



Designation: **D396—12 D396 – 13**

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 High Pressure Decomposition Device 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, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer 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

- D1552 Test Method for Sulfur in Petroleum Products (High-Temperature Method)
- 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
- 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)
- D7039 Test Method for Sulfur in Gasoline and Diesel Fuel by Monochromatic Wavelength Dispersive X-ray Fluorescence Spectrometry
- D7220 Test Method for Sulfur in Automotive, Heating, and Jet Fuels by Monochromatic Energy 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 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).

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.

TABLE 1 Detailed Requirements for Fuel Oils^{A,B}

Property	ASTM Test Method ^C	No. 1 S500 ^C	No. 1 S5000 ^C	No. 2 S500 ^C	No. 2 S5000 ^C	No. 4 (Light) ^C	No. 4	No. 5 (Light) ^D	No. 5 (Heavy) ^D	No. 6
Flash Point, °C, min	D93 – Proc. A D93 – Proc. B	38 ...	38 ...	38 ...	38 ...	38...	...	...	...	...
Water and sediment, % vol, max	D2709 D95 + D473	0.05 ...	0.05 ...	0.05 ...	0.05 ...	...	55 (0.50) ^D	55 (1.00) ^D	55 (1.00) ^D	60 (2.00) ^D
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 ^E			
Kinematic viscosity at 100°C, mm ² /s	D445									
min		...	...	...	...	...	...	5.0	9.0	15.0
max		...	...	...	...	...	...	8.9 ^E	14.9 ^E	50.0 ^E
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 ^F	D129 D2622	...	0.5 ...	...	0.5...	...	...	...	...	...
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 ^G	...	...	...	...
max		850	850	876	876	...	...	...	...	...
Pour Point °C, max ^H	D97	-18	-18	-6	-6	-6	-6	...	...	...

^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 Refer to 7.1.2.1 for Low Temperature guidance for <1000 gal outside or unheated storage containers for the United States.

^C 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.

^D 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 %.

^E 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.

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

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

^H 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.

^I 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.

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.

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 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.

7.1.2.1 The maximum Pour Point limits specified in **Table 1** should be adequate under most circumstances for shipment and use of Fuel Oil from April through September and in operations year round where larger storage tanks (>1000 gallons) are in use and appropriate consideration has been given to operating conditions as described in **X2.1.2**.

7.1.2.2 **Table 2** lists 10th percentile ambient temperatures as guidance for smaller Fuel Oil storage conditions (<1000 gallons in outside or unheated storage) in the United States (see **X2.1.3**, Current Practices). Appropriate low temperature operability properties should be agreed upon between the fuel supplier and purchaser for the intended use and expected ambient temperatures. The 10th percentile ambient temperatures are divided by month (October through March) and by state or by specific portion of a state. Smaller storage containers are commonly used and stored outside in home heating oil applications (275 gal and 550 gal outside storage tanks are typical).

7.1.2.3 The low temperature recommendations discussed in **X2.1.3** may be met by Test Method **D2500** Cloud Point (or an approved alternate test method) or by Test Method **D97** Pour Point (or an approved alternate test method). If Pour Point is used then the difference between the Cloud Point and the Low Temperature guidance found in **Table 2** should not exceed 10°C.

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*—**Table 3** 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

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.

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

TABLE 2 Tenth Percentile Minimum Ambient Air Temperatures in °C for the United States (except Hawaii)

