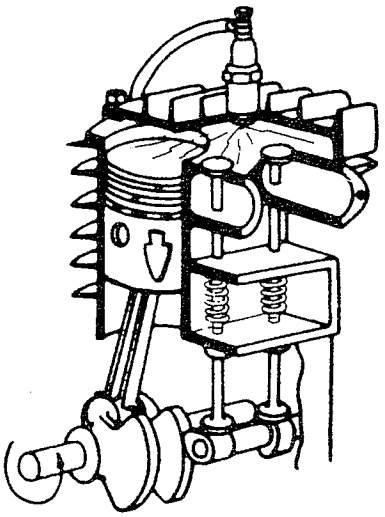


unit 5

fundamentals of the four-stroke-cycle engine

An engine is a machine that changes fuel and into power. A fuel, such as gasoline, is mixed air. The mixture of air and gasoline is then bu to create an expanding gas. The expanding g used to develop power. In this unit we are goi see how an engine works to develop the po We will study an engine called the four-st cycle. Many small engines are four-stroke-c engines.

LET'S FIND OUT: **When you finish reading and studying this unit, you should be able to:**

1. **List the basic parts of an engine.**
2. **Explain how a basic engine works.**
3. **List and describe what happens in the four strokes.**
4. **Name the parts of a small four-stroke-cycle engine.**
5. **Explain how the valve train works.**

ENGINE OPERATION

The burning of the mixture of air and fuel is called combustion. In the kind of engines we will study, combustion takes place inside the engine. For this reason, such machines are called internal combustion engines. An internal combustion engine is really just a container in which we burn air and fuel.

Basic Parts

The tube used for burning the air and fu called a *cylinder,* Figure 5-1. An engine cylind simply a metal tube closed at one end. We cal moving part that fits inside the cylinder a *pis* There is a small space between the piston and top of the cylinder where the burning takes pl This space is called the *combustion chambe*

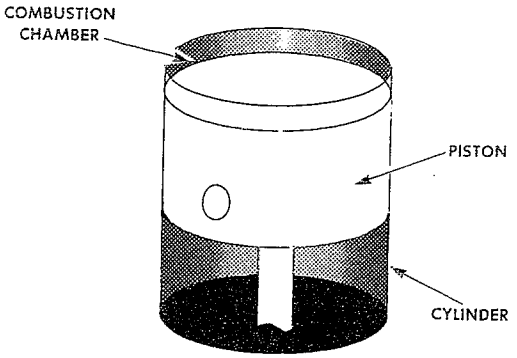


Figure 5-1. The tube is a cylinder and the plug is a piston.

As the mixture of air and fuel is burned in the combustion chamber, the expanding gas forces the piston down the cylinder. We want to use the power from the moving piston. To do this we must connect the piston to something. This can be done by attaching a rod to the bottom of the piston. The other end of the rod may be connected to a pin on the spoke of a wheel, as shown in Figure 5-2. The rod is called a *connecting rod.*

As the piston is forced downward, the connecting rod attached to the pin on the spoke of the wheel moves downward. This causes the wheel to turn. So a downward push on the piston is changed to a round-and-round movement at the wheel as shown in Figure 5-3.

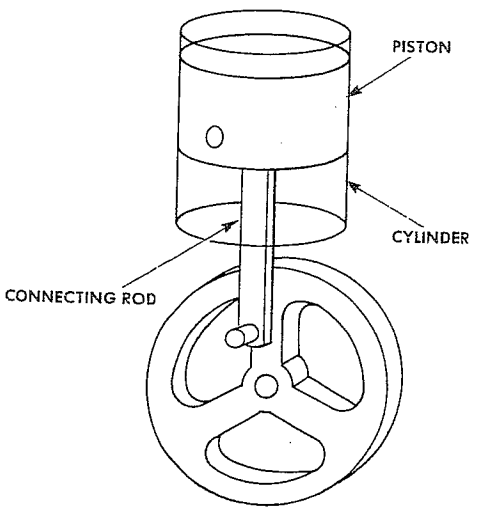


Figure 5-2. A connecting rod connects the piston to a spoke on a wheel.

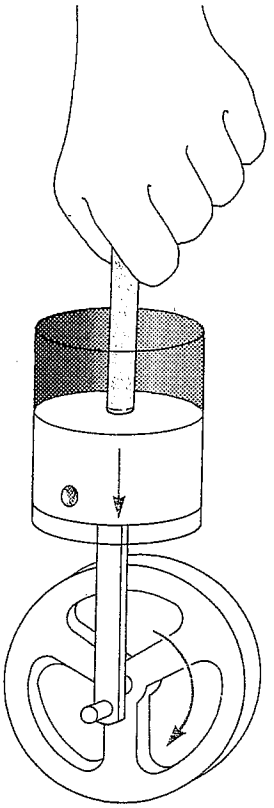


Figure 5-3. When the piston is pushed down, the wheel turns.

In a real engine, we do not use a wheel with a spoke. We use a part called a *crankshaft.* The crankshaft is a bar with its ends mounted so that it can turn freely. The middle of the crankshaft is bent up or offset. The lower end of the connecting rod is connected to the middle of the crankshaft as shown in Figure 5-4. At the upper end, the connecting rod is connected to the piston with a piston pin, as shown in Figure 5-5. This lets the connecting rod follow the crankshaft's motion.

The action of the piston, connecting rod and crankshaft is similar to the action of riding a bike. When your leg pushes down on a pedal, the sprocket goes around. Your legs go up and down

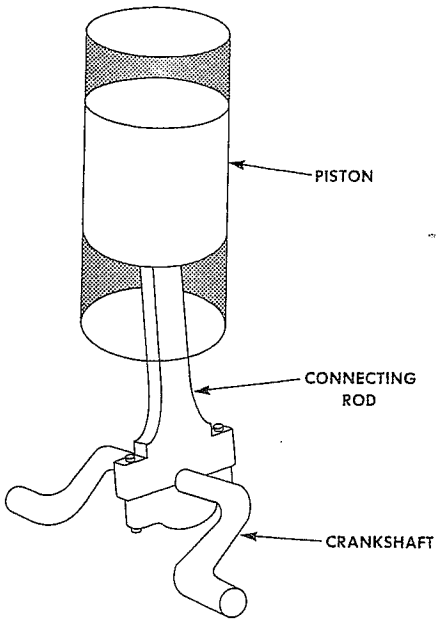


Figure 5-4. The connecting rod is connected to an offset shaft called the crankshaft.

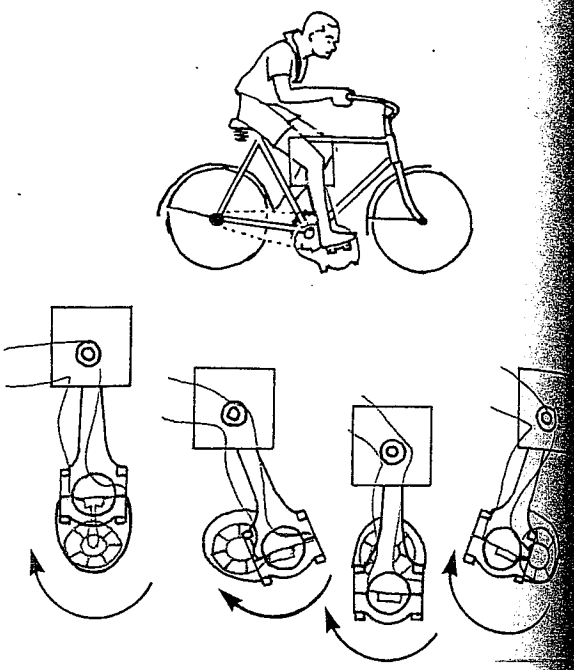


Figure 5-6. Piston and pedal action are much same.

