GET THE PICTURE

What are your Oil Analysis reports really saying?

TESTOIL

REMARKABLE IN EVERY WAY

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ABOUT TESTOIL

TestOil has been in the oil analysis business since 1988.

We started out providing Analytical Ferrography services to power customers and in the early 90's expanded our services. We have focused exclusively on assisting large industrial facilities reduce their maintenance costs and avoid unexpected downtime through oil analysis program implementation.

Our customers rely on us to be their technical experts when it comes to diagnosing oil related issues in equipment such as turbines, hydraulics, gearboxes, pumps, compressors, and diesel generators.

Our state-of-the-art-laboratory has the capacity to process and analyze 2000 samples per day. We employ lean process management to drive excellence and ensure that we maintain our guarantee of providing same day turn around on all routine testing.

“Management, operations, engineering, and financial personnel should adopt the concept that: Maintenance Doesn’t Cost, It Pays.”

- AISE Steel Technology Magazine –

SECTION 1

INTRODUCTION TO REPORT ANALYSIS

The ability to interpret lubrication analysis results is vital to making significant maintenance decisions. It is important to review the whole report, from top to bottom, to determine what action should be taken, if any. Refer to your most recent report as you review these next few steps.

Proper interpretation begins with the top section of your report. Be sure to confirm that the correct lube type, machine MFG, and machine type is listed. Next, review the upper right-hand corner where it states the machine and lubricant condition. The ratings you should see are either: Normal, Marginal or Critical. The top section also includes comments from the analyst who reviewed the results. These comments help gauge the criticality of the problem and provide a suggested course of action.

The body of the report contains the data from the analysis of the sample and is organized by test. The left-hand column contains reference lubricant data if a sample of new lubricant was provided. The column to the right of the new lubricant column, is the most current sample followed by historical sample data.

SECTION 2

TRENDING VERSUS ALARM LIMITS

At TestOil, we prefer to employ trending techniques when evaluating the sample data versus relying on static alarm limits. In the following text, you will learn about the benefits of our linear-regression method.

Many static alarm limits are based on statistical analysis of a common grouping of machines under similar operating conditions. As long as the machine is operating under similar conditions (load, speed, temperature, ambient environment) for a similar sampling and drain interval, the limits may have merit.

Common Alarming Issues

Sampling Interval

- Most limits are set for an end-of-service (scheduled drain) interval or as a condemning limit, but samples taken early in the expected life of the lubricant usually have significantly lower results than these limits, therefore the alarm limit is perceived as being set too high.

Eventuality Factor

- Given a long enough service interval on the lubricant, the alarm should eventually be exceeded. Yet, for many parameters, this does not necessarily signify a problem.
- Typically seen when desiring condition-based lubricant drains, or simply extending drain intervals.

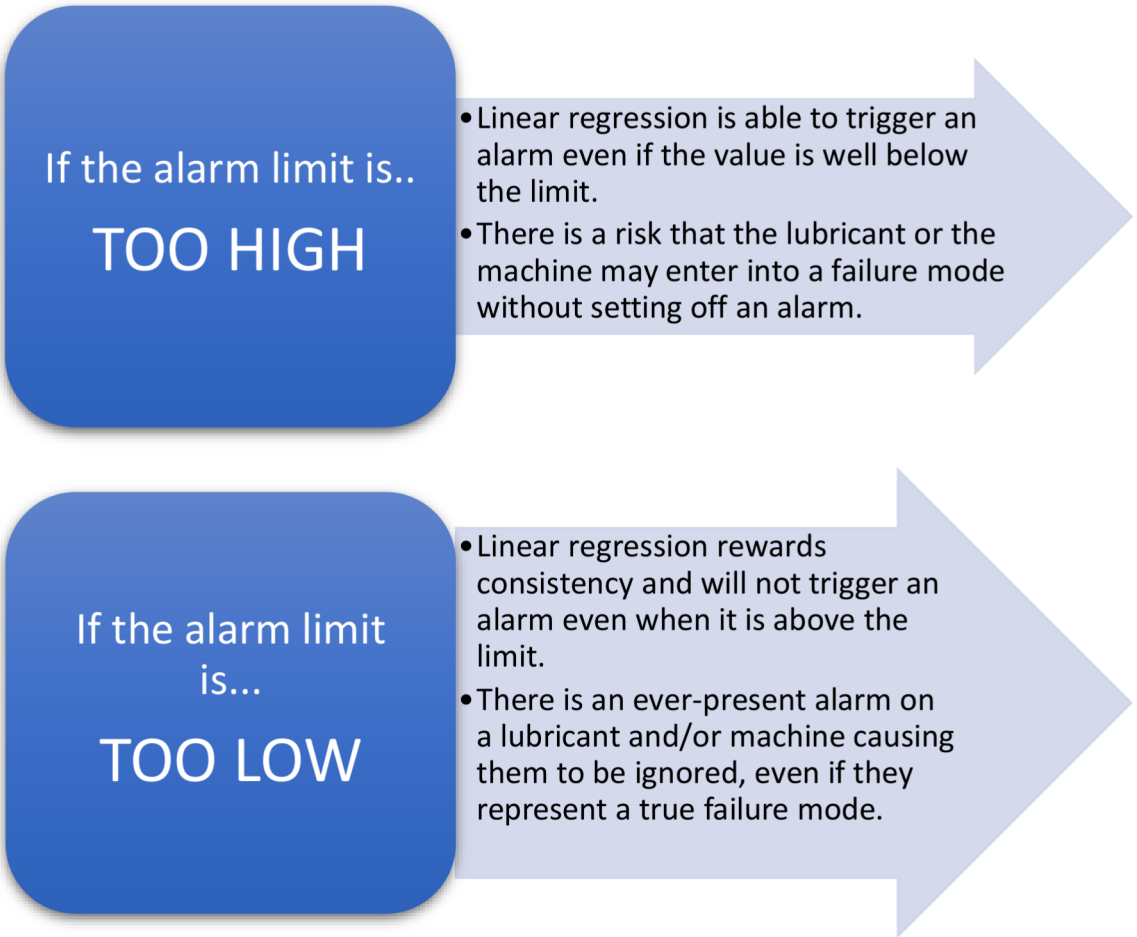
Over-Reliance

- Shifts the focus from detecting an underlying trend that may serve to truly predict a failure before it occurs, to whether or not the lubricant or machine is simply in alarm.

The Solution

Using linear regression as the predominant method for evaluating the data eliminates such problems. Linear regression begins on the fourth sample from the same machine, as a minimum of data is required for the calculations to be practical. Based on historical data, the software predicts a range for the latest result; data within this range is considered normal for that individual machine, therefore alarms may appear at differing values for similar machines.

