IO-550 and TSIO-550 Engine Oil Loss

Fred Moreno
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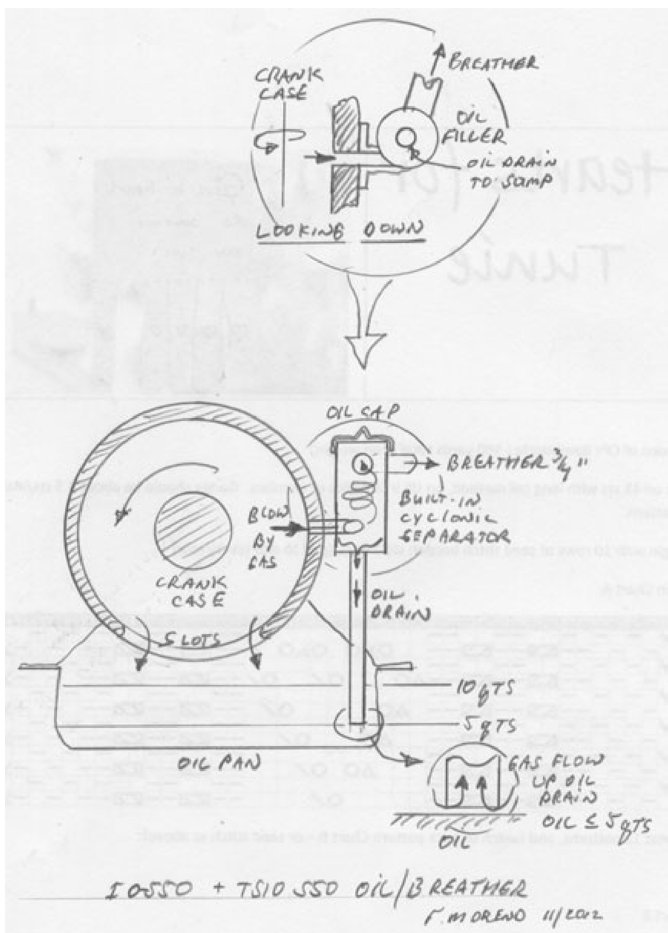
Many Lancairs have experienced strange and in some cases massive engine oil loss events. This monograph describes experience gained and summarizes major causes and their solutions.

Summary: some oil loss is inevitable but can be "tweaked" with operating changes. Sometimes installation errors with air/oil separators can actually worsen oil loss. A much more serious problem can arise with installation of high compression pistons with improper piston clearance. This can create massive intermittent oil loss under a narrow range of operating conditions that can quickly compromise safety.

Oil Breather System

The 550 series Continental engines use a 7 bolt cylinder attachment instead of the 6 bolt pattern of the earlier 520 series. This resulted in a changed oil breather system shown in simplified form below. The 7 bolt pattern restricts the space available for blow-by gases to exit the crankcase to a half inch diameter hole exiting the left side of the crankcase into the oil filler. The oil filler bolted to the side of the crankcase includes an integral cyclonic separator that swirls the exiting blow-by gases to hurl droplets outward to the wall where they drain to the bottom and then down a half inch diameter drain tube back to the oil pan as illustrated . The gases rise to the top and exit out the ¾ inch diameter breather port located below the oil filler cap. A flex line from the breather port passes the flow to a second air oil separator, or down toward the cooling air exit to be dumped overboard. Oil from this tube usually ends up on the belly.



IO-550 and TSIO-550 Oil Breather System Schematic

Some Variables that Affect Oil Loss Rate

Normal operational variables give rise to different oil level readings and also affect oil loss rate in flight.

