CHAPTER 23

VALVE AND SEAT SERVICE

OBJECTIVES

After studying Chapter 23, the reader will be able to:

1. Prepare for Engine Repair (A1) ASE certification test content area "B" (Cylinder Head and Valve Train Diagnosis and Repair).
2. Discuss various engine valve types and materials.
3. Describe how to test valve springs.
4. Explain the purpose, function, and operation of valve rotators.
5. List the steps necessary to reface a valve.
6. Describe how to grind valve seats.
7. Discuss how to measure and correct installed height and valve stem height.

KEY TERMS

Collet (p. 411)
Deflector Valve Stem Seal (p. 426)
Dressed (p. 412)
Elastic Valve (p. 400)
Expandable Pilots (p. 417)
Finishing Stone (p. 417)
Forming Stone (p. 417)
Gas Metal Arc Welding (GMAW) (p. 421)
Guttering (p. 403)
Insert Valve Seats (p. 421)
Integral Seat (p. 402)
Interference Angle (p. 414)
Keepers (Locks) (p. 400)
Metal Inert Gas (MIG) (p. 421)
Necking (p. 405)
Overhang (p. 415)
O-Ring Valve Stem Seal (p. 426)
Peened (p. 404)
Poppet Valve (p. 400)
Positive Valve Stem Seal (p. 426)
Retainer (p. 400)
Rigid Valve (p. 400)
Roughing Stone (p. 417)
Scuff (p. 407)
Stellite (p. 402)
Tapered Pilots (p. 416)
Thermal Shock (p. 405)
Throating Angle (p. 415)
Topping Angle (p. 415)
Total Indicator Runout (TIR) (p. 419)
Truing (p. 411)
Umbrella Valve Stem Seal (p. 426)
Valve Face (p. 400)
Valve Face Angle (p. 412)
Valve Lift (p. 400)
Valve Seat (p. 400)
Valve Spring (p. 400)
Valve Spring Inserts (VSI) (p. 424)
Valve Spring Surge (p. 408)

Valves need to be reconditioned more often than any other engine part.

INTAKE AND EXHAUST VALVES

Automotive engine valves are of a **poppet valve** design. The valve is opened by means of a valve train that is operated by a cam. The cam is timed to the piston position and crankshaft cycle. The valve is closed by one or more springs.

Typical valves are shown in Figure 23-1. Intake valves control the inlet of cool, low-pressure induction charges. Exhaust valves handle hot, high-pressure exhaust gases. This means that exhaust valves are exposed to more severe operating conditions. They are, therefore, made from much higher-quality materials than the intake valves. This makes them more expensive.

The guide is centered over the **valve seat** so that the **valve face** and seat make a gas-tight fit. The face and seat will have an angle of 30 degrees or 45 degrees. These are the nominal angles. Actual service angles might be a degree or two different from these. Most engines use a nominal 45-degree valve and seat angle. A **valve spring** holds the valve against the seat. The valve **keepers** (also called **locks**) secure the spring **retainer** to the stem of the valve. For valve removal, it is necessary to compress the spring and remove the valve keeper. Then the spring, valve seals, and valve can be removed from the head. A typical valve assembly is shown in Figure 23-2.

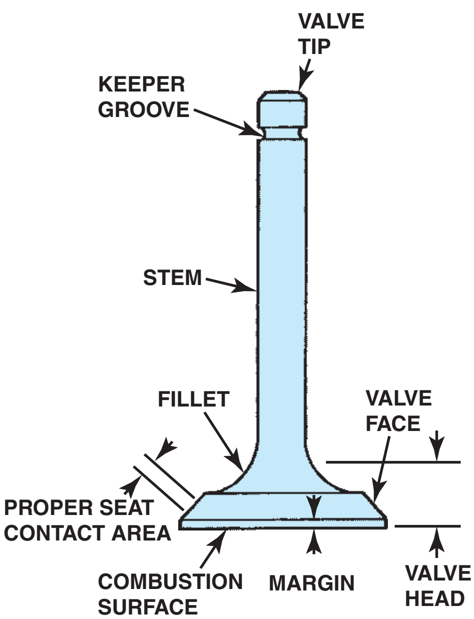


FIGURE 23-1 Identification of the parts of a valve.

VALVE SIZE RELATIONSHIPS

Extensive testing has shown that a normal relationship exists between the different dimensions of valves. Engines with cylinder bores that measure from 3 to 8 inches (80 to 200 millimeters) will have intake valves that measure approximately 45% of the bore size. The exhaust valve size is approximately 38% of the cylinder bore size. The intake valve must be larger than the exhaust valve to handle the same mass of gas. The larger intake valve controls low-velocity, low-density gases. The exhaust valve, however, controls high-velocity, high-pressure, denser gases. These gases can be handled by a smaller valve. Exhaust valve heads are, therefore, approximately 85% of the size of intake valve heads. See Figure 23-3. For satisfactory operation, valve head diameter is nearly 115% of the valve port diameter. The valve must be large enough to close over the port. The extent to which the valve opens, called **valve lift,** is close to 25% of the valve diameter.

VALVE DESIGN

Poppet valve heads may be of various designs, from a **rigid valve** to an **elastic valve,** as shown in Figure 23-4. The rigid valve is strong, holds its shape, and conducts heat readily.

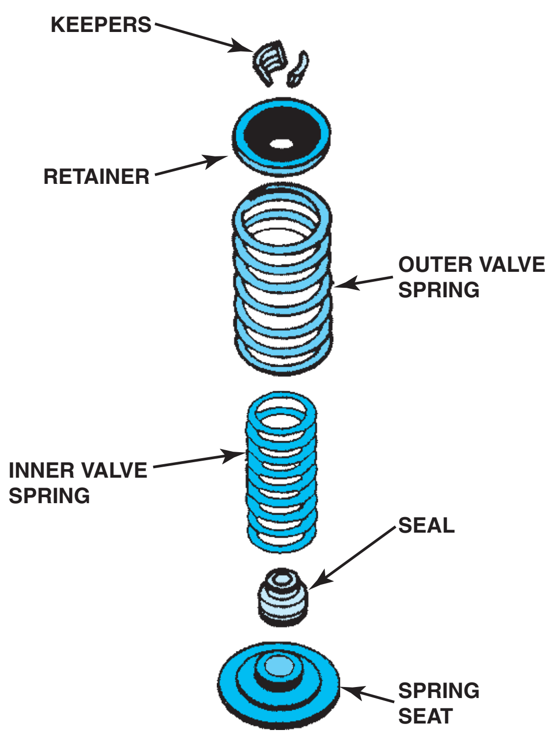


FIGURE 23-2 Typical valve spring and related components. Dual-valve springs are used to reduce valve train vibrations and a spring seat is used to protect aluminum heads.

It also causes less valve recession. Unfortunately, it is more likely to leak and burn than other valve head types. The elastic valve, however, is able to conform to valve seat shape. This allows it to seal easily, but it runs hot and the flexing to conform may cause it to break. A popular shape is one with a small cup in the top of the valve head. It offers a reasonable weight, good strength, and good heat transfer at a slight cost penalty. Elastic valve heads are more likely to be found on intake valves, and rigid, valve heads are found on exhaust valves.

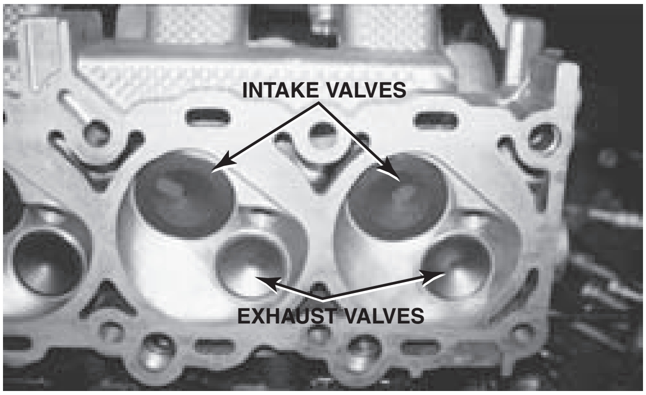


FIGURE 23-3 The intake valve is larger than the exhaust valve because the intake charge is being drawn into the combustion chamber at a low speed due to differences in pressure between atmospheric pressure and the pressure (vacuum) inside the cylinder. The exhaust is actually pushed out by the piston and, therefore, the size of the valve does not need to be as large, leaving more room in the cylinder head for the larger intake valve.

VALVE MATERIALS

Alloys used in exhaust valve materials are largely of chromium for oxidation resistance, with small amounts of nickel, manganese, and nitrogen added. Heat-treating is used whenever it is necessary to produce special valve properties. Some exhaust valves are manufactured from two different materials when a

TECH TIP

HOT ENGINE + COLD WEATHER = TROUBLE

Serious valve damage can occur if cold air reaches hot exhaust valves soon after the engine is turned off. An engine equipped with exhaust headers and/or straight-through mufflers can allow cold air a direct path to the hot exhaust valve. The exhaust valve can warp and/or crack as a result of rapid cooling. This can easily occur during cold windy weather when the wind can blow cold outside air directly up the exhaust system. Using reverse-flow mufflers with tailpipes and a catalytic converter reduces the possibilities of this occurring.

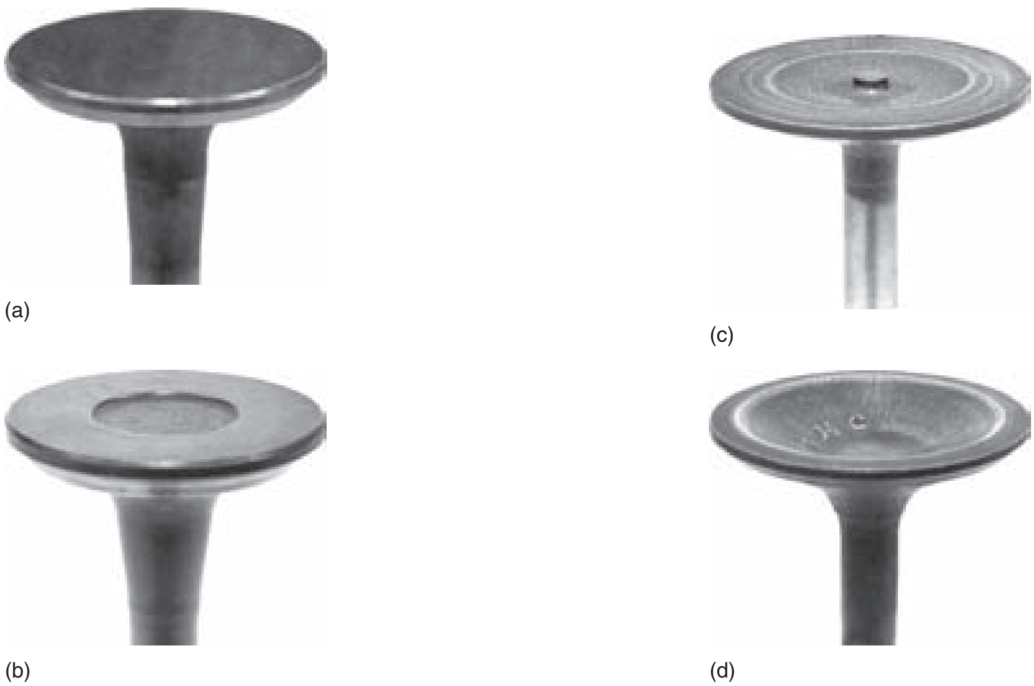


FIGURE 23-4 Valve head types, from rigid (a) to elastic (d).

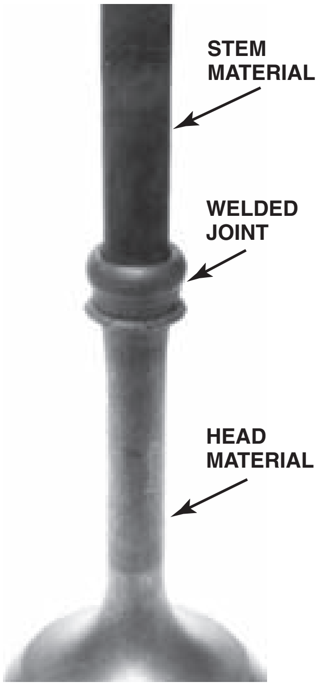


FIGURE 23-5 Inertia welded valve stem and head before machining.

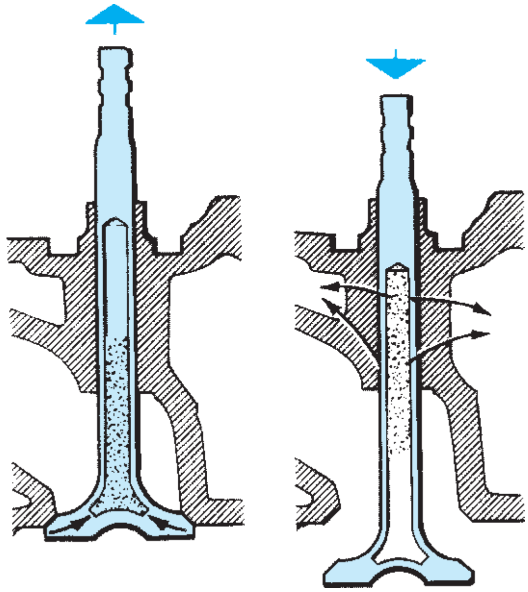


FIGURE 23-6 A sodium-filled valve uses a hollow stem, which is partially filled with metallic sodium that is a liquid when hot, to conduct heat away from the head of the valve.

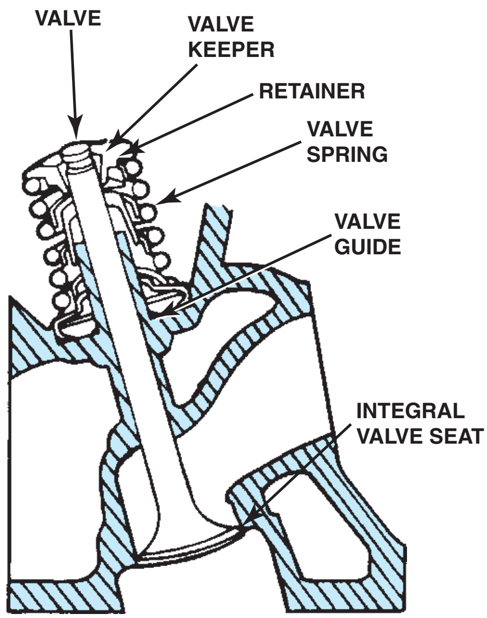


FIGURE 23-7 Integral valve seats are machined directly into the cast-iron cylinder head and are induction hardened to prevent wear.

one-piece design cannot meet the desired hardness and corrosion resistance specifications. The joint cannot be seen after valves have been used. The valve heads are made from special alloys that can operate at high temperatures, have physical strength, resist lead oxide corrosion, and have indentation resistance. These heads are welded to stems that have good wear resistance properties. Figure 23-5 shows an inertia welded valve before final machining. In severe applications, facing alloys such as stellite are welded to the valve face and valve tip. **Stellite** is an alloy of nickel, chromium, and tungsten that is nonmagnetic. The valve is aluminized where corrosion may be a problem. Aluminized valve facing reduces valve recession when unleaded gasoline is used. Aluminum oxide forms to separate the valve steel from the cast-iron seat to keep the face metal from sticking.

SODIUM-FILLED VALVES

Some heavy-duty applications use hollow stem exhaust valves that are partially filled with metallic sodium. An unfilled hollow valve stem is shown in Figure 23-6. The sodium in the valve becomes a liquid at operating temperatures. As it splashes back and forth in the valve stem, the sodium transfers heat from the valve head to the valve stem. The heat goes through the valve guide into the coolant. In general, a one-piece valve design using properly selected materials will provide satisfactory service for automotive engines.

VALVE SEATS

The valve face closes against a valve seat to seal the combustion chamber. The seat is generally formed as part of the cast-iron head of automotive engines, and is called an **integral seat.** See Figure 23-7. The seats are usually induction hardened so that unleaded gasoline can be used. This minimizes

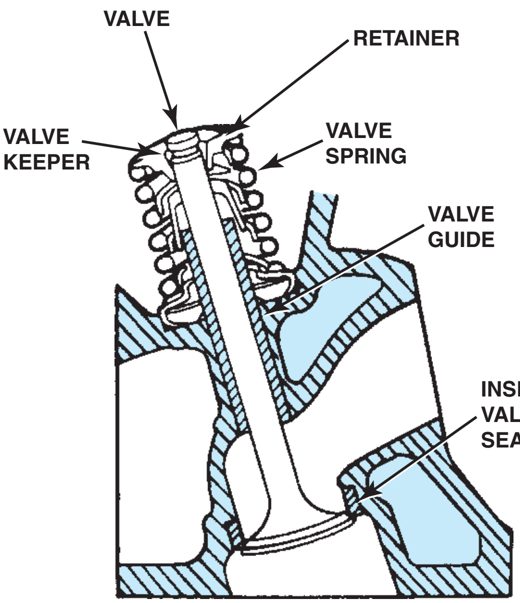


FIGURE 23-8 Insert valve seats are a separate part that is interference-fitted to a counter bore in the cylinder head.

