has a direct effect on the performance of the two-stroke engine's operational characteristics. The parts of the expansion chamber that create the shape and allow for differences in power delivery are shown in Figure 7. The shape of the expansion chamber also aids in the scavenging of residual exhaust gases and allows for an adjustment of the power band characteristics of the engine.

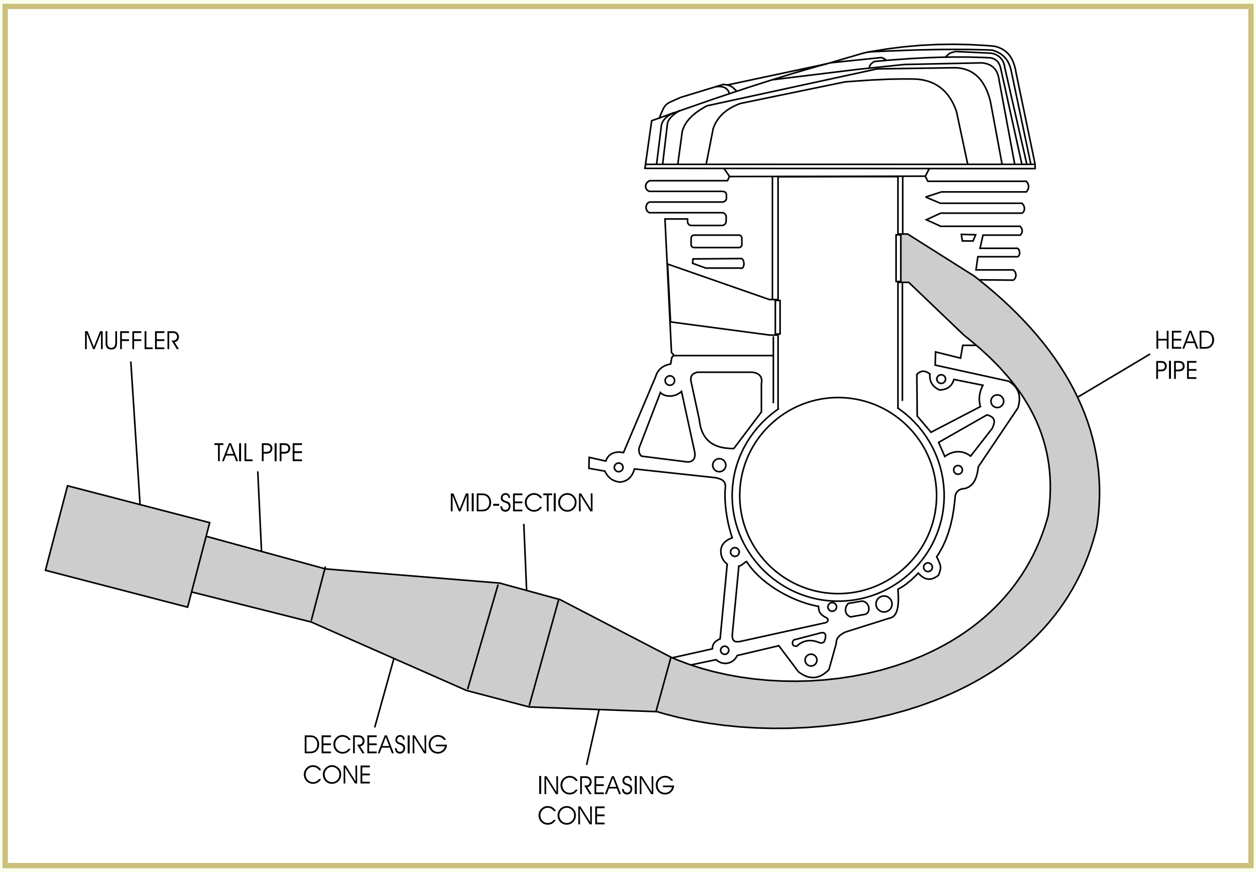
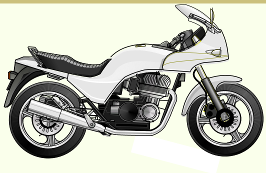



***FIGURE 7—Expansion Chamber Used with a Two-Stroke Engine*** (Courtesy of American Suzuki Motor Corporation)

# *Road Test 1*



**At the end of each section of *Two-Stroke Internal-Combustion Engines*, you'll be asked to check your understanding of what you've just read by completing a "Road Test." Writing the answers to these questions will help you review what you've learned so far. Please complete *Road Test 1* now.**

1. The three types of piston rings used on the two-stroke engine are the _______ ring, the _______ ring, and the _______ ring.

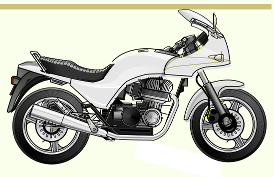
2. The two-stroke piston uses _______ placed in the piston grooves to prevent the piston rings from rotating in the cylinder.

3. The two-stroke engine normally uses a _______ crankshaft.

4. The crown of the piston controls the duration of the _______ and the _______ ports.

*(Continued)*

# *Road Test 1*



5. The two-stroke piston ______ may be cut away or have slots machined in it on the intake side when used with reed valve induction systems.

6. *True or False?* The labyrinth seal is stationary and doesn't touch the crankshaft journal.

7. *True or False?* Crankcases used on the two-stroke engine are sealed from the atmosphere.

8. The cylinders used on the two-stroke engine contain ______ to allow for the flow of gasses through the engine.

**Check your answers with those on page 29.**

# TWO-STROKE ENGINE THEORY OF OPERATION

Although a two-stroke engine has many of the same components as a four-stroke engine, its method of operation is very different. You'll remember that in a four-stroke engine, one power stroke occurs every two revolutions of the crankshaft. In a two-stroke engine, one power stroke occurs for each crankshaft revolution. Two-stroke engines are much simpler in design than the four-stroke engine. The basic two-stroke engine has only three moving parts: the piston, the connecting rod, and the crankshaft. However, the two-stroke engine is much more complex in its operation.

The moving parts in all engines must be lubricated with oil to prevent wear. Although we'll discuss the lubrication systems used on two-stroke engines at a later time, it should be noted that the two-stroke engine mixes the oil used for lubrication of the engine components with the fuel supply.

## The Four Stages of Engine Operation

Remember, the two-stroke engine must go through the same four stages of engine operation as any internal-combustion engine—intake, compression, power, and exhaust. However, where the four-stroke engine uses one piston stroke to accomplish each stage, the two-stroke engine accomplishes the four stages in just two piston strokes (Figure 8). Each time the piston moves upward, it completes the intake and compression stages. Each time the piston moves downward, it completes the power and exhaust stages. Because two stages of engine operation occur for each piston stroke, the operation of the two-stroke engine is more complex.

