After studying this chapter, you will be able to:

- Describe the function of the connecting rod and the bearings.
- Define bearing spread and bearing crush.
- Summarize the function of the crankshaft.
- Service conventional and overhead valve assemblies.
- Explain the operation of ports, reeds, and rotary valves.
- Describe the purpose of the camshaft.
- Explain the purpose of an automatic compression release.

Introduction

Like pistons and piston rings, connecting rods, bearings, and valves are used in areas of the engine that demand close fits. Due to high temperatures, however, some clearance must be allowed for part expansion. While there are differences between makes of engines, maintenance of the rods, bearings, and valves is much the same for all.

Special attention must be given to four-cycle engines because they contain more parts that require service. Rod and bearing service is the same for both two-cycle and four-cycle types. The valve system of four-cycle engines (major area of difference) will be covered in detail near the end of the chapter.

Connecting Rods and Bearings

The connecting rod attaches the piston to the crankshaft. The upper end of the connecting rod has a hole through which the piston pin is passed. The lower end contains a large bearing that fits around the crankshaft journal. See Figure 17-1.

The lower end of the connecting rod is usually split when friction bearings are used. Friction bearings use smooth, sliding surfaces to reduce friction between moving parts. The place at which the halves separate is called the parting line.

Friction-type rod bearings

There are three types of friction bearings commonly used in the big end of connecting rods. The three types of friction bearings are:

- Rod metal (used when rod is made of aluminum alloy). See Figure 17-4.
- Bearing bronze (cast into rod end, bored, and finished).
- Removable precision insert bearings (steel shells lined with various materials).

The thin lining material on removable bearing inserts can be lead-tin babbitt, aluminum, or copper-lead-tin. Figure 17-5 shows a steel-backed insert (1) that is coated with cast babbitt (2). This type of bearing is called a precision insert because it is made to an exact size for proper fit.

Bearing inserts are kept from turning in the rod end by a locating tab on the parting line edge of each insert. The tab fits into a slot in the rod itself. Figure 17-6 illustrates this tab and slot arrangement.

Bearing spread

The diameter across the parting surfaces of insert bearing halves is slightly larger than the...
diameter across the curve machined into the rod and rod cap. This condition is called bearing spread. To seat the insert, the ends must be forced down and snapped into place. Never press down in the center of the insert to seat it in the rod bore. The correct amount of bearing spread gives tight insert-to-bore contact around the entire bearing and provides support and alignment. It also helps to carry heat away through the rod and bearing cap and holds the bearing in place during assembly.

**Bearing crush**

When precision inserts are snapped into the rod bore, the ends will protrude slightly above the parting surface. See Figure 17-7A. This built-in design feature is called bearing crush. Generally, bearing crush varies from .001" to .002".

When the rod cap is installed and drawn into place, the insert ends meet first and force the insert halves tightly against the rod bore. This provides firm support for the insert. The forced fit makes the insert round and, through close metal-to-metal contact, allows heat to be carried away through the rod. Figure 17-7B shows how radial pressure is exerted against the rod bore.

**Inserts are matched**

Precision inserts must be kept in matched pairs. Never mismatch bearing inserts. Always use the exact size needed. Bearings cannot be made larger or smaller in the shop. Standard and various undersizes are available.

**Antifriction bearings**

Many small gasoline engines use an antifriction bearing in the big end of the connecting rod. Antifriction bearings use rollers or balls to reduce friction between moving parts. Often, needle rollers are used. These roller elements can be held together by a roller cage or separator. See Figure 17-8A. The rollers can also be left free as in Figure 17-8B. Antifriction bearing assemblies are hardened and ground to an exact size. They must fit accurately, but still have some clearance for expansion.

During manufacture, the rod cap is bolted into position on the rod. Then, the assembly is bored to an exact size. It is important, therefore, that the rod cap is always put back in its original position. If the cap is turned 180°, the upper and lower halves can be offset. This error in assembly will cause bearing and shaft failure. See Figure 17-9A.

Connecting rods are usually marked with either a line, punch mark, number, special boss, or chamfered edge to show correct cap alignment during assembly. If a mark is not apparent, punch mark the rod end and cap for later reference, Figure 17-9B.

**Caps must never be switched from one rod to another.**

**Rod bolt locking devices**

To stop connecting rod bolts or cap screws from loosening in service, locking devices are used. One common device is a thin sheet metal strip with locking tabs. See Figure 17-10. The cap screw is inserted through holes in the locking strip, holding it in place against the rod. After the cap screw is tight, the metal tabs are bent up against the flat sides of the screw head. See Figure 17-11.
Self-locking nuts, lock washers, and specially shaped cap screws are also used to prevent loosening. The final tightening of the cap screws is especially important. Always use a torque wrench to tighten rod fasteners to the exact torque specified by the manufacturer.

**Crankshaft**

The crankshaft converts the reciprocating (back and forth) motion of the piston into rotary (circular) motion. It transmits engine torque to a pulley or gear, so that some object may be driven by the engine. The crankshaft also drives the camshaft (on four-cycle engines), supports the flywheel, and, in many engines, operates the ignition system.

