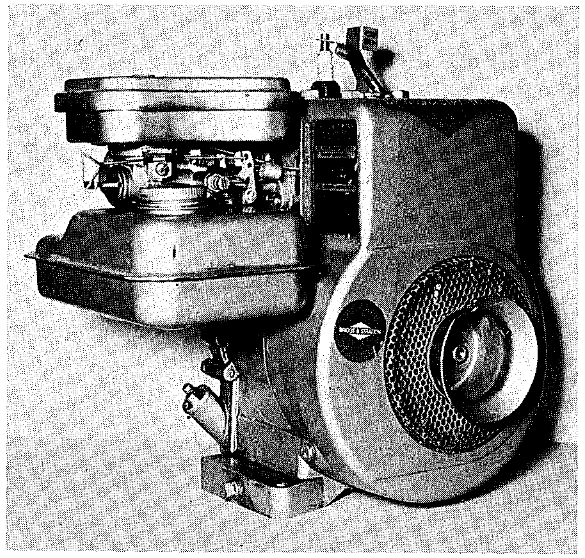


CHAPTER 3

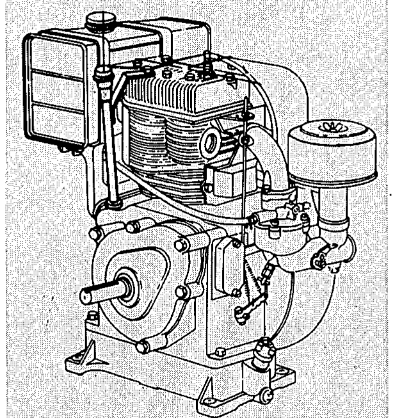
FOUR STROKE CYCLE ENGINES

Watch for These Words

pilot	*peen*	*hone*
abrasive	*alloy*	*sprocket*
lapping	*combustion*	*intake manifold*
reamer	*corrosion*	*gaskets*

How to Use These Words

1. The *pilot* of the valve seat grinder fits into the valve guides of the engine.
2. Fine grinding *abrasive* is used when *lapping* valves and valve seats for a tight fit.
3. A *reamer* is used to make the hole through a valve guide the same size as the valve stem.
4. *Peen* the metal around a new valve seat insert in order to hold it in place.
5. An *alloy* is a metal made by carefully mixing two or more metals and special materials together.
6. The high temperatures and gases from fuel *combustion* can cause *corrosion* of valves and valve seats.
7. A *hone* is a tool used to smooth and straighten cylinder walls.
8. A *sprocket* is a type of gear made to fit the links of a chain.
9. The short pipe between the carburetor and cylinder on some engines is called the *intake manifold*.



A four stroke cycle engine

10. *Gaskets* are made of flexible material to seal the joints between engine parts.

Find the Answers to These Questions

1. Name the four strokes that make up the four stroke operating cycle.
2. In which direction is the piston moving during each of the four strokes?
3. Describe the position of the intake and exhaust valves during each stroke.
4. What is the correct name for the type of valve used in four stroke engines?
5. Why is it important to replace each valve in its original position after reconditioning?
6. How does a worn valve affect the operation of the engine?
7. Name the part of the engine that opens the valves.
8. How would a weak or broken valve spring affect the operation of the engine?
9. List at least three flaws in a valve that show it should be replaced.
10. Why must there be a gap between the valve stem and the lifter?

Four Stroke Cycle Engine Operation

All gasoline engines must do four basic actions to operate properly. They must:

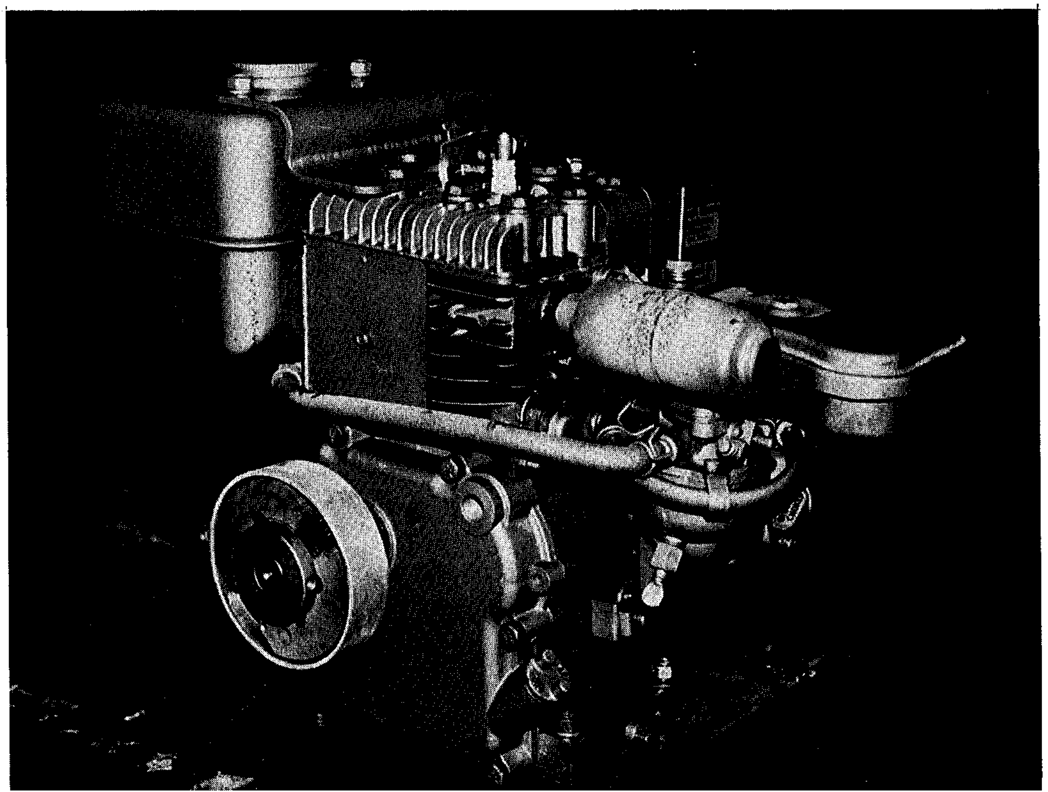
(a) suck in a mixture of fuel and air,

(b) squeeze the mixture into a small space,

(c) fire the mixture and use the force of the burning fuel to turn a crankshaft, and

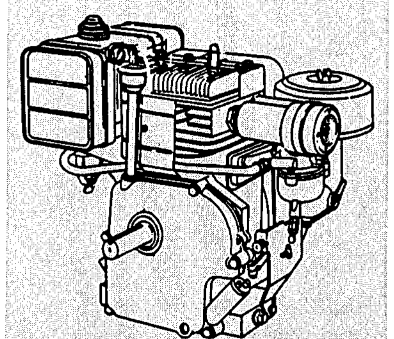
(d) push the burned gases out of the cylinder into the air.

Some engines can complete these operations with only two strokes of the piston, up and down. Others need four strokes of the piston, up and down twice, to complete the cycle. In this chapter we will see how a four stroke cycle works.

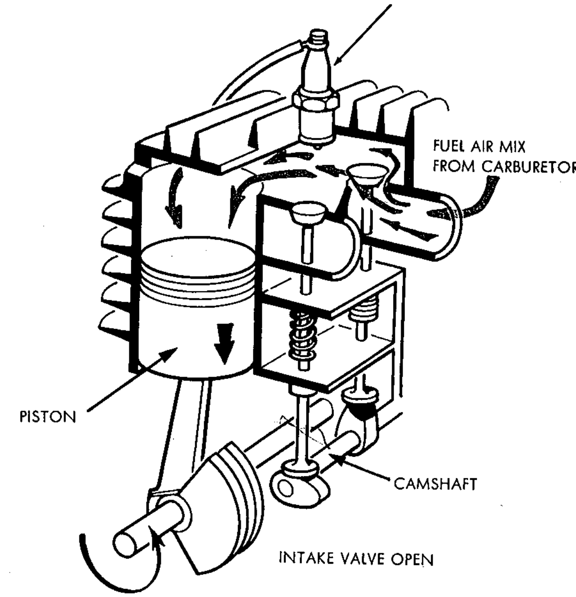


THE INTAKE STROKE

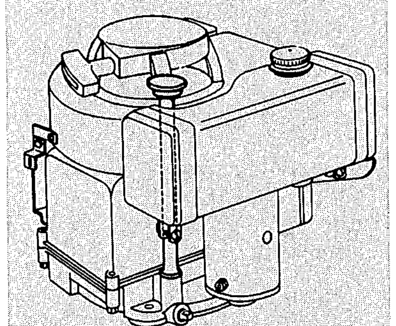
With the exhaust valve closed and the intake valve open, the piston moves down in the cylinder as the engine crankshaft turns. This movement causes a fuel and air mixture to be sucked from the carburetor into the cylinder past the intake valve. The intake valve is held open by one of the cam lobes on the camshaft.



A four stroke cycle engine with a horizontal crankshaft



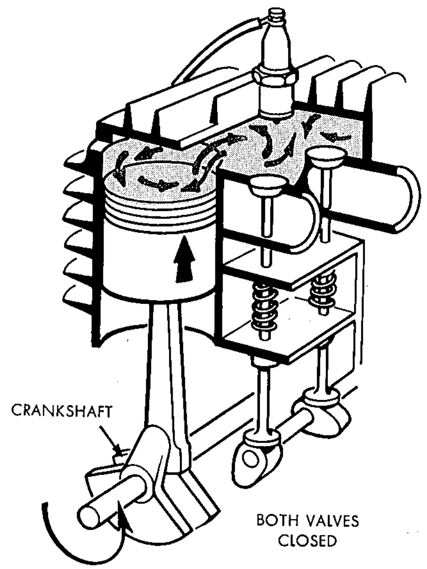
Single cylinder engine cutaway — intake stroke



A four stroke cycle engine with a vertical crankshaft

THE COMPRESSION STROKE

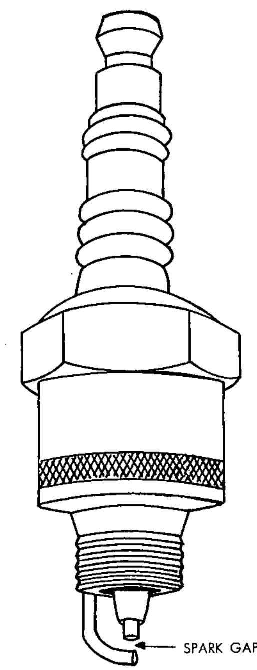
When the piston reaches the bottom of the intake stroke, the camshaft allows the intake valve to close, the crankshaft continues to turn, and the piston moves upward on the compression stroke. The fuel mixture is trapped and squeezed into the small space between the top of the piston and the cylinder head. Squeezing gases into a small space is called compression.

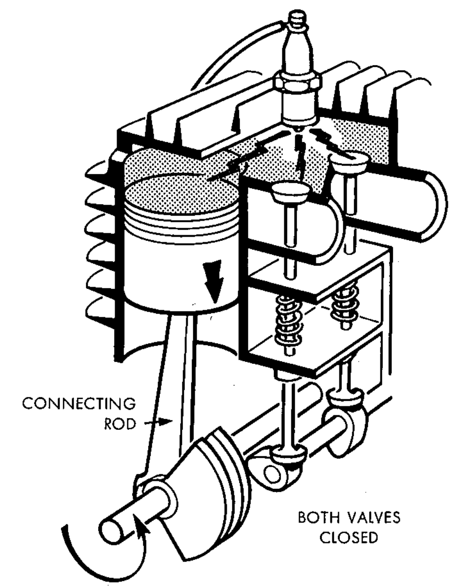


Single cylinder engine cutaway — compression stroke

THE POWER STROKE

As the piston nears the top point of its travel, called *top dead centre (TDC),* the ignition system is timed to cause a spark to jump across the gap between the electrode points of the spark plug. The fuel then begins to burn and the gases that form expand quickly in the tremendous heat. Pressure builds up and pushes outward on the cylinder walls, the cylinder head, and the top of the piston. The piston is the only part free to move, so it is pushed down in the cylinder, making the crankshaft turn around. The power that is created on this stroke must be great enough to keep the piston moving through the other three strokes of the operating cycle and do the work for which the engine was designed. The heavy flywheel helps to smooth out the surge of power and keep the crankshaft in motion.

