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Standard Specification for 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 (see Note 1) covers grades of fuel oil intended for use in various types of fuel-oil-burning equipment under various climatic and operating conditions. These grades are described as follows:

1.1.1 Grades No. 1 S5000, No. 1 S500, No. 2 S5000, and No. 2 S500 are middle distillate fuels for use in domestic and small industrial burners. Grades No. 1 S5000 and No. 1 S500 are particularly adapted to vaporizing type burners or where storage conditions require low pour point fuel.

1.1.2 Grades No. 4 (Light) and No. 4 are heavy distillate fuels or middle distillate/residual fuel blends used in commercial/industrial burners equipped for this viscosity range.

1.1.3 Grades No. 5 (Light), No. 5 (Heavy), and No. 6 are residual fuels of increasing viscosity and boiling range, used in industrial burners. Preheating is usually required for handling and proper atomization.

NOTE 1—For information on the significance of the terminology and test methods used in this specification, see Appendix X1.

NOTE 2—A more detailed description of the grades of fuel oils is given in X1.3.

1.2 This specification is for the use of purchasing agencies in formulating specifications to be included in contracts for purchases of fuel oils and for the guidance of consumers of fuel oils in the selection of the grades most suitable for their needs.

1.3 Nothing in this specification shall preclude observance of federal, state, or local regulations which can be more restrictive.

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

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

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

D95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation

D97 Test Method for Pour Point of Petroleum Products

D129 Test Method for Sulfur in Petroleum Products (General Bomb Method)

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)

D473 Test Method for Sediment in Crude Oils and Fuel Oils by the Extraction Method

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 (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

D1552 Test Method for Sulfur in Petroleum Products (High-Temperature 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.E0 on Burner, Diesel, Non-Aviation Gas Turbine, and Marine Fuels.

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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.

- D2500 Test Method for Cloud Point of Petroleum Products
- 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
- D2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
- D3245 Test Method for Pumpability of Industrial Fuel Oils
- D3828 Test Methods for Flash Point by Small Scale Closed Cup Tester
- 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
- D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products
- D4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry
- D4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
- 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
- D5842 Practice for Sampling and Handling of Fuels for Volatility Measurement
- D5854 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products
- 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
- D6749 Test Method for Pour Point of Petroleum Products (Automatic Air Pressure Method)
- D6751 Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels
- D6892 ~~Test Method for Pour Point of Petroleum Products (Robotic Tilt Method)~~ Test Method for Pour Point of Petroleum Products (Robotic Tilt Method)
- D7039 Test Method for Sulfur in Gasoline and Diesel Fuel by Monochromatic Wavelength Dispersive X-ray Fluorescence Spectrometry

2.2 Other Documents:

- 26 CFR Part 48 Diesel Fuel Excise Tax; Dye Color and Concentration³
- 40 CFR Part 80 Regulation of Fuel and Fuel Additives³
- EN 14078 Determination of fatty acid methyl ester (FAME) content in middle distillates — Infrared spectrometry method⁴

3. Terminology

3.1 Definitions:

- 3.1.1 *biodiesel*, *n*—fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100.
- 3.1.2 *biodiesel blend (BXX)*, *n*—blend of biodiesel fuel with fuel oils.
 - 3.1.2.1 *Discussion*—In the abbreviation BXX, the XX represents the volume percentage of biodiesel fuel in the blend.

4. General Requirements

- 4.1 The grades of fuel oil specified herein shall be homogeneous hydrocarbon based oils, free from inorganic acid, and free from excessive amounts of solid or fibrous foreign matter.
- 4.2 All grades containing residual components shall remain uniform in normal storage and not separate by gravity into light and heavy oil components outside the viscosity limits for the grade.
- 4.3 *Fuels Blended with Biodiesel*—The detailed requirements for fuels blended with biodiesel shall be as follows:
 - 4.3.1 *Biodiesel for Blending*—If biodiesel is a component of any fuel oil, the biodiesel shall meet the requirements of Specification D6751.
 - 4.3.2 Fuel oil containing up to 5 vol% biodiesel shall meet the requirements for the appropriate grade No. 1 or No. 2 fuel as listed in Table 1.
 - 4.3.3 Test Method EN 14078 shall be used for determination of the vol% biodiesel in a biodiesel blend.
 - 4.3.4 Fuel oils containing more than 5 vol% biodiesel component are not included in this specification.
 - 4.3.5 Biodiesel blends with Grades 4, 5, or 6 are not covered by this specification.

5. Detailed Requirements

- 5.1 The various grades of fuel oil shall conform to the limiting requirements shown in Table 1. A representative sample shall be taken for testing in accordance with Practice D4057.

³ Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

⁴ Available from the National CEN members listed on the CEN website (www.cenorm.be) or from the CEN/TC 19 Secretariat (astm@nen.nl).

