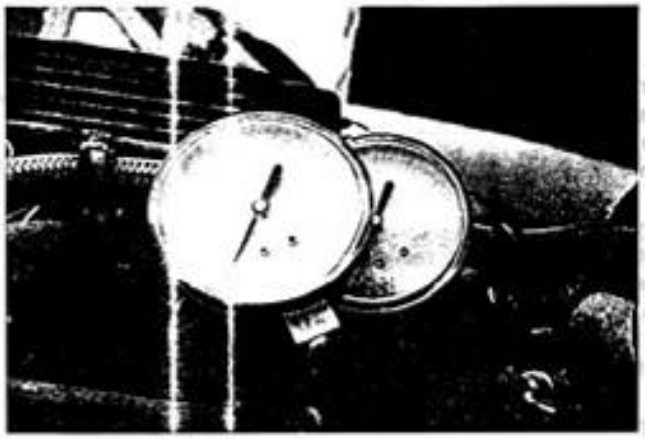
# Compression Testing Realities

*Cylinder compression testing is a tool that can fool, unless you know what it can and can't tell you*



*Compression testing may one of the most misunderstood and abused maintenance tools around. It's also indespensable.*

You'd have to look long and hard to find a routine maintenance procedure that's done incorrectly as often as compression testing is. You'd have to look equally hard to find a procedure that's as likely to wind up costing an owner hundreds or even thousands of dollars needlessly. And you'd be hard pressed to find a testing procedure that's as valuable, and yet as unreliable, as cylinder compression testing.

If all this sounds like a gathering paradox, that's only because it is. Compression testing is poorly understood by many, perhaps even most practitioners. Yet, for a quick check of overall cylinder health there is nothing to compare with compression testing. However, to get the most out of this procedure, it not only has to be done right—the results have to be interpreted correctly.

To this end, let's get a quick look at the correct way to do compression testing, and how to interpret some of the possible results.

### Blow 'Em Up

There are actually two types of compression tests that can be done. Many will be familiar with the automotive-style compression testing. Although this can be effective on cars, it's not generally recommended for aviation use. For starters, it really beats on starters and batteries—overheating the one and draining the other. And there's the danger posed by trying to read the gauge with a propeller swinging just a few feet away.

So, for aviation purposes we use differential compression testing. This involves pressurizing a cylinder with 80 psi compressed air and measuring how much of that pressure the cylinder can maintain. In other words, what you're actually measuring is how much leakage there is in the cylinders. The more leakage, the lower the compression reading will be.

Actually doing compression testing (properly, at any rate) requires an understanding of what you're trying to measure. Let's go through a compression test and see what some of the ins, outs, tricks and traps are.

The first thing you need to know about compression testing is that it's done hot. The engine should be at operating temperature, so if you're about to do a compression check with an airplane straight from the ramp, take it out and run it first. Get the engine up to temperature. And while you're at it, give it a few of the run-up checks like cycling the prop, checking mag function, mixture settings and so forth (see *LPM*, October 1992 for more on ground-run inspections).

With the engine up to temperature, remove the top cowling and the most easily accessible spark plug from each cylinder. On the vast majority of installations, this will be the upper plugs. Remove only one plug per cylinder, but do all the cylinders at the same time. The reason for this is that you don't want to be fighting compression humps later on as you're doing the compression check. And a word of caution here: Those plugs are *hot*, so handle them carefully. It's a good idea to have a rag handy to pick the plugs out of the wells in the cylinder heads so you don't wind up playing hot potato with them and dropping one.

With the plugs removed, screw in the compression tester. It doesn't matter which cylinder you start with, just be methodical and make sure you do them all. As an example, we'll start with the No. 1 cylinder.

Right here is where techniques start to diverge. Some prefer to find the compression stroke on the cylinder before hooking up the compression tester. They do this by putting a thumb over the plug hole or on the end of the compression tester quick coupler (after it's been screwed into the plug hole) and then rotating the prop until they get pressure against their thumb. This technique works, but unless you've got a high pain threshold, it hurts because you wind up putting your thumb against a hot

cylinder head.

A better, less painful technique is to attach the compression tester (with the air turned off) and then swing the prop. When the cylinder pressure needle jumps, you know you're on the compression stroke.

**The First Trap**

Now comes finding top dead center of the compression stroke. Despite what you may have heard, there is some latitude in how you do it. However, you've got to pay attention to what you're doing.

With the subject cylinder on the compression stroke, turn the air pressure up to about 20 psi. Now, slowly rotate the prop in the normal direction until you feel a flat or dead spot—a point where the prop isn't pulling or pushing in either direction. That's top dead center.

