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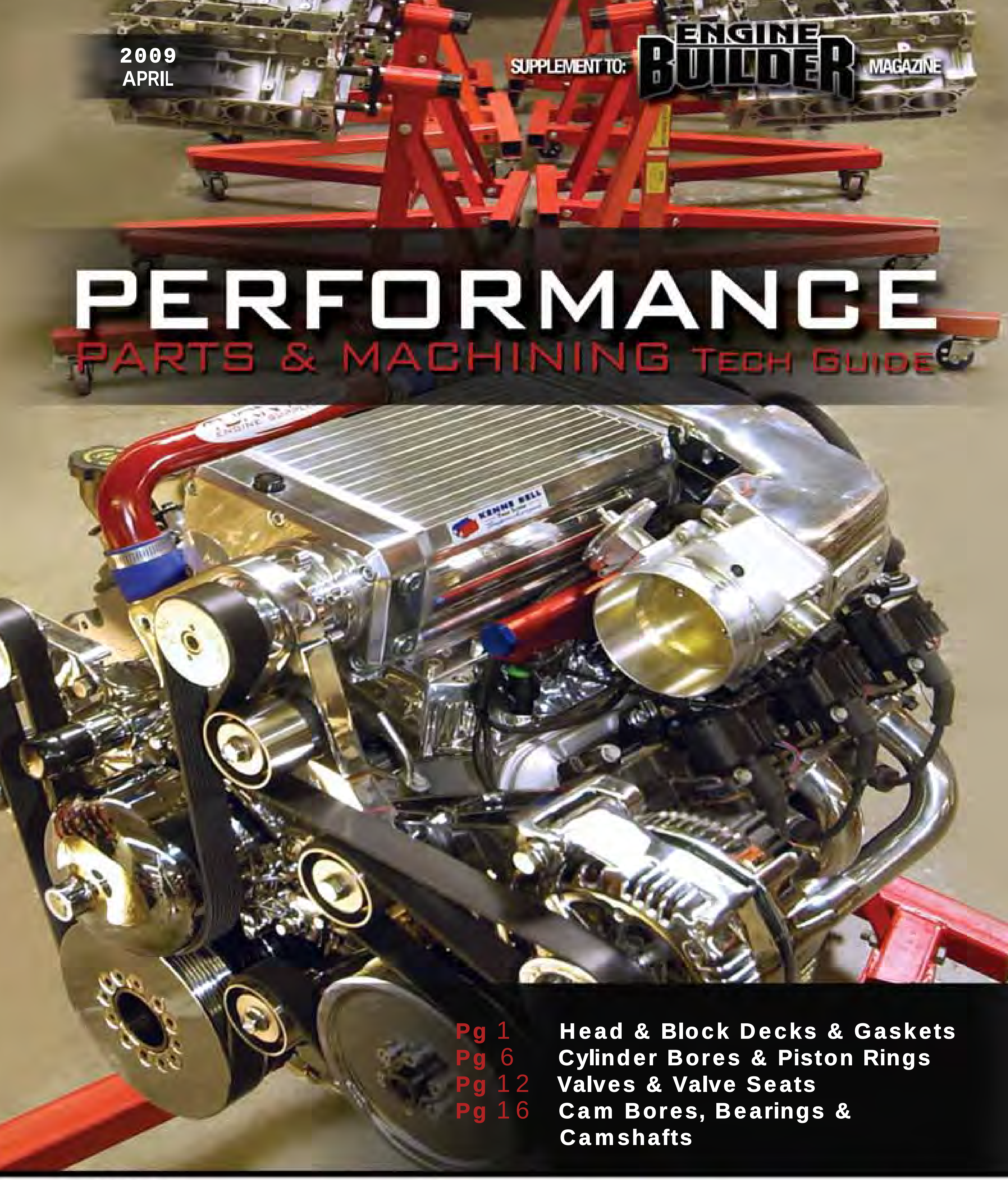

PERFORMANCE
PARTS & MACHINING TECH GUIDE

HEAD & BLOCK
DECKS & GASKETS GUIDE

Since the days of sealing engines with asbestos, cork, rope and paper are, for the most part, ancient history, new-age materials and designs have elevated the critical role gaskets and seals play in the longevity of an engine. Finding the optimum sealing material and design remain a challenge many gasket manufacturers face as engines are asked to do more.

Gaskets that combine high performance polymers with metal or fiber substrates are being used in more and more engine applications. Furthermore, engines that are sealed using these higher quality gaskets are lasting longer, performing better and with less maintenance or chance of the dreaded warranty comeback claim.

There are many considerations engine builders must take into account when selecting the best gaskets for an application. With engines having higher performance requirements, stricter emission regulations, and tighter design tolerances along with production cost considerations and quality standards that are increasing, the last thing any engine builder wants to worry about is a gasket or seal failure.

It doesn't matter if you're building a Pro Stock or stock production engine: the risks are simply too great to use a subpar gasket or seal.

It's more complicated to seal today's engines because, depending on the application, modern engines are expected to last well over 150,000 miles without fail. Performance engines are pumping out more power than ever. So keeping these engines sealed can be a tall order and creates a hefty job for engine gaskets and seals to handle.

Engine seals and gaskets are supposed to prevent the leakage of oil, coolant and air between mating surfaces, internal passages and the outside of the engine. Seals and gaskets also prevent the entry of dirt and air into the engine.

Smooth Operation

How smooth is smooth enough? You used to be able to tell by dragging your fingernail across the surface of a cylinder head or engine block. And besides, it didn't really matter because the composite head gasket would fill any gaps that your equipment or technique left behind.

But with MLS gaskets the requirements have changed. To seal properly, a head gasket requires a surface finish that is within a recommended range. This range varies depending on the type of gasket. Too rough (or in some cases too smooth) and the gasket may not seal properly and leak or fail.

According to surfacing experts, the recommended surface finish for a traditional composite-style soft-face head gasket in an engine with cast iron heads and block is 60-120 microinches Ra (roughness average). The recommended finish for the same head gasket with an aluminum head on a cast iron block is typically 20-50 microinches Ra.

For engines with MLS gaskets, the OEM surface finish recommendations are even smoother, perhaps 20-30 or even 7-15 Ra.

Accurately measuring the surface finish can be done using a profilometer, an electronic instrument that drags a diamond-tipped stylus across the surface to calculate its profile characteristics. The profilometer then shows various values for the surface including roughness average (Ra), average peak height (Rpk), average valley depth (Rvk) and even waviness.

These critical surface finishes require high quality resurfacing equipment to achieve low Ra numbers. Extremely smooth finishes require high quality resurfacing equipment to achieve really low Ra numbers. It doesn't matter if you use carbide, cubic boron nitride (CBN) or polycrystalline diamond (PCD) tool bits to resurface a head as long as you use the correct feed rate and speed – and the equipment is rigid enough to hold the cutter steady so the tool bit doesn't lift or chatter when it makes an interrupted cut.

For example, a converted grinder may be able to mill heads and blocks. But the spindles and table drives in many of these older machines cannot hold close enough tolerances to achieve a really smooth, flat finish. One equipment manufacturer said grinding and milling machines that are more than five years old are probably incapable of producing consistent results and should be replaced.