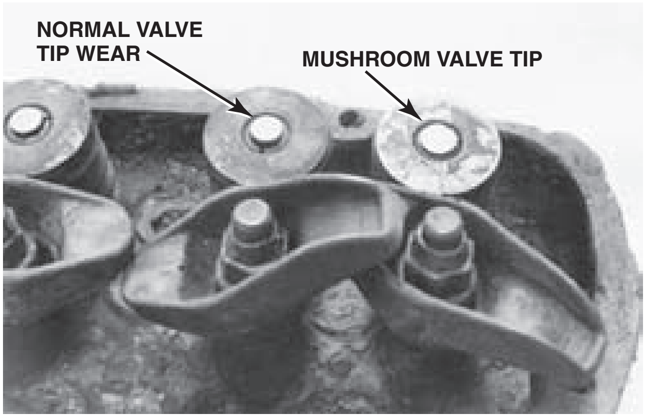


FIGURE 23-9 A mushroomed valve tip may indicate other valve train damage, such as excessive valve clearance (lash).

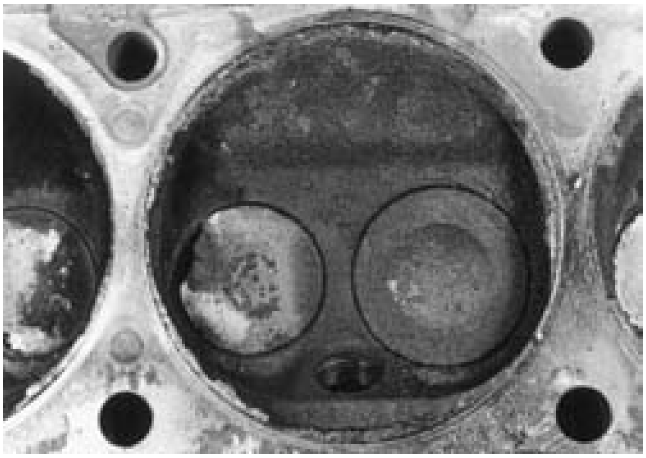


FIGURE 23-10 Badly burned exhaust valve.

FIGURE 23-11 Valve face burning.

valve recession as the engine operates. Valve recession is the wearing away of the seat, so that the valve seats further into the head. Insert seats are used in applications for which corrosion and wear resistance are critical. Insert seats and guides are always required in aluminum heads. See Figure 23-8. It should be noted that the exhaust valve seat runs as much as 180°F (100°C) *cooler* in aluminum heads than in cast-iron heads. Insert seats are also used as a salvage measure in the reconditioning of integral automotive engine valve seats that have been badly damaged.

VALVE INSPECTION

Careful inspection of the cylinder and valves can often reveal the root cause of failure. Excessive valve lash (clearance) can cause the top of the valve to be pounded until it becomes mushroomed, as shown in Figure 23-9. Valve face burning (Figures 23-10 and 23-11) and valve face **guttering** (Figure 23-12) result from poor seating that allows the high-temperature and high-pressure combustion gases to leak between the valve and seat. Poor seating results from too small a valve lash, hard carbon deposits, valve stem deposits, excessive valve stem-to-guide clearances, or out-of-square valve guide and seat. A valve lash that is too small can result from improper valve lash adjustments on solid lifter engines. It can also result from misadjustments on a valve train using hydraulic lifters. The clearance will also be reduced as a result of valve head cupping or valve face and seat wear. Figure 23-13 shows typical intake valve and seat wear.

Hard carbon deposits are loosened from the combustion chamber. Sometimes, these flaking deposits stick between the

FIGURE 23-12 Valve face guttering.

FIGURE 23-14 Valve face peening.

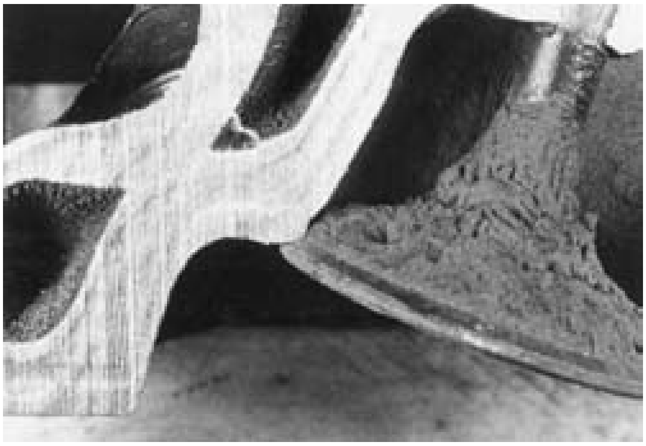


FIGURE 23-13 Typical intake valve seat wear. Also notice the excessive deposits on the valve. These deposits not only reduce the amount of air and fuel flow into the engine, but can also cause hesitation by absorbing fuel instead of allowing the fuel into the combustion chamber.

valve face and seat to hold the valve slightly off its seat. This reduces valve cooling through the seat and allows some of the combustion gases to escape. Continued pounding on hard carbon particles gives the valve face a **peened** appearance, pictured in Figure 23-14.

Fuel and oil on the hot valve will break down to become hard carbon and varnish deposits that build up on the valve stem. Heavy valve stem deposits are shown in Figure 23-15. These deposits cause the valve to stick in the guide so that the valve does not completely close on the seat and therefore cause the valve face to burn. This is one of the most common causes of valve face burning.

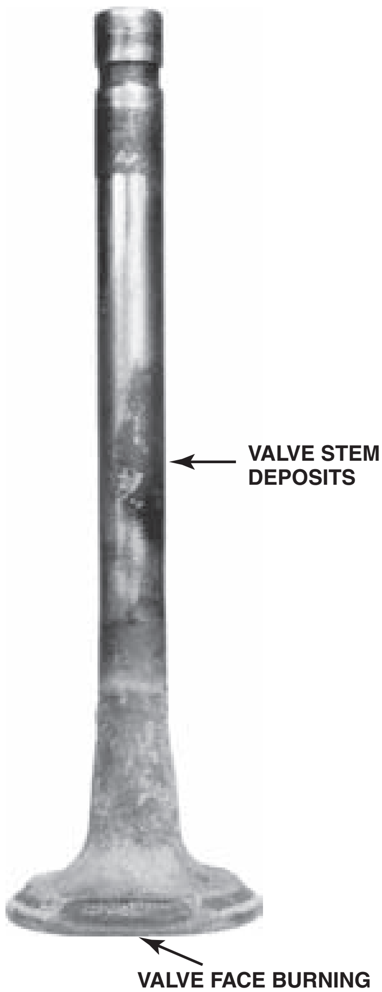


FIGURE 23-15 Valve stem with heavy deposits and valve face burning.

FIGURE 23-16 Intake valve with heavy deposits.

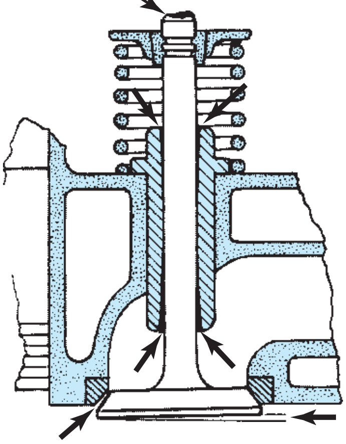


FIGURE 23-17 Excessive wear of the valve stem or guide can cause the valve to seat in a cocked position.

If there is a large clearance between the valve stem and guide or faulty valve stem seals, too much oil will go down the stem. This will increase deposits, as shown on the intake valve in Figure 23-16. In addition, a large valve guide clearance will allow the valve to cock or lean sideways, especially with the effect of the rocker arm action. Continued cocking keeps the valve from seating properly and causes it to leak, burning the valve face. See Figure 23-17.

Sometimes, the cylinder head will warp slightly as the head is tightened to the block deck during assembly. In other cases, heating and cooling will cause warpage. When head

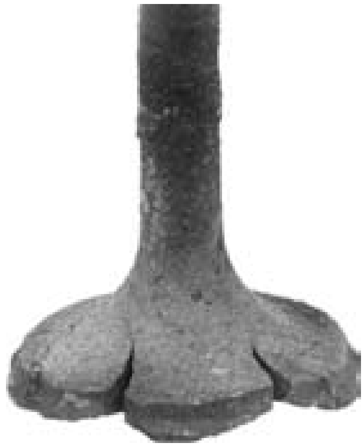


FIGURE 23-18 Badly guttered valve face.

warpage causes valve guide and seat misalignment, the valve cannot seat properly and it will leak, burning the valve face.

Excessive Temperatures

High valve temperature occurs when the valve does not seat properly; however, it can occur regardless. Cooling system passages in the head may be partially blocked by faulty casting or by deposits built up from the coolant. A corroded head gasket will change the coolant flow. This can cause overheating when the coolant is allowed to flow to the wrong places. Extremely high temperatures are also produced by preignition and by detonation. These are forms of abnormal combustion. Both of these produce a very rapid increase in temperature that can cause uneven heating. The rapid increase in temperature will give a **thermal shock** to the valve. A thermal shock is a sudden change in temperature. The shock will often cause radial cracks in the valve. The cracks will allow the combustion gases to escape and gutter the valve face. A badly guttered valve face is shown in Figure 23-18. If the radial cracks intersect, a pie-shaped piece will break away from the valve head. A thermal shock can also result from rapid cycling of the engine from full throttle to closed throttle and back again. Valves with hard metal facings have special problems. Excess heat causes the base metal to expand more than the hoop of the hard face metal. The hard face metal hoop is stressed until it cracks. The crack allows gases to gutter the base metal, as shown in Figure 23-19.

High engine speeds require high gas velocities. The high-velocity exhaust gases hit on the valve stem and tend to erode or wear away the metal mechanically. The gases are also corrosive, so the valve stem will tend to corrode. Corrosion removes the metal chemically. The corrosion rate doubles for each 25°F (14°C) increase in temperature. Erosion and corrosion of the valve stem cause **necking,** which weakens the stem and leads to breakage. Necking is shown in Figure 23-20.

FIGURE 23-19 Hoop stress cracks in a valve head.

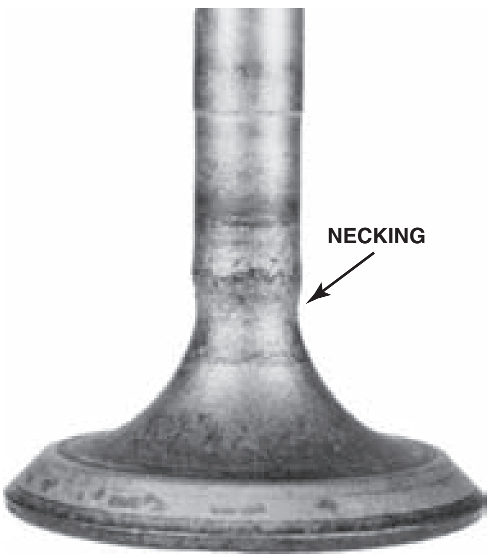


FIGURE 23-20 Necked valve stem.

Misaligned Valve Seats

When the valve-to-seat alignment is improper, the valve head must twist to seat each time the valve closes. If twisting or bending becomes excessive, it fatigues the stem, and the valve head will break from the stem. An example of this can be seen in Figure 23-21. The break appears as lines arching around a starting point. The head of the valve usually damages the piston when it gets trapped between the piston and the cylinder head.

FIGURE 23-21 Valve head broken from the stem.

FIGURE 23-22 Broken piston caused by a valve breaking from the stem.

High-Velocity Seating

High-velocity seating is indicated by excessive valve face wear, valve seat recession, and impact failure. It can be caused by excessive lash in mechanical lifters and by collapsed hydraulic lifters. Lash allows the valve to hit the seat without the effects of the cam ramp to ease the valve onto its seat. Excessive lash may also be caused by wear of parts, such as the cam, lifter base, pushrod ends, rocker arm pivot, and valve tip. Weak or broken valve springs allow the valves to float away from the cam lobes so that the valves are uncontrolled as they hit the seat. The normal tendency of hydraulic lifters is to pump up under valve float conditions, which reduces valve impact damage.

Impact breakage may occur under the valve head or at the valve keeper grooves. The break lines radiate from the starting point. Impact breakage may also cause the valve head to fall into the combustion chamber. In most cases, it will ruin the piston before the engine can be stopped, as pictured in Figures 23-22 and 23-23.

FIGURE 23-23 Everything in the valve train has to be working correctly or an engine can be destroyed. The valve in this engine separated from the retainer at high engine speed, turned around in the cylinder, and punctured the piston.

High Mileage

Excessive wear of the valve stem (Figure 23-24), guide, face, and seat is the result of high mileage. The affected valves usually have a great buildup of deposits. The valves will, however, still be seating, and they will show no sign of cracking or burning.

When the valve stems do not have enough lubricant, they **scuff.** In scuffing, the valve stem temporarily welds to the guide when the valve is closed. The weld breaks as the valve is forced to open. Welded metal tears from the guide and sticks to the valve stem. An example of valve stem scuffing is shown in Figure 23-25. The metal knobs on the valve stem scratch the valve guide as it operates. This also scuffs the valve guide. In a short time, the valve will stick in the guide and not close. This will stop combustion in that cylinder. Both the valve and valve guide will have to be replaced.

Often, valve tips become damaged. This damage can be seen before the valves are removed from the head. Some valve tip problems are caused by rapid rotation as the valve is being

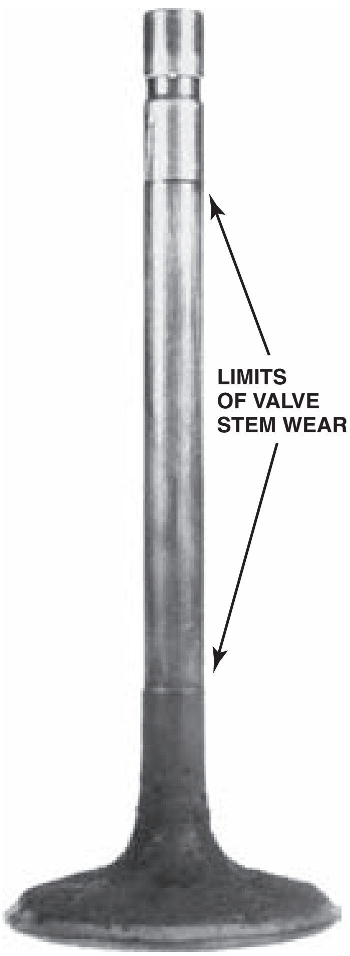


FIGURE 23-24 High-mileage valve stem wear.

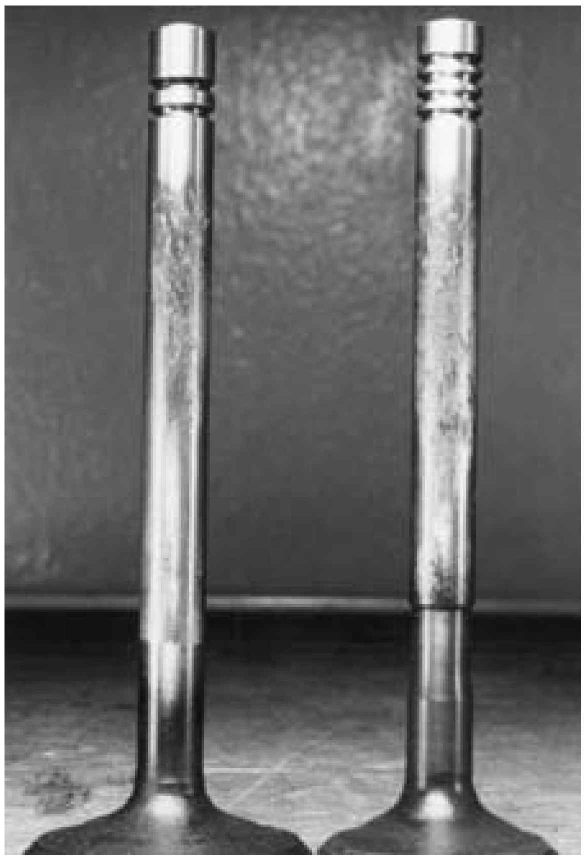


FIGURE 23-25 Valve stems scuffed as a result of loss of valve train lubrication.

opened. This causes circles on the valve tip. Still other valves do not rotate at all. These valves wear in the direction of the rocker arm or finger follower movement. Examples of excessive valve tip wear can be seen in Figure 23-26.