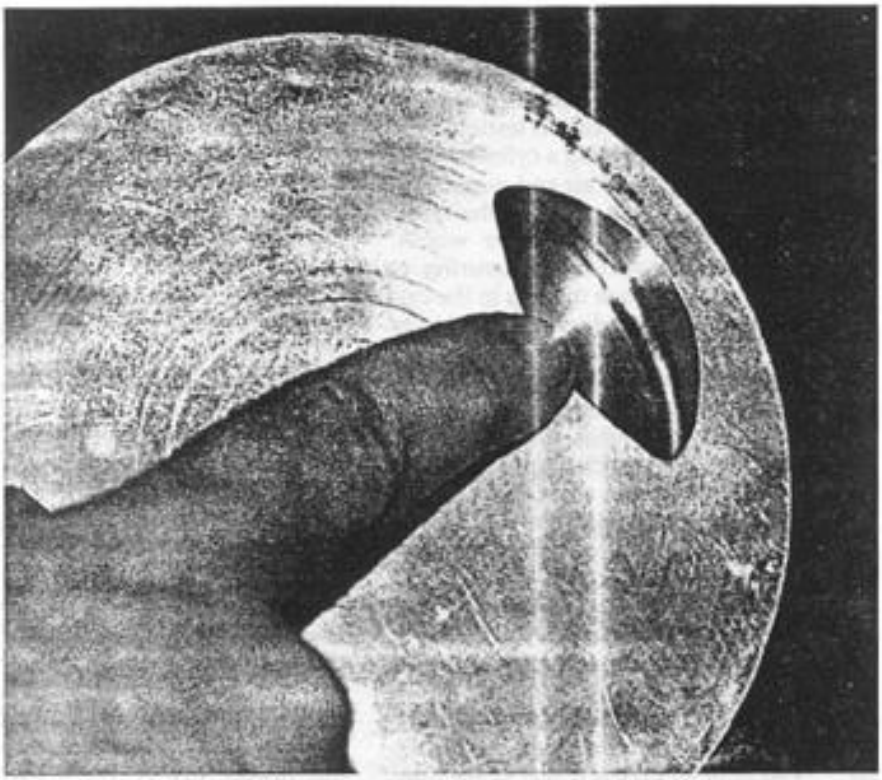
If you go past TDC, you can back the prop up past it the other way (opposite normal rotation) and try again. Now, some say it makes no difference if you do it this way. Others claim you've got to turn the prop back almost to bottom dead center in order to eliminate any possible lash from the valve train. In reality, the only thing you've really got to be concerned with here is ring position.

*Getting the lower compression rings seated on four- or five-ring pistons can be problematic due the the fall-off in combustion gas pressures at each succeeding ring.*

Think about it: When the piston is on the compression or expansion stroke, both valves should be closed for most of the stroke. If you've got enough lash and slack in the valve train that one or the other is going to remain open because you didn't back the prop up far enough, you've got bigger problems than simple loss of compression.

Instead, what you're looking for here is to have the piston all the way at the top of its stroke *with the rings on the bottom of the ring lands*. This is important because what you're measuring with a compression test is the sealing ability of the cylinder under "normal" operating conditions. When the engine is running, the rings will be at the bottom of their lands through the compression and firing strokes, so you've got to make sure that they're on the bottom of the lands during the compression check to get a true reading.

What this means is that you have to establish top dead center without wiggling the prop back and forth. If you do, you'll get compression readings that are essentially meaningless. If you don't believe this, try an experiment next time you're doing a compression check. Try wobbling the prop slightly—enough to get the rings off the bottoms of the lands. Watch the cylinder pressure needle change readings. In many engines you'll find you get better compression readings with the rings at the tops of the lands than at the bottoms. This is because



*Despite the valve recesses in the piston dome, the piston must be moved to bottom dead center before you attempt to improve a compression reading by valve staking.*

the tops of the lands don't wear as quickly as the bottoms, and so provide a better seal. However, the "improved" compression reading is useless, since the ring will always be at the bottom of the land when the cylinder fires.

So, if anyone gives you a lecture about which way to approach TDC, listen patiently, smile knowingly and ignore them. Remember that you're looking at how well those rings seal in the bottoms of their lands.

**Second Trap: Deafness**

Now, with TDC identified and the piston at the top of its travel and the rings at the bottoms of their lands, dial up the pressure to 80 psi. Hang on tight to that propeller. If you're not exactly at TDC, the prop may want to swing due to the pressure in the cylinder. Even though 80 psi is comparatively low pressure compared to the cylinder firing, the prop can still swing with enough force to hurt. So hang on tight.

With the cylinder pressurized, check the reading of the cylinder pressure gauge and make a note of it. Many mechanics just write the reading right on the rocker cover in crayon or grease pencil for both convenience and for the reference of the next guy who does a compression check. Whether on the rocker cover or a separate sheet of paper, write it down for future reference.

