Designation: D4378 – 22

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

This standard is issued under the fixed designation D4378; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 configured as combine cycle turbines. Combined cycle turbines are of two types; the first type connects a gas turbine with a steam turbine, with separate lubricant circuits, and the second type mounts a steam and a gas turbine on the same shaft and has a common lubricant circuit. 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 from 2 to 5 years depending on severity of the operating conditions. One of the benefits of the gas turbine is the ability to respond quickly to electrical power generation dispatching requirements. Consequently, a growing percentage of modern gas turbines are being used for peaking or cyclic duty (frequent unit stops and starts) subjects the lubricant to a wide range of temperatures from ambient conditions to normal operating temperatures, which put additional stresses on the lubricant.

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 service. This practice is performed in order to collect data and monitor trends which suggest any signs of lubricant deterioration and to ensure a safe, reliable, and cost-effective operation of the monitored plant equipment.

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. This practice is not intended for condition monitoring of lubricants for auxiliary equipment; it is recommended that the appropriate practice be consulted (see Practice D6224).

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.C0.01 on Turbine Oil Monitoring, Problems and Systems.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
D665 Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water
D892 Test Method for Foaming Characteristics of Lubricating Oils
D943 Test Method for Oxidation Characteristics of Inhibited Mineral Oils
D974 Test Method for Acid and Base Number by Color-Indicator Titration
D1401 Test Method for Water Separability of Petroleum Oils and Synthetic Fluids
D1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
D2272 Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel
D2273 Test Method for Trace Sediment in Lubricating Oils
D2422 Classification of Industrial Fluid Lubricants by Viscosity System
D2668 Test Method for 2,6-*di-tert*-Butyl- *p*-Cresol and 2,6-*di-tert*-Butyl Phenol in Electrical Insulating Oil by Infrared Absorp
D3427 Test Method for Air Release Properties of Hydrocarbon Based Oils
D4057 Practice for Manual Sampling of Petroleum and Petroleum Products
D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
D4898 Test Method for Insoluble Contamination of Hydraulic Fluids by Gravimetric Analysis
D5185 Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D6224 Practice for In-Service Monitoring of Lubricating Oil for Auxiliary Power Plant Equipment
D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
D6439 Guide for Cleaning, Flushing, and Purification of Steam, Gas, and Hydroelectric Turbine Lubrication Systems
D6450 Test Method for Flash Point by Continuously Closed Cup (CCCFP) Tester
D6810 Test Method for Measurement of Hindered Phenolic Antioxidant Content in Non-Zinc Turbine Oils by Linear Sweep Voltammetry
D6971 Test Method for Measurement of Hindered Phenolic and Aromatic Amine Antioxidant Content in Non-zinc Turbine Oils by Linear Sweep Voltammetry
D7042 Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
D7094 Test Method for Flash Point by Modified Continuously Closed Cup (MCCCFP) Tester
D7155 Practice for Evaluating Compatibility of Mixtures of Turbine Lubricating Oils
D7464 Practice for Manual Sampling of Liquid Fuels, Associated Materials and Fuel System Components for Microbiological Testing
D7647 Test Method for Automatic Particle Counting of Lubricating and Hydraulic Fluids Using Dilution Techniques to Eliminate the Contribution of Water and Interfering Soft Particles by Light Extinction
D7669 Guide for Practical Lubricant Condition Data Trend Analysis
D7687 Test Method for Measurement of Cellular Adenosine Triphosphate in Fuel and Fuel-associated Water With Sample Concentration by Filtration
D7720 Guide for Statistically Evaluating Measurand Alarm Limits when Using Oil Analysis to Monitor Equipment and Oil for Fitness and Contamination
D7843 Test Method for Measurement of Lubricant Generated Insoluble Color Bodies in In-Service Turbine Oils using Membrane Patch Colorimetry
D7978 Test Method for Determination of the Viable Aerobic Microbial Content of Fuels and Associated Water—Thixotropic Gel Culture Method
D8072 Classification for Reporting Solids and Insoluble Water Contamination of Hydrocarbon-Based Petroleum Products When Analyzed by Imaging Instrumentation
D8112 Guide for Obtaining In-Service Samples of Turbine Operation Related Lubricating Fluid
F311 Practice for Processing Aerospace Liquid Samples for Particulate Contamination Analysis Using Membrane Filters
F312 Test Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters

2.2 *International Organization for Standardization Standards:*[3]

ISO 4406 Hydraulic fluid power—Fluids—Method for Coding the Level of Contamination by Solid Particles, Second Edition, 1999
ISO 4407 Hydraulic Fluid Power—Fluid Contamination—Determination of Particulate Contamination by Counting Method Using an Optical Microscope, Second Edition, 2002
ISO 11500 Hydraulic Fluid Power—Determination of the Particulate Contamination Level of a Liquid Sample by Automatic Particle Counting Using the Light Extinction, Second Edition, 2008
ISO 11171 Hydraulic Fluid Power—Calibration of Automatic Particle Counters for Liquids

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3. Terminology

3.1 For definitions of terms used in this practice, refer to Terminology D4175.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bulk oil tote, n*—any container for lubrication or control fluid with working volume approximately 1000 L to 1300 L designed for fluid storage at atmospheric pressure.

