BLACKSTONE LABORATORIES


# The Oil Report
# February 2023

Oil the News that's Fit to Print!


Heads up! Next time you get kits, you'll find the **oil slips in the envelope, not the black mailer.** This speeds up the kit building process, getting you kits faster! You can also print slips from our website, under Services.

# TBN and TAN

## *Do you need one?*

**by Suzanne Herman**

"Do I need a TBN?" It's a question that comes up a lot. The TBN is a test we do on engine oil, while the TAN is meant for transmissions and other gear lubes or hydraulic oils. These tests are widely discussed on internet forums, where facts and misconceptions can be hard to distinguish. So let's dig into the science behind them!

**What is a TBN or TAN?**

The Total Acid Number and Total Base Number are ways to determine how acidic oil has become (TAN), or how effectively it can neutralize the acids that form from combustion and other factors (TBN). An increasing TAN indicates more acidity, while a decreasing TBN shows an oil's acid-neutralizing additives are being used up. You may remember the pH scale from science class. pH is a more familiar measure of acidity in everyday life. So why don't we use pH on oil?

pH stands for "potential of hydrogen" and measures the flow of hydrogen ions in a water-based solution. pH doesn't apply to oil because these ions can't flow through oil – it's a poor conductor. That's why oil is used as an insulator for transformers and other applications that call for interrupting the flow of electrical current. Fortunately, we can use titration to get around this obstacle.

**Running the tests**

We start by mixing one gram of oil with a happy blend of toluene, chloroform, isopropyl alcohol, and a splash of H2O. (Kids, don't try this at home!) The solvent breaks down the oil into a solution that is a better conductor, so we can measure the pH. The next step differs slightly for the TAN or TBN.

**What is Titration?**

Titration is used to determine the concentration (in this case, the acidity level) of an unknown solution (oil) by exposing it to measured quantites of a known solution (acid or base).

For the TAN, we add a cocktail of chemicals – let's call it Bruce – to the toluene solution, a little at a time. This continues until the pH reaches 11. The lab techs then use an equation to calculate the TAN from the amount of Bruce added to the oil-toluene blend.

The TBN follows a similar methodology, except the solution added is more acidic – more of a Boris than a Bruce.

The end goal for the TBN titration is a pH of 3, and as with the TAN, the lab people are doing some math to transform the amount of Boris added to the oil into your TBN number.

**Why get a TBN?**

As the oil circulates through the harsh environment of a hot, running engine, combustion causes acids to form. These acids can cause increasing wear and corrosion. To prevent this, the oil manufacturers add detergent additives to the oil, which help it buffer those acids and stabilize the oil's pH. The higher the TBN, the better your oil can resist becoming acidic. That's the main reason to check the TBN. It's a helpful data point if you want to extend your oil change interval beyond manufacturer recommendations.