Now, while the cylinder is pressurized, take a moment to listen carefully. No cylinder will read 80 psi, unless you've got a real oil pumper of a jug. So the air has to be escaping from someplace. That place should be the rings. If you can hear a whistling or blowing noise coming from the exhaust, you may have valve or valve seat trouble. The valves should be sealing perfectly, so you shouldn't hear any air leaking past them.

If you do, you can try the old trick of "staking" the valves. This involves giving them a whack with a fiber drift and a hammer. This unseats them for an instant and may allow any debris trapped between the valve and the seat to dislodge. To do this properly under a mechanic's supervision, rotate the piston down to bottom dead center to prevent the valves from striking the piston head. Then give each valve tip a couple of smacks with the a fiber drift and a 16 ounce hammer. Then, run the engine for a few minutes, both to reheat the engine and to reseat the valves. Compression should come right up, providing that stuff stuck under the valves was actually the problem. However, if this doesn't do the trick, it's time to investigate further. You've probably got a problem.

You should also be listening carefully to the cylinder itself. Jugs that are cracked through can sometimes have good compression readings, but still be blowing air out through the cracks. I've had this happen on a TSIO-520 mounted on a Cessna 310. The cylinder showed a compression reading in the high 60s, but you could hear the air blowing out the crack. Pouring a little soap solution on the cylinder produced big bubbles around the head—the jug had cracked completely through. So listen carefully around the cylinder.

**Third Trap: Readings**

Once all cylinders have been tested, it's time to look at the numbers. Right about here is where owners sometimes get needlessly worried and cylinders sometimes get needlessly changed. But again, realizing just what it is you're checking can make the difference between many happy hours of service and a premature top overhaul.

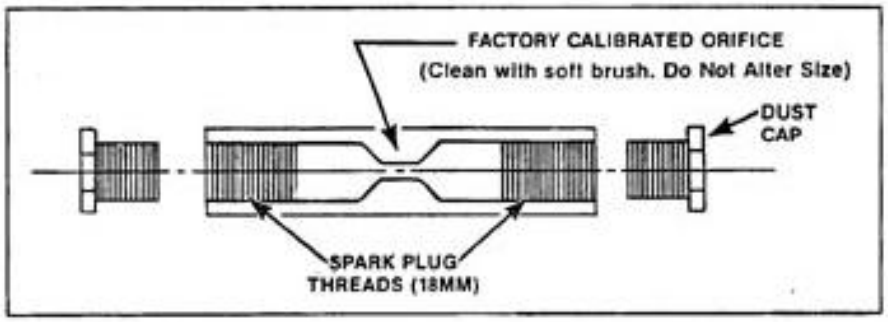
One of the more contentious issues of compression testing is just what constitutes a "failing" score. Most everyone agrees that compressions in the upper 60s or 70s is good, and if your cylinders come up with readings like those you should just cowl up and go fly unless you've detected some other problem (like a cracked jug).

But it's the lower readings that cause concern. How low is too low? FAA, in AC43.13, states, "A loss in excess of 25 percent of the input air pressure is cause to suspect the cylinder of being defective." Using this measure, any reading below 60 means a bad jug. But that's not necessarily so.

First off, there's the variations in compression testers. Continental realized this back in 1984 when it issued service bulletin M84-15 calling for use of the Borroughs master orifice to calibrate compression testers. The reading of the compression testing unit with the orifice connected is the lowest acceptable reading for that unit. For example, in the shop where I occasionally work, the Borroughs orifice showed our lower acceptable limit to be a reading of 42. Before calibration with the orifice, any cylinder reading below 50 would have been rejected out of hand, but now, according to Continental, that reading is acceptable.

Then there's the question of just what the piston rings are doing. You might well dial up the pressure, get a low reading and hear air blowing out the breather. No doubt about it—air is getting past the rings in larger-than-acceptable quantities. A reject jug? Maybe. But maybe not. Your rings' end gaps may have rotated around enough so that they all line up, providing what is effectively a straight slot for air to blow past the piston and into the crankcase.

There's two things to try if you get a low-reading jug and hear air coming from the breather. First, try coming at TDC from the opposite direction you did the first time. This




*Is the output reading of your compression tester meaningful? For Continental owners, the answer is NO, unless they've checked it against the Master Orifice Tool. The calibrated orifice is designed to mimick a "tired" engine by allowing a controlled leak.*