Most of the surfacing equipment that's being sold to shops today has been redesigned for high speed milling with CBN and PCD. The machines have been beefed up with more powerful motors, heavier castings, electrically driven ball screw tables, and tighter assembly tolerances. Some can hold machining tolerances to .0001″!

Doing the job right may be more challenging than ever, but doing the job wrong may cost you even more.

Head Gasket Evolution

The cylinder head gasket is arguably the most important seal in the engine. Since the very first internal combustion engines were produced, gasket designers have specified many materials to meet this difficult sealing challenge.

Three Types of Head Gaskets

Composite – this technology is used mostly on older stock engine applications and in some performance applications. Typically these types of gaskets are made from graphite and can be more prone to blowouts than MLS gaskets. In the aftermarket, composite gaskets are still required for many older applications and are also more forgiving of less than perfect surface finishes.

Copper - A solid sheet of copper typically requires machining for O-rings that place a piece of wire around the circumference of the cylinder to bite into the copper. When used with O-rings, copper gaskets are extremely durable. Copper gaskets are mostly used in performance applications where there is a lot of cylinder pressure. Recently some gasket companies have started producing copper gaskets with integral sealing wires permitting their retrofit into engines without the need to machine the engine block.

Copper and brass gaskets were some of the earliest materials used but gave way to metal and asbestos composite gaskets in the 1950s, superseded in turn by composite metal and impregnated fiber or graphite composites by the 1980s. However, those systems were largely overtaken by the development of the Multi-Layer Steel (MLS) gasket in Japan during the early 1990s.

Multiple Layer Steel (MLS) – this type of head gasket typically consists of three layers of steel. Most modern engines today are produced with MLS gaskets. The contact layers are usually coated with a rubber-like coating such as Viton that adheres to the cylinder block and cylinder head respectively while the thicker center layer is bare, allowing for movement as if it were like a spring.

MLS gaskets remain the automotive industry's preferred method of sealing the cylinder head and block, and is unmatched by any other sealing system to this point. Today, it is roughly estimated that 80 percent of new engines are designed with MLS gaskets as standard equipment and further growth is projected.

In the MLS gasket, multiple thin layers of cold-rolled spring grade stainless steel are coated with 7-25 microns of elastomeric material. The resilient elastomer is essential to the structure by providing micro-sealing of metal surface imperfections while resisting aggressive combustion gases, oils and coolants at temperatures up to 250°C or 480° F.

Better Sealing Through Chemistry

Gasket manufacturers use all kinds of materials and designs to keep engine oil, coolant, vacuum and compression separated from each other. Through the use of computer aided design (CAD), finite element analysis (FEA) and polymer science, gasket engineers can now more thoroughly understand many facets of the joint they are trying to seal and are able to design a gasket with materials that will withstand the pressures of the environment.

Materials such as Teflon, Viton, Graphite and other specialized materials are taking the place of older, less compatible and less durable materials. The following list shows the types of materials used in automotive applications and the characteristics of each type.

Viton – Viton is a registered trademark of DuPont Performance Elastomers and is commonly called Fluoroelastomer/ Viton (FPM). It is best known for its ability to tolerate high temperature environments (400°F), which makes it well suited for automotive applications.

Viton can also easily withstand aggressive fuels and chemicals and has excellent mechanical properties as well. This material is also resistant to abrasion and cuts. With a broad array of applications in the automotive, chemical processing and industrial markets, Viton fits many performance specifications.

Neoprene Polychloroprene – Neoprene polychloroprene was the first synthetic elastomer able to resist oil and is still a popular material in a number of automotive applications. Neoprene remains a popular choice for many automotive applications that require a reasonably priced, mid-performance polymer with a good all-around balance of performance properties.

Nitrile (NBR) – NBR provides excellent resistance to petroleum oils and gasoline as well as mineral and vegetable oils. However, NBR has poor resistance to the swelling action of oxygenated solvents such as acetone and ketones. It has good resistance to acids and bases except those having strong oxidizing effects. Resistance to heat aging is good, which is a key advantage over natural rubber.

Higher acrylonitrile contents increase solvent resistance but decrease low-temperature flexibility, and compounding this material to improve low-temperature flexibility decreases oil and solvent resistance. This material does not crystallize on stretching and reinforcing materials are required to obtain high strength. With compounding, it is possible to get a good balance between low creep, good resilience, low permanent set and good abrasion resistance. Tear resistance and electrical insulation properties of NBR are inferior to natural rubber.

Silicone Rubber – Silicone rubber offers stability over a wide temperature range, resistance to harsh environments, and long lasting performance exceeding many organic elastomers. Silicone rubber offers incredible resistance to extreme temperatures, being able to operate normally from minus 100°C to plus 250°C (212° to 482° F). When compared to natural rubbers, silicone has better fire resistant properties and is an excellent electrical insulator. Thermal stability means that properties such as volume resistivity, dielectric strength and power factors are not affected by changes in temperature.

Fluoroelastomer – FKM has been utilized by much of the European OEs and is the most successful coating material for long-term functionality critical sealing environments such as automotive engines. Although nitrile rubber (NBR) has been widely used for MLS coatings in the US and Japan, the use of FKM is expected to grow rapidly among the OEs in both of these markets in next few years.

Head Gasket Failures

With most OEMs choosing to use aluminum rather than iron cylinder heads, the chance of a head gasket failure is increased. Even though aluminum is lighter than iron, it has a much greater thermal expansion rate, which in turn creates more stress on the head gasket. Engine manufacturers have responded to this by adding a non-stick coating such as Teflon or some other type of slick coating to the surface of the head gasket.

Most engine builders know that when a head gasket fails, a whole range of problems can occur, from compression loss to exhaust gases being forced into the cooling system, leading to the engine overheating and increased engine wear due to the oil being mixed with antifreeze. Coolant can leak into the cylinders, causing the exhaust to blow off steam and the steamy coolant mixture can damage the catalytic converter.

If a very large amount of coolant does this, hydrolock can occur, causing extensive engine damage. Sometimes, all that may happen when a head gasket is blown is an eruption of steam from the tailpipe, though the engine may act and drive like normal.

If your customer suspects a blown head gasket you or your installer can investigate the situation by checking the compression with a pressure gauge, but the preferable method is a leak-down test, noting any indication of combustion gasses in the cooling system. Oil mixed with coolant and excessive coolant loss with no apparent cause, or presence of carbon monoxide or hydrocarbon gases in the expansion tank of the cooling system can also be signs of head gasket problems.

Intake Manifold Gaskets

The head casting-to-intake manifold joint is critical because if you experience a failure it will create a vacuum leak which will in turn create a poor running engine and an unhappy customer.

It is recommended that you check the head and manifold sealing surfaces with a straightedge and machine them flat if any warpage is found. As with the head/block seam, premium gaskets of graphite or with synthetic faces and perhaps a printed-on bead are commonly available, and usually no retorquing is needed.

Another relatively new type of manifold gasket has a metal or plastic carrier with rubber inserts or deposited rubber beads. You have to try pretty hard to make a mistake while installing these gaskets because the carrier acts as a positive stop so the rubber cannot be over compressed. These gaskets don't require any sealant either.

Also, V8 and V6 engines that have tabs or endstrips on the manifold gaskets should be handled carefully. The tabs are easy to dislodge while you're lowering the manifold into place. You can use a light coat of adhesive if you want to try and keep them in place.