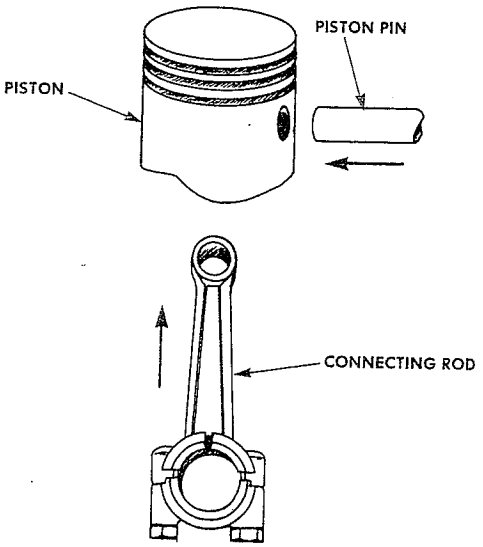


Figure 5-5. The connecting rod is attached to the piston by a pin so it can move.

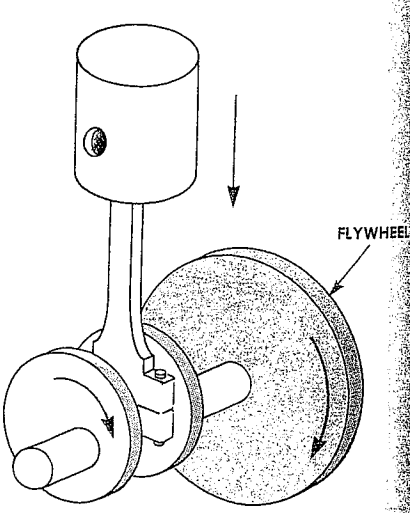


Figure 5-7. A heavy wheel called the flywheel with the crankshaft.

like pistons. The sprocket goes around and around like the crankshaft. This action is shown in Figure 5-6.

We need one more part to complete our basic engine. We want to push the piston down the cylinder more than one time. This means we bring it back up to the top of the cylinder. A wheel called a flywheel is mounted to the e the crankshaft as shown in Figure 5-7. Whe piston is forced down, the crankshaft

around. The flywheel goes around too. Since it is heavy, it does not slow down easily. The weight of the moving flywheel keeps the crankshaft turning. This movement causes the piston to go back up to the top of the cylinder.

A Stroke

In the last section, we saw how the piston was pushed down in the cylinder. The flywheel weight brought the piston back up to the top of the cylinder. When the piston shown in Figure 5-8 moves from the top of the cylinder to the bottom, we call it a *stroke*. A stroke is movement of the piston. When the piston shown in Figure 5-9 moves from the bottom of the cylinder to the top, we call that a stroke, too.

FOUR-STROKE CYCLE

In many engines, the power is developed using four piston strokes. This is why it is called a four-stroke-cycle engine. A cycle is a sequence of events that is repeated over and over.

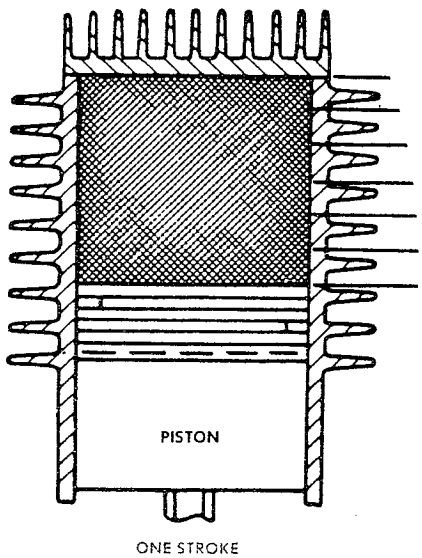


Figure 5-8. Piston movement from the top of the cylinder to the bottom is a stroke. (Briggs & Stratton Corp.)

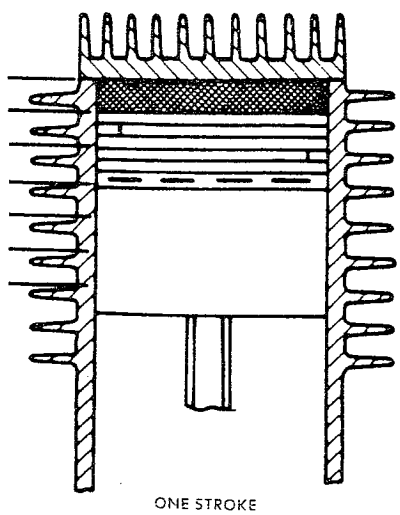


Figure 5-9. When the piston goes back up, it is another stroke. (Briggs & Stratton Corp.)

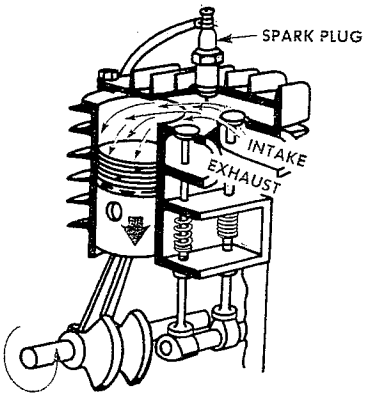


Figure 5-10. On the intake stroke the piston moves down, pulling in air and fuel. (Briggs & Stratton Corp.)

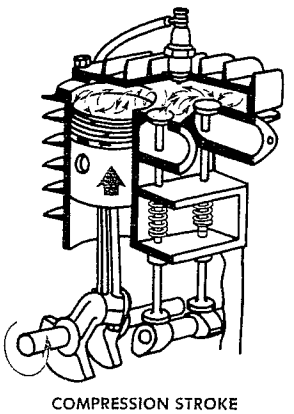


Figure 5-11. The piston moves up, squeezing th ture for the compression stroke. (Briggs & St Corp.)

Before we start, we must add something to our basic engine. We must have two holes in the top of the cylinder. These holes can be opened or closed as needed. One will be used to let air and fuel into the cylinder. It is called the intake port or passage. The other hole is used to get the burned air and fuel out of the cylinder. This is called the exhaust port or passage.

Intake Stroke

Now we are ready to see how this engine works during one complete cycle. We will start with both the intake and exhaust ports closed. The piston is as far up in the cylinder as it can be.

The first stroke is called the intake stroke, Figure 5-10. The piston moves down the cylinder very fast. This fast downward movement causes a vacuum in the cylinder. At the same time, the intake port is opened. The air-fuel mixture is pulled into the cylinder by the vacuum.

When the piston has gone down as far as it can go, the crankshaft has turned half-way around. The combustion chamber is filled with a mixture of air and fuel. We can now close the intake port.

Compression Stroke

As the piston starts back up the cylinde compression stroke, Figure 5-11, begins. piston moves to the top, it squeezes the a mixture. This squeezing of the mixture, w called *compression,* is very important. compression, or a tighter squeeze, results in heat during the burning.