**Figure 1: Average starting TBNs of various oils**

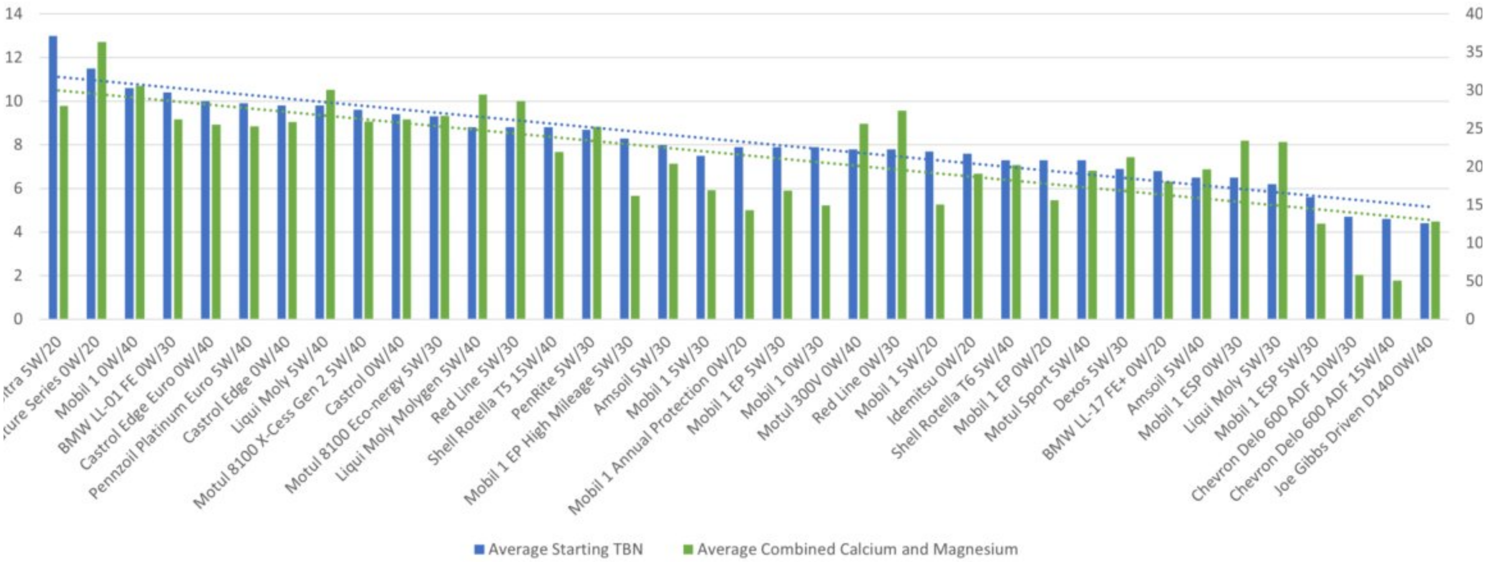



**Figure 2**

| Mobil 1 5W/30 at various mileage points | | | | |
|---|---|---|---|---|
| **Miles on Oil** | **Calcium (ppm)** | **Magnesium (ppm)** | **TBN** | **TAN** |
| 741 | 1043 | 624 | 6.2 | 1.9 |
| 2,100 | 1021 | 695 | 5.8 | 3.2 |
| 3,848 | 1103 | 779 | 4.4 | 2.8 |
| 5,300 | 1169 | 592 | 4.2 | 5.1 |
| 5,651 | 956 | 682 | 4.6 | 4.7 |

**This oil has a starting TBN of 7.5. Note the roughly inverse relationship of the TBN and TAN readings; as the TBN decreases, the TAN increases, as less "active additive" is available to neutralize acids.**

**Figure 3**

| Mobil 1 Annual Protection 0W/20 at various mileage points | | | | |
|---|---|---|---|---|
| **Miles on Oil** | **Calcium (ppm)** | **Magnesium (ppm)** | **TBN** | **TAN** |
| 2,543 | 1057 | 725 | 6.4 | 4.8 |
| 4,215 | 994 | 669 | 5.5 | 4.9 |
| 3,188 | 1217 | 912 | 4.6 | 2.6 |
| 7,206 | 1150 | 827 | 4.5 | 4.2 |
| 4,845 | 1121 | 755 | 4.1 | 5 |
| 6,526 | 1145 | 745 | 3.8 | 4.3 |
| 5,659 | 1259 | 972 | 3.8 | 3.1 |
| 8,329 | 1254 | 577 | 3.4 | 6.9 |
| 10,052 | 1157 | 842 | 3.1 | 4.2 |

The TAN does essentially the same thing, but we use the TAN on oils that don't have detergent additives (like hydraulic oil and ATF). Some industrial equipment manufacturers will set standards for when to change the oil based on the TAN.

**Which oil has the highest TBN?**

The TBN is mainly based on the amounts of calcium and magnesium (detergent additives) in the oil. Oils with more of those additives typically have a higher starting TBN, and those with less will rank lower on the list. Is more better? Not necessarily (and we'll get into that a little later). Meanwhile, Figure 1 lists a slew of virgin engine oils and their average starting TBNs, from highest to lowest. The progression isn't perfectly consistent, because we don't test for every conceivable substance the oil manufacturers might include that determines the TBN.

The TBN drops pretty fast when you start using the oil. Then it levels out and drops more slowly. Figures 2 and 3 show two types of Mobil and how the TBN tends to fall as acidic substances start to "use up" the detergent additives. That's what they're there for, and we consider any TBN over 1.0 sufficient, while a TBN of 2.0 or greater is ideal when choosing to run the oil longer than you currently are. Note that parts per million of calcium and magnesium stay roughly the same – it's their ability to neutralize acids that decreases.

## Is more better? A look at two novel blends

It's easy to see how you might feel like you want an oil with a starting TBN that's as high as possible. But Figure 1 makes it clear that oils with all sorts of starting TBNs are available. Did the manufacturers at the low end of the scale just cheap out on additive? Not at all. Oil manufacturers have to cater to an array of unique engine designs, operating conditions, etc. As technology evolves, so does oil.

