BLACKSTONE LABORATORIES

The Oil Report

February 2019

Oil the News that's Fit to Print!

We'll be at Oshkosh this year! Find us at booth 4064 to stock up on discounted bulk samples, ask questions, and meet our analysts.

We were sorry to hear of the passing of Howard Fenton. We bought Howard's aircraft analysis business from him in 2002 and worked with him on filter analysis in subsequent years. He will be missed.

Do I Need to Worry?

By Amanda Callahan

"Do I need to worry?" is a common question we get, and one there's not one easy answer for. We've had people pull the bearings out of a Corvette when lead was only a few ppm above average and we actually said in the report, "You don't need to do anything about this yet." (For the record, that guy called us and said his bearings looked fine and was kind of honked off about it.) We've had people with metals that are high all along, but not changing, and it never turns into a problem. And we've had people not pursue what appeared to be a problem, and regret it in the end. That's especially problematic when the engine is in an airplane! So how do we decide what's a problem and what's not? It would be great if there was a magic number, but there's not. We assess each engine individually, mainly focusing on these things:

1. How your sample compares to your trends
2. How your sample compares to average
3. The balance of metals to each other
4. What kind of cylinders you have installed
5. How your twin engines are wearing in relation to one another
6. Oil type
7. Corrosion

Figure 1: Continental O-300-C

				UNIVERSAL AVERAGES
MI/HR on Oil	25	26	25	
MI/HR on Unit	1,007	982	3,408	
Sample Date	4/7/2017	2/13/2016	11/27/2015	
Make Up Oil Added	1.5 qts	1.5 qts	1 qt	
ELEMENTS IN PARTS PER MILLION				
ALUMINUM	**21**	**24**	**18**	8
CHROMIUM	10	9	10	4
IRON	44	40	50	31
COPPER	15	15	19	13
LEAD	3479	3342	3376	1951
TIN	3	2	0	1
MOLYBDENUM	1	0	0	1
NICKEL	2	4	0	1
MANGANESE	2	1	1	1
SILVER	0	0	0	0
TITANIUM	0	0	0	0
POTASSIUM	2	0	2	1
BORON	2	0	3	0
SILICON	6	5	5	7
SODIUM	0	1	0	1
CALCIUM	0	0	0	11
MAGNESIUM	6	10	8	10
PHOSPHORUS	1173	1172	1161	499
ZINC	1	0	1	4
BARIUM	0	0	0	0

Elevated metals may be okay if they're steady.

Trends

If you have them, trends are the number one most helpful thing we look at in determining your engine's health. It takes about three samples to get a good trend going (though we can often tell if something is amiss earlier than that). All engines are different, as are their operators and the amount/frequency/type of use they receive, and where they are in the country. As such, it's very helpful to sample a few oil changes in a row, at least at first, and have a baseline established for your specific engine.

Consistency counts for a lot. If your engine is wearing a lot but it's doing so steadily, it's entirely possible that the metal isn't a problem. Problems tend to get worse over time – not remain stagnant. Figure 1 is a good example where aluminum (a piston metal) read consistently high in this Continental O-300. The owner wasn't having any problems, and our recommendation was to just watch aluminum as time goes on.

But on the other hand, look at Figure 2. Copper (from brass/bronze parts like bushings and bearings) wasn't unusually high compared to averages for this IO-550-N27, but it was higher than before, and as such we flagged it as something to monitor going forward.

Figure 2: Continental IO-550-N27

							UNIVERSAL AVERAGES
	MI/HR on Oil	36	37	34	40	35	35	
	MI/HR on Unit	1,570	1,496	1,459	1,425	1,385	1,350	
	Sample Date	10/22/2018	8/1/2018	6/21/2018	2/16/2018	11/28/2017	9/28/2017	
	Make Up Oil Added		2.5 qts			2.5 qts	2 qts	
ELEMENTS IN PARTS PER MILLION	ALUMINUM	9	9	5	5	5	8	7
	CHROMIUM	3	3	2	3	3	5	7
	IRON	31	34	29	26	27	38	44
	COPPER	8	5	4	4	3	5	5
	LEAD	4660	4163	3486	3751	3781	4628	5427
	TIN	2	0	1	1	1	2	1
	MOLYBDENUM	1	1	1	1	1	2	3
	NICKEL	6	6	4	5	5	7	10
	MANGANESE	0	0	0	0	1	0	1
	SILVER	0	0	0	0	0	0	0
	TITANIUM	0	0	0	0	0	0	0
	POTASSIUM	1	0	0	0	0	0	1
	BORON	2	0	2	1	3	0	1
	SILICON	5	4	3	5	5	5	6
	SODIUM	2	1	3	3	1	2	1
	CALCIUM	128	97	96	97	99	103	54
	MAGNESIUM	1	0	1	1	1	0	1
	PHOSPHORUS	201	58	69	62	100	110	382
	ZINC	6	3	3	3	2	4	5
	BARIUM	0	0	0	0	0	0	0

The increase in copper is worth watching, even if the level isn't high.

