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An American National Standard

Standard Practice for In-Service Monitoring of Mineral Turbine Oils for Steam and Gas Turbines[1]

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INTRODUCTION

The in-service monitoring of turbine oils has long been recognized by the power-generation industry as being necessary to ensure long trouble-free operation of turbines.

The two main types of stationary turbines used for power generation are steam and gas turbines; the turbines can be used as individual turbines, or can be coupled to combine cycle turbines. The lubrication requirements are quite similar but there are important differences in that gas turbine oils are subjected to significantly higher localized "hot spot" temperatures and water contamination is less likely. Steam turbine oils are normally expected to last for many years. In some turbines up to 20 years of service life has been obtained. Gas turbine oils by comparison have a shorter service life. Many of the monitoring tests used for steam turbine oils are applicable to gas turbine oils.

This practice is designed to assist the user to validate the condition of the lubricant through its life cycle by carrying out a meaningful program of sampling and testing of oils in use. This practice is performed in order to collect data and monitor trends which suggest any signs of lubricant deteriorating. This can be used as a guide for the direction of system maintenance to ensure a safe, reliable, and cost-effective operation of the monitored plant equipment. Also covered are some important aspects of interpretation of results and suggested action steps so as to maximize service life.

1. Scope

1.1 This practice covers the requirements for the effective monitoring of mineral turbine oils in service in steam and gas turbines, as individual or combined cycle turbines, used for power generation. This practice includes sampling and testing schedules to validate the condition of the lubricant through its life cycle and by ensuring required improvements to bring the present condition of the lubricant within the acceptable targets.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 92 Test Method for Flash and Fire Points by Cleveland Open Cup[2]

D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test[2]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[2]

D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration[2]

D 665 Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water[2]

D 892 Test Method for Foaming Characteristics of Lubricating Oils[2]

D 943 Test Method for Oxidation Characteristics of Inhibited Mineral Oils[2]

D 974 Test Method for Acid and Base Number by Color-Indicator Titration[2]

D 1401 Test Method for Water Separability of Petroleum Oils and Synthetic Fluids[2]

D 1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)[2]

D 2272 Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel Oxidation Test[2]

D 2422 Classification of Industrial Fluid Lubricants by Viscosity System[2]

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.C0 on Turbine Oils.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.

D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products[3]

D 4241 Practice for Design of Gas Turbine Generator Lubricating Oil Systems[3]

D 4248 Practice for Design of Steam Turbine Generator Oil Systems[3]

D 6810 Test Method for the Measurement of Hindered Phenolic Antioxidant Concentration in HL Turbine Oils by Linear Sweep Voltammetry[4]

F 311 Practice for Processing Aerospace Liquid Samples for Particulate Contamination Analysis Using Membrane Filters[5]

F 312 Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters[5]

2.2 *ISO Standard:*

ISO 4406:1999 Hydraulic fluid power—Fluids—Method for coding the level of contamination by solid particles[6]

3. Significance and Use

3.1 This practice is intended to assist the user, in particular the power-plant operator, to maintain effective lubrication of all parts of the turbine and guard against the onset of problems associated with oil degradation and contamination.

4. Properties of Turbine Oils

4.1 Most turbine oils consist of a highly refined paraffinic mineral oil compounded with oxidation and rust inhibitors. Depending upon the performance level desired, small amounts of other additives such as metal deactivators, pour depressants, extreme pressure additives, and foam suppressants can also be present.

4.2 New turbine oils should exhibit good resistance to oxidation, inhibit sludge formation, and provide adequate antirust, water separability, and nonfoaming properties. However, these oils cannot be expected to remain unchanged during their use in the lubrication systems of turbines, as lubricating oils experience thermal and oxidative stresses which degrade the chemical composition of the oil's basestock and gradually deplete the oil's additive package. Some deterioration can be tolerated without prejudice to the safety or efficiency of the system. Reinhibition may improve some properties of the oil. Good monitoring procedures are necessary to determine when the oil properties have changed sufficiently to justify scheduling corrective actions which can be performed with little or no detriment to production schedules.

5. Operational Factors Affecting Service Life

5.1 The factors that affect the service life of turbine lubricating oils are as follows: (*1*) type and design of system, (*2*) condition of system on startup, (*3*) original oil quality, (*4*) system operating conditions, (*5*) contamination, (*6*) oil makeup rate, and (*7*) handling and storage.

