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Standard Specification for Gas Turbine Fuel Oils¹

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers the selection of fuels for gas turbines, excepting gas turbines used in aircraft, for the guidance of interested parties such as turbine manufacturers and the suppliers and purchasers of fuel oils. The specification sets forth the properties of fuels at the time and place of custody transfer to the user.

1.2 Three appendixes are provided for informational purposes only and do not constitute a requirement of this specification unless mutually agreed upon between the interested parties.

1.2.1 **Appendix X1** describes the five grades of gas turbine fuels covered by this specification. Further, it states the significance of various test methods used in inspecting the fuels.

1.2.2 **Appendix X2** discusses the sources of fuel contaminants and notes the significance of such contaminants in the operation of gas turbines and gas turbine fuel systems. The particular significance of trace metals in gas turbine fuels is noted. Upper limits of trace metals are recommended for the various grades of gas turbine fuels, but these recommended limits do not constitute a requirement of the specification unless mutually agreed upon by the interested parties. Limitations due to the use of used or recycled oil are also noted.

NOTE 1—The gas turbine operator should consult Practice **D4418** for methods of ensuring fuels of adequate cleanliness and for guidance on long-term storage of distillate fuels and on liquids from non-petroleum sources as gas turbine.

NOTE 2—Nothing in this specification shall preclude observance of federal, state, or local regulations which may be more restrictive.

NOTE 3—The generation and dissipation of static electricity can create problems in the handling of distillate gas turbine fuel oils. For more information on the subject, see Guide **D4865**.

¹ This specification is under the jurisdiction of ASTM Committee **D02** on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee **D02.E0** on Burner, Diesel, Non-Aviation Gas Turbine, and Marine Fuels.

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2. Referenced Documents

2.1 *ASTM Standards:*²

- D56** Test Method for Flash Point by Tag Closed Cup Tester
- D86** Test Method for Distillation of Petroleum Products at Atmospheric Pressure
- D93** Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
- D97** Test Method for Pour Point of Petroleum Products
- D129** Test Method for Sulfur in Petroleum Products (General High Pressure Decomposition Device Method)
- D396** Specification for Fuel Oils
- D445** Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
- D482** Test Method for Ash from Petroleum Products
- D524** Test Method for Ramsbottom Carbon Residue of Petroleum Products
- D975** Specification for Diesel Fuel Oils
- D1266** Test Method for Sulfur in Petroleum Products (Lamp Method)
- D1298** Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
- D1552** Test Method for Sulfur in Petroleum Products (High-Temperature Method)
- D1796** Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)
- D2622** Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
- D2709** Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge
- D3605** Test Method for Trace Metals in Gas Turbine Fuels by Atomic Absorption and Flame Emission Spectroscopy
- D3828** Test Methods for Flash Point by Small Scale Closed Cup Tester

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**

- D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
- D4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry
- D4418 Practice for Receipt, Storage, and Handling of Fuels for Gas Turbines
- D4865 Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems
- D5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
- D5949 Test Method for Pour Point of Petroleum Products (Automatic Pressure Pulsing Method)
- D5950 Test Method for Pour Point of Petroleum Products (Automatic Tilt Method)
- D5985 Test Method for Pour Point of Petroleum Products (Rotational Method)
- D6469 Guide for Microbial Contamination in Fuels and Fuel Systems
- D6728 Test Method for Determination of Contaminants in Gas Turbine and Diesel Engine Fuel by Rotating Disc Electrode Atomic Emission Spectrometry
- D7220 Test Method for Sulfur in Automotive, Heating, and Jet Fuels by Monochromatic Energy Dispersive X-ray Fluorescence Spectrometry
- 2.2 *Other Documents*.³
- 26 CFR Part 48 Diesel Fuel Excise Tax; Dye Color and Concentration
- 40 CFR Part 80 Regulation of Fuels and Fuel Additives

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *fuel contaminants*—fuel components other than hydrocarbon oils. In the present context the contaminants are foreign materials that make the fuel less suitable or even unsuitable for the intended use.

3.1.1.1 *Discussion*—The contaminants of primary interest are foreign materials introduced subsequent to the manufacture of specification quality fuel. Hence they are materials introduced in the distribution system (that is, storage tanks, pipelines, tank trucks, barges, etc.) or in the user's storage and handling system, or generated within these systems (rust generated in steel pipes and tanks by moist fuel, and so forth). Contaminants may be soluble or insoluble in the fuel.

