
The Lubrication Field Test and Inspection Guide

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Introduction

Most people associate oil analysis with scientific laboratories and exotic analytical instruments. Indeed, oil analysis is usually done this way and it generates considerable value and benefit. However, there is a growing trend among practitioners to enhance the value of oil analysis further by frequently applying simple onsite methods. Such field and plant-level techniques don't require university training or cutting-edge technologies, but rather the use of inexpensive devices and inspection methods, especially sight, sound, smell, and touch. After all, there are no instruments or technologies more capable and sophisticated than human senses combined with an experienced mind.

Another important advantage of using simple on-site oil analysis tests is the positive impact it has on the organization. The lab is cold and distant. It produces meaningful, but confusing information. When an organization employs on-site methods for analyzing its oil, they have ownership in the process. It is their data and it is their program. Suddenly, the information is affecting decisions about managing lubrication and equipment maintenance. Interest in effectively managing lubrication increases as technicians and crafts people talk informally amongst themselves. Slowly, you see the entire organization begin to take pride in assuring lubrication excellence. The pride gives way to passion and all of the sudden we see the right oil going into the right machine; filters that are malfunctioning are replaced; reservoir caps get properly replaced after a top-off, etc. The sophisticated analysis information produced by the lab takes on a new meaning and is seen in a new light. Likewise, management begins to depend on oil analysis to the point that important maintenance decisions aren't made without it. The path to lubrication excellence is lined with people. Get the people issues right and the technical issues will resolve themselves. Simple on-site oil analysis produces ownership, pride and passion, and gets the people issues right.

This book explains the use and application of several such methods that can be easily applied during common walk-around inspections, maintenance, and oil sampling. The general procedure of their use will be covered including the interpretative tactics relating to the health of the oil and machine. Because the maintenance organization is changing to emphasize planned and condition-based activities, so too, the skill set of the maintenance professional will need to change accordingly. In lubrication this new skill set is a nurturing activity involving a heightened sense of awareness about changing oil properties and machine conditions. When done onsite, it is not unlike the Indian guide who, using nothing but his senses, is totally alive to his surroundings, from the subtle movement of approaching wildlife to the faint scent of fruit-bearing trees.

Benefits of Instant Information

Occasionally oil analysis labs are asked to quantify the amount of moisture in a sample that is so contaminated that a thick layer of water rests at the bottom of the bottle. Common sense tells us that this sample did not need to go to a laboratory since a simple desk ruler would have provided an adequate estimate of the water present. Because laboratory analysis was requested, valuable time was lost that instead could have been applied towards solving the water ingress problem. The technician who took the sample should have known how to inspect for water and initiate the corrective action.

Examples such as this are not uncommon. It is not because such problems are so prevalent; it is because there is no real understanding of what to look for and its meaning to machine reliability. The solution lies in a strong interest by management to modernize lubrication and oil analysis practices combined with a generous amount of training to those who have routine contact with lubricating oils and machinery. This training should include basic inspection skills relating to the oil in detecting such things as contamination, oxidation, thermal degradation, filter condition, and wear debris (machine condition).

The following is a listing of common ways an in-service lubricating oil can be inspected and analyzed for a variety of key properties and operating conditions. This list will enlarge over time as new practices surface and traditional practices are refined. To this end, the authors are interested in any contributions.

Safety Considerations

Safety is of the utmost concern when performing these tests. Be sure to follow the following safety precautions.

- Check lube temperature prior to sampling. If greater than 120° F, wear appropriate thermal insulating gloves to protect hands.
- Wear protective eyewear at all times when performing oil sampling or analysis.
- Wear latex type gloves to protect hands when handling lubricants, reagents and solvents. Confirm chemical compatibility between lubricants, reagents, solvents and the glove material.
- Wash any lubricant that contacts the skin immediately with a high quality industrial hand cleaner and plenty of water.
- Should any lubricant, reagents or solvents get into the eye, refer to instructions in the appropriate material safety data sheet (MSDS) and seek immediate medical care.
- Should any lubricant be ingested, refer to instructions in the appropriate material safety data sheet (MSDS) and seek immediate medical care.
- Dispose of used reagents, solvents and lubricants properly.
- Never perform these tests near an open flame, or in a poorly ventilated area.
- Do not smoke when performing these tests.

Potential Sources of Interference (Error)

- Failure to ensure that the sample is drawn from the same point each time due to variable distance into the tank or sump.
- Failure to ensure that the sample is drawn from the same point each time due to the drop tube coiling up, in or out.
- Failure to ensure that the machine is sampled during operation, or the same time period after shutdown, each time.
- Scraping side-wall deposits into the drop tube when entering the tank or sump.
- Picking up bottom sediment and water.
- Contaminating the sample during handling.
- In circulating systems, failure to obtain live samples downstream of ingestion points.
- Contamination of the plastic tubing.
- Contamination from the vacuum pump.

Visual External Machinery Inspection

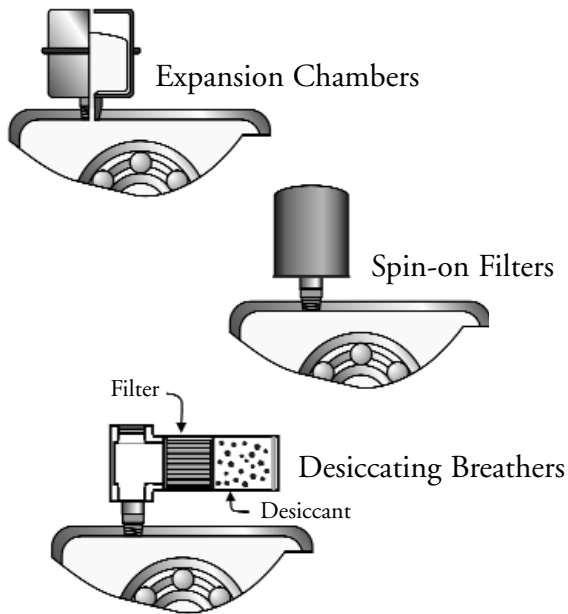
The outside appearance of machinery can help us come to certain conclusions about the oil and abnormal conditions inside. Operators, technicians, millwrights and maintenance personnel should all be alert to visual telltale signs of trouble. Below are few things to watch for during routine walk-around inspections:

Ventilation

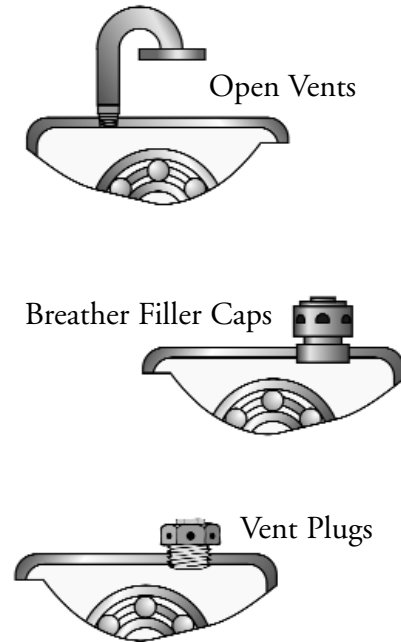
The quality and condition of the vents/breathers have a large impact on oil condition. They should be secured tightly to the reservoir top or machine casing. Breather elements should be inspected frequently and changed according to a schedule. Dehydrating breathers will also need the desiccant replaced "on condition." Occasionally fumes/vapors can be seen billowing out of the vent. This could be steam or another volatile contaminant. If steam is suspected, this might be confirmed by placing a mirror over the vapor. Fogging of the mirror generally confirms steam. This could be due to exceptionally high operating temperatures and a sudden ingress of water into the oil.

Occasionally foam may be observed extruding out of a vent. This is a serious condition suggesting key properties of the oil have changed sharply. There are many causes of foam formation relating to contamination, defoamant additive, oil degradation, oil level, and mixed lubricants.

Good, Protective Ventilation



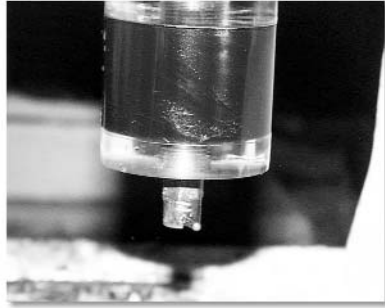
Poor, Ingression Prone Ventilation



Sight Glasses

As the name implies the sight glass permits visual observation of the oil in-service. However, more information can be obtained other than the level of the fill. When taken together with other information a number of general conclusion about the oil can be made.