Crankshafts can be made of cast or drop-forged steel. One-piece and multi-piece crankshafts are used. Figure 17-12 shows a typical one-piece small engine crankshaft. A multi-piece crankshaft is shown in Figure 17-13.

**Crankshaft throw**

The crankshaft throw is the offset portion of the shaft measured from the centerline of the main bearing bore to the centerline of the connecting rod journal. The connecting rod journal is commonly referred to as the crank throw or crankpin.

**Crankshaft balance**

To help offset the unbalance created by the force of the reciprocating mass (connecting rod, piston, and crankpin), counterweights are added to the crankshaft. By placing these weights opposite the crankpin, engine vibration is greatly reduced. As shown in Figures 17-12 and 17-13, the counterweights are usually forged as an integral part of the crankshaft.

**Crankshaft main bearings**

The crankshaft is supported by one or more main bearings. Often, the main bearing journal surfaces are hardened by an induction hardening process to provide long service life. The three types of main bearings used are:

- Sleeve or bushing. See Figure 17-14.
- Roller bearing. See Figure 17-15.
- Ball bearing. See Figure 17-16.

**Crankshaft clearances**

To allow space for lubricant between the moving parts, as well as to provide room for expansion when heated, crankshaft bearings must have a slight end clearance. See Figure 17-17. Shaft movement from end to end is controlled by the bearing adjustment when tapered roller bearings or ball bearings are used.
With friction bearings, a thrust surface on the shaft rubs against a similar surface on the crankcase. A precision insert main bearing may have a thrust flange for the crank to rub against. In some applications, a bronze thrust washer is used.

Clearances will vary with engine type, design, and use. Bearing and thrust surface clearances are critical. They must be held to exact tolerances as recommended by the manufacturer.

**Figure 17-18** illustrates the method of measuring the bearing surfaces on a crankshaft with a micrometer. A measurement must be taken in at least two positions 90° to each other. If any of the dimensions are smaller than specified, or if there are any score marks, the bearing surfaces should be reground. Basically, wear and taper should not exceed .001".

### Measuring bearing clearance

**Bearing clearance** is the space between the inner bearing surface and the crankshaft main or rod journal. When checking bearing clearance, use a special compressible plastic material called **Plastigage**. This material is color coded and selected according to the recommended clearance range. It comes in a thin, round strand, which is stored in a paper package.

To use Plastigage, select the correct color for the specified clearance. Cut a piece of plastic equal to the width of the bearing and lay it across the bearing surface. See **Figure 17-19A**. Torque the bearing cap in place. Then, remove the cap and compare the compressed width of the plastic with the comparison chart printed on the Plastigage package. See **Figure 17-19B**. The number within the graduation on the package (envelope) indicates the bearing clearance in thousandths of an inch or in millimeters depending on which side of the package is used. Taper is indicated where one end of the Plastigage is flattened wider than the other end. Measure each end of the flattened Plastigage and the difference between reading is the approximate amount of taper. Excessive amount of taper indicates that a new or reground crankshaft is required. In effect, the wider the plastic, the less clearance there is.

If bearing clearance is too great, undersize inserts will have to be used. If the crank journal is worn, it will require grinding to clean it up. After grinding the journal, recheck the clearance with a Plastigage.

On many small engines, the main bearings are simply machined bores in the crankcase halves or pressed inserts. Plastigage will not measure wear in these bearings. To check clearance, first measure the crankshaft diameter with a micrometer. Next, measure the inside diameter of the main bearing with a telescoping gauge. See **Figure 17-20**. Lock the gauge, remove it from the bearing, and measure the setting with a micrometer. The difference between the shaft reading and the bearing reading is the amount of bearing clearance.

### Crankcase seals

**Crankcase seals** prevent leakage of oil from the areas where the crankshaft and crankcase come together. The shell of the seal makes fixed contact with the crankcase, while the knife edge of the sealing lip rubs lightly against the crankshaft. See **Figure 17-21**.

Seals are made of neoprene, leather, graphite, or other materials, depending on how they are used. A typical crankcase seal has a steel outer shell with a neoprene center. A small coil spring keeps the sealing lip in constant contact with the shaft it seals. See **Figure 17-22**.

Note in **Figure 17-21** that the sealing lip must face the fluid being sealed in. In this application, it faces the crankcase. In this way, the pressure of the oil will tend to force the lip against the shaft. If the seal is installed backwards, oil pressure will force the sealing lip away from the shaft and oil leakage will occur.

When removing the crankcase cover from the crankcase and crankshaft, as in **Figure 17-23**, place tape over the keyway. This will keep the sharp keyway edges from cutting the neoprene oil seal. **Figure 17-24** shows how a press is used to push the old seal out of the backplate. In **Figure 17-25**, the seal is being readied for installation. A liquid sealant is applied to the outside of the shell of the seal before pressing it in place in the backplate. Often, seals can be replaced by tapping them into the bore of the backplate with a special driving tool. See **Figure 17-26**.
Valve Service

Four-cycle engines contain **poppet valves**, which are subjected to tremendous heat. The normal operating temperature of the exhaust valve exceeds 1000°F. To withstand this heat, high-quality, heat-resistant steel must be used and the correct operating clearances must be maintained.

