BLACKSTONE LABORATORIES

The Oil Report
March 2021

Oil the News that's Fit to Print!

Inspecting Your Oil Filter

by Luke Miller, Senior Analyst

In addition to an oil analysis program, routine oil filter inspections are a useful tool in the aircraft owner's diagnostic toolbox. We use spectrometers to test for metals on a microscopic level, smaller than you can see and smaller than an engine's oil filter will remove from the oil. Larger pieces of metal that might not show up in spectral testing will be trapped in the oil filter. By checking the filter at each oil change, you'll get a good idea of what normal is for your engine and be able to quickly identify any changes that might be the early signs of a problem.

Cutting the Housing

In order to inspect the filter pleats, they must first be removed from the housing. While a hacksaw or angle grinder might get you there, we strongly recommend using a filter cutter to remove the lid of the filter housing. A filter cutter cleanly cuts the robust steel housing without producing metal shavings that might find their way onto the filter pleats you are about to examine. Plus, who doesn't like a good specialty tool?

The AFC-470 from Airwolf Filter Corp is our go-to cutter here at the lab: http://www.airwolf.com/aw/products/oil-filter-cutter. This tool fits the filter from any Lycoming or Continental engine we've come across. Airwolf also offers a smaller cutter for Rotax engine filters. For those who might also want to examine filters from other engines, like their car or truck, filter cutters that cover a wider range of filter sizes are available from speed shops such as Summit Racing. (https://www.summitracing.com/parts/sum-900511)

1. Secure the filter in a vice.

1. Be sure to wear gloves during this process, since the oil will have lead in it. Secure the filter lug in a bench vice. If the filter doesn't have a lug, you can secure the lower section of the filter housing in the vice - just be careful to not crush the housing or it may trap the internal cartridge with the filter pleats. Poking a hole in the housing to allow oil to drain can also trap the internal cartridge, so we recommend avoiding that as well.

2. Place the filter cutter on the filter and gently tighten the cutting wheel. We take a conservative approach in cutting the housing, progressively tightening the cutting wheel over a few rotations, rather than trying to cut through in one pass.

2. Place cutter on filter.

3. Once the lid has been cut, the cartridge with pleats can then be removed from

the housing. It is also good to inspect the inside of the filter housing for metallic particles and other debris that may not be trapped in the filter pleats.

3. Cutting the filter lid and removing the pleats.

Removing Pleats from Cartridge

You have two options at this point. You can use a solvent such as mineral spirits to wash debris from the pleats, leaving the cartridge assembly intact. The resulting solvent/debris slurry is then filtered for examination. In our experience, this flushing method may not always remove all of the debris from the filter pleats. We prefer to cut the filter pleats from the cartridge for examination by the following method.

Note! There is the potential to guillotine a finger or two during this process. Proper technique greatly reduces the chances of extensive cursing and an unplanned trip to the local emergency room.

1. Place the filter cartridge horizontally on the bench and hold with your non-dominant hand. Locate the filter seam that adjoins the two ends, usually with a metal band or glue.

4. Cutting the filter pleats.

2. Hold the knife with your knuckles against the bench for stability. Starting at the seam and using only downward force, cut along the edge of the pleats opposite the side you are holding. We prefer to rotate the pleats into the knife blade, firmly holding the knife in a fixed position. This method, when done properly, protects your fingers from the knife blade, where the knife moves downward into the bench if it were to slip.

3. Flip the cartridge around and repeat steps 1-2 on the other side. You may have to make a few passes on each side to fully cut the pleats. Using a new razor blade helps.

5. Cut pleats in the valley next to the filter seam (metal band) to remove.

4. Again locate the seam where the two ends of the filter pleats are joined together. Cut across the pleats on either side of the seam.

5. The pleats can now be removed for examination. If properly cut, the pleats will come out in one long piece with a clean edge on both sides.

6. The pleats will still contain a fair amount of oil at this point. If time allows, you can place the pleats on paper towels to drain overnight. You can also squeeze the pleats like an accordion and mop up the oil that squeezes out with paper towels.

