## Bottom End Bits

The bottom half of an engine and its contents - that large hunk of cast metal below the cylinder head - are commonly referred to as the short-block or bottom end. A short-block is comprised of major components such as the cylinder block, the crankshaft, connecting rods, and pistons. Between the friction surfaces of these large, metal parts are metal-shell bearings, which with the help of a film of engine oil allow the engine to spin to the ridiculous velocities we all seem to enjoy. The crankshaft, connecting rods, pistons, bearings, and rings make up the reciprocating assembly, which (as its name implies) is made up of several hunks of metallurgy that turn the piston's vertical motion into reciprocating motion.

Not exactly the makings of a killer plot for the next Jerry Bruckheimer production, but know that from this short block assembly comes all of the sacred power that you devote most of your waking life looking for. The condition, and capability of this assembly, combined with a keen eye toward cautious preparation and assembly will go a long way to letting you make durable power. Since understanding the technology involved will be the first step on the road to power making nirvana, here's our first in a series of Power-Making Primers.

### Your Cylinder Block

Most of today's auto manufacturers are producing excellent motors. Utilizing superior and more consistent manufacturing techniques, and given the progression of improved design, modern, small displacement engines provide an excellent basis for power enhancement straight from the factory. Engine blocks, such as those offered by Honda, are normally cast from premium heat-treated aluminum and sleeved with ductile-iron cylinders that serve as piston-sealing thrust surfaces. This combination of the lightweight aluminum and steel create a sturdy assembly that takes advantage of the lightweight and heat-dissipating properties of aluminum and the low expansion thermal properties of iron. Ultimately, all engine component failure can be traced back to the demands of excessive heat and stress placed on the metals. As the tolerances of the larger metal components is improved through more precise and consistent manufacturing, heat-related friction failure is reduced and the engine's capability of withstanding the tremendous inertia of greater revolutions is enhanced to ultimately tolerate more stress and produce more power.

The tooling, factory machining, and quality controls of these blocks tend to be so high that, little in the way of traditional blueprinting and machining procedures, is necessary to make tremendous power. As long as the basic clearances check out and the block has not liberated any moving parts during its lifetime, it should remain serviceable (with re-sleeving in worst case scenarios). Engine blocks that tend to suffer under heaps of forced induction would benefit from the addition of a block guard (like Nuformz) or T-shaped sleeves that help stabilize the cylinder bore's deck surface beneath the head for improved sealing and stability. Other basic upgrades would include high-strength specialty hardware, such as high-grade head studs that allow more precise torque to be applied to the heads and main studs to help align and stabilize the main caps. Seasoned cast-iron blocks require all of the detail-oriented procedures of blueprinting to achieve the correct tolerances. Deck tolerances and aligned boring of bearing surfaces are especially critical for cast-iron blocks, and all boring should be done with the aid of torque plates that mimic the stress placed on the block by the cylinder head.

**Crankshafts Explained**

The largest single piece of moving metal in the reciprocating assembly is the crankshaft. As the main rotating member that runs the length of the crankcase, the crankshaft's offset journals are attached to the pistons by the connecting rods. Luckily, most import engines come with a very strong forged steel crankshaft that serve as an excellent basis for higher performance duty. Once again, the factory materials and machine work are exquisite enough on these production pieces that examples have seen up to 400-500 turbocharged horses or more without failure. This is testament to modern manufacturing and the improved control of component tolerances.

In addition, various machining procedures can be employed to improve a crank's performance and longevity. The manufacturing process and metallurgy of these forgings typically result in a component of fairly uniform grain structure and incredible strength for resistance to detonation and twisting. While factory crankshafts often come forged, certain procedures can improve their durability under harsh race conditions. Selecting a used crankshaft for a buildup should begin with a magnafluxing procedure that inspects the piece for cracks. Manufacturing leaves casting flash or risers on forgings, which can be deburred to relieve the chances of these elements later stretching into cracks in the metal after repeated heat cycles.

Shot-peening is a process that helps relieve a metal component's surface stress by projecting high velocity shot against the surface and removes microscopic cracks that can lead to subsequent failure. Crank journals also receive machining to restore their uniformly round shape. Then, they are micro-polished with a fine band sander to remove any further imperfections from the bearing surfaces.

Gas nitriding, hard chroming, and tuftriding are surface-hardening procedures designed to improve crankshaft longevity and, in particular, bearing surface durability. Nitriding is a heat-treating process, while chrome-plating is electrochemical, and tuftriding uses superheated cyanide to achieve the desired surface hardness.

For certain applications where throttle response is key, the crankshaft can have material machined off its counterweights to reduce weight and inertia. Also, the leading edges of the crankshaft’s large counterweight can be machined at a 45-degree angle for what is commonly referred to as a knife-edging treatment. Knife-edging a crankshaft is a procedure designed to reduce the crank's wind resistance to the oil vapors that rise from the crankcase and oil pan. For sustained high rpm use or endurance racing, it is best to leave the counterweights intact. A crankshaft must also be checked for straightness and proper tolerances after machining or heat-treating procedures. Oil passages can be enlarged with chamfers around oil holes for improved high rpm lubrication of the main and rod bearing surfaces.

