SOLUBLE VARNISH REMOVAL™

THE PROVEN LUBE OIL VARNISH SOLUTION

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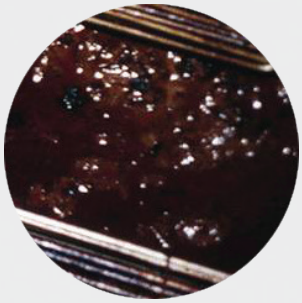
- Prevent varnish related gas turbine unit trip or fail-to-start conditions.
- Remove dissolved oxidation by-products to prevent varnish deposit formation.
- Restore fluid solvency and overall health.
- Prevent rapid anti-oxidant additive depletion.
- Lower ISO Fluid Cleanliness Codes with high efficiency post filter.
- Rapid on-site recovery services available.
- Oil analysis, results interpretation, and varnish mitigating strategy implementation.

BEFORE

AFTER

What is Varnish?

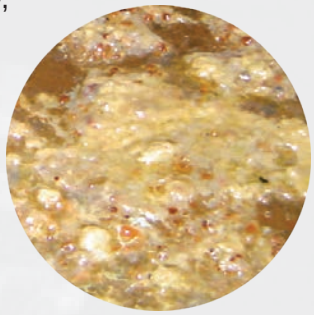
A thin, hard, lustrous, oil-insoluble deposit, composed primarily of organic residue, & most readily definable by color intensity. It is not easily removed by wiping with a clean, dry, soft, lint-free wiping material and is resistant to saturated [light hydrocarbon] solvents. Its color may vary, but it usually appears in gray, brown or amber hues.
ASTMD02.C01 WK27308 definition



Varnish can be soft and gooey *(Sludge)*

Varnish can be hard and brittle *(Lacquer)*

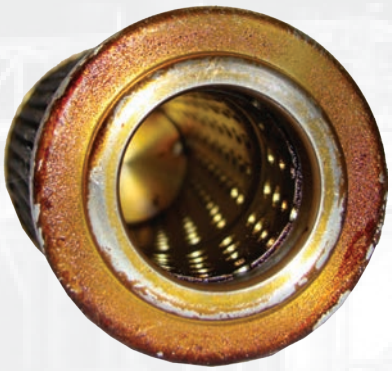
Varnish on reservoir ceiling *(Stalactites)*



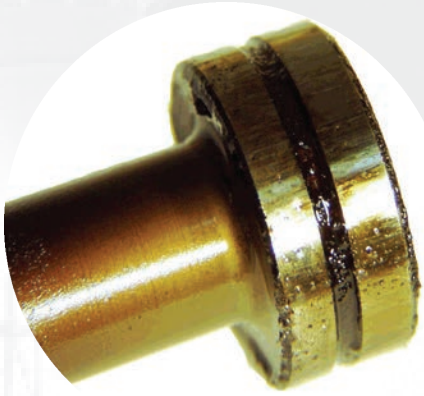
Varnish deposits on reservoir floor *(Plated)*

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

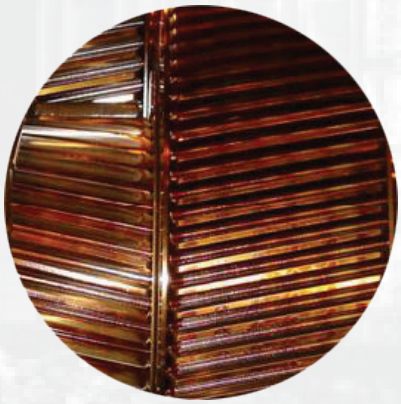
Filter element cross section (Lacquer Varnish Deposits, Support Tube)



