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# LUBRICANT VARNISH: WHAT IT IS, HOW IT FORMS AND HOW TO MITIGATE IT

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Whitepaper

## SYNOPSIS

*The thorough examination of oil varnish, including the description, formation, identification, mitigation strategies, lifecycle and removal of oil varnish.*

## OVERVIEW

Oil varnishing is a widespread problem. Fully one-third of industrial gas turbines (GTs) suffer from oil varnishing, which is a major issue because varnish causes outages and limits the reliability of turbines. Unfortunately, many strategies designed to solve or mitigate these problems are misguided. That's why we've created this guide!

In it, we give you a complete rundown of varnish, walking you through what it is, what causes it and how various mitigation strategies can limit its effect on your operation

## WHAT IS VARNISH?

Oil varnish is a thin, hard, lustrous, oil-insoluble deposit composed mainly of organic residue. It starts out as a soluble, dissolved degradation product then converts into particulates, depositing onto metal surfaces. In other words, varnish takes multiple forms and can be insoluble (particulate) or soluble (dissolved) in your lubricant.

To learn how varnish deposits form in your system and, more importantly, how to remove them, you'll need to determine whether they're soluble or particulate.

## IDENTIFYING VARNISH

The quickest way to spot varnish is by its color intensity. Then, if you try to wipe it off, varnish will cling on and refuse to be removed. In this case, it's time for varnish removal techniques!

## LUBRICANT SOLVENCY

Turbine oils are a mixture of additives, base stocks, contaminants and breakdown products. In typical operating conditions, turbine oils oxidize, producing polar molecules from non-polar ones (oil base stocks). The polar molecules are the precursors to and start of the varnish life cycle.

A lubricant's solvency is defined as its ability to dissolve these distinct components. Everything in your lubricant has a defined solubility affected by various factors. Solubility is important because it determines whether a molecule will stay dissolved or precipitate to form a potentially harmful deposit.

## FACTORS IMPACTING LUBRICANT SOLVENCY

### Molecular polarity

- Varnish precursors produced by oxidative oil degradation have finite solubility in a lubricant's non-polar mineral oil matrix
- Products with more polar degradation are less soluble
- At a basic level, "like dissolves like"

### Contaminant levels

- Lubricants have a finite capacity to dissolve other molecules (i.e. additives, contaminants and varnish precursors)
- As oil degrades and oxidation products accumulate, fluid solvency decreases
- Beyond a certain point, the saturation point, fluid no longer dissolves precursors and varnish starts precipitating as a solid

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## Temperature

- The solubility of varnish and its precursors decreases as temperature drops
- This process is responsible for the formation of varnish deposits in cooler regions of a turbine's oil circulation system
- Metals are more polar than lubricant base stocks, so precipitated polar varnish adheres to metal, forming deposits

Varnishing in cooler regions happens when the level of varnish precursors in oil is close to the fluid's saturation point.

## THE VARNISH LIFE-CYCLE

### 1. Oxidation

- A chemical reaction occurs between a lubricant base stock and oxygen in the air
- When new oil goes into service, it's exposed to higher temperatures, increasing its oxidation rate
- In time, oxidation products build up in the oil, remaining dissolved at operating temperature
- Eventually, they exceed the fluid's saturation point

### 2. Particulate Formation

- As lubricant circulates from hotter system regions to cooler areas, its temperature drops
- As temperature drops, the solubility of varnish precursors decreases
- Precursors start precipitating from solution and form particulate—a physical change (not a chemical reaction)

### 3. Deposit Formation

- Once formed, varnish particles collect and form deposits on metal surfaces
- Deposits often cause unit trips or fail-to-start conditions (this process is also a physical change, not a chemical reaction)

While the chemical reaction that forms varnish precursors (oxidation) can't be reversed, physical changes (particulate and deposit formation), are

reversible. So once varnish particles and deposits form, they may be reabsorbed—if the oil solvency is increased. This is at the core of varnish mitigation strategies.