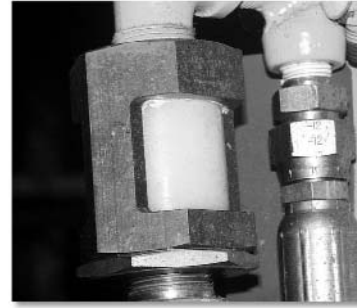
- A sudden increase in oil level suggests water contamination (e.g., heat exchanger rupture), process chemical contamination, fuel dilution, or incorrect oil fill.
- A sudden decrease in oil level suggests internal or external leakage.
- Sight glass fouling (heavy deposits on glass wall) might be an indication of sludge and high varnish potential. This could be due to oxidation, thermal failure, or aeration.
- The color and condition of the oil can be observed as well. This is especially true for tank/sump mounted sight glass used as level gages. In-line sight glasses are less helpful in this area. Darkening oil and cloudy oil suggest problems with oxidation, wrong oil, or contamination. Foam in the sight glass is always a concern. Occasionally a layer of water can even be observed in the level gage.
- BS&W (bottom sediment and water) bowls are sight glasses located at the base of machine reservoirs and sumps. They collect contaminants that settle in the oil and are extremely helpful in alerting operators to water contamination and heavy sediment/sludge. At times the accumulations of wear particles could appear. Exercise caution in cold climates. The acrylic bowls, if filled with water, can freeze rapidly causing a break and total loss of lubricant.



BS&W Bowl



Level Gage/Sight Glass



In-line Sight Glass
Shows Water

Note, varnished or fouled (clouded) sight glasses and level gages will obscure the oil level and quality. Service and clean sight glasses as required.

Other Visual Observations Relating to the Oil

- Exhaust pipe smoke may indicate problems with crankcase oil. An engine that is burning a lot of oil may show a bluish exhaust smoke. Coolant in the oil may appear as white smoke (vapor). Over-fuelling conditions lead to black, sooty smoke.
- Leakage may be due to a failed seal or pipe connection. However, a moderate increase in leakage may be caused by low oil viscosity (wrong oil, cracked oil, diluted oil, or hot oil) or low surface tension. A loss of surface tension occurs when oil is contaminated with water, floor soaps, detergents, or process surfactants.
- Hydraulic systems with aerated fluids will run hot and sluggish.

VISUAL INTERNAL MACHINERY INSPECTION

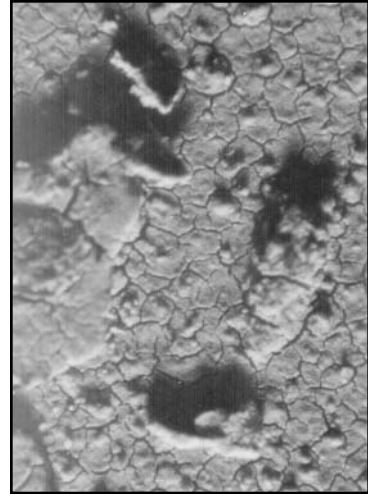
Some internal inspections of the machine can be performed “on the run” while others require a shutdown. These are critical inspections that can reveal very important pieces of information about the oil without the need for instrumentation. Those who routinely do oil changes, filter changes, flushing, repairs, and PM inspections should be alert to all the symptoms of non-conforming conditions.

The Used Filter

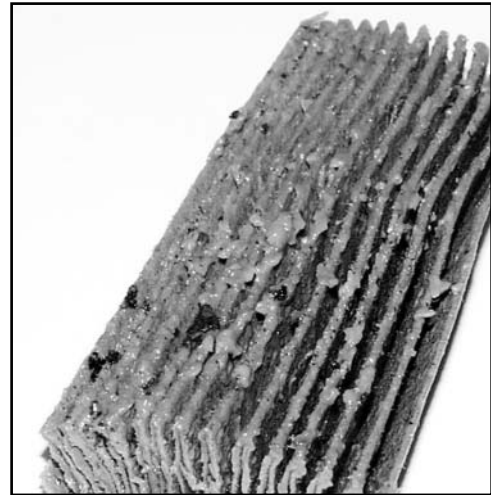
The used filter offers a repository of information about the history of both the machine and the oil. There is a wide assortment of problems than can be observed.

- A used filter having swollen and/or very wavy paper is typically due to water contamination. This occurs with cellulose filter media, not glass fiber media.

-
- If the filter media is heavily loaded and has the appearance of a dry creek bed (see photo) this suggest large amounts of airborne contaminants have ingressed into the oil. Check breathers, seals, and hatch covers.
 - The used filter surface may have more of a seashore appearance (i.e., an assortment of colors, sizes, shapes, etc.). This could be the result of debris left behind during repairs or the installation of a dirty hydraulic hose.
 - A high concentration of bright metal particles on a spent filter having a glittery appearance is wear debris and is always a cause for concern.



- If the filter is coated with sticky sludge-like material the oil is probably failing. This sludge may have the appearance of drab green to dark black. In diesel engines, a sticky mayonnaise-like deposit on the filter is probably due to antifreeze ingress (glycol).
- Metal surfaces on the filter can also pick up varnish coatings. This might appear as a gold tint on the filter element's end-cap and perforated rap. There are various causes of varnish. Refer to reference #1 for specifics.
- Paint chips, hose fibers, corrosion debris, coal dust, fly ash, process materials, seal debris, etc. are all occasionally observed on filter surfaces. Once in a while the debris in question should be rinsed off the used filter with a solvent and transferred to a membrane for examination by microscope. This procedure is described later.



Filter Coated with Sludge-like Material Could Indicate Additive or Base-Stock Failure

Internal Tank Inspections

It is not always possible to gain easy access to tanks, housings, casings, sumps, and other oil compartments. However, if possible, the internal conditions should be inspected by someone with a trained eye.

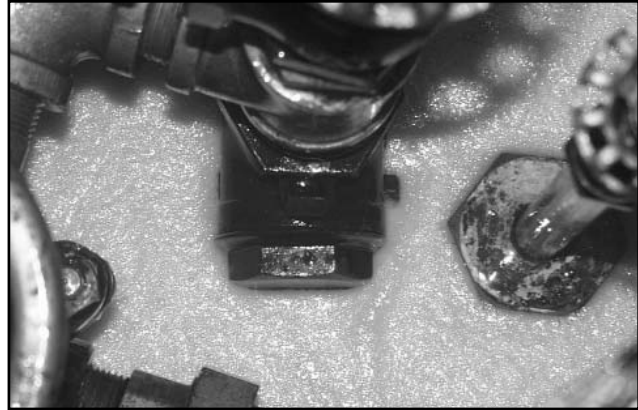
- The headspace of many tanks maintain a continuous moist fog. This can lead to a build up of water in the oil, especially accumulations at the tank floor. The moisture in the headspace typically condenses on the



Cleanout Hatch Shows Machine is a Rainmaker

ceiling then drips or runs to the bottom forming puddles. Tanks like this are referred to as “rainmakers.” This can be observed by touching the inside ceiling with your fingers. If moisture is picked up (sometimes rust as well) the risk is great.

- Rust/corrosion is a major problem with many machines. When corrosion is occurring in the reservoir it is very likely to be occurring elsewhere on machine oil-wetted surfaces.



Foam in Reservoir

- If large tanks and reservoirs can be accessed during operation (hinged hatches, access covers, etc.), using a flashlight, look for aeration, foam, floating debris, and excessive turbulence. When the system is at rest, a stable foam is an indication of problems with the oil (contamination, oxidation, etc.) including the defoamant additive.
- Heavy varnishing sometimes occurs inside of tanks and reservoirs. The appearance can range from gold colored tank walls to thick dark deposits. Occasionally the “Fruit Roll-up” effect is observed when a putty knife is used to peel away a tarry adherent film. A varnish gage can be used to rate the severity.

Inspection of Working Surfaces

Working surfaces include gears, bearings, cams, valve components, and pistons. These surfaces experience rolling and/or sliding tribological contacts during operation. During routine PM’s and repairs they should be examined for corrosion, abrasion, varnish, burnishing, denting, cavitation, galling, pitting, fretting, tempering, fatigue, etc. Many of these problems are oil related. For instance, a highly polished surface may be caused by an overly aggressive EP additive or high concentrations of abrasive fines in the oil. There are many references available to guide in the inspection and interpretation of surface abnormalities and as such no detailed description will be added here.

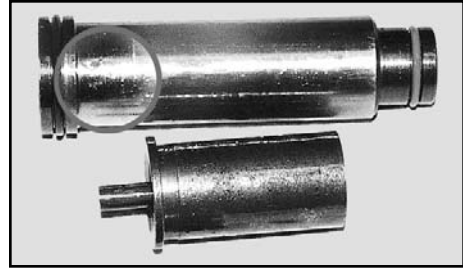
Other Internal-State Observations

- Magnetic plugs and chip collectors are occasionally used in system tanks and return lines. They can provide a quick picture of past and ongoing active wear. If they are inspected at uniform time intervals the rate of wear can be estimated. Debris particles can occasionally be transferred to patches and slides for microscope examination. One of the advantages of using magnetic chip collectors is the fact that the particles are usually presented in the original shape and size. Otherwise these particles tend to get reworked by the moving elements, crushing them into smaller unidentifiable sizes.