Aftermarket crankshafts can be custom-made (Crower, for example) to a desired stroke requirement, often utilize metal alloys that are superior in strength to factory castings and lower-grade forgings. Custom cranks can be used to increase the engine's stroke and displacement in conjunction with specific rods and pistons. Superior materials and application-specific counterweighting of some of the finer aftermarket crankshafts, such as those manufactured by Crower, are geared toward resistance to flexing which is a cause of bearing failure.

Custom cranks can also be designed for more aggressive oiling of the rod journals. Custom cranks can be drop-forged out of dies and then machined to position their masses in the optimum locations for a given application. Materials such as 4340 chrome-moly steel create a torsionally resistant crank that will better withstand elevated cylinder pressures and the occasional spat of detonation better than a prepped factory unit.

Above the drop-forged custom crank on the crankshaft food chain is the 4340 billet crank. What begins as with a round log of 4340 billet weighing several hundred pounds is then machined into an extremely rigid and durable billet crankshaft. Billet crankshafts are what the Top Fuel teams use in the bottom-end of nitromethane burning, blown, hemi engines. If you're not familiar with what this means, simply understand that import motors will be hard-pressed to duplicate these levels of cylinder pressure and temperature.

**Connecting Rods and Bolts**

The stresses placed on an engine's connecting rods are such that during engine operation, these components actually stretch. Connecting rods are the most stressed component in the reciprocating assembly. Most rods require basic Magnafluxing, polishing, and shot-peening procedures in addition to wrist pin oiling holes, heat-treating, and stronger rod bolts (such as ARP pieces) to tackle higher horsepower. Specialized rod bolts made of very high-grade steel can better cope with the high inertial stresses placed on the rod's big end caps. Once again, applying precision-machining procedures to factory rods, in conjunction with improved aftermarket fasteners, will prepare them for more serious performance duties.

When these measures are not enough, it becomes necessary to make an improvement in the materials of the rod. A variety of companies can create custom forged rods in any possible length. This is important because in building a dream short-block, one should adhere to the principal of utilizing the longest rod possible in the assembly. The longest rod allows the piston to dwell at (or near) TDC for the greatest duration possible. The longer the piston can dwell at or near top dead center, the greater cylinder pressures can be built, and the engine can then produce more mid-range torque.

Custom rods are available in 4340 steel forgings machined to various weight configurations, as well as extra strong 4340 billet steel units, titanium rods, and aluminum connecting rods. Each material offers advantages for specific engine applications. Aluminum connecting rods are geared toward the builder who is looking to dramatically reduce the weight of the reciprocating assembly to improve acceleration and throttle response. Aluminum rods are not considered durable enough for endurance racing motors. Most endurance racing motors make some use of either an I-beam or H-beam 4340 forging with a set of high-grade cap-screw fasteners. Billet steel rods are the strongest due to the high homogeneity of the billet material's metal grain structure as they are precision-machined from a large uniform chunk or premium metal. A compromise between the two would be the titanium rod, but these are very expensive, and the titanium metallurgy can "grab" bearing surfaces if the titanium is not properly treated.

## Forged and Cast Aluminum Pistons

Your engine’s pistons reside in the cozy inferno under the combustion chamber of the cylinder head in a round slot that likely feels like the thirteenth level of hell when thing are working right. Attached to the small end of the connecting rod, these units move up and down in the cylinder at tremendous speeds pushing air in and out of the engine. Most engines, even many performance-minded motors, come from the factory with some sort of cast aluminum pistons. There are both high-and low-pressure cast pistons and their resistance in a hostile cylinder environment is relative to the density of their composition and its related resistance to friction and pressure.

Simply put, cast pistons cannot withstand the levels of heat, friction, and speed that aluminum forgings, with their denser mass, can survive. Casting involves a metal-pouring-into-a-mold mass production process that allows for minute imperfections and porosity in the piston. Cast pistons, which are stock in popular motors, are often high-pressure castings with friction-fighting coatings to survive more revs. The advantages of cast pistons are that they're lightweight, there's a lower thermal expansion rate compared to forgings, and they cost less. For most mild performance applications, these castings are quite effective due to their lower heat conductivity and tendency to reflect heat back to the combustion chamber.

Hypereutectic pistons, which became the rage in the early '90s, offered the reliability and lightweight of cast pistons but were resistant to higher cylinder temperatures. These pistons are cast with a material high in silicone content to achieve the low expansion rate and cylinder wall tolerance of a common cast piston, with near forged piston strength. Hypereutectic pistons are ideal for high-performance, naturally aspirated and low to moderate boost applications. They are not suitable for high boost applications or nitrous, which can destroy this strong, but inflexible style of piston. These pistons are priced in between economical pressure castings and forgings.