Removing valve assembly

The engine valve assembly includes the valve, valve spring, and one or more retainers. **Figure 17-27**. The locking-type retainers are called **valve keepers**. Once the cylinder head has been removed, remove the valve by compressing the valve spring with a compressor. See **Figure 17-28**. Remove the valve spring retainer from the groove in the valve stem using a pair of pliers. See **Figure 17-29**. Then, slowly release pressure on the spring and remove the compressor. The valve can be pulled out the top and the spring taken from the side.

Inspecting valves and seats

When the valves have been removed, clean them with a power-operated wire brush and inspect them for the following defects:

1. Eroded, cracked, or pitted valve faces, heads, or stems.
2. Warped head. See **Figure 17-30**.
3. Worn or improperly ground valve stems. See **Figure 17-30**.
5. Margin less than 1/64".
6. Partial seating.

Heavy carbon deposits on intake valves sometimes cause faulty valve operation by restricting the flow of fuel into the cylinder. If any serious defects are observed, the valve should be replaced. In any case, valve faces should be machined to a smooth, true finish.

**Inspecting valve springs**

Through overheating and extensive use, valve springs can lose their elasticity and become distorted (warped or bent). Check each spring for squareness and proper length with a square and a surface plate. See Figure 17-31. Replace all springs that are badly distorted or reduced in length. Test spring tension and compare with the specifications in the engine manual. See Figure 17-32. Lack of spring tension can cause valve flutter or incomplete closing and sealing of the valves.

**Valve guides**

Valve guides align and steer the valves so that they can open fully and close completely. Guide-to-valve stem clearance must not exceed tolerances, since this would permit the valve to tip. Tipping causes the valve face to strike the seat at an angle, allowing hot combustion gases to escape. Some clearance is required, however, to allow for heat expansion and lubrication. Generally, guide-to-valve stem clearance should run about .002" to .003".

Valve guides can be a replaceable insert or an integral part of the block. See Figure 17-33.

Inspecting valve guides

Valve guides must be cleaned before inspection. A special cylindrical wire brush, driven by a power drill, is made for this job. After cleaning the guide, measure the bore with a small hole gauge. See Figure 17-34. Expand the gauge until it lightly touches the sides of the bore. Remove the gauge and measure it with a micrometer.

Next, measure the valve stem diameter with a micrometer. See Figure 17-35. Subtract the stem diameter from the guide diameter to find the precise amount of clearance. Compare this with the clearance specified.

**Valve guide reaming**

If the clearance between the stem and the guide exceeds the allowable limit, enlarge the guide to the next oversize dimension with an adjustable reamer. See Figure 17-36. Select and install a valve with the correct oversize stem. Do not enlarge the tappet guides, because oversize tappet stems are seldom available.

Alternate valve guide replacement

There are many engine makes and models available that may need valve reconditioning. Some engines have valve guides that are replaceable by pulling out the worn guide bushings and pressing in new bushings. For each make and model, the manufacturer’s service manuals should be examined to determine the proper method, bushings, and tools to use.

**Rebushing worn aluminum guides**

1. If this special plug gauge tool can be inserted into the valve guide a specified distance, the valve guide is worn and should be replaced. See Figure 17-37A.
2. Place pilot of counterbore reamer in valve guide. Slide pilot bushing down over counterbore reamer until bushing rests on valve seat. See Figure 17-37B.
3. Place proper replacement bushing on top of pilot bushing and mark reamer 1/16" above top of bushing.
4. Ream worn valve guide until mark on counterbore reamer is even with top of pilot bushing. Use kerosene or aluminum cutting fluid to lubricate reamer.
5. After guide is counterbored, withdraw reamer while turning it in the same direction used to ream guide. See Figure 17-37B.

6. Position new bushing in counterbored guide. Press bushing with valve guide bushing driver until bushing is flush with top of guide. See Figure 17-37D.

7. Finish ream bushing with proper size finishing reamer through to breather chamber. Use kerosene or similar lubricant. See Figure 17-37E.

8. Flush all chips away before removing reamer. Withdraw reamer by turning it in the same direction used for reaming while pulling up on reamer.

9. Measure valve stem diameter to determine valve stem-to-guide clearance. See Figure 17-35.

Replacing worn brass or sintered iron guides

1. Use modified reamer guide to align 7mm tap. See Figure 17-38. Measure shank of 7mm tap and drill reamer guide to assure tap will be square to the bushing to be pulled.

2. Using a tap wrench and pilot guide bushing, turn tap into bushing clockwise until tap is 1/2" deep.

3. Remove tap and wash chips out of bushing.

4. Rotate puller nut up to head of puller screw. Insert puller screw down through puller washer. See Figure 17-39.

5. Thread puller screw into threaded bushing until screw bottoms in tapped hole.

6. Back off screw 1/8 to 1/4 turn and place a drop of engine oil on threads of puller screw.
7. Hold puller screw stationary and turn puller nut down on washer until guide bushing is removed.

8. Press correct new bushing into cylinder with bushing driver tool until bushing bottoms in hole. See Figure 17-40.


10. Wash chips away and remove reamer.

**Valve seat angle and width**

The correct *valve seat angle* is necessary for proper valve seating. Valve seats are generally cut to a 45° angle, although 30° seat angles are used in a few engines. Follow all of the manufacturer’s recommendations.

