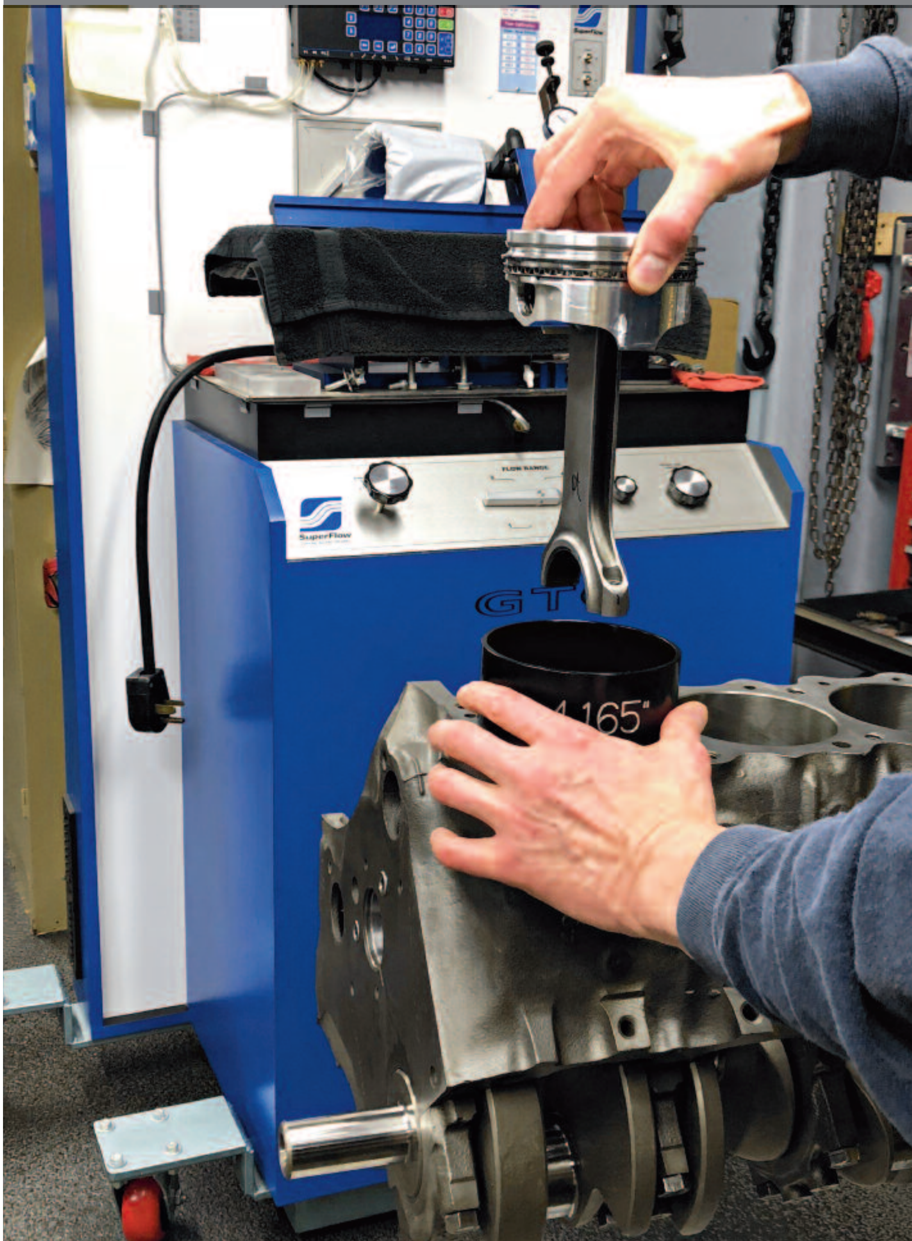
Blueprinting Basics:

Build a Bulletproof Bottom End

Nitemare Performance Shares Some of its Blueprinting and Prep Processes While Building a Giveaway Engine That You Could Win!



Nowhere within your Pontiac's engine is blueprinting more important than its reciprocating assembly.