Checking Oil Level

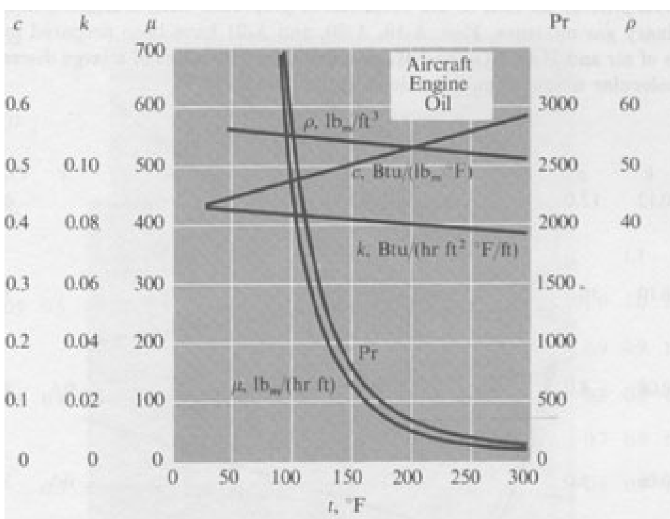
When the engine is shut down, oil may or may not run out of the oil cooler and oil filter back to the pan. Oil in these areas is above the pan oil level, and thus it will try to drain by gravity, but is held back because no air may flow into the cooler or filter to fill the space left by the oil. And then again air <u>might</u> find its way to these locations and the oil can then drain affecting the reading on the dip stick. The air can come in by flowing "backward" from various oil discharge locations. The air flow will depend on how well the oil drains after shutdown, and this will depend on oil viscosity. Viscosity after shutdown will depend on:

- Oil viscosity: what weight oil, is multi-weight being used, how many hours on the oil?
- Engine and oil temperature after shutdown – hot or cool?
- Ambient temperature after shutdown – hot or cool?
- Overnight temperature after the airplane is parked.
- How long the airplane is parked before oil is checked.

So depending on these variables, the oil may drain down by the next morning, or it may not, and the impact on pan level is about a quart. So the reality is the uncertainty in "true" oil level is about a quart.

Oil Operating Temperature

Oil viscosity drops dramatically with temperature as illustrated below. Viscosity is represented by the Greek letter mu and the viscosity curve runs alongside the curve for the Prandtl number Pr.



This shows that in the range from 150F to about 220F which we normally experience while flying the viscosity falls by about a factor of four or so. This has a big effect in two ways. First, the lower the viscosity, the faster the oil runs down into the pan and there is less oil "on its way" than if the oil is cooler. The result can be significant if the pan level is low to start with and the oil is cool and viscous. If more oil is draining slowly, the level in the pan is lowered, perhaps below the level of the oil drain tube, and blow by gas may blow up the drain tube. Or the oil pump may suck air and cause low oil pressure alarms. My old diesel truck has an oil level alarm that comes on during cold mornings because so much oil gets stored up above the head in the rocker covers when it is cold and thick. The alarm light goes off when the oil warms and thins, drainage improves, and the pan level rises. It is a reminder that it is time to add oil.

In flight, viscosity is important because hotter oil (lower viscosity) gives rise to much smaller oil droplets that exit the crankcase to the cyclone separator. Smaller droplets are harder to capture, and more will be swept out the breather, particularly if an appreciable number of droplets are of “fog” size. These will go straight out with the blow-by gases. Hotter oil leads to more oil loss due to smaller droplets that can escape the integral separator. Solution: run lower oil temperatures (180F is a nice compromise oil temperature that also drives off collected water) and/or add a secondary air oil separator to keep the belly clean.

More on air oil separators and the problems they can cause below.

Operating Altitude

Oil loss can increase dramatically with altitude. Consider an engine operating at a fixed power output of manifold pressure and RPM. It will produce some mass flow of blow-by gas that escapes past piston rings to the crankcase and then out the breather. If you start at sea level and climb to, say, 7500 feet, the ambient pressure will fall by about 7.5 inches of mercury, about a quarter which means the VOLUME of gas flow escaping out through the integral separator and breather will increase by a third. Go to 18,000 feet and the pressure is half of sea level and the gas volume (and thus velocity carrying droplets of oil with the gas flow) has doubled. At about 27,000 feet the blow-by gas velocity has tripled. Much larger droplets can be carried overboard.