Magnetic Plug

-
- Sludge and varnish is often observed on machine parts. The spool on a directional control hydraulic valve might have a gold tint for instance. The practice of removing the spool and pressing it hard against a white sheet of paper makes it easy to assess the extent of this adherent material. This transfers the varnish for observation. Dark scab-like deposits are occasionally observed on thrust bearing pads, pistons, and seal faces. Bearing housings and drain lines might accumulate hard carbon stones and tar-like deposits. And, sludge and polymers are sometimes seen on strainers and screens. All of these conditions suggest problems with the oil and the quality of lubrication.



- Some deposits are agglomerates from additive precipitants and wax condensates. These can appear light brown to bright yellow. Some of this material is associated with cold operating conditions and water contamination. For instance, a waxy curd-like deposit on engine rocker covers and oil pans may be rich in additive elements and water. Bright yellow deposits from certain machines may be high in sulfur from additives and/or process gases such as H₂S (hydrogen sulfide).
- If a centrifugal separator is used to remove free water there will be concentrations of sediment as well. If this sediment is analyzed some of the material will be found to be additive floc, oxidation products, wear debris, and contaminants. Look for a marked change in the appearance and consistency of the sediment.

VISUAL INSPECTION OF THE OIL IN A SAMPLE BOTTLE

A trained eye can typically pick up a host of useful information by careful inspection of the oil in the sample bottle. As with most endeavors there are certain tricks to being successful. Training and practice is key. Below is a brief outline of possible visual analysis techniques and strategies:

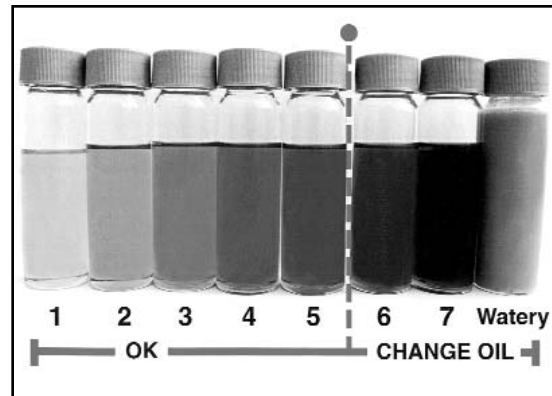
Color

An oil's color comes from the light transmitting through it. Different colors are formed depending on the concentration and type of light-absorbing compounds suspended in the oil. These "chromophoric" compounds are commonly called color bodies. With new oil, the higher the oil's viscosity the more likely naturally occurring color bodies will exist. Also, naphthenic base oils and oils high in sulfur and aromatics are typically darker in color.

The degradation and contamination of used oils can have a marked effect on the resulting clarity and color. Coke and carbon insolubles from thermal failure (high localized temperatures) can sharply darken an oil. The mixture of incompatible oils can cause darkening from additive floc and other reaction products that form. Contaminants such as soot, process chemicals, detergents, and entrained air can lead to a change in the color and brightness of the oil. Photo catalytic reactions (UV) from exposure to sunlight (bottle oilers, etc.) can sharply discolor oil.

Oxidation is yet another common cause of color bodies forming and an over-all darkening to occur. The color change is more acute in oils high in sulfur and aromatics. There is a synergy between aromatics and sulfur compounds that appears to degrade the oil and form the color bodies during thermal oxidation reactions.

In many cases abnormal discoloration is a reliable field indicator of an oil that is distressed. In one study, 90 percent of lubricants that were abnormally dark were also found by laboratory analysis to be non-compliant.



Ref: ARCO

There are other cases, however, where a dark oil may not be a real concern. The combination of experience with the specific lubricant and routine analysis is necessary in making these determinations.

The best strategy is to deploy a prepared color gage for standard oil types used (see photo). Used oils can be compared to the gage periodically. As shown in the photo, a condemning limit can be specified based on past oil analysis experience. In addition to comparing the current sample to a gage, a comparison can be made to the new oil (retained) and to the previous sample (retained).

Emulsions

Water emulsified in an oil can take on different forms and appearances. For many light industrial oils the simple fact that water forms a stable emulsion is often an indication of an oil that is distressed or contaminated. If a haze remains in the oil sample after several hours without agitation the oil might be contaminated, oxidized, or mixed with another oil. If in doubt, suspend a trace amount of water in the new oil, agitate, and look for a stable emulsion. If the new oil fails to form a stable emulsion the used oil may indeed have a problem. Laboratory analysis can be used to confirm.



Occasionally most of the water will separate efficiently out of the used oil but a thin layer, between the oil and water phase, will remain behind. This layer is a tight emulsion commonly called a “cuff” (see photo, center & right bottles). Used oils that retain a cuff are typically not acceptable for continued service.

Occasionally an oil has a water content near that of saturation (100 percent relative humidity) and only a slight haze might appear. Sometimes no haze appears at all. If such a borderline water concentration is suspected one approach would be to place the sample in a refrigerator for a few

hours. If the haze is more turbid (denser) after the oil was chilled there was indeed a borderline water concentration. The visual crackle (to be discussed later) is yet another approach to confirm trace concentrations of emulsified water.

Separated Free Water

The highly polar nature of water readily attracts many water-soluble contaminants. If the water phase is dark and murky the oil is probably heavily contaminated (see photo). However, if the water is relatively clear the opposite may be true.



Sediment Rating Chart Ref: Mobil Oil

Sediment

A sample with visible sediment is an indication of a highly contaminated oil. This can occur due to ineffective filtration or lack of filtration. Additive floc and reaction products with water can also form heavy precipitants. Samples taken from the bottom of reservoirs and sumps are often loaded with sludge and insoluble matter. In all cases where sediment is observed there is reason for concern about the quality of the lubricant and contamination control practices.

Froth

Sometimes during sampling there is gaseous release from the oil. This appears as a rapidly forming froth in the sample bottle. In a hydraulic system a sample taken from a pressurized line will occasionally release dissolved air. This is an indication of excessive amount of entrained air in an unpressurized zone, either at the reservoir or due to a suction line leak.

Lubricants from gas compressors and refrigeration system compressors are often loaded with low boiling point volatiles. During sampling the dissolved gas or refrigerant emerges out of solution in the form of froth. Excessive amounts of these gasses can substantially degrade the quality of lubrication.

Lumps and Fish-Eyes

Occasionally there are lumpy semi-solid suspensions in used oil. These may be associated with gels from thermal and oxidative reactions. Or they may be generated from an incompatible interaction between two oils. Gels might also be media migration from starch-based superabsorbants used in water-removing filters. Yet another possible source of such suspensions is the methyl silicon defoamant additive. Occasionally these micro-globules of silicone will coalesce forming large lumps in the oil. Sometimes this is due to ineffective introduction of the defoamant additive during formulation. Finally, aftermarket retrofit additives will sometimes incite a reaction (with contaminants and/or additives) forming semisolids.

These semisolids are typically extremely difficult to observe directly due to the fact that their refractive index may be nearly identical to that of the oil. For instance, a Pyrex glass rod in a beaker of water is readily visible (different refractive indices) however the same glass rod in corn oil becomes invisible (same refractive indices). In such cases where gels are suspected they may be observed by slowly pouring the oil over the rim of a beaker. The appearance of lumps and “fish eyes” across the edge flow of the beaker is a positive indication.

Streamers

Two incompatible oils mixed together may produce an odd refractive index effect referred to as “streamers.” This is similar to the optical distortion that occurs as heat is released from hot surfaces. Streamers can also be observed when rubbing alcohol is mixed with water, until the two liquids are fully in solution. The appearance of streamers in used oils is rare but is always an indication of a problem with the lubricant.

OTHER SENSORY TESTS

Audible Symptoms of Oil Related Problems

Is the old saying that a “singing gear is a happy gear” true? Well, it depends entirely on the song. If a strong rhythmic beat is produced there is a failure on the horizon. Maybe the song cycles like a 12-bar blues, again problems ahead. However, if the song is high-pitched and monotonous the gear may be “in tune” and well lubricated. Some gear units, by design, are noisy such as right-angled spiral beveled drives that often produce an annoying whine.

In general, impending gear failures will really sing and changes in such things as lubrication, alignment, and balance may be first observed by a change in audible pitch or rhythm. Operators are best suited to notice such changes.

