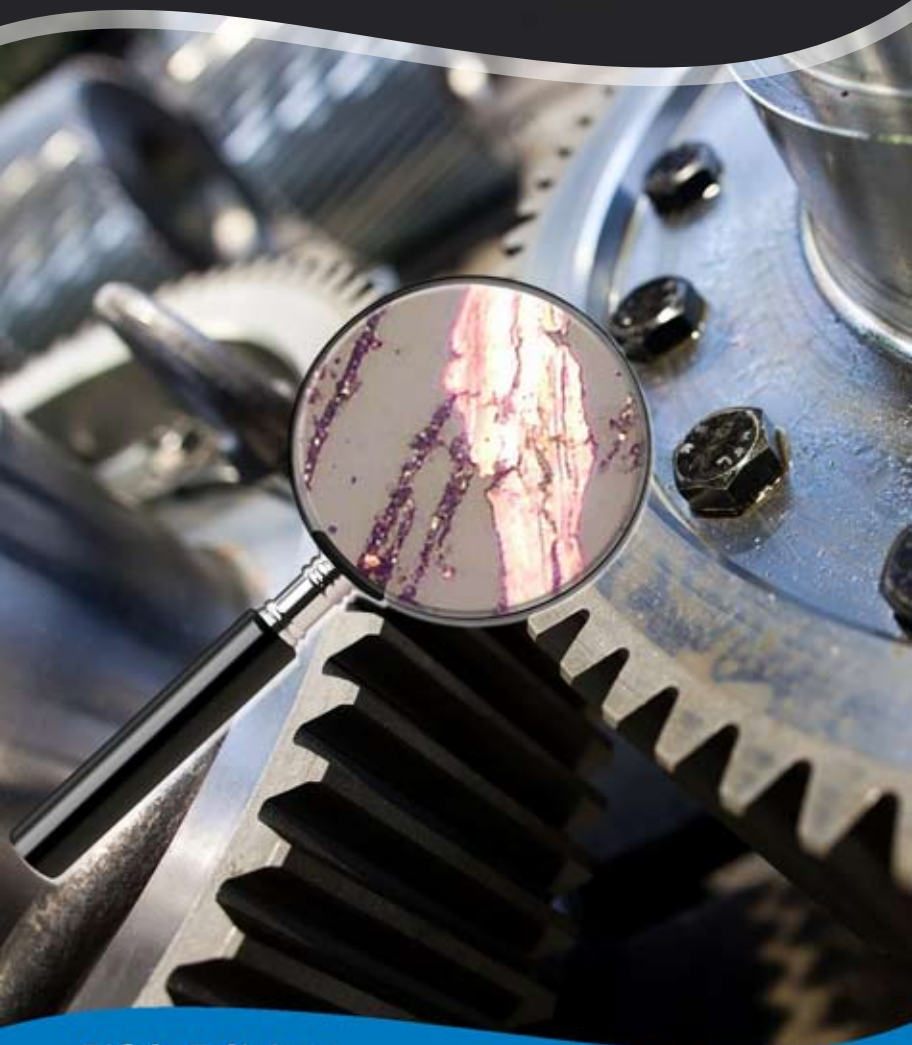


The Practical Guide to **Oil Analysis**



Fifth Edition

TABLE OF CONTENTS

Introduction	2
What Are Lubricants?	3
Functions of a Lubricant	3
How Do Lube Oils Fail?	5
What Does Oil Analysis Measure?	6
Why Analyze Used Oil	7
How to Design a World-Class Oil Analysis Program	8
Oil Sampling Tips	11
Lubrication Storage & Handling	15
Introduction To Report Interpretation	17
Basic Oil Analysis Tests	22
Viscosity	22
Elemental Spectroscopy	24
The Crackle Test	26
Karl Fischer Water	28
Demulsibility	30
FT-IR Spectroscopy	31
Rust	32
Foam	33
Base Number	34
Acid Number	35
Rotating Pressure Vessel Oxidation Test (RPVOT)	36
Fuel Dilution	37
Particle Count	38
Ferrous Wear Concentration	41
Advanced Oil Analysis Tests	43
Analytical Ferrography	43
Varnish Potential Analysis	49
Turbine Oil Analysis	51
Non-Fluid Analysis	52
Filter Debris Analysis	52
Grease Analysis	54
Materials Identification Analysis	55

SECTION 1

Introduction

Oil analysis can uncover, isolate and offer solutions for abnormal lubricant and machine conditions when used as a predictive maintenance tool. These abnormalities can result in expensive, sometimes catastrophic damage causing lost production, extensive repair costs and even operator accidents.

The goal of an effective oil analysis program is to increase the reliability and availability of machinery while minimizing maintenance costs associated with oil change-outs, labor, repairs, and downtime. Accomplishing this goal takes time, training, and patience. However, the results are dramatic and the documented savings and cost avoidance are significant.

Many organizations throughout the world have implemented oil analysis programs to help manage their equipment reliability. Some have experienced substantial savings, cost reductions, and increased productivity, while others have received only marginal benefits.

A successful oil analysis program requires a dedicated commitment to taking repeatable and representative samples, understanding the test results and taking action on those results to eliminate future problems.

WHAT ARE LUBRICANTS?

Industrial oils are specially designed fluids composed of a base oil and a compliment of additives.

The **Base Oil** performs the following functions:

- Form a fluid film between moving parts in order to reduce friction and wear
- Carry away contaminants to the filter
- Remove heat generated within the machine

Additives are chemical compounds added to the base oil to significantly enhance the performance characteristics of the lubricating oil. Typical enhanced properties include:

- Oxidation Stability
- Wear Protection
- Addition of Corrosion Inhibitors
- Viscosity Index Improvers

FUNCTIONS OF A LUBRICANT

From cooling to cleaning to lubricating, the absolute key to keeping your equipment running.

Lubricate: By introducing a film between moving parts, opposing friction surfaces are separated and allowed to move freely without any interlocking of the asperities at the metal surface. By physically separating the moving parts, friction is greatly reduced. The result is less wear generated and less energy required to perform the work.

Cool: Lubricants absorb the heat generated at the friction surface and carry it away to a reservoir where it is allowed to cool before returning for service. Oil coolers and heat exchangers are sometimes used to more efficiently disperse heat. Lubricants are an excellent dissipator of heat.

Clean: Oil picks up solid contaminants and moves them away from the contact zone. The contaminants can then be removed by filtration or settling in the reservoir. Many oils have detergent characteristics to hold tiny dirt and soot particles in suspension to help prevent sludge and varnish in a system.

Protect: Lubricants coat component surfaces providing a barrier against moisture. The presence of moisture in the air causes oxidation, eventually leading to corrosion. Rust occurs when steel surfaces are attacked by moisture. Corrosion occurs when a metal surface is attacked by acids, a byproduct of oxidation. Oils can be fortified with alkaline reserves to counter the corrosive contaminants.

Seal: Many lubricants form a viscous seal to keep contaminants out of a component. Greases form physical barriers to protect against dirt and water ingress.

Transmit Power: Hydraulic systems use lubricants to protect sliding, contacting surfaces and as a source of fluid power. Fluid under pressure actuates moving parts.