During the compression stroke, the cran has turned another half turn. During intak compression, it has gone completely aroun time.

Power Stroke

The power stroke, Figure 5-12, starts wh piston reaches the top of the compression s Here an electric spark starts the air-fuel m burning. The explosive force developed b burning pushes the piston down. When the reaches the bottom of the cylinder, the stroke is over. The crankshaft turns anothe turn during this stroke. The exhaust and ports remain closed.

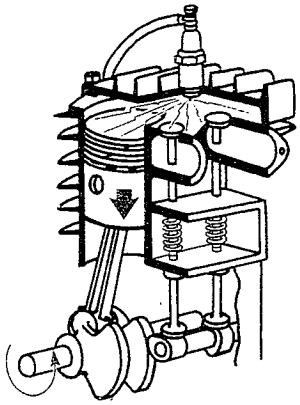


Figure 5-12. The mixture is burned, pushing the piston down for the power stroke. (Briggs & Stratton Corp.)

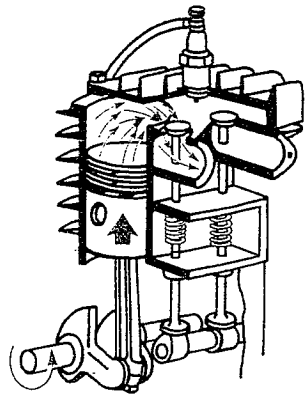


Figure 5-13. The piston moves up, pushing out the burned mixture on the exhaust stroke. (Briggs & Stratton Corp.)

Exhaust Stroke

The piston starts back up the cylinder for the exhaust stroke, Figure 5-13. The exhaust port is opened. Exhaust gases are forced out of the cylinder through the exhaust port by the piston. When the piston reaches the top of this stroke, the exhaust port is closed. The crankshaft has gone around another one-half turn.

The piston can then start down for another intake stroke, and the whole cycle begins again. All four strokes are shown in Figure 5-14.

THE ENGINE'S PARTS

The engines we have been studying are called basic engines because they have only a few basic parts. A *real engine* has more parts than the basic engine. In this section, we are going to look at the parts of a real engine and see how they all fit together.

Very few of an engine's parts can be seen from the outside. There are two types of pictures that help us study parts inside an engine. One is called a cutaway. If you cut an orange down the center,

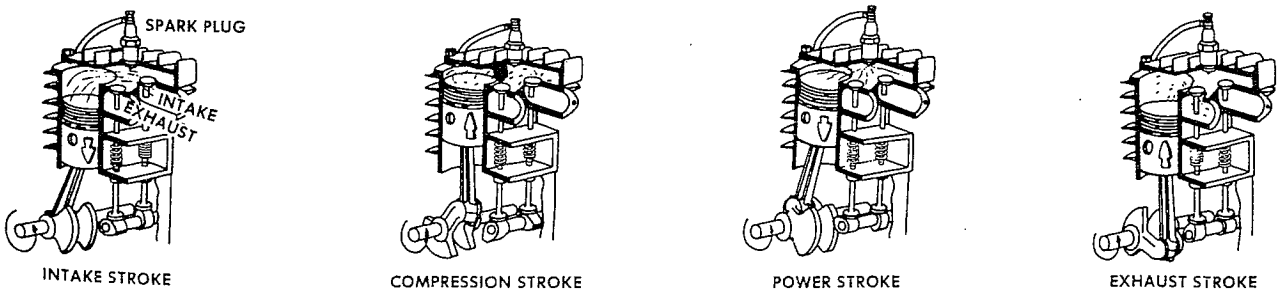


Figure 5-14. The four strokes of a four-stroke-cycle engine. (Briggs & Stratton Corp.)

you can see the inside. You have a cutaway view of the inside of an orange, as shown in Figure 5-15. We can look at an engine in a similar way. A cutaway view of a four-stroke-cycle engine is shown in Figure 5-16. The outside of the engine has been cut away so the inside parts can be seen.

Another useful type of picture is calle exploded view. An exploded view shows the separated from each other. The parts are pla the picture the way they would fit back tog Figure 5-17 shows an exploded view of an e

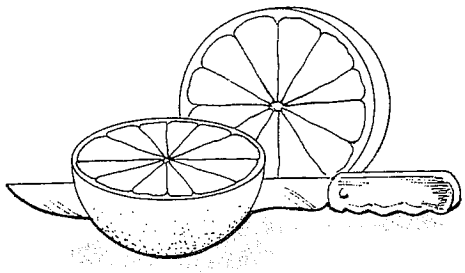


Figure 5-15. An orange cut this way gives us a view.

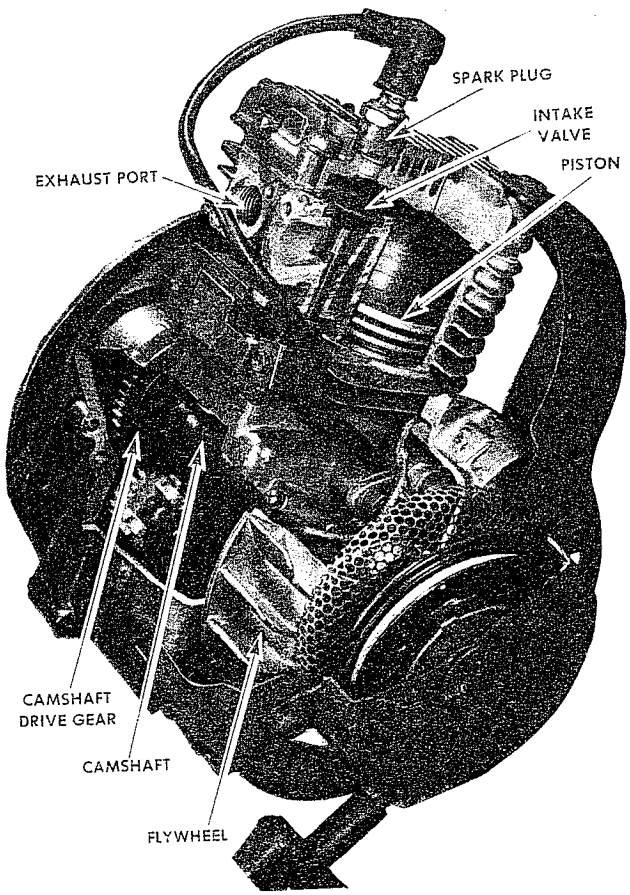


Figure 5-16. A cutaway view of an engine.