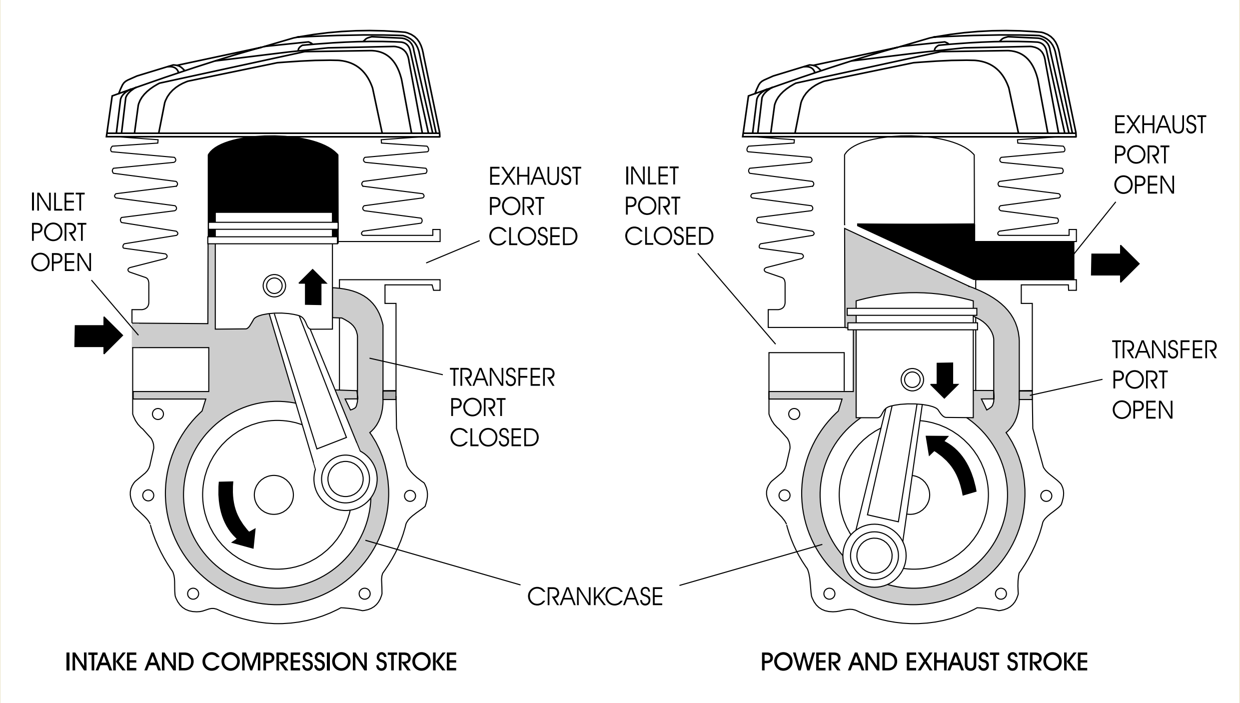



***FIGURE 8—In a two-stroke engine, as the piston moves upward, it completes the intake and compression stages of operation. As the piston moves downward, it completes the power and exhaust stages of operation.***

## Two-Stroke Engine Areas

The two-stroke engine is split into two different areas (Figure 9). The *primary area* is the area below the piston crown including the crankcase. The crankcase in a two-stroke engine must be sealed to allow for the compression of the intake gases while they're in the primary area. The *secondary area* is the area above the piston crown including the combustion chamber where the air-and-fuel mixture is compressed to prepare for ignition.

## Two-Stroke Engine Ports

Two-stroke engines don't use the same mechanical valves in the combustion chamber as the four-stroke engine. Instead, the two-stroke engine has holes in the cylinder walls that are called *ports* (Figure 10). These ports control the flow of the air-and-fuel mixture and exhaust gases. As the piston moves up and down in the cylinder, it covers and uncovers these ports, allowing the air-and-fuel mixture to enter while also allowing the removal of the exhaust gases.

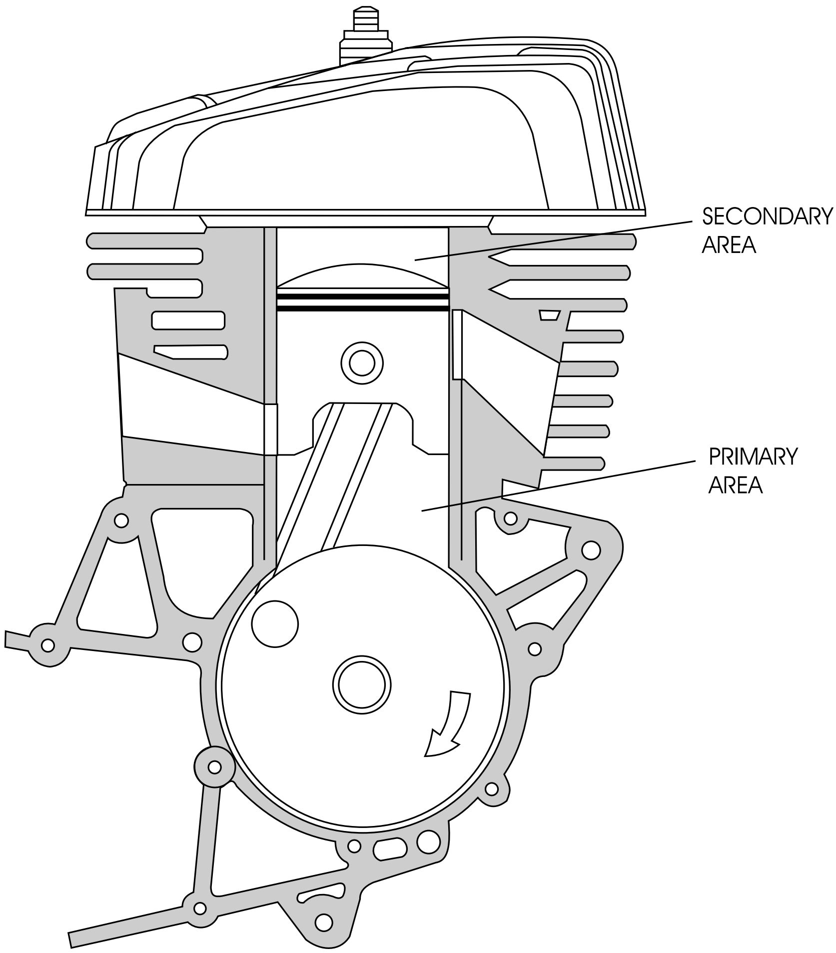



***FIGURE 9—The area below the piston is called the primary area. The area above the piston is called the secondary area.*** (Courtesy of American Suzuki Motor Corporation)

Two-stroke engines have different types of ports to allow for the flow of intake and exhaust gases.

- The *intake port* is used to control the flow of fresh air and fuel into the primary area (crankcase area). Depending on the induction system used, the intake port either is the lowest port in the cylinder or is in the crankcase.

- The *boost port* isn't used on all two-stroke cylinders. It's found primarily on two-stroke engines using reed valves. When boost ports are used, there may be one or more which are located at the rear of the cylinder, opposite the exhaust port. The purpose of a boost port is to allow an extra amount of the air-and-fuel mixture to flow into the combustion chamber directly from the intake port area. This directly bypasses the crankcase and transfer ports to help fill the secondary area with additional fresh air and fuel to produce more power.

