Removing dissolved soft contaminants from oil

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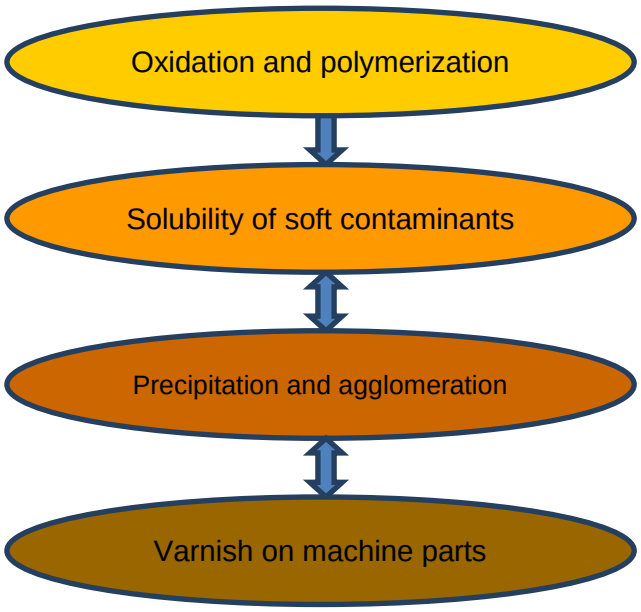
Oil degradation products, oxidation and varnish are known to cause problems in many industries but especially within power generation. Oil contamination very often causes costly turbine trip-outs, revenue loss, and potential penalties for not producing electricity or steam.

Varnish related problems seem to have escalated the last few years and many have found that the so-called dissolved soft contaminants are a major part of the problem. This paper describes the formation of soft contaminants and how to detect them. Cases involving a new improved method of removing varnish will be covered as well.

Varnish Theory - warm vs. cold oil

Many resources have been put into understanding the oil degradation process. The most recent studies describe how much the oil temperature influences the varnish precipitation and thus, how difficult it is to remove the degradation products.

Basically oil degradation can be described as:



The last 3 steps are reversible.

As the oxidation process continues, the polymerization causes soft contaminants to form which alters the oil color and acidity level. These soft contaminants are precursors to varnish and are soluble in the warm oil. However, changes in temperature will affect the equilibrium.

A decrease in oil temperature will lead to a higher concentration of insolubles which precipitate out and agglomerate into varnish formation. Conversely, an increase in temperature will make the agglomerated contaminants go back into solution.

Conclusion: Warm oil will dissolve soft contaminants while cold oil will let them fall out as varnish. Most oils will let soft contaminants precipitate out between 10 – 35°C (50 – 95°F).

A comparison can be drawn to sugar in coffee. Hot coffee can dissolve a lot of sugar but if the coffee is left to cool down, the saturation point will drop and sugar will fall out in the bottom of the coffee cup. Reheating the coffee will make the sugar go back into solution again.

Consequences of soft contaminants

When soft contaminants are dissolved, typically in turbine oil at temperatures above 40ºC (100 ºF), they cannot be removed through standard mechanical filters nor electrostatic filters.
The soft contaminants are polar in nature and adsorb onto dipolar (colder) metallic surfaces in "cold spots" or during outages when the turbine is stopped and the oil temperature drops.
The soft contaminants also have lower thermal stability than the oil so they are more likely to bake onto hot surfaces, e.g. journal bearings.
The varnish hardens into a lacquer like coating on valve spools and sleeves, bearings, heat exchangers and other internal surfaces of the lubrication/hydraulic system.
Even a thin layer of varnish is capable of shutting down an entire power plant.
Varnish is often formed in "cold spots" in the hydraulic system where sticking and malfunction of servo valves creates problems in turbine regulation and start-up.
The sticky nature of varnish captures hard contaminants as they flow within the system, forming an abrasive, sandpaper like finish on the metal surface that accelerates component wear.

