COMBINED CYCLE Journal

An article published in Combined Cycle Journal, Q4 2005

"The Lowdown on the Sticky Subject of Lubricant Varnish"

Written by Analysts, Inc.

Varnish issues on the minds of 501D5/D5A Users

Chairman Gabe Fleck of Associate Electric Cooperative Inc tries to have a compelling lubrication presentation at every meeting of the 501D5/D5A Users because of its great importance to reliable plant operation. At the group's annual conference and expo, June 7-9, in Branson, Mo, the presentation "Understanding and Solving Lubrication and Varnish Issues" was particularly well-received. Speakers Greg Livingstone, manager of Sovice, a subsidiary of Analysts Inc, and Brian Thompson, laboratory manager, Analysts Inc, Louisville, developed this article from their presentation notes.

Turbine lube-oil systems have many missions. Among the most important: cooling bearings, flushing contaminants away from rotating parts, preventing inleakage of gases, providing hydrostatic lift for shafts, actuating valves in the hydraulic circuit, and protecting lube-system internals.

Formulating a lubricant capable of performing all these tasks well is a difficult job, one that must consider the impacts of large temperature fluctuations and ingress of contaminants such as dirt and water, as well as other physical and chemical challenges.

After the turbine sump is charged with new oil, responsibility for its condition rests with the powerplant's O&M staff. You must ensure that its condition is monitored regularly, system maintenance is conducted periodically, and contamination control is a top priority.

Despite the effort that went into formulating your lubricant and the work you and your colleagues put into maintaining a clean lube-oil system, a serious problem still can occur: varnish formation. Recall that about 99% of your turbine oil is highly refined base stock; remainder is comprised of functional additives. Various stresses placed on the turbine oil cause additive depletion. As this condition worsens, the lubricant degrades and the integrity of the hydrocarbon base stock becomes compromised. In time, the lubricant fails.

During lubricant degradation, the additives and base stock undergo irreversible molecular changes, producing insoluble byproducts called soft contaminants. They are electrochemically polar by nature; the base fluid is neutral. Soft contaminants find the neutral lubricant environment hostile. Result: They agglomerate and bond to metallic surfaces to form varnish (Fig 1).

This micro layer of contamination is capable of abruptly shutting down a turbine. The sticky nature of varnish captures hard contaminants as they shuttle by, forming an abrasive, sandpaper-like finish on the metal surface that accelerates component wear. Varnish is an efficient insulator, too. Bearing surfaces with varnish coatings typically run at much higher temperatures than those without deposits. Heat exchanges coated with varnish

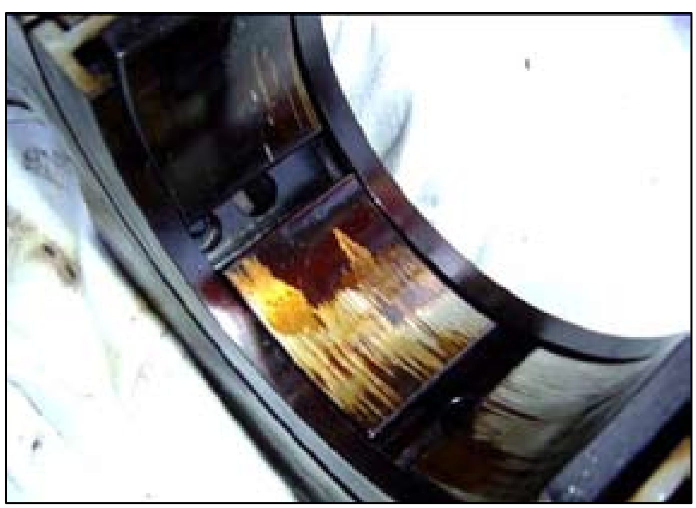

***Fig 1. Soft Contaminants Agglomerate** and bond to metallic surfaces to form varnish as shown on this bearing*

have lower efficiencies than those with clean tubes or plates.

The components varnish impacts most severely are those in the hydraulic control circuit (see "Maintain servos to ensure top GT performance" elsewhere in this issue). Valve-related trips are responsible for many unplanned outages and fail-to-start conditions. The servo valves used to operate fuel control valves and inlet guide vanes may have spool body clearances as small as 0.5 micron. Thus it takes very little varnish buildup to reduce clearances to the point where the spool sticks or seizes.

