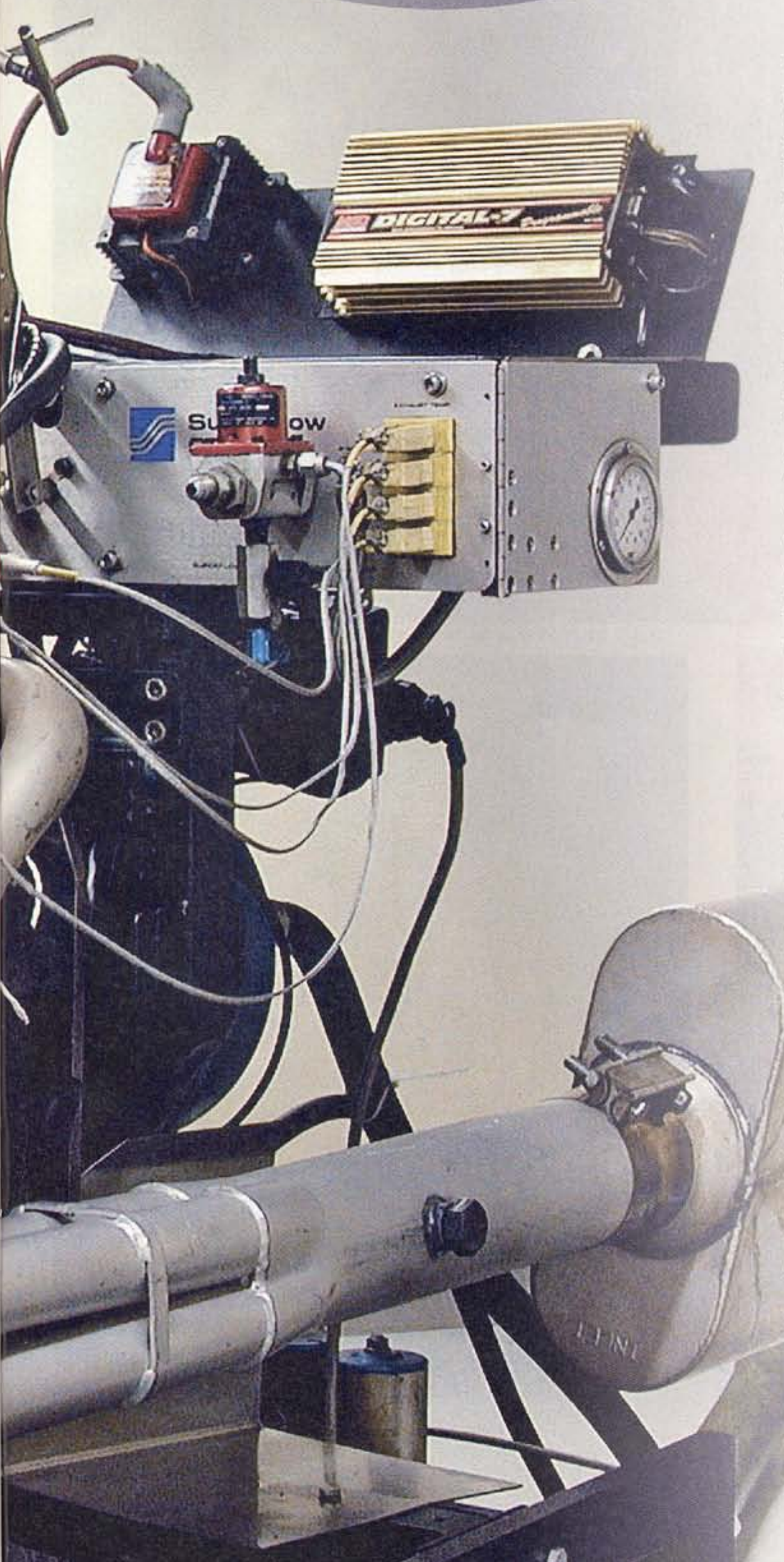
TRILOGY OF

Pre-Gapped, File Fit, or Gapless; What's best?

By Steve Dulcich

THE RINGS



Though most rebuilt engines are put together with out-of-the-box pre-gapped ring sets, performance and race engine builders seem to spend a lot of time fiddling with ring gaps. Why? The piston ring is charged with the task of sealing the cylinder, and the endgap of the ring is a leak in that seal. While it doesn't take an engineering degree to recognize that the endgap represents a leak, the question is just how much horsepower is really blowing out those little gaps? Performance engine builders must be under the impression that it's a noticeable amount, since file-fitting the rings to a prescribed endgap specification has become standard practice. We have a hunch that these guys aren't just wasting their time.

