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RECIP TECHNOLOGY

Piston Engine Troubleshooting

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You work in a shop that specializes in turbine equipment. The few cabin class piston twins for which the FBO is responsible get their maintenance done elsewhere. From time to time, however, piston engine problems do arise that demand your attention. And since everyone else is busy, guess who the boss chooses to evaluate the problem?

If you don't do this every day, it can be a little intimidating; trying to rattle the rust out enough to remember the systems and what to do first. So let's examine some troubleshooting fundamentals for piston engines that will both simplify and speed up the process.

CLARITY OF INFORMATION

This is the first and most important principle. A common mistake is to rely on unclear or vague descriptions of the symptom. Often, there are subtle events or symptoms which occur that someone else may miss, especially if they are otherwise occupied flying the aircraft. It is important to get information on as many other parameters as possible, even ones that seem unrelated. Many things are better sorted out later, in the shop. A good situational awareness is a great asset in this phase of troubleshooting.

The best way to get a good read on the symptom is to experience it yourself. Do your best to emulate the same conditions and duplicate the problem. This way you will find the problem and not create a different one; if you end up creating a different one, the old one will come back to haunt you. Remember, the same problem can give different symptoms in different conditions.

Sometimes it will be necessary to rely on secondhand descriptions of the symptons. It is then imperative that clear and concise information is exchanged both ways. The person experiencing the symptom, usually the pilot, needs clear and definite instructions to troubleshoot when the symptom occurs again (provided safety of flight is not compromised).

Avoid wasteful speculation. This is different from hypothesizing. Speculation is where your mind sort of goes off without you and causes you to start working on things before a test has confirmed that what you are doing will actually fix the problem. Whereas, hypothesizing is based upon educated guesses that presupposes that one is well educated. This brings up the next important principle.

SYSTEMS KNOWLEDGE

Systems knowledge is somewhat similar to clarity of information in that good system information is a must when diagnosing a symptom. You don't need to have mastery of all systems to be effective at this. Accurate systems information can come from any number of sources. Maintenance manuals, training materials, experienced personnel, or manufacturer customer service

"Flower pot" for checking magneto to engine timing. Inaccurate timing can give excessive mag drops or high cylinder head temperatures. This is also the preferred timing check method for Continental engines per TCM.

are some good starting points. Caution: Don't let unqualified sources lead you down the wrong path.

DIAGNOSIS

At this point, sit down with your systems knowledge (whatever the source) and go through the system operation step by step. Note which component and situation would cause the symptoms you're experiencing. List these possible causes and move to the next step.

TESTING

Start with the most likely and simple causes first and test to eliminate or confirm them. Tests should be limited in effect to the suspect component. Don't apply a test that involves too many components or you won't narrow your field of suspects. Use as specific of a test as possible; one that will eliminate possible causes. Accurate information is essential throughout this process. Reevaluation may be needed after testing a suspected cause.

If no test indicates the source of the symptom then the dreaded shotgun may be pulled out. Again, limit the replacement of components to those which will affect your symptom. Start with the most inexpensive ones first. If you have access to these components without having to purchase them, or have the ability to return them if not needed, the process will be much cheaper. This one, however, is a time eater. It may take a lot of shop time and shipping charges if it starts to go very far.

There are innumerable problems that can and do occur in piston engines. There is, however, a group of problems that are generally the most common. What follows is an aid to help quickly troubleshoot six frequently encountered problems. We'll call them the top six.

1. NO START / HARD STARTING:

There are three requirements to get an engine to start — fuel (in the right proportion), oxygen (air), and fire (timed spark). If the engine won't run, one of these things is missing.

Air is almost a given. Even with a significant intake obstruction there will be at least enough air getting into the engine to get it to fire at an idle speed. One exception here is a totally sealed off induction. This would most likely occur after the engine has been removed from storage and someone forgot to remove the intake plug. This source of the no start problem is, however, rarely encountered.

Fuel is a much more common culprit. Over priming an engine will prevent it from firing even once. The presence of a strong fuel smell in the exhaust pipe indicates a flooded engine. Moving the mixture to idle cutoff and throttle to wide open while cranking will solve this one whether you have a carbureted or injected engine. Letting the engine sit for awhile also helps get rid of excessive fuel. Use wide open throttle and mixture idle cutoff while cranking.

Lack of fuel can be just as puzzling. A slight fuel smell in the exhaust pipe can usually tip you off that you need more prime. A note on the Teledyne Continental TSIO-360. These engines take a seemingly excessive amount of prime to start. Fuel may be running out the induction drains but the engine often still does not have enough fuel to start. Best method: one, three second shot of prime and small bursts of the same while cranking.

