Motorcycle and ATV Engine Configurations

By

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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

Now that you've learned about the many different types of motorcycles and ATVs, let's look at the different types of engines. This study unit introduces you to the different types of motorcycle and ATV engine designs and configurations.

First, we'll learn how manufacturers determine engine sizes and power ratings. Then we'll look at the basic component layout of both two-stroke and four-stroke engine designs. Finally, we'll cover the different two-stroke and four-stroke engine configurations that you may find in both motorcycles and ATVs.

When you've completed this study unit, you'll be able to

- Explain how an internal combustion engine operates
- Demonstrate how engine displacement is measured
- Define the terms *horsepower* and *torque*
- Point out the major components of both two-stroke and four-stroke engines
- Identify the different motorcycle and ATV two- and four-stroke engine configurations

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Motorcycle and ATV Engine Configurations

INTRODUCTION

In this study unit, we'll look at the different motorcycle and ATV engine designs and configurations. We'll also look at how they're rated by their manufacturer. We'll start by giving you a very simple overview of how a motorcycle engine operates. Keep in mind that you'll learn more about engine operation in later sections.

Motorcycles use reciprocating engines. A *reciprocating engine* has pistons that move alternately *up* and *down* inside cylinders. All reciprocating engines—from tiny model airplane engines to large truck engines—have a number of common components.

Our first illustration shows a cylinder with a piston positioned inside it (Figure 1). A *cylinder* is a circular tube that's closed at one end. The *piston* is a circular plug that moves up and down inside the cylinder. The closed end of the cylinder is sealed by a *cylinder head.* When a piston is at its lowest position in the cylinder, it's said to be at *bottom-dead-center (BDC)*. When the piston is at its highest position in the cylinder, it's said to be at *top-dead-center (TDC).*

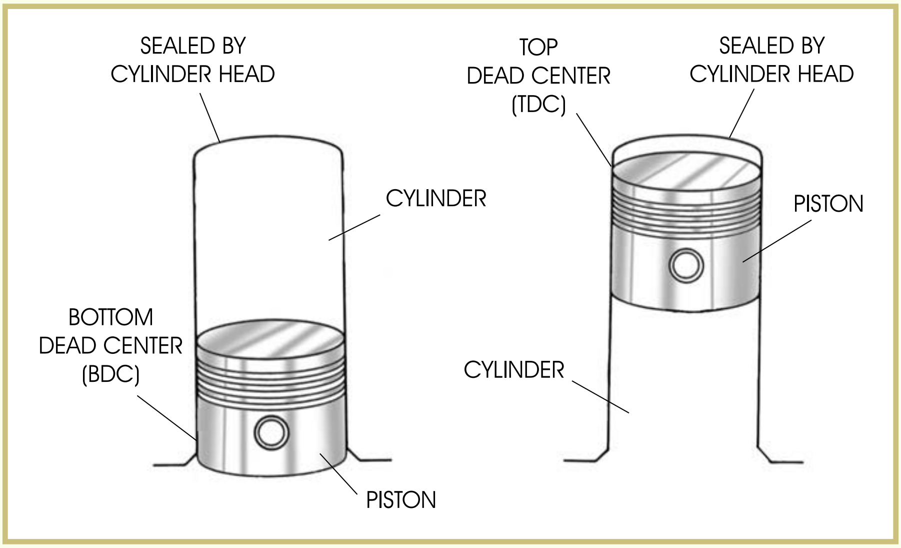


FIGURE 1—A Simplified Drawing of a Cylinder and Piston. Note the position of the cylinder at top-dead-center (TDC) and bottom-dead-center (BDC).

When the piston is at TDC, a small amount of space remains in the cylinder head. This small space above the top of the piston and below the cylinder head is called the *combustion chamber* (Figure 2). In the combustion chamber, a mixture of fuel and air is burned to produce power. When the air-and-fuel mixture burns in the combustion chamber, it produces a small, contained explosion. This explosion is strong enough to force the piston downward into the cylinder. Each time the piston moves either up or down, it's called a piston *stroke*.

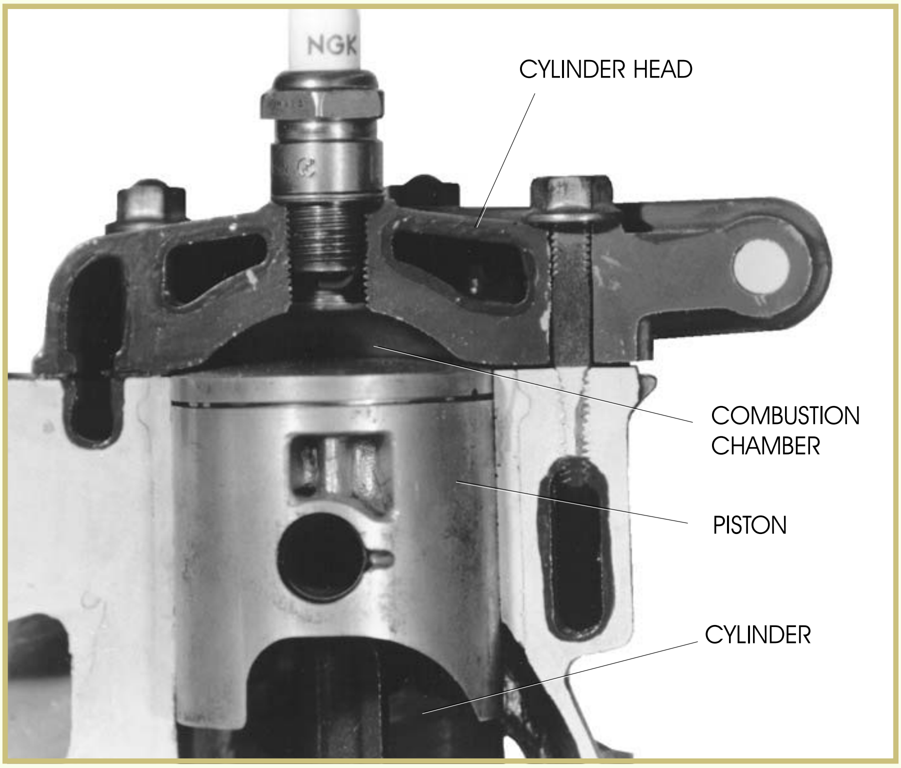


FIGURE 2—In this cutaway picture, you can see the small space between the top of the piston and cylinder head of an actual engine. This space is called the combustion chamber.

The bottom end of the piston is attached to a connecting rod and crankshaft (Figure 3). When the piston is forced downward in the cylinder, the piston's motion is transferred to the connecting rod and crankshaft. The rod and crankshaft convert the up-and-down *(reciprocating)* motion of the piston into a circular *(rotary)* motion. You can compare this conversion of reciprocating motion into rotary motion to the motion produced when you pedal a bicycle. When you pedal a bike, the up-and-down motion of your legs is converted into circular motion that drives the rear wheel.

Four-stroke Engine Operation

The operation of four-stroke engines is divided into four stages—(1) intake, (2) compression, (3) power, and (4) exhaust. When a four-stroke engine is operating correctly, it continually runs through these four stages. The following is a brief description of each stage.

- *Stage 1: Intake*. The piston moves downward and draws an air-and-fuel mixture into the cylinder.
- *Stage 2: Compression*. The piston rises and compresses the air-and-fuel mixture into the combustion chamber.
- *Stage 3: Power*. The air-and-fuel mixture is ignited. The explosion pushes the piston back down in the cylinder. The downward motion of the piston is transferred to the rod and crankshaft.

- *Stage 4: Exhaust*. The piston rises and pushes the exhaust gases out of the cylinder.

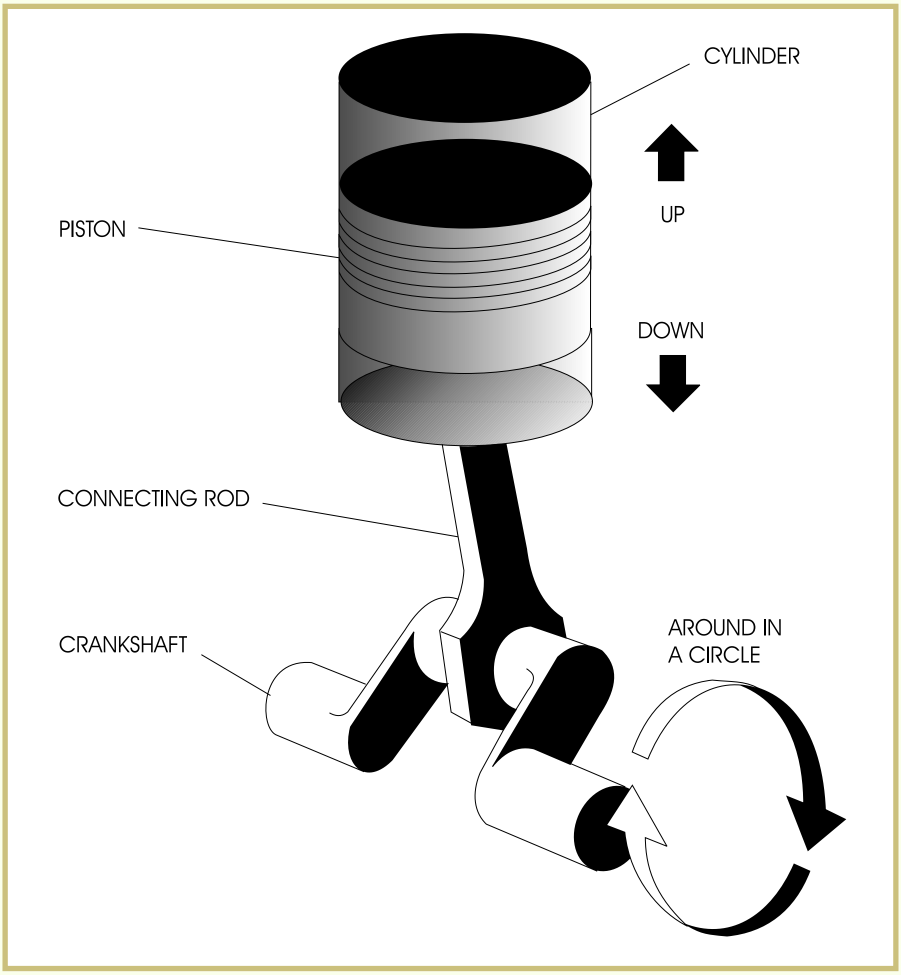


FIGURE 3—The connecting rod connects the piston to the crankshaft. The up-and-down motion of the piston is changed to circular motion at the crankshaft.

Two-stroke Engine Operation

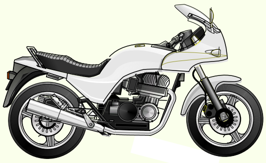
The two-stroke engine operates somewhat differently from the four--stroke engine. In a four-stroke engine, the four stages (intake, compression, power, and exhaust) require four piston strokes. In a two-stroke engine, these stages are accomplished in only two piston strokes.

The two-stroke engine has inlet and outlet holes (called *ports*) located at different heights in the sides of the cylinder. As the piston moves up and down in the cylinder, the ports are covered (closed) or uncovered (opened) at different times by the piston.

The air-and-fuel mixture in the two-stroke engine enters below the piston into the area around the crankshaft. The air-and-fuel mixture typically contains oil to lubricate the crankshaft and related components of a two-stroke engine. The air-and-fuel mixture is delivered from the crankshaft area to the combustion chamber through a port above the piston. As the air-and-fuel enters the combustion chamber, exhaust gases are forced out an exhaust port. As the piston rises, all ports are eventually sealed off. The air-and-fuel mixture is compressed and ignited, producing a power stroke which forces the piston downward and transfers motion to the rod and crankshaft.

Motorcycles and ATVs have either a two-stroke engine or a four-stroke engine. Each type of engine has advantages and disadvantages which we'll cover in later study units. For now, just keep in mind the primary difference between these two engine designs. The two-stroke engine has a power stroke every full turn (360 degrees rotation) of the crankshaft, which is every two piston strokes. The four-stroke engine has a power stroke for every two turns (720 degrees rotation) of the crankshaft, which is every four piston strokes.

Road Test 1



At the end of each section of *Motorcycle and ATV Engine Configurations*, you'll be asked to pause and check your understanding of what you've just read by completing a "Road Test." Writing the answers will help you review what you've studied so far. Please take time to complete *Road Test 1* now.

1. The small space between the cylinder head and the top of the piston while at TDC is called the _______.
2. What are the four stages of the basic operation of a four-stroke engine?

   ____
3. What is the *stroke* of an engine?

   ____
4. When a piston is at its lowest position in the cylinder, it's said to be at _______.
5. The piston is connected by a connecting rod to the _______.

Check your answers with those on page 41.

HOW MOTORCYCLE ENGINES ARE RATED

Now that you know the stages of basic engine operation, let's take a look at how motorcycle engine manufacturers rate and classify their engines. Motorcycle and ATV engines are normally classified in one of the following ways:

- By the size of the engine
- By the amount of power it produces

Before we begin to discuss how engine power is measured, let's define a few basic terms that we'll be using in our discussion.

Work

We're all familiar with the term *work*. People work in some way or another every day of their lives. However, when we refer to mechanical work, we can actually measure the amount of work that's done.

By definition, *work* is a force that's applied over a specific distance. We can calculate the amount of work that's being performed by a device (or a person) by multiplying the amount of force being applied by the distance over which it's applied. Therefore, the formula for work is

Work = Distance × Force

In this formula, if the amount of force applied is measured in pounds and the distance is measured in feet, the amount of work performed is measured in units called *foot-pounds* (ft-lb).

Let's look at a simple example. Suppose you want to move a box from the floor to a shelf. The box weighs 10 pounds (lb), and the shelf is located 5 feet (ft) from the floor. If you lift the box and place it on the shelf, you perform a certain amount of work. You can calculate the amount of work by using the formula. The box weighs 10 lb, so the amount of force you applied is 10 lb. You lifted the box 5 ft off the floor, so the distance is 5 ft. Substitute these values into the formula and solve.

Work = Distance × Force

Work = 5 ft × 10 lb

Work = 50 ft-lb

Thus, the amount of work you performed in this example was 50 ft-lb.

Note that this work formula doesn't mention time. The same amount of work is performed whether a person took 10 seconds or 10 minutes to move the box from the floor to the shelf. The time required to perform the task is directly related to the strength of the person doing the job. If we don't consider the amount of time it took to perform a task, we're unable to determine the strength of the person who did the work. The same idea applies to motorcycle engines. We can use the formula to calculate how much work an engine can perform, but without a time factor we can't determine the true strength of the engine. In order to calculate the engine's strength, we have to figure in the time the engine takes to complete a job. The rate at which work is accomplished is called *power*. In other words, power is work per unit of time. The following formula is used to calculate power:

Power = Work ÷ Time

In this formula, we'll divide the amount of work (ft-lb) by the amount of time in seconds (s). The amount of power in this case will be measured in units called foot-pounds per second (ft-lb/s).

Let's return to our earlier example of the box and the shelf. We calculated that 50 ft-lb of work was required to move the 10 lb box from the floor onto the 5 ft-high shelf. Suppose that you completed this job in 2 seconds. We can use the power formula to calculate the power involved in doing the job.

Power = Work ÷ Time

Power = 50 ft-lb ÷ 2 s

Power = 25 ft-lb/s (foot-pounds per second)

So, from our calculations you can see that you required 25 ft-lb/s of power to complete your task. Now that we've looked at the basic concepts of work and power, let's see how they apply specifically to motorcycle and ATV engines.

Horsepower

Many years ago, when internal combustion engines were invented, no one knew how to express the amount of work they could do. At that time, horses provided most of the transportation and power. As a result, inventors of the first engines developed the idea of horsepower. They determined that an average-sized horse could produce approximately 550 ft-lb/s of work. This fact was used to develop the standard unit of *horsepower (hp)*. One horsepower is therefore equal to 550 ft-lb/s of work.

1 hp = 550 ft-lb/s

Even though horses are seldom used to perform work nowadays, we still use the standard unit of horsepower to describe the power output of motorcycle engines. So, the next time you're looking at a motorcycle in a showroom and the salesperson tells you it has 80 hp, you can just imagine that motorcycle being pulled by 80 horses. That's pretty impressive!

Today, we rate almost all engines by their horsepower output. Stronger engines produce more horsepower. Now that you understand how to calculate horsepower, let's look at how we measure it.