VALVE SPRINGS

A valve spring holds the valve against the seat when the valve is not being opened. One end of the valve spring is seated against the head. The other end of the spring is attached under compression to the valve stem through a valve spring retainer and a valve spring keeper (lock), as shown in Figure 23-27.

Valves usually have a single inexpensive valve spring. The springs are generally made of chromium vanadium alloy steel. When one spring cannot control the valve, other devices are added. Variable-rate springs add spring force when the valve is in its open position. This is accomplished by using closely spaced coils on the cylinder head end of the spring. The closely spaced coils also tend to dampen vibrations that may exist in an equally wound coil spring. The damper helps to reduce valve seat wear. Some valve springs use a flat coiled damper inside the spring. This eliminates spring surge and adds some valve spring tension. The normal valve spring winds up as it is compressed. This causes a small but important turning motion as the valve closes on the seat. The turning motion helps to keep the wear even around the valve face. Figure 23-28 illustrates typical valve springs.

Multiple valve springs are used where large lifts are required and a single spring does not have enough strength to control the valve. Multiple valve springs generally have their coils wound in opposite directions. This is done to control valve spring surge and to prevent excessive valve rotation. **Valve spring surge** is the tendency of a valve spring to vibrate.

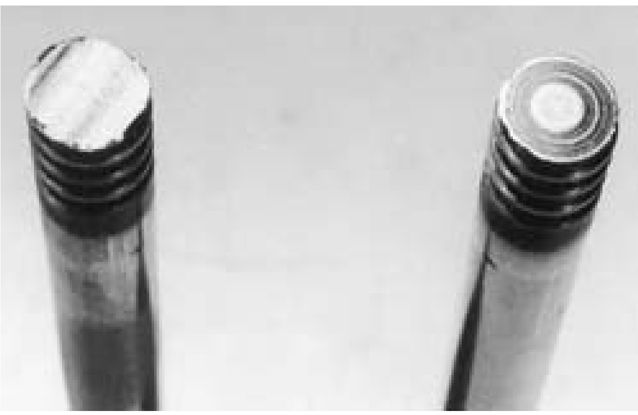


FIGURE 23-26 Excessive valve tip wear.

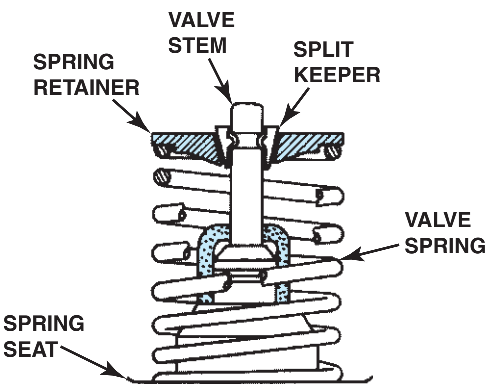


FIGURE 23-27 A retainer and two split keepers hold the spring in place on the valve. A spring seat is used on aluminum heads. Otherwise, the spring seat is a machined area in the head.

VALVE SPRING INSPECTION

Valve springs close the valves after they have been opened by the cam. They must close squarely to form a tight seal and to prevent valve stem and guide wear. It is necessary, therefore, that the springs be square and have the proper amount of closing force. The valve springs are checked for squareness by rotating them on a flat surface with a square held against the side. They should be within 1/16 inch or 1.6 millimeters of being square, as shown in Figure 23-30. Only the springs that

FREQUENTLY ASKED QUESTION

WHAT IS VALVE FLOAT?

Valve float occurs when the valve continues to stay open after the camshaft lobe has moved from under the lifter. This happens when the inertia of the valve train overcomes the valve spring tension at high engine speeds. See Figure 23-29.

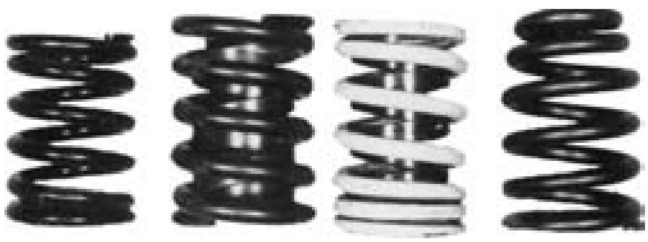


FIGURE 23-28 Valve spring types (*left to right*): coil spring with equally spaced coils; spring with damper inside spring coil; closely spaced spring with a damper; taper wound coil spring.

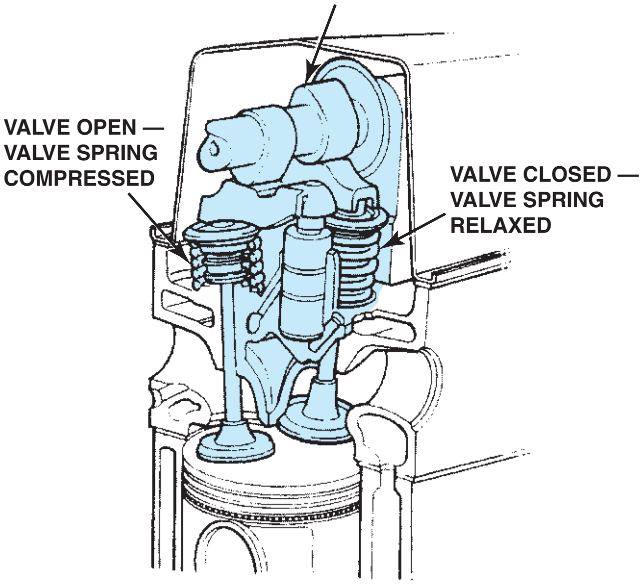


FIGURE 23-29 Valve springs maintain tension in the valve train when the valve is open to prevent valve float, but must not exert so much tension that the cam lobes and lifters begin to wear.

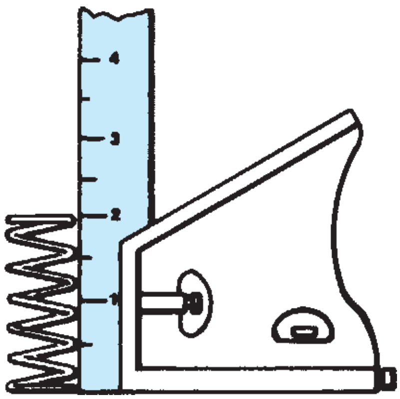


FIGURE 23-30 Determine the squareness of a valve spring with a square on a flat surface. The spring should be replaced if more than 1/16 inch (1.6 mm) is measured between the top of the spring and the square.

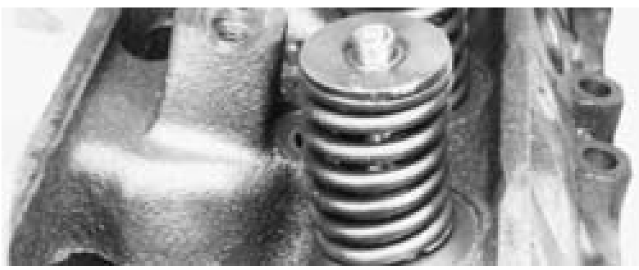


FIGURE 23-31 Out-of-square valve spring. This spring should not be tested further, but should be replaced. A distorted valve spring exerts side loads on the valve, which often causes excessive valve guide wear.

are square should be checked to determine their compressed force. See Figure 23-31. Out-of-square springs will have to be replaced. The surge damper should be *removed* from the valve spring when the spring force is being checked. A valve spring scale is used to measure the valve spring force. One popular type, shown in Figure 23-32, measures the spring force directly. Another type uses a torque wrench on a lever system to measure the valve spring force. Valve springs are checked for the following:

1. Free height (without being compressed) [should be within 1/16 (0.060) inch]
2. Pressure with valve closed and height as per specifications
3. Pressure with valve open and height as per specifications

Most specifications allow for variations of plus or minus 10% from the published figures.

FIGURE 23-32 One popular type of valve spring tester used to measure the compressed force of valve springs. Specifications usually include (1) free height (height without being compressed), (2) pressure at installed height *with valve closed,* and (3) pressure *with valve open* the maximum amount and height to specifications.

FIGURE 23-33 Valve split lock types (a) and stem grooves (b).

VALVE KEEPERS

A valve keeper (lock) is used on the end of the valve stem to retain the spring. The inside surface of the split keeper uses a variety of grooves or beads. The design depends on the holding requirements. The outside of the split keeper fits into a cone-shaped seat in the center of the valve spring retainer (see Figure 23-33).

VALVE ROTATORS

Some retainers have built-in devices called valve rotators. They cause the valve to rotate in a controlled manner as it is opened. The purposes and functions of valve rotators include the following:

- Help prevent carbon buildup from forming
- Reduce hot spots on the valves by constantly turning them
- Help to even out the wear on the valve face and seat
- Improve valve guide lubrication

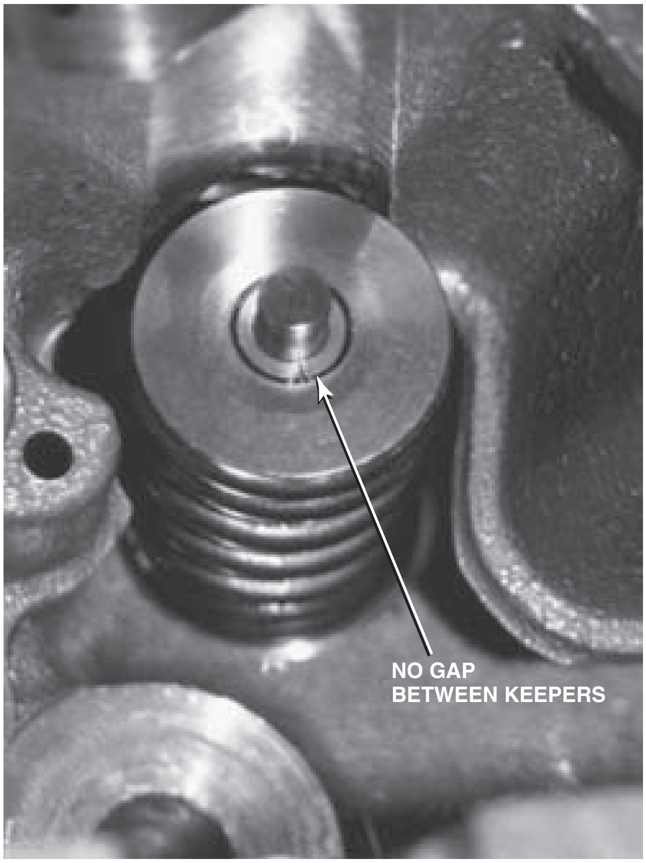


FIGURE 23-34 Notice that there is no gap between the keepers on this Chrysler 4.7 L, V-8. As a result, the valve is free to rotate because the retainer applies a force holding the keepers in place but not tight against the stem of the valve.

The two types of valve rotators are free and positive.

- **Free rotators**—The free rotators simply take the pressure off the valve to allow engine vibration to rotate the valve. See Figure 23-34.
- **Positive rotators**—The opening of the valve forces the valve to rotate. One type of positive rotator uses small steel balls and slight ramps. Each ball moves down its ramp to turn the rotor sections as the valve opens. A second type uses a coil spring. The spring lies down as the valve opens. This action turns the rotator body in relation to the collar. Valve rotors are only used when it is desirable to increase the valve service life, because rotors cost more than plain retainers. See Figures 23-35 and 23-36.

VALVE RECONDITIONING PROCEDURE

Valve reconditioning is usually performed using the following sequence:

Step 1 The valve stem is lightly ground and chamfered. This step helps to ensure that the valve will rest in the

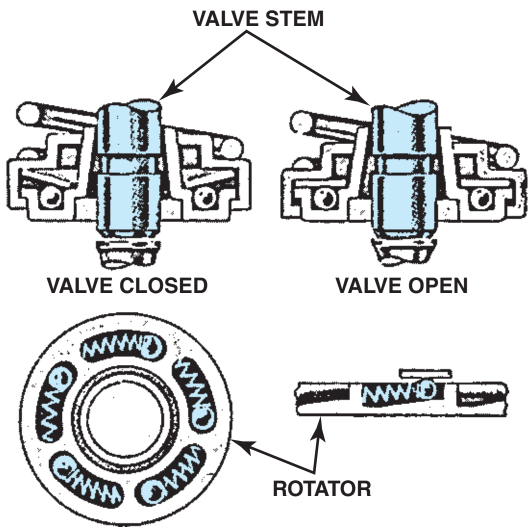


FIGURE 23-35 A ball-type positive valve rotator turns the valve slightly every time the valve opens.

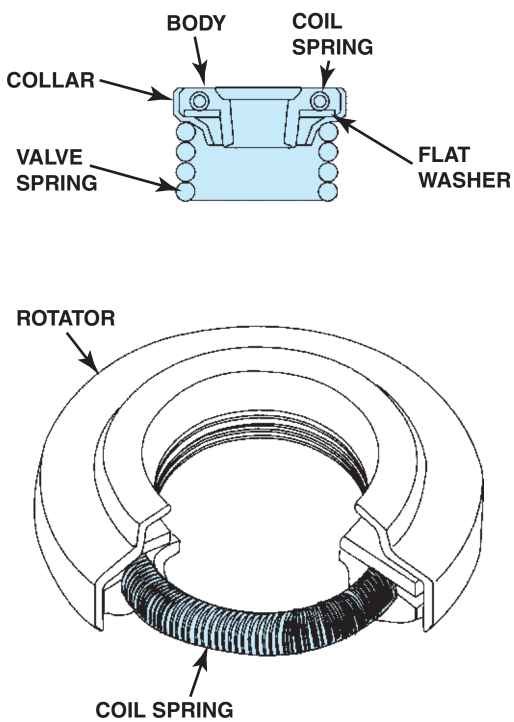


FIGURE 23-36 A coil spring-type positive valve rotator turns the valve when it is open by returning to its original shape and size as the valve is being closed.

collet (holder of the valve stem during valve grinding) of the valve grinder correctly. This process is often called **truing** the valve tip.

Step 2 The face of the valve is ground using a valve grinder.

Step 3 The valve seat is ground in the head. (The seat must be matched to the valve that will be used in that position.)

Step 4 Installed height and valve stem height are checked and corrected as necessary.

TECH TIP

GRINDING THE VALVES FOR MORE POWER

A normal "valve job" includes grinding the face of the valve to clean up any pits and grinding the valve stems to restore the proper stem height. However, a little more airflow in and out of the cylinder head can be accomplished by performing two more simple grinding operations.

- Use the valve grinder and adjust to 30 degrees (for a 45-degree valve) and grind a transition between the valve face and the valve stem area of the valve. While this step may reduce some desirable swirling of the air–fuel mixture at lower engine speeds, it also helps increase cylinder filling, especially at times when the valve is not fully open.
- Chamfer or round the head of the valve between the top of the valve and the margin on the side. By rounding this surface, additional airflow into the cylinder is achieved. See Figure 23-37.

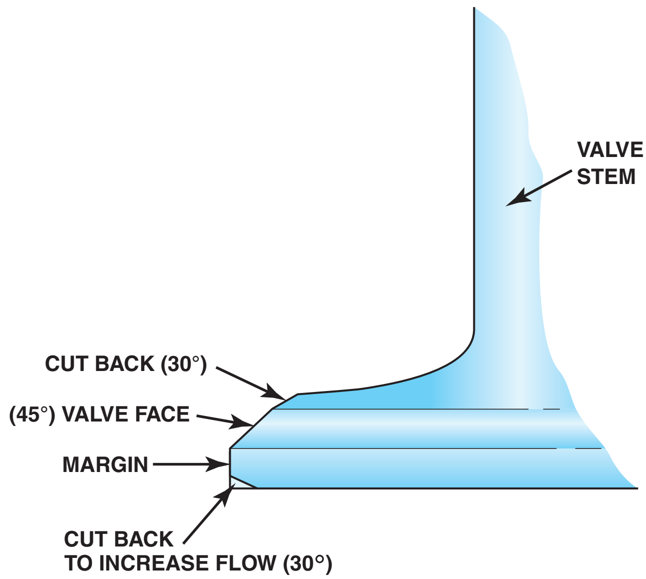


FIGURE 23-37 After grinding the 45-degree face angle, additional airflow into the engine can be accomplished by grinding a transition between the face angle and the stem, as well as angling or rounding the transition between the margin and the top of the valve.

Step 5 After a thorough cleaning, the cylinder head should be assembled with new valve stem seals installed.

The rest of the chapter discusses valve face and seat reconditioning and cylinder head reassembly.

VALVE FACE GRINDING

Each valve grinder operates somewhat differently. The operation manual that comes with the grinder should be followed for lubrication, adjustment, and specific operating procedures. The general procedures given in the following paragraphs apply to all valve grinding equipment.

CAUTION: Safety glasses should *always* be worn for valve and seat reconditioning work. During grinding operations, fine hot chips fly from the grinding stones.