The caution here is to be aware of conditions when you are operating at high altitude with high oil temperature and high power settings. Oil carried overboard by the blow-by flow will be much greater than if you were flying lower, cooler, and with less power.

Oil Loss Arising from Low Oil Level

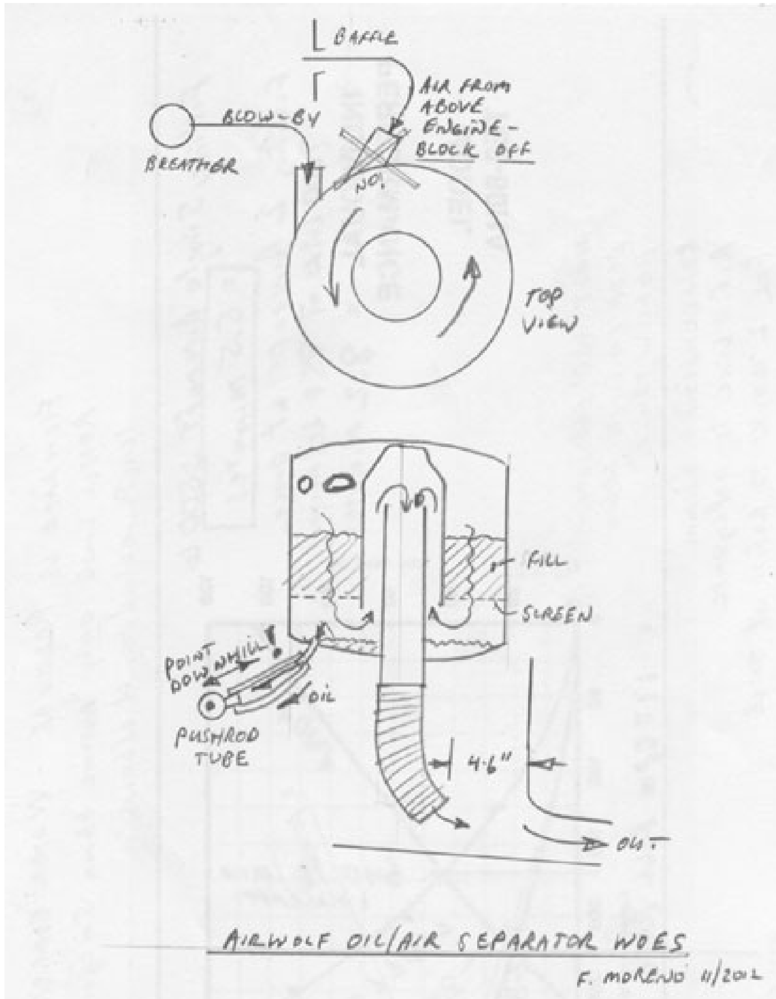
If the oil level of the 12 quart pan (most commonly found in the Lancair community, but check yours) is allowed to fall to below 6 quarts, when running, it will fall further to as low as 4.5 quarts depending on operating conditions and oil temperature. When the oil level in the pan falls below about 5 quarts, the bottom of the oil drain tube from the breather cyclone is uncovered as illustrated in the smaller detail figure at the lower right. Under these conditions, blow-by gases can preferentially escape up the drain tube as well as through the normal vent hole in the side of the crankcase. This is because the pressure at the center of the spinning gases in the cyclone is lower than at the tangential entry point. Both tubes are about half an inch in inside diameter. Thus more gas will flow up the drain tube than through the normal crankcase vent, and the cyclone action will be diminished. When the gas flow goes up the drain tube, it can carry the falling oil upward causing the cyclone to fill with oil which is then carried out the breather in large quantities.

