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SOLUBLE VARNISH REMOVAL

THE PROVEN LUBE OIL VARNISH SOLUTION

- Prevent gas turbine unit trip or fail-to-start conditions caused by lube fluid degradation
- Remove varnish-causing contaminant while in solution (before deposited)
- Restore fluid solvency allowing removal of varnish deposits & extend useful oil life
- Achieve & maintain target varnish potential numbers
- Lower ISO Fluid Cleanliness Codes with high efficiency post filter
- Removes soluble varnish while turbine is running or off-line
- Rapid on-site recovery services available
- Oil analysis, results interpretation, and varnish mitigating strategy implementation

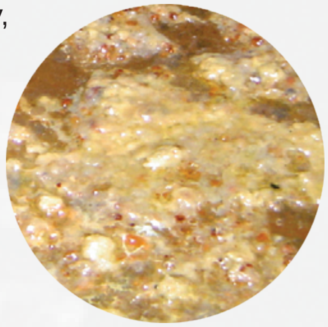
What is Varnish?

A thin, hard, lustrous, oil-insoluble deposit, composed primarily of organic residue, & most readily definable by color intensity. It is not easily removed by wiping with a clean, dry, soft, lint-free wiping material and is resistant to saturated [light hydrocarbon] solvents. Its color may vary, but it usually appears in gray, brown or amber hues.
ASTMD.02C.01 definition

Varnish can be soft and gooey *(Sludge)*

Varnish can be hard and brittle *(Lacquer)*

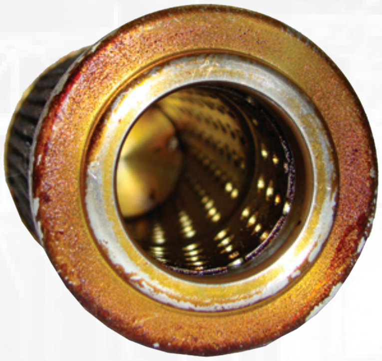
Varnish on reservoir ceiling *(Stalactites)*



Varnish deposits on reservoir floor *(Plated)*

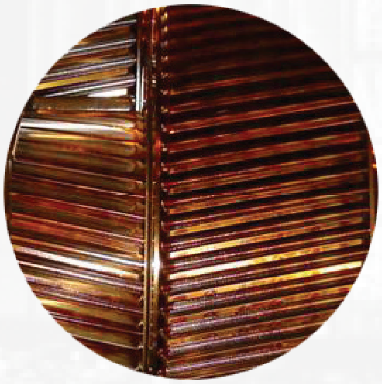
When gas turbines fall casualty to unit trip or fail-to-start conditions, lube oil varnish is the usual suspect!

Filter element cross section (Lacquer Varnish Deposits, Support Tube)

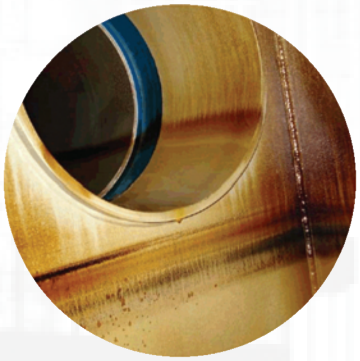


Varnish deposits on filter element (GE Frame 6B)

IGV valves and fuel control valves are typically the first problem components



Varnish on load gear (Frame 6)



Lube oil reservoir coated (Varnish Deposits)