The *valve seat width* is important for effective valve system operation. The seat must be wide enough to prevent cutting into the valve face. It also must provide enough contact area to provide for adequate heat dissipation. On the other hand, the seat must not be too wide. If it is, carbon will pack between the seat and the valve face, holding the valve off the seat. A valve that fails to seat produces a rough-running engine and will quickly warp and burn. Specified seat widths range from .030” to .060” (1/32” to 1/16”). See Figure 17-41.

<table>
<thead>
<tr>
<th>Guide Bushing Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bushing Removed from Cylinder</td>
</tr>
<tr>
<td>0.300”</td>
</tr>
</tbody>
</table>

Figure 17-40. Valve guide bushings used in some Briggs & Stratton engines. Note code system. (Briggs & Stratton Corp.)

Figure 17-41. A typical integral valve seat. Hole for seat is bored in the block metal. Note valve seat angle and valve seat width.

Some valve seats are ground to an angle of 44° and the valve face is ground to an angle of 45°, or vice versa. The 1° variation produces a hardline contact that gives fast initial seating. Some manufacturers believe that, upon heating, the valve will form a perfect seal. The difference in the angle between the valve face and the valve seat is called an *interference angle*. See Figure 17-42. Valve seat contact must be near the center of the valve face. See Figure 17-43.

Valve seats should be cut with a special valve seat cutting tool that has sharp carbide blades, such as the one in Figure 17-44. These tools can be purchased separately or in a kit like the one in Figure 17-45. If the carbide cutter blades become dull, they can be easily replaced. The cutting blades have angular teeth to give a smooth shearing cut as they are turned. See Figure 17-46. The pilot rod is placed in the valve guide first and the valve seat cutter is placed over the pilot. The tee handle wrench is used to turn the cutter. Apply moderate downward pressure and turn the cutter clockwise only. Cutting action is controlled by steady pressure and even, smooth turning of the handle. When doing any cutting operation such as reaming valve guides, or cutting valve seats, it is important to thoroughly wash away any chips or grit afterwards. Figure 17-47 illustrates the correct procedure to follow when using a valve cutter and pilot. Figure 17-48 shows how to correct poor valve seat geometry.

Figure 17-42. A 1° difference between valve face and valve seat provides better seating.

Figure 17-43. Comparison of correct and incorrect location of seating area on valve face. (Deere & Co.)

Figure 17-44. A valve seat cutting tool with carbide cutting blades. This tool is used to recondition valve seats by hand. (Neway Mfg. Co.)

Figure 17-45. A valve seat cutting tool kit. Cutter heads have carbide cutter blades that are very hard and will cut smooth and precise angles. Pilot rods accommodate various valve guide sizes. (Neway Mfg. Co.)

Figure 17-46. Valve cutter heads have angled cutting edges that provide a chatterless shearing cut for smooth valve seat surfaces. (Neway Mfg. Co.)

**Lapping valves**

Good used valves may be reseated by lapping. Some manufacturers do not recommend lapping. When a valve expands, it does not seat in the same place that it does when it is cold. Therefore, any benefits from the lapping process will cancel out. Nevertheless, the procedure can be followed if you wish to seat valves this way.
Some engine manufacturers recommend hand lapping of the valve seats. Lapping compound is available from engine parts distributors. Some suppliers package it in two-compartment containers. One compartment contains a coarse silicon carbide abrasive combined with a special grease. The second compartment contains a finer compound. The condition of the valve will dictate which grade to use.

If the coarse lapping compound is used, follow up with the finer compound. Figure 17-49 shows how to apply the compound to the valve face only. The compound should not be allowed to contact the valve stem or guide. Next, a lapping tool is attached to the valve head by means of a suction cup. See Figure 17-50. The tool shown has a spring-loaded piston in the handle to help create suction. With the tool attached, the valve is placed in the guide and twisted back and forth. See Figure 17-51.

The lapping process is complete when a dark gray, narrow band, which is equal to the seat width, can be seen all the way around the valve face. Do not lap more than is necessary to show a complete seat.
After lapping, thoroughly clean the valve and valve seat chamber so that none of the abrasive finds its way into the engine. The best way to get the cleaning job done is to turn engine upside down and wash the chamber with solvent, from the bottom.

Valve seat inserts

Valve seat inserts can be removed and new inserts installed to replace them. The following illustrations show the procedure for removing and installing inserts for certain models of Briggs & Stratton engines. They are examples only, and it is imperative that the manual pertaining to a specific engine make and model be studied first.

If the engine is a cast iron block, the exhaust valve may already have an insert. The intake valve may, or may not, have an insert. If not, one may have to be installed. To do so will require a pilot to be inserted into the valve guide as shown in Figure 17-52. A counterbore tool of correct diameter will be needed to cut a recess for the valve seat insert. See Figure 17-53. The counterbore cutter in Figure 17-54 is designed so it will cut only to the correct depth. If another tool is used, a depth micrometer will be necessary to measure depth. Do not cut too deep.

To counterbore insert cylinder
1. Select the correct seat insert, cutter shank, counterbore cutter, pilot, and driver. Refer to engine manual, model number, and tool list.
2. Insert pilot in valve guide. See Figure 17-52.
3. Assemble the counterbore cutter shank. See Figure 17-53.
4. Counterbore cylinder by hand until cutter stop touches top of cylinder. See Figure 17-54.