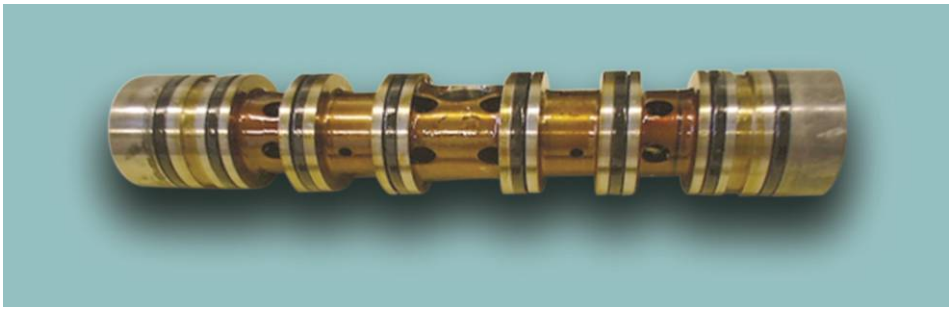


Photo of valve spool covered in varnish

Furthermore, varnish can obstruct oil flow and be an efficient insulator that causes bearing surfaces to run hotter and heat exchangers to have lower efficiencies.

Many gas turbines operate with an oil temperature of about 60°C (140°F) in the reservoir, while the oil leaving the bearings is hotter than 80°C (175°F). At these temperatures the soft contaminants are dissolved completely in the lube oil.

How can soft contaminants be detected?

While many laboratories offer different varnish potential tests C.C.JENSEN has experienced good repeatability and easily understandable results when using the Membrane Patch Colorimetric test (MPC) and the Ultra Centrifuge test (UC). Below follows a brief description.

The Membrane Patch Colorimetric test (MPC) shows soft contaminants (sludge/varnish) present in the oil by discoloration of the white cellulose patch. It is important that the oil sample is stored at maximum 20°C for 3 days before mixed with a solvent and passed through the membrane patch. This will quantify all oil degradation products in the oil, also the dissolved “ghost riders” that have not yet fallen out onto system components.
The darker the membrane color and the higher the MPC value (ΔE), the more the oil is prone to form varnish deposits. Typical MPC values:

Normal: 0-15
Monitor: 16-30
Critical: >30

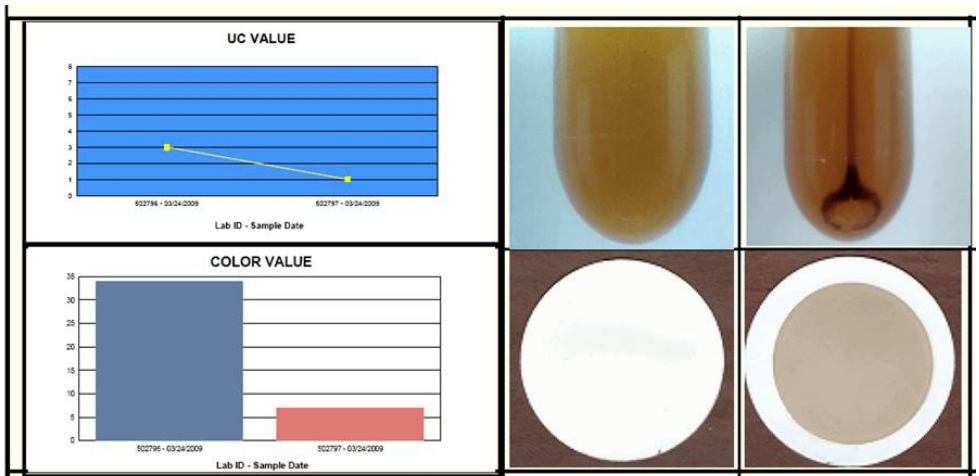
Be aware that the new revised ASTM D 7843-12 standard measures quite incorrectly at low MPC values. The reason for this is that the new standard requires all samples to be heated before the dwell time. This "resets" the varnish precursors, since this re-dissolves the varnish, and not enough time is given for the precursors to reform.

Another useful test is the **Ultra Centrifuge test (UC)** which uses centrifugal forces to extract the insolubles and varnish precursors and drive them to the bottom of the test tube. The size of the concentrated material is then compared to a visual sediment-rating scale of 1 – 8 (8 being worst).

The UC test shows the actual varnish and insoluble contaminants in the oil. Soft contaminants observed in this test will result in varnish falling out as deposits on system components.

The UC test is not recommended for oil highly contaminated with particles as they mask the result. It is not recommended for Ester or Glycol based fluids either, since varnish will not separate out.

UC and MPC tests are very useful tools to trigger an action e.g. a filter or an oil change.