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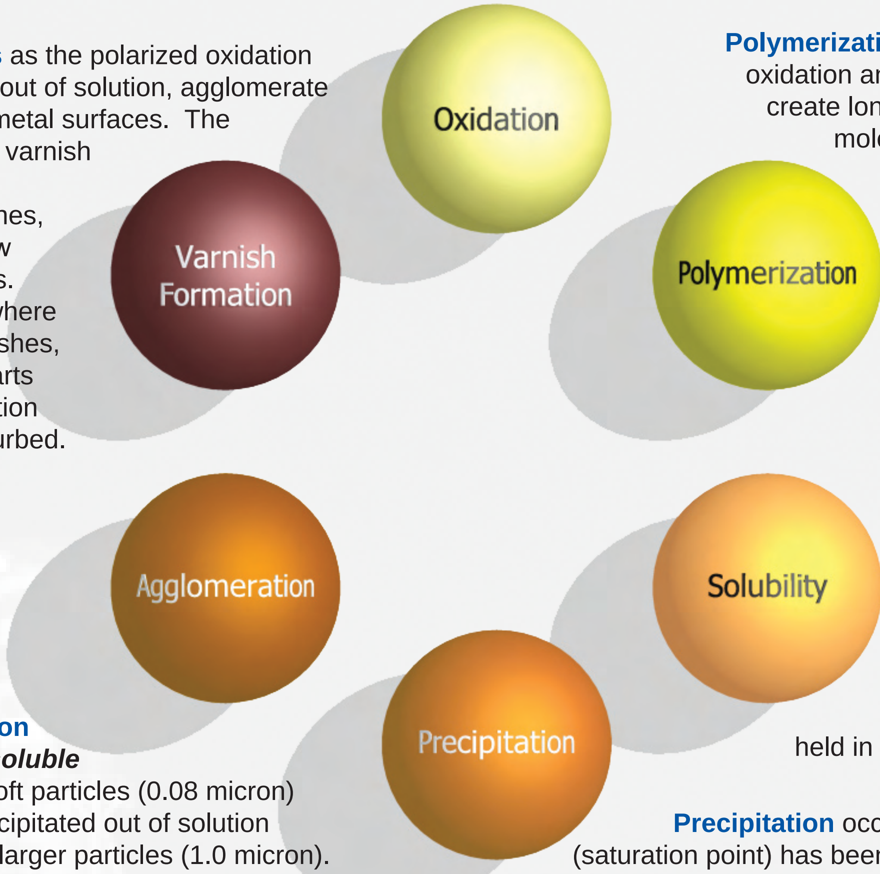
Varnish Formation Starts with Oxidation

Oxidation is the root cause of the problem. It creates free radicals resulting in acids, alcohols, esters and lactones. Anti-oxidant (AO) additives are designed to neutralize the products of oxidation. As oxidation occurs the phenol and amine additives are depleted. The products of oxidation become the building blocks of varnish.



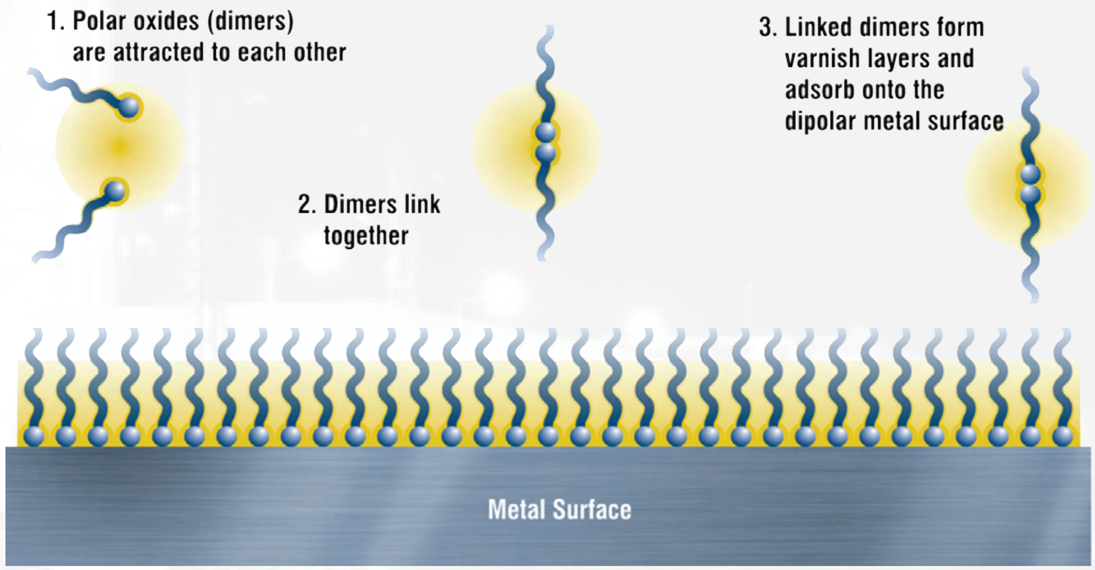
Varnish Forms as the polarized oxidation products come out of solution, agglomerate and collect on metal surfaces. The surfaces where varnish typically forms include cool zones, low flow and low clearance areas. Why? This is where solubility diminishes, precipitation starts and agglomeration goes on undisturbed.