3.1.2 *fuel entering the combustor(s)*—the fuel that is actually burned in the gas turbine. Fuel may be sampled at a point upstream from the point of entry into the combustor(s), provided the sample is representative of the fuel actually entering the combustor(s).

3.1.3 *hydrocarbon oil, n*—a mixture with elemental composition primarily of carbon and hydrogen, also containing sulfur, oxygen or nitrogen from residual impurities and contaminants associated with the fuel's raw materials and manufacturing processes, and excluding added oxygenated materials.

3.1.3.1 *Discussion*—Examples of excluded oxygenated materials include but are not limited to alcohols, esters, ethers and triglycerides.

NOTE 4—Additives are generally included in finished gas turbine fuel oil to improve performance properties (corrosion and so forth).

4. General Requirements

4.1 The grades of gas turbine fuels herein specified shall be homogeneous mixtures of hydrocarbon oils with the use of additives to enhance performance properties, if required. The hydrocarbon oils shall be free of inorganic acid, and free of excessive amounts of solid or fibrous foreign matter likely to make frequent cleaning of suitable strainers necessary.

4.2 All grades containing residual components shall remain homogeneous in normal storage and not separated by gravity into light and heavy oil components outside the viscosity limits for the grade.

5. Detailed Requirements

5.1 The various grades of gas turbine fuel oil shall conform to the limiting requirements shown in **Table 1**. As noted in the supplementary footnotes to **Table 1**, the requirements for Grade Nos. 1-GT and 2-GT conform in most respects to corresponding Grade Nos. 1 and 2 fuels in Specification **D396**, and to Grade Nos. 1-D and 2-D in Specification **D975**. The viscosity range of Grade Nos. 3-GT and 4-GT fuel brackets the Grade Nos. 4, 5, and 6 of Specification **D396** and Grade No. 4-D of Specification **D975**. It is the intent that fuels meeting Specification **D396** and **D975** requirements may also be supplied under these specifications provided they meet the requirements listed in **Table 1**.

5.2 Modifications of limiting requirements and the inclusion of fuel additives to meet special operating conditions may be agreed upon between the interested parties.

5.3 The properties listed in this specification are those of greatest significance in obtaining acceptable performance of the turbine. However, trace metals, even in fractional parts per million, are detrimental to gas turbine service life. Information on the maximum concentration of critical metallic elements in the fuel as it enters the turbine combustor(s) is provided in **Appendix X2**. Distillate fuels are usually of satisfactory purity as refined, but suppliers rarely have control over possible contamination by trace metals in distribution and storage. The limits in **Appendix X2**, although required as the fuel enters the combustor(s), do not apply to the fuel as delivered unless mutually agreed upon by the interested parties. Fuels may, therefore, require on-site clean-up, quality control procedures, special handling, or other arrangements.

6. Test Methods

6.1 The requirements enumerated in this specification shall be determined in accordance with the following ASTM methods except as noted:

6.1.1 *Flash Point*—Test Methods **D93**, except where other methods are prescribed by law. For all grades, Test Method **D3828** may be used as an alternate with the same limits. For

³ Available from Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.

TABLE 1 Detailed Requirements for Gas Turbine Fuel Oils at Time and Place of Custody Transfer to User^{A,B,C}

Property	ASTM Test Method ^D	Grade ^E				
		No. 0-GT	No. 1-GT ^F	No. 2-GT ^F	No. 3-GT	No. 4-GT
Flash point °C (°F) min	D93	^G	38 (100)	38 (100)	55 (130)	66 (150)
Water and sediment % vol max	D2709 D1796	0.05 ...	0.05 ...	0.05 ...	... 1.0	... 1.0
Distillation Temperature °C (°F)	D86					
90 % volume recovered min max		... ...	... 288	282 338	......	......
Kinematic viscosity 2 mm ² /s ^H	D445					
AT 40°C (104°F) min max		^G ...	1.3 2.4	1.9 4.1	5.5 ...	5.5 ...
AT 100°C (212°F) max Ramsbottom			...	...	50.0	50.0
Carbon residue on 10 % distillation Residue % mass, max	D524	0.15	0.15	0.35	...	...
Ash % mass, max	D482 D1298	0.01	0.01	0.01	0.03	...
Density at 15°C kg/m ³ max		...	850	876	...	...
Pour point ^H °C (°F) max	D97	...	-18	-6	...	...

