Gauging Health

Through Compression and Leak-Down Testing

By Bruce Smith

Your car's power and torque are fundamentally governed by its cylinder compression. Measuring the ability of an engine's cylinders to develop and hold pressure is a fairly standard process, easily falling in the DIY category. This is done through a compression test, a leak-down test, or both. These tests differ with regards to the tools used, the testing methods employed, and what's actually being measured. A few of the commercially available testers are shown in the picture below. A compression test gauge, as shown on the right, measures the dynamic pressure that can be built up in a cylinder while the engine is cranked. Compression tests can be influenced by things like cranking speed, camshaft configuration, and environmental conditions (i.e. temperature, pressure, and humidity), in addition to wear or damage to rings and valves. Because of this, results from a compression test are best evaluated by comparing between cylinders as a single cylinder pressure value has limited meaning. A leak-down test involves externally pressurizing cylinders to measure the amount lost through leaks in valves, rings, or the cylinders themselves. Typical leak-down gauges are pictured at the left. The information gained from a leak-down test can usually point to more specific problem areas than a compression test. We'll review both here, with some insight into the equipment used and the types of results to expect.

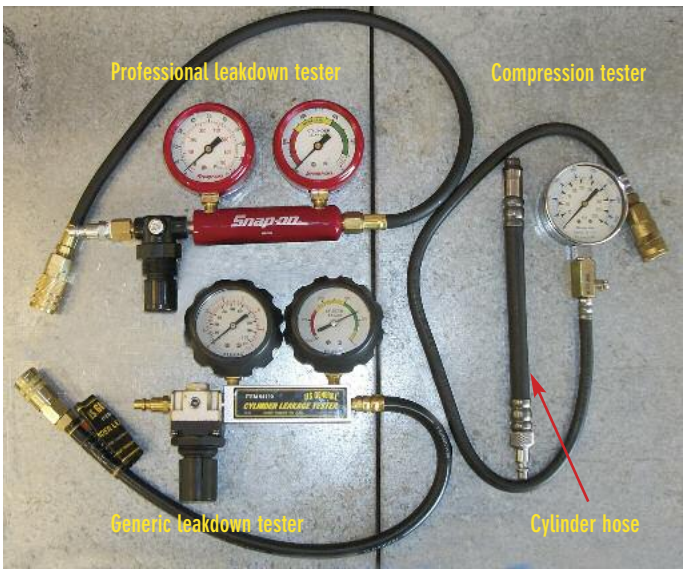
Compression Testing

Measuring a cylinder's ability to build compression can confirm the overall condition of a motor. This is a useful test when considering a car for purchase, exploring a suspected problem, or just carrying out routine maintenance. The basic approach is to replace a cylinder's spark plug with a pressure gauge and monitor the pressure developed during cranking. But because testing can be influenced by so many factors, it's difficult to interpret much from the results unless there is significant pressure variation across the cylinders. Low pressure from one or more cylinders can suggest internal problems, where consistent values are generally a good sign. A compression tester consists of a pressure gauge, a release valve, and a cylinder hose. Though it'd be pretty straight forward to rig one from parts, testers are widely available at most auto parts stores for as little at $25. A tester will only be as good as its pressure gauge and the cheapest are likely to be poor quality. Better tool brands are worth the investment - as we'll see a bit later.

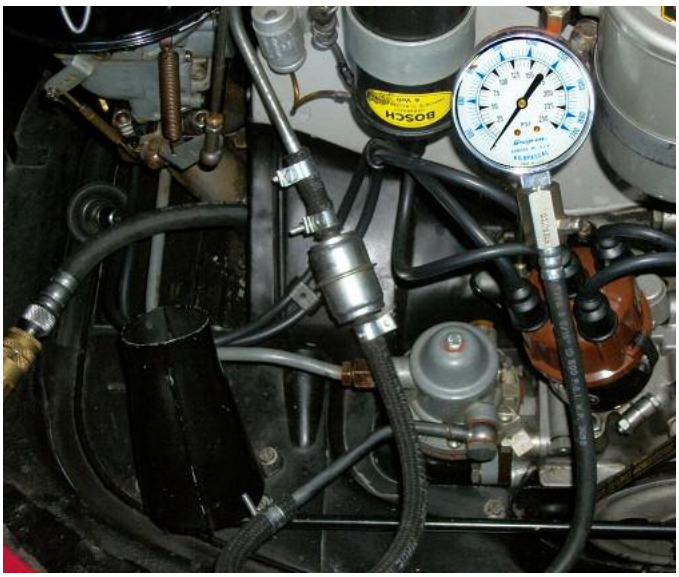
The most accurate compression test results will come from an engine that has been brought up to operating temperature. Since it's not a good idea to remove spark plugs from a hot engine, it's best to loosen the plugs when the engine is cold and re-tighten them lightly before warm-up. This will reduce the possibility of damaging the threads into the head. Once warmed, shut off the engine and remove the spark plugs. The ignition should also be disabled, which can be done by removing the coil lead. Carefully screw in the cylinder hose into a spark plug hole, tightening only by hand, and connect the other end of the hose to the test gauge. Care must also be taken to select a cylinder hose with an end does not protrude too deep into the cylinder as damage to a piston can otherwise result. With the throttle open for maximum air flow, the engine should be cranked over 6-8 compression strokes, or until no further rise is seen in pressure. This can be done with a remote starter but can require three hands to do so. So the simpler approach is to have a helper crank the motor over from the driver's seat with the accelerator pedal fully depressed. While watching the pressure rise with each crank, take a mental note of the progression from the first to the last stroke and record the final pressure. Then move onto the next cylinder and do the same.