Story and Photos by Jason Scott

Long, long ago, back in the days before CNC-machined this and laser-cut that, the parts that comprise an engine's reciprocating assembly – its crankshaft, connecting rods, pistons, rings, etc. – weren't made nearly as accurately as they are today. Measurements were all over the place, both in terms of dimensions, and in terms of weights. Specifications seemed like unobtainable suggestions. And let's not get into how far we've come on metallurgy that results in lighter, stronger, more consistent parts.

Thanks to computer-controlled milling machinery and laser-precise measuring devices, it's easy to expect that modern parts will be hyper-accurate in just about every way, so you might be tempted to think that you don't need to spend the time to blueprint your engine. But you'd be wrong.

Case in point: while measuring components prior to assembling one of Nitemare Performance's signature crate engines recently, Darrin Magro discovered a problem: the difference between the new crankshaft's journal diameters and the inside diameters of the main bearing shells that he'd ordered with the crank left too little clearance for a sufficient film of oil during operation. Not enough oil at the crank could quickly lead to spun bearings, a ruined crank, seized pistons, scored cylinder walls, and other catastrophic forms of failure.

Fortunately, Magro's methodical and meticulous preparation processes enabled him to identify what was wrong and to correct it before it ever became an issue – in this case, by using a different set of main bearings.

Of course, Magro is quick to point out that – in addition to preventing problems before they occur – there are numerous other reasons to blueprint an engine, including that it can affect how much power an engine makes, its efficiency, its durability, and there are several ways in which it can affect its operation.

So, when Magro offered to walk us through some of the many (many!) steps that he goes through to blueprint the reciprocating assembly of each and every Nitemare Performance crate engine, we jumped at the chance.

One of the nicer things about blueprinting your engine is that it's not particularly difficult and it doesn't have to cost a lot of money, if you do it yourself. With only a few extra tools and … well … a fair amount of time, you can carefully measure the various components and adjust your assembly plans based on what you find and what your goals are for your engine.

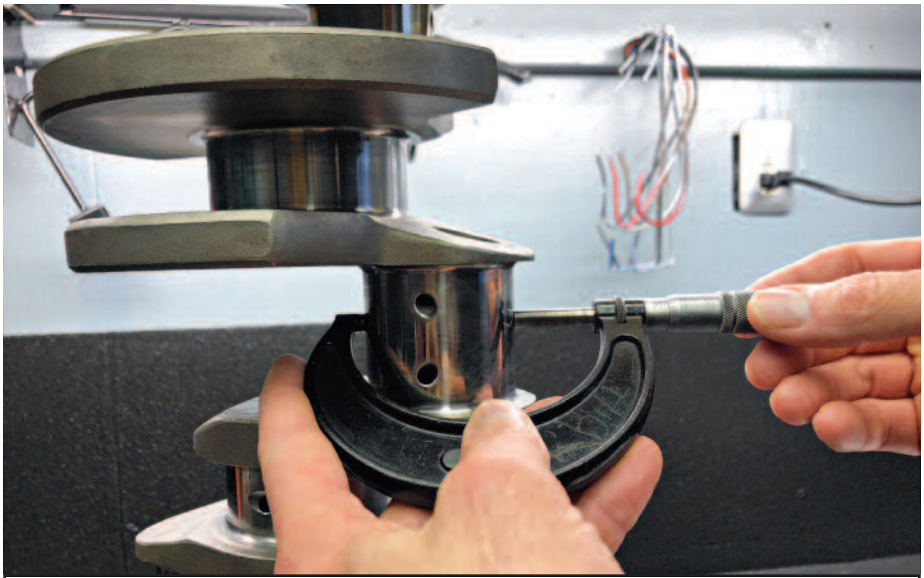
Block

In a previous blueprinting article, Magro showed us what Nitemare Performance does to blueprint blocks for their crate motors. Refer to that story for details, but short version is that the block needs to be carefully machined, including having the main bearing saddles align-honed and the cylinders bored and honed to accommodate the pistons you'll be running and the clearance that you need … among other things.

