Valve Stem Seals Materials and Designs

By Larry Carley

Valve stem seals play a critical role in controlling valve lubrications well as oil consumption. If the seals do not fit properly or are not installed correctly, the guides may be either starved for lubrication or flooded with oil. Either way, the engine is going to have problems ï and youôre going to have an unhappy customer and perhaps a warranty claim.

Seal longevity is another issue that should be considered when choosing replacement valve stem seals. The material from which the seals are made must be capable of withstanding the harsh operating environment inside the engine for an extended period of time (not just the warranty period). Some materials are longer lived than others, which is usually reflected in the materialôs price.

High operating temperatures cause lower grade materials such as nitrile to harden and become brittle over time. Eventually, this can lead to cracking, loss of oil control and seal failure. When a valve stem seal loses its ability to control the amount of oil that enters the guide, it can cause a variety of problems.

Spark plug fouling may occur as oil ash builds up on the plugôs electrodes. The accumulation of heavy, oily carbon deposits on the backs of the intake valves may cause hesitation and performance problems in some fuel injected engines. As carbon deposits build up in the combustion chamber, compression may increase to the point where it causes engine-damaging detonation and/or pre-ignition problems.

Increased oil consumption due to worn or leaky valve stem seals will also increase hydrocarbon (HC) emissions in the exhaust ï which may cause a vehicle to fail an emissions test. Oil burning can also damage the catalytic converter because phosphorus in motor oil contaminates the catalyst. If oil is fouling the spark plugs, misfiring can cause HC emissions to soar as unburned fuel passes into the exhaust. This may damage the converter because unburned fuel in the exhaust makes the converterôs operating temperature soar.

The converter may overheat to the point where the substrate breaks down or melts creating a restriction or blockage in the exhaust.

Debris from deteriorating seals is another concern that can cause additional problems inside an engine. Pieces of the seal may clog oil passages starving lifters or rockers for lubrication. Debris may also end up in the crankcase where it may be sucked into the oil pickup screen creating an obstruction that causes a loss of oil pressure ï and you know what that means!

A material difference

Depending on the application and the design of the seal, the material used may be nitrile, polyacrylate, fluoroelastomer (Viton), silicone, nylon or Teflon®. Nitrile is one of the least expensive materials, and has been used for many years in umbrella or deflector type seals for older pushrod engines. Nitrileôs temperature range is -40º to 250º F. It can withstand intermittent operating temperatures of up to 300º F, which is usually good enough for intake valve seals but not exhaust valve seals.

A step up from nitrile is polyacrylate. Polyacrylate is about twice the cost of nitrile and has a temperature range of -30º to 350º F; it is a good step up from nitrile for umbrella seals.

It is also used for some positive seals as well. Some engines such as older big block Chevy V8s have positive seals made of nylon. Nylon is a hard material with a temperature rating of -40º to 300º F. Nylon is impervious to oil, but it can melt if the engine overheats.

A higher grade seal material is silicone, which is rated from -60º to over 400º F, depending on the grade of the material. Some silicone seals can operate at 330º F continuously and handle up to 400ºF intermittently, while others can take 375º and go as high as 450º to 500º F intermittently without damage. Silicone is a good high-temperature material, but costs four to five times as much as nitrile.

In the mid-1980s, positive valve stem seals made of fluoroelastomer materials (FKM and Viton) began to appear in import and domestic overhead cam engines. Fluoroelastomer seals cost roughly 12 times as much as nitrile, but have a temperature range of -5º to 450º F, making them one of the best high-temperature seals available.

Viton has good flexibility like nitrile, which means it can handle some run-out between the valve stem and guide. It is also considered to be a more durable material than silicone. Viton also has better wear resistance than most other seal materials, making it a good choice for applications where long term durability is a must.

The highest rated positive seal material is Teflon, with a range of -5º to 600ºF. Like nylon, Teflon is a hard material so it cannot handle as much run-out between the stem and guide as more flexible seal material scan. Whatôs more, Teflon is expensive ï costing 20 to 25 times as much as nitrile.

