

# VALVE SPRINGS

BY MIKE MAVRIGIAN

In this article, we'll try to cover the basics of performance valve springs, in terms of dimensions, selection advice, handling precautions and more. Consider this somewhat of a basic overview of valve spring technology.

## INSTALLED HEIGHT, OPEN PRESSURE AND COIL BIND

Valve spring installed height refers to the dimension measured from the bottom of the spring retainer (where the top of the outer spring contacts the retainer) to the spring pocket in the cylinder head, when the valve is closed.

Installed height affects spring tension, and is the determining factor of what the spring closed tension will be. The camshaft specification card will list the suggested spring installed height for that cam with the cam maker's recommended springs. For example, if the card notes that a specific valve spring part number should be installed at 105 lbs at 1.700", that means that if the spring is installed at a height of 1.700", this should place 105 lbs of tension with the valve closed. Never assume that this is correct. Always check this on a bench-mounted valve spring tester.

Changing installed height will affect spring tension. If you need to reduce installed height, you can place a shim (of the needed thickness) under the spring, or you can use a different design retainer with a shallower dish (using a retainer with a deeper dish will increase installed height). You can also use a valve lock that is designed to change the retainer height location.

As the installed height is decreased, spring tension will increase. This also reduces the distance that

the spring can travel before reaching coil bind. If installed height increases, spring tension will decrease, but the spring travel will increase before reaching coil bind.

The valve spring needs to have enough travel (from closed-valve installed height to a safe margin before coil bind) to suit the valve lift created by the camshaft lift and rocker arm ratio. The safety margin (full travel before coil bind) should be kept at a minimum of 0.060".

Valve spring open pressure represents the pressure (in psi) that's placed against the spring retainer at maximum valve lift. You need enough pressure to control the lifters as they accelerate up the cam lobe and when decelerating when ramping down past the lobe peak (when the valve changes direction from opening to closing). If the spring doesn't provide enough open pressure, the lifter can bounce over the cam lobe (valve float), resulting in the lifter smacking into the closing ramp of the lobe, potentially reducing cam lobe and lifter life.

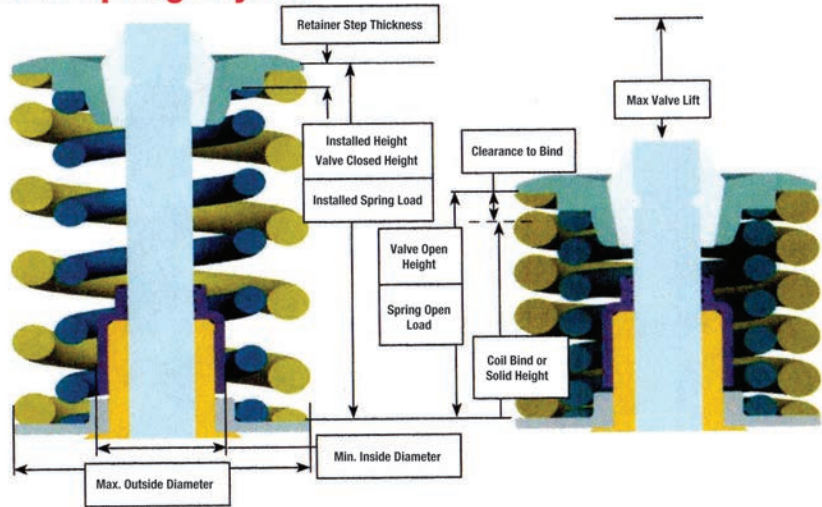
Open spring pressure is a function of the combination of spring rate, net valve lift and seat pressure. Excessive open spring pressure results in stresses placed on the pushrods and in turn, valve bounce. Lighter valves require lower spring pressures, which reduces the risk of pushrod flexing.

Valve spring coil bind takes place when the spring is compressed to a point where the coils contact each other. You can measure coil bind height by placing a retainer on top of the spring, and compressing the spring (carefully) until the coils touch each other. The distance from