There are several different ways to measure horsepower. The most common is to measure the horsepower output of an engine as it runs on a device called a *dynamometer (dyno)*.

During a typical dyno test, the technician places the motorcycle on the dyno and runs it at full throttle. The dyno places a load (resistance) on either the output shaft or rear wheel. Usually, the load is either hydraulic or electronic. As the load increases, its force tries to prevent the engine from turning. Therefore, the engine speed decreases as the load increases. Since the load applied is a known value, the dyno can determine the amount of torque produced by the engine. If we know the torque produced, we can calculate the horsepower of the engine.

Because this type of test involves the slowing or braking of the engine, the type of horsepower measured this way is commonly referred to as the *brake horsepower (bhp)*. The brake horsepower rating is the maximum power output of the engine. You'll usually see the specifications for an engine given in bhp.

In practical use, a motorcycle or ATV engine is normally operated at a level well below its maximum power output. If the engine was always run at maximum horsepower, it would have a very short life span. You can compare an engine that's running at its maximum rated power to a person running at top speed. That person wouldn't be able to keep up the pace for long, and neither would an engine running at its maximum horsepower.

Torque

The other method we use to rate an engine is by the maximum amount of torque it produces. *Torque* is a measurement of twisting or rotational force. Remember that an engine's output is in the form of rotational motion. The power output from the crankshaft is used to turn the rear wheel of the motorcycle. You can compare the torque produced by an engine to the twisting force a person exerts when opening a jar lid. Engine torque is usually measured in foot-pounds (ft-lbs) and can be measured by a dynamometer.

As you've probably figured out by now, the ideal engine would have high horsepower and lots of torque. Unfortunately, we don't see this combination too often in real life. In a typical motorcycle or ATV engine, the horsepower and torque that are developed will vary with the speed of the engine (Figure 4). This speed is measured in *revolutions per minute (rpm).* The rpm is a measure of how many complete turns (360°) the crankshaft makes in one minute.

In a typical engine, horsepower generally increases as the rpm increases. Remember that power is related to the rate (speed) that work can be done. Therefore, the maximum horsepower develops near the maximum rpm limit of the engine. Torque, on the other hand, is produced somewhat differently. The maximum torque is normally produced at a lower rpm range and then declines as the rpms increase. This means that the maximum torque and the maximum rpm don't usually occur at the same time. So, when manufacturers design motorcycles and ATV engines, they compromise. The design usually depends on the particular application.

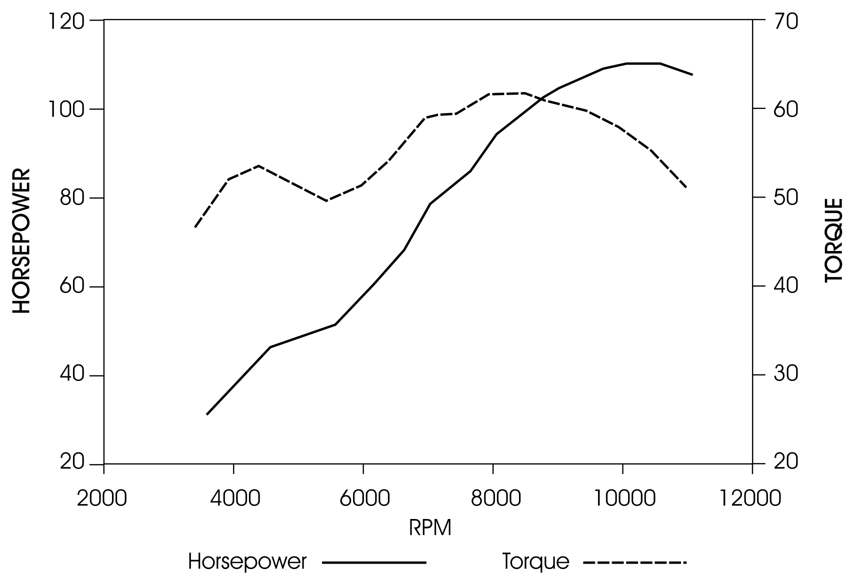


FIGURE 4—This graph shows the relationship between torque and horsepower for a typical four-stroke motorcycle engine.

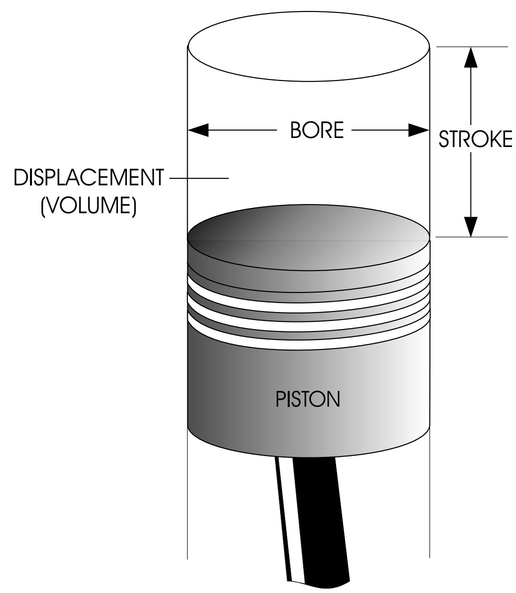
More torque usually means better acceleration and more towing capacity. Higher horsepower usually means a higher top speed. The amount of horsepower and torque an engine develops depends on many design factors. The displacement, compression ratio, fuel mixture, engine design, ignition timing, and valve timing (on four-stroke engines) all affect horsepower and torque.

Engine Displacement

When you hear people refer to the size of an engine, they don't mean the overall size of the engine but rather the size of the area inside the engine where the air-and-fuel mixture is burned. The size of this area is known as the engine displacement.

By definition, *engine displacement* is the volume of space that the piston moves as it moves from BDC to TDC. The distance that the piston travels up or down in a cylinder is called the *stroke* of the engine (Figure 5). The diameter of the cylinder is called the *bore*. Displacement on motorcycle engines is usually measured in *cubic centimeters (cc)*; but it may also be measured in *cubic inches (ci)*. The displacement of an engine is usually stated in the service manual and stamped on the engine itself.

FIGURE 5—This figure illustrates the engine bore, stroke, and displacement.



You can calculate the displacement of an engine if you know the diameter of the cylinder and the length of the stroke of the engine. The displacement of an engine can be calculated by using the following formula:

Displacement = B × B × 0.7854 × S × N

In the formula, the letter *B* stands for the diameter (bore) of the cylinder. The number 0.7854 is a constant. A constant is a number used in a formula that never changes. The letter *S* stands for the length of the stroke of the engine. The letter *N* stands for the number of cylinders in the engine.

To see how this formula works, let's look at an example. Suppose an engine has one cylinder with a diameter of 54.0 millimeters (mm). The stroke length of the engine is also 54.0 mm. To calculate the displacement, we must first convert millimeters into centimeters (cm). Most motorcycles are rated in cubic centimeters. This is done by simply moving the decimal point one space to the left: 54.0 mm equals 5.4 cm (one centimeter equals 10 millimeters). Substitute these values into the formula to determine the size of the engine.

Displacement = B × B × 0.7854 × S × N

Displacement = 5.4 cm (bore) × 5.4 cm (bore) × 0.7854 × 5.4 cm (stroke) × 1 (number of cylinders)

Displacement = 123.672 cc

This particular example is a very common bore and stroke for a 125 cc off-road motorcycle engine. Note that the motorcycle manufacturer will round off the displacement number to describe the size of the engine.

We can use this same formula to determine the displacement of an engine in cubic inches. For instance, if we have a four-cylinder engine with a bore of 2.76 inch and a stroke of 1.91 inch, the displacement equation would look like this.

Displacement = 2.76 in. (bore) × 2.76 in. (bore) × 0.7854 × 1.91 in. (Stroke) × 4 (number of cylinders)

Displacement = 45.709 ci (cubic inches)

This is a common size engine used in today's four-cylinder motorcycles. Displacement is the most common way of describing a motorcycle or ATV engine. Motorcycle engine displacements range from 50 cc to 1500 cc, and ATVs have a general displacement range of 50 cc to 500 cc.

An engine's displacement has an effect on the power that the engine develops. In most cases, the larger the displacement, the more power the engine will develop. However, this doesn't mean that a smaller engine can never develop more horsepower than a larger one. There are many factors besides displacement that affect an engine's power. However, in general, an engine with a larger displacement will develop more horsepower.

Compression Ratio

You learned that the displacement of an engine is the volume of space that a piston moves as it travels up and down in a cylinder. When a piston is at BDC, the *cylinder volume (CV)* is at its largest. When the piston is at TDC, the cylinder volume is at its smallest. This is known as *combustion chamber volume (CCV).* The ratio of the largest cylinder volume to the smallest cylinder volume is called the *compression ratio* (Figure 6). A ratio is simply a comparison between two values. The compression ratio can be calculated by using the following formula:

Compression Ratio = CV ÷ CCV

The volumes at BDC and TDC can be determined by using a combination of mathematical calculations and special test instruments. The typical technician will never be required to measure these volumes, so we won't get into the details of how the volumes are determined. However, you should be aware that the compression ratio of an engine affects the amount of power that the engine develops.

Let's examine the compression ratio in a typical motorcycle engine. For example, the volume of a cylinder (CV) at BDC is 100 cc, and the volume of a combustion chamber at TDC (CCV) is 10 cc. The compression ratio of this engine is therefore 10 to 1. This ratio may be written as 10 to 1 or abbreviated as 10:1. The compression ratio is important in a motorcycle engine because it determines how effectively fuel is burned in the cylinder. As you learned earlier, fuel burns inside the cylinder to produce power.

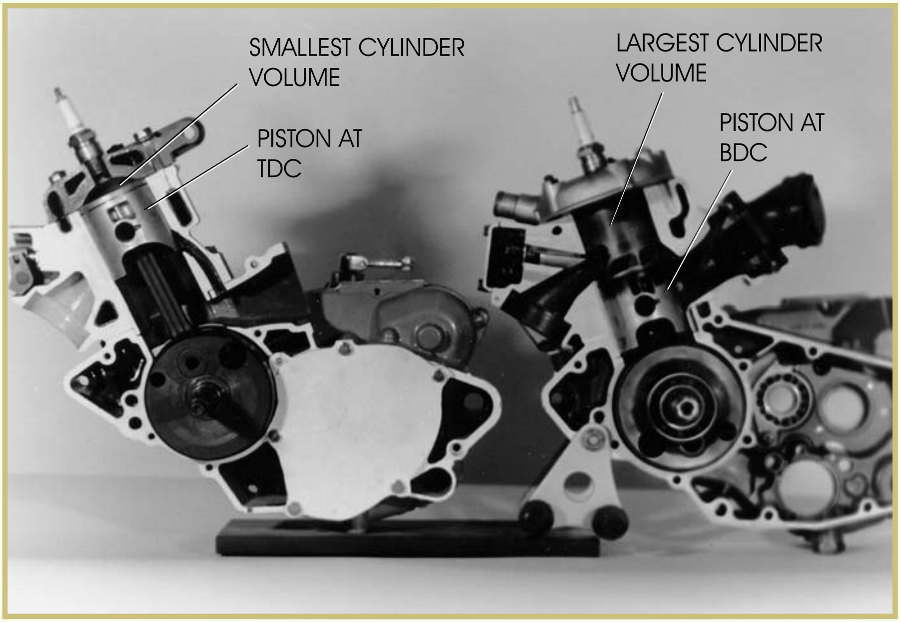
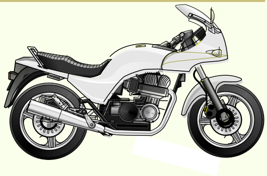


FIGURE 6—The compression ratio is a comparison of the cylinder volume when the piston is at BDC compared to the cylinder volume when the piston is at TDC.

An engine's compression ratio determines how much the fuel mixture will be compressed when the piston rises. The higher the compression ratio, the more the mixture is compressed. Our example engine had a compression ratio of 10 to 1. This means that when the air-and-fuel mixture first enters the cylinder, the mixture has a volume of 100 cc. When the piston is at TDC, the 100 cc of mixture is compressed into a 10 cc space. When this compression occurs, the pressure of the mixture increases dramatically. This large increase in pressure makes the mixture burn more completely and produce more power when it's ignited.

The compression ratio is important, but every engine has its limitations. If an engine's compression ratio is too high, the excessive pressure can damage the engine. If the compression ratio is too low, the engine doesn't develop much power. Different engines have their own specified compression ratios. Most motorcycle engines have a compression ratio in the range between 8:1 and 12:1.



Road Test 2

1. What are the two ways that motorcycle engines are normally classified?

 ____

2. What is the formula used to calculate power?

 ____

3. What is the name of the device used to measure torque and horsepower?

 ____

4. *True or False?* Horsepower and torque vary with engine speed.

 ____

5. What do the letters CCV stand for?

 ____

6. How much work is performed if a 20-pound box is lifted 3 feet?

 ____

7. Engine speed is measured in _______.

Check your answers with those on page 41.

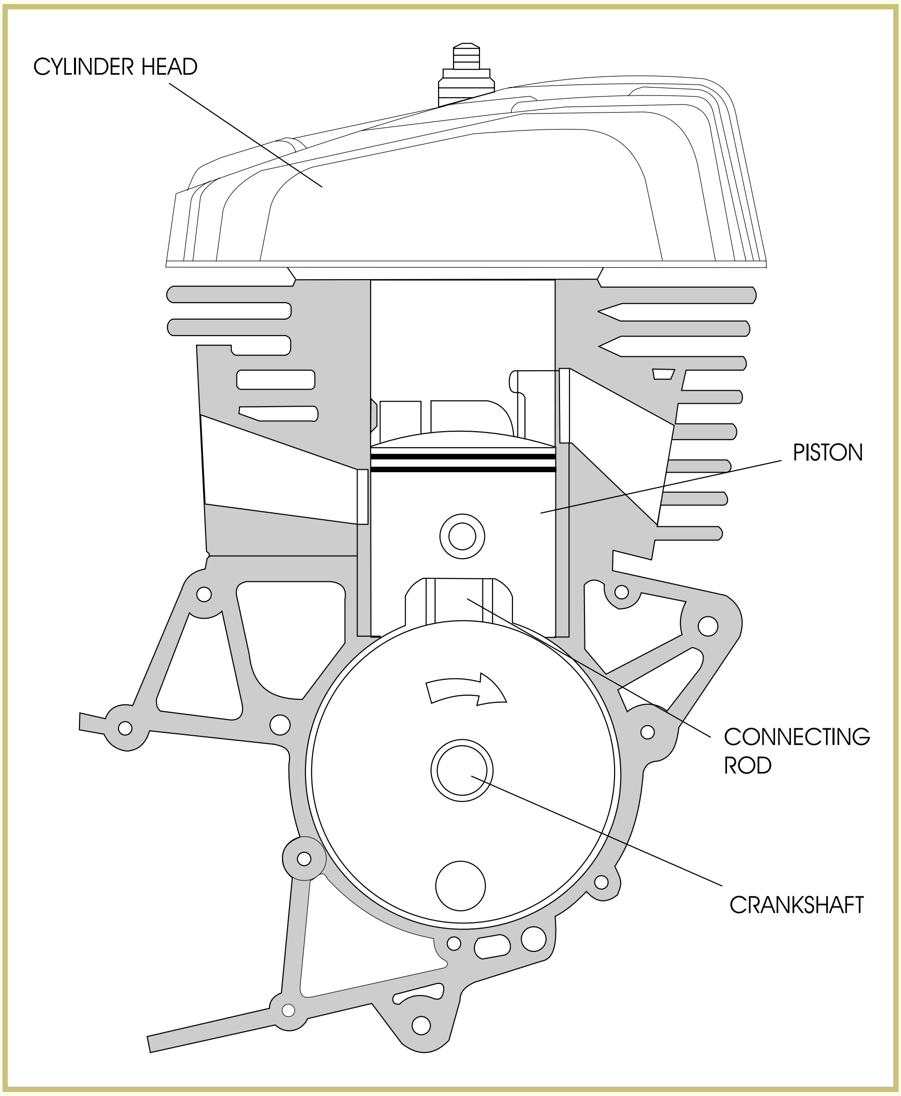
TWO-STROKE ENGINE DESIGN

Now that we've established the required components of a simple internal combustion engine, let's discuss ways of making it work for us as a suitable motorcycle power source. Of all the engine designs used on motorcycles and ATVs, the two-stroke engine is the least complex. In this section, we'll cover the two-stroke engine's major components and their layout. In later sections, we'll give you a more detailed explanation of how these components work. But for now, let's concentrate on the basic components.