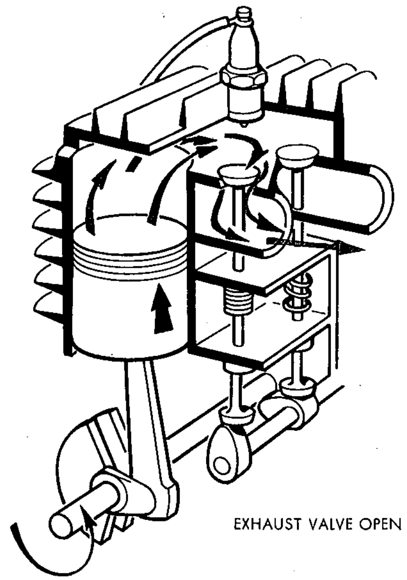




Single cylinder engine cutaway — power stroke

THE EXHAUST STROKE

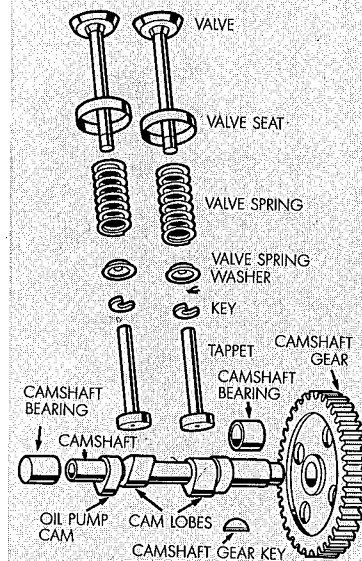
When the piston is moving downward at the end of the power stroke, the exhaust valve begins to open. It is fully opened by the time the *bottom dead centre (BDC)* position is reached. The upward travel of the piston on the exhaust stroke pushes the burned gases past the exhaust valve and out through the muffler.



Single cylinder engine cutaway — exhaust stroke

After the exhaust stroke is completed, the whole cycle of operation starts again. The camshaft allows the exhaust valve to close, opens the intake valve, and the piston begins its downward travel on the intake stroke.

The operation of the four stroke cycle style of engine depends on the timing of its valves and their condition, on the piston rings, and on the cylinder walls. The remainder of this chapter deals with these parts in detail.



The valves are opened by the cam lobes on the revolving camshaft.

Lobe: a rounded, projecting part of a revolving shaft.

Valves

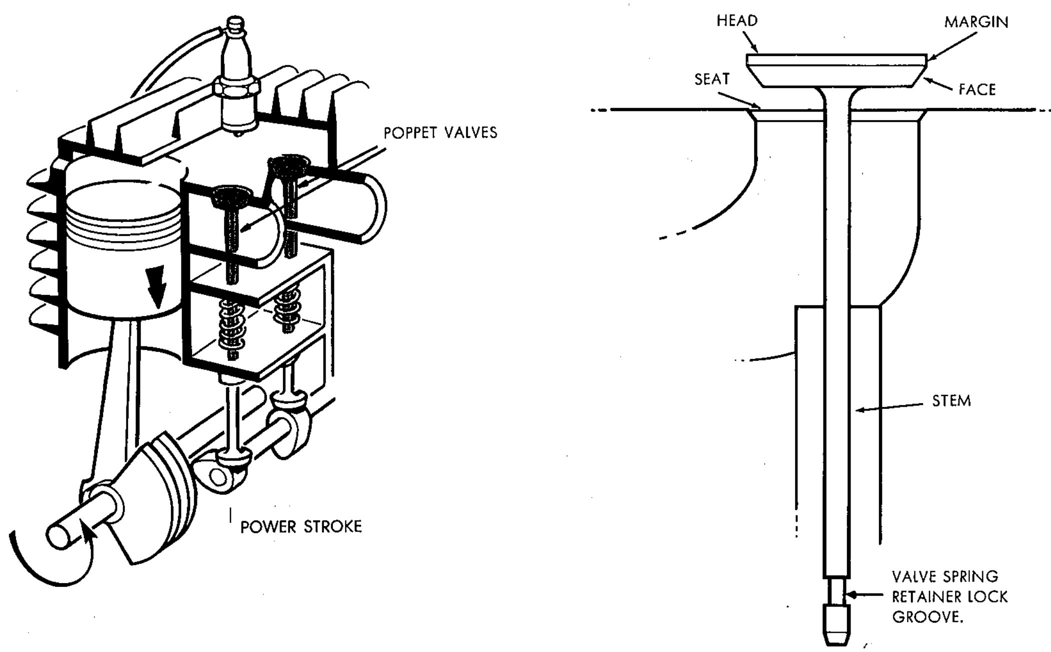
Look for Answers to These Questions

1. What is a valve seat insert?
2. How are valve seat inserts held in place?
3. Why is it important that the insert fit tightly in its mounting hole?
4. Why should the valve seat be no wider than 1.5 mm or $^{1}/_{16}$ inch?
5. What is valve overlap?
6. What is the purpose of valve overlap?
7. Name the two common types of camshaft drives.
8. How does a mechanic know whether he has replaced a camshaft in its correct position?
9. Why must the camshaft revolve at only half the speed of the crankshaft?
10. What causes the valves to close tightly against their seats?

Notice in the first drawings in this chapter that a single cylinder engine has two valves. This is the standard number per cylinder in almost all four stroke cycle engines, with the exception of some aircraft engines and racing car engines, which have four valves per cylinder.

Each valve is like an automatic gate or stopper, opening and closing passages leading to the cylinder. One closes off the passage from the carburetor to the cylinder and is called the intake valve. The other closes off the passage from the cylinder to the muffler and is called the exhaust valve.

Since this type of valve pops open and closed, it is known as a *poppet valve.* The camshaft is made so that its lobes push the valves open at the right time. Heavy coil springs hold the valves closed until the cam lobes push them open.



Poppet valve and its parts

Combustion: what happens when fuel, such as gas, coal, or wood, starts to burn.

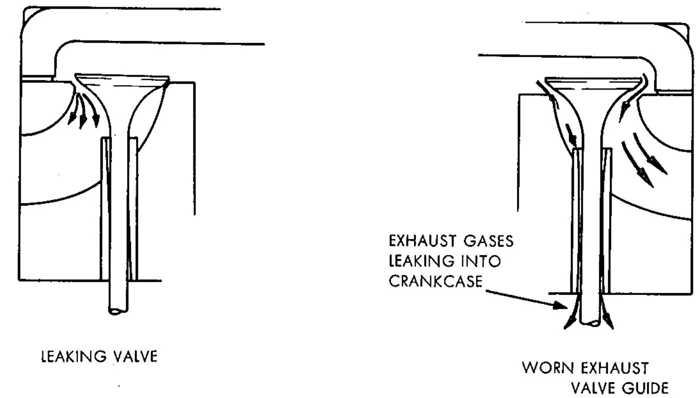
Corrosion: a chemical process which causes metal or other materials to be slowly eaten away.

The condition of the valves and valve seats has a great deal of control over cylinder compression and power output. Valves operate in very high temperatures inside the combustion chamber, and must maintain a tight seal when closed, whether the engine has just been started or has been running for a long period of time. Although both valves are subjected to the heat of combustion, the intake valve is partly cooled by each fresh charge of fuel entering the cylinder. The exhaust valve is usually made of a special steel that can resist heat and corrosion from the exhaust gases. It must never be exchanged with the intake valve.

The heat soaked up by the head of the valve must escape through the valve seat to the cylinder block. Then the heat must be taken away by the cooling system, as described in the chapter on cooling systems. Some of the heat travels down the stem of the valve and escapes through the valve guide. When a valve, valve seat, or valve guide becomes worn, heat cannot escape and the head of the valve burns or warps out of shape. A burned or warped valve can lower the compression of a cylinder so that it no longer operates.

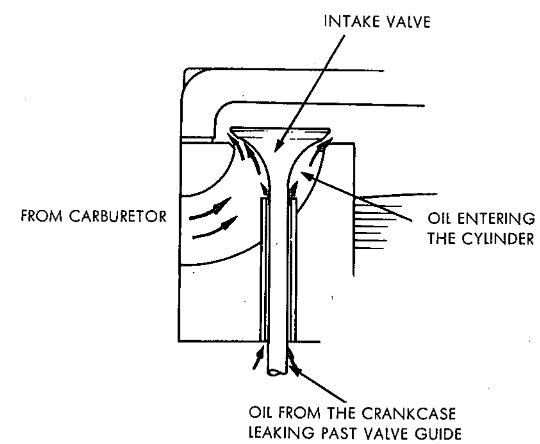
VALVE GUIDES

The poppet valves must open and close hundreds of times every minute. Each time they must close tightly against the valve seats. Worn valve guides that allow the valve stem to wobble back and forth will cause one side of the valve to ride high on the seat. Compression pressure and power can then leak past the face of the valve.

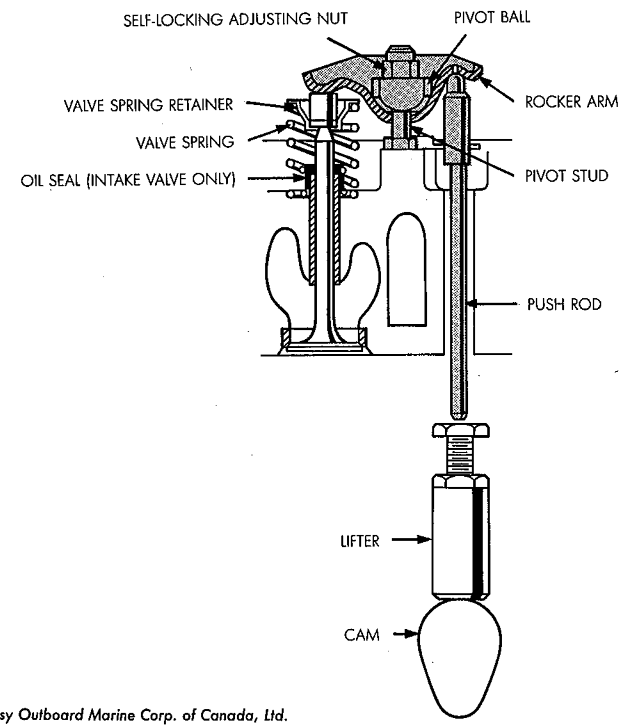


Heat also cannot now escape from the valve head to the seat and cylinder block. Exhaust valves warp and burn very quickly in this condition.

Since valve guides extend into the crankcase, worn guides will allow lubricating oil to be sucked into the cylinder right past the stem of the intake valve, and also allow exhaust gases to be drawn into the crankcase past the exhaust valve. Oil burning, and carbon deposits in the oil are the results.



Reamer: a tool used to make a hole larger. Reamers make very accurate holes. Reamers may be twisted by hand or by machine.