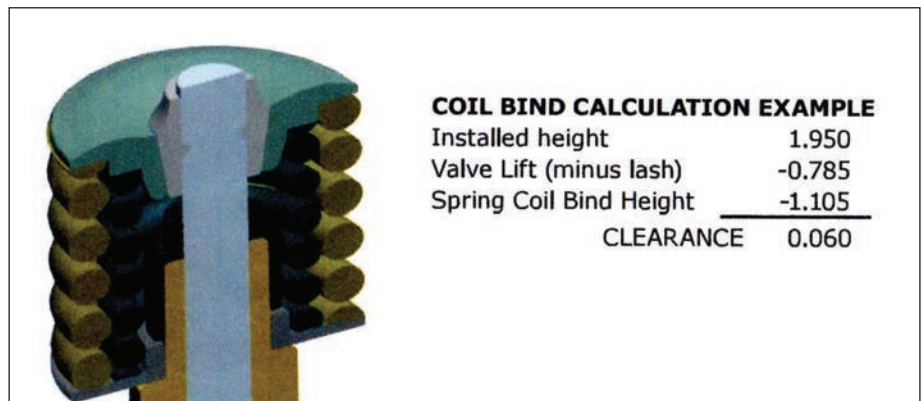




## Basic Spring Layout



Example of basic valve spring layout and applicable dimensions.  
(illustration courtesy PAC Racing Springs)



Example of coil bind determination. Installed height of this spring is 1.950". When we subtract combined valve lift (minus lash) of 0.785", we determine a coil bind height of 1.105". This provides a safety clearance of 0.060" to avoid coil bind. (illustration courtesy PAC Racing Springs)

the bottom of the retainer to the bottom of the spring is the coil bind height.

Subtract the coil bind height from the installed height. The result is the maximum spring travel. The standard recommendation to provide a safety margin is to have a minimum of 0.060" spring compression travel greater than the full lift of the valve. If the coils bind, this creates a dead-stop during valvetrain operation, so something's gotta give, including potential pushrod bending, lifter or cam damage or rocker arm failure.

The use of a bench spring tester offers a convenient method of pre-determining coil clearance. Reference the spring's installed height. Install the valve into

the cylinder head (remember to dedicate each valve to each valve location in each head...that way, once measured and cleared, you know that the particular valve will fit properly in a specific location. Don't assume that you can mix up the valves). With the valve fully inserted into the (intake or exhaust) location, with the valve fully seated, install locks and the retainer. Pull up on the retainer and measure the distance between the underside of the retainer (where the spring contacts the retainer) to the spring seat. If you're using hardened spring seats, be sure to install for this check.

Remove the spring from the head and place the spring on the tester. Compress

# VALVE SPRINGS

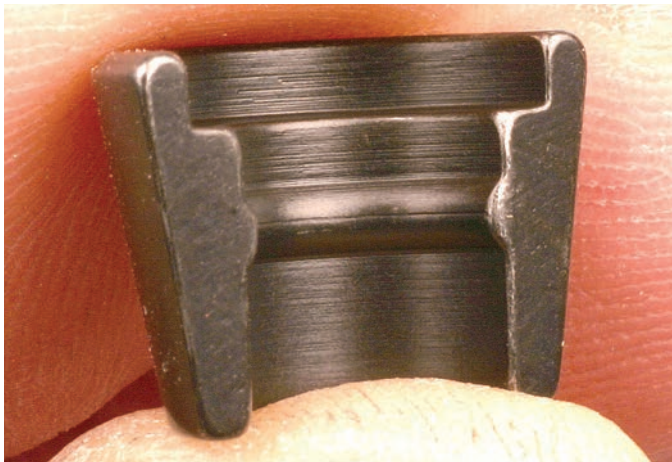
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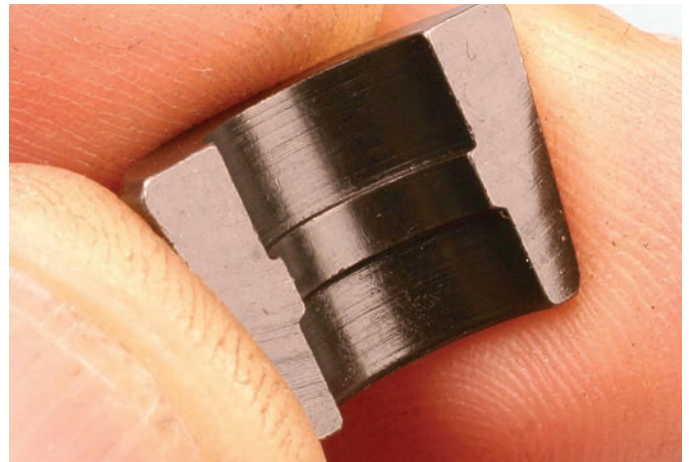
This valve features a radius lock groove. You need to pay attention to this. Only a “beadlock” style lock (keeper) will work with this type of groove.