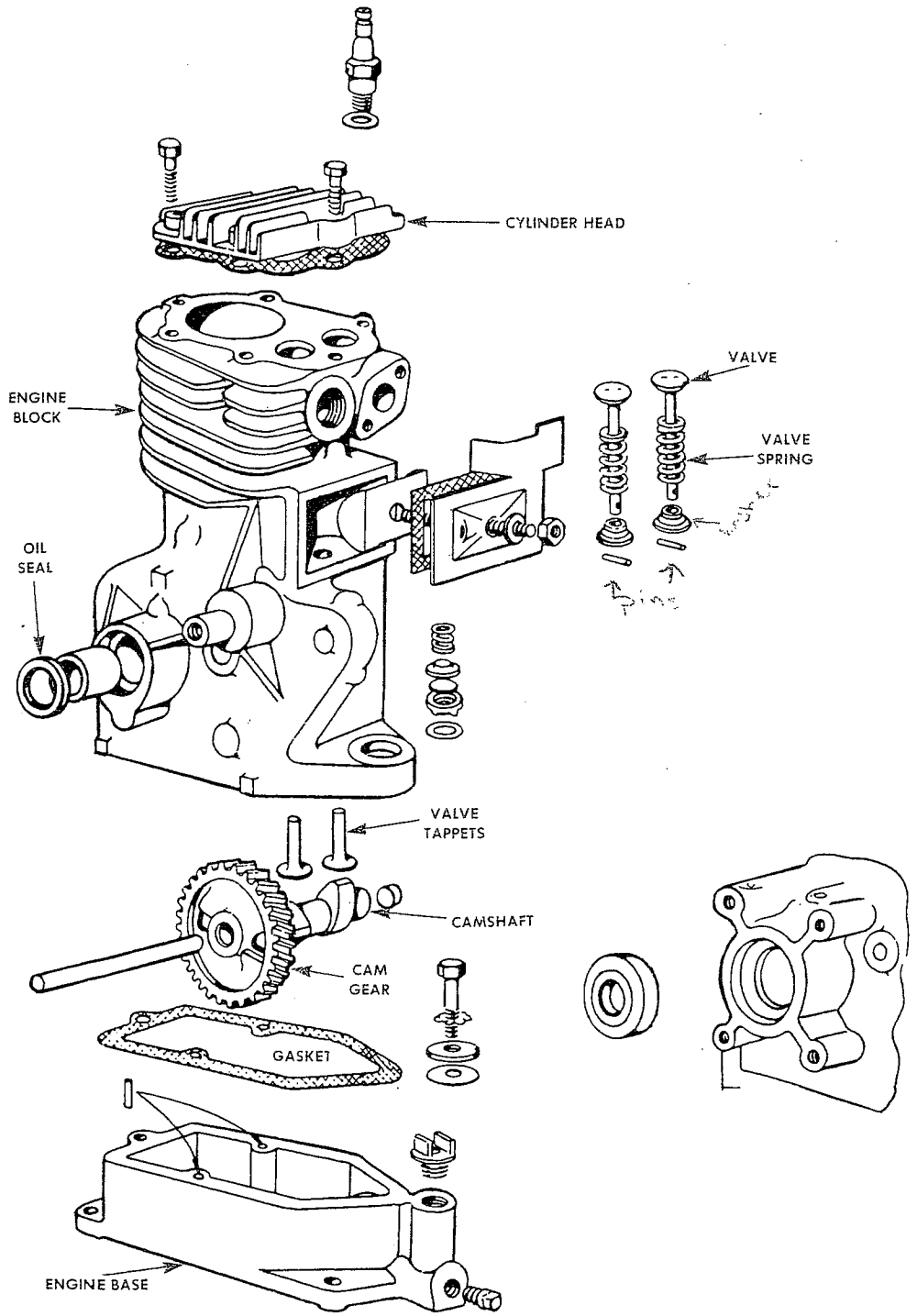


Figure 5-17. An exploded view of an engine.

Crankcase and Main Bearings

Let's begin our study of the parts of an engine. The crankcase Figure 5-18, is a metal box or housing that holds the crankshaft. The crankcase may be made in one piece, or it may come apart. A hole in each side of the crankcase holds the crankshaft ends.

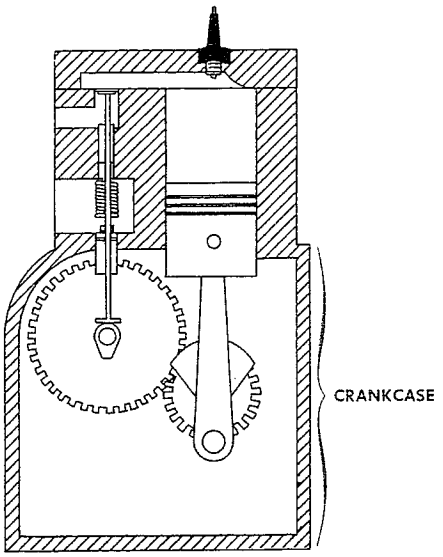


Figure 5-18. The crankcase holds the crankshaft.

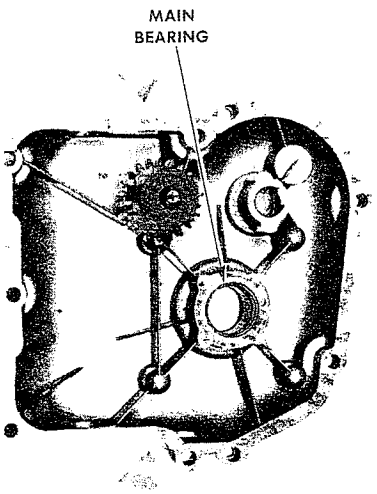


Figure 5-19. A side cover or base plate.

These holes are called the *main beari* main bearing support holes. The cranksha fit very closely into the main bearings, l crankshaft can still turn. A side cover or attached to the crankcase. One of the mai ings is in this plate, Figure 5-19. When the taken off, the crankshaft can be removed.

Cylinder and Block

As we saw earlier, the cylinder is a hollc for the piston. The piston slides up and dc the cylinder walls. The cylinder must be j right size for the piston to move freely.

Cylinders for small engines often are from aluminum. Aluminum is a light meta loses heat very rapidly. Aluminum cylind very soft. They could wear out quickly. I engines, a thin tube of a stronger metal, eitl iron or steel, is placed in the aluminum cy This is called a *liner* or *sleeve*. The piston sl the liner instead of on the aluminum.

Cylinders on some engines are made removed from the crankcase. Many mot

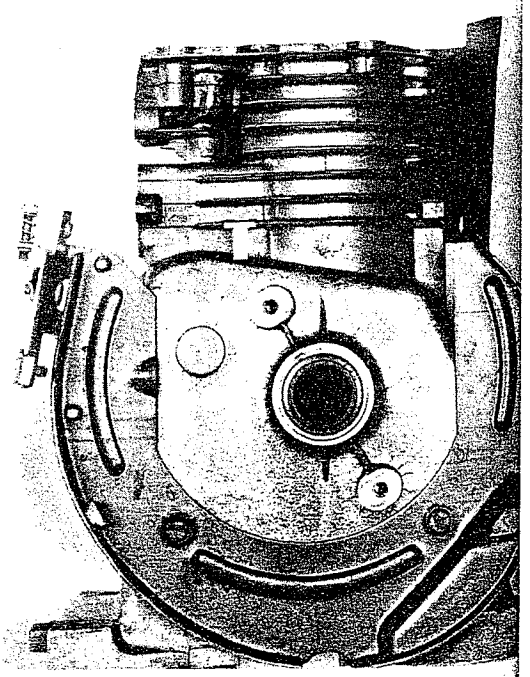


Figure 5-20. A cylinder assembly.

engines have a cylinder that can be removed. If a cylinder is damaged, it may be replaced with a new one. Most small engines have a cylinder that is made as one piece with the crankcase. When the crankcase and cylinder are one piece, the whole part is called a *block*, or cylinder assembly. A cylinder assembly is shown in Figure 5-20.