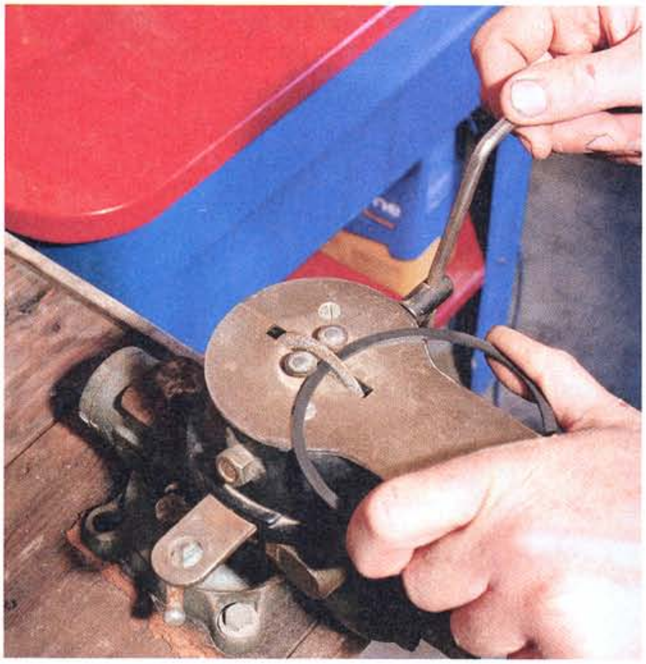
Ring endgap in a running engine isn't constant, as the heat of combustion and friction will cause the ring to expand. As the ring expands, the endgap narrows in running to something less than the installed measurement. The characteristic closing of the ring gaps in running is generally favorable, unless the point is reached where the endgap closes entirely, and the ring ends butt up. This condition will cause numerous problems, from scuffing and loss of ring seal, to destructive engine failure and grenaded pistons. Standard pre-gapped piston rings come packaged to a specific bore size with gaps generally on the conservatively wide side, to minimize the potential for destructive endgap butting. For popular applications, oversized file-fit rings are available, which allow the engine builder to custom tailor the ring endgap.

FILE FITS

File-fit rings are typically diametrically 0.005-inch over the final bore size, which equates to about 0.012-inch larger in circumference on a typical 4-inch bore size. Essentially, the file-fit rings will start with near-zero endgap, and the engine builder must file the ring to the desired end clearance before installation. Ring manufacturers provide their endgap recommendations, which will vary according to the engine's application. Generally, as the heat and load expectation become greater, such as with nitrous or supercharging, the ring endgap recommendation becomes wider. This is to compensate for the increased heat and expansion the ring will be subjected to in these applications, with the goal being to avoid the possibility of the ring endgaps butting.

Conventional wisdom is that top rings set with the tightest endgap under the anticipated operating conditions without causing butting will produce the best power. Clearly, there is a balancing act involved here, in deciding what endgap will provide optimal power without danger of going too tight. Further complicating the situation, piston design can play a role in the amount of expansion the ring will see. Ring placement, land design, and the piston's material and thermal conductivity all affect the running clearance at the ring's endgap. Unless you have the resources to test and try specific endgap settings for a particular combination, a luxury few can afford, it's best

File fitting a ring set is standard procedure these days in building a performance or race engine. To take an accurate measurement of the ring end-gap, the ring has to be dead square in the bore. While there are special tools available to do the job, an inverted piston with a second ring installed does the job.



Engine builders have their favorite tools for cutting the ring gaps. We use this hand-crank wheel from Summit. Some practice is required to cut a parallel gap, manipulating how hard the ring is squeezed and pushed against the stop pins while cutting. Always turn the wheel so that it is rotating into the ring, rather than pulling away from it or the wheel will chip the moly on a top ring. File a little and measure and then file some more, until the desired gap is obtained.

The endgap is measured with a feeler gauge. Work up from a smaller size until the next one won't fit to determine the endgap.

to stick to the ring maker's recommendations. As noted, the piston design can play a role as well, and ultimately, if the piston maker has specific recommendations on endgap, these should take precedence when deciding on a ring's setting.

