



Standard Practice for In-Service Monitoring of Mineral Turbine Oils for Steam and Gas Turbines¹

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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 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 understand how oils deteriorate and to carry out a meaningful program of sampling and testing of oils in use. 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 used for power generation. It includes sampling and testing schedules and recommended action steps, as well as information on how oils degrade.

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 Cup²
- D 95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation²
- D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test²
- 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 Titration²

- D 665 Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water²
- D 892 Test Method for Foaming Characteristics of Lubricating Oils²
- D 943 Test Method for Oxidation Characteristics of Inhibited Mineral Oils²
- D 974 Test Method for Acid and Base Number by Color-Indicator Titration²
- D 1401 Test Method for Water Separability of Petroleum Oils and Synthetic Fluids²
- D 1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)²
- D 1533 Test Methods for Water in Insulating Liquids (Karl Fischer Reaction Method)³
- D 1744 Test Method for Water in Liquid Petroleum Products by Karl Fischer Reagent²
- D 2272 Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Bomb²
- D 2422 Classification of Industrial Fluid Lubricants by Viscosity System²
- D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products⁴
- D 4241 Practice for Design of Gas Turbine Generator Lubricating Oil Systems⁴
- D 4248 Practice for Design of Steam Turbine Generator Oil Systems⁴

¹ This practice is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02 on Turbine Oils.

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² Annual Book of ASTM Standards, Vol 05.01.

³ Annual Book of ASTM Standards, Vol 10.03.

⁴ Annual Book of ASTM Standards, Vol 05.02.



F 311 Practice for Processing Aerospace Liquid Samples for Particulate Contamination Analysis Using Membrane Filters⁵

F 312 Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters⁵⁶

2.2 *International Organization for Standardization:*

ISO 4406 Hydraulic Fluid Power-Fluids—Method for coding level of contamination by solid particles

2.3 *Other Standard:*

National Aerospace Standard 1638⁷

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 properties cannot be expected to remain unchanged during the life of the oil. 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 properties have changed sufficiently to warrant corrective action.

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, and (6) oil makeup rate.

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).

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.

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 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. 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 temperatures, metals, and water are always present to some extent in these oil systems. These elements promote oil degradation.

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 use of the

⁵ Annual Book of ASTM Standards, Vol 14.02.

⁶ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

⁷ Available from Aerospace Industries Association of America, Inc., 1725 De Sales St., N.W., Washington, DC.



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
RBOT	B

^AShould meet Classification D 2422.

^BShould be consistent with user purchase specifications, new oil reference, or manufacturer's requirement, or combination thereof.

^CShould pass D 665A for land-based turbines. Should pass D 665B for marine turbines.

^DDefinition 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
RBOT	B,D

^AFollow recommended flushing procedures prior to installing a new oil charge whether it is an initial fill or an oil replacement.

^BShould be consistent with user purchase specifications and new oil reference.

^CDefinition 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.

^DImportant 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	RBOT
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	RBOT
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

^AIf 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.

^BFrequency is based on continuous operation or total accumulated service time.

^CIf product is hazy or contains water in suspension, check water content.

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.

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.

5.2 The combination of all of the preceding operational factors for a given turbine determine 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. The more severe a turbine system, the shorter the service