FLUID LIFE
EQUIPMENT RELIABILITY SERVICES
LABORATORY SERVICES

REMAINING USEFUL LIFE EVALUATION ROUTINE (RULER)

RULER PROVIDES AN INTUITIVE RESULT THAT CAN SUPPORT CONDITION BASED MAINTENANCE

REMAINING USEFUL LIFE EVALUATION ROUTINE FOR EXTENDING DRAINAGE INTERVALS

Overview

- This test is useful in monitoring the oxidative health and remaining useful life of lubricants which have an anti-oxidant additive package, as found in most turbine, gear, compressor, hydraulic and gearbox lubricants.
- RULER provides an intuitive result that can support extended drainage intervals by determining the percentage of anti-oxidants remaining in your lubricant, and planning maintenance around the predicted end of the useful life of the lubricant
- Whether under extremely variable or consistent load conditions, RULER can monitor the ability to prevent oxidative stress, corrosion, and risk of varnish potential of your oil in real-time via routine analysis, or as a series of periodic checks.

BACKGROUND

In maintaining the operation and service of machines requiring the use of turbines, gear, compressor, and hydraulic oils, it is desirable to maximize the time between drainage and replenishment of their respective lubricants (drainage interval), without overextending the useful life of the lubricant which may cause corrosion, wear, and increase safety risk.

There are a multitude of metrics by which to monitor the quality of a lubricant, including viscosity, corrosivity, and oxidation. These properties can often be independent of each other, creating a constellation of points of potential failure, exacerbating the task of troubleshooting the remaining life of your lubricant.

Oxidative stress specifically, can have measurable impact on multiple properties of a lubricant; this impact is mitigated through a category of anti-oxidant (AO) additives called 'inhibited phenols and amines. These additives intercept oxygen and other oxidative molecules like free radicals and peroxides, preventing them from causing damage to both the base oil and other additives present in the lubricant. These anti-oxidants are also regenerative, extending the life of the oil even further.

However, when the phenols and amines are oxidized into quinones and nitrosylated aromatics and can no longer be regenerated, the remaining life of the oil will begin to drop. As anti-oxidant additives are depleted through repetitive stress, the lubricant is at much higher risk for failure due to corrosion or wear.

The useful life of an oil is measured through a test method abbreviated as RULER (i.e. Remaining Useful Life Evaluation Routine). RULER can be used to measure the relative concentration of these anti-oxidants from new oil and trended over time. Drainage and maintenance can then be predicted and appropriately scheduled at predetermined intervals, alleviating the stress of lost-time incidents or undue wear of valuable assets.

VALUE

Unscheduled shut-downs as a result of poor lubrication are problematic as they result in lost time and reduced output, but may also be a trailing indicator on other long-standing issues that are hidden until observations are made during a critical failure. The RULER method allows for real-time monitoring of lubricating oils, at intervals set to suit the needs and use of any given machine. The RULER result provides a percent (%) based result that indicates how much life, proportional to the remaining AOs, remains on the used sample.

As a general principle, samples that return a result of 25% or less are flagged to indicate drainage may be required; however this principle can be altered to suit the specific needs of the lubricant and machine. The indicated impending drainage allows for sensible timing of maintenance with either scheduled downtime, or to plan multiple oil drainages concurrently, saving time.