HOW DO LUBE OILS FAIL?

Contamination , degradation , or the loss of specific properties provided by additives.

Contamination

- *External Sources:* Dirt, water, and process related liquids or materials
- *Internal Sources:* Machine wear and degradation by-products

Oil Degradation

- *Oxidation:* Atmospheric oxygen combines with hydrocarbon molecules. The hotter the oil and the greater exposure to air, the faster oxidation proceeds. The initial by-products of oxidation are sludges and varnishes. However, further oxidation converts these by-products into carboxylic acids. The presence of these acids increases the speed of oxidation.

Additive Depletion

- Additives are consumed or chemically changed while performing their function. The performance characteristics of the lubricant are altered and the enhanced properties are eliminated.

WHAT DOES OIL ANALYSIS MEASURE?

Physical and chemical properties of the oil, contamination, and mechanical wear.

Lubricating Oil Properties. Uncover contamination or degradation by trending rates of change in selected lube properties.

- **Fourier Transform Infrared Spectroscopy**
Degradation by-products (oxidation, nitration, sulfate)
External contaminants (water, glycol, fuel, soot)
- **Viscosity**
Physical property
- **Karl Fischer Water**
Contamination
- **Acid Number**
Degradation
- **Particle Counting**
Both contamination and wear debris
- **Base Number**
Degradation
- **Fuel Dilution**
Fuel Contamination

Mechanical Wear. Uncover machine related problems.

- **Elemental Spectroscopy**
Wear metals, contaminant metals, additive metals
- **Ferrous Wear Concentration**
Ferrous wear particles
- **Analytical Ferrography**
Type and severity of wear particles

WHY ANALYZE USED OIL

Oil analysis is a quick and easy way to monitor the health of rotating equipment. Sampling and analyzing oil on a regular basis establishes a baseline for normal wear and can help indicate when abnormal wear or contamination is occurring.

Lubricating oil inside any rotating equipment over a period of time reflects the condition of the equipment. Because oil is in contact with internal components, any microscopic wear particles or contaminants found in the machine will also materialize in the oil.

By identifying and measuring these particulates, you get an indication of the equipment wear rate and any excessive contamination. An effective oil analysis program will assess lubricant condition, qualify/quantify contaminants and trend machine wear.

Lubricant Condition. The assessment of lubricant condition reveals whether the system fluid is healthy and fit for further service, or is ready for a change.

Contaminants. Ingressed contaminants from the surrounding environment in the form of dirt, water and process contamination are the leading cause of machine degradation and failure. Increased contamination alerts you to take action in order to save the oil and avoid unnecessary machine wear.

Machine Wear. An unhealthy machine generates wear particles at an exponential rate. The detection and analysis of these particles assist in making critical maintenance decisions. Machine failure due to worn out components can be avoided. Remember, healthy and clean oil lead to the minimization of machine wear.

SECTION 2:

How to Design a World-Class Oil Analysis Program

The most successful oil analysis programs are those that are thoughtfully designed after careful evaluation and development of clearly defined goals. The emphasis should be on designing quality and excellence in the beginning, not force-fitting it in along the way.

An oil analysis program is considered one of the critical technologies to increasing equipment reliability while maintaining a safe and cost-effective plant operation. The following seven steps will provide a guideline for implementing an effective program.

#1 - Identify Critical Equipment

When you start implementing an oil analysis program, you need to decide which equipment in the plant to sample. Equipment critical to plant operations should be identified first. This equipment often does not have a backup unit to replace it when it is not in service. In addition, major repairs and overhaul of critical equipment often require a complete plant shutdown, substantial manpower and subsequent loss of production activities.

#2 - Determine Test Packages

Oil analysis test packages should be carefully considered. Having an idea about what the various tests are, what they can accomplish, and taking into account the maintenance philosophy being practiced, test packages can easily be drawn up to accomplish the desired results. If you are not sure what tests are right for your equipment, it is best to consult a quality lab for assistance in this area.

#3 - Choosing The Right Laboratory

Partnering with an external oil analysis laboratory is a strategic decision. There are many aspects of the oil analysis service that need to be considered and choosing a commercial oil analysis lab should not be taken lightly. Consider these factors:

- Turnaround Time
- Certification of Analysts
- Laboratory Certification
- Depth of Interpretation
- Readability of the Reports
- Range of Tests Offered
- Experience Working In Your Industry

#4 - Invest in Training

Maintenance professionals should receive continual training and education in lube analysis. Trained technicians that understand how important quality lubrication procedures are will be key in maintaining a program. There are several companies that offer excellent training in lubrication fundamentals and practices.

#5 - Learn How to Interpret an Oil Analysis Report

The oil analysis report is a vital tool for a smooth running

operation. Going deeper than the report summaries and knowing how to analyze the oil analysis report can help prevent equipment breakdown and unnecessary equipment teardowns. However, reading an oil analysis report can be overwhelming unless you know what you are reading. Too often the failure of a program can be attributed to the lack of interpretation and an inappropriate response to the results.

#6 - Use Proper Lubrication Storage and Handling

Having lubrication storage and handling systems in place is important. Lubrication products are expensive, so they need to be handled in a fashion that maximizes the return on investment. Make sure your storage and handling areas are clean, well-organized, and climate controlled. If you have oil storage racks, consider separate pumps and filters for each lubricant product. Furthermore, make sure your transfer containers are clean and take care not to expose lubricants to contamination in route to the equipment.



#7 - Justify Your Program

One common way of justifying oil analysis is keeping records of all predictive oil changes, filtration requests, dehydration requests, and so on. You also need to annually evaluate your oil analysis program's effectiveness, which includes a cost-benefit evaluation of money saved by avoiding maintenance issues or machine downtime due to oil analysis. Evaluation allows for continuous improvement of the program by realigning the program with either preexisting or new reliability objectives.

SECTION 3:

Oil Sampling Tips

Sampling is the most important part of any lube analysis program and the quality of your samples is vital to the success of your program. Poor sampling methods can lead to incorrect diagnoses which can initiate unnecessary corrective actions, or, prevent abnormal conditions from being observed.

Oil Sampling Problems

The two most common problems that many businesses encounter when it comes to oil sampling are contamination and misrepresentation. The first of these issues, contamination, is caused when improper sampling techniques (like unclean extraction tools) suggest the presence of problems that do not exist in the equipment sampled. Misrepresentation, on the other hand, becomes an issue when a problem that is there gets missed due to a non-representative sample. Avoiding these issues takes a precise set of procedures and techniques.

Oil Sampling Procedures

Proper management of your oil sampling program starts with putting the right processes in place. There are three basic ways that an oil sample can be extracted from your equipment: through the drain port, via a drop-tube with a vacuum pump or from a dedicated sampling point.

Oil Sampling Consistency

Once you have established a solid set of oil sampling best practices for your business, it is important to make sure every member of your team sticks to these procedures. Oil samples extracted using inconsistent procedures or sampling locations may suggest significant variations in important result parameters. Keeping your oil sampling program consistent ensures that the results of your oil analyses are as accurate as possible.