Cylinder Head and Head Gasket

The cylinder head, Figure 5-21, gives us the top for the cylinder. It is attached to the top of the block with bolts, as shown in Figure 5-22. The combustion chamber is part of the cylinder head. High pressure is built up during the power stroke.

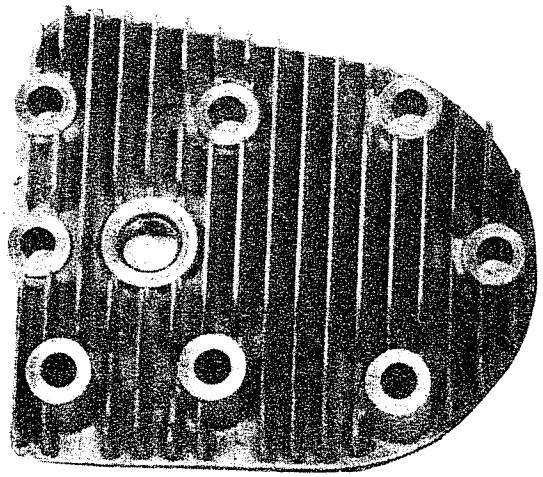


Figure 5-21. Cylinder head.

This high pressure must not leak out between the cylinder head and block, or power will be lost. A part commonly called the *head gasket* goes between the cylinder head and block, forming a seal. The head gasket is shown in Figure 5-23.

Crankshaft

The crankshaft changes the up-and-down movement of the piston to a round-and-round movement. The parts of a crankshaft are shown in

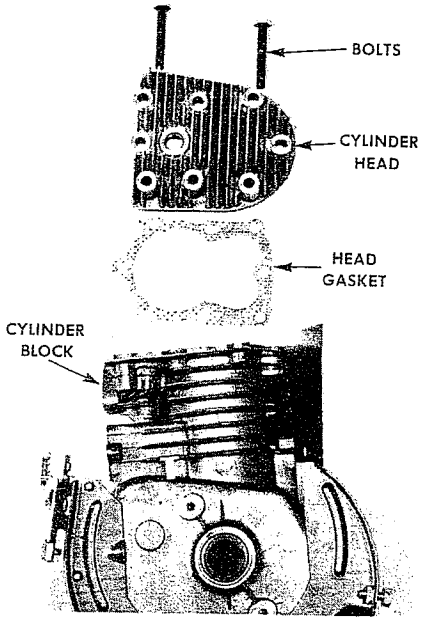


Figure 5-22. Bolts hold the cylinder head to the cylinder block.

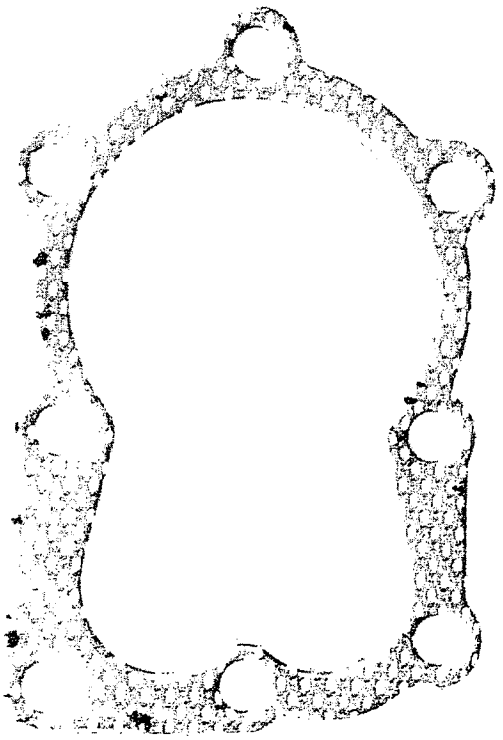


Figure 5-23. A head gasket forms a seal between the cylinder head and block.

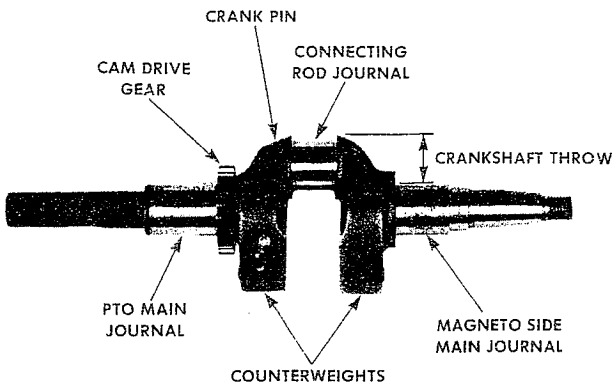


Figure 5-24. The parts of a crankshaft.

Figure 5-24. The parts of the crankshaft that fit in the main bearings are called main bearing journals. They are made very carefully for a good fit in the main bearings. The offset part of the crankshaft is called the *crankpin*. The connecting rod is attached to the connecting rod journal on the crankpin.

Some heavy weights, called counterweights, are attached to the crankshaft. These weights balance the weight of the piston and connecting rod. Counterweights help the engine run smoothly.

Crankshafts may fit into the crankcase of two ways. Some engines have a hori crankshaft. Others have the crankshaft in a cal position. Horizontal and vertical crank are shown in Figure 5-25. A horizontal cran engine and a vertical crankshaft engine loc ferent on the outside. A horizontal cran engine is shown in Figure 5-26. A vertical c shaft engine is shown in Figure 5-27.

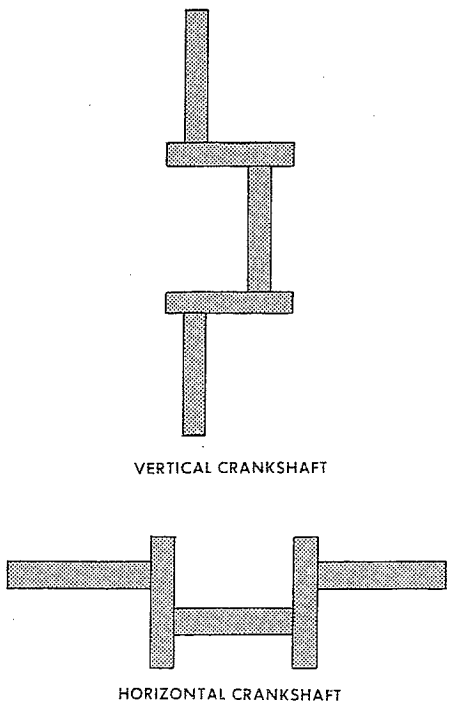


Figure 5-25. There are two kinds of crankshafts.