Whether you're reusing an old crankshaft or starting with a newly cast or forged piece, you absolutely must measure each journal (including the rear main seal journal) to determine the size of each. Record them on a piece of paper to use in calculations later.

Crankshaft

The crankshaft should be magnafluxed to inspect for cracks, then the diameter of each main and rod journal should be measured with a micrometer and written down. To determine main bearing clearances, subtract those journal diameters from the inside diameter of corresponding main bearing saddles with their bearing shells installed or the respective



If you don't have a set yet, you'll need micrometers of a few sizes to accurately measure the journals, down to a thousandth of an inch. Note that many aftermarket Pontiac cranks use a Big Block Chevy-sized 2.200" rod journal instead of the typical 2.250" Pontiac journal size. Your rods will need to be sized correspondingly.

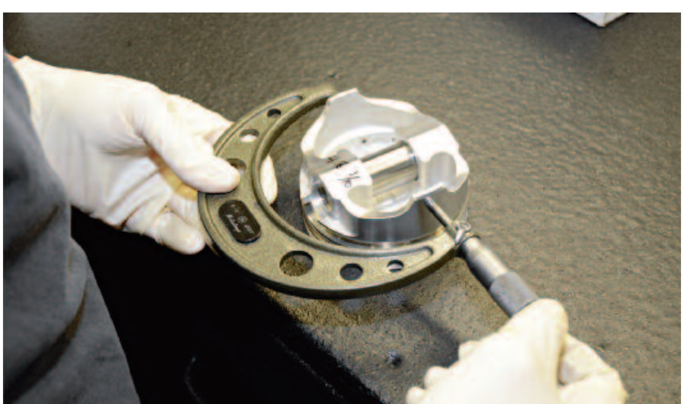
Many engine rebuilders overlook the importance of installing new woodruff keys in crank snouts. Old keys can be bent or just fit too loosely to key the cam gear accurately indexed to the crank. A new key is cheap insurance against problems.

Modern pistons — like this forged aluminum Keith Black unit with bore-specific valve reliefs — are made from superior metal alloys and are machined to far more exact tolerances. Whether re-using old pistons or opting for new ones, your pistons will need some love prior to installation. Start with a good cleaning and deburring, to minimize any sharp edges that could damage cylinder walls or lead to detonation-inducing hot spots.

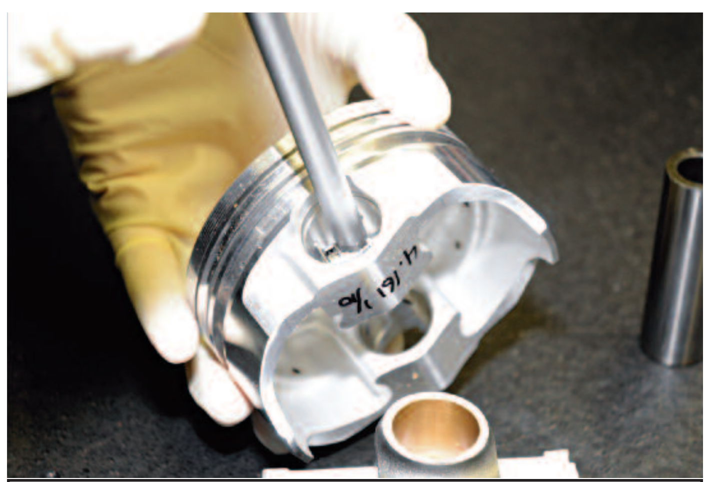
connecting rod with its bearing shells in place. See the accompanying table for the factory specs for your vintage Pontiac engine. Different size bearing shells can be ordered or the crank can be polished to achieve the optimal clearance. Factory cranks can also be nitrided to harden the surface of the crank for improved wear, durability, and friction characteristics. The crankshaft should be dynamically balanced to match the weight of your piston and rod assemblies, including the rings you'll be using. When installing the crank, be sure to measure end play by prying it back and forth in the saddles with a pry bar with a dial indicator touching the snout. Again, the specs are in a nearby table. Even if you go with a new crankshaft, check all dimensions, because you never know if or when something might be "off."