Polymerization occurs as the by-products of oxidation and additive reactions combine to create longer chain molecules with higher molecular weight. These molecules have lower ***solubility*** and are polarized. The rate of molecular polymerization is a function of ***temperature*** (as a catalyst) and the concentration of oxidation by-products (free radicals).

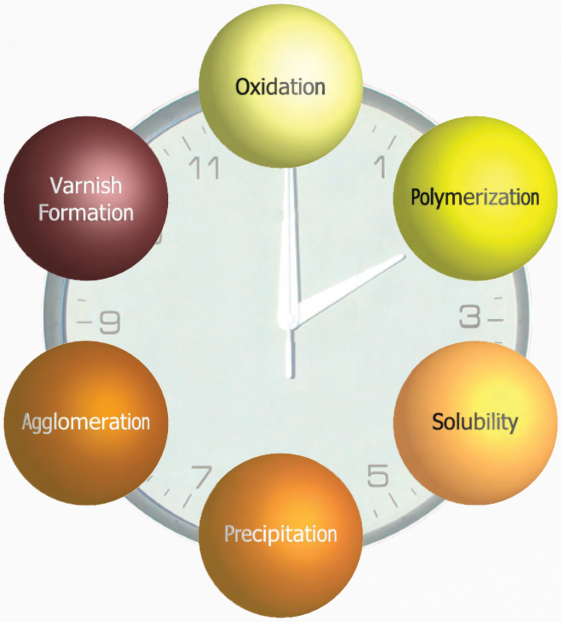
Solubility describes fluid's capacity to hold the varnish producing molecules in solution (dissolved). Solubility is directly affected by ***temperature***. As more oxidation by-products are generated the fluid approaches it's solubility saturation point, beyond which no additional polymerized molecules can be held in solution and can precipitate out.

Agglomeration begins as ***insoluble*** sub-micron soft particles (0.08 micron) that have precipitated out of solution bond to form larger particles (1.0 micron). These agglomerated soft particles remain ***insoluble***, remain polarized, and maintain a higher molecular weight than the fluid itself.

Precipitation occurs once the solubility threshold (saturation point) has been crossed or if there is a ***drop in temperature*** which reduces the solubility of the fluid. As additional oxidation by-products (free radicals) are generated they become ***Insoluble*** and precipitate out and are free to form varnish deposits.



SVR breaks the Varnish Formation Cycle before it stops you!



By removing the polymerized molecules in solution SVR prevents the oil from becoming saturated and losing it's ability to hold the high density varnish molecules, **in solution**. **SVR stops varnish before it starts** by removing the feedstock of varnish formation while still in solution, fighting varnish right on time, **2:00 on the varnish formation cycle clock.**

Competing technologies cannot remove varnish causing contaminant until the oil is saturated, or the oil temperature drops, and it precipitates out of solution. As the varnish precipitates only then can it be removed by an electrostatic oil cleaner (EOC) or depth filtration, but the oil will remain saturated with soluble varnish contamination. SVR is the only full time varnish removal technology that addresses the soluble contamination to stop varnish before it starts!

Electrostatics and depth filtration are part time solutions to lube oil varnish that do not remove varnish until it is too late, **10:00 on the varnish formation cycle clock.**

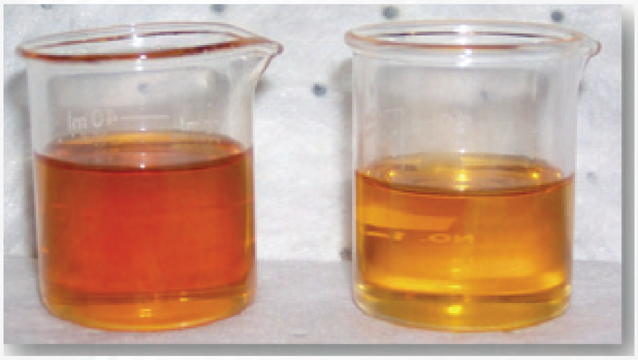
What happens when the oil cools?

