Designation: D4304 – 06a

Standard Specification for Mineral Lubricating Oil Used in Steam or Gas Turbines[1]

This standard is issued under the fixed designation D4304; 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.

1. Scope*

1.1 This specification covers mineral oils used in steam and gas turbine lubrication systems where the performance requirements demand a highly refined mineral base oil compounded with rust and oxidation inhibitors plus selected additives as needed to control foam, wear, demulsibility, and so forth. This standard may also be applied to "combined cycle" turbine systems, where a single lubricant circulating system is used to supply oil to a steam and gas turbine configured in tandem either on a single or separate shaft for enhanced energy efficiency.

1.2 This specification is intended to define the properties of mineral oil-based turbine lubricating oils that are functionally interchangeable with existing oils of this type, are compatible with most existing machinery components, and with appropriate field maintenance, will maintain their functional characteristics.

1.3 This specification is intended to define only new lubricating oil before it is installed in the machinery.

1.4 This specification is intended to be used as a guide. It is possible that oils that do not meet this specification may perform satisfactorily in some turbines.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
D97 Test Method for Pour Point of Petroleum Products
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
D2422 Classification of Industrial Fluid Lubricants by Viscosity System
D3339 Test Method for Acid Number of Petroleum Products by Semi-Micro Color Indicator Titration
D3427 Test Method for Air Release Properties of Petroleum Oils
D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
D4057 Practice for Manual Sampling of Petroleum and Petroleum Products
D4310 Test Method for Determination of Sludging and Corrosion Tendencies of Inhibited Mineral Oils
D5182 Test Method for Evaluating the Scuffing Load Capacity of Oils (FZG Visual Method)

[1] This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products 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.**

D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration

2.2 *ISO Standards:*

ISO 4406 Particle Count Analysis

3. Terminology

3.1 *Definitions:*

3.1.1 *Type I mineral oils*, *n*—oils for steam and gas turbine lubricating systems where the machinery does *not* require lubricants with enhanced load carrying capacity.

3.1.1.1 *Discussion*—Type I oils usually are available in ISO VG 32, 46, 68 and 100 (see Classification D2422). Such oils normally contain rust and oxidation inhibitors in addition to other additives as required to meet the specified performance characteristic. Type I oils are generally satisfactory for turbine sets where bearing temperatures do not exceed 110°C.

3.1.2 *Type II mineral oils*, *n*—oils for steam and gas turbine lubricating systems where the machinery requires enhanced load carrying capacity.

3.1.2.1 *Discussion*—Type II oils usually are available in ISO VG 32, 46, 68, 100, and 150. These oils are similar to Type I but contain additional anti-wear additives for use in turbines equipped with a gearbox. Oils ISO VG 68 and above have been used in marine, hydro, or water turbines.

3.1.3 *Type III mineral oils*, *n*—oils for heavy duty gas or combined cycle turbine lubricating systems where the lubricant shall withstand higher temperatures and exhibit higher thermal stability than Type I mineral oils.

3.1.3.1 *Discussion*—Type III oils usually are available in ISO VG 32 and 46. Such oils are normally comprised of a highly refined mineral base oil with suitable rust and oxidation inhibitors in addition to other additives as needed to meet specified performance characteristics. Type III oils are formulated for use in turbine sets where bearing temperatures may exceed 110°C. The turbine lubrication systems using Type III oils may be equipped with a gearbox that may require the selection of oils that contain additional anti-wear additives to impart the specified load carrying capacity.

3.1.4 *functional properties*, *n*—those properties of the mineral lubricating oil that are required for satisfactory operation of the machinery. These properties are listed in Section 5.

4. Sampling and Testing

4.1 *Sampling*—Generally, take all oil samples in accordance with Practice D4057.

4.2 Use the ASTM and other test methods described in Tables 1-3.

5. Functional Property Requirements

5.1 Mineral lubricating oils conforming to the specification shall meet the functional property limits specified in 5.2-5.4 and Tables 1-3. The significance of these properties is discussed in Appendix X1.

TABLE 1 Requirements for Type I Turbine Oils

NOTE—The nature of some turbine oil tests are such that they are not necessarily run on each batch of lubricant. The values are only recommended values. A turbine oil that has been shown to perform successfully in the intended application may be suitable for use even if all values or limits in Table 1 have not been satisfied.