The face of the valve is ground on a **valve grinder.**

NOTE: Many valve grinders use the end of the valve to center the valve while grinding. If the tip of the valve is not square with the stem, the face of the valve may be ground improperly.

See Figure 23-38. After grinding the tip, set the grinder head at the **valve face angle** as specified by the vehicle manufacturer (Figure 23-39). The grinding stone is **dressed** with a special diamond tool to remove any roughness from the stone surface (Figure 23-40). The valve stem is clamped in the work head as close to the fillet under the valve head as possible to prevent vibrations. The work head motor is turned on to rotate the valve. The wheel head motor is turned on to rotate the grinding wheel. The coolant flow is adjusted to flush the material away, but not so much that it splashes (Figure 23-41). The rotating grinding wheel is fed slowly to the rotating valve face. Light grinding is done as the valve is moved back and forth across the grinding wheel face. The valve is never moved off the edge of the grinding wheel. It is ground only enough to clean the face (Figure 23-42). The margin of the exhaust valve should be over 0.030 inch (0.8 millimeter) when grinding is complete (Figure 23-43).

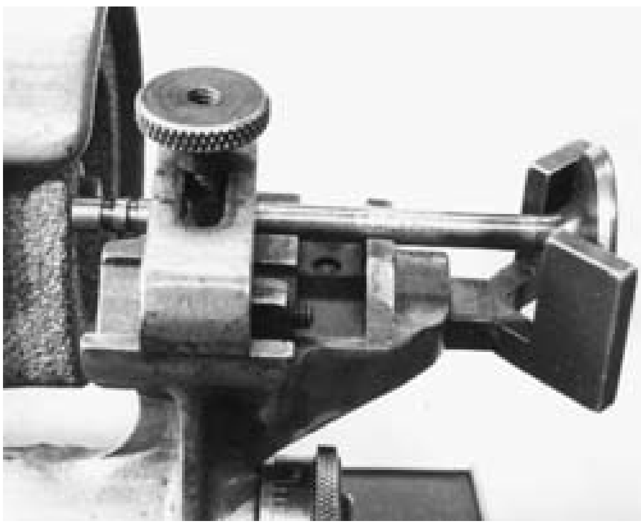


FIGURE 23-38 Valve in a fixture to grind the valve tip.

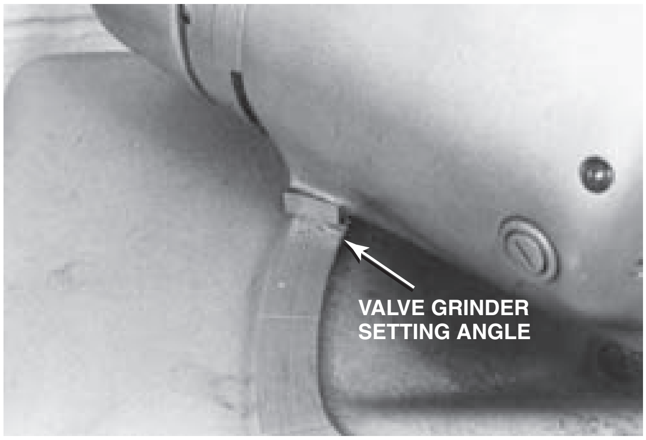


FIGURE 23-39 Valve grinder set to the recommended angle to refinish a valve face. In this case, the angle is set to 44 degrees to provide a 1-degree interference angle between the valve face and the 45-degree valve seat angle.

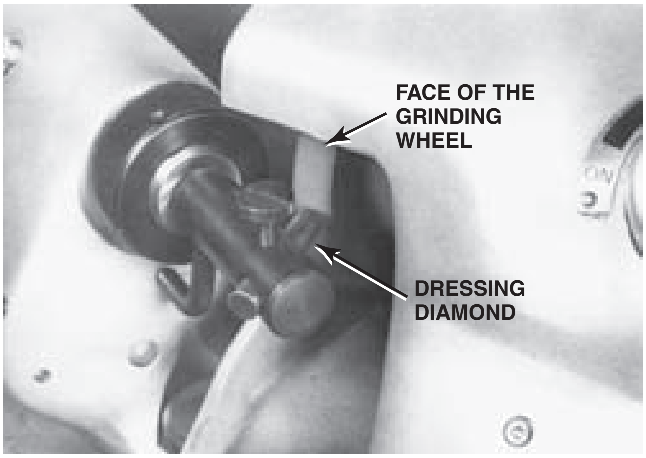


FIGURE 23-40 Dressing the face of the grinding wheel with a diamond dressing tool. This operation helps ensure a good-quality valve face finish.

NOTE: To help visualize a 0.030-inch margin, note that this dimension is about 1/32 inch or the thickness of an American dime.

Intake valves can usually perform satisfactorily with a margin less than 0.030 inch. Always check the engine manufacturer's specifications for the cylinder being serviced. Aluminized valves will lose their corrosion resistance properties when ground. For satisfactory service, aluminized valves must be replaced if they require refacing. Figure 23-44 shows the refacing of a valve using a lathe.

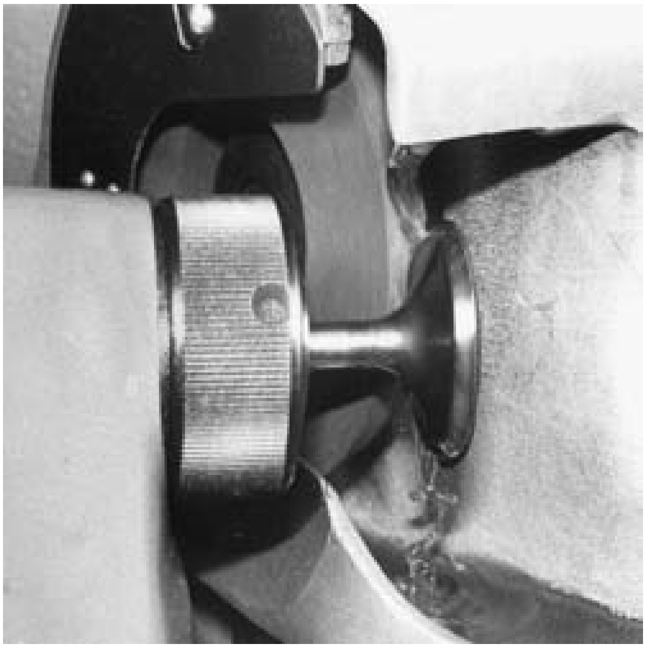
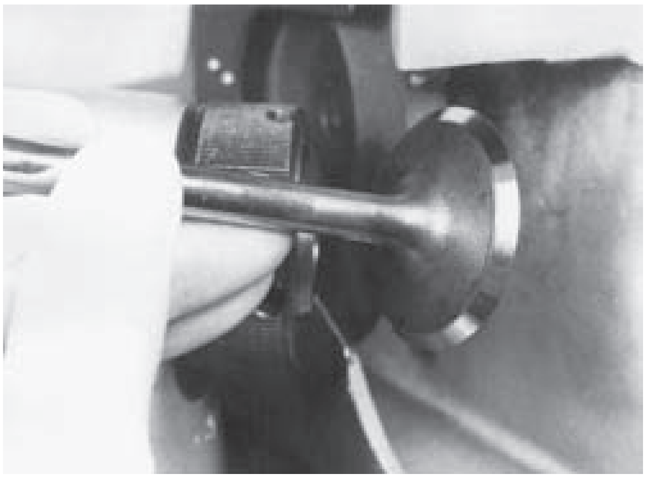


FIGURE 23-41 Grinding the face of a valve. Note the use of cutting oil to lubricate and cool the grinding operation.



(a)

(b)

FIGURE 23-42 (a) Finished valve face after grinding. Do not remove any more material than is necessary. (b) A valve that is bent. Notice how the grinding stone only removed material from about one-half of the valve face. This valve should be replaced.

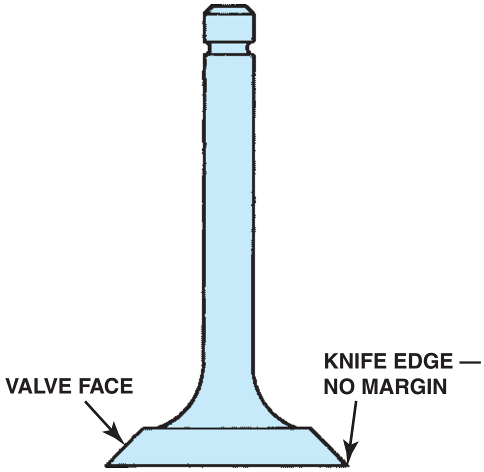


FIGURE 23-43 Never use a valve that has been ground to a sharp edge. This weakens the valve and increases the chance for burning the valve.

FIGURE 23-44 Refacing a valve on a lathe using a special silicon carbide tool bit. The valve face is smoother than it would have been if the valve had been refaced with a stone.

VALVE SEAT RECONDITIONING

The valve seats are reconditioned after the head has been resurfaced and the valve guides have been resized. The final valve seat width and position are checked with the valve that is to be used on the seat being reconditioned.

Valve seats will have a normal seat angle of either 45 degrees or 30 degrees. Narrow 45-degree valve seats will crush carbon deposits to prevent buildup of deposits on the seat. The valve will therefore close tightly on the seat. While the valve is closed on the seat, the valve heat will transfer to the seat and cylinder head. The 30-degree valve seat is more likely to burn than a 45-degree

TECH TIP

VALVE SEAT RECESSION AND ENGINE PERFORMANCE

If unleaded fuel is used in an engine without hardened valve seats, valve seat recession is likely to occur in time. Without removing the cylinder heads, how can a technician identify valve seat recession?

As the valve seat wears up into the cylinder head, the valve itself also seats higher in the head. As this wear occurs, the valve lash *decreases.* If hydraulic lifters are used on the engine, this wear will go undetected until the reduction in valve clearance finally removes all clearance (bottoms out) in the lifter. When this occurs, the valve does not seat fully, and compression, power, and fuel economy are drastically reduced. With the valve not closing completely, the valve cannot release its heat and will burn or begin to melt. If the valve burns, the engine will miss and not idle smoothly.

If solid lifters are used on the engine, the decrease in valve clearance will first show up as a rough idle only when the engine is hot. As the valve seat recedes farther into the head, low power, rough idle, poor performance, and lower fuel economy will be noticed sooner than if the engine were equipped with hydraulic lifters.

To summarize, refer to the following symptoms as valve seat recession occurs.

1. Valve lash (clearance) decreases (valves are *not* noisy).
2. The engine idles roughly when hot as a result of reduced valve clearance.
3. Missing occurs, and the engine exhibits low power and poor fuel economy, along with a rough idle, as the valve seat recedes farther into the head.
4. As valves burn, the engine continues to run poorly; the symptoms include difficulty in starting (hot and cold engine), backfiring, and low engine power.

NOTE: If valve lash is adjustable, valve burning can be prevented by adjusting the valve lash regularly. Remember, as the seat recedes, the valve itself recedes, which decreases the valve clearance. Many technicians do not think to adjust valves unless they are noisy. If, during the valve adjustment procedure, a *decrease* in valve lash is noticed, then valve seat recession could be occurring.

seat because some deposits can build up to keep the valve from seating properly. The 30-degree valve seat will, however, allow more gas flow than a 45-degree valve seat when both are opened to the same amount of lift. See Figure 23-45. This is especially true with valve lifts of less than 1/4 inch (6 millimeters). The 30-degree valve seat is also less likely to have valve seat recession than is a 45-degree seat. Generally, when 30-degree valve seats are used, they are used on the cooler-operating intake valves rather than on hot exhaust valves.

The valve seats are only resurfaced enough to remove all pits and grooves and to correct any seat runout. As metal is removed from the seat, the seat is lowered into the head (Figure 23-46). This causes the valve to be located farther into the head when it is closed on the seat. The result of this is that the valve tip extends out farther from the valve guide. The valve being low in the head also tends to restrict the amount of valve opening. This will reduce the flow of gases through the opened valve. The reduced flow of gases, in turn, will reduce the maximum power the engine can produce.

Ideally, the valve face and valve seat should have exactly the same angle. This is impossible, especially on exhaust valves, because the valve head becomes much hotter than the seat and so the valve expands more than the seat. This expansion causes the hot valve to contact the seat in a different place on the valve than it did when it was cold.

Interference Angle

As a result of its shape, the valve does not expand evenly when heated. This uneven expansion also affects the way in which the hot valve contacts the seat. In valve and valve seat reconditioning, the valve is often ground with a face angle 1 degree less than the seat angle to compensate for the change in hot seating. This is illustrated in Figure 23-47. The angle between the valve face and seat is called an **interference angle.** It makes a positive seal at the combustion chamber edge of the seat when the engine is first started after a valve job. As the engine operates, the valve will peen itself on the seat. In a short time, it will make a matched seal. After a few thousand miles, the valve will have formed its own seat. The interference angle has another benefit. The valve and seat are reconditioned with different machines. Each machine must have its angle set before it is used for reconditioning. It is nearly impossible to set the exact same angles on both valve and seat reconditioning machines. Making an interference angle will ensure that any slight angle difference favors a tight seal at the combustion chamber edge of the valve seat when the valve servicing has been completed.

Valve Seat Width

As the valve seats are resurfaced, their widths increase. The resurfaced seats must be narrowed to make the seat width

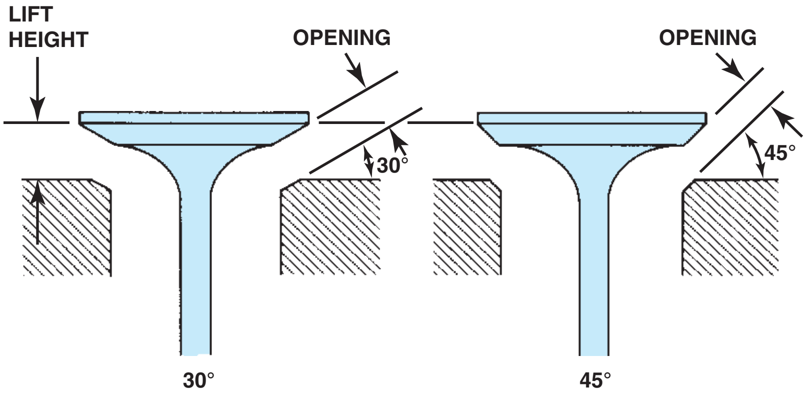


FIGURE 23-45 Relationship of the valve seating angles to the opening size with the same amount of valve lift. Note that the 30-degree valve angle results in more flow past the valve than is seen with a 45-degree valve.

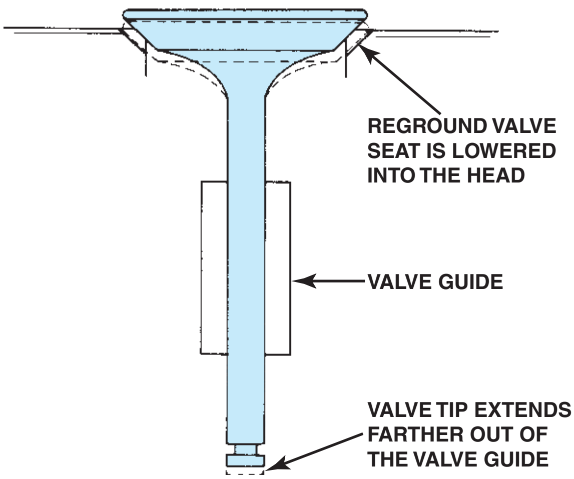


FIGURE 23-46 The valve seat is lowered into the cylinder head when ground. This places the valve tip farther from the valve guide toward the rocker arm side of the cylinder head.

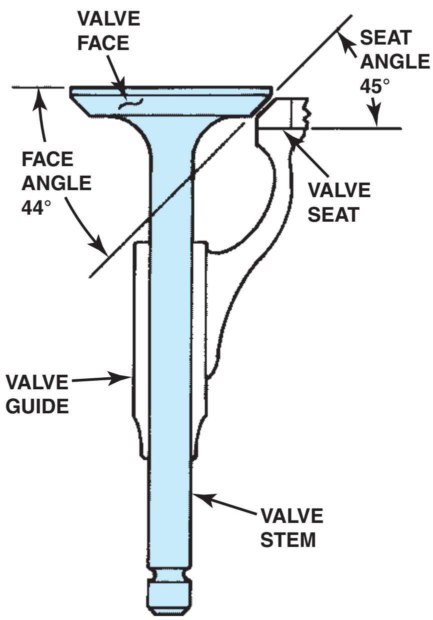


FIGURE 23-47 Some vehicle manufacturers recommend that the valve face be resurfaced at a 44-degree angle and the valve seat at a 45-degree angle. This 1 degree difference is known as the interference angle.

correct and to position the seat properly on the valve face. The normal automotive seat is from 1/16 to 3/32 inch (1.5 to 2.5 millimeters) wide. There should be at least 1/32 inch (0.8 millimeter) of the ground valve face extending above the seat. This is called **overhang.** The fit of a typical reconditioned valve and seat is shown in Figure 23-48. Some manufacturers recommend having the valve seat contact the middle of the valve

FREQUENTLY ASKED QUESTION

WHAT IS A THREE-ANGLE VALVE JOB?