This valve features a square-cut groove. Only a square-key lock will work here. Never assume that your locks (keepers) are correct for the valves at hand. Installing the incorrect style locks will lead to disengagement (locks and retainers popping off), which can lead to a very quick catastrophic valve failure, including bashed pistons.



This closeup shows a typical beadlock style valve lock. Only use this style if the valve features a radius groove.



This is a square-cut lock. Again, this will only work with a valve that features a square-cut groove. This may sound very basic, but it's easy to make a mistake if you're not paying attention during valve/spring assembly.

to the afore-measured height. The pressure tester will display the seat pressure at that installed height.

Reference the maximum (gross) lift of the valve, based on your cam lift and rocker arm ratio. The difference between the two measurements should indicate how much additional travel is available to the spring. For example, if the installed height of the valve spring is 2.000”, and the maximum lift of the valve is 0.5000”, the open spring height should be 1.500”.

Sufficient seat pressure is needed to keep the valves from bouncing when they return to their seats (valves closed). Bouncing valves results in not only re-

duced cylinder pressure (reduced power) but this can also result in deforming (tuliping) the valve head, to the point where the head can actually snap off of the stem.

With hydraulic lifters, the springs need to place enough pressure at the valve lifter to keep the lifter plunger centered in its travel to prevent lifter “pump up.” Pump-up causes the valve to be held slightly off of its seat, which reduces power and can also be mis-diagnosed as a misfire (with resulting misplaced blame on the ignition or fuel system).

Unnecessarily high oil pressure and/or higher-than-necessary oil viscosity can cause hydraulic lifter pump-up. If oil

pressure and/or oil thickness is increased, valve spring pressure must be increased as well in order to maintain lifter control and to prevent pumping up. So, if your engine is supposed to use, say, 10W-30 oil and you move up to a straight 50W oil, you're not doing the engine any favors. Thicker is not always better.

A common misconception involves the belief that higher spring pressures reduce horsepower, due to the increased resistance of the springs. What we need to bear in mind is that for every valve that is opening and the spring being compressed, another valve is closing and its valve spring is expanding. This expansion force actually returns the energy to the

## VALVE SPRINGS

BY MIKE MAVRIGIAN

valvetrain and the engine, resulting on zero horsepower loss. This phenomenon is referred to as the valvetrain's regenerative characteristic. In short, when in doubt, run slightly more spring seat pressure, not less.

### TIPS ON CHOOSING VALVE SPRINGS

Flat-tappet cam/lifters for street and street/strip:

Small block engines will generally require 105 – 125 lb seat pressure

Big block engines (due to heavier valves) usually require 115 – 130 lb seat pressure.

Flat-tappet open pressures should not exceed 330 lbs open pressure. Open pressure should be at least 220 lbs for engines that rev to 4000 rpm. For higher engine speeds, open pressures should be at least 260 lb with stock-weight valves (lighter valves require less open pressure). Be aware that open pressures of 280 lbs or more can cause press-in rocker studs to pull loose, so screw-in studs are needed when open spring pressures exceed about 280 lb.

Hydraulic roller cams/lifters require higher spring seat pressures in order to control the heavier roller lifters, as well as to control the more aggressive opening and closing rates common to roller cams.

Small block engines generally require seat pressures in the 120 – 145 lb range.

Big block engines usually need seat pressures in the range of 130 – 165 lb.

General-purpose street small block engines with hydraulic roller cams require at least 260 lb open pressures for applications up to about 4000 rpm. Healthy (moderate performance) hydraulic roller smallblocks prefer open pressures in the 300 – 360 lb range.

Serious-performance smallblocks can use up to about 400 – 435 lb open pressures for reasonable valvetrain life.

Big block general-purpose street roller cam engines require at least 280 lb open pressure for engine speeds up to about 4000 rpm.

"Moderate" performance big block roller setups would generally require open pressures in the 325 – 375 lb range.

Kick-butt big block roller cam setups

can use springs in the 450 lb range (again, here we're referring to also obtaining decent valvetrain life/durability).

Open spring pressures that exceed 360 lb open pressure should really be mated with billet steel roller lifter bodies (not OE-level cast iron roller lifter bodies).

Solid lifter roller cams/lifters are generally reserved for race applications or "serious" street/strip use. Solid lifter roller cams are designed with more aggressive opening and closing rates, requiring high seat pressures to avoid valve bouncing. High-strength, 1-piece valves are needed for durability.

