

## **Valves, Retainers & Springs**

**By Larry Carley**

New materials, improved designs and lower prices (at least for some valves). That pretty much sums up what's going on with valves, retainers and springs today. These are extremely important parts in every engine because of their impact on engine performance, durability and cost.

### **New Or Reman Valves?**

You can now sell a reman cylinder head with new valves for about the same price as a head with reclaimed valves. More rebuilders moving away from reclaiming valves and are buying new valves. The prices have are competitive with reclaimed valves. You don't have to clean, sort, rechrome or grind valves if you use new ones, and you don't have to install guides or liners either. All you have to do is ream out the guides to accept a new valve with an oversized stem and drop in the valve. It's a much faster and easier process for most people.

For many years, production engine builders were the only ones who were buying new valves in significant numbers; however, now most of the smaller shops are buying new valves. Why the change? Buying new valves eliminates a bottleneck in the shop and speeds everything up. Rebuilders can turn jobs around faster, lower their labor costs, and be more productive and profitable. In fact, most production engine builders today buy new valves and ream out the old guides to .015" oversize, then drop in the new valves with oversize stems.

Today's engines also require higher quality valves that contain more nickel to withstand the heat. Modern exhaust valves are 21-4N, an alloy which contains four percent nickel. Exhaust valves require tougher alloys because they're exposed to much higher operating temperatures than the intakes. They receive little cooling from the incoming air/fuel mixture. Consequently, exhaust valves typically see temperatures of up to 1,400° to 1,600° F. So the alloy must be tough enough to withstand this kind of punishment mile after mile.

Even intake valves are feeling the heat. On some of the later model Chrysler turbocharged engines, the intake valves are "HNV" alloy, which is a high chromium steel alloy capable of withstanding higher operating temperatures.

### **Valve Alloys**

Valve alloys have gradually improved over the years as the demands on valvetrain longevity and durability have gone up. Since the 1950s, exhaust valves made of 21-2N (2 percent nickel) stainless steel have been commonly used for original equipment exhaust valves in many passenger car and light truck engines. It's a good alloy that can usually go up to 100,000 miles in normal use. But in recent years, the OEMs have raised their durability requirements to 150,000 miles or higher, which has required upgrading to tougher materials such as 21-4N (4 percent nickel) stainless steel. Nickel improves strength, heat transfer and ductility. 21-4N steel meets the "EV8" SAE specification for exhaust valves and is now the preferred alloy by many valve manufacturers and engine rebuilders.

Valve alloys are classified by various letter and number codes that correspond to the type of material used. The Society of Automotive Engineers (SAE) has a letter/number classification system that identifies the various valve alloys.

Intake valves are typically made of low alloy steels, or heat and corrosion resistant high alloy steels. A "NV" prefix in the identification code designates a low alloy structural steel while a "HNV" designates a high alloy steel.

With exhaust valves, "EV" prefix denotes an austenitic steel (which is magnetic) while "HEV" denotes a high strength (usually nonmagnetic) alloy for a severe service application. The commonly used 21-4N stainless steel alloy is classified as an "EV8" alloy by SAE. It contains 21 percent chromium and 3.75 percent nickel. Inconel® 751, by comparison, is classified as an HEV3 alloy by SAE.

Valves made of stainless steel can usually be sorted from carbon steel alloys with a magnet because most stainless alloys are nonmagnetic. But beyond that, you can't tell much about the alloy a valve is made from without referring to the OEM specifications (which can be found in service manuals, OEM literature or AERA bulletins, as well as PERA's EngineDataSource.com and other sources).

The type of valve alloy that's required for a particular application will depend on how the engine will be used, the type of fuel it burns, the speed at which it will operate, its power output, the design of the valvetrain and head, how many miles the engine is expected to last, and most importantly, how much you or your customer are willing to spend on the valves themselves.