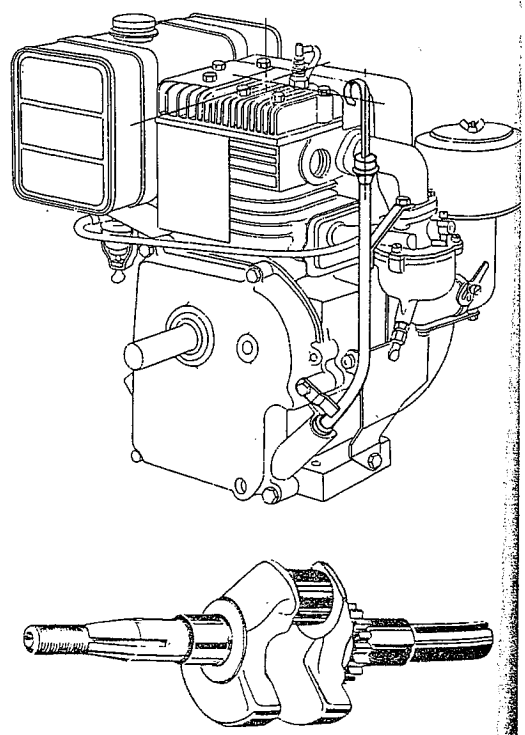
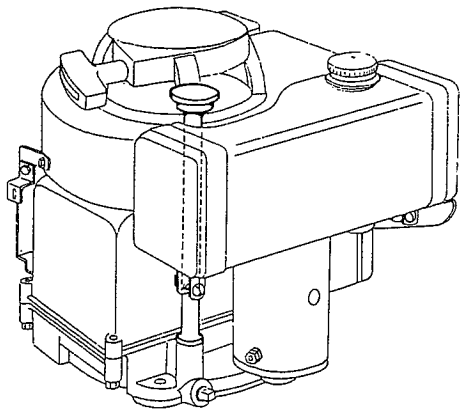


Figure 5-26. An engine with a horizontal cran (Briggs & Stratton Corp.)



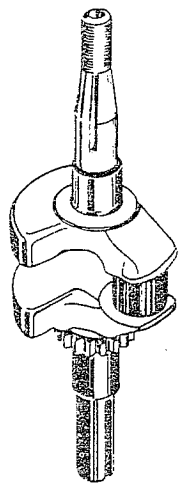


Figure 5-27. An engine with a vertical crankshaft. (Briggs & Stratton Corp.)

Piston

The piston, which gets its push from the burning air-fuel mixture, must be strong but light. Most small engines have aluminum pistons. They are made carefully to fit in the cylinder.

The main parts of a piston are shown in Figure 5-28. The head is the top of the piston where it gets its push. Grooves are cut around the top for rings. The sides of the piston slide against the cylinder. This area is called the piston skirt. A hole in the piston, called the *pin hole,* is used to connect the piston to the connecting rod.

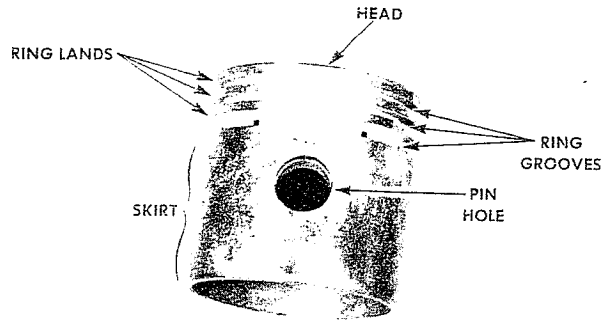


Figure 5-28. The parts of a piston.

Piston Rings

Two types of piston rings are used, Figure 5-29. One type, called the compression ring, is located in the groove or grooves near the piston head. It seals in the compression pressure. One or more oil control rings (oil rings) are located in the groove or grooves below the compression rings. To prevent excessive oil consumption, the oil ring wipes excess oil off the cylinder wall and routes it back into the crankcase. The number and type of piston rings used are determined by the requirements of a particular engine.

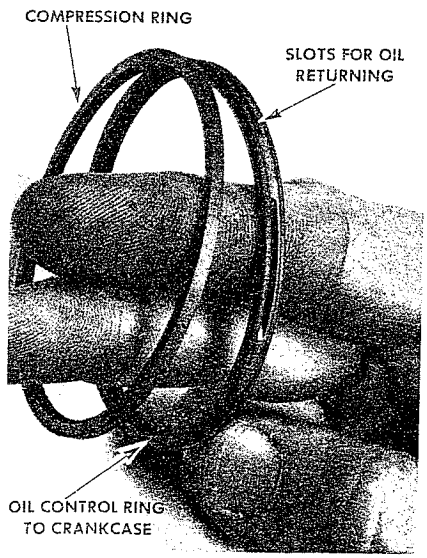


Figure 5-29. Piston rings seal compression and control oil.

Most small engines used two compression rings. The first compression rings made were rectangular in cross section and formed a simple mechanical seal against the cylinder wall. The rings, in their free state, were larger than the cylinder diameter. When compressed in the cylinder, they pushed out against the cylinder wall to provide a seal. Rings for modern engines make use of torsional twisting and compression pressures to improve upon a simple mechanical seal.

The job of the oil control ring is to scrape oil off the cylinder wall and direct it through the ring and into holes in the piston. Oil flows through the piston holes and runs back into the crankcase. Oil rings for small engines are one-piece rings with holes for oil flow. The pressure of an oil ring on the cylinder wall comes from tension and face width of the ring. As the face of a cast-iron oil ring wears, spring tension is decreased, and in most instances the width of the faces is increased. This results in a lower pressure and reduced oil control.

To increase ring tension, an expander, Figure 5-30, sometimes is used with an oil control ring. The expander is slightly larger around than the cylinder. When assembled behind the piston ring and in the cylinder, the expander pushes out on the ring. This forces the ring uniformly against the cylinder wall. An expander has the disadva of causing more rapid cylinder wear. It shou used only when recommended by the e manufacturer.

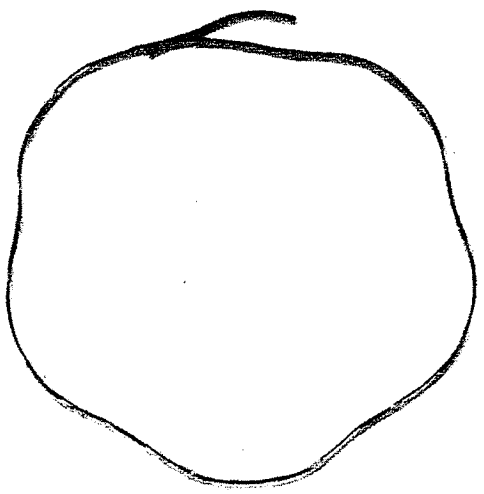


Figure 5-30. An expander often is used behind the oil control ring.

Connecting Rod and Piston Pin

The connecting rod connects the piston crankshaft, Figure 5-31. The connecting rod be strong and light. It is often made from a num. There is a small hole called a *pin hole* top of the connecting rod. A pin fits throug hole in the piston. The pin is called a *wrist piston pin*. It may be held in place in the pis retaining rings. The pin allows the connecti to move back and forth as the crankshaft

The other end of the connecting rod fits a the crankshaft. To get it on the cranksha rod must split apart. The rod cap is the pa comes off to let us attach the connecting ro crankshaft. Connecting rod bolts hold the the connecting rod.