Connecting Rods

These days, new connecting rods with improved designs, materials, and vastly superior fasteners are so cost-effective that it rarely makes sense to recondition original Pontiac connecting rods, unless you're doing a full restoration of an ultra-rare Super Duty, Ram Air IV or V engine or



Pistons need to be measured carefully, at several heights up and down the skirt and around it, too. Then, based on your desired piston-to-cylinder wall clearance, determine which piston will go in which cylinder to achieve (or come closest to) that clearance. Some cylinders may need additional honing to achieve the right clearance.



You also need to measure the piston's wrist pin bores, to ensure that they'll provide the proper clearance for that piston's pin. Nitemare Performance's Darrin Magro is using an inside micrometer to gauge the pin bore size.

something along those lines … and even then, modern rods would be lighter and stronger.

If you do rebuild old rods, the first steps are to clean them and check them for cracks, since there's no point rebuilding junk rods. Rods – even new ones – should then have their big and small ends measured for roundness and diameter. Measuring the center-to-center distance of each rod will indicate whether all your connecting rods have the same length (for even power production). Rods should also be checked for straightness, to ensure they are neither twisted nor bent. The rods' surfaces can be shot-peened to minimize the chance of cracking, and deburred to remove any potential stress risers. Connecting rod failures almost always occur at the rod bolts, so don't reuse old ones. Ever.

Lastly, the rods should be balanced by weighing the entire rod (for an overall weight), as well as each end individually on a special device, then machining each rod to make its weight match that of the lightest rod of the set.

Pistons

Piston casting and machining technology has improved considerably since the 1960s and '70s. While there used to be loads of variation between any two pistons in a set, today, it's rare to find any variation in size or weight … at all. But you still have to check, to know for sure.

Measure the diameter in multiple places, up and down the skirt and around it; you should discover that the pistons are tapered (narrower at the top than bottom, by between 0.005-0.010") and that they're intentionally slightly elliptical (oval-shaped), because as a piston heats, it expands and becomes more round, so they seal better when warmed up. Forged pistons expand more than cast, so they typically need looser piston-to-wall clearances. Hypereutectic pistons fall in-between cast and forged units, in terms of necessary clearances.

You also need to measure the diameter of the piston pin bores. The goal is to have all pistons in a set as equal as possible, so that each cylinder will behave the same. After measuring, pistons – even new ones – should be deburred to remove any potential hot spots that could lead to detonation, especially on the top surface and around the top edge.

Of course, each piston should be weighed and reduced to match the lightest piston in your set during balancing.

And while it's beyond the scope of this article, it's worth noting that there are piston coatings available to minimize friction and improve heat resistance.

Piston Rings

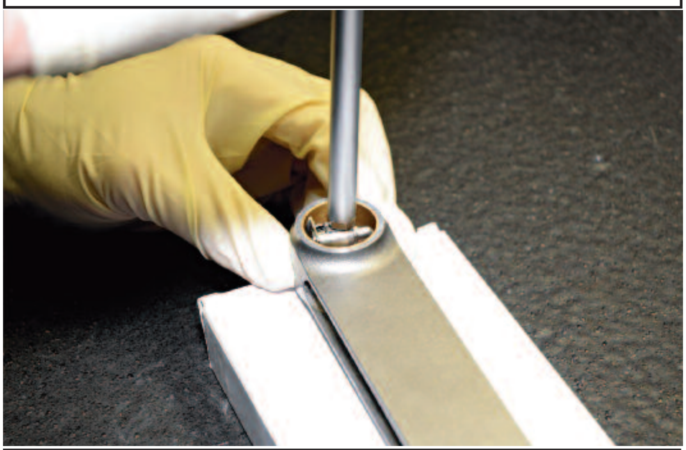
Piston rings have three jobs: they seal compression in; seal oil out; and transfer heat from the piston to the cylinder walls (and eventually to the coolant flowing through jackets around the cylinders). That's a lot to ask of some fairly small, fragile parts, so your rings need to be prepared carefully. Rings are available in a variety of metal alloys and explaining why could literally be an entire article of its own; suffice it to say that most street/high-performance rebuilds today will use moly-faced ductile iron top compression and second rings, and a "standard tension" oil control ring package.