There is no such thing as a universal valve alloy that's right for every application. That's why there's a broad spectrum of valve alloys in use today. Ideally, you should try to use replacement valves that are made of the same or better alloy than the original. But sometimes you may not know what kind of alloy was used in the OEM valves - which may cause problems if you replace the OEM valves with ones that are made of a less robust alloy. This is especially important in turbocharged and supercharged engines as well as diesels. The valves used in diesel engines frequently have a high chromium content to protect against sulfur corrosion caused by the fuel. If that protection isn't restored, the valves won't last.

It's of the utmost importance to consider material selection, not just size, with regard to valves and other components, especially with a lot of heavy duty applications. Just because a valve fits doesn't necessarily mean it's right for the end use.

For example: There are two versions of a Cummins K-Series engine—one standard, one premium. The standard engine is often used as a standby generator while the premium engine is usually a full-time generator. The valves and the valve seat inserts inside both are identical in size, but the materials are vastly different. If someone thinks he has one head and not the other, he very easily could wind up using inferior grade valves in a demanding application.

It's also an issue with turbocharged and non-turbo applications. Material selection is at least as critical as size selection. This requires rebuilders to get their questions answered from their

suppliers ahead of time. Such can be an issue when ordering head parts from some aftermarket suppliers: if you think you're buying one kind of product, you actually could be getting another. If you think you're getting a deal on a particular size valve and then it turns out to that it's the wrong material for the application, any savings are gone when premature failure occurs.

## **Exotic Alloys**

Other valve materials include Stellite® (a registered trademark of the Deloro Stellite Company), the aforementioned Inconel (a trademark of the Inco family of companies) and titanium.

Stellite is a hard facing material that's often required for heavy-duty diesel and gasoline exhaust valve applications. Stellite is a cobalt base material with a high chromium content. It comes in various grades depending on the mix of ingredients that are used in the alloy. The hard facing is applied to the valve face to protect against oxidation and corrosion. It may also be used on the stem tip for added wear resistance.

Inconel is another "superalloy" that's sometimes used for exhaust valves because of its superior high temperature strength. Inconel is a nickel base alloy with 15 to 16 percent chromium and 2.4 to 3.0 percent titanium (the mix depends on the grade of alloy that's used). General Motors has switched to exhaust valves made of Inconel 751 in some of its late model medium duty truck engines to solve a valve erosion problem it was experiencing with 21-4N stainless exhaust valves.

One of the more exotic alloys is titanium. You won't find it in any normal production engines, but it is often used in racing and high performance applications. Titanium's main advantage is its light weight. A titanium valve weighs a third to half as much as a comparable valve made out of steel. The light weight allows the engine to handle more rpms before the valves start to float. Lighter valves also allow the use of more radical cam profiles that open and close the valves more quickly. From a durability standpoint, titanium is in the same ballpark as stainless. But from a cost standpoint, it's for racers with deep pockets only.

## **Stem Finishes**

Chrome-plated stems are used on most valves today to protect the stem from galling when the engine is first started. It also helps reduce valve seal wear on engines that use positive valve seals.

The thickness of the chrome plating can vary from a thin flash of .0002 to .0007" up to a hard plating of as much as .001". It's interesting to note that chrome plating actually produces a rougher, not smoother, surface. So it's important that the valve stem be properly finished to around 18 microinches before the stem is plated.

Many Japanese OEMs use a black nitride coating on the valves instead of chrome plating. The nitride coating, which is applied in a salt bath treatment, protects the stems against scuffing and wear.

When used valves are salvaged and the stems reground, grinding removes the chrome flashing (or nitriding) that was originally on the stem. This means a reground valve must be used with either a bronze liner or guide, or replated to restore the original scuff protection if used with a cast iron guide.

## **Tapered Stems**

Though most engines use valves with straight stems, some exhaust valves have stems that are tapered. The diameter of the stem nearest the valve head is reduced to compensate for thermal expansion. The temperature of the valve gets progressively cooler as you move up the stem. If the stem-to-guide clearance is not enough to handle the heat, the valve stem will scuff. So either the guide clearance has to be increased along the entire length of the guide for the hottest region of the stem, or a valve with a tapered stem can be used to reduce clearances for better cooling. The heat profile of the stem is mapped so the taper is right to handle the thermal expansion. An inverse taper allows the stem to become straight in the guide as the valve heats up. The result is no scuffing or transfer of metal even if the engine is allowed to overheat to 320° F.

