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CESSNAPILOTS MAGAZINE

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FEATURES

ON THE COVER

Cover photo and this page courtesy of Amelia Earhart Hangar Museum

THE OILY WIZARDS OF FORT WAYNE

Mike Jones
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Ask ten flyers to name the single most essential ingredient in aviation and if you don't get at least five different answers I'll buy you a pizza. The results from my unofficial poll at a weekend EAA meeting included av gas, money, and a poetic "long runways and blue skies." I heard "maintenance" from a pilot who also was an A&P, "training" from a CFI, a vague assertion of "safety," and coffee, to which almost everyone nodded their heads.

Oddly, no one mentioned oil. But nobody gets far off the ground without at least a couple quarts of dinosaur juice splashing under the cowling. Aircraft oil works all sorts of magic. It reduces the friction between moving parts, which enables our engines to work longer and harder with astounding reliability. Oil enhances the seals between the piston rings and the walls of each cylinder, preventing power loss and "blow-by." Oil keeps the engine cool, removing roughly 40% of the heat created by the engine, and collects dirt, soot and metals.

Oil keeps working even when the plane is not. Oil forms a temporary layer over the bare innards of your engine, protecting those parts from corrosive humidity. Abundant, clean, cool engine oil is the secret to a happy engine. It's also quite a bargain, delivering truckloads of functionality for about $9 a quart.

The Doctor Is "In"

At my old airport, the resident A&P scoffed at oil analysis. "It won't tell you anything I can't see," he told me. "Save your money and the aggravation." Sadly, that is the attitude of many mechanics who tout their observational skills over a "second opinion" from a desk jockey in a distant lab.

I ignored that talented but ill-informed gentleman, and for twenty years I've been sending half-pint samples to a lab for analysis after every oil change. Oil analysis is like the "DEW line" for my engine (Google it, youngsters), making visible the changes my eyes cannot see. It is as essential for aeronautical well-being as frequent oil changes. Oil analysis can save you an arm and a leg, and maybe your life.

Aircraft maintenance guru Mike Busch, of Savvy Aviation, agrees. "I'm a big believer in oil analysis. We recommend it to our clients," he told me. "But it is kind of misunderstood, which is why some mechanics are reluctant to recommend it to their owners."

Busch went on to explain the layers of self-protection built into an aircraft engine. The first layer is the oil itself, cooling parts and preventing friction. The oil pump is an engine's "heart" which moves the oil to where it is needed. Because of the importance of the oil pump, the second layer of defense is a small metal screen directly in front of it. The screen captures metal particles bigger than 1/16th-inch because those pieces could cause the oil pump to fail catastrophically. Basically, the oil screen prevents engine "heart attacks."

Ryan Stark is a vibrant entrepreneur, a skilled engineer, and an enthusiastic pilot with almost 500 hours in his logbook. His bird is an RV-12 he built with his dad, Jim Stark. It's a glossy speedbird with a handsome panel, a rugged Rotax engine, and the shiniest black and white paint job I've ever seen.

The oil pump then forces the oil through the third layer of defense, which is the oil filter itself. Importantly, the filter only removes small particulates. It does not remove liquid contamination like acids, water or fuel carried in the oil, nor does it remove microscopically small particles. Both of those remain in suspension in the oil until the next oil change, which is the fourth and final layer of defense of the engine.

That's why my old A&P didn't like oil analysis: only the liquids and microscopic particles end up in the oil sample jar. The big chunks never make it that far. Since oil analysis doesn't predict every failure, only certain kinds of failures, he felt it was less than useful.

"Engine failures come in two categories," Busch told me. "There are fast events which happen in a few hours, and slow events which accumulate over years." Fast events, like lifter spalling, can be detected by an alert pilot and an energetic A&P. "But a slow event like a gradually wearing exhaust valve guide shows up in the oil analysis long before anywhere else."

I asked Busch about my mechanic's assertion that oil analysis causes "false alarms." Busch felt people making that claim were misusing oil analysis, looking at transient anomalies instead of trends. They were asking oil analysis to do a job for which it is not designed.

"The two engines on my C310 have very different oil analysis signatures," he told me, suggesting that if he wasn't cautious he could spend a lot of time and money trying to figure out exactly what was happening under each cowling. "You have to baseline each engine with multiple oil samples. Then look for substantial departures from those baselines."

He suggested oil analysis should be used like a medical MRI. It's not the individual scan that's important but the changes from scan to scan that give the most relevant information. Oil analysis isn't an emergency-room procedure but a long-term diagnostic tool.