Static alarm limits can still be applied as a secondary evaluation, which may be necessary if certain targets must remain for warranty/service agreements, regulatory compliance, or until enough historical data has been obtained.



The eventuality factor is also dealt with, as steady changes are expected with continued service on the lubricant. Only cases where the rate changes significantly will be alarmed, while normal trends will not be alarmed even when the static limit has been exceeded.

Underlying trends are also identified, providing more feedback to the end-user, even in situations where the lubricant or machine is constantly going in and out of alarm (often due to fluid changes).

Benefits of Linear Regression

Identification of Abnormalities Below Alarm Limit & Historical Results

- Typically ignored under the presumption that previous results were worse and no failure occurred

Identification of Abnormalities Under Guise of Significant Improvement

- Given a long enough service interval on the lubricant, the alarm should eventually be exceeded, yet, for many parameters, this does not necessarily signify a problem
- Typically seen when desiring condition-based lubricant drains, or simply extending drain intervals

Depth of Interpretation

- Allows for more relevant alarms that account for variations in operating conditions
- Provides the ability to predict and anticipate a future sample exceeding an alarm, instead of waiting for the alarm and having to react with greater immediacy

SECTION 3

ELEMENTAL SPECTROSCOPY

Testing Process

A diluted oil sample is atomized by inert gas (argon) to form an aerosol. This is magnetically induced to form a plasma at a 9000° C. The high temperature causes metal ions to take on energy and release new energy in the form of photons. A spectrum with different wavelengths is created for each element. The instrument quantifies the amount of energy emitted and determines the concentration in parts per million (ppm) of 20 elements present in the sample. TestOil reports a value below the detection limit as a dash (-).

Analysis of Results

What is important to note, is that this test measures soluble and suspended particulates in the 0-5 µm range, and is essentially blind to particles larger than ~10 µm, so gross contamination and severe wear may go undetected. Gross contamination can be seen with particle count testing and severe wear can be seen with Ferrous Wear Concentration and Analytical Ferrography.

The results are separated into three categories:

Wear Metals

- Trended for significant increases, rather than compared against an arbitrary limit that does not take into account variables such as sampling intervals, sump size or operating conditions.
- Potential Wear Metal Sources:

	Gearbox	Turbine	Hydraulic
Aluminum	Airborne Dirt Bushings Grease Contamination Oil Pump Thrust Washers	Airborne Dirt Alumina Media Contamination Bearings Oil Cooler	Airborne Dirt Cylinder Gland Pump Housing
Chromium	Roller/Taper Bearings Shaft Coating	Bearings Shaft Coating	Rods Roller/Taper Bearings Spools
Copper	Bushings Oil Cooler Thrust Washers	Bearings Oil Cooler	Bushings Cylinder Glands Guides Oil Cooler Pump Pistons Pump Thrust Plates
Iron	Bearings Gears Pinions Shaft Thrust Washers	Bearings Reduction Gear	Bearings Cylinder Bores Gears Pistons Pump Housing Pump Vanes Rods Valves
Lead	Bearings Thrust Washers	Shafts	Bearings
Nickel	Bearings Gear Plating	Bearings Gear Plating	Pumps
Silver	Bearing Cage Solder from Coolers	Roller Bearings Thrust Bearings	Bearing Cage Solder from Cooers
Tin	Bushings	Bearings Solder from Coolers	Bearings Polyol Ester Catalyst Pump Thrust Plates Solder from Coolers

	Compressor	Engine	Transmission
Aluminum	Airborne Dirt Bearings Block (Corrosion) Cylinder Guides Oil Cooler Oil Pump Pistons Rotors Thrust Washers Wear Plates	Airborne Dirt Bearings Block (Corrosion) Blowers Bushings Oil Cooler Oil Pump Pistons Thrust Bearings	Airborne Dirt Bushings Clutch/Friction Disc Pumps Thrust Washers
Chromium	Cylinder Guides Rings Roller/Taper Bearings Thrust Washers	Bearings Exhaust Valves Liners Rings Roller/Taper Bearings	Roller/Taper Bearings
Copper	Bearings (Recips) Rings Roller/Taper Bearings Thrust Washers Wear Plates	Bearings (Near Failure) Cam Bushings Connecting Rod Bearings Governor Oil Additive Oil Cooler Oil Pump Thrust Washers Valvetrain Bushings Wrist Pin Bushings	Bearings Bushings Clutch/Friction Disc Oil Cooler Steering Discs Thrust Washers
Iron	Bearings Block Camshaft Cylinder Lobes Oil Pump Rings Screws Shafts	Block Camshaft Crankshaft Cylinder Gears Liners Oil Pump Rings (Cast) Valvetrain Wrist Pins	Bearings Brake Bands Clutch/Friction Disc Gears Housings Power Take-Off (PTO) Pumps Shift Spools
Lead	Bearings	Bearings Thrust Washers	Bearings Clutch/Friction Disc
Nickel	Bearings	Bearings	Bearings
Silver	Bearings	Bearing Cage Solder from Coolers Wrist Pin Bushings	Bearing Cage Solder from Coolers
Tin	Bearings Bushings Piston Overlay	Bearings Bushings Con-rod Bearings Governor Piston Overlay Solder from Coolers Thrust Washers	Bearings Clutch Solder from Coolers Thrust Washers

Additives

- Compared to values in the new lubricant or reference column.
- Deviations of up to 25% are expected, based on batch-to-batch variability and the limitations of the test.
- The most common reason for a change in value greater than 25% is mixing with another product.
- Potential Additive Sources:

	Source
Barium	Rust Inhibitor Detergent Dispersant Additive
Boron	Anti-wear additive
Calcium	Detergent Dispersant Additive Corrosion Inhibitor
Copper	Anti-wear Additive
Magnesium	Detergent Dispersant Additive Corrosion Inhibitor
Molybdenum	Friction Modifier
Phosphorus	EP Additive Anti-wear Additive Corrosion Inhibitor
Silicon	Defoamant Additive
Sodium	Detergent Dispersant Additive Corrosion Inhibitor
Zinc	Anti-wear Antioxidant Additive Rust Inhibitor EP Additive

Contaiminants

- Trended similarly to wear metals.
- Increases in contaminants will frequently correlate to increases in wear metals.
- Potential Contaminant Sources:

	Source
Aluminum	Airborne Dirt (correlation ~3:1 Silicon/Aluminum) Grease Thickener
Barium	Grease Additive
Boron	Coolant Additive Detergent Additive Oil Drum Cleansing Agent
Calcium	Fuller's Earth Dust Gypsum Hard Water
Lithium	Grease Thickener
Magnesium	Fuller's Earth Hard Water
Potassium	Coolant Additive Fly Ash
Silicon	Airborne Dust or Dirt (as above) Defoamant Additive Sealant
Sodium	Coolant Additive Detergent Dispersant Additive Airborne Salt
Titanium	Machinist Layout Paint Aerosol Paint
Vanadium	Residual Fuel Contamination (Bunker C)