A three-angle valve job means that the valve seats are ground three times.

- The first angle is the angle of the valve seat specified by the vehicle manufacturer, usually 45°. See Figure 23-49.
- The second angle uses a 60-degree stone or cutter to remove material right below the valve seat to increase flow in or out of the combustion chamber. This angle is called the **throating angle.** See Figure 23-50.
- The third angle uses a 30-degree stone or cutter and is used to smooth the transition between the valve seat and the cylinder head again to increase flow in or out of the combustion chamber. This angle is called the **topping angle.** See Figure 23-51.

The three stones or cutters can be used in combination to create the desired seat width and where it contacts the face of the valve. The 60-degree throating stone will rise and narrow the seat. The 45-degree stone will widen the seat and the 30-degree stone will lower and narrow the seat. See Figure 23-52.

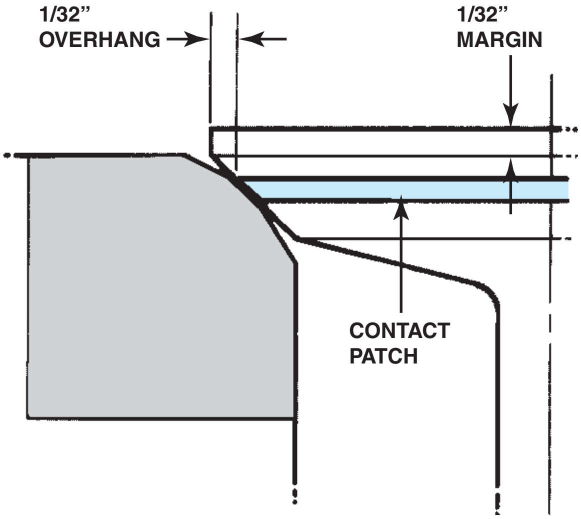


FIGURE 23-48 The seat must contact evenly around the valve face. For good service life, both the margin and the overhang should be at least 1/32 inch (0.8 mm).

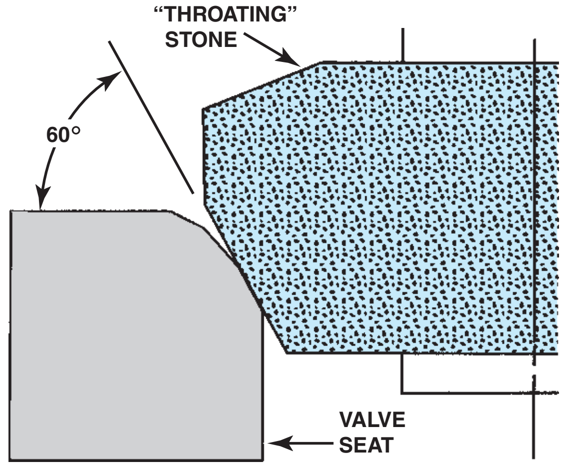


FIGURE 23-50 Grinding a 60-degree angle removes metal from the bottom to raise and narrow the valve seat.

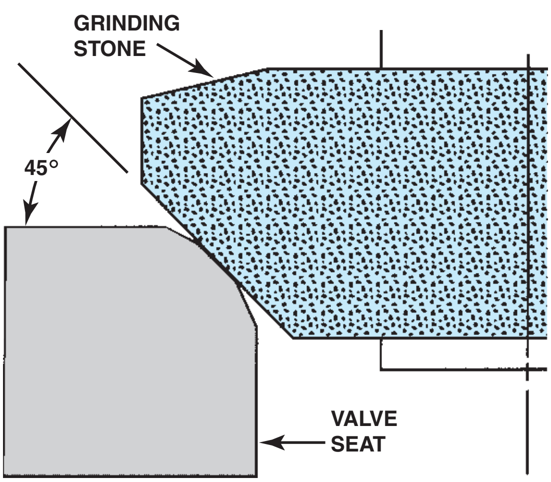


FIGURE 23-49 Grinding a 45-degree angle creates the valve seat in the combustion chamber.

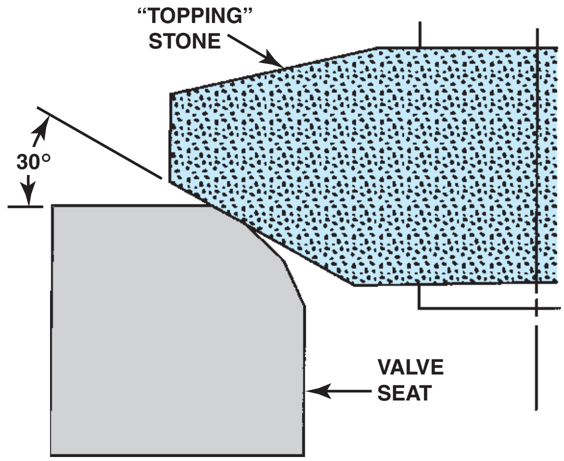


FIGURE 23-51 Grinding a 30-degree angle removes metal from the top to lower and narrow the valve seat.

face. In all cases, the valve seat width and the contact with the valve face should comply with the manufacturer's specifications.

VALVE GUIDE PILOTS

Valve seat reconditioning equipment uses a pilot in the valve guide to align the stone holder or cutter. Two types of pilots are used: tapered and expandable. Examples of these are pictured in Figure 23-53. **Tapered pilots** locate themselves in the least worn section of the guide. They are made in standard sizes and in oversize increments of 0.001 inch, usually up to 0.004 inch oversize. The largest pilot that will fit into the

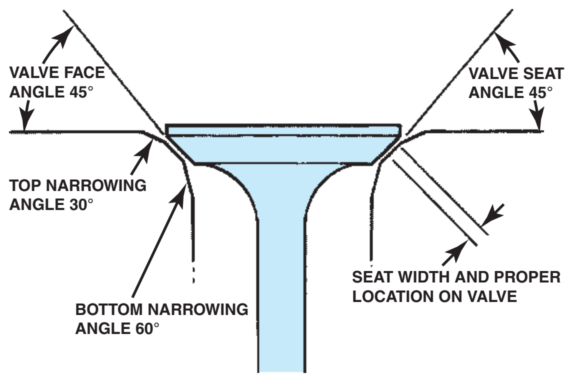


FIGURE 23-52 A typical three-angle valve job using 30-, 45-, and 60-degree stones or cutters.

FIGURE 23-53 The two pilots on the left are of a solid tapered type. The three pilots on the right are adjustable (expandable) types.

guide is used for valve seat reconditioning. This type of pilot restores the seat to be as close to the original position as possible when used with worn valve guides.

Two types of **expandable pilots** are used with seating equipment. One type expands in the center of the guide to fit like a tapered pilot. Another expands to contact the ends of the guide where there has been the greatest wear. The valve itself will align in the same way as the pilot.

NOTE: If the guide is not reconditioned, the valve will match the seat when an expandable pilot is used.

The pilot and guide should be thoroughly cleaned. A guide cleaner, as shown in Figures 23-54 and 23-55, that is rotated by a drill motor does a good job of cleaning the guide. The pilot is placed in the guide to act as an aligned support or pilot for the seat reconditioning tools. An expandable pilot is shown in a cutaway valve guide in Figure 23-56.

VALVE SEAT GRINDING STONES

Three basic types of grinding stones are used. All are used dry. A **roughing stone** is used to rapidly remove large amounts of seat metal. This would be necessary on a badly pitted seat or when installing new valve seat inserts. The roughing stone is sometimes called a seat **forming stone.** After the seat forming stone is used, a **finishing stone** is used to put the proper finish on the seat. The finishing stone is also used to recondition cast-iron seats that are only slightly worn. **Hard seat stones** are used on hard stellite exhaust seat inserts.

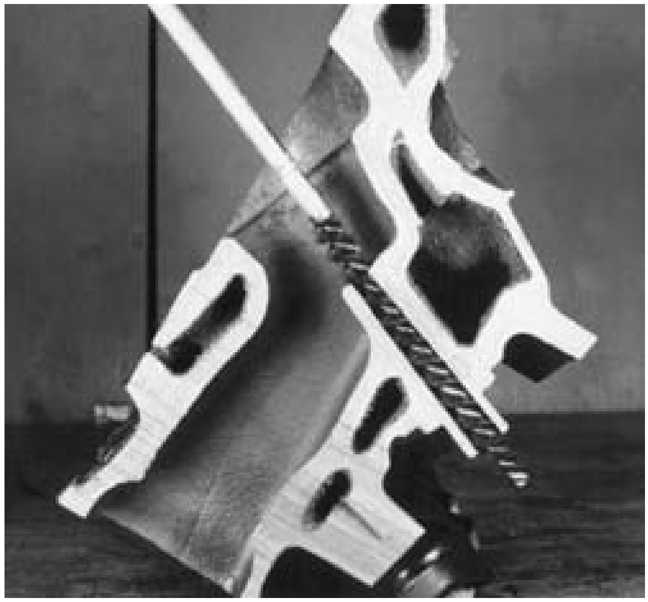


FIGURE 23-54 Sectioned head showing how a brush valve guide cleaner is used.

FIGURE 23-55 Using a valve guide brush with an electric drill. This cleaning of the valve guides is very important for proper valve seat reconditioning.

NOTE: Stellite is a nonmagnetic hard alloy used for valve seats in heavy-duty applications.

The stone diameter and face angle must be correct. The diameter of the stone must be larger than the valve head, but it must be small enough that it does not contact the edge of the combustion chamber. The angle of the grinding surface of the stone must be correct for the seat. When an interference angle is used with reground valves, it is common practice to use a seat with the standard seat angle. The interference

FIGURE 23-56 Expandable pilot shown in the valve guide of a sectioned head to illustrate how the pilot fits.

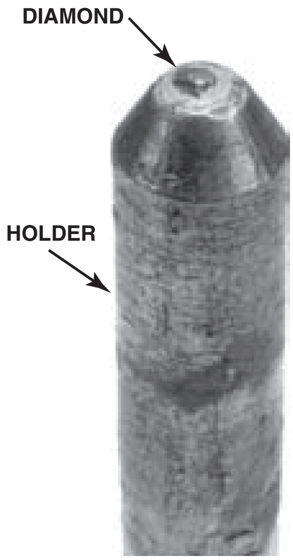


FIGURE 23-57 Tip of a diamond dressing tool.

angle is ground on the valve face. In some cases, such as with an aluminized valve, the valve has the standard angle and the seat is ground to give the interference angle. The required seat angle must be determined *before* the seat grinding stone is dressed.

DRESSING THE GRINDING STONE

The selected grinding stone is installed on the stone holder. A drop of oil is placed on the spindle of the dressing fixture, and the assembly is placed on the spindle. The dressing tool diamond (Figure 23-57) is adjusted so that it extends 3/8 inch or less from its support. The valve seat angle is adjusted on the fixture. The driver for the seating tool is placed in the top of the stone holder. This assembly is shown in Figure 23-58. The holder and grinding stone assembly is rotated with the driver. The diamond is adjusted so that it just touches the stone face. The diamond dressing tool is moved slowly across the face of the spinning stone, taking a very light cut. Dressing the stone in this way will give it a clean, sharp cutting surface. It is necessary to redress the stone each time a stone is placed on a holder, at the beginning of each valve job, and any time the stone is not cutting smoothly and cleanly while grinding valve seats.

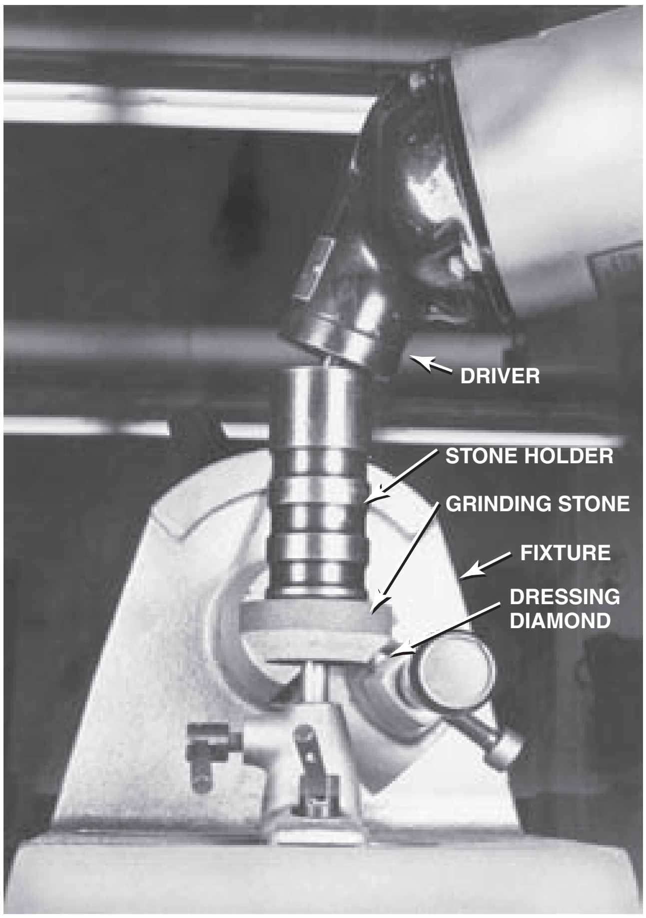


FIGURE 23-58 Typical assembly for dressing a valve seat grinding stone.

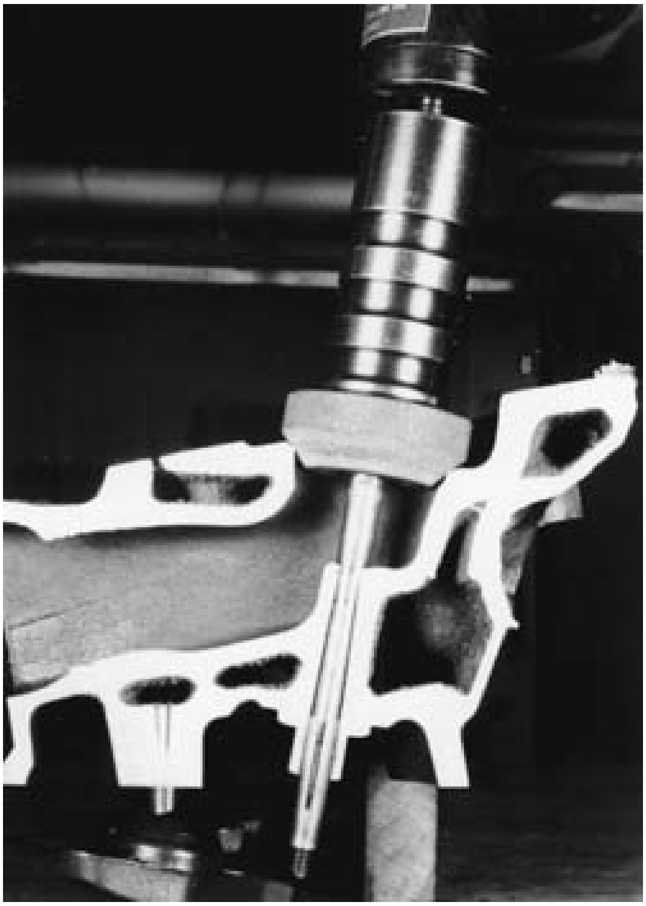


FIGURE 23-59 Typical setup for grinding a valve seat shown on a cutaway head.

VALVE SEAT GRINDING

It is a good practice to clean each valve seat before grinding. This keeps the soil from filling the grinding stone. The pilot is then placed in the valve guide. A drop of oil is placed on the end of the pilot to lubricate the holder. The holder, with the dressed grinding stone, is placed over the pilot. The driver should be supported so that no driver weight is on the holder. This allows the stone abrasive and the metal chips to fly out from between the stone and seat to give fast, smooth grinding. Grinding is done in short bursts, allowing the seating stone to rotate for approximately 10 turns. See Figure 23-59. The holder and stone should be lifted from the seat between each grinding burst to check the condition of the seat. The finished seat should be bright and smooth across the entire surface, with no pits or roughness remaining (Figure 23-60).