Swirl polishing is used by many valve manufacturers to improve durability of high-performance street valves. Polishing the back of the head relieves stress risers that can cause the stem to break under severe loads. Many valves that are swirl polished also have necked down stems in the port area to reduce the amount of restriction created by the stem for better air flow and breathing.

## **Springs**

Weak or broken valve springs can't hold compression and may even lead to bent valves if the valves can't close quickly enough to keep out of the way of the pistons. That's why most engine builders pay close attention to the springs that go into their engines.

As far as stock springs are concerned, spring heights and pressures can be tested to see if they are still within specifications. As long as a reclaimed spring meets OEM specifications and is not out of square, severely corroded or damaged, it should be safe to reuse. But if the springs have seen a lot of miles, there's always a chance that metal fatigue may be setting in increasing the risk of spring breakage and failure. New springs don't have any miles on them and are starting out fresh, so the risk of breakage is extremely low—as long as rpms are held within normal limits.

For high performance applications, stock springs rarely cut the mustard. Upgrades are almost always necessary. Most stock springs and valvetrain components are designed for engine speeds of 5,500 to 6,500 rpm. For higher revving engines, stiffer springs are needed to keep the valvetrain under control.

Stiffer springs exert more force to keep the lifters in constant contact with their lobes and to overcome the increased momentum of the valves, rocker arms and pushrods at higher rpms. But springs that are too stiff for an application can create just as many problems as ones that are too weak. A really stout set of springs will increase cam lobe and lifter wear. They may also be too much for the stock rocker arms, pushrods, spring retainers and keepers and exert more force than the stock parts were designed to handle.

The key here is to follow the recommendations of the cam manufacturer when it comes to choosing stiffer springs. Better yet, buy a cam kit that includes new lifters and springs with the cam. This way you'll know the parts are properly matched.

For small block street/strip flat tappet cams with up to about a .450" lift, you can usually get by with stock springs. Or, you can upgrade to stiffer single springs that give about 100 to 115 lbs. of seat pressure when the valves are closed and no more than about 300 lbs. when the valves are fully open. For small block street/strip flat tappet cams with .450" to about .500" lift, stiffer springs are a must.

For a cam with more than .500" lift, even stiffer "conical" springs or "double-springs" are necessary. This, in turn, usually requires additional changes:

- Flycutting the spring seats in the heads to accept larger diameter springs, or dual or triple springs.
- Changing the spring retainers to ones that are designed for double or triple springs.
- Changing the valve seals to accommodate conical or double springs. This may require machining the guides.
- If the heads have push-in rocker studs, the studs will have to be pinned or replaced with screw-in studs.
- Replacing the stock pushrods with stronger and stiffer 4130 chrome moly pushrods (to prevent pushrod flexing and breakage).
- If the springs provide more than 350 psi of pressure when the valves are open, the stock stamped steel rockers will also have to be replaced with stronger steel or aluminum rockers.
- For highly modified/racing engines, a "stud girdle" can be installed to reinforce and steady the rocker arm studs. A "rev kit" is another add-on that can improve reliability and rpm potential. The kit consists of extra springs that fit over the lifters to assist the valve springs and to keep the lifters in their bores should a rocker arm or pushrod break.

## **Spring Retainers**

Two alternatives here for upgrading valvetrain performance are aftermarket hardened steel retainers or lightweight titanium retainers (aluminum retainers are generally considered too soft). For the street, steel retainers with stock 7 degree keepers work fine. For racing or high rpm roller cams, titanium retainers with 7 or 10 degree keepers are best. Some keepers have an extra step inside that reinforces the bottom of the retainer and reduces the risk of the valve pulling through at high rpm.

Finally, be sure to check the clearance between the retainer and the top of the valve guide/seal at maximum valve lift when using non-stock retainers and springs. A minimum clearance of .060 in. is usually recommended to prevent any interference.

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