5.1.1 *Type and Design of System*—Most modern turbine lubricating systems are similar in design, especially for the larger units. For lubrication, the usual practice is to pressure-feed oil directly from the main oil pump. The rest of the system consists of a reservoir, oil cooler, strainer, piping and additional purification or filtration equipment, or a combination thereof. Miscellaneous control and indicating equipment completes the system. If there is an opportunity to participate in system design, it is recommended that appropriate practices be consulted (see Practice D 4241 and Practice D 4248), as well OEM guidelines and oil monitoring specifications.

5.1.2 *Condition of System on Start-up*:

5.1.2.1 The individual components of a lubrication system are usually delivered on-site before the system is installed. The length of on-site storage and means taken to preserve the integrity of the intended oil wetted surfaces will determine the total amount of contamination introduced during this period, the magnitude of the task of cleaning and flushing prior to use, and the detrimental effects of the contaminants. Guidance on contamination control, flushing, and purification may be sought from the equipment supplier or other industry experts.

5.1.2.2 Turbine oil system contamination prior to startup usually consists of preservatives, paint, rust particles, and the various solids encountered during construction, which can range from dust and dirt to rags, bottles, and cans. Their effect on turbine oil systems is obvious.

5.1.3 *Original Oil Quality*:

5.1.3.1 Use of a high-quality oil is the best assurance of potentially long service life. Oils meeting recognized standards are generally available, and one that at least meets the requirements of the turbine manufacturer shall be used. Careful oil storage, including labeling and rotation of lubricant containers, is vital to ensure proper use and prevent degradation of the physical, chemical, and cleanliness requirements of the lubricant throughout storage and dispensing.

5.1.3.2 It is advisable to obtain typical test data from the oil supplier. Upon receipt of the first oil charge, a sample of oil should be taken to confirm the typical test data and to use as a baseline. This baseline should act as a starting point for the physical and chemical properties of the lubricant, and for future comparisons with used oil information. This is most important! Recommended tests for new oil are given in the schedules of this practice (see Table 1 and Table 2).

5.1.3.3 When new turbine oil is to be mixed with a charge of a different composition prior checks should be made to ensure no loss of expected properties due to incompatibility (see lubricant suppliers' specifications). These should include functional tests and checks for formation of insolubles.

5.1.4 *System Operating Conditions*:

5.1.4.1 The most important factors affecting the anticipated service life of a given lubricating oil in a given turbine system are the operating conditions within the system. Air (oxygen), elevated operating temperatures, metals, and water (moisture) are always present to some extent in these oil systems. These elements promote oil degradation and must consequently be recorded.

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[3] *Annual Book of ASTM Standards*, Vol 05.02.

[4] *Annual Book of ASTM Standards*, Vol 05.04.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

TABLE 1 Steam Turbines—Sampling and Testing Schedules [Mineral Oils]

Schedule 1 New Oil

Samples:	
(a) From transport or drums	
(b) From storage tank	
Tests:	
Viscosity	[A]
Acid No.	[B]
Appearance	clear and bright
Water content	no free water
Color	[B]
Rust test	Pass[C]
Cleanliness	[D]
RPVOT/Voltammetry/FTIR	[B]

[A] Should meet Classification D 2422.
[B] Should be consistent with user purchase specifications, new oil reference, or manufacturer's requirement, or combination thereof.
[C] Should pass D 665A for land-based turbines. Should pass D 665B for marine turbines.
[D] Definition of suitable cleanliness levels depends on turbine builder and user requirements. Filtration or centrifugation, or both, of oil into turbine and during service is strongly recommended.

Schedule 2 Installation of a New Oil Charge[A]

Sample:	
After 24-h circulation. Retain approximately 4 L (1 gal).	
Tests:	
Viscosity	[B]
Acid No.	[B]
Appearance	clear and bright
Water content	no free water
Color	[B]
Cleanliness	[B,C]
RPVOT/Voltammetry/FTIR	[B,D]

[A] Follow recommended flushing procedures prior to installing a new oil charge whether it is an initial fill or an oil replacement.
[B] Should be consistent with user purchase specifications and new oil reference.
[C] Definition of suitable cleanliness levels depends on turbine builder and user requirements. Filtration or centrifugation, or both, of oil into turbine and during service is strongly recommended.
[D] Important as a baseline to determine turbine system severity.