The behavior is that oil loss is initially minimal, and then suddenly increases dramatically when oil level falls below the critical level in the oil pan. This may also occur during flight in turbulence when oil slopping around in the oil pan may cause the drain tube to become intermittently uncovered as oil “waves” roll back and forth in the pan and gas sometimes rushes up the tube and blocks oil drainage. The fix is simple: add more oil. Never let it get low, particularly on a hot, high, bumpy flight. As a general rule, try to run 9-10 quarts with perhaps 7-8 as an absolute minimum. Six or below could lead to problems.

Air Oil Separator Woes

I had a lot of grief with oil loss with my Airwolf Air Oil Separator, most of it self induced. But lessons learned apply to all of us. I spent a lot of effort changing my cooling air inlets, minimizing leakage of cooling air around the engine, and I added cowl flaps to increase airflow a lot during climb and cut back on air flow in cruise. Oil loss was complicated by high compression pistons fitted with improper clearances (more below) and had a couple of problem sources associated with the air separator. Learn from my painful experience.

The figure below shows a top sectional view and a side cross sectional view of the Airwolf Air Oil Separator. These have been around for years, and I had one for 20 years on a Turbo C182-RG where it worked like a charm on the blown Lycoming 540 engine. Not so on my Lancair. Have a look at the figure.



Airwolf Air Oil Separator

The Airwolf design is described in a patent issued long ago. In addition to spinning the breather gas flow around a cyclone to throw droplets out against the wall, it also has a second inlet port that takes cold air from the top of the engine and mixes it in the cyclone. The patent says this is to “precipitate” oil out of the gas flow. You can “precipitate” salt out of water as crystals, liquid to solid phase change, but oil does not “precipitate.” In fact the air flow adds more spin to the cyclone to help catch droplets. It also cools the blow-by gases and may condense a bit of water, not good, but probably not bad since there is water in the oil anyway because water is a major combustion product of gasoline. The “fog” droplets are captured by a fill layer of metal mesh and oil drops to the bottom of the separator while the gases turn around and rise up, reverse direction, and then flow overboard.

<u>Problem number one</u>: Because of high forward Lancair speed coupled with my custom air inlets and careful work to avoid cooling air leakage across the engine, the pressure drop across the engine on my plane is very high when the cowl flaps are open in cruise climb and before I close them in cruise. This high pressure rams a lot of air into the air oil separator. A LOT of ram air. That high flow rate through the fill material picks up oil droplets falling from the fill and carries them up and out the separator and overboard.

Solution: DO NOT use the supplemental air inlet on the Airwolf separator. It works fine on C-182 class airplanes, but Lancairs produce way too much ram pressure above the engine which leads to problem.

Problem number two took a while to figure out. The drain tube that carries the oil out of the separator sump to the push rod tube (or valve cover) MUST be configured to let oil flow continuously downhill with NO low spots or even level spots. If oil can pool in the tube, it can cause intermittent problems because gas flow is also coming UP the tube out of the crankcase at the same time. This gas flow is driven by the pressure drop across the integral cyclone separator in the Continental oil filler assembly. Thus there is a bit more pressure in the crankcase than at the breather exhaust. Result: gas flows up the drain tube while a little oil flows down simultaneously. They are going opposite directions. If the oil pools, the gas flow blocks drainage, the air oil separator sump can fill, and then the blow-by gases in the breather bubble through the oil trapped in the bottom of the separator and carry a lot of oil overboard. You land, the oil drains out of the separator, and you cannot figure out what is going wrong.

Solution: make sure that the drain line from the separator sump goes continuously downhill so that the oil can drain down the bottom half of the tube, and the small bit of gas flow flowing the other way can flow up and out the separator. It is not much, but it can be enough to trap oil under some circumstances.