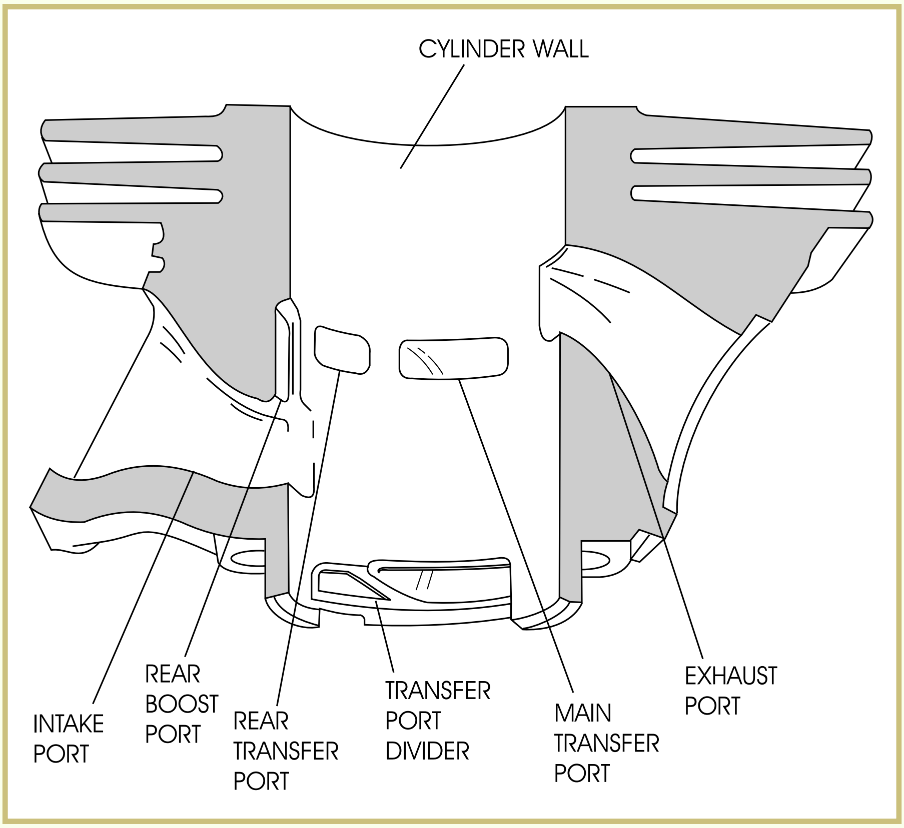



***FIGURE 10—This cutaway view of a two-stroke cylinder shows the ports.***
(Image courtesy of Yamaha Motor Corporation, U.S.A.)

- The *transfer ports* are used to control the transfer of the air-and-fuel mixture from the primary area to the secondary area. The transfer inlet is located at the bottom of the cylinder where it meets the crankcase assembly. The transfer outlet is located in the middle of the cylinder, attached to the crankcase through a transfer tube which is cast into the cylinder. The transfer ports are controlled by the position of the piston crown. The number of transfer ports varies from engine to engine. When more than two transfer ports are used, the extra ports are called auxiliary ports.
- The *exhaust port* controls the flow of the exhaust gases from the cylinder. The exhaust port is the highest port in the cylinder. The opening and closing of the exhaust port is controlled by the position of the piston crown.

## Two-Stroke Engine Events

There are five physical events that occur in each engine cycle of a two-stroke engine (Figure 11). To complete all five events, it takes only two strokes of the piston, which is one revolution of the crankshaft.

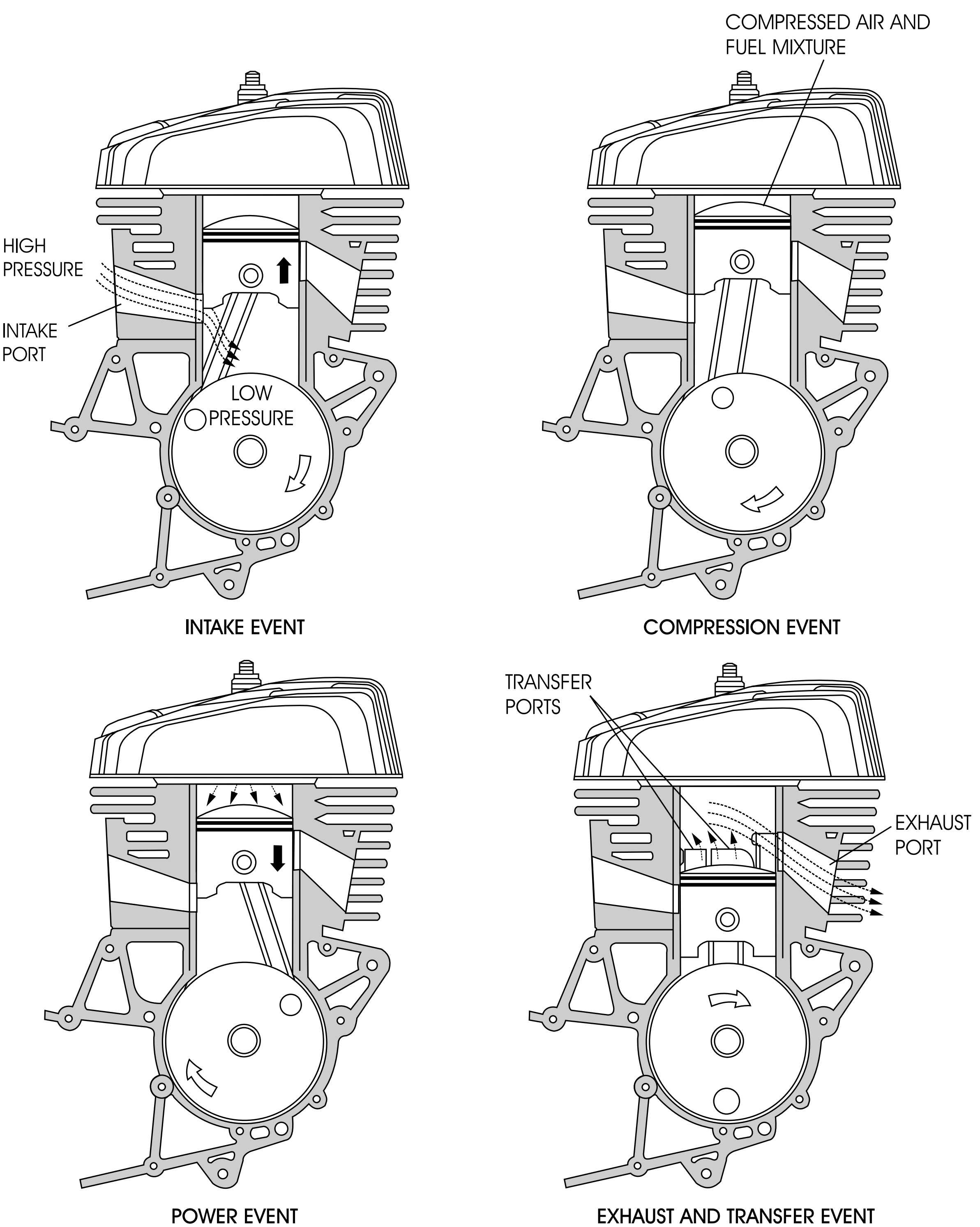



***FIGURE 11—This illustration shows the five events that occur in one crankshaft revolution on a two-stroke engine.*** (Courtesy of American Suzuki Motor Corporation)

