

Section 9

LUBRICATION PROGRAMS, MONITORING AND REDUCING LUBRICANT CONSUMPTION

Five Rights of Lubrication

“Five rights of Lubrication” – Getting the right amount, right type, right quality of lubricant to the right place at the right time.

The five rights of lubrication are important, particularly when receiving a new piece of equipment where you want to get started on the “right” foot. The lubrication engineer should have a mental or physical checklist that the following are verified.

Right amount – Each lubrication point should be identified, and next to each should be a comment on the amount of lubricant to be added. It is a good idea to include points that are sealed for life so that the person who is responsible for lubricating the machine doesn't think that the component was inadvertently left off the list.

Right type – The equipment manufacturer should be the primary source of lubricant recommendations. If there are any questions, the lubricant supplier should work closely with the OEM.

If the plant has an internal coding system, the type should include the generic type of lubricant and the grade, as well as any temperature or operating restrictions. If there is no coding system, the type should include brand name and alternates, if appropriate.

The right type of oil includes choosing the right viscosity grade. Choosing the right viscosity grade depends upon the temperature. How do you determine the upper operating temperature of an oil?

1. The viscosity of the oil should be high enough to carry the load.
2. The oil should have a flash point at least 20°F above system temperature.
3. Keep the temperature low to reduce oxidation and extend drain intervals.
4. Stay below the coking temperature of the oil.

Right quality – The lubrication engineer should set standards for the quality level of lubricants in the plant, including the choice of supplier, acceptance testing and oil monitoring.

Right place – All lubrication points should be labeled. Many plants tag them with markers, stickers or plastic cards.

Right time – Relubrication intervals should first be set according to OEM recommendations. If the plant wants to extend lubrication intervals, first evaluate historical oil analysis and maintenance reports. If the oil still looks good, and there are no other indications that the equipment is unhealthy, then extend intervals cautiously and test more frequently. Look for changes in viscosity, total acid number and spectrographic metals. Also check to see if the oil make-up rate has held steady or increased. Adding more fresh oil into the system is another good reason to extend oil drain intervals.

When changing lubricant suppliers, it is a good time to evaluate the current lubricants and their applications to see if there can be any improvements. First, find out the original equipment manufacturer's (OEM) recommendation for each machine. Second, see if there can be any consolidation of inventory. Consult with the oil supplier or the equipment OEM to see if there is any leeway in the original recommendation based on operating conditions.

It is always good manufacturing practice to flush systems thoroughly when switching to another brand of product. If this is not possible, make sure the competitive products are compatible with each other. It may be necessary to run compatibility tests, depending upon the size of the application and how critical it is.

When a new system has been installed, it is important to flush the system of all impurities. Each system is different, but the guidelines set by ASME for turbine systems, "ASTM-ASME-NEMA Recommended Practices for the Cleaning, Flushing and Purification of Steam and Gas Turbine Lubrication Systems" can apply to other equipment. Some of the procedures from this publication include:

The system should be designed to allow successful cleaning, and pipes and other equipment must be properly cleaned and preserved.

"The knowledge that an oil flush will be performed before startup should not be allowed to lead to the misconception that contaminants entering the oil system are not harmful because: "they will all be removed by the flush".

Insure compatibility of the flushing oil with the entire lubrication oil system.

Temporary strainers and fine screens should be installed and the oil may be heated to 60° - 82°C (140° - 180°F).

Flushing times of at least 12 hours to as much as several days may be necessary to insure proper system cleanliness.

General practice is to allow the oil temperature to drop for 2 to 3 hours during flushing to allow for pipe contraction. This procedure aids in removing any scale that may be on the

pipe. During early stages of flushing, piping should be vibrated or hammered to dislodge any scale or weld splatter.

After inspection of strainers or bags and temporary filters discloses that there is no evidence of contaminants, other parts of the system should then be flushed by removing blanks or jumpers.??? The flushing procedure should be continued until it is considered that the entire system is thoroughly cleaned. At this point, a sample should be taken for verification.

Follow guidelines for draining flushing oil, using a displacement oil and interim corrosion protection before adding new oil charge.

Remember to properly bleed the system of air. When the new oil is circulating, check for leaks and make sure that the reservoir level is maintained.

Once the new product is in the system, take a sample for analysis to establish a base line for future testing.