**Figure 4**

| Joe Gibbs Driven D140 0W/40 | | | | |
|---|---|---|---|---|
| **Miles on Oil** | **Calcium (ppm)** | **Magnesium (ppm)** | **TBN** | **TAN** |
| 6,500 | 1,191 | 5 | 2 | 3 |
| 5,161 | 1,320 | 27 | 1.9 | 3.6 |
| 5,781 | 1,354 | 11 | 1.8 | 4.5 |
| 6,000 | 1,353 | 11 | 1.4 | 3.2 |
| 6,640 | 1,128 | 5 | 1 | 5.2 |

### Joe Gibbs

See, for example, Figure 4, which lists a few different samples of Joe Gibbs Driven D140 oil. It had the lowest average starting TBN (4.4) thanks to fairly low levels of calcium and magnesium. This left the TBN between 2.0 and 1.0 after just 5,000-6,000 miles.  But the engine that produced those numbers was a Porsche 911 that had excellent wear trends (see Figure 5). This oil is specifically formulated with lower calcium and higher moly to combat low speed pre-ignition and reduce abnormal combustion and wear. While we can't say whether this oil really does reduce LSPI, it seems to work as well as others do and we see no problems with the novel additive blend.

**Figure 5**

| ELEMENTS IN PARTS PER MILLION | | UNIT / LOCATION AVERAGES | | | | | | UNIVERSAL AVERAGES |
|---|---|---|---|---|---|---|---|---|
| MI/HR on Oil | 4,955 | | 5,781 | 5,161 | 6,640 | 6,000 | 6,500 | |
| MI/HR on Unit | 87,890 | | 82,935 | 77,154 | | 65,353 | 59,000 | |
| Sample Date | 12/28/2021 | | 11/6/2021 | 9/11/2021 | 7/13/2021 | 4/24/2021 | 2/5/2021 | |
| Make Up Oil Added | 0 qts | | 0 qts | 0 qts | 0 qts | 0 qts | 0 qts | |
| ALUMINUM | 4 | 4 | 2 | 3 | 5 | 3 | 4 | 4 |
| CHROMIUM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| IRON | 2 | 3 | 2 | 3 | 3 | 3 | 3 | 9 |
| COPPER | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 7 |
| LEAD | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| TIN | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| MOLYBDENUM | 248 | 256 | 272 | 224 | 245 | 280 | 257 | 81 |
| NICKEL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MANGANESE | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| SILVER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TITANIUM | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| POTASSIUM | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| BORON | 7 | 10 | 10 | 13 | 9 | 9 | 6 | 123 |
| SILICON | 4 | 3 | 3 | 3 | 4 | 3 | 2 | 7 |
| SODIUM | 2 | 5 | 4 | 3 | 5 | 4 | 4 | 9 |
| CALCIUM | 1162 | 1257 | 1354 | 1320 | 1128 | 1353 | 1191 | 2554 |
| MAGNESIUM | 7 | 10 | 11 | 27 | 5 | 11 | 5 | 95 |
| PHOSPHORUS | 813 | 857 | 923 | 803 | 791 | 958 | 827 | 903 |
| ZINC | 917 | 963 | 1027 | 900 | 885 | 1093 | 942 | 1023 |
| BARIUM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Wear trends for the five samples in Figure 4 (and one additional sample, not included there because TBN and TAN were not requested). Wear is consistent over time and compares favorably to averages, despite the low TBNs.**

### Chevron Delo

Chevron Delo 600 ADF is another oil that breaks the traditional additive mold, and it's fairly new to the market. The 15W/40 and 10W/30 formulations hold the 2nd and 3rd place spots for lowest starting TBN in Figure 1, which is surprising, since they're formulated for diesel engines - diesel oil tends to have more dispersant additive than oil designed for gasoline engines (most of the oils in Figure 1 are gas engine oil). Figure 6 shows the Delo 600's TBN reaching our "1.0 limit" starting around 9,090 miles. Chevron also had particular goals in mind for this oil – it uses "ultra-low ash additive technology" and is meant for engines with SCR and EGR emissions systems that need to meet state emissions standards.