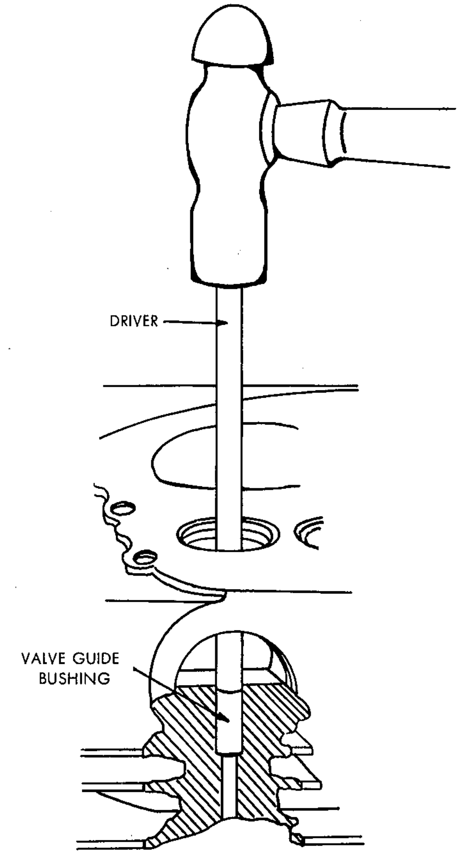
Courtesy Outboard Marine Corp. of Canada, Ltd.

A push rod and rocker arm are needed to open valves in an overhead valve engine

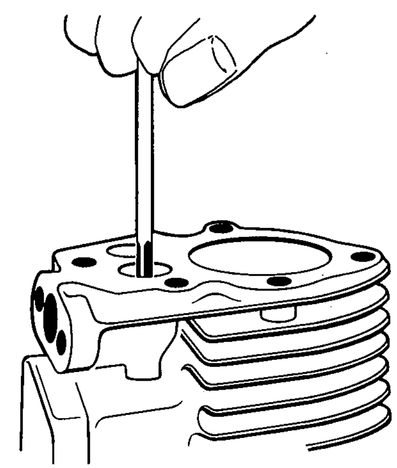
In some engines the valve guides are nothing more than holes drilled carefully through the crankcase. When these become worn, they can be reamed oversize with a special reamer, as shown below.

A valve guide bushing is then driven into the hole and reamed to fit the valve stem.

A reamer

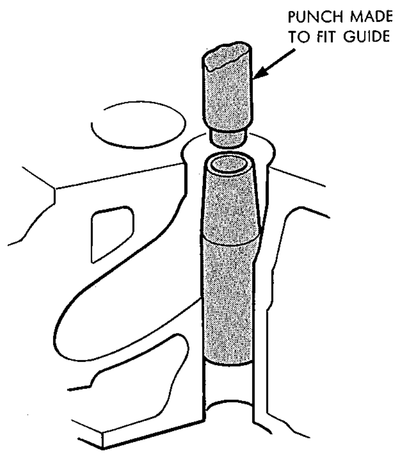


A valve guide bushing being driven in place



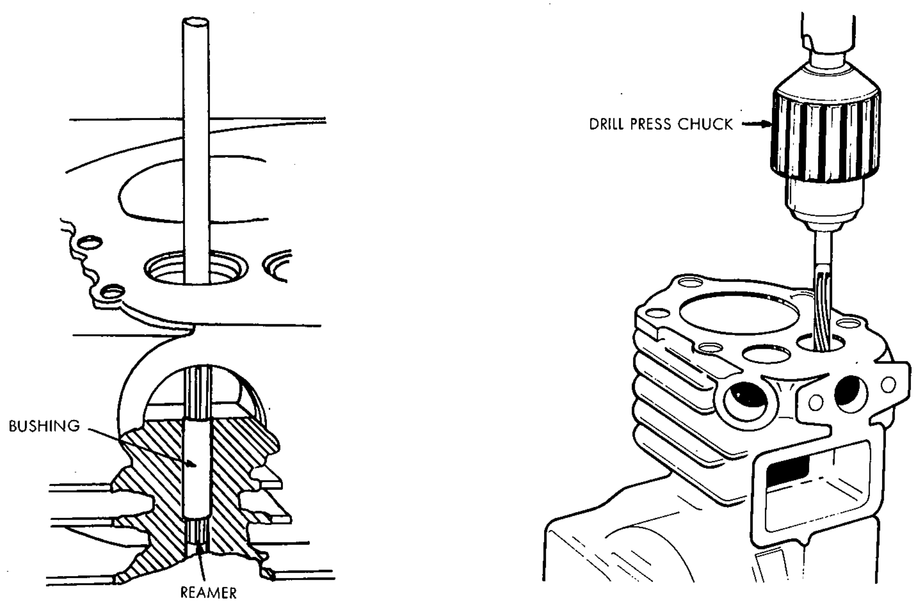
Reaming for a new valve guide

When the engine is equipped with removable valve guides, it is a simple job to press out the old guide and drive or press in a new one.



Fitting a new valve guide

It is then usually necessary to ream the new guide bushing so the valve stem will just fit into it. Check the repair manual for the correct stem to guide clearance.



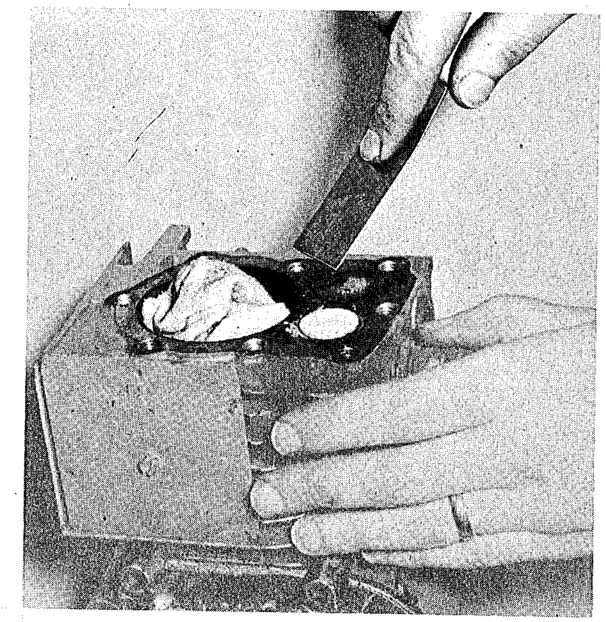
Reaming to fit valve stem

Gasket: a flat piece of material, usually rubber, paper, or asbestos, which is fitted between metal parts to keep fluids like oil from leaking out.

Be careful: Place all the engine parts in order on the bench as you remove them. This will make it easy to put the engine back together.

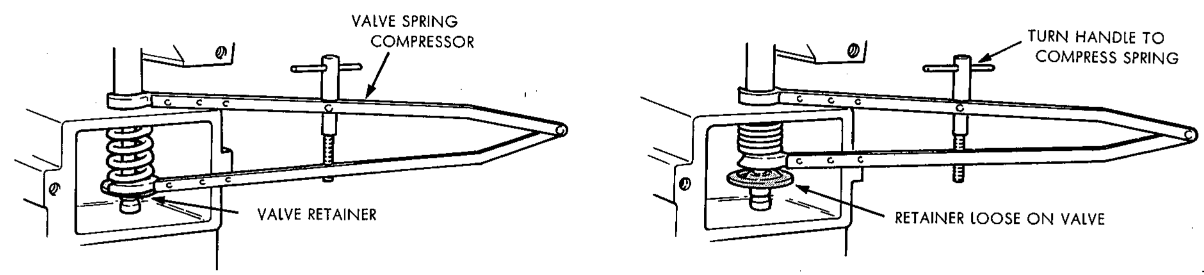
REMOVING VALVES

1. Remove the cylinder head and scrape off the old gasket. A putty knife is a good tool for this job, but remember to stuff a soft cloth into the cylinder to catch any dirt that falls in.



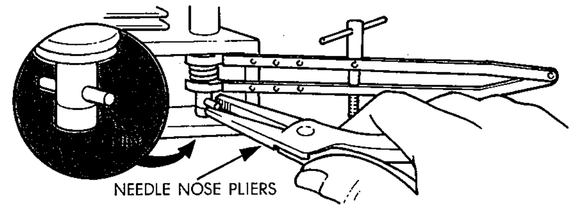
Scraping off old gasket

2. Remove the cover plate on the side of the cylinder block and use a valve spring compressor to lift the spring free of its retainer.



Lifting the spring free of its retainer

3. Use a pair of needle nose pliers to remove the valve spring retainer. The valve can now be lifted out of the cylinder block.

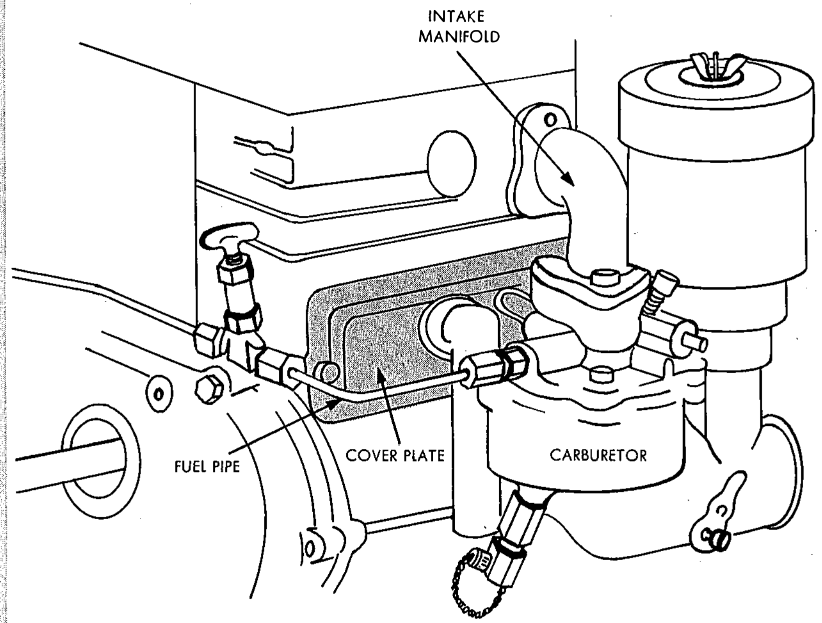


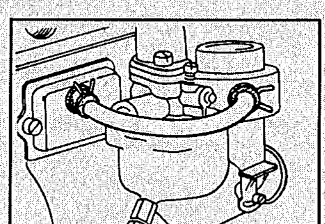
NEEDLE NOSE PLIERS USED TO REMOVE SPRING RETAINER

Removing the spring retainer

Note that some engines require the removal of other parts, such as the carburetor and intake manifold, before the cover plate can be removed. Reverse the steps to replace the valve.

Intake manifold: the pipe used to bring the fuel-air mixture from the carburetor to the cylinder for combustion.



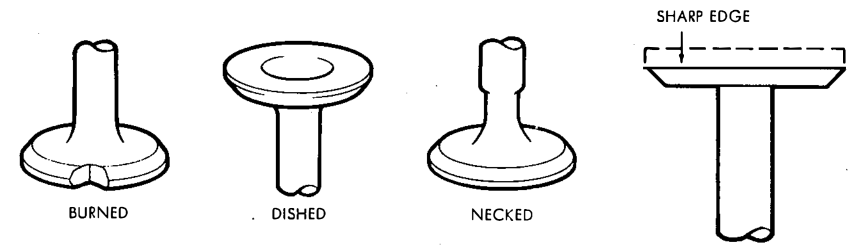


Breather vented through carburetor

The cover plate also serves as the crankcase breather location, and should be inspected to make sure the one way valve is working. The valve should allow air to escape when the engine's piston moves down in the cylinder, and then close to prevent air from entering on the up-stroke. This causes a partial vacuum in the crankcase to prevent oil from being forced out of the engine past the piston rings, oil seals and gaskets. Most modern engines have the breather connected to the carburetor after the air cleaner to prevent dirt from entering the crankcase.

RECONDITIONING VALVES

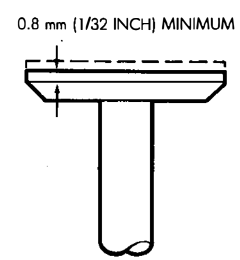
It is wise to carefully inspect each valve before any cleaning or grinding is attempted. If the valve head is burned or warped, the stem bent, the margin too thin, or the face worn too deeply, the valve should be thrown away and a new one installed.