SECTION 4

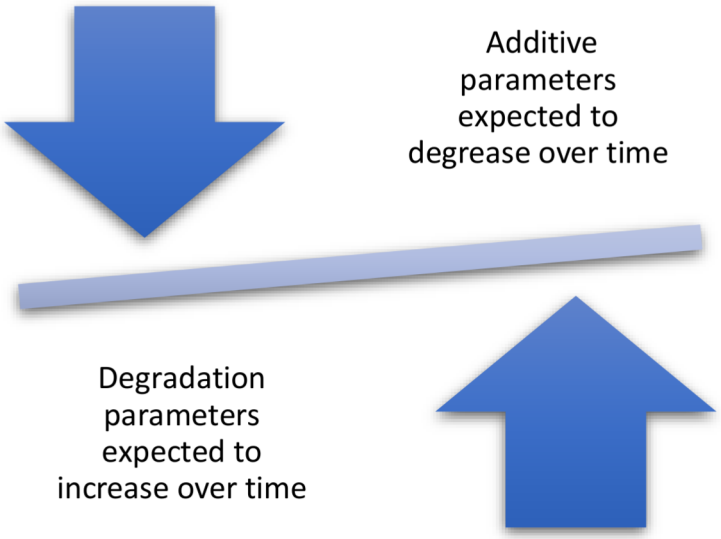
FOURIER TRANSFORM INFRARED (FT-IR)

Testing Process

Infrared radiation is passed through a sample. Different molecular structures within the sample will absorb the radiation at specific wave numbers and a spectrum is generated. By comparing the amount of energy absorbed or transmitted at specific locations on the spectrum, various molecular features can be quantified.

Analysis of Results

These results reflect a molecular analysis of lubricant where infrared light absorption is used for assessing additive depletion, contaminant buildup (soot and incorrect oils) and base stock degradation (oxidation, nitration and sulfation)



Any sudden change in multiple parameters, particularly in the opposite to expected direction, likely indicate a top-up with a different product.

SECTION 5

PARTICLE COUNT

Testing Process – Optical Particle Counting

A known volume of oil (5ml) is injected through a sampling cell; on one side of the cell is a beam of laser light and on the other side is a detector. As particles pass through the cell, they block the beam and cast shadows on the detector. The drop in light intensity received by the detector is proportional to the size of particle blocking the light beam. Both the number and size of the particles are measured.

Testing Process – Pore Blockage

Oil is passed through a screen of known mesh size (5, 10, or 15 microns) and the rate of flow decay is determined. The instrument then calculates the distribution of the other predetermined size ranges by extrapolation.

Analysis of Results

The broad approach is to first look at the ISO cleanliness code, which represents the cumulative number of particles greater than 4, 6 and 14 microns in the fluid.

Changes to any one code compared to the previous result is mostly considered normal. Only when all three codes increase should the result be considered noteworthy. With optical particle counting, the increase may be due to water or soft contaminants, not just hard particulate.

Use the following table as rough guide, to provide you with the upper thresholds for when a particle count will receive an alarm, if one or more codes exceeds them.

Alarm Parameters	
Hydraulic System	19/17/16
Turbines	18/16/14
Centrifugal Compressor	19/17/15
Axial Compressor	18/16/14
Screw Compressor	18/16/14
Reciprocating Compressor	21/18/15
Gearbox	24/22/20

SECTION 6

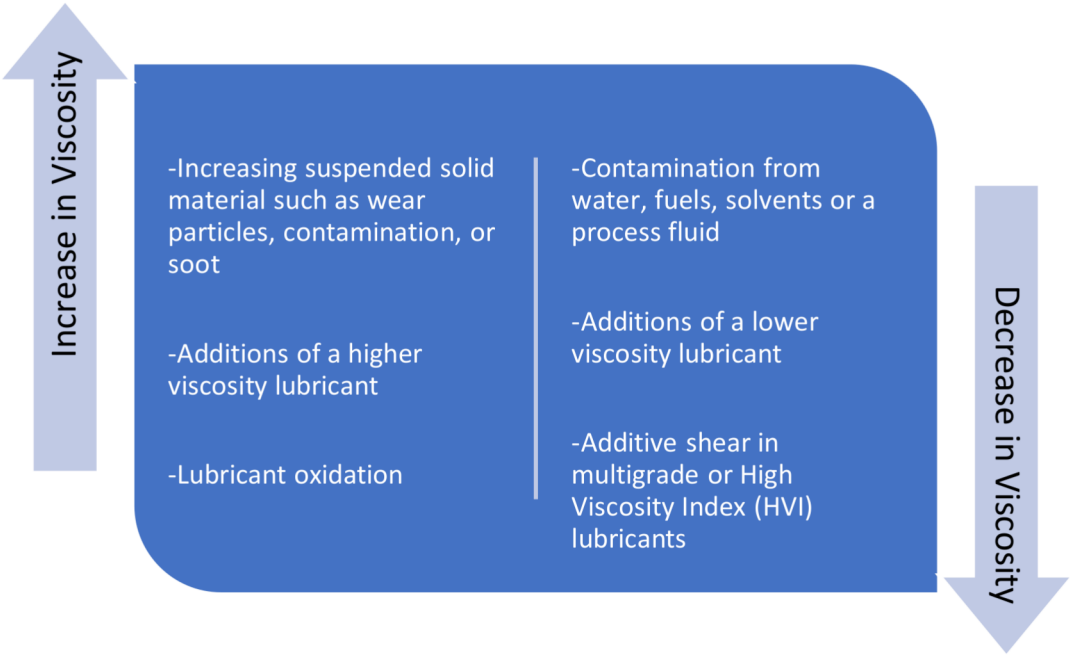
VISCOSITY

Testing Process

A sample is brought up to measurement temperature, 40°C or 100°C, and allowed to flow via gravity down the capillary glass tube where it is timed as it passes through one or more sections of the tube. The viscosity in centistokes (cSt) is the flow time (seconds) multiplied by the tube constant.

Analysis of Results

Viscosity should always remain in grade for the specified oil. Deviation outside of grade indicates significant oxidation or breakdown of the fluid, or simply mixing with another product.