Property	ASTM Test Method	Limits			
Physical:					
ISO—viscosity grade	D2422	32	46	68	100
ASTM Color, rating	D1500	report	report	report	report
Specific Gravity at 15.6/15.6°C	D4052	report	report	report	report
Flash point, °C, min	D92	180	180	180	180
Pour point, °C, max	D97[A]	–6	–6	–6	–6
Water Content, m%, max	D6304	0.02	0.02	0.02	0.02
Viscosity, cSt (mm^2/s) 40°C	D445	28.8–35.2	41.4–50.6	61.2–74.8	90–110
Visual examination at 20°C	...	clear and bright			
Chemical:					
Total Acid Number, mg KOH/g, max	D974[B]	report	report	report	report
Performance					
Emulsion characteristics:	D1401[C]				
at 54°C, minutes to 3 mL emulsion, max		30	30	30	...
at 82°C, minutes to 3 mL emulsion, max		...	...	...	60
Foaming characteristics:	D892				
Sequence I, tendency/stability, mL, max		50/0	50/0	50/0	50/0
Air release, 50°C, minutes max	D3427	5	5	8	17
Rust preventing characteristics	D665, Procedure B	Pass	Pass	Pass	Pass
Copper corrosion, 3 h at 100°C, max	D130	1	1	1	1
Oxidation stability[D]:					
Hours to neut. No. 2.0, min	D943	2000	2000	1500	1000
Minutes to 175 kPa drop, min	D2272	350	350	175	150
1000–h TOST Sludge, mg, max	D4310	200	200	200	...
1000–h TOST, Total acid number, mg KOH/g, max	D4310	report	report	report	...
Cleanliness at the delivery stage, max	ISO 4406	-/17/14	-/17/14	-/17/14	-/17/14

[A] Lower pour point may be required for some applications.

[B] Test Method D664 may be used as an alternative test method.

[C] Applies only to steam turbine oils and combined cycle turbine oils.

[D] Test Method D943 is the accepted test method for oxidation stability of new steam turbine oils. It is recognized that Test Method D943 is a lengthy procedure. Test Method D2272 is a shorter test for quality control. See X1.3.6 for significance of Test Method D2272.

TABLE 2 Requirements for Type II Turbine Oils

NOTE—The nature of some tests are such that they are not necessarily run on each batch. The values are only recommended values. An oil that has been shown to perform successfully in the intended application may be suitable for use even if all values in Table 2 have not been satisfied.

Property	ASTM Test Method	Limits				
Physical:						
ISO—viscosity grade	D2422	32	46	68	100	150
ASTM Color, rating	D1500	report	report	report	report	report
Specific Gravity at 15.6/15.6°C	D4052	report	report	report	report	report
Flash point, °C, min	D92	180	180	180	180	210
Pour point, °C, max	D97[A]	–5	–5	–5	–5	–5
Water Content, m%, max		0.02	0.02	0.02	0.02	0.02
Viscosity, cSt, 40°C (mm^2/s)	D445	28.8–35.2	41.4–50.6	61.2–74.8	90–110	135–165
Visual examination at 20°C	...	clear and bright				
Chemical:						
Total Acid Number, mg KOH/g, max	D974[B]	0.2	0.2	0.2	report	report
Performance:						
Emulsion Characteristics:[C]	D1401					
at 54°C, minutes to 3 mL emulsion, max		30	30	30	...	...
at 82°C, minutes to 3 mL emulsion, max		...	...	...	60	60
Foaming characteristics:	D892					
Sequence I, tendency/stability, mL, max		50/0	50/0	50/0	50/0	50/0
Air release, 50°C minutes max	D3427	5	5	10	17	25
Rust preventing characteristics	D665, Procedure B	pass	pass	pass	pass	pass
Copper corrosion, 3 h at 100°C, max	D130	1	1	1	1	1
Oxidation stability:[D]						
Hours to neut. No. 2.0, min	D943	3500	3000	2500	1000	1000
Minutes to 175 kPa drop, min	D2272	350	350	175	150	150
Cleanliness at the delivery stage, rating, max	ISO 4406		- /17/14	-/17/14		
Load carrying capacity:						
fail stage, min	D5182[E]	8	8	8	9	9

[A] Lower pour point may be required for some applications.
[B] Test Method D664 may be used as alternative method.
[C] Applies only to steam turbine oils and combined cycle turbine oils.
[D] Test Method D943 is the accepted test method for oxidation stability of new steam turbine oils. It is recognized that Test Method D943 is a lengthy procedure. Thus, Test Method D2272 is a suggested shorter test for quality control. See X1.3.6 for significance of Test Method D2272.
[E] Higher values may be required for some applications.