Universal averages

Of course, when you first start sampling, you don't have trends to rely on. So our second line of defense, when we're looking at your numbers, is universal averages.

We have averages established for most of the engines out there, though we're always adding to our database. When you do your first sample, we'll compare your metals to averages for your specific engine.

It's very helpful for us to know what kind of engine you have. Take a look at Figure 3, which shows average wear levels for a Lycoming IO-360-A1A and a Continental TSIO-520-R9B. The big, turbo-charged Continental makes a lot more metal than the Lycoming does. If we don't know what kind of engine you have, we might end up comparing your numbers to the wrong set of averages, or just a generic engine file. We can still often tell if something is way out of line, but the more subtle differences between your engine and averages are harder to see.

Figure 3: Lycoming IO-360-A1A and Continental TSIO-520-R9B

		LYCOMING IO-360-A1A	CONTINENTAL TSIO-520-R9B
	MI/HR on Oil		
	MI/HR on Unit		
	Sample Date		
	Make Up Oil Added		
ELEMENTS IN PARTS PER MILLION	ALUMINUM	6	12
	CHROMIUM	4	15
	IRON	20	82
	COPPER	5	6
	LEAD	3350	5528
	TIN	1	1
	MOLYBDENUM	0	6
	NICKEL	2	26
	MANGANESE	0	1
	SILVER	0	0
	TITANIUM	0	0
	POTASSIUM	1	1
	BORON	1	1
	SILICON	6	9
	SODIUM	1	1
	CALCIUM	23	18
	MAGNESIUM	1	1
	PHOSPHORUS	633	349
	ZINC	4	4
	BARIUM	0	0

Different engines produce different wear patterns.

Balance of metals

We also look at the balance of metals relative to each other. In Figure 4, chrome read a bit out of balance relative to the aluminum and iron readings. Chrome should be about 20% of iron, but instead it's closer to 50%. That suggests the piston rings might be wearing a bit more than they should be. Or, maybe that metal is related to having chromed cylinders on board, which brings us to our next point…

Cylinder metallurgy

Most aircraft engines come with steel cylinders from the factory, and as such, most of the samples in our average files are based on having steel cylinders on board. If your cylinders have been swapped for chromed or nickel cylinders, you can expect those metals to read high. See figure 5, for example, which shows the wear trends from a Lycoming O-320-H2AD with nickel cylinders on the left side of the average column and one with chromed cylinders on the right side. Since replacement cylinders can affect wear trends, it's always helpful to

Figure 4: Continental TSIO-520

ELEMENTS IN PARTS PER MILLION		UNIVERSAL AVERAGES
MI/HR on Oil		
MI/HR on Unit		
Sample Date	11/1/2018	
Make Up Oil Added		
ALUMINUM	17	13
CHROMIUM	**27**	14
IRON	47	73
COPPER	10	8
LEAD	3661	5195
TIN	2	2
MOLYBDENUM	9	6
NICKEL	7	20
MANGANESE	1	1
SILVER	0	0
TITANIUM	0	0
POTASSIUM	0	0
BORON	0	0
SILICON	9	9
SODIUM	1	1
CALCIUM	8	7
MAGNESIUM	2	1
PHOSPHORUS	9	356
ZINC	10	6
BARIUM	0	1

A metal reading out of balance relative to the others (chrome here) can indicate poor wear.

have as much information about the brand/type of cylinders you have installed.

Twin engine comparisons

Twin engines of the same age that see the same type of operation should wear similarly, and as such we always compare left and right (or front and rear) engines if we have the opportunity. Figure 6 shows left and right engine samples from a Beechcraft Baron. The left engine is wearing very well for the type, but the additional metal in the right engine's report suggests something might be amiss – perhaps at steel parts and/or the exhaust valve guides, though cylinder-area metals are elevated as well.

