



Designation: D4293 – 15<sup>ε1</sup>

# Standard Specification for Phosphate Ester Based Fluids for Turbine Lubrication and Steam Turbine Electro-Hydraulic Control (EHC) Applications<sup>1</sup>

This standard is issued under the fixed designation D4293; 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.

<sup>ε1</sup> NOTE—Corrected the spacing/formatting of a row in Table 4 editorially in March 2018.

## 1. Scope\*

1.1 This specification covers the minimum requirements for phosphate ester based fluids for turbine lubricants and electro-hydraulic control fluids, as delivered.

1.2 The use of this type of fluid is restricted to turbine systems that have been designed or modified to accommodate phosphate ester fluids.

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

1.4 *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.*

1.5 *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:<sup>2</sup>

- 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

<sup>1</sup> 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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<sup>2</sup> 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.

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

D892 Test Method for Foaming Characteristics of Lubricating Oils

D974 Test Method for Acid and Base Number by Color-Indicator Titration

D1169 Test Method for Specific Resistance (Resistivity) of Electrical Insulating Liquids

D1298 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

D1401 Test Method for Water Separability of Petroleum Oils and Synthetic Fluids

D2422 Classification of Industrial Fluid Lubricants by Viscosity System

D3427 Test Method for Air Release Properties of Hydrocarbon Based Oils

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

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

D7546 Test Method for Determination of Moisture in New and In-Service Lubricating Oils and Additives by Relative Humidity Sensor

### 2.2 EN Standards:<sup>3</sup>

EN 14832 Petroleum and Related Products—Determination of the Oxidation Stability and Corrosivity of Fire-resistant Phosphate Ester Fluids

EN 14833 Petroleum and Related Products—Determination of the Hydraulic Stability of Fire Resistant Phosphate Ester Fluids

<sup>3</sup> Available from British Standards Institution (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., <http://www.bsigroup.com> or from Deutsches Institut für Normung e.V.(DIN), Am DIN-Platz, Burggrafenstrasse 6, 10787 Berlin, Germany, <http://www.din.de>.

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

2.3 IEC Standard:<sup>4</sup>

IEC 60247 Insulating Liquids—Measurement of Relative Permittivity, Dielectric Dissipation Factor ( $\tan \delta$ ) and d.c. Resistivity

2.4 Energy Institute Standard:<sup>5</sup>

IP 510 Energy Institute Standard—Petroleum Products—Determination of Organic Halogen Content—Oxidative Microcoulometric Method

2.5 ISO Standards:<sup>6</sup>

ISO 760 Determination of Water—Karl Fischer Method (General Method)

ISO 2160 Petroleum Products—Corrosiveness to Copper—Copper Strip Test

ISO 2592 Determination of Flash and Fire Points—Cleveland Open Cup Method

ISO 3016 Petroleum Products—Determination of Pour Point

ISO 3104 Petroleum Products—Transparent and Opaque Liquids—Determination of Kinematic Viscosity and Calculation of Dynamic Viscosity

ISO 3170 Petroleum Liquids—Manual Sampling

ISO 3448 Industrial Liquid Lubricants—ISO Viscosity Classification

ISO 3675 Crude Petroleum and Liquid Petroleum Products—Laboratory Determination of Density—Hydrometer Method

ISO 4259 Petroleum Products—Determination and Application of Precision Data in Relation to Methods of Test

ISO 4406 Hydraulic Fluid Power—Fluids—Method for Coding the Level of Contamination by Solid Particles

ISO 6072 Rubber—Compatibility Between Hydraulic Fluids and Standard Elastomeric Materials

ISO 6247 Petroleum Products—Determination of Foaming Characteristics of Lubricating Oils

ISO 6614 Petroleum Products—Determination of Water Separability of Petroleum Oils and Synthetic Fluids

ISO 6618 Petroleum Products and Lubricants—Determination of Acid or Base Number—Colour Indicator Titration Method

ISO 6619 Petroleum Products and Lubricants—Neutralization Number—Potentiometric Titration Method

ISO 7537 Petroleum Products—Determination of Acid Number—Semi-micro Colour-indicator Titration Method