He offered me an example from not too long ago. One owner repeatedly saw high levels of silicon in his oil analysis, which was alarming because silicon is abrasive and there are no silicon parts in an aircraft engine. However, silicon is found in sand and dirt. High levels of silicon meant the engine was breathing dirty air. As they tracked the problem down, they found the carb heat door was not sealing tightly. It was allowing small quantities of unfiltered air into the engine even when the carb heat was off. Fixing the carb heat system was trivial and prevented gritty silicon from abrading the engine. But without the prodding of the oil analysis, it is highly unlikely anybody would have noticed such a subtle failure.

Left: *The Stark family of oil analysis entrepreneurs: Jim Stark, Kristen Huff, and Ryan Stark enjoyed a baseball game a few years before Jim passed.* ***Right:*** *The volume of samples racing through the Blackstone facility is amazing to see, but each sample gets personalized handling and tracking every step of the way. Here, Mary unpackages an incoming oil sample and categorizes it by the source: aviation, diesel, marine, and so on.*

Off to Fort Wayne

While many labs perform oil analysis, only a few are both capable of and willing to test aircraft engine oils. I have been sending my samples to Blackstone Laboratory in Fort Wayne, Indiana. In return, I have received insightful and sometimes amusing full-page reports on the health of my engine. This month I decided to deliver my sample to Blackstone. I spent a fun day with the Blackstone team plus Ryan Stark, the company's president, and VP Kristen Huff, Ryan's sister and co-owner. I learned more about oil analysis than I ever expected.

Stark greeted me at the Fort Wayne FBO with a big smile and a tiny, yellow MINI Cooper. Blackstone's facility is a four-building campus, roughly halfway between the airport and downtown. Part warehouse, part strip mall, part unexpected opportunity, the Blackstone strategy is "make it work"—buy what they can get, use what they need, and adapt as the business evolves. It's not glamorous but it's highly functional and affordable.

The business was founded by Stark and Huff's dad, Jim Stark, in 1985. Jim learned about lab processes while working at Dana Corp., which is a billion-dollar leader in "propulsion solutions that power mobility across the globe." Whew. A real person would say they make axles for pickup trucks, but that's not quite as sexy. In any case, Jim was laid off during a recession and migrated to a lab at a company that made diesel fuel additives, but he wanted to get out on his own.

"My father planned to be in the photography business. He came up with the name 'Blackstone Photography' and had a logo," Stark recalled. "But when he started the lab business, he just swapped out the word 'photography' and put in 'laboratory' and it worked."

The early years were tough. Jim sold testing services to factories with compressors and generators like GM, Ford, and some trucking firms. Gradually Blackstone expanded into new regions and markets, acquiring a bit more stability along the way. Aviation and marine engines now make up about 50% of their business.

"At least with boats and airplanes, you're usually talking to the owner, and they're a little less price sensitive," Stark explained. "But we do a lot of work for farmers and individuals, so I want to keep our services affordable."

A surprising discovery was that neither Stark nor Huff is a chemist. Stark studied mechanical engineering at Purdue and came to the business after he graduated in 1996. He says chemistry isn't the big mystery, the engines are.

"If you think about what we're testing, it's all mechanical, you don't need to be a chemist," he elaborated. "You need to know where the aluminum's from, what kind of problems can happen with pistons, and the metallurgy of rings. It helps being a mechanical engineer."

Into the Lab

All of the sample kits Blackstone receives are born in the Test Kit Assembly Building on the Blackstone campus. Just two members of the Blackstone team, Ashley and Amber , are responsible for assembling and shipping thousands of test kits each week. They pre-build the kits by application (aviation, diesel, hydraulic, and so on). Ashley and Amber even individualize sample slips for existing customers. "We send out a ton of them," Ashley told me.

And a ton of them come back, thousands of samples, every week. The pre-lab receiving area is staffed by Mary, Eric, Maggie, Megan, Jason, and Ben. The process starts on a long

Left: *Maggie is an expert at processing the oil samples, handling as many as 500 or more each day. It is vital that each sample be assigned a computerized tracking code so when the results come out of the lab, they can be properly matched back to the correct customer.* ***Right:*** *Lydia is one of the many lab techs working at Blackstone. She is monitoring the kinematic viscosity bath, which measures the viscosity of the oil; behind that is the flashpoint testing bay.*

steel shelf filled with Post Office crates, each one brimming with oil samples. Mary opens the packages and sorts them. Eric checks the billing paperwork, ensuring that Blackstone gets paid. Maggie organizes the samples into lots of 36 items, looking for special requests or double samples, like Mike Busch's paired left- and right-hand engines. Megan is "email central," answering questions and selling supplies, while Ben enters the technical details of each sample into the computer before it goes to the labs.