Oil types

Aeroshell 15W/50 oil tends to cause high copper readings in Lycoming engines. The copper isn't poor wear from brass/bronze parts, but rather it's a chemical reaction that happens between the oil and a coating applied to the engine parts in the nitriding process. The copper itself is harmless, but because it can mimic brass/

Figure 5: Lycoming O-320-H2AD

ELEMENTS IN PARTS PER MILLION	NICKEL CYLINDERS			LYCOMING O-320-H2AD	CHROMED CYLINDERS		
MI/HR on Oil	48	50	23		50	50	50
MI/HR on Unit	592	495	394		391		
Sample Date	10/23/2018	7/9/2018	2/23/2018		10/10/2018	8/13/2018	6/18/2018
Make Up Oil Added	4 qts	2 qts	4 qts		3 qts	3 qts	3 qts
ALUMINUM	1	1	1	6	7	7	7
CHROMIUM	0	0	0	3	8	**9**	**8**
IRON	2	2	3	16	8	9	11
COPPER	0	1	0	3	2	2	2
LEAD	2426	3065	1162	3817	5186	4897	3981
TIN	0	1	2	1	1	1	1
MOLYBDENUM	0	1	0	0	0	0	0
NICKEL	4	**7**	**7**	1	1	1	2
MANGANESE	0	0	0	0	0	0	0
SILVER	0	0	0	0	0	0	0
TITANIUM	0	0	0	0	0	0	0
POTASSIUM	1	2	0	1	1	1	0
BORON	0	4	0	1	0	1	2
SILICON	6	4	5	6	6	6	5
SODIUM	4	1	0	1	1	1	2
CALCIUM	5	7	7	12	2	4	13
MAGNESIUM	0	4	0	1	0	1	1
PHOSPHORUS	249	429	9	1265	1127	1111	735
ZINC	1	2	0	3	3	3	3
BARIUM	0	0	0	0	0	0	0

The universal averages are based on having steel cylinders. These two engines have different wear patterns because of their non-factory cylinders.

Figure 6: Twin Continental IO-470 engines

	LEFT ENGINE		RIGHT ENGINE
MI/HR on Oil	35	UNIVERSAL AVERAGES	35
MI/HR on Unit			
Sample Date	6/23/2017		6/23/2017
Make Up Oil Added			
ALUMINUM	6	11	17
CHROMIUM	3	10	16
IRON	48	52	**204**
COPPER	2	7	8
LEAD	3577	3779	4480
TIN	2	1	5
MOLYBDENUM	1	2	8
NICKEL	4	4	**16**
MANGANESE	1	1	3
SILVER	0	0	0
TITANIUM	0	0	0
POTASSIUM	0	1	0
BORON	0	1	0
SILICON	5	9	8
SODIUM	3	1	3
CALCIUM	94	17	110
MAGNESIUM	1	2	1
PHOSPHORUS	168	448	177
ZINC	2	5	2
BARIUM	0	0	0

Different wear patterns between twin engines can indicate trouble.

Figure 7: Lycoming IO-360-A1A

MI/HR on Oil	41	52	57	UNIVERSAL AVERAGES
MI/HR on Unit	854	812	768	
Sample Date	2/27/2017	12/4/2016	10/8/2016	
Make Up Oil Added	3 qts	4 qts	5 qts	
ALUMINUM	4	3	4	6
CHROMIUM	3	3	4	4
IRON	15	14	15	20
COPPER	16	**16**	**14**	5
LEAD	5494	5475	5371	3350
TIN	2	1	2	1
MOLYBDENUM	0	0	0	0
NICKEL	2	1	1	2
MANGANESE	0	0	0	0
SILVER	0	0	0	0
TITANIUM	0	0	0	0
POTASSIUM	0	0	5	1
BORON	0	0	0	1
SILICON	5	5	4	6
SODIUM	1	2	1	1
CALCIUM	2	0	1	23
MAGNESIUM	0	0	0	1
PHOSPHORUS	1090	956	860	633
ZINC	5	4	3	4
BARIUM	0	0	0	0

Copper is high in this engine because of a harmless chemical reaction with the oil.

bronze wear in a used oil analysis, it's important to know the brand of oil you're using to rule out actual brass/bronze wear. Figure 7 shows the high copper trend in a Lycoming IO-360-A1A using Aeroshell 15W/50. In the most recent report, we decided to stop marking copper in bold, given its steadiness and the likelihood that it's just a chemical reaction in this case.

Corrosion

Because of their open breather tubes, aircraft engines are more susceptible to corrosion than other types of engines are. Our general rule of thumb is anytime an engine sees fewer than five hours of use in a month, it's inactive enough to possibly allow for some corrosion to settle in. Corrosion typically shows in our reports as high aluminum and iron. Look at Figure 8. Frequency and amount of use dropped suddenly for this TSIO-520-NB from July 2017 to April 2018, and aluminum and iron increased at about the same time, so corrosion is the primary suspect in this case. You might note that iron isn't much higher than before, though because the interval was shorter, the rate per-hour has increased significantly.

How much metal is too much?