The question of optimal second-ring gap is a subject open to debate. The second ring can physically run a significantly tighter clearance than the top ring, since it's exposed to less heat, and will expand less than the top ring. As a result, traditionally, second ring endgaps were set considerably tighter than the top rings. In recent years, some ring manufacturers began recommending running a wider gap in the second ring. The theory is that a wider second gap would allow an escape path for any high-pressure gases caught between the compression rings, which can cause the top ring to unload, or flutter at high rpm. Some engine builders embrace this idea, while others dismiss it entirely, though we have heard the claim that wider second gaps also result in less oil reaching the combustion chamber. We can't make your mind up for you on this one, though we wouldn't recommend going against a ring maker's specifications.

File-fitting rings is a fairly simple procedure, simply a matter of squarely inserting each ring into the engine's bore, measuring the endgap with a feeler gauge, and adjusting the gap by filing or grinding until the desired gap is achieved. There are a variety of tools that can be used to open the ring endgap, from simple hand files, to inexpensive hand-operated cutting wheels, to more elaborate precision electric ring grinders. Whatever the method used, the goal is to create a square and parallel gap with the desired clearance—which requires reasonable amount of skill and care. Typically, each ring is sized to and assigned to the specific bore in which it will be run, accounting for any minor variations in actual bore sizing, which will affect the endgap.

CLOSING THE GAP

Gapless rings have been around for many years, though many enthusiasts are unclear on the concept behind them. All piston rings are open at the ends to allow them to be installed into the ring grooves of the piston, but more importantly, the open end allows the ring to act as a spring. The radial tension of the ring acts outwardly on the cylinder walls, providing a seal (with the aid of the gas forces), and allowing for small diametrical changes in the cylinder bore. With Total Seal's unique design, the ring is made as a two-piece assembly—a main ring section similar to a conventional ring, but machined with a recess to accept a second rail. When the rail is installed into the recess of the main ring section, staggering the gaps in the two effectively seals off the endgap of the ring assembly.

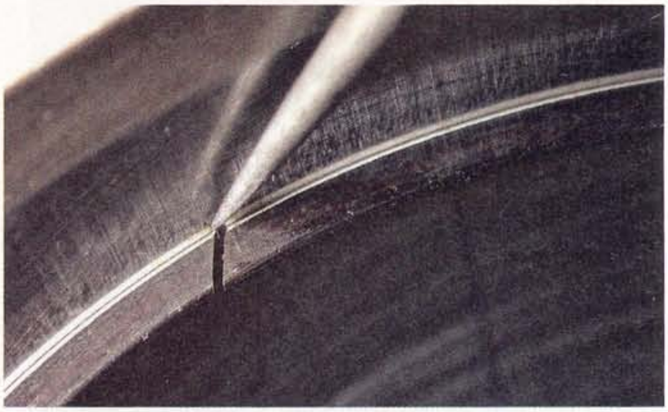
In any ring installation, as both the cylinder and ring wear, the ring expands radially outward under the ring's tension, allowing the ring to adjust to the bore condition and size for a continued seal throughout the service life of the engine. However, as the ring continues to wear outward, with a conventional ring, those carefully set ring gaps increase at the rate of 3.14 times the change in diametrical clearance. With the Total Seal's Gapless rings, the overlapping gaps of the two ring segments will remain closed, even as bore and ring wear increase the end clearance of the individual segments. It sounds like a valid concept, but the question still remains of just how much of a difference in real world horsepower is up for grabs in that little flowpath at the endgap of a ring?

THE TEST:
STANDARD PRE-GAPPED RINGS; 0.030-INCH ENDGAP

PEAK HP	434.7 HP @ 5700 RPM
PEAK TORQUE	450 LB-FT @ 4400 RPM
AVERAGE HP; 3000-6000 RPM	363.3 HP
AVERAGE TORQUE; 3000-6000 RPM	425.6 LB-FT
CRANKING COMPRESSION	160 PSI
AVERAGE LEAKDOWN	NOT RECORDED
PEAK VOLUMETRIC EFFICIENCY	NOT RECORDED

While theory and conjecture make for nice bench racing conversations, what better or more ambitious way to test the effects of ring endgap on power output than to run the various configurations in on the dyno and let the numbers do the talking? Our test engine was a Vortec-headed 350 small-block Chevrolet. The bottom end in this mild 350 featured conven-

Total Seal's Gapless rings actually arrive at their Gapless status by employing a two-piece ring assembly. The main ring (foreground) is machined to accept a secondary rail segment (background) which seals the gap.