Schedule 3A (First 12 Months Operation—New Turbine)

Test[A]	Viscosity	Acid No.	Appearance	Water Content	Color	Rust Test	Cleanliness	RPVOT/Voltammetry/FTIR
Frequency[B]	Every 1–3 months	Monthly	Daily[C]	Monthly[C]	Weekly	Every 6 months	Every 1–3 months	Every 2–3 months

Schedule 3B Normal Operation

NOTE 1—This schedule should be used as a guide. Increased frequency is required for a severe turbine or for oils approaching the end of their service life. Most turbines should be covered by this schedule.

Test[A]	Viscosity	Acid No.	Appearance	Water Content	Color	Rust Test	Cleanliness	RPVOT/Voltammetry/FTIR
Frequency[B]	Every 3–6 months	Every 1–3 months	Daily[C]	Every 1–3 months[C]	Weekly	1 Year	Every 1–3 months	Every 6–12 months

[A] If contamination is suspected, additional tests such as Flash Point, Foam, and Water Separability, may be useful to determine degree and effect of contaminants present. An outside laboratory or oil supplier can also assist in a more in-depth analysis.
[B] Frequency is based on continuous operation or total accumulated service time.
[C] If product is hazy or contains water in suspension, check water content.

5.1.4.2 Most turbine oil systems are provided with oil coolers to control temperature. In many cases, bulk oil temperatures are maintained so low, below 60°C (140°F), that moisture condensation can occur. Even with low bulk oil temperatures, however, there can be localized hot spots such as in bearings, at gas seals, and in throttle control mechanisms that can cause oil degradation and eventually cause system oil to show signs of deterioration.

5.1.4.3 Under the higher temperature conditions which are present in gas and steam turbines, oxidation of the oil can be accelerated by thermal-oxidative cracking leading to the production of viscous resins and deposits particularly at the point of initiation.

5.1.5 *Contamination*:

5.1.5.1 Contamination of turbine oils occurs both from outside the system and from within due to oil degradation and moisture condensation or leaks. Development of a clean turbine oil system on start-up or following maintenance is essential. Once attained, the danger of external contamination is less but should be guarded against. The oil can be contaminated by the introduction of different type oils, which are of the wrong type or are incompatible with the system oil. The oil supplier or the turbine manufacturer, or both, should be consulted before additions are made.

5.1.5.2 External contamination can enter the system through bearing seals and vents. Internal contaminants are always being generated. These include water, dirt, fly ash, wear particles, and oil degradation products. From whatever source, contamination must be dealt with by monitoring oil condition and the use of purification devices such as filters and centrifuges on a regular basis. These can be removed by purification devices such as filters, centrifuges, coalescers, and vacuum dehydrators.

TABLE 2 Gas Turbines—Sampling and Testing Schedules [Mineral Oils]

Schedule 4 New Oil	
Samples:	
From transport or drums	
From storage tank	
Tests:	
Viscosity	A
Acid No.	B
Appearance	clear and bright
Color	B
Cleanliness	C
RPVOT/Voltammetry/FTIR	B

[A] Should meet Classification D 2422.
[B] Should be consistent with user purchase specifications, new oil reference, or manufacturer's requirement, or combination thereof.
[C] Definition of suitable cleanliness levels depends on turbine builder and user requirements. Filtration or centrifugation, or both, of oil into turbine and during service is strongly recommended.

Schedule 5 Installation of a New Oil Charge[A]	
Sample:	
After 24-h (h) circulation. Retain approximately 4 L (1 gal).	
Tests:	
Viscosity	B
Acid No.	B
Appearance	clear and bright
Color	B
Cleanliness	BC
RPVOT/Voltammetry/FTIR	BD

[A] Follow recommended flushing procedures prior to installing a new oil charge whether it is an initial fill or an oil replacement.
[B] Should be consistent with user purchase specifications, new oil reference, or manufacturer's requirements, or combination thereof.
[C] Should agree with turbine builder and user requirements. Filtration of oil into turbine and during service is strongly recommended.
[D] Important as a baseline to determine turbine system severity.

