The Oil Report
February 2022

Oil the News that's Fit to Print!

Did you know we analyze filters? We prefer you send just the pleats (not the whole canister). Cost is $125 for filter pleats, and $200 if you send the entire filter. (We really don't want the entire filter.) Or, check out this article to learn how to do it yourself!

Pre-Ignition & Detonation

The information (and harrowing pictures!) in this article are reprinted courtesy of the FAA.

Pre-ignition. Detonation. Both can be deadly. But what's the difference? And how can you avoid them?

This engine is from a Beech S35 Bonanza's fatal accident. The #6 piston was eroded and began to melt. The rings and piston skirt were compromised by thermal expansion and metal transfer. Note the deep pitting and erosion of the piston face. This caused combustion gases to bleed into and over-pressurized the crankcase, forcing engine oil out the breather. The connecting rods then failed due to the lack of lubrication and smashed holes in the crank case, causing loss of power and engine failure.

Piston pitting and erosion of the piston face

Normal combustion vs. pre-ignition

Normal combustion is an orderly, progressive burning of the fuel-air mixture in the cylinders. The gasses within the cylinders are ignited from the top. The flame then travels down in an organized way. This combustive force, equally applied to the piston in a stable manner, pushes the piston down. The downward motion of the piston is then mechanically transferred to the propeller. This makes pilots very happy.

Bonanza end result

In a **pre-ignition** event, combustion is abnormal. It happens when the air-fuel mix ignites before the spark plug fires, while the piston is still moving up in the compression cycle. The ignition can be caused by a cracked spark plug tip, carbon or lead deposits in the combustion chamber, a burned exhaust valve, an ignition system fault, or anything that can act as a glow plug to ignite the charge prematurely.

When this happens the engine works against itself. The piston compresses and at the same time the hot gas expands. This puts tremendous mechanical stress on the engine and transfers a great deal of heat into the aluminum piston face damaging the piston. Engine failure can happen in minutes.

This bent connecting rod is from a car, but it's a good example of the damage pre-ignition and detonation can do.

Detonation

Detonation is an explosion of the fuel-air mixture inside the cylinder. It occurs after the compression stroke near or after top dead center. During detonation, the fuel/air charge (or pockets within the charge) explodes rather than burning smoothly. Because of this explosion, the charge exerts a much higher force on the piston and cylinder, leading to increased noise, vibration, and excessive cylinder head temperatures. The violence of detonation also causes a reduction in power. Some engines can operate with mild detonation. However, severe detonation can cause engine failure in minutes. Because of the noise that it makes, detonation is called "engine knock" or "pinging" in cars.

These cylinder #2 spark plugs are packed with melted piston material.

High heat is detrimental to piston engine operation. Its cumulative effects can lead to piston, ring, and cylinder head failure and place thermal stress on other operating components. Excessive cylinder head temperatures can lead to detonation, which in turn can cause catastrophic engine failure. Turbocharged engines are especially heat sensitive.

Some causes of detonation include:

- improper ignition timing
- high inlet air temperature
- engine overheating
- oil in the combustion chamber
- carbon build-up in the combustion chamber

A combination of high manifold pressure and low rpm creates a very high engine load, which can also cause detonation. In order to avoid these situations:

- When increasing power, increase the rpm first and then the manifold pressure
- When decreasing power, decrease the manifold pressure first and then decrease the rpm

Pre-ignition and detonation results

The explosion of pre-ignition and detonation is like hitting the piston with a sledgehammer. The automotive term for the sound it makes is "ping" (something pilots cannot hear in aircraft). The ping sound is the entire engine resonating at 6400 hertz. It sounds like a ping, but it is an explosion with enough power to make the engine resound like a gong.

Both pre-ignition and detonation put tremendous mechanical stress on the engine and transfer a great deal of heat into the piston deck. This can cause the piston to melt (EGT is 1600 degrees; aluminum pistons melt at 1200 degrees). The force of these explosions can knock holes in pistons, bend connecting rods, overcome the lubrication film in the rod bearings, and hammer the babbitt out of rod bearings. Engine failure can happen in minutes.

