



# A Guide to Varnish Testing Methods



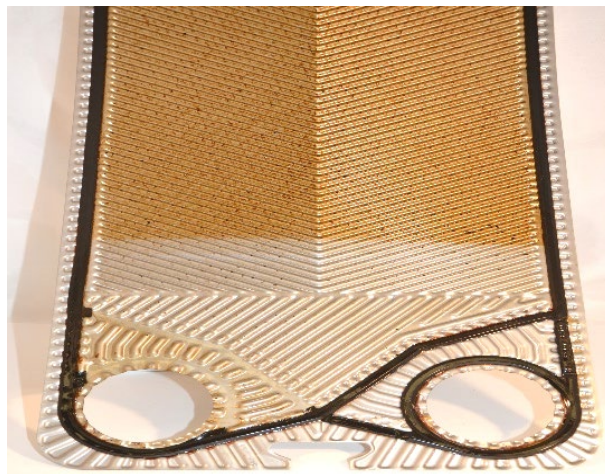
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## 1 Why care about varnish?

Varnish is a common issue in circulating systems where oil is used to provide a continuous flow of lubricant to bearings, gears, and other components of industrial equipment. Even the smallest amount of varnish can result in reduced system performance and/or equipment failures. Sludge or varnish adhering to servo or thermostatic valves can cause the valves to stick, bearings to overheat, and poor heat exchange performance, often producing elevated oil temperatures. Solid particle contaminants that imbed into varnish can also lead to increased component wear in valves, gears, and bearings.

Varnish build-up in turbine systems can have a serious adverse effect on system performance, equipment longevity, operational flexibility, and lubricant life. Over the life of a piece of equipment, this can equate to huge financial losses. This guide is focused on in-service oil testing related to identifying the potential for varnish in turbine systems. It is not meant to be an exhaustive guide to oil health monitoring.



*Top left: varnish-covered thermostatic control valve*

*Top right: varnish in oil reservoir head space*

*Bottom left: varnish bathtub ring in oil reservoir*

*Bottom right: heat exchanger cooling plate with partially removed varnish*

## 2 What is varnish?

A lubricating oil degrades when it undergoes thermal and mechanical stress. The rate of degradation is accelerated by many factors, such as:

- Oxidation
- Thermal stress (equipment hot spots, bubble adiabatic compression, micro dieseling)
- Contaminants such as water, solvents, gas, air, and dirt
- Additive depletion or drop out through operating conditions or over filtering
- Electrostatic discharge from filters
- Cross contamination or fluid incompatibility

Any of these factors could play significant roles in oil degradation, creating varnish precursors that, over time, form layers of varnish.

Once formed, varnish:

- Can be defined as a thin, lustrous, oil-insoluble deposit composed primarily of organic residue; mixed with metals, inorganic salts, and other contaminants; that cannot easily be removed by wiping with a dry, soft rag
- Forms a coating that adheres to internal surfaces
- Can take on different forms, from a sticky coating to a hard lacquer, and ranges in color from gray to brown to amber

## 3 What are the symptoms of varnish?

The most definitive means to assess varnish formation in your equipment is through visual inspection of the parts inside of the equipment casing. However, this usually requires a partial or full-system shutdown, therefore, is not always feasible outside of planned system maintenance.

While not a definitive list, the symptoms below may be indicative that a system may be suffering from the effects of varnish.

Erratic component operation:

- Valve sticking
- Hydraulic cylinders sticking
- Sub-synchronous vibration in high-speed bearings and seals
- Decrease in oil inlet flow
- Increased frequency of filter replacement

System temperature indicators:

- System alarms triggered due to higher temperatures
- Main bearing temperature increase relative to average (safe zone)
- Header temperatures increase relative to average (safe zone)
- Poor heat exchange performance in an oil cooler, leading to high overall oil temperatures
- Derating of the equipment to stay below alarm limits

Oil condition, including:

- Oil darkening
- Foul odor
- Acid number increase
- Viscosity increase
- Evidence of sediment and/or sludge
- Increased Particulate Count
- High MPC (Membrane Patch Colorimetry) values
- Rapid depletion of lubricant oxidation life

It is important to note that while oil analysis is a good way to monitor the health of your lubricating system, it alone cannot definitively diagnose varnish formation. Therefore, multiple methods for monitoring varnish should be part of an on-going holistic lubricant and system health management program.

