



# 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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

## 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
- 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 Petroleum 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
- ### 2.3 IEC Standard:<sup>4</sup>
- IEC 60247 Insulating Liquids—Measurement of Relative Permittivity, Dielectric Dissipation Factor (tan  $\delta$ ) and d.c. Resistivity

<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](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<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>.

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

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

#### 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 Triaryl 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.

### 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.

<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>.

6.3 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   | 1000 |
|                      | EPDM 1             | 100                   |   |      |

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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 <b>D2422</b> /ISO 3448                                  |
| Appearance   | rating             | Clear and bright, no visible particulate matter under visible light at ambient temperature |         | Visual   |
| Kinematic Viscosity                                      |                    |  |         |  |
| at 0 °C max  |                    | 2000   | 2500    |  |
| at 40 °C min   | mm <sup>2</sup> /s | 28.8   | 41.4    | ASTM <b>D445</b> /ISO 3104                                   |
| at 40 °C max   |                    | 35.2   | 50.6    |  |
| Pour Point (max)   | °C                 | -15  | -15     | ASTM <b>D97</b> /ISO 3016                                    |
| Density at 15 °C (max)                                   | kg/m <sup>3</sup>  | 1200   | 1200    | ASTM <b>D1298</b> /ISO 12185 or ISO 3675                     |
| Fire Point (min)   | °C                 | 300  | 300     | ASTM <b>D92</b> /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 <b>D974</b> /ISO 6618 or<br>ASTM <b>D664</b> /ISO 6619  |
| Water content (max)                                      | % (m/m)            | 0.10   | 0.10    | ASTM <b>D6304</b> /ISO 760 or ISO 20764 or ASTM <b>D7546</b> |
| Foaming (tendency/stability) (max)                       |                    |  |         |  |
| Sequence 1 at 24 °C                                      |                    | 150/0  | 150/0   |  |
| Sequence 2 at 93 °C                                      | mL/mL              | 30/0   | 30/0    | ASTM <b>D892</b> /ISO 6247                                   |
| Sequence 3 at 24 °C after 93 °C                          |                    | 150/0  | 150/0   |  |
| Air release time at 50 °C (max)                          | minute             | 5  | 6       | ASTM <b>D3427</b> /ISO 9120                                  |
| Copper corrosion (3 h at 100 °C) max                     | rating             | 1  | 1       | ASTM <b>D130</b> /ISO 2160                                   |
| Demulsibility (max time to reach 3 mL emulsion at 54 °C) | minute             | 15   | 15      | ASTM <b>D1401</b> /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                                     |                    |  |         |  |
| Acid Number (max)  | mg KOH/g           | 0.5  | 0.5     | EN 14833   |
| 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 <b>D2422</b> /ISO 3448  |
| Appearance   | rating             | Clear & bright, no visible particulate matter under visible light at ambient temperature |         | Visual   |
| Kinematic Viscosity                                      | mm <sup>2</sup> /s |  |         |  |
| at 0 °C max  |                    | 2000   | 2500    | ASTM <b>D445</b> /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 <b>D97</b> /ISO 3016  |
| Density at 15 °C (max)                                   | Kg/m <sup>3</sup>  | 1200   | 1200    | ASTM <b>D1298</b> /ISO 12185/ISO 3675                                      |
| Fire Point (min)   | °C                 | 300  | 300     | ASTM <b>D92</b> /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 <b>D974</b> /ISO 6618 or<br>ASTM <b>D664</b> /ISO 6619 or<br>ISO 7537 |
| Water Content (max)                                      | % (m/m)            | 0.10   | 0.10    | ASTM <b>D6304</b> <sup>B</sup> /ISO 760 or ISO 20764 or ASTM <b>D7546</b>  |
| Foaming (tendency/stability) (max)                       |                    |  |         |  |
| Sequence 1 at 24 °C                                      |                    | 150/0  | 150/0   | ASTM <b>D892</b> /ISO 6247   |
| Sequence 2 at 93 °C                                      | mL/mL              | 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 <b>D3427</b> /ISO 9120  |
| Copper corrosion (3 h at 100 °C) max                     | rating             | 1  | 1       | ASTM <b>D130</b> /ISO 2160   |
| Demulsibility (max time to reach 3 mL emulsion at 54 °C) | minute             | 15   | 15      | ASTM <b>D1401</b> /ISO 6614  |
| Chlorine Content (Max)                                   | mg/kg              | 50   | 50      | ISO 15597/IP 510   |
| Volume Resistivity (min)                                 | MΩ·m               | 50   | 50      | ASTM <b>D1169</b> /IEC 60247   |
| Oxidation Stability (max)                                |                    |  |         |  |
| Acid number  | mg KOH/g           | 1.5  | 1.5     | EN 14832   |
| Mass change Fe   | mg                 | 1.0  | 1.0     |  |
| 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)             |                    | -/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.

## 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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