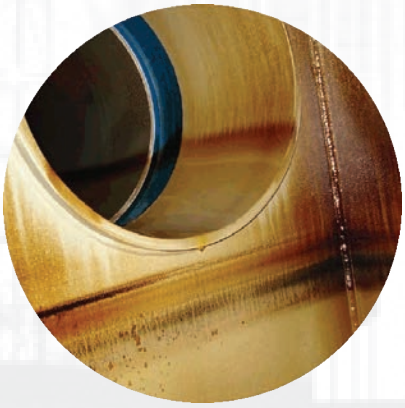
Varnish deposits on filter element (GE Frame 6B)



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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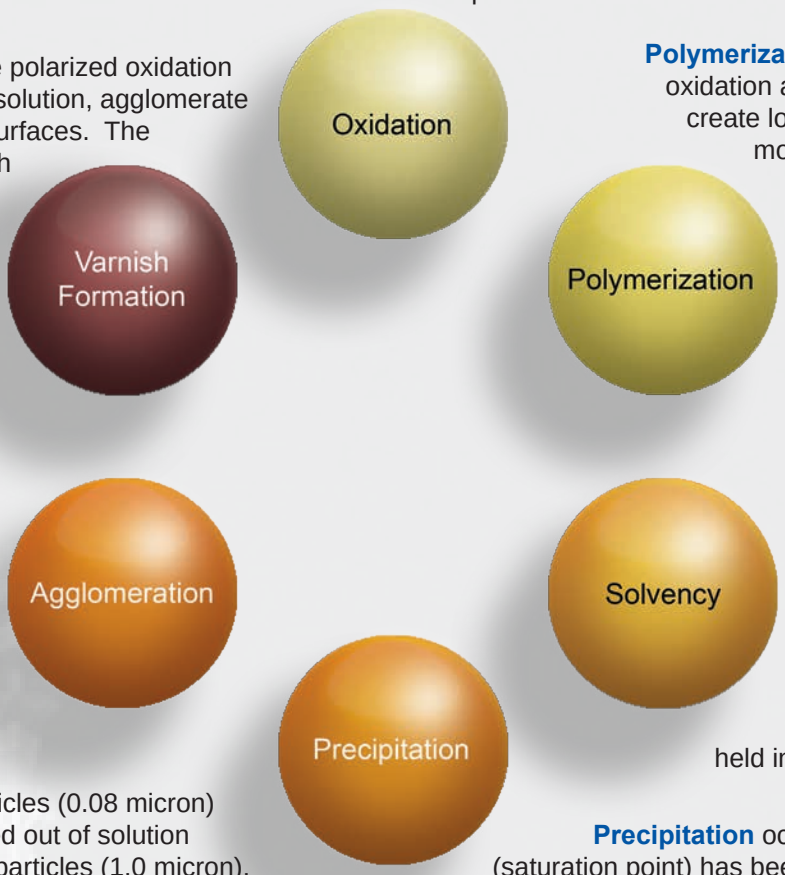
Varnish Formation Starts with Oxidation

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. Deposit formation also occurs locally where hot spots or sparking lead to varnish.