State		Oct.	Nov.	Dec.	Jan.	Feb.	March
Alabama		4	-3	-6	-7	-3	-2
Alaska							
	Northern	-25	-37	-45	-49	-47	-43
	Southern	-11	-13	-18	-32	-32	-29
	South East	-4	-11	-16	-19	-13	-12
Arizona							
	North 34° latitude	-4	-12	-14	-17	-16	-12
	South 34° latitude	7	0	-2	-4	-3	-1
Arkansas		2	-4	-7	-11	-7	-3
California							
	North Coast	3	0	-2	-2	-1	-1
	Interior	2	-3	-4	-7	-6	-6
	South Coast	6	2	0	-1	0	2
	Southeast	1	-6	-8	-11	-7	-5
Colorado							
	East 105° long	-2	-12	-14	-19	-15	-12
	West 105° long	-8	-18	-25	-30	-24	-16
Connecticut		-1	-7	-16	-17	-16	-9
Delaware		2	-3	-10	-11	-10	-6
Florida							
	North 29° latitude	7	1	-2	-3	-1	2
	South 29° latitude	14	7	3	3	5	7
Georgia		3	-2	-6	-7	-6	-2
Idaho		-4	-13	-18	-21	-18	-13
Illinois							
	North 40° latitude	-1	-9	-19	-21	-18	-11
	South 40° latitude	1	-7	-16	-17	-15	-8
Indiana		-1	-7	-16	-18	-16	-9
Iowa		-2	-13	-23	-26	-22	-16
Kansas		-2	-11	-15	-19	-14	-13
Kentucky		1	-6	-13	-14	-11	-6
Louisiana		5	-1	-3	-4	-2	1
Maine		-3	-10	-23	-26	-26	-18
Maryland		2	-3	-10	-12	-10	-4
Massachusetts		-2	-7	-16	-18	-17	-10
Michigan		-2	-11	-20	-23	-23	-18
Minnesota		-4	-18	-30	-34	-31	-24
Mississippi		3	-3	-6	-6	-4	-1
Missouri		1	-7	-14	-16	-13	-8
Montana		-7	-18	-24	-30	-24	-21
Nebraska		-3	-13	-18	-22	-19	-13
Nevada							
	North 38° latitude	-7	-14	-18	-22	-18	-13
	South 38° latitude	8	0	-3	-4	-2	1
New Hampshire		-3	-8	-18	-21	-21	-12
New Jersey		2	-3	-11	-12	-11	-6
New Mexico							
	North 34° latitude	-2	-11	-14	-17	-14	-11
	South 34° latitude	4	-4	-8	-11	-7	-3
New York							
	North 42° latitude	-3	-8	-21	-24	-24	-16
	South 42° latitude	-1	-5	-14	-16	-15	-9
North Carolina		-1	-7	-10	-11	-9	-5
North Dakota		-4	-20	-27	-31	-29	-22
Ohio		-1	-7	-16	-17	-15	-9
Oklahoma		1	-8	-12	-13	-8	-7
Oregon							
	East 122° long	-6	-11	-14	-19	-14	-9
	West 122° long	0	-4	-5	-7	-4	-3
Pennsylvania							
	North 41° latitude	-3	-8	-19	-20	-21	-15
	South 41° latitude	0	-6	-13	-14	-14	-8
Rhode Island		1	-3	-12	-13	-13	-7
South Carolina		5	-1	-5	-5	-3	-2
South Dakota		-4	-14	-24	-27	-24	-18
Tennessee		1	-5	-9	-11	-9	-4
Texas							
	North 31° latitude	3	-6	-9	-13	-9	-7
	South 31° latitude	9	2	-2	-3	-1	2
Utah		-2	-11	-14	-18	-14	-8
Vermont		-3	-8	-20	-23	-24	-15
Virginia		2	-3	-9	-11	-9	-4
Washington							
	East 122° long	-2	-8	-11	-18	-11	-8
	West 122° long	0	-3	-3	-7	-4	-3

TABLE 2 *Continued*

State	Oct.	Nov.	Dec.	Jan.	Feb.	March
West Virginia	-3	-8	-15	-16	-14	-9
Wisconsin	-3	-14	-24	-28	-24	-18
Wyoming	-4	-15	-18	-26	-19	-16

TABLE 3 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
D7220	3 to 942 mg/kg (0.0003 to 0.0942 mass%)	S500 grades	mg/kg

APPENDIXES

(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.

X1.2 Classes

X1.2.1 Because of the methods employed in their production, fuel oils fall into two broad classifications: distillates and residuals. The distillates consist of overhead or distilled fractions. The residuals are bottoms remaining from the distillation, or blends of these bottoms with distillates. In this specification, Grades No. 1 and No. 2 are distillates and the grades from No. 4 to No. 6 are usually residual, although some heavy distillates can be sold as Grade No. 4.

X1.3 Grades

X1.3.1 *Grades No. 1 S5000 and No. 1 S500* are middle distillates intended for use in burners of the vaporizing type in which the oil is converted to a vapor by contact with a heated surface or by radiation. High volatility is necessary to ensure that evaporation proceeds with a minimum of residue. The low sulfur grade S500 may be specified by federal, state, or local regulations and can result in reduced deposits on ferrous heat exchanger surfaces compared to Grade No. 1 S5000 when burned under similar conditions.

X1.3.2 *Grades No. 2 S5000 and No. 2 S500* are middle distillates somewhat heavier than grades No. 1 S5000 and No. 1 S500. They are intended for use in atomizing type burners which spray the oil into a combustion chamber where the tiny droplets burn while in suspension. These grades of oil are used in most domestic burners and in many medium capacity commercial-industrial burners where ease of handling and ready availability sometimes justify higher cost over the residual fuels. The low sulfur grade