The main dimensions to concern yourself with during blueprinting are the ring end gaps, as measured with the rings squared in the block, about an inch into the cylinder. Each ring must be identified for the cylinder in which it will ultimately be installed, as minor variations in diameter, cylinder to cylinder, would affect ring gap. As with most other measurements, the gap that you need will vary depending on the ring material and how your engine will be driven. For example, race engines or ones fitted with a turbocharger or supercharger experience more heat than a street engine, so parts will expand more, thus the ring typically needs a larger end gap.

A rule-of-thumb for end gap for the top compression ring is 0.004" of gap for every inch of bore diameter; so, for a typical, naturally-aspirated Pontiac 400 with a standard 4.120" bore, you'd want a bit more than 0.016" end gap. And don't be stingy here; while you might give up a little cylinder sealing with a slightly larger gap than necessary, you definitely don't want a gap that's too tight, which could result in ring failure.

Second compression rings experience less heat than top rings, but modern thinking calls for the same or greater gap than the top ring – up to 25 percent greater – to allow any gases that get passed the top ring to escape. So, if your top ring runs 0.016" gap then your second ring should have 0.016-0.020" gap. Again, this all depends on your application, though, so it's worth contacting your ring manufacturer for recommenda-

Of course, to know which pin fits which piston best, you need to mic each pin where it'll pass through each pin bore, and measure around the pin in a few spots, to ensue it's round. Again, an inside mic is the tool for the job.



Just as he measured the piston's pin bores, Magro measures the Scat connecting rod's pin bore with an inside mic. The raffle engine will use full-floating pins that slide in both the piston and the rod for minimal friction, and the sizes have to be just right.

This is a piston ring squaring tool, which will ensure that your rings are aligned square to the bore as they'd be when installed on pistons, and at the proper depth so that you can accurately measure ring gap.

Here, Magro is using a larger inside micrometer to check the diameter and roundness of the big end of the Scat forged H-beam connecting rods that are going into the raffle engine. Rods will be matched to the journals that will most closely provide the desired rod bearing clearance. The crank journals can be polished slightly or different bearing shells can be used to fine-tune the clearance.

While rod bolts can be tightened based on a torque spec, the better method – like with the ARP bolts in the Scat rods – is to measure how much they stretch when tightened. Bolts are sort of like elastics: they can only stretch so far before they can snap. To do that, you need to know the length prior to tightening, which Magro is measuring here with a special stretch gauge.

It only takes a second to accurately square the ring and set it at the proper depth in the cylinder, using a ring squaring tool. You can't get that kind of precision or speed with an upside piston. Here's a tip: Magro squares the top rings in every bore at the same time, then does the same for the second rings. This saves time compared to doing the top ring in one bore, then its second ring, before moving onto the next cylinder.

Each of the top and second compression rings needs to be matched to a specific cylinder. Once you square the ring within the bore, measure the gap using feeler gauges. Typically, you'll want 0.004" per 1.0" of cylinder bore diameter, so for a typical 4.120" Pontiac, you'll want around 0.016-0.018" gap.

If your ring gaps are too tight, you can open them up slightly using a ring filer, as Magro is doing here. Rings are fragile and can break if you try to file the ends with anything other than a ring filer. If your gaps are too loose, the only real solution is to get oversized rings … and file them to fit.