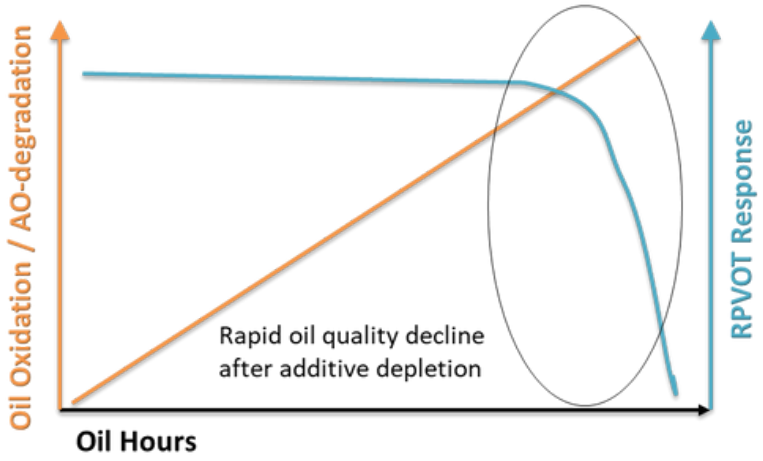
As an add-on to assets with conventional remaining life analysis as part of their condition monitoring program (i.e. RPVOT), the incremental cost results in significant gains in real-time data trending, and information and data inputs, improving decision making capabilities. By directly measuring the available anti-oxidant concentration of the lubricant, rapid losses and long-term degradation can be observed and differentiated. These trends may also indicate looming sources of corrosion such as nitration, acid number, and i-pH, allowing you to make informed decisions and act on high corrosion risks before they become problematic.

METHODOLOGY

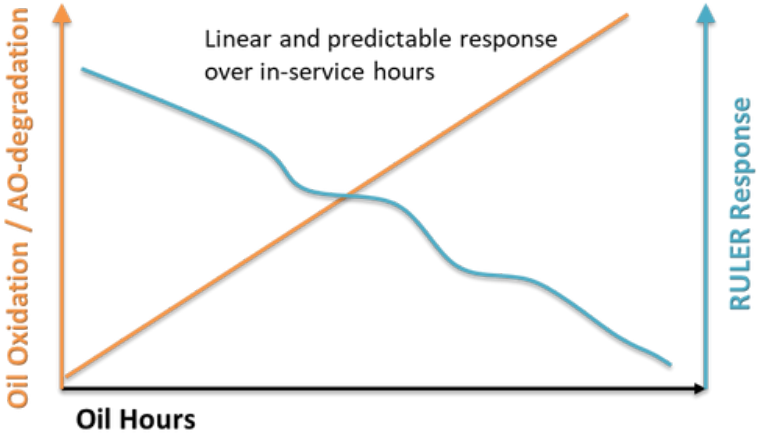
REMAINING USEFUL LIFE EVALUATION ROUTINE (RULER)

Previously, the most effective way to monitor the remaining life of an oil was to challenge it via a stress test called RPVOT (rotating pressure vessel oxidation test). While costly and time consuming, this method does measures the ability of a lubricant to resist oxygenation, which is an indirect measurement of anti-oxidant concentration and performance. However, oxidation occurs via many mechanisms, not just the presence of dissolved oxygen.

When the previously described regenerative mechanism of anti-oxidants is interrupted or inhibited, the RPVOT test response can drop precipitously, making it a challenge to intervene soon enough if the useful life of the oil is nearing its end. The result is therefore unpredictable if the in the absence of frequent and continuous monitoring. The inferred data from RPVOT testing is therefore indirect and incomplete, and does not capture the potential risks from other oxidative sources (such as free radical damage).



Comparatively, the RULER test response demonstrates linearity with the absolute concentration of the anti-oxidant additives, avoiding abrupt changes in the test response, and providing predictability in the length of a drainage interval.



METHODOLOGY CONTINUED

In the absence of long-term trending from previous RPVOT data associated with a new oil type, supplementary data is required to make direct inferences about the life remaining of the machine's lubricant. RULER is one such supplementary test, and is a direct measurement of the inhibited phenols and aryl-amines present in the oil. Many oil formulations might use variations or substitutions on their chemical composition, but the anti-oxidant functionality remains the same, and thus can be measured using the same methodology.

Detection of phenolic and aminic species is performed with an analytical technique called 'Linear Sweep Voltammetry'. This analysis is done by performing a liquid phase extraction of phenols and amines into a solvent solution containing an oxidation accelerant. Once the phenols and amines are fully extracted, the immiscible oil is absorbed into a solid phase (typically diatomaceous earth).