Oil Sampling Frequency

There is no universal formula for determining oil sampling frequency, but most experts consider monthly sampling to be optimum for critical machinery. However, when making this decision, it is important to consider the objectives of the oil analysis program. If the only objective is to perform condition-based oil changes, the sampling frequency should be determined relative to the lubricant's expected service life, which is defined by the OEM recommended oil change frequencies.

In most situations, this is not the only objective, or even the most important one. The real value of oil analysis is its ability to serve as a proactive condition-monitoring tool, allowing for the detection and quantification of machine wear, particle contamination, moisture, foreign lubricants or fluids and assessing overall lubricant condition. With this goal, a monthly sampling schedule is appropriate.

SAMPLING BEST PRACTICES

- Alert production that you are in the area
- Wear rubber gloves and other proper safety attire
- Use an approved sample container
- Clean a sample point before sampling
- Flush a sample point before sampling
- Never close a valve in the middle of a sample
- Always use clean tubing for each sample
- Keep all sample points capped until ready to use
- Cap sample bottle immediately
- Use a proper sample bottle
- Make sure bottle caps are tight
- Properly label a sample bottle
- Ship samples the same day they are collected

SAMPLING PITFALLS

- Re-use sample bottles
- Use anything except approved sample bottles
- Re-use sample tubing
- Sample from a dead leg
- Sample during rain, snow or fog if outside
- Sample equipment that is not running except after shutdown
- Open sample bottle until ready to collect sample
- Leave samples exposed to the environment
- Collect several days samples before shipping
- Sample from a drain if avoidable
- Collect the initial oil from a sample point (flushing)
- Leave bottle caps loose

SECTION 4:

Lubrication Storage & Handling

The proper handling and storage of lubricating oils and greases is a very important aspect of an oil analysis program. These products are formulated for specific applications, and contamination or deterioration can result from improper handling or storage. The end result of this could be inadequate lubrication and machine failure.

Here are some tips to help outline the best practices for proper lubrication storage and handling:

Storage Area

Whether your lubricants are stored indoors or outside, environmental conditions can reduce their shelf life. The fluids are vulnerable to contamination by dust and dirt. Fluctuating temperatures cause a reaction known as thermal siphoning, in which air moves in and out of the container's head space and the atmosphere — even in sealed containers with no oil going in or out. Moisture and airborne particles travel with the air, resulting in contamination and degradation of the oil. Extreme hot or cold temperatures can lead to chemical degradation as well.

Ideally, lubricants should be stored indoors, if possible, where the environment can be better controlled. A clean, dry environment kept at a stable, moderate temperature is best.

If outdoor storage cannot be avoided, lubricants should be sheltered as much as possible from environmental conditions that may degrade them. In addition, place containers on blocks or racks to help protect them from ground moisture.

Proper Labeling

Lubricant labeling is one aspect of storage and handling that is often overlooked. Labeling is critical and without proper labeling it is very easy for lubricant cross contamination to occur. Use of an incorrect lubricant could cause equipment damage or failure, health and safety issues, and a host of other problems. Proper labeling can help ensure that each lubricant is always used in the right component.

New Oil Cleanliness

In many cases, new oil can be the dirtiest oil in the plant. The containers used to store lubricants are often reused and may be subjected to many extreme conditions before they reach your plant. Lubricant manufacturers are not required to ensure cleanliness of a lubricant unless it is advertised as meeting a specified cleanliness rating. Therefore, it is good practice to perform oil analysis on new oil to ensure effective contamination control.

Lubricant Shelf Life

Most lubricants can be stored for a substantial period without consequence, but they do have a shelf life. If a lubricant is stored too long, even in perfect conditions, it can lose performance capabilities and eventually become useless. The best way to avoid this is to rotate inventory on a first-in, first-out basis. Arrange storage shelves so that new purchases are placed in the back and older stock moves forward.

SECTION 5:

Introduction To Report Interpretation

The ability to interpret oil analysis results is vital to making significant maintenance decisions. Having someone in your organization that can pick up a report and interpret it in the context of the environment is absolutely essential.

Once an analysis is complete, it is important to review the report to determine what action should be taken, if any. Based on the report, you can determine whether action is needed. The report does not always pinpoint specific problems, but does provide a starting point for analysis.

When reviewing your reports, the first thing you should do is make sure the reports are actually your reports. Next, check that the correct lube type, machine MFG, and machine type are listed.

Your report should clearly state your machine and lubricant condition. Your lab should have a rating system that notifies you of Normal, Marginal and Critical levels.

Your report should include comments from the analyst who reviewed your results. The comments will help you gauge the criticality of the problem and provide you with a suggested course of action.

Each test should be identified and the data should be organized to clearly communicate test results.

The following is a general process that can be followed when reviewing standard oil analysis tests.

Interpreting Viscosity Results

Viscosity is the most common test run on lubricants because viscosity is considered a lubricant's most important property. The test measures a lubricant's resistance to flow at a specific temperature. If a lubricant does not have the proper viscosity, it cannot perform its functions properly. A lubricant with the improper viscosity can lead to overheating, accelerated wear, and, ultimately, the failure of the component.

If the oil's viscosity is within plus or minus 10 percent of its ISO grade, it's considered normal. If the oil's viscosity is greater than plus or minus 10 percent and less than plus or minus 20 percent, then it is considered marginal. Viscosity greater than plus or minus 20 percent from grade is critical.

Measuring Metals: Elemental Spectroscopy

Elemental spectroscopy is a test used to determine the concentration of wear metals, contaminant metals, and additive metals in a lubricant. A concentration of wear metals can be indicative of abnormal wear. However, spectroscopy cannot measure particles larger than roughly seven microns, which leaves this test blind to larger solid particles.

When oil additives containing metallic elements are present, significant differences between the concentrations of the additive elements and their respective specifications can indicate that either incorrect oil is being used or a change in the formation has occurred.

Understanding Wear Limits

When reviewing wear levels of your test results, we recommend that you look at the trend history of each machine, not just the OEM recommendations. OEMs offer good benchmarks, but because most machines are used differently, it is not wise to only follow the OEM recommendations.

For example, if you have two identical pieces of equipment, they can have vastly different elemental spectroscopy results, due to variations in load, duty cycle and maintenance practices performed on each machine. In addition, their results might even show a variety of particle count levels, but both machines could still be considered healthy based on the trending of the analysis. Trending is extremely important in determining a machine's health.

Stay On The Look Out For Contaminants

When talking about contaminants, the objective is to detect the presence of foreign materials, where they came from and how to prevent further entry or generation. Contaminants act as a catalyst for component wear and if the cycle is not broken, wear accelerates and downgraded serviceability results.

Contamination takes the form of insoluble materials such as water, metals, dust particles, sand and rubber. The smallest particles, those below 2 μm , are typically silt, resin or oxidation deposits, and can cause significant damage.

Quantifying the Amount of Water

The Karl Fischer coulometric moisture test is the most common method used to analyze water levels in oil. When reviewing your Karl Fischer test results remember that low levels of water are typically the result of condensation and higher levels can

indicate a source of water ingress. In most systems, water should not exceed 500ppm. Common sources of water:

- External contamination: Breathers, Seals, Reservoir covers
- Internal leaks: Heat exchangers, Water jackets
- Condensation

Determining Oil Condition: Acid Number

Oil oxidation causes acidic by-products to form. High acid levels can indicate excessive oil oxidation or additive depletion.