- The *intake event* begins when the piston moves toward *top dead center* (*TDC*). The primary area located below the piston increases in size, which causes the pressure to decrease. Because of the pressure difference, fresh air and fuel are pushed into the primary area through the intake port. The intake event has the longest port duration of all of the two-stroke events.
- The *compression event* (also known as *secondary compression*) occurs as the secondary area decreases above the piston. The air-and-fuel mixture that was previously brought into the cylinder is compressed while the piston is still moving towards TDC. At a precise time, the ignition fires and creates a spark at the spark plug.
- The *power event* begins after TDC when the expanding combustion gases caused by the ignition force the piston downward. The power event ends when the exhaust port is uncovered by the piston (opens).
- The *exhaust event* begins when the piston crown uncovers (opens) the exhaust port while moving down towards *bottom dead center* (*BDC*). Because of the high pressure in the cylinder, the exhaust gases are pushed into the exhaust system.
- The *transfer event* also occurs as the piston is moving toward BDC. While the piston is traveling downward, the primary area is decreasing, which increases the primary-area pressure. This is known as *primary compression* on a two-stroke engine. While this is occurring in the primary area, the secondary-area pressure is decreasing. Because of the pressure differences between the primary and secondary area, the fresh air-and-gas mixture located in the primary area is pushed through the transfer ports into the secondary area. The transfer event occurs during the exhaust event, which helps scavenge (similar to four-stroke valve overlap) residual exhaust gases by pushing the remaining exhaust gases out the exhaust port. The transfer event has the shortest port duration time. The transfer event uses what's known as *loop scavenging*, in which the transfer ports are angled away from the exhaust ports. The angle of the transfer ports directs the fresh air-and-fuel mixture up and away from the exhaust port to prevent the mixture from directly flowing out of the port.

## Expansion Chambers

The two-stroke engine exhaust systems used on motorcycles and ATVs provide much more than just a simple escape path for exhaust gases. As the piston moves downward on the power stroke, the exhaust port opens (Figure 12A). A high-pressure wave of exhaust escapes from the combustion chamber and travels down the head pipe to the expansion chamber. The wave expands and slows as it enters the large portion of the expansion chamber. As the wave expands, a vacuum is created behind it, helping to draw out any remaining exhaust gases from the combustion chamber.

The wave flows through the center section of the expansion chamber, then compresses and accelerates as it reaches the tapered exhaust end. A portion of the high-pressure wave is reflected back toward the exhaust port as it contacts the tapered end of the expansion chamber (Figure 12B). The reflected pressure travels back up the head pipe and helps keep the fresh air-and-fuel mixture from escaping out the exhaust port (Figure 12C).

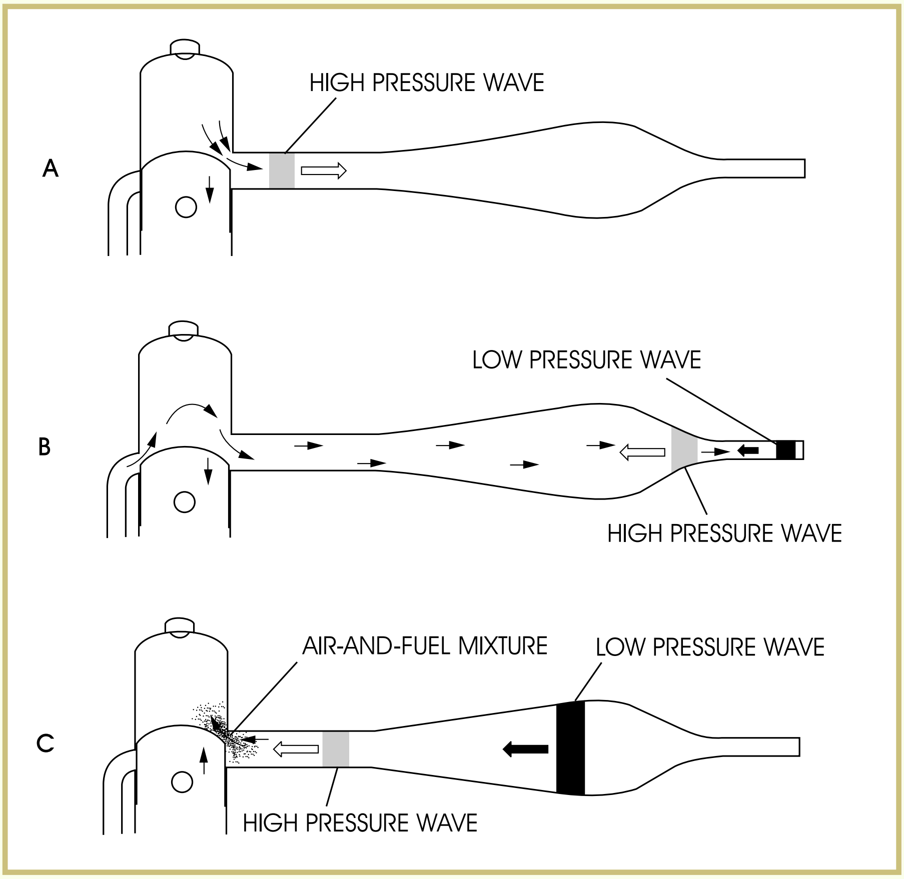


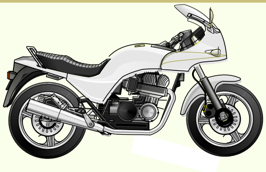

***FIGURE 12—This illustration shows how a two-stroke engine expansion chamber operates.*** (Image courtesy of Yamaha Motor Corporation, U.S.A.)

The remainder of the high-pressure wave travels out the tailpipe and is exhausted to the atmosphere. As the wave exits the tailpipe, it creates a low-pressure wave that moves back up the tailpipe behind the reflected high-pressure wave. The low-pressure wave is timed to arrive at the exhaust port to draw or scavenge the exhaust gases after the next power stroke. The expansion chamber must be properly tuned to permit the pressure waves to cause the desired effect.

Exhaust pressure waves have a direct relationship to engine speed; therefore, exhaust-pulse scavenging isn't always effective. The scavenge effect works only within a narrow range (or power band) of engine speed. This means that different exhaust-system designs are required for different motorcycle and ATV applications.

Be aware that a damaged exhaust system affects exhaust scavenging and results in a loss of power. Likewise, if the exhaust system is allowed to get excessively dirty, performance is also affected.

# *Road Test 2*



1. There are _______ physical events that allow the two-stroke engine to operate.
2. *True or False?* The two-stroke engine completes one power cycle for every revolution of the crankshaft.
3. The three basic moving parts of a two-stroke engine are the _______, the _______, and the _______.
4. The lowest port in a two-stroke cylinder is the _______ port.
5. The highest port in a two-stroke cylinder is the _______ port.
6. *True or False?* The two-stroke engine uses mechanical valves to control the flow of intake and exhaust gases.
7. The _______ port is located in the middle of the cylinder.
8. The _______ event has the longest port duration time in the two-stroke engine.
9. The _______ event has the shortest port duration time in the two-stroke engine.
10. The _______ opens and closes the ports in a two-stroke engine.

**Check your answers with those on page 29.**

## TWO-STROKE ENGINE INDUCTION SYSTEMS

As we've discussed, the intake air-and-fuel mixture flows through ports inside the engine. Two-stroke engines use different methods of controlling the intake flow by what's known as induction. *Induction* is the method used to pass the air-and-fuel mixture through the intake port of the engine. Two-stroke motorcycle and ATV engines use three different types of induction.

# Piston Port Induction

The piston port engine is the oldest and simplest type of two-stroke engine. This engine design contains all three engine ports (intake, transfer, and exhaust) in the cylinder walls. As the piston moves up and down, it covers or uncovers the ports.