5.2 Requirements for Type I oils are shown in Table 1.

5.3 Requirements for Type II oils are shown in Table 2.

5.4 Requirements for Type III oils are shown in Table 3.

6. Keywords

6.1 combined cycle turbine oil; gas turbine oil; mineral oil; R and O oils; steam turbine oil; turbine lubricating oils; turbine lubrication systems

TABLE 3 Requirements for Type III Turbine Oils

NOTE—The nature of some turbine oil tests is such that they are not necessarily run on each batch of lubricant. The values are only recommended values. A turbine oil that has been shown to perform successfully in the intended application may be suitable for use even if all values or limits in Table 3 have not been satisfied.

Property	ASTM Test Method	Limits	
Physical:			
ISO—viscosity grade	D2422	32	46
ASTM Color, rating	D1500	report	report
Specific Gravity at 15.6/15.6°C	D4052	report	report
Flash point, °C, min	D92	200	200
Pour point, °C, max	D97[A]	–6	–6
Water Content, m %, max	D6304	0.02	0.02
Viscosity, cSt (mm^2/s) 40°C	D445	28.8–35.2	41.4–50.6
Visual examination at 20°C	...	clear and bright	
Chemical:			
Total Acid Number, mg KOH/g, max	D974[B]	report	report
Performance:			
Emulsion characteristics:	D1401[C]		
at 54°C, minutes to 3 mL emulsion, max		30	30
Foaming Characteristics:	D892		
Sequence I, tendency/stability, mL, max		50/0	50/0
Air release, 50°C, minutes max	D3427	5	5
Rust preventing characteristics	D665, Procedure B	Pass	Pass
Copper corrosion, 3 h at 100°C, max	D130	1	1
Oxidation stability[D]:			
Hours to neut. No. 2.0, min	D943	3500	3500
RPVOT, minutes to 175 kPa drop, min	D2272	750	750
RPVOT, retention after nitrogen treatment, % , min	D2272, modified[E]	85	85
1000-h TOST sludge, mg, max	D4310	200	200
1000-h TOST, total acid number, mg KOH/g, max	D4310	report	report
Cleanliness at the delivery stage, max	ISO 4406	–/17/14	–/17/14
Load carrying capacity: (optional)	D5182[F]	report	report
fail stage, min			

[A] Lower pour point may be required for some applications.
[B] Test Method D664 may be used as an alternative test method.
[C] Applies only to steam turbine oils and combined cycle turbine oils.
[D] Test Method D943 is the accepted test method for oxidation stability of new steam turbine oils. It is recognized that Test Method D943 is a lengthy procedure. Test Method D2272 is a shorter test for quality control. See X1.3.6 for significance of Test Method D2272.
[E] FZG may be required for some geared applications. The required value should be negotiated with the end user.
[F] Test Method D2272 is performed after the treatment of oil at 121°C by bubbling clean and dry nitrogen for 48 h at the rate of 3 l/h. The result is expressed as the percent of life versus the sample without treatment.

APPENDIX

(Nonmandatory Information)

X1. SIGNIFICANCE OF FUNCTIONAL PROPERTIES OF TURBINE OILS

X1.1 Physical Properties

X1.1.1 *ISO-Viscosity Grade, Classification* D2422—The International Standards Organization has established a viscosity classification system for industrial fluid lubricants. Such lubricants are classified by grades designated as ISO-VG based on their viscosities in centistokes at 40°C. The choice of viscosity grade for use in a particular turbine should comply with the turbine manufacturer's recommendations.

X1.1.2 *Flash Point, Test Method* D92—Flash point is the temperature at which the fluid contained in a test cup and heated at a constant rate will flash but not continue to burn when a flame is passed over the cup. It is indirectly a measure of both the volatility of the oil and the flammability of these volatiles contained therein. This is mainly of value as a quality control test and for regulatory reasons.

X1.1.3 *Pour Point, Test Method* D97—The pour point is an indication of the lowest temperature at which the oil will flow by gravity. The fluid viscosity must allow the system to start up and operate at low temperatures. As a practical rule, the fluid should have a pour point 10°C below the minimum expected ambient temperature.