Seat (closed) pressures generally are required in the 180 – 200 lb range for moderate performance engines, while high-end race applications such as Pro Stock and blown alcohol applications commonly use around 340 – 370 lb seat pressure.

Open pressures for street/strip applications are usually in the 350 – 450 lb range. Circle track and bracket racing applications generally run in the 450 – 600

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# VALVE SPRINGS

BY MIKE MAVRIGIAN



Whenever you're using aluminum cylinder heads, a hard steel spring seat is a must. This prevents the valve springs from digging into the softer aluminum. These spring seats are available in various styles, including those that center onto the guide boss. The outer edge of the seats may or may not feature raised lips. In order to prevent the springs from walking eccentrically, the base needs to capture the spring. If the cylinder head features a flat area with no spring cup recess, the spring seats must feature a raised lip to capture the springs. Steel spring seats are available in various thicknesses to suit installed spring height requirements. The spring seat must locate snugly to prevent spring walk.

lb range. Really serious, extreme output drag engines and short-track circle race engines may require 600 or more lbs (open pressures, depending on the application, can run as high as the 900 lb range). Again, you need to pay attention to the spring specs recommended by the cam maker. If in doubt, go a bit higher instead of a bit lower. In maximum-output engines, it may be beneficial to run different spring rates on intakes and exhaust locations, since intake valves are larger and may provide heavier mass, and because the intake valve is opening against higher cylinder pressure, a higher-rate spring may be helpful on the intake valves.

## SPRING BREAK-IN

Before measuring and installing, it's a good idea to compress the springs on a valve spring compressor/measuring tool, up to the coil bind height, three or four times before measuring or installing the springs. This will help to relieve any stored stress/energy and will help them to "stabilize" for more accurate measurements. This should be done on a quality valve spring compressor.

## CONICAL SPRINGS

There seems to be an ongoing debate regarding conical springs (often referred to as "beehive" or tapered springs). A conical spring features a diminishing radius

(larger in spring diameter at the bottom and smaller at the top). The theoretical advantages of a conical spring is the ability to use smaller retainers for decreased mass, improved spring harmonics for reduced wear, heat and friction, and increased clearance/reduced coil bind on higher lift camshafts. The debate continues, with some builders favoring this design while others prefer a traditional non-tapered design and the ability to run dual or triple spring setups as opposed to a single coil design.

## VALVE SPRING SEATS

Aluminum cylinder heads require the use of hardened steel seats under the

# VALVE SPRINGS

BY MIKE MAVRIGIAN

springs in order to prevent the springs from digging into the parent aluminum. The steel spring seat also serves another function: to keep the spring centered and to prevent spring “walk,” which can lead to excessive valve stem side-deflection. Excessive spring wander will eventually wear out the guide and guide seal.

Spring seats are available in two basic styles, including spring cups and spring locators. Spring cups feature an O.D. raised lip to capture the O.D. of the outer spring. Spring locators feature a raised shoulder at the center to register to the inner spring I.D. If using spring cups, measure the diameter of the raised lip and make sure that it clears the outer diameter of the outer spring. If using spring locators, measure the O.D. of the raised shoulder and measure the I.D. of the inner spring. In either case, you should have a fairly close/snug fit. Consider a maximum clearance of 0.050” (for example, with a spring locator, where the inner spring’s inside diameter is 0.050” larger than the shoulder O.D.).

## SPRING CARE AND CAUTIONS

Never handle a valve spring with any type of hard, sharp tool. For example, when separating double or triple springs, never use an tool such as a screwdriver that can nick the spring. Any knicks or gouges can result in isolated stress risers. Never place a spring in a vise or handle with vice-grip pliers.

Valve springs are shipped already coated with a rust preventative that should remain on the springs during the entire handling and installation process. Don’t clean this off using any type of solvent. This can dry out the surfaces, leading to rusting, which can potentially result in spring failure. It’s a good idea to apply a light lube to the springs during or after assembly. Keep the springs lightly coated at all times.