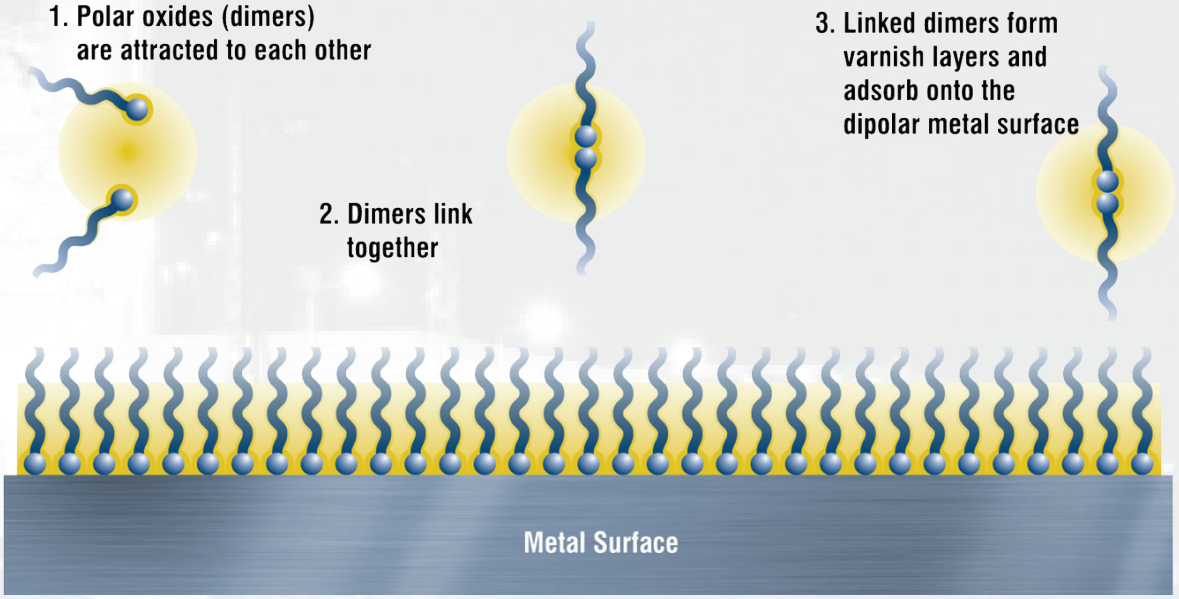


Polymerization occurs as the by-products of oxidation and additive reactions combine to create longer chain molecules with higher molecular weight. These molecules have lower ***solubility*** and are polarized. The rate of molecular polymerization is a function of ***temperature*** (as a catalyst) and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

Solvency 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.



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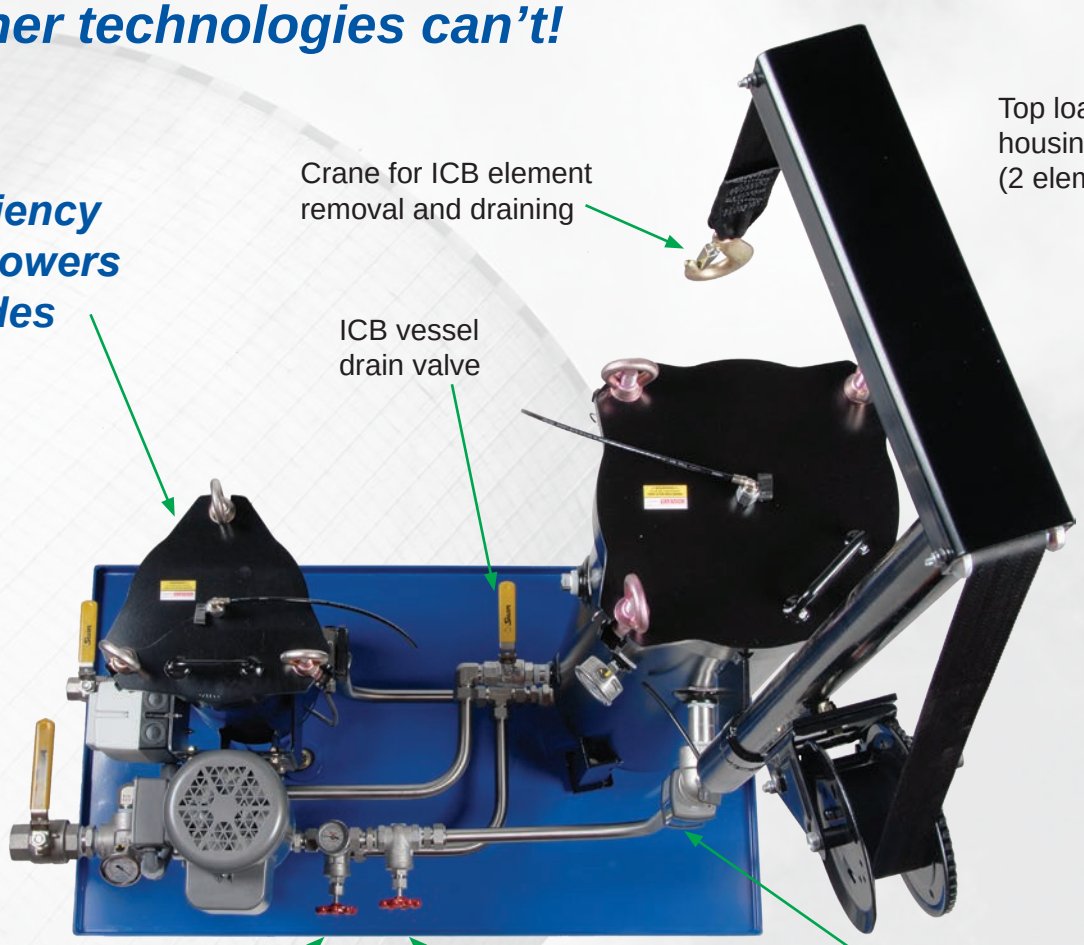
SVR™ removes varnish-causing soluble contamination where other technologies can't!