When adding makeup oil to a reservoir, clean the area around the fill pipe; verify type, grade, and cleanliness of new oil; thoroughly flush the pump and hose through which the new oil will be added, use a dedicated pump and hose, if possible; filter the oil as it is being added; pump slowly to prevent air entrainment.

Lubricant Surveys

At the very minimum, the following information should appear on a lube survey:

- Department (and/or location) – to identify where the equipment is located
- Equipment (components and lube points) – including models and operating conditions
- Lubricant – name and grade
- Amount – in lbs, gallons, cc's, squirts
- Frequency – i.e. weekly, monthly, yearly, as required, daily, every shift
- Method – by hand, brush, swab, add to reservoir, grease gun, drip, and bottle oiler
- Comments

Failure Analysis

When investigating failure of equipment, the tendency is to look at symptoms rather than root cause. Root cause is defined as the primary reason for failure in a chain of events. Root cause analysis can prevent further failures by correcting the source rather than the symptoms of an event. Failure mode, on the other hand, describes the sequence of events that lead to failure.

The oiler can perform quick on-site checks to determine the health of the equipment. He or she can make a quick physical evaluation of vibration, heat noise, oil level, excessive

foam or leakage. Anything unusual in these areas should be recorded and reported if they seem to be of concern.

The departments listed below have responsibilities for making sure that equipment is lubricated properly. However, the ultimate responsibility for making the lubrication recommendation should come from the plant engineer and maintenance engineer, who should advise the purchasing agent.

The following information is quoted from the Lubrication Engineers Manual and Plant Engineering Magazine as referenced in the bibliography.

Department responsibilities

<u>Production</u>	Must release machines for scheduled service – such as changing hydraulic oil.
<u>Purchasing</u>	Must procure only those lubricants and lube equipment approved by the lubrication engineer. Must order by specifications – not price.
<u>Inventory Control</u>	Must keep an adequate supply of required lubricants on hand.
<u>Maintenance</u>	Must arrange for prompt repair of reported failures, such as hydraulic leaks.
<u>Laboratory</u>	Must verify specifications of purchased oils and analyze reservoir samples submitted by the lubrication engineer for viscosity and contamination.
<u>Engineering</u>	Must follow and enforce specifications established by lubrication engineer when buying new equipment.

How to avoid the 12 Most Common Lubrication Errors

Error 1	Failure to assign overall responsibility for equipment lubrication to one man.
Error 2	Failure to adequately survey equipment lubrication requirements. The physical survey is only part of the job – the appropriate manufacturer’s instruction books for each machine must be checked to determine lubrication requirements.
Error 3	Failure to limit the number of lubricants used. Remember, for every 18 F rise in operating temperature above 140°F, the service life of the lubricant is normally reduced by about one-half.
Error 4	Failure to schedule lubrication properly.
Error 5	Failure to keep adequate records.
Error 6	Failure to prevent lubricant contamination. Contamination is the greatest single cause of lubricant malfunction.
Error 7	Failure to use the right lubricant. Selection of the right lubricant for each application should always be based on the following factors: Type of part to be lubricated Operating temperature extremes

	Speed and load
	Hours of expected use per day
	Age and condition of equipment
	Importance of the equipment to the production process
	Recommendations of the manufacturer
	Current lubrication procedures
	Lubricants available in the plant
Error 8	Failure to investigate all mechanical malfunctions
Error 9	Failure to prevent unauthorized personnel from lubricating equipment
Error 10	Failure to hire competent personnel and train them for the job
Error 11	Failure to respond to feedback from the lubricators
Error 12	Failure to update and refine the lubrication program

To evaluate a particular method for a specific application, certain characteristics should be considered. The following evaluation criteria can serve as a check list to aid in selection of lubrication devices.

Delivery of Lubricant:

- Regulation
- Adaptability
- Uniformity
- Continuity

Reliability:

- Human Element
- Automatic Operation
- Positive Operation
- Contamination Resistance

Cost Considerations:

- Initial Cost
- Maintenance Costs

Overall Design Considerations:

- Accessibility
- Safety
- Lubricant Leakage
- Consistency in Design

The basis of the plant program is an outline of the Lubrication Engineer's activities. The twelve points enumerated below are fundamental since they include all the essential factors recognized as being part of every successful plant lubrication program.