When the oil cools (off-peak) the solubility goes down and varnish causing molecules will fall out of solution at a rapid rate to create varnish. Even if the electrostatic oil conditioner is cleaning the reservoir, varnish collects throughout the system on valves, filters, gears, bearing pads and many other critical metal surfaces. With the SVR on-line the soluble varnish causing polymers have already been removed and are not available to precipitate and form varnish.

SVR is a recovery and permanent prevention solution!

When fitted to a system with high varnish potential and or visible varnish deposits the Ion Charge Bonding element technology goes right to work on the source of the problem, the polymerized molecules. As soluble contamination is removed the solvency of the oil is restored. Once the oil regains its solvency it can remove the varnish deposits that plague lubrication and hydraulic systems.

The ICB elements used in the SVR system are sized to provide a gradual recovery where a **CRITICAL** varnish condition can be reduced to **NORMAL** in about 60 days. Once **NORMAL** is achieved the system will remove the soluble varnish contamination at a rate faster than it is generated. This approach ensures a constant **NORMAL** condition even if the antioxidant additive package is completely depleted.



Whether the goal is preventing varnish formation, optimizing oil health and useful life or system recovery by removing varnish deposits and restoring oil health, SVR is a key component for your success.

Before installing the SVR, proper baseline oil analysis is required to understand current oil condition and establish realistic expectations for recovery and permanent varnish prevention. Throughout the recovery period frequent oil sampling is recommended to track improvement and ICB element condition.

SVR removes varnish-causing soluble contamination while in solution!

Rugged stainless steel construction & axial flow design ensures rupture free operation and optimizes removal of varnish-causing soluble contamination.

ICB element technology removes the contaminants in solution that lead to varnish formation. Removing the soluble oxidation by-products eliminates the possibility of varnish formation.

Restores healthy oil solvency allowing the clean oil to remove varnish deposits which are then captured by the ICB element.

The SVR process will not remove critical oil additives.

ICB element technology eliminates varnish feedstock

High efficiency particulate filtration lowers ISO Codes

SVR Skid improves fluid cleanliness and takes pressure off main bearing lube filter elements by removing particulate contamination off-line. Achieve lower than target ISO Codes of 14/12/10 and better.

The SVR particulate filter also removes some larger insoluble varnish particles.

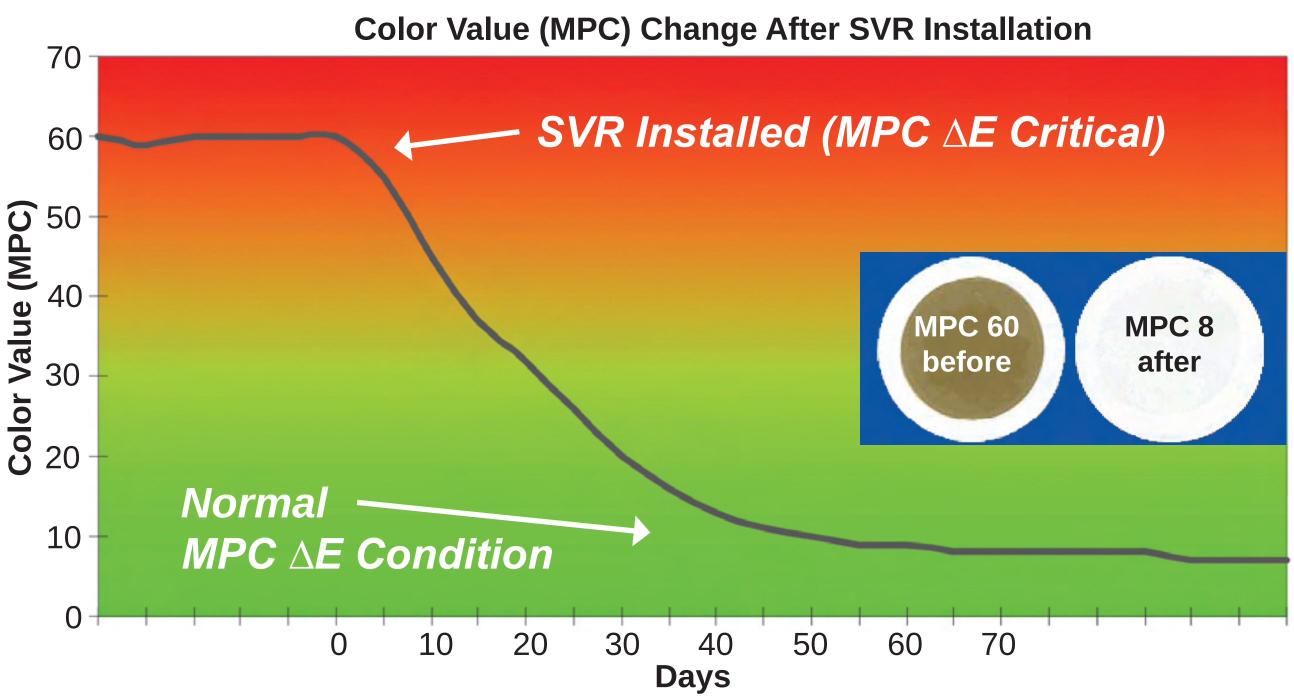
Membrane Patch Colorimetric MPC value dropped from 60 to 8 in 60 days!