ISO 8068 Lubricants, Industrial Oils and Related Products (Class L)—Family T (Turbines)—Specification for Lubricating Oils for Turbines

ISO 9001 Quality Management Systems

ISO 9120 Petroleum Products—Determination of Air-release Properties of Steam Turbine and Other Oils—Impinger Method

ISO 10050 Lubricants, Industrial Oils and Related Products (Class L)—Family T (Turbines)—Specifications of Tri-

aryl Phosphate Ester Turbine Control Fluids (Category ISO-L-TCD)

ISO 11500 Hydraulic Fluid Power—Determination of the Particulate Contamination Level of a Liquid Sample by Automatic Particle Counting Using the Light-extinction Principle

ISO 12185 Crude Petroleum and Petroleum Products—Determination of Density—Oscillating U-tube Method

ISO 14935 Petroleum Products—Determination of Wick Flame Persistence of Fire-resistant Fluids

ISO 15597 Petroleum Products—Determination of Chlorine and Bromine Content—Wavelength X-ray Fluorescence Spectrometry

ISO 20764 Petroleum and Related Products—Preparation of a Test Portion of High-boiling Liquids for the Determination of Water Content—Nitrogen Purge Method

ISO 20823 Petroleum and Related Products—Determination of the Flammability Characteristics of Fluids in Contact with Hot Surfaces—Manifold Ignition Test

### 3. Significance and Use

3.1 This is a specification to define the minimum requirements of fire-resistant fluids for satisfactory performance in turbine applications. Fire-resistant fluids are more difficult to ignite and show little tendency to propagate a flame. The term “fire-resistant fluid” does not mean that the fluid will not burn if enough energy is supplied.

### 4. Safety Precautions

4.1 The fire safety tests are used to measure and describe the properties of phosphate esters in response to heat and flame under controlled laboratory conditions and should not be considered or used for the description or appraisal of the fire hazard of the fluids under actual fire conditions.

4.2 Fires that have occurred in operating turbines have usually been caused by fluid or vapors contacting hot surfaces. For example, fluid that may spill and be absorbed into unprotected thermal insulation can experience an exothermic reaction with resultant, potential, rapid temperature increase. The ignition of the absorbed fluid can occur at temperatures below the fluid auto-ignition temperature.

### 5. Sampling

5.1 Sampling shall be in accordance with the applicable clauses of Practice D4057 or ISO 3170. Drum shipments shall be represented by an “all-levels sample” obtained by tube sampling.

5.2 Clean, dry, and free sampling apparatus from any substance that might contaminate the fluid during the sampling process.

5.3 Care shall be taken to ensure that the fluid is mixed properly before samples are withdrawn for the test and that the samples are representative of the whole.

5.4 The fluid shall normally meet the specification requirements at the point where it passes from the supplier to the user unless other contractual arrangements have been made.

<sup>4</sup> Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland, <http://www.iec.ch>.

<sup>5</sup> Available from Energy Institute, 61 New Cavendish St., London, W1G 7AR, U.K., <http://www.energyinst.org>.

<sup>6</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

## 6. Functional Property Requirements

6.1 Phosphate ester fluids used in turbine applications shall not contain any viscosity-index improver.

6.2 Most of the test methods specified in the tables contain a precision statement. In cases of dispute, the procedure described in ISO 4259 shall be used.

6.3 The elastomer compatibility index shall be determined according to ISO 6072 under the conditions listed in **Table 1**, according to product category. **Table 2** gives guidelines on acceptable changes of properties.

6.4 The turbine fluids shall also be compatible with all material constituents of the lubrication and EHC systems.

6.5 The fluid manufacturer should use Chemistry Laboratories with QA programs accredited against the latest version of ISO 9001 to ensure that the product meets the requirements specified in this standard.

6.6 The fluid manufacturer shall supply evidence to the user that the fluid meets the requirements specified in this standard in the form of a “Certificate of Analysis” for each lot with the actual measured values. The Certificate of Analysis (COA)

shall accompany each lot delivered to the user. The content of the COA may be separately negotiated with the user depending on the application criticality.

6.7 If the fluid is more than 12 months old at the time of receipt, the product shall be retested by the Manufacturer or Vendor and a new COA issued.