Acid number testing measures the concentration of acids in the oil, but dilution effects often negate the effectiveness of this test. Similarly, oils containing antiwear (AW) or extreme pressure (EP) additives are mildly acidic and can provide false high or low readings (due to additive depletion). Acid number values should be considered in concert with other factors, such as additive health and water content.

Gauging Particle Count

Particle count analysis is conducted on a representative sample of the fluid in a system. The particle count test provides the quantity and particle size of the various solid contaminants in the fluid. The actual particle count and subsequent ISO Cleanliness Code are compared to the target code for the system. If the actual cleanliness level of a system is worse than the desired target, corrective action is recommended. (see page 40 for more information about ISO Codes).

By measuring and reporting these values, you can gain an understanding of the solid particles in the oil. Monitoring these values can also help confirm the presence of large wear particles that cannot be seen through other test methods. However,

particle counting simply indicates the presence of particles and does not indicate the type of particles present.

Analytical Ferrography: A Forensic Science

The results of the Analytical Ferrography test typically include a photomicrograph of the debris found, along with specific descriptions of the particles and their suspected cause. Particles are categorized based on size, shape, and metallurgy.

Conclusions can be drawn regarding the wear rate and health of the component that the sample was drawn from. The analyst relies on composition and shape to determine the characteristics of the particles.

Due to the subjective nature of this test, it is best to trust the interpretation of the analyst related to action to be taken.

However, remember that this test is qualitative, which means it relies on the skill and knowledge of the ferrographic analyst.



SECTION 6:

Basic Oil Analysis Tests

VISCOSITY

Measure of lubricant's resistance to flow at a specific temperature.

Operating Principle. (ASTM D445)

Measured using a viscometer. The sample is introduced into a calibrated glass tube, submerged in a constant temperature bath. The oil is warmed to a desired temperature of 40°C or 100°C and allowed to flow via gravity down the tube. The number of seconds the oil takes to flow through the calibrated region is measured. The viscosity in centistokes (cSt) is the flow time (seconds) multiplied by the tube constant.



Significance. Viscosity is measured at 40°C for industrial applications and 100°C for engine oil applications. Viscosity for industrial lubricants is classified using the ISOVG (International Standard Organization Viscosity Grade) system which is the average viscosity (cSt) at 40°C. Viscosity determination provides a specific number to compare to the recommended oil in service. An abnormal viscosity (+10%) is usually indicative of a problem. Viscosity for engine oils is classified according to SAE (Society of Automotive Engineers). SAE lubricants that are the wrong grade are flagged on the analysis report.

Viscosity (centistocks) ASTM D 445

Date	Reference	1/11/15	12/7/14	11/2/14	10/19/14
Lab Number	107391	168113	168112	168111	168110
40 cSt	219.3	221	220.9	221.3	220.7

↑ An increase in viscosity may indicate:

- Increasing suspended solid material such as wear particles, contamination, or soot
- Additions of a higher viscosity oil
- Lubricant oxidation

↓ A decrease in viscosity may indicate:

- Contamination from fuels, or process fluid
- Additions of a lower viscosity oil
- Additive shear

Advantages. Quickly detects the addition of a wrong oil. Quick and inexpensive to run. Best measurement of oil serviceability.

Alarm Parameter. *(applicable for ISO VG)*

High Viscosity

- >10% from specification = Marginal
- >20% from specification = Critical

Low Viscosity

- >10% from Grade = Marginal
- >20% from Grade = Critical

ELEMENTAL SPECTROSCOPY

Measures the concentration of wear metals, contaminant metals and additive metals in a lubricant.

Operating Principle.

(ASTM D 5185) 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.



Significance. The Inductively Coupled Plasma (ICP) Spectrometer measures and quantifies the elements associated with wear, contamination, and additives. This information assists decision makers in determining the oil and machine condition.

Advantages. Very repeatable, proven technology.

Disadvantages. Cannot detect particles greater than 7 microns in size. Level of additive elements not necessarily indicative of additive package depletion.

Alarm Parameter. Alarms are based on change in relation to linear regression values - static limits secondary.

SPECTROSCOPIC ANALYSIS (ppm) ASTM D 5185

Date	Reference	1/11/15	12/7/14	11/2/14
Lab Number	107391	168113	168112	168111
Iron	0	277	142	55
Copper	0	10	6.1	4.3
Lead	0	4.7	0	0
Silicon	2	105	55	25
Boron	0	3.4	1.6	1.2
Phosphorous	47	56	57	48
Zinc	87	55	35	21

Elements

Possible Sources

Iron	(Fe)	Shafts, Gears, Housings, Piston Rings, Cylinder Walls
Copper	(Cu)	Brass/Bronze Alloys, Bearings, Bushings, Thrust Washers
Lead	(Pb)	Bearings, Anti-Wear Gear
Tin	(Sn)	Bearing Alloys, Bearing Cages, Solder
Aluminum	(Al)	Pumps, Thrust Washers, Pistons
Chromium	(Cr)	Roller Bearings, Piston Rings, Cylinder Walls
Nickel	(Ni)	Pumps, Gear Platings, Valves
Titanium	(Ti)	Exotic Alloy
Silver	(Ag)	Some Bearings
Magnesium	(Mg)	Detergent Additive, Coolant Additive
Silicon	(Si)	Dirt, Defoamant Additive
Boron	(B)	Anti-corrosion in Coolants
Sodium	(Na)	Detergent Additive, Coolant Additive
Barium	(Ba)	Rust and Corrosion Inhibitors
Calcium	(Ca)	Detergent/Dispersant Additive
Phosphorus	(P)	Anti-wear Additive, EP Gear Additive
Potassium	(K)	Coolant Additive
Molybdenum	(Mo)	EP Additive
Zinc	(Zn)	Anti-wear Additive
Vanadium	(V)	Turbine Blades
Lithium	(Li)	Grease Additive

THE CRACKLE TEST

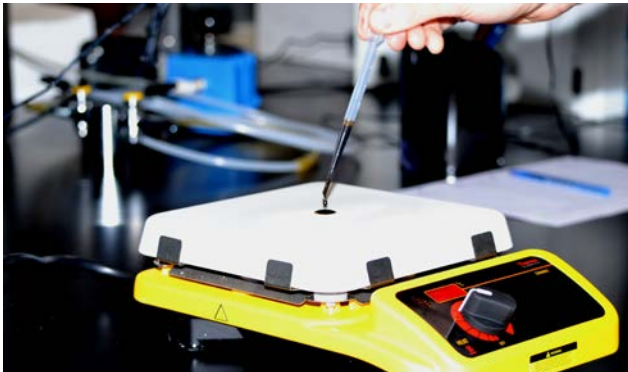
Quick screen to determine if a sample contains moisture.

Operating Principle. 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.

Significance. A crackle test is a good screening test to use to determine if a sample contains moisture.

Advantages. This is a very low cost test. It is a good way to determine the need for further moisture analysis.