6. Squeeze pleats to remove oil if necessary.

Inspecting Pleats for Metal

Stretch the pleats out under a bright light or outside on a sunny day. Larger metal slivers will be obvious, but you may have to look quite closely to identify smaller particles. Here at the lab, we have a dedicated space with clamps that stretch the filter pleats out in one long section. You can improvise in the shop by placing something heavy on both ends of the pleats.

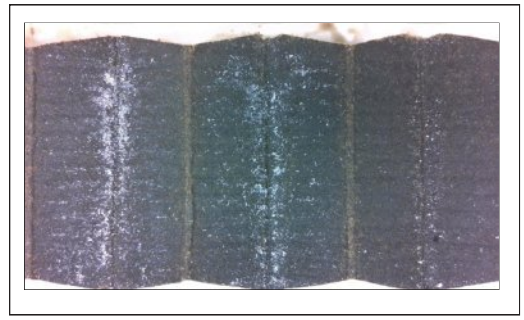
A strong magnet (covered with a plastic baggie or cling wrap) will remove ferrous particles from the pleats. Non-ferrous metals such as aluminum or brass are non-magnetic and will remain in the pleats. The close-up pictures we show were taken with a digital USB miscroscope.

Pictured below: aluminum

Aluminum has a bright, silver appearance and will not react to a magnet.

Close-up of an aluminum sliver

Close-up of aluminum flakes



Severe aluminum particles in filter

Pictured below: copper

Copper-containing alloys, such as brass or bronze, vary from a light straw to copper color and will not react to a magnet.

Close-up of brass or bronze flake

Mixture of bras/bronze particles and carbon

Pictured below: carbon

It is also common to find carbon, especially in the filters from turbocharged engines. Carbon looks like black, hard particles that can be broken apart between your fingers (see the pictures below). A large amount of carbon might indicate excess blow-by, but what counts as excessive is unique to each engine. Regularly checking the oil filter will give you a good idea of how much carbon is normal for your engine. You might find carbon with steel embedded in it, so it is good to check carbon particles with a magnet.

Close-up of carbon particle

Carbon particles in filter pleat

Pictured right: sealer material
Small bits of sealer material may be found, especially after repairs. We generally don't worry about this sort of non-metallic debris.

Sealer material isn't typically worrisome

Lead deposits (see below)
You might also find lead deposits from fuel blow-by. These particles have a bright, foil-like appearance that can look very much like a metallic wear particle. These deposits can be distinguished from metallic wear by their soft and "smudgy" texture. It is worth mentioning that these deposits are not lead from the wearing surface of a crank or camshaft bearing.

Both photos: lead deposits

Evaluating Filter Debris/Conclusion
In some cases, a filter will contain so much metal that a looming problem is almost certain. But it is more often the case for the findings to land in an ambiguous gray area, where the severity of the metal is situationally dependent. You can expect to find some metal and other debris in the filter from a fresh overhaul, for example, where the same findings would be unusual in a routine filter inspection for that same engine at 500 hours since major.

Lycoming offers good guidance on the identification and evaluation of filter debris in Service Bulletin 480F. In our opinion, a lot of the information in that bulletin can also be applied to Continental engines. We also published a newsletter in 2008 on the topic of filter inspections that contains a lot of information about the identification of various metals and their possible sources. Blackstone offers a filter and filter screen examination service as a compliment to oil analysis, but we recommend doing routine filter screenings yourself to get familiar with what's normal for your particular engine. Save your money for flying — check your filter yourself!

Further Reading

https://www.blackstone-labs.com/wp-content/uploads/2018/04/Aircraft-2008-03-01-March-Newsletter.pdf

https://www.lycoming.com/sites/default/files/Piston Pin Plug Wear Inspection.pdf

https://www.lycoming.com/sites/default/files/SB480F Oil ServicingMetallic Solids Identification After Oil Servicing and Associated Corrective Action.pdf

BLACKSTONE LABORATORIES

Report of the Month

This IO-320 has a problem. Can you tell what it is?