X1.1.4 *Viscosity, Test Method* D445—The viscosity of a turbine oil determines its ability to flow in a lubrication system and to support bearing loads, transfer heat, and operate hydraulic controls.

X1.1.5 *Visual Examination and ASTM Color, Test Method* D1500—In the manufacture, distribution, and use of turbine oils, fresh oils should be examined for appearance and clarity as a check against contamination. Oils may be compared to a standard reference sample.

X1.1.6 *Cleanliness Test Methods*—Insoluble contaminants, including metallic and nonmetallic materials, can cause abrasive wear of bearings, pumps, and seals; faulty control functioning; plugged oil lines; and reduced filter life. There are

several recommended standards for lubrication system cleanliness published by technical societies and equipment manufacturers.

X1.1.6.1 Insolubles particles may be evaluated by different techniques, such as microscopic particle analysis and counting or electronic particle counting according to ISO 4406, Hydraulic Fluid Power--Fluids--Method for Coding Level of Contamination by Solid Particles, is recommended. (No standard test method is identified.)

X1.1.7 *Water Content, Test Method* D6304—This test method covers the direct determination of water in the range of 10 to 25 000 mg/kg entrained water in petroleum products. Knowledge of the water content of turbine oils is important for assessing quality during transfer and use. Alternate methods suitable for determining trace amounts of water may also be used.

X1.1.8 *Specific Gravity, Test Method* D4052—For shipping and handling logistics, specific gravity, which is the ratio of the mass of a given volume to the mass of an equal volume of water, is used. Therefore, specific gravity is dimensionless. The specific gravity of mineral oils generally varies from 0.83 to 0.98.

X1.2 Chemical Properties

X1.2.1 *Acid Number by Color–Indicator Titration, Test Method* D974—The total acid number is the milligrams of potassium hydroxide (KOH) required to neutralize the acidic constituents in a gram of sample. The initial acid number is influenced by base oil and additives. Oils in service oxidize to form acids. Thus changes in acid number can be used to monitor the progress of oxidation of the oil.

X1.2.2 *Acid Number by Semi-micro Color-Indicator Titration, Test Method* D3339—This test method, which can be used in cases in which the amount of sample available to be analyzed is too small to allow accurate analysis by Test Method D974, is an alternative to Test Method D974. Test Methods D974 and D3339 correlate within the precision for the two test methods.

X1.3 Performance Properties

X1.3.1 *Emulsion Characteristics, Test Method* D1401—This test method is used to measure the ability of an oil to separate gross amounts of water. Water in turbine systems can promote oil oxidation, reduce oil stability, promote sludge formation, promote foaming, form emulsions, promote rusting and corrosion, reduce additive concentration, impede lubrication, alter fluid viscosity, reduce filter life, and foster bacterial growth.

X1.3.2 *Foaming Characteristics, Test Method* D892—In oil systems having high circulation rates, it is important that air introduced through seals or at the reservoir tank is rapidly released from the fluid without collecting as foam. Foam can produce cavitation and impede proper oil circulation. Test Method D892 measures the tendency of the oil to form foam and the stability of such foam. There are three sequences: Sequence I at 24°C; Sequence II at 93.5°C; and Sequence III at 24°C, using the same sample tested in Sequence II.

X1.3.3 *Air Release, Test Method* D3427—Agitation of lubricating oil with air in equipment may produce a dispersion of finely divided air bubbles in the oil. If the residence time in the reservoir is too short to allow air bubbles to rise to the surface, a mixture of air and oil will circulate through the lubrication system. This may result in the loss of oil pressure, incomplete oil films in contact zones, and if the oil is used in a hydraulic system, poor system performance. This test method measures the time for entrained air content to fall to the relatively low value of 0.2 % volume under standardized test conditions, and hence permits the comparison of the oil's capacity to separate entrained air over a period of time.

X1.3.4 *Rust Preventive Characteristics, Test Method* D665—This test method measures the ability of an oil to prevent rusting of steel surfaces when water is present. Distilled water is used with Procedure A and synthetic sea water with Procedure B.

X1.3.5 *Copper Corrosion, Test Method* D130—This test method indicates the relative tendency of oils to corrode copper and copper alloys that may be present in the lubrication system.