***Fig 2. Varnish coating on servo-valve piston** can cause part to stick or seize in normal operation*

Fig 2 shows a varnished valve piston. Turbine manufacturers usually outfit their control valves and actuators with sensors that warn of an impending trip. Typically, a warning is activated if the valve is only 3% off its design response time; unit trips at 5%. Preventing unnecessary trips is a primary goal of all plant operating staffs because of their cost in machine wear and tear (see "Optimizing O&M costs for combined-cycle plants" elsewhere in this issue).

Varnish: A new trend?

Experienced O&M managers sometimes ask: "Why is varnish suddenly a high-profile problem in our industry? I operated for years without ever having a varnish problem." There's no simple answer to the question because many factors have contributed to the problem.

One is the higher operating temperatures of popular F-class gas turbines (GTs) compared to the mature frames. New lubricants were developed to accommodate the demanding working environment in these machines. Chemists blended complex additive formulations with highly refined base stocks to produce thermally robust lubricants capable of resisting oxidation at high temperatures.

These new turbine oils outperform older products in all categories with the exception of solubility, which is very important to powerplant engineers. Reason: The lower the solubility of a product, the more likely it is to produce varnish.

Another factor contributing to the varnish problem is that lube-oil flow rates have been increased to provide more cooling to the bearings without a corresponding increase in reservoir size. This means reduced dwell time and less opportunity for entrained air to escape the fluid, thereby accelerating lubricant degradation. In addition, if the air bubbles are sucked into the pump they may collapse—a condition that produces extremely high local temperatures from adiabatic heating or so-called micro dieseling.

Better filtration is a logical way to remove soft contaminants that result in varnish. Ironically, this may compound the problem. A phenomenon known as electrostatic spark discharge from filters has been observed and documented in several plants worldwide. It is described this way: As oil flows through the small openings of a filter, molecular friction is produced and it creates static electricity. When the electrical charge in the fluid accumulates to a given point, the energy is released in the form of a spark, arcing from the sharp edges inside the filter housing (Fig 3).

Yet another contributing factor to varnish formation is the need to cycle gas turbines today. Rapid heating/cooling of the lubricant further stresses the oil. Combine this with the need for pressures up to about 5000 psig to lift the rotor and you have a recipe for varnish creation. The lubricant also may be subjected to thermal cycling in exposed hydraulic pipe and in oil coolers, typically positioned just ahead of the bearings.

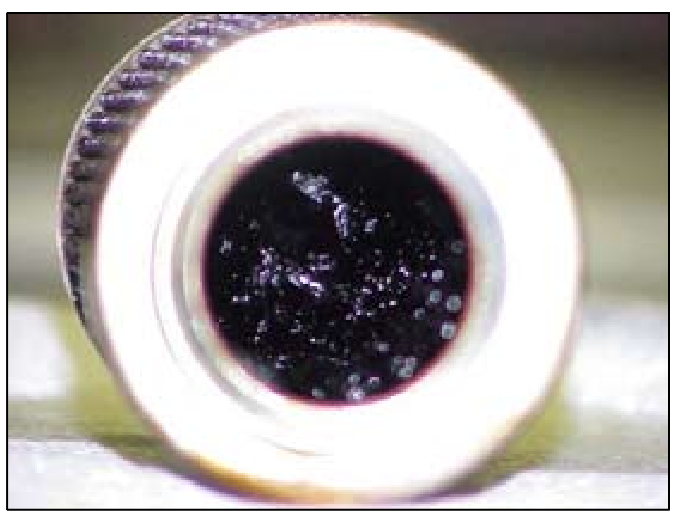

***Fig 3. Filter that experienced electrostatic spark discharge** is plugged with large chunks of coal-like debris*

Varnish prediction not easy

Well-managed generating facilities incorporate condition monitoring programs to increase plant reliability and maximize equipment life. Virtually all powerplants value oil analysis as a predictive tool in the overall monitoring program. Industry groups such as the American Society for Testing and Materials (ASTM) have developed reference standards and practices for turbine operators.