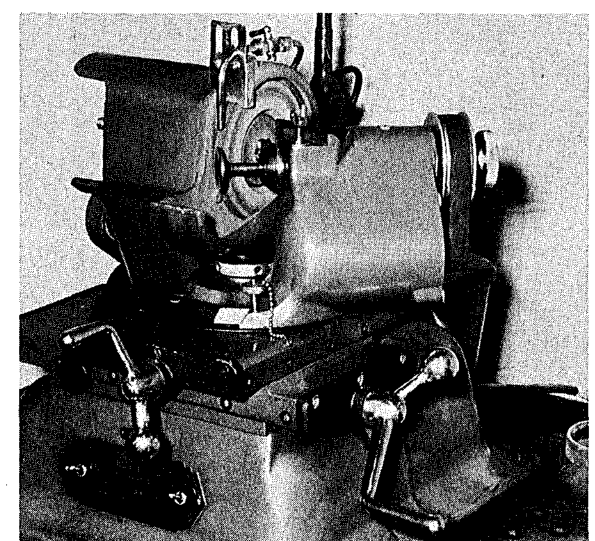


Valve conditions that cannot be fixed

Lapping: polishing, using an abrasive mounted on a special backing, such as brass, wool, leather, etc.

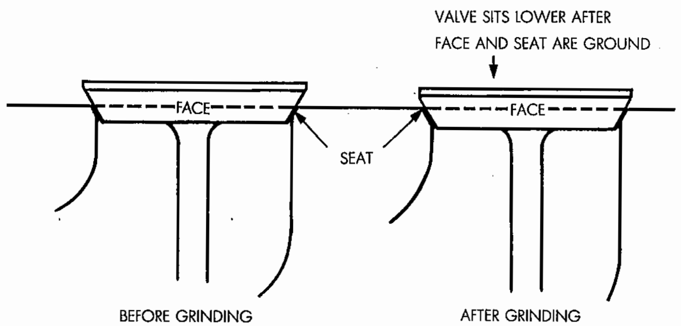
When lack of compression has been traced to leaking valves, and they show no serious damage, the valve faces will need grinding. This can be done only on a valve grinding machine, which can be adjusted to the exact angle of the face and will produce a finish that needs little or no lapping to the seat (wearing to a fine close fit).



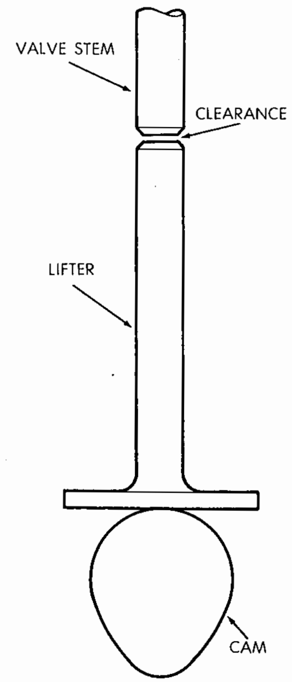


Valve grinding machine in operation

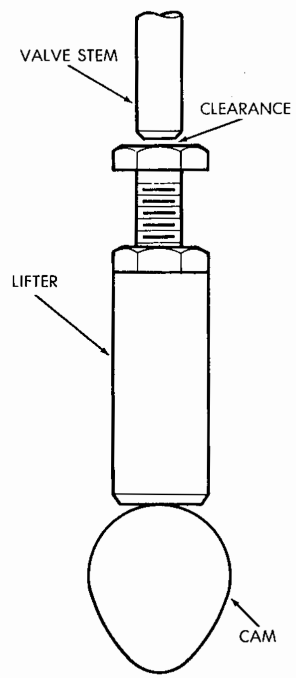
Be careful: Is the valve margin going to be wide enough after grinding?



Since the grinding operation removes metal from the face, the valve will sit lower in its seat than before. Resurfacing the valve seat will add to this condition. It then becomes necessary to adjust the gap between the valve stem and the valve lifter.



Gap adjustment: solid lifter

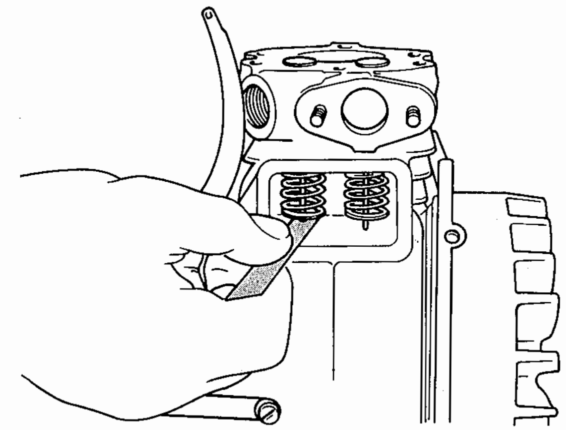


Gap adjustment: adjustable lifter

This clearance gap must be set according to the maker's suggestions, to allow the parts to expand when the engine gets hot while running.

Be careful: If you grind the valve stem too short, you must buy a new valve. Refer to the engine manual for the grinding allowance. The end of the stem has been hardened to resist wear.

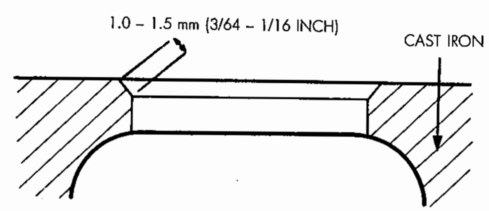
If the gap were too small the valve would be lifted up off its seat when the valve and lifter expanded with the heat. Then the valve would burn and a lot of compression would be lost. Some engines have adjustable lifters, but most small engines have solid lifters that cannot be adjusted. In order to get the right gap with solid lifters, the tip of the valve stem must be ground off the correct amount, using the valve grinding machine. Take care when adjusting or grinding to arrive at a gap that is the same as the maker suggests. Check the clearance with a flat feeler gauge as shown.



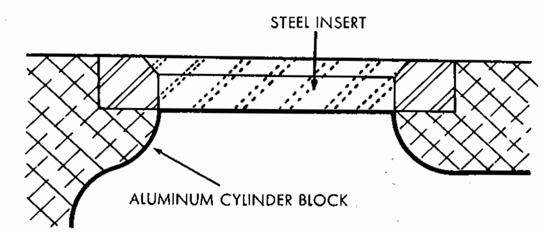
Using a thickness feeler gauge to check clearance between valve stem and lifter

VALVE SEAT RECONDITIONING

In cast iron engines, the valve seats are often machined directly on the edges of the intake and exhaust passages. Other engines, especially aluminum ones, use a steel insert.



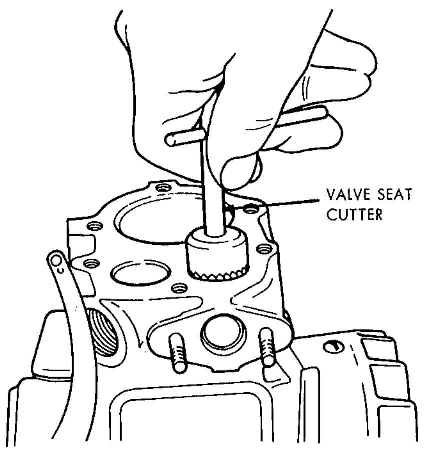
Valve seat machined on cast iron cylinder block



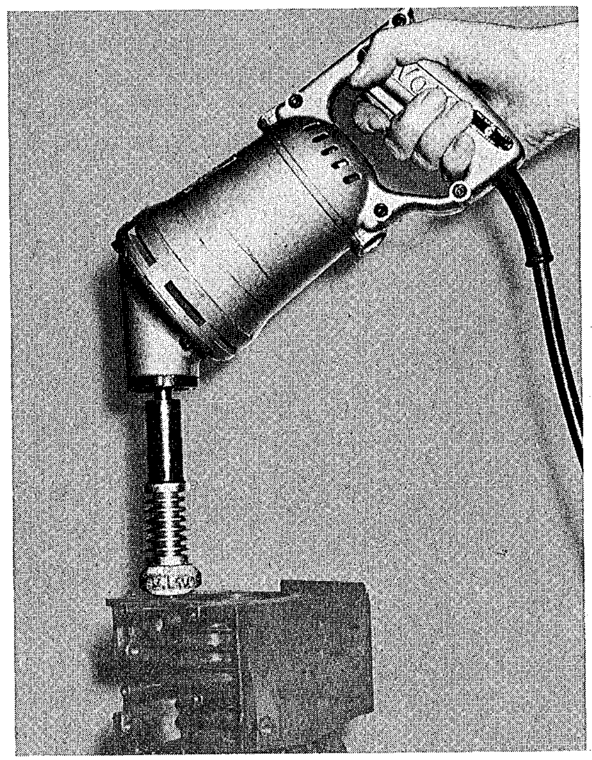
Steel valve insert in aluminum block

Pilot: a device which is used on valve seat cutters and grinders to guide and hold them in the correct position while cutting and grinding.

In either case, the seat should be ground or machined whenever the valve faces are reconditioned. Special cutters and grinders are used for this job. Steel seat inserts in aluminum engines can be removed and replaced with new seats when they are badly worn. The new seats must be ground to line up with the valve head. Valve seat cutters and grinders are equipped with several pilots to fit the valve guides of any engine. The pilot is the part that holds the tool in position.



Valve seat cutter in operation



Grinding the valve seat

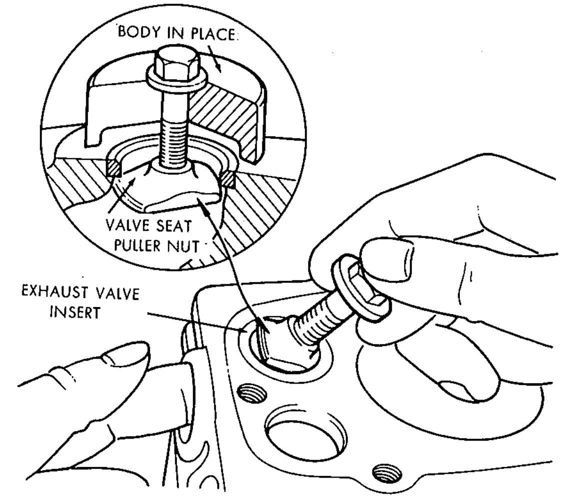
Peen: to bend or flatten some material (usually metal) with the round end of a ball peen hammer, or with a hammer and punch.

Valve seat inserts are usually held in position by peening the metal around them up against the insert.

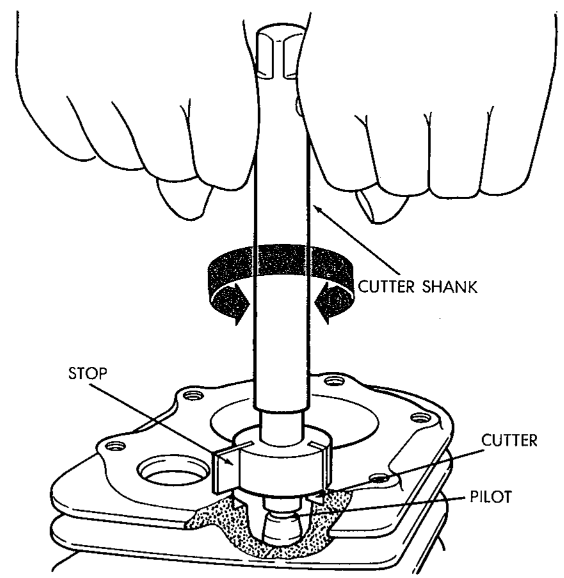
A seat puller can be used to remove the old seat, but often it is necessary to break the old insert to get it out, and then use a cutting tool to take off the old peened edge.