Do not apply side pressure to the cutter to avoid cutting cylinder oversize.

5. Blow out all chips with compressed air.
6. Remove cutter from cutter shank with a knockout pin.
7. Remove pilot from valve guide.

Removing a valve seat insert
1. Figure 17-55 shows a special tool used for pulling an insert out of an engine block. The puller nut must be of correct size so it does not score or damage the insert seat. It should pull only on the lower surface of the insert. It must also pass through the insert.
2. Hold the valve seat bolt and nut in place with one finger inserted through the port. Slide and center the puller body over the bolt. Tighten the bolt by hand.
3. The puller body must not rest on any part of the valve insert.
4. Turn the bolt with a wrench until the insert is pulled out of the cylinder. See Figure 17-56.

Installing new valve insert
1. Select proper valve seat insert, pilot, and driver according to the engine manual. One side of the insert will be chamfered at the outer edge. This side should go down into the cylinder recess. See Figure 17-57.
2. Insert the pilot in the valve guide.
3. Place the insert over the cylinder and the driver over the pilot. All should be aligned.
4. Drive the valve insert into place with the driver. See Figure 17-58.
5. Reface the seat as previously described in this chapter with a carbide valve seat cutter.

Installing new valve insert (aluminum alloy block)

1. Use the old insert as a spacer between the dri- 
vver and the new insert (aluminum alloy 
engine only). Drive new insert until it bottoms. 
Top of insert will be slightly below cylinder 
head gasket surface. See Figure 17-59.

2. Use a 1/8″ diameter flat ended drift or pin 
punch to peen around the insert to secure it as 
shown in Figure 17-60.

Valve lifter-to-stem clearance

Valve clearance refers to the space between 
the end of the valve stem and the top of the valve 
lifter when the valve is closed. The amount of 
clearance needed depends upon engine design and 
use. Due to hotter operation, the exhaust valve 
often requires more clearance than the intake 
valve. Clearances of around .008″ for the intake 
valve and .012″ for the exhaust valve are fairly 
common. Follow manufacturer’s specifications.

When there is too little valve clearance, the 
valve may be held open when the valve stem heats 
up and lengths (expands). As a result, engine 
performance is poor and both the valve face and 
valve seat will burn. See Figure 17-61.

Insufficient clearance can also alter valve timing, 
making it too far advanced.

Too much valve clearance, on the other hand, 
will make valve timing late and reduce valve lift.

Valve refacing can be done on a specially 
designed grinder. See Figure 17-63. The valve is 
revolved while being fed over an abrasive wheel. 
The collet that holds the valve is adjusted to achieve 
the desired face angle. Coolant flows over the valve 
head during grinding to reduce heat and produce a 
good surface finish. The infed wheel is used to 
precisely control the amount of material being 
ground from the valve face. In some cases, a lathe 
can be used to reface valves. See Figure 16-64. 
The valve is placed tightly into a machinist’s vise. Then, the 
valve refacer is placed on the valve. The crank 
lever turns the 45° (or 30°) cone against the sta-
tionary valve face. The cone has carbide blades 
that cut the valve face to the desired angle. The 
crank lever provides enough leverage to make the

Figure 17-59. The old insert is used to drive in the 
new insert and seat it so that it will be slightly below 
the surface. (Briggs & Stratton Corp.)

Figure 17-60. 1—If the space between the insert 
and cylinder are more than .005″ a new insert must be 
installed. 2—A center punch is used in three equally 
spaced locations to hold insert for peening operation. 
3—a flat end punch about 1/8″ diameter is used to 
force metal against insert and hold it tightly in place. 
(Briggs & Stratton Corp.)

Figure 17-61. Valve clearance setting is essential to 
good engine performance. A—Correct clearance permits 
valve to seat. B—Lack of clearance keeps valve open.

This results in sluggish engine performance. It 
can also cause rapid lifter wear because of the 
pounding action involved. Under these conditions, 
the engine will be noisy and the valve could break. 
Figure 17-62 shows a complete small engine 
valve train.

Refacing valves

Valve refacing can also be done using a 
manual valve refacer. See Figure 16-65. The valve 
is placed tightly into a machinist’s vise. Then, the 
valve refacer is placed on the valve. The crank 
lever provides enough leverage to make the
job effortless. The second lever is used to control the feed rate of the blades.

When valve lifters become concave or deformed, they can be ground flat as in Figure 17-66. Likewise, the end of the valve stem can be dressed and shortened to produce correct valve clearance. See Figure 17-67.

Adjusting valve clearance

When a valve has been refaced, it rides lower in the guide, and, therefore, valve-to-tappet clearance is reduced. If the engine does not have adjustable tappets, the end of the valve stem must be ground to obtain correct clearance. To check clearance, turn the camshaft until the lobe is away from the tappet. Hold the valve against its seat while testing clearance with a thickness gauge, Figure 17-68. If there is too little clearance, remove the valve and grind .001” or .002” off of the stem. Repeat the clearance check and grinding operation until the clearance is correct.