X1.3.6 *Oxidation Stability*—Several laboratory tests are used to indicate oxidation stability of mineral oils, and there is a continuing search to correlate these test results with field experience. The test methods referenced in this document are Test Methods D943 and D2272.

X1.3.6.1 Test Method D943 reports the time in hours for the acidity to reach 2.0 mg of KOH per gram of sample in a sample of oil containing water, in the presence of a steel and copper wire coiled together and maintained at a temperature of 95°C (203°F) with oxygen passing through. This test method includes the following statements:

"This method is widely used for specification purposes and is considered of value in estimating the oxidation stability of lubricants, especially those that are prone to water contamination."

"It should be recognized, however, that correlation between results of this test method and the oxidation stability of a lubricant in field service may vary markedly with field service conditions and with various lubricants."

"Furthermore, in the course of testing a lubricant by this test method, other signs of deterioration, such as sludge formation or catalyst coil corrosion, may appear which are not reflected in the calculated oxidation lifetime. For cases when it is desired to measure sludge formation or catalyst coil corrosion, Test Method D4310 should be used."

X1.3.6.2 In Test Method D2272, the test oil, water, and copper catalyst coil, contained in a covered glass container, are placed in a pressure vessel equipped with a pressure gage. The pressure vessel is charged with oxygen to a pressure of 90 psi (620 kPa), placed in a constant-temperature oil bath set at 150°C, and rotated axially at 100 rpm at an angle of 30° from the horizontal. The time for the test oil to react with a given volume of oxygen is measured, completion of the time being indicated by a specific drop in pressure. This test method includes the following statements:

"This test method utilizes an oxygen-pressured vessel to evaluate the oxidation stability of new and in-service turbine oils having the same composition (base stock and additives). This estimation of oxidation stability is useful in controlling the continuity of this property. For batch acceptance of

production lots having the same composition. It is not intended that this test method be a substitute for Test Method D943 or be used to compare the service lives of new oils of different compositions. This test method is also used to assess the remaining oxidation life of in-service oils."

X1.3.6.3 *Sludge Tendency*—Test Method D4310 is used to evaluate the tendency of inhibited mineral oil based steam turbine oils and anti-wear hydraulic oils to form sludge during oxidation in the presence of oxygen, water, and metal catalysts at 95°C (203°F) for 1000 h. The test is performed using the Test Method D943 test apparatus. The weight of insoluble material is determined gravimetrically by filtration of the oxidation tube contents through a 5-µm pore size filter disk. The determination of the acid number at 1000 h also provides some indication of the degree to which the oil has become oxidized.

(1) Test Method D4310 is most applicable to systems prone to water ingression. In the case of standalone gas turbine systems, excessive water ingress is abnormal. A modification of Test Method D4310 without water together with a higher test temperature might be considered. It should be recognized that no correlation has been established between results of this test method and actual field service, which may vary markedly with turbine operating conditions and with various lubricants. Oil samples have exhibited acceptable Test Method D4310 results, and yet some turbine systems have encountered sludge and varnish deposits that can cause unplanned trips or control device failures.

X1.3.6.4 The correlation of oxidation laboratory test results with field service is a difficult one. The tests used and the values given in this specification are a representation of the present state of the art.

X1.3.7 *Load Carrying Capacity Test Method* D5182—This test method measures the scuffing load capacity of a turbine oil in a four square-type gear rig. An FZG Gear Test Machine (A/83/90°C) is operated at constant speed for a fixed period at successively increasing loads until a predetermined level of gear scuffing and scoring is reached.

SUMMARY OF CHANGES

Subcommittee D02.C0 has identified the location of selected changes to this standard since the last issue (D4304–06) that may impact the use of this standard. (Approved July 1, 2006.)

(*1*) Revised Tables 1 and 2.
(*2*) Added combined cycle turbine oil to the Keywords.
(*3*) Revised X1.1.6 and X1.1.6.1.
(*4*) Added X1.1.7 and X1.1.8.

Subcommittee D02.C0 has identified the location of selected changes to this standard since the last issue (D4304–00) that may impact the use of this standard. (Approved May 1, 2006.)

(*1*) Revised 1.1.
(*2*) Added Discussions to 3.1.1 and 3.1.2.
(*3*) Added 3.1.3.
(*4*) Added Table 3.
(*5*) Added X1.3.6.3.