Colorimetric analysis per ASTM D02.C0.01 WK13070 is used to determine varnish potential. A petroleum ether mixture agglomerates soluble by-products rendering them insoluble and visible for patch analysis. The membrane patch is analyzed with a calibrated spectrophotometer measuring ΔE to yield a value reported as the MPCΔE value (range 1 ~ 100).

After the SVR1200 installation MPC ΔE Color value trended down from a level **60 CRITICAL** to a level **8 NORMAL** over a period of 60 days.

MPC ΔE Condition Scale

Normal	Monitor	Abnormal	Critical
<15	15-29	30-40	>40



RULER Test: antioxidant additive levels unaffected!

RULER plots the aromatic amine and hindered phenol antioxidant levels against a new oil reference sample to determine the relative concentration of remaining sacrificial additive levels. Trending antioxidant levels is an important piece of condition monitoring. As the antioxidant additive levels are depleted, varnish causing by-product formation can accelerate. The results from this case study show that the installation of the SVR system had no measurable effect on antioxidant additive levels.

Antioxidant	Baseline	Day 30	Day 45	Day 60
Amine	85	82	89	80
Phenolic	7	4	8	4

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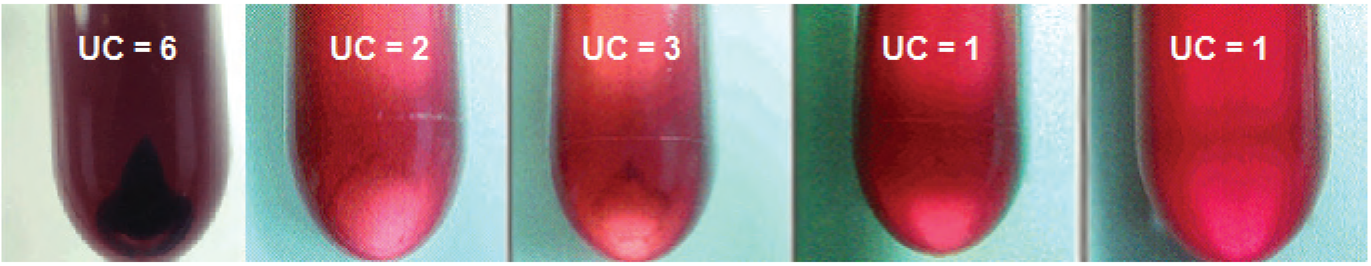
Ultra Centrifuge Test Color Value dropped from 6 to 1 in 45 days!