### 3.1 Varnish composition variability

Not all varnish is created equal. Varnish deposits within different parts of a system often have dissimilar chemistries and physical properties. Changing lubricant brands, products or formulations can cause the different oil chemistries to make their own unique contributions to varnish composition. Varying pressure, flow, and temperature combinations in different parts of the system also affect areas in the system differently. Slight variations in these factors can make significant differences in varnish composition between otherwise identical systems.

Using a high-quality lubricant (with varnish control performance attributes) can inhibit the formation of varnish, but not always eliminate it. Equipment operators must be able to identify the symptoms of varnish in their system so they can evaluate their option to either continue operating the equipment or scheduling a time to shut down. System cleaning is oftentimes the most widely used recommendation to remove varnish build-up and other contaminants. The most widely used and proven approach involves the addition of a chemical cleaner to the end-of-life in-service oil. Understanding the suspected degree of varnish-fouling helps to determine the cleaner concentration and residence time the cleaner can remain in the system.

## 3.2 Test execution

All oil analysis tests that can help to identify varnish in equipment present challenges such as:

- The oil sample tested may not be representative of the oil in the entire system
- The potential for varnish may change throughout the year depending on the system utilization rates as degradation products often precipitate out of the oil to form deposits in an idle system
- Varnish precursors are difficult to measure as (a) they are very small (sometimes < 0.1µm) and (b) test methodologies measure only soft varnish precursors in suspension, but some precursors are in a continual balance between being in solution and precipitating out of solution depending on sample handling
- The amount, nature, and location of varnish deposits affect system performance, but measuring the overall ‘health’ of the oil and the additive package or the amount of varnish precursors in the oil does nothing to quantify these factors

There is no direct, definitive way of identifying varnish-related system issues that do not involve measuring critical parameters like valve hysteresis or oil cooler effectiveness or even tearing down the system to visually ascertain the root cause. Monitoring for varnish potential needs to be part of an on-going holistic lubricant and system health management program.

This guide provides testing methodologies that can be used to help identify the potential for varnish. The general guidance herein should not replace any specific product use instructions for industrial system cleaning chemicals and OEM recommendations.

## 4 Testing methodologies and frequencies

ASTM International publishes a good resource for turbine oil testing recommendations in *ASTM D4378 Standard Practice for In-Service Monitoring of Mineral Turbine Oils for Steam, Gas, and Combined Cycle Turbines*. Standard (industry-accepted) oil analysis tests are listed in **Table 1**. Frequency of testing depends on factors such as:

- Severity of the equipment operating conditions
- Criticality of the equipment
- Degree of varnish-related problems
- Whether the equipment is a steam turbine, a combustion turbine, or combined cycle
- Level of operator experience and comfort level with the equipment
- Degree and/or rate of change in test results
- The specific operational constraints of the equipment
- Approaching end of lubricant life

In an ideal world, an operator would perform all the tests listed in **Table 1**. In the real world, resource constraints mean decisions to choose which tests to conduct need to be made. In the absence of varnish-related issues, a reasonable initial prioritization might consist of the following:

1. Viscosity (ASTM D445)
2. Metals analysis (ASTM D5158)
3. Varnish potential using Membrane Patch Colorimetry or MPC (ASTM D7843)
4. Oxidation performance reduction using a combination of Rotating Pressure Vessel Oxidation Test further referenced as RPVOT (ASTM D2272), RULER® (ASTM D6971), and FTIR (ASTM D7414 et al)

1. All other tests

The tests displayed in **Table 1** are best utilized when establishing trending since the rate of change is more informative than the absolute values. Baseline tests should be conducted. Fresh oil contained in a package or bulk tank should not be used for baseline testing; rather, fresh oil recently charged into the turbine system (with residual in-service oil, residual chemical cleaner, contaminants, etc.) should be used as the baseline. Conduct baseline tests after filling the equipment with fresh oil after 24 hours of circulation in the system. Furthermore, a fresh baseline should be taken at every step change in the oil (oil top-off, top-treat additive boosters, etc.), after a similar circulation period.