High efficiency post-filter lowers ISO Codes



SVR element technology (ION Charge Bonding) eliminates varnish feedstock so deposits can't form.

SVR restores oil solvency & reduces anti-oxidant additive depletion rates.

Single use element design eliminates double freight.

Top to bottom (axial flow) maximizes fluid and resin bead contact time for improved efficiency.

Rugged stainless steel construction ensures rupture free operation.

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Why SVR™ (Soluble Varnish Removal)?

SVR goes where other technologies can't to remove soluble contamination!

By removing the oxidation by-products while in solution SVR prevents the oil from becoming saturated and losing it's ability to hold varnish molecules, ***in solution***. SVR stops varnish before it starts by removing the feedstock of varnish formation while still in solution.
Electrostatic, depth, and agglomerating technologies can't remove the varnish building blocks until the fluid is saturated and the molecules precipitate out of solution putting turbines at risk for unit trip or fail to start conditions.

Before SVR | After SVR

What happens when the oil cools?
Solubility goes down, Varnish forms!

When the oil cools (off-peak, turning gear) the solubility of varnish feedstock decreases and varnish causing molecules will fall out of solution at a rapid rate to create varnish.
With SVR installed the soluble oxidation by-products have already been removed and can't precipitate out (they're gone).

Serious Problem! SVR is the proven recovery solution, Guaranteed!

High varnish potentials unaddressed will inevitably lead to valve and/or bearing problems. When fitted to a system with varnish deposits SVR attacks the source of the problem (polarized molecules, free radicals). 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.

Turbine lube oil reservoir (up to 8000 gallons) restoration timelines with the SVR1200 takes up to 90 days. Depending on the severity of the deposits and oil condition; installing a second set of elements might be required to achieve single digit varnish potential results (per MPC). Hy-Pro varnish potential test kits (VFTK, VLTK) provide critical oil condition data before starting the fluid restoration and to track results toward success (weekly). Check our case studies!

Extend useful fluid life, the case for prevention with SVR!

Modern Group II turbine oil formulations rely on Phenol and Amine AO additives to arrest the products of oxidation and prevent sludge and deposit formation. Once AO levels are depleted to 20% of new the oil may be condemned. The Phenol AO is typically the first to be depleted leading to high risk of varnish formation.

SVR performs a parallel function to the Phenol AO by removing products of oxidation while still in solution. It is proven that with SVR installed, the life of oil even with no remaining phenols can be extended without the formation of varnish deposits.

One plant specifically was losing ~20% of Phenol additives each year and after one oil change installed the SVR 1200. After 20 months Phenol levels were still above 92% of new proving that SVR can substantially extend oil life.