The crankshaft must turn freely when tached to the connecting rod. This mea

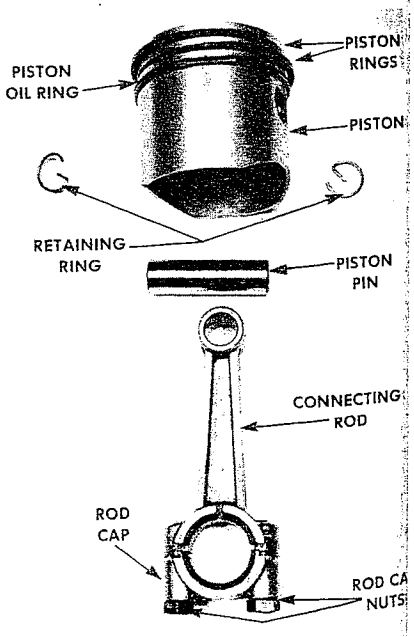


Figure 5-31. Parts of piston and conne assembly.

there must be very little friction between the connecting rod and crankshaft. The rod cap must fit around the crankshaft just right. It cannot be too loose or too tight. Some engines use insert bearings between the crankshaft and connecting rod.

The Valve Train

The four-stroke-cycle engine must get the air and fuel into the cylinder on the intake stroke. We must also have a way of getting the burned air and fuel out of the cylinder on the exhaust stroke. In our basic engine, we used passageways called *ports* to get the new mixture in and the burned gases out. The ports in a real engine are opened and shut with valves. The parts used to open and shut the valves are called the *valve train*. In this section we will see how the valve train works.

Valves. The valves in an engine work much like a plug in the bottom of a sink or bathtub. When the plug or stopper is pushed into the hole, Figure 5-32, water cannot get out. If we pull the plug up out of its hole, water can get around it and down the pipe as shown in Figure 5-33.

An engine works much the same way. A valve is a round metal plug connected to a rod called a *stem*. The head of the valve is tapered, or shaped at an angle. This tapered part is called the *valve face*. When the valve is closed, the valve face seals tightly against the valve seat. The valve seat is a tapered part of the cylinder block, Figure 5-34.

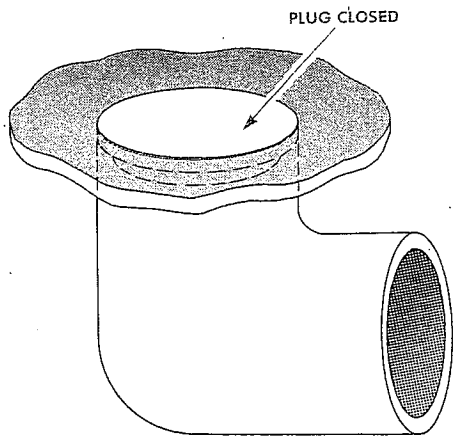


Figure 5-32. A closed plug will stop water from draining out.

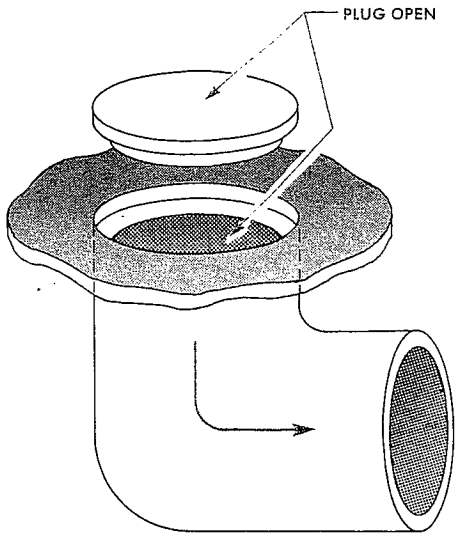


Figure 5-33. An open plug lets the water drain out.

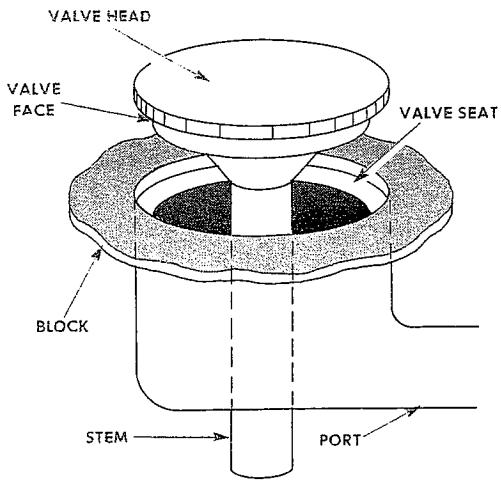


Figure 5-34. A valve is like a plug with a stem attached.

There are two valves in every cylinder. One is called the *intake valve*. It is opened on the intake stroke to let air and fuel into the cylinder. The other is called the *exhaust valve*. It opens on the exhaust stroke. Burned gases can get out of the cylinder through it.

Camshaft. The job of opening the valves at just the right time belongs to the camshaft. There are

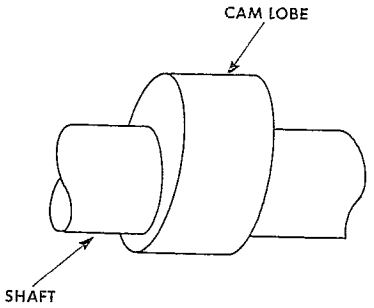


Figure 5-35. A camshaft is a shaft with a bump or lobe.

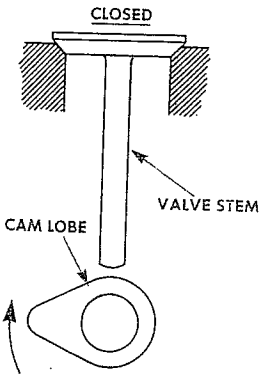


Figure 5-36. The stem is on the small part of the lobe so the valve is closed.

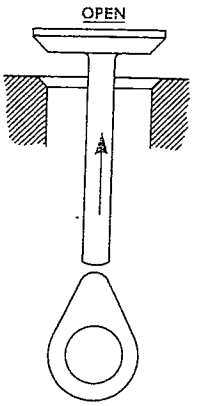


Figure 5-37. As the high part of the lobe com it pushes the valve open.

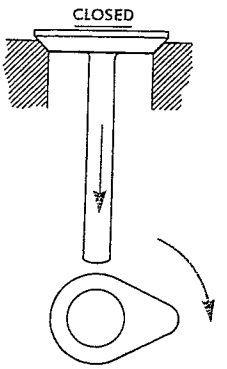


Figure 5-38. As the lobe passes by the stem, t closes.

bumps on the shaft called cam lobes. A camshaft with one cam lobe is shown in Figure 5-35.

The camshaft is located under the valves. When the smallest part of a cam lobe is under the valve stem, the valve is closed, Figure 5-36. As the camshaft turns, the high part of the cam lobe pushes up on the valve stem. The valve opens as shown in Figure 5-37. As the cam turns some more, the lobe passes under the stem. The valve can then be closed, as shown in Figure 5-38.

The camshaft for a small single-cylinder engine has two lobes. One lobe works the intake valve. The other works the exhaust valve.

There is a gear on the end of the camshaft. This gear fits into another gear on the crankshaft as shown in Figure 5-39. When the crankshaft turns, the camshaft is forced to turn. The camshaft gear is twice as big as the crankshaft gear, which causes the camshaft to turn only one-half as fast as the crankshaft. They are designed this way valves open only on two strokes: the inta exhaust. There are marks on the two gears in Figure 5-40. These are to assist the mech putting in the camshaft correctly, so the will open at the right times.

Valve Lifter. In most engines, the camsha not push directly on the valve. There ar small parts called *lifters* that ride on th lobes. The lifters, shown in Figure 5-41 p the valve stems.