Rolling element bearings, hydraulic pumps, rotary hydraulic actuators, compressors, and engines may emit characteristic sounds when lubrication condition change. For instance starvation of a hydraulic pump might lead to cavitation with sounds like marbles falling on a tin roof. Heavy water contamination will result in an increasing metallic sound.

Using Touch to Troubleshoot Problems

Our sense of touch is not a good oil analysis instrument. In fact, it is even difficult to detect highly contaminated oils with your fingers. Most particles that are large enough to be felt have very short life in the oil. They become filtered, crushed, or simply settle to the bottom of tanks and sumps. Therefore, in order to feel these contaminants, to get a sense of the consistency, hardness, and size, it is best to go to the places where they accumulate. These places include the bottom of the sample bottle, a tank/sump BS&W sample, sediment from centrifugal separators, and debris on the surface of a used filter.

Tools can be used to enhance the sense of touch. For instance, your fingernail can be used as a tool to test for particle hardness. By pressing the back of your fingernail along the bottom corner

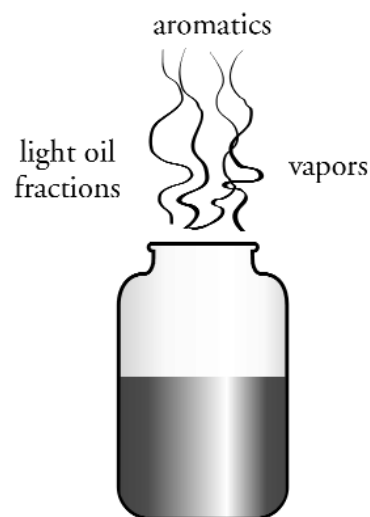
in a sample bottle, large hard granular particles can be felt. Particles from a filter or bottom sediment can be transferred to a glass slide for evaluation. Using a dental tool to apply pressure they can be examined for hardness, friability, and elasticity.

Specimen debris can also be positioned between two glass laboratory slides. By pressing down on the slides and sliding them against each other hard abrasives, typically larger than 100 microns, can be detected. If the particles are hard enough to scratch the slides this suggest silica or alumina.

The Sniff Test

Researchers are currently developing “artificial noses” to discern thousands of odors for various industrial, scientific, and medical applications. These chip-size sensors will use conducting polymer materials to recognize the character of a large library of gas and odor “signatures”. Until this new technology reaches the market the biological counterpart is still available and quite useful in oil analysis.

Because changes in oil chemistry and contaminants will usually alter odor, this is a reasonably effective means to detect abnormal conditions. Many odors can be easily recognized while others are subtler or become masked by stronger odors. The new oil by itself will often have a very sharp odor. Much of this is contributed by the additive package. For the same reason, a loss of a characteristic odor associated with the new oil’s additives may suggest depletion of the additives.



From a practical standpoint it is best to use odor comparitors. These are special samples that are known to contain certain contaminants or oil degradation products. Each bottle is marked accordingly and stored for later reference. When a used oil is suspected to have a certain problem, say oxidation for example, its scent is compared to the reference standard to see if there is a match.

Scenting, as an oil analysis procedure, is best applied to detect contaminants that are in close proximity to the lubricant. These could include solvents, refrigerants, degreasers, hydrogen sulfide, gasoline, diesel, kerosene, ammonia, etc. Most of these contaminants are easily detected by just taking a brief sniff.

When an oil degrades through oxidation pathways it will develop a sour or pungent odor. Oil analysis laboratories can supply oxidized oils for reference purposes. Thermally degraded oils can have either a burnt food smell or no odor at all. Lubricants operating for sustained periods at relatively high temperatures lose all of their volatile constituents and odors.

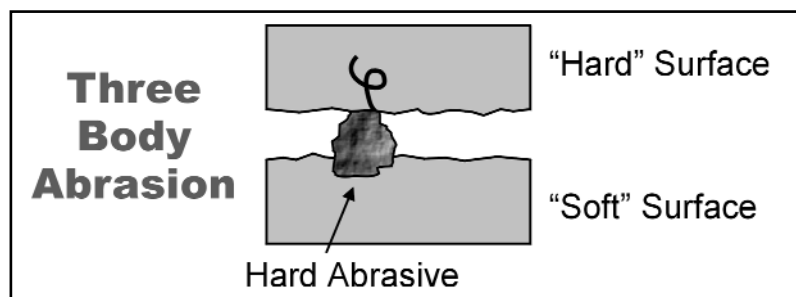
The most recognizable odor in used oils is the road-kill smell. This strong stench is caused by microbial contamination (bacteria) and is most prevalent in water-based fluids.

Simple Oil Analysis Tests

There are many products available on the market today for oil analysis. Some of these are laboratory instruments ranging over \$100,000. Others are simple field test kits for measuring one or two basic oil properties. Surprisingly, many of the field test kits offer very accurate and useful information for the practitioner. The following is a summary of a few of these test kits and products currently available.

The Patch Test Kit for Particle Contamination

Studies have shown that particle contamination is responsible for up to 80% of lubrication-related machinery failures. Particles enter the system through seals, breathers, new oil changes, top-offs and a variety of methods.



Because particles cause so many problems, they should be monitored regularly and controlled by filtering the oil or changing as required. Particles are also generated when a machine is failing. Monitoring for increased generation of wear debris alerts the technician of an impending failure so that corrective action can be planned. The simple patch test enables the technician to quickly identify abnormal levels of contamination and wear debris so that corrective actions can be scheduled accordingly.

You will need a few supplies for this test:

- Patch making funnel. Available from:
 - EasyVac Inc. Knoxville, TN, 423-691-7510
 - Gorman Industries, Cedar Hill, TX, 972-723-8318
 - Gelman Sciences, Ann Harbor, MI, 800-521-1520
- Oil sampling vacuum pump
- 25 mm filter disc
- Tweezers
- Mineral spirits
- 100X or better microscope. The one shown can be purchased at Radio Shack.

The Patch Test Kit for Particle Contamination Procedure

Step One

Prepare a filter patch for viewing under a microscope.

- a) Insert patch making funnel into the top of the vacuum pump and tighten the seal by tightening the knurled fitting.



- b) Remove funnel from white base by turning it counter-clockwise



- c) Using Tweezers, carefully place 25mm filter disc onto the screened surface of the funnel's interior and return funnel to the white base.



- d) After aggressive agitation of the sample, pour oil into the funnel precisely to the 25 ml mark.



- e) Fill the funnel to the 50 ml mark with mineral spirits dispensed through a filter installed on the bottle.



- f) Draw the diluted sample through the filter by activating the vacuum pump until the funnel is empty.



- g) Fill the funnel to the 25 ml mark with mineral spirits dispensed through a filter installed on the bottle.



- i) Using tweezers, remove the patch and place it on a clean surface to dry for 10 minutes.



- h) Draw the rinse fluid through the filter by activating the vacuum pump until the funnel is empty.

- j) Rinse the interior of the funnel with filtered mineral spirits, dry and carefully put it away for future use.

Step Two

Remove the base from the 100X microscope.

Step Three

Switch the microscope's light to the 'on' position.

Step Four

View the dry filter patch under the microscope and focus the image.



Step Five

Compare the sample patch to standard visual and microscopic images (see next page) to determine condition using the Particle Contaminant Diagnosis Table (see below).

Step Six

If the contamination is in a caution, severe or critical condition, diagnose according to the particle contamination analysis flow-chart.

Step Seven

Record findings, comments and recommended actions on the oil analysis summary report.

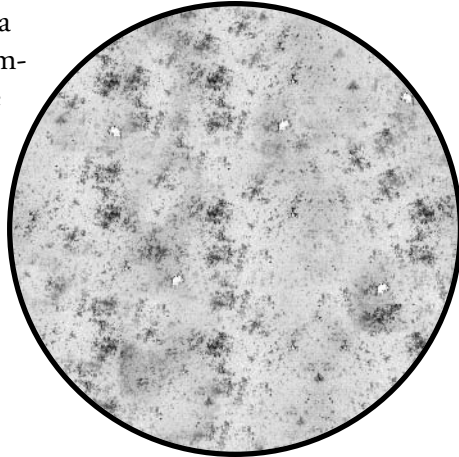
Particle Contaminant Diagnosis Table

Observation	Condition
Sample patch has fewer particles than the standard reference patch marked "Caution"	OK
Sample patch has about as many particles as the reference patch marked "Caution," but fewer than the patch marked "Severe"	Caution
Sample patch has about as many particles as the reference patch marked "Severe," but fewer particles than the reference patch marked "Critical"	Severe
Sample patch looks like the reference patch marked "Critical" or worse	Critical

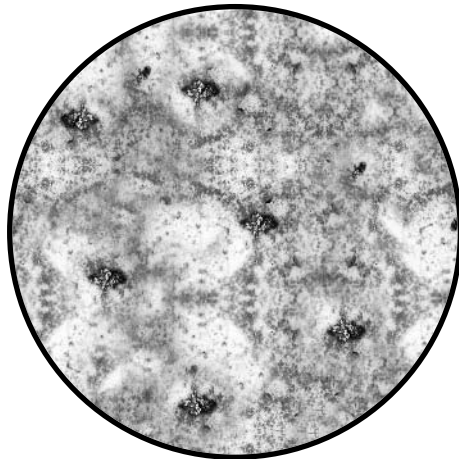
Patch Comparison Images

The images below are a general representation of caution, severe and critical ratings and don't apply to all machinery.