An excellent resource that many operators use for guiding their monitoring of machine health and lubricant condition is ASTM D4378, "The Practice for In Service Monitoring of Mineral Turbine Oils for Steam and Gas Turbines." But even the most advanced oil analysis program may not be able to predict the formation of varnish. Reason is that routine oil analysis is not capable of measuring the quantity of soft contaminants in a lubricant, which directly impacts the varnish potential of the fluid.

The typical oil analysis package includes particle count, water content, wear metals content, acid number, and viscosity. While these analyses are invaluable for monitoring common contaminants and the physical properties of new and used fluids, they have proven to be inadequate for accurately measuring the subtle changes in fluid condition that are associated with (or indicate) the formation of varnish deposits.

Common screening tests such as ASTM Color and Visual Appearance may provide "after the fact" information that the fluid has gone beyond its useful service life, but are not sensitive enough to be used as a predictive tool.

A test recently developed by Analysts Inc, Quantitative Spectrophotometric Analysis (QSA℠), specifically measures the type and quantity of soft contaminants present in used turbine oils. Through induced agglomeration, followed by a series of extractions, a laboratory is able to separate the varnish causing contaminants from the fluid for further analysis.

The concentration and species of contaminant is then used to assign the fluid a Varnish Potential Rating. The VPR℠ is calculated by correlating the measured level of soft contaminants to confirmed varnish related incidents in the field. Soft contaminants are like debt. The more you have, the worse off you are. QSA℠ tells you your balance.

By routinely monitoring the turbine oil's VPR℠, plant personnel know when their lubrication system is at risk for developing varnish and can take action to prevent a unit trip.

Have varnish? What to do

Many plants have attempted to solve varnish problems by making mechanical changes to their lube-oil systems. But the jury is still out on what conclusively works. Here are a few ideas that have been tried:

- Heat tracing of lube-oil lines exposed to ambient temperatures to minimize the amount of thermal cycling on the oil (Fig 4).
- Shut down peakers rather than run on turning gear—this to minimize the adverse impact of thermal cycling and high lift pressures on the oil.
- Reduce the potential for electrostatic spark discharge by changing out oil filters with ones having a larger pore size.

Once varnish occurs, many plants attempt to correct the situation by simply changing the oil. Unfortunately, recharging the system with new oil may not remove any varnish that has already formed throughout the system. The most aggressive means to remove varnish is a chemical flush. This is a risky and expensive proposition, because the chemicals used in the flush are not compatible with turbine oil. This practice should only be performed by experienced service companies knowledgeable in the chemistry of turbine oil.

Fig 4. ***Heat tracing of lube-oil lines*** *minimizes the possibility of thermal cycling*

Once varnish occurs, many plants attempt to correct the situation by simply changing the oil. Unfortunately, recharging the system with new oil may not remove any varnish that has already formed throughout the system. The most aggressive means to remove varnish is a chemical flush. This is a risky and expensive proposition, because the chemicals used in the flush are not compatible with turbine oil. This practice should only be performed by experienced service companies knowledgeable in the chemistry of turbine oil.

Two promising technologies for preventing varnish formation are electrostatic separation and charged-particle separation. Both are in use at powerplants today and both work by applying an electrical charge to the oil to remove soft contaminants.

The separators are connected in a kidney-loop fashion to the reservoir and provide slip-stream filtration. Although these systems typically have low flow rates, they can quickly clean up the turbine oil. The most promising part of this technology is the fact that once the soft contaminants are removed from the oil, the fluid has the ability to re-adsorb the varnish from the internals of the system. There are some published scientific papers on how this mechanism is accomplished, but Figs 5 and 6 show conclusive evidence of this process. These pictures show a last chance filter from a servo valve one month after electrostatic separation technology was installed. All but a shadow of the brown, sticky deposits have been removed.

End note. Varnish is a widespread and complex problem in modern turbines. Collaboration between plant operators and lubrication professionals is essential to better understanding of the problem and to develop solutions for this industry-wide problem.

Fig 5,6. Last-chance filter from a servo valve *one month after electrostatic separation technology was installed in lube-oil system (right) shows only a shadow of the brown, sticky deposit that existed prior to the modification (left)*