Gap a Gapless ring? You bet. Each segment of the Total Seal ring has a gap, which must be gapped to the manufacturer's specifications. The rail segment of the Gapless ring in this set is Total Seal's Slant Gap design, which angles the gap to minimize the probability of the ring rotating and aligning in use with the gap of the primary ring segment. The rails on our set checked on spec without filing.

tional pre-gapped rings in a budget-minded short block. We ran a test session on the dyno to establish a baseline with the pre-gapped rings. The engine was making a respectable power, as noted in the figures above. The numbers were so good, in fact, that the crew at Westech's engine test facility was skeptical that there was much room to the upside with a ring change.

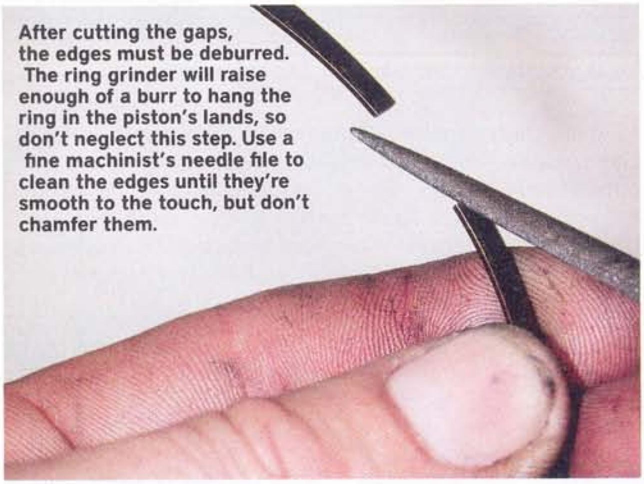
Upon disassembly, we noted that the ring gaps were very much to the wide side, swallowing a 0.030-inch feeler gauge with ease. Some of the clearance was no doubt gained in the nearly 100 dyno pulls this engine has been subjected to. Despite the wide ring gap, this little Chevy was delivering strong power, as the numbers reveal, without any visible signs of excessive blowby. With the gaping wide gaps, and still credible power output, we had to wonder how this test would turn out. Was there really anything to be gained goofing around with ring files and feeler gauges?

THE TEST:
FILE FIT DUCTILE MOLY CONVENTIONAL RINGS; 0.018/0.014-INCH ENDGAP

PEAK HP	441 HP @ 5700 RPM
PEAK TORQUE	459.2 LB-FT @ 4500 RPM
AVERAGE HP; 3000-6000 RPM	370 HP
AVERAGE TORQUE; 3000-6000 RPM	433.9 LB-FT
CRANKING COMPRESSION	165 PSI
AVERAGE LEAKDOWN	12%
PEAK VOLUMETRIC EFFICIENCY	94.8%

The pre-gapped rings in our test engine were much wider than any custom engine builder would let out the door, so we broke out our trusty hand-crank ring file from Summit Racing Equipment to custom fit a fresh set. The rings we chose were Total Seal's Classic set, a conventional file-fit ductile iron/moly ring package. In accordance to the recommendations from Total Seal, the top rings were gapped with 0.0045-inch of clearance per 1 inch of cylinder bore diameter, for a total of 0.018-inch. The second ring was gapped to 0.014-inch, per the 0.0035-inch per inch of bore diameter recommendation. The rings were changed without any additional cylinder wall prep, and the engine was reassembled for another turn at the dyno. After a short running load cycle to seat the rings, the numbers were in, and they were impressive. Across the board, the output swept up the score turned in by the pre-gapped rings. Most notable to us were the higher numbers turned in over the averages, showing that the engine was stronger across the board. Maybe there's something to this ring-gapping stuff after all.

We spun the engine over for a cranking compression check, and found a gain of 5 psi. The cylinders were sealing measurably better, and making use of the increased seal by producing more power. We also hooked up a leakdown tester, and ran a leakage check of every cylinder, and found an average leakage as recorded of 12 percent. This was higher than we expected, and air escaping the ports indicated that the valve sealing on our Vortec heads was less than optimal. Unfortunately, we did not perform a leakdown test with the original ring set, but the amount getting past the valves would remain as a constant over the base escaping the rings.