The following parameters are used to confirm products are in grade:

Alarm Parameter Applicable for ISO VG, measured at 40°C

- >±10 % variance from grade = Marginal
- >±20 % variance from grade = Critical

Alarm Parameter Applicable for SAE, measured at 100°C

- 30 weight oils (0W-30, 5W-30, 10W-30, 30) are 9.3-12.5 cSt
- 40 weight oils (0W-40, 5W-40, 15W-40, 40) are 12.5-16.3 cSt

SECTION 7

ACID NUMBER

Testing Process

A weighed amount of sample in titration solvent is titrated with a potassium hydroxide solution to a definite end point.

Analysis of Results

Acid Number can be measured on any product, but it cannot necessarily be compared only to new lubricant values. Organic acids, a by-product of oil oxidation, degrade oil properties and lead to corrosion of the internal components A commonly uttered “rule-of-thumb,” is to condemn a lubricant at double its new lubricant value, however there are far too many exceptions for this to be universally applied.

Trending should remain linear with usage, and once the AN begins to increase faster, corrective actions should be taken.

Causes for Accelerated Increasing

- Water Content
- Increase in Operating Temperature

Alarm Parameter

Some OEM's specifiy limits (rare)

- Alarms are based on increases from the trend using linear regression

SECTION 8

BASE NUMBER

Testing Process

A weighed amount of sample in titration solvent is titrated with a hydrochloric acid solution to a definite end point.

Testing Process - FTIR

Infrared spectroscopy determines the BN of a sample by measuring the absorbance of the lubricant through a 100 to 200-micron transmission cell.

Analysis of Results

Base Number is a parameter only measurable on products containing a Base Number additive (mostly engine oils), but results should always be trended and compared to the new oil value.

The amount of reserve alkalinity in a lubricant is critical for certain oils. Motor oil is fortified with alkaline additives to combat acid formation during the engine combustion process. The Base Number is expected to decrease with increased service, however accelerated decreases can happen.

Causes for Accelerated Decreasing

- Blow-by
- Increase in Operating Temperature

Alarm Parameter

- 50% of new oil value = Marginal
- 25% of new oil value = Critical

SECTION 9

WATER CONTENT

Testing Process

A drop of oil is placed on a hotplate that has been heated to approximately 400°F. The sample drop bubbles, spits, crackles or pops when moisture is present. When moisture is detected, a Karl Fischer water test is performed.

Analysis of Results

Water is inherently present in all oils; therefore, a negative crackle should never be interpreted as containing absolutely no water. Positive crackle test results simply indicate a significant amount of water is present, but the detection limit varies according to the oil type.

The Karl Fischer titration provides an accurate quantification of the water content, and these results can be trended for significant increases.

Water Contamination Causes

- Fluid breakdown, such as additive precipitation and oil oxidation
- Reduced lubricating film thickness
- Corrosion
- Accelerated metal surface fatigue

Water Contamination Sources

- Heat exchanger leaks
- Seal leaks
- Condensation of humid air
- Inadequately sealed reservoir covers

Alarm Parameter

Different lubricants may have different water limits.

- 0.06% = Marginal
- 0.5% of new oil value = Critical

FUEL DILUTION

Testing Process

A sample is heated and injected into a gas chromatograph (GC). The chromatographic procedure separates components of mixed substances. The process consists of three steps: injection, separation, and detection.

A sample is injected into a flowing stream of inert gas (mobile phase) in the GC and rapidly vaporizes. The mobile phase then carries the sample onto the analytical column where the separation of the components takes place.

The detector used in this analysis is a flame ionization detector (FID). A small hydrogen flame inside the detector ionizes the components as they pass through the FID. The ions created in this process conduct electricity that is measured through a collector electrode. As the components pass through the detector, the current (mA) increases and the data is graphically represented as a scan (time vs. mV). The graph is integrated to measure the area under the curve (peak) and quantified based on a standard curve.

Analysis of Results

This test quantifies the amount of residual fuel in the sample and may not reflect total fuel contamination due to some of the fuel being driven off by heat.

Conversely, with the heat of normal operating temperatures, extensive idling, short trips, or a recent cold start may produce fuel content that can be misinterpreted as a mechanical issue.

Alarm Parameter

- 2% = Marginal
- 4%= Critical

SECTION 11

ANALYTICAL FERROGRAPHY

Testing Process

To create a ferrogram, a sample is passed over a glass slide. The slide rests on a magnetic plate that attracts ferrous wear particles in the oil onto the surface of the slide. The ferrous wear particles line up in rows with the largest particles forming rows at the top of the ferrogram. Nonferrous particles are easily detected because they deposit randomly across the slide.

Analysis of Results

The severity of wear and contaminant particles deposited onto the substrate are identified and classified according to size, shape, and metallergy. Due to the subjective nature of this test, it is best to trust the interpretation of the analyst related to action to be taken. Remember, this test is qualitative, which means it relies on the skill and knowledge of the ferrographic analyst.

Alarm Parameter

- Trace and light amounts can be considered somewhat normal for parameters like rubbing wear and dust/dirt, but indicate abnormal wear in most other parameters, even at these levels.
- Moderate and heavy levels in any parameter should always be considered abnormal and require corrective action.

SECTION 12

DEMULSIBILTY

Testing Process

Combine 40 ml of distilled water with 40 ml of lubricant in a graduated cylinder. Place in a constant temperature bath and stir for 5 minutes. The amount of lubricant separation is recorded at 5-minute intervals over a period of 30 minutes. Failure is considered an emulsion layer greater than 3 ml at the end of the test. Lubricants with a viscosity over 90 cSt are placed in a bath with an increased temperature and the test is run over a period of 60 minutes.

Analysis of Results

Demulsibility measures the ability of a lubricant to separate from water. These results are reported as a series of values, starting with the volume (in ml) of lubricant, water and emulsion, and then the time (in minutes) the sample took to reach ≤3 ml of emulsion.

A perfect result would appear as 40/40/0 (0) indicating that no emulsion formed at all; 40/40/0 (20) would still indicate no permanent emulsion, but that it took 20 minutes before the emulsion layer reduced to ≤3 ml.

Failing demulsibility results are often correlated against contamination, either with another product or with microscopic particulate.

Alarm Parameter

- Alarm Parameter >3 ml of emulsion after designated time period running demulsibility test.

SECTION 13

RPVOT

Testing Process

In the Rotating Pressure Vessel Oxidation Test a sample of lubricant along with water and a copper catalyst is placed in a pressure vessel and pressurized with pure oxygen. Antioxidants present in the lubricant will act to resist oxidation, but once they have been consumed the lubricant will begin to react with the oxygen and the pressure in the vessel will drop. The time it takes to reach the specified drop in pressure is recorded and compared to new lubrication specifications.

