Fluid analysis critical to maximizing lube-oil service life

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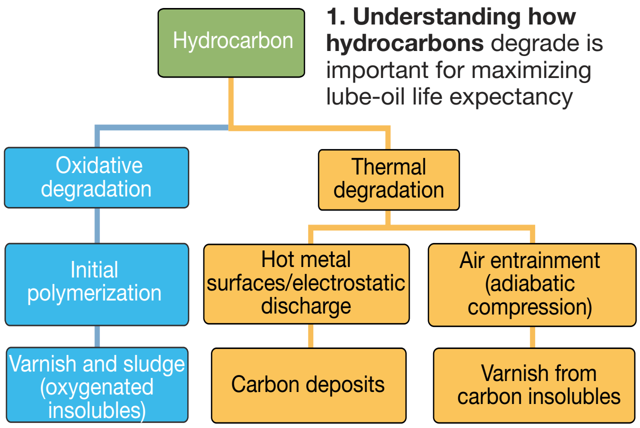
Gas turbine firing temperatures continue to increase as OEMs relentlessly chase efficiency improvements. This demands that lubricant manufacturers formulate products capable of withstanding the more rigorous service conditions. Compounding the challenge are the owner/operators, who want turbine oils to last longer.

To meet these demands, turbine oils have undergone significant changes over the last decade or so. For example, base oils have changed from Group I (solvent-refined) to Group II (hydrotreated). Important to plant personnel is that Group II base stocks, while more oxidation-resistant, have a lower solvency, which means varnish issues are a real possibility.

The antioxidants added to protect the fluid also have changed. Combinations of antioxidants, referred to as complex additive packages, are used to take advantage of the synergies among the various constituents.

Fluid degradation. Critical to optimizing your lube-oil's life expectancy is understanding how a lubricant degrades (Fig 1) and what tests are available to measure the amount of degradation. Oxidation and/or heat are what cause Group 1, Group 2, and synthetics to degrade.

Generally, oxidative degradation doubles for every 18-deg-F increase in lube-oil temperature. Group I oils are the most susceptible to this type of degradation because they contain the highest levels of unsaturates and impurities. The initial degradation products are aldehydes, ketones, and carboxylic acids; they undergo further reaction to form higher molecular-weight products. As these byproducts combine, sludge and varnish are formed.



1. Understanding how hydrocarbons degrade is important for maximizing lube-oil life expectancy

Test methods

One of the first tests designed to measure a turbine fluid's ability to resist oxidation was the Rotating Pressure Vessel Oxidation Test (RPVOT, ASTM D2272). In this test, the fluid is subjected to pressure and heat in the presence of water, oxygen, and a copper catalyst inside an enclosed vessel. Pressure drop indicates when the fluid is oxidized—that is, once it absorbs (reacts with) the oxygen. The time it takes for the pressure to drop by a predetermined amount is the end point.

The older Group I fluids typically had RPVOT values of about 600 minutes or less. Group II fluids with sophisticated additive packages may have values in excess of 3000 minutes. ASTM D4378 (Standard Practice for In-Service Monitoring of Mineral Turbine Oils for Steam and Gas Turbines) states that oil should be changed when its RPVOT falls below 25% of the RPVOT for that same oil when it was new.

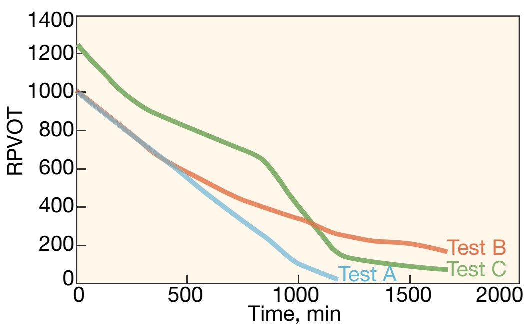
The universal validity of RPVOT test results have been called into question by some industry experts recently because of issues regarding repeatability and reproducibility with at least some new oils. However, RPVOT is still listed routinely on most oil manufacturers' product data sheets and remains the most widely used indicator of a fluid's oxidative condition.

Running the RPVOT test regularly helps in predicting the fluid's useful life. ASTM D4378 recommends that RPVOT testing be done annually, and more frequently as the fluid ages. RPVOT does not necessarily decrease linearly. A recent analysis of data from tests performed at regular intervals on several oils found that the RPVOT results for some fluids decreased linearly while those for others did not.