## RETAINERS AND LOCKS

Always check for potential interference between the retainer and valve guide, especially if you’ve moved to a higher lift camshaft. When the valve is fully opened, it’s critical that the bottom of the retainer doesn’t contact the top of the guide or guide seal. This is most easily done by installing light checking springs (to avoid unnecessarily fighting the compression force of the “real” springs. During test-fitting (with the cam, valves, pushrods and rockers installed), rotate the cam



When using aluminum heads, you need hardened steel seats to prevent the springs from digging into the aluminum. In addition, the seat needs to locate the spring to prevent the spring from walking eccentrically. The choices include either spring cups or spring locators. Spring cups feature an O.D. raised lip to capture the O.D. of the outer spring. Spring locators feature a raised shoulder at the center to register to the inner spring I.D. This spring seat/locator features a raised inboard shoulder. This not only captures the seat onto the guide boss, but provides a centering reference for the inner valve spring. Measure the diameter of the raised shoulder and make sure that it clears the inner diameter of the inner spring. It can be a snug fit to the spring but should keep the inner spring centered to eliminate excess spring walk. The inner spring I.D. should be a close fit to the outer diameter of the locator’s shoulder. Consider a maximum clearance of 0.050” (where the inner spring’s inside diameter is 0.050” larger than the shoulder O.D.). Excessive spring wander will eventually wear out the guide and guide seal.



Valve spring retainers are available in both hardened steel and titanium. Considering their added cost, lightweight titanium retainers are really not necessary for street use, but can provide an advantage in competition applications to reduce valvetrain mass.

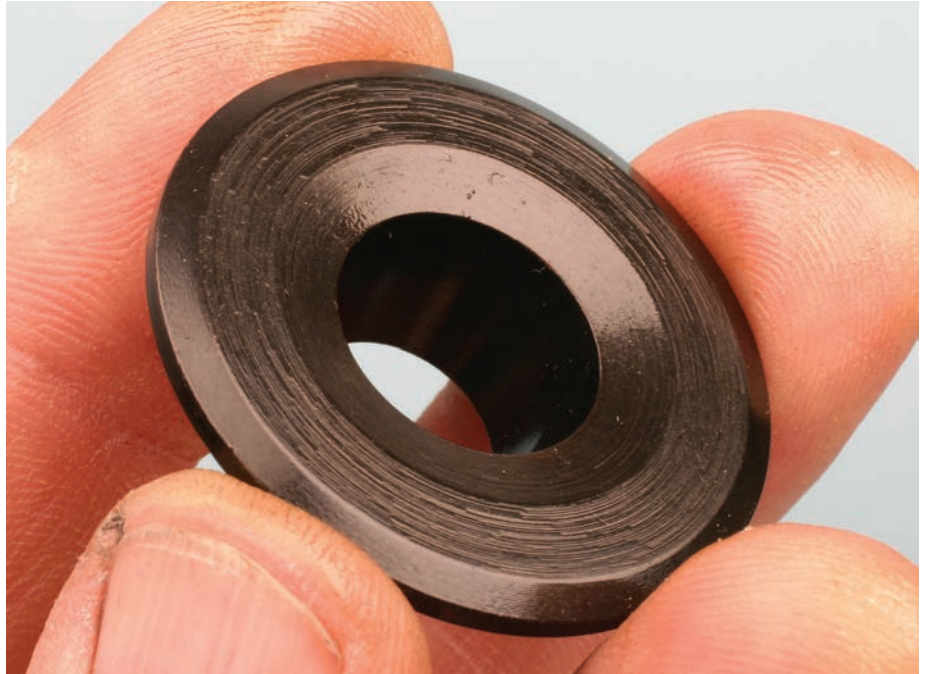
## VALVE SPRINGS

BY MIKE MAVRIGIAN

and observe the clearance between the retainer and guide seal at each valve location. At maximum lift, you should have at least 0.050"-0.060" clearance.

Note: If you're planning to use hydraulic lifters, unpressurized lifters will give you a false reading, so it's best to substitute solid lifters (of the same length as you hydraulics) for checking purposes (the plunger in a hydraulic lifter will depress, preventing you from reading the cam's true maximum lift).

Pay attention to the design of the valve's locking groove. Most valves will feature a "square cut" groove, which will require locks (keepers) that feature square-cut keys on the inside diameter of the locks. However, some performance valves feature a "bead lock" design, with a radiused "bead" type groove on the valve stem, which requires a bead-style lock. If you mix them up (square cut locks on a bead grooved valve or bead locks on a square-cut groove), the retainers will pop off and you'll drop the valves  
(continued)



When purchasing retainers, make sure that the inside diameter matches the angle of the outside diameter of the valve locks. If the valve locks are 7-degree, you must use 7-degree retainers. If the locks are 10-degree, use 10-degree retainers, etc. If you mismatch lock/retainer angle, you'll have problems.