VFTK

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SVR1200 Dropped MPC value from 60 to 6 in 45 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 patch is analyzed with a spectrometer measuring DE reported as the MPC ΔE value.

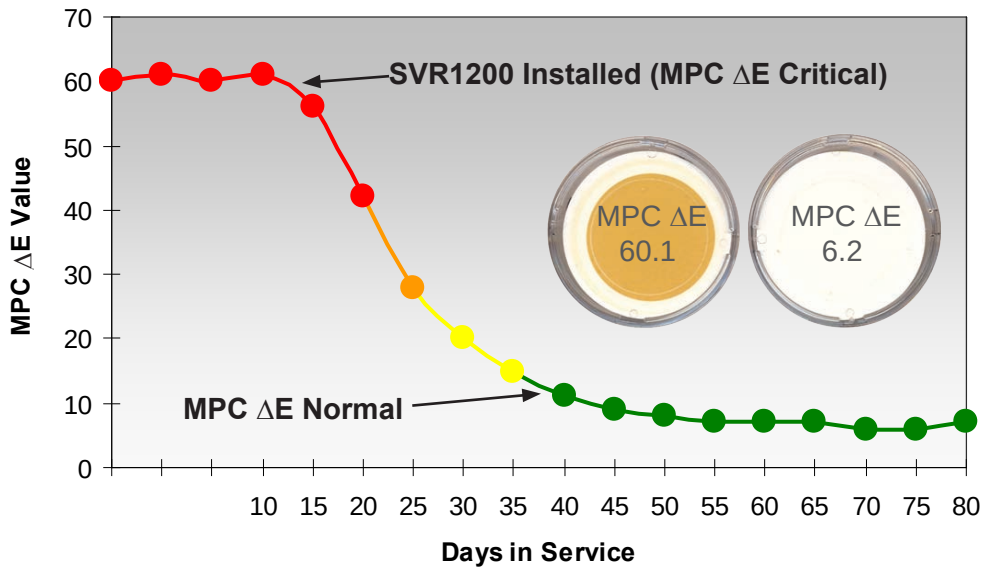
MPC ΔE Condition Scale

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

Figure 1 depicts SVR1200 installed on 7FA gas turbine experiencing unit trips from sticking servos. The SVR1200 had an immediate impact on the 6000 gallon turbine lube reservoir running GST32 lube oil. Within 45 days the lube oil varnish potential had been reduced from critical to condition normal.

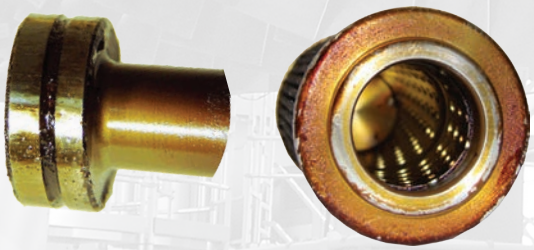
Starting phenol level was ~5 which means it only had 5% phenols relative to a new sample, well below the lower threshold to condemn the oil for low levels of anti-oxidant additive package. Even though phenols were depleted the SVR was able to restore and maintain condition normal.

1 **Varnish Potential (MPC) Trend After SVR Installation**



Since installing the SVR1200 there have been no CT varnish related fail-to-start conditions or unit trips!

Before installing the SVR the filter elements and servo valves were accumulating varnish deposits. To prevent unit trips the plant was changing servos and elements monthly in hopes of avoiding unit trip. After the successful restoration of the fluid with the SVR1200 the filter change interval has been extended back to 12 months PM and there has been no evidence of varnish deposits on filter elements or servo valve components.



Varnished element and servo valve prior to SVR installation.