^A To meet special operating conditions, modifications of individual limiting requirements may be agreed upon between purchaser, seller, and manufacturer.

^B Gas turbines with waste heat recovery equipment may require fuel sulfur limits to prevent cold end corrosion. Environmental limits may also apply to fuel sulfur in selected areas in the United States and in other countries.

^C See Section 4 and 5 for further statements on gas turbine fuel oil requirements.

^D The test methods indicated are the approved referee methods. Other acceptable methods are indicated in 6.1.

^E No. 0-GT includes naphtha, Jet B fuel and other volatile hydrocarbon liquids. No. 1-GT corresponds in general to specification **D396** Grade No. 1 fuel and **D975** Grade 1-D diesel fuel in physical properties. No. 2-GT corresponds in general to Specification **D396** No. 2 fuel and **D975** Grade 2-D diesel fuel in physical properties. No. 3-GT and No. 4-GT viscosity range brackets specification **D396** Grades No. 4, No. 5 (light), No. 5 (heavy), and No. 6, and **D975** Grade No. 4-D diesel fuel in physical properties.

^F Under United States regulations, Grades No. 1-GT and No. 2-GT are required by 40 CFR Part 80 to contain a sufficient amount of dye Solvent Red 164 so its presence is visually apparent. At or beyond terminal storage tanks, they are required by 26 CFR Part 48 to contain the dye Solvent Red 164 at a concentration spectrally equivalent to 3.9 lb per thousand barrels of the solid dye standard Solvent Red 26.

^G When the flash point is below 38°C (100°F) or when kinematic viscosity is below 1.3 mm²/s at 40°C (104°F) or when both conditions exist, the turbine manufacturer should be consulted with respect to safe handling and fuel system design.

^H For cold weather operation, the pour point should be specified 6°C below the ambient temperature at which the turbine is to be operated except where fuel heating facilities are provided. When a pour point less than -18°C is specified for Grade No. 2-GT, the minimum viscosity shall be 1.7 mm²/s and the minimum 90 % recovered temperature shall be waived.

Grades No. 1-GT and No. 2-GT, Test Method **D56⁴** may be used as an alternative with the same limits provided the flash point is below 93°C and the viscosity is below 5.5 mm²/s at 40°C. This test method will give slightly lower values. In case of dispute, Test Method **D93** shall be used as the referee method.

6.1.2 *Pour Point*—Test Method **D97**. For all grades, the automatic Test Methods **D5949**, **D5950**, or **D5985** can be used as alternates with the same limits. In case of dispute, Test Method **D97** shall be used as the referee method.

6.1.3 *Water and Sediment*—Test Method **D2709** is used for Grades 0-GT, 1-GT, and 2-GT. Test Method **D1796** is used for Grades 3-GT and 4-GT.

6.1.4 *Carbon Residue*—Test Method **D524**.

6.1.5 *Ash*—Test Method **D482**.

6.1.6 *Distillation*—Test Method **D86**.

6.1.7 *Viscosity*—Test Method **D445**.

6.1.8 *Density*—Test Method **D1298** or **D4052**.

6.1.9 *Sulfur*—Test Method **D129**, Test Methods **D1552**,⁵ **D2622**, and **D4294** can also be used for all grades. In addition, Test Method **D1266** can be used for Grades No. 0 and No. 1, but only with samples having sulfur contents of 0.4 mass percent and less (down to 0.01 %). Test Method **D5453** can be used for Grades 0, 1, and 2 GT oils, but only with samples having sulfur contents of 0.8 mass % and less (down to 0.001 %). Test Method **D7220** may be used for Grades 0, 1, and 2 GT oils, but only with samples having sulfur contents of 0.942 mass % and less (down to 0.0003 %). Test Method **D129** is the referee sulfur test method for Specification D2880.

7. Keywords

7.1 fuel oils; gas turbine; petroleum and petroleum products

⁵ For information on the precision of the ASTM methods of test for fuel oils refer to “An Evaluation of Methods for Determination of Sulfur in Fuel Oils” by A. R. Crawford and G. V. Dyroff (1969). This document is available from the Publications Section, American Petroleum Institute, 1220 L St., N.W., Washington, DC 20005.

⁴ Other mutually acceptable methods may be used.