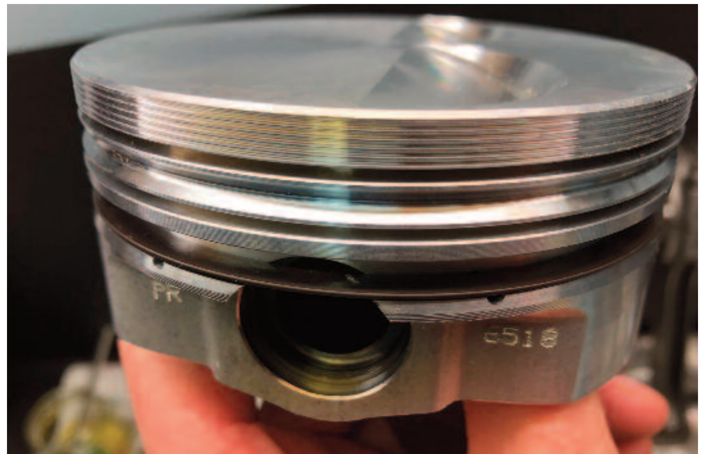
With full-floating wrist pins, a spiral lock (sort of like a snap ring) fits into a groove inside the piston's pin bores, to prevent the pin from exiting the piston and gouging into the cylinder wall. Here, Magro is installing the first spiral lock into a piston.

The beauty of full-floating pins – aside from reduced friction – is that it's a snap to assembly your rods and pistons, compared to press-fit pins. The pin just slides through the piston and rod and you install the spiral locks to keep it in place.

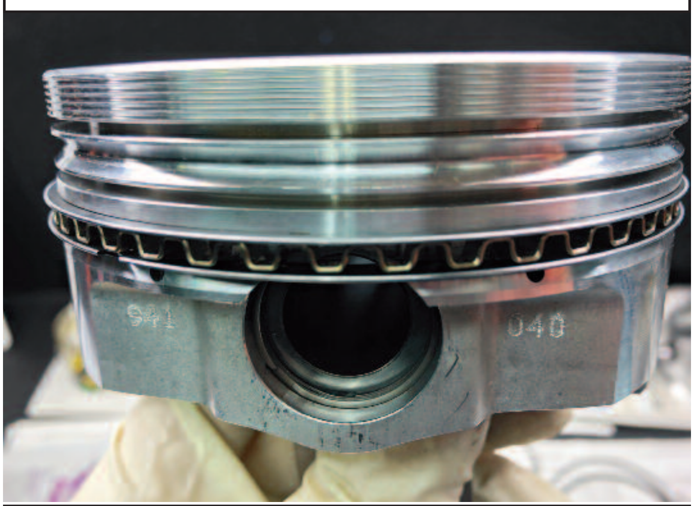
Here, Magro is installing the second spiral lock, to capture the piston pin. There are special tools that simplify spiral lock installation, but Magro finds it's often just as easy to do them by hand.

With the piston, pin, and rod assembled, check to ensure that everything moves freely, and then move on to the next piston and rod assembly.

Repeat the process a few times, as Magro did here, and you, too, will have your Pontiac's eight piston/rod assemblies ready for rings and insertion into the block.

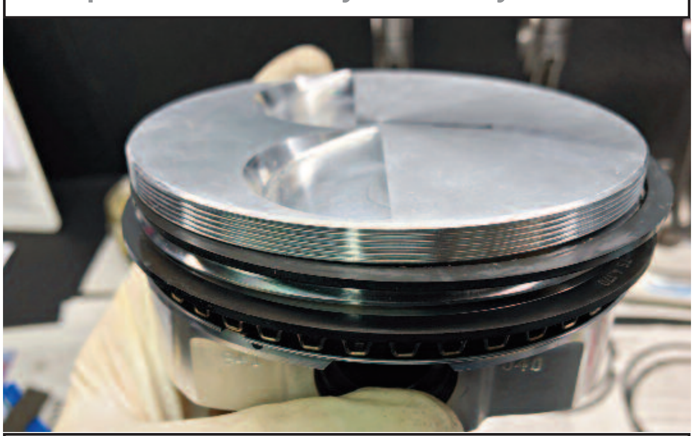


Start installing your piston's rings by installing the bottom oil control rail, as shown here. The oil control rails have a fair amount of flex and should be easy to install by hand.



The oil control ring pack consists of upper and lower rails separated by an expander ring, in between. All three pieces should be easy to install by hand.