**Table 1. Standard Tests (Industry accepted)**

Type	Test	Priority (1 = Highest)	Name	Issuer	Frequency (months)
Oil degradation	Viscosity <sup>1</sup>	1	D445 Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)	ASTM	3
	Oxidation byproducts (Acid)	2	D664 Acid Number of Petroleum Products by Potentiometric Titration (can be substituted with D974)	ASTM	3
	Oxidation byproducts (Acid)	2	D974 Acid and Base Number by Color-Indicator Titration (can be substituted with D664)	ASTM	3
	Oxidation (RPVOT)	3	D2272 Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel	ASTM	3
	Oxidation (RULER®)	3	D6971 Measurement of Hindered Phenolic and Aromatic Amine Antioxidant Content in Non-zinc Turbine Oils by Linear Sweep Voltammetry	ASTM	3

Type	Test	Priority (1 = Highest)	Name	Issuer	Frequency (months)
	Oxidation, Sulfate, Nitrate (FTIR)	3	D7414 Condition Monitoring of Oxidation in In-Service Petroleum and Hydrocarbon Based Lubricants by Trend Analysis Using Fourier Transform Infrared (FT-IR) Spectrometry D7415 Condition Monitoring of Sulfate By-Products in In-Service Petroleum and Hydrocarbon Based Lubricants by Trend Analysis Using Fourier Transform Infrared (FT-IR) Spectrometry D7418 Set-Up and Operation of Fourier Transform Infrared (FT-IR) Spectrometers for In-Service Oil Condition Monitoring D7624 Condition Monitoring of Nitration in In-Service Petroleum and Hydrocarbon-Based Lubricants by Trend Analysis Using Fourier Transform Infrared (FT-IR) Spectrometry	ASTM	3
Contamination	Elemental analysis <sup>1</sup>	1	D5185 Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)	ASTM	3
	Water separability	3	D1401 Water Separability of Petroleum Oils and Synthetic Fluids	ASTM	3
	Water content	3	D6304 Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer	ASTM	3
Particle count	Characterization	2	ISO 4406 Coding the level of contamination by solid particles	ISO	3
	Count and characterization	2	D7647 Automatic Particle Counting of Lubricating and Hydraulic Fluids Using Dilution Techniques to Eliminate the Contribution of Water and Interfering Soft Particles by Light Extinction (can be substituted with D7596)	ASTM	3
	Count and characterization	2	D7596 Automatic Particle Counting and Particle Shape Classification of Oils Using a Direct Imaging (can be substituted with D7647)	ASTM	3



Type	Test	Priority (1 = Highest)	Name	Issuer	Frequency (months)
	Count	2	ISO 4407 Determination of particulate contamination by the counting method using an optical microscope	ISO	3
	Count	2	ISO 11500 Determination of the particulate contamination level of a liquid sample by automatic particle counting using the light-extinction principle	ISO	3
	Count	2	F311 Processing Aerospace Liquid Samples for Particulate Contamination Analysis Using Membrane Filters	ASTM	3
	Count and size	2	F312 Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters	ASTM	3
<b>Varnish potential</b>	Insoluble contamination	3	D4898 Insoluble Contamination of Hydraulic Fluids by Gravimetric Analysis	ASTM	3
	Insoluble contamination (MPC)	2	D7843 Measurement of Lubricant Generated Insoluble Color Bodies in In-Service Turbine Oils using Membrane Patch Colorimetry	ASTM	6
<b>Compatibility</b>	Sediments	2	D2273 Trace Sediment in Lubricating Oils	ASTM	3

In addition to the standard (industry-accepted) oil analysis tests listed in **Table 1**, there are several tests that are not yet broadly accepted by the industry, but which show promise for helping to identify varnish issues. Several testing laboratories have also developed and use their own customized oil analysis tests that also may be helpful although these too are not universally accepted or available. **Table 2** lists examples of both test types.

