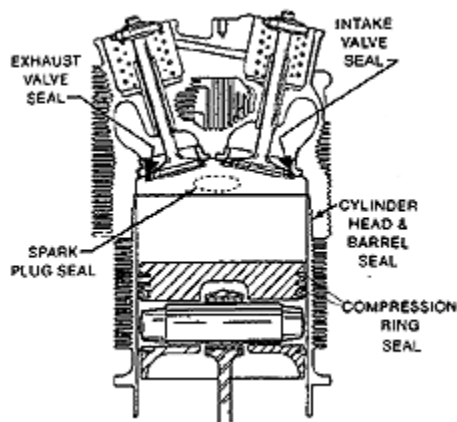


Compression Testing

The differential compression check is one of the quickest, easiest, and most useful tools we have for measuring the top-end health of a piston aircraft engine. Yet many owners, mechanics, and even the FAA seem confused about how to perform the test properly and how to interpret the results. It's not rocket science.

The differential compression check has been a mainstay of piston aircraft engine maintenance for the last 70 years, give or take. Like anything else in aviation that's been around for a long time, various Old Wives' Tales (OWTs) have evolved about the procedure, passed on from journeyman mechanic to apprentice, and later taught in A&P schools and documented in various textbooks and advisory circulars. Ask your mechanic why he performs a compression check a certain way or interprets the test results as he does, and if he's honest he'll probably answer, "That's the way I was taught to do it and that's the way I've always done it."



A low compression reading can be caused by leakage at any of a number of different locations. It is essential for the mechanic performing the compression test to identify the location of the leak by listening for where the air is coming out: oil filler (rings), exhaust pipe (exhaust valve), air intake (intake valve), etc.

I've watched a good number of mechanics perform a lot of compression checks over the years, and indeed done quite a few myself. The usual procedure I've observed -- and indeed the one I was taught -- is to rotate the prop to bring the piston in the cylinder being tested to top-dead-center (TDC), hold the prop firmly while turning on the air valve to apply 80 psi through the test gauge, and then rock the prop back and forth a few degrees either side of TDC until the highest stable reading is obtained.

Wrong, says Teledyne Continental Motors (TCM)! The piston should be positioned so that it's just starting to come up on the compression stroke in the normal direction of crankshaft rotation. Then while firmly holding the prop stationary (preferably with the help of an assistant), the cylinder should be pressurized to 20 psi and the prop slowly rotated (against the air pressure) until the piston reaches TDC -- you can tell when you get there by a sudden decrease in force required to turn the crankshaft. At this point, the prop is held stationary, the air pressure is increased to 80 psi, and the leakage reading is noted. The prop may be rocked back and forth a few degrees to obtain the highest possible reading.

With the piston at TDC and the cylinder pressurized at 80 psi, the cylinder must be checked to determine the location of any leakage. This is done by listening carefully for any sound of air leaking through the exhaust port (exhaust pipe) or the intake port (induction inlet) to determine if air is leaking past the exhaust valve or intake valve; if the leakage is past the rings, it can be heard by listening at the oil filler or engine breather.

TCM's current guidance, Service Bulletin SB03-3, starts out by emphasizing that the differential compression test has significant

limitations that necessitate its results to be corroborated by other non-invasive methods. It states that TCM requires a cylinder borescope inspection to be accomplished in conjunction with the differential compression test. It also makes clear that SB03-3 takes precedence over the old 60/80 guidance found in FAA AC43.13-1B.

In addition to the differential compression test and borescope inspection, SB03-3 instructs mechanics to consider several other factors -- oil consumption, the appearance and color of engine oil, and evidence of crankcase pressurization (such as excessive oil on the belly of the aircraft) -- when evaluating the airworthiness of a suspect cylinder.

SB03-3 also contains specific guidance on the procedure to be used for borescope inspections. A borescope is an optical device that can be inserted into a cylinder through the upper spark plug hole, and allows the mechanic to get a good look at the condition of the cylinder's barrel, combustion chamber, and intake and exhaust valve. While boscopes have long been used for routine inspections of turbine engines, their use has been rare in the maintenance of piston engines.

Clearly, TCM intends to change that. SB03-3 makes it mandatory to perform a borescope inspection in conjunction with each compression check. Since many shops didn't even own a borescope prior to the issuance of SB03-3, the service bulletin even includes a recommendation about what kind of borescope to buy (Autoscope 6600K from Lennox Instrument Company, approximately \$1,000). If your shop doesn't have a borescope, it cannot legally perform a compression test on a TCM engine.