**Figure 6**

| Chevron Delo 600 ADF 10W/30 | | | |
|---|---|---|---|
| **Miles on Oil** | **Calcium (ppm)** | **Magnesium (ppm)** | **TBN** |
| 4,306 | 509 | 199 | 2.4 |
| 9,090 | 613 | 155 | 1 |
| 10,000 | 478 | 109 | 1 |
| 14,200 | 511 | 195 | 1.2 |
| 15,619 | 722 | 84 | 0.9 |

**This oil had an average starting TBN of 4.7. The chart shows the low levels of calcium and magnesium that resulted in fairly low TBNs after typical oil runs for diesel engines.**

Since additive packages tend to be proprietary and Chevron never did respond to my email, we can only speculate as to how the elements we find in our testing relate these constraints. Maybe such low calcium and magnesium reflect a reduction in calcium sulfonate and magnesium sulfonate (the compounds that register as calcium and magnesium). While these compounds work well as detergent/dispersants and their alkalinity helps buffer acids, their presence would also boost the sulfur content – a potential problem for emissions goals. But the additive package is unique in other ways too.

Figure 7 is a virgin sample of Chevron Delo 600 ADF 15W/40. Note the high levels of molybdenum, potassium, and boron, and low levels of phosphorus and zinc, in contrast to the more typical additive package shown in the universal averages column. Moly seems to be providing most of the anti-wear properties that phosphorus and zinc ordinarily would. Potassium is noteworthy and caught our attention right away, since it's one of two potential markers for anti-freeze.

**Figure 7: Chevron Delo 600**

| | | UNIVERSAL AVERAGES |
|---|---|---|
| MI/HR on Oil | | |
| MI/HR on Unit | | |
| Sample Date | 2/24/2021 | |
| Make Up Oil Added | | |
| ALUMINUM | 1 | 1 |
| CHROMIUM | 0 | 0 |
| IRON | 1 | 1 |
| COPPER | 0 | 0 |
| LEAD | 0 | 0 |
| TIN | 0 | 0 |
| MOLYBDENUM | 1113 | 35 |
| NICKEL | 0 | 0 |
| MANGANESE | 0 | 0 |
| SILVER | 0 | 0 |
| TITANIUM | 0 | 2 |
| POTASSIUM | 408 | 1 |
| BORON | 730 | 81 |
| SILICON | 14 | 5 |
| SODIUM | 8 | 5 |
| CALCIUM | 424 | 1960 |
| MAGNESIUM | 85 | 368 |
| PHOSPHORUS | 8 | 985 |
| ZINC | 4 | 1138 |
| BARIUM | 0 | 0 |

| PROPERTIES | | Values Should Be* |
|---|---|---|
| SUS Viscosity @ 210°F | 74.9 | 69-79 |
| cSt Viscosity @ 100°C | 14.24 | 12.7-15.5 |
| Flashpoint in °F | 475 | >415 |
| Fuel % | - | <2.0 |
| Antifreeze % | - | 0.0 |
| Water % | 0.0 | 0.0 |
| Insolubles % | TR | <0.6 |
| TBN | 4.6 | >1.0 |
| TAN | | |

We're not certain what additive compound registers as potassium in this oil, but because potassium is alkaline, perhaps it performs some of the same functions calcium sulfonate and magnesium sulfonate do in more traditional additive packages.

**Figure 8: Valvoline 10W/30**

| | | UNIVERSAL AVERAGES |
|---|---|---|
| MI/HR on Oil | | |
| MI/HR on Unit | | |
| Sample Date | 2/17/2020 | |
| Make Up Oil Added | | |
| ALUMINUM | **33** | 3 |
| CHROMIUM | 2 | 1 |
| IRON | **77** | 13 |
| COPPER | 27 | 15 |
| LEAD | **39** | 6 |
| TIN | 3 | 1 |
| MOLYBDENUM | 6 | 69 |
| NICKEL | 1 | 0 |
| MANGANESE | 2 | 4 |
| SILVER | 0 | 0 |
| TITANIUM | 1 | 1 |
| POTASSIUM | **321** | 5 |
| BORON | 0 | 48 |
| SILICON | **24** | 13 |
| SODIUM | **3551** | 50 |
| CALCIUM | 1125 | 1934 |
| MAGNESIUM | 232 | 182 |
| PHOSPHORUS | 577 | 698 |
| ZINC | 708 | 837 |
| BARIUM | 0 | 0 |

| PROPERTIES | | Values Should Be* |
|---|---|---|
| SUS Viscosity @ 210°F | **95.1** | 58-65 |
| cSt Viscosity @ 100°C | **19.20** | 9.7-11.9 |
| Flashpoint in °F | 400 | >385 |
| Fuel % | <0.5 | <2.0 |
| Antifreeze % | **>5.0** | 0.0 |
| Water % | 0.0 | 0.0 |
| Insolubles % | **2.0** | <0.6 |
| TBN | 10.0 | >1.0 |
| TAN | | |