I was surprised to learn that Blackstone offers a semi-secret, priority service.

"Say a sample comes from a pre-buy inspection. Everybody's always hot to get those answers back," Stark explained. "If you pay that extra money to overnight your sample, we'll unpack it before the others, run it through the lab first, do the report first, and email it back to you all in the same day. It's our fastest turnaround time, no charge."

Once the samples are all prepped, they go to two different labs. The more sophisticated lab is spectroscopy but the most exciting one is the flashpoint lab.

Flashpoint Flares

We visited Lydia in the Flashpoint and Viscosity Lab. The room is spacious but dark; everything seems to be coated with smokey residues. Digital read-outs glow brightly, throwing pinpoints of color into the dungeon-like room. Bunsen burners hiss like diminutive dragons. The pungent smell of hot oil fills the air. Lydia moves skillfully and precisely, working in the semi-dark space like a wizard in a Harry Potter movie. She poured a tiny sample of oil into a thimble-sized caldron (more Harry Potter!) and heated it with a gas flame. She listened to each sample as it warmed.

"When you have [a sample] that's got water in it you can hear 'em crackle a little. They sizzle, like bacon in a frying pan." Water in airplane engines is a bad idea, suggesting corrosion will be a problem.

The darkened room allowed Lydia to observe the flashpoint test more

The flashpoint test is fairly boring until the sample flashes, then it's like a strobe going off in your face. The sample of about an ounce of oil is heated in a calibrated manner until the gas flame causes the oil to ignite with a "poof" of flames and smoke. The aviation lab runs this test on three samples simultaneously which keeps the techs very busy.

precisely. This test requires a bit of nerve because you're waiting for the sample to explode. When the oil reached its "flashpoint" there was an eye-popping burst of flame that made me jump. A puff of soot lazily floated over the room before being sucked out by the exhaust system. Lydia carefully recorded the temperature into Blackstone's custom software.

The flashpoint for most aircraft oils, like Aeroshell 15/50, should be around 440˚F. "If there's a leaking cylinder or something, a little bit of fuel gets into the oil," Lydia told me. "It'll flash at a really low temperature which means the oil's not protecting the engine."

The second test Lydia performed was the viscosity test. Stark told me this test was developed a century and a half ago when engines were just beginning to be used for transportation and machinery. "The kinematic viscosity bath is really simple, as old as the hills," he said. "It sim-

Left:*Luke is running this heavyweight centrifuge that spins oil samples at 2,000 rpm to measure the quantity of particulates in the oily liquid. These particles are so small they are not captured by a traditional oil filter. Subsequent spectrographic analysis determines the composition of the residues, which helps with diagnostics.* ***Right:*** *The digital spectroscopes heat the oil samples to determine the quantities of twenty different elements which are tracked to measure engine performance. At this moment, Justin was recalibrating the machine, a task they perform every dozen samples just to be sure their samples are pin-point precise.*

ply measures the speed at which the oil will flow at a given temperature." Lydia used a vacuum to "suck" a tiny sample of the oil up into a glass tube that is heated to a calibrated temperature. "Then we let gravity take over," she said. "The oil flows down the glass tube. I use digital timers that plug directly into the software, which computes the viscosity. This way you can identify if it's within normal margins or not."

Watching these tests was fascinating, but I wondered if it might be boring to work there day after day. That would be true, Lydia told me, except everybody is cross-trained. "We're not doing the same thing every day," she said. "We divvy up the jobs so that we switch every day, like a weekly rotation."

It's Elementary, Watson

We visited the non-aviation spectroscopy lab which is in a completely separate building. As dark and gloomy as Lydia's lab was, this space is vibrantly white and hospital clean. Techs expertly move around the room, test tubes in hand. Four principal measurements are collected in these labs. The labs can add other tests if a customer or chemistry requires it, such as pH tests, but just four tests are their bread-and-butter.

Blackstone has three spectrometers (one for aviation, two for all other samples), each of which cost more than a luxury car. The staff treats them with the respect they deserve. I spoke with Justin, the lab manager, as he tweaked one of the machines. "This is the most important test in the lab. It tells us the elements, in parts per million, of chrome, steel and aluminum," he explained. "If I could only run one test, this would be it. I can get by with a one-mil sample of oil."