1. Conducting lubrication survey
2. Classifying lubricants

3. Compiling lubrication charts
4. Punch card lubrication control
5. Establishing consumption reports
6. Improving application methods
7. Improving lubricant handling and storage
8. Evaluating new lubricants
9. Establishing maintenance methods
10. Assisting in new equipment design
11. Training personnel
12. Investigating special problems

The lubrication engineer should take the following eight steps when establishing a new lubrication program:

- Perform a lubrication survey
- Determine fewest correct lubricants
- Determine critical pieces of equipment
- Establish an Oil Analysis Program
- Establish a Portable Filtration Program
- Minimize wastes
- Conduct lubrication training
- Improve storage and handling
- Test new oils

Monitoring and Reducing Consumption of Lubricants

The first step in controlling oil losses is to make a commitment. The company should recognize that lubricant losses are costly over time and should commit to reducing consumption. Commitment should come from several departments including maintenance, engineering, operations, environmental, accounting and the laboratory.

Costs of high oil losses

- Cost of replacement lubricant
- Storage and handling of extra lubricant
- Cost of catching the spilled lubricant
- Waste oil disposal cost
- Environmental cost/fines
- Cost of in-plant transfer and resulting empty drums
- Extra drum disposal cost
- Temptation to switch to cheaper lubricant
- Extra labor involved to maintain oil level
- Shorter equipment life due to poor in-service maintenance
- Shorter equipment life due to lubricant starvation

Substitution of product due to emergency fills operation
Housekeeping costs
Safety concerns

The second step is to evaluate the current situation. This could include checking historical records of the amount of lubricant purchased compared with the amount sent for disposal. Try to account for the difference by looking for leaks, products consumed in the process, misting and evaporative losses. Try to distinguish unneeded waste due to contamination, misapplication or carelessness from normal disposal due to aged product.

The third step is to make a plan of action using some of the suggestions below, or by consulting the references in the bibliography. The fourth step is to implement the plan. The fifth, and very crucial step, is to reevaluate and start over with step one.

Reducing lubricant usage

Oil conservation can be divided into three categories – Reduce, recover and recycle.

One step in reducing waste is to choose the proper lubricant. High quality lubricants with appropriate additives have a long and productive service life. Consolidation of lubricants reduces inventory, and also minimizes waste from lubricants that are misapplied or cross-contaminated.

Synthetics in high heat applications can reduce oil consumption because they have fewer volatile components than refined oil. Over time, less oil evaporates or vaporizes into the process.

Oil Analysis helps extend the life of lubricant and the equipment. At minimum, most industrial lubricants should be tested for spectrographic metals, total acid number and viscosity. Total base number takes the place of total acid number for testing the useful life of engine oils. Both applications can also use infrared spectroscopy as a tool to check for oxidation products. In the case of turbine systems that run for decades, the Rotary Pressure Vessel Oxidation Test (formerly RBOT) can gauge remaining life of the turbine oil.

By comparing historical oil analyses and plotting trends in wear metals, viscosity and oxidation, an engineer can reasonably extend oil drain intervals.

Cooling lubricants can dramatically increase their life. Elsewhere it was stated that the rate of oxidation doubles for every 10°C (18°F to 20°F) increase in temperature. The converse is true. For every 10°C the temperature DROPS, the life of the oil DOUBLES (down to about 160°F).

Filtration, either by using by-pass, continuous full flow, or batch processing can effectively extend the life of the lubricant. Contamination from fluids and solids is one of the greatest causes of wasted lubricant.

Hand-in-hand with filtration come other system designs that extend lubricant life. Reservoirs can be modified to maximize residence time to allow solids and water to drop to the bottom and air to dissipate. Very large reservoirs should have electronic or sight-glass oil level gauges that can be monitored for excessive consumption.

Mist lubrication commonly saves lubricant, saves energy, and improves reliability where such systems can be used.

Recovering lubricant that may be wasted

The following methods are considered “All Loss”, meaning that the oil is not recirculated or reused as a lubricant.

Open mist, drip, brush, oil cup, bottle oiler

Wherever possible, All Loss methods should be replaced with systems where the lubricant can be recovered, reused or recycled.

Grease drums and pails can be lined, and follower plates installed on drum pumps. Even the best follower plates leave some grease behind. It is good procedure to scavenge the last bits of grease, if not contaminated, and add it to the top of the next container.