The piston skirt opens and closes the intake port. As with all two-stroke engines, the piston port engine has a sealed crankcase. As the piston moves upward, low pressure is created in the crankcase. The intake port is uncovered and the air-and-fuel mixture is drawn into the crankcase. As the piston continues to move up the cylinder, the exhaust and transfer ports are covered and the air-and-fuel mixture that's already in the combustion chamber is compressed.

When the piston approaches TDC, the spark plug fires and ignites the air-and-fuel mixture in the combustion chamber. The piston is forced downward by the expanding gases and the exhaust gases flow out the exhaust port. As the piston is moving downward, the air-and-fuel mixture in the crankcase is compressed. The transfer port is still closed at this time. As the piston continues downward, the piston uncovers the transfer port. When the transfer port is uncovered, the air-and-fuel mixture moves from the crankcase area, through the transfer port, and into the combustion chamber side of the piston. As the air-and-fuel mixture enters the combustion chamber, it helps to remove the remaining exhaust gases. When the piston starts to rise, the intake and compression stage begins again.

The piston port engine has the narrowest power band of all two-stroke engines. This engine design may be tuned to run at low speed or high speed, but not both. If the piston port engine is tuned to run at high speed but is operated at low speed, the carburetor tends to allow fuel to come back out the carburetor. This occurrence is called *spit back.*

# Reed Valve Induction

To aid in keeping the crankcase sealed and prevent a loss of pressure as the piston moves downward, most modern two-stroke motorcycle and ATV engines use small one-way valves called *reed valves* (Figure 13). A reed valve opens during the intake-and-compression stage and then closes tightly during the power-and-exhaust stage to seal the crankcase area and prevent any of the fuel mixture from escaping back into the carburetor. This prevents spit back.

A reed valve is generally placed between the carburetor and the intake port of the engine. As the piston moves upward during the intake-and-compression stage of operation, the air-and-fuel mixture is pulled through the reed valve into the crankcase. When the piston reaches TDC, the reed valve closes to prevent the air-and-fuel mixture from flowing back through the carburetor. In this way, the air-and-fuel mixture is compressed more completely in the crankcase, which allows it to be pushed more forcefully into the combustion chamber as the piston reaches BDC.

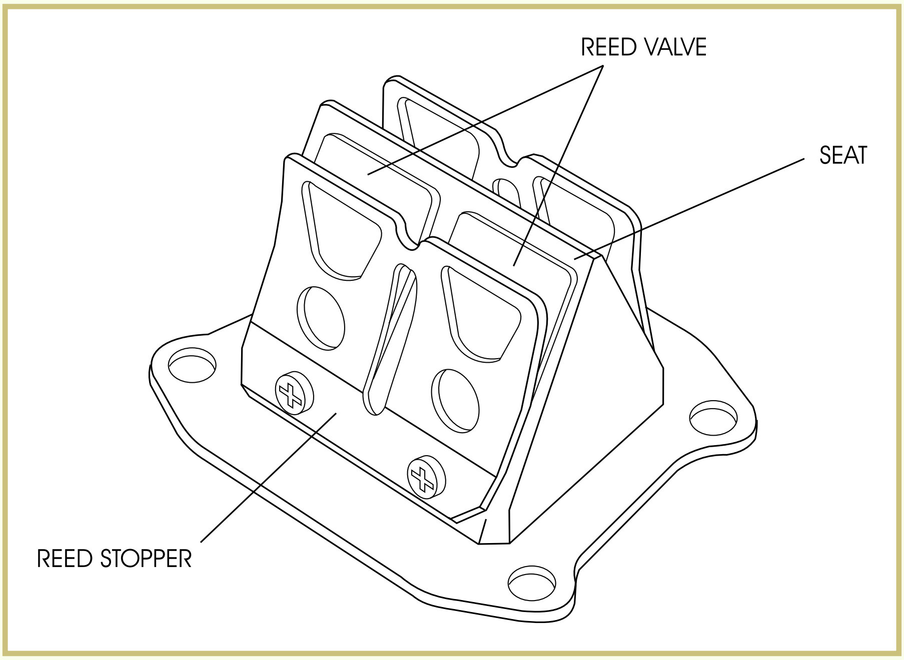



***FIGURE 13—A Typical Reed Valve*** (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

The piston of a reed valve engine has either a cutaway or holes on the intake side of the piston skirt to allow the flow of the intake mixture at all possible times (Figure 14). Reed valves are made from one of two materials: stainless steel or fiber resin material (fiberglass or carbon fiber). There are different types of reed valve induction systems used on motorcycle and ATV two-stroke engines.

- The *cylinder reed* valve induction design (Figure 15) has the intake port in the same location as the piston port engine (located on the cylinder). With a cylinder reed valve engine, the intake port never closes. The purpose of the cylinder reed valve engine is to broaden the standard piston port engine power band. By using reed valves on a piston port engine, we can tune the engine to run at high speed while the valve prevents spit back through the carburetor at lower speeds.

- The *crankcase reed* valve induction system (Figure 16) has the intake port located directly on the crankcase. This design can develop a very wide power band because it allows a shorter and more direct path to the crankcase and permits approximately ⅓ more transfer port area. This lets more air and fuel enter the combustion chamber.

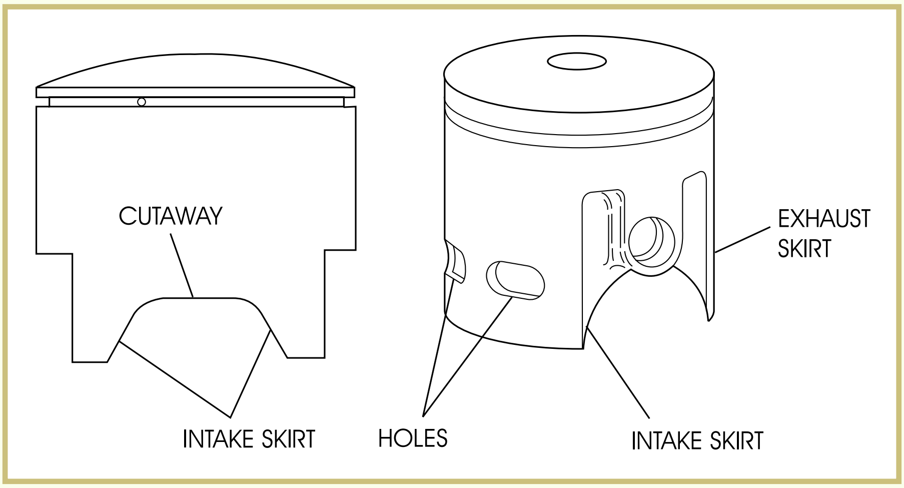



***FIGURE 14—This illustration shows two types of reed valve pistons. The piston on the left uses a cutaway on the intake side of the piston skirt. The piston on the right has holes on the intake side of the piston skirt.*** (Image courtesy of Yamaha Motor Corporation, U.S.A.)