**This Valvoline 10W/30 has an average TBN of 7.2 out of the bottle. The oil was used in an engine with a major coolant problem, seen in the very high potassium and sodium, thick viscosity, high insolubles, and high wear levels. The TBN is very high at 10.0, but that doesn't mean the oil is ready for more use; rather, coolant is skewing the reading.**

Interestingly, even when potassium (and sodium, which is also alkaline) is truly from coolant contamination, it can skew the TBN. Figure 8 is an example of an engine suffering from coolant contamination, which is taking a heavy toll on the bearings and physical properties of the oil. An oil change (and probably major repairs) are needed, yet out of context, the 10.0 TBN looks great. But that doesn't mean the oil is ready for more use; rather, coolant is skewing the reading. That's why we never judge a used oil sample by a single data point!

As for Chevron 600 ADF? The jury is still out on what kind of results this oil will produce over time, since most of the samples we've tested so far are from young engines going through wear-in. It will be interesting to see how these engines mature, but we suspect in the end, this unique oil will perform as well as any other in the most crucial ways: lubricating, cleaning, and cooling engine parts. We'll just have to give it some special treatment on our end, to avoid false positives for anti-freeze, and avoid putting too much stock in "low" TBNs.

We hope you're walking away armed with knowledge and a pretty good idea whether adding a TBN or TAN is going to serve your particular aims. If you're wanting to extend your oil changes, go for it! If you just want a basic assessment of how your engine and oil are holding up, not to worry! We can provide that with the core tests in the standard analysis. Stay tuned for Part 2 next newsletter, where we venture into the lab, and learn about the effects of heat on TBNs and TANs.

# Report of the Month

**Check out the oil from a 1936 Cat bulldozer!**

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

| UNIT | | | |
|---|---|---|---|
| MAKE/MODEL: | Cat D4 | OIL TYPE & GRADE: | Diesel Engine Oil |
| FUEL TYPE: | Diesel | OIL USE INTERVAL: | Hours |
| ADDITIONAL INFO: | 1936 Cat RD-4 Bulldozer/Crawler | | |

**COMMENTS**

Holy cow, that YouTube video was wild! The engine in this rescued Cat doesn't look great - as expected for oil that's been sitting the better part of 50 years. We put up averages for Cat's D4 engine though that's not likely an exact match for this engine type. This is a lot of metal in comparison, but what would be really interesting is the next sample - does wear improve? Aluminum (pistons) isn't bad, but iron (cylinders/shafts), copper (brass/bronze parts), lead (bearings) are high. Coolant is present (sodium/potassium) and 3.5% fuel. The TBN is low at 1.6.

| | | UNIT / LOCATION AVERAGES | UNIVERSAL AVERAGES |
|---|---|---|---|
| MI/HR on Oil | | | |
| MI/HR on Unit | 8,100 | | |
| Sample Date | 4/10/2022 | | |
| Make Up Oil Added | | | |
| **ELEMENTS IN PARTS PER MILLION** | | | |
| ALUMINUM | **9** | | 5 |
| CHROMIUM | 1 | | 2 |
| IRON | **729** | | 34 |
| COPPER | **254** | | 13 |
| LEAD | **214** | | 62 |
| TIN | **4** | | 1 |
| MOLYBDENUM | 1 | | 29 |
| NICKEL | 3 | | 0 |
| MANGANESE | 15 | | 0 |
| SILVER | 0 | | 0 |
| TITANIUM | 0 | | 1 |
| POTASSIUM | **19** | | 2 |
| BORON | 7 | | 72 |
| SILICON | 11 | | 12 |
| SODIUM | **25** | | 11 |
| CALCIUM | 2509 | | 2063 |
| MAGNESIUM | 13 | | 326 |
| PHOSPHORUS | 447 | | 1030 |
| ZINC | 384 | | 1188 |
| BARIUM | 496 | | 1 |

| PROPERTIES | | Values Should Be* |
|---|---|---|
| SUS Viscosity @ 210°F | 63.6 | |
| cSt Viscosity @ 100°C | 11.22 | |
| Flashpoint in °F | **380** | >415 |
| Fuel % | **3.5** | <2.0 |
| Antifreeze % | **?** | 0.0 |
| Water % | **POS** | 0.0 |
| Insolubles % | 0.2 | <0.6 |
| TBN | 1.6 | >1.0 |
| TAN | | |
| ISO Code | | |

