Print Article | Close Window

Today's Varnish Control Technologies

Nguyen Truong, Noria Corporation

Varnish formation has been regarded as a costly and dangerous problem for industrial lubricants in various industries such as power generation, injection molding, petrochemical, pulp and paper, and marine applications. So, what remedies are available when your system fluids are found to have high varnish potential or show signs of varnish insolubles? This buyers guide provides basic information on the varnish formation process as well as the associated tests to detect and measure problem severity. It also provides a summary of different varnish removal technologies available in today's market.

Figure 1. Varnish on Spool Valves (Courtesy of Insight Services, Inc.) [2]

Process of Varnish Formation

Solid contaminants are often classified as either hard or soft. Hard particles (such as dirt) can cause mechanical wear such as abrasion while soft contaminants can form sludge or surface deposits known as varnish. The sticky film resulting from varnish can further damage the system by attracting other hard contaminants such as dust and wear metals, which contribute to failure in journal bearings, the plugging of small oil flow cavities and filters, increased part movement friction and wasted heat and energy.

Oxidation of in-service oil is often the root cause of varnish formation - the process where the oil and its additive package react with oxygen. Products of these reactions include the breakdown of base oil, additive molecules and energetic free radicals, which all act as precursors to varnish formation. During its service life, the natural occurrence of high levels of heat and hot spots in the operating systems can degrade and promote oxidation in lubricating oil. Fragments of oxidation products can form deposits leading to a sticky insoluble film which causes the aforementioned problems. Some of the principal factors that contribute to varnish formation include heat, entrained air, incompatible gases, moisture, internal or external contamination, process constituents, radiation and inadvertent mixing of a different fluid. Continued exposure to air, moisture and high operating temperature accelerates the lubricant's degradation process.

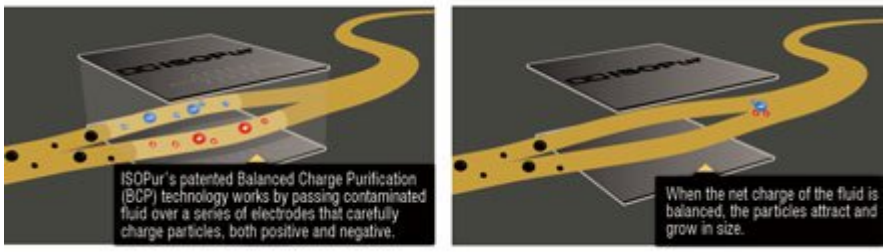

Figure 2. Balance Charge Agglomeration Technique (Courtesy of ISOPur)

Analytical Methods to Identify Varnish in In-service Lubricants
Research has discovered that varnish contains components that are difficult to detect. These components are referred to as varnish potential insolubles (VPI). One fraction of VPI is the quasi-insolubles - or the incipient soluble portion; and the other is the already-formed insoluble suspensions - or the active (most destructive) form of VPI.

Control of varnish and sludge can be viewed on two fronts. The first is controlling the root cause leading to the formation of VPI. Such root causes include additive dropout, bulk oil oxidation, microdieseling and electrostatic discharge. Because many of the root causes are not easily controlled, the second approach has been to treat the symptom by removing VPI from the oil before they agglomerate into sludge or condense into varnish.

To identify the problem and ultimately the root cause, it is important to employ a wide range of condition monitoring analytical methods to routinely assess the health of the fluid and machine. Among these methods are the quantitative spectrophotometric analysis (QSA) and the ultracentrifuge (UC) tests. To learn more about the full range of tests for varnish potential, the article published in *Practicing Oil Analysis* (May 2006) entitled "Sludge and Varnish in Turbine Systems" can serve as an excellent reference.

QSA
Using a combination of colorimetric and gravimetric methodology, the QSA assesses the varnish potential of an in-service lubricating oil. Varnish potential relates to an impurity that, if left in the oil over a period of time, may condense on fluid surfaces forming sludge and varnish. The QSA was originally used primarily on gas turbine oils, but has subsequently been applied to a range of lubricants used in large volumes including compressor oils, hydraulic fluids, paper machine oils and steam turbine lubricants.

The QSA purposely isolates and measures the specific lubricant degradation by-products that are responsible for the formation of varnish. The process begins by a 72-hour room-temperature aging process to enable insolubles and some soluble impurities to agglomerate; therefore they can be separated by filtration. Next, the sample is mixed with a petroleum-ether to isolate and agglomerate insoluble by-product material (including submicron species). Then, using a 0.45-micron membrane, a separation process extracts the varnish-forming insoluble degradation by-products (soft contaminants) and concludes with a quantitative measurement of the isolated contaminant. The concentration of the contaminant correlates directly to the varnish potential of the fluid. A rating of one to 100 indicates the propensity of the lubricant to form sludge and varnish.