SAMPLE DATE	03/24/2009	03/24/2009
LABID	502797	502796
ULTRA CENTRIFUGE TEST		
UC VALUE	1	3
MEMBRANE PATCH COLORIMETRY		
COLOR VALUE	7	34

Example of UC and MPC results

Introducing the CJC™ Varnish Removal Unit

Very few of the oil maintenance equipment currently available on the market are capable of removing the dissolved soft contaminants. However, a new improved product from C.C.JENSEN utilizing a special cellulose depth media has proven to be highly effective.

Several hundreds of oil analysis results prove the efficiency of the new CJC™ Varnish Removal Unit (VRU) and shows that specialized cellulose depth media is superior when it comes to removing dissolved and agglomerated varnish.

The varnish level in turbine oil is typically cut in half within a few weeks of operating the CJC™ VRU i.e. reduced from critical values to normal values.

The CJC™ VRU reduces varnish, water and particle contamination without the use of any chemicals or beads that may be harmful to the integrity of an oil's additive package.

The function can be compared to a sacrificial anode, only that the active filter isn't consumed, but saturated with contaminants that fall out and adsorb in the new "cold spot" of the lube/control oil system instead of on bearings, valves and inline filters.

When the system oil is getting cleaner it starts to work as a detergent and continues to clean all system components in contact with the lubricant until a completely varnish free system is reached after some weeks or months, depending on the initial amount of varnish built-up.

The CJC™ Varnish Removal Unit is quickly becoming the new standard for turbine oil conditioning as it takes care of ALL contaminants. Worldwide over 120 VRU's are in operation - all of them with exceptional results.

Picture showing the Varnish Removal Unit

The CJC™ VRU – Why has it become so successful?

- It is based on **60 year** old proven, reliable technology
- It has the **highest** dirt holding capacity
- It tells the operator when it's **time to replace** filter inserts
- It has the **lowest** running costs in terms of filter inserts
- It needs **no chemicals** for efficient varnish removal
- It needs **no adjustments** to chemical bead mixtures
- It works on **any turbine** type
- It works on **all oil brands**
- It works with **any oil temperature**
- It guarantees **MPC 5** or lower

The following case study illustrates how the varnish and dissolved soft contaminants are removed from turbine oil utilizing the CJC™ VRU.

Cogeneration plant in Spain

Energyworks Cartagena-Iberdrola is a 95 MW combined cycle power plant, which supplies steam and energy to SABIC (former GE Plastics).

The production setup consisting of two natural gas fired, 45 MW GE turbines and one 11 MW Alstom steam turbine was installed in 2002.

The 6,500 litres (1,700 gal) of Mobil DTE 832 on each GE gas turbine has been in operation since March 2007 and the oil operating temperature is between 66 – 85°C (150 – 185°F).

The inline pressure filters operate at 5 micron filtration rate.

Photo shows inline filter from hydraulic system covered in varnish

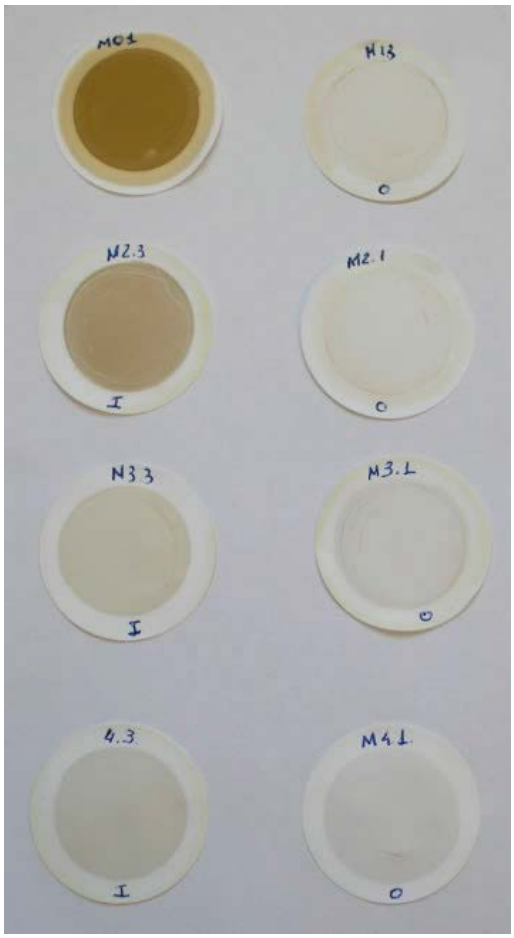
The Problem

The plant had experienced turbine trips due to malfunction of the hydraulic IGV valves and clogged inline filters. Dangerously high Membrane Patch Colorimetric values above MPC 50 also indicated soft contaminants and varnish deposits as result of turbine oil degradation. The company was ready to replace the oil when another possibility was presented.