**Table 2. Other Tests**

Type	Test	Output	Notes	Frequency (months)
<b>Oxidation strength</b>	Pressurized Differential Scanning Calorimetry (PDSC)	Measures the oxidative induction time (OIT) of oils under high temperature and pressure in the presence of pure oxygen.	Influenced by other lubricant components and base oil so result may not directly relate to the health of the antioxidant system. The accelerated oxidation uses oil temperatures higher than those commonly found in turbines so replicates neither operating conditions nor chemical kinetics of the in-service oil. It also has limited contaminants, very high levels of water and high levels of oxygen not normally found in turbine applications.	On Demand
<b>Particle count</b>	Ultracentrifuge Rating (UC)	Identifies suspended particles in the oil. The amount of sediment is correlated to deposit precursors.		On Demand
<b>Varnish potential</b>	MPC + weighing	Weighing of the MPC patch before and after the test to determine varnish amount after solvent washing.		On Demand
<b>Varnish potential</b>	Recalibrated MPC	The used MPC patch is rinsed with a polar solvent and the remaining insoluble particles, which contributed to the measured color, are not varnish particles - the measured color can be adjusted down to account for these non-varnish particles.		On Demand

## 5 Oil analysis tests that can help determine potential for varnish formation

### 5.1 Oil Degradation

#### 5.1.1 Viscosity (D445)

Viscosity data is classified as a lagging indicator to a change in the system. This is because the viscosity measurement provides information of what has happened to the oil rather than what will happen. The size of the reservoir also has a strong influence on how quickly a change from the baseline in the viscosity will be noticed compared to increases or changes in the baseline of the other UOA tests. This masking of the data until significant changes have occurred, along with it being classified as a lagging indicator makes it difficult to use viscosity alone to deduce a problem in the system.

This test is still relevant to include in any UOA testing program because it supports trending and helps to deduce problems. It is an indicator of the addition of the wrong fluid, if the viscosity of the contaminate fluid is different, or viscosity can change due to oxidation. Oil degradation can cause an increase in the viscosity of the oil over time. The viscosity increase due to oxidation can be correlated to the increases in both Total Acid Number (TAN) (as measured by D664 or D974) and insoluble content/varnish precursors (as measured by MPC, UC, or FTIR) which can detect a change in the system sooner than the viscosity measurement, but these are also influenced by top off volumes due to dilution. If changes are being observed that have not been linked to the addition of a different viscosity fluid and trending is showing increase TAN or other indicators of oxidation then more frequent testing should be undertaken, especially if the trending shows the rate of change is accelerating.

#### 5.1.2 Oxidation Life RVPOT (D2272)

Oxidation life is the most common parameter evaluated to determine remaining turbine oil life.

The Rotating Pressure Vessel Oxidation Test (RPVOT) measures the oxidation life of the oil by taking the used oil, subjecting it to precise extreme conditions and measuring how many minutes it takes before the pressure of the oxygen in the vessel decreases by 24 PSI. This is due to the antioxidants or inhibitor system becoming overwhelmed by the oxygen present in the system and the reaction accelerates consuming the oxygen. Therefore, an in-service oil is going to start the test with fewer antioxidants or inhibitors when tested and the length of time before the in-service oil is overwhelmed is decreased from the baseline of the system. This value is compared to the RVPOT of the starting baseline oil to get a percentage of the original oxidation life. The condemning limit is typically 25 percent.

RVPOT:

- Is influenced by other lubricant components and base oil so result may not directly relate to the health of the antioxidant system.

- Depends on an accelerated oxidation that uses oil temperatures higher than those commonly found in turbines and so replicates neither operating conditions nor chemical kinetics of the in-service oil.
- May change little for some oils that have significant deposit formation potential. This can be due to the degradation materials being removed from the system keeping the antioxidant levels high.

### 5.1.3 Oxidation Life RULER® (D6971)

The Remaining Useful Life Evaluation Routine® test (RULER) identifies the antioxidant type (both amine and phenolic) and measures the quantity in used oil as a percent of fresh oil. If different oil formulas are mixed the reference levels of the new product references shifts and used oil levels become far less meaningful.