Some components, such as electric motor bearings, can be purchased sealed-for-life.

Oils should be purchased in bulk containers to reduce waste. Bulk packaging also has secondary benefits. It reduces transportation costs, minimizes storage space, and reduces costs for container recycling and disposal. It opens the door for discounts from the supplier because they reap the benefit of less handling, delivery and packaging costs as well as the benefit of economies of scale.

Oilers visit each area of the plant regularly. They should be responsible for checking for leaks and to watch for differences in sump levels or oil feed rates that could indicate a leak or that oil is being consumed.

Surveying the plant for leaks can reap many benefits. Leaks may be a symptom of an underlying engineering or maintenance problem. By addressing the leak, other more insidious problems can be identified and avoided.

There are a number of ways for oil leakage to develop in a system. The packing or seal around a roller shaft may wear and leak. Under certain severe operations, the shocks imposed on the equipment may cause cracks to develop in gear casings. Vibration may cause leaks to develop in pipe joints. The piping may be damaged or broken by being struck with heavy objects.

To minimize leaks, replace worn packing or seals, repair cracked oil casings, tighten loose pipe joints or replace damaged piping and periodically clean scale from the side of gear casings to assure free circulation of the oil. Leaks can also be controlled by using grease instead of oil, substituting mechanical seals for lip seals, reducing temperature to control volatility and increase lubricant viscosity, and making sure fittings are sealed and tightened according to specification.

Reuse or recycle lubricants

Most waste oil is “recycled” by being burned in industrial boilers. This can technically be called recycling because energy is recovered.

Some waste oil can be cleaned up and reused as lubricant. There is a subtle difference between reclaiming and reprocessing lubricants. Reclaiming removes solids and water. Reprocessing removes solids, water and soluble contaminants. A reprocessor will generally send spent lubricant through a vacuum dehydrator and/or centrifuge. The lubricant will be filtered. Then, in the step that separates them from reclaimers, they will filter the oil through a clay or absorption medium that removes dissolved contaminants and additives; at that point, the reprocessor readditizes the product.

Federal and local laws provide incentives to reduce consumption. The following legislative acts impact the use or disposal of lubricants:

RCRA	Resource Conservation and Recovery Act
TSCA	Toxic Substances Control Act
SARA	Superfund Amendment and Reauthorization Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
EPCA	Energy Policy and Conservation Act
ORA	Oil Recovery Act

As a result of regulation and voluntary measures, the petroleum industry has improved conservation of lubricants by optimizing manufacturing processes for lubricants, and making formulations more effective. The industry has standardized on viscosity grades and test methods to help reduce inventory and compatibility of products. Packaging and handling has improved with more use of bulk and intermediate sized containers. There are now companies who reprocess and reclaim lubricants for reuse.

Section 10

OIL ANALYSIS

American Society for Testing and Materials (ASTM) sets the standards for most industrial oil tests. In addition, other standards are set by American Petroleum Institute (API) for engine oils, National Lubricating Grease Institute (NLGI) for greases, American Gear Manufacturers Association (AGMA) for gears, and there are also international standards set by the International Standards Organization (ISO) and Deutscher Industrie Normen (DIN). Most of the following are based on ASTM standards.

It is important to take samples from an area that is as representative of the system as possible. In a circulating system, this should be taken while the system is operating at normal loads, speeds, temperatures. Whenever possible, it should be drawn from the most turbulent part of the system. It is wise to test a sample of unused oil to use it as a reference to see how the oil in the system changes with time.

Make sure that the area around the sample port, valve or drain is clean and that sample bottles have not been contaminated. It is important to purge some fluid from the sample port first.

How often should samples be taken? It depends on several factors, including how critical the equipment is to the operation. Other factors to consider are the severity of the operation environment, how often oil is drained, the amount of make-up oil and whether the equipment is in continuous or intermittent use.

Samples should be labeled clearly. It is a good idea to identify the sample on the bottle itself as well as on accompanying paperwork. Labels should include:

- Oil type (manufacturer and product)
- Equipment ID code
- Equipment type
- Date
- Person responsible
- Company name
- Location
- Test program or tests required

Bear in mind that there is a certain amount of error expected in oil analysis tests. ASTM generally puts repeatability and reproducibility limits on each standard. Repeatability refers to test results generated by the same person at the same lab. Reproducibility give the range of results expected if different people at different laboratories ran the same test on the same sample.