Material identification

Itôs important to know what type of material the valve stem seals are made of when rebuilding an engine so you can replace same with same, or better. Upgrading to a better grade of material should certainly be considered if the original seals are badly deteriorated and you have a choice as to the type of seal material thatõs available for the engine. Upgrading from nitrile to polyacrylate, silicone or Viton, for example, would provide better durability and longevity if the original nitrile seals were found to be hardened or falling apart.

Identifying seal material

How can you tell one type of seal material from another? Color is not necessarily an accurate guide because the same material may come in several different colors. Nitrile seals may be black, green or blue. Polyacrylate is usually black, while Viton may be brown, orange or black. Nylon has a translucent appearance while Teflon is white. Silicone is usually black.

Replacement seals may not be the same color as the OEM seals even if the materials are identical, while others maybe the same color but made of a different material. The color identification information contained in some OEM service manuals is also inaccurate. So going by color alone is not a very good way to tell what type of material is in a valve stem seal.

Some engines may also have two different types of seal materials which may be color coded to distinguish the intake and exhaust valve guide seals (a higher temperature material being used for the exhaust valves). AERA has published a technical bulletin (September1997, TB 1488) identifying the seals used in 1984 to õ96 Chrysler/Jeep2.5L and 4.0L engines. On this application, black seals (polyacrylate) are used on the intake valves and brown seals (Viton) are used on the exhaust valves. One way to identify an unknown seal material is with a burn test:

- Nitrile will burn easily and produce thick black smoke that smells like burning rubber.
- Polyacrylate will also burn easily producing a less dense black smoke that smells like burning plastic.
- Silicone will turn white when burned, regardless of the original color of the seal, producing smoke that has little color and no odor.
- Viton/fluoroelastomer seals will be difficult to burn and produce white smoke with no odor. The seal color will either remain the same or turn black.

Choosing the "right" seal

Most aftermarket suppliers of valve stem seals use the same type of seal material as that used by the original equipment engine manufacturer. Thatõs because many aftermarket suppliers source their seals directly from the OEM supplier rather than make the seals themselves. Others who do manufacture some of their own seals may use the same or a higher grade of material in their seals.

Some suppliers substitute silicone or Viton for nitrile to provide better, higher temperature performance for extended durability. But there are also aftermarket suppliers who cater to those who are looking for the least expensive seals they can buy. Such suppliers typically use the least expensive grade of seal material (nitrile) to reduce cost.

The "right" seal material for any given engine application will depend on the design of the engine and OEM seal, the "normal" engine operating temperature, how the engine will be used (normal service or heavy-duty use), whether or not the OEM seals performed adequately in the new engine application, and how important seal longevity is to you and your customer.

A lower grade seal material such as nitrile may be okay in a low-priced rebuilt engine for normal everyday driving, but may not be adequate in a more demanding application. Chuck Wible of Anderson Automotive, Louisville, TX, is an example of a rebuilder who says he usually likes to go up a step when replacing seals in his rebuilt engines. "If the original seals are nitrile, I usually replace them with polyacrylate or silicone. I prefer silicone for umbrella seals and Viton for positive seals," he said.

Seal design

Valve stem oil seals come in two basic types ï umbrella seals and positive seals. Used mostly on older pushrod engines, umbrella or deflector style seals (which also include O-rings) are installed on the valve stem and ride the stem up and down as the valve opens and closes.

An umbrella seal controls the amount of lubrication the valve guide receives by deflecting oil splash away from the guide. An O-ring does the same thing by preventing oil from flowing down the valve stem into the guide. Umbrella seals are a simple and effective design, and are easy to install. But they do not provide the same degree of oil control as positive seals.

Positive seals are used on most late model engines for two reasons: emissions control and oil control. A positive valve stem seal provides a tighter seal which reduces the amount of oil that enters the guides. This minimize soil consumption and hydrocarbon emissions, and also helps to keep intake vacuum high for better idle quality (air being sucked past worn valve guides and seals can cause lean misfire and a rough idle).

A positive seal is also needed in most overhead cam engines to prevent oil from flooding the guides. An umbrella seal cannot handle the amount of oil thatõs found in most OHC heads.