Interpreting the Results

The most meaningful interpretation of a compression test is to compare the values across all cylinders. Pressures in the 125-160 psi range with little variation among the cylinders is a pretty good indication of a healthy motor. A good rule of thumb is for no cylinder to fall below about



A pair of dual gauge leak-down testers (left) and a compression tester (right). The cylinder hose is used to connect to the cylinder under test by threading it into the spark plug hole. The quick-disconnect style hose fitting makes for easier threading.



A compression test gauge is connected to the #4 cylinder, which is ready to test. The engine has been warmed up and plugs removed. With the carb throttle plates open, the engine is cranked over several strokes until max pressure is reached.

90% of the highest value, though a bit lower is not necessarily cause for alarm. For example, an engine with a maximum cylinder pressure of 140 psi and with no other cylinders falling below about 125 psi is acceptable. All cylinders measuring near the maximum value with a single cylinder at the low end may be cause for further testing. It can't hurt to re-measurer low values to confirm that a particular cylinder is indeed low. Ensuring correct valve adjustment beforehand is also important as this can impact compression in one or more cylinders. There can be several causes of poor results. Leaking at intake or exhaust valves will reduce compression in the affected cylinders, though a compression test will not distinguish the cause. To determine if leaking is originating at the rings, a few ounces of motor oil can be squirted into a cylinder and re-measured. Although a bit challenging in a horizontally opposed boxer motor, the oil will temporarily coat the cylinder walls to provide a seal with the rings, raising compression after a few strokes. Overall pressure readings can also be lower than expected simply because of elevation. For example, pressure readings at 4500 ft. will be reduced from those at sea level by about 10%. Slow cranking from a weak starter or battery can also lead to lower overall readings. Beyond this, it's difficult to draw more specific conclusions from a compression test. Although it's a simple method to confirm overall engine condition, more specific troubleshooting requires externally pressurizing the cylinders to hunt down the root causes of specific problems.

Leak-down Testing

The limitations of a compression test can be overcome by carrying out a cylinder leak-down test. Such a test provides several advantages. First, by using an external air source to pressurize a cylinder, testing can be done through a range of pressures. Also, since a cylinder is not pressurized by cranking, results are not influenced by other engine components (e.g. cranking speed and camshaft). And since the engine does not need to be turned over to be tested, it needn't be in a car or be running. As seen in the earlier photo, a leak-down tester consists of two gauges, a regulator, a manifold between the gauges, an inlet for a pressurized air source, and an outlet for connection to a cylinder adapter. The first pressure gauge at the inlet side measures the regulated pressure to the tester, with a range generally from 0-100 psi. The manifold between the gauges has a channel with a small orifice, about 0.04" (1mm). This orifice provides an air flow restriction and a pressure drop to the second pressure gauge when there is no restriction at the outlet. The second gauge is usually labeled in percent drop rather than psi pressure, where 0% and 100% corresponds to a closed and opened path respectively. When connected to a cylinder under test, the amount of air escaping will fall within this range, giving an indication of the extent of a leak. The choice of a 1mm orifice as a standard is a bit of a compromise so that testers can be used for a range of applications – from a small displacement lawn mower motor to a big bore engine. Gauges dedicated to specific motor sizes also exist, where an orifice size corresponds to the application. True leak rate calibration is difficult as all other restrictions in the flow path will influence readings. Instead, gauges are normally marked with low, moderate, and high leak ranges where a leak back below about 20% is usually considered acceptable. Since results are impacted by all restrictions in the path, including the influence of the hose length, orifice size, and manifold geometry, variations between testers should be expected.