To learn more about where the elements are coming from, click here.

UNIT

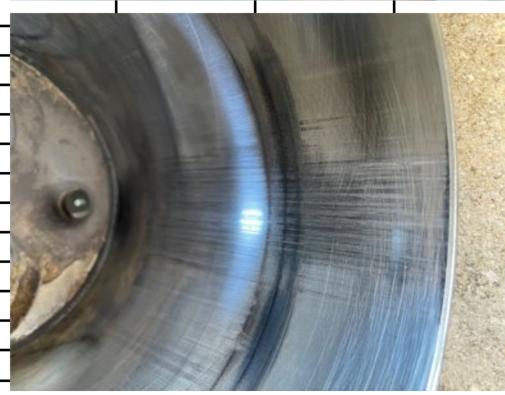
MAKE/MODEL: Lycoming IO-320-E2A
FUEL TYPE: Gasoline (Leaded)
ADDITIONAL INFO: Piper PA18-160, Chrome Cyls
OIL TYPE & GRADE: Aircraft Engine Oil
OIL USE INTERVAL: 5 Hours

COMMENTS

Thanks for discussing this sample with us on the phone. As you know, we're concerned about the amount of chrome this IO-320 is making. To give the engine some credit, chrome did improve nearly 400 ppm compared to the first sample, though the shorter run helped significantly. But at the same time, you only did a partial oil change after the first sample, so a good portion of the chrome could be carryover. We suggest 1. Compression test/borescope of cylinders 2. Looking into why the engine's running hot 3. Another run of 5 hours to see how chrome trends.

ELEMENTS IN PARTS PER MILLION

		UNIT / LOCATION AVERAGES		UNIVERSAL AVERAGES
MI/HR on Oil	5		30	
MI/HR on Unit			220	
Sample Date	11/30/2020		8/4/2020	
Make Up Oil Added			5 qts	
ALUMINUM	**17**	27	**27**	8
CHROMIUM	**219**	611	**611**	5
IRON	**43**	129	**129**	36
COPPER	3	9	9	7
LEAD	1516	4275	4275	2303
TIN	1	3	3	1
MOLYBDENUM	0	1	1	0
NICKEL	1	3	3	2
MANGANESE	1	2	2	0
SILVER	0	0	0	0
TITANIUM	0	0	0	0
POTASSIUM	0	1	1	1
BORON	1	2	2	1
SILICON	6	10	**10**	5
SODIUM	3	4	4	1
CALCIUM	5	33	33	17
MAGNESIUM	1	2	2	1
PHOSPHORUS	28	104	104	844
ZINC	2	6	6	4
BARIUM	0	0	0	0



The owner knew something was obviously up when he got that first sample. In addition to metal in the oil report, the engine was seeing consistently high oil temps in cruise (210-230°F), and high CHT temps in #1 & #3 cylinders, as well as slightly rough running/vibrations in cruise & climb. Additionally, he reported, the engine felt very underpowered. “My engine is supposed to be rated at 160HP, but we had quite a difficult time getting off the water with two passengers, and one instructor who flew it said it felt like it had about as much power as his 100HP super cub. (His plane however is not on floats.)

I suspected the high oil temps might be from a poorly designed/located oil cooler, but several mechanics said that's likely not enough to cause the consistent high temps I was getting, especially since we had the issue when flying in colder temperatures. Since I bought the aircraft used and didn't know the complete history on it, and since the engine only had ~225 hours on it in the 20 years since the major overhaul was done, I decided that I'd play it safe and pull all the cylinders after getting your oil analysis results of the extremely high chrome content, twice in a row.