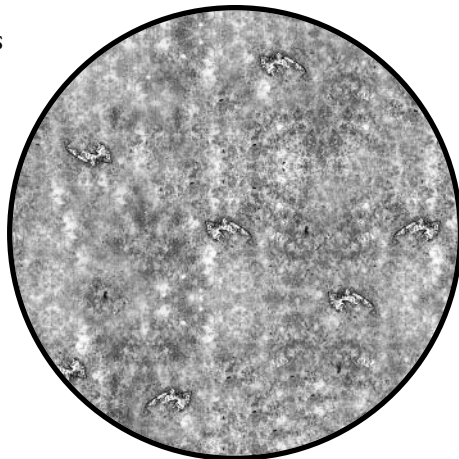
Caution - This patch shows a generally high level of contamination. The presence of the shiny particles suggests some wear is occurring. This machine requires attention to avoid a severe condition that could lead to failure or poor operation.



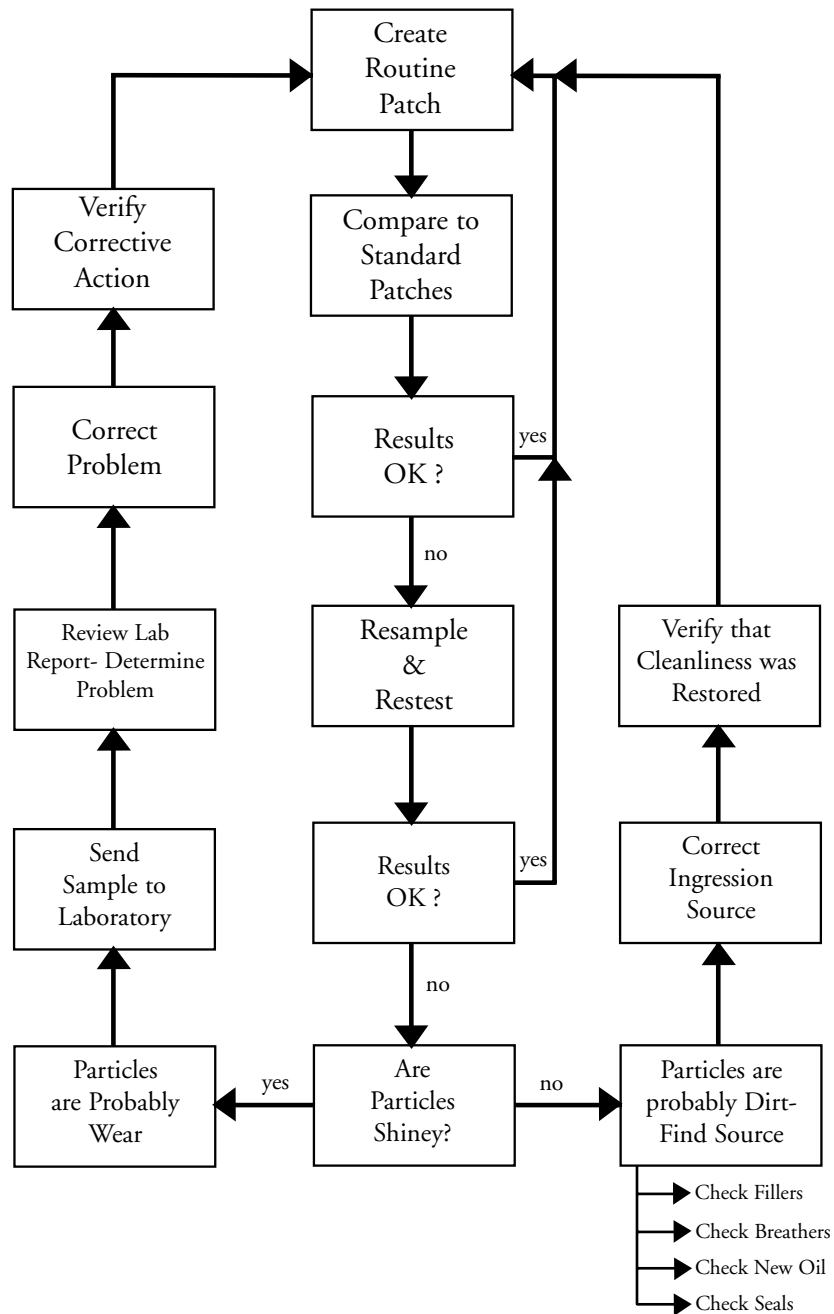
Severe - This heavily loaded patch indicates a very high dirt load. The presence of numerous shiny particles suggests a concerning wear trend. Action should be taken immediately before catastrophic failure. The elevator may already be showing signs of operational failure.



Critical - This dense patch is loaded with dirt. The heavy load of shiny particle suggests a critical situation. Operational failure is probably occurring and catastrophic failure is probable.



Flow Model for Patch Test Diagnostics



Patch Test with a Magnet

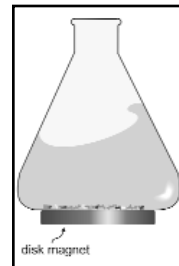
Sometimes it is necessary to quickly determine if a machine is generating an unusual amount of wear debris. One way to accomplish this is to simply pull a patch and look at the particles with a simple top-light microscope. Wear particles tend to be shiny because they reflect light, especially freshly generated particles that have not had a chance to oxidize.

Sometimes, however, one needs to separate the wear particles from the dirt particles to get a clearer view. Here is an easy on-site method for separating magnetic debris (e.g., iron and steel) that is quick and inexpensive. Once separated, the particles can be viewed under an inexpensive field microscope for evaluation.

Patch Test With A Magnet Procedure

Step One

1) Mix a measured amount of oil with kerosene (or other suitable solvent) about 50/50 in a flat-bottomed flask or beaker.



Step Two

Hold a disc magnet tightly to the flask bottom and slosh around the mixture for three minutes.

Step Three

Without removing the magnet, decant the liquid and non-magnetic debris out of the flask through a membrane (patch) using a common vacuum apparatus. This leaves the magnetic particles behind.



Step Four

Remove the magnet and add about 50 ml of filtered kerosene or solvent and slosh around a little more.

Step Five

Next, transfer the magnetic particles to another patch.

Step Six

View the patches using the top-light microscope. The first patch will be primarily dirt, polymers, rust, oxides, sludge, and non-ferrous wear metals (e.g., copper, babbitt, aluminum, etc.). The second patch will show particles generated from critical surfaces such as shafts, bearings, and gearing.



Step Seven

Refer to a wear particle atlas as required to interpret your findings.

This technique is very flexible and provides on-the-spot information. It can be used to verify high particle count, abnormal vibration readings, rising temperatures, or even a suspected failed filter. Visual conformation like this increases your confidence in making decisions and recommendations.

Suppliers of patch test gear include:
Pall Corporation/Gelman & Millipore.

This method is simple, but yields excellent results. You will get more value if you employ the following tips:

- Use clean glassware.
- Use a strong rare-earth type disc magnet.
- Use the same volume of sample oil every time you employ this procedure. Otherwise, you will see sporadic changes in particle concentrations unrelated to the machine's condition.
- Use a microscope with top-lighting for viewing reflected light. A number of different options are available ranging from under \$20 to thousands.

TAN/TBN Kits

When an oil degrades, it generally becomes more acidic and corrosive because the aging process, namely oxidation, produces measurable organic acids. We can effectively time oil change decisions by measuring the oil's total acid number (TAN) which increases as the oil ages. The following factors influence the rate at which a lubricant degrades:

- Temperature
- Moisture
- Aeration
- Particles (especially metal wear particles)

There are several products on the market that permit rapid analysis of an oil's TAN/TBN in the field. These are simple wet chemistry procedures that correlate very closely to procedures such as ASTM D 664, ASTM D 2896, and ASTM D 974. At first, use of these kits will seem complicated, but with just a little practice, results can be obtained in less than ten minutes. Because reagents and solvents are pre-measured, many of the commercial oil labs use these same kits for routine analysis.