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## VALVE SPRINGS

BY MIKE MAVRIGIAN

(not a good thing).

As compared to a traditional square groove lock, the stresses in the valve are minimized with a single round groove. The lowest stress system is a top lock design with a small round groove at the top of the lock, and the lock is designed with a slightly smaller angle than the retainer so that the valve is held by the collet force squeezing more at the bottom region of the lock-to-valve interface.

Round grooves are superior in high stress applications because they address the issue of stress concentration zones associated with a very small radius of the inside corner of a square groove lock. In high-end racing regardless of the materials featured in the valves, retainers and locks, a single round groove is preferred because it forces the lock to grip the valve stem and hold it in place. While many OEM engines feature multiple-groove steel locks and valves that allow the valve to spin in the locks, this may be acceptable for street and low-end performance, but because there



Pay attention to valve spring diameters when choosing spring seats/locators in order to choose the correct size of spring locator or spring cup (if spring centering relies on the outer spring outside diameter or the inner spring inside diameter). Due to availability of sizes/styles for a given application, you may need either spring cups or spring locators.

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# VALVE SPRINGS

BY MIKE MAVRIGIAN

is a loose fit between the valve and locks, it could cause an over-stress condition if used in severe racing.

Also, retainers and locks are machined with a specific degree match-up... the angle of the outer surface of the locks and the inner wall of the retainer bore. These angles must match (7-degree locks with 7-degree retainers, 10-degree locks with 10-degree retainers, etc.).

We can debate the advantages of different degree designs all day long, but basically you need to remember that you must match the assemblies. If you buy 7-degree retainers, you must use 7-degree locks, etc.

Also, always buy the retainers and locks from the same maker. Even though retainers and locks may be listed as featuring 7 or 10 degrees (or whatever degree style might be available), there may be slight differences in angles between manufacturers. If you buy Crane retain-

**Using a valve spring tester, compress the valve spring to its recommended installed height and record the seat pressure at that dimension.**



This triple-spring setup's inner spring features an inside diameter of 0.640", requiring a spring locator with a shoulder that will both clear the spring I.D. and provide decent spring centering. In this example, spring locators with shoulder O.D. of 0.590" were available, providing 0.050" clearance.

**Before handling or installing a new set of springs, perform a simple "break-in" by compressing each spring 3-4 times on a spring tester.**



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Beehive/conical springs feature a "tapered" profile, with coil diameter decreasing at the upper portion of the coils. Beehive springs (so-called because they resemble a beehive) are common in GM LS engines, and are also offered in high performance versions from several performance valve spring makers. The theoretical advantage is that this design reduces harmonics and makes the valvetrain more stable. In addition, since the top coils are smaller, a smaller (and subsequently lighter) retainer is used, decreasing valvetrain mass on the high-speed side of the valvetrain.

ers, buy Crane locks. If you buy Comp cams retainers, buy Comp Cams locks, etc. Sometimes parts from different makers will match up, but sometimes they won't.

Lock/retainer packages are available in three basic "styles," including rotating, clenching and semi-clenching. OEMs tend to use rotating styles, which allow the valves to rotate during engine operation. This ever-changing valve clock position places the seat contact in random locations to extend the service life of the valves and seats. However, this isn't what you want for any high performance or racing setup, since valve rotation diminishes the optimum sealing (as set during the build). Clenching styles lock the valve in place (via a slight interference fit), preventing rotation. Semi-clenching styles holds the valve tightly in its clock position, while allowing a small bit of rotation. For all-out racing or any high-rpm use, it's best to lock the valve with a clenching style lock/retainer setup.

### REDUCING VALVE MASS

The most critical point is to reduce valve mass. The lighter the valve, the stiffer the valve train system is in relation to the mass it must move. Also, as the valve mass is decreased, you can reduce the spring force needed to control a given valve motion and/or go to a more aggressive cam design that can make more power.

### PERFORMANCE COATINGS

Dedicated internal engine component coatings have been in use within the professional racing community for decades. These coatings have come of age and today offer benefits in terms of increased horsepower and engine longevity.

Anti-friction coatings (which are commonly applied to components such as bearings and piston skirts in today's performance market) not only provide a much lower coefficient of friction (when and if physical contact between two moving surfaces takes place), but also serve to retain surface oil between moving parts, which is exactly what you'd want in terms of valve springs.

In addition, heat emitter coatings are specially-formulated coatings that promote the release of heat. Common applications include valve springs, with the coating intended to prolong spring life.