We left the comments on this sample since they're pretty self-explanatory. The owner told us, "This oil came from a long-neglected 1936 Caterpillar RD-4 bulldozer/crawler. This machine was rescued from its 40-50 year resting place in a hedgerow in South Dakota and is undergoing a complete restoration. To the best of our knowledge, the machine was used as an agricultural crawler from 1937-1970 when it was parked, and has been sitting ever since. The owner and I thought it would be interesting to get samples on the lubricants in the tractor at the time of rescue." Note that the additive package is quite different from what you find in engine oil nowadays. This video shows the pan coming off and gives us a good look inside the engine. The whole thing is interesting, but to see the pan come off forward to about 12 min: https://youtu.be/R-bf0W6M5RU

# Report of the Month

**You don't see gear oil from a 1936 Cat bulldozer very often!**

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

| UNIT | | | |
|---|---|---|---|
| MAKE/MODEL: | Differential | OIL TYPE & GRADE: | Gear Lube |
| FUEL TYPE: | | OIL USE INTERVAL: | |
| ADDITIONAL INFO: | 1936 Cat RD-4 Bulldozer/Crawler, Trans/Rear End | | |

**COMMENTS**

Wow, this rear end lube looks as gnarly in analysis as it does in Kyle's video. Insolubles made up 10% of the sample so this oil was heavily oxidized. Enough water was present to cause the sample to boil, preventing us from obtaining the flashpoint. Contamination certainly played a role in the oxidization of the oil too. Silicon may be from dirt/debris if not from a harmless source like lube or sealer. On the wear front, we found a lot of excess metal. Steel wear (iron/nickel) is the most notable. Best of luck restoring this old Cat, guys! Pet the shop dogs for me! -Miranda

**ELEMENTS IN PARTS PER MILLION**

| | | UNIT / LOCATION AVERAGES | | | | | | UNIVERSAL AVERAGES |
|---|---|---|---|---|---|---|---|---|
| MI/HR on Oil | | | | | | | | |
| MI/HR on Unit | | | | | | | | |
| Sample Date | 4/9/2022 | | | | | | | |
| Make Up Oil Added | | | | | | | | |
| | | | | | | | | |
| ALUMINUM | **18** | | | | | | | 5 |
| CHROMIUM | 2 | | | | | | | 2 |
| IRON | **1020** | | | | | | | 260 |
| COPPER | 3 | | | | | | | 12 |
| LEAD | **13** | | | | | | | 4 |
| TIN | 1 | | | | | | | 1 |
| MOLYBDENUM | 1 | | | | | | | 7 |
| NICKEL | **29** | | | | | | | 2 |
| MANGANESE | 7 | | | | | | | 7 |
| SILVER | 0 | | | | | | | 0 |
| TITANIUM | 2 | | | | | | | 0 |
| POTASSIUM | 7 | | | | | | | 30 |
| BORON | 10 | | | | | | | 146 |
| SILICON | **144** | | | | | | | 46 |
| SODIUM | 35 | | | | | | | 12 |
| CALCIUM | 24 | | | | | | | 620 |
| MAGNESIUM | 6 | | | | | | | 47 |
| PHOSPHORUS | 179 | | | | | | | 1128 |
| ZINC | 83 | | | | | | | 307 |
| BARIUM | 12 | | | | | | | 13 |

**PROPERTIES**

| | | Va<br>Sho | | | | | |
|---|---|---|---|---|---|---|---|
| SUS Viscosity @ 210°F | 108.0 | | | | | | |
| cSt Viscosity @ 100°C | 22.22 | | | | | | |
| Flashpoint in °F | BOIL | | | | | | |
| Fuel % | - | | | | | | |
| Antifreeze % | - | | | | | | |
| Water % | **POS** | 0.0 | | | | | |
| Insolubles % | **10.0** | <0.6 | | | | | |
| TBN | | | | | | | |
| TAN | | | | | | | |
| ISO Code | | | | | | | |