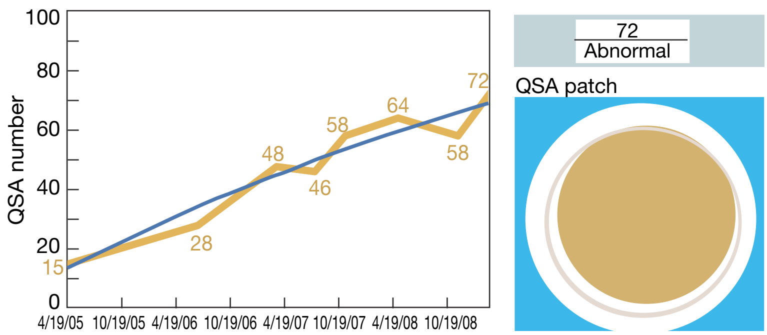
Fig 2 shows three possible ways in which a fluid's RPVOT may decrease. Keep in mind that these results are from tests run under controlled laboratory conditions. Under field conditions, the odds are even higher that RPVOT will not decay linearly. Note, too, that RPVOT was not developed as a means for comparing oils—that is, for comparing the absolute RPVOT values of alternative fluids against each other. Rather, its value is in charting the decrease in RPVOT for a given fluid.

Two relatively new tests useful for assessing a fluid's oxidative health are QSA® (Quantitative Spectrophotometric Analysis, Analysts Inc) and RULER™ (Remaining Useful Life Evaluation Routine, Fluitec International). Though neither of these tests measures a fluid's ability to resist oxidation under simulated conditions—as RPVOT does—they do provide useful information about a fluid's oxidative health.

Traditional oil analysis, while a valuable preventive maintenance tool, is unable to detect varnish or varnish precursors. By contrast, QSA is designed to detect varnish precursors. The amount of soft contaminants present in a sample is quantified using a spectrophotometer and is reported by use of a proprietary scale,



2. Data from tests under controlled laboratory conditions illustrate how RPVOT may decrease



3. Varnish Potential Rating for a Frame 7 engine increased unchecked for years

developed by correlating lab results with known instances of varnish occurrences in field studies.

QSA has proven more reliable for predicting varnish than alternatives such as the ultracentrifuge. It is recognized by several OEMs as the preferred method for varnish testing. Fig 3 illustrates the Varnish Potential Rating (VPR) for a Frame 7 engine at a combined-cycle plant.

RULER works on the principle that some chemical species—such as antioxidants—are electrochemically active. A compound is considered electrochemically active if, when a voltage is passed through a solution containing that compound, current flows. Different chemical species respond at different voltages. The amount of antioxidant is directly related to the amount of current produced.

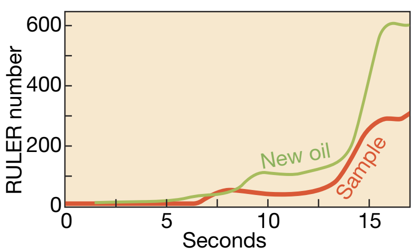
By increasing the applied voltage at a constant rate, one can develop a graph that reveals the antioxidants present. The quantity of antioxidants remaining in the fluid can be calculated as a percentage of the initial amount by comparing the area under the curve created for the oil in service to that for the same oil when new (Fig 4).

Thus RULER measures the amount of antioxidants remaining in the fluid, not the oil's useful life. This is important because some of the degradation products from the antioxidants may themselves be antioxidants.

RULER also requires a reference fluid to calculate the percentage of additives remaining, which may limit its effectiveness in some situations. Here's why: Some gas-turbine fluids may remain in service for 10 years, steam-turbine oils even longer. Over the years, the original fluid may have been reformulated or topped off with a different product. The resulting fluid mixture could complicate interpretation of RULER results.

However, the test has several advantages, including: small sample size, rapid analysis; plus, technicians require little training to perform the test.

The bottom line: RPVOT, RULER, and QSA each provide valuable information regarding the health of your turbine oil. Including all as part of your fluid-analysis program enables the most accurate decision-making.



4. Antioxidants remaining in lube oil can be calculated as a percentage of the initial amount by comparing the areas under the curves for both sump and new oil

Condition-based maintenance

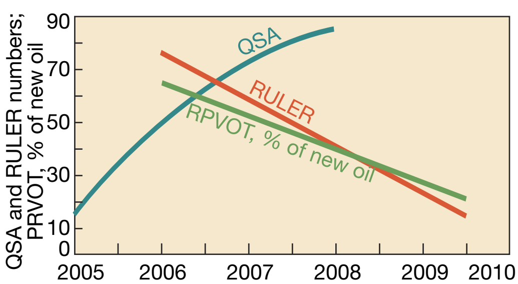
Lubricating oil is changed by some users on a fixed schedule. This approach, while convenient, does not assure optimum machine and fluid life. Oil changed prematurely increases the cost of lubrication—you wind up buying more new fluid than you need and pay for disposal of oil that may still have some life in it. By contrast, if fluid remains in service beyond its useful life, you place critical rotating equipment at risk. If a forced outage results, revenue loss could be significant.