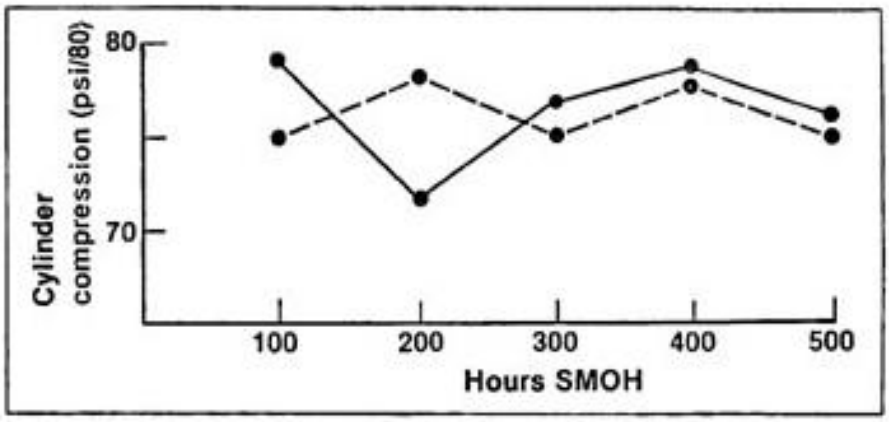
changes which side of the piston presses against the cylinder wall. If all your ring end gaps happen to be aligned on one of the piston's thrust faces, coming at TDC from the opposite direction may cause them to pinch together enough to raise your compression reading to an acceptable level.

If that doesn't work, try running the engine for 15 to 30 minutes (maybe a short hop around the pattern) and checking compression again. That should be enough to re-randomize the ring gap distribution, and your "defective" cylinder will now be acceptable.

And if that doesn't work, does it mean you should yank the jug immediately? Not necessarily. Again, consider just what it is you're measuring. You may be dealing with stuck rings here. It could be that an overnight soak in a solvent could free them up. For example, some have reported good results by filling a suspect cylinder with Microlon, Slick 50, de-varnishing solvent or some similar chemical and letting it sit overnight. After draining the jug, rocking the rings and blowing the interior completely dry, compression readings returned to normal. We pass this along as more of a desperation/curiosity note, since we know of no approved procedure for freeing stuck rings that doesn't involve removing the cylinder.

Now, all through here we've been saying that you shouldn't be too quick about yanking low-reading cylinders. Even Lycoming and Continental say you shouldn't yank a cylinder based on a single compression test. However, there does come a point where a cylinder really and truly is dead. A zero compression reading with little or no improvement after trying some of the tricks above is not going to get better with another 10 hours of running. It's got to come off. Likewise, a cracked jug is not going to heal itself and must be removed regardless of how high its compression reading might be.

The tough ones to call are those with slight leakage past a valve and those that pass marginally after doing all the above tricks. As far as valve leakage goes, the manufacturers both say that none is acceptable. But your problem may just be a little bit of carbon on the valve seat. Yanking the jug is sure an expensive fix for that. On the other hand, you may have an eroded seat or a cracking valve face, in which case delaying action might wind up being very expensive indeed. Here's where a borescope pays for itself. A good borescopic exam may tell you whether your problem is carbon or valve frying without having to remove the cylinder in question.




*Unless the numbers are dramatically low, the results of a single compression test should not be deemed significant. What you really need is to monitor compression readings over a period of time in order to detect any trends in cylinder health.*

As for the marginal jugs, your best bet is to schedule another compression test real soon. Getting another test in five hours is about right, but certainly no more than ten hours. If compression is still low after that much time, you've got to get digging and find out why.

### The Extremes

There are times, though, when a low cylinder is excusable with no further action. For example, an engine straight out of overhaul or top overhaul is going to have pretty poor compression readings (poor, but not zero). The reason for this is that the rings and valves haven't completely seated, so air in the cylinder has many small paths of escape. However, if compression hasn't improved after 30 to 50 hours or so, you've got a problem and had better investigate.

At the other end of the spectrum, you should realize that it's possible to have a compression reading that's too high. In the real world, no cylinder is going to read 80/80. If it does, you've probably got an oil ring problem. Oil is getting past the ring in enough quantity to act as a sealant around all the rings. This is not good. So, a cylinder that reads "perfect" merits further investigation.

Finally, there's the question of context. Compression readings out of context are meaningless. You should have a whole string of them to establish trends amongst your cylinders. Ideally, you should have a record of every compression test done during the life of your engine.

At the same time, you should be comparing your compression readings with other engine data you have at hand. Oil analysis and engine instrument readings can add meaning to any single compression test, and taken with the background of past data can point you at a present problem.

Finally, be aware of the limitations of compression testing. It may or may not reveal a problem. The cracked cylinder mentioned earlier is a classic example of this. A not-so-well-known example is ring breakage on four- and five-ring pistons (five-ringers especially). All those rings can allow for good sealing even with one ring badly broken up.

Also, compression testing tells you nothing about the condition of the rest of the cylinder. Your valve guides may be loosening up, or your cylinder walls may be washboarding, and you'd never know it from compression testing alone.

So use compression testing often and regularly, but don't allow it to dictate your maintenance actions. It is a tool, and like any tool it can be most useful to those who know how to use it and who understand how it works.