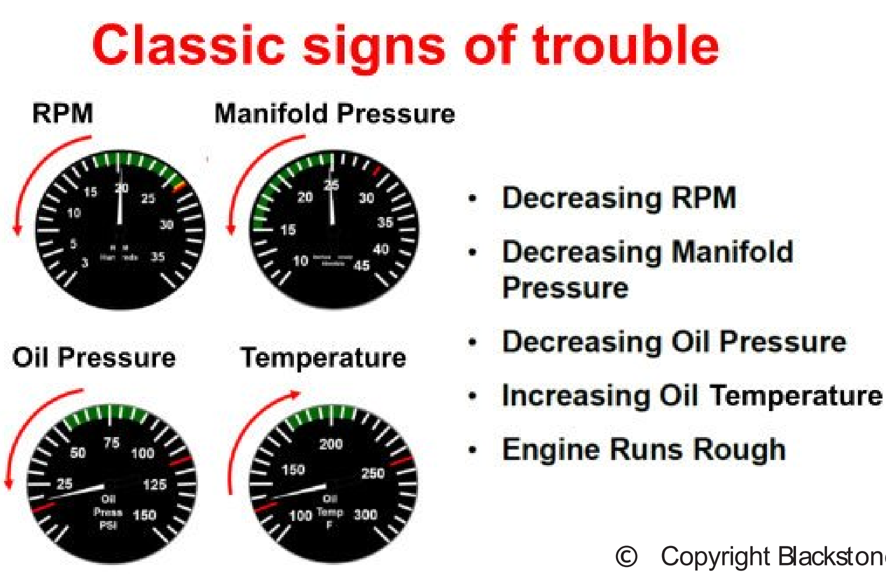
The picture to the left above is a cylinder head showing signs of pre-ignition or detonation. The carbon coating that normally lines the head dome is knocked off. There is melted piston material in the head and the cylinder sleeve is scored by the overheated piston.

Above and to the right is the same piston. Note that the piston deck is eroded. The rings are broken. The piston skirt is scuffed from rubbing on the cylinder wall. A piston in this condition allows combustion gases into the crank case. This over-pressurizes the crankcase and blows engine oil out of the crank case breather -- all of the engine oil, in minutes.

Soon after the engine oil departs the connecting rods try to make a break for it, resulting in giant holes in the crank case - see the image to the right.

How do I detect pre-ignition?

A rough-running engine can be the first sign of pre-ignition or detonation. High EGTs or CHTs can be a sign of a problem so be sure to keep an eye on that if you can.



What do I do when it happens?

Since excessive heat can be so damaging, your main priority is to cool the engine:

- Reduce power

- Increase airspeed
- Enrich the fuel mix
- Open the cowl flaps.
- Land immediately!

Preventing Pre-ignition

- Do not take off unless the run-up is perfect
- Maintain the ignition system
- Pay attention to cylinder compression tests
- Use the proper heat range spark plugs
- Make sure cooling baffles are in good repair

Pre-Ignition and Detonation Can Be Deadly!

Don’t Let it Happen To you!

Preventing Detonation

- Lean the engine per the flight manual
- Keep engine load to a minimum
- Do not over boost
- Use only the recommended fuel grade
- Make sure engine timing is properly set
- Make sure cooling baffles are in good repair
- Be wary on hot, dry days
- If in doubt, run rich

Some detonation/pre-ignition accidents from the FAA
Cessna R172K: Broken spark plug insulator: 1 minor injury
Cessna 210N: Left magneto timed to 30 BTC, should be 22 BTC: 4 fatalities
Cessna A188B: Faulty magnetos: No injuries
Vans RV4: Aftermarket ECU provided too lean mixture: 1 minor injury
Mooney M20E: Turbo over-boost: 2 fatalities
Mooney M20K: Spark plug failure: No injuries
Eros 1600: Improper fuel/oil mix, cracked carb adaptor: 1 fatality
Beechcraft A36: Unapproved turbo installation/over boost: No injuries
Cessna 175A: Ignition system failure, magneto drop over limit: No injuries
Cessna 172: Left magneto bearing race loose: No injuries
Beechcraft M35: Ingestion of an air intake bypass door: 2 minor injuries
Cessna 421C: Used 50% jet fuel: 2 fatalities
Cessna 411: Fuel system obstructed by crud after storage: 1 fatality, 3 serious injuries
Cessna 172F: Auto/AvGas mix, spark plug maintenance: 1 fatality
Piper PA28R: Fuel system misadjusted to run lean: No injuries

BLACKSTONE LABORATORIES

Report of the Month

This Lycoming IO-320 has a problem. What is it?