The plant agreed to test the CJC™ VRU 27/108, Varnish Removal Unit as a possible solution.

After two weeks in operation, the MPC value in the main reservoir dropped from MPC 42 to MPC 25 on one turbine. The MPC value decreased from MPC 55 to MPC 15 in four weeks on the second turbine.

The oil from the discharge of the CJC™ VRU was also analyzed and showed well below MPC 10 in varnish level – free from soft contaminants.



Photos of MPC membranes, four successive samples Spain May 2011. VRU inlet (I) vs. outlet (0)

Oil sample bottles showing the oil before and after a single pass through the CJC™ VRU

Customer benefits and savings

By removing the dissolved soft contaminants with the CJC™ VRU, not only did the plant avoid an oil change, they also minimized future turbine trips.

Replacing the 6,500 litres of Mobil DTE 832 lube oil cost approximately 18,000 € ($25,000) per gas turbine. When the flushing and oil disposal costs were added, the total cost was estimated at roughly 25,000 € ($35,000) for one oil change.
The gas turbines in this combined cycle plant are part of a complex energy production chain so any downtime immediately results in very high costs.
If a turbine stops, the plant loses energy worth 3,360 € per hour ($4,600) plus the loss of steam production which results in penalties. This adds up to approx. 120,000 € per turbine trip ($166,000).

From the environmental point of view, the benefits are very clear. Without the varnish removal unit, the plant would have changed the oil after only four years in use. This is a short time considering the cost that goes into oil production; extracting, refining, blending and shipping etc.
In a real-world, sustainable solution, the oil should be able to last 10 – 20 years in operation

without compromising its properties and without need for flushing and cleaning tanks or components.

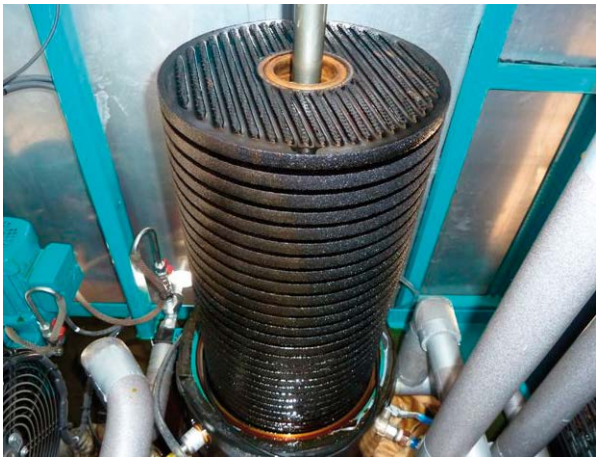


Photo of varnish covered VRi 27/27 inserts after 10 days in operation

Conclusion

Although soft contaminants and varnish can result in very costly downtime in the power industry a solution based on environmentally friendly cellulose is capable of removing even dissolved soft contaminants from oil. By incorporating this technology, varnish related turbine trips can be avoided, ensuring the long-term reliability and availability of the plant.

For more information please visit www.cjc.dk

About the author, Steffen D. Nyman, Corporate Trainer at C.C.JENSEN.
Steffen earned his B.Sc. Mechanical Engineering degree in 1996 and was in technical sales for three and a half years. Since February 2000, he has been responsible for developing and conducting technical training and documentation for sales, service and technical staff.
He is certified Machinery Lubrication Technician II & Analyst I, as well as 4-MAT trainer in adult teaching skills. He has worked as Corporate Trainer for C.C.JENSEN since 2004, conducting hundreds of customized seminars in understanding oil maintenance including oil filtration technologies for the Marine, Mining, Power, Off-Shore and Wind industries.

Steffen Nyman has been representing Noria Corporation in Denmark since Dec. 2012.