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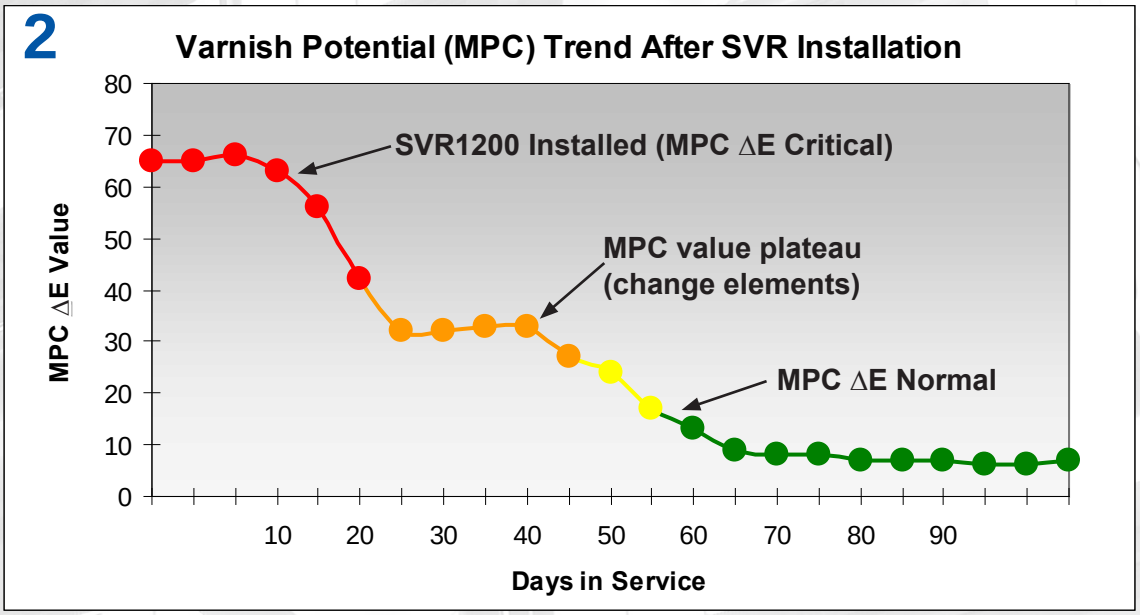
SVR1200 Restores Heavily Varnished Gas Turbine!

Figure 2 depicts the restoration of a heavily varnished CT where the MPC varnish potential value dropped to ~35 and then remained at that level indicating the need to change the SVR filter elements. Once the elements were changed the MPC drop continued and single digit MPC values were achieved. Condition monitoring via MPC or QSA is the most reliable way to know the elements are spent. A heavily varnished system might require two sets of elements to reach "Normal" condition and get into maintenance mode.

2



Extending Fluid Life - Preventing Anti-Oxidant Depletion

RULER (Remaining Useful Life Evaluation Routine) is used to quantify and trend remaining levels of Phenol and Amine anti-oxidant (AO) levels which is one of the factors considered in determining useful oil life. Once phenol AO levels drop below 20% of new, the rate of sludge and deposit formation can potentially increase and the oil may be condemned.

Figure 3 shows AO level trending after the installation of SVR1200 on a combustion turbine lube reservoir after the oil was replaced. After a year in service with SVR on board there is very little change in AO levels. This same turbine was losing ~20% of the phenol AO package annually without SVR. In addition to controlling varnish the SVR also extends the useful life of the oil by protecting the AO additive package.

3

RULER TEST (EXAMPLE)						
Date		7/22/2009	4/15/2009	1/6/2009	8/29/2008	6/1/2008
Lab No	Reference					
RUL %	>25%	92.3	86.7	91.2	96.7	91.3
Amines		94.7	100	98.2	98.0	
Phenols		99.1	97	94.7	93.6	

SVR™ The case for prevention!

As long as the elements are maintained, this turbine lube oil system will not have problems with varnish deposit formation and this new group II fluid has the potential to greatly exceed useful life expectations with high anti-oxidant additive levels. In addition to reducing AO additive depletion the SVR enables oil below 20% remaining phenols to stay in service.

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