Intake manifold bolts should be tightened in a pattern similar to the sequence used to torque the cylinder head down. The goal here is to work from the center outward unless manufacturer specifications say otherwise. Do not over-torque these bolts. Not only will this save you from the disaster of a snapped bolt, but on some applications it can prevent a head gasket failure. The pressure from the weight of the manifold can push the heads outward enough to reduce clamping force that could lead to a blown head gasket.

Valve Cover and Pan Gaskets

The most basic type of gasket is the cut gasket, which are made by die-cutting sheets of fiber-reinforced paper-like material or ground cork/rubber to create the flange shape of the cover. Cut gaskets are most often used in timing covers, valve covers, oil pans, intake manifolds, carburetors, throttle bodies, water pumps, thermostat housings, etc. Cut gaskets are also the least expensive to make and allow the OEMs to use stamped steel valve covers, timing covers and oil pans instead of more costly cast aluminum.

Older style cork/rubber gaskets don't last forever and have a tendency to leak, which is why most of these gaskets are no longer used by OEMs. Most manufacturers use molded rubber or plastic carrier gaskets for these applications. The plastic carrier gasket is much more durable and can last as long as the engine without failure.

Over-tightening these gaskets will often crush or crack the gasket, which then leads to a failure down the road.

Some pan and cover gaskets have extra features that allow them to be installed more easily than standard cork/rubber gaskets. Features include grommets for lining up the holes and metal carriers to make the gasket stiffer so it won't flop all over when you try to line everything up.

In order for pan and cover gaskets to seal properly the surfaces must be clean, dry and as flat as possible, free from anything that might catch or tear the gasket material. The surface must also be free of any old gasket residue.

Oil pan sealing innovations include metal grommets in the boltholes or shouldered fasteners to guard against over-torquing, and one-piece rubber gaskets.

For timing chain covers, thermostat housings, etc, a thin paper-type gasket is often used with a thin bead of a good sealant. Like all other parts of the engine, careful torquing procedures are required with these gaskets. **PPMG**

CYLINDER BORES & PISTON RINGS GUIDE

Trying to classify the American performance market into a single niche is an exercise in futility. Simply saying "performance is alive and well" can be proved by looking at the scope of the performance piston market.

Cubic inches is the name of the game today. The performance piston market is being driven by bigger bore blocks and stroker crankshafts. Top rings are running hotter than ever before, thanks to higher combustion temperatures and piston loads combined with rings that are relocated closer to the top of the piston for longer stroke crankshafts.

With the performance piston market being driven by a wider range of variables than ever, piston ring suppliers have had to work hard to keep up as well. Most performance pistons have some type of coating or anodizing treatment in the top ring groove to prevent the ring from welding itself to the piston or pounding out in the groove. The top ring, in most cases, must also be steel or ductile iron, and faced or coated with some type of wear-resistant material such as moly, chrome, nitriding or one of the new "aerospace" vapor disposition or plasma spray coatings.

Moly is still the most popular facing material for many piston rings because of its excellent wear and scuff resistance. Another material is tungsten carbide (for hard liners), and chrome. Chrome-faced rings are still a good choice for abrasive environments like dirt tracks, and work best with cast iron blocks and cylinder liners. Chrome rings don't work well with chrome plated bores or hard faced cylinder bore liners such as those coated with nickel/carbide coatings.

Thin is in, both at the beach and on the track. Thinner rings generate less tension and reduce friction, so ring dimensions have been shrinking in many racing engines. Many top level drag racing and stock car engine builders go with compression rings as thin as 0.7 mm, and most Formula One engines are now built with 0.6 mm rings. These skinny rings produce very little tangential load (about 1.5 pounds), which minimizes friction and allows the rings to conform more easily to any bore distortion. Many of these engines are also using Napier-style second rings, with a small notch in the bottom face of the ring to improve oil control and sealing as the ring scrapes against the cylinder wall. The napier design is also used with a positive twist to improve its sealing characteristics, effectively helping to prevent detonation by keeping oil out of the combustion chamber.

Even at the Sportsman racing level, advancements in ring technology have been seen. While cast iron piston rings remain popular with many budget-minded dirt track claimer motors as well as many street performance and other racing applications, ductile iron or steel rings are usually required for higher output engines. Ductile iron rings have roughly twice the tensile strength of gray cast iron, and three times the fatigue strength. Steel rings, by comparison, have almost four times the tensile strength and fatigue strength of gray cast iron.

For high boost turbocharged and supercharged engines, and engines using large doses of nitrous oxide to add horsepower, ductile iron or steel top rings are probably a must. Many racers prefer to use nitrided rings made from steel wire because the rings can handle high loads and thermal shock better than other materials. Nitriding penetrates into the metal and won't flake off like other surface coatings.

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Another reason for the smaller rings in many performance engines is that pistons are getting shorter. Longer connecting rods with shorter pistons change the combustion dynamics and provide better angularity during the power stroke. Shorter pistons also weigh less, which means the engine can rev higher. But when the piston is shorter, the rings have to move up higher. This means they have to be narrower, stronger and more heat resistant because the top ring is closer to the combustion chamber.

So what does this mean inside an engine? It means ductile iron and steel rings can survive in racing environments that may be too demanding for grey cast iron rings. Stronger rings reduce the risk of ring breakage under severe loads. Steel rings also show less side wear and ring groove pound out.

Bore Finish

Regardless of what kind of rings or liners are used in a performance motor, rings usually work best when the cylinder bores are given a plateau finish. A plateau finish essentially duplicates a "broken-in" bore finish, so there is less scrubbing and wear on the rings when the engine is assembled. What's more, if the surface is finished correctly it will provide plenty of flat, smooth bearing surfaces to support the rings while also retaining oil in the crosshatch valleys to lubricate the rings.

The only exception to this is in motors where there is a lot of bore distortion. If the bores go out of round when the head bolts are torqued down, the rings may not seat as well allowing increased blowby and oil consumption. Thinner rings that can conform to the bore will work better in these kinds of applications, but it's also a good idea to use torque plates when honing when honing the bores to simulate the distortion that occurs when the cylinder heads are installed. The other option is to go with a slightly rougher "peaked" finish to seat the rings.

Most ring manufacturers recommend using a two- or three-step honing procedure to achieve a plateau finish. First, rough hone to within .003˝ of final bore size to leave enough undisturbed metal for finish honing. For plain cast iron or chrome rings in a stock, street performance or dirt track motor, hone with #220 grit silicon carbide stones (or #280 to #400 diamond stones) to within .0005˝ of final size. Then finish the bores with a few strokes using an abrasive nylon bristle plateau honing tool, cork stones or a flexible abrasive brush.

For moly faced rings in a street performance, drag or circle track motor, hone with a conventional #280 grit silicon carbide vitrified abrasive, then finish by briefly honing to final size with a #400 grit vitrified stone or #600 grit diamond stone (or higher), plateau honing tool, cork stones or a brush.

For stock and street performance engines with moly rings, an average surface finish of 15 to 20 Ra is typically recommended. For higher classes of racing, you can go a little smoother, provided you don't glaze the cylinders.

For moly or nitrided rings in a performance motor, hone with #320 or #400 vitrified stones, and finish with #600 stones, cork stones, a plateau honing tool or brush.