To learn where the elements are coming from, click here and scroll down.

UNIT

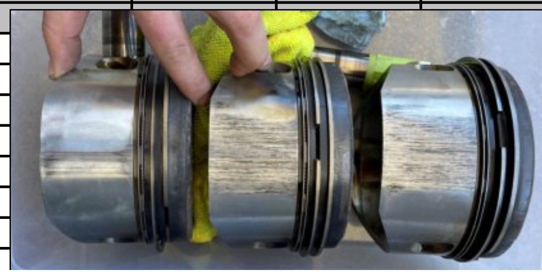
MAKE/MODEL: Lycoming IO-320-E2A
FUEL TYPE: Gasoline (Leaded)
ADDITIONAL INFO: Piper PA18-160, Chrome Cyls
OIL TYPE & GRADE: Aircraft Engine Oil
OIL USE INTERVAL: 5 Hours

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**					7
CHROMIUM	**219**	611	**611**					5
IRON	**43**	129	**129**					35
COPPER	3	9	9					6
LEAD	1516	4275	4275					2254
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					19
MAGNESIUM	1	2	2					1
PHOSPHORUS	28	104	104					821
ZINC	2	6	6					4
BARIUM	0	0	0					0



Note the sides of the pistons. You don't want yours to look like that.

The owner writes: Symptoms of the problem were mainly high oil temps in cruise (210-230°F), and high CHTs in #1 & #3 cylinders, as well as rough running/vibrations in cruise & climb. Additionally 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.

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
- small cracks in the cylinders
- 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)

I'm getting two new (reman'd) cylinders to replace the ones with cracks. And overhauling everything else.

Report of the Month

This Franklin 6A has a problem. What's going on?

To learn where the elements are coming from, click here and scroll down.

BLACKSTONE LABORATORIES

UNIT

MAKE/MODEL: Franklin 6A-350-C1
FUEL TYPE: Gasoline (Leaded)
ADDITIONAL INFO: Maule M5-220C
OIL TYPE & GRADE: Aeroshell 100 Mineral
OIL USE INTERVAL: 20 Hours

COMMENTS

Thanks for noting the good borescope results. We're a little surprised to see so much aluminum in this sample. And tin too, though it only increased 1 ppm and it's not really all that high in the grand scheme of things. This engine is still young enough that we don't yet know what's going to be normal, so maybe aluminum will settle down, though we're glad you're looking for anything unusual on your end. Metals (especially aluminum) should be decreasing, not increasing, so there could be some piston wear going on. Monitor for visible metal and check back.

ELEMENTS IN PARTS PER MILLION

		UNIT / LOCATION AVERAGES						UNIVERSAL AVERAGES
MI/HR on Oil	20		9					
MI/HR on Unit	88		66					
Sample Date	1/15/2022		5/1/2021					
Make Up Oil Added	10.5 qts							
ALUMINUM	**35**	25	14					9
CHROMIUM	2	2	1					7
IRON	31	35	38					52
COPPER	6	6	5					8
LEAD	1325	1235	1144					2110
TIN	**5**	5	4					1
MOLYBDENUM	0	0	0					0
NICKEL	1	1	0					2
MANGANESE	1	1	1					1
SILVER	0	0	0					0
TITANIUM	0	0	0					0
POTASSIUM	0	0	0					0
BORON	1	1	0					0
SILICON	13	14	14					9
SODIUM	1	2	3					1
CALCIUM	2	19	36					15
MAGNESIUM	2	3	3					4
PHOSPHORUS	83	673	1263					192
ZINC	2	3	3					3
BARIUM	0	0	0					0

