



## Standard Specification for Fuel Oils<sup>1</sup>

This standard is issued under the fixed designation D 396; 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 approval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*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 **D 4865**.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.E0.01 on Burner Fuels.

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### 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

**D 56** Test Method for Flash Point by Tag Closed Cup Tester

**D 86** Test Method for Distillation of Petroleum Products at Atmospheric Pressure

**D 93** Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

**D 95** Test Method for Water in Petroleum Products and Bituminous Materials by Distillation

**D 97** Test Method for Pour Point of Petroleum Products

**D 129** Test Method for Sulfur in Petroleum Products (General Bomb Method)

**D 130** Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test

**D 445** Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

**D 473** Test Method for Sediment in Crude Oils and Fuel Oils by the Extraction Method

**D 482** Test Method for Ash from Petroleum Products

**D 524** Test Method for Ramsbottom Carbon Residue of Petroleum Products

**D 975** Specification for Diesel Fuel Oils

**D 1266** Test Method for Sulfur in Petroleum Products (Lamp Method)

**D 1298** Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

**D 1552** Test Method for Sulfur in Petroleum Products (High-Temperature Method)

**D 2500** Test Method for Cloud Point of Petroleum Products

**D 2622** Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry

**D 2709** Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge

**D 2887** Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography

<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.

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



- D 3245 Test Method for Pumpability of Industrial Fuel Oils
  - D 3828 Test Methods for Flash Point by Small Scale Closed Cup Tester
  - D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter
  - D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products
  - D 4177 Practice for Automatic Sampling of Petroleum and Petroleum Products
  - D 4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy-Dispersive X-ray Fluorescence Spectrometry
  - D 4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
  - D 4865 Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems
  - D 5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
  - D 5842 Practice for Sampling and Handling of Fuels for Volatility Measurement
  - D 5854 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products
  - D 5949 Test Method for Pour Point of Petroleum Products (Automatic Pressure Pulsing Method)
  - D 5950 Test Method for Pour Point of Petroleum Products (Automatic Tilt Method)
  - D 5985 Test Method for Pour Point of Petroleum Products (Rotational Method)
  - D 6469 Guide for Microbial Contamination in Fuels and Fuel Systems
- 2.2 Other Documents:<sup>3</sup>
- 26 CFR Part 48 Diesel Fuel Excise Tax; Dye Color and Concentration
  - 40 CFR Part 80 Regulation of Fuel and Fuel Additives

### 3. General Requirements

3.1 The grades of fuel oil specified herein shall be homogeneous hydrocarbon oils, free from inorganic acid, and free from excessive amounts of solid or fibrous foreign matter.

3.2 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. Detailed Requirements

4.1 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 D 4057.

4.2 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.

### 5. Sampling, Containers, and Sample Handling

5.1 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.

5.2 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.

### 6. Test Methods

6.1 The requirements enumerated in this specification shall be determined in accordance with the following ASTM test methods,<sup>4</sup> except as may be required under 6.1.1.

6.1.1 *Flash Point*—Test Method D 93 (Procedure A) for Grades No. 1 S5000, No. 1 S500, No. 2 S5000, No. 2 S500, and No. 4 (Light), and Test Method D 93 (Procedure B) for Grades No. 4, No. 5 (Light), No. 5 (Heavy), and No. 6, except where other 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 D 3828 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 D 56 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 mm<sup>2</sup>/s at 40°C. This test method will give slightly lower values. In cases of dispute, Test Method D 93, with the appropriate procedure, shall be used as the referee method.

6.1.2 *Pour Point*—Test Method D 97. For all grades, the automatic Test Methods D 5949, D 5950, and D 5985 can be used as alternates with the same limits. In case of dispute, Test Method D 97 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.

6.1.3 *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 D 2709 and in Grade Nos. 4, 5, and 6 by Test Method D 95 and Test Method D 473. A density of 1.0 kg/L shall be used for the Test Method D 95 water.

6.1.4 *Carbon Residue*—Test Method D 524.

6.1.5 *Ash*—Test Method D 482.

6.1.6 *Distillation*—Distillation of Grade No. 1 and No. 2 oils shall be determined in accordance with Test Methods D 86 or D 2887.<sup>5</sup> In case of dispute, Test Method D 86 shall be used as the referee test method.

6.1.7 *Viscosity*—Viscosity shall be determined in accordance with Test Method D 445.

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

<sup>4</sup> 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.

<sup>5</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02-1553.