Disadvantages. The crackle test can only detect moisture greater than approximately 0.05% (500ppm). For certain types of fluids, the minimum detectable concentration may be up to 0.2% (2000ppm). A sample with entrained gas often results in false positive results.



The Limitations of The Crackle Test

The limitations of the crackle test were documented in a recent study conducted by TestOil. A total of 493 samples, comprised of a variety of lubricant types, were run on a 400°F hot plate. The samples were assessed for a positive or negative crackle. These same samples were then analyzed for water contamination using a Karl Fischer titration. The table below summarizes the results of the study.

The lowest positive values represent those samples that exhibited a positive crackle and the associated Karl Fischer result, while the highest negative values represent those samples that clearly had water present according to the Karl Fischer results, yet didn't crackle. Clearly, the study demonstrates the variability in the detection limit inherent in the crackle test. As such, if water is an inherent problem, a Karl Fischer is recommended.

OIL TYPE	Samples Tested	Detection Limit (ppm)	Lowest Positive (ppm)	Highest Negative (ppm)
Turbine	111	110-610	110	610
Mineral Gear	62	240-1190	240	1190
Synthetic Gear	86	100-460	100	460
AW Hydraulic	86	320-750	320	750
Polyol Ester	36	340-1830	340	1830
Phosphate Ester	37	450-1140	450	1140
Engine	40	320-580	320	580
Wind Turbine (Optigear)	35	780-1070	780	1070
Combined	493	100-1830	100	1830

KARL FISCHER WATER

Quantifies the amount of water in the lubricant.

Operating principle.

(ASTM D 6304-C) Samples are placed in sealed vials which are placed in a temperature-controlled oven. The vial is pierced with a needle through which the water vapor travels to a titration vessel. Only water is evaporated while the oil sample remains in the vial to eliminate interferences and contamination. Water content is determined via a reaction with iodine. The titration endpoint is reached when the instrument detects unreacted iodine. Results are reported as either percent water or parts-per-million (ppm). These units are easily converted by recognizing that 1% = 10,000 ppm. Other methods of detecting water may be more appropriate.



Significance. Water seriously damages the lubricating properties of oil and promotes component corrosion. Increased water concentrations indicate possible condensation, coolant leaks, or process leaks around the seals.

Advantages. Accurate to .001%. Quantifies both emulsified and free water.

Disadvantages. Sulfur, acetones and ketones can sometimes trigger erroneous readings.

Alarm Parameter. 0.06% Marginal; 0.5% Critical.
Different lubricants may have different water limits.

KARL FISCHER WATER (%)

Date	Reference	1/11/15	12/7/14	11/2/14	10/19/14
Lab Number	107391	168113	168112	168111	168110
% Water	.001	.92	.81	2.604	.024

Forms of water in oil:

- Free water (emulsified or in droplets)
- Dissolved water

Water contamination causes:

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

Sources of water contamination:

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



DEMULSIBILITY

Measures the ability of a lubricant to separate from water.

Operating Principle. (ASTM D 1401)

Combine 40 ml of distilled water with 40 ml of oil in a graduated cylinder.

Place in a constant temperature bath and stir for 5 minutes. The amount of oil separation is recorded at 5 minute intervals over a period of 30 minutes.

Failure is considered an emulsion layer greater than 3ml at the end of the test. Oils 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.



The results are reported as such: [40-40-0 (30)]

ml oil	ml water	ml emulsion	Minutes
40	40	0	30

After 30 minutes this sample passed. It contained 40 ml of oil, 40 ml of water and 0 emulsion. This sample readily separates from water and therefore, has good demulsibility.

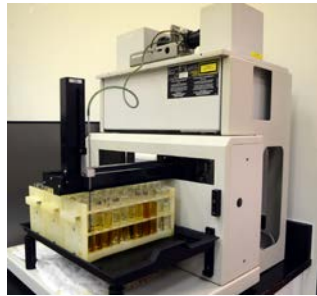
Significance. Lubricating oils used in circulating systems should separate readily from water that may enter the system as a result of condensation or other means. If the water separates easily, it will settle to the bottom of the reservoir where it can be periodically drained.

Alarm Parameter. >3 mL of emulsion after designated time period running demulsibility test (ASTM D1401)

FT-IR SPECTROSCOPY

Measures the chemical composition of a lubricant.

Operating Principle. Every compound has a unique infrared signature. Using a Fourier Transform Infrared (FT-IR) Spectrometer, these key signature points of a specific lubricant in the spectrum are monitored. These signatures are usually common contaminants and degradation by-products unique for a particular lubricant.



Significance. Molecular analysis of lubricants and hydraulic fluids by FT-IR spectroscopy produces direct information on molecular species of interest, including additives, fluid breakdown products and external contamination. Infrared spectrum of used oil is compared to baseline spectrum (baseline spectrum chosen from one of five groups depending on oil type). The differences in IR spectrum are quantified. Levels of oxidation, nitration and sulfate by-products are reported along with soot, water, and glycol.

Oil Degradation by chemical change:

- **Oxidation.** At elevated temperatures, oil exposed to oxygen from the air will oxidize to form a variety of compounds. The majority of these are carbonyl containing compounds e.g. carboxylic acid.
- **Nitration.** Results from the reaction of oil components with nitrogen oxides.

Oil Degradation by chemical change (cont.):

- **Sulphate.** Various oxides of sulfur and water react together to form acid. Their acid is neutralized by basic reserve and normally results in formation of metallic sulfates

Specific to Engine Oils

- **Soot.** Measure of the level of partially burned fuel in oil. Relevant for diesel engines.
- **Glycol.** Coolant leak

Advantages. Provides information on the overall degradation of an oil. Assists in optimizing oil change outs.

Disadvantages. Imprecise quantification of water and glycol levels.

Alarm Parameter. IR information is secondary in nature and provides additional information for the analyst recommendations.

RUST

Rust preventing characteristics of oil in the presence of water.

Operating Principle.

(ASTM D 665) A portion of the oil is placed in a beaker along with water and a polished steel rod. The beaker is then immersed in a heated bath and is stirred for 4 hours. At the end of the 4 hours, the steel rod is inspected for the presence of rust / corrosion.



Significance. Evaluates the ability of the lubricant to prevent the corrosion of ferrous parts should water become mixed with the oil.

Alarm Parameter. Pass or Fail

FOAM

Measures the foaming tendency of a lubricant.

Operating Principle. (ASTM D 892) Air is forced through a diffuser within a portion of oil creating foam. After 5 minutes of blowing, the amount of foam is recorded. Then, the sample is observed for the clearing of generated foam. Then either time of full dissipation is recorded or amount of foam remaining after 10 minutes.



Significance. The tendency of lubricants to foam can cause serious issues in systems with high-speed operations. Not only can foam cause inadequate lubrication but also other problems such as overflowing reservoirs.

Alarm Parameter. >450ml or 250 seconds

BASE NUMBER

Measures the reserve alkalinity in a lubricant.

Operating Principle.

(ASTM D4739)

A weighed amount of sample in solvent is titrated with a hydrochloric acid solution to a specified end point detected by electrodes across the solution. This technique is known as a potentiometric titration.