Single-cylinder Two-stroke Engine Layout

The single-cylinder two-stroke engine is the least complex of all two-stroke engines (Figure 7). The one cylinder may be positioned at any angle but most modern engines position the piston upright or vertical to the motorcycle frame. The major components are located in the top and bottom ends of the engine. Let's start with the bottom end.

FIGURE 7—The single-cylinder two-stroke engine is the least complex of all two-stroke designs.



The bottom end of a two-stroke engine contains the heart of the engine—the crankshaft. The two-stroke *crankshaft* is made up of two flywheel halves, a connecting rod, a connecting rod pin, and a connecting rod bearing (Figure 8). A bearing on each end supports the crankshaft and allows it to rotate. The crankshaft is located inside the engine crankcases.

The engine crankcases are used to hold all of the engine components together and supply the main engine mounting points (Figure 9). There are two crankcases—center and side. The center crankcase holds all of the major components together. The side crankcases enable you to gain access to the various parts of the engine without having to fully disassemble it. The side crankcases are also known as *side covers*.

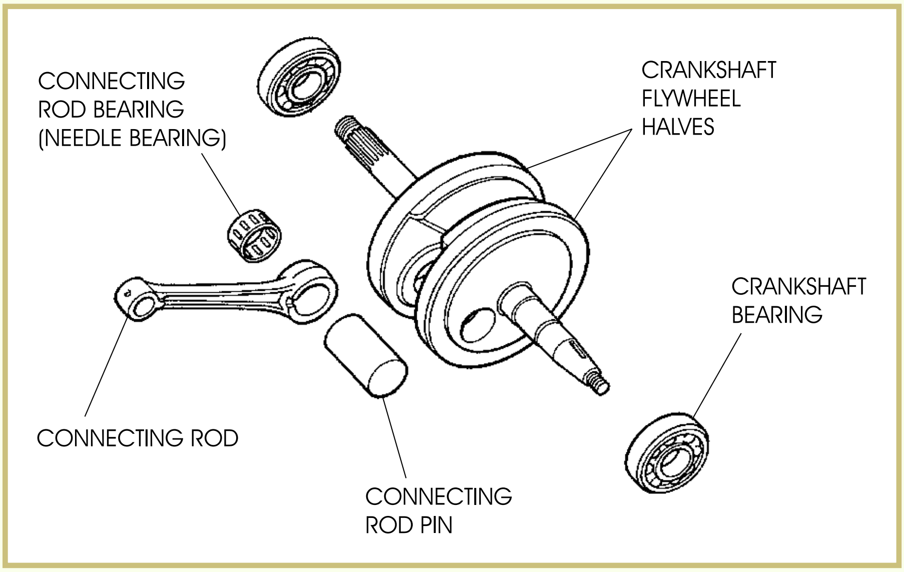


FIGURE 8—The parts of a two-stroke single-cylinder crankshaft are illustrated here.

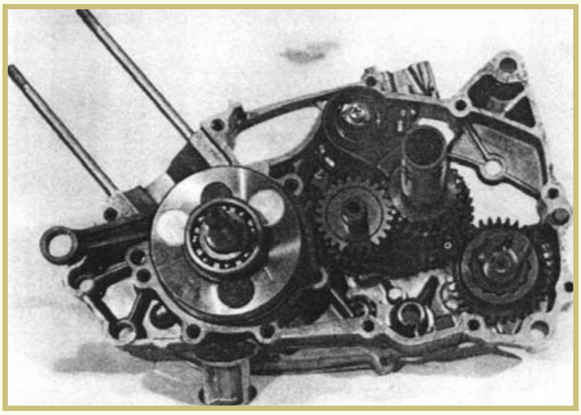


FIGURE 9—The engine crankcases are used to hold all of the various components together.

Seals are used to protect rotating shaft bearings (Figure 10). The seals are typically located at the ends of the rotating shafts. These seals prevent the loss of gases and oil from the crankcases. Their sealing action also prevents outside substances from getting into the crankcases.

Bearings are found primarily in the crankcases of the two-stroke engine. *Bearings* are designed to reduce friction and to allow shafts to rotate freely under various engine loads.

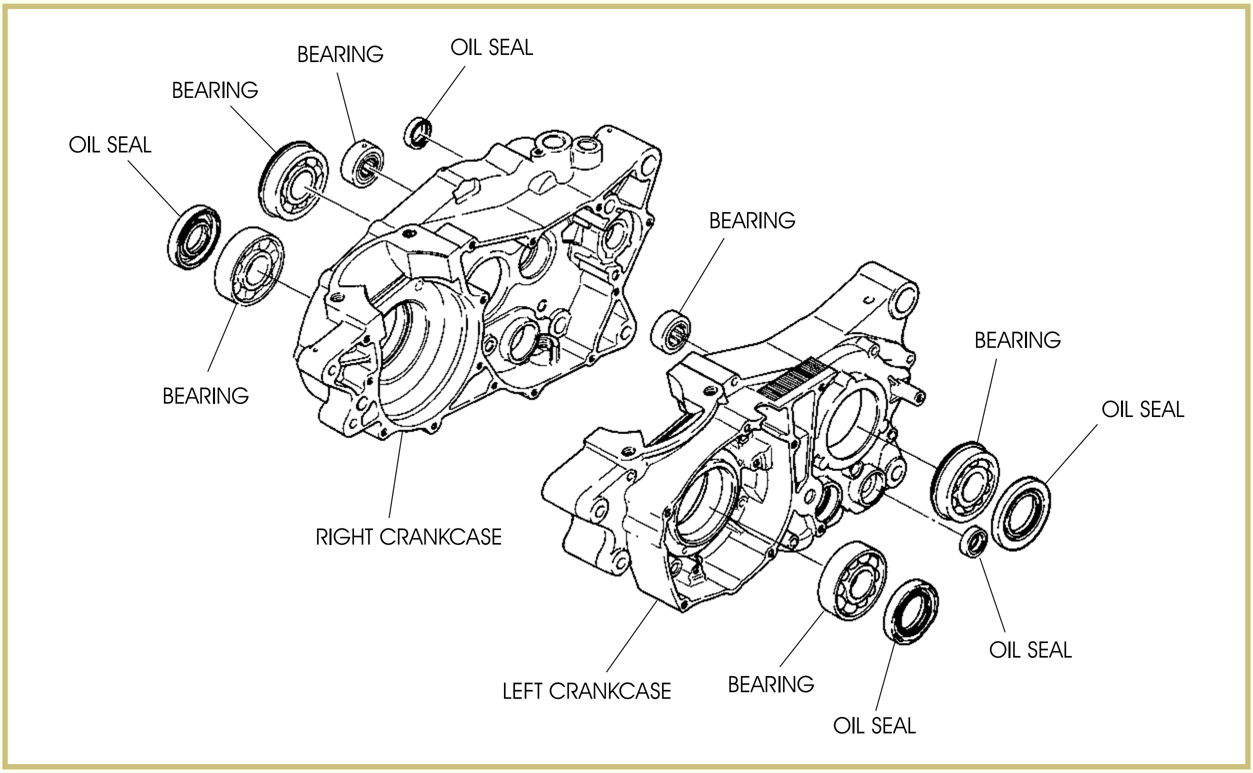


FIGURE 10—This illustration shows the seals and bearings located in the crankcases.

You'll also find the two-stroke single-cylinder engine's transmission in the crankcases. *Transmissions* consist of gears, shafts, and shifting mechanisms. These components work together to transmit power from the crankshaft to the rear wheel and to help keep the engine running in the desired rpm range. The *clutch* in the two-stroke engine is used to engage and disengage the transmission and the rear wheel from the crankshaft power output (Figure 11).

FIGURE 11—This illustration shows a typical motorcycle clutch.

Gaskets are used to seal the mating surfaces of various parts of the engine (Figure 12). These surfaces are usually both metal. Gasket material may be rubber, cork, or metal.

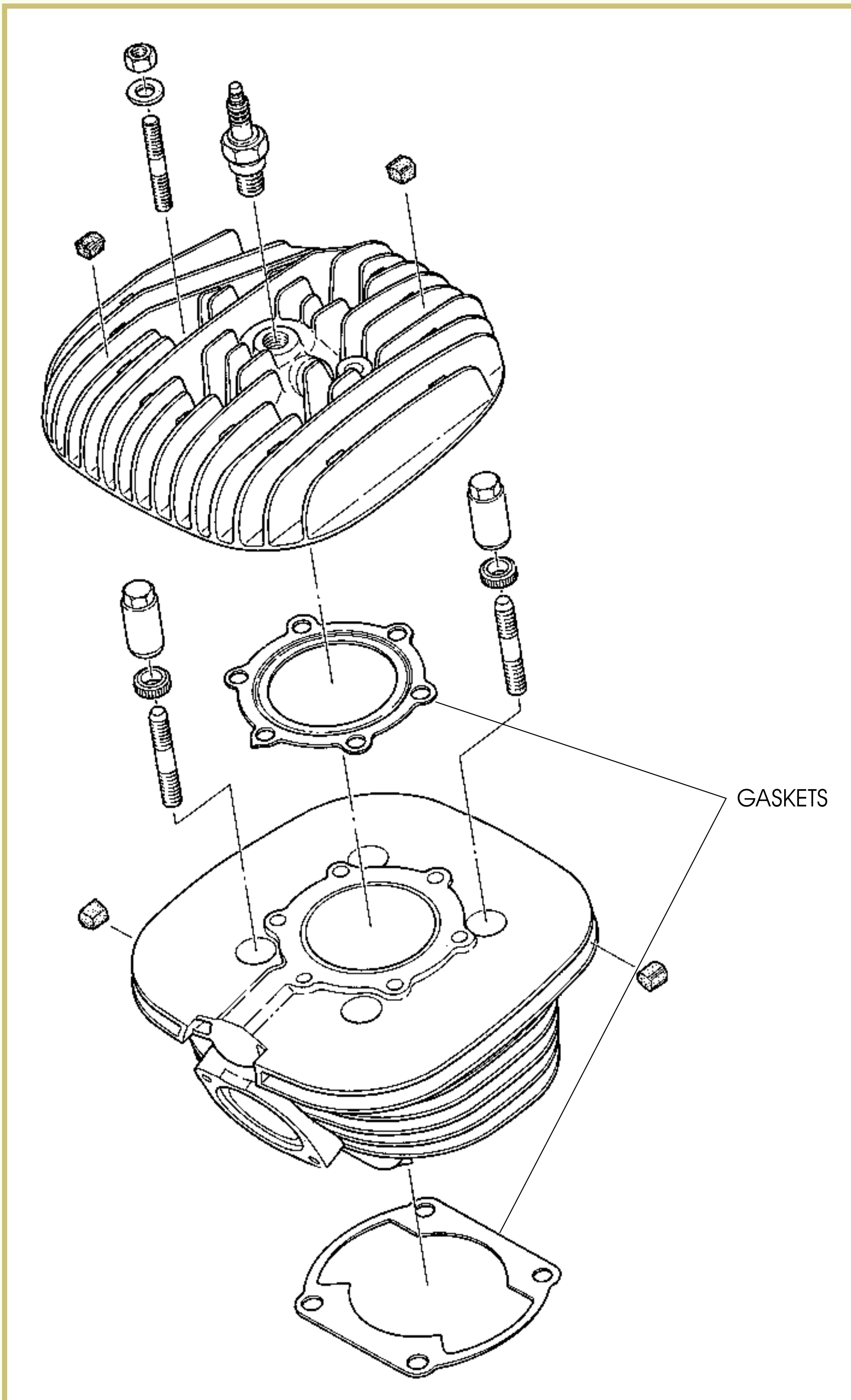


FIGURE 12—This illustration shows typical gaskets found on engine mating surfaces.

The last part of the bottom end is the *starting mechanism*. The two-stroke engine uses one of three different starting mechanisms. A *kick starter* has an external lever on the side crankcase. The rider pushes the lever down with his or her foot to turn the crankshaft. Turning the crankshaft starts the engine.

The *electric start* mechanism is similar to an automobile's starter mechanism. It uses an electric motor with a reduction gear to turn the motorcycle engine's crankshaft. The rider energizes the starter motor with a push-button or key-lock mechanism.

The *recoil starter* mechanism uses a pull cord that's attached to a pulley on the crankshaft. The rider pulls the cord to turn the crankshaft, similar to starting a gasoline-powered lawnmower. The cord has a return spring to rewind it into the housing. All of the items mentioned up to now are found in the bottom end of a single-cylinder two-stroke engine. Now let's look at the top end.

The piston is attached to the crankshaft connecting rod (Figure 13). The piston is held in place by a *piston pin* (also known as a *wrist pin*). Clips prevent the wrist pin from moving laterally. There's usually a bearing where the piston pin attaches to the connecting rod. Each piston has one or more rings around its outside surface. These rings are called *piston rings*. The rings form a seal between the piston and the cylinder surfaces to improve the compression and exhaust functions.

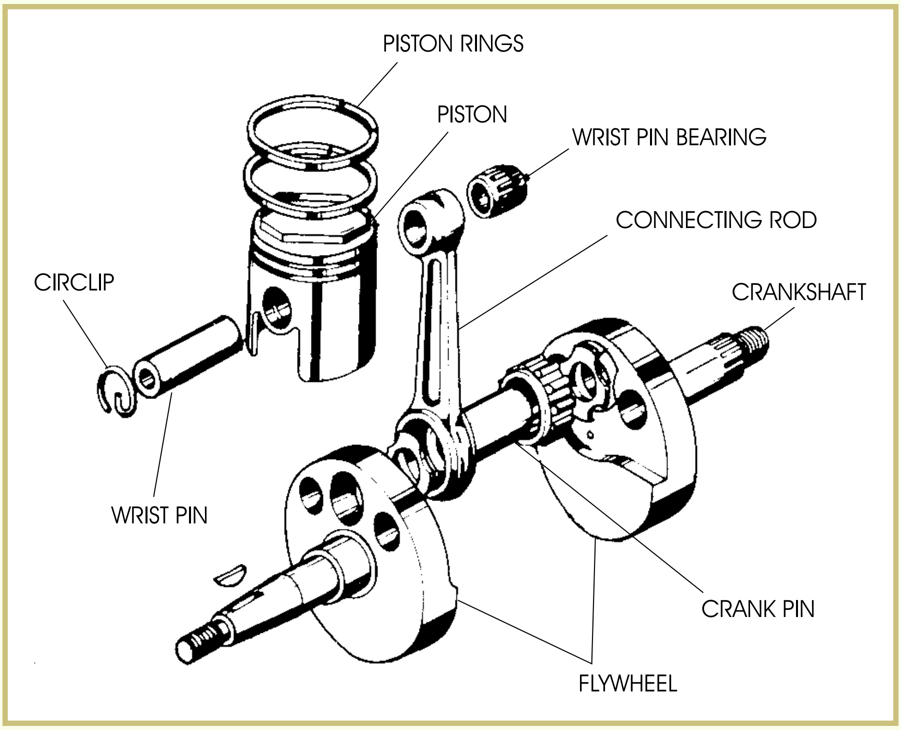


FIGURE 13—The piston and its related parts are attached to the crankshaft connecting rod.

A two-stroke engine has holes in the sides of the cylinder called *ports*. The ports allow fuel mixtures to enter the cylinder and exhaust gases to be removed from the cylinder (Figure 14). A cylinder head is attached to the cylinder block and seals the top of the cylinder block from the outside of the engine.