3.2.2 *continuous sampling loop, n*—a limited flow of fluid from a point in a pressurized system to a point of lower pressure used to decrease required purge fluid and sample time during the sampling process.

3.2.3 *disposable sample tubing, n*—any single-use flexible plastic tubing used to transfer fluid during the sampling process.

3.2.4 *drain sampling, n*—a method of sampling used fluid for non-pressurized reservoirs or lines occurring when the lubricating fluid is being drained from the reservoir during a fluid change.

3.2.4.1 *Discussion*—As part of a fluid change, the drain plug is removed to allow the fluid to drain into an appropriate container under gravity. Mid way through the draining, a sample bottle is filled by placing it in the fluid stream and once filled immediately capped.

3.2.5 *drop tube sampling, n*—a method of sampling used fluid for non-pressurized reservoirs when sampling is completed by dropping an appropriate length of sampling tubing into the reservoir and using a vacuum generating device to extract the sample.

3.2.6 *permanent sample tube, n*—any tubing installed in a reservoir or pipe used to extract a sample from a specific location within the system.

3.2.7 *purge, v*—to remove the existing non-representative fluid and contaminants from the sample valve and tubing during the sampling process.

3.2.8 *remote access hose, n*—any permanently installed metallic or elastomeric tube or hose used to transfer fluid from the system to a point outside the system to facilitate sampling.

3.2.9 *reservoir, n*—any equipment-based container that holds a volume of fluid, usually under atmospheric condition, for use in the lubrication, sealing or control process.

3.2.10 *sample container, n*—a clean, fresh plastic bottle used for system fluid analysis (see Section 7).

3.2.11 *sample valve, n*—a system consisting of a male and female component used specifically for the extraction of a fluid sample either by internal system pressure or by an externally generated vacuum.

3.2.11.1 *Discussion*—The male component, referred to as a probe, may be for one time use or permanently attached to the female component, referred to as a sample valve, is used by either threading the probe onto the valve or pushing the probe into the valve for the purpose of opening the valve and allowing fluid to flow out.

3.2.12 *sample valve sampling, v*—to obtain a sample from either pressurized or non pressurized lines or reservoirs.

3.2.12.1 *Discussion*—When sampling non-pressurized reservoirs this sampling method usually applies a vacuum generating device and sampling tubing to extract a sample into a sampling container from a strategically located sampling valve. When sampling pressurized reservoirs or lines, this sampling method is completed by using system pressure to force lubricating fluid into a sampling container through a sampling valve.

3.2.13 *vacuum generating device, n*—a pump used to create a low pressure in a sample container to cause fluid to move from a non-pressurized reservoir to the container through disposable tubing.

3.2.14 *weighted drop tube device, n*—a mass attached to a piece of steel or stainless steel tubing with a method to attach disposable sampling tubing to the steel or stainless steel tubing.

3.2.14.1 *Discussion*—This device is used during drop tube sampling.

4. Significance and Use

4.1 This practice is intended to assist the user, in particular the power-plant operations and maintenance departments, to maintain effective lubrication of all parts of the turbine and guard against the onset of problems associated with oil degradation and contamination. The values of the various test parameters mentioned in this practice are purely indicative. In fact, for proper interpretation of the results, many factors, such as type of equipment, operation workload, design of the lubricating oil circuit, and top-up level, should be taken into account.

5. Properties of Turbine Oils

5.1 Most turbine oils consist of a highly refined paraffinic mineral oil compounded with oxidation and rust inhibitors with a lesser number of turbines using a synthetic type of fluid. 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. The turbine oil's primary function is to provide lubrication and cooling of bearings and gears. In some equipment designs, they also can function as a governor hydraulic fluid.

5.2 New turbine oils should exhibit good resistance to oxidation, inhibit sludge and varnish deposit formation, and provide adequate antirust, water separability, and non-foaming 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 harming the safety or efficiency of the system. 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.

6. Operational Factors Affecting Service Life

6.1 The factors that affect the service life of turbine lubricating oils are as follows: (*1*) type and design of system, (*2*)