Engines with badly worn valve seats may also show a great deal of wear on other parts. It may be less expensive to replace the engine cylinder and crankcase assembly. This is known as a short block replacement.

Be careful: Do not remove too much metal from the valve seat or the valve will not fit properly.



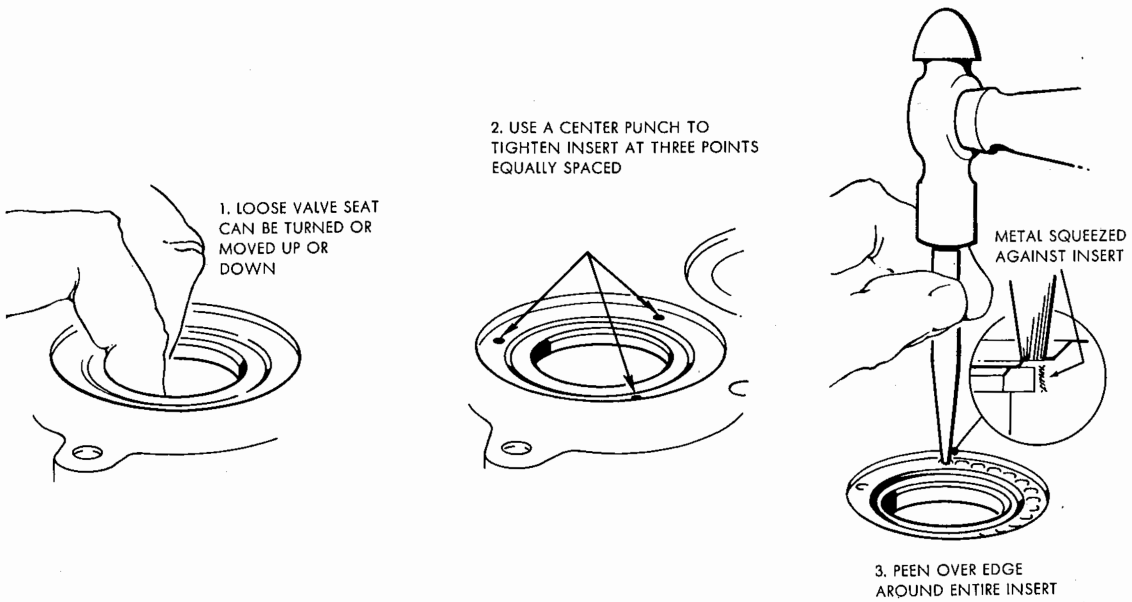
Removing a badly worn valve seat



Using a ridge cutter to remove peened edge

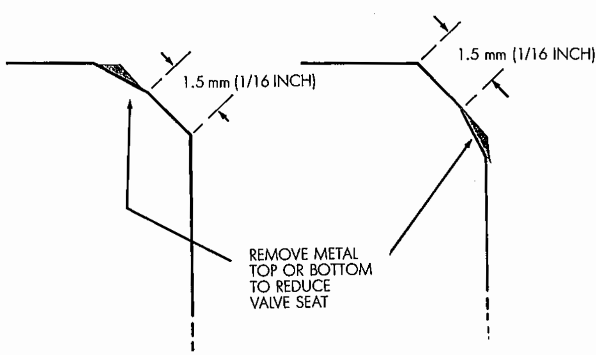
Be careful: Don't touch very cold objects or dry ice with your bare hands.

The new inserts must fit tightly to allow heat to travel quickly to the cylinder block. For this reason, a new insert is made very slightly oversize. To make it fit into its mounting hole, place it in a freezer or in dry ice for a few minutes. The cold will cause it to shrink. When it is cold enough, it will fit into the hole easily. After fitting the insert, wait until it has reached normal room temperature, then use a small ball peen hammer and a punch to peen the cylinder block as shown.



Fitting new valve seat insert

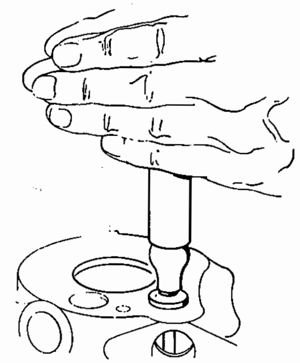
When installing new valve inserts or repairing old ones, the top or bottom edge of the seat should be ground off as shown, leaving a 1.5 mm (1/16 inch) seat width that touches the middle of the valve face. A narrow valve seat prevents carbon from building up and holding the valve open.



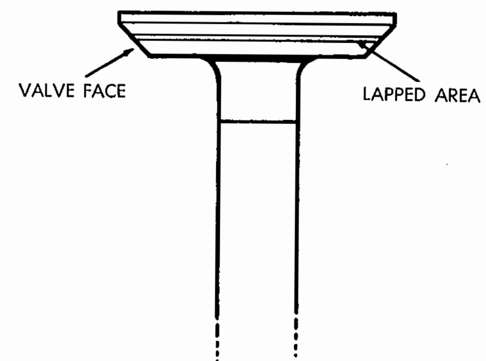
Reducing valve seat width

Abrasive: a substance which can be used to slowly abrade, or wear away, some surface. The "sand" on sandpaper is an abrasive.

The drawing on the left shows a valve seat being hand lapped, with a small amount of abrasive between the seat and valve face. Move the tool back and forth between the palms of your hands until an even gray colour shows on the seat and face. Do not overdo this job.



Handlapping a valve and seat

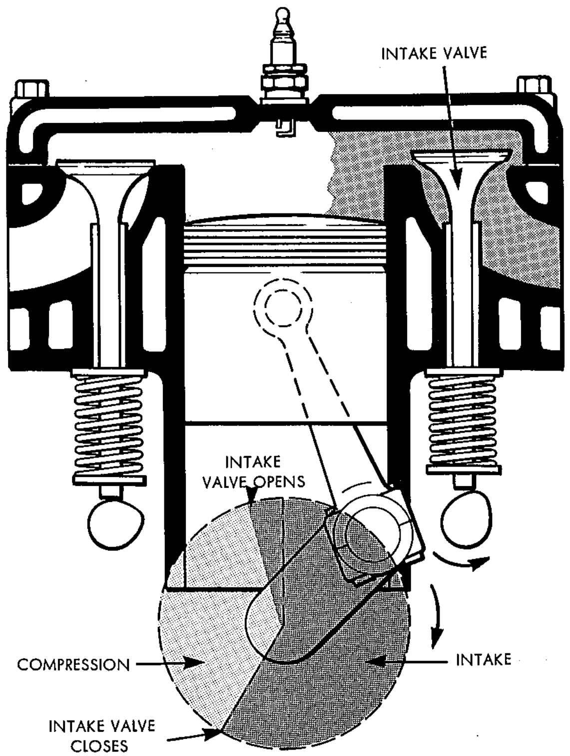


A handlapped valve

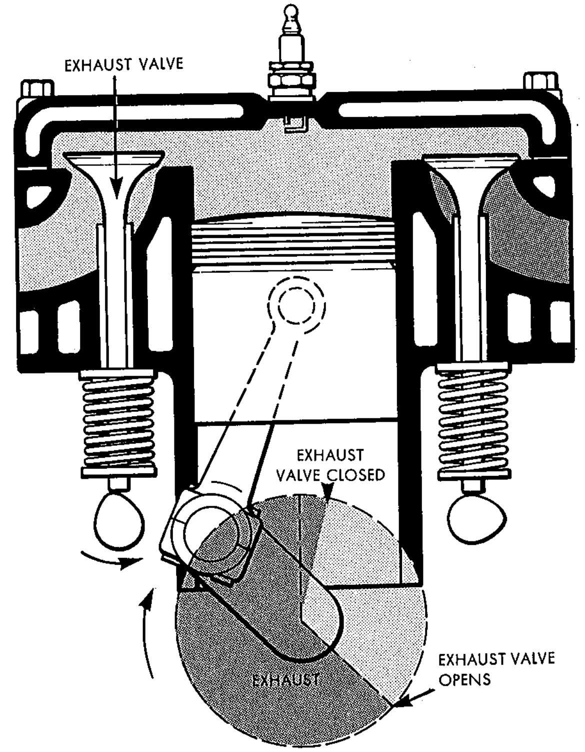
VALVE TIMING

It is important that each valve opens and closes at exactly the right time in each cycle of operation. The exhaust valve should open when the power stroke has been completed and stay open until the piston has reached the top of the exhaust stroke. As the piston starts down on the intake stroke, the intake valve should open and remain open until the piston travels all the way to the bottom of the intake stroke. Both valves must be tightly closed during the compression and power strokes.

It is common design practice for manufacturers to allow some valve overlap between strokes when designing engines. This means that the intake valve may open two or three degrees before the actual start of the intake stroke and close as much as 35° after the stroke ends, allowing more time for the fuel to enter the cylinder. The next drawing shows the number of degrees of crankshaft revolution during which the intake valve would stay open in a typical engine.



Amount of crankshaft revolution with intake valve open



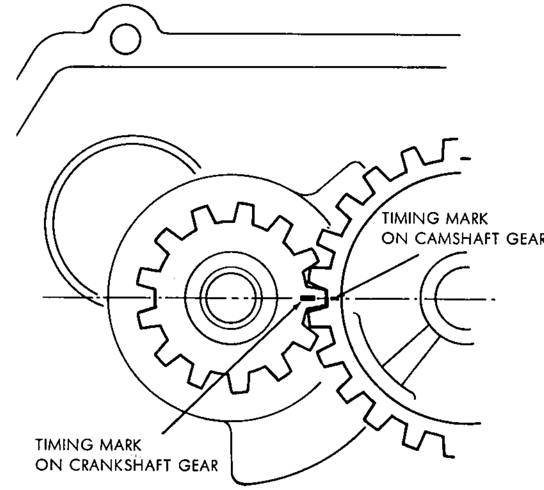
Amount of crankshaft revolution with exhaust valve open

Sprocket: a wheel with teeth on its edge. The teeth catch in holes between chain links to make another wheel turn.

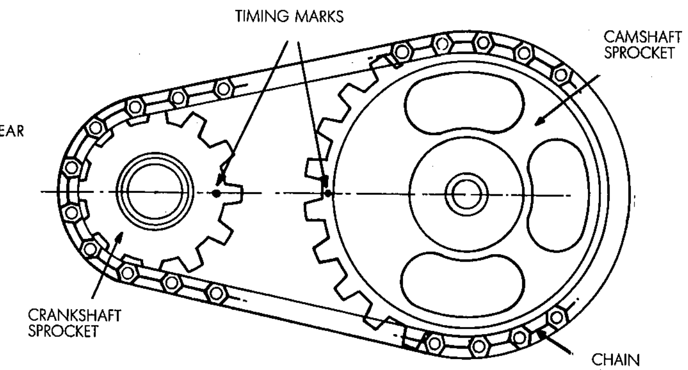
To allow more time for exhaust gases to escape, the exhaust valve may open 40° to 45° ahead of the exhaust stroke and close 5° late. This means both valves are open at the same time between the intake and exhaust strokes.

To do this, the crankshaft, camshaft, and valves are timed to work together. During the complete four stroke cycle of operation, each valve must open only once. The camshaft therefore must turn at half the speed of the crankshaft. The drawings show two methods used to drive the camshaft and make it revolve at exactly half the speed of the crankshaft.

The gear or chain sprocket on the camshaft is exactly twice the size of the gear or sprocket on the crankshaft and has twice the number of teeth. Whenever these parts are removed they must be replaced so the timing marks are in their original position.

