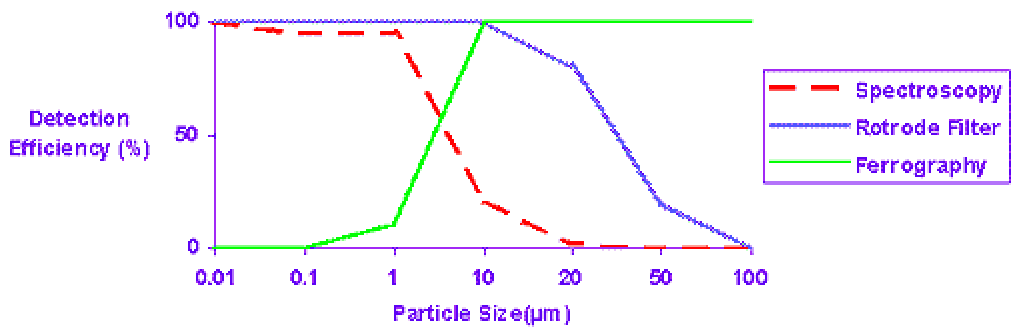
Application Note - Important Tests in Oil Analysis

Oil analysis is widely used and a very cost effective form of machinery condition monitoring. Advances in computers and instrumentation have recently brought great changes to the technology, to the point that a modern oil analysis program is both easy to manage and provides a high return of maintenance investment dollars(1). Many companies are using software to track their equipment data, and there are a few excellent stand-alone oil analysis software programs available, as well as several modules to vibration analysis software. Much has been written about defining alarm limits using relatively generic methodologies for all aspects of predictive maintenance technologies.

Oil Analysis - The basics revisited

It is well worthwhile to review some basic tenets of oil analysis and it's application to condition monitoring. There are may different types of tests that are used to evaluate lubricants. The tests specified must cover three areas : machine condition, contamination condition, and lubricant condition. Failure to test in all three areas may result in a unnoticed system failure, thus showing up a disregard for the equipment and the technology by both maintenance and the laboratory. The following tests are the most applicable to condition monitoring. some may overlap the three areas of interest, but that is reassuring, as it provides corroborating evidence of an abnormality.



Spectrometric Analysis:

Technique for detecting and quantifying metallic elements in a used oil resulting from wear, contamination and additives. The oil sample is energized to make each element emit or absorb a quantifiable amount of energy, which indicates the element's concentration in the oil. The results reflect the concentration of all dissolved metals (from additive packages) and particulates. This test is the backbone for all oil analysis laboratories today, as it provides information on machine, contamination and wear condition relatively quickly and accurately. It's major limitation is that it's particle detection efficiency is poor for particles 5 microns(µm) in size or greater (fig. 1). Particles greater than 10 µm in major diameter are the result of abnormal; wear modes, and these particles must be quantified. The technique is accurate to 10%, although new equipment is now reporting within 3%.

Rotrode Filter Spectroscopy:

First introduced in 1992, this spectrometric technique detects and large or coarse wear metals and contaminants in a used oil sample. "Coarse" particles include all particulates up to 25 µm in size but excludes all additives. "Coarse" particles are especially important since these particles are the first indicators of abnormal wear situations. RFS provides a low cost efficient screen for ferrography, and is superior to DR(direct read)ferrography because it detects ferrous, nonferrous and contaminant elements(usually 12 elements). Detection efficiency of large material gets poorer as particle size increase above 25 µm diameter. It's accuracy range is within 15%.

Viscosity:
The resistance of a fluid to flow. Viscosity is the most important lubricant physical property. Lubricants must have suitable flow characteristics to insure that an adequate supply reaches lubricated parts at different operating temperatures. The viscosities of lubricants vary depending on their classification or grade, as well as the degree of oxidation and contamination in service. If viscosity of the lubricant differs by more than 10% from nominal grade, a change of oil is recommended by the lubricant supplier. When the equipment is on a condition monitoring program, more specific controls may be put in place. Oil viscosity is expected to rise over time and use, and loss of viscosity is considered to be more serious than an increase. Therefore, a working alarm range is +20%, -!0%, i.e. not more than 20% over nominal, and not less than 10% under nominal grade. Accuracy of this test is very good, at 0.5%.