Analysis of Results

RPVOT results are an indicator of a lubricant's ability to resist oxidation and are best trended continuously, with the goal of predicting the amount of time to a near-zero result. Most lubricants will trend very linearly with time. Others may experience a sudden drop in values initially, before stabilizing for the remainder of its life.

RPVOT results are expected to slowly trend downwards with increased lubricant service.

Causes for Accelerated Elevation

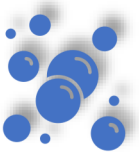
- Water Content
- Increase in Operating Temperature

Alarm Parameter

- <25% of new lubricant value

SECTION 14

FOAMING TENDENCIES

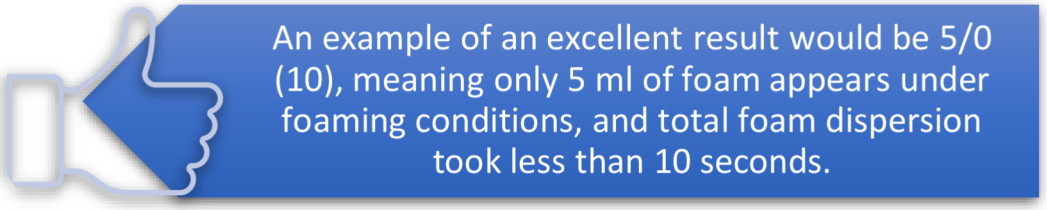


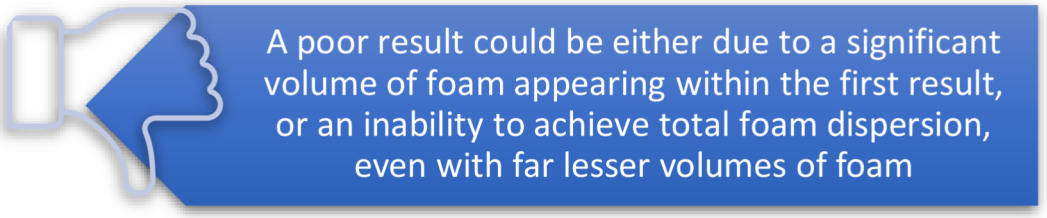
Testing Process

Air is forced through a diffuser within a portion of lubricant creating foam. After 5 minutes of blowing, the amount of foam is recorded. Then, the sample is observed for the clearing of generated foam. At this point, either time of full dissipation is recorded or the amount of foam remaining after 10 minutes.

Analysis of Results

Foaming tendency results are reported as a series of values, starting with the volume of foam (in ml) after 5 minutes of blowing air through the lubricant, followed by the volume of foam (in ml) after 10 minutes without air. The time (in seconds) until total foam dispersion is also reported.





Causes for Failed Foaming Tendency

- Contamination with Another Fluid (either water or another product)
- Increases in Water Content

Alarm Parameter

- >450ml or >250 seconds

SECTION 15

RULER

Testing Process

The RULER® test uses linear sweep voltammetry technology to detect antioxidant additives. Antioxidants are extracted from the lubricant sample into a special solution. The instrument passes a current through the prepared sample, increasing the voltage over a set timeframe.

Antioxidants will accept electrons at certain voltages, producing a peak on the RULER graph. The areas of the peaks produced by the in-use fluid are compared to the areas of the peaks produced by new oil to calculate the percent remaining antioxidants.

Analysis of Results

RULER® is another test that detects the presence of antioxidant additives present in the lubricant and is best trended continuously, with the goal being to predict the amount of time to a near-zero result.

Most lubricants will trend very linearly with time; however, they may be accelerated by elevated water content or operating temperatures.

Alarm Parameter

- <25% of new oil value

SECTION 16

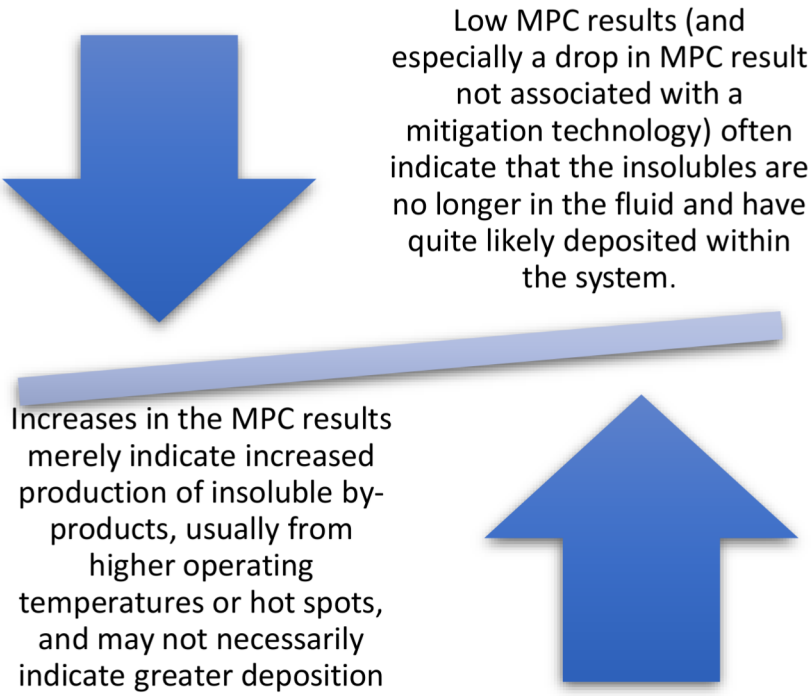
MEMBRANE PATCH COLORIMETRY

Testing Process

Insoluble deposits are extracted from the sample using a membrane patch. The color of the patch is analyzed using a spectrophotometer. Results are reported as a ΔE value in the CIE LAB scale.

With MPC, a direct correlation is made between the color and intensity of the insoluble contaminants and lubricant degradation byproducts suspended in the fluid.

Analysis of Results



For these reasons, MPC is a result that is best interpreted by trending over time, and any sudden change warranting corrective action.

As part of the MPC the L, a, b color values are also documented. The L, a, b values provide additional information on the varnish degradation mode as well as offer clues about the effectiveness of filtration, targeting specific varnish modes.

"L" Value

- Black to White Scale
- Higher values representing higher concentrations of black particles possibly due to soot particles, which can point to micro-dieseling, spark discharge, or hot spots.

"a" Value

- Red to Green Scale
- Higher values representing a greater the danger of sludge-building corrosive particles or diminished extreme pressure (EP) additives.

"b" Value

- Yellow to Blue Scale
- Higher values indicating the more susceptible the lubricant is to sticky deposits.