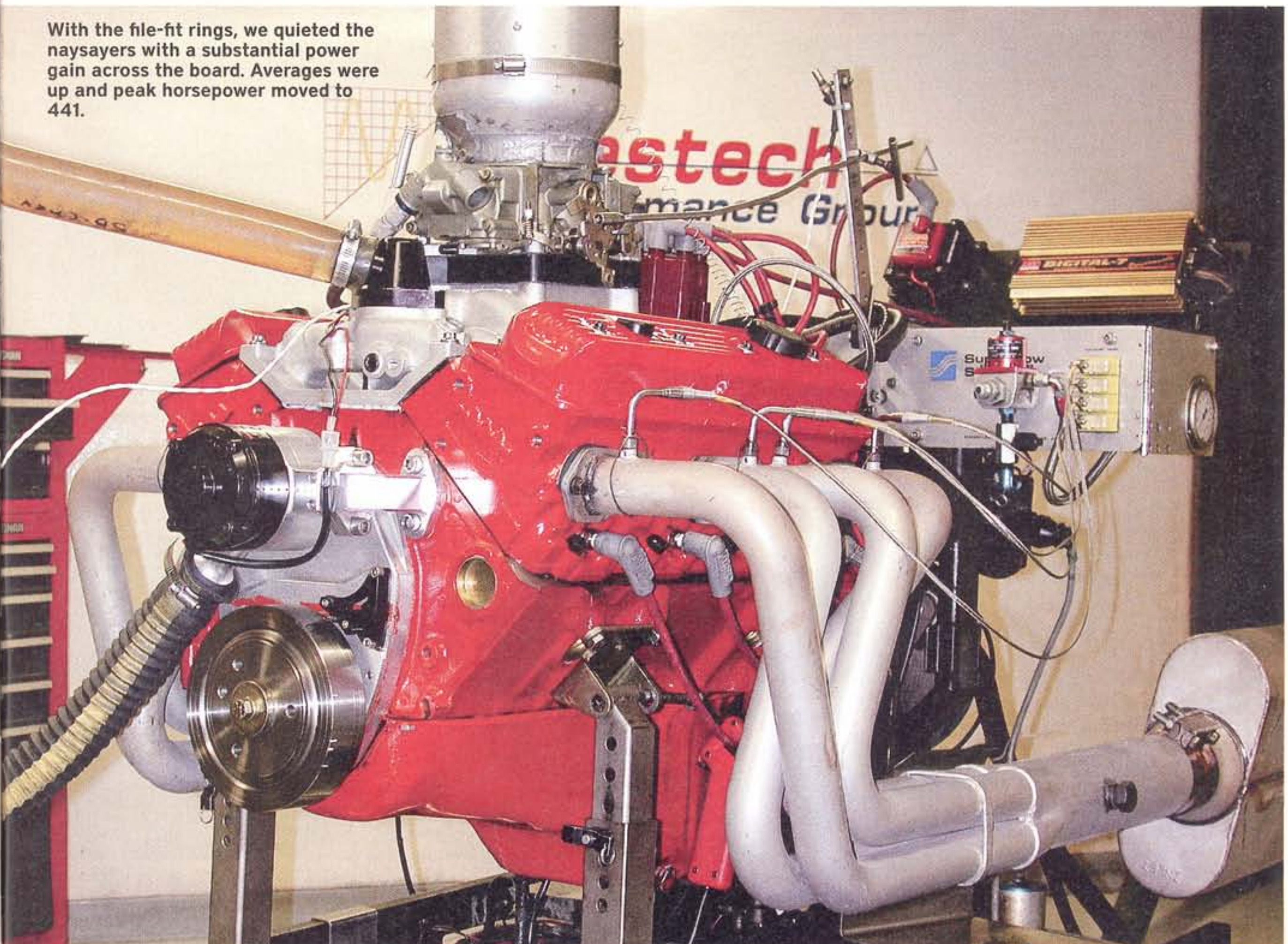
After cutting the gaps, the edges must be deburred. The ring grinder will raise enough of a burr to hang the ring in the piston's lands, so don't neglect this step. Use a fine machinist's needle file to clean the edges until they're smooth to the touch, but don't chamfer them.

All iron and innocent looking, this 350-cube Mouse made 434 hp with the plain and well-used standard pre-gapped rings.

Down for a re-ring, the engine was torn down to install the file fit rings, gapped to the manufacturer's recommended 0.018 top/0.014-inch second.