The last starting requirement can be a little more troublesome. The magneto on a piston engine is designed with a start feature that retards the timing to prevent "kick back" and provides additional energy to the spark event. This additional energy is required because of the slow cranking of the engine during starting. These requirements are commonly achieved in two ways — the impulse coupling and the Bendix "Shower of Sparks."

The engine with an impulse coupling will have a snapping sound while starting. The engine employing the Shower of Sparks system will have a buzzing sound in the cabin whenever the starter switch is activated. Know which system the aircraft has before attempting to start the engine.

The absence of the clicking in an impulse coupling engine denotes a problem with the impulse coupling, probably a broken main or flyweight return spring. This problem requires removal of the magneto(s) with the impulse coupling for repair. If the engine is very cold, stiff oil can also prevent the flyweights from returning to "snap" the coupling. A thorough preheat solves this one.

The absence of buzzing in the shower of sparks system, or the malfunction of the retard points in the magneto, is accompanied many times by the occasional firing of the engine when you let up on the start switch but no firing when the start switch is engaged. This is because of the grounding of the right and left main breaker points by the start switch when in the start position. When the start switch is returned to the normal position, the mags are back in the "both" position. (This is also true of Shower of Spark systems with separate mag switches. The R & L main breaker points ground with the start switch engaged.) Since the engine is still turning at this instant, a cylinder at or slightly after normal firing position may fire and even allow the engine to start. If the Shower of Sparks unit is not buzzing, the unit needs repair or replacement. If there's "buzz" but no spark, check the continuity and points in the retard system.

"Bullet plug" used to set top center with the "flower pot."

A cold cylinder exhaust stack just after shutdown indicates the malfunctioning plug or injector. A small amount of water squirted on the stack will steam and possibly boil.

Hot starts can be troublesome if you're not experienced with the procedures for the particular engine fuel system. Space doesn't allow for the discussion of this problem here. Consult the Pilots Operating Handbook or engine operators manual for specifics.

Another common problem encountered is magneto timing. If the engine has just shown up from the overhaul shop or maintenance has just been performed on the magneto, look for these symptoms and their source problems.

Kickback is caused by the start firing event happening too soon, before the piston reaches top center. The usual causes here are: improper retard point timing (Shower of Sparks system) or improper magneto to engine timing (Shower of Sparks and impulse couplings).

If no firing by the engine is observed at any time, but you know the magneto is firing (don't use your tongue), the probable cause is the magneto-to-engine timing 180 off. When the "flower pot" method is used it is not too difficult to set timing to before top center on the exhaust stroke instead of the compression stroke.

2. MISS / ROUGH RUNNING:

The two most common sources of this symptom are ignition misfire and clogged fuel injector. The misfire most usually shows up on the preflight mag check. To find the offending plug, run the engine on the magneto with the bad drop. If a four or six point EGT/CHT system is installed, note the cold cylinder. Trace the ignition lead back to the magneto with the miss. That plug circuit (plug, high tension lead, or tower in the distributor block) has a short or open. The most common cause here is a dirty/bad spark plug or a chaffed ignition lead.

A clogged injector will act very similar to the misfire. The miss is always apparent if the injector is fully clogged (or nearly so). If the injector is partially clogged, the miss will show up while leaning the engine for cruise. (On the multiple point EGT check for a very early peak and a higher head temperature on one cylinder.) In either case, run the engine in the configuration with the noted miss (rich or leaned out) and note the cold cylinder the same as you would for a misfire. Hint: If the aircraft is not equipped with a four or six point EGT/CHT or some of the probes aren't working, run the engine in the configuration with the noted miss. While running with the noted miss or immediately after engine shutdown, use a squirt gun or bottle and squirt a small, fine stream of water on each exhaust collector approximately one inch from the cylinder exhaust port. The cylinder with the miss will show up with a much colder exhaust collector at this point.

Another common malfunction that is difficult to troubleshoot on the ground is the altitude miss. This is where a plug circuit will misfire only when the aircraft is at or above a certain altitude. If the aircraft has the four or six point EGT/CHT, you can find this one in the air. If not, the "shotgun" method should be used on the ignition system.

A small amount of water squirted on firing cylinder's exhaust stack will ball, sizzle, and immediately fall off stack.

The most common culprit is large plug gaps. Clean, gap, and test all the plugs. Also, test the ignition high tension lead harness with a high tension lead tester. Check the distributor block for cleanliness, tracking, and cracks.