*** THIS COLUMN APPLIES ONLY TO THE CURRENT SAMPLE**

Kyle Christ, the owner, posted a series of videos on the process of rehabbing this bulldozer. This oil was the consistency of tar! You can see it at about the 6:10-minute mark here: youtu.be/4o623Xcx9PM

BLACKSTONE LABORATORIES

# Report of the Month

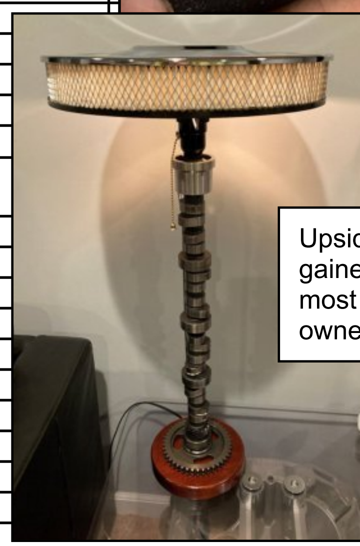
**This ‘65 Mustang’s got trouble.**
**Can you tell what’s wrong?**

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

| UNIT | | | |
|---|---|---|---|
| MAKE/MODEL: | Ford 5.0L 302 CID V-8 | OIL TYPE & GRADE: | Motorcraft 10W/30 |
| FUEL TYPE: | Gasoline (Unleaded) | OIL USE INTERVAL: | 540 Miles |
| ADDITIONAL INFO: | | | |

| | | UNIT / LOCATION AVERAGES | | UNIVERSAL AVERAGES |
|---|---|---|---|---|
| MI/HR on Oil | 540 | | 334 | |
| MI/HR on Unit | 14,202 | | 13,662 | |
| Sample Date | 6/12/2022 | | 7/21/2021 | |
| Make Up Oil Added | 0 qts | | 0 qts | |
| **ELEMENTS IN PARTS PER MILLION** | | | | |
| ALUMINUM | **9** | 5 | 1 | 4 |
| CHROMIUM | **6** | 4 | 1 | 1 |
| IRON | **144** | 77 | 9 | 21 |
| COPPER | **20** | 11 | 1 | 6 |
| LEAD | **30** | 17 | 3 | 10 |
| TIN | 3 | 2 | 0 | 1 |
| MOLYBDENUM | 9 | 25 | 40 | 66 |
| NICKEL | 1 | 1 | 0 | 1 |
| MANGANESE | 2 | 1 | 0 | 2 |
| SILVER | 0 | 0 | 0 | 0 |
| TITANIUM | 0 | 1 | 1 | 1 |
| POTASSIUM | 13 | 7 | 1 | 2 |
| BORON | 79 | 80 | 81 | 49 |
| SILICON | **65** | 38 | 10 | 11 |
| SODIUM | 20 | 15 | 10 | 45 |
| CALCIUM | 1369 | 1501 | 1633 | 1708 |
| MAGNESIUM | 696 | 598 | 499 | 283 |
| PHOSPHORUS | 1005 | 887 | 768 | 772 |
| ZINC | 1103 | 987 | 871 | 908 |
| BARIUM | 0 | 0 | 0 | 0 |

| PROPERTIES | | Values Should Be* | |
|---|---|---|---|
| SUS Viscosity @ 210°F | 63.0 | 59-69 | 68.5 |
| cSt Viscosity @ 100°C | 11.07 | 9.9-12.9 | 12.55 |
| Flashpoint in °F | 420 | >385 | 435 |
| Fuel % | <0.5 | <2.0 | <0.5 |
| Antifreeze % | 0.0 | 0 | 0.0 |
| Water % | 0.0 | 0.0 | 0.0 |
| Insolubles % | 0.4 | <0.6 | 0.3 |
| TBN | | | |
| TAN | | | |
| ISO Code | | | |



Upside: The wiped cam gained a new life as the most expenisive lamp the owner ever hopes to own!

The owner reported back: “You nailed it when you suggested wear at a steel-on-steel interface like cams/lifters. I tore the engine down to find four hydraulic roller lifters failed, with damage to cam lobes. One lifter dogbone was found broken on cylinder #1’s intake lifter, likely due to the lifter dropping lower into the block. The only other damage found was a chunk of bearing material missing from the #3 crank bearing. The big question is, why did the roller lifters stop rolling? I am going to take these bits to a local engine builder for further inspection and analysis.