## VARNISH POTENTIAL TESTING

If enough varnish deposits form in your turbine lubrication system, they can cause costly downtime, so it's mission-critical to test lubricants for varnish potential. ASTM recommends conducting at least quarterly varnish potential testing, also known as membrane patch colorimetry (MPC). Other tests, such as patch weight, can also help determine oil condition.

When using MPC testing, it's crucial to follow the ASTM method to maintain consistent test results, which can otherwise vary with the length of time an oil sample is stored. MPC values can increase during oil storage, or when lubricant is exposed to UV light, because oxidation reactions that started when the lubricant was in service will continue to cause breakdown.

This also demonstrates how oil reservoirs with accumulated breakdown products can continue to form varnish even while a turbine is inactive—why it's so critical to have a continuous varnish removal system.

## VARNISH MITIGATION STRATEGIES

Most producers today create turbine lubricants using American Petroleum Institute Group II mineral oil base stocks, which contain an antioxidant additive package. The advantage is that the chemistry of Group II base stocks is more oxidatively stable than that of traditional Group I base stocks.

### Antioxidant Oil Additives

- Antioxidants slow oxidative degradation, delaying varnishing
- Lubricant producers add antioxidants that oxidize more readily than oil base stocks
- But once the additives are consumed as they oxidize, fluid degradation accelerates
- Once lubricant oxidizes and varnish precursors form, varnish removal systems are necessary to prevent degradation products from accumulating to the point where varnishing occurs

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There are two primary types of varnish removal systems:

- Systems that remove soluble varnish and its precursors
- Systems that remove suspended particles (particulates)

### Soluble Varnish Removal

Soluble Varnish Removal (SVR™) systems use specialized Ion Charge Bonding (ICB™) ion exchange resins that contain billions of polar sites to adsorb soluble varnish and its precursors. Unlike conventional ion-exchange resins, which essentially exchange one contaminant for another, ICB™ resins adsorb the entire contaminant—without returning another to the oil.

One key benefit of ICB™ adsorption is that oxidation products can be removed at any temperature, meaning SVR™ systems can be used continuously, ensuring degradation products don't accumulate in your lubricant. This also eliminates the risk of varnish formation during normal turbine shut down cycles. One other advantage—continuous soluble varnish removal produces oil with high solvency.

As physical changes that form varnish particles and deposits are reversible, the high solvency of SVR™-treated lubricant forces varnish already present on turbine surfaces back into the soluble form, where it can be adsorbed and removed. With all remaining oxidation byproducts removed, the varnish formation cycle is halted.

### Suspended Particle Removal Systems

There are several more advanced systems specifically design for particulate removal, including:

- Depth filtration
- Balanced Charge Agglomeration (BCA™)

- Electrostatic oil cleaning
- And combinations of these systems

Since oil solubility decreases at lower temperatures (causing particulate formation) and particulate systems can't remove soluble varnish and its precursors during active operation, these systems are best used periodically, during outages, when your turbine is inactive and oil is at ambient temperatures.

To work around this limitation, you can use oil coolers to accelerate the varnish formation cycle so particulate forms just before it passes through your removal system. The drawback is cool oil is highly viscous, making it harder to pass through filtration systems. Also, oil can't be cooled to the temperatures required for complete removal of soluble varnish.

### SUMMARY

Varnish particles and deposits are typically created from reversible physical changes that start with soluble oxidation products (chemical process). For these changes to be reversible, the chemistry of the deposits has to be similar to the chemistry of the lubricant from which the deposits originated. Once fluid solvency has been increased (by removing soluble varnish at normal operating temperature), deposits will dissolve back into the fluid and can be removed.

*\*Source credit—Combined Cycle Journal (<http://www.ccj-online.com/4q-2013/lube-oil-maintenance-lubricant-varnishing-and-mitigation-strategies/>)*



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