As an alternative, FTIR technology to determine Base Number (BN). A weighed amount of sample is reacted with a strong organic acid in a solvent. An infrared spectrum of the reacted solution is measured, and the BN is determined in units of milligrams KOH per gram.

Significance. The amount of reserve alkalinity in a lubricant is critical for certain oils. Often oil is fortified with alkaline additives to combat acid formation. The BN is at its highest as a new oil and decreases with service.

Alarm Parameter.

50% of new oil value = Marginal

25% of new oil value = Critical

Base Number (mg KOH / g)					
Date	Reference	1/11/15	12/7/14	11/2/14	10/19/14
Lab Number	107391	168113	168112	168111	168110
Base #	8.5	6.0	5.8	7.1	7.5

ACID NUMBER

Measures the acidity of a lubricant.

Operating Principle.

(ASTM D 974) A weighed amount of sample in titration solvent is titrated with a potassium hydroxide solution to a definite end point.



Description. Organic acids, a by-product of oil oxidation, degrade oil properties and lead to corrosion of the internal components. The AN is lowest as a virgin oil and can gradually increase with use. High acid levels are typically caused by oil oxidation.

Applications. All lubricating systems where extended drain intervals are considered. Limited applications for combustion engines.

Alarm Parameter. Alarms are based on increases from the trend using linear regression. Some OEMs specify limits (rare).

ACID NUMBER (mg KOH / g)					
Date	Reference	1/11/15	12/7/14	11/2/14	10/19/14
Lab Number	107391	168113	168112	168111	168110
Acid #	1.6	1.95	1.98	1.67	1.7

ROTATING PRESSURE VESSEL OXIDATION TEST (RPVOT)

This test measures oxidation stability of new and used oils.

Operating Principle. (ASTM D 2272) A sample of oil along with water and a copper catalyst is placed in a pressure vessel and pressurized with pure oxygen. Antioxidants present in the oil will act to resist oxidation, but once they have been consumed the oil 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 oil specifications. Results are considered to be in alarm when they drop below 25% of new oil value.

Significance. Oxidation is a critical mode of lubricant degradation. As oil oxidizes it forms acids and insoluble oxidation products, which can lead to formation of sludge or varnish. These degradation products can coat bearing and oil cooler surfaces, preventing adequate cooling of the bearings. Areas with tight tolerances such as hydraulic control valves can also become coated causing operational issues.

Alarm Parameter. 25% of new oil value.



FUEL DILUTION

Measures amount of fuel (%) present in an engine oil.

Operating Principle. A tiny drop of a sample is injected into a gas chromatograph (GC), where it is rapidly heated and vaporized. A steadily flowing carrier gas carries the vaporized oil through a long capillary column to a



detector at the other end. The various components of the sample travel through the column for differing lengths of time (retention time) depending on their physical and chemical properties. More volatile components (such as gasoline or diesel fuel) reach the detector much earlier than the lubricating oil. Software is used to plot a curve of retention time versus detector response, called a chromatogram. The chromatogram is integrated over a specified interval to measure the area under the curve. The concentration of fuel is quantified (in percent) by comparison of the measurement to calibration standards.

Significance. Fuel dilution in engine oils is measured by this process and returns a value in percent fuel dilution. Excessive fuel dilution can cause a drastic drop in viscosity which may lead to increased wear.

Alarm Parameter.

2% = Marginal

4% = Critical

PARTICLE COUNT

Measures the size and quantity of particles in a lubricant.

Operating Principle. (ISO 4406)

Light Blockage Principle. 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 particles are measured.



Operating Principle. Fluid Flow Decay Principle. Oil is passed through a screen of known mesh size (10 micron) and the time taken to plug the screen is determined. The instrument then calculates the distribution in the other predetermined size ranges by extrapolation.

Significance. *Optical particle counters* use the light blockage method and are particularly effective in clean systems such as turbines and hydraulics. However, this method yields inaccurate results in the presence of water or air bubbles. *Pore blockage particle counters* are based on the fluid flow decay principle. Their data is not affected by air bubbles or water.

PARTICLE COUNT (per ml) ISO 4406:99

Date	Reference	1/11/15	12/7/14	11/2/14	10/19/14
Lab Number	107391	168113	168112	168111	168110
ISO CODE	15/14/11	21/19/17	19/17/15	18/17/13	17/16/13
> 4	311	10156	2518	1456	899
> 6	114	2695	789	654	401
> 14	12	1256	198	78	52
> 50	0	25	5	2	1
> 100	0	12	2	0	0

Advantages. Excellent for “clean” systems (turbines, hydraulics etc.). Limits provided by equipment manufactures determine filter efficiency.

Disadvantages. Abnormal wear can be masked on systems with routinely high levels of particulate matter. Does not determine what TYPE of debris is in sample.

Alarm Parameter.

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

Target Cleanliness

Component	Pressure Range		
	>2500	1500-2500	<1500
Servo Valve	14/12/10	15/13/11	16/14/12
Proportional Valve	15/13/11	16/14/12	17/15/12
Fixed Piston Pump	17/15/12	17/16/13	18/16/14
Vane Pump	17/16/13	18/16/14	19/17/14
Pressure Control Valve	17/16/13	18/16/14	19/17/14
Gear Pump	17/16/13	18/16/14	19/17/14
Roller Bearing System			16/14/12
Journal Bearings			18/16/14

This chart demonstrates that with greater pressures, it is desirable to have cleaner systems to prevent system malfunctions.

ISO Cleanliness Code

The ISO cleanliness code references a three-digit code that represents the cumulative number of particles greater than 4, 6 and 14 microns in the fluid. The number of particles at each size range is cross-referenced to the following table to locate the ISO contamination code.

The code is written as three numbers with a slash, “ / ” , between them. For example: 21/19/15. The first number represents the code number at 4 micron, the second number the code number at 6 micron, and the third number the code number at 14 micron.

Making Sense Out of ISO Particle Counts

**ISO 4406:99
R4/R6/R14**

TestOil Particle Count	
Size (micron)	Particles
>4	3471
>6	1198
>14	107
>25	8
>50	2
>100	0

There are 3471 particles greater than 4 microns.

There are 1198 particles greater than 6 microns.

There are 107 particles greater than 14 microns.

= ISO 19/17/14

Number of Particles per ml		
More than	Up To	Range Number (R)
80,000	160,000	24
40,000	80,000	23
20,000	40,000	22
10,000	20,000	21
5,000	10,000	20
2,500	5,000	19
1,300	2,500	18
640	1,300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2.5	5	9
1.3	2.5	8
.06	1.3	7
0.32	0.64	6
.016	0.32	5
0.8	0.16	4
0.4	0.08	3
0.02	0.04	2
0.01	0.01	1

What does it mean?

Using ISO 4406:99, a sample is assigned a cleanliness rating using the chart on the right. To arrive at the reading test oil performs a particle count to determine the number of particles greater than three size ranges parentheses 4, 6, and 14 μm) in 1 mL of the sample. The chart on the left depicts the actual particles of one of our particle count tests. This particle distribution translates to an ISO 4406:99 rating of 19/17/14.

FERROUS WEAR CONCENTRATION

Measures the amount of ferrous wear in a lubricant.