Alarm Parameter

- >23 = Marginal
- >33 = Critical

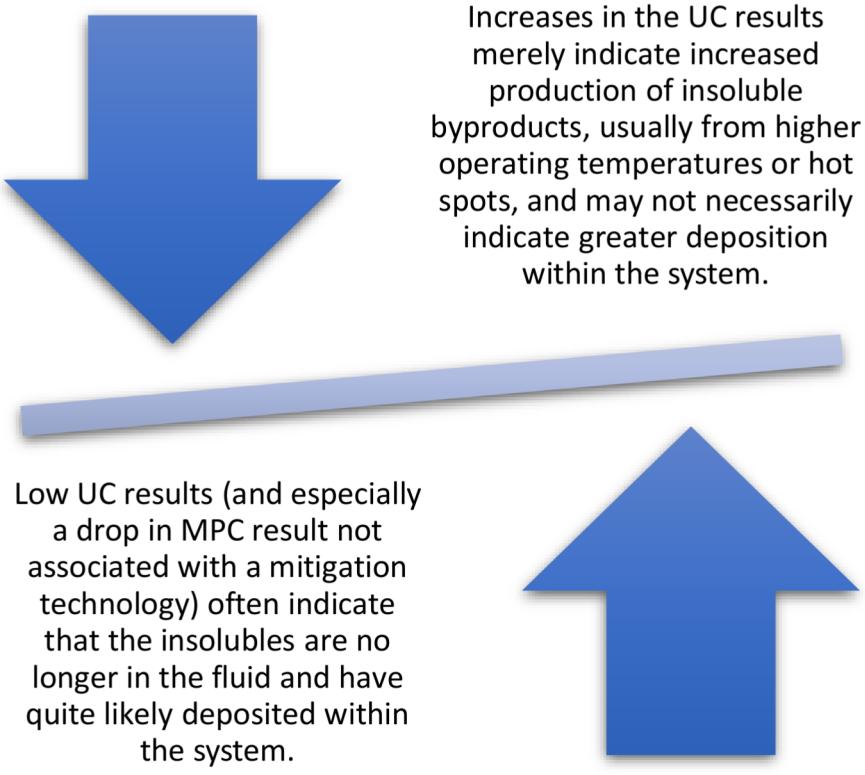
ULTRA-CENTRIFUGE

Testing Process

As a sample is spun at 17,000 rpm in the ultra-centrifuge the soft contaminant oxidation by-products which have a higher molecular weight than the lubricant will be forced to the bottom of the centrifuge tube.

Analysis of Results

Ultra-centrifuge is another method that measures the amount of insoluble contaminants that are suspended in the fluid, and offers no direct interpretation of how much varnish or other material has deposited in the system.



For these reasons, UC is a result that is best interpreted by trending over time, and any sudden change warranting corrective action.

Alarm Parameter

- ≥5 = Marginal
- ≥7= Critical

SECTION 18

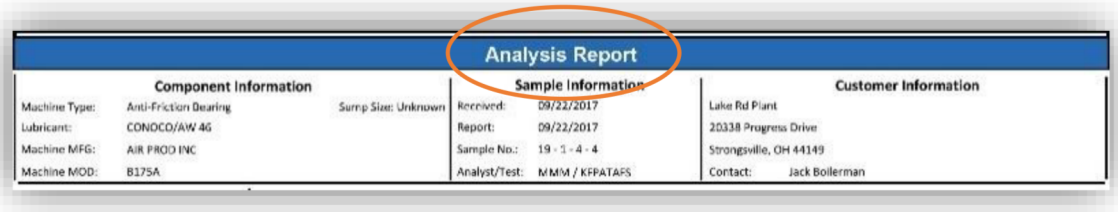
REPORT INTERPRETATION

Proper report interpretation is crucial to the success of an oil analysis program; however, many users struggle to decipher the more than 40 pieces of data included on a routine report. The best procedure is to read the whole report in a methodical order, section by section. The following three steps will outline how this can be done yet take less than two minutes per report.

Step 1: Reading The Report

Read the whole report from top to bottom, without skipping any information or jumping to highlighted sections. Starting at the top, look at which machine the sample belongs to, and how the sample was rated. Consider known information about the machine (recent issues, maintenance, or failure history) and then review the severity (normal, marginal or critical) of both the machine and the lubricant.

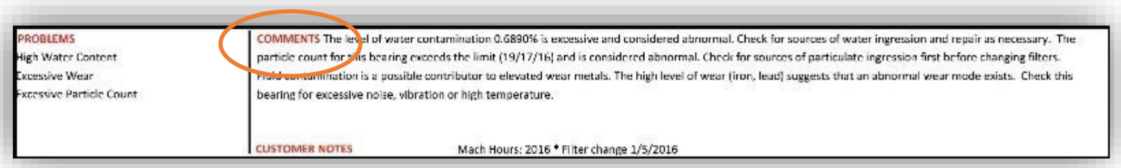
Next, review the machine and lubricant information to establish expectations, e.g. is this a gearbox that is expected to have higher wear compared to hydraulic system? or does the machine lack filtration and particle counts are expected to be higher? Is this an AW (antiwear), EP (extreme pressure) or R&O (rust and oxidation inhibited) oil and what is its grade?



Analysis Report

Component Information			Sample Information		Customer Information	
Machine Type:	Anti-Friction Bearing	Sump Size: Unknown	Received:	09/22/2017	Lake Rd Plant	
Lubricant:	CONOCO/AW 46		Report:	09/22/2017	20338 Progress Drive	
Machine MFG:	AIR PROD INC		Sample No.:	19 - 1 - 4 - 4	Strongsville, OH 44149	
Machine MOD:	B175A		Analyst/Test:	MMM / KFPATAFS	Contact:	Jack Boilerman

Then review the laboratory's comments to get a preview of the factors that drove the report's severity.

