

Valve Seat Installation Procedures

By Larry Carley

Valve seats are an extremely important part of a cylinder head because the seats cool and seal the valves. They also support the valve when it closes, which affects both valvetrain geometry and valve lash. If a seat is damaged, cracked, loose, receded or too badly worn to be recut or reground, it can cause a variety of problems: loss of compression, valve burning, valve failure, valvetrain wear and breakage, even head and valve damage if the seat comes loose.

For that reason, replacing valve seats is often necessary when reconditioning aluminum or cast iron cylinder heads. Another reason to replace a seat is if a valve has broken because the seat is not concentric with the guide. Misalignment between the seat and guide causes the valve stem to flex every time the valve closes. Eventually, this flexing leads to metal fatigue and valve failure. When this happens, the counterbore must be remachined (if the head is salvageable) to realign the seat with the guide.

New seats may also be required if a cylinder head has been straightened or welded, if there's any evidence of corrosion around the outside diameter of a valve seat, or if the engine is being converted to run on a dry fuel such as propane (LPG) or natural gas.

Integral seats in cast iron heads are no less important even though the seats are part of the head itself. An integral seat may have to be cut out and replaced with a new insert if the seat has receded, is badly worn or damaged.

How Often?

Some experts say when late model aluminum heads are reconditioned the valve seats should always be replaced to maintain correct valvetrain geometry. This applies to overhead cam engines as well as pushrod engines. It's expensive but is usually necessary to restore proper installed valve height and valvetrain geometry.

Most valve seat failures—more than 50 percent—are mainly due to one of two things: Misapplication by using the wrong valve/valve seat combination, or valvetrain "mismotion," which includes incorrect valvetrain geometry or lack of valve seat/valve guide concentricity. Pre-ignition causes a lot of seat failures, too.

When seats get too hot, micro-welding occurs between the valves and seats. The valves are harder than the seats so microscopic particles of metal from the seats stick to the valves. When the engine cools, these particles are then washed into the exhaust. This causes rapid recession of the seats and is most common in dry fuel (LPG or natural gas) engines.

Another reason for replacing seats in some late model heads is because the OEM powder metal seats become too hard to machine. Many late model gasoline engines with aluminum heads from Ford, GM, Chrysler and many imports are factory-equipped with sintered powder metal seats. Powder metal seats are used because they are harder and more durable.

Powder metal seats combine various materials to achieve special properties. Many powder metal formulas work-harden as the engine runs. A new powder metal seat that has a hardness of RC 25 when it is first installed will develop a hardness of RC 40 to 50 after several thousand miles. Seats that hard are difficult to refinish by cutting, so one alternative to grinding is replacing the old seats with new powder metal or alloy seats.

Cast alloy seats are recommended for most applications because they are easier to machine. But aftermarket powder metal seats are available for those who want to install the same kind of seats as original equipment. However, installing powder metal seats in diesel engines isn't recommended because powder metal seats can't take the heat and compression in this kind of application and may shatter.

Cast iron seats are still used for light duty intake valve applications but should never be used on the exhaust side. The metal is just too soft to withstand the operating temperatures. For exhaust valves, a hard insert made of high chrome stainless steel, high nickel alloy or a heat resistant alloy must be used. Stellite seats, which are made of a nonmagnetic cobalt alloy and are the hardest inserts available, are recommended for the exhaust valves in heavy-duty, high temperature engines and those that burn dry fuels such as propane or natural gas.

Preliminary Steps

Seats should not be replaced until the head has been thoroughly cleaned and inspected. This includes checking for cracks (especially around and near the valve seats) and checking the deck surface and cam bore for straightness. Any welding and/or straightening that may be needed must be done before re-machining the valve seats or installing new inserts.

Also, the valve guides should be replaced or reconditioned before the seats are machined. Concentricity between the seat and guide is absolutely essential for a proper alignment, good compression and long term valve durability.

The cylinder head must be dimensionally and geometrically within specifications before seat counterbores are machined. That includes cylinder head thickness, valve guide clearances, concentricity and perpendicularity. There should be no warping, twisting or any type of misalignment anywhere in the head.

Seat Removal

The first step in seat replacement is removing the old seats. A variety of methods can be used to remove valve seat inserts from aluminum heads. Putting the head in a cleaning oven is sometimes used to loosen the seats enough to where they may fall out. Knowing the secret password necessary to keep good seats in place while allowing the damaged heads to release is critical (of course, there is no password). Using an oven in this way is a lengthy process that offers no real "predictability" regarding seat loosening.

Another method that does not involve heat is to use a cutter slightly smaller than the outside diameter of the existing valve seat insert to cut away most of the old insert (this works on softer

alloy seats but not very well on powder metal seats). Stop cutting when the old seat begins to rotate in the head. What remains of the old seat can now be easily removed.

Another method of cutting out a seat is to use a die grinder to slit and weaken the seat. Just be careful not to cut all the way through the seat and into the counterbore.

Prying out valve seats also works if there is enough of a lip under the inside edge of the seat, but this technique also risks damaging the counterbore if not done carefully.

To remove hard seats, arc weld a bead all the way around on the seat. As the bead cools, it will shrink and loosen the seat.

Another trick is to place a valve that's somewhat smaller than the seat in the head and weld the valve to the seat. The valve stem can then be used like a driver to push out the seat.