Schedule 6A In-Service (First 6 Months Operation—New Turbine)

Test	Viscosity	Acid No.	Appearance	Color	Cleanliness	RPVOT/ Voltammetry/FTIR
Frequency[A]	500 h	500 h	100 h	200 h	500 h	500–1000 h

Schedule 6B In-Service Normal Operations

Note 1—This schedule should be used as a guide. Frequency should be varied depending on the turbine severity and oil condition

Test	Viscosity	Acid No.	Appearance	Color	Cleanliness	RPVOT/ Voltammetry/FTIR
Frequency[A]	500 h	500–1000 h	100 h	200 h	1000 h	1500–2000 h

[A] Frequency is based on hours of actual service.

5.1.6 *Oil Makeup Rate*—The amount and frequency of makeup oil added to the system plays a very significant part in determining the life of a system oil charge. Makeup varies from below 5 % per year to as much as 30 % in extreme cases. In turbines where makeup is relatively high compared to the oil degradation rate, the degree of degradation is compensated for and long oil life can be expected. In turbines where the makeup is very low (below 5 %), a truer picture of oil degradation is obtained. However, such a system should be carefully watched since the oil life is dependent almost exclusively on its original quality. In the United States, the average makeup is typically around 7 to 10 % per year.

5.1.7 *Handling and Oil Storage*—Handling and dispensing methods must ensure that the quality and the cleanliness of the lubricant meet the specifications required by the equipment. Oils must be properly labeled to ensure proper selection and use. Proper stock rotation and storage methods must be considered to prevent the possible degradation of the physical and chemical properties of the lubricant during storage and dispensing.

5.2 The combination of all of the preceding operational factors for a given turbine determines its *severity level*. Each unit is different and the equilibrium operating conditions for each system must be determined in order to fix its severity level; OEM operating and maintenance specifications can also be used in setting the severity levels. The more severe a turbine system, the shorter the service life for a given oil. A useful approach to determine the severity of a turbine is given in Appendix X1.

6. Sampling

6.1 *General*—When taking oil samples from storage tanks or equipment in service, it is important that the extracted sample will be representative and be taken from a specified location(s) to monitor the properties of the lubricant. Correct sampling techniques are vital to achieve this. The following are some suggested guidelines for proper sampling technique and sampling handling techniques (see Practice D 4057).

6.2 *Representative Sampling*—A sampling location that supports repeatable and representative sampling to monitor the health of the equipment and the properties of the lubricant. To be representative, a sample must be obtained either from an agitated tank or a free-flowing line.

6.2.1 The primary sampling port is the location where routine oil samples are taken for monitoring oil contamination, wear debris and the chemical and physical properties of the oil and is as follows:

6.2.1.1 *Dipping from the Tank*—Oil samples should be taken by dipping from the tank. Lubricant should be thoroughly circulated before the sample is taken.

6.2.1.2 *Oil Return Line Sampling Port*—For circulating systems, the preferred location for oil samples should be taken on a single return line prior to entering the sump or reservoir.

6.2.2 The secondary sampling methods are to be used for measuring contamination and wear debris contributed by individual components, and can be located anywhere on the system to isolate upstream components. This is where contamination and wear debris contributed by individual components will be found:

6.2.2.1 *Sampling from a Line*—The line should contain lubricating oil which is free flowing and not deadheaded. For instance, the lines in a bearing header, an active filter, and active heat exchanger are free flowing; the lines to a gage cabinet are deadheaded. In equipment with dual filters or heat exchangers, the inactive filters or heat exchangers do not have flowing fluid and are not suitable sampling points. When using a sampling line, it is necessary that the line has been thoroughly flushed before taking a sample. Adequate amount of flushing will depend on sampling line dimensions, length, and diameter.

NOTE 1—Test values obtained will differ depending on the sample locations. Use caution when comparing sample results from different sample points.

6.2.2.2 *Tapping from a Reservoir*—As previously described, the lubricating oil must be thoroughly agitated in the reservoir and the tap line flushed before a sample can be taken.

6.2.3 An oil sample is probably not representative if: (*1*) the system oil is hot while the sample is cold, (*2*) the oil in the system is one color or clarity in a sight glass while the sample is a different color or clarity, and (*3*) the viscosity of the reservoir oil is different from that of the sample when both are at the same temperature.

6.2.4 It should be noted that on occasion a sample may be requested which will not be representative. At that time, sampling instructions, as specified by the requestor, must be followed. For example, a sample might be taken off the top or the bottom of a tank to check for contamination. In all cases the sample point should be marked on the sample bottle.