6.8 The maximum fluid ISO Cleanliness Codes are provided in **Table 3** and **Table 4**. Although fluid as manufactured should meet this requirement, contamination can occur during transportation and storage. It is therefore good practice to filter the fluid when transferring from drums into the turbine system.

## 7. Specification Tables

### 7.1 Specification for turbine lubricating oils

7.1.1 Requirements for phosphate ester fluids used as turbine lubricants are shown in **Table 3**.

7.1.2 The choice of viscosity grade for use in a particular turbine should comply with turbine manufacturer's recommendations. Usually ISO 32 or ISO 46 viscosity grades (VG) are used for lubrication of main bearings, hydrogen seals and turning gearboxes.

### 7.2 Specification for Steam Turbine EHC Fluids:

7.2.1 Requirements for phosphate ester fluids used in EHC systems are shown in **Table 4**.

7.2.2 Typical viscosity grade used for EHC application is ISO 32 or ISO 46.

7.2.3 EHC systems with high pressure servo-valves are vulnerable to electro-kinetic wear. High conductivity may cause erosion of the valve spools.

7.2.4 Chlorine, in the form of chloride ions, can also promote electro-kinetic wear in high pressure systems.

7.2.5 High air release value can cause loss of pump suction leading to a low pressure trip, sluggish governor controls, accelerated fluid aging/oxidation, and bubble-choked filters.

7.2.6 Foam formation can cause pump cavitation, overflow of reservoirs, inadequate lubrication, and inability to achieve full flow conditions.

**TABLE 1 Test Conditions According to ISO 6072 for Determination of Elastomer Compatibility Index<sup>A</sup>**

Fluid	Suitable Elastomer	Test Temperature (°C)	Examples of Test Duration (hrs) <sup>B, C</sup>
Aryl phosphate ester	FKM 2	100	168
	EPDM 1	100	1000

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<sup>B</sup> The elastomer test temperatures for FKM2 and EPDM1 are 150 °C and 130 °C, respectively, in Table 1 of ISO 8068.

<sup>C</sup> The test duration of 1000 h is recommended for evaluation of elastomer compatibility with fluids which cause longer term changes to the elastomer.

**TABLE 2 Guidelines on Acceptable Changes of Properties, According to ISO 6072<sup>A, B</sup>**

Immersion Time (h)	Maximum Volume Swell (%)	Maximum Volume Shrinkage (%)	Hardness Changes (IRHD)	Maximum Tensile Stress Change (%)	Maximum Elongation Change (%)
168	15	-4	±8	-20	-20
1000	20	-5	±10	-50	-50

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<sup>B</sup> The limits shown for seal compatibility are for reference purpose and should not be taken as the direct basis on which elastomer compatibility is to be determined, because compatibility evaluation also depends on the purpose and conditions of use.

**TABLE 3 Requirements for Fire-Resistant Phosphate Ester Lubricants<sup>A</sup>**

Property	Unit	Viscosity Grade		Test Method
ISO Viscosity Grade	-	32	46	ASTM D2422/ISO 3448
Appearance	rating	Clear and bright, no visible particulate matter under visible light at ambient temperature		Visual
Kinematic Viscosity				
at 0 °C max	mm <sup>2</sup> /s	2000	2500	ASTM D445/ISO 3104
at 40 °C min		28.8	41.4	
at 40 °C max		35.2	50.6	
Pour Point (max)	°C	-15	-15	ASTM D97/ISO 3016
Density at 15 °C (max)	kg/m <sup>3</sup>	1200	1200	ASTM D1298/ISO 12185 or ISO 3675
Fire Point (min)	°C	300	300	ASTM D92/ISO 2592
Manifold-Ignition Test (min)	°C	650	650	ISO 20823
Wick-flame Persistence (max)	s	10	10	ISO 14935
Acid Number (max)	mg KOH/g	0.1	0.1	ASTM D974/ISO 6618 or ASTM D664/ISO 6619
Water content (max)	% (m/m)	0.10	0.10	ASTM D6304/ISO 760 or ISO 20764 or ASTM D7546
Foaming (tendency/stability) (max)				
Sequence 1 at 24 °C	mL/mL	150/0	150/0	ASTM D892/ISO 6247
Sequence 2 at 93 °C		30/0	30/0	
Sequence 3 at 24 °C after 93 °C		150/0	150/0	
Air release time at 50 °C (max)	minute	5	6	ASTM D3427/ISO 9120
Copper corrosion (3 h at 100 °C) max	rating	1	1	ASTM D130/ISO 2160
Demulsibility (max time to reach 3 mL emulsion at 54 °C)	minute	15	15	ASTM D1401/ISO 6614
Oxidation stability (max)				
Acid number	mg KOH/g	1.5	1.5	
Mass change Fe	mg	1.0	1.0	EN 14832
Mass change Cu	mg	2.0	2.0	
Hydrolytic Stability				EN 14833
Acid Number (max)	mg KOH/g	0.5	0.5	
ISO Cleanliness Code at delivery stage (max)	rating	-/17-14	-/17/14	ISO 4406 for classification and ISO 11500 for determination