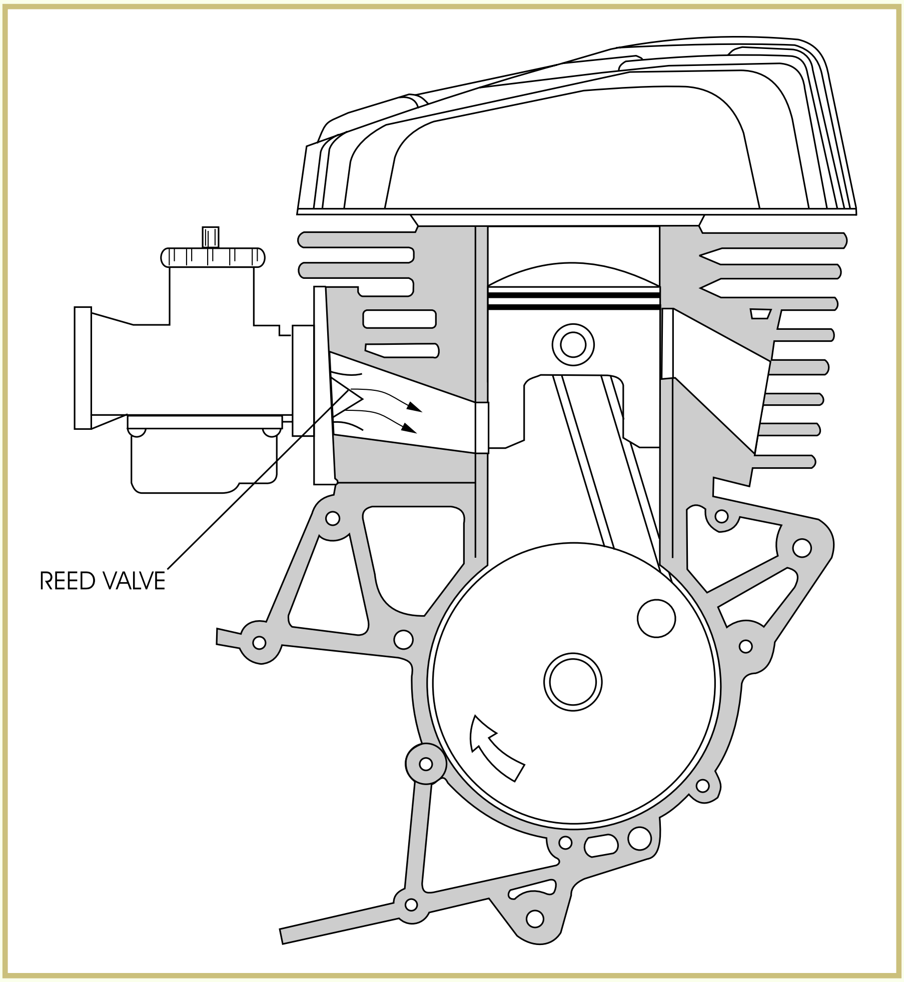



***FIGURE 15—This illustration shows the location of the reed valve in a cylinder reed valve induction system.*** (Courtesy of American Suzuki Motor Corporation)

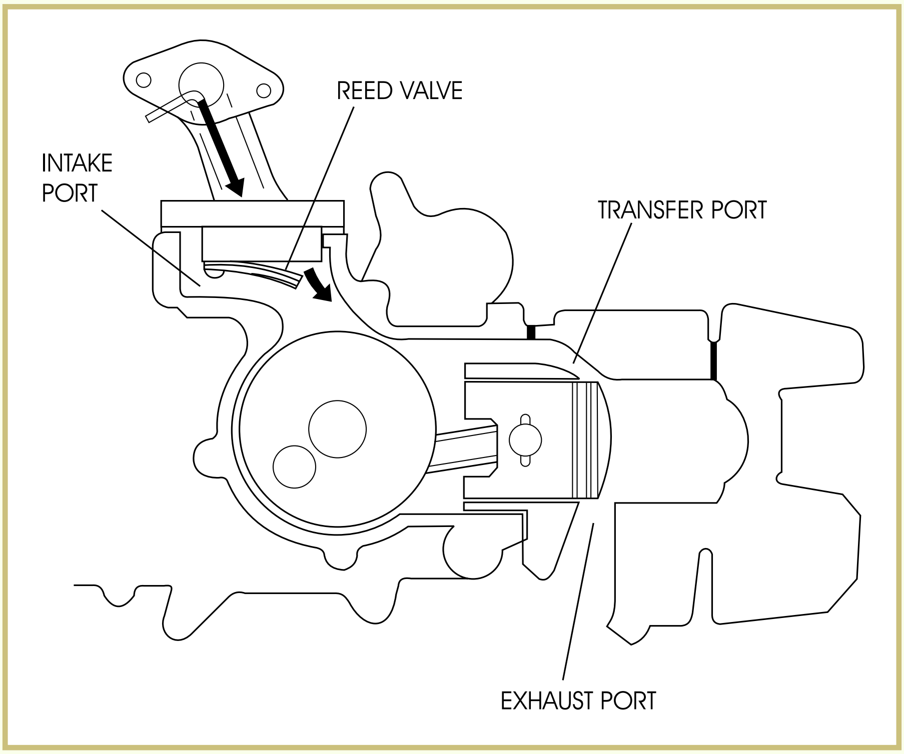



***FIGURE 16—This illustration shows the location of the reed valve in a crankcase reed valve induction system.*** (Courtesy of American Suzuki Motor Corporation)

- The *piston port/crankcase reed* induction system (Figure 17) takes the benefits of both the piston port type of induction to control the lower-speed range of the engine and the crankcase reed induction system for high-speed operation. This system is found primarily on Suzuki motorcycles.

## Rotary Valve Induction

The rotary valve induction system has the intake port located on the crankcase of the engine (Figure 18). The opening and closing of the port is controlled by a rotary disk that covers and uncovers the intake port. The disk is attached directly to the crankshaft. When the cutaway opening on the disk aligns with the intake port, fuel flows into the crankcase. In a rotary valve assembly, the rotary plate rotates between two fixed plates, or between a fixed plate and the crankcase. The two fixed plates, or fixed plate and crankcase, also contain openings. Fuel enters the crankcase only when all three holes line up during the rotation of the rotary plate. At all other times, the passage from the carburetor to the crankcase is blocked by the rotary valve.

The rotary valve engine design is seldom used on newer motorcycles because of its size. Rotary valve engines have the carburetors attached to the crankcase near the crankshaft and each cylinder has its own disk, which requires that the engine be wider than other designs. This engine design generally has the widest power band because it has the shortest and most direct intake path into the primary area of the crankcase.