More cost-effective is scheduling preventive maintenance on a condition-based approach. A condition-based lube program relies on the results of fluid analyses to maximize the use of your oil, thereby minimizing the life-cycle cost of lubrication.

Decisions involving lube-oil reconditioning and replacement demand careful consideration and planning. To illustrate: Replacement requires that time be budgeted for review of alternative fluids, the purchasing process, delivery, etc. In addition, cleaning and flushing of the lube system may be necessary to maximize the effectiveness of the new oil and to return performance to "as new." Arrangements for safe disposal also must be made.

What follows are three examples of how fluid analysis was used to decide between lubricant replacement and conditioning.

Case history 1. A combined-cycle plant annually assessed the condition of its turbine fluids. After the 2008 turbine lube assessment, plant personnel questioned whether the fluid would be suitable for continued use until the next scheduled outage in fall 2009. Options included replacing the lube oil, removing existing varnish and precursors with a proven clean-up technology and/or topping off the existing fluid.



5. Meaningful data can be extrapolated to estimate when new oil will be needed

Because the plant had been testing its fluids regularly to assess oxidative stability, meaningful data were available for predicting the fluid's expected condition a year hence (Fig 5). Data extrapolation indicated that the fluid's RPVOT would be well below the 25% minimum recommended by ASTM D4378 and most turbine manufacturers.

Additionally, RULER predicted only 10% of the antioxidants would remain by the fall 2009 outage. Based on this information, the plant opted to change the fluid rather than risk an unscheduled outage because of fluid failure.

Case history 2. A plant experienced varnish-related trips on both of its Frame 7s, which had been charged with new lube in 2007. QSA results revealed that both lube-oil systems had critical levels of varnish present. Fig 6 presents test data for one of the turbines.

Interestingly, both the RPVOT and

RULER values are within acceptable limits. Recall that those tests focus on antioxidant levels, not the fluid's tendency to form varnish, so they might not provide adequate warning for the user in situations such as this.

The plant was remiss in not assessing the condition of its turbine oils at least annually and personnel were caught off-guard with the varnish problem. At this plant, varnish build-up was such that it was difficult to remove. Three different types of varnish mitigation technologies were tried without success.

In cases such as this, if varnish cannot be removed, the plant may have to drain the oil and possibly chemical-flush the system before recharging with fresh oil. Lesson learned: It is much better to deal with lubricant issues early, before the problem has reached the critical stage.

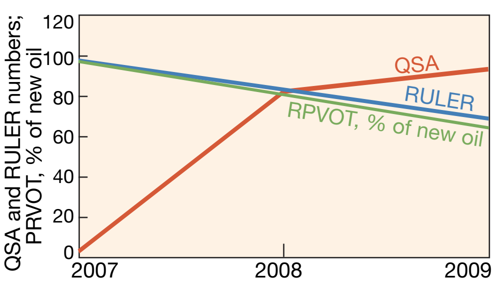
The first two scenarios illustrate the difference between proactive and reactive maintenance philosophies. At the first facility, proactive fluid analysis enabled management to weigh benefits and risks and make an informed decision. The second plant has lost production time and may have to change the oil prematurely.

Case history 3. An F-class combined-cycle facility became aware of varnish formation in lube oils through the OEM's TIL-1528 and began performing the QSA test regularly. A small QSA spike several years ago prompted investigation of the various varnish removal technologies available and the plant opted to install an electrostatic process.

For several years test results have been very favorable. Recently, however, the varnish potential increased (Fig 7). The plant has an outage scheduled for later this year; the first one after that will be in 2012. So "what to do this year" questions are on the minds of plant supervisors.

Had the plant been performing RPVOT and RULER tests regularly, supervisors would be better equipped to determine the reason for the latest spike—specifically, if the increase in varnish potential was a result of diminished additive levels and insufficient oxidative reserve to provide fluid protection. Only by having all this information, can you make an informed decision on fluid replacement now or in 2012.

Another lesson learned: Just having a proactive "approach" to varnish control is not enough. A complete fluid-analysis program is needed to provide sufficient information for decision-making regarding fluid change-out. CCJ



6. QSA test data reveal sharp increase in varnish potential (left)

7. First spike on the QSA plot prompted investigation of varnish removal technologies. An electrostatic process was selected for this plant (right)