RULER:

- Does not indicate the inherent antioxidant properties of the complete formulation as it says nothing about the base oil or other components that may have either a synergistic or negative effect on antioxidant properties,
- Provides misleading values in systems that are mixed (various products used in the system).
- Is most commonly used to measure amine and phenolic antioxidants.

### 5.1.4 RPVOT vs. RULER

Both RULER® and RPVOT are helpful tests for evaluating turbine oil condition, but they measure different aspects of oxidation life and neither is 100 percent reliable in all circumstances. RPVOT measures oxidation life by measuring the actual resistance to oil oxidation rather than detecting oxidation. RULER measures antioxidant additives. RPVOT can be used with mixed fluids or complex systems but RULER can have difficulties with complex antioxidant systems and mixtures. Other tests including FTIR and potentially PDSC can also be used to evaluate turbine oil oxidation health but are less commonly used techniques. RULER is quicker and easier than RPVOT to perform, uses a smaller sample volume, lower cost and can be done on site. Where typically due to the equipment RPVOT is run in a laboratory setting. RULER® is therefore more commonly used but caution should be used in interpreting its results. Both methods require the establishment of baseline data to create trends.

Complex oil formulations can contain numerous performance additives which can combine with one another over time through equilibrium processes to form new, temporary chemical species that contribute to the antioxidant influence of the fluid and can potentially create an anomaly in the trending data for the fluid. These temporary or new species may not be measurable by RULER and can lead to incorrect interpretations. The synergistic reactions of the additives will result in the RULER plots evolving over time with no corresponding change in the oil performance. A zero result in RULER for a phenolic does not necessarily mean that there is no phenolic in the lubricant. Variations in base oil molecular weight distribution can also affect the voltammetry measurement by RULER® and the infrared fingerprints of our products.

In summary, complex antioxidant systems in certain oils can present difficulties in interpreting the data by the RULER® test. As a single data point it will not be able to fully determine the exact level of antioxidant additive in the oil because of the shift to alternate peaks forming due to the complexing. In general, the RULER results should be used as a trending tool and not as an indication of absolute values. Caution should be taken when evaluating in-service oils as the synergistic effects between phenolic and aminic antioxidants can often mean RULER underestimates the effective antioxidants remaining in the oil and the efficacy of those remaining to protect the oil and system.

In combination with the RULER, the RPVOT test can better represent the oxidation life left in products that have a complex additive system. This is because the RPVOT, as mentioned above in the description, is measuring total oxidation stability or the remaining antioxidant performance. Therefore, Texaco recommends using RULER trending results **combined** with RPVOT (as well as standard condition monitoring tests) for predicting the remaining useful life of the oil. This information from industry experts using these methods support the importance to **avoid** relying on any single test and specifically that RULER should not be used as a replacement for RPVOT.

#### 5.1.5 Oxidation byproducts Acid (D974/D664)

Total Acid Number (TAN) is a test that determines the amount of both weak and strong organic acids. The test is conducted by adding a base, potassium hydroxide (KOH), until the 1 gram of sample is neutralized.

There are several reasons for an increase in TAN including contamination, alkaline-reserve depletion, and acidic byproducts from oxidation. Although TAN does not directly measure the oxidation occurring in the system due to antioxidants and other components that neutralize the acids over time it will start to increase because the antioxidants are consumed. High acid numbers can lead to internal corrosion and accelerate polymerization of the base oils increasing the viscosity of the fluid.

#### 5.1.6 Oxidation Life FTIR (D7414 et al)

FTIR uses the light absorption properties of molecules to detect common contaminants, lubrication degradation byproducts and additives. It may thus be unable to differentiate between light absorption due to the presence of water, glycol contamination, or antioxidant additives because their absorptions peaks are usually broad and may overlap.

Most used oils are complex mixtures of thousands of different molecules, so their infrared spectrum is typically complex and difficult to interpret.