Unlike an umbrella seal, a positive seal does not move. It is pressed in place on the end of the valve guide and wipes the oil off the valve stem as the stem moves up and down. The seal does not actually make direct contact with the stem but rides on a thin film of oil creating a hydrodynamic seal. This allows a small amount of oil to slip past the seal to lubricate the guide. For this reason, a precise fit is extremely important with a positive seal to get accurate oil metering.

If a positive seal fits too loose around the valve stem, too much oil will get past the seal and flood the guide. Oil consumption will go up along with all the problems that go with too much oil in the combustion chamber. If a positive seal fits the stem too tight, the hydrodynamic seal may be lost as the oil film is scraped off the stem. This will starve the guide for lubrication causing increased valve stem and guide wear (seal wear, too), and may even cause the valve stem to overheat, gall and stick.

Subtle differences in the design of the sealing lip and the wire or spring around the neck area of the seal play a big role in the seal’s ability to do its job. The wire or spring in the neck area helps support the seal so it can conform to the valve stem. Design differences here and in the design of the lip determine how much deviation in valve stem diameter the seal can handle.

Most positive seals can’t tolerate more than .005" difference in the valve stem diameter from the stock size. If you’re installing new valves with oversized stems, therefore, replacement seals with a larger inside diameter (I.D.) would be required. Likewise, if you’re reusing valves and grinding the stems, replacement seals with a smaller I.D. would be needed.

Even so, some aftermarket positive seals are designed to handle valve stems from .005" undersize to .015" oversize. So before choosing a seal, check with the seal supplier to determine the range in valve stem sizes it can accommodate.

Lip abrasion of a positive seal can occur if oversized valves are used with standard sized seals. Lip damage can also occur if the valve stems have been reground and the finish of the stems is too rough. But one of the most common causes of lip damage is not lubricating the seals and stems when the engine is assembled.

Some type of lubrication must always be used with positive seals (motor oil or assembly lube). The seal I.D. must also be protected during installation by using a sleeve over the end of the valve. The sharp edges around the keeper grooves may cut or tear a positive seal, so that’s why some type of protection is required during assembly.

Another thing that needs to be considered with positive seals is concentricity. The metal jacketed-type of positive valve stem seals found on many Japanese engines and late model domestic OHC engines provide good support and help hold the seal perpendicular to the valve stem. However, they are more rigid than the non-jacketed-type of positive seals (the same is true for Teflon positive seals).

Consequently, the outside diameter (O.D.) of the guide chimney needs to be concentric with the inside diameter of the guide for a good seal. On most applications, there should be no more than about .010" of run-out. Too much run-out can deform the seal lip preventing it from sealing properly resulting in increased oil consumption and uneven seal wear.

On small block Chevy and Ford V8 engines where positive seals are used on cast iron guides, lack of concentricity is often a cause of oil consumption and premature seal failure. Some engines may be off as much as .030" from the factory! The same kinds of problems have been seen in Ford 6.9L and 7.3L engines. Concentricity problems can usually be avoided by centering off the valve guide I.D. when machining the guide chimney O.D.

Some newer engines such as GMœs 3.1L and 4.3L V6 and Fordœs 4.6L V8 use a positive seal design that has an integral spring seat. This keeps the valve spring from galling the aluminum head and also helps center the seal on the valve stem. On heavy-duty diesels this design is often used to keep the seals from blowing off the guides when the engine is under boost pressure.

Replace same with same?

Most seal suppliers say rebuilders should stick with the same design of seal that was originally used in an engine. In other words, replace umbrella style seals with umbrella seals, and replace positive seals with positive seals.

Older pushrod engines usually have O-rings or umbrella style valve stem seals because that was the type of seal design that was in general use at the time the engine was originally designed and built. So, in most instances, replacing same with same should provide the same degree of oil control and lubrication.

Positive seals, on the other hand, are used on most late model engines and OHC engines to minimize oil consumption and emissions. Positive seals are also required on most OHC engines because umbrella seals canœt handle the volume of oil found in most OHC heads.