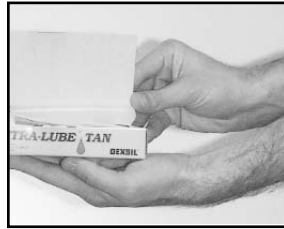
Suppliers include: Dexsil Corporation, The Gerin Corporation, Kittiwake, Oilab, I.T.S., & Airborne Analytical Labs.



TAN Test Kit Procedure

Step One

Open the TAN test kit, remove the components and familiarize yourself with the kit's contents.



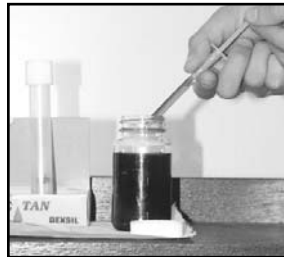
Step Two

Place the test-tubes in the holder in front of the box.



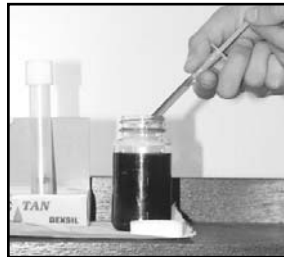
Step Three

Remove the black cap from tube #1 and work the plunger several times to verify smooth operation.



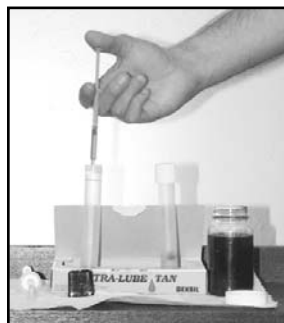
Step Four

Fully depress the plunger of the sampling syringe, place it into the well mixed lubricant sample and pull back on the plunger until it reaches the stop and can't be pulled further taking care to ensure that there are no air bubbles.



Step Five

Remove the syringe from the oil sample bottle and wipe away any excess with the provided towel.

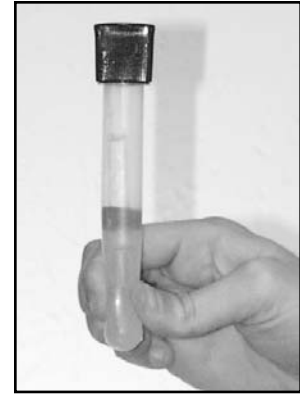


Step Six

Dispense the oil into tube #1.

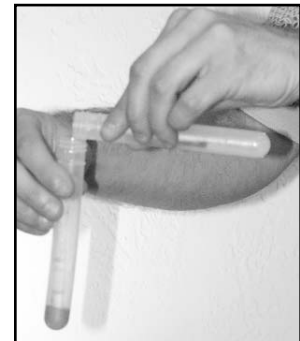
Step Seven

Tightly replace the black cap on the test tube and squeeze firmly ONCE the bottom ampule with the white dot (squeeze the ampule within the black-capped test tube). This breaks the ampule and releases its chemicals. Shake the test-tube well for 15 seconds.



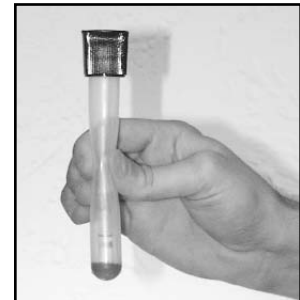
Step Eight

Remove the caps from both caps and pour the liquid from tube #2 (white cap) into tube #1 (black cap) and tightly replace the black cap on tube #1.



Step Nine

Break the top ampule with the blue dot within tube #1 by squeezing firmly ONCE and vigorously shake the mixture for 30 seconds.



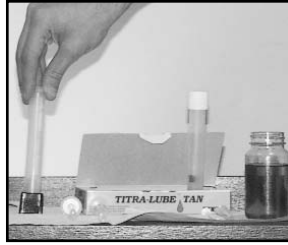
Step Ten

Vent tube #1 by loosening the black cap one-half turn, then retighten the cap on the tube.



Step Eleven

Stand the tube #1 on its end and let it rest for a full three (3) minutes to allow the phases to separate.



Step Twelve

Place the plastic filtration funnel into tube #2.



Step Thirteen

While keeping tube #1 vertical with its black cap down, position the tube over the filter funnel inserted into tube #2, slowly open the pour spigget on tube #1 and carefully dispense 5 mls (up to the 5 ml line) into tube #2. It is important not to mix the contents of tube #1. Phase separation in tube #1 must be maintained. If the tube must be squeezed twice to dispense 5 mls, allow air to inhale into tube # 1 very slowly to avoid agitation of the fluids.

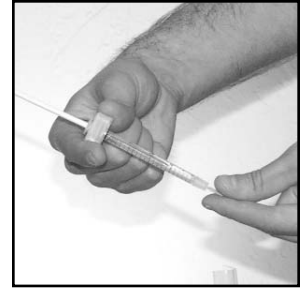


Step Fourteen

Close the dispenser spigget on tube #1 and remove the filter funnel from tube # 2.

Step Fifteen

Place the white plunger rod into the titrating syringe and press it until it clicks into place and break (do not pull) the tip off of the syringe.



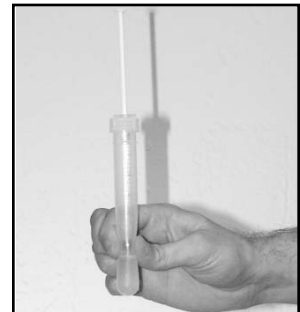
Step Sixteen

Place the syringe into tube #2, tightening the cap.



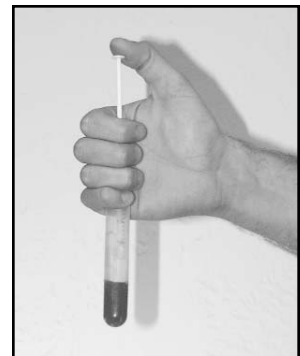
Step Seventeen

Break the red (yellow-dot) ampule by firmly squeezing the sides of the test tube ONCE.



Step Eighteen

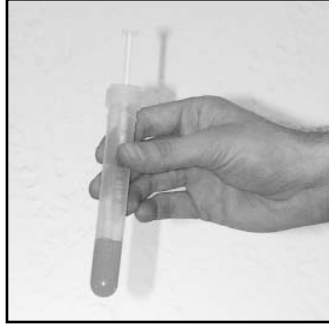
Shake the test tube for 10 seconds while simultaneously squeezing the contents of the syringe into tube two and watching for a color change.



THE MOMENT
THE COLOR
CHANGES FROM
BLUE TO ORANGE,
STOP DEPRESSING
THE PLUNGER.

Step Nineteen

Read the TAN number directly off the titrating syringe right at the tip of the black plunger.



Step Twenty

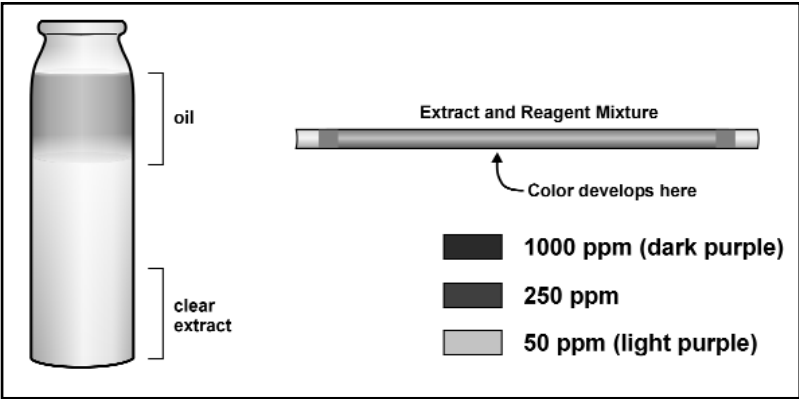
Diagnose TAN results:

- If TAN level exceeds 0.5, the oil is in a caution state. Inspect for air, water, excessive temperature and/or metal particles and address as required. Schedule an oil change.
- If TAN level exceeds 1.0, the oil is in a critical state. Inspect for excessive aeration, water contamination, excessive running temperature and/or metal particles and address as required. Schedule a prompt oil change.

Glycol Test Kits

There is often a need to do a quick field-test for antifreeze in used crankcase oil. There is a standard procedure for this known as the Schiff's Reagent Method if the antifreeze is formulated with ethylene glycol; ASTM D 2982. The procedure involves mixing toluene solvent with the oil, then adding sulfuric acid and a reagent. In sum, the glycol is converted to formaldehyde and the concentration of formaldehyde is estimated by colorimetry. The procedure is simple enough that it can be performed in the field although it does involve wet chemistry.