If the cylinders are rough honed with diamond, they can be finish honed with a finer grit diamond, a fine-grit vitrified abrasive or a plateau honing tool or brush. Because diamond is a harder material and wears more slowly than conventional abrasives, it cuts differently and may require more honing pressure. But many newer diamond stones now use a more friable bond that stays sharp and doesn't load up, allowing the stones to cut smoother and leave a rounder, smoother bore finish.

When using diamond-honing stones instead of vitrified abrasives, you generally have to use a higher number grit to achieve the same Ra (roughness average) surface finish. The actual numbers will vary somewhat depending on the brand and grade of the stones.

Bristle style soft hones (plateau honing tools) have mono-filament strands that are extrude molded with a fine abrasive material embedded in the strands. The filaments are mounted in different types of holders for use with portable or automatic honing equipment. Another type of brush uses molded abrasive balls that are mounted on flexible metal shafts so the balls can easily conform to the surface. Brushing helps sweep away torn and folded metal on the surface while removing many of the sharp peaks to make the surface smoother.

When finishing the cylinders with a brush, only light pressure is required. The rpm of the brush should be similar to that which the cylinder was originally honed, and no more than 16 to 18 strokes should be applied (some say 8 to 10 strokes is about right). Too many strokes with a brush may produce too smooth a finish in a cast iron cylinder that won't retain oil. Reversing the direction of rotation while brushing helps to remove the unwanted material on the surface. The end result should be a cylinder that provides immediate ring seal with little if any wear on the cylinder wall or rings when the engine is first started.

With the right plateau honing techniques, you should be able to get the surface down to an average roughness of 8 to 12 Ra or less, with Rpk (relative peak height) numbers in the 5 to 15 range, and Rvk (relative valley depth) numbers in the 15 to 30 range. These numbers are meaningless unless you have a surface profilometer that can measure them (which a growing number of performance shops now have).

Crosshatch

Crosshatch is also important because the amount, depth and angle of the crosshatch in the cylinder bores determines how much lubrication the rings receive and the rate of ring rotation.

Excessive shallow crosshatch angles can hinder or slow down the necessary ring rotation that allows the rings to dissipate heat. It can also leave too much oil on the cylinder wall allowing the rings to skate over the surface and the engine to use oil. Too steep of a crosshatch angle may not provide enough oil retention and can result in dry starts and premature ring wear. A steep crosshatch angle can also create excessive ring rotation that accelerates ring and piston groove wear.

Ring manufacturers typically recommend a crosshatch angle of 22° to 32° from horizontal and uniform in both directions.

Ring End Gaps

Tradition said the end gaps on second compression rings could be tighter because the number two ring is not exposed to as much heat as the top ring. Today's theory says it's better to open up the second ring gap 20 to 30 percent so pressure doesn't build up between the rings and cause the top ring to lose its seal at high rpm. The result is better compression, better piston cooling and reduced oil consumption.

Any pressure that builds up between the rings will blow down into the crankcase, keeping oil out from between the rings. This trick works best on engines that are running a dry oil sump and pull a vacuum in the crankcase.

Some performance pistons also have "accumulator grooves" machined into the piston land between the first and second ring grooves. The added space traps blowby gasses and helps prevent the top ring from unseating and fluttering.

For naturally aspirated engines, a top ring end gap of .004˝ per inch of bore diameter is often recommended for a stock or moderate performance engine. For a 4-inch bore, that translates into a top ring end gap of .016˝to .018˝. But this will vary depending on the power output of the engine.

For drag or oval track racing, the recommended end gap is somewhat larger (.0045˝ per inch of bore diameter). With four-inch bores, that would be an end gap of .018˝ to .020˝.

For a nitrous oxide street performance engine, the recommended end gap is .005˝ per inch of bore diameter (.020˝ to .022˝ for an engine with four-inch bores). For a nitrous oxide drag engine, the recommended end gap for the top ring is .007˝ per inch of bore diameter (.028˝ to .030˝ with four-inch bores).

With a turbocharged or supercharged racing engine, the top ring gap should be .006˝ per inch of bore diameter (.024˝ to .026˝ with a four-inch bore).

The recommended end gaps for second compression rings are also the same, with slightly larger gaps if you want to minimize pressure buildup between the rings.

The recommended ring end gap for most oil rings (except the new super narrow one-piece rings) regardless of engine application is typically .015˝.

Another trick to improve ring sealing at high rpm is to run pistons that have gas ports behind the top ring. Combustion pressure blows through the port to help seal the ring from behind and underneath. Some use vertical gas ports with holes drilled from the top of the piston to the top ring groove just behind the ring. Others use lateral gas ports that are drilled through the bottom side of the top land and extend to the back wall of the ring groove. Gas ports work best at high rpm (above 7,000 rpm) and are not recommended for street engines.

Getting rid of the end gap altogether can also improve sealing, cooling and horsepower. Gapless rings eliminate the gap between the ends of the ring by overlapping slightly. Gapless rings are available in popular sizes with various wear-resistant face and side coatings. Some engine builders who have switched to "gapless" top or second compression rings say they've gained three to five percent more horsepower with no other changes. Gapless rings are said to allow less than 1 cubic foot per minute (CFM) of blowby and on alcohol-fueled engines, a gapless top ring or second ring helps keep alcohol out of the crankcase. **PPMG**


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VALVE SEATS
& MACHINING GUIDE

Engine cooling doesn't only happen at at the radiator. The valves (particularly the exhaust valves) take a lot of heat from the combustion chamber and the valve seats have the responsibility of helping to cool them off. The seats draw heat away from the valves and conduct it into the cylinder head, providing most of the cooling that the valves receive.

Anything that interferes with the seat's ability to cool the valves (such as a loose fit or deposits between the seat and its counterbore) can lead to premature valve failure and expensive comebacks, so a cylinder head job often requires valve guide and seat work to restore it for service or to improve performance. In order for a valve to seat correctly, for efficiency and power, engine builders must replace or bring back to spec all valve seats and guides.

When considering the steps necessary to repair or replace valve seats, be aware that with two types of cylinder heads you have three options: aluminum with removable valve seats or cast iron, with removable or integral hardened seats. If the cast iron head has integral seats it will need to be machined to replace the seat. If the head is aluminum, the seat counterbore may have to be machined to accept an oversize seat if the bore is loose, deformed or damaged. Either way, you'll need to figure the amount of interference that is required for the new seat before cutting the head on a seat-and-guide machine.

Valve seat replacement is required if the cylinder head was warped and needed to be straightened before resurfacing. Similarly, if an aluminum head was cleaned by heating, the seats will need to be replaced.

If the valve's mating surface has receded below factory specifications or if machining the head would cause the seat to fall below factory specs, it must be replaced.

Replace the integral seats in a cast iron head if the head has been ground before, because the hardened depth of the head used in the seat area will be too shallow to allow a second grinding.

If the valve seat insert shows evidence of being loose or doesn't have adequate interference; if there is evidence of corrosion on the cylinder head around the outside diameter of the valve seat; or if there is evidence that the seat has any cracking, burning, pitting or fissures, the seats must be replaced.

The seat alloy and hardness must also be matched to the type of fuel used and the engine application and compatible with the type of valves that are installed in the engine. Again, there are often differences of opinion regarding the selection and use of various seat materials.

Nonintegral valve seats can fail for a number of reasons. Most of the seats that end up being replaced are either cracked or too worn to be reground or remachined. Seats can crack from thermal stress (engine overheating usually), thermal shock (a sudden and rapid change in operating temperature) or mechanical stress (detonation, excessive valve lash that results in severe pounding, etc.).