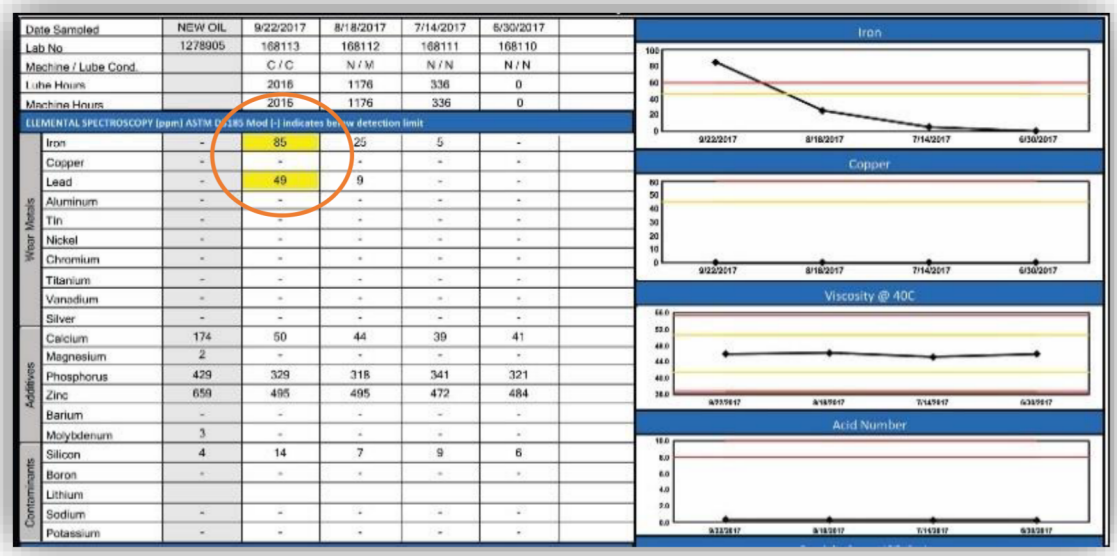


PROBLEMS	COMMENTS
High Water Content Excessive Wear Excessive Particle Count	The level of water contamination 0.6890% is excessive and considered abnormal. Check for sources of water ingression and repair as necessary. The particle count for this bearing exceeds the limit (19/17/16) and is considered abnormal. Check for sources of particulate ingression first before changing filters. Fluid contamination is a possible contributor to elevated wear metals. The high level of wear (iron, lead) suggests that an abnormal wear mode exists. Check this bearing for excessive noise, vibration or high temperature.
CUSTOMER NOTES	Mach Hours: 2016 * Filter change 1/5/2016

Step 2: Analyzing Abnormality of Values

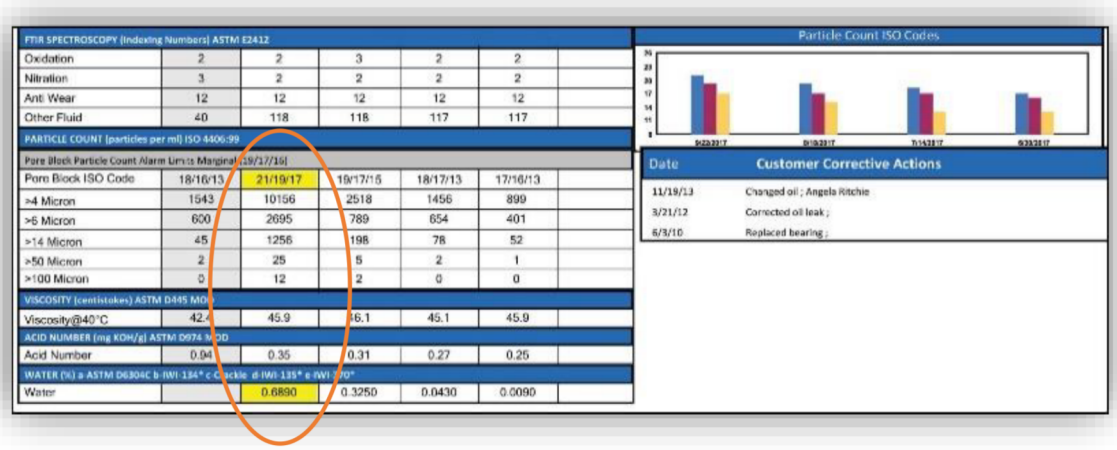
Decide which values appear to be abnormal, but do not attempt to decipher how or why, simply assign each abnormal value a label of "cause" or "effect".

Upon beginning to look at the sample data portion of the report, first review the lubricant and machine hours (if reported) to ascertain the predicted trend, i.e. continued service would suggest wear, contamination and degradation to increase, whereas a recent oil change would see the opposite effect.



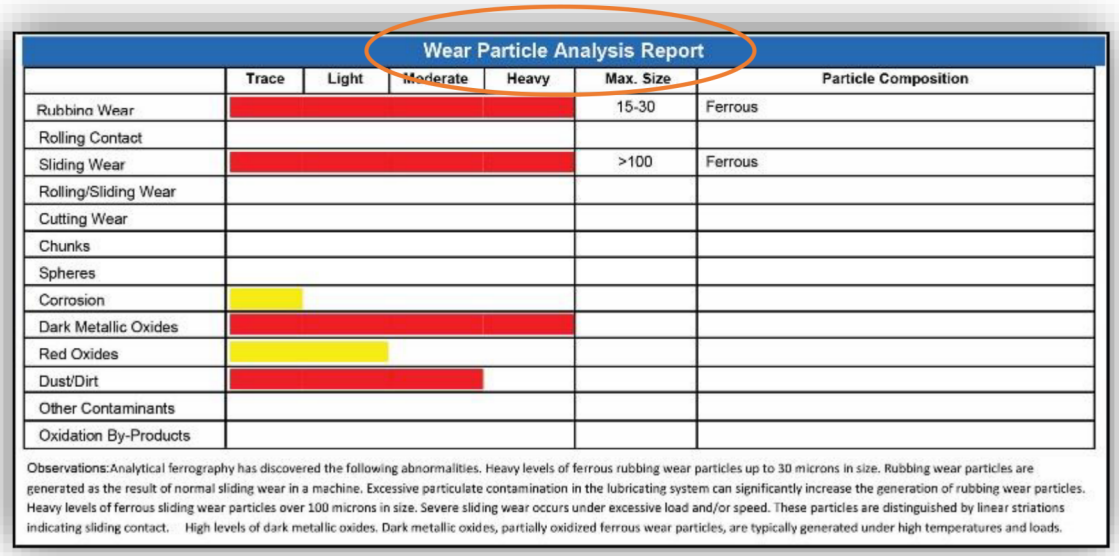
Date Sampled	NEW OIL	9/22/2017	8/18/2017	7/14/2017	6/30/2017
Lab No	1278905	168113	168112	168111	168110
Machine / Lube Cond.		C / C	N / M	N / N	N / N
Lube Hours		2016	1176	336	0
Machine Hours		2016	1176	336	0
ELEMENTAL SPECTROSCOPY (ppm) ASTM D5185 Mod [-] indicates below detection limit					
Wear Metals: Iron	-	85	25	5	-
Wear Metals: Copper	-	-	-	-	-
Wear Metals: Lead	-	49	9	-	-
Wear Metals: Aluminum	-	-	-	-	-
Wear Metals: Tin	-	-	-	-	-
Wear Metals: Nickel	-	-	-	-	-
Wear Metals: Chromium	-	-	-	-	-
Wear Metals: Titanium	-	-	-	-	-
Wear Metals: Vanadium	-	-	-	-	-
Wear Metals: Silver	-	-	-	-	-
Additives: Calcium	174	50	44	39	41
Additives: Magnesium	2	-	-	-	-
Additives: Phosphorus	429	329	318	341	321
Additives: Zinc	659	495	495	472	484
Additives: Barium	-	-	-	-	-
Additives: Molybdenum	3	-	-	-	-
Contaminants: Silicon	4	14	7	9	6
Contaminants: Boron	-	-	-	-	-
Contaminants: Lithium					
Contaminants: Sodium	-	-	-	-	-
Contaminants: Potassium	-	-	-	-	-

From the first section of this example, iron and lead are clearly abnormal and would likely be labelled as “effects”, since some other mechanism (time, viscosity, contamination) would have caused the wear metals to appear. Though silicon was not highlighted by the lab, it could be labelled a “cause” since high iron or lead would not cause silicon to appear, but high silicon could cause more iron and lead wear. Continue reading, allowing previously assigned labels to be changed, if warranted.