Problem number three occurs if the SCAT tube carrying the breather flow out the bottom of the separator is terminated too close to the cooling air exit. When this happens, the local static pressure is falling as the flow accelerates out of the lower cowl, so there is a greater pressure drop between the top of the engine where the high ram pressure exists, and the separator discharge at the hot air exist. This increases the flow across the separator and carries more oil droplets out.

Solution: block the Airwolf air inlet from above the engine as suggested above, and keep the SCAT hose breather outlet well away from the hot air discharge area.

High Compression Piston Woes

This one bit me and anecdotal evidence suggests that at least five and perhaps as many as a dozen engines built by Performance Engines of La Verne California have suffered the same fate. It was explained by the folks at ECI (the cylinder manufacturers in Texas). I researched it further and confirmed their suspicions.

In a nutshell: stock pistons (typically 8.5:1 on aspirated engines, 7.5:1 on turbo engines) are cast, not forged, from a "hypereutectic" aluminum alloy with lots of silicon included. The high silicon content improves wear characteristics, and dramatically reduces the thermal expansion coefficient of the alloy permitting much tighter piston to cylinder clearances to be used. This reduced clearance reduces or eliminates "piston slap" which can be heard when the engine is cold, a nice feature in cars.

In contrast high compression pistons (normally 10:1 in aspirated engines) are made by the same folks that make race car pistons. They are forged for toughness to tolerate racing conditions (think 60 inches of manifold pressure, water/alcohol injection, and 3200 RPM at Reno). Forging alloys are MUCH lower in silicon content. Consequently forged pistons have much greater thermal expansion coefficient and thus require much greater piston to cylinder clearance.

The problem arises when the forged high compression pistons are fitted with stock piston clearances. The forged pistons expand, rub the cylinder wall early in the engine life, and overheat the ring land between the piston rings. The ring land and subsequently the ring grooves are damaged, and the rings begin to pound out the ring grooves increasing width. This behavior usually appears when the engine has 50-100 hours.

The damage to ring grooves progresses until under some conditions (usually higher RPM and lower manifold pressure during descent) the gas pressure is no longer able to hold the ring against the bottom of the ring groove when the piston decelerates at the top of the power stroke. The ring lifts from the groove floor, and the combustion gases rush into the crankcase, and carry a flood of oil out the breather. The loss is so severe that it can dump three quarts out in just a few minutes during descent, and paint oil all the way down your belly to the tail. Do it twice and you could run low on oil so it is a flight safety issue.

The behavior is no oil loss on takeoff, climb, or cruise, but massive oil loss on descent or while in the pattern preparing to land. It is diagnosed by putting a small tube up the breather tube to measure the pressure below the breather cap, usually using an air speed indicator carried by the copilot who watches and records data. The pressure shows normal, and then suddenly rises dramatically when manifold pressure is reduce usually below about 18 inches of mercury. If you see this, you are about to spend a pile of money.

If you see this sudden pressure rise in the crankcase pressure, pull a spark plug and put in a boro-scope and look at the cylinder walls of several cylinders. They will probably show scoring marks. If you pull a cylinder, you will see the scoring and also scuffing on the sides of the piston, and probably some piston discoloration from overheating arising from rubbing the cylinder wall.

At this point the pistons and rings are scrap. The scoring may require re-machining of cylinders. If they are plated ECI cylinders, ECI can re-plate them and re-hone the cylinder bores.

Solution: Install stock pistons with recommended piston clearance, or if you must have high compression pistons, determine if they are forged (most likely they are) and then increase your piston to cylinder clearance appropriately. DO NOT use stock clearances.

Are high compression pistons worth it? My experience was that 10:1 pistons yielded “65%” power at 12.5 gallons per hour while the stock 8.5:1 pistons required 13.5 gallons per hour to get the same power output and cruise speed. So the potential savings is maybe $5000 per 1000 hours of flight time. However, one can obtain the same savings by pulling the throttle back and flying 3% slower. You decide and then you can choose.

Safe flying.

Fred Moreno
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