A small amount of valve recession results from normal high mileage wear, but it can also occur when unleaded gasoline or a "dry" fuel such as propane or natural gas is used in an engine that isn't equipped with hard seats. Recession takes place when the seats get hot and microscopic welds form between the valve face and seat.

Every time the valve opens, tiny chunks of metal are torn away and blown out the exhaust. Over time, the seat is gradually eaten away and the valve slowly sinks deeper and deeper into the head. Eventually the lash in the valvetrain closes up and prevents the valve from seating. This causes the valve to overheat and burn. Compression is lost and the engine is diagnosed as having a "bad valve." The seat also has to be replaced, but in many instances it may not be recognized as the underlying cause of the failure.

As a rule, most experts recommend replacing OEM valve seats with ones that are of a similar material – except in cases where extra durability is required because of a change in fuels (converting to propane or natural gas, for example), or an engine is being built for racing.

There are a number of different valve seat materials from which engine builders can choose. Many of these materials will work in a wide variety of performance applications while others are designed primarily for special applications such as industrial engines that run dry fuels like propane or natural gas. The only consensus is that different valve seat materials can be used successfully in most performance engines.

What kind of materials are we talking about? Everything from nodular/ductile iron alloys and powder metal steel seats to hard aluminum-copper and bronze alloys, and beryllium copper alloys. Many valve seat suppliers have their own proprietary alloys while others use industry standard alloys. But you don't have to be a metallurgist to appreciate the differences between some of these materials.

A valve seat must do several things. It must support and seal the valve when the valve closes, it must cool the valve, and it must resist wear and recession. Consequently, a performance valve seat material should provide a certain amount of dampening to help cushion the valve when it closes at high rpm. Very hard materials, especially on the intake side, are not the best choice here because intake valves tend to be larger, heavier and close at faster rates than exhaust valves. The wilder the cam profile, the more pounding the valve and seat undergo at high rpm.

Many late model domestic and import engines have seats that are made of powder metal. These types of seats are very hard and durable, so they typically show little wear at high mileages. Consequently, the seats may need little work when the cylinder head is rebuilt.

One difference between cast alloy seats and powder metal seats is the way the seats are manufactured. Cast alloy seats are made by melting and mixing

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different metals together so they combine chemically. The molten soup is then poured into a mold and cast to shape. The rate of cooling and subsequent heat treatment of the metal determines its microstructure, hardness, strength and other physical properties.

Powder metal seats, by comparison, are made by mixing together various dry metal powders such as iron, tungsten carbide, molybdenum, chromium, vanadium, nickel, manganese, silicon, copper, etc.), pressing the mixed powders into a die, then subjecting the die to high heat and pressure (a process called "sintering"). This causes the powders to bond together and form a solid composite matrix with very uniform and consistent properties.

One of the advantages of powder metal sintering is that materials that are difficult or impossible to mix together in a molten state can be blended together and bonded to create totally unique materials. For example, in powder metal bushings and ball joints, graphite is combined with steel to make the material "self-lubricating."

Another advantage of the powder metal process is that parts can be manufactured very close to final tolerances, reducing the amount of machining that's needed to finish the part to size. This lowers production costs and boosts manufacturing productivity.

The main reason why vehicle manufacturers have switched from cast alloy seats to powder metal seat inserts is to extend durability. Most late model engines have to be emissions-certified to 150,000 miles or higher depending on the application and model year. If the valve seats can't go the distance during durability testing, the vehicle manufacturer can't certify the engine.

Powder metal seats are very good at handling thermal stress as well as impact stress, and typically show minimal wear after tens of thousands of miles of use. The homogeneous consistency of a powder metal seat also improves heat transfer, which is good for the valves, too. Powder metal seats also tend to experience less microwelding between the seat and valve even at high combustion temperatures, which helps extend the life of both components.

Exhaust valves run much hotter than intake valves so cooling is more critical on the exhaust side. Heat transfer from the valve to the seat provides cooling during the time when the valve is closed, and by conduction up through the valve stem and into the valve guide and head.

It's more noticeable in performance engines. Titanium valves do not shed heat as quickly as stainless steel valves, so the tradeoff for switching from steel to titanium to save weight is often hotter running valves. The higher the temperature of the exhaust valve, the greater the risk of the valve causing a preignition or detonation problem. There is also increased risk of the valve burning. That's why many suppliers of titanium valves recommend seat materials such as beryllium copper.

For racing applications using either stainless steel or titanium exhaust valves, some suppliers recommend a sintered valve seat insert, which includes a blend of finely dispersed tungsten carbide in a matrix of tempered M22 tool steel and special alloy iron particles. These powder metal seats have a very uniform microstructure, and are highly machinable. Because powder metal seats work harden as they age, they don't have to be as hard initially to provide good long term durability, and the self-lubricating qualities of the material allows it to handle a wide variety of fuels, including unleaded and leaded gasoline, straight alcohol, nitrous oxide and nitro methane. A shot of nitrous will cause combustion temperatures to soar, but the dose usually doesn't last long enough to have any detrimental effect on the seats.

The next step up is a high alloy seat material, for applications where high heat resistance is required, such as a propane or natural gas fired stationary engine but also for high performance engines, heavy-duty and extreme duty engines where longevity is a must. Seats are made out of a high speed tungsten carbide tool steel, which gives it ceramic-like characteristics for extreme temperature resistance.

Conversely, because they tend to run much cooler than exhaust valves, low alloy seats work well with intake valves in performance applications, even in such extreme cases as offshore racing boats that run for hours on end.

Equipment Selection

Seats that are cracked, loose, sunken or destroyed in some manner must be replaced with new. Drilling, reaming, replacing valve guides, removing worn, loose or damaged valve seats, cutting new seat counterbores and machining valve seats are all part of the reconditioning process that your shop must be able to handle as efficiently as possible and with precision and accuracy.

There are a few different kinds of seat and guide machines available today to fit most budgets. The first kind of machine is not much more complex than a drill press and is often referred to as such. In these seat and guide machines the tooling sets in a solid column and the table floats to move from guide-to-guide. These are very basic seat and guide machines that have some limitations compared to more advanced machines, however, there are still some small shops and hobbyists that use this style of machine. A small shop may not be able to justify the larger, more expensive machines, and many of these small shops simply don't have the volume to be concerned about doing hand grinding and lapping.

The second level of seat and guide machines is the floating powerhead system. These machines have become the industry-standard for many engine builders today. This equipment, according to the manufacurers we surveyed, run in the price range of about $18,000-$30,000, depending on the options and manufacturer you choose. On these machines, the cylinder head is stationary underneath a floating powerhead. The powerhead floats above on flat ways that adjust front-to-back and side-to-side.

The powerhead weighs much less than the cylinder heads, so when you center the powerhead, a procedure similar on most models, it floats and centers with the pilot. Once it is centered over the pilot, you let off the foot pedal to lock it in place. This setup gives you a very rigid platform.

Modern cylinder heads often have canted valves so on an older-style machine you have to tilt the fixture to machine canted valve seats and guides. The fixture is relocated and set for each guide. When using a modern seat and guide machine, the powerhead tilts, allowing you to adjust the powerhead for whatever angle you need. Once you've set the powerhead angle you can go up and down the line with the same tilt angle for each valve seat. Some machines can accommodate up to 15 degrees of rotating tilt.