Suppliers of glycol test kits (or reagents) include: Hach Company, Nelco, & Accurate Manufacturing Chemists.



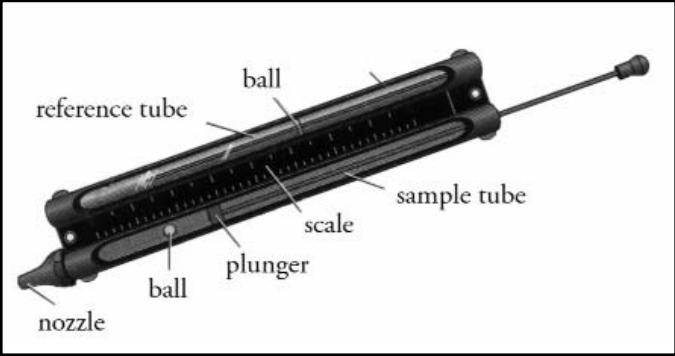
Schiff's Reagent Method

Field Viscometry

Viscosity is the lubricant’s most important property. It determines the degree to which machine component surfaces are separated by a lubricant film. As such, viscosity monitoring is an important part of a lubricant monitoring and management program. The table below describes the problems associated with viscosity that is either too high or too low.

Over - Limit Viscosity	Under - Limit Viscosity
<ul style="list-style-type: none"> • High pressure drops • High fluid temperature - surface to fluid friction • Sluggish response • Increased cavitation • Reduced mechanical efficiency 	<ul style="list-style-type: none"> • Increased internal leakage • High oil temperature - surface to surface friction • Cylinder creep • Increased rates of wear generation • Loss of positive hydraulic control

There is an assortment of simple field viscometers and viscosity comparitors on the market. Some use falling steel balls, others time the oil traveling down an inclined track. The most well-known viscosity comparitor is called the Visgage. The unit employs two parallel tubes: one for a reference oil and the other for the sample oil. There is a steel ball in each tube. After the temperatures of both oils are allowed to equalize, the unit is tilted, permitting the balls to travel from top to bottom. When the first ball reaches the bottom the unit is immediately set level and the position of the other ball is noted. A nomograph is supplied to calculate the estimated viscosity of the sample oil.



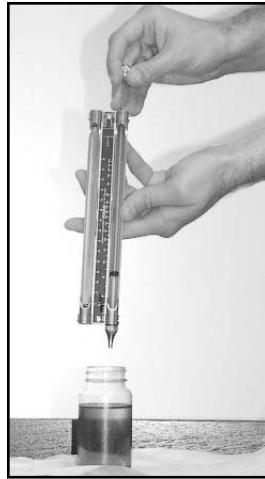
NOTE: Comparative viscometry assumes a Viscosity Index of 95.

Suppliers of low cost field viscometers include: Louis C. Eitzen Co. (Visgage), Kittiwake, DJ Scientific, Cole-Parmer, & Gerin.

Field Viscometry Procedure

Step One

Insert Viscometer nozzle into the oil being tested.

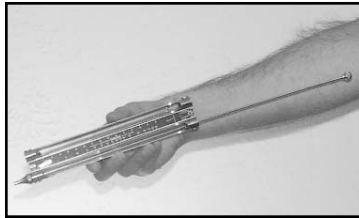


Step Two

Slowly draw oil into the instrument until full (if air is ingested, invert the instrument and expel the air with the plunger).

Step Three

Tilt the instrument to allow both balls to settle at the zero point on the scale.



Step Four

Place the instrument in its case with the plunger rod in its cradle as pictured.

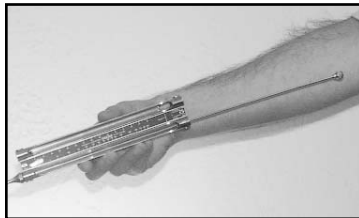


Step Five

Close, lock the case and leave it undisturbed for 15 minutes so the temperature of the reference oil and the test oil can equalize.

Step Six

Remove the instrument from the case and tilt the case at a 25° to 30° angle to induce movement of the balls set at the zero-point on the instrument's scale.



Step Seven

As the leading ball approaches the 38.6 point on the scale, slowly return the instrument to the horizontal so the leading ball stops precisely at the 38.6 point.

Step Eight

Read the centistoke (cSt) position of the lagging ball the ascertain the viscosity of the test fluid.

Step Nine

Compare readings to the viscosity limits table.

Viscosity Limits Table		
ISO VG	Lower Limit	Upper Limit
32	27	37
46	39	53
68	58	78
100	85	115
150	127	172
220	187	253
320	272	368
460	391	529
680	578	782

Step Ten

If readings are unacceptable, employ the viscosity troubleshooting table.

Viscosity Troubleshooting Table		
ISO VG	Cause	Check or Correct
Under Limit Viscosity	Wrong Oil	<ul style="list-style-type: none"> Correct change or top-off procedure Change the oil
	Fuel or Solvent Contamination	<ul style="list-style-type: none"> Remove contamination source Change the oil
Over Limit Viscosity	Oxidation	<ul style="list-style-type: none"> Reduce aeration or foaming Remove water Reduce temperature Change the oil
	Thermal Failure	<ul style="list-style-type: none"> Reduce temperature Eliminate cavitation Change the oil

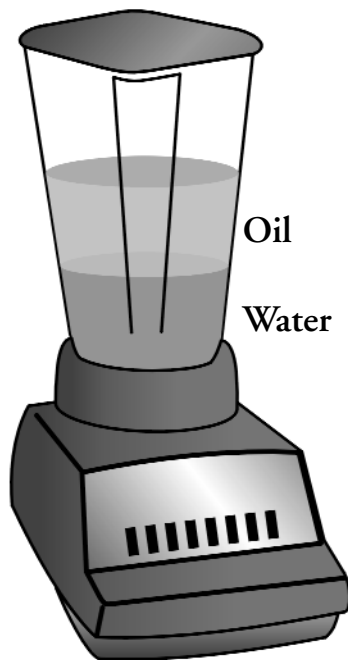
Oil and Water Demulsibility Test

This is a simple test to examine the demulsibility and other properties of used oils. Simply mix the sample at room temperature, fifty-fifty with water in a blender for two minutes. Then, quickly pour the blended mixture into a graduated cylinder. With practice, a host of information about the condition of used oils can be obtained from this simple test. Always test with identical procedures, i.e., oil/water quantity, temperature, blend time, wait time, etc.

Begin by experimenting with the new oil. Get acquainted with its behavior. Develop skill by comparing observations of used oils with laboratory test data. Take notes of everything observed and include photos if possible. Use the notes and photographs to develop a library or atlas for future reference. Compare results from the most current sample to previous sample and the new oil.

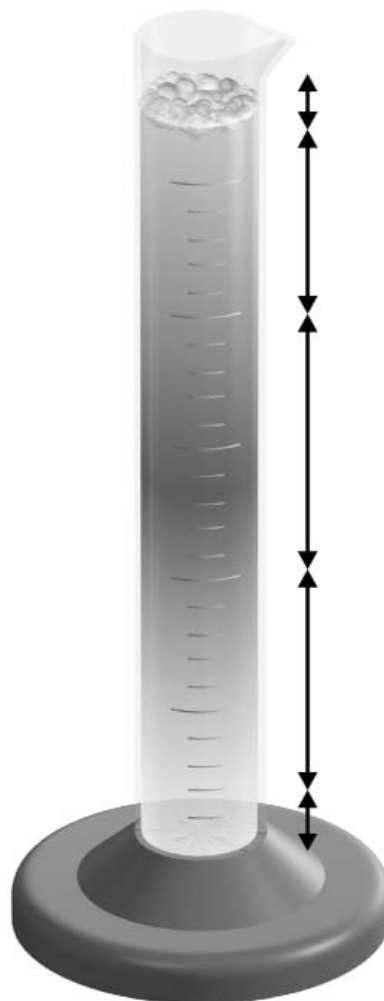
Step One

Mix used oil (at room temperature) with water (50/50) in a blender for two minutes at high speed.



Step Two

Quickly pour blended mixture into graduated cylinder.



Foam Zone. A significant froth after 5 minutes suggests possible loss of anti-foam additive, oxidized oil, or presence of polar impurities/surfactants.

Oil Zone. Cloudy oil zone after 30 minutes suggests loss of demulsification additive and/or oxidized oil.

Collar Zone. Large milky collar zone after 30 minutes suggests oxidized or contaminated oil.

Water Zone. Murky water zone suggests oxidized oil, sludge, additive precipitation, and/or presence of polar impurities.

Bottom Zone. Sediment in bottom zone after 2 hours suggests additive precipitation, contamination, sludge, and/or wear debris.