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Some engine builders like beehive springs and some don't. It all boils down to builder preference. Being able to use smaller retainers, thus reducing mass, is a definite advantage.

Heat-emitter coatings do what the term implies... this type of coating promotes the release of heat from a coated component, with obvious advantages. Examples of applications would include valve springs (shed heat faster = longer spring life and maintainability of spring performance). Heat emitter coatings function opposite of a thermal barrier coating. The emitter coating has a high heat transfer ability, allowing a part to shed, or radiate, heat away. In engineering terms, this is called high "emissivity." This is typically used on valve springs, preventing heat-soak-caused fatigue and wear.

These coatings specific to valve spring application are available from sources such as Swain Tech Coatings, Polydyn, Calico and others.

### STRESS RELIEF

While quality performance valve spring manufacturers do an outstanding job of preparing their springs for performance and competition use, some builders are advocates for additional treatment to further insure spring stability and extended durability. Treatments include the use of either cryogenics or vibratory stress relief.

The process of deep cryogenic freezing changes the structure of the metal being treated. Inside the metal, areas of weaker, potentially brittle deposits called "austenites" may exist. These are flaws that create the potential for cracking. Deep cryogenics changes these areas into harder, more uniform "martensites." The process also creates a vast distribution of very fine carbide particles throughout the metal. The theoretical result is increased strength and structural uniformity. The process is intended to result in a more-dense molecular structure and resulting larger surface area of contact, reducing friction, heat and wear. While the process will create a slightly higher Rockwell hardness, that isn't the real directive. Cryogenic processing benefits a part by stabilizing the metal structure, creating a stronger molecular "grain" pattern uniformity within the metal.

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# VALVE SPRINGS

BY MIKE MAVRIGIAN

Vibratory stress relief utilizes sub-harmonic vibrations to stabilize metal, inducing a controlled series of vibrations to metal components which can provide a safe, effective and non-destructive method of achieving stress relief. The end result: longer life and increased component stability.

Bonal Technologies (to my knowledge, the only provider of this technology) designs and manufactures a complete system for subharmonic stress relief.

There are two forms of stress that can exist within a metal part: mechanical and thermal. “Subharmonic Vibratory Stress Relief” (VSR), as it’s officially known, is a method that relaxes metal (hence the name Meta-Lax), but only in terms of the metal part’s thermal stress, leaving the mechanical stresses unchanged.

Vibrating a part serves to relieve any stresses that were created due to the heat involved in welding, casting, machining or forging, but it does not alter the metal’s strength. VSR does not generate heat, and won’t alter the part’s hardness. As a result, VSR is safe to use on a repeated basis.

Let’s say that you have a part that is rated with a strength of 50,000 psi. because of internal thermal stress that may be present, the actual strength of the part might be reduced by (for the sake of example) 20%. If the part is heat-relieved in an oven, the internal stress will be relieved, but the part might now only offer a strength of, say, 45,000 psi due to the “softening” created by the heat. By contrast, VSR will remove the internal stress while maintaining the metal’s full 50,000 psi strength.

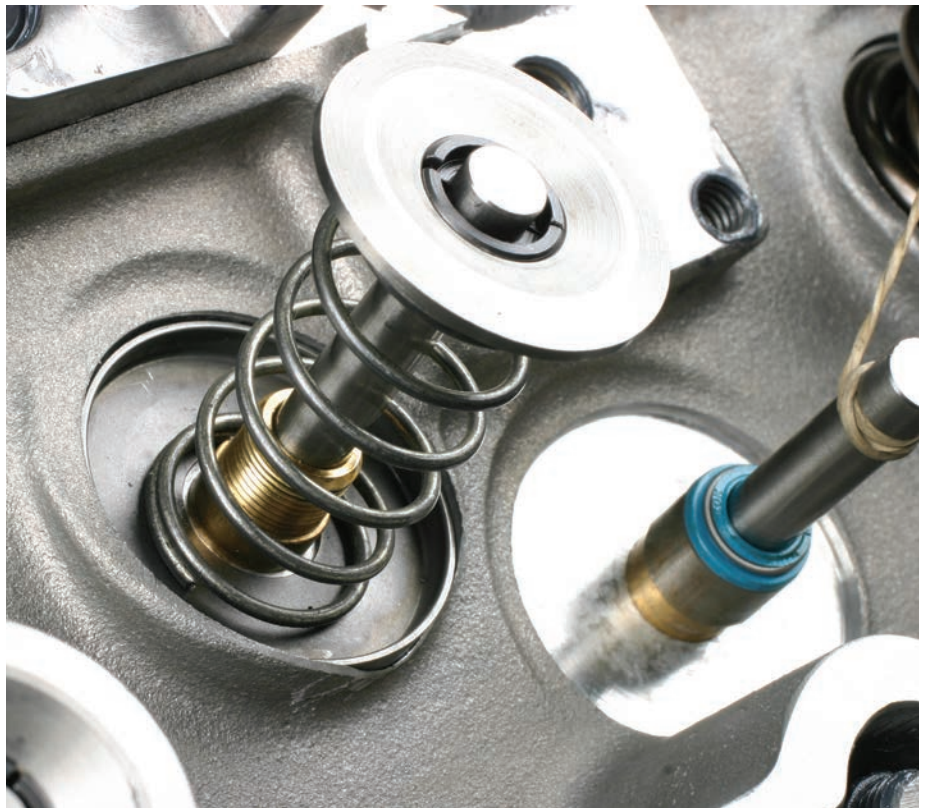
The vibration process searches for the harmonic peak of the workpiece by vibrating it (the peak is where the piece tends to create the maximum harmonic disturbance, just as a tuning fork vibrates when subjected to a force, or as a fishing rod tends to whip and vibrate when dynamic force is present).