Today's valve seat and guide machines also use three-blade carbide cutters with three-angles or more. These cutters, or form tools, give you a very consistent profile and concentricity because the profile is built into the tooling. Manufacturers vary with the type of tooling each offers, but all are essentially a form tool with built-in angles.

The third style seat and guide machine is the "live pilot" design. Whereas a "dead pilot" design remains stationary in the guide as the tooling rotates, a live pilot spins with the tooling in the guide. You have to be very precise when fitting live pilots into guides otherwise too much play could result in a seat that isn't completely round. Some live pilot machines have a single blade carbide cutter that can adjust while it spins to create almost an infinite number of profiles. **PPMG**

CAMSHAFTS

BEARINGS & BORING GUIDE

Which cam is right for you? You might as well ask which color car is fastest. They're both questions that can only be answered with an emphatic "it depends."

It depends on a variety of factors, each of which is determined by a number of others.

Unless you are doing a totally stock rebuild and reusing the original camshaft, selecting a camshaft depends on what kind of engine you are building and how that engine will be used. A stock engine for a daily driver is obviously an entirely different application than a big stroker motor for a Pro Stock racer. So how do you navigate the daunting process of selecting the "best" camshaft for a particular engine?

One approach is to stick with what works. If you've used a particular cam grind before that delivers good torque and horsepower for a certain kind of application, you might want to play it safe and stick with a tried-and-true grind that has worked well in the past. But in today's highly competitive world of professional racing, the hot cam, cylinder head and valvetrain combination that worked well last season may not be the best choice for this season.

Since technology is constantly changing with regard to cylinder heads, rotating assemblies, cylinder head port configurations and engine blocks, intake manifold manufacturers have had to redesign many of their manifold plenums and runners to flow more air for these stroker motors. Aftermarket engine blocks with larger cylinder bores and bore spacing are adding more and more cubic inches of displacement.

More and more camshaft profiles are required to fill the gaps not covered by currently available cams. While this can make it much more difficult for an engine builder to pick an off-the-shelf cam that will deliver the best possible performance for a given combination of engine parts, gearing and usage it means cam suppliers are more able than ever to create custom camshafts for engine builders.

As long as an engine builder provides technically accurate specifications as well as detailed information about what he expects from the engine, many cam suppliers will make a custom cam for almost any engine. Sometimes the answer is an off the shelf cam. Other times the right answer is a custom cam.

The variables that must be considered include all of the following:

• Engine Displacement – A smaller displacement engine usually needs a shorter duration camshaft for good low end torque and throttle response. A large displacement stroker motor, on the other hand, can usually handle more cam duration without sacrificing low end torque and throttle response.

• Bore & Stroke – Long stroke engines develop more torque than short stroke motors, but short stroke motors can typically rev much higher. So for a high revving engine, you want a cam that develops power from maybe 3,500 rpm up to 9,500 rpm. A big stroker motor, on the other hand, may never see the high side of 6,000 rpm, so it would need a cam that works better at lower rpms.

• Rod Length – Rod length affects the angularity and torque on the crankshaft as well as piston speed, factors that are used to optimize airflow in the desired rpm range.

• Engine RPM Range – Are you building a low rpm torquer motor or a high revving engine? The cam grinder has to know where you want maximum torque to occur so he can choose the optimum duration, lift and lobe separation numbers for your cam.

• Compression Ratio – The higher the static compression ratio, the more duration the engine can handle without going into detonation.

• Cylinder Heads – Are the heads stock, modified stock or aftermarket? If aftermarket, which brand and model of aftermarket head? Are they off-the-shelf heads or have the ports been reworked or CNC machined? If so, what are the port runner volumes? How big are the intake and exhaust valves? How about the volume of the combustion chambers (open chamber or small chamber)? Are the heads aluminum or cast iron? Aluminum runs cooler and can handle more heat with less risk of detonation. All of these factors influence the lift, duration and overlap that will be ground into the new cam profile.

• Valvetrain – What is the ratio of the rocker arms? Are they stock or high-lift, and if so what is their exact ratio? This will affect both cam lift and duration at the valves. Are the rockers steel or aluminum? How stiff are the valve springs? Can the springs and pushrods handle the anticipated rpms? The cam has to work with the lifters, pushrods, rocker arms and valve springs to achieve the desired lift, duration and rpm you want to achieve.

• What Type of Cam and Lifters? If you want a flat tappet cam, will you be using oversize lifters? Roller cams cost more but provide a significant reduction in internal engine friction, and typically make more torque and horsepower because a roller lifter can handle a much steeper ramp on a cam lobe than a flat bottom lifter. This allows roller cams to open the valves more quickly so they can reach maximum lift earlier in the timing cycle. If you plot valve lift and duration on a graph, the area under the curve of a roller cam with an aggressive lobe profile will be greater than that of a flat lifter cam for the same lift and duration specifications. This makes more power.

• Induction System – Will the engine be naturally aspirated, boosted with a supercharger or turbocharger (if so, how much boost pressure?), and/or fitted with a power adder (nitrous oxide)? Blown engines typically run better with slightly milder cams that have a wider lobe separation to reduce valve overlap. Does it have a carburetor or more than one carburetor? If so, what's the cfm rating of the carburetor(s). If the engine is fuel injected, what type is it (multiport or throttle

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HYDRAULIC FLAT TAPPET KITS

Part#	Duration @ .050" Int. / Exh.	Gross Lift Int. / Exh.	Lobe Sep. Angle / Intake Center Line	RPM Range
CHEVY SMALL BLOCK (1955-1998)				
10000LK	204 / 214	.420" / .443"	112 / 107	1000-5000
10001LK	214 / 224	.443" / .465"	112 / 107	1500-5500
10002LK	224 / 234	.465" / .488"	112 / 107	2000-6000
CHEVY BIG BLOCK (1965-1996)				
10200LK	204 / 214	.476" / .501"	112 / 107	idle-4500
10201LK	214 / 224	.501" / .527"	112 / 107	idle-5000
10202LK	224 / 234	.527" / .553"	112 / 107	1500-5500
FORD SMALL BLOCK (302 FIRING ORDER)				
11200LK	204 / 214	.448" / .472"	112 / 107	1200-5200
11201LK	214 / 224	.472" / .496"	112 / 107	1500-5500
11202LK	224 / 234	.496" / .520"	112 / 107	1800-5800
FORD SMALL BLOCK (351W FIRING ORDER)				
11000LK	204 / 214	.448" / .472"	112 / 107	1200-5200
11001LK	214 / 224	.472" / .496"	112 / 107	1500-5500
11002LK	224 / 234	.496" / .520"	112 / 107	1800-5800
FORD BIG BLOCK (1968-1996)				
11600LK	204 / 214	.490" / .516"	112 / 107	idle-4500
11601LK	214 / 224	.516" / .543"	112 / 107	idle-5000
11602LK	224 / 234	.543" / .569"	112 / 107	1500-5500

RETRO-FIT HYD. ROLLER KITS

Part#	Duration @ .050" Int. / Exh.	Gross Lift Int. / Exh.	Lobe Sep. Angle / Intake Center Line	RPM Range
SMALL BLOCK CHEVY (1955-1998)				
10020LK	218 / 228	.503" / .503"	112 / 108	1800-5800
10021LK	232 / 242	.507" / .507"	112 / 108	2000-6400
SMALL BLOCK CHEVY (1987-UP LT1, LT4)				
10030LK	218 / 228	.503" / .503"	112 / 108	1800-5800
10031LK	232 / 242	.507" / .507"	112 / 108	2000-6400
BIG BLOCK CHEVY				
10220LK	218 / 228	.570" / .570"	112 / 108	1500-5500
10221LK	232 / 242	.575" / .575"	112 / 108	2000-6000

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Circle 117 on Reader Service Card for more information body, original equipment or aftermarket)? How big is the throttle body? What kind of manifold is on the engine (brand, split-plane or single-plane, low rise, high rise, tunnel ram or multi-carburetor)? Split-plane manifolds typically produce more low end torque and are better for street engines.