Once the inserts are out, check for cracks or erosion damage under the seats in the counterbores – a common problem on many aluminum heads. If cracked or eroded, the metal can be rebuilt by TIG (tungsten inert gas) welding, and remachining the head to a new seat.

Cutting Counterbores

Many experts recommend recutting the counterbores to accept new oversized seats. Some engine builders will install new standard-sized inserts in the existing counterbores. It works on some large cast iron cylinder heads with thick walls, but it's risky on most automotive applications. The recommended approach is to remachine the counterbores to accept oversized inserts. This allows you to control the interference fit between the seat and head so the seats don't come loose.

Recutting the counterbore also allows you to control runout in the counterbore and concentricity with the valve guide. The counterbores must be smooth, round, have flat bottoms and be centered to their valve guides for proper alignment and good heat transfer between the seat and head. The final dimensions of the counterbores must be within .0005" for the proper fit.

If a counterbore is too rough, distorted or out of round, it won't make good metal-to-metal contact with the seat. It can also distort the seat. This will reduce heat flow from the seat to the head and make the valve run hot. That you don't want because it leads to valve burning and warranty problems down the road.

If you're replacing an integral seat in a cast iron head (and the cylinder head has enough thickness to accept a new seat), the counterbore should be cut to a diameter approximately .100" larger than the valve head diameter. The inside diameter of the replacement seat will typically be about .100" smaller than the valve head diameter and require a depth of about .188" to .250" depending on the application.

Accurate cuts also require proper fixturing. Keep your tooling setup as "short and tight" as possible to assure maximum rigidity. The less deflection in the tooling, the more accurate the dimensions of the cut and the greater the concentricity of the counterbore.

Be careful not to distort or put a twist into the head when clamping it to a fixed rail holding fixture.

You'll get the most accurate cut with correct size pilots (which must be straight), and using the correct spindle speeds and feeds. Machining recommendations vary depending on the type of equipment and tooling used.

Something else to keep in mind when cutting counterbores is that the seats for many late model heads don't go by fractional sizes anymore. Seat sizes can vary considerably so using a fixed size cutter is not the best choice. An adjustable cutter will provide the flexibility you need to properly size the counterbores.

Interference?

The recommended amount of interference between the valve seat insert and head may vary depending on the size of the insert, the type of insert (alloy or powder metal) and type of head (cast iron or aluminum). The best advice is to use the amount of interference recommended by the OEM engine manufacturer.

Too much interference runs the risk of cracking the head while too little interference increases the risk of the seat coming loose or falling out. One of the leading causes of seats coming loose, however, is not the amount of interference between the seat and head but elevated operating temperatures. Anything that causes the exhaust valve to run hot may also cause the seat to loosen.

The sound rule of thumb is to use .005" press fit when installing seats in cast iron heads, and .007" minimum in aluminum heads regardless of what type of valve seat inserts they are installing. You should be able to put a concentric seat into a concentric hole with the right amount of interference and have it stay there without using any type of locking fluid, staking or peening when installing seats; however, a lot of non-production engine rebuilders use a locking fluid because they believe that it helps fill any voids between the seat and head for improved heat transfer and valve cooling.

Seat Installation

Installing the new seats once the counterbores have been cut is a fairly simple procedure. A piloted driver is used to push the seat into position. Many aftermarket seats have a bevel or radius on the outside lower edge to make installation easier. Make sure this side faces down when installing the seat.

Some engine builders preheat the head or chill the inserts in a freezer or with nitrogen prior to installing them to make the job easier. Others say this should not be necessary if you use the normal amount of interference fit. Even so, it's another trick that may come in handy on a problem head or application that requires something out of the ordinary.

Seat Finishing

After the seats have been installed, they can be finished as required. The guides must be reconditioned or replaced before doing this, however, because all seat work is done by centering off the guides.

Seats should be as concentric as possible for a tight compression seal and proper valve cooling. The rounder the seat, the better. Seat runout should not exceed .001" per inch of seat diameter. Some shops aim for .0005" or less of runout. The best way to check concentricity is with a runout gauge. Pulling vacuum on the valve port with the valve in place is another method for checking the mating of the seat and valve. But the ability to hold vacuum is no guarantee of concentricity. Both methods should be used to check the quality of your work.

Seat width is also important for good heat transfer, proper sealing and long valve life. If the seat is too narrow, wear resistance and heat transfer can suffer. And if the seat is too wide, there may not be enough pressure to provide a tight seal. A wide seat also tends to trap deposits that can hold the valve off its seat. This too, can reduce heat transfer as well as compression. As a rule of thumb, the ideal seat width for intake valves is usually around 1/16". For exhaust valves, it's 3/32" – or whatever the manufacturer specifies.

The point at which the valve and seat mate is also important. If the area of contact is too high on the valve face (too close to the margin), the valve may be sunken into the head. This increases installed height, upsets valvetrain geometry and restricts free breathing. If the area of contact is too low on the face (too far from the margin), the valve will ride too high on the seat. As the engine warms up and the valve expands, the contact point moves down the valve face away from the margin. The valve may lose partial contact with the seat causing it to lose compression and run hot.

Ideally, the valve should contact the seat about one third of the way down the valve face (about 1/32" from the margin) so there is about 1/64" of overhang between the margin and top of the seat.

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