Designation: ~~D4304 – 13~~ D4304 – 17

Standard Specification for Mineral and Synthetic 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 and synthetic (API group I, II, III, or IV) oils used in steam and gas turbine lubrication systems where the performance requirements demand highly refined mineral or synthetic base oils 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 and synthetic 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 This specification does not include API Group V fluids. For polyol ester fluids used to lubricate land-based gas turbines, the user is referred to the current version of military specification MIL-PRF-23699 for fluid performance requirements. For phosphate ester fluids used as turbine lubricants or steam turbine electro-hydraulic control (EHC) fluids, the user is referred to the current version of Specification D4293 for fluid performance requirements.

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

1.7 *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]

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

[1] This specification 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**

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 Hydrocarbon Based 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
D4293 Specification for Phosphate Ester Based Fluids for Turbine Lubrication and Steam Turbine Electro-Hydraulic Control (EHC) Applications
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)
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
D7155 Practice for Evaluating Compatibility of Mixtures of Turbine Lubricating Oils
D7546 Test Method for Determination of Moisture in New and In-Service Lubricating Oils and Additives by Relative Humidity Sensor
D7547 Specification for Hydrocarbon Unleaded Aviation Gasoline
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

2.2 *ISO Standards:*[3]

ISO 4406–99 Particle Count Analysis
ISO 6072 Rubber—Compatibility Between Hydraulic Fluids and Standard Elastomeric Materials
ISO 8068 Lubricatns, Industrial Oils and Related Products (Class L)—Family T (Turbines)—Specification for Lubricating Turbines

2.3 *Military Standards:*

MIL-PRF-23699G Performance Specification Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Code Numbers: O-152, O-154, O-156, and O-167[4]

3. Terminology

3.1 *Definitions:*

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

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY ~~10036.~~10036, http://www.ansi.org.
[4] Available from US Military document web site, http://quicksearch.dla.mil/

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.~~110 °C.

3.1.2 *Type II mineral or synthetic oils, n*—oils for steam, gas, or combined cycle 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. Type II oils are generally satisfactory for turbine sets where bearing temperatures do not exceed ~~110°C.~~110 °C. Oils ISO VG 68 and above have been used in marine, hydro, or water turbines.

3.1.3 *Type III mineral or synthetic 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 or Type II 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 or synthetic base oil (API group I, II, III, or IV) 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.~~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 or synthetic lubricating oil that are required for satisfactory operation of the machinery. These properties are listed in Section 5.

4. Sampling, Testing, and System Preparation

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.

4.3 Test Method D6439 should be referenced for turbine flushing guidance.

4.4 Practice D7155 should be referenced to confirm oil to oil compatibility.

5. Functional Property Requirements

5.1 Mineral and synthetic 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.

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; synthetic turbine oil; turbine lubricating oils; turbine lubrication systems

TABLE 1 Requirements for Type I Turbine Oils

NOTE 1—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.

Physical	Test Method	Limits			
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~~
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 (mm²/s) 40°C~~	~~D445~~	~~28.8–35.2~~	~~41.4–50.6~~	~~61.2–74.8~~	~~90–110~~
Viscosity, cSt (mm²/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~~		
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~~	~~N/A~~
at 54 °C, minutes to 3 mL emulsion, max		30	30	30	N/A
~~at 82°C, minutes to 3 mL emulsion, max~~		~~N/A~~	~~N/A~~	~~N/A~~	~~60~~
at 82 °C, minutes to 3 mL emulsion, max		N/A	N/A	N/A	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~~
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~~
Copper corrosion, 3 h at 100 °C, max	D130	1	1	1	1
Oxidation stability:[D]					
Hours to neut. No. 2.0, min	D943[D]	2000	2000	1500	1000
Minutes to 175 kPa drop, min	D2272	350	350	175	150
1000–h TOST Sludge, mg, max	D4310[C]	200	200	200	...
1000–h TOST, Total acid number, mg KOH/g, max	D4310	report	report	report	...
~~Elastomer Compatibility SRE NBR1, or SRENBR- 28P or SRE-NBR-28PX (168 ± 2 h at 100°C ± 1°C) volume change % minimum to maximum~~	~~ISO 6072[E]~~	~~–4 to 15~~	~~–4 to 15~~	~~–4 to 15~~	~~N/A~~
Elastomer Compatibility SRE NBR1, or SRENBR- 28P or SRE-NBR-28PX (168 h ± 2 h at 100 °C ± 1 °C) volume change % minimum to maximum	ISO 6072[E]	–4 to 15	–4 to 15	–4 to 15	N/A
~~Elastomer Compatibility SRE NBR 1, or SRENBR- 28P or SRE-NBR-28PX (168 ± 2 h at 100°C ± 1°C), hardness change minimum to maximum~~	~~ISO 6072[E]~~	~~–8 to 8~~	~~–8 to 8~~	~~–8 to 8~~	~~N/A~~
Elastomer Compatibility SRE NBR 1, or SRENBR- 28P or SRE-NBR-28PX (168 h ± 2 h at 100 °C ± 1 °C), hardness change minimum to maximum	ISO 6072[E]	–8 to 8	–8 to 8	–8 to 8	N/A
Cleanliness as filled into turbine, rating, max	ISO 4406–99[F]	18/16/13	18/16/13	18/16/13	18/16/13

[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, for example, turbine oils with exposure to water.
[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] Test limits based on ISO 8068 guidance for turbine oils.
[F] Systems where the turbine oil is used as the control oil may require lower particle counts, suggest 16/14/11.