Some rebuilders, though, donœt always replace same with same. The reasons vary depending on the application. On some engines, a rebuilder may replace the original umbrella style seals with positive seals to get better oil control. Some rebuilders are also replacing positive seals in certain pushrod engines with umbrella style seals to save money and make installation easier.

Chuck Wible of Anderson Automotive says heœs had great success converting newer small block Chevy and Fords as well as173 Chevys from positive seals to umbrella seals. "It saves half the cost, and makes it easier and quicker to install the seals," said Wible. "But it only works on some engines. You have to look at the angle of the head. If thereœs no risk of flooding the guide area with oil, you can probably change to an umbrella style seal. Otherwise, you should stick with a positive type of seal. The Chevy 151, for example, has a flat head that puddles oil so it would not be a good choice for an umbrella seal."

Keeping “tabs” on temperature

Heat is an engineôs worst enemy. Heat can damage valve seals as well as many other engine parts, so itôs not surprising that overheating is a common cause of engine failures and warranty claims.

The most common cause of overheating is loss of coolant, often due to a failed radiator or heater hose and/or a leaky radiator. An engine can also overheat if the thermostat sticks shut (a good reason for using a "fail-safe" type of thermostat). But overheating can also occur if the cooling system is not filled properly after installing a rebuilt engine or when changing the coolant (air pockets in the block).

An engine can also run hot if thereôs a blockage in the radiator, the cooling fan or fan clutch fails, thereôs a blockage in the exhaust system, ignition timing is incorrect or the fuel mixture is off. Regardless of what caused the engine to overheat, itôs often hard to prove that overheating resulted in engine damage.

The telltale symptoms of severe overheating may include piston seizure and scuffing, galled valve stems, damaged valve guides, and/or a warped or cracked cylinder head. But these conditions may also be blamed on other factors such as incorrect assembly tolerances or a lack of lubrication.

Your first line of defense in such instances is proof that the engine did indeed overheat (regardless of the cause). A heat tab can provide such proof by indicating a certain temperature was exceeded in operation.

A typical heat tab for a gasoline engine has a center plug that melts out at 250º to 255º F. If the engine has gotten hot enough to melt the heat tab, any damage it suffered is likely not the rebuilderôs fault. Lower temperature heat tabs are also available for other applications such as marine (187º to 192º F) and diesel (225º to 230º F).

Heat tabs, used properly, provide an acceptable defense against unjust warranty claims. The validity of heat tabs as a reliable and proven means for monitoring engine temperature has also held up successfully in court cases involving engine warranty claims.

Heat tabs can be mounted almost anywhere on the engine block or cylinder head. Many rebuilders will install one heat tab on the block and one on each cylinder head in a V6 or V8 engine.

The heat tab should be positioned where it will give a good indication of average head temperature, but away from exhaust ports, manifolds or pipes. The heat tab should also be located in a protected position so it isn’t accidentally damaged or knocked off during engine installation or normal use. For engine blocks, a good location is in the recess of a freeze plug. For heads, almost any exterior surface not adjacent to the exhaust ports will work.

Traditional heat tabs are small round metal buttons that are attached to the engine with high-temperature, high-strength adhesive. For a secure attachment, the mounting surface on the engine must be clean (no oil, dirt or grease).

Heat indicating labels available through Engine Rebuilders Association (AERA) can also be used to monitor temperature readings. The self-adhesive labels have a series of windows from 180º to 280º F that turn black when the indicated temperature is reached.

One very important point to keep in mind when using heat tabs or labels for warranty protection is to make sure your customer understands why the tab or label is on the engine. They should know that the engine warranty is void if the tab indicates overheating has occurred or if the tab is removed.

For added protection, some rebuilders have been known to hide an additional heat tab in a less obvious location just in case the most visible heat tab has been removed or tampered with.

Using a "personalized" heat tab with your company’s name or logo on it is also a good way to identify parts you’ve rebuilt, and to assure the heat tab on the engine is the same one you installed.

Heat tabs are relatively inexpensive. Metallic heat tabs generally cost less than about 35 cents each, and heat-sensitive labels can be bought for less than 95 cents each. Considering the potential expense of a warranty claim, heat tabs are very cheap insurance.