FTIR SPECTROSCOPY (Indexing Numbers) ASTM E2412					
Oxidation	2	2	3	2	2
Nitration	3	2	2	2	2
Anti Wear	12	12	12	12	12
Other Fluid	40	118	118	117	117
PARTICLE COUNT (particles per ml) ISO 4406:99					
Pore Block Particle Count Alarm Limits Marginal (19/17/16)					
Pore Block ISO Code	18/16/13	21/19/17	19/17/15	18/17/13	17/16/13
>4 Micron	1543	10156	2518	1456	899
>6 Micron	600	2695	789	654	401
>14 Micron	45	1256	198	78	52
>50 Micron	2	25	5	2	1
>100 Micron	0	12	2	0	0
VISCOSITY (centistokes) ASTM D445 MOD					
Viscosity@40°C	42.4	45.9	46.1	45.1	45.9
ACID NUMBER (mg KOH/g) ASTM D974 MOD					
Acid Number	0.94	0.35	0.31	0.27	0.25
WATER (%) a ASTM D6304C b-IWI-134* c Crackle d-IWI-135* e IWI-720*					
Water		0.6890	0.3250	0.0430	0.0090

In this next section, the elevated particle count would be labelled a “cause”, along with the previously assigned silicon. Though acid number is trending higher, it has followed a very steady 0.04 increase between each sample. Water, however, has not and should be considered abnormal and labelled as a “cause”.



Wear Particle Analysis Report

	Trace	Light	Moderate	Heavy	Max. Size	Particle Composition
Rubbing Wear					15-30	Ferrous
Rolling Contact						
Sliding Wear					>100	Ferrous
Rolling/Sliding Wear						
Cutting Wear						
Chunks						
Spheres						
Corrosion						
Dark Metallic Oxides						
Red Oxides						
Dust/Dirt						
Other Contaminants						
Oxidation By-Products						

Observations:Analytical ferrography has discovered the following abnormalities. Heavy levels of ferrous rubbing wear particles up to 30 microns in size. Rubbing wear particles are generated as the result of normal sliding wear in a machine. Excessive particulate contamination in the lubricating system can significantly increase the generation of rubbing wear particles. Heavy levels of ferrous sliding wear particles over 100 microns in size. Severe sliding wear occurs under excessive load and/or speed. These particles are distinguished by linear striations indicating sliding contact. High levels of dark metallic oxides. Dark metallic oxides, partially oxidized ferrous wear particles, are typically generated under high temperatures and loads.

In the final section it is first noted that rubbing wear is very high, yet rubbing wear is considered a normal wear mode. What makes this an issue is that normal rubbing wear generates small particles (near 5 microns), while abnormal rubbing wear generates larger particles. Though it is a wear mode, rubbing wear would be labelled as an “effect” since another factor would be driving it.

The same can be said for sliding wear, which is never considered normal, regardless of size. Corrosion is also an “effect”, as would be red oxides, as they were likely accelerated by the water content noted earlier. Dark metallic oxides are caused by high contact pressure, usually from lubricant starvation, so they must be labelled as an “effect”.

Lastly is the elevated level of dust/dirt which will likely be labelled as a “cause”, which would force silicon and particle count to be relabeled as “effects”, since dust/dirt could cause both to increase.

By the time you reach the end of the report, there should only be one or two causes noted, with every other abnormal value labelled as an effect of one or more of these causes. For the example above, the causes would be elevated dust/dirt and water content.

Step 3: Determine Follow-Up Actions

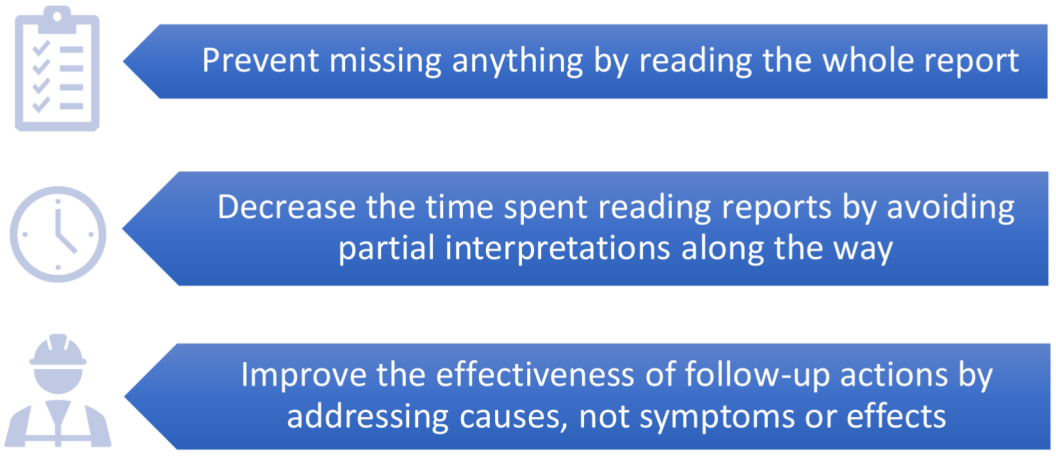
Decide what follow-up action would either confirm the cause or remedy the situation. The best action is rarely to simply change the lubricant.

In the previous example, investigating all points of ingression (fill cap, dipstick, breather, hatch cover, etc..) could potentially address the root cause of both “causes”. While simply changing the lubricant would see these abnormalities disappear from the next sample, the same problem would recur in due course.

Even if an obvious fault was found, e.g. broken or missing breather and even after the repair, the lubricant should still not be changed. If the current level or wear or contamination can be tolerated, leaving the same fluid in service gives the next sample the definitive ability to confirm if the repair was successful by returning with nearly identical results, not lower/better.

The Big Idea

Following these three steps will:



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