QSA vs. Ultracentrifuge
Another popular method to determine varnish potential is called ultracentrifuge (UC). UC tests subject the oil sample in a test tube to high-velocity spinning (approximately 18,000 rpm) for 30 minutes to yield the insoluble contaminants at the bottom of the test tube. For this technique, gravity is the driving force.

While the QSA method appears to be able to characterize a higher percentage of the total

soft impurities in the oil (including quasi-soluble oxides), the UC targets only the insoluble fraction that can be separated in a laboratory centrifuge. Used together, this could serve as a synergistic advantage.

Because of these differences, it is possible for an oil to have a relatively high QSA value and a low UC value. In this example, the high QSA value would correspond to the quasi-insolubles fraction that is immeasurable by the centrifugation. It could be said that the analytical difference between the QSA and the UC may represent the incipient portion of varnish potential where the UC alone represents the active presence of varnish potential insolubles (VPI).

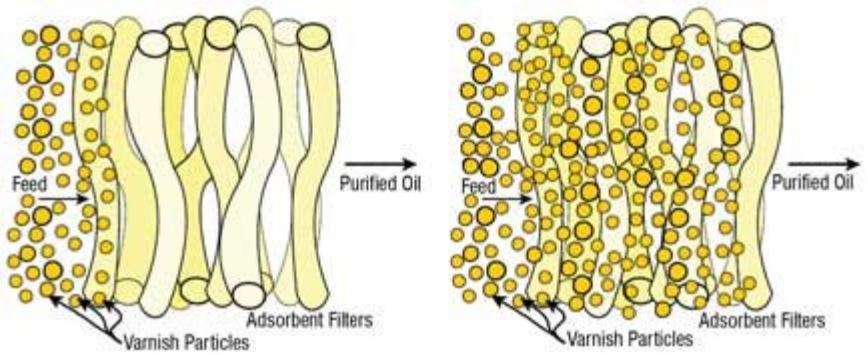

Figure 3. Filtration through Adsorption Method (Courtesy of C.C. Jensen) [7]

Varnish Removal Technologies
Soft contaminants are often in the equilibrium state of being both insoluble and dissolved within the oil. They can be difficult to extract due to the high operating temperature of many in-service lubricants, which can cause them to change into a soluble state. In addition, soft particles are generally submicron in size. However, their concentration and effect on the system still need to be monitored and controlled.

Several filtration and separation technologies are currently on the market that can intervene with the formation of varnish. By continuous removal of harmful degradation by-products, the concentration of these varnish precursors is reduced, thus providing cleaner working oil. Two means of removing varnish insolubles are available: one employs the use of various filtration media to adsorb or filter the undesired particles in the oil, while the other makes use of the charged or polar nature of target contaminants and electrostatically separates them from the oil.

Balance Charge Agglomeration
The balance charge agglomeration (BCA) technology works by dividing the fluid into two streams then charging the contaminant particles with opposite charges (positive [+] and negative [-]) (Figure 2). These charged particulates are then recombined and mixed under turbulent flow to form neutral and larger particles that can now be removed through traditional mechanical filtration devices.

Electrostatic Particle Removal System
The electrostatic particle removal (EPR) system operates on the basic principle of physics stating that opposite charges attract. With the use of a constant electric field, a particle with a positive charge is drawn toward a negative electrode within the system, while particles with an inherent negative charge are drawn toward a grounded plate. Polar contaminants (molecules having nonuniformed charge distribution, which is usually the main component of varnish) are drawn to the area of greatest field strength on the collector media. Note that the EPR does not charge the particles but merely enables the already-charged contaminants in the oil to separate onto collectors (Figure 4).

Adsorption Method

Adsorption is the physical and/or chemical binding of atoms, molecules or particles to a surface. Many materials can be used as adsorbents, including compressed cellulose, cotton linters, rice hulls and even news print. Adsorption is divided into two types: physisorption and chemisorption (Figure 3).

Because of its chemical structure, varnish molecules are believed to be attracted to the adsorbent through weak molecular forces such as van der Waals (or dispersion) and hydrogen bonding.