PROPERTIES

		Values Should Be*					
SUS Viscosity @ 210°F	93.9	82-105	**82.8**				
cSt Viscosity @ 100°C	18.91	16.0-21.8	**16.23**				
Flashpoint in °F	500	>440	475				
Fuel %	<0.5	<1.0	<0.5				
Antifreeze %	-		-				
Water %	0.0	0.0	0.0				
Insolubles %	0.5	<0.6	0.2				
TBN							
TAN							
ISO Code							

The owner writes: I appreciate your commentary on the results. After sending this sample we pulled the quick drain off to re-seal and found what ended up being quite a lot of aluminum in the pan. We also found one piece of steel that used to be the tach drive gear. The aluminum was from the mag-driven gears. Yes, on the Franklin those are alumnum. They were of course shelled out. We've cleaned things up and once the part overhauls and the annual are done, we'll run a couple hours and drop the oil and send in another sample. Hopefully that tin will settle back down.

BLACKSTONE LABORATORIES

Report of the Month

This O-470-R had a problem. What was it?

To learn where the elements are coming from, click here and scroll down.

UNIT

MAKE/MODEL:	Continental O-470-R	OIL TYPE & GRADE:	Aeroshell W100 (AD)
FUEL TYPE:	Gasoline (Leaded)	OIL USE INTERVAL:	11 Hours
ADDITIONAL INFO:	Cessna 182N, Nickel & Superior cyls		

COMMENTS

(We removed the first line of the comments, which gave away the problem.) Since this engine just got two new Superior cylinders, it's no surprise to find some chrome and iron wear-in. Superior jugs often produce more chrome than nitrided steel ones, so as long as we find progress there, we wouldn't assume poor ring wear. Most of the silicon in this sample is probably sealer or lube, but it wouldn't be a bad idea to check over air filtration in case it's coming from dirt. Check back to monitor for progress.

ELEMENTS IN PARTS PER MILLION

		UNIT / LOCATION AVERAGES						UNIVERSAL AVERAGES
MI/HR on Oil	11		3	33	17			
MI/HR on Unit	14		52	49	17			
Sample Date	1/26/2022		6/18/2021	4/19/2021	11/4/2020			
Make Up Oil Added	1 qt		0 qts	3 qts	2 qts			
ALUMINUM	13	12	**30**	10	3			9
CHROMIUM	**23**	12	**24**	15	1			9
IRON	**66**	83	**88**	76	9			42
COPPER	9	16	9	**13**	**15**			6
LEAD	692	1556	1146	1283	273			2889
TIN	1	1	1	2	0			1
MOLYBDENUM	0	1	0	1	0			1
NICKEL	1	3	1	1	0			5
MANGANESE	3	2	1	1	1			1
SILVER	0	0	0	0	0			0
TITANIUM	0	0	0	0	0			0
POTASSIUM	0	0	0	0	0			1
BORON	0	2	1	2	3			1
SILICON	**17**	35	**17**	**37**	**60**			8
SODIUM	2	4	3	3	9			1
CALCIUM	5	17	80	7	36			34
MAGNESIUM	1	1	2	1	1			1
PHOSPHORUS	41	37	229	86	22			440
ZINC	4	3	4	3	5			6
BARIUM	0	0	0	0	0			0

PROPERTIES

		Values Should Be*					
SUS Viscosity @ 210°F	94.4	86-105	**84.9**	89.8	86.3		
cSt Viscosity @ 100°C	19.04	17.0-21.8	**16.75**	17.92	17.09		
Flashpoint in °F	515	>460	495	490	505		
Fuel %	<0.5	<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	0.3	0.3	0.2		
TBN							
TAN							
ISO Code							

When we received the 6/18/21 sample, the note with the sample said an incident was under investigation that caused very high CHTs in flight and total loss of compression in the #5 cylinder - note that there were only 3 hours on that sample. The follow-up sample in January said the engine was returned to the overhaul shop for disassembly following a detonation event in the #5 cylinder at 52 hours post-overhaul. The cause of detonation is currently unknown.