Forging is a process that creates a solid chunk of uniformly grained metal. The details, features and sizes are then precision-machined from this piece to create a near jewel-like finished product. Forged pistons come from the aftermarket in various sizes, pin and ring locations, and dome configurations. Forged pistons signify a serious commitment to the engine's performance potential; their ability to withstand heat and pressure at greater speeds inevitably means greater outputs than cast pistons. Most forged piston manufacturers offer two different alloys as the base material for the forged pistons. Forged pistons become stable at higher rpm, once their material expands, but can cause noise as they slap around in the cylinder walls at low speed when cold.

The aluminum used for forged pistons differs in its proportion of silicone and copper, and thus offer different expansion rates. Additional silicone in a 4032 grade alloy yields a piston with lower heat expansion properties that maintains a tighter piston to wall clearance. Another grade of aluminum, 2618, contains less than one percent silicone with a higher content of copper. The composition of such pistons permit greater expandability and require greater piston-to-wall clearances, making this type suitable for the extreme heat and pressure caused by high-boost turbo or supercharger applications and/or loads of nitrous.

Specialty pistons designed for turbocharged applications have a dished surface to help increase chamber volume to lower compression. They also wear a lowered ring pack that protects the top ring from heat and pressure. Lightweight forged pistons have material machined away from non-critical areas to help reduce the piece's inertia and improve throttle response. The same custom-machining procedures can also re-position the pin location higher in the piston to take advantage of a longer rod. Custom piston manufacturers often have two or three grades of piston pins, which vary from a venerable carbon steel unit, to a thin wall tool steel unit that can withstand severe pressures, while still reducing the piston's overall mass.

Most factory motors utilize pressed in pin-fit arrangements, but for high performance, the general practice is to drill the small end of the connecting rod for oiling and convert to a full-floating piston pin arrangement. Full-floating pistons create less friction and utilize specialized pin retainers. As the engine spins, floating pins allow the rod to compensate for the inevitable slight misalignment of the rod, crank, and piston, and orient itself more precisely with the crank journal and pin.

If we're operating in the high stakes world of custom pistons, it is advantageous to address the ring sealing for optimum performance. Today's high performance engines afford many options for those greedy to find more power. The standard theory had been that narrower, higher tension rings possible would provide the greatest reduction in fractional drag, and result in greater power. Such ring packages, however, prompt increased wear on the cylinder wall. The truth is that, in many cases, the power improvement is not so great to justify the additional wear.

**Piston Rings and Things**

Traditionally, piston rings are made of cast iron. Cast-iron rings are effective because they are porous and can retain oil to minimize wear. Ductile iron improves on cast iron as it has the same porous properties coupled with improved flexibility that allow it to bend before it breaks. These rings then evolved into chrome-plated cast-iron rings, which afforded a very slick and durable ring finish that's resistant to scuffing. This placed additional emphasis on the machining of the cylinder bores to achieve the correct seal for these "hardened rings". These rings evolved into stainless steel rings that provided many of the advantages of the chrome-plated cast-iron rings but with improved durability.

The effort to provide improved ring life with rapid break-in, led to the development of the moly ring, and this has become the basic ring material favored by the performance industry. This ring is essentially a cast-iron base metal with a molybdenum coating sprayed on the surface. Popular ring packs from agencies like Total Seal and Childs and Albert offer gapless or zero gap ring sets that reduce the blow-by of compressed gases between the edges of ring surfaces for additional power. While ring material is certainly an important consideration, the design of the ring and its correct placement on the piston contribute to effective cylinder sealing and oil-controlling.

**Glossary of Machining Procedures:**

**Chamfering:** a hand-grinding procedure to bevel the sharp edge of an object or a hole.

**Balancing:** a detail-oriented process of verifying component dimensions, weights, and clearances for uniformity in the moving assembly. The process relies on accurate precision-measuring tools.

**Blueprinting:** disassembly and re-assembly of a motor to exact specifications with verified measurement for clearances.

**Cylinder boring:** renewing of the cylinder walls by cutting them out to specified size, usually larger than stock to increase displacement.

**Boring bar:** an electric cutting tool implemented to machine, or to cut a cylinder wall to remove metal and enlarge the bore.

**Deburring:** removal of casting or forging risers or imperfections with a high-speed electric grinder. These risers can often lead to cracks in the assembly.

**Gas-nitriding:** a process that improves the surface hardness of metal by heating to more than 500 degrees Celsius to produce a surface layer of nitrogen.

**Heat treatment:** a process combining heating and cooling cycles applied to metal to improve its strength.

**Hard chroming:** an electrochemical process that adds surface hardness and uniformity to a metal friction surface.

**Micropolishing:** a crankshaft-machining process that utilizes high-speed, motor-driven, fine-grit, abrasive belts that polish the bearing surfaces of the crank to remove imperfections.

**Magnafluxing:** a process using electromagnets and iron filings to detect fissures or imperfections in ferrous metal parts.

**Shot-peening:** a process of projecting shot at the metal of hard parts to relieve surface stress and improve strength. The shot-peening process relieves the crank or rods of microscopic imperfections that could later lead to cracks.

**Tuftriding:** A hardening process that involves submerging the metal component in a bath of molten cyanide to achieve better surface hardness.