6.3 *Oil Sample Bottles*—Samples should be taken in a suitable sample bottle. To be suitable the bottle should be:

6.3.1 *Clean*—If in doubt about its cleanliness, use another bottle; if this is not possible, flush it out with the oil to be sampled.

6.3.2 *Resistant to the Material Being Sampled*—To verify the bottle's resistance, if time permits, allow the sample to stand in the bottle and observe its effects. Aluminum foil makes a good, resistant cap liner.

6.3.3 *Appropriate for Whatever Handling is Required*—Bottles with leaking tops and glass bottles improperly protected are not suitable for shipment. Appropriate regulations for handling and shipment of samples must be observed.

6.3.4 *Appropriate for the Analyses Required*—An extensive chemical analysis, if that is why a sample is required, cannot be done on the contents of a bottle which is too small.

NOTE 2—Some lubricant suppliers and commercial laboratories provide sample bottles which meet all these requirements. These should be used whenever possible. If frequent samples are taken, an adequate supply of containers should be kept.

6.4 *Sample Markings*—A sample should be properly marked. Markings should include at least the following information:

6.4.1 Customer name (if appropriate),

6.4.2 Site or plant name,

6.4.3 Location (unit number, tank number, compartment number, and so forth),

6.4.4 Turbine serial number (or other ID),

6.4.5 Turbine service hours,

6.4.6 Oil service hours,

6.4.7 Date sample taken,

6.4.8 Type of oil sampled (lubricant ID),

6.4.9 Sampling point/port ID,

6.4.10 Type of purification system (filters/centrifuge, and so forth), and

6.4.11 Makeup (volume) since last sample was taken.

6.5 *Sampling of New Oil Deliveries*:

6.5.1 A sample of the new lubricant is required to provide a base line for the physical and chemical properties of the lubricant. Also samples taken should be representative of the oil being examined but obtained from the point(s) most indicative of gross contamination by debris and water, that is, just above the bottom of the drum or tanker compartment bottom.

6.5.2 When consignments of oil are in drums, sample them in accordance with Practice D 4057.

6.5.3 For bulk consignments, sample each tanker compartment. If these are clear of debris and water, then the samples can be combined for subsequent laboratory analysis of the consignment.

6.5.4 In cases where the product is suspected of being nonuniform, sample a larger number of drums. Where contamination is suspected there is no alternative to sampling every drum.

6.5.5 From tanker deliveries, in addition to sampling individual tanker compartments, further sample(s) should be taken preferably from the outlet of the flexible pipework or at least from the tanker bottom valve manifold. This further sampling is necessary because the tanker contents can become contaminated by residual material left in the bottom valve manifold. This can occur particularly when different products are being carried in separate compartments or previous deliveries of a different product have been made to other locations without subsequent adequate cleaning and flushing.

6.5.6 Bottom samples must be collected by either a tube or thief sampler (for example, Bacon bomb). These samplers permit collection of settlings on the bottom of the container without introducing false contamination by scraping the container lining or wall.

6.5.7 Take the sample(s) from the outlet of the flexible pipework or the tanker bottom valve manifold while maintaining a good flow after flushing the line.

6.6 *Preservation of Sample*—If tests are not run immediately, store the sample(s) away from strong light or excessive heat.

7. Examination of New Oil on Delivery

7.1 Experience has shown the need for standardizing procedures to be undertaken for the sampling, examination, and acceptance of incoming supplies of turbine oil. It is essential that personnel responsible for sampling and testing shall have the necessary experience and skills, and that scrupulous attention to detail be applied at all times to avoid erroneous results.

7.2 It is equally essential that all incoming supplies of oil be adequately monitored to guard against incorrect or contaminated material being delivered. Cleanliness of the delivery container should be noted; if the container is dirty on the outside, there may be particulate contamination on the inside. Particulate contamination can also be a problem when the lubricant comes in contact with dirty or poorly maintained equipment.

7.3 Sampling of incoming supplies should be in accordance with proper sampling procedures (see Section 6).

7.4 All samples should be immediately examined for appearance.

7.5 A testing schedule for new oil is included in this practice (see Table 1 and Table 2). With drums, tests should be completed on the bulk sample before the oil is used in service. Individual samples should be retained until the bulk sample is passed as satisfactory.