Test Descriptions

The following are brief descriptions of common oil and grease analysis tests.

Appearance and Color are easy means to detect changes that have taken place in the oil including contamination with other products, water (often evidenced by haziness/cloudiness when in excess of 200 PPM) and oxidation (darkening of the product). The product should be clear and bright with no visible water or particulate. Comparison to new unused product is useful for evaluating color.

Bulk Modulus is the measure of the incompressibility of a fluid.

Carbon Residue Test measures the amount of carbon residue remaining in an oil after the oil has been subjected to extreme heating in the absence of air. Test results are reported as Conradson Carbon and Ramsbottom Carbon.

Cloud Point of petroleum oil is the temperature at which paraffin wax, or other solidifiable compounds present in the oil, begins to crystallize or separate from solution when the oil is chilled under prescribed conditions.

The **Coking Test** is a procedure for determining the tendency of oils to form solid decomposition products when in contact with surfaces at elevated temperatures. The panel coker test measures the residue on hot panels that have been coated with oil.

ASTM D 130 **Copper Corrosion** measures corrosion on a copper strip when it is immersed in a lubricant under standard conditions. Results are reported on a scale from 1a (slight tarnish) to 4c (jet-black corrosion).

Demulsibility Tests indicate the ability of oil to separate from water under static conditions. This is an important test for turbine and paper machine oils where complete separation in less than 30 minutes is desirable. The results are expressed as ml oil/ ml water /ml emulsion. So a test result of 40/40/0 would mean clear oil and water, with no emulsion.

The **Dynamic Demulsibility Test** measures the ability of an oil to separate from water under actual circulating conditions.

Density is reported as specific gravity or API gravity. Specific Gravity is the ratio of the weight in air of a given volume of material at a stated temperature to the weight in the air of an equal volume of distilled water at the same temperature. A hydrometer is an instrument that measures the specific gravity of a liquid.

API Gravity is an arbitrary scale (chosen by the American Petroleum Institute) in which the specific gravity of pure water is taken as 10. Liquids lighter than water have values greater than 10 and liquids heavier than water have values less than 10° API. It is calculated from the specific gravity of a petroleum oil.

Dielectric Strength is a measure of an oil's ability to resist conducting electricity. The test is run by immersing two electrodes in a bath of oil and subjecting them to increasing voltage until there is an arc. This and other tests suggested by IEEE and ANSI are used to determine suitability of continued use of transformer oils.

The **dropping point** of grease is that temperature at which grease passes from a semi-solid to a liquid state. Dropping point is a measure of the heat resistance of grease, and can be thought of as its melting point. It measures the temperature at which a drop of fluid is released from a grease test cup.

Use of **emission spectrometry** measures the level of 20 metals, but only if they are less than 10 microns in size. It is used for measuring common water, additive and contaminant metals.

Spectrometric or "spectro" analysis is now a generic term for either of two distinct analytical processes: emission spectroscopy and absorption spectroscopy. Emission technique relates to light given off by an element whereas absorption technique relates the absorbency upon excitation.

Here are metals that are commonly measured by spectrometry, and their possible sources.

Aluminum	piston, shell bearing, bushing, thrust washer, block, head, blower, crankcase paint, grease additive
Barium	additive (high-TBN detergent)
Boron	coolant additive, oil additive (dispersant)
Calcium	additive (high-TBN detergent), sea water
Chromium	plating, liner, ring, shaft, gear, coolant additive
Copper	bearing, bushing, thrust washer, piston insert, gear, axial hydraulic piston assembly, seal, additive (anti-oxidant), copper in an engine oil shortly after initial fill may come from an oil cooler
Iron	piston, ring, cylinder, gear, block, head, cam, shaft, roller bearing, shell bearing back, and seal
Lead	bearing, shaft, thrust plating, piston insert, wet clutch, gas additive, off-the-shelf-supplement (OTSS)
Magnesium	additive (high-TBN detergent), sea water, some gas turbine metallurgy