Some of the induction hardness from the exhaust valve seat will sometimes extend over into the intake seat. It may be necessary to apply a slight pressure on the driver toward the hardened spot to form a concentric seat. The seat is checked with a dial gauge to make sure that it is concentric within

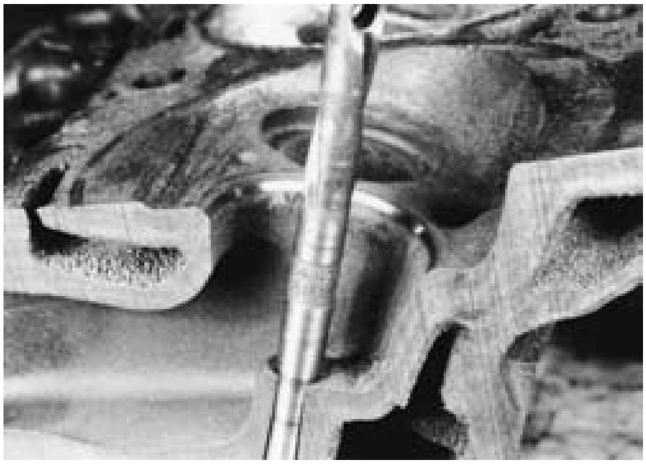


FIGURE 23-60 Finished valve seat shown on a cutaway head.

0.002 inch (0.05 millimeter) before the seat is finished. See Figure 23-61. The dial gauge measurement of the valve seat is very important. The maximum acceptable variation is 0.002 inch. This reading gives the **total indicator runout (TIR)** of the valve seat.

NARROWING THE VALVE SEAT

The valve seat becomes wider as it is ground. It is therefore necessary to narrow the seat so that it will contact the valve properly. The seat is **topped** with a grinding stone dressed to 15 degrees less than the seat angle. Topping lowers the top edge of the seat. The amount of topping required can best be checked by measuring the maximum valve face diameter using dividers. The dividers are then adjusted to a setting 1/16-inch smaller to give the minimum valve face overhang. The seat is measured and then topped with short grinding bursts, as required, to equal the diameter set on the dividers. The seat width is then measured. If it is too wide, the seat must be **throated** with a stone with a 60-degree angle. This removes metal from the port side of the seat, raising the lower edge of the seat. Generally accepted seat widths are as follows:

- For intake valves: 1/16 inch or 0.0625 inch (about the thickness of a nickel) (1.5 millimeters)
- For exhaust valves: 3/32 inch or 0.0938 inch (about the thickness of a dime and a nickel together) (2.4 millimeters)

The completed seat must be checked with the valve that is to be used on the seat. This can be done by marking across the valve face at four or five places with a felt-tip marker. The valve is then inserted in the guide so that the valve face contacts the seat. The valve is rotated 20 to 30 degrees and then removed. The location of the seat contact on the valve is observed where the felt-tip marking has been rubbed off from

FIGURE 23-61 Typical dial indicator-type of micrometer for measuring valve seat concentricity.

the valve. Valve seating can be seen in Figure 23-62. Valve seat grinding is complete when each of the valve seats has been properly ground, topped, and throated.

To summarize:

- Using a 30-degree topping stone (for a 45-degree seat) *lowers* the upper outer edge and narrows the seat.
- Using a 60-degree throating stone *raises* the lower inner edge and narrows the seat.
- Using a 45-degree stone *widens* the seat.

VALVE SEAT CUTTERS

Some automotive service technicians prefer to use valve seat cutters rather than valve seat grinders. See Figure 23-63. The valve seats can be reconditioned to commercial standards in much less time when using the cutters rather than the grinders. A number of cutting blades are secured at the correct seat angle in the cutting head of this valve seat reconditioning tool. The cutter angle usually includes the interference angle so that new valves with standard valve face angles can be used without grinding the new valve face. The cutters do not require dressing as stones do. The cutting head assembly is placed on a pilot in the same way that the grinding stone holder is used. The cutter is rotated by hand or by using a special speed reduction motor. Only metal chips are produced. The finished seat is checked for concentricity and fit against the valve face using the felt-tip marker method previously described.

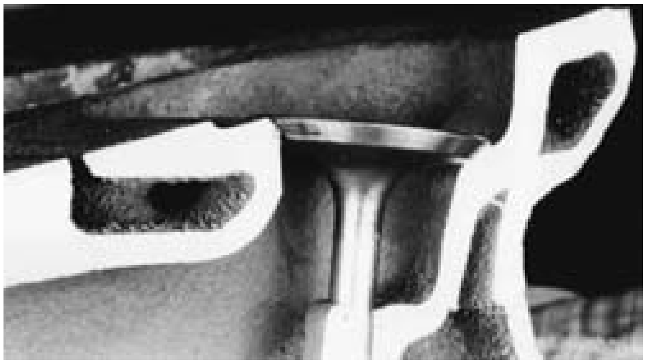


FIGURE 23-62 On this cutaway head, the location of the valve seat is shown where the ink from the felt-tip pen has transferred from the seat to the valve face. Prussian blue can also be used instead of a felt-tip marker.

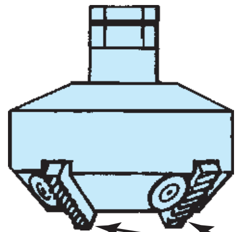


FIGURE 23-63 A cutter is used to remove metal and form the valve seat angles.

CAUTION: A cutter should only be rotated clockwise. If a cutter is rotated counterclockwise, damage to the cutting surfaces ruins the cutter.

VALVE SEAT TESTING

After the valves have been refaced and the guides and valve seats have been resurfaced, the valves should be inspected for proper sealing and to make certain that the valve seat is concentric with the valve face. Several methods that are often used to check valve face-to-seat concentricity and valve seating include the following:

1. Vacuum testing can be done by applying vacuum to the intake and/or exhaust port using a tight rubber seal and

a vacuum pump. A good valve face-to-seat seal is indicated by the maintaining of at least 28 inches Hg of vacuum. This method also tests for leakage around the valve guides. Put some engine oil around the guides; if vacuum increases, valve guides may have excessive clearance.

2. The ports or chamber can be filled with mineral spirits or some other suitable fluid. A good seal should not leak fluid for at least 45 seconds.
3. Valve seating can be checked by applying air pressure to the combustion chamber and checking for air leakage past the valve seat. See Figure 23-64.

VALVE SEAT REPLACEMENT

Valve seats need to be replaced if they are cracked or if they are burned or eroded too much to be reseated. A badly eroded valve seat is shown in Figure 23-65. It may not be possible to determine whether a valve seat needs to be replaced before an attempt is made to recondition the valve seat. Valve seat replacement is accomplished by using a pilot in the valve guide. This means that the valve guide must be reconditioned *before* the seat can be replaced. Damaged **insert valve seats** are removed and the old seat counter bore is cleaned to accept a new oversize seat insert. Damaged integral valve seats must be counter bored to make a place for the new insert seat.

The old insert seat is removed by one of several methods. A small pry bar can be used to snap the seat from the counter bore. It is sometimes easier to do this if the old seat is drilled to weaken it. Be careful not to drill into the head material. Sometimes, an expandable hook-type puller is used to remove the seat insert. See the Tech Tip, "The MIG Welder Seat Removal Trick." The seat counter bore must be cleaned before the new, oversize seat is installed. The replacement inserts have a 0.002- to 0.003-inch (0.05- to 0.07-millimeter) interference fit in the counter bore. The counter bores are cleaned and properly sized, using the same equipment described in the following paragraph for installing replacement seats in place of faulty integral valve seats.

Cracked or badly burned integral valve seats can often be replaced to salvage the head. All head cracks are repaired *before* the old integral seat is removed. The replacement seat is selected first. It must have the correct inside and outside diameters and it must have the correct thickness. Manufacturers of replacement valve seats supply tables that specify the

TECH TIP

THE MIG WELDER SEAT REMOVAL TRICK

A quick and easy method to remove insert valve seats is to use a **metal inert gas (MIG)** welder, also called a **gas metal arc welding (GMAW)** welder. After the valve has been removed, use the MIG welder and lay a welding bead around the seat area of the insert. As the welder cools, it shrinks and allows the insert to be easily removed from the cylinder head.

FIGURE 23-64 Testing for leakage past the valves by injecting compressed air into the combustion chamber through the spark plug hole. To prevent leakage at the head gasket surface, the cylinder head is placed on a foam rubber pad.

FIGURE 23-65 Badly eroded valve seat.

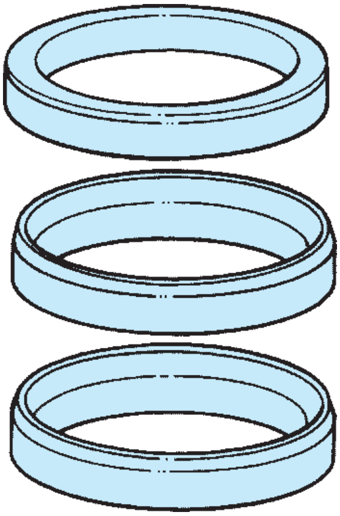


FIGURE 23-66 Insert valve seats are rings of metal driven into the head.

proper seat insert to be used. See Figure 23-66. If an insert is being replaced, the new insert must be of the same type of material as the original insert or better. Insert exhaust valve seats operate at temperatures that are 100° to 150°F (56° to 83°C) hotter than those of integral seats up to 900°F (480°C). Upgraded valve and valve seat materials are required to give the same service life as that of the original seats. Removable valve seats are available in different materials including:

- Cast iron
- Stainless steel
- Nickel cobalt
- Powdered metal (PM)

A counter bore cutting tool is selected that will cut the correct diameter for the outside of the insert. The diameter of the bore is smaller than the outside diameter of the seat insert. The cutting tool is positioned securely in the tool holder so that it will cut the counter bore at the correct diameter. The tool holder is attached to the size of pilot that fits the valve guide. The tool holder feed mechanism is screwed together so that it has enough threads to properly feed the cutter into the head. This assembly is placed in the valve guide so that the cutting tool rests on the seat that is to be removed.

The new insert is placed between the support fixture and the stop ring. The stop ring is adjusted against the new insert so that cutting will stop when the counter bore reaches the depth of the new insert. See Figure 23-67. The boring tool is turned by hand or with a reduction gear motor drive. It cuts until the stop ring reaches the fixture. See Figure 23-68. The support fixture and the tool holder are removed. The pilot and the correct size of adapter are placed on the driving tool. Ideally, the seats should be cooled with dry ice to cause them to shrink. Each

FIGURE 23-67 Adjusting the cutting tool stop ring with the new valve insert as a guide.

insert should be left in the dry ice until it is to be installed. This will allow it to be installed with little chance of metal being sheared from the counter bore. Sheared chips could become jammed under the insert, keeping it from seating properly. The chilled seat is placed on the counter bore. The driver with a pilot is then quickly placed in the valve guide so that the seat will be driven squarely into the counter bore. The driver is hit with a heavy hammer to seat the insert, as shown in Figure 23-69. Heavy blows are used to start the insert, and lighter blows are used as the seat reaches the bottom of the counter bore. It serves no purpose to hit the driver after the insert is seated in the bottom of the counter bore. The installed valve seat insert is peened in place by running a peening tool around the metal on the outside of the seat. The peened metal is slightly displaced over the edge of the insert to help hold it in place. A fully installed seat insert is shown in Figure 23-70 on page 424. Seats are formed on the replacement inserts using the same procedures described for reconditioning valve seats.

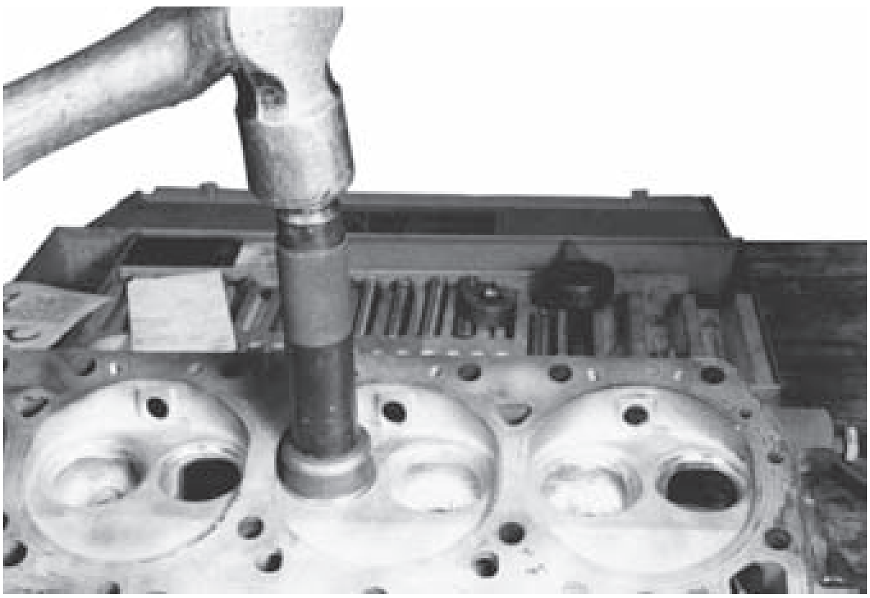
FIGURE 23-68 Seat cutting tool boring out the old eroded valve seat.

TECH TIP

USE THE RECOMMENDED SPECIFICATIONS

A technician replaced valve seat inserts in an aluminum cylinder head. The *factory* specification called for a 0.002-inch interference fit (the insert should be 0.002-inch larger in diameter than the seat pocket in the cylinder head). Shortly after the engine was started, the seat fell out, ruining the engine.

The technician should have used the interference fit specification supplied with the replacement seat insert. Interference fit specifications depend on the type of material used to make the insert. Some inserts for aluminum heads require as much as 0.007-inch interference fit. Always refer to the specification from the manufacturer of the valve inserts when replacing valve seats in aluminum cylinder heads.



(a)

OUTSIDE DIAMETER (IN.)	INSERT DEPTH (IN.)	INTERFERENCE FIT (IN.)
0 – 1	$0–\frac{1}{4}$	0.001 – 0.003
1 – 2	$\frac{1}{4}–\frac{3}{8}$	0.002 – 0.004
2 – 3	$\frac{3}{8}–\frac{9}{16}$	0.003 – 0.005
3 – 4	$\frac{9}{16}–1$	0.004 – 0.006

(b)

FIGURE 23-69 (a) Seating the new chilled insert in the counter bore by hitting the driver with a heavy hammer. (b) Interference fit for valve inserts (hard cast or wrought inserts).

FIGURE 23-70 Fully installed valve seat insert.

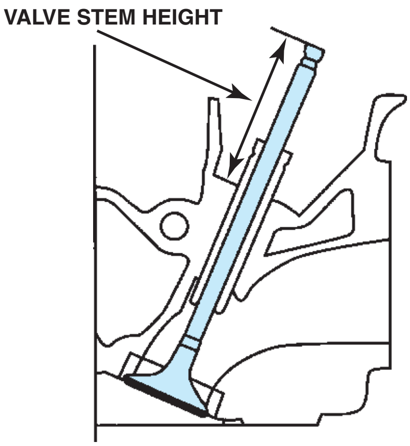


FIGURE 23-71 Valve stem height is measured from the spring seat to the tip of the valve after the valve seat and valve face have been refinished. If the valve stem height is too high, up to 0.020 inch can be ground from the tips of most valves.

VALVE STEM HEIGHT

Valve stem height is a different measurement from installed height. See Figure 23-71. Valve stem height is important to maintain for all engines, but especially for overhead camshaft engines. When the valve seat and the valve face are ground, the valve stem extends deeper into the combustion chamber and extends higher or further into the cylinder head.

The valve is put in the head, and the length of the tip is measured. The tip is ground to shorten the valve stem length to compensate for the valve face and seat grinding. The valve will not close if the valve tip extends too far from the valve guide on engines that have hydraulic lifters and nonadjustable rocker arms. If the valve is too long, the tip may be ground by as much as 0.020 inch (0.50 millimeter) to reduce its length. If more grinding is required, the valve must be replaced. If it is too short, the valve face or seat may be reground, within limits, to allow the valve to seat deeper. Where excessive valve face and seat grinding has been done, shims can be placed under the rocker shaft on some engines as a repair to provide correct hydraulic lifter plunger centering. These shims must have the required lubrication holes to allow oil to enter the shaft.

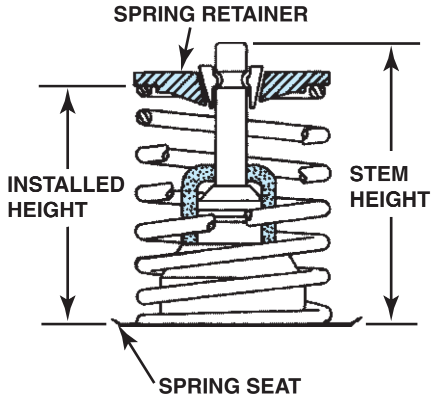


FIGURE 23-72 Measure the distance from the spring seat to the bottom of the retainer to find the installed height.