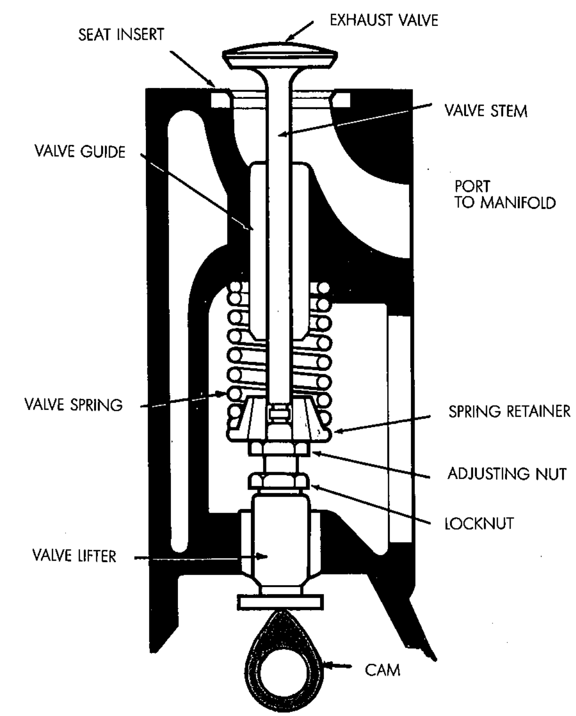


Gear method of driving camshaft



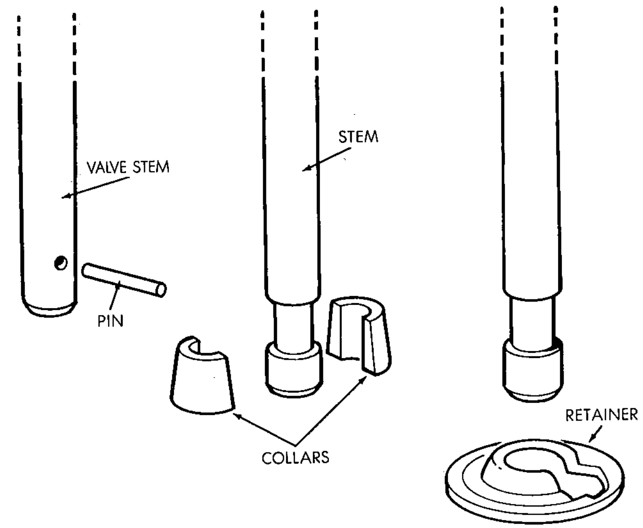
Chain and sprocket method of driving camshaft

Cam lobes on the camshaft push the valves open gradually. A strong spring pulls each valve closed after the cam moves away from the lifter.



Cam holding valve open

The drawings below show three methods of holding valve springs in place on the valve stem.



Valve spring retainers

Pistons and Piston Rings

Find the Answers to These Questions

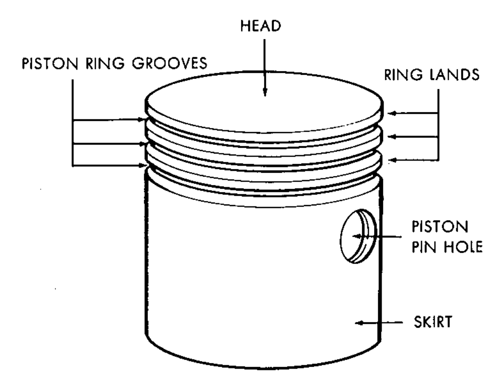
1. From what two materials are pistons made?
2. Why are holes drilled through the piston at the bottom of the lower ring groove?
3. Why are light mass pistons so popular in modern

4. What are two things about aluminum that cause piston design problems?
5. How might a plugged cooling system affect an aluminum piston?
6. What types of piston design are used to keep the piston from seizing in the cylinder? Describe these designs.
7. Name the two types of piston rings installed on pistons used in four stroke cycle engines.
8. How are some piston rings designed to put greater force against the cylinder walls?
9. Why must there be a certain amount of side clearance for a piston ring in its groove?
10. List the flaws that show a piston should be replaced.
11. What tool is used to measure piston ring end gap?
12. Why should cylinder head bolts be tightened in a particular order?

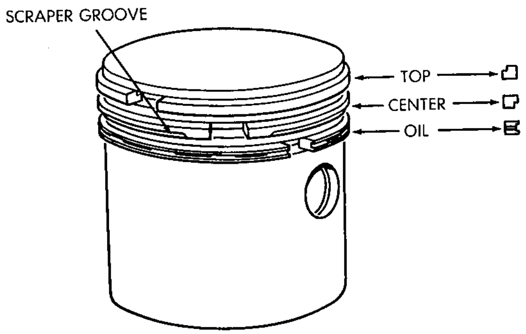
Be careful: When two people are working on the same machine, never, ever, start the engine before telling your partner. His or her hands may be in danger.

The pistons used in small four stroke cycle engines are can-shaped, with the bottom end open. The closed end is either flat or slightly rounded and is called the piston head.

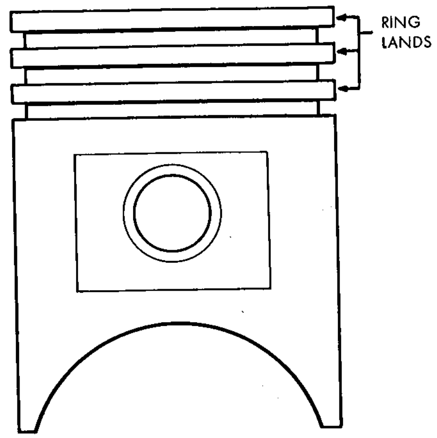
Just below the head are three or four grooves to hold the piston rings. Holes drilled through the piston in the bottom groove allow oil, scraped off the cylinder walls, to return to the crankcase. The metal surrounding the open end of the piston is called the skirt and is machined to a very close fit in the cylinder to keep the piston from tilting to one side or the other. The skirt is not always square edged, as shown in the drawing of a piston with a "slipper" skirt.



Parts of the piston



Piston and rings

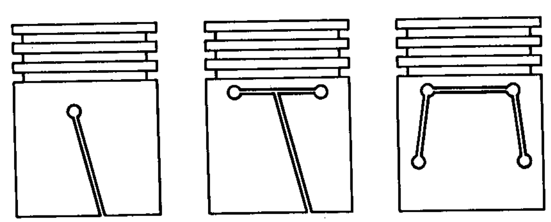


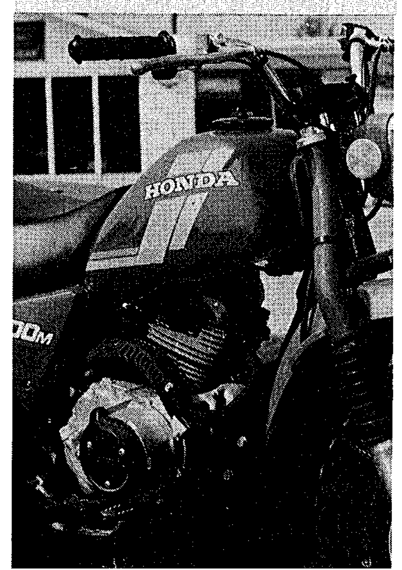
Slipper skirt piston

Alloy: a metal which has been made by mixing two or more pure metals. Brass is an alloy of copper and zinc.

Pistons are made of cast iron or aluminum alloys. The majority of the modern high speed engines use the aluminum piston because of its light mass. Since a piston must slow to a stop and reverse its direction at the end of each stroke, the light mass of aluminum becomes very important as the speed increases. Another good feature of aluminum is its ability to transfer the heat of combustion to the cylinder block more quickly than cast iron does. However, aluminum has two characteristics that cause problems. It has a low melting point, near 670°C, and a high rate of heat expansion. Poorly maintained cooling systems, or ignition systems causing heavy spark knock can cause piston failure. This failure can be a holed piston head, warped or collapsed skirt, or collapsed ring lands.

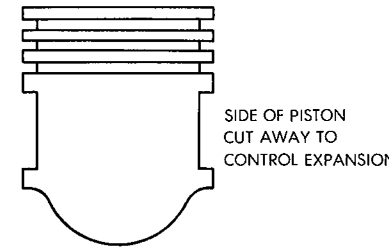
Because of the large amount of heat expansion of aluminum, pistons in the less expensive engines are fitted loosely in the cylinder, and the piston rings are used to provide the compression seal. Since this allows the piston to rattle in the cylinder until full operating temperature is reached, several other solutions have been found to the expansion problem. One of the solutions is slots cut in the skirts of pistons. These pistons can


Three common slot patterns



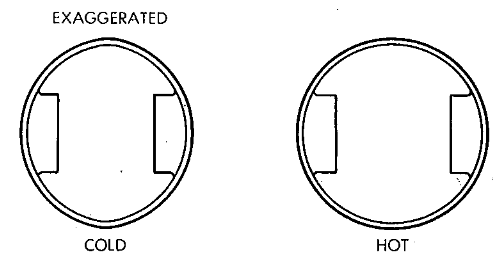
then be machined to close fits in their cylinders. Then when the piston expands with the heat most of the expansion can be taken up by the slot, which tends to close.

Another solution is to cast steel rings into the piston, or cut away the area around the piston pin to control expansion. This is called a relieved piston.



Relieved piston

Cam grinding the piston has proved to be one of the better solutions to the problem. The piston is machined to an oval shape, with the narrow area across the pin bosses. The piston expands to a round shape at full operating temperature.



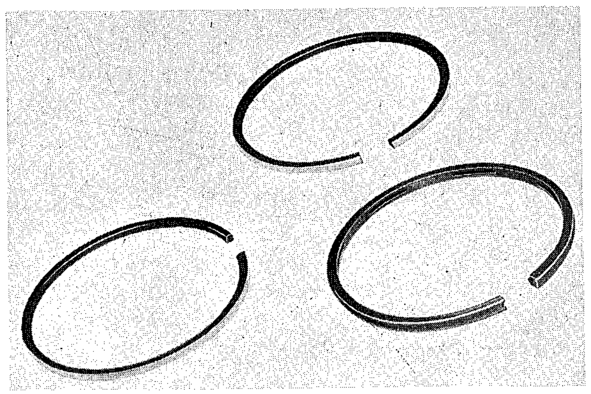
Bottom views of cam ground piston

All of these ideas are aimed at providing a tight fitting piston, but the tightest fitting piston would still not provide a good compression seal. Whether the piston is made of aluminum or cast iron, three or four piston rings must be used to complete the seal.

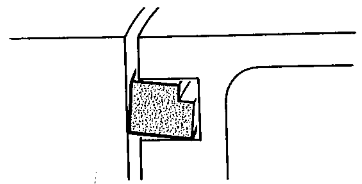
PISTON RINGS

Piston rings are circles of specially treated steel, open on one side. When installed on the piston, they are free to move in the ring grooves and are made to keep a steady pressure outward against the cylinder wall. The top two rings are solid steel compression seal rings. The lower ring or rings are shaped to conoil from the cylinder walls and return it to the crankcase. A three ring set of compression and oil control rings is shown below.

When replacing compression rings, you may find that their inside or outside edge has been cut away. This causes the ring to twist slightly in its groove, forcing one edge more tightly against the cylinder wall. Follow the piston ring manufacturer's instructions carefully to avoid installing this style of ring upside down.