## 5.2 Contamination

### 5.2.1 Metals Analysis (Multi-element Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry ASTM D5185)

While alternate test methods can be used to determine metals in lubricants and sludge this is one of the most common methods being used today in used oil analysis. The test method is used for the determination of additive elements, wear metals and contaminants in used and unused lubricating oils and base oils by inductively coupled plasma atomic emission spectrometry (ICP-AES). For a full list of the elements that have been identified for this method see the method Table 1. This method will determine for the most part the soluble metal species in the oils. If it is a fine dispersion of wear particles it can detect these as well, but particles larger than a few microns will not be detected using this method. The wear metals that are being detected is not capturing the full assessment of wear if it is happening because of this limitation. The metals that the method can determine is the soluble species which can be from wear but not mentioned in the above scope is coming from corrosion. The corrosion could lead to a corrosive wear mechanism but would first start to show up as trace elements in the oil. This corrosion is due to the change in the oil properties and acidity due to the degradation of the oil and accelerated with the presence of water. The acidic organic species chelate with the metals keeping them in the oil. Trending of the data is necessary to track the changes occurring within the system and is correlated to the TAN monitoring. These soluble metals can also further degrade the oil. Tracking metals during a UOA program can indicate oxidation and degradation of the oil while also showing potential warning signs of corrosion in the system and to critical components like valves and bearings. The oxidation and degradation would be indicators of a potential varnish problem as well.

### 5.2.2 Water Separability (D1401)

Water separability in most turbine oils depends on the natural separation characteristics of the high-quality base oils used without the addition of ‘demulsifier’ additives. Loss of water separability is most often associated with contamination. Tiny amounts of emulsifying oil can ruin the water separation performance of a lot of good turbine oil. Oxidation can also lead to changes in the performance of the oil to be able to separate from water. Varnish precursors that are suspended in the oil can have a polar end to the molecules and these tend to attract/interact with the water preventing it from coalescing and separating. Removing the varnish precursors from the system tends to improve water separability performance.

A fluid with poor water separability is not damaging to a turbine system, but when there is the presence of water it can be very damaging to the system and cause accelerated degradation of the fluid. If a fluid is tested and shows that its water separability performance is poor, the oil may still be fine for service if the water content is low, which then moving forward water content should be watched more closely if water separability remains an issue. If water content rises, water removal technologies such as vacuum dehydration or membrane filtration can eliminate the contamination without requiring an oil change.

### 5.2.3 Water Content (Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration ASTM D6304)

This is one of many test methods that can be used to determine the water content. We have chosen it because of its common use and accuracy of results. The method covers the direct determination of water in the range of 10mg/Kg to 2500 mg/Kg of entrained water in petroleum products and hydrocarbons. Sulfur species can interfere with this test method being able to determine the concentration of the water due to it being a titration-based method. There are other elements that also interfere and are listed in the method directly. This test supports UOA programs to ensure low water content in the lubricating oils. High water content can lead to accelerated degradation, corrosion, and be an indicator of coolant system leaks. The water content is not directly linked to having a varnish problem within the system but if the water content is managed it would lower the varnish potential of the system.

The water content increase can be linked to the high formation of polar varnish precursors as indicating in the water separability test where the oil cannot separate out the water the content rises. If the water separability test is not performed routinely but the water content is, then this test can indicate that something is occurring within the system which could be related to an increase in the TAN and degradation species preventing the release or ability to separate from the water. The best solution is to find the source of any incoming water and keep the system as dry as possible and continue to monitor with UOA.

## 5.3 Particle Count

### 5.3.1 Characterization (ISO 4406)

ISO 4406 is often referred to as the particle counting method, but this is misleading, because it is only a method for reporting particle counts, not how to measure particles. Several factors can skew particle counts including:

- Laser particle counters measure shadows cast by assumed hard particles. Air bubbles, water droplets, foam inhibitors and even varnish precursors can be mistakenly measured as hard particles
- Solvent methods can help mask some mistaken shadows, but many laboratories avoid these as they are time-consuming and expensive
- Laser net fines and direct imaging evaluate the shape of a shadow and can therefore mistake bubbles or droplets for varnish precursors
- Currently only effective for particles larger than 10 microns
- Pore blockage will ignore soft contaminants but only correlates a backpressure increase across its screens to number of particles, so is not particularly precise
- Patch testing can allow a manual count of particles caught in a filter patch and is quite revealing, but white particles are often overlooked as they are camouflaged against the white patch. The test is biased toward antioxidant chemistries that produce dark deposits. It also doesn't account for soluble degradation products.