**TABLE 1 Detailed Requirements for Fuel Oils<sup>A</sup>**

Property	ASTM Test Method <sup>B</sup>	No. 1 S500 <sup>B</sup>	No. 1 S5000 <sup>B</sup>	No. 2 S500 <sup>B</sup>	No. 2 S5000 <sup>B</sup>	Grade No. 4 (Light) <sup>B</sup>	No. 4	No. 5 (Light)	No. 5 (Heavy)	No. 6
Flash Point °C, min	D 93 – Proc. A D 93 – Proc. B	38 ...	38 ...	38 ...	38 ...	38 ...	... 55	... 55	... 55	... 60
Water and sediment, % vol, max	D 2709 D 95 + D 473	0.05 ...	0.05 ...	0.05 ...	0.05 ...	... (0.50) <sup>C</sup>	... (0.50) <sup>C</sup>	... (1.00) <sup>C</sup>	... (1.00) <sup>C</sup>	... (2.00) <sup>C</sup>
Distillation—one of the following requirements shall be met:										
1. Physical Distillation <b>D 86</b>										
Distillation Temperature, °C										
10 % volume recovered, max		215	215	...	...					
90 % volume recovered, min		...	...	282	282					
90 % volume recovered, max		288	288	338	338					
2. Simulated Distillation <sup>D</sup> <b>D 2887</b>										
Distillation Temperature, °C										
10 % volume recovered, max		195	195	...	...					
90 % volume recovered, min		...	...	300	300					
90 % volume recovered, max		304	304	356	356					
Kinematic viscosity at 40°C, mm <sup>2</sup> /s										
min	D 445	1.3	1.3	1.9	1.9	1.9	>5.5	...	...	...
max		2.1	2.1	3.4	3.4	5.5	24.0 <sup>E</sup>			
Kinematic viscosity at 100°C, mm <sup>2</sup> /s										
min	D 445	...	...	...	...	...	...	5.0	9.0	15.0
max		...	...	...	...	...	...	8.9 <sup>E</sup>	14.9 <sup>E</sup>	50.0 <sup>E</sup>
Ramsbottom carbon residue on 10 % distillation residue % mass, max	D 524	0.15	0.15	0.35	0.35	...	...	...	...	...
Ash, % mass, max	D 482	...	...	...	...	0.05	0.10	0.15	0.15	...
Sulfur, % mass max <sup>F</sup>	D 129	...	0.50	...	0.50	...	...	...	...	...
	D 2622	0.05	...	0.05	...	...	...	...	...	...
Copper strip corrosion rating, max, 3 h at 50°C	D 130	No. 3	No. 3	No. 3	No. 3	...	...	...	...	...
Density at 15°C, kg/m <sup>3</sup>										
min	D 1298	...	...	...	...	>876 <sup>G</sup>	...	...	...	...
max		850	850	876	876	...	...	...	...	...
Pour Point °C, max <sup>H</sup>	D 97	-18	-18	-6	-6	-6	-6	...	...	...

<sup>A</sup> 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.

<sup>B</sup> 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.

<sup>C</sup> The amount of water by distillation by Test Method D 95 plus the sediment by extraction by Test Method D 473 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 %.

<sup>D</sup> Test Method D 2887, Simulated Distillation, was determined to be an acceptable alternative test method to Test Method D 86, Physical Distillation, based on Research Report RR:D02-1553. This report has been filed at ASTM International Headquarters and may be obtained by request.

<sup>E</sup> 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.

<sup>F</sup> Other sulfur limits may apply in selected areas in the United States and in other countries.

<sup>G</sup> This limit ensures a minimum heating value and also prevents misrepresentation and misapplication of this product as Grade No. 2.

<sup>H</sup> 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 mm<sup>2</sup>/s and the minimum 90 % recovered temperature shall be waived.

<sup>I</sup> 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.

6.1.8 *Density*—Test Method D 1298. Test Method D 4052 can be used as an alternate with the same limits. In case of dispute, Test Method D 1298 shall be used as the referee method.

6.1.9 *Corrosion*—Test Method D 130, 3 h test at 50°C.

6.1.10 *Sulfur*—Test Method D 129 for Grades 1, 2, 4, 5, and 6 and Test Method D 2622 for Grades No. 1 S500 and No. 2 S500. Test Methods D 1552, D 2622, and D 4294 can also be used for all grades. In addition, Test Method D 1266 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 D 5453 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 D 129 is the referee test method for Grades 1, 2, 4, 5, and 6 of this specification and Test Method D 2622 is the referee test method for Grades No. 1 S500 and No. 2 S500.

## 7. Keywords

7.1 burner fuels; fuel oils; furnace oils; petroleum and petroleum products