The machines are highly automated and aren't hard to operate, but they do take some babysitting. "Sometimes they get out of calibration," he explained. "Generally, you could go a whole day without calibration, but we check [the calibration] every twelve samples. That way, if the system goes out of line, we don't have that many samples to rerun."

The insoluble test uses a centrifuge as large as a home

There are about a dozen report writers at Blackstone who have the technical skills to interpret the oil analyses and the writing skills to make them understandable. Each of these people were hired for their writing skills. They endured months of technical training to learn the chemical and mechanical aspects of oil analysis. Summer (left) started her career in construction, moved to Hawaii and then came to Fort Wayne to enjoy the winters. Brianna (right) is an effervescent soul who decorates her office (and the Blackstone web site) with photos of Max the Supercat.

clothes washing machine but many times heavier, which was being loaded by Luke. “It spins at about 2000 rpm,” Luke explained as he placed racks of tiny test tubes into the machine. “We take five milliliters of the sample oil and mix it with five milliliters of petroleum ether, which is a solvent. You shake it up, spin it, see what solids settle out.” For example, lead forms a gray sludge at the bottom of the test tube.

Stark also showed me a new service for their customers: oil filter analysis. Healthy engine oil filters shouldn't contain anything but oil, but Stark showed me a scary example: the pleats of the filter were lined with metals. It’s a messy job but can provide a mechanic with powerful insights into the health of the engine.

Report Writers

Blackstone hides their report writers in an undisclosed secure location (behind an old restaurant kitchen) because they are the “secret sauce” of Blackstone’s success. The report writers translate the arcane lab results into short, simple words even a pilot can understand. That means, first and foremost, they are all writers.

The analysts have diverse backgrounds. Brian spent time in both the Marine Corps and the restaurant industry. Brett has a master's in poetry and works a side hustle as a college professor. Summer worked in Colorado and Hawaii, while Arryn was a screenwriter in California. Brianna majored in writing at Indiana Westland. Master Analyst Anna has a bachelor's degree in history and was lured to Blackstone by “the siren call of good writing.”

Not all the report writers are based in Fort Wayne. Amanda is in Illinois and Samir is in Montana. "We're flexible. We want to keep our highly-trained people even if their husbands or significant others need to move," Stark said. "They can stay with their family and we can still keep 'em on." Report writing is the perfect "remote work" job because all of the analytical data is in digital form. A sample of a Blackstone report is dissected in the sidebar with this article.

Anna and Stark do most of the training, which is expensive and time-consuming. About a month of classroom time is required before new writers are ready to test their wings on automotive reports. There's a second round of training before they graduate into aircraft applications.

Blackstone also offers their employees an unusual corporate perk: pilot training. "We helped Amanda get her pilot's license. She got her instrument and commercial, and now she's working on her instructor ticket," Stark said. "We'll pay half of the costs. Plus, some of our customers call the office and like to talk to a fellow pilot."

The Long View

Mike Busch is highly supportive of oil analysis and particularly fond of Blackstone. "We steer our customers to Blackstone," he said. "They seem to do a more comprehensive job." With kudos like that and business booming, I asked Stark about the future of Blackstone; what were his plans, what did he wish for? His surprising answer: he'd just like to know the punchline.

"We'll call a mechanic and tell him, hey, this engine's making a lot of metal, check it out. Maybe we've seen copper, brass, or aluminum. Maybe some bearing material, which can fail quickly," he said. "That call gets their attention, which is what they want; and they'll say thanks. But then they don't call us back. We don't get any feedback at all. I wish they'd call us once in a while and tell us how the story ended."

Dr. Mike Jones is a 4,000-hour general aviation pilot and retired businessman. He has served on his local airport authority for the better part of a decade. His recently-completed doctoral research was a statistical analysis of the managerial elements of an organization that make for better airports..

SIDEBAR: TRANSLATING YOUR OIL ANALYSIS REPORT

My maintenance logbook is fat with Blackstone oil analyses I have collected over the years, but I was interested in the thought processes report writers use when a lab report appears on their screen. I perched on Brian's shoulder for fifteen minutes as he reviewed my latest submission.

Before he looks at the lab results, he double-checks to make sure he's got all the facts straight. He looks at the address, the tail number, the engine type, and so on. He also reads any notes the owner has added. "You're good about giving us notes [on the sample slip]," he complimented me. "They're always useful. I see you added a quart every seven to eight hours, that's awesome." He went on to add that more notes are generally better; even just a few headlines are helpful.