So how much metal is too much? In truth that number is different for every engine. You already know that we take a lot of things into account in trying

Figure 8: Continental TSIO-520-NB

MI/HR on Oil	24	52	43	58	32	20	UNIVERSAL AVERAGES
MI/HR on Unit	1,252	1,279	122	1,190	1,070	829	
Sample Date	4/15/2018	7/31/2017	5/6/2017	8/30/2016	3/23/2016	8/23/2015	
Make Up Oil Added	1 qt.	1 qt.	2 qts	2 qts	2 qts	2 qts	
ELEMENTS IN PARTS PER MILLION							
ALUMINUM	**30**	20	19	18	15	12	11
CHROMIUM	33	28	27	28	26	13	10
IRON	104	97	89	96	84	49	51
COPPER	8	9	7	10	7	6	6
LEAD	4003	4564	4028	4524	3253	2244	5560
TIN	1	2	1	0	4	3	1
MOLYBDENUM	9	8	7	7	5	4	5
NICKEL	48	45	43	45	43	18	21
MANGANESE	2	2	1	2	1	1	1
SILVER	0	0	0	0	0	0	0
TITANIUM	2	1	1	1	1	0	0
POTASSIUM	0	1	0	0	2	1	1
BORON	1	1	2	1	0	2	1
SILICON	16	19	16	**18**	**16**	**19**	9
SODIUM	2	2	2	1	2	0	1
CALCIUM	76	65	72	63	66	9	16
MAGNESIUM	1	2	4	2	4	1	1
PHOSPHORUS	98	91	109	92	171	33	345
ZINC	3	5	9	20	11	4	4
BARIUM	0	0	0	0	0	0	0

Corrosion may account for the high aluminum and iron readings in the most recent sample.

to answer that question. We'll call you to get more information if we're not sure. Usually, we'll suggest giving it an oil change or two to see how trends shake out, and as always we suggest checking the oil filter or screen for metal, as anything large enough to be picked up by the filter or screen isn't something that will show up in our testing. If something is seriously out of line we can usually tell, even if we don't know your engine type or how you use it.

We will say this, though: it's pretty rare for a major mechanical problem to happen unexpectedly overnight. Most engines will give at least some warning before things go south, and that's why you do analysis. Follow the trends to see what's normal for your engine, and when deviations occur, you're informed enough to make a good decision.

Report of The Month

This Austro AE300 diesel engine saw a dramatic spike in lead in December. Can you guess what happened?

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

ELEMENTS IN PARTS PER MILLION		UNIT / LOCATION AVERAGES			UNIVERSAL AVERAGES
MI/HR on Oil	107		87	84	
MI/HR on Unit	278		170	84	
Sample Date	12/1/2018		7/10/2018	3/6/2018	
Make Up Oil Added	1 qt		2 qts	1 qt	
ALUMINUM	4	3	3	4	3
CHROMIUM	4	3	3	4	3
IRON	53	54	57	93	66
COPPER	6	4	4	6	3
LEAD	**2543**	637	2	1	3
TIN	0	0	0	1	0
MOLYBDENUM	1				1
NICKEL	4				1
MANGANESE	1				1
SILVER	0				0
TITANIUM	29				10
POTASSIUM	2				2
BORON	35				68
SILICON	6				10
SODIUM	3				3
CALCIUM	1539				2769
MAGNESIUM	9				15
PHOSPHORUS	861				933
ZINC	604				1064
BARIUM	0				0

	Engine oil Sample	Fuel tank Sample
MI/HR on Oil	25	
MI/HR on Unit	303	
Sample Date	12/20/2018	12/20/2018
Make Up Oil Added	0 qts	
ALUMINUM	2	0
CHROMIUM	1	0
IRON	14	0
COPPER	0	0
LEAD	0	0
TIN	0	0
MOLYBDENUM	0	0
NICKEL	0	0
MANGANESE	1	0
SILVER	0	0
TITANIUM	49	0
POTASSIUM	2	0
BORON	67	1
SILICON	3	0
SODIUM	2	0
CALCIUM	2647	0
MAGNESIUM	9	0
PHOSPHORUS	949	0
ZINC	1056	0
BARIUM	0	0

The follow-up samples.

Most piston aircraft engines run 100LL and fuel blow-by causes lead to read at several hundred (or thousand) ppm. But Jet A doesn't have any lead in it, so lead should read very low in this engine's report. Upon seeing this high lead reading, we cautioned the owner that some 100LL may have been used. He immediately grounded the aircraft. Before draining the fuel and flushing the fuel system, he took samples from both the engine oil and the fuel tanks to determine the extent of lingering contamination. Both of those samples came back without any lead whatsoever, which led us to consider another alternative: sample contamination. As it turns out, his sample was contaminated by his mechanic before it was sent. This report stands as a good reminder to track the trends before proceeding with costly repairs, and to always make sure you get a clean sample.