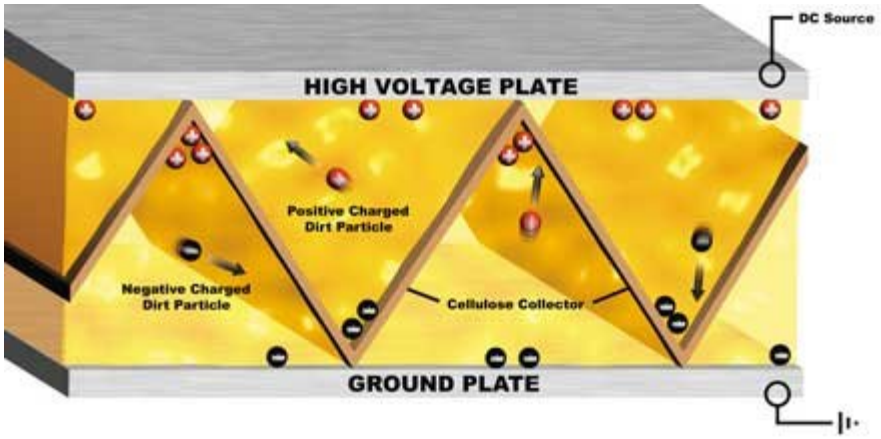

Figure 4. EPR Process (Courtesy of Kleentek Ltd.) [1]

Conclusion
Separation technology for removing VPI from in-service lubricants varies from the simple mechanical filtration commonly used to extract hard particles from an oil. In recent years, interest in varnish removal technology has surged due to the expansive use of gas turbines in the power generation field and changes in gas turbine design and turbine oil formulation. Collectively, they've contributed to the occurrence of varnish and sludge-related problems.

To evaluate the various vendor options, many issues should be considered:

- The number of installed users of the technology and the ability to contact these users as referenced.
- Industry/application specialty - Do they work only with turbine oils or do they also have performance credentials with hydraulic fluids, compressor oils, gear oils, etc?
- What range of geography do they service for rental equipment and support?
- Flow rate capabilities - While the VPI capture efficiency is important, an equally important feature is flow rate.
- The type and cost of filter elements used to remove the VPI (after agglomeration in the case of CPS technology).
- Laboratory and bench testing capabilities - Many of these companies will accept samples of test fluid possessing high varnish potential values to run in the laboratory to evaluate how well the technology can reclaim the fluid after a certain number of passes.

In summary, identifying the best technology and vendor for any given oil reclamation application is no easy task. Considerable judgment must be applied after researching all aspects of the project needs and the vendor capabilities.

References

1. Buddy Atherton. "Discovering the Root Cause of Varnish Formation." *Practicing Oil Analysis* magazine, March 2007.

2. Michael Barrett. "Varnish Potential Analysis." *Practicing Oil Analysis*, May 2007.

3. Greg Livingston, Brian Thompson and Dave Wooton. "Determining the Root Causes of Fluid Degradation." *Practicing Oil Analysis*, January 2007.

4. Jim Fitch and Sabrin Gebarin. "Sludge and Varnish in Turbine Systems." *Practicing Oil Analysis*, May 2006.

5. Buddy Atherton. "Electrostatic Particle Removal Technology."

6. Akira Sasaki and Shinji Uchiyama. "A New Technology for Oil Management: Electrostatic Oil Cleaner." National Fluid Power Association and Society of Automotive Engineers, Inc., 2002.