He then considered the metals reported in the latest sample, comparing those outcomes to previous samples and the "universal average" results. The universal average is computed from decades of oil samples from engines of exactly the same make and model. "For some engines, like the Lycoming 360s, we've got thousands in there," Brian explained. "But there are other ones, rare ones, like

automotive engines converted for aircraft use, there might only be a handful." The same goes for other types of machinery, such as marine engines or industrial compressors.

In my case, Blackstone has about 200 samples from Continental TSIO-520R9 engines, which is sufficient to provide a good baseline. Blackstone's customized software flags any score if it is greater than two times the universal average. Brian pondered the results, judging if the higher readings were an issue (red boxes on the attached report). He looked at the trend from earlier samples and looked for patterns between the different metals. Studying my report, he paused for a minute.

"I'd consider this one a significant increase over the last one. I'm gonna flag that as a potential sign of excess wear, maybe a developing problem," he said. "Only potentially though. It's not like it was ten times higher than the last one. In that case I would be a lot more concerned."

Stark joined the conversation and they gently debated the numbers. Aluminum is usually from pistons, I learned, so the increase may have been caused by a little corrosion due to inactivity. (This was a winter sample when I was flying five hours/month or less.) "It [the aluminum reading] doesn't look like piston scuffing because the molybdenum didn't increase," Stark opined. Molybdenum is used in anti-scuff coatings applied to Continental pistons.

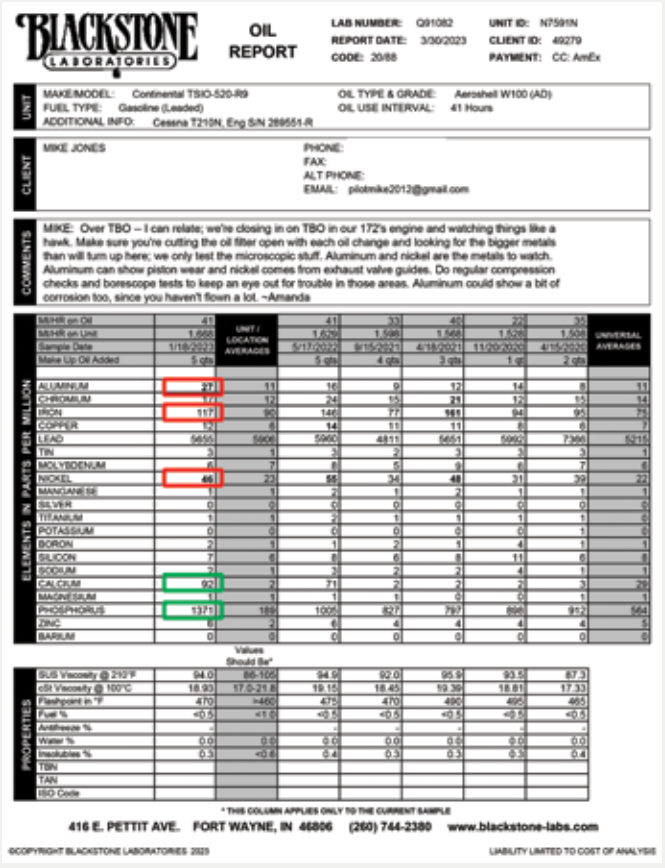
The elevated iron score is from steel parts like cylinders and rotating shafts. "That improvement is nice, and the current reading wasn't too far off earlier scores, so I don't think we need to highlight it," Stark added.

Brian noted that nickel usually is from exhaust valve guides and my engine has been trending higher as of late. The big concern might be a burned exhaust valve, so he thought a borescope inspection would be useful the next time I put the plane in the shop. Old '91N is equipped with a digital engine monitor but it is an older design without a data collection option. "That's too bad," Stark said. "Otherwise, I'd look at the graphs of EGTs and CHTs from your last flight. If you see any unusual spikes or dips, that would confirm a valve issue."

I asked about two other numbers that looked weird to me (green boxes), but they were unconcerned. Calcium is just from the use of CamGuard, while phosphorus often is an additive in the oil itself. "Aeroshell W100 doesn't use phosphorus," Stark said, "so the chances are good you were actually using Aeroshell W100 Plus." These people are really smart about aircraft engines and oils!