TABLE 1 Detailed Requirements for Fuel Oils^A

Property	ASTM Test Method ^B	No. 1 S500 ^B	No. 1 S5000 ^B	No. 2 S500 ^B	No. 2 S5000 ^B	Grade No. 4 (Light) ^B	No. 4	No. 5 (Light)	No. 5 (Heavy)	No. 6
Flash Point, °C, min	D93 – Proc. A	38	38	38	38	38	...	...	...	...
	D93 – Proc. B	...	...	...	...	...	55	55	55	60
Water and sediment, % vol, max	D2709	0.05	0.05	0.05	0.05	...	...	...	...	...
	D95 + D473	...	...	...	...	(0.50) ^C	(0.50) ^C	(1.00) ^C	(1.00) ^C	(2.00) ^C
Distillation Temperature, °C	D86									
10 % volume recovered, max		215	215	...	...			
90 % volume recovered, min		...	...	282	282					
90 % volume recovered, max		288	288	338	338					
Kinematic viscosity at 40°C, mm ² /s	D445									
min		1.3	1.3	1.9	1.9	1.9	>5.5	...	...	...
max		2.4	2.4	4.1	4.1	5.5	24.0 ^D			
Kinematic viscosity at 100°C, mm ² /s	D445									
min		...	...	...	...	...	...	5.0	9.0	15.0
max		...	...	...	...	...	...	8.9 ^D	14.9 ^D	50.0 ^D
Ramsbottom carbon residue on 10 % distillation residue % mass, max	D524	0.15	0.15	0.35	0.35	...	...	...	...	...
Ash, % mass, max	D482	...	...	...	...	0.05	0.10	0.15	0.15	...
Sulfur, % mass max ^E	D429	...	0.50	...	0.50	...	...	...	...	...
Sulfur, % mass max ^E	D129	...	0.5	...	0.5	...	...	...	...	...
	D2622	0.05	...	0.05	...	...	...	...	...	...
	D2622	0.05	...	0.05	...	...	...	...	...	...
Copper strip corrosion rating, max, 3 h at a minimum control temperature of 50°C	D130	No. 3	No. 3	No. 3	No. 3	...	...	...	...	...
Density at 15°C, kg/m ³	D1298									
min		...	...	...	...	>876 ^F	...	...	...	...
max		850	850	876	876	...	...	...	...	...
Pour Point °C, max ^G	D97	-18	-18	-6	-6	-6	-6	...	...	H

^A It is the intent of these classifications that failure to meet any requirement of a given grade does not automatically place an oil in the next lower grade unless in fact it meets all requirements of the lower grade. However, to meet special operating conditions, modifications of individual limiting requirements may be agreed upon among the purchaser, seller, and manufacturer.

^B Under United States regulations, Grades No. 1 S5000, No. 1 S500, No. 2 S5000, No. 2 S500, and No. 4 (Light) are required by 40 CFR Part 80 to contain a sufficient amount of the 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.

^C The amount of water by distillation by Test Method D95 plus the sediment by extraction by Test Method D473 shall not exceed the value shown in the table. For Grade No. 6 fuel oil, the amount of sediment by extraction shall not exceed 0.50 mass %, and a deduction in quantity shall be made for all water and sediment in excess of 1.0 mass %.

^D Where low sulfur fuel oil is required, fuel oil falling in the viscosity range of a lower numbered grade down to and including No. 4 can be supplied by agreement between the purchaser and supplier. The viscosity range of the initial shipment shall be identified and advance notice shall be required when changing from one viscosity range to another. This notice shall be in sufficient time to permit the user to make the necessary adjustments.

^E Other sulfur limits may apply in selected areas in the United States and in other countries.

^F This limit ensures a minimum heating value and also prevents misrepresentation and misapplication of this product as Grade No. 2.

^G Lower or higher pour points can be specified whenever required by conditions of storage or use. When a pour point less than -18°C is specified, the minimum viscosity at 40°C for grade No. 2 shall be 1.7 mm²/s and the minimum 90 % recovered temperature shall be waived.

^H Where low sulfur fuel oil is required, Grade No. 6 fuel oil will be classified as Low Pour (+15°C max) or High Pour (no max). Low Pour fuel oil should be used unless tanks and lines are heated.

5.2 Modifications of limiting requirements to meet special operating conditions agreed upon between the purchaser, the seller, and the supplier shall fall within limits specified for each grade, except as stated in supplementary footnotes for Table 1.

6. Sampling, Containers, and Sample Handling

6.1 The reader is strongly advised to review all intended test methods prior to sampling in order to understand the importance and effects of sampling technique, proper containers, and special handling required for each test method.

6.2 Correct sampling procedures are critical to obtaining a sample representative of the fuel oil to be tested. Refer to X1.4 for recommendations. The recommended procedures or practices provide techniques useful in the proper sampling or handling of fuels oils.

7. Test Methods

7.1 The requirements enumerated in this specification shall be determined in accordance with the following ASTM test methods,⁵ except as may be required under 7.1.1.