Particle count is critical to turbine oil health and should be monitored. Understanding methods and using a consistent measurement method and sampling technique is critical for obtaining useful data.

Refer to [Table 2](#) for test methods.

## 5.4 Potential of varnish formation

Testing for the potential of varnish formation measures only varnish precursors **in the oil** and do not give a true indication of harmful deposits **on surfaces in a system**. Only visual inspection or symptom evaluation can indicate actual deposits. Varnish potential and actual varnish often correlate, but not always. Varnish filtration technologies such as electrostatic, balanced charge agglomeration (BCA), depth media and absorptive resin can often successfully remove varnish precursors from the oil lowering varnish potential but can also deplete oil performance additives including rust inhibitors, foam inhibitors and EP additives in EP type turbine oils. It is possible to solve one problem while creating another.

### Insoluble Contamination (D4898)

This test method is used to measure the total amount of solid and soft insoluble contamination present in an oil. It is important to keep the levels of insoluble contamination minimal to maintain equipment performance and life. In this test, a given volume of sample is pulled through a filter using a vacuum. The filter is then weighed to determine the amount of insoluble material collected. Additionally, the filter is inspected under a microscope to profile larger particles such as dirt, rust, fibers, and metals to help determine the source of the contamination.

#### 5.4.1 Insoluble Contamination - MPC (D7843)

The Membrane Patch Test (MPC) is a test designed to assess the oil's varnish potential by identifying the level of insoluble material present. In this test, the oil sample is mixed with a non-polar solvent and passed through a 0.45-micron filter patch. Varnish materials tend to be polar, which makes them insoluble in the oil/solvent mixture. As the sample is passed through the filter, the insoluble material is captured. The patch is then analyzed. A colorimeter is used to analyze the L (black to white), A (red to green), and B (yellow to blue) values and calculate a  $\Delta E$  value that indicates the hue and intensity of the insoluble material present. The  $\Delta E$  value gives an overall indication of the level of insoluble material present; however, each of the L, A, and B values can also be interpreted to help determine the source of the insoluble. Looking at black particles, a high L-value can indicate soot. Higher A, red to green scale, values might be indicative of corrosive material. An increased B, yellow to blue, value highlights that the oil is vulnerable to sticky deposits.

The MPC results indicate the amount of insoluble matter that is suspended in the oil. There are scenarios where a low MPC value is seen, but varnish is visually observed. With this, the MPC test is best interpreted through trending.



## 5.5 Compatibility

### 5.5.1 Sediments (D2273)

This test measures the amount of trace sediment in the oil sample through centrifuging. Small particles can enter a system more easily than large particles and are not removed by filtration. Because of their size, these small particles are less likely to precipitate out of solution and usually remain suspended in the oil. Excessive amounts of sediment can lead to system failures.

## 6 Summary

Varnish occurs to some degree in most turbine systems, whether through varnish precursors, the breakdown of the turbine oil or filtration. Using proper lubricant storage, handling and transfer techniques in a clean and dry environment will go a long way in helping to control the problems of varnish that can escalate if left untreated. Proper maintenance schedules and condition monitoring help operators look for evidence of equipment issues and oil testing can aid in deducing suspected problems that varnish can create.

Texaco Lubricants delivers focused expertise, advanced products, and tailored programs to help our customers' equipment and operations Run Better Longer.