Molybdenum	ring plating, additive (anti-wear), off-the-shelf-supplement (OTSS)
Nickel	steel alloy, “heavy” fuel contaminant, stellite valve seat
Phosphorus	additive (anti-wear), synthetic phosphate ester lube, phosphoric acid (plant environment)
Potassium	coolant additive
Silicon	dirt, oil additive (defoamant), coolant additive, seal, synthetic lube, wet clutch
Silver	EMD wrist pin bushing, turbo bearing, bearing plating or alloy, silver solder
Sodium	coolant additive, oil additive, sea water
Tin	bearing, bushing, piston, plating, alloy
Titanium	gas turbine bearing, hub, blade, ‘white’ lead, paint
Vanadium	steel alloy, ‘heavy’ fuel contaminant
Zinc	additive, galvanized metals/plumbing, brass component

The **Falex Lubricant Tester** is a steel journal and bearing loaded by a spring-gage micrometer and driven by a 1/3-hp 290-rpm motor. The test measures bearing load and resulting wear produced by extreme pressure forces under constant speed and temperature.

Analytical ferrography is a microscopic visual and photographic evaluation of wear particles. It is an in-depth analysis that helps identify how particles originated. The test can determine particle makeup: steel, copper, bronze, babbitt (used as a bearing material), cast iron and silicon (from sediment). It also analyzes particle shape to pinpoint whether particles are generated through machining, corrosion or other types of wear.

Direct reading ferrography uses magnets to strip iron-laden and other susceptible particles from a lube for study. Optical sensors measure the density of particles collected. Unlike particle counting, this test can be run on opaque fluids.

Results include both the number of particles and the ratio of large to small particles. The number of particles reflects wear, while the ratio of large to small indicates the severity of the problem: the higher the ratio, the greater the risk of failure.

The **flash point** of a lubricant is the lowest temperature at which oil gives off sufficient vapors so that the vapors will ignite when a small flame is periodically passed over the surface. This is a measure of the temperature required to produce an ignitable vapor-air mixture above the liquid when exposed to an open flame. It helps determine if oil is contaminated with a lower viscosity fluid. For example, low flash point of engine oil may indicate fuel dilution. Three commonly used flash point tests are ASTM D 92 Cleveland Open Cup, ASTM D 93, Pensky-Martens Closed Cup, ASTM D 56 Tag Closed Cup. Closed cup tests are normally used for substances with a low flash point such as solvents and fuels.

The **fire point** is the lowest temperature at which oil ignites and continues to burn for at least five seconds. Fire point ranges from 10°F to 70°F higher than the flash point of a product.

The **foam test** measures the volume of oil foam generated by blowing air through a sample of oil in a graduated cylinder at specified temperatures. The air inlet tube is fitted with a 1-inch diameter spherical glass diffuser stone of fused crystalline alumina grain at the bottom of the cylinder. The air pressure is maintained at a constant rate for a specified blowing time (usually 5 minutes). Sequence I is run at 75°F, Sequence II at 200°F, and Sequence III after the sample has cooled to 75°F again.

The level of foam is measured immediately after each sequence, and then after a 10 minute settling time. The two numbers are reported as foam tendency/stability. A test result of 150/20 would mean that there were 150 mls of foam immediately after blowing, and 20 mls after it had settled for 10 minutes.

In the **4-ball test**, four ½ inch steel balls are arranged with one ball atop three others. The three lower balls are clamped together, and the fourth sits on top like a pyramid and is rotated under increasing load. In the 4-Ball wear test, after a measured time and load, the scars on the balls are measured. In the EP test, load is applied until the balls weld together. That point is recorded as the weld point.

Load Wear Index is a proportion of the weight and scar diameters when load is applied just before the weld point. It indicates the level of EP performance in oil. A high level of EP would be 50 to 75, and moderate EP would be 35 to 45.

Fourier Transform Infrared Spectroscopy (FTIR) identifies organic functional groups by measuring their infrared absorption at various wavelengths. Results are expressed in absorbance units per centimeter and range from 1 to 100. It is useful in measuring oxidation, nitration, and glycol contamination. A good new oil reference sample is needed to get good used oil results. Also, a special unit is used to measure soot. It can measure water, hydrocarbons, oxidation products, nitration products, and glycol.

Water	-	Typical value is <5
Hydrocarbon		Typical values are >1000 for hydrocarbon oils, < 800 for synthetics. It is used to determine the type of oil or whether mixtures have occurred.
Oxidation		Typical values is < 20
Nitration		Typical value is <20.
Glycol		Typical value is <50 but may be much higher due to some additive materials that read as glycol. Many motor oils test at over 100 when new. A significant change above that number will be flagged.