Operating Principle. A wear particle analyzer quantifies the amount of ferrous material present in a sample of fluid. A measured amount of sample is inserted into the analyzer and amount of ferrous material is determined by change in magnetic flux. This change is then converted into ferrous



concentration in parts per million. Instead of using a light sensor to measure particles and report a unitless number, this instrument measures concentration and reports the results in parts per million. Using this method, there are no interferences with non-ferrous particles.

Significance. This test gives a direct measure of the amount of ferrous wear metals present in a sample. Trending of ferrous concentration reveals changes in the wear mode of the system.

Advantages. Excellent trending device for “dirty” systems such as large splash lubricated gearboxes. No particle size limitation.

Disadvantages. Does not detect non-ferrous particles.

Alarm Parameter. Alarms are based on change in relation to linear regression values, static limits are secondary.

SECTION 7:

Advanced Oil Analysis Tests

ANALYTICAL FERROGRAPHY

Analytical Ferrography is among the most powerful diagnostic tools in oil analysis today. When implemented correctly it is an excellent tool when attempting to diagnose an active wear problem.

The test is qualitative, which means it relies on the skill and knowledge of the ferrographic analyst. While this can have definite advantages, the interpretation is somewhat subjective and requires detailed knowledge of wear debris failure modes.

The test procedure is also complex. As such, there are significant costs in performing Analytical Ferrography not present in other oil analysis tests.

Nevertheless, if time is taken to fully understand what Analytical Ferrography uncovers, most agree that the benefits significantly outweigh the costs and elect to automatically incorporate it when abnormal wear is encountered.

Analytical Ferrography

Allows analyst to visually examine wear particles present in a sample.

Operating Principle.

To create a ferrogram, a sample of oil 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. Non-ferrous particles are easily detected because they deposit randomly across the slide.



The ferrous wear particles line up in rows with the largest particles forming rows at the top of the ferrogram. Non-ferrous particles are easily detected because they deposit randomly across the slide.

Significance. A trained analyst visually determines the type and severity of wear deposited onto the substrate by using a high magnification microscope. The particles are readily identified and classified according to size, shape, and metallurgy.

Advantages. Best method for determining severity and type of wear present. There are no particle size or metallurgy limitations. Wear can be documented by digital photography.

Disadvantages. Subjective results dependent upon the analyst. The test is time consuming, labor intensive, and, therefore, expensive.

Examining The Evidence

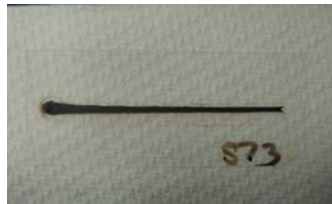
The particles contained in a lubricating fluid carry detailed and important information about the condition of the machine components.

Analytical Ferrography requires extensive analyst training to properly interpret the results. Evaluation of a ferrogram can differ between analysts due to the subjectivity of the analysis. The level of training and experience will also impact the accuracy of the ferrographic evaluation.

A trained oil analyst can visually determine the severity of wear on the unit using a microscope to classify the particles. The analyst can evaluate the concentration, size, shape, composition, and condition of the particles, which indicates where and how they were generated.

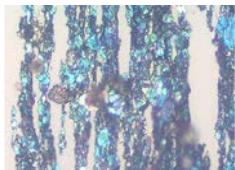
A test report for Analytical Ferrography typically includes a photomicrograph of the debris found, along with specific descriptions of the particles and their suspected cause.

The following pages are the photomicrographs and classifications of wear that are detected using Analytical Ferrography.



Particle Identification

Normal Rubbing Wear



Description. Ferrous particles, less than 30 microns in size. Some Sources: Rubbing wear is typically found in both reciprocating and non-reciprocating units.

Comments. On a ferrogram the particles tend to align in chains. Normal ferrous wear can be categorized as low alloy, cast iron and high alloy steel.

Small Cutting Wear



Description. Shaved metal particles that look like wood shavings from a lathe. Seen in sleeve bearings and shaft couples. Abrasives embedded in soft bearing or burrs on hardened metals create these wear particles.

Comments. Worm drives have a tendency to create this type of particle. When seen it indicates abnormal wear.

Laminar Particles



Description. Thin, smooth particles which appear to have been rolled flat. Roller bearings, areas where high-pressure angled or lateral contact occurs.

Comments. Wear created by extraneous particle if the laminar has small holes or indents.

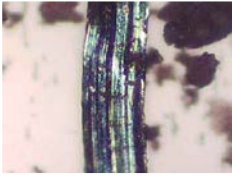
Fatigue Crack Spheres



Description. A relatively smooth spherical particle. Spheres are created in bearing fatigue cracks, typically roller bearings.

Comments. Spheres are often precursors of bearing spalls. A large increase in quantity is indicative of imminent spalling.

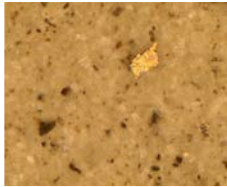
Severe Sliding Wear



Description. Metallic particles, both normal and severe, with sliding striations along one or more surfaces. Sliding wear can be created when two parts of a machine scrape together.

Comments. Sliding striations are often a good clue as to what part of a machine is causing wear.

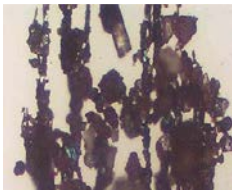
Contaminants



Description. Dirt, sand and other silica particulate. Contaminants can enter into a system by a variety of ways: poor seals, incorrectly installed breather, during oil change, etc.

Comments. Some can appear like crystals. Contaminants are easily identified by using only the transmitted light source on the microscope.

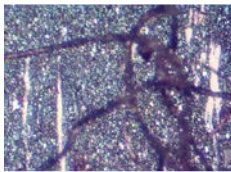
Dark Metal Oxide Wear



Description. Grey to black chunks with a semi-metallic appearance and mottled edges. Some Sources: Breakdown of boundary film, excessive operating temperatures, lubricant oxidation.

Comments. The darker the color, the more severe the oxidation of the particle.

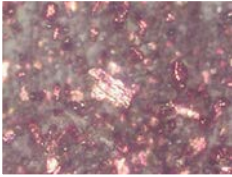
Fiber



Description. Fibers are thread like material made of asbestos, paper, glass or a synthetic material. Most common source is filter material. Could be from machine housing, cleaning rags, or air contaminants.

Comments. A small amount of fibrous material in oil is common.

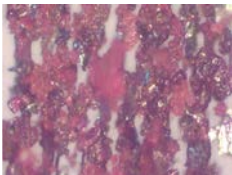
Non-Ferrous Metal Wear



Description. Any metallic particle that is not ferrous. Most common include aluminum, copper alloy, chrome, and babbitt. Non-ferrous wear can be created specific components within the machines.

Comments. Non-ferrous metallic wear can be across the entire length of a ferrogram. These particles will not be aligned with the ferrous wear chains.

Red Oxide



Description. Iron oxides or rust. It appears as orange/red in color. Red oxides are produced when moisture enters into a system. Water does not have to be present when red oxides are seen, as they are often difficult to filter out of oil.

Comments. Red oxides are not necessarily magnetic like ferrous wear. Alpha hematite is paramagnetic and will be found on all regions of a ferrogram.