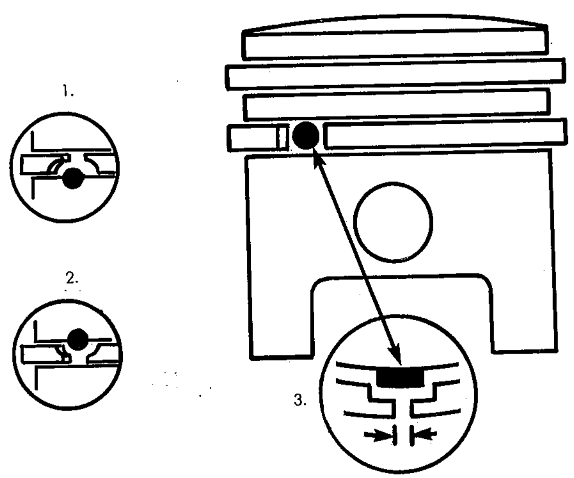


Piston ring set



Section view of compression ring in its groove, showing twist effect

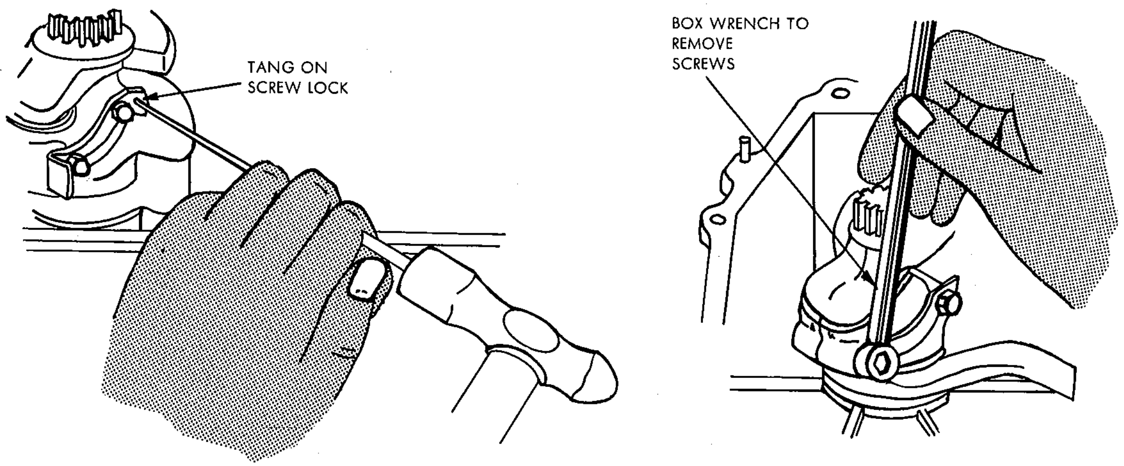
The piston rings on many pistons are held in position by small pins. This stops the rings from turning so their end gaps are in line. Compression leakage through the gaps is reduced. The drawing shows three locations of the pins in the ring grooves.



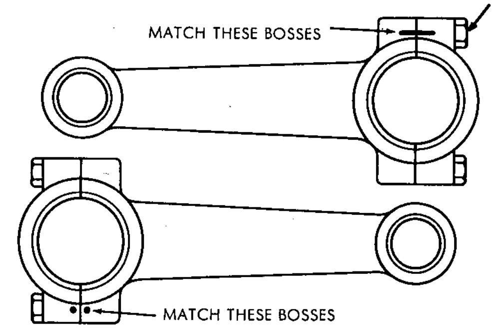
Piston ring locating pins

INSTALLING PISTON RINGS

1. Drain the oil from the crankcase and remove the crankcase cover and cylinder head.
2. Remove the connecting rod cap and push the connecting rod and piston out of the cylinder. Note the cap alignment marks and their position. They must be replaced in the original position later.



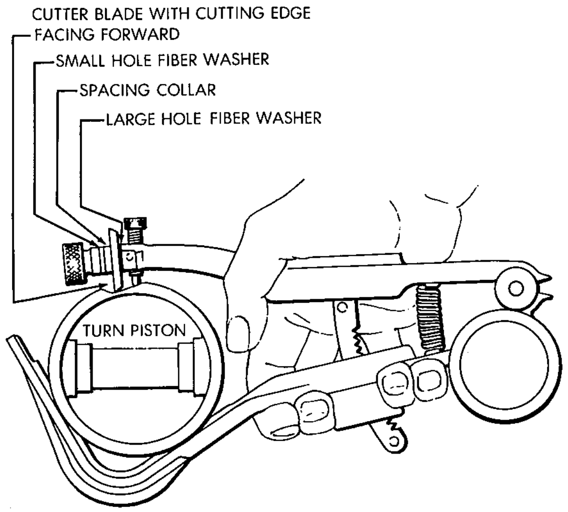
Removing connecting rod cap



Cap and rod alignment marks

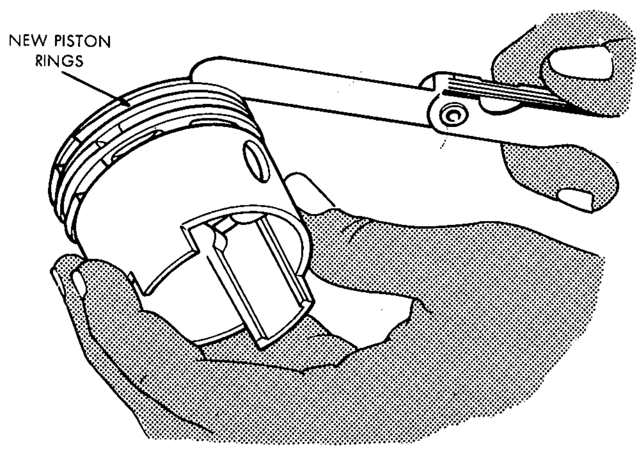
Be careful: The sides of the ring grooves must not be damaged. Do not scratch or dent the grooves.

3. Clean the connecting rod and piston assembly. Use a ring groove cleaner or the end of a broken piston ring to remove dirt and carbon from the ring grooves.



Carbon removal tool in use

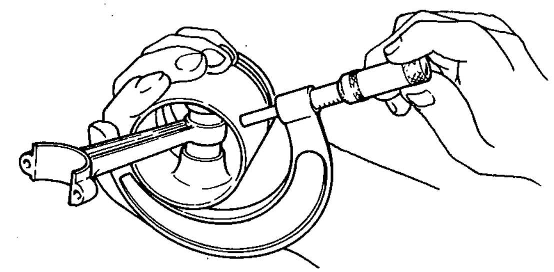
4. Replace a piston if it is collapsed or if it shows ring lands that are cracked or chipped, ring grooves that are worn beyond allowable clearances, or a cracked skirt or head. The drawing below shows ring groove clearance being checked with a feeler gauge.



Checking ring clearance

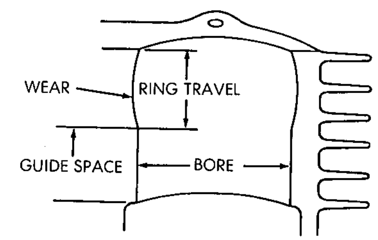
Hone: an abrasive tool used to enlarge holes and make them very accurate. If a fine abrasive is used, the finish will be very smooth.

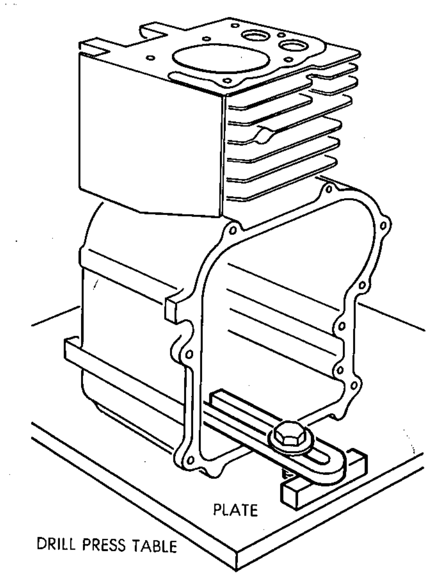
Use a micrometer at two or more points around the piston to check for out-of-round condition. You should get the same reading. Remember that some pistons have been cam ground and are supposed to be out of round. Check the engine repair manual.



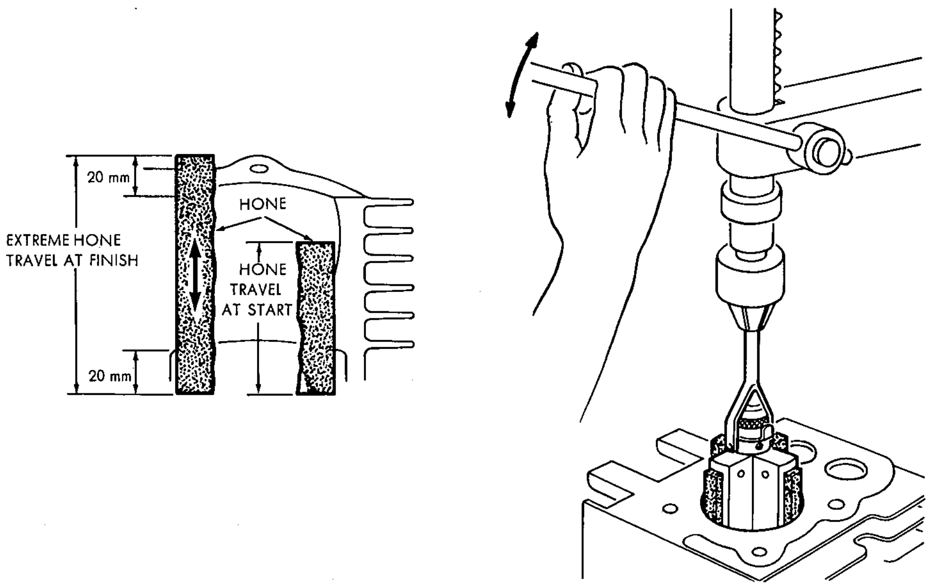
Checking piston for roundness

5. Check the cylinder for scuffing or score marks. These conditions can be corrected with a cylinder hone if the damage is light.





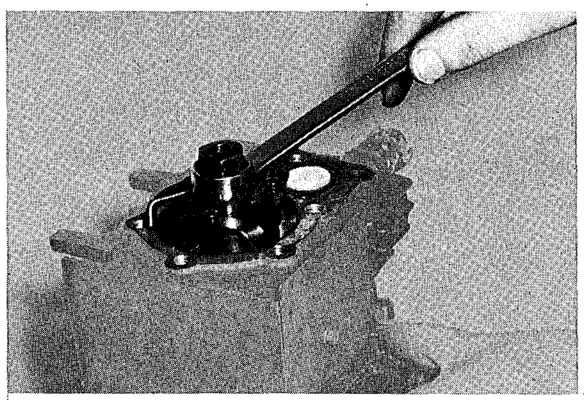
Engine set up for honing



Using a hone to re-condition a cylinder

Some manufacturers and mechanics do not like using a hone in aluminum cylinders because bits of abrasive may become stuck in the soft metal. The piston and new rings would then be quickly damaged.

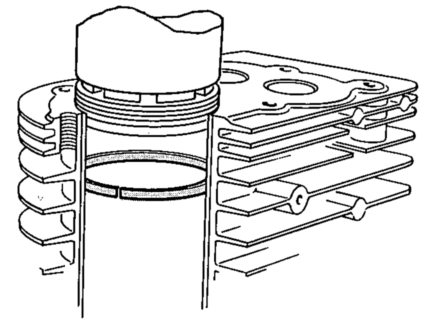
6. If the cylinder does not need honing, remove any ridge that may be found at the top of the cylinder with a ridge remover. This ridge occurs because no ring wear is taking place at the very top of the cylinder. Often it is necessary to remove the ridge in order to slide the piston out of the cylinder.



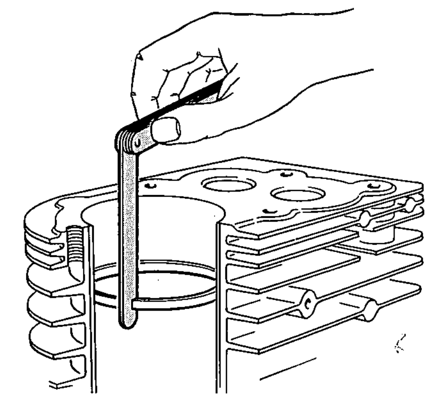
Ridge remover in use

Be careful: Piston rings break easily.