If none of these are the problem, other but less common sources are things such as improper E-gap (magneto internal timing) and weak rotating magnets or coils. For these internal mag problems, the magneto(s) must be removed and troubleshot on a test bench. Note of caution: Do not attempt to do in-flight mag checks for high altitude miss diagnosis. Very often high altitude misses turn into crossfires. Crossfire is when the electrical energy from a miss-fire finds a path of least resistance in one of the electrodes next to it. A mag check while attempting to diagnose which magneto is miss/crossfiring can literally blow the exhaust system into pieces. This is especially true of turbo-charged engines. Mag checks at even low cruise power settings will over temp most cylinder and exhaust components.

A note on bad mag checks for Cessna 180/182s. In very cold weather the O-470 will show bad mag checks (200-300 rpm drop). This is because of the poor fuel atomization in very cold air. Try pulling the carb heat on, releaning (if altitude requires) and rechecking. Rough running of these engines during cruise in cold weather can sometimes be cured by flying with carb heat on to bring induction air temperatures back up to normal. A carb air temp gauge is perfect for this malady.

3. HIGH CYLINDER HEAD TEMPERATURE:

You may have run into this with a partially clogged injector. If not, try these other sources. Baffling: Bad inter-cylinder or cylinder head baffling can cause localized cooling air loss. Check for stiff or loose baffle seals.

The classic birds' nest is often a common culprit here too. A healthy starling can build a very effective air block in 15 to 30 minutes.

If a cylinder has recently been changed, expect higher head temps on that cylinder for the next 30 to 50 hours of operation.

If all the head temps are high look for a more generalized problem. Check for numerous gaps and holes in the baffling. A small air leak goes a long way in dropping the cooling air pressure and causing temperatures to rise. Also, check the cowl flaps for proper rigging. Some models of aircraft have different cowl flap rigging for different years and engines in the same model.

Another, but less common cause of high cylinder head temps, can be magneto

External damage to a magneto caused by chaffing screw and aggravated by internal arcing and burning of the coil.

Cracked and burned coils, such as that pictured here, will often show up only at altitude as altitude misses. Without an external damage indication, these can usually be found best by disassembly or bench check of the mags.

to engine timing. Advanced timing is generally characterized by smaller than normal mag drops and higher than normal cylinder head temperatures. A simple timing check will confirm or eliminate this one.

4. HIGH OIL TEMP:

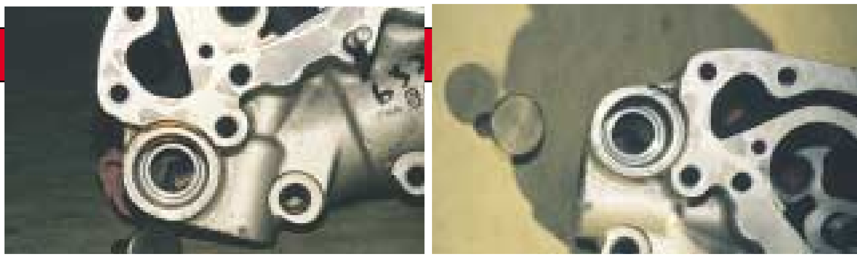
High cylinder head temperatures and high oil temps often go together. In this case look for the common causes of both: bad or damaged baffling or its seals, cowl flap rigging, mag timing, or cooling air blockage.

If just the oil temp is high and cylinder head temps are normal, look for these common sources:

Birds are culprits here, too. A favorite spot for nests is the pockets formed above or in front of the oil cooler. Rags or other debris also lodge here easily. The oil cooler to baffling seal is also important. Air going around instead of through the cooler cuts down on the volume and velocity of the flow through the cooler as well as the cooling air pressure in front of it.

Dirty or excessive paint on the fins will slow heat conductivity and allow the temperature to rise more than normal also. This one will be seen mostly on hot summer days where the cooler needs all the help it can get. A quick visual inspection will cue you to this culprit.

Another common source here is what's called the "Vernatherm" or temperature bypass valve. This unit is a thermostatic valve that works much the same as the coolant thermostat in your car or truck. As the oil gets hotter, the valve closes harder, forcing more oil through the cooler.



Any debris caught between the plunger and seat of the oil pressure relief valve (TCM newer style shown) will cause low oil pressure with hot oil but not with cold. When the oil is hot, pressures at idle can even drop below redline. This is true for any abnormal/excessive internal oil leakage. If cleaning the plunger and seat doesn't help, or if the debris is metal, further investigation is definitely warranted.

Removal of the vernatherm is required to check. The culprits here are abnormal wear of the valve face and seat, or loss of the expanding medium (some sort of wax).

An abnormal pattern for the valve face on the unit is obvious contact or wear on one side and not the other. The face will be worn on high time units but shouldn't be gouging into the seat.

Loss of expanding medium is harder to pin down. The easiest way to find out is replacement with one that is known to work properly.