Some builders use a ring expander to spread the rings over the grooves, but we favor the quicker method of spiraling them on, particularly when dyno time is ticking away.

With no fear of hot slippery oil on our not-so-tender hands, we swapped over to the Total Seals. Here the secondary sealing rail of the top ring is being installed with the gap properly staggered 180 degrees from that off the primary portion of the ring.



With the file-fit rings, we quieted the naysayers with a substantial power gain across the board. Averages were up and peak horsepower moved to 441.

The Total Seal concept is to use a two-piece ring assembly in order to close the flow path through the ring gap. Like any other ring, each ring segment has a gap, and is filed to an end-clearance specification to prevent butting. The endgap specs on Total Seal's rings are wider than the conventional rings, since the rings will contain more heat and pressure. The wide clearance provides plenty of insurance against butting, while the rail segment closes the gap to assure a gas seal. That theory works for us, but would we find any power?

We tore the 350 down again for yet another re-ring to find out. In a couple of hours we had the engine back up and it was showtime once again. The numbers didn't disappoint, with the engine now cracking over 450 hp, and again showing a gain in power across the board. Impressive! Interestingly, the volumetric efficiency was up across the board as well, indicating that the engine was taking in more air as a result of the ring change. This would be a result of an increase of displacement pull on the intake stroke. Though it is often neglected, the ring seal efficiency is just as relevant on the induction stroke as it is in holding gas pressure in the power stroke. Subsequent leakdown testing showed a marked improvement in cylinder leakage rate, essentially minimizing the leakage past the rings, though we still registered leakage as a result of the inadequate valve sealing. In other tests we have seen total recorded cylinder leakage of 1 percent with the Total Seal rings.

Perhaps one of the most significant things we learned is that even though the area open to leakage at the piston rings endgap seems small, it can have a significant effect on output. Our initial baseline was performed with the rings having seen some hard dyno duty, not unlike a season's strip time. We don't know exactly what the initial installed gap was with those original pre-gapped rings, but we can be certain that it was something less than the 0.030-inch we found when the engine was torn down. With enough dyno time, our carefully file-fit set would no doubt eventually open up that large or more. With Total Seal's overlapping two-piece rings, the endgap will remain closed even as the rings wear and the individual ring segment's gaps open up. That's something to think about. *EM*

THE TEST: TOTAL SEAL'S GAPLESS TOP; FILE FIT TO .026/.022-INCH	
PEAK HP	451 HP @ 5600 RPM
PEAK TORQUE	465 LB-FT @ 4500 RPM
AVERAGE HP; 3000-6000 RPM	375 HP
AVERAGE TORQUE; 3000-6000 RPM	440 LB-FT
CRANKING COMPRESSION	185 PSI
AVERAGE LEAKDOWN	7%
PEAK VOLUMETRIC EFFICIENCY	96.4

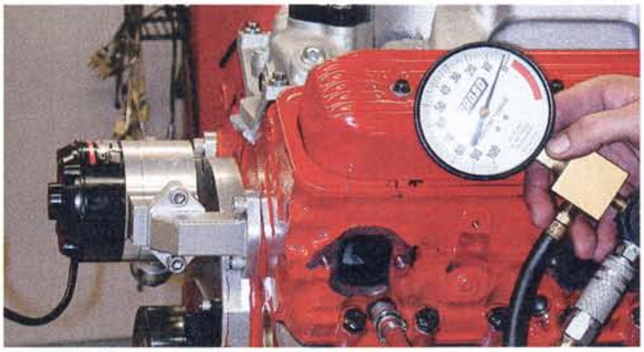
We had hoped to get a blowby meter reading with the various rings, but were foiled by a faulty gage. Nevertheless, the power told the story, with the Total Seal ring pack upping the ante to 450 hp, and 465 lb-ft of torque, with accompanying healthy gains in the averages.

SOURCES:

SUMMIT RACING EQUIPMENT
(800) 230-3030
www.summitracing.com

TOTAL SEAL, INC
(800) 874-2753
www.totalseal.com

We did get a cranking compression reading on all three ring sets, and found a gain from 160 to 165 going to the file fits, and an unbelievable rise to 185 with the Total Seals. We conferred with the engineers at Total Seal and were told that such gains are not unusual.



Leakdown test were performed with the file fits and Total Seals, and though we clearly had some leakage past the valves, the Total Seals significantly decreased the average leakage, indicating that static leakage past the rings was effectively reduced.