Brianna joined our conversation, sharing a more alarming report. This sample was from a new customer who had just bought the plane. The aluminum was 50 ppm and the iron was high, too, even though there were just eight hours on the oil. "These readings look bad," Brianna said grimly. "Iron means corrosion. You wouldn't necessarily get that level in just six months, even sitting on the ramp. But [the owner] wrote that the airplane had not flown from 2017 to October '22. That's five years, going on six."

Brian agreed. "I would pick up the phone on that one."



BLACKSTONE LABORATORIES

OIL REPORT

LAB NUMBER: Q91082 UNIT ID: N7591N
REPORT DATE: 3/30/2023 CLIENT ID: 49279
CODE: 20/88 PAYMENT: CC: AmEx

UNIT
MAKE/MODEL: Continental TSIO-520-R9 OIL TYPE & GRADE: Aeroshell W100 (AD)
FUEL TYPE: Gasoline (Leaded) OIL USE INTERVAL: 41 Hours
ADDITIONAL INFO: Cessna T210N, Eng S/N 289551-R

CLIENT
MIKE JONES
PHONE:
FAX:
ALT PHONE:
EMAIL: pilotmike2012@gmail.com

COMMENTS
MIKE: Over TBO – I can relate; we're closing in on TBO in our 172's engine and watching things like a hawk. Make sure you're cutting the oil filter open with each oil change and looking for the bigger metals than will turn up here; we only test the microscopic stuff. Aluminum and nickel are the metals to watch. Aluminum can show piston wear and nickel comes from exhaust valve guides. Do regular compression checks and borescope tests to keep an eye out for trouble in those areas. Aluminum could show a bit of corrosion too, since you haven't flown a lot. ~Amanda

ELEMENTS IN PARTS PER MILLION								
MI/HR on Oil	41	UNIT / LOCATION AVERAGES	41	33	40	22	32	UNIVERSAL AVERAGES
MI/HR on Unit	1,668		1,629	1,596	1,588	1,628	1,628	
Sample Date	1/18/2023		5/17/2022	9/15/2021	4/18/2021	11/20/2020	4/15/2020	
Make Up Oil Added	5 qts		5 qts	4 qts	3 qts	1 qt	2 qts	
ALUMINUM	27	11	16	9	12	14	8	11
CHROMIUM	17	12	24	15	21	12	15	14
IRON	117	90	146	77	101	94	95	75
COPPER	12	6	14	11	11	8	6	7
LEAD	5655	5906	5960	4811	5651	5992	7366	5215
TIN	3	1	3	2	3	3	3	1
MOLYBDENUM	6	7	8	5	9	6	7	6
NICKEL	46	23	55	34	48	31	39	22
MANGANESE	1	1	2	1	2	1	1	1
SILVER	0	0	0	0	0	0	0	0
TITANIUM	1	1	2	1	1	1	1	0
POTASSIUM	0	0	0	0	0	0	1	0
BORON	2	1	1	2	1	4	1	1
SILICON	7	6	8	6	8	11	6	8
SODIUM	2	3	3	2	2	4	1	1
CALCIUM	92	2	71	2	2	2	3	29
MAGNESIUM	1	1	1	1	0	0	1	1
PHOSPHORUS	1371	189	1005	827	797	898	912	564
ZINC	6	2	6	4	4	4	4	3
BARIUM	0	0	0	0	0	0	0	0

PROPERTIES	Values Should Be*						
SUS Viscosity @ 210°F	94.0	86-105	94.9	92.0	95.9	93.5	87.3
cSt Viscosity @ 100°C	18.93	17.0-21.8	19.15	18.45	19.39	18.81	17.33
Flashpoint in °F	470	>460	475	470	490	495	465
Fuel %	<0.5	<1.0	<0.5	<0.5	<0.5	<0.5	<0.5
Antifreeze %	-	-	-	-	-	-	-
Water %	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Insolubles %	0.3	<0.6	0.4	0.3	0.3	0.3	0.4
TBN							
TAN							
ISO Code							

* THIS COLUMN APPLIES ONLY TO THE CURRENT SAMPLE

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 LIABILITY LIMITED TO COST OF ANALYSIS

Here's a typical Blackstone oil analysis report. Notice the highly personalized commentary offered in the notes by Amanda, one of the report writers who is also a private pilot. Three metals are showing up a little high, which is to be expected on an older engine that didn't fly much during winter. Calcium and phosphorous have also jumped up while viscosity, flashpoint, fuel, water, and insoluble readings all remained stable. By comparing six different samples over three years in this one report, the Blackstone experts can read the tea leaves of the engine.