## 7 References

- Analysis of Varnish Potential  
<https://www.machinerylubrication.com/Read/1027/varnish-potential-analysis>
- ASTM D4378 Standard Practice for In-Service Monitoring of Mineral Turbine Oils for Steam, Gas, and Combined Cycle Turbines

## 8 ASTM tests common to turbine oils and compressor oils

<b>Turbine Oils</b>		
<b>Description of Test</b>	<b>ASTM/ISO Test</b>	<b>Testing Results and/or Why the Numbers are Important to Consider</b>
Air Release Properties of Hydrocarbon Based Oils	D3427	Time that entrained air in the fluid reduces in volume to 0.2 percent
Conradson Carbon Residue of Petroleum Products	D189	The percentage of carbon residue remaining after heating, indication of relative coke-forming tendencies
Copper Strip Corrosion by Industrial Aromatic Hydrocarbons (copper panel test)	D849	Value of (1 is best; 4 is worst) 1A, 1B, 2A, 2B, 2C, 2D, 2E, 3A, 3B, 4A, and 4C
Flash Point Cleveland Open Cup	D92	Drops 1.11°C (30°F) or more compared to new oil
Foaming Characteristics of Lubricating Oils	D892	Sequence I: 450 ml with a stability of 10 ml
Hydrolytic Stability of Hydraulic Fluids	D2619	Observes the results of D2688 copper weight loss, D130 Copper Strip and D664/D974 TAN
ISO Cleanliness Requirement (Particle Counting)	ISO 4406	18/16/13
Membrane Patch Colorimetry (MPC) test	D7843	Reported as a dE value: Good ( $\Delta E < 15$ ), Monitor ( $\Delta E = 15-25$ ), Abnormal ( $\Delta E = 25-35$ ) and Critical ( $\Delta E > 35$ )
Multielement Determination - Dissolved Metals by Spectrometry (ICP-AES)	D5185	Between samples, an Increase of 4 or more ppm or > 10 ppm
Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel (RPVOT)	D2272	RPVOT value decline to 25 percent of new oil RPVOT value with an increase in TAN
Remaining Useful Life Evaluation Routine (RULER) test	D6971	25 percent of phenolic and aromatic amines antioxidant content
Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water	D665	Light fail
Total Acid Number (TAN), mg KOH/g, max	D664/D974	0.3 to 0.4 mg increase over new oil value
Viscosity @ 40°C	D445	5 percent change in viscosity
Water Separability of Petroleum Oils and Synthetic Fluids	D1401	15 ml emulsion (or greater) after 30 minutes
Water, vol percent, max (Karl Fischer)	D6304	0.1 percent (1000 ppm); Never > 0.25 percent (2500 ppm)

<b>Compressor Oils</b>		
<b>Description of Test</b>	<b>ASTM/ISO Test</b>	<b>Testing Results and/or Why the Numbers are Important to Consider</b>
Air Release Properties of Hydrocarbon Based Oils	D3427	Time that entrained air in the fluid reduces in volume to 0.2 percent
Conradson Carbon Residue of Petroleum Products	D189	The percentage of carbon residue remaining after heating, indication of relative coke-forming tendencies
Copper Strip Corrosion by Industrial Aromatic Hydrocarbons (copper panel test)	D849	Value of (1 is best; 4 is worst) 1A, 1B, 2A, 2B, 2C, 2D, 2E, 3A, 3B, 4A, and 4C
Flash Point Cleveland Open Cup	D92	Drops 1.11°C (30°F) or more compared to new oil
Foaming Characteristics of Lubricating Oils	D892	Sequence I: 450 ml with a stability of 10 ml
Hydrolytic Stability of Hydraulic Fluids	D2619	Observes the results of D2688 copper weight loss, D130 Copper Strip and D664/D974 TAN
ISO Cleanliness Requirement (Particle Counting)	ISO 4406	18/16/13
Membrane Patch Colorimetry (MPC) test	D7843	Reported as a dE value: Good ( $\Delta E < 15$ ), Monitor ( $\Delta E = 15-25$ ), Abnormal ( $\Delta E = 25-35$ ) and Critical ( $\Delta E > 35$ )
Multielement Determination - Dissolved Metals by Spectrometry (ICP-AES)	D5185	Between samples, an increase of 4 or more ppm or > 10 ppm
Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel (RPVOT)	D2272	RPVOT value decline to 25 percent of new oil RPVOT value with an increase in TAN
Remaining Useful Life Evaluation Routine (RULER) test	D6971	25 percent of phenolic and aromatic amines antioxidant content
Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water	D665	Light fail
Total Acid Number (TAN), mg KOH/g, max	D664/D974	0.3 to 0.4 mg increase over new oil value
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