7.1.1 *Flash Point*—Test Method D93 (Procedure A) for Grades No. 1 S5000, No. 1 S500, No. 2 S5000, No. 2 S500, and No. 4 (Light), and Test Method D93 (Procedure B) for Grades No. 4, No. 5 (Light), No. 5 (Heavy), and No. 6, except where other

⁵ For information on the precision of the ASTM test methods for fuel oils refer to “An Evaluation of Methods for Determination of Sulfur in Fuel Oils” by A. R. Crawford, Esso Mathematics and Systems Inc. and G. V. Dyroff, Esso Research and Engineering Co., 1969. This document is available from the Publications Section, API Library, American Petroleum Institute, 1220 L St., NW, Washington, DC 20005.

methods are prescribed by law. For Grades No. 1 S5000, No. 1 S500, No. 2 S5000, No. 2 S500, and No. 4 (Light), Test Methods D3828 may be used as an alternate with the same limits. For Grades No. 1, No. 1 Low Sulfur, No. 2, and No. 2 Low Sulfur, Test Method D56 may be used as an alternate 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 cases of dispute, Test Method D93, with the appropriate procedure, shall be used as the referee method.

7.1.2 *Pour Point*—Test Method D97. For all grades, the automatic Test Methods D5949, D5950, D5985, D6749, and D6892 can be used as alternates with the same limits. In case of dispute, Test Method D97 shall be used as the referee method. Alternative test methods that indicate flow point properties can be used for low sulfur residual fuels by agreement between purchaser and supplier.

7.1.3 *Water and Sediment*—The water and sediment in Grade No. 1 S500, No. 1 S5000, No. 2 S500, and No. 2 S5000 shall be determined in accordance with Test Method D2709 and in Grade Nos. 4, 5, and 6 by Test Method D95 and Test Method D473. A density of 1.0 kg/L shall be used for the Test Method D95 water.

7.1.4 *Carbon Residue*—Test Method D524.

7.1.5 *Ash*—Test Method D482.

7.1.6 *Distillation*—Distillation of Grade No. 1 and No. 2 oils shall be determined in accordance with Test Methods D86 or D2887.⁶ Results from Test Method D2887 shall be reported as “Predicted D86” results by application of the correlation in Appendix X5 Test Method D2887 to convert the values. In case of dispute, Test Method D86 shall be used as the referee test method.

7.1.7 *Viscosity*—Viscosity shall be determined in accordance with Test Method D445.

7.1.8 *Density*—Test Method D1298. Test Method D4052 can be used as an alternate with the same limits. In case of dispute, Test Method D1298 shall be used as the referee method.

7.1.9 *Corrosion*—Test Method D130, 3-h test at a minimum control temperature of 50°C.

7.1.10 *Sulfur*—Test Method D129 for Grades 1, 2, 4, 5, and 6 and Test Method D2622 for Grades No. 1 S500 and No. 2 S500. Test Methods D1552, D2622, and D4294 can also be used for all grades. In addition, Test Method D1266 can be used for Grade No. 1 S5000, but only with samples having sulfur contents of 0.4 mass % and less (down to 0.01%). Test Method D5453 can be used for Grades 1 and 2 fuel oils, but only with samples having sulfur contents of 0.8 mass% and less (down to 0.001%). In case of dispute, Test Method D129 is the referee test method for Grades 1, 2, 4, 5, and 6 of this specification and Test Method D2622 is the referee test method for Grades No. 1 S500 and No. 2 S500. —Table 2 shows the referee test methods and alternate test methods for sulfur, the range over which each test applies, and the corresponding fuel grades.

8. Keywords

8.1 biodiesel; biodiesel blend; burner fuels; fuel oils; furnace oils; petroleum and petroleum products

APPENDIX 09a

<https://standards.iteh.ai/catalog/standards/sist/0306-772-94ae-4443-b833-ed84b782508d/astm-d396-09a>
(Nonmandatory Information)

X1. SIGNIFICANCE OF ASTM SPECIFICATION FOR FUEL OILS

X1.1 Scope

X1.1.1 This specification divides fuel oils into grades based upon the types of burners for which they are suitable. It places limiting values on several of the properties of the oils in each grade. The properties selected for limitation are those that are believed to be of the greatest significance in determining the performance characteristics of the oils in the types of burners in which they are most commonly used.

⁶ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report D02-1553.

TABLE 2 Sulfur Test Methods

Sulfur Test Method	Range	Grades	Units Used to Report Results
D129 (referee)	>0.1 mass%	No. 1 S5000, No. 2 S5000, No. 4 (Light), No. 5 (Heavy), No. 6	mass%
D1266	0.01 to 0.4 mass%	No. 1 S500, No. 2 S500	mass%
D1552	>0.06 mass%	No. 1 S5000, No. 2 S5000, No. 4 (Light), No. 4, No. 5 (Light), No. 5 (Heavy), No. 6	mass%
D2622 (referee for S500 grades)	0.0003 to 5.3 mass%	All Grades	mass%
D4294	0.0150 to 5.00 mass%	All Grades	mass%
D5453	1.0 to 8000 mg/kg (0.0001 to 0.8 mass%)	All Grades	mg/kg
D7039	4 to 17 mg/kg (0.0004 to 0.0017 mass%)	S500 grades only if the sulfur result is less than 17 mg/kg	mg/kg