TABLE 2 Requirements for Type II Turbine Oils

NOTE 1—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.

Physical	Test Method	Limits				
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~~
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~~
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~~		
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 54 °C, minutes to 3 mL emulsion, max		30	30	30	...	...
~~at 82°C, minutes to 3 mL emulsion, max~~		~~...~~	~~...~~	~~...~~	~~60~~	~~60~~
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~~
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~~
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[D]	3500	3000	2500	1000	1000
Minutes to 175 kPa drop, min	D2272	350	350	175	150	150
~~Elastomer Compatibility SRE-NBR1, or SRE-NBR-28P or SRE-NBR-28PX (168 ± 2 h at 100°C ± 1°C) volume change % minimum to maximum~~	~~ISO 6072[E]~~	~~–4 to 15~~	~~–4 to 15~~	~~–4 to 15~~	~~N/A~~	~~N/A~~
Elastomer Compatibility SRE NBR1, or SRE-NBR-28P or SRE-NBR-28PX (168 h ± 2 h at 100 °C ± 1 °C) volume change % minimum to maximum	ISO 6072[E]	–4 to 15	–4 to 15	–4 to 15	N/A	N/A
~~Elastomer Compatibility SRE NBR 1, or SRE-NBR-28P or SRE-NBR-28PX (168 ± 2 h at 100°C ± 1°C), hardness change minimum to maximum~~	~~ISO 6072[E]~~	~~–8 to 8~~	~~–8 to 8~~	~~–8 to 8~~	~~N/A~~	~~N/A~~
Elastomer Compatibility SRE NBR 1, or SRE-NBR-28P or SRE-NBR-28PX (168 h ± 2 h at 100 °C ± 1 °C), hardness change minimum to maximum	ISO 6072[E]	–8 to 8	–8 to 8	–8 to 8	N/A	N/A
Cleanliness as filled into turbine, rating, max	ISO 4406–99[F]	18/16/13	18/16/13	18/16/13	18/16/13	18/16/13
Load carrying capacity:						
FZF Scuffing fail stage, min	D5182[G]	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, for example, turbine oils with exposure to water.
[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] Test limits based on ISO 8068 guidance for turbine oils.
[F] Systems where the turbine oil is used as the control oil may require lower particle counts, suggest 16/14/11. Confirm OEM specific guidance.
[G] Higher values may be required for some applications.

TABLE 3 Requirements for Type III Turbine Oils

NOTE 1—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.

Physical	Test Method	Limits	
ISO—viscosity grade	D2422	32	46
ASTM Color, rating	D1500	report	report
~~Specific Gravity at 15.6/15.6°C~~	~~D4052~~	~~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 (mm²/s) 40°C~~	~~D445~~	~~28.8–35.2~~	~~41.4–50.6~~
Viscosity, cSt (mm²/s) 40 °C	D445	28.8–35.2	41.4–50.6
~~Visual examination at 20°C~~	~~...~~	~~clear and bright~~	
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~~
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~~
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~~
Copper corrosion, 3 h at 100 °C, max	D130	1	1
Oxidation stability:[D]			
Hours to neut. No. 2.0, min	D943[D]	5000	5000
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[C]	200	200
1000-h TOST, total acid number, mg KOH/g, max	D4310	report	report
~~Elastomer Compatibility SRE NBR1, or SRE-NBR-28P or SRE-NBR-28PX (168 ± 2 h at 100°C ± 1°C) volume change % minimum to maximum~~	~~ISO 6072[F]~~	~~–4 to 15~~	~~–4 to 15~~
Elastomer Compatibility SRE NBR1, or SRE-NBR-28P or SRE-NBR-28PX (168 h ± 2 h at 100 °C ± 1 °C) volume change % minimum to maximum	ISO 6072[F]	–4 to 15	–4 to 15
~~Elastomer Compatibility SRE NBR 1, or SRE-NBR-28P or SRE-NBR-28PX (168 ± 2 h at 100°C ± 1°C), hardness change minimum to maximum~~	~~ISO 6072[F]~~	~~–8 to 8~~	~~–8 to 8~~
Elastomer Compatibility SRE NBR 1, or SRE-NBR-28P or SRE-NBR-28PX (168 h ± 2 h at 100 °C ± 1 °C), hardness change minimum to maximum	ISO 6072[F]	–8 to 8	–8 to 8
Cleanliness as filled into turbine rating, max	ISO 4406–99[G]	18/16/13	18/16/13
Load carrying capacity: (optional)			
FZG Scuffing, fail stage, min	D5182[H]	report	report

[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, for example, turbine oils with exposure to water.
[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] Test Method D2272 is performed after the treatment of oil at ~~121°C~~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.
[F] Test limits based on ISO 8068 guidance for turbine oils.
[G] Systems where the turbine oil is used as the control oil may require lower particle counts, suggest 16/14/11. Confirm OEM specific guidance.
[H] FZG scuffing test may be required for some geared applications. The required value should be negotiated with the end user.