Freon floc point (or flocculation) test cools down an oil in the presence of Freon. The test results are reported as the coldest temperature at which the oil remains clear with no wax formation. This test is important to determine if the oil is suitable as a refrigeration lubricant in Freon systems, such as R 22, where the oil is in intimate contact with Freon.

Fuel dilution can be tested by using gas chromatography. This method detects fuel and other volatile hydrocarbons that can contaminate lubricants. Some of the causes of fuel dilution in a diesel engine include extended idling or defective fuel injectors, pumps, fuel lines and timing. If fuel is indicated in gasoline engines, check for problems with fuel injectors, carburetor, choke, ignition or poor warm up.

Fuel soot is run in a special infrared analysis unit designed specifically for fuel soot. It shows the amount of carbon produced by combustion. Fuel soot is a contributing factor in viscosity increase. For diesel engines, elevated fuel soot can indicate faulty injectors and/or inefficient engine operation.

Neutralization number, acid number (AN) is expressed as the amount of potassium hydroxide (KOH) required to neutralize the acid in one gram of oil. An oil's acid number is a measure of the concentration of strong and weak acids in the sample. New oils have a total acid number; oils with more additives usually have a higher number. An increase in TAN, as the oil ages, indicates an increase in weak acids, which are caused by oxidation. High TAN can reflect over-extended drain intervals, excessively high system temperatures or oil oxidation.

Base number (BN) is a measure of oil's reserve alkalinity to neutralize acids occurring in engine oil. It is obtained by titration with hydrochloric acid, but is expressed in mg of KOH equivalent. TBN reflects the life left in the lubricant. Very low TBN indicates over-extended drain intervals or the use of oil with insufficient TBN for the sulfur content of the fuel.

The **oil spot test** is a quick field method of evaluating used lubricating oils in internal combustion engine operation. Also called a blotter test or a patch test, the test shows whether the oil has been contaminated and whether it has lost its power of detergency or dispersancy.

Other Oil Analysis Tests

Rotating pressure vessel oxidation test (formerly Rotary bomb oxidation test (**RBOT**)) indicates the level of the oxidation inhibitor content remaining in used oil. Its test results are recorded as the number of minutes it takes for a test sample to reach an oxygen pressure drop of 25 psig. RBOT is a useful trend analysis tool for monitoring the remaining life of turbine oils and paper machine oils.

ASTM D 943 Turbine Oil Stability Test (TOST) is a test that more closely approximates the conditions in a turbine. Test results are expressed in thousands of hours.

Staeger Oxidation Test, Universal Oxidation Test, CIGRE IP 280.85 are all oxidation tests under different controlled conditions. ASTM D 942 Oxidation Stability of Greases, as its name suggests, is the test most often used to determine the expected life of grease.

Particle Count is conducted by running a sample through a small orifice with a light source on one side and an optical sensor on the other. The pulse generated by the interruption of the light source is proportional to the size of each particle. Six particle size ranges are detected. This test requires relatively transparent fluids.

Particles come from two sources: wear and contamination. High particle counts indicate potential wear and large particles (greater than 10-15 microns) predict fatigue-oriented catastrophic failure. This test is particularly important in preventing catastrophic failures, since elemental analysis will not detect particles larger than 10 microns. When large numbers of sizes of particles are found, analytical ferrography testing should be done.

Particle count can help determine that overall cleanliness of the equipment, whether filters are effective, whether abnormal wear is occurring. If it does indicate abnormal wear, it is a screening test for more comprehensive tests such as ferrography. (See Sect. 11B for explanation of the ISO Cleanliness Code, ISO 4406.)

Penetration is the depth (in tenths of a millimeter) that a standard cone penetrates a sample of the grease under prescribed conditions of weight, time, and temperature. If the cone penetrates between 445 to 475 tenths of a millimeter, it is NLGI grade 000 and is so fluid it almost flows. NLGI 6 grade have a penetration between 85 to 115 tenths of a millimeter and have the consistency of a semi-solid block.

pH values ranges from 0 to 14 where 0 is the most acidic and 14 is the most alkaline, pH is generally not run on petroleum products because it is measured in an aqueous solution and oil and water don't mix. PH is generally run on cutting oil emulsions and 95:5 water based fire resistant hydraulic oils.