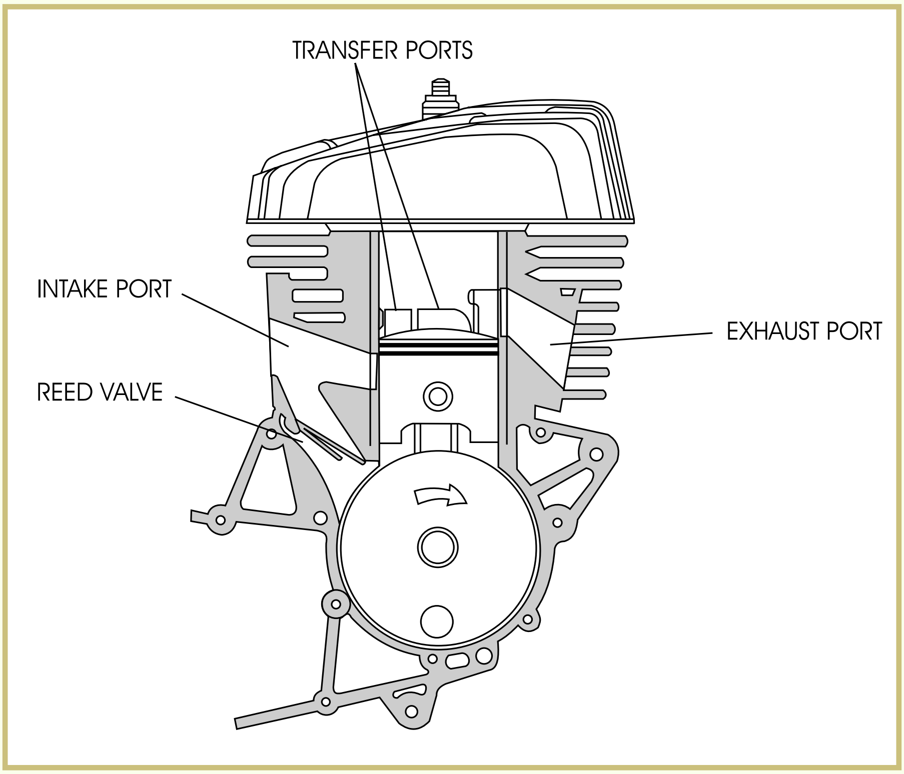



***FIGURE 17—This illustration shows the location of the reed valve in a piston port/crankcase reed induction system.*** (Courtesy of American Suzuki Motor Corporation)

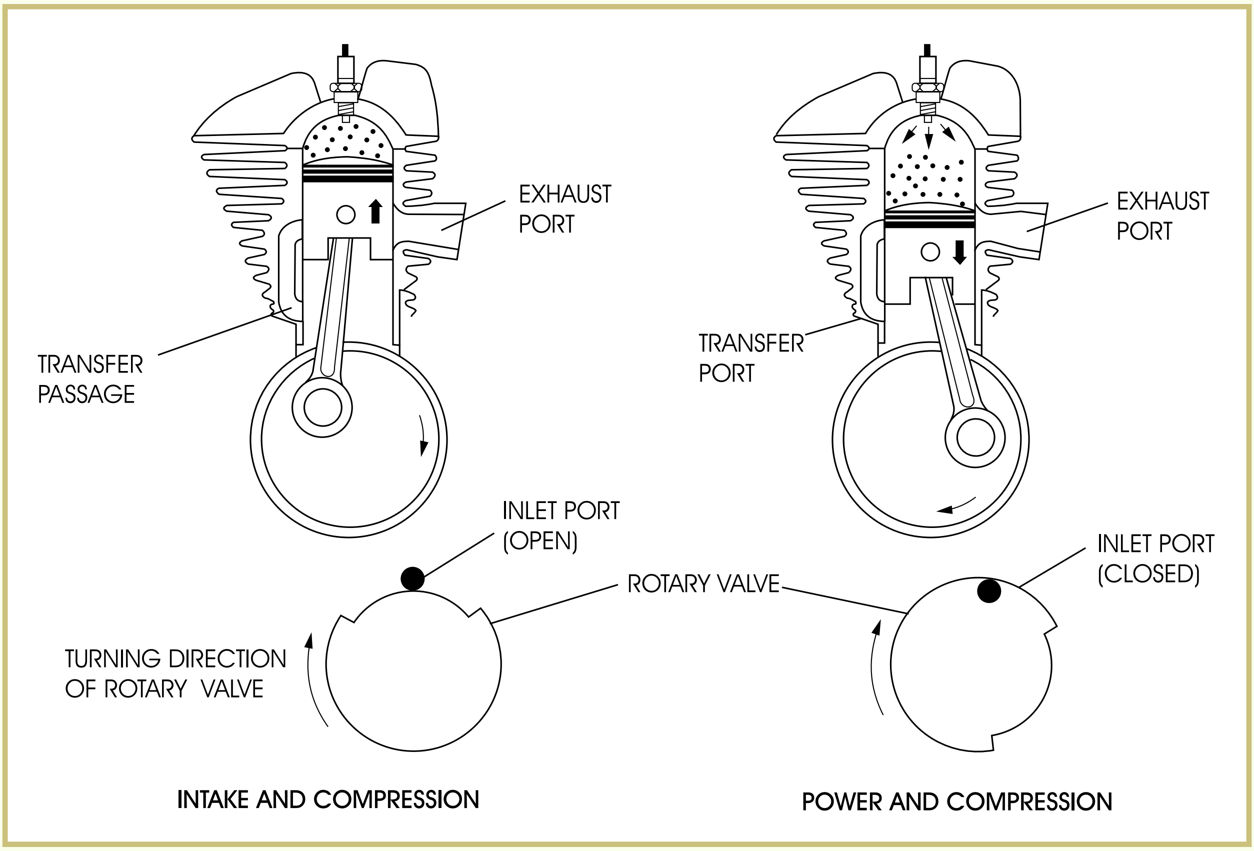
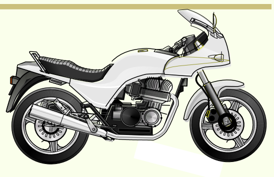



***FIGURE 18—This illustration shows a rotary-valve two-stroke induction system.*** (Image courtesy of Yamaha Motor Corporation, U.S.A.)



# Road Test 3

1. The _______ induction system is the oldest and simplest design.
2. *True or False?* The cylinder reed valve engine generally has the widest power band of all two-stroke engine induction systems.
3. *True or False?* The rotary valve engine has the shortest and most direct path into the crankcase.
4. There are _______ different types of induction systems used on motorcycles and ATVs.
5. A reed valve is typically made of _______ or _______.
6. The reed valve is _______ (open/closed) during the intake-and-compression stage.

**Check your answers with those on page 29.**

# COMPARING TWO-STROKE ENGINES TO FOUR-STROKE ENGINES

There are many advantages and disadvantages when comparing two-stroke and four-stroke engines. Because each engine is specifically designed to produce good power over a broad range of engine speeds, you would think that manufacturers would tend to make only one type of engine or the other. Motorcycle and ATV manufacturers are constantly working on building better, longer-lasting, and more powerful engines. Much progress has been made in a very short period of time. For example, in the early 1980s it was almost unheard of to see a stock motorcycle of any size (including the large 1000 cc engines) with 100-horsepower engines. Today, many 600 cc engines develop over 100-horsepower.

So, which engine is better—the two-stroke engine or the four-stroke engine? Let's look at the two-stroke engine and compare it to the four-stroke engine design.

## Two-Stroke Engine Advantages over Four-Stroke Engines

The most noticeable advantage of the two-stroke engine over the four-stroke engine is that the two-stroke engine has fewer internal moving parts. This allows the two-stroke engine to be smaller in physical size and made lighter in weight than the four-stroke engine, as shown in Figure 19. The engine on the left is a liquid-cooled two-stroke engine and the engine on the right is a liquid-cooled four-stroke engine. Both engines have the same engine displacement (250 cc). Note the physical size difference between the two. The four-stroke engine is taller than the two-stroke because of the valve train needed to open and close the ports in the cylinder head. In almost all cases, the two-stroke engine will be lighter in weight than the four-stroke engine when comparing equal displacement engines.