Ring expanding pliers, demonstrated here with a spare piston from another project, are inexpensive and prevent scratching your pistons when installing rings, which often happens if you try to "spiral" the rings onto your pistons. They're the proper way to install rings.

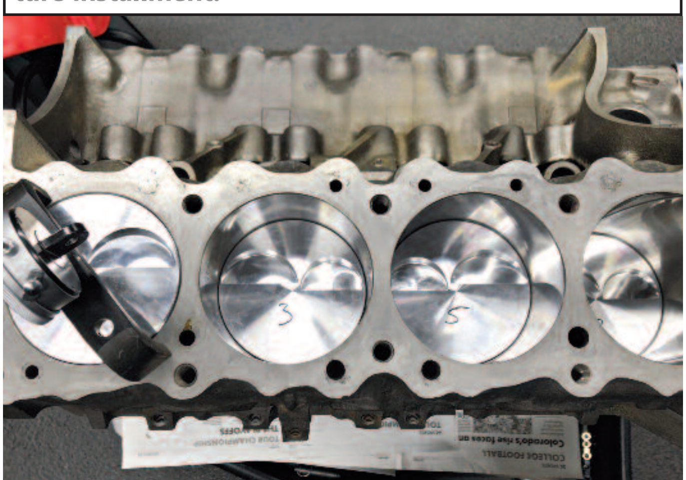


While the top and second rings may look similar, they're specific for each ring land, so don't confuse them. And the only proper way to install them is with a ring expander, or you risk damaging the ring, the piston, or both. When you do get them on the piston, orient the gaps so that they're 180 degrees apart, to maximize cylinder sealing.

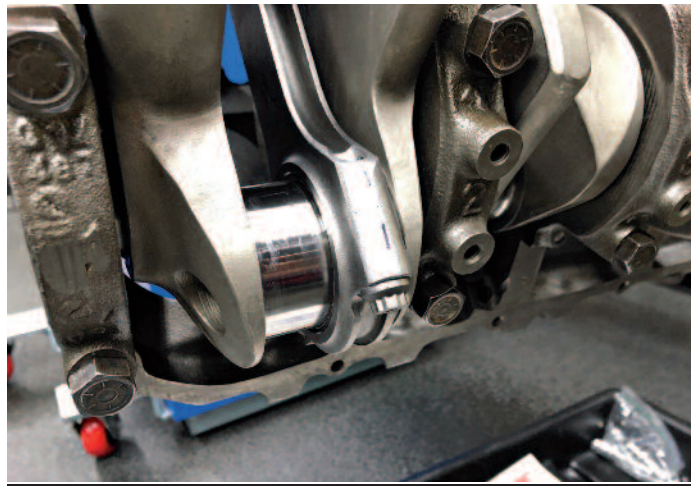
Before the crank can be set into the block of the raffle engine, Magro test fits and measures the BOP Engineering one-piece rear main seal, to ensure it's within BOP's recommended tolerances.

A quality ring compressor like this one prevents damaging the rings during installation of the piston into the cylinder. The compressor's bore is tapered to narrow toward the bottom, thus gently squeezing the rings into the piston's ring grooves until they're safely inside the cylinder. One-piece compressors like this are considerably easier to use than the old ratcheting-band style, especially when working alone.

Accurately measuring piston depth is critical to ensure that pistons won't accidentally come in contact with the underside of the cylinder head, even at operating temperature and high rpm, when things tend to grow and stretch a little. We'll cover how to measure to guard against piston-to-valve contact in a future installment.



Once you've installed all eight piston and rod assemblies, your short block assembly is ready for an oiling system ... but more on that in a future installment.



Once the piston and rod are carefully in place with the bearing shells in both halves of the rod, the rod cap must be installed and the bolts torqued to yield the proper stretch, as measured with a stretch gauge, as shown before.

When you have both rods installed on a crank journal, you need to measure the side clearance between them, to ensure the rods won't bind or grind on one another. A simple feeler gauge does the trick.

Ordering a raffle ticket to try to win this Nitemare Performance crate engine? Mail a check that must include your weekend phone number, name, and address to the address listed in the ad on page 58.