• Firing Order – Is it stock, or are you swapping the firing order on cylinders #4 and #7 on a big block or small block Chevy for a broader torque curve? Obviously, you'll need a different cam if the firing order has been changed.

• Street, Street/Strip or Race Only – If the engine is being built for the street, will it be emissions exempt or will it have to meet emission regulations? If a customer wants you to build him or her a street/strip engine, how much time will it actually be run on the strip? The customer may believe it will be a 50/50 split, but realistically it will likely be more like 95 percent street and 5 percent strip. That affects where you want the engine to develop peak torque for everyday drivability.

• Transmission – Manual or Automatic? Automatics typically need more low end torque, especially in a heavier vehicle. But this can be affected by the stall speed of the converter. A higher stall speed allows the engine to rev higher before it grabs, but hurts fuel economy in a street driven vehicle. If the engine will go in front of a manual transmission, how many gears does the transmission have, and is the gear spacing wide ratio or close ratio?

• Final Gearing – The final drive ratio of the differential and the size of the tires will also affect the rpm of the engine as it accelerates and cruises. The engine's power curve should match the gearing for optimum performance.

• Exhaust System – If the engine has headers, what is the style, diameter and length of the headers? Does the exhaust system have mufflers or a cross-over H-pipe or X-pipe?

• What Does Your Customer Want? Does the customer you are building the engine for want lots of low end torque or high rpm power? Does he want a lumpy idle or a smooth idle? Is he willing to spend more for a custom cam or will an off-the-shelf cam be good enough?

You can often select cams online using software programs that literally walk you through the process. However one of the most common mistakes novice engine builders and DIYers alike make is over-camming an engine.

They want the cam with the biggest numbers, never mind the fact that such a cam may be a poor match for the engine or vehicle they are sticking it into. A wild cam in a slightly modified engine may sound great with a loping erratic idle. But if the engine has no low end torque or throttle response and never reaches the rpm range where the cam starts to really work, the engine will be a dog.

Understanding Duration

Duration is one of the factors in cam design that affects where the cam develops peak power. Duration is how long the cam lobe holds a valve open and is specified in degrees of crankshaft rotation. The duration specification will vary depending upon how and where it is measured.

As the cam spins around and a lobe begins to push its lifter up, the valve starts to open. But if the engine has solid lifters, the lash in the valvetrain must first be compressed before the valve starts to open. If duration is measured from the point where the lifter has risen .004˝above the base circle of the cam lobe to when it comes back down to within .004˝ of base circle, it creates a somewhat inflated value. Some cam manufacturers refer to this as the "advertised duration" because it gives the biggest numbers, and thus appeal to engine builders who subscribe to the "bigger is always better" philosophy of cam selection.

By comparison, the Society of Automotive Engineers (SAE) method for measuring duration says it is to be measured at .006˝ above the base circle for hydraulic cams, and .006˝ plus the specified valve lash for mechanical solid lifter cams.

Another way duration may be specified is to measure it at .050˝ above the base circle of the cam lobe. The .050˝specs are the ones most commonly cited in aftermarket catalogs.

What does a duration spec tell you about a cam? It reveals something about the rpm range where the cam will make the most power. Generally speaking, the longer the duration the higher the rpm where the cam makes power. Short duration cams are good for low speed torque and throttle response while long duration cams hold the valves open longer for better high speed breathing and top end power.

Cams with durations in the 195 to 210 degree range (measured at .050˝cam lift) are usually considered best for stock unmodified engines and those with computerized engine controls. Once you go beyond 210 to 220 degrees of duration, intake vacuum starts to drop. This upsets idle quality and affects the operation of computerized engine control systems.

Performance cams typically have durations ranging from 220 up to 280 degrees or more. The longer the duration, the choppier the idle and the higher the cam's power range on the rpm scale. A cam with a duration of 240 degrees or higher will typically produce the most power from 3,500 rpm to 7,000 rpm.

If you try to compare duration specs between different cams, though, you don't always get an accurate comparison because duration specs don't tell you anything about the lobes themselves. Though cams from two different manufacturers may have identical lift and duration specs, the lobes on one cam may be ground differently from those on the other. One cam may have more of a peak shaped lobe while the other has a "fatter" lobe. A "V" shaped lobe will breathe differently from a "U" shaped lobe because it doesn't hold the valve at its maximum opening as long.

One lobe profile may also close the

valve more softly than the other, to reduce valve bounce at high speed. Valve float can also be a problem with lobes that change shape abruptly unless valve spring pressure is increased. The profile of the lobes on one cam may also be the same on both the up and down sides of the lobe (which is the norm for most stock and street performance cams) compared to an "asymmetrical" grind (different profiles on each side of the lobe) on the other cam.

The only way to really compare cam grinds, therefore, is to measure and plot lift versus rotation on a graph. This can be done manually with a degree wheel and dial indicator (which is a tedious job), or with an electronic stylus that plots the results on a computer.

Overlap and Separation

Another spec you need to look at when selecting a cam is the relative timing of the intake and exhaust valves. This can be expressed either as "valve overlap" (the time during which both the intake and exhaust valves are both open) or "lobe separation" (the number of degrees or angle between the centerlines of the intake and exhaust lobes). Decreasing the lobe separation increases overlap, while increasing the separation decreases overlap.

Most stock replacement cams with durations of less than 200 degrees will have lobe separations of 112 to 114 degrees. Higher duration cams for mid-range performance typically have 110 to 112 degrees of lobe separation. With racing cams, you'll find lobe separations that range from 106 to 108 degrees for more valve overlap.

Overlap occurs when the intake valve starts to open before the exhaust valve has finished closing. Increasing overlap can be a desirable thing in a naturally aspirated high rpm engine because the outgoing exhaust actually helps scavenge the cylinder to draw more air and fuel into the combustion chamber. But too much overlap at low rpm kills low end torque and throttle response by reducing intake vacuum excessively. It can also create idle emission problems by allowing unburned fuel to be drawn through into the exhaust.

Why Bore?

There are three basic reasons for line boring the main bearing and cam bearing bores in engine blocks. One is to restore worn, out-of-round or damaged bores. If an engine overheats or loses oil pressure, one or more bearings on the crankshaft or camshaft may seize and spin. The resulting damage to the bearing bore must then be repaired by either machining the hole to accept a standard sized bearing or an oversized bearing.

With main bearings, a worn, out-of-round or damaged bore can be restored back to standard ID by grinding or milling the mounting surface of the main caps, bolting the caps back on the block, and then cutting the holes back to their original dimensions.