An electric potential (voltage, V) is then applied to the mother liquor solution, and a current (amps, A) is measured in response. This is the basis for any voltammetry based analysis. The electric potential applied is increased at a fixed rate each second, starting at 0 V, incrementally 'sweeping' through the applied voltages up to a maximum of 1.7 V. At a specific voltage ranges, the electric potential is high enough to react the phenols or amines with the oxidation accelerant, causing a change in the current moving through the solution. This change in current is directly proportional to the amount of phenol or amine that was present in the oil.

When compared with measurements on brand new oils, this data can directly return a percentage of the remaining chemical species. As this value trends down from 100%, the proportionate remaining life of the oil can be measured, giving rise to predictability and confidence in the operation of the associated machine.

EXAMPLE

Figure 1: Linear sweep voltammogram of new (green) and used (red) oil in Compressor A.

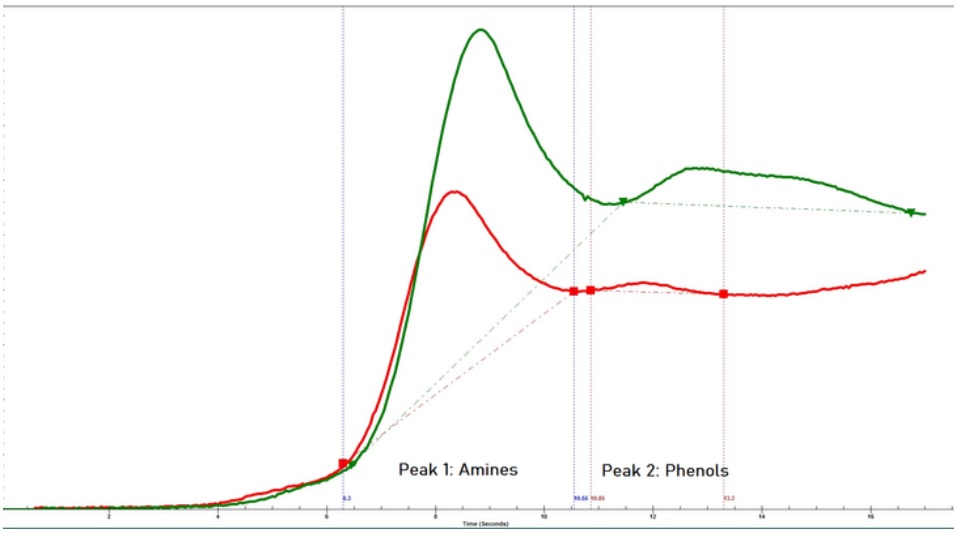
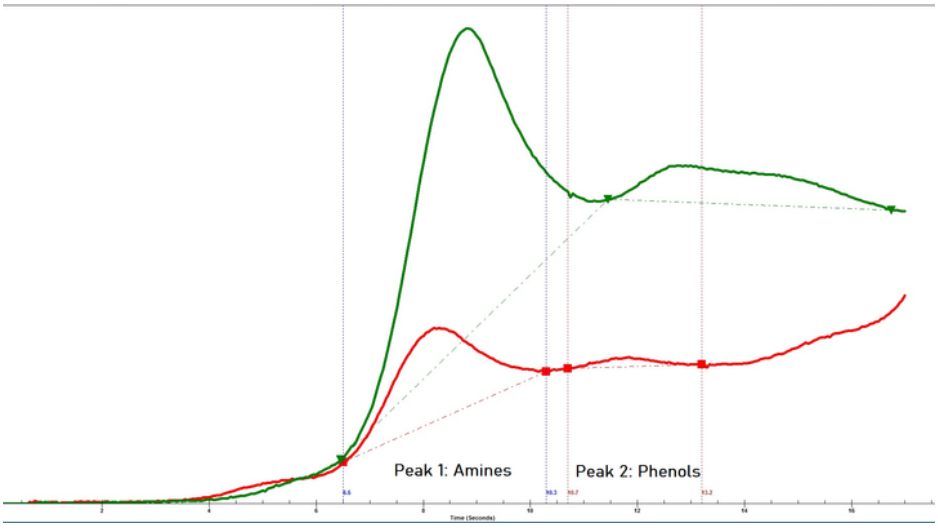


Figure 2: Linear sweep voltammogram of new (green) and used (red) oil in Compressor B.