As a harmonic disturbance is sent through the workpiece, those signals are sent back to the system’s controller (via the transducer). The force inducer is then automatically adjusted to vibrate the workpiece in a frequency range that begins just before the peak. This energy area at the base of the peak is where maximum damping energy occurs. Sending these adjusted, or “tuned” vibrations through the workpiece serve to remove stress.

*(continued)*



A valve height checker (barrel micrometer) allows you to determine the exact installed valve height and compare this to required installed spring height. With the steel spring seat in place, the mic is dropped over the valve stem and the retainer and locks are installed to secure the valve. With the checker mic adjusted to full height (eliminating freeplay), the height reading is recorded. Additional shims may be added under the springs to adjust spring height.



Light checking springs are useful for measuring purposes, to avoid unnecessarily fighting valve spring pressures during height checking, cam degreasing, etc. Note that this cylinder head (a Dart Big Chief II race head) features machined valve spring pockets. A steel cup-style spring seat is used here, since the machined recess in the head captures the raised outer lip of the spring cup.

## VALVE SPRINGS

BY MIKE MAVRIGIAN



Here several sets of valve springs are clamped to a vibrational stress relief table. A transducer send ultrasonic vibrations to the table and springs. The frequencies are captured and sent

back to the computer via a transponder, in a closed-loop path, allowing the system's computer to monitor and adjust the input vibrations. Vibratory stress relief is a totally non-destructive process that's safe to treat any engine component.

A harmonic peak is first established to determine where the subharmonic area is in the component. A vibration at that frequency is the induced until the part stabilizes. It's as though the part tells you that up to a point, it can dampen the vibrations on its own, but beyond a certain point, it can't. This process shifts the harmonic peak to its natural location, from an artificial frequency to a stress-free frequency.

Conventionally, if you find the harmonic peak, you might add weight to dampen that vibration. With VSR, the metal is relaxed in order to alter the harmonics that can take place. Think of a stressed engine component as a musical instrument that's out of tune. VSR brings the part back into tune.

Subharmonic vibratory stress relief essentially serves to "season" a part, but on an accelerated basis.

All four types of stress relief, including heat treating, cryogenic freezing, vibratory relief and natural seasoning, address the issue of thermal stress. VSR offers a theoretical advantage, simply because it's faster and won't affect mechanical stresses.

The system includes a force inducer (this unit attaches to the workpiece and applies the vibrations), a transducer (this sends a feedback signal from the workpiece to the control computer) and a control console unit (computer).

The object is to transmit the programmed vibrational forces to the engine parts. An entire set of valve springs can be secured to the tabletop by means of a flat steel bar placed on top of the springs, with the bar clamped to the tabletop. ■



Mike Mavrigian has written thousands of technical articles over the past 30 years for a variety of automotive publications. In addition, he has written many books for HP Books. Contact him at Birchwood Automotive Group, Creston, OH. Call (330) 435-6347, email: [mike@birchwoodautomotive.com](mailto:mike@birchwoodautomotive.com) or visit [www.birchwoodautomotive.com](http://www.birchwoodautomotive.com).

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