In the Ultra Centrifuge Test a small sample of oil is spun in a test tube for 30 minutes at 18,000 rpm. Oil degraded insoluble contaminants too small to be detected by traditional particle counting are collected. The density of the agglomerated material is compared to scale (range 1 ~ 8) to obtain the UC value. UC value > 5 is considered **CRITICAL**. Ultra Centrifuge is a valuable tool for identifying varnish causing contaminant levels that are insoluble.



In this case study the baseline UC value was at a level **6 CRITICAL**. After only 30 days the UC value dropped to a level **2 NORMAL** before dropping to a level **1 NORMAL** after 45 days. Once the SVR removed the soluble contaminant the solvency of the oil returned. As the oil health improved the insoluble varnish causing contaminant was dissolved back into solution then removed by the ICB elements.

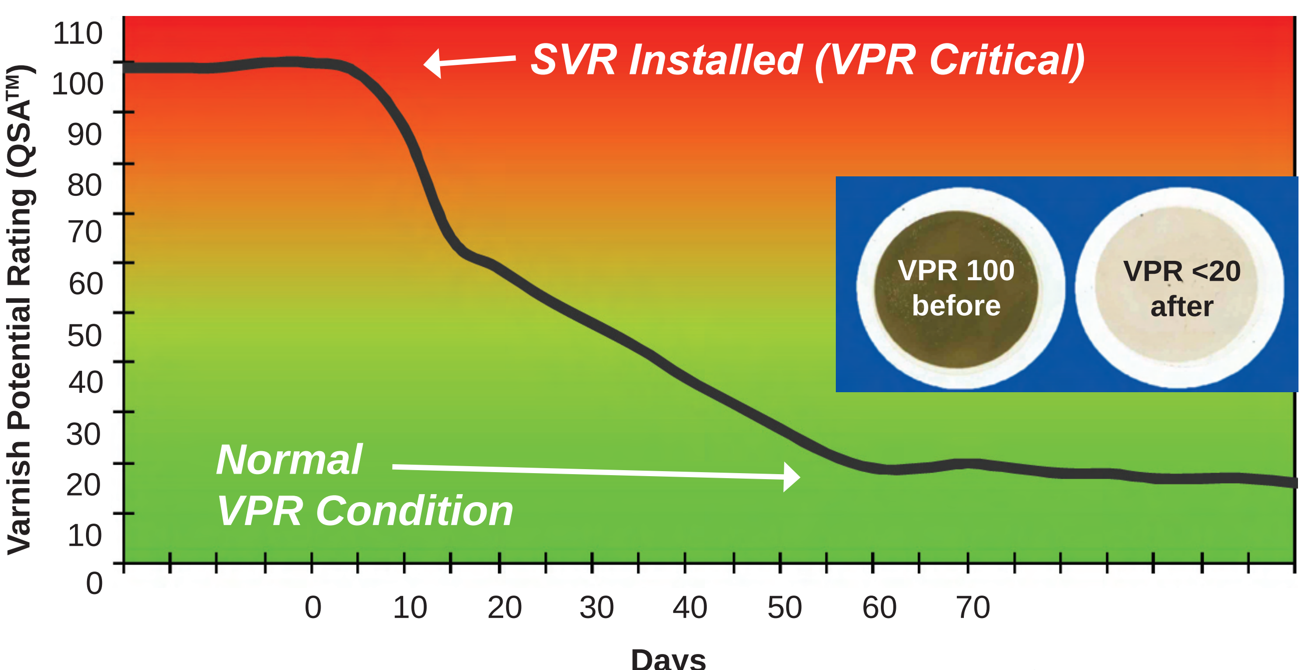
Varnish Potential Rating (QSA™) to < 20 in 60 days!

QSA™ is a colormetric patch analysis used to quantify molecular oil degradation by-products that have a tendency to deposit on surfaces as varnish. The color of the membrane patch is compared to a relative scale to yield a Varnish Potential Rating (range 1 ~ 100).
After the SVR1200 installation VPR value dropped from **VPR 100 CRITICAL** to a level **VPR < 20 NORMAL** over a period of 60 days.

VPR Oil Condition Scale (QSA™)

Normal	Monitor	Abnormal	Critical
<36	37-59	60-79	>80

Varnish Potential Rating (QSA™) Change After SVR Installation



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