Two broad peaks can be measured representing the amine (1, left) and phenol (2, right) components of the oil. Measuring the area difference between the red (used oil) peaks from the reference green (new oil) peaks, provide the percent depletion of the anti-oxidant additive package.

EXAMPLE

Comparing the voltammograms of the two compressors in Figures 1 and 2 where RULER monitoring was performed, it can be seen that the standard metrics of oil quality (like viscosity, i-pH, and AN) remained unchanged (table 1, below), while the RULER results provide significant insight into the how the oil has degraded relative to the new oil reference (shown in green).

This RULER information is an actionable leading indicator for the operator, allowing for predictive and condition-based drainage intervals.

Table 1: Comparative metrics for used Compressor oil (A and B). RULER results (blue box) show condemning limits for A, while B still has some remaining useful amine AO additives. By comparison, the standard parameters (black box) show minimal or no changes between the two samples.

	New Compressor Oil	Used Compressor A	Used Compressor B
Total RULER %	100%	35 %	64 %
RULER 1 (% Amines)	100%	25 %	55 %
RULER 2 (% Phenols)	100%	10 %	9 %
Viscosity @ 40C (cSt)	48	46	48
Viscosity @ 100 C (cSt)	7.58	7.37	7.58
i-pH	5.87	4.53	4.52
TAN (mg KOH/kg)	0.04	0.67	0.44

Without RULER testing, used oil A would be kept in service, increasing potential for oxidation, corrosion, and varnish. RULER is therefore an integral and holistic part of oil analysis, allowing for the most effective condition based monitoring program.

RECOMMENDATIONS

If your organization has large compressors, turbines, gearboxes, and hydraulics, and you rely on condition based monitoring for your drain intervals, we recommend performing RULER analysis as part of your ongoing, proactive testing.

Testing is recommended quarterly for long-service lubricants, however short-term monthly or routine analysis may be desired if you perform frequent maintenance or sweetening / top-up, or are making significant changes during scheduled shut-downs and turn-around.

For operators utilizing hours of service to schedule changes, you may find that you can perform fewer drains per year on a condition-based monitoring program. While routine testing may incur additional costs, there may be commensurate gain in the cost savings from less lubricant consumption and downtime.

SUMMARY

To ensure that a lubricant is not used past the end of its useful life, periodic oil changes are inherently conservative, which often results in the discarding of lubricants that are still suitable for use. Understanding and forecasting the oxidation process of turbine oils will provide added value to your Oil Analysis Program.

With the addition of the RULER® test, your reliability and maintenance team will be able to proactively:

- Quantify the relative concentrations of antioxidants in new and used oils in order to monitor the depletion rates of the antioxidant protection package in the oil.
- Quantify antioxidant levels of incoming and stored oil supplies.
- Identify abnormal operating conditions prior to equipment failure following the detection of abrupt antioxidant depletion rates.
- Determine proper oil change intervals and extend oil change intervals through timely antioxidant additive replenishment.

To learn more about how the RULER test can support your condition based maintenance planning, contact a Fluid Life representative.

ALWAYS RELIABLE.
ALL WAYS.

REMAINING USEFUL LIFE EVALUATION ROUTINE (RULER)

We're a company that's All Ways Reliable. As a leading provider of lubrication analysis and asset management solutions, Fluid Life uses its best-in-class software, training, tools and programs to help keep your equipment running at peak performance. From analysis and evaluation to planning and strategy, Fluid Life has the expertise to help you achieve a higher level of reliability.

Contact a Fluid Life representative today to learn how we can support your reliability programs.

ALL WAYS RELIABLE.

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