7. Kent S. Knaebel. "Adsorption and Filtration with Cellulose Media." Adsorption Research, Inc. March 2006.

Brand/ Manufacturer (Web Site)	Reclamation Technology	QSA/UC Reduction?	Cool Incoming Oil Capability?	New Equipment Rental/Sale/Service?			Flushing Service	Applications/Descriptions (Flow Rate, Capacity)	Performance Capabilities/Limitations
				Sale	Rental	Service			
OilKleen International Inc. 16585 N. 92nd St. Suite 105 Scottsdale, AZ 85260 Tel: 480-556-1520 Fax: 480-556-1640 www.oilkleen.com	High-speed electrostatic oil cleaner	Yes	Yes (with pending patent for a built-in heat exchanger for cooling the oil sample before being reclaimed)	✓	✓	✓	✓	Filtrates down to 0.001 um particles with 18 electrostatic fields for up to 500 gph flow rate and is completely computerized controlled. Built-in water removal system. For reservoirs up to 15K gallon. Typical application in power generation, paper industry, plastic injection. Offers oil reclamation, flushing, varnish removal, stationary diesel fuel reclamation, and on-site lab analysis.	-Must be installed in a kidney loop configuration. - If the oil temperature is more than 180 degrees F, please let us know.
LIAS Kleentek 4440 Creek Road Cincinnati, OH 45242 Local: 513-891-0400 Toll-free: 800-252-4647 Fax: 513-891-4071 sales@uasinc.com www.kleentek.com	Electrostatic oil conditioning (EOC)	Yes	Yes	✓	✓	✓		Steel injection molding, power generation, hydraulic systems. Filters down to 0.01 um contaminant particles in lubricants and hydraulic oils.	Not recommended for systems with greater than 800 ppm of water concentration, 2200 cSt in viscosity and detergent package additives in the oil.
EPT Inc. 9040 Railwood, Suite 100 Houston, TX 77078 Toll-free: 888-246-3040 Tel: 403-246-3044 Fax: 403-249-8096 www.cleanoil.com	ECR™ or electrostatic contamination removal	Yes	Yes (recommend to cool for 12-72 hours before filtering)	✓	✓	✓		Works primarily with QSA/varnish potential reduction applications. Max flow rate of 600 gph.	Not recommended for systems with greater than 800 ppm of water concentration, 2200 cSt in viscosity and detergent package additives in the oil.
C. C. Jensen Inc. 1557 NW Ballard Way Seattle, WA 98107 Tel: 206-789-1710 Fax: 206-789-1747 ccjensen@ccjensen.com www.cjc.dk	Depth filter that features cellulose adsorption media	Yes	Yes	✓	✓			Marine, mining, injection molding, power generation applications. Flow rates up to 80 gpm; capacities up to 50,000 gallons. Water if present will also be filtered simultaneously; the filtration system is much less expensive and they last longer when compared to the electrostatic techniques.	The most unique performance capability is the ability to remove 8 pounds of varnish precursors per filter insert. Multiple filter inserts can be added to the filter system so service life is long. The singular limitation is that there is no sensor (pressure gauge) to monitor when the filters are near exhaustion.
ISOPur Fluid Technologies, Inc. 185 S. Broad St. Pawcatuck, CT 06379 Toll-free: 888-270-9889 Tel: 860-571-8590 Fax: 860-571-8815 info@isopurfluid.com www.isopurfluid.com	Balance charge agglomeration	Yes	No	✓	✓			Requires a low voltage of 10-15KV compared to that of other electrostatic processes (75-100KV). 2-3 times longer operational life. Flow rate from 30-1200 gph. Effective with water concentration up to 20%.	Not designed for oil and water emulsions used for machining and for high-pressure hydraulic power and control.
Hydac Technology Corporation 1718 Fry, Suite 150 Houston, TX 77084 Tel: 281-579-8100 Fax: 281-579-8116 www.hydacusa.com	A combination of mechanical barrier and adsorption filtration	Yes (providing that the filters can be installed in an off-line configuration and the oil can be subjected to a sufficient number of turnovers)	Not in a standard configuration but it could be augmented with a heat exchanger if desired					Handles nearly all industrial hydraulic and lubricating systems and a wide variety of fluids employed in those systems. Offers filtration products for lube oils, hydraulic fluids, coolant and water. Also particle and water contamination sensor.	The main limitation is the pressure drop: the higher the filtration efficiency (micron rating) for the given flow rate and viscosity, the higher the pressure drop will be, so we would need to consider target contaminant level, fluid flow rate, viscosity and the operating temperature as well as the tolerable pressure drop and target filter element service life.
RSI - USA 6922 Calvacade Houston, TX 77028 Tel 713-946-4020/877-4RSIUSA info@rsi-usa.com www.rsi-usa.com	Electrostatic (slower flow rate), ICB media	Yes	Yes			✓		Serves primarily with large-volume hydraulic/turbine/metal-working systems of up to 160,000 gallons and wide range of flow rates.	
Petrolink USA 19939 W. 162nd St. Olathe, KS 66062 Toll-free: 800-770-4510 Tel: 913-782-6600 Fax : 913-782-6611 voicemail : 913-322-6245 kansas@petrolinkusa.com www.petrolinkusa.com	Electrostatic filter, chemical flushing	Yes	No						
Lormar Reclamation Service Tel: 800-299-3456 Fax: 405-321-0680 info@lormar.net www.lormar.net	Centrifuge	Yes	No			✓		Power generation (cap changers), hydraulic/diesel engines. Customize and sell new equipment.	
The Hilliard Corporation 100 W. Fourth St. Elmira, NY 14902-1504 Tel: 607-733-7121 Fax: 607-737-1108 hilliard@hilliardcorp.com www.hilliardcorp.com	Pleated paper, fuller's earth element and activated alumina			✓				Filters down to 0.45 microns absolute. Filtration flow rate of up to 4000 gph.	
COT-Puritech 3713 Progress St. NE Canton, OH 44705 Tel: 888-478-6996 Fax: 330-478-6990 sales@cot-puritech.com www.cot-puritech.com				✓	✓	✓	✓	Offers varnish removal flush/filtration services and rentals.	

Please reference this article as:
Nguyen Truong, Noria Corporation, "Today's Varnish Control Technologies". *Practicing Oil Analysis* Magazine. November 2007

Issue Number: 200711
Practicing Oil Analysis
Buyers Guide