After the valves and seats have been properly reconditioned, place each valve in its respective guide. Use a valve spring compressor to compress the spring and, then, install the keepers. Make sure that the oil drainback holes are open before reinstalling the valve breather cover. See Figure 17-69.

Overhead Valve Systems

Many four-cycle engines use an overhead valve system, which transmits motion through pushrods and rocker arms to open and close valves. See Figure 17-70. The overhead valve design improves volumetric efficiency and eliminates combustion chamber hot-spots, which can cause cylinder distortion. Overhead valve systems increase fuel efficiency by as much as 25% and improve engine service life.
**Overhead valve system disassembly**

The following procedure should be observed when disassembling an overhead valve system:

1. Remove engine accessories that interfere with the removal of the valve cover.
2. Remove the valve cover bolts and the cover. See Figure 17-71. The rocker arm assembly should now be exposed.
3. Remove the rocker arm locking screws and nuts as shown in Figure 17-72. Remove the rocker arms. Some engines have rocker arms that pivot on a rocker arm shaft. See Figure 17-73. To remove, loosen the adjusting screws, remove the retaining rings, and slide the rocker arms off the shaft.
4. When the rocker arms are removed, lift out the pushrods. See Figure 17-74. (Note the location of each pushrod and do not interchange them when reassembling the engine.) After cleaning the pushrods, check them for straightness by rolling them on a flat, machined surface. If they are bent, replace them. Do not try to straighten pushrods.
5. Remove the cylinder head bolts and the cylinder head. See Figure 17-75.

**Removing valves**

To remove the valves in an overhead valve system, locate the cylinder head on a workbench and place small wooden blocks under the valve faces to hold them in place. If there are wear buttons or caps on the valve stems, remove them.

When removing valves and valve springs, identify the parts to prevent interchanging them during reassembly.

On some engines, you can compress the valve springs by pressing on the spring retainers with your thumbs. Push the spring retainer toward the large end of its slot and release pressure. See Figure 17-76. Remove the retainer, spring, and valve stem seals. Discard the seals.

If the valve springs cannot be compressed with your thumbs, a special valve spring compressing tool may be necessary. See Figure 17-77. In this illustration, split-type retainers are used to secure the valve springs to the valve stems. When removing the valve springs, note that the coils are closer together on one end of the spring than on the other. These are called dampening coils and they should be located opposite the valve cap and retainers. See Figure 17-78.
Servicing overhead valves, seats, and guides

The valves, seats, and guides used in overhead valve systems are serviced in the same way as those in conventional systems. Valves should be cleaned and resurfaced to a 45° angle (or a 30° angle) on a valve grinding machine.

Valve seats can be reconditioned with a valve seat cutting tool. Valves should be lapped if recommended by the manufacturer. Thoroughly clean lapping compound from valve seats and faces. Inspect, measure, and test valve springs. Replace any parts that do not meet specifications.

Measure intake and exhaust valve guides. See Figure 17-34. If dimensions are not within specifications, the guides must be replaced. To remove worn guides, use a bushing driver or flat-ended pin punch. Support the cylinder head and press the guides out. See Figure 17-79. When pressing new guides into a cylinder head, press only to the specified depth. See Figure 17-80. This dimension will vary from one engine model to another.

Installing overhead valves

Before starting assembly, inspect valve stems for foreign material and burrs, which can cause sticking and damage the new stem seals. Coat the valve stems with valve guide lubricant. Do not allow the lubricant to contact the valve face, valve seat, or end of the valve stem.

Place the cylinder head on a workbench and support the valve faces with wooden blocks. Place the valve springs over the valve stems and set the retainers on the springs. Compress the springs and install the retainers. See Figure 17-81. If stem seals are used, place them over the stems as required. Do not attempt to install the rocker arms until after the cylinder head is installed on the engine.

Installing cylinder head

The mating surfaces of the cylinder and the cylinder head should be completely clean. Use a new head gasket and place the cylinder head on the cylinder. See Figure 17-82. Never use gasket cement or sealer on a head gasket. Lubricate the cylinder head bolt threads with oil. Install the bolts through the head and into the cylinder block holes. Tighten the bolts evenly by hand and, then, use a torque wrench to tighten them to the proper torque specifications. See Figure 17-83. Torque the head bolts in sequential increments to avoid causing the cylinder head to warp. Finally, place the pushrods into their respective holes.

Installing rocker arms

Place the rocker arms on the studs and install the rocker arm nuts. Turn the nuts until they just touch the rocker arms. Carefully rotate the crankshaft to verify proper pushrod operation.

Adjusting valve clearance

Proper clearance between the rocker arm and the valve stem is essential. Too much clearance will reduce volumetric efficiency. Too little clearance can cause valve burning or warpage.

Before checking valve clearance, position the piston as recommended by the manufacturer. To accomplish this, simply rotate the crankshaft until the piston reaches the position specified. Top Dead Center may be the correct piston position for some engines; others may require the piston to be a certain distance beyond Top Dead Center. Always check specifications. If necessary, the distance past Top Dead Center can be measured through the spark plug hole with a ruler, dial indicator, or similar tool. Once the piston position is attained, place the proper feeler gauge leaf between the rocker arm and the valve stem. See Figure 17-84. Check engine specifications for the required clearance. Some engines require equal clearance for both intake and exhaust valves. However, some engine manufacturers use a different metal for exhaust valves than intake valves, and, therefore,
the coefficient of thermal expansion is not the same for each valve. Therefore, clearances must be different for each valve.