The **pour point** of petroleum oil is the lowest temperature at which the oil will pour or flow under prescribed conditions when it is chilled without disturbance at a fixed rate. To determine pour point, a sample of oil is cooled in a test jar under specified conditions: the temperature is observed in increments of -5°F until no movement is apparent on the surface of the oil when the test jar is held in a horizontal position for 5 seconds. This temperature is recorded as the solid point. By definition the pour point is 5°F above this temperature.

A **refractometer** is (usually) a hand-held device that give a quick measurement of the amount of oil in an emulsion such as may be found in water based hydraulic fluid or cutting oil emulsion. It measures the amount of oil by refracting light through the emulsion.

Roll Stability is a measure of the mechanical stability of grease. It determines the changes in the consistency of greases when worked in the roll stability tester.

The **rust prevention** test indicates the ability of lubricating oil to prevent corrosion during the lubrication of ferrous parts in the presence of water. A steel test rod is placed in the beaker of oil and water at 140F for 24 hours and the results are reported as pass or fail. The degree of failure may be light, moderate, or severe.

The **saponification number** test indicates the amount of fatty substances in an oil. It can distinguish between a compounded and non-compounded lubricant.

Shear or mechanical stability of grease is its ability to withstand repeated working with minimum change in its structure or consistency.

Sulfated ash, also known as the sulfated residue test, indicates the concentration of metal additives in new oil including barium, calcium, magnesium, sodium, tin, zinc and potassium. An oil sample is heated in a porcelain dish until the oil ignites and burns readily. The ash is treated with sulfuric acid and additional burning to remove the carbon.

Timken OK load test is used to measure the load supporting capabilities of gear oils. It is run by pressing a steel block against a rotating shaft. The load is measured as the heaviest load that can be applied without scoring the block. A 40-lb. Timken load is an indication of a good extreme pressure oil or grease.

Viscosity is a fluid's resistance to flow and is the oil's most important property. Kinematic viscosity is the time required for a fixed amount of oil to flow through a capillary tube under the force of gravity. Kinematic viscosity is expressed in centistokes (cSt) and is usually measured at 40°C for industrial oil and 100°C for engine oils. Saybolt Universal Viscosity, also known as SUS, SSU or SUV is measured as the amount of time required to measure 60 ml through a standard orifice.

Absolute viscosity is the tangential force on a unit area of either one of two parallel planes at a unit distance apart when the space is filled with liquid and one of the planes moves relative to the other with unit velocity in its own plane. It is expressed in Centipoise (cP).

Apparent viscosity is absolute viscosity measured at a given shear rate relating to non-Newtonian fluids (e.g., multigrade motor oils).

Other tests for expressing viscosity of petroleum fluids under different conditions include Redwood Universal, Redwood Admiralty, Engler, Saybolt Furol and Brookfield.

ASMA and SAE set up their own standards for expressing viscosity. As a reference, an AGMA 5 gear oil is approximately 100 cSt @ 40°C or 500 SSU @ 100°F, and is similar to an SAE 90 gear oil and an SAE 50 engine oil.

Viscosity Index is an empirical number indicating the rate of change in viscosity of an oil within a given temperature range. It is calculated from viscosities measured at 40°C and 100°C.

Water is measured qualitatively through use of the crackle test. More accurate measurement is obtained with the Karl Fischer test or distillation tests. Water is the most common contaminant in a steam turbine reservoir.

Water and sediment test is also known as BS&W for Bottom Sediment and Water. It is the measure of the amount of water and sediment accumulated by the oil while in service. The modified test using naphtha indicates water and sediment plus oxidized material.

Water washout is a method for determining the water washout characteristic of lubrication greases from a bearing under prescribed laboratory conditions and measures the tendency of grease to withstand water washout in bearings. A ball bearing is rotated 600 rpm; 100°F water impinges on the bearing plate. The test measures the per cent of grease washed out in one hour. The test is repeated with 175°F water.

Wheel bearing test is a service evaluation of ball and roller bearing greases. It simulates conditions of these lubricants in actual operation. It measures the leakage of a lubricant from the hub and shows the tendency of the grease to form varnish-like deposits on the bearing.