7.6 With tanker deliveries the additional tests to be completed before the tanker is discharged can only be judged from the risk involved by the acceptance of nonspecification product, that is, can the charge be readily recovered and corrected before passing into service if the subsequent tests indicate this to be necessary.

7.7 Handling and dispensing methods contribute to the required health and cleanliness specifications of the lubricant. All sources and opportunities of contamination must be avoided.

8. Deterioration of Turbine Oils in Service

8.1 *How Turbine Oils Degrade*—Irrespective of initial quality, during their use in lubrication systems of turbines, lubricating oils will experience thermal and oxidative stresses, loss of foam control, poor oil demulsibility and loss of wear protection, which degrade the chemical composition of the oil. In order to avoid these degradation problems, lubricating oils are developed with a strong ability to control oxidation process, degradation by wear, and other degradation mechanism, by using a combination of good quality base oil together with a mixture of additives. For turbine oils it is very common for high quality products to have long periods of successful field operation, so that for many years the oil may perform like new. Lubricant deterioration occurs by one or more of the following processes:

8.1.1 *Oxidative Degradation*—This occurs as the result of chemical changes brought about by oxygen in the atmosphere and proceeds by a chain reaction.

8.1.2 *Thermal/Oxidative Degradation*—This can occur at hot spots in turbines. During thermal degradation at elevated temperatures, hydrocarbons are subject to thermal degradation to form unstable and insoluble compounds. These unstable compounds are easily oxidized and also tend to polymerize to form resins and sludge.

8.1.3 *Water Accumulation in the System*—Accumulated water promotes oil degradation as well as additive depletion, corrosion, reduced lubricating film thickness and microbial growth. It is advised to operate without the presence of free or emulsified water.

8.1.4 *Loss of Additives*—This can result in more rapid oxidation and premature rusting.

8.1.5 *Influx of Contaminants*—Contaminants arising within the system (corrosion and wear products) or from without (fly ash, dirt, and fluids) cause lubrication and wear problems.

8.2 *Properties of Oils Which Must Be Retained*—In determining the condition of the system oil for continued service, the most important properties of the used oil are: (*1*) viscosity, (*2*) oxidation stability reserve, (*3*) freedom from sludge, (*4*) freedom from abrasive contaminants, (*5*) anticorrosion protection, (*6*) demulsibility, (*7*) air release, and (*8*) freedom from water contamination.

8.2.1 *Viscosity*—Viscosity is the most important characteristic of a turbine oil, as the oil film thickness under hydrodynamic lubrication conditions is critically dependent on the oil's viscosity characteristics. Most commercial turbine oils are sold under ISO (International Standards Organization) viscosity classification system. Oils fall into ISO-VG-32, VG-46, VG-68, and VG-100 viscosity grades corresponding to 32, 46, 68, and 100 cSt at 40°C and to approximately 165, 240, 350, and 515 SUS at 100°F (Classification D 2422). The main purpose for checking the viscosity of used turbine oil is to determine if the correct oil is being used and to detect contamination. Used turbine oils rarely show significant viscosity changes due to degradation. Occasionally, viscosity increases due to an emulsion with water contamination. The method normally used for viscosity determinations is Test Method D 445.

8.2.2 *Oxidation Inhibitor*—The monitoring of antioxidant concentration is important for controlling the oxidation of industrial lubricants and their remaining useful life. Some practices for measuring the concentration of phenolic (or amine) antioxidants include infrared spectrometry (including Fourier Transform Infrared) and voltammetry. When setting up one of these techniques, it is advisable to consult with the lubricant supplier who has a working knowledge of the antioxidants used in the turbine oil formulation.

8.2.2.1 *FTIR*—The Fourier Transform Infrared (FTIR) practice is a refined infrared spectroscopy method, which can be used to monitor change in the availability of the original antioxidants blended into the oil. It can also be used to monitor the change in oxidation products as the oil degrades. Peak locations for the additives will vary from oil to oil and the peak location must be established to obtain benefit from this technique. Each antioxidant is a specific chemical substance and will absorb infrared light at a particular wavelengths and absorptivities; some antioxidants may not be detectable by infrared spectroscopy. (Test Method D 2668 may be used for antioxidants if the wavelengths and absorptivities are known.)

8.2.2.2 *Voltammetry*—Voltammetry is an electrochemical test technique, which can be used for measuring many antioxidant additives. The technique applies a voltage ramp through a