Turn the locking/adjusting nut clockwise to reduce clearance or counterclockwise to increase clearance. The feeler gauge should drag slightly when pulled out. Hold the adjusting nut with a wrench and tighten the locking screw.

Replace the valve cover and gaskets. See Figure 17-85. Tighten the valve cover bolts to the recommended torque setting.

Overtightening the valve cover bolts can warp the cover flanges, causing oil to leak. Be careful! See Figure 17-85.

Ports, Reeds, and Rotary Valves

Two-cycle engines generally use porting of the cylinder wall (instead of poppet valves) in the fuel-feed and exhaust systems. Porting basically consists of two holes (ports) in the cylinder wall. One port admits the air-fuel mixture and the other port allows exhaust gases to escape.

Ports have no service requirements other than keeping them free of carbon. Unlike poppet valves, they cannot be replaced since they are part of the cylinder. Reed valves are used in two-cycle engines to control fuel flow from the carburetor to the crankcase, which serves as a second combustion chamber. A reed valve, operating on vacuum, opens during the compression stroke of the piston and closes before the start of the power stroke.

The openings through the reed plate and the reeds must be kept clean. The surface of the plate must be smooth so that there is a good seal when the reed closes against it. If the reed valve has lost its springiness or tension, install a new one. High-speed, two-cycle engines use reed stops to prevent distortion and damage to the reeds. See Figure 17-88. If the reeds are bent, they must be replaced.

Some two-cycle engines use rotary valves (instead of reeds) to control air-fuel intake. These valves are generally attached to the end of the crankshaft, although some run on a separate shaft geared off of the crankshaft. In operation, a valve rotates against a wear plate. Both the valve and plate have holes in them. When the holes align, an air-fuel charge enters the crankcase.

Inspect rotary valve ports for wear or damage. Replace defective parts. Keep openings clean and see that the surface of the wearplate is smooth and flat. If the wearplate or the mating surface of the valve is pitted or bent, replace the assembly. If a spring holds the parts in contact, check it against specifications for proper length and tension.

The camshaft of an engine is designed to operate the valves. A single camshaft is used in most small engines, with a cam (lobe) for each valve. When the camshaft rotates, the lobe of the cam lifts the valve from its seat.

Camshafts are made of steel or cast iron. The surface of the shaft is hardened to improve wearability. The ends of the camshaft may turn in bearings or in the block metal. See Figure 17-89A. Some small engine camshafts are hollow and have a second shaft running through them, Figure 17-89B. With this setup, the inner shaft is fixed and the hollow camshaft revolves on it.

Most small gasoline engines use gears to turn the camshaft. A gear on the crankshaft meshes with and drives a gear on the camshaft. Since the camshaft gear is exactly twice the size of the crankshaft gear, it runs at half crankshaft speed. See Figure 17-90. Also note that the timing mark on the cam gear is aligned with the keyway on the crankshaft. This is the correct procedure for
Timing valve operation to the crankshaft on this particular engine.

**Automatic Compression Release**

To make hand cranking easier, some small engines have an automatic compression release mechanism on the camshaft. This device lifts the exhaust valve slightly during cranking and releases part of the compression pressure.

One manufacturer’s compression release mechanism is pictured in Figure 17-91. In view A, the camshaft is at rest and springs are holding the flyweights in. In this position, the tab on the larger flyweight protrudes above the base circle of the exhaust cam, holding the exhaust valve partially open. In view B, the tab prevents the exhaust lifter from resting on the cam.

After the engine starts and its speed reaches about 600 rpm, centrifugal force overcomes spring pressure and the flyweights move outward. Movement of the flyweights causes the tab to be retracted, and the exhaust valve seats fully. See views C and D in Figure 17-91. The flyweights remain in this position until the engine is stopped.

The compression release mechanism in the starting position is shown in Figure 17-92A and in the running position in Figure 17-92B. Automatic compression release is one of the many advances in small engines that ease the chore of engine start-up.

**Summary**

The connecting rod attaches the piston to the crankshaft. There are three types of friction bearings commonly used in the large end of the connecting rod: rod metal bearings, cast bronze bearings, and precision insert bearings. Many small engines use antifriction bearings in the large end of the connecting rod.

The crankshaft converts the reciprocating motion of the piston into rotary motion. To help offset the unbalanced condition created by the force of reciprocating mass, counterweights are added to the crankshaft. The crankshaft is supported by one or more main bearings. Crankcase seals prevent leakage of oil from areas where the crankshaft and crankcase come together.

A four-cycle engine’s valve assembly includes the valve, the valve spring, and one or more retainers. After valves are removed, clean and inspect them for defects. Valves with serious defects must be replaced. Valve springs should be checked for squareness, length, and tension. Replace all springs that are not within specifications.

Check valve guides with a small hole gauge. If clearance between guide and stem exceeds the allowable limit, enlarge the guide with an adjustable reamer. A new valve with an oversize stem must be installed.

Valve seats are generally cut to a 45° angle. Seat contact must be near the center of the valve face. A valve seat cutter is used to recondition
seats. Good used valves can be reseated by a hand-lapping process.