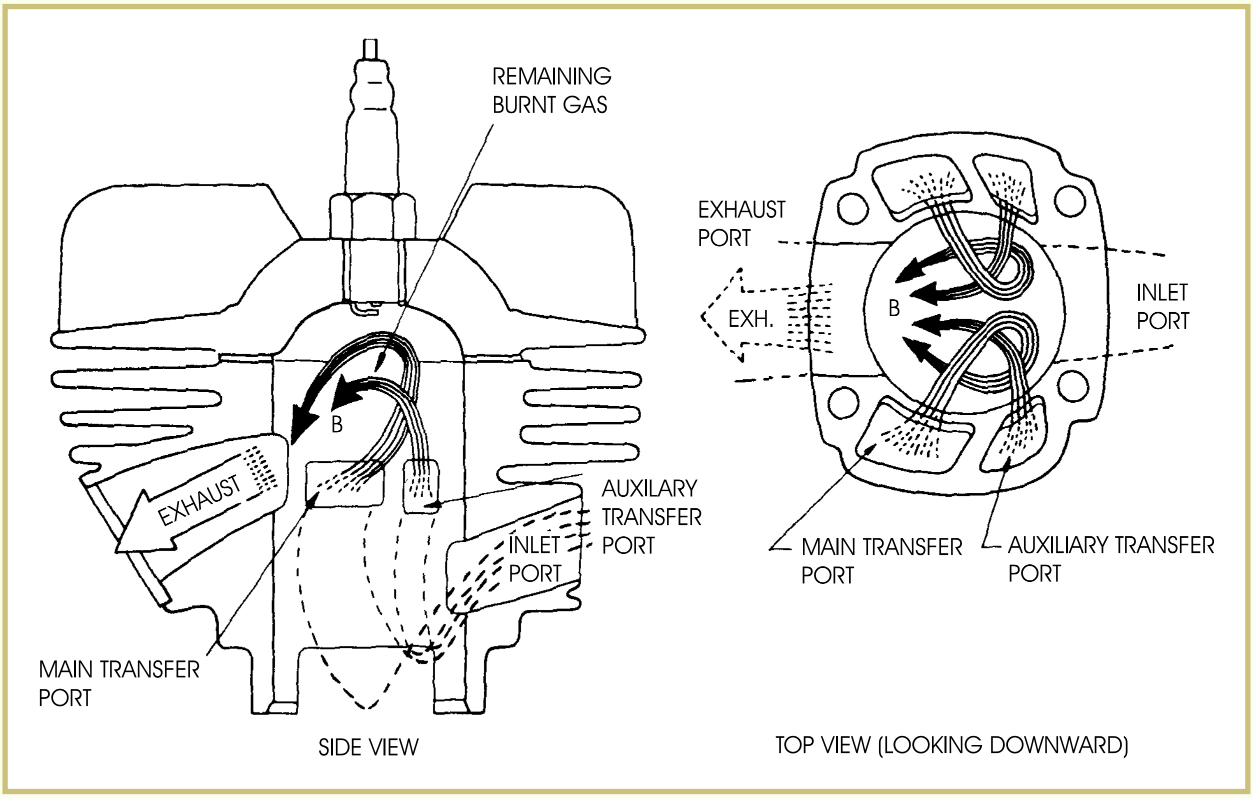


FIGURE 14—The ports in a two-stroke cylinder allow the flow of gases in and out of the engine.

Air-cooled Two-stroke Engines

A significant amount of heat is generated in any internal combustion engine during the combustion stage of the engine's operation. Two-stroke engines must have a way to dissipate this heat. Excessive heat could damage the components. Two-stroke engines use one of two ways of maintaining ideal operating temperature—*air-cooled* and *liquid-cooled* temperature control.

Air-cooled, two-stroke, single-cylinder engines use cooling fins on the cylinder block and the cylinder head to remove any excess heat from the engine. This is done using either the open draft design or the forced draft design. The *open draft* design uses the movement of the open air over the fins while the motorcycle is moving (Figure 15). The *forced draft* design uses air from an engine-driven fan to move cool air through ducts. These ducts, called *shrouds*, surround the engine and keep it cool by forcing the air in towards the cylinder and head fins (Figure 16).

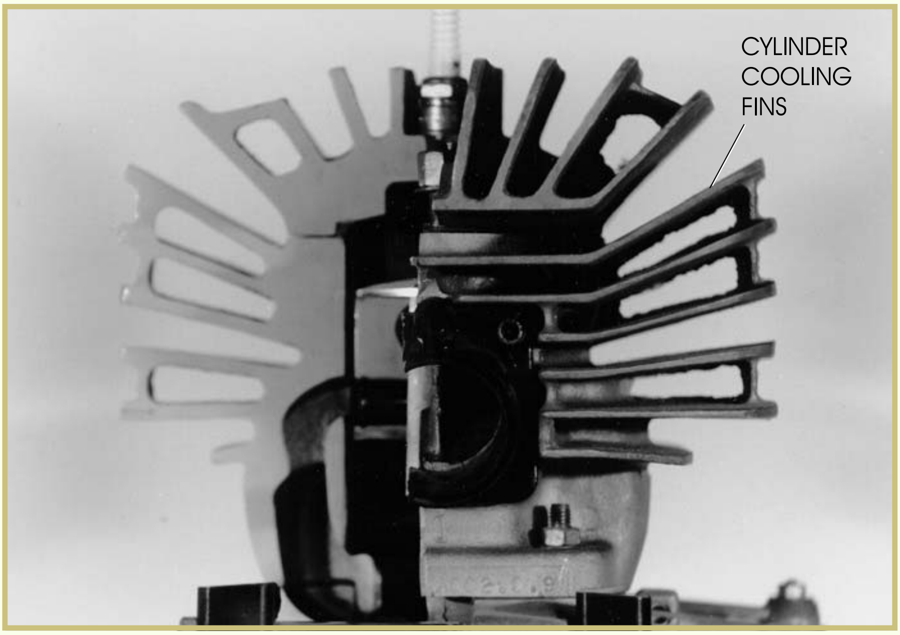


FIGURE 15—An open draft air-cooled cylinder and head are pictured here. Note the cylinder fins that are used to dissipate heat away from the engine.

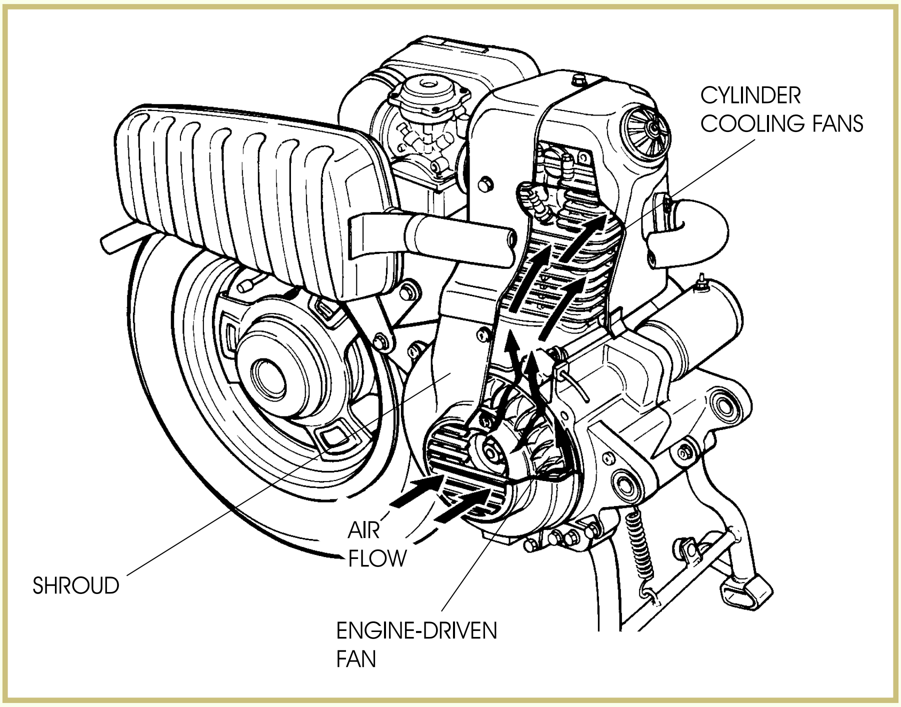


FIGURE 16—A forced draft air-cooled engine uses an engine-driven fan to move air.

Liquid-cooled Two-stroke Engines

The main difference between an air-cooled two-stroke engine and a liquid-cooled two-stroke engine (Figure 17) is the use of a liquid instead of air to maintain proper engine operating temperature. This liquid is usually made up of a 50/50 mixture of *distilled water* and *anti-freeze (ethylene glycol)*. The cylinder and cylinder head have water jackets (Figure 18). A *water jacket* is a series of passageways surrounding the combustion chamber. As the liquid circulates through these passageways, the heat is transferred from the metal to the liquid. Other components such as the radiator, water pump, thermostat, hoses, and a reservoir tank assist with circulation and cooling of the liquid coolant (Figure 19).

A prime advantage of liquid-cooling is the ability to keep the engine at a constant temperature. Another advantage with liquid-cooled engines is that the engines run quieter because the coolant provides sound dampening to the internal engine noises.

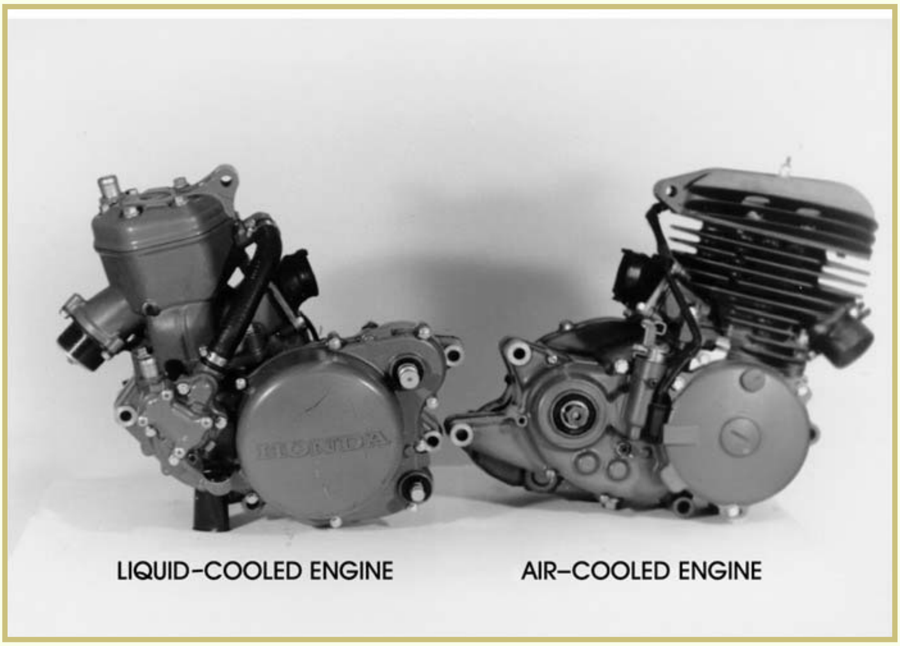


FIGURE 17—Side by side, the differences are easily seen between a liquid-cooled engine on the left and an air-cooled engine on the right. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

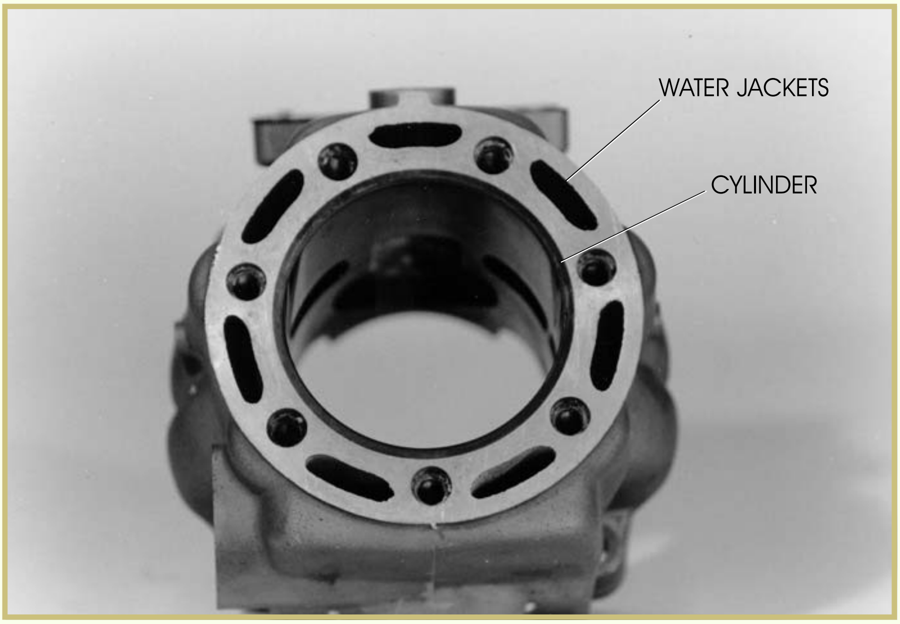


FIGURE 18—The liquid-cooled engine has "water jackets" surrounding the cylinder.

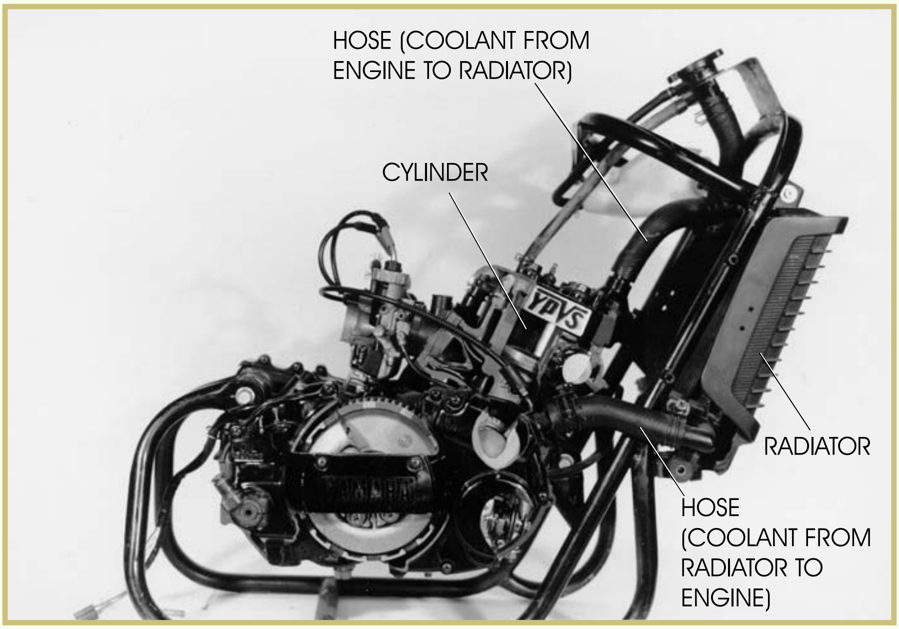
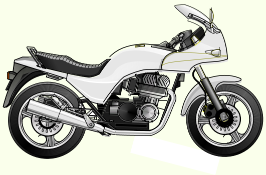


FIGURE 19—A two-stroke liquid-cooled engine and its components is shown here.

Road Test 3



1. What are the two methods used to cool an air-cooled two-stroke engine?

 ____

 ____

2. What is the purpose of the engine crankcases?

 ____

3. The mating surfaces of engine parts are sealed using _______.
4. What are three methods used to start an engine?

 ____

5. What is the purpose of the transmission in a two-stroke single-cylinder engine?

 ____

6. In a two-stroke engine, ports are located in the sides of the _______.
7. What is the job of a clutch in a two-stroke single-cylinder engine?

 ____

8. The coolant in a liquid-cooled two-stroke engine consists of a 50/50 mixture of ethylene glycol and _______.

Check your answers with those on page 41.

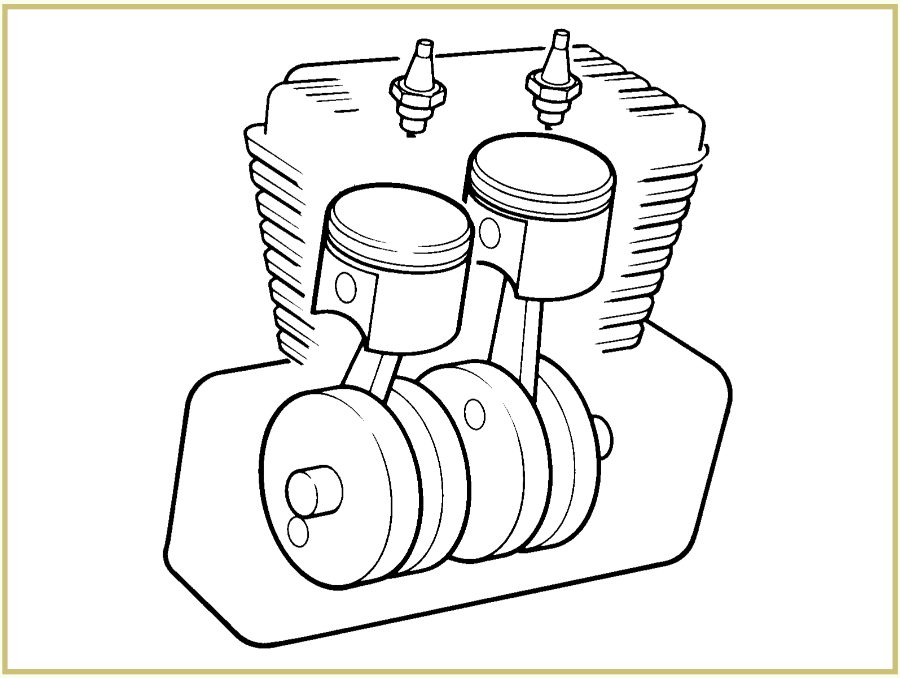
TWO-STROKE ENGINE CONFIGURATIONS

Now that you understand more about the basic two-stroke engine design, let's take a look at the different engine configurations that you might see in a motorcycle or ATV. The obvious difference between a single-cylinder two-stroke engine and a multi-cylinder two-stroke engine is the number of cylinders and pistons. Multi-cylinder engines run more smoothly because there are more power strokes per 360° of crankshaft rotation. More cylinders also means more displacement and more power. Multi-cylinder two-stroke engines may be either air-cooled or liquid-cooled.