CHECKING INSTALLED HEIGHT

When the valves and/or valve seats have been machined, the valve projects farther than before on the rocker arm side of the head. (The valve face is slightly recessed into the combustion chamber side of the head.) The valve spring tension is, therefore, reduced because the spring is not as compressed as it was originally. To restore original valve spring tension, special valve spring spacers, inserts, or shims are installed under the valve springs. These shims are usually called **valve spring inserts (VSI).** Valve spring inserts are generally available in three different thicknesses:

- **0.015 inch (0.38 millimeter)**—Used for balancing valve spring pressure.
- **0.030 inch (0.75 millimeter)**—Generally used for new springs on cylinder heads that have had the valve seats ground and valves refaced.
- **0.060 inch (1.5 millimeter)**—Necessary to bring assembled height to specifications. (These thicker inserts may be required if the seats have been resurfaced more than one time.)

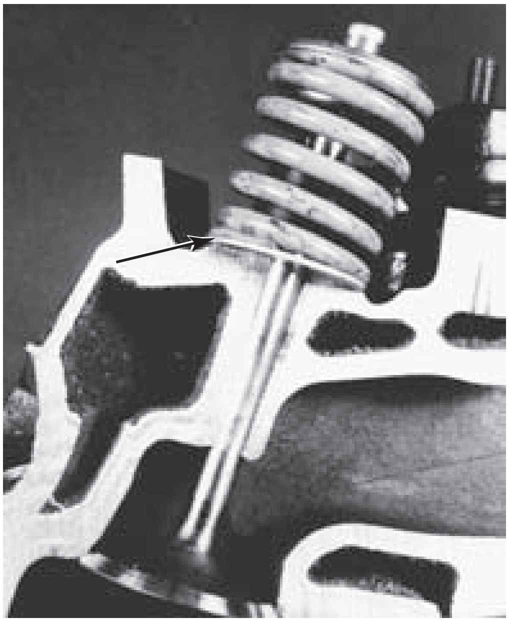
Step 1 To determine the exact thickness of insert to install, measure the valve spring height (as installed in the head). See Figure 23-72.

Step 2 If the installed height is greater than specifications, select the insert (shim) that brings the installed height to within specifications. See Figure 23-73.

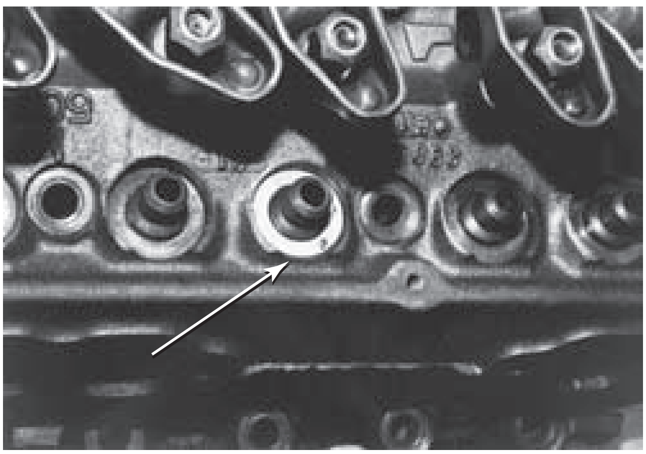
VALVE STEM SEALS

Leakage past the valve guides is a major oil consumption problem in any overhead valve (or overhead cam) engine. A high vacuum exists in the intake port, as shown in Figure 23-74. Most engine manufacturers use valve stem seals on the exhaust valve, because a weak vacuum in the exhaust port area can draw oil into the exhaust stream, as illustrated in Figure 23-75.

Valve stem seals are used on overhead valve engines to control the amount of oil used to lubricate the valve stem as it moves in the guide. The stem and guide will scuff if they do not have enough oil. Too much oil will cause excessive oil consumption and will cause heavy carbon deposits to build up on the spark plug nose and on the fillet of the valves.



(a)



(b)

FIGURE 23-73 (a) Valve spring inserts (VSI) (also called shims) are installed between the cylinder head and valve spring to restore the valve to its proper installed height. (b) The serrations of the valve spring insert should face toward the cylinder head. The purpose of the serrations is to allow air to flow between the insert and the head to help keep the spring cooler.

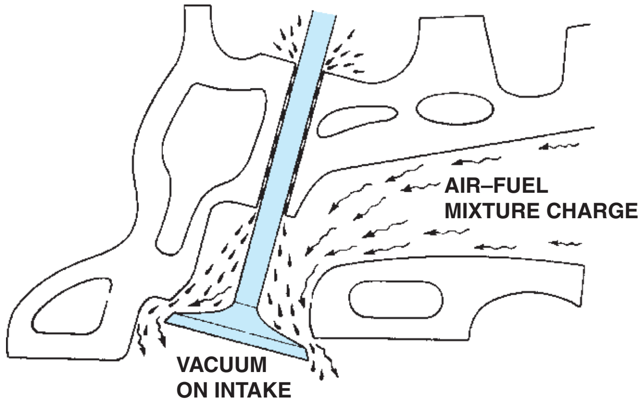


FIGURE 23-74 Engine vacuum can draw oil past the valve guides and into the combustion chamber. The use of valve stem seals limits the amount of oil that is drawn into the engine. If the seals are defective, excessive blue (oil) smoke is most often observed during engine start-up.

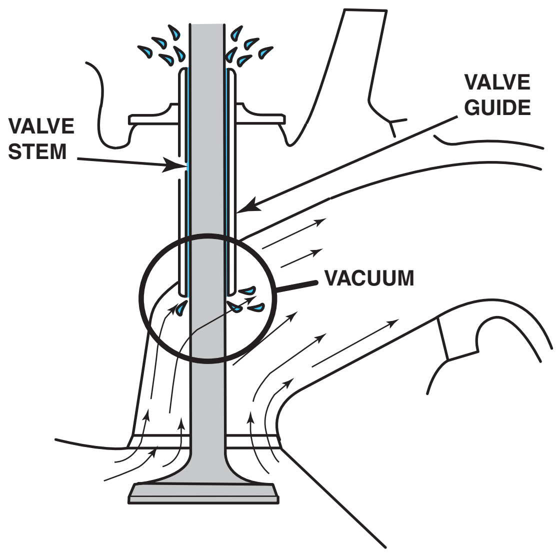


FIGURE 23-75 Engine oil can also be drawn past the exhaust valve guide because of a small vacuum created by the flow of exhaust gases. Any oil drawn past the guide would simply be forced out through the exhaust system and not enter the engine. Some engine manufacturers do not use valve stem seals on the exhaust valves.

TYPES OF VALVE STEM SEALS

- The **umbrella valve stem seal** holds tightly on the valve stem and moves up and down with the valve. Any oil that spills off the rocker arms is deflected out over the valve guide, much as water is deflected over an umbrella. See Figure 23-76. As a result, umbrella valve stem seals are often called **deflector valve stem seals.**
- **Positive valve stem seals** hold tightly around the valve guide, and the valve stem moves through the seal. The seal wipes the excess oil from the valve stem. See Figure 23-77.
- **O-ring valve stem seal** used on Chevrolet engines keeps oil from leaking between the valve stem and valve spring retainer. The oil is deflected over the retainer and shield. See Figure 23-78. The assembly controls oil like an umbrella-type oil seal. Both types of valve stem seals allow only the correct amount of oil to reach the valve guide to lubricate the valve stem. The rest of the oil flows back to the oil pan.

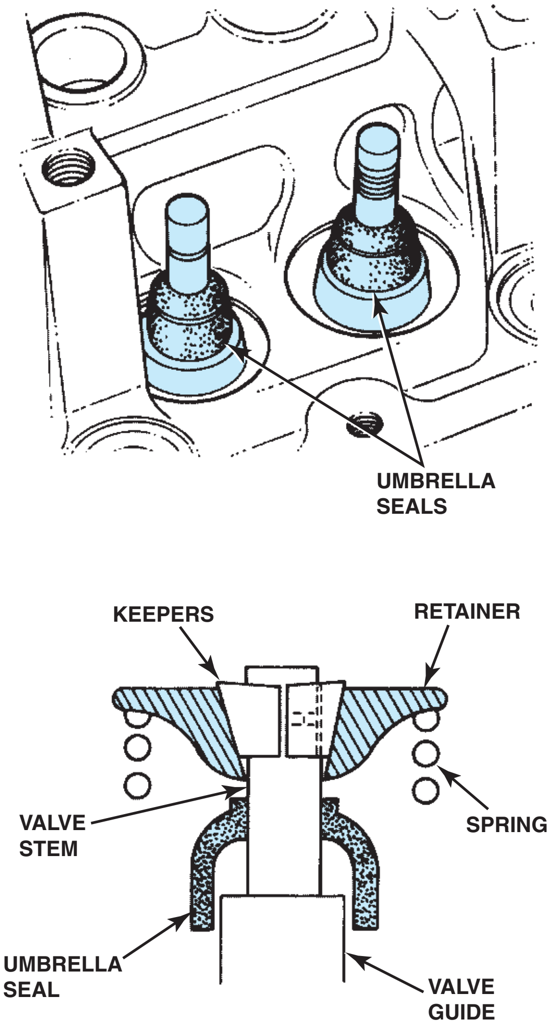


FIGURE 23-76 Umbrella seals install over the valve stems and cover the guide.

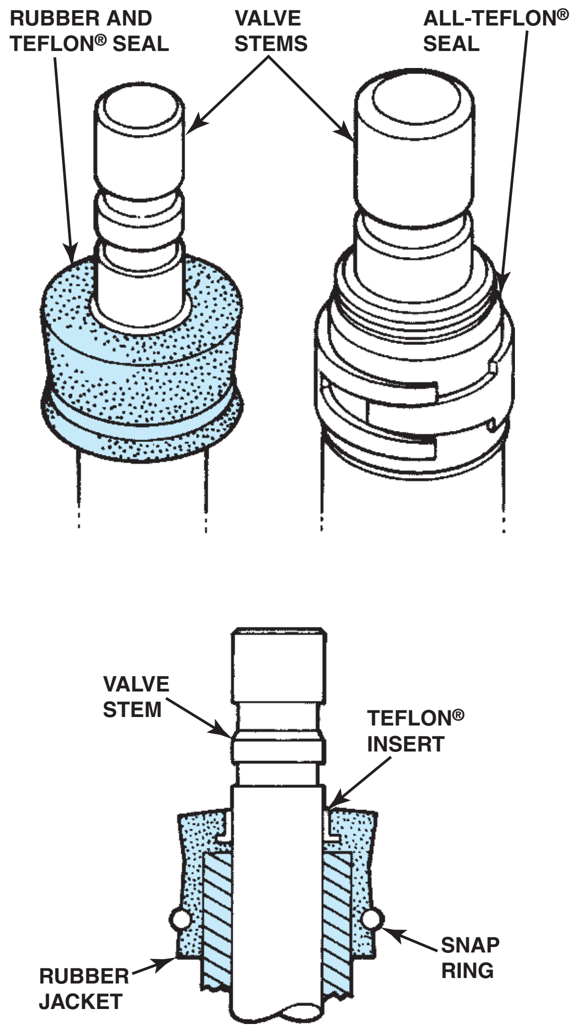


FIGURE 23-77 Positive valve stem seals are the most effective type.

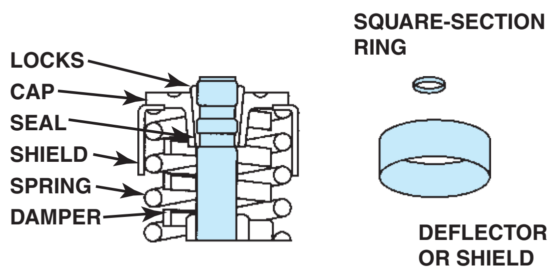


FIGURE 23-78 A small square cut O-ring is installed under the retainer in a groove in the valve under the groove(s) used for the keepers (locks).

Valve Seal Materials

Valve stem seals are made from many different types of materials. They may be made from nylon or Teflon®, but most valve stem seals are made from synthetic rubber. Three types of synthetic rubbers are in common use:

- Nitrile (Nitril)
- Polyacrylate
- Viton

Nitrile is the oldest valve stem seal material. It has a low cost and a low useful temperature. Engine temperatures have increased with increased emission controls and improved efficiencies, which made it necessary to use premium polyacrylate, even with its higher cost. In many cases, it is being retrofit to the older engines because it will last much longer than Nitrile. Diesel engines and engines used for racing, heavy trucks, and trailer towing, along with turbocharging, operate at still higher temperatures. These engines may require expensive Viton valve stem seals that operate at higher temperatures. See Figure 23-79.

It is interesting to note that an automotive service technician cannot tell the difference between these synthetic rubber valve stem seals if they have come out of the same mold for the same engine. Often suppliers that package gasket sets for sale at a low price will include low-temperature Nitrile, even when the engine needs higher-temperature polyacrylate. Your best chance of getting the correct valve stem seal material for an engine is to purchase gaskets and seals packaged by a major brand gasket company.

INSTALLING THE VALVES

The cylinder head can be assembled after the head is thoroughly cleaned with soap and water to wash away any remaining grit and metal shavings from the valve grinding operation. Valves are assembled in the head, one at a time. The valve guide and stem are given a liberal coating of engine oil, and the valve is installed in its guide. Umbrella and positive

TECH TIP

"CC" THE HEADS FOR BEST PERFORMANCE

For best engine performance and smooth operation, all cylinders should have the same compression. To accurately measure the volume of the combustion chamber, a graduated burette is used with mineral spirits (or automatic transmission fluid) to measure the exact volume of the chamber in cubic centimeters (cc). See Figure 23-80.

FIGURE 23-79 Poor-quality umbrella-type valve stem seal after several months of use. Note how heat has softened this seal and destroyed its sealing ability.

FIGURE 23-80 Setup needed to measure the combustion chamber volume in cubic centimeters (cc).

valve stem seals are installed. Push umbrella seals down until they touch the valve guide. Use a plastic sleeve over the tip of the valve when installing positive seals. Make sure that the positive seal is fully seated on the valve guide and that it is square. See Figure 23-81. Hold the valve against the seat as the valve spring seat or insert, valve spring, valve seals, and retainer are placed over the valve stem. One end of the valve spring compressor pushes on the retainer to compress the spring. See Figure 23-82. The O-ring type of valve stem seal is installed in the lower groove. The valve keepers are installed while the valve spring is compressed. See Figure 23-83. Release the valve spring compressor slowly and carefully while making sure that the valve keepers seat properly between the valve stem grooves and the retainer. See Figure 23-84. Each valve is assembled in the same manner. Attach the hose from a vacuum pump to the top of the assembled valve.

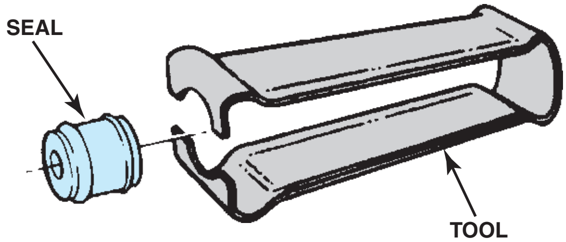


FIGURE 23-81 Use a seal installation tool to push positive-type valve stem seals onto the guides.

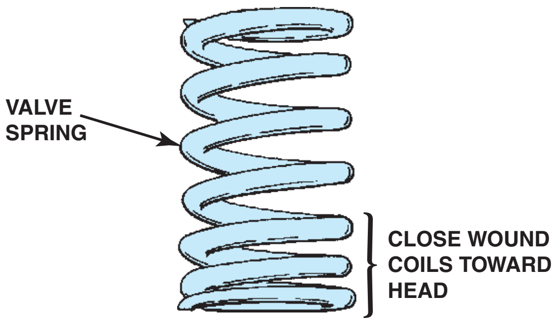


FIGURE 23-82 The tightly coiled end of a variable pitch spring should be installed toward the cylinder head.

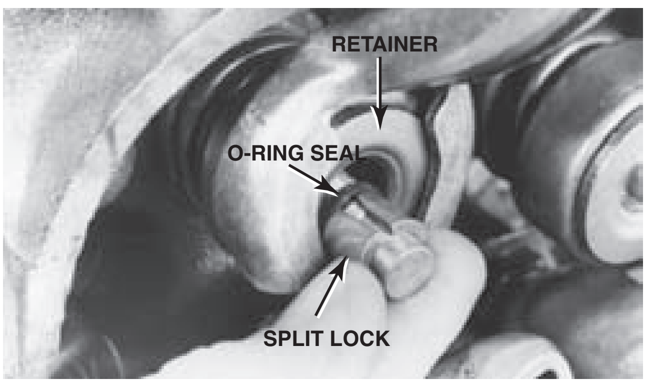
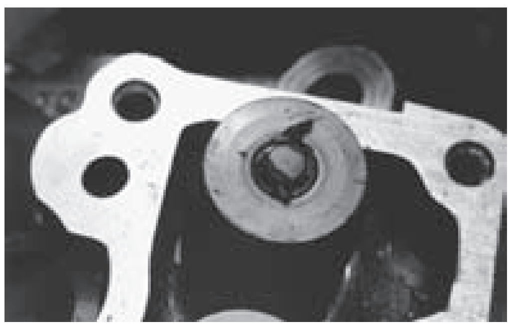


FIGURE 23-83 Proper installation of a typical Chevrolet O-ring valve stem seal and valve locks.