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**TABLE 4 Requirements for Fire-Resistant Phosphate Ester Used in EHC Systems<sup>A</sup>**

Property	Unit	Viscosity Grade		Test Method
ISO Viscosity Grade	-	32	46	ASTM D2422/ISO 3448
Appearance	rating	Clear & bright, no visible particulate matter under visible light at ambient temperature		Visual
Kinematic Viscosity at 0 °C max	mm <sup>2</sup> /s	2000	2500	ASTM D445/ISO 3104
at 40 °C min		28.8	41.4	
at 40 °C max		35.2	50.6	
Pour Point (max)	°C	-15	-15	ASTM D97/ISO 3016
Density at 15 °C (max)	Kg/m <sup>3</sup>	1200	1200	ASTM D1298/ISO 12185/ISO 3675
Fire Point (min)	°C	300	300	ASTM D92/ISO 2592
Manifold-Ignition Test (min)	°C	650	650	ISO 20823
Wick-flame Persistence (max)	s	10	10	ISO 14935
Acid Number (max)	mg KOH/g	0.1	0.1	ASTM D974/ISO 6618 or ASTM D664/ISO 6619 or ISO 7537
Water Content (max)	% (m/m)	0.10	0.10	ASTM D6304 <sup>B</sup> / ISO 760 or ISO 20764 or ASTM D7546
Foaming (tendency/stability) (max)				
Sequence 1 at 24 °C	mL/mL	150/0	150/0	ASTM D892/ISO 6247
Sequence 2 at 93 °C		30/0	30/0	
Sequence 3 at 24 °C after 93 °C		150/0	150/0	
Air release time at 50 °C (max)	minute	5	6	ASTM D3427/ISO 9120
Copper corrosion (3 h at 100 °C) max	rating	1	1	ASTM D130/ISO 2160
Demulsibility (max time to reach 3 mL emulsion at 54 °C)	minute	15	15	ASTM D1401/ISO 6614
Chlorine Content (Max)	mg/kg	50	50	ISO 15597/IP 510
Volume Resistivity (min)	MΩ·m	50	50	ASTM D1169/IEC 60247
Oxidation Stability (max)				
Acid number	mg KOH/g	1.5	1.5	
Mass change Fe	mg	1.0	1.0	EN 14832
Mass change Cu	mg	2.0	2.0	
Hydrolytic Stability				
Acid Number (max) <sup>†</sup>	mg KOH/g	0.5	0.5	EN 14833
ISO Cleanliness Code at delivery stage (max)		-/15/12	-/15/12	ISO 4406 for classification and ISO 11500 for particle determination

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<sup>B</sup> The ISO 20823 manifold test minimum temperature is 700 °C in Table 1 of ISO 10050.

<sup>†</sup>Editorially corrected.

## SUMMARY OF CHANGES

Subcommittee D02.C0 has identified the location of selected changes to this standard since the last issue (D4293 – 83 (2008)) that may impact the use of this standard. (Approved June 1, 2015.)

(1) Entire standard was revised to provide current requirements for phosphate ester fluids used in turbine lubrication systems and in steam turbine EHC applications.

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