Twin-cylinder Two-stroke Engines

The twin-cylinder two-stroke engine is normally configured as an *in-line* or *parallel twin* (Figure 20). The main bottom end components are virtually the same as with a single-cylinder two-stroke engine except for the crankshaft. The crankshaft on a twin-cylinder two-stroke has two connecting rods and pistons attached to it. The two-cylinder crankshaft design used most often is the 180° design. This means that when one piston is at TDC, the other is at BDC (Figure 21). This design allows for two power strokes every 360° of crankshaft rotation. The crankcases are larger to accommodate the extra cylinder and cylinder head. The transmission and clutch are stronger to handle the extra power. Although not very common, one other twin cylinder two-stroke engine configuration that you may see is the *V-twin* (Figure 22). This configuration has one cylinder mounted at an angle (usually 45°) from the other.

FIGURE 20—A two-stroke in-line or parallel twin-cylinder engine is illustrated here.



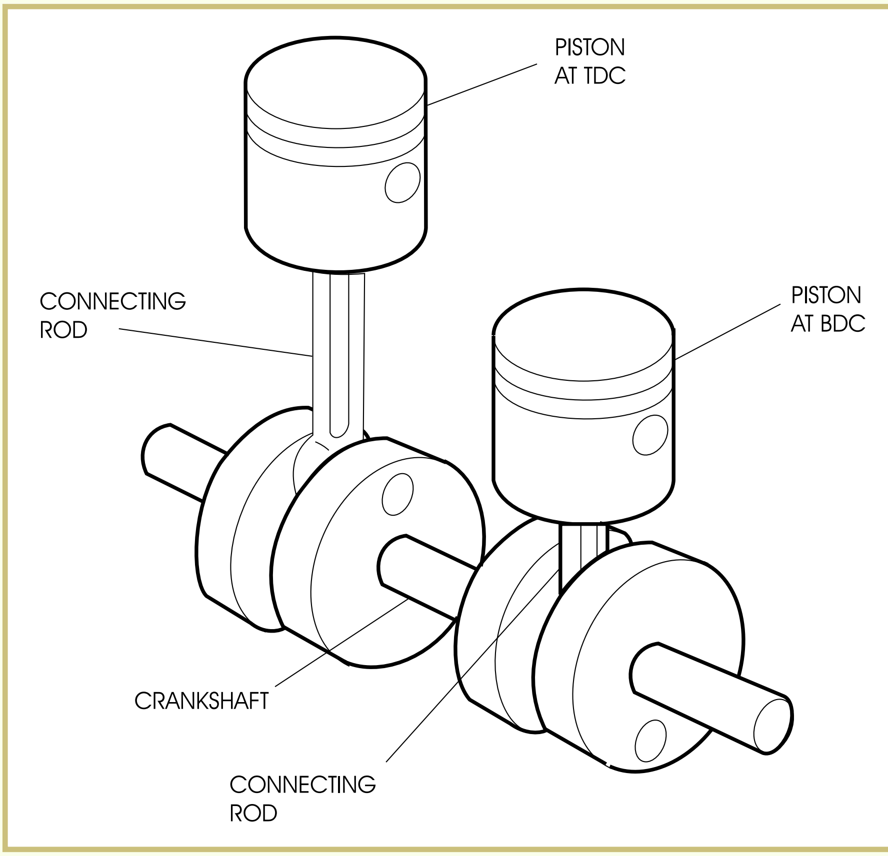


FIGURE 21—A 180-degree crankshaft design has one piston at TDC while the other piston is at BDC as illustrated here.

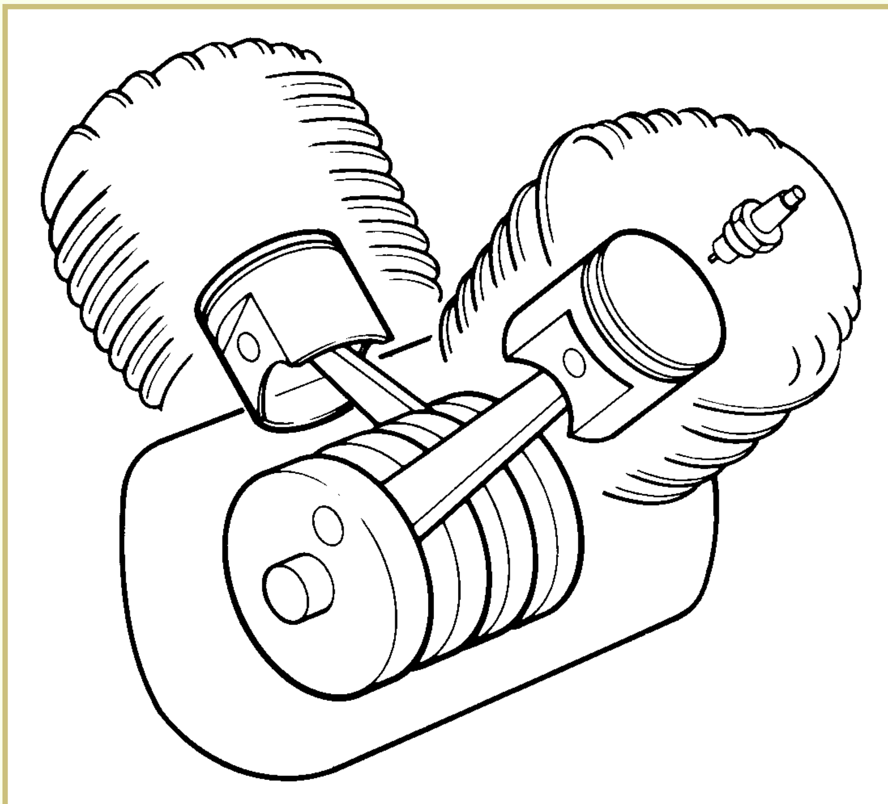


FIGURE 22—Although not very common, some two-strokes are produced in a V-twin configuration.

Three-cylinder Two-stroke Engines

Multi-cylinder two-stroke engines are also available in three-cylinder configurations. The three-cylinder two-stroke engine is normally configured as an in-line or parallel cylinder engine. It's better known as a "triple." The main bottom end components are virtually the same as found in the twin-cylinder two-stroke engine except for the crankshaft. The crankshaft on a three-cylinder two-stroke engine has three connecting rods and pistons attached to it. An in-line triple-cylinder two-stroke engine has a 120° crankshaft design; one piston is at TDC every 120° (Figure 23). This design produces three power strokes every 360° of crankshaft rotation. The crankcases in a "triple" are larger than the twin-cylinder configuration to accommodate the extra cylinder and cylinder head. Also, the transmission and clutch are designed to handle the extra power.

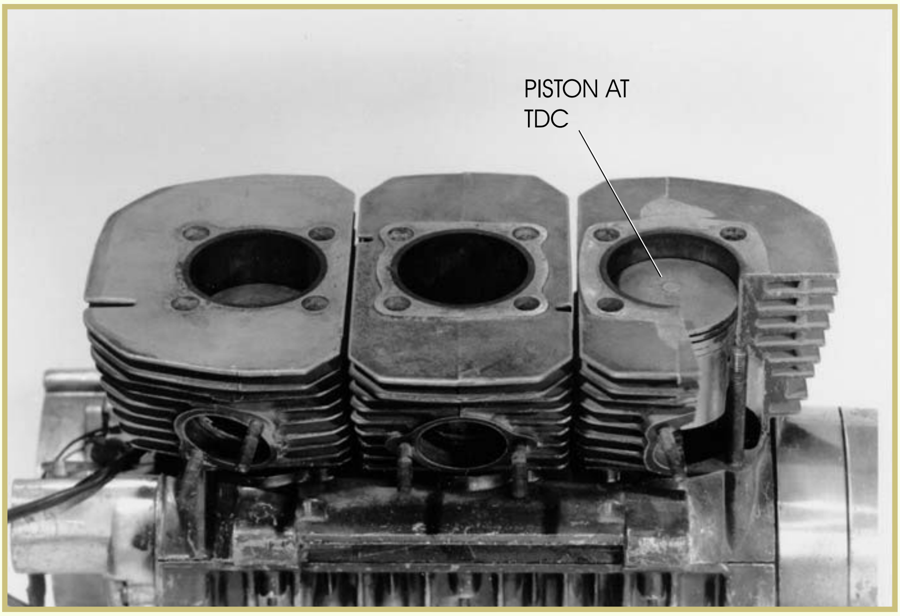


FIGURE 23—A 120° crankshaft has one piston at TDC every 120 degrees. This provides three power strokes in one crankshaft revolution.

Another three-cylinder two-stroke engine configuration that you may encounter is the *V-three*. This configuration has two cylinders attached to the front of the engine and one attached 90° behind the front cylinders (Figure 24). This design is mainly found on high-performance road-racing motorcycles and looks similar to the V-twin cylinder engine design.

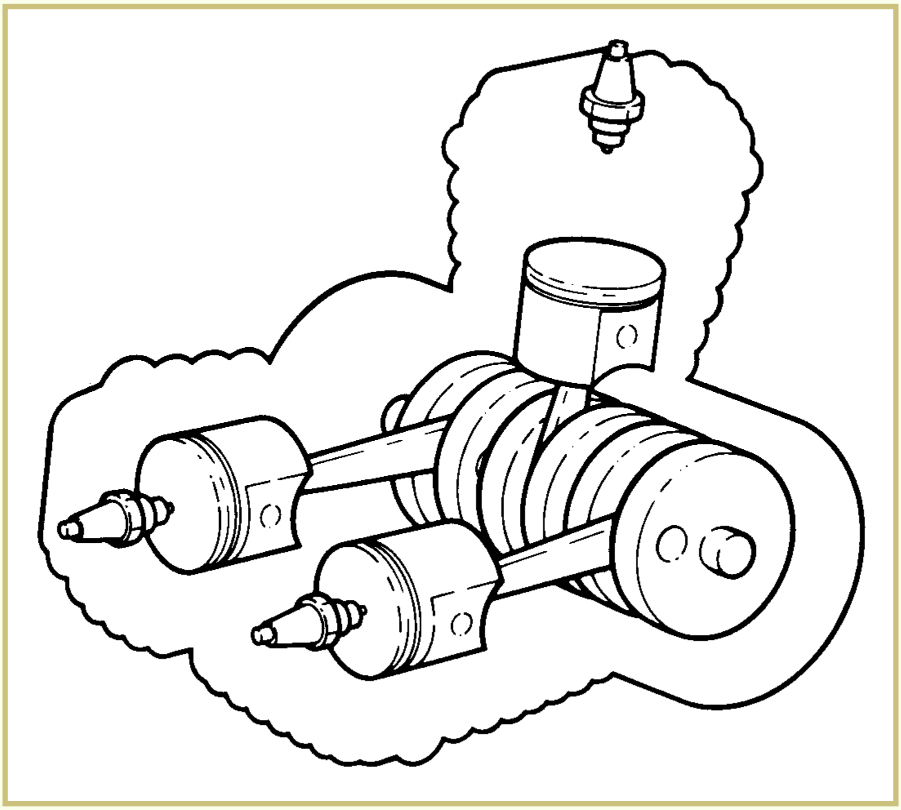


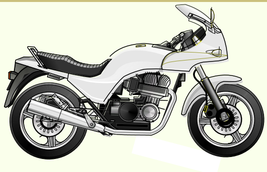
FIGURE 24—The V-three two-stroke configuration is illustrated here.

Four-cylinder Two-stroke Engines

Although not common, there are some four-cylinder two-stroke engines. The four-cylinder two-stroke engine has the highest power-to-weight ratio of any engine found on modern motorcycles. These engines are used primarily on high-performance, high-priced *Grand Prix 500 cc* road-racing machines. The four-cylinder two-stroke engine is so powerful that very few manufacturers provide them for use on public highways. There are very few riders that can handle this kind of power safely.

The four-cylinder two-stroke engine can come in any standard configurations including *in-line-four*, *V-four*, or *square-four*. The square-four engine uses two separate crankshafts that sit parallel to the motorcycle frame. The cylinders sit on top of the crankcases as if they were back-to-back in-line twin-cylinders.

Road Test 4



1. How many power strokes will a three-cylinder two-stroke engine have in 360° of crankshaft rotation?

____

2. Name two advantages of a multi-cylinder two-stroke engine over a single-cylinder two-stroke engine.

____

____

3. How is a twin-cylinder two-stroke engine normally configured?

____

4. What type of two-stroke engine will you most likely find on a 500 cc Grand Prix road-racing motorcycle?

____

5. *True or False?* The most common crankshaft used on a twin-cylinder two-stroke engine is a 360° design.

Check your answers with those on page 41.

FOUR-STROKE ENGINE DESIGN

The four-stroke engines used on motorcycles and ATVs have a more complex design than the two-stroke engines. In this section, we'll cover the four-stroke engine's major components and where they're located. We'll give you a more detailed explanation of how these components work in later sections. You'll find that both the two-stroke and the four-stroke engine share many of the same components.

Single-cylinder Four-stroke Engine Layout

Like we did with the two-stroke engine, let's start with the single-cylinder. Most single-cylinder engines are used in small, lightweight motorcycles (under 500 cc). But a few engines are rated at 600 cc displacement or larger. The single-cylinder four-stroke engine is the least complex of all four-stroke engine configurations (Figure 25). Let's take a look at the bottom end of the engine first.

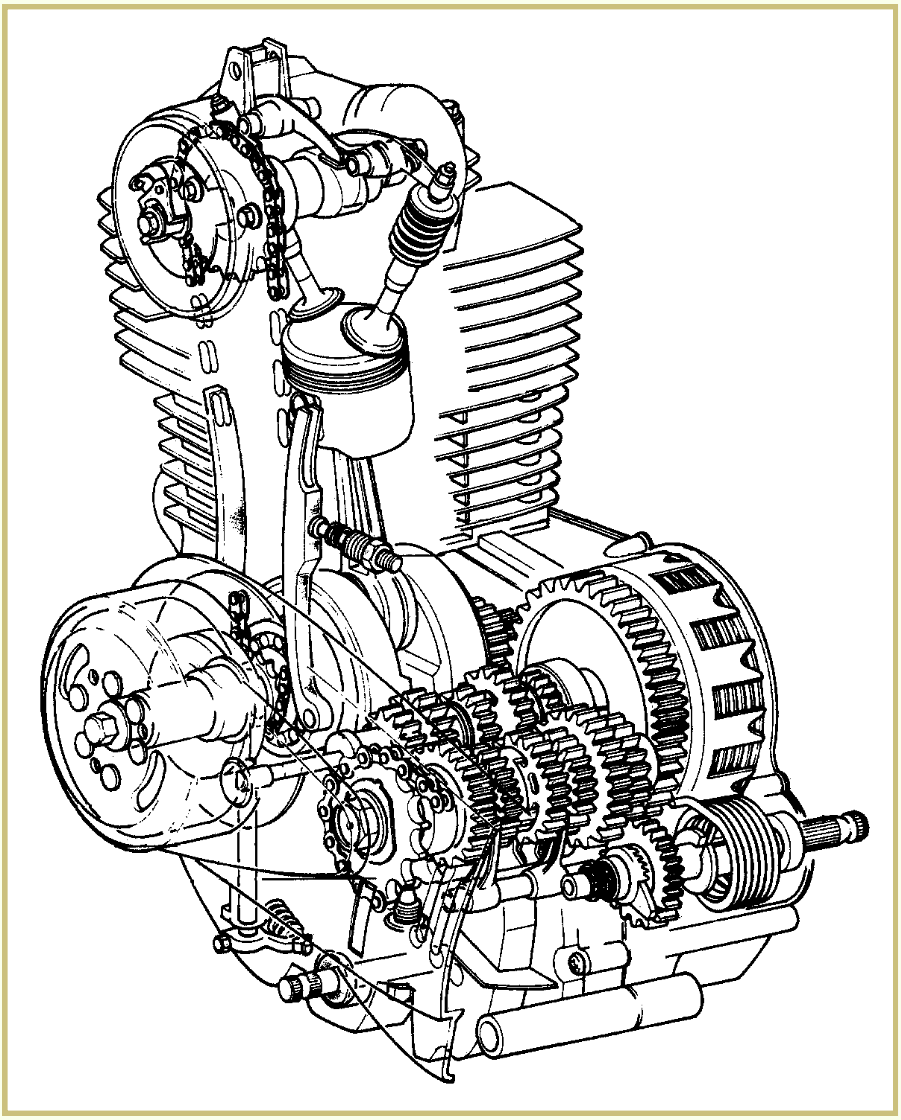


FIGURE 25—An Illustration of a Four-stroke Single-cylinder Engine (Courtesy of Kawasaki Motor Corp., U.S.A.)