Valve Springs. The camshaft opens the va spring, called the *valve spring*, closes the The valve spring must hold the valve tight a

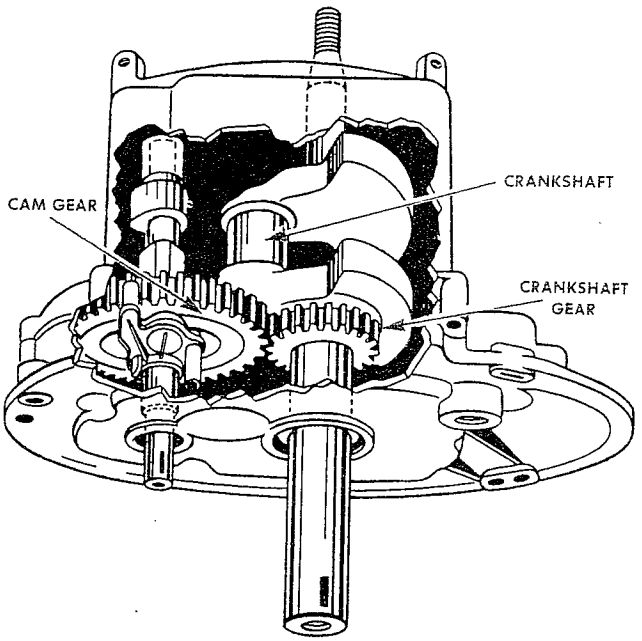


Figure 5-39. A gear on the crankshaft turns a gear on the camshaft. (Clinton Engines Corp.)

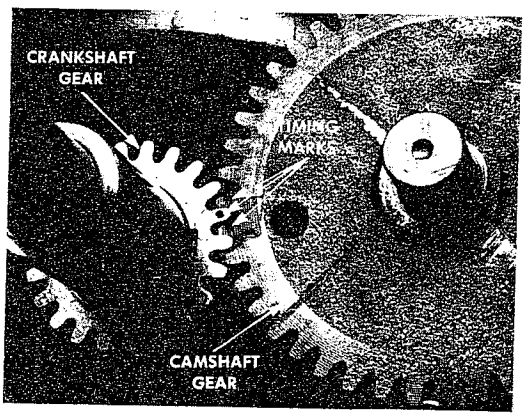


Figure 5-40. Timing marks are used to line up cam and crankshaft.

Figure 5-41. Valve lifter.

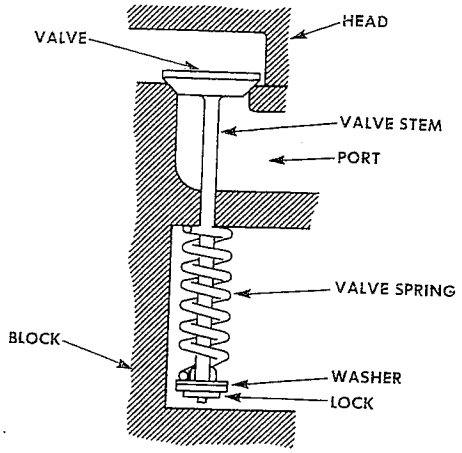


Figure 5-42. Valve spring, washer, and lock.

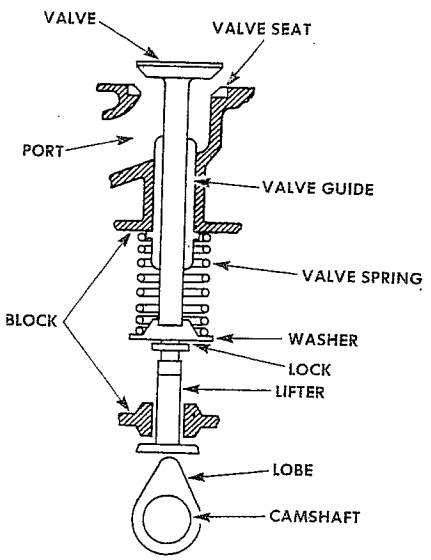


Figure 5-43. The parts of the valve train.

its seat for an airtight seal. A valve spring is shown in Figure 5-42. One end of the spring rests against the block. The valve stem goes through the spring coils. The other end of the spring rests on a small round washer. A keeper or retainer lock holds the washer on the valve stem.

When the valve is opened, the spring gets squeezed. As the cam turns around, the spring is released and pulls the valve closed again.

Valve Guide. The valve guide is a s
tube. It fits in the block. The val
through the guide. The guide keeps t
tered over the valve seat.

All the parts of the valve train we
are shown in Figure 5-43.

NEW TERMS

camshaft: A shaft with lobes used
engine's valves at the proper time.

combustion chamber: Part of the eng
the burning of the air and fuel tak

compression ring: A piston ring u
compression pressures inside the
chamber.

compression stroke: The stroke of
stroke engine during which the air-f
is compressed.

connecting rod: An engine part that c
piston to the crankshaft.

connecting rod bearing: The device us
the connecting rod and the cra
reduce friction and wear.

crankcase: The part of the engine tha
the crankshaft.

crankshaft: An offset shaft to which
and connecting rods are attached.

cylinder: A tube in which the piston ri

cylinder head: Large casting bolted to
the engine containing the combustion

engine: A machine that converts heat e
mechanical power to perform work.

exhaust ports: Passages used to route o
gases from the cylinder.

exhaust stroke: The stroke of a four-str
engine during which the burned
expelled.

exhaust valve: Valve used to control
burned exhaust gases from the cylinc

flywheel: Heavy wheel used to store en
smoothe out engine operation.

four-stroke-cycle engine: Engine that g
power using four strokes of a piston.

intake ports: Passages in the cylinder h
to route the flow of air and fuel
cylinder.

intake stroke: The stroke of the four-stroke-cycle engine during which air and fuel enter the engine.

intake valve: Valve used to control the flow of air and fuel into the engine.

internal combustion engine: An engine such as the four-stroke-cycle engine in which the burning of the fuel takes place inside the engine.

lobe: A raised bump on the camshaft used to lift a valve.

piston: A round metal part attached to the connecting rod which slides up and down in the cylinder.

piston pin: A pin used to attach the piston to the connecting rod.

piston ring: Expanding sealing ring placed in a groove around the piston.

power stroke: The stroke of the four-stroke-cycle engine during which power is delivered to the crankshaft.

valve: A device for opening and closing a port.

valve guide: A part installed to support and guide the valve.

valve lifter: A part that rides on the cam and pushes open the valve.

valve spring: Coil spring used to close the valve.

valve train: An assembly of parts in an engine that opens and closes the passageways for the intake of air and fuel as well as the exhausting of burned gases.

SELF CHECK

1. Write a definition for *engine*.
2. What happens to the piston when air and fuel are burned?
3. How do the connecting rod and crankshaft change the up-and-down motion to rotary motion?
4. What does the flywheel do?
5. What fits in the main bearings?
6. What is a crankcase?
7. Where does the cylinder head fit?
8. What are the two types of piston rings?
9. Describe how a valve can open and close a port.
10. What closes the valves?

DISCUSSION TOPICS AND ACTIVITIES

1. Use a cutaway model of an engine and describe four-stroke-cycle engine operation.
2. Point out all the parts you can on a real engine.