Later, he reported: The engine builder inspected the valvetrain bits and believes the failure was due to an incorrectly set-up valve train. We found ALL of the pushrods were bent; some only very slightly. It is likely the pushrods were the incorrect length, or the rocker arm height was set incorrectly.

BLACKSTONE LABORATORIES

# Report of the Month

**A BMW with lead…you might think you know where it's from, but you don't.**

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

| UNIT | | |
|---|---|---|
| MAKE/MODEL: BMW 2.0L (N47D20) I-4 | OIL TYPE & GRADE: Mobil 1 ESP 5W/30 | |
| FUEL TYPE: Diesel | OIL USE INTERVAL: 8,951 Miles | |
| ADDITIONAL INFO: Wagon, Stage 2 tune, Some track use | | |

| ELEMENTS IN PARTS PER MILLION | | UNIT / LOCATION AVERAGES | | | | | | UNIVERSAL AVERAGES |
|---|---|---|---|---|---|---|---|---|
| MI/HR on Oil | 8,951 | | 8,951 | 1,986 | 9,206 | 8,882 | 8,385 | |
| MI/HR on Unit | 75,496 | | 75,496 | 68,531 | 66,545 | 57,362 | 48,480 | |
| Sample Date | 10/2/2021 | | 10/2/2021 | 12/13/2020 | 9/12/2020 | 12/14/2019 | 5/4/2019 | |
| Make Up Oil Added | 0 qts | | 0 qts | | 0 qts | 0 qts | 0 qts | |
| ALUMINUM | 6 | 7 | 6 | 6 | 6 | 6 | 8 | 8 |
| CHROMIUM | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| IRON | 29 | 40 | 30 | **33** | 35 | 45 | 54 | 40 |
| COPPER | 4 | 5 | 4 | 3 | 4 | 5 | 5 | 5 |
| LEAD | **49** | 22 | **50** | **9** | **60** | 3 | 2 | 0 |
| TIN | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| MOLYBDENUM | 71 | 54 | 72 | 94 | 84 | 79 | 64 | 47 |
| NICKEL | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 |
| MANGANESE | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| SILVER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TITANIUM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| POTASSIUM | 4 | 5 | 4 | 0 | 3 | 3 | 7 | 6 |
| BORON | 86 | 108 | 84 | 154 | 94 | 110 | 86 | 51 |
| SILICON | 7 | 5 | 7 | 6 | 7 | 4 | 5 | 5 |
| SODIUM | **16** | **11** | **17** | 8 | 9 | 5 | 5 | 16 |
| CALCIUM | 931 | 1236 | 931 | 1205 | 1075 | 1048 | 1065 | 1707 |
| MAGNESIUM | 8 | 12 | 7 | 11 | 7 | 8 | 9 | 49 |
| PHOSPHORUS | 606 | 703 | 615 | 838 | 716 | 693 | 655 | 709 |
| ZINC | 684 | 787 | 708 | 933 | 794 | 772 | 738 | 804 |
| BARIUM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| PROPERTIES | | Values Should Be* | | | | | |
|---|---|---|---|---|---|---|---|
| SUS Viscosity @ 210°F | 60.0 | 57-65 | 58.7 | 63.2 | 63.9 | 61.9 | 60.0 |
| cSt Viscosity @ 100°C | 10.22 | 9.4-11.9 | 9.85 | 11.11 | 11.30 | 10.76 | 10.23 |
| Flashpoint in °F | **410** | >410 | 460 | 450 | 445 | 430 | **405** |
| Fuel % | TR | <2.0 | <0.5 | <0.5 | <0.5 | <0.5 | 0.5 |
| Antifreeze % | **?** | 0.0 | **?** | 0.0 | 0.0 | 0.0 | 0.0 |
| Water % | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Insolubles % | 0.2 | <0.6 | 0.2 | 0.1 | 0.2 | 0.2 | 0.3 |
| TBN | | | 2.0 | | | | |
| TAN | | | | | | | |
| ISO Code | | | | | | | |

* THIS COLUMN APPLIES ONLY TO THE CURRENT SAMPLE

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Okay, so finding out the answer to this one is a bit of an investment. The owner made a video to report his findings, and we aren't going to give it away here. The video is long, but it's worth it. Not to go all buzzfeed.com on you, but you'll have to trust us when we say that this is something we've never come across in 35 years of oil analysis reports. (Forward to the end for the big reveal, but you'll be missing the journey he went through to get there!) https://youtu.be/ay59KjlQ8Bg