The bottom end of a four-stroke engine contains the heart of the engine—the crankshaft. The four-stroke crankshaft may be made up of two flywheel halves (Figure 26), or it may be a one-piece design (Figure 27). It will have a connecting rod, rod *(crank)* pin (if it's a multi-piece design), and a connecting rod needle bearing. At least one bearing on each end supports the crankshaft and allows it to rotate freely. The crankshaft is located in the engine crankcases.

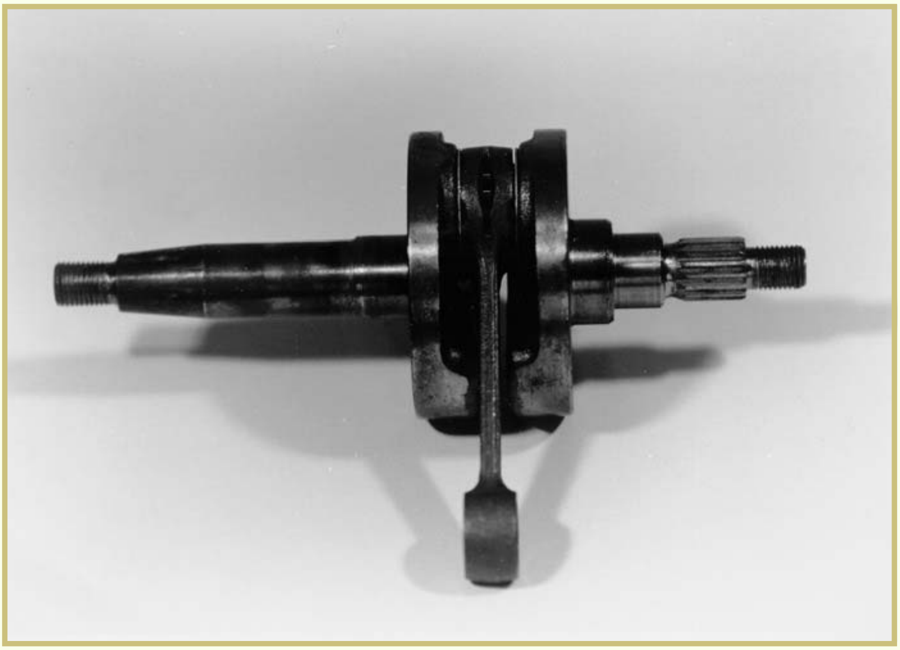


FIGURE 26—An actual multi-piece four-stroke crankshaft is pictured here.

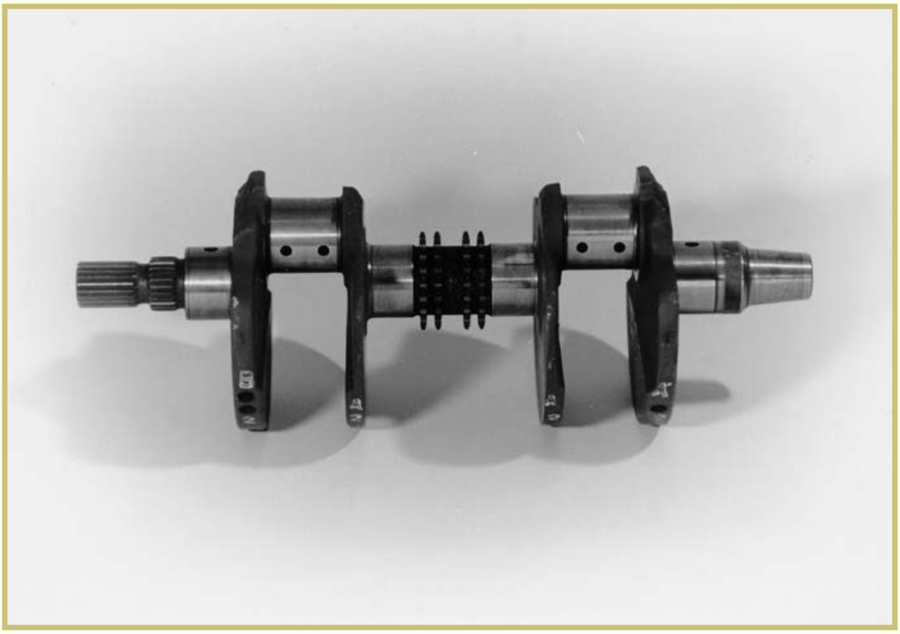


FIGURE 27—This illustration shows a one-piece four-stroke crankshaft.

Just as with the two-stroke engine, the engine crankcases are used to hold all of the engine components together and provide the main engine mounting points (Figure 28). There are two crankcases—center and side. The center crankcases hold the major components. The side crankcases enable you to gain access to various parts of the engine without having to fully disassemble it. The side crankcases are also known as side covers.

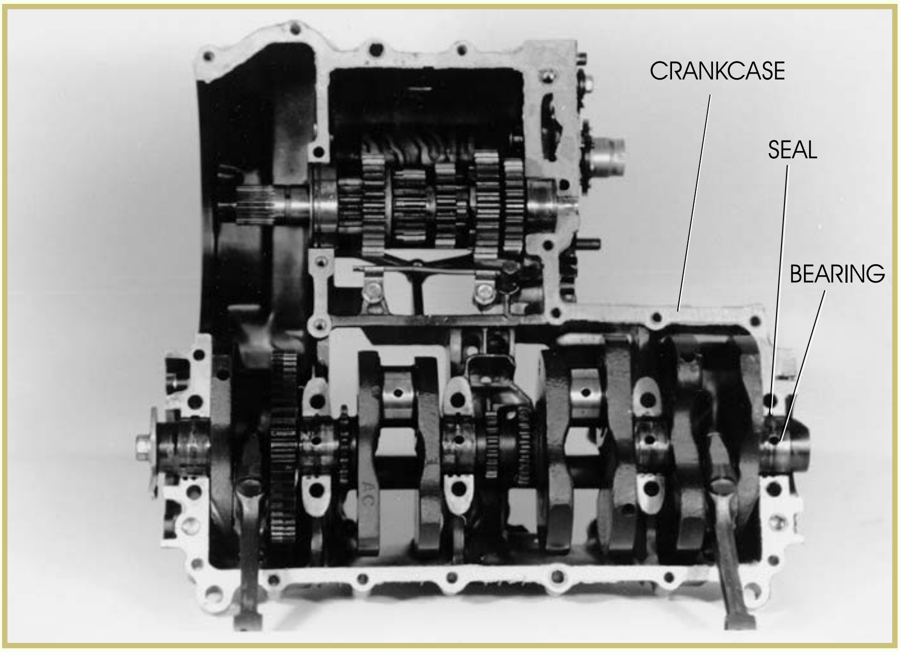


FIGURE 28—The crankcases hold the components together. One half of a crankcase set is pictured here.

Seals are used to protect rotating shaft bearings. The seals are typically located at the ends of the rotating shafts. These seals prevent gases and oil from escaping from the crankcases and also prevent outside substances from getting into the crankcases.

Bearings are found primarily in the crankcases of the four-stroke engine. Bearings are designed to reduce friction and to allow shafts to rotate freely under various engine loads.

You'll also find a four-stroke single-cylinder engine's transmission in the crankcases.

Transmissions found on four-strokes are identical in design to those found on the two-stroke engine (Figure 29). The transmission consists of gears, shafts, and shifting mechanisms. These components work together to transmit power from the crankshaft to the rear wheel and to help keep the engine running in the desired rpm range. The clutch in the four-stroke engine is used to engage and disengage the transmission and the rear wheel from the crankshaft power output, just as we found in the two-stroke engine.

Gaskets are used to seal the mating surfaces of various parts of the engine. The two surfaces are usually both metal. Gasket material may be rubber, cork, or metal.

The four-stroke single-cylinder engine uses the same starting methods found on the two-stroke engine—kick start, recoil start, or electric start. As you can see, the four-stroke engine bottom end is almost identical to the two-stroke engine bottom end. The biggest difference is in the top end. Let's look at the top end of the four-stroke engine.

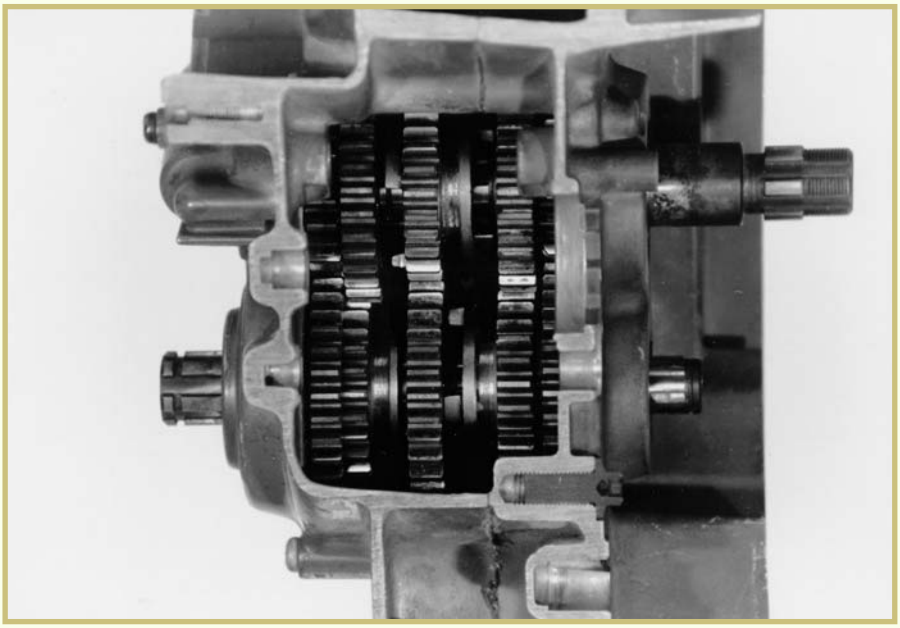


FIGURE 29—Transmissions are identical in both design and function in the two-stroke and four-stroke motorcycle and ATV engines.

The piston is attached to the crankshaft connecting rod (Figure 30). The piston is held in place by a wrist pin. Clips prevent the pin from moving. The wrist pin usually has a bushing between it and the connecting rod. Piston rings are located in the slots on the outer diameter of the piston to make a seal between the piston and cylinder wall. The piston travels up and down in the cylinder, which is usually positioned vertically (Figure 31).

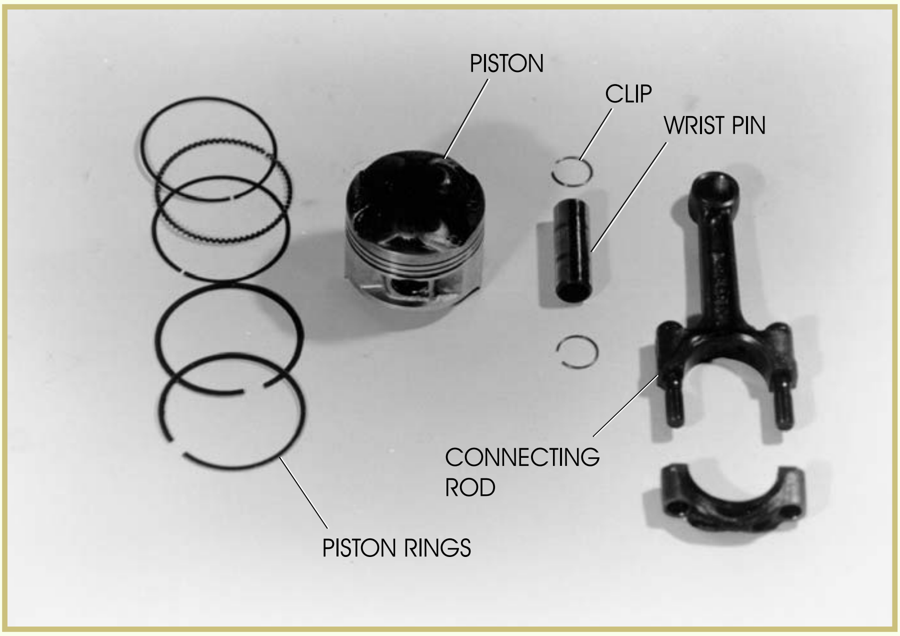
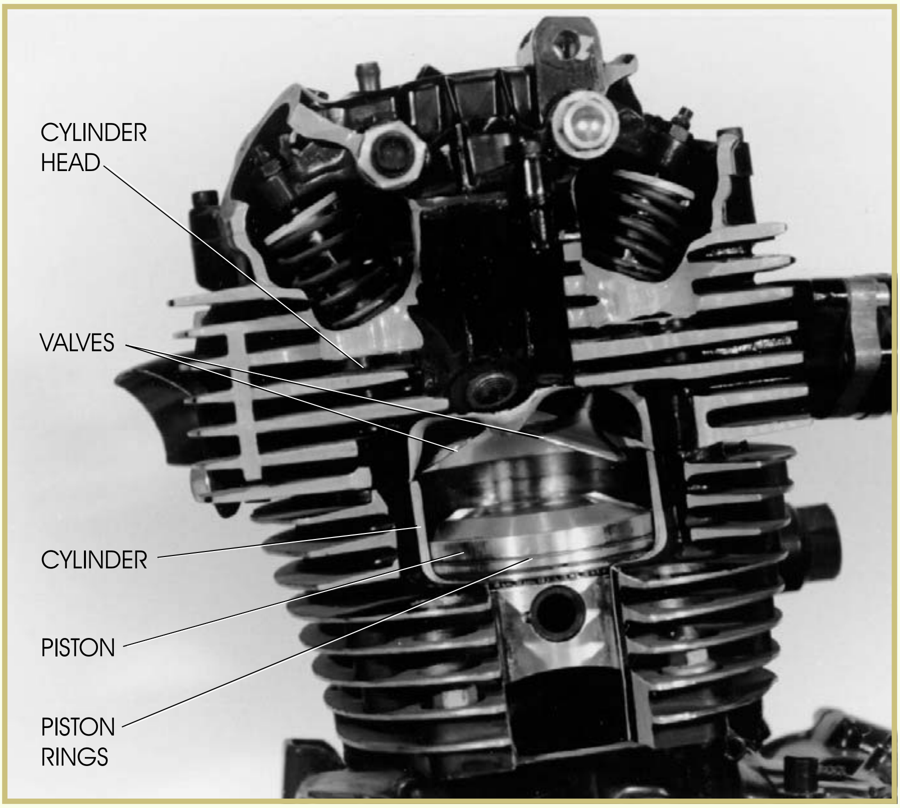


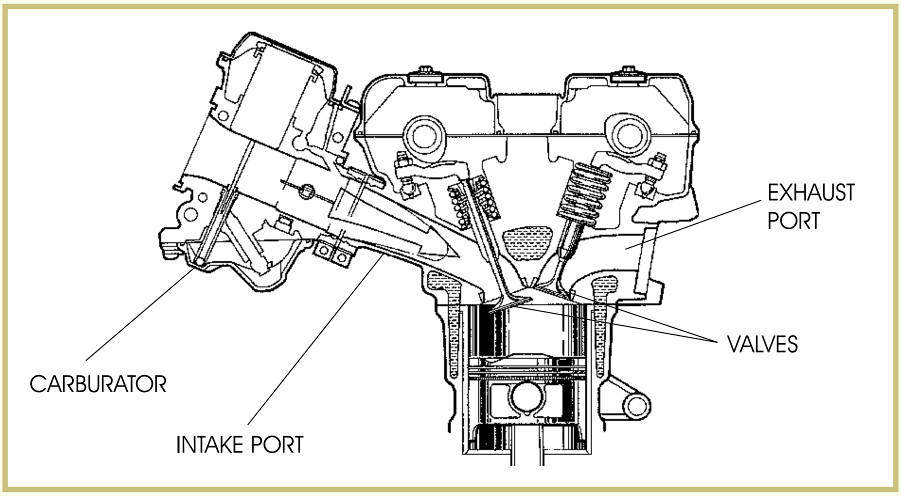
FIGURE 30—This picture shows a four-stroke piston and its related parts.