Two Tester Types

I started off thinking that this article could include a review of how useful an inexpensive leak-down tester might be for the DIY mechanic as an alternative to costlier professional tool. For less than $50 at the discount tool store, even an occasional use might justify such a purchase. I've discovered instead that you're going to have to open up your wallet a bit more if you want a reliable tester in your toolbox. The earlier photo shows two leak-down testers: a well-respected professional brand on top and a generic import below it. Out of the box, the generic one looks fine. The regulator quality is alright and the hoses and connectors are solid, though the gauges are a bit cheap. But by reviewing the sketchy instructions and putting it to the test a few times, I quickly realized that trying to get useful results from this tester would be difficult. Though similar in appearance, these are actually two different types of dual-gauge leak-down testers. One type is a high-input pressure tester, which is used at about 100 psi to test for leaks at pressures close to what might be expected during combustion. The professional brand tester falls into this category. The generic tester is the second type: a low-input unit which operates at a much lower 10-20 psi pressure. If engine cylinder leak rates are low enough, the results from such a tester might be able to indicate that things are OK. For use in small displacement engine diagnostics, this might suffice. But for a car motor with valve, ring, or cylinder problems, relying on low-input pressure tester (especially one of poor quality) could be worse than a simple compression test – you're likely to get results you can't trust with a pressure too low to identify the source. Here's the bottom line: don't be tempted by a low price or discount coupons to buy a cheap tester. Buy or borrow a good quality high-pressure input leak-down tester if you want results that you can have faith in. At 4-5X the cost of a cheap one, it's still a good investment.

Getting to it

The procedures for a leak-down test are a bit more involved than for a compression test, but no more difficult. Since we're only talking about high-input type testers from here on, you'll need a compressor capable of delivering the needed 120-200 psi with sufficient capacity. Preparation of the engine is similar as for compression testing, warming it up if it is running and then disabling the ignition system by disconnecting the coil. All spark plugs should be removed as the engine will be turned by hand and this will eliminate cylinder pressure buildup. The air cleaner, engine dipstick, and oil filler cover should be removed to facilitate the detection of air leaks at these sources. The hookup for an engine outside of the car is shown in the picture below.

Here is a list of steps to follow once the engine is prepared:

- Fit the proper cylinder hose into the #1 cylinder, taking precautions as described earlier. The hose should not yet be connected to the tester.
- With an appropriate wrench, turn the crank to find #1 top dead center, noting the position of the pulley OT mark aligned with the case mark and the distributor to the TDC mark (normally 5 o'clock). Always only rotate the engine clockwise.
- In the next steps, pressure will be externally applied to the cylinder. This can cause the engine to rotate if not at TDC so care should be taken with the wrench removed from the crankshaft before proceeding. To confirm TDC for a particular cylinder, a low pressure (a few psi) can be introduced into the cylinder while rocking near TDC to confirm the sealing of exhaust and intake valves. This approach may also be useful once a cylinder leak is suspected, but this should also only be done at low pressures.
- With the tester still disconnected from the cylinder hose, the regulator should be turned all the way out and connected to the compressed air source. The tester's regulator is then adjusted to 100 psi on the left gauge, which will also result in the right gauge reading zero or "set". This is the static input pressure setting
- The tester is then connected to the cylinder hose and the leak-down rate read from the gauge. The pressure gauge will drop to a dynamic input pressure, or the pressure that the cylinder is testing at. There are some dual-gauge testers that use a second 0-100 psi gauge to read flow after the orifice. In this case, the dynamic input pressure would be needed to calculate the leak-down rate. For testers with percent leak-down gauges, this calculation isn't necessary. Pressure should be reduced to about 50 psi before removing the tester from the cylinder.
- Rotation of the crank clockwise 180° places cylinder #4 at TDC and ready to test. At 180° steps, the progression through the cylinders is 1-4-3-2. Testing of each cylinder is identical to the first. ***Continued P. 71***

Interpreting the Results

Leak-down rates of a percent or two shouldn't be expected as new engines are often not even that good. Instead, values less that about 10% should be considered good, 10-20% is acceptable, and 20-30% might be alright for an occasional driver. Beyond this is an indication of problems and some exploration is necessary to determine what next steps should be taken. In addition to the numbers, the real value of a leak-down test is what can be learned during the testing. Air leaks from problem areas can be audibly detected to pinpoint their source. If air is escaping from an intake valve not sealing correctly, this can be heard through intake manifold or carburetor. Similarly, a leaking exhaust valve can be heard through the exhaust ports or tailpipe. If leaking at a valve seats is suspected, a light hammer tap may alter the result. If air is heard escaping from the crankcase, there may be leaking past the rings. If air is heard leaking between cylinders, there is likely a problem with the cylinder heads themselves. Another thing to note is the role that carbon deposits will play on compression readings and results. The buildup of carbon on valves can reduce compression over time and heavy deposits can prevent valves from seating properly. Exhaust valves that cannot seat can become overheated and burned if run for prolonged periods. Conditions will become progressively worse and can lead to catastrophic failure and massive engine damage. These sorts of things should be considered when borderline results are discovered from a leak-down test. Good enough may not be something you'd really want to live with.

In the end, if you get yourself a simple single gauge compression tester, you'll probably use it much more than just once. And for better insight into problems with your engine, it's handy to have a high-pressure leak-down gauge. If you'd rather rely on a friend for this, tell him not to buy the cheap one.

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A dual gauge leak-down tester is connected to cylinder #4 and the crank is set to its corresponding TDC. Once the pressure is set to zero out the right gauge, it is connected to the cylinder under test to read leakage. A leak at the intake valve seat is the reason for this cylinder's 50% reading.

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