SB03-3 advises that each cylinder should be inspected twice: once with the piston at bottom-dead-center at the end of the power stroke (so that the exhaust valve is open), and again with the piston at bottom-dead-center at the end of the intake stroke (so that the intake valve is open). Items that should be looked for during borescope inspection include:

- Erosion and burning of valve seat inserts.
- Protrusion of spark plug helicoils into the combustion chamber.
- Heavy carbon deposits or the presence of excessive oil in the combustion chamber.
- Localized discoloration of the intake and exhaust valve faces.
- Cracks or erosion on the edges of the valves.
- Scoring, piston rub, or piston pin rub on the cylinder walls.
- Corrosion on the cylinder walls.
- Erosion of the piston crown.
- Visible damage to the piston crown or cylinder head by foreign debris.
- SB03-3 includes a number of photographs to help mechanics identify what normal and abnormal cylinders look like through the borescope.



Normal Combustion Chamber. Exhaust valve has reddish combustion deposit in center with dark outer edge. Intake valve has light brown combustion deposits. Combustion chamber has light brown deposits.



Burned exhaust valve. Note edge of valve face that has lost all combustion residue and striations moving toward center of valve.

In addition to explaining exactly how to perform the compression test and borescope inspection, SB03-3 provides precise guidance on how mechanics should interpret the test results. Here are some highlights:

If the compression test reveals that a cylinder is below the no-go leakage limit, the aircraft should be flown at 65%

to 75% cruise power for at least 45 minutes and then the compression test should be repeated. Only if the cylinder is still measures below the no-go limit during the re-test should it be removed for repair.

If the engine has abnormally high oil consumption (in excess of 1/2 quart per hour) with excessive oil discharge out the breather (i.e., oily belly syndrome) and borescope inspection reveals heavy carbon deposits in the combustion chamber and on the piston crown and excessive oil puddling in the cylinder barrel, then the cylinder should be removed for repair regardless of the compression reading.

If there is any detectable leakage of air at the spark plug boss or at the head-to-barrel junction (between the fins), then the cylinder should be removed for repair regardless of the compression reading.

TCM's SB03-3 applies only to Continental engines, but its fundamental concepts make a lot of sense for any piston aircraft engine. The most important of these concepts is that cylinders should never be removed on the basis of any single compression reading. If a cylinder shows substandard compression, the airplane should be flown and the test repeated. Absent any other abnormal symptoms, a substantial amount of leakage is acceptable during the compression test (down to 50/80 or lower for most test gauges). On the other hand, excessive oil and carbon deposits in the combustion chamber coupled with excessive oil discharge from the breather may warrant cylinder removal even if the compression reading is okay.

Never allow a cylinder to be pulled on the basis of a single compression test -- unless the gauge reads zero or something close enough to zero that you're pretty sure you have a hole in the piston or a chunk missing from the exhaust valve. If the compression is simply weak (as opposed to non-existent), fly the airplane for another three to five hours and then recheck the compression again. There's at least a fair chance that the cylinder will pass muster on the re-test, and that you'll be spared the expense and hassle of an unnecessary cylinder replacement.

Another tip: If you're worried about a particular cylinder, check its compression first, before the cylinder has much of a chance to cool off. The cooler the engine gets, the looser the fit of the piston in the cylinder, and the larger the compression ring gap. All other things being equal (which they never are), the first cylinder to be checked will have the best compression reading, and the last will have the worst.

If the compression reading for a particular cylinder is lower at this year's annual inspection than it was last year, don't necessarily assume that those two data points define a downward trend that will continue. That cylinder might well come out better at next year's test, while some other cylinder shows a downturn.

Just remember that there's a substantial element of random noise in differential compression readings, which is why they're notoriously non-repeatable. The differential compression check remains one of the oldest and most useful tools for measuring the top-end health of a piston aircraft engine. But it's essential to understand the limitations of the test, and how to properly interpret

the results. TCM's Service Bulletin SB03-3 is the most helpful guidance ever published in this regard, so make sure you and your mechanic are familiar with what it says.

Despite what the Friendly Aviation Agency would have you believe, there's simply no meaningful difference in airworthiness between a cylinder that measures 62/80 and one that measures 58/80. There's nothing magic about the number 60 ... unless, of course, you happen to be an airline captain.

By Mike Busch