FIGURE 31—This picture shows a four-stroke engine cylinder and related components.



The cylinder head is attached to the cylinder to seal the top of the cylinder from the outside of the engine. The cylinder head of the four-stroke motorcycle and ATV contains holes that are called ports (Figure 32). These ports are opened and closed with *valves*. The valves control the air-and-fuel mixture that's drawn into the cylinder and the exhaust gases that are expelled. These valves are actuated by one (Figure 33) or two *camshafts* (Figure 34) that are normally installed on top of the cylinder head. This engine style is known as an *overhead camshaft*. The camshaft is connected to the crankshaft via a chain, belt, or set of gears.

FIGURE 32—The four-stroke cylinder head has ports and valves to allow the flow of intake and exhaust gases.



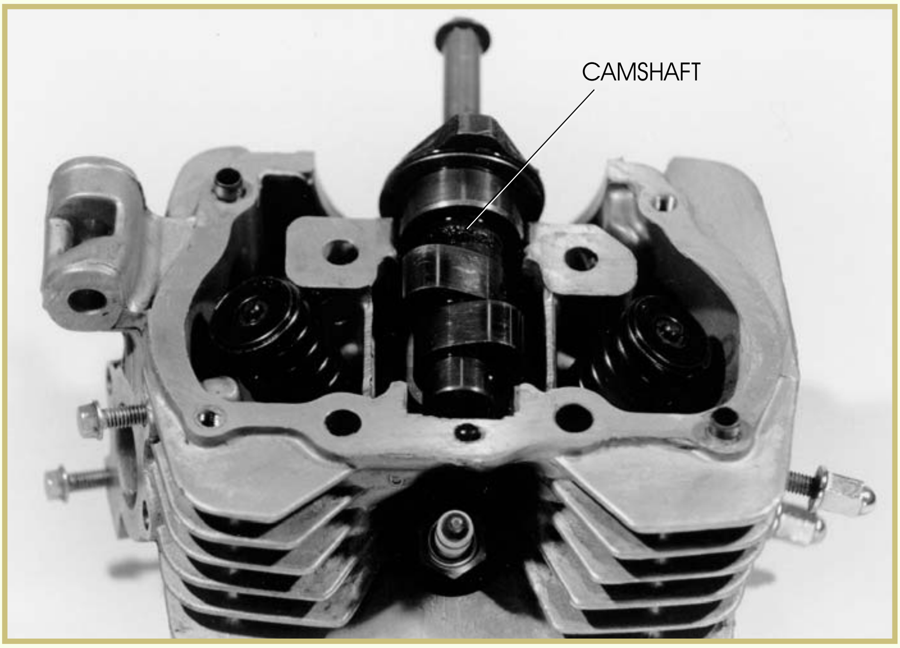


FIGURE 33—This picture shows a single overhead camshaft.

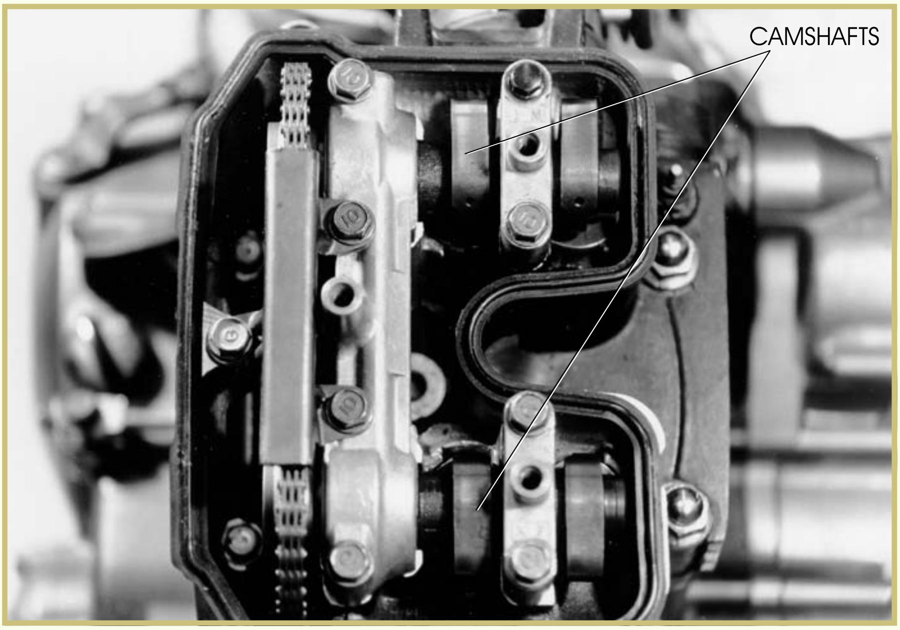


FIGURE 34—This picture shows a double overhead camshaft.

Many single- and twin-cylinder, large displacement engines use a counterbalancer to help keep the engine running smoothly. The *counter-balancer* is a device that balances the power pulses created by the power strokes (Figure 35). Many manufacturers of single- and twin-cylinder engines use a gear- or chain-driven counterbalancer to offset the uneven forces that create vibration. This system requires additional parts but very little maintenance.

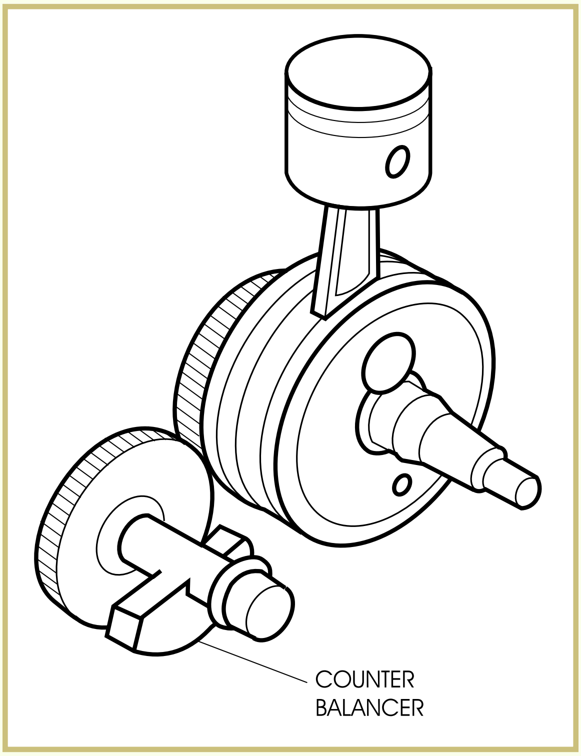


FIGURE 35—Counter-balancers are used to help some four-stroke singles and twins run smoothly.

Air-cooled Four-stroke Engines

Air-cooled engines use cooling fins on the outside of the cylinder block and the cylinder head to dissipate excess heat from the engine (Figure 36). As on the two-stroke engine, this cooling method is either open draft or forced draft.

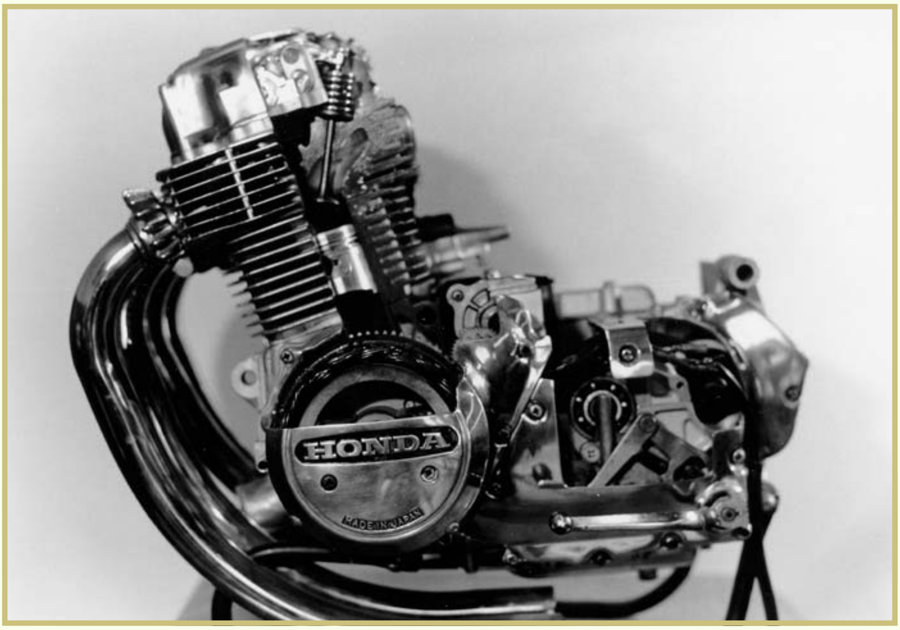


FIGURE 36—Cylinder and cylinder head cooling fins control temperatures on the air-cooled engine. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

Liquid-cooled Four-stroke Engines

Just like the two-stroke engine, the main difference between an air-cooled and a liquid-cooled four-stroke engine is the use of a coolant instead of air to control the engine's temperature. The coolant is usually made up of a 50/50 mixture of distilled water and ethylene glycol. The cylinders and cylinder heads are kept at the proper operating temperature by the use of a water jacket and other components such as a radiator, water pump, and hoses to assist with circulation of the coolant (Figure 37). The same advantages of a liquid-cooled two-stroke engine are found with the four-stroke engine. Liquid cooling has the ability to keep the engine at a constant temperature. The other advantage with liquid-cooled engines is that the engine runs quieter because the coolant provides sound dampening to the internal engine noises.

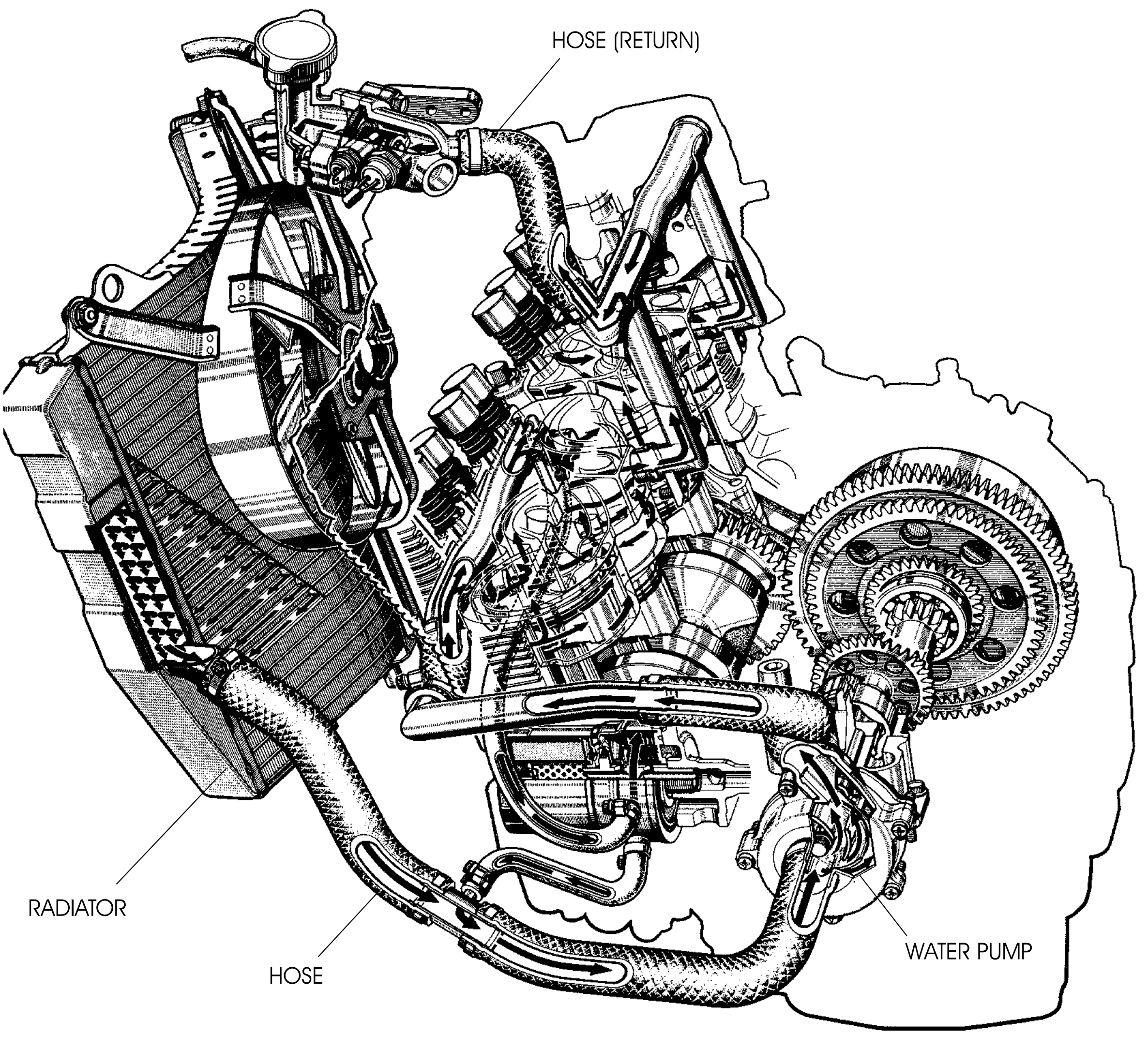
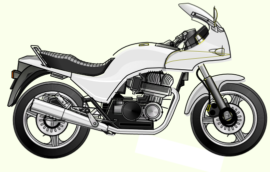


FIGURE 37—This illustration shows the system components in a four-stroke liquid-cooled engine.

Road Test 5



1. In an air-cooled engine, the cooling fins are located on the _______ and the _______.
2. A _______ activates the valves in a four-stroke engine.
3. _______ reduce friction and allow shafts to rotate freely while carrying a load.
4. What is the purpose of a counterbalancer on a four-stroke engine?

 ____

5. In a four-stroke engine, the ports are located in the _______.

Check your answers with those on page 41.

FOUR-STROKE ENGINE CONFIGURATIONS

Four-stroke engine design, layout, and configuration are factors in cooling and vehicle handling. Like the two-stroke engine, the number of cylinders determines the number of power strokes produced relative to crankshaft rotation. The number of cylinders, compression ratio, camshaft design, and engine displacement determine the amount of horsepower and torque produced by a four-stroke engine. These factors will be discussed in future study units.

Vertical Twin-cylinder Four-stroke Engines

Vertical twin-cylinder four-stroke motorcycle engines use either a 180° or 360° crankshaft design (Figure 38). If one piston is up while the other is down, it's a 180° crankshaft. If both pistons rise and fall together, it's a 360° crankshaft.