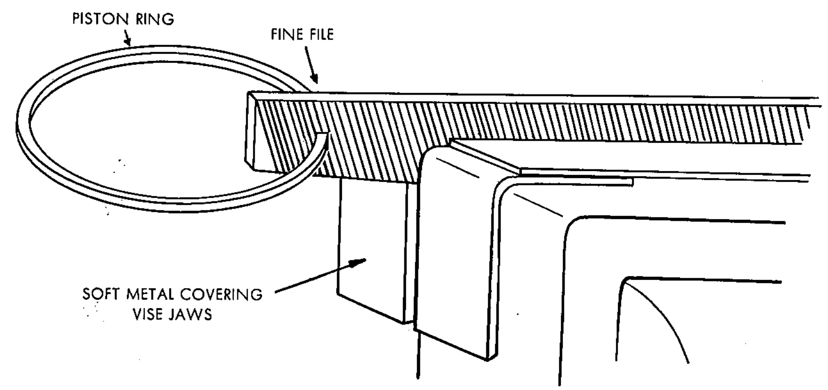
7. Check the amount of piston ring end gap of each new ring by pushing it into the lower cylinder with the head of the piston. Use a feeler gauge as shown. If the gap is smaller than the manufacturer says it should be, carefully file one end of the ring. Remove any burr that the file may cause, then push the ring back in the cylinder and check the end gap again.



New ring pushed into the cylinder with the piston



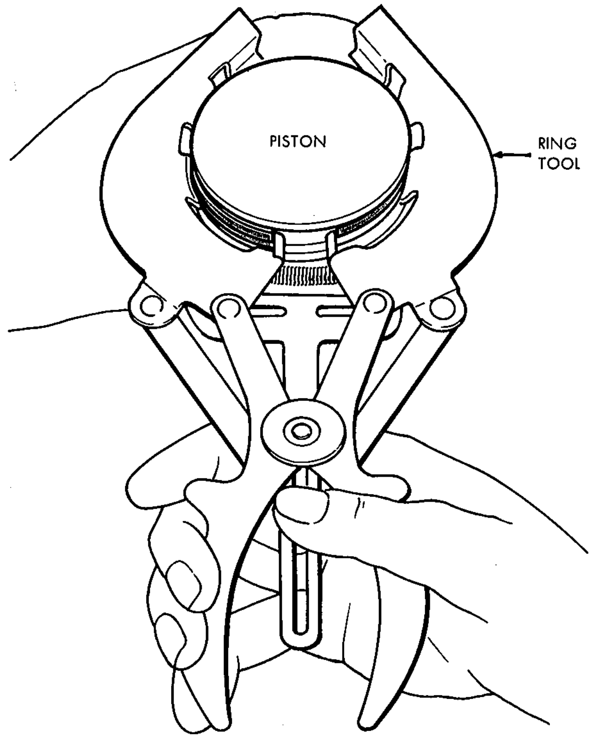
Checking the end gauge clearance of a new piston ring



Making the ring gap the correct size

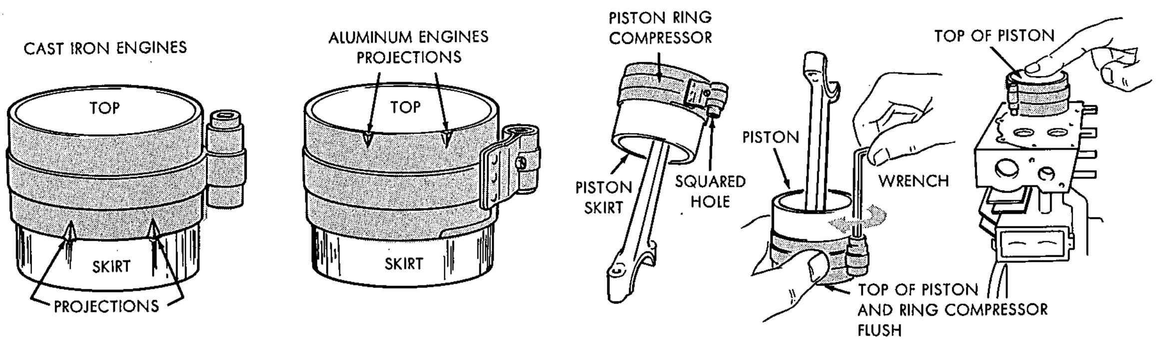
8. Install the new rings on the piston with a ring tool to avoid breaking or bending them. Arrange the end gaps so they are not one above the other.

Be careful: If the end gaps of the piston rings are above each other they will form a hole that oil, air, and fuel can go through.



Installing new rings

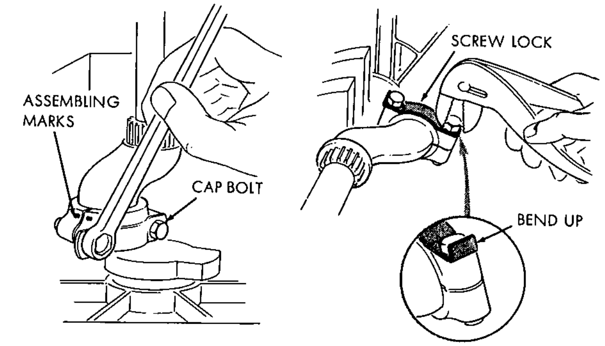
9. Use a piston ring compressor to install the piston in the cylinder. Some pistons are marked to show the correct position in the cylinder. Check the engine manual.



Installing piston with piston ring compressor

Be careful: Turn the crankshaft to make sure the connecting rod is clear of all other engine parts; then lock the cap bolts in place. The rod may be made to clear when facing one way only.

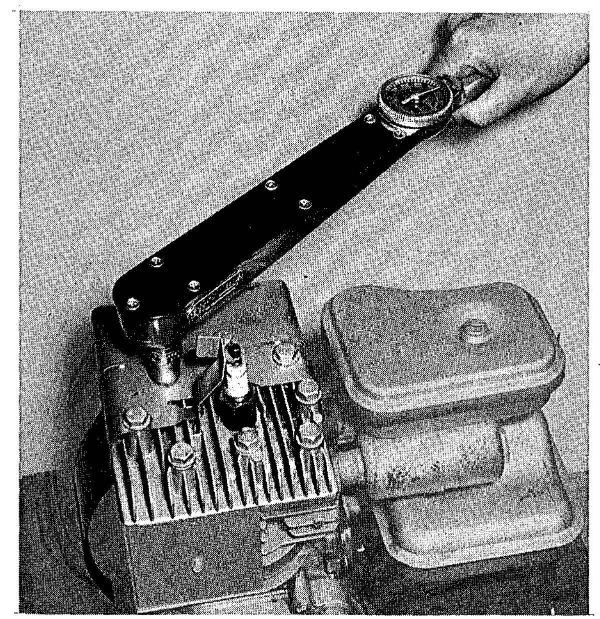
10. Install the connecting rod cap so the alignment marks match and are in the same position as before. Some caps and rods have no marks but are made to fit in one position only. Tighten the cap bolts to the specified torque.



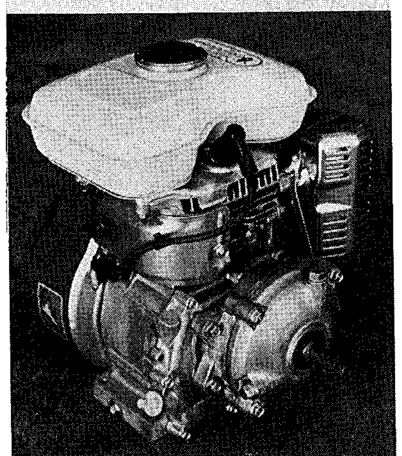
11. Bend the lugs of any lug-type lock washer or strap to prevent the bolts from working loose.

12. Replace the crankcase cover and cylinder head, using new gaskets, and fill the crankcase with oil to the correct level.

Use a torque wrench to tighten all cylinder head and crankcase bolts. Refer to a tightness chart for the particular engine you are repairing. Do not over-tighten.

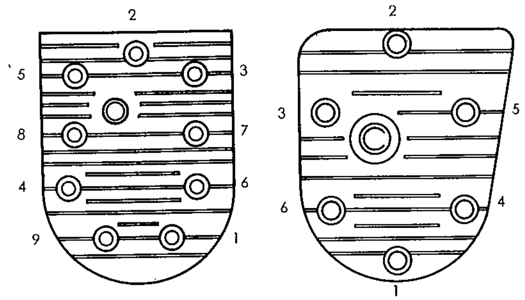


Tightening cylinder head bolts



A four stroke cycle engine with gear box to slow down the shaft speed

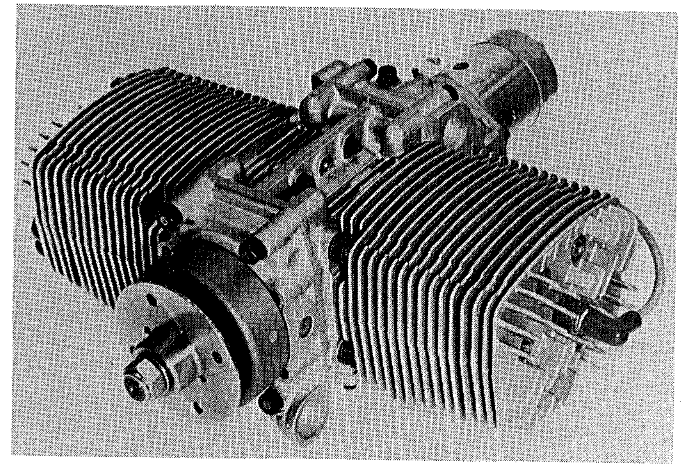
Cylinder head bolts should be tightened in a definite pattern to prevent warping of the head. When no instruction is available, any pattern that avoids tightening two adjacent bolts one after the other can be used. The drawings show two head bolt patterns used on small engines.



Head bolt patterns

Things to Do

1. Remove the cylinder head from a small four stroke engine. Turn the crankshaft slowly by hand and watch the action of the valves during each of the four strokes. Notice the intake and exhaust valve overlap.
2. Remove one or both valves as described in the text. Examine the condition of the face, margin, and stem of the valve. Do the valves wobble in their guides?
3. Replace the valves, valve springs, and retainers and measure the clearance between the valve stem and the lifter. Compare this measurement to the engine specifications.
4. Remove the crankcase cover and locate the valve timing marks on the timing gears.
5. Remove the piston and connecting rod assembly, as described in the text. Measure piston ring side clearance. Remove one ring and measure its end gap.
6. Clean all parts and re-assemble the engine. Use a torque wrench to tighten all bolts.



CHAPTER 4
TWO STROKE CYCLE ENGINES

Watch for These Words

lubrication	*diesel*
reed	*vacuum*
rotary	*ports*
sump	*carbon*

How to Use These Words

1. Two stroke cycle engines get their *lubrication* by having oil mixed with their fuel.
2. *Reed* valves and *rotary* valves are used in small two stroke cycle engines instead of poppet valves.
3. Small two stroke cycle engines do not need a *sump* to hold oil.
4. Heat from very high compression starts the fuel burning in *diesel* engine cylinders.
5. Air pressure works to fill any *vacuum* in an engine.
6. The exhaust *ports* of two stroke cycle engines may get plugged with *carbon.*

Be careful: Gasoline fumes are explosive. Always mix gasoline and oil outside.

Chapter 3: Four Stroke Cycle Engines

1. Name the four strokes that make up the four stroke operating cycle.

2. How does a worn valve affect the operation of the engine?

3. List at least three flaws in a valve that show it should be replaced?

4. Why must there be a gap between the valve stem and the lifter?