Valve clearance refers to the space between the end of the valve stem and the top of the lifter. Valves must be closed when measuring clearance. If there is too little clearance, a valve may be held open when the stem expands.

Valve refacing can be done on a specially designed grinder or with a manual valve refacer. Valve clearance is reduced when a valve is refaced. Therefore, the tappets must be adjusted or the valve stem end must be ground to obtain the correct clearance.

Overhead valve systems transmit motion through pushrods and rocker arms to open and close the valves. These systems improve volumetric efficiency and eliminate hot spots.

Two-cycle engines generally use intake and exhaust ports instead of poppet valves. Ports have no service requirements other than keeping them free from carbon.

The camshaft is designed to operate the valves. When the camshaft rotates, the lobe of the cam lifts the valve from its seat. To make hand cranking easier, some engines have an automatic compression release mechanism on the camshaft. This device lifts the exhaust valve during cranking to release compression pressure.

Know These Terms

connecting rod
friction bearings
bearing spread
antifriction bearings
rod cap
 crankshaft
throw counterweights
main bearings
bearing clearance
Plastigage
 crankcase seals
poppet valves
valve keepers
valve springs
 valve guides
valve seat angle
valve seat width
interference angle
lapping
valve clearance
valve refacing
overhead valve system
pushrods
tockers arms
 dampening coils
porting
reed valves
 camshaft
automatic compression release

Chapter 17
Review Questions

Answer the following questions on a separate sheet of paper.

1. Properly fitted friction bearing ends protrude slightly above the parting surface of the connecting rod cap. This characteristic produces what is commonly called __________.
   a. bearing crush    b. bearing seat
   c. bearing spread    d. bearing swell
2. Bearing caps must never be __________ when being replaced on the rods.
   a. loose
   b. tight
   c. correct
   d. any
3. What tool must always be used to tighten rod caps?
   a. wrench
   b. spanner
   c. torque wrench
   d. hand tool
4. Name three types of crankshaft main bearings.
   a. plain bearings
   b. roller bearings
   c. ball bearings
   d. needle bearings
5. What do you call the special plastic substance used to measure bearing clearance?
   a. Plastigage
   b. Telescoping gauges
   c. Bearing end shims
   d. Bearing caps
6. When removing the crankcase cover from the engine, __________.
   a. always pry it loose with screwdrivers
   b. pry out the oil seal first
   c. place tape over the keyway to protect the oil seal
   d. hold the cover while hammering on the crankcase end
7. When replacing oil seals, the knife edge of the seal lip should face fluid being sealed. True or False?
8. After reaming a valve guide, bushing, or cutter.
   a. always pry it loose with screwdrivers
   b. pry out the oil seal first
   c. place tape over the keyway to protect the oil seal
   d. hold the cover while hammering on the crankcase end
9. Why is it important to select the correct valve face angle and the valve seat angle called?
10. What is the 1° difference between the valve face angle and the valve seat angle called?
11. Name the process of placing abrasive compound on the valve face and twisting it back and forth in the valve seat.
12. Too little valve clearance will cause the valve to __________.
   a. break
   b. be noisy
   c. open late
   d. open early
13. What is the 1° difference between the valve face angle and the valve seat angle called?
14. Name the process of placing abrasive compound on the valve face and twisting it back and forth in the valve seat.
15. Too little valve clearance will cause the valve to __________.
   a. break    c. burn
   b. be noisy    d. open late
16. The camshaft revolves at __________.
   a. twice crankshaft speed in all engines
   b. four times crankshaft speed in four-cycle engines
   c. one-half crankshaft speed in four-cycle engines
   d. one-half crankshaft speed in two-cycle engines
17. An automatic compression release is used on some engines to __________.
   a. make cranking easier
   b. prevent knocking due to excessively high compression
   c. control speed
   d. prevent overheating
18. What are the advantages of overhead valves?
19. Why should parts be identified as they are disassembled?
20. How should pushrods be checked for straightness?
21. When the coils are closer together on one end of a valve spring than on the other, they are called __________.
22. When new or reconditioned valves are being installed in guides, what should be placed on the valve stems first?
23. What tool is used to check valve clearance?
24. Why should valve cover screws never be tightened excessively?

Suggested Activities

1. Measure crankshaft bearing clearances with Plastigage and telescoping gauges.
2. Install new main and rod bearing inserts. Observe rules of cleanliness and torque tighten rod bolts to specified value.
3. Replace oil seals in the crankcase.
4. Grind valves on a grinding machine or turn and true valve faces on a valve lathe.
5. Recondition old valve seats with a valve seat cutter.
6. Lap valves into seats after the valve faces and seats are reconditioned by grinding.
8. Remove old valve guide bushings and install new guide bushings.
10. Demonstrate counterboring cylinder for a new valve seat insert.
11. Demonstrate peening a valve seat on an aluminum engine block.
12. Test valve springs for length, straightness, and tension.
13. Ream valve guides to fit an oversize valve seat insert.
14. Adjust valve lifter to valve clearance by grinding valve stems or adjusting tappets.
15. Adjust valve clearances in an overhead valve assembly.
16. Time the camshaft to the crankshaft.