VARNISH POTENTIAL ANALYSIS

Lubricating oil in gas turbines and hydraulic systems is unfortunately subject to the ravages of varnish. It is well-documented that varnish is an insoluble contaminant comprised of oil degradation by-products and sometimes depleted additive molecules. It is generally caused by some type of thermal (heat-related) stress placed on the oil. The debilitating effects of varnish include the loss of operating clearances within machinery and a loss of heat transfer due to thermal insulating. As more operators face the prospect of varnish in their lube oil systems, they are turning to oil analysis labs for answers.

Varnish potential, or the measure of a lubricant's tendency to form varnish deposits, cannot accurately be measured using



standard oil analysis tests. The specific lubricant degradation by-products associated with varnish formation remain elusive for tests like viscosity, acid number, spectroscopy, and particle counts to measure. For this reason specific tests have been developed which can assess the likelihood of varnish formation in a lube oil system.

Varnish Potential Analysis correlates the results of several individual tests to provide a complete picture of a lubricant's varnishing potential. These tests include Acid Number, Karl Fischer, Particle Count and FTIR Spectroscopy (outlined in Section 6), and the following tests:

Membrane Patch Colorimetry

Operating Principle. 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 deltaE value in the CIE LAB scale.

Significance. The delta E value can be trended and used to monitor oil condition with regard to varnish potential.

Alarm Parameter.

23 marginal, 33 critical



Ultra Centrifuge

Operating Principle. As an oil 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 oil will be forced to the bottom of the centrifuge tube.

Significance. The amount of deposited contaminants can be visually compared to a scale to quantify the level of contaminants present in the oil.

Alarm Parameter. ≥ 5 marginal ≥ 7 critical

Remaining Useful Life Evaluation Routine

Operating Principle. Antioxidants are removed from the oil by mixing sample with a solvent. The dissolved antioxidants are then measured using linear sweep voltammetry.

Significance. The remaining useful life of the used oil can be estimated by comparing the levels of antioxidants in the used oil sample to the levels present in a virgin reference sample of the same lubricant.

TURBINE OIL ANALYSIS

Turbines are widely used in the power industry and are generally run on continuous operating schedules. Maintenance professionals are challenged with implementing tactics that enhance equipment performance given the turbine's extreme operating conditions such as high temperatures, water contamination and lengthy periods of time in service.

Lubrication plays a vital role in supporting turbine performance. Achieving long-term operating success requires testing in-service oil on regular intervals to detect degradation issues early enough so they do not lead to costly or catastrophic consequences. By taking this proactive approach, maintenance professionals will help promote optimized turbine efficiency and generate valuable cost savings.

Turbine oil testing should provide a detailed analysis of the health of the turbine oil through the following tests:

Test	Method
Acid Number	ASTM D974
Color	ASTM D1500
Demulsibility	ASTM D1401
Foam	ASTM D892
FTIR	TestOil Turbine Method
Karl Fischer Water	ASTM D 6304 C
Membrane Patch Colorimetry	ASTM WK27308
Particle Counting	Pore Blockage/Optical
Rotating Pressure Oxidation	ASTM D2272
Ruler	ASTM D6971
Rust A	ASTM D665 Procedure A
Spectroscopic Analysis	ASTM D5185
Ultra Centrifuge	IWI-251
Viscosity	ASTM D445

SECTION 8:

Non-Fluid Analysis

FILTER DEBRIS ANALYSIS

The Filter Debris Analysis (FDA) instrument is a self-contained unit which employs an automated method for filter washing to extract all inorganic debris from the filter with high



repeatability and reproducibility. The modular design can accommodate irregular filters such as large sized filters and bag or sock filters. A used filter is placed in the system wash chamber and all debris is removed from the filter using a combination of fluid and compressed air. In addition, attachments are connected to the filter in order to seal them and perform a true “back-flush” with the solvent and compressed air. The attachments are also capable of performing a more repeatable wash of the filter, and achieve a better representation of debris caught within the media for analysis. The wash fluid carrying the filter debris is collected and then analyzed in the lab.

Once testing is complete the data is assembled in a comprehensive test report. Analysts review the data and conclude an appropriate determination of the machine's condition. In addition, the report displays images of the filter and patches, microscopic views of the patches, and pie charts displaying elemental data.

Benefits of Filter Debris Analysis

In traditional oil analysis, the only particles available for analysis are those circulating in the oil (smaller than the filter size) or immediately released in the oil prior to filtering. Given the fine filtration used in rotating equipment today to produce longer life cycles, 95% of the wear debris that could provide useful insight into machinery condition is caught in the filter and never ends up in an oil sample. Typically, all the debris is discarded with the filter. Increasingly, fine filtration is making conventional monitoring techniques less effective at providing reliable indication of machinery component wear. FDA captures this lost information and identifies the specific components that are wearing, providing improved diagnostic and prognostic information about impending failures.

- FDA fills a gap left by atomic emission spectroscopy and analytical ferrography with improved diagnostic and prognostic information about impending failures.
- FDA captures valuable data lost by fine filtration.
- FDA provides a fingerprint of what has happened since last filter change.

FDA allows accurate quantification of elemental particle debris without interference from the oil.

GREASE ANALYSIS

A complete grease analysis program monitors contamination levels, grease degradation characteristics and wear rates.



Contamination: Contamination of grease is detrimental to the lubricating quality of the grease. Whether the contamination is from water, dirt, or an incompatible grease, the performance levels of grease are severely impaired. Contamination can cause serious bearing damage if gone undetected and thus uncorrected.

Degradation: As grease is used the beneficial additives that are blended into the grease to protect against base oil oxidation are depleted. Once these additives are depleted, the grease will become oxidized and the designed performance characteristics will be dramatically altered. One of the most important performance characteristics, is the viscosity of the base oil and the base oil viscosity will increase when the antioxidants can no longer protect the oil.

Wear: Measuring the concentration, metallurgy and topographical characteristics of wear metals in used grease not only gives the user a measurement of how much wear is taking place, but the source and mechanisms of the wear. Wear rates can be compared over time, for a single bearing and/or against like bearings to evaluate abnormal conditions. When coupled with other technologies, such as vibration analysis (where applicable) metals analysis becomes an indispensable part a complete condition monitoring program.

MATERIALS IDENTIFICATION ANALYSIS

Routine oil analysis test slates are geared towards testing liquid lubricants. The problem occurs when the sample collected is a non-liquid material. The standard instrumentation used in oil analysis laboratories cannot handle samples in other physical states, such as solids, or semi-solids (like sludge and gels). In addition, there are times when sampling fails to collect a representative portion of the lubricant, such as a portion of the sump containing large particles or strange debris that may be found during an oil change.

TestOil has developed Materials Identification Analysis (MIA) for identifying foreign materials, also known as sludge and varnish, and to identify a potential source. MIA is a process; it is not a standardized list of tests. Our analyst creates a testing agenda that is unique to each sample based on the lubricant type and information provided by the customer including, the type of machine involved, activity of the machine, and other details that may shed light on the root cause of the problem.



TESTOIL
REMARKABLE IN EVERY WAY

www.TestOil.com