In the case of worn, out-of-round or damaged cam bearings in an engine block, there are no removable caps. The only option is to enlarge the bores so new oversize cam bearings with a larger outside diameter (OD) can be installed.

Reason number two for line boring a block is to restore proper bore alignment - a process which is often called "align" boring (or honing if a line hone is used instead of a boring bar). As rigid as an engine block might seem, there is actually quite a bit of residual stress in most castings. As a new "green" block ages and undergoes repeated thermal cycles, the residual stresses left over from the original casting process tend to distort and warp the engine. This affects the alignment of the crankshaft and camshaft bores as well as cylinders.

Eventually things settle down and the block becomes more or less stable (a "seasoned" block). The bearings as well as the crankshaft and camshaft journals gradually develop wear patterns that compensate for the distortion that has taken place.

Additional warpage can occur if the engine is subjected to extreme stress (like racing) or overheats. If the original crankshaft or camshaft is then replaced without align boring the block, it may bind or cause rapid bearing wear. Likewise, if you're building a high performance engine with close tolerances, you don't want any misalignment in the main bores or cam bores.

The third reason for line boring or honing a block is to correct or change bore centers or bore alignment (as when "blueprinting" a high performance engine). The camshaft and crankshaft should be parallel in the block. If they are not, line boring can correct the misalignment to restore the proper geometry. With performance engines, there may also be a reason to change the centerline of the crankshaft or camshaft slightly to alter the piston or valvetrain geometry.

Even though the end goal of line boring has remained constant, some innovations in the recent past have made line boring anything but a boring subject.

One of the disadvantages of using a traditional horizontal boring bar is that it tends to sag. This has to be countered by using adequate support so all the bore holes are cut straight and true with no misalignment between holes and no variations in bore size.

One way to eliminate the effects of gravity on the boring bar is to use a vertical boring machine. Rotating the block and bar 90° so the block and bar are straight up and down provides a truer, straighter cut says one manufacturer of this type of equipment. It also saves floor space because the machine has a smaller footprint.

Another way to circumvent the issue of bar sag is to use a 90° right angle cutter attachment on a milling machine. Instead of using a long steel bar to pass single or multiple cutters through the main bores, the 90° cutter is lowered into the space between each main bore, then moved sideways to machine the bore ID. It's sort of like working around a corner.

With computer numeric controls (CNC), each hole can be precisely machined to exact dimensions and the centerline of each hole perfectly located and aligned with all the rest. This technique works especially well on large, heavy blocks that may be too long for most boring bars.

OHC Applications

When overhead cam cylinder heads came into widespread use, it quickly became apparent that line boring or honing would be needed to correct a variety of problems (cam bore wear, distortion and damage as well as cylinder head warpage). Aluminum heads can be easily warped by overheating. When the head gets hot, it tends to swell the most in the center area. The head bulges up in the middle causing misalignment in the cam bores. This, in turn, can cause uneven wear in the cam bores, camshaft sticking or even cam breakage.

If an OHC cam won't turn in the head, it means the cam is sticking because either the cam is bent or the head is warped. In the case of a bent cam, the center cam bores will show excessive wear or be worn out of round. If the head is warped (which many aluminum heads are), the head should be straightened BEFORE it is line bored or resurfaced.

In the past, a popular fix for OHC heads with worn cam bores was to line bore the head to accept bearing shells or inserts. Nowadays, the more popular fix seems to be cutting the head to accept a cam with oversized journals.

Alignment Checks

The alignment of the crankshaft and camshaft bores in blocks and OHC heads can be checked by placing a straight edge in the bores or along the bore parting lines and using a feeler gauge to check for misalignment.

How much misalignment is too much? It depends on the engine and the application. A light duty passenger car engine is not as critical as a high revving performance engine or a hardworking diesel engine. As a rule, most passenger car and light truck engines call for .002˝ or less of misalignment between all the bores, and .001˝ or less misalignment between adjacent main bores. For performance engines, you can reduce these maximum tolerances by half or more.

Another dimension to look at is bore wear. Bore diameters should usually be within .001˝ of specifications to support the bearings properly, with no more than .001˝ out-of-roundness if the horizontal dimension is greater than the vertical dimension.

Also check for wear on the thrust bearing surface of the main cap. If worn or damaged, this surface should also be remachined.

Installation Tips

For stock, street performance and some racing applications, a cam kit that includes lifters is a good way to go. Some kits also include new, stiffer valve springs for higher revving applications. But for professional racing, most cams are sold outright. This gives the engine builder more flexibility in choosing lifter configurations.

Regardless of what kind of engine you are building, or the application it is going into, always use new lifters with a new camshaft. Reusing old, worn lifters can ruin a new cam.

Be sure to check valve-to-piston clearance, especially with high lift cams and/or high lift rocker arms. Also, make sure the springs do not bind with high lift cams or rockers.

Lubrication is also critical. All cam lobes should be coated with a high pressure assembly lube, not just motor oil (which will run off if the engine sits for any period of time). Also, if the engine has a flat tappet cam and will be used for racing, special racing oil that contains higher levels of zinc than ordinary motor oil may be necessary to prevent premature lobe and lifter wear.

Camshaft break-in after the initial engine start up typically requires running the engine at 2,000 to 2,500 rpm for up to 30 minutes. Don't let it idle or you may wipe out a lobe. Be sure to check valve-to-piston clearance, especially with high lift cams and/or high lift rocker arms. Also, make sure the springs do not bind with high lift cams or rockers. **PPMG**


Engine-building
BOOK OF REVELATIONS
If you ask Jason Line, the current point's leader and 2006 NHRA Pro Stock champion about racing pistons, he will tell you:
"Our KB Racing pistons are custom-made. With Pro Stock engines turning in excess of 10,000 rpm, the pistons must be perfect for repeatability. We inspect each of them to the closest tolerances—there is no room for error. We use Diamond pistons—we've been using Diamond for six years. They make the best pistons, they are easy to deal with, and they go the extra mile when we're in a hurry."
2009: 2 wins from 3 races
Jon Kaase on Diamond pistons:
"Virgin piston forgings aren't always perfect. But Diamond is really good at repeating the shape of the piston crown on the underside. Their attention to detail in their machining processes is second to none. I use Diamond pistons in our Jon Kaase Boss Nine kits and in our P51 kits. And for our new crate motor program, Diamond will be my piston of choice."
When 3-time Engine Master's Challenge winner Kaase comments, it usually attracts attention.
"For the past four or five years, I've been running Diamond pistons.
Today, I order them with Casidiam-coated wrist pins. The pistons have sound supports and load paths around the pin, they are resistant to flexing, and have well-configured ring lands and good skirt designs. They are the best pistons I have found, and as a company, Diamond is easy to deal with—and I've tried them all." Larry Pritchett
Midsouth Racing Engines, Clarkrange, TN
Ray Barton Racing Engines, the pre-eminent Chrysler Hemi specialist, has been building race engines for forty years. Today, their annual output of Hemi engines is around 300; they specialize in Super Stock engines and produce the 528 Hemi crate engines for the Chrysler Corporation. All of them are with Diamond—Ray Barton uses only one brand of piston.
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"Diamond is the most dependable piston I've ever used. They build them to our specifications and they deliver on time. I've been with Diamond for seven years."
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