The company who is inspecting and fixing/replacing my cylinders called me yesterday saying the following was wrong with my cylinders: the wrong piston rings were installed for chrome cylinders; heavy wear in every cylinder- scratches/gouges in #1 & #3 which tells him the plane likely sat for over a year in between startups; evidence of blow by in #1 & #3 - those cylinders also had small cracks developing; and several valves installed backwards (intake installed on exhaust side, & vice versa). He said this isn't a huge issue, but shows the laziness or inattention to detail by the mechanic who installed them (aka a warning sign that they did other things wrong, like use the completely wrong piston rings). So I'm having to get 2 new (reman'd) cylinders to replace the ones with cracks. And then he's overhauling everything else.”

Report of the Month

This O-300 has a problem. Can you tell what it is?

To learn more about where the elements are coming from, [click here](#).

UNIT

MAKE/MODEL: Continental O-300-A
FUEL TYPE: Gasoline (Leaded)
ADDITIONAL INFO: Cessna 172, Mixed Cyl
OIL TYPE & GRADE: Phillips XC (A/C) 20W/50
OIL USE INTERVAL: 31 Hours

CLIENT

The owner says: In reference to the oil analysis surprise of a week and a half ago and the loaded oil filter media, we found the source of the aluminum flakes - worn piston pin plugs. This single plug was from cylinder # 4 and two more were worn on cylinder # 2. Also, we think the (front) thrust bearing is worn beyond limits, allowing the crankshaft to move too much. Looks like a major overhaul is coming.

COMMENTS

Thanks for noting the stuck exhaust valve. Aluminum is really high - high enough to show a problem. If temps got high in the cylinder with the stuck exhaust valve, aluminum could be the result. We are also seeing copper, which in this engine is often from piston pin plugs, connecting rod piston pin bushings, or wrist pin problems. With iron, copper can be from the starter adaptor. Maybe all this will improve now that you've freed the valve, but check for problems anyway. Borescope the cylinders and check compressions. Watch for metal.

ELEMENTS IN PARTS PER MILLION

		UNIT / LOCATION AVERAGES						UNIVERSAL AVERAGES
MI/HR on Oil	31		38	23	21			
MI/HR on Unit	1,079		1,048	1,011	972			
Sample Date	1/17/2021		5/28/2020	10/2/2019	3/31/2019			
Make Up Oil Added	2 qts		4 qts	1.5 qts	1 qt			
ALUMINUM	**140**	45	10	7	**23**			8
CHROMIUM	5	5	3	3	**10**			4
IRON	31	45	19	**21**	**108**			35
COPPER	**25**	14	10	10	10			9
LEAD	912	1658	1374	1380	2965			2146
TIN	1	2	2	1	2			1
MOLYBDENU	0	1	0	0	2			1
M NICKEL	1	1	1	[illegible]	[illegible]			2
MANGANESE	1	1	0	[illegible]	[illegible]			1
SILVER	0	0	0	[illegible]	[illegible]			0
TITANIUM	0	0	0	[illegible]	[illegible]			0
POTASSIUM	0	0	0	[illegible]	[illegible]			1
BORON	0	1	2	[illegible]	[illegible]			1
SILICON	8	15	10	[illegible]	[illegible]			7
SODIUM	3	3	3	[illegible]	[illegible]			1
CALCIUM	53	74	62	[illegible]	[illegible]			18
MAGNESIUM	28	20	26	[illegible]	[illegible]			10
PHOSPHORUS	87	241	99	[illegible]	[illegible]			443
ZINC	27	20	30	[illegible]	[illegible]			5
BARIUM	0	0	0	0	0			0

PROPERTIES

		Values Should Be*					
SUS Viscosity @ 210°F	93.6	86-105	**85.8**	88.8	**84.3**		
cSt Viscosity @ 100°C	18.84	17.0-21.8	**16.97**	17.70	**16.59**		
Flashpoint in °F	**410**	>430	480	475	445		
Fuel %	**1.0**	<1.0	<0.5	<0.5	<0.5		
Antifreeze %	-		-	-	-		
Water %	0.0	0.0	0.0	0.0	0.0		
Insolubles %	0.3	<0.6	0.2	0.3	0.5		
TBN							
TAN							
ISO Code							

* THIS COLUMN APPLIES ONLY TO THE CURRENT SAMPLE

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