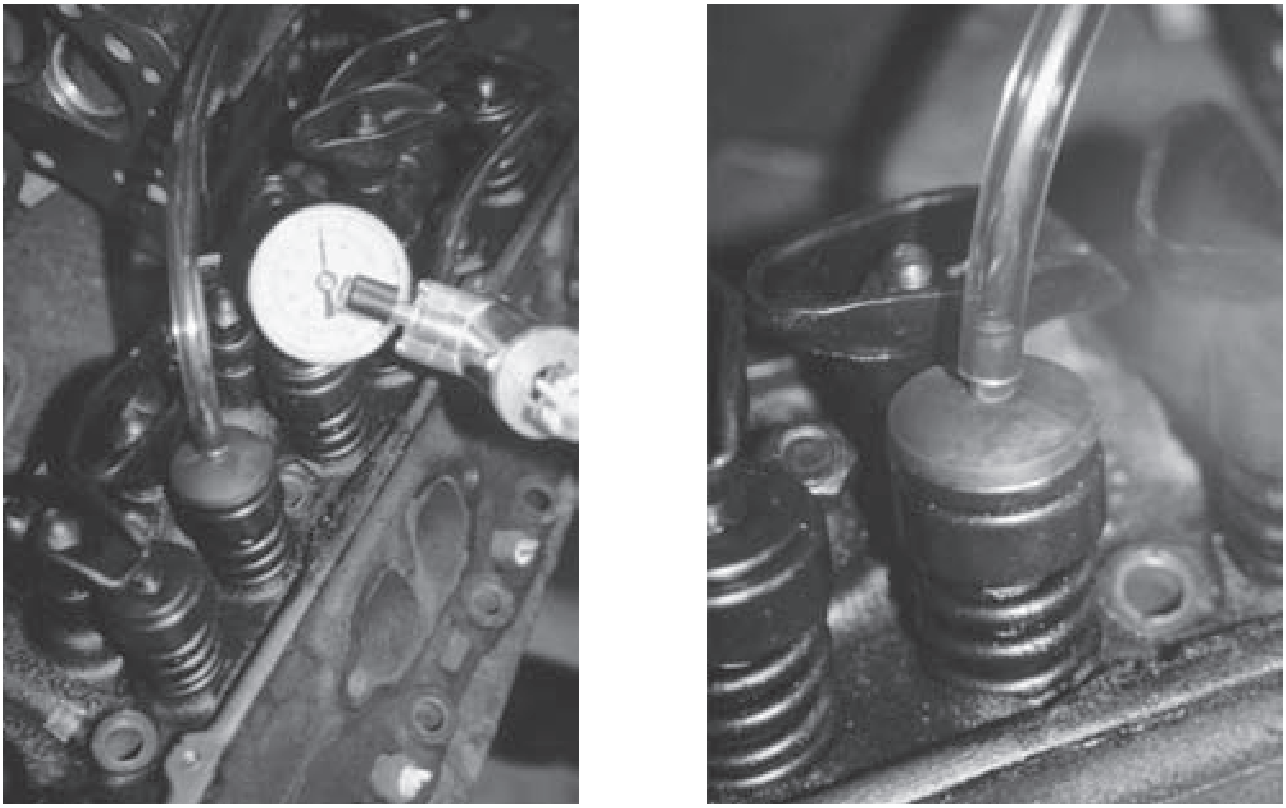
(a)

(b)



(c)

FIGURE 23-84 (a) Air-operated valve spring compressor being used to install valves. If the compressor compresses the valve spring too much, the O-ring valve stem seal may be knocked out of location when the compressor is released. (b) Putting grease on the split locks (keepers) helps to retain them when releasing pressure on the valve spring compressor to help prevent improper seating. (c) Valve after installation. Note the grease on the valve. The grease should be wiped off to prevent the possibility of certain greases clogging oil filters after the engine starts.



(a)

(b)

FIGURE 23-85 (a) A hand-operated vacuum pump is used to check the O-ring valve stem seals on this Chevrolet V-8 cylinder head. (b) A close-up showing the sealing cup over the retainer.

A vacuum will hold if the O-ring type of valve stem seal is correctly installed, as shown in Figure 23-85.

FLOW TESTING CYLINDER HEADS

Many specialty engines are tested for the amount of air that can flow through the ports and valves of the engine. A flow bench is used to measure the amount of air [measured in cubic feet per minute (cfm)] that can flow through the valves at various valve openings.

After completion of the valve job and any port or combustion chamber work, weak valve springs are installed temporarily. See Figure 23-86. Modeling clay is then temporarily applied around the ports to improve flow characteristics around the port area where the intake manifold would normally direct the flow into the port. See Figure 23-87.

Various thicknesses of metal spacers are placed between the cylinder head holding fixture and the valve stem. See Figure 23-88. Typical thicknesses used are 0.100 through 0.700 inch in 0.100-inch increments. The results are recorded on a work sheet. See Figure 23-89.

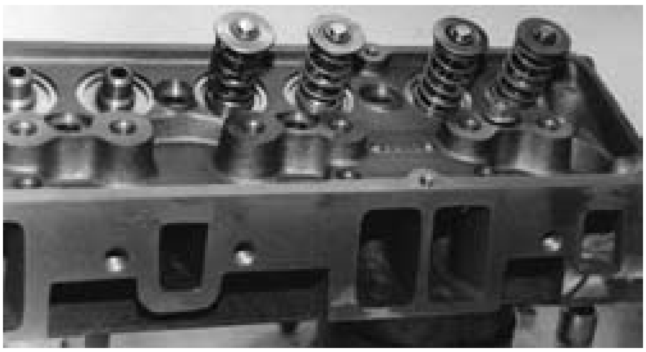


FIGURE 23-86 Cylinder head setup for flow testing. Note the weak valve springs that are strong enough to keep the valves shut, yet weak enough to permit the flow bench operator to vary the intake valve opening amount.

CYLINDER HEAD FLOW VERSUS HORSEPOWER

Most comprehensive engine machine shops have the equipment to measure the airflow through cylinder head ports and valves. After the airflow through the open intake valve has

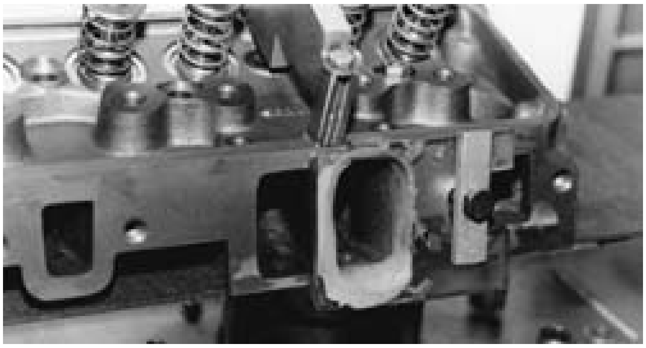


FIGURE 23-87 Modeling clay is installed around the port to duplicate the flow improvement characteristics of an intake manifold.

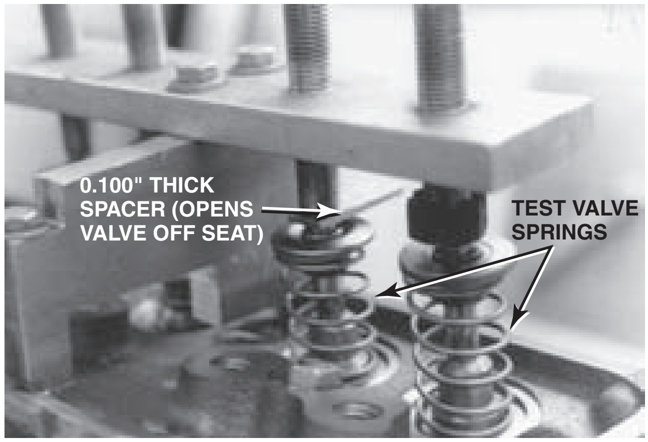


FIGURE 23-88 By varying the thickness of the metal spacers, the flow bench operator can measure the airflow through the intake and exhaust ports and valves at various valve lifts.

PRESSURE DROP 28"

NAME Test Info

APPLICATION Dart II Iron S.B/K.

In = 2.055 Ex = 1.600

3 Angle Grind Only

VALVE LIFT (in.)

AIR FLOW

CYL. #	COMMENTS	R 0.100		R 0.200		R 0.300		R 0.400		R 0.500		R 0.600		R 0.700	
IN		3	57.5	3	93.8	4	63.5	4	73.6	4	74.8	4	76.5	4	77.5
	CFM		88		144		189		219		223		228		231
IN															
	CFM														
IN															
	CFM														
IN															
	CFM														
EX		2	60.5	3	58.5	3	70.0	3	76.0	3	80.2	3	82.0	3	83.2
	CFM		54		95		113		123		130		133		135
EX															
	CFM														
EX															
	CFM														
EX															
	CFM														

FIGURE 23-89 A typical flow bench worksheet. Note that the cylinder head was tested up to 0.700 inch of lift.

been determined, a formula can be used to estimate horsepower. The following formula has proven to be a fairly accurate estimate of horsepower when compared with dynamometer testing after the engine is built.

NOTE: The first part of the formula is used to convert airflow measurement from a basis of being tested at 28 inches of water to that of being tested at 20 inches of water.

$$\text{Horsepower per cylinder} = \text{Airflow at 28 inches of water} \times 0.598 \times 0.43$$

For example, for a V-8 that measures 231 cfm of airflow at 28 inches of water:

$$\text{Horsepower} = 231 \times 0.598 = 138 \text{ cfm at 20 inches of water} \times 0.43 = 59.4 \text{ hp per cylinder} \times 8 = 475 \text{ hp}$$

CAUTION: Even though this formula has proven to be fairly accurate, there are too many variables in the design of any engine besides the airflow through the head for this formula to be accurate under all conditions.

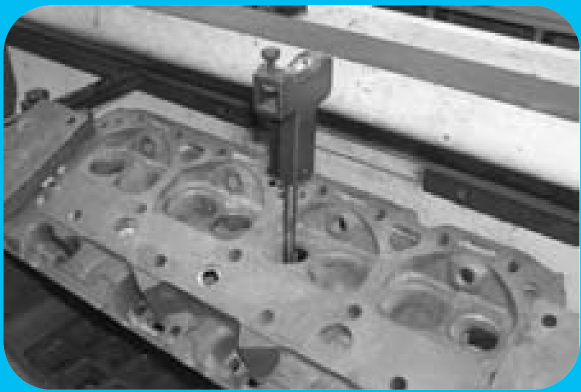
TECH TIP

DO NOT SIMPLY BOLT ON NEW CYLINDER HEADS

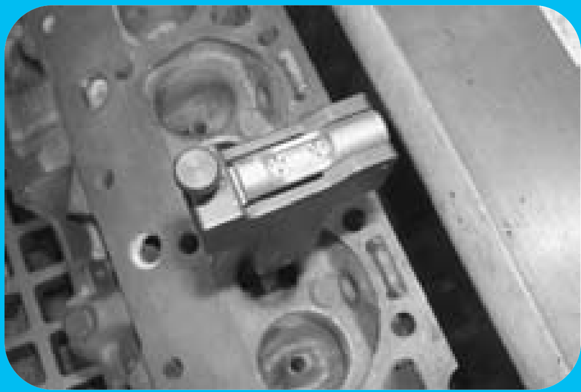
New assembled cylinder heads, whether aluminum or cast iron, are a popular engine buildup option. However, experience has shown that metal shavings and casting sand are often found inside the passages.

Before bolting on these “ready to install” heads, disassemble them and clean all passages. Often machine shavings are found under the valves. If this debris were to get into the engine, the results would be extreme wear or damage to the pistons, rings, block, and bearings. This cleaning may take several hours, but how much is your engine worth?

INSTALLING A NEW VALVE SEAT Step-by-Step



STEP 1 After the valve guide has been replaced or checked for being within specification, insert a pilot into the valve guide.



STEP 2 Level the bubble on the pilot by moving the cylinder head, which is clamped to a seat/guide machine.

STEP 3 Select the proper guide for the application. Consult guide manufacturer's literature for recommendations.

STEP 4 Select the correct cutter and check that the cutting bits are sharp.

STEP 5 Carefully measure the exact outside diameter (O.D.) of the valve seat.

STEP 6 Adjust the depth of the cutter bit to achieve the specified interference fit for the valve seat.

INSTALLING A NEW VALVE SEAT continued

STEP 7 Install the pilot into the valve guide to support the seat cutter.

STEP 8 Install the seat cutter onto the pilot.

STEP 9 Adjust the depth of cut, using the new valve seat to set it to the same depth as the thickness of the seat.

STEP 10 With the cylinder head still firmly attached to the seat and guide machine, start the cutter motor and cut the head until it reaches the stop.

STEP 11 The finish cut valve seat pocket. Be sure to use a vacuum to remove all of the metal shavings from the cutting operation.

STEP 12 Place the valve seat over the pilot being sure that the chamfer is facing toward the head as shown.

(continued)

INSTALLING A NEW VALVE SEAT continued

STEP 13 Install the correct size driver onto the valve seat.

STEP 14 Using the air hammer or press, press the valve seat into the valve pocket.

STEP 15 A new valve seat is now ready to be machined or cut.

SUMMARY

1. The exhaust valve is about 85% of the size of the intake valve.
2. Valve springs should be kept with the valve at the time of disassembly and tested for squareness and proper spring force.
3. Free and positive are two types of valve rotators.
4. Valve grinding should start with truing the valve tip; then the face should be refinished. A pilot is placed into the valve guide to position the stone or cutter correctly for resurfacing the valve seat.
5. The installed height should be checked and corrected with valve spring inserts, if needed.
6. Valve stem height should be checked and the top of the valve ground, if necessary.
7. After a thorough cleaning, the cylinder head should be assembled using new valve stem seals.

REVIEW QUESTIONS

1. Why is valve guide reconditioning the first cylinder head servicing operation?
2. When is the valve tip ground? How do you know how much to remove from the tip?
3. What is an interference angle between the valve and the seat?
4. Describe the difference between cutting and grinding valve seats.
5. How is a valve seat insert installed?
6. How are the correct valve spring inserts (shims) selected and why are they used?

CHAPTER QUIZ

1. In a normally operating engine, intake and exhaust valves are opened by a cam and closed by the ______.
   - **a.** Rocker arms or cam follower
   - **b.** Valve spring
   - **c.** Lifters (tappets)
   - **c.** Valve guide and/or pushrod
2. If an interference angle is machined on a valve or seat, this angle is usually ______.
   - **a.** 1 degree
   - **b.** 0.005 degree
   - **c.** 1 to 3 degrees
   - **d.** 0.5 to 0.75 degree
3. Never remove more material from the tip of a valve than ______.
   - **a.** 0.001 inch
   - **b.** 0.002 inch
   - **c.** 0.020 inch
   - **d.** 0.050 inch
4. A valve should be discarded if the margin is less than ______ after refacing.
   - **a.** 0.001 inch
   - **b.** 0.006 inch
   - **c.** 0.025 inch
   - **d.** 0.060 inch
5. A valve seat should be concentric to the valve guide to a maximum TIR of ______.
   - **a.** 0.006 inch
   - **b.** 0.004 inch
   - **c.** 0.002 inch
   - **d.** 0.00015 inch
6. To lower and narrow a valve seat that has been cut at a 45-degree angle, use a cutter or stone of what angle?
   - **a.** 60 degrees
   - **b.** 45 degrees
   - **c.** 30 degrees
   - **d.** 15 degrees

7. Valve spring inserts (shims) are designed to ______.
   a. Increase installed height of the valve
   b. Decrease installed height of the valve
   c. Adjust the correct installed height
   d. Decrease valve spring pressure to compensate for decreased installed height

8. The proper relationship between intake and exhaust valve diameter is ______.
   a. Intake valve size is 85% of exhaust valve size
   b. Exhaust valve size is 85% of intake valve size
   c. Exhaust valve size is 38% of intake valve size
   d. Intake valve size is 45% of exhaust valve size

9. Dampers (damper springs) are used inside some valve springs to ______.
   a. Prevent valve spring surge
   b. Keep the valve spring attached to the valve
   c. Decrease valve spring pressure
   d. Retain valve stem seals

10. Umbrella-type valve stem seals ______.
   a. Fit tightly onto the valve guide
   b. Fit on the valve face to prevent combustion leaks
   c. Fit tightly onto the valve stem
   d. Lock under the valve retainer