Crackle Tests

There are a number of ways to measure the presence of water in oil, but most of them are complicated, expensive or difficult to use in the field because they employ wet chemistry. An easy way to detect the presence of free and emulsified water, the most hazardous forms of water in oil, is with the hot-plate crackle test. This simple, tried and true method alerts the user to the presence of any free water.

In this application, the crackle test has been used as a reliable indicator of emulsified water, a go/no-go test. However, with practice and keen eyes and ears, the procedure can be advanced considerably and made more quantitative. Rather than simply listening for the crackle (scintillation), by adding visual observation of vapor bubbles, a rough indication of the amount of moisture present can be obtained.

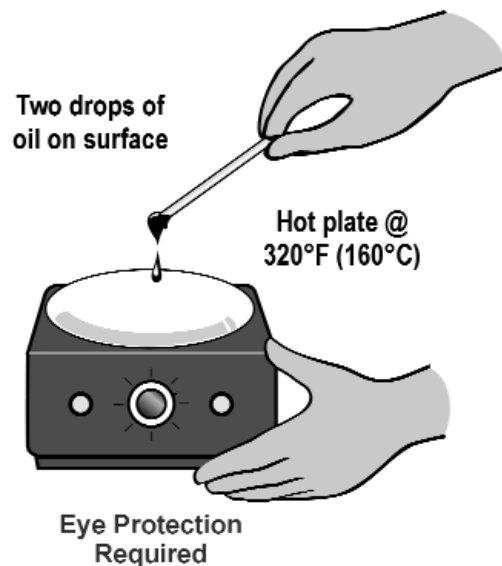
The revised method is referred to as the “visual crackle”. Success in using the procedure depends on practice with varying moisture concentrations in different common fluids. A laboratory syringe and a paint shaker can help create the experimental suspensions. As an alternative to the hot plate a soldering iron can be used with the oil in a glass test tube (see photo). By holding the tube at an angle (about 45 degrees), the presence of water will appear as a stream of rising vapor bubbles. While the visual crackle does not replace the need for other more precise techniques, it does provide vital information when and where you need it.



An alternative to the hotplate crackle test is using a soldering iron and glass test tube.

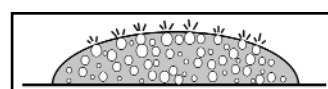
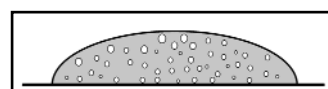
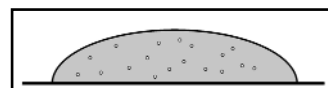
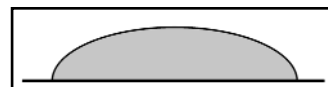
Crackle Test Procedure

1. Achieve surface temperature on a hot plate of 320°F (160°C). Always use the same temperature.
2. Violently agitate oil sample to achieve homogenous suspension of water in oil.
3. Using a clean dropper, place a drop of oil on the hot plate.
4. Observe visual and audible results.



Observable Results:

1. If no crackling or vapor bubbles are produced after a few seconds, no free or emulsified water is present.
2. If very small bubbles (0.5 mm) are produced but disappear quickly; approximately 0.05-0.1% water is present.
3. If bubbles approximately 2 mm are produced, gather to center of oil spot, enlarge to about 4 mm, then disappear, approximately 0.1 to 0.2% water is present.
4. For moisture levels above 0.2%, bubbles may start out about 2-3 mm then grow to 4 mm, with the process repeating once or twice. For even higher moisture levels violent bubbling and audible crackling may result.



Limitations:

1. The method is non-quantitative.
2. Hot plate temperatures above 300°F induce rapid scintillation that may be undetectable.
3. The method does not measure the presence of chemically dissolved water.

Safety Considerations:

1. Protective eyewear is suggested.
2. Long sleeves are suggested.
3. Test should be performed in a well-ventilated area.

Equipment Required:

1. Hot plate capable of achieving and maintaining 300°F surface temperature.
2. Paint shaker (or equivalent) for oil agitation.
3. Oil dropper tube or lab syringe.

Interferences:

Refrigerants and other low boiling-point suspensions may interfere. Different base stocks, viscosities, and additives will exhibit varying results. Certain synthetics, such as esters, may not produce scintillation.

Calcium Hydride Water Testers

This simple test for water is based on a well known chemical reaction occurring between water and calcium hydride. One of the products of this reaction is molecular hydrogen gas. A small cylinder-shaped pressure vessel is used for the test. A measured amount of oil is added to the vessel plus kerosene. Then, a pre-measured quantity (capsule or pillow) of calcium hydride (or calcium carbide) is added. With the vessel sealed the mixture is agitated and allowed to sit. The volume of gas released is directly proportional to vessel pressure. Likewise, the volume of gas is directly proportional to the amount of water in the oil. One design uses a pressure gage, showing a water concentration scale instead of pressure units. This device is sensitive to free water, not dissolved water, and offers practical quantitative measurement.

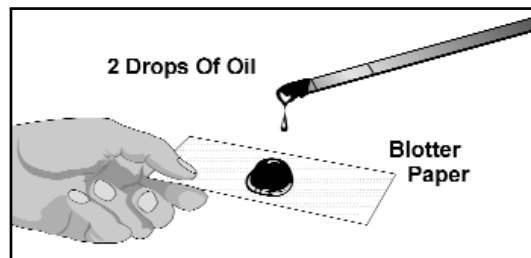


Suppliers of calcium hydride water testers include: Kittiwake, Sandy Brae, Dexsil, Mobil Oil, & Distribution Specialists.

Blotter Spot Testing

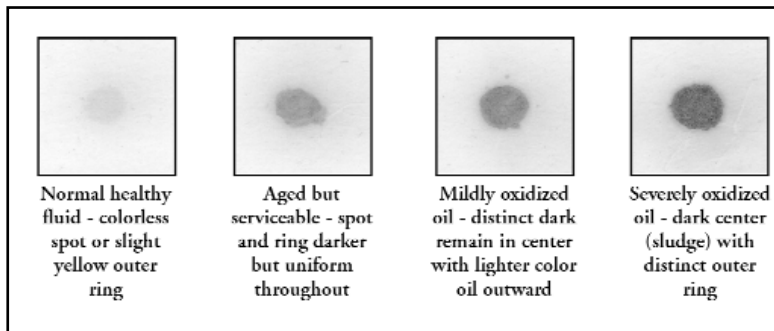
Blotter spot testing dates back to the early 1950's when it was first being used to test soot load in diesel engines crankcase oils. Since then it has seen sporadic use and success in various oil analysis applications. However, in the past several years there has been a sharp rise of interest as new applications and techniques have surfaced among users.

The procedure is extremely simple and low in cost. It involves placing a couple drops of used oil on the surface of chromatography paper (available from most laboratory supply catalogs). Place the paper in such a way that it is horizontal and does rest directly on a flat surface. One way to do this is to prop it up on the rim of a drinking glass. When the oil makes contact with the absorbent blotter paper it will begin to wick outward into the paper. For high viscosity oils this could take several hours. Once all of the oil has moved into the interstices (pores) of the paper the blotter is ready to be examined.



Interpretation of the blotter goes well beyond the scope of this paper; however, there are a few very simple interpretation rules:

-
1. For crankcase oils the density (darkness) of the center spot indicates the soot load and the distance of radial travel, and the presence of defined absorption peripheries point to the quality of dispersancy.
 2. Any blotter from an oil that has no dark spot, rings, halos, sticky center, orange/yellow stain, or other noticeable structure is usually serviceable. That is, the oil has not oxidized, hydrolyzed, thermally degraded, or thrown sludge and is probably not heavily contaminated with wear debris, glycol, or sediment.
 3. The blotter spot test is not helpful in determining particle count, viscosity, elemental analysis, or water contamination. It is somewhat useful in detecting fuel dilution and glycol contamination.
 4. Any blotter from an oil that has a considerable amount of structure is usually non-complying in critical applications. It should be immediately sent to a lab for exception testing.



Conclusion

Oil analysis doesn't have to be expensive and technically sophisticated. There are many answers to routine problems that can be defined onsite without a laboratory. The use of simple field tests and inspection techniques offer many daily opportunities to carry out both proactive and predictive maintenance.

References:

Fitch, J.C., "Using Oil Analysis to Control Varnish and Sludge," *Practicing Oil Analysis* magazine, May-June, 1999.

Fitch, J.C., *Oil Analysis for Maintenance Professional Coursebook*, Noria, 1998.

Troyer, D.D., "The Visual Crackle, A New Twist to an Old Technique," *Practicing Oil Analysis* magazine, Sept-Oct, 1998.