With either problem, the fix is replacement of the whole unit. The valve seat may also be in need of refacing.

In the winter the problem may be nothing more than a congealed oil cooler. The oil will get thick enough when bitterly cold to obstruct flow through the cooler. This will cause the oil temperature to rise and the oil pressure to fall. When a congealed oil cooler does free up a near instantaneous rise in oil pressure and fall in oil temperature will be noted. The fix here is the proper grade engine oil for ambient temperatures (consult the engine operators manual) and winter baffling for the oil cooler or possibly the whole engine.

Excessive piston ring blowby will also elevate oil temperatures because of the hot gases escaping into the crankcase. See the section on low cylinder compression for tips to troubleshoot this source.

5. LOW OIL PRESSURE:

The three most important factors that determine oil pressure in any given engine are: oil pump volume, engine internal clearances/leakage, and oil viscosity. The two most common causes of this symptom are oil viscosity and internal clearances/leakage.

Oil viscosity is affected by oil grade, temperature and oil damage. The wrong oil grade for ambient temperatures or high oil temperatures will often cause low oil pressure. Oil can be damaged by excessive heat and/or excessive operating time before oil change. All these factors will tend to thin the oil and cause a pressure drop.

This near new "Vernatherm" was the culprit in oil temperature problems. Upon removal and inspection there is usually no external indication of a problem unless the valve face is excessively worn. A new vernatherm solved the problem immediately.

Any excessive internal leakage in the engine will also cause a drop in pressure even at normal operating temperatures. The most common culprit here is debris under the oil pressure relief valve. This acts to hold the valve off it's seat and bleed off oil, dropping the pressure. Remove the valve and clean the face and seat. Note the type of debris that was caught in the valve. This may be an indication of larger problems as noted in the next section.

Excessive clearances from worn bearings, worn valve lifter bores, worn oil pump gears, bad prop oil transfer collars, or missing/loose internal oil passage plugs (just back from the engine shop) will cause a drop in oil pressure. An oil analysis and a look at the oil filter will usually cue you to internal engine problems from worn parts as the cause of this symptom.

Oil pump volume is not something that we can change in the field usually, but is an aggravating factor on some engines. Engines with standard volume oil pumps but high flow demands are very sensitive to viscosity and clearance/leakage factors. This is most common on naturally aspirated engines that have been turbo-normalized by someone other than the engine manufacturer. If a higher volume oil pump is not a part of the package, the oil pump may be hard pressed to deliver normal pressure when the viscosity gets lower (higher temperatures, aggravated by hot turbochargers).

Some aircraft have flow restrictor orifices in the turbo supply line just to keep the oil pressure up. In these engines, any change in flow demand, clearance, or leakage is directly reflected in the oil pressure when at normal operating temperature.

6. LOW CYLINDER COMPRESSION:

This problem is usually found during a scheduled engine inspection. However, excessively low compression on one cylinder is usually noticeable when running the engine as well.

The three most common leakage points are intake valve, exhaust valve, and rings.

If an intake or exhaust valve is leaking it will be plainly audible in the intake (intake valve) or exhaust (exhaust valve) system. If the leakage is not bad the valve may be relapped without pulling the cylinder.

The valve may also be sticky and just require some cleaning of the guide to devolve deposits. This can be found by checking the looseness of the valve in the guide when the valve rocker cover is removed.

Worn or sticky rings will cause a loss of compression and power also. This is called "blowby." There is always a certain amount of blowby present in every engine. The best way to determine if blowby is excessive is to make sure the intake and exhaust valves aren't leaking when the compression test is done. Remove the oil fill cap and listen for escaping air past the rings.

Continental allows compressions much lower than Lycoming but only under special conditions, namely no valve leakage and using a special compression tester. Consult Continental service bulletins for more details.

Excessive blowby is almost always accompanied by higher oil consumption and slightly higher oil temperature than normal.

Annealed rings, caused by piston overtemp, will give high oil consumption and, in advanced stages, low compression. Notice the oil burned and blackened piston. If the top compression ring can be twisted to take a set at or more than 90 degrees without breaking, it is generally considered annealed. The usual culprits of piston overtemp are lean mixtures at high power settings (70 percent or higher) or partially clogged fuel nozzles.

A not so common but serious cause of low compression is a bad crack in the cylinder. This one is a serious safety issue and deserves a little attention here. If hissing is heard outside the cylinder, make sure the source is pinpointed before you go any further. This kind of crack sounds just like an air leak (it is). A crack this bad is immediate cause for cylinder removal and replacement before further flight.

Books have been written on this subject, but my hope is this article has given you a few pointers on making the piston engine troubleshooting experience a little more hassle-free. When you get good at it, it will be gratifying and even fun.

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