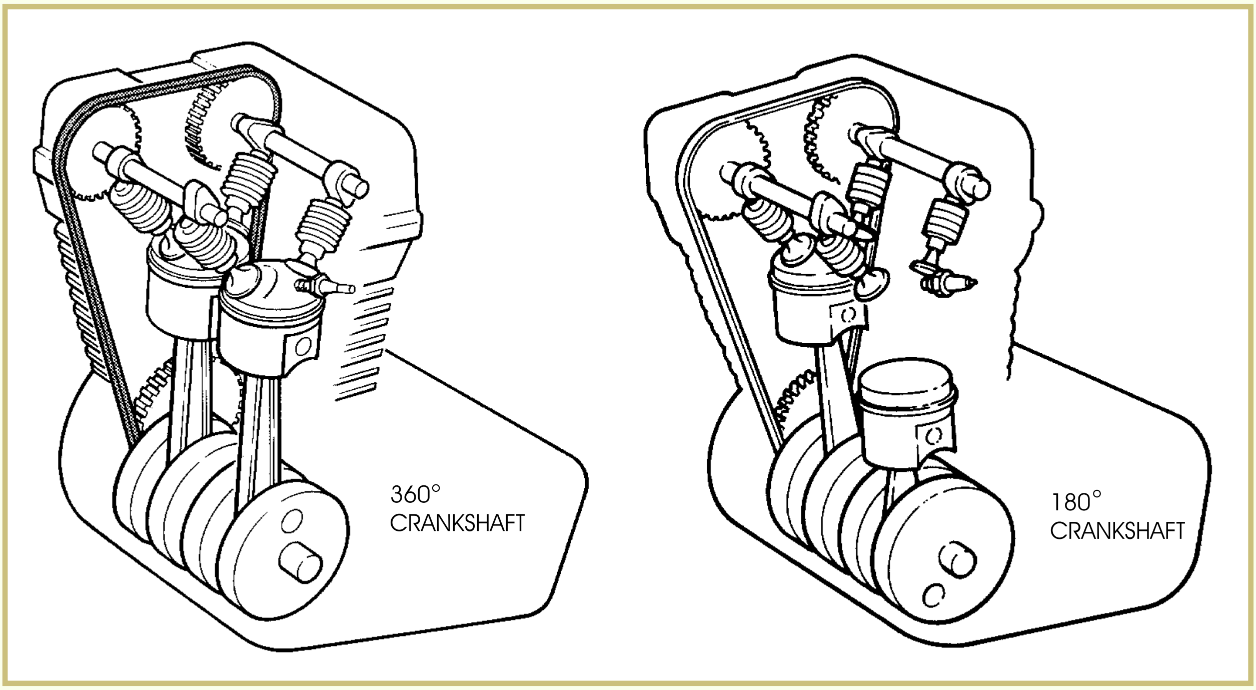
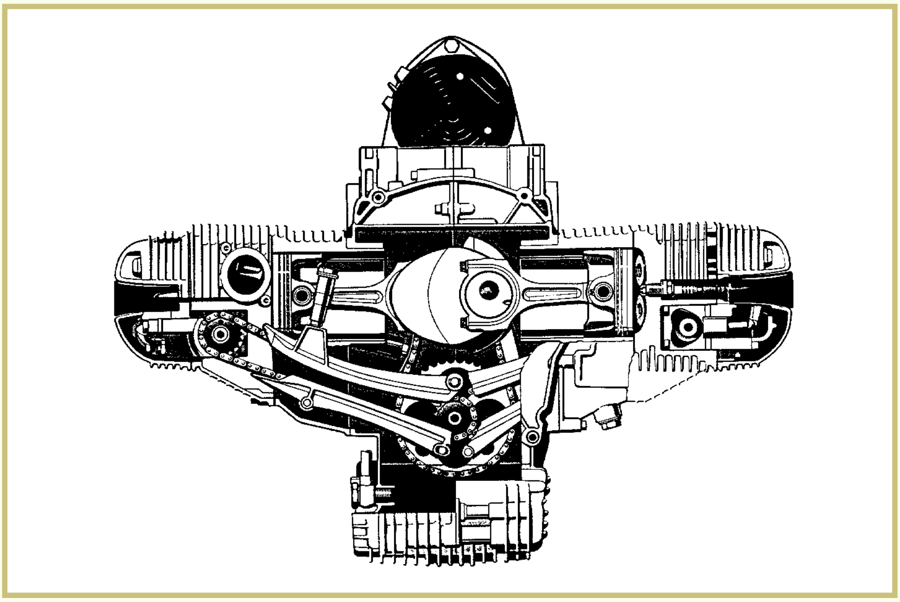


FIGURE 38—A four-stroke, twin-cylinder, 180° crankshaft design is shown on the right. A 360° design is shown on the left.

Horizontally-opposed Twin-cylinder Four-stroke Engines

On horizontally-opposed, twin-cylinder, four-stroke motorcycle engines, the crankshaft is in line with the motorcycle frame (Figure 39). The crankshaft layout is a 180° design. Because the cylinders oppose each other, the pistons move in and out at the same time and keep the engine in balance. This design allows the engine to be mounted lower in the frame, creating a lower center of gravity and improving weight distribution.

FIGURE 39—A horizontally-opposed twin is illustrated here. Note the 180° crankshaft design.



V-Twin Four-stroke Engines

The V-twin four-stroke engine design (Figure 40) allows for the greatest amount of engine displacement in the smallest overall area. This type of engine design is most often found on custom cruiser-type motorcycles, although recently it has also been adapted for use on sport-type motorcycles.

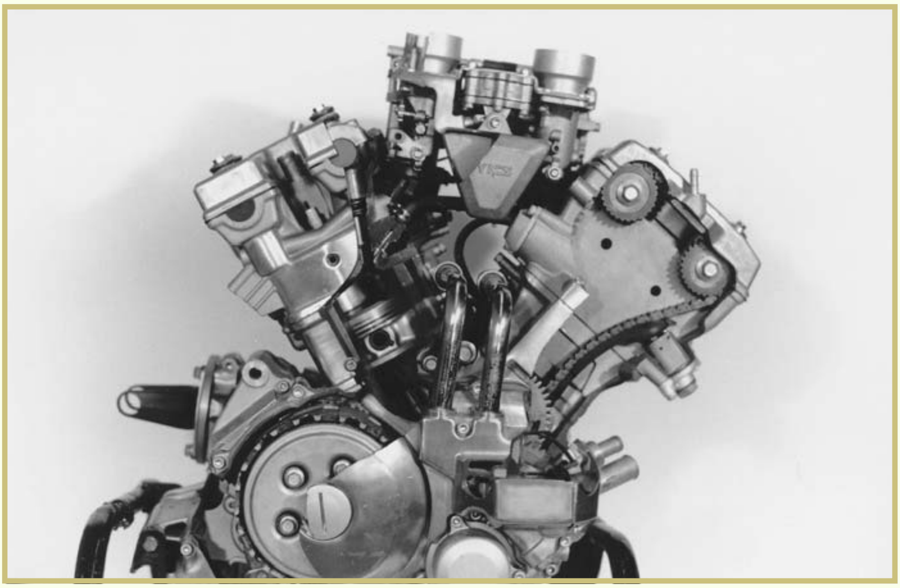


FIGURE 40—The V-twin allows for the largest displacement in the smallest overall space. It's found most often on custom cruiser motorcycles.

In-line Multi-cylinder Four-stroke Engines

In-line multi-cylinder engines are found in three-, four- , and six-cylinder designs. The cylinders may be vertical, horizontal, or positioned at any angle in between. The cylinders may be transversely positioned from left to right or longitudinally positioned parallel with the frame.

An in-line multi-cylinder engine is usually designed so that the power strokes are spaced to occur at an equal number of degrees apart. In a four-cylinder engine, four power strokes occur in two full turns of the crankshaft (720° of rotation). The crankshaft and camshaft are designed so that there's 180° between each power stroke. This engine design creates a very smooth-running engine.

V-Four Four-stroke Engines

The four-stroke V-four engine design is more compact than the in-line four-cylinder engine and produces minimal vibration (Figure 41). It may have either a 180° or 360° crankshaft design (Figure 42). A negative with this V-four design is the cost involved to manufacture the engine. It's much more complex and costly because it uses essentially twice as many top end components as the in-line four-cylinder engine.

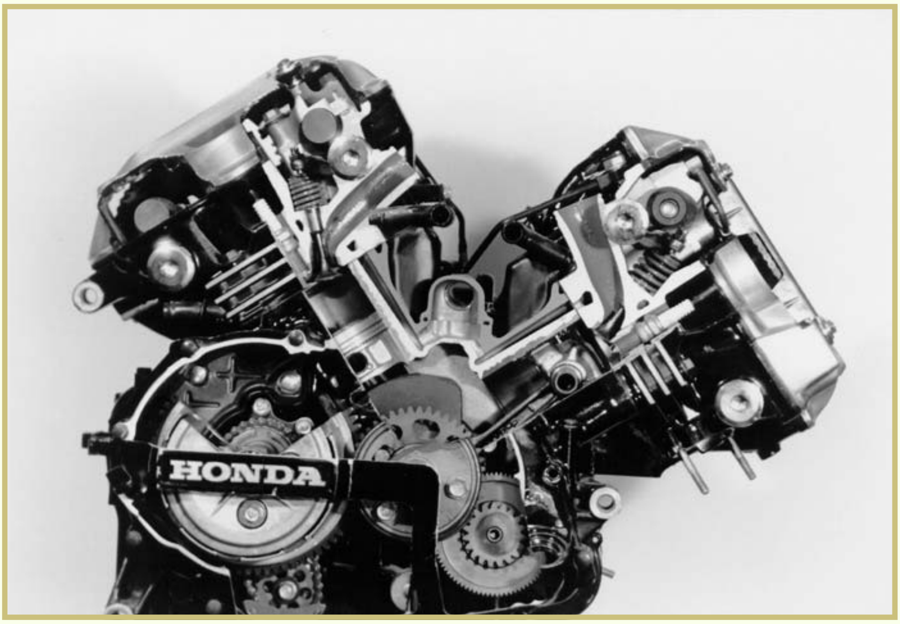


FIGURE 41—The V-four motorcycle engine is very complex. (Copyright by American Honda Motor Co., Inc. and reprinted with permission)

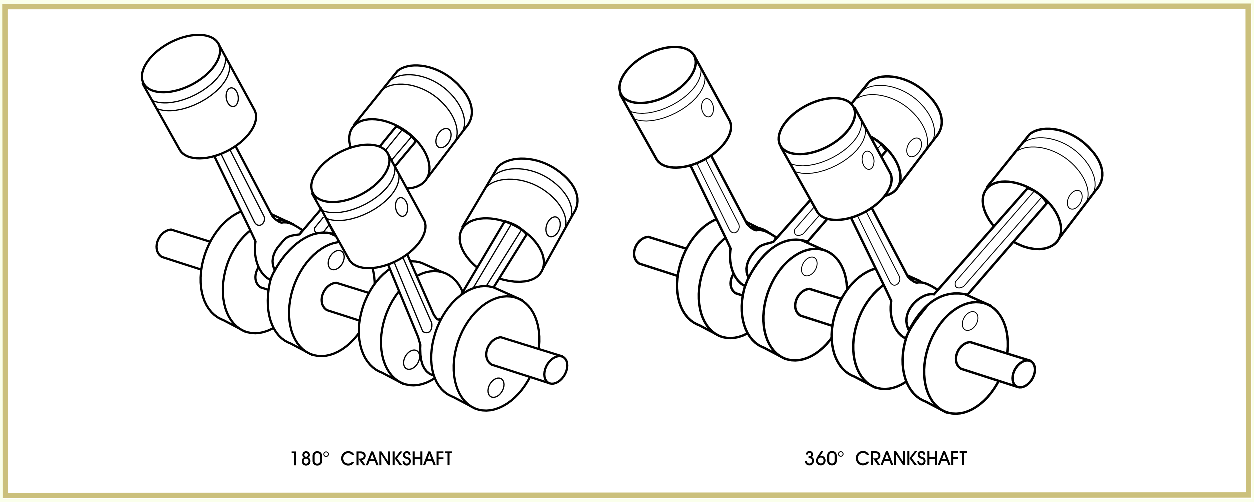
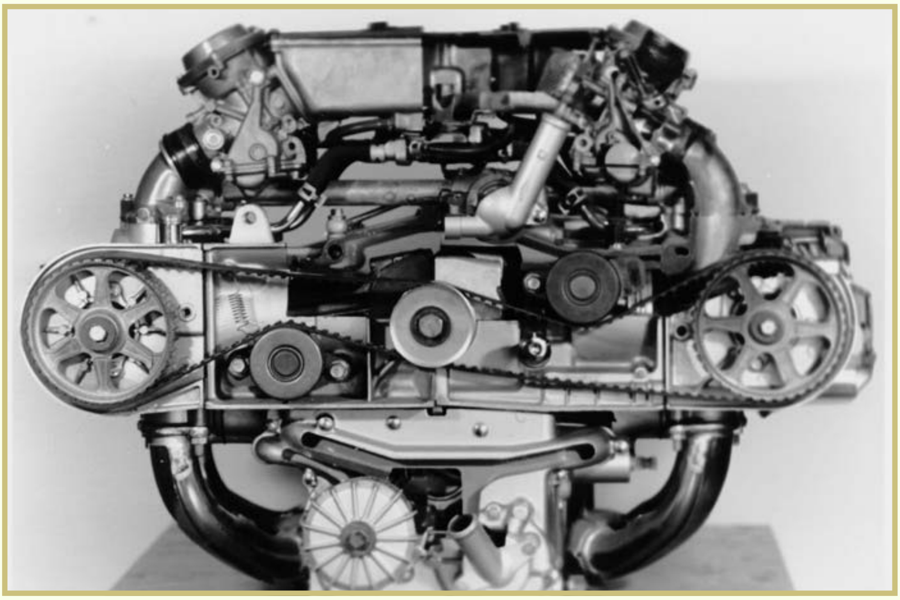


FIGURE 42—This illustration shows the V-four, four-stroke, 180° and 360° crankshaft designs.

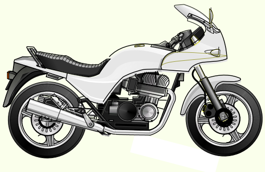
Horizontally-opposed Multi-Cylinder Four-stroke Engines

Horizontally-opposed multi-cylinder engines (Figure 43) are similar to the flat twin design with additional cylinders on each side. They come in both four- and six-cylinder configurations. Because the cylinders lie side by side, most engines using this design are liquid-cooled to ensure adequate rear cylinder cooling. The opposed multi-cylinder engine is mounted lower in the frame than an in-line engine to lower the center of gravity and improve weight distribution. The Honda Goldwing is a popular model of this design.

FIGURE 43—The horizontally-opposed engine is very wide and is usually liquid-cooled to prevent the rear cylinders from overheating.



Road Test 6



1. What are the two crankshaft designs that you'll find on a vertical twin-cylinder four-stroke engine?

   ____

2. How many power strokes will occur in 720° of crankshaft revolution in an in-line, four-cylinder, four-stroke engine?

   ____

3. *True or False?* In a horizontally-opposed, twin-cylinder, four-stroke engine with a 180° crankshaft, the pistons move in and out at the same time.

4. Why are horizontally-opposed multi-cylinder (four or six) engines normally liquid-cooled?

   ____

5. On a twin-cylinder engine, if both pistons rise and fall together, the engine has a _______ degree design crankshaft.

Check your answers with those on page 41.

Road Test Answers

1

1. combustion chamber
2. Intake, compression, power, and exhaust
3. The distance that the piston travels up or down in a cylinder
4. BDC (bottom-dead-center)
5. crankshaft

2

1. The size of the engine and the amount of power it produces
2. Power = Work ÷ Time
3. Dynamometer, or dyno for short
4. True
5. Combustion chamber volume
6. 60 ft-lb
7. rpm (revolutions per minute)

3

1. Open draft and forced draft
2. The crankcases hold all of the engine components together and supply the main engine mounting points.
3. gaskets
4. Kick start, electric start, and recoil start
5. To transmit power from the crankshaft to the rear wheel while keeping the engine running at the desired rpm
6. cylinder
7. To engage and disengage power from the crankshaft to the transmission, and then to the rear wheel
8. distilled water

4

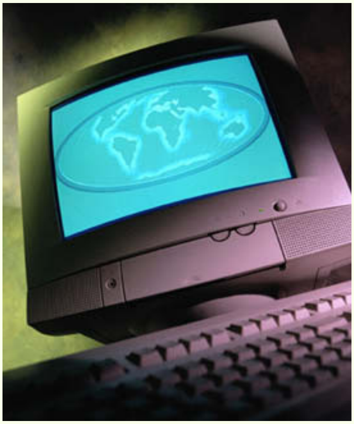
1. Three
2. More power, runs smoother
3. In-line or parallel
4. Four-cylinder
5. False

5

1. cylinder, cylinder head
2. camshaft
3. Bearings
4. To help smooth the power pulses
5. cylinder head

6

1. 180° and 360°
2. Four
3. True
4. To keep the rear cylinders cooled
5. 360



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