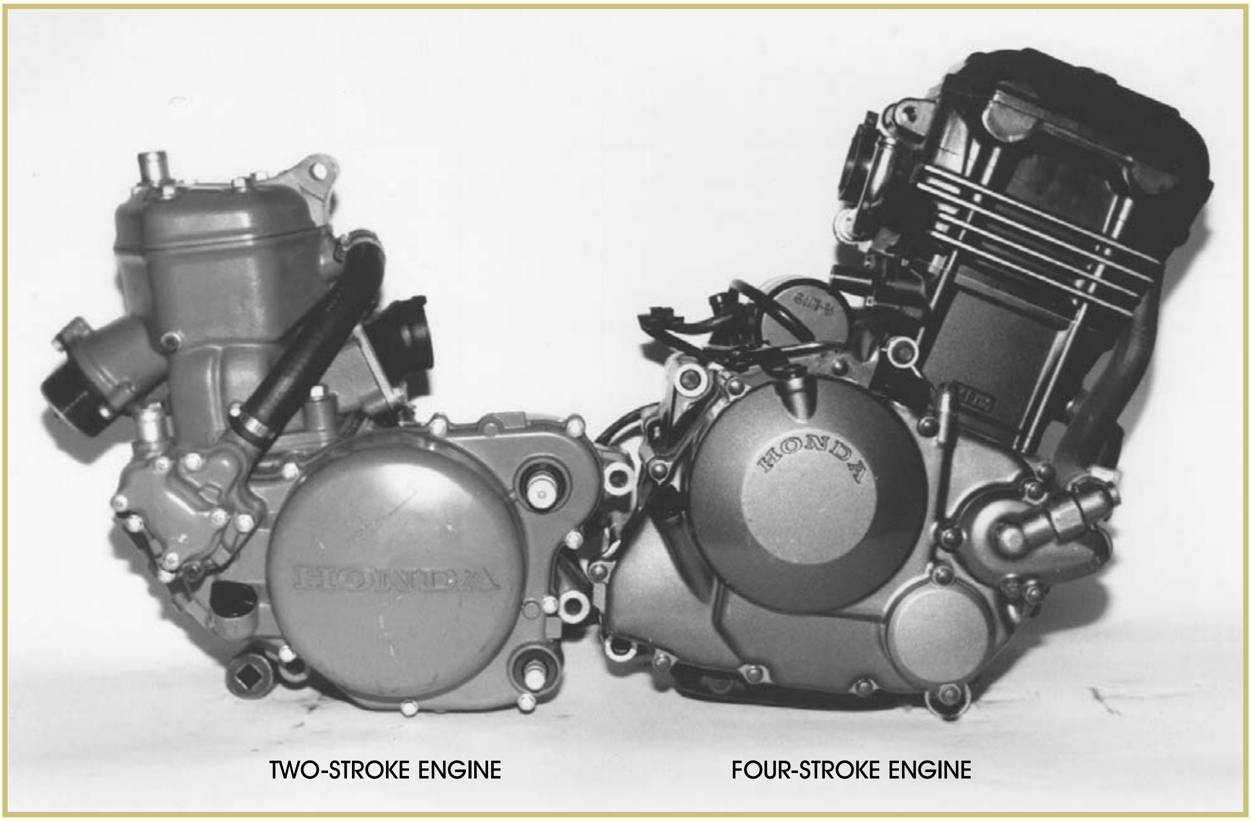



***FIGURE 19—A water-cooled two-stroke and four-stroke engine having equal displacements are pictured here for comparison.***

Another advantage of the two-stroke engine is that it normally produces more horsepower compared to a four-stroke engine of equal size. This is because the two-stroke engine has twice as many power strokes in the same given period of time as the four-stroke engine, resulting in better mechanical efficiency.

With these advantages, why aren't all motorcycle and ATV engines two-strokes? To answer that question, let's look at the disadvantages of the two-stroke engine.

## Two-Stroke Engine Disadvantages When Compared to Four-Stroke Engines

The primary disadvantage of the two-stroke engine is that it emits a high amount of hydrocarbon emissions (unburned fuel) from the exhaust, making it a very high air-polluting engine design. This occurs during the transfer and exhaust events of operation. While the intake gases are being transferred from the primary area to the secondary area of the engine, some of the raw, unburned fuel mixture escapes directly out the exhaust system and into the atmosphere. Even with a properly tuned expansion chamber, some raw fuel escapes from the exhaust port at certain engine speeds.

Other disadvantages of the two-stroke engine are directly related to one of its primary advantages. Because the two-stroke engine creates a power stroke every time the crankshaft makes one revolution, it burns more fuel than the four-stroke engine in the same time period. This generally results in poorer fuel economy. The two-stroke engine also runs at hotter temperatures compared to four-stroke engines for this same reason. Because the two-stroke engine runs hotter, it's prone to wear out internal parts sooner than the four-stroke engine. This tends to make the two-stroke engine less reliable and require more frequent service than the four-stroke engines used in today's motorcycles and ATVs.

Finally, as we mentioned earlier, the basic two-stroke engine has a narrow power band when compared to the four-stroke engine's generally wide power delivery over a range of speeds.

For these reasons most motorcycle and ATV manufacturers primarily build four-stroke engines. However, almost all manufacturers are working hard at solving the disadvantages of the two-stroke engine to enable them to build a better motorcycle or ATV.

## Comparison Tables

Table 1 summarizes our discussion of the advantages and disadvantages of the two-stroke engine compared to the four-stroke engine.

Table 2 compares the four-stroke engine design advantages and disadvantages to the two-stroke engine design.

**Table 1**

| TWO-STROKE ENGINE ADVANTAGES AND DISADVANTAGES | |
|---|---|
| **Two-Stroke Advantages** | **Two-Stroke Disadvantages** |
| Fewer internal parts | High HC emissions (air pollution) |
| Lighter weight | Poor fuel economy |
| More horsepower | Hotter engine temperatures |
| Better mechanical efficiency | Generally less reliable |
| | Requires frequent servicing |
| | Narrow power band |

**Table 2**

| FOUR-STROKE ENGINE ADVANTAGES AND DISADVANTAGES | |
|---|---|
| **Four-Stroke Advantages** | **Four-Stroke Disadvantages** |
| Lower HC emissions (less air pollution) | More moving internal parts |
| Better fuel economy | More weight |
| Cooler engine temperatures | Less horsepower |
| Generally more reliable | Lower mechanical efficiency |
| Less vibration (smoother running) | |
| Wider power band | |

# *Road Test Answers*

## 1

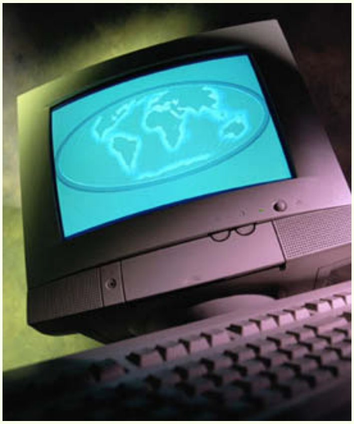
1. standard, keystone, Dykes
2. pins
3. multipiece
4. transfer, exhaust
5. skirt
6. True
7. True
8. ports

## 2

1. five
2. True
3. piston, crankshaft, connecting rod
4. intake
5. exhaust
6. False
7. transfer
8. intake
9. transfer
10. piston

## 3

1. piston port
2. False
3. True
4. three
5. stainless steel, fiber resin
6. open



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