Infrared Analysis(FT-IR):
Spectrometric technique for detecting organic contaminants, water and oil degradation products in a used oil sample. During a lubricant's service life, oxidation products accumulate, causing the oil to become degraded, and in most instances, slightly acidic. If oxidation becomes severe, the lubricant will corrode the equipment's critical surfaces. The greater the "oxidation number", the more oxidation is present. Similarly, the "nitration number" reflects the level of nitrogen compounds in the oil resulting from nitrogen fixation(common in natural gas fueled engines). Conditions such as varnishing, sludge deposits, sticky rings, lacquering and filter plugging occur in systems with oxidation and/or nitration problems. Infrared spectroscopy also indicates contamination due to free water, glycol antifreeze, soot deposits and fuel dilution. There are guidelines issued for oxidation numbers and liquid contaminants by manufacturers, but this is essentially a trending tool.

Total Base Number:
The converse of the TAN, this titration is used to determine the reserve alkalinity of a lubricant. The TBN is generally accepted as an indicator of the ability of the oil to neutralize harmful acidic byproducts of engine combustion.

Total Acid Number:
A titration method designed to indicate the relative acidity in a lubricant. The acid number is used as a guide to follow the oxidative degeneration of an oil in service. Oil changes are often indicated when the TAN value reaches a predetermined level for a given lubricant and application. An abrupt rise in TAN would be indicative of abnormal operating conditions (e.g. overheating) that require investigation. Most lubricant suppliers give TAN condemnation limits in the bulletins. Accuracy of this test is within 15%.

Water:
Usually not desirable in oil, water can be detected visually if gross contamination is present (cloudy appearance). Excessive water in a system destroys a lubricant's ability to separate opposing moving parts, allowing severe wear to occur with resulting high frictional heat.Water contamination should not exceed 0.25 % for most equipment, and not more than 100 ppm for turbine lube and control systems. There are several methods used for testing for moisture contamination, each with a different level of detection. They are summarized here.

Tests	Limit of Detection	Test Cost	Advantages	Disadvantages
Crackle	1000 ppm (0.1%)	low	A good field indicator, easy to perform	qualitative only, not suitable for trending
FT-IR water	1000 ppm (0.1%)	low	quantitative, good for trends, easy to perform	other liquid contaminants (glycol) present can confuse the spectrometer.
Centrifuge	1000 ppm (0.1%)	low	Still widely used for fuels testing and the BS&W tests	not as effective nowadays because of demulsifier additives
Karl Fischer	10 ppm (0.001%)	high	The best test for low moisture levels. Very accurate. Required for turbine systems & transformers	Unless lab has a nitrogen spurge, lubricant additives may cause interference. Need lab expertise to run correctly.

Particle Count:
A method used to count and classify particulate in a fluid according to accepted size ranges, usually to ISO 4406 and NAS 1638. There are several different types of instrumentation on the market, utilizing a

variety of measurement mechanisms, from optical laser counters to pore blockage monitors. Turbine and hydraulic systems ("clean systems") require particle counting , and should not exceed ISO 16/12 (NAS 8) in most cases, although some applications require more stringent limits.

Analytical Ferrography:

A technique which separates magnetic wear particles
from the oil and deposits them on a glass slide known as a ferrogram. Microscopic examination permits characterization of the wear mode and probable sources of wear in the machine. This technique is known as analytical ferrography. An automated version of this magnetic separation technique is DR (direct read) ferrography. It measures the ratios of large and small particles in the sample, and the data may be used to calculate the wear particle concentration and the severity index, two parameters which allow for trending. it is an excellent indicator of abnormal; ferrous wear occurring. It is unsuitable for nonferrous wear, however, and the test is most useful when a wear trend has been established.

Equipment Applications

Industrial equipment needs a combination of the above tests for condition monitoring . The following table is a summary of the test applicability.

Tests for Condition Monitoring

Equipment	**Spectro Analysis**	**Viscosity**	**FT-IR**	**Particle Count**	**Karl Fisher**	**Total Acid No.**	**Total Base No.**	**Rotrode Filter**
Engines	R	R	R				R	A
Compressor	R	R	R		A	R		R
Gearboxes	R	R	R					R
Bearings	R	R	R	A				R
Hydraulics	R	R	R	R	A	A		R
Turbines	R	R	H	R	R	R		R
Motors	R	R	R					R

R: Required test
A: Advisable test, provides extra detail, particularly during problem solving