



Standard Specification for Fuel Oils¹

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This standard has been approved for use by agencies of the U.S. 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**.

¹ 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.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
- 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
- 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

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

- 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, Diesel Fuel, Jet Fuel, Kerosine, Biodiesel, Biodiesel Blends, and Gasoline-Ethanol Blends by Monochromatic Wavelength Dispersive X-ray Fluorescence Spectrometry
- D7042** Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
- D7094** Test Method for Flash Point by Modified Continuously Closed Cup (MCCCFP) Tester
- 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.

3.1.2.1 *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**.

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.

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,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)	No. 5 (Heavy)	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 D86	0.05	0.05	0.05	0.05	...	55	55	55	60
Distillation Temperature, °C						(0.50) ^D	(0.50) ^D	(1.00) ^D	(1.00) ^D	(2.00) ^D
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	D2622	0.05	0.5	0.05	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.

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** and **D7094** may be used as an alternative 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 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 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

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.

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**. Bias-corrected values from Test Method **D7042** may be used as alternative results for Test Method **D445** on Grades No. 1 and No. 2 with the same limits. Section 15 of Test Method **D7042** contains bias-correction information. In case of dispute, Test Method **D445** shall be used as the referee method.

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 **D2622**. See **Table 3** for alternate test methods for sulfur, the range over which each applies, and the corresponding fuel grades.

8. Keywords

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

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
D2622 (referee for all grades)	0.0003 to 5.3 mass%	All Grades	mass%
D129	>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%
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 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. 2 S5000 when burned under similar conditions.

X1.3.3 *Grade No. 4 (Light)* is a heavy distillate fuel or distillate/residual fuel blend meeting the specification viscosity range. It is intended for use both in pressure-atomizing commercial-industrial burners not requiring higher cost distillates and in burners equipped to atomize oils of higher viscosity. Its permissible viscosity range allows it to be pumped and atomized at relatively low-storage temperatures.

X1.3.4 *Grade No. 4* is usually a heavy distillate/residual fuel blend but can be a heavy distillate fuel meeting the specification viscosity range. It is intended for use in burners equipped with devices that atomize oils of higher viscosity than domestic burners can handle. Its permissible viscosity range allows it to be pumped and atomized at relatively low storage temperatures. Thus, in all but extremely cold weather it requires no preheating for handling.

X1.3.5 *Grade No. 5 (Light)* is residual fuel of intermediate viscosity for burners capable of handling fuel more viscous

than grade No. 4 without preheating. Preheating may be necessary in some types of equipment for burning and in colder climates for handling.

X1.3.6 *Grade No. 5 (Heavy)* is a residual fuel more viscous than Grade No. 5 (Light) and is intended for use in similar service. Preheating may be necessary in some types of equipment for burning and in colder climates for handling.

X1.3.7 *Grade No. 6*, sometimes referred to as Bunker C, is a high-viscosity oil used mostly in commercial and industrial heating. It requires preheating in the storage tank to permit pumping, and additional preheating at the burner to permit atomizing. The extra equipment and maintenance required to handle this fuel usually preclude its use in small installations.

X1.3.8 Residual fuel oil supplied to meet regulations requiring low sulfur content can differ from the grade previously supplied. It may be lower in viscosity (and fall into a different grade number). If it must be fluid at a given temperature, Test Method **D97** need not accurately reflect the pour point which can be expected after a period of storage. It is suggested that the purchaser and supplier discuss the proper handling and operating techniques for a given low-sulfur residual fuel oil in the installation where it is to be used.

X1.4 Sampling, Containers, and Sample Handling

X1.4.1 *Introduction*—This appendix section provides guidance on methods and techniques for the proper sampling of fuel oils. As fuel oil specifications become more stringent, and contaminants and impurities become more tightly controlled, even greater care needs to be taken in collecting and storing samples for quality assessment.

X1.4.2 *Sampling, Containers, and Sample Handling Recommendations:*

X1.4.2.1 Appropriate manual method sampling procedures found in Practice **D4057**, and automatic method sampling is covered in Practice **D4177**.

X1.4.2.2 The correct sample volume and appropriate container selection are important decisions that can impact test results. Refer to Practice **D4306** for aviation fuel container selection for tests sensitive to trace contamination. Refer to Practice **D5854** for procedures on container selection and sample mixing and handling.

X1.4.2.3 For volatility determination of a sample, refer to Practice **D5842** for special precautions recommended for representative sampling and handling instructions.

X1.5 Significance of Test Methods

X1.5.1 The significance of the properties of fuel oil on which limitations are placed by the specification is as follows:

X1.5.1.1 *Flash Point*—The flash point of a fuel oil is an indication of the maximum temperature at which it can be stored and handled without serious fire hazard. The minimum permissible flash point is usually regulated by federal, state, or municipal laws and is based on accepted practice in handling and use.

X1.5.1.2 *Reduced Temperature Properties*—The fuel's cloud and pour points are good measures for determining low temperature operability with a batch of fuel oil. It is especially

important to consider these fuel properties if the heating oil will be subjected to low ambient temperatures at time of use. Fuel temperatures can fluctuate markedly in small, residential, outdoor, above ground tanks compared with indoor, basement tanks, or underground tanks. A decrease or stoppage of fuel flow can occur in small transfer lines used for residential heating applications because the fuel line temperature will fluctuate with ambient temperature faster than will bulk tank contents. Fuel oils purchased during the summer, but not used until the cold heating season arrives, can be a serious source of problems. This is because when these fuels are produced they are intended for use during the warm season and thus typically have higher cloud and pour points than fuels produced for use during the cold season. Fuels can be produced for use at low temperatures with lower cloud and pour points by blending with low paraffin fuels, such as kerosine or No. 1 fuel, and additives, or a combination thereof, to improve low temperature operability. The key to effective treatment is routine monitoring of incoming and stored fuels, and testing of the treated fuels. Although this specification only sets maximum limits for the pour point, the recommendations for cloud point of distillate fuels in Specification **D975** may be applied to heating fuels under extreme cold conditions. Some pipeline companies or local specifications have included requirements for both cloud and pour points for certain grades of fuel oil.

(1) *Pour Point*—The pour point is an indication of the lowest temperature at which a fuel oil is capable of flowing under very low forces. The pour point is prescribed in accordance with the conditions of storage and use. Higher pour point fuels are permissible where heated storage and adequate piping facilities are provided. An increase in pour point can occur when residual fuel oils are subjected to cyclic temperature variations that can occur in the course of storage or when the fuel is preheated and returned to storage tanks.

(2) *Cloud Point (Test Method **D2500**)*—The cloud point defines the temperature at which a cloud or haze of wax crystals appears in the oil under prescribed test conditions which generally relates to the temperature at which wax crystals begin to precipitate from the oil in use. It is generally observed that cloud point temperature of a fuel oil is higher than its pour point by several degrees Celsius. Fuel oils stored at, or below, their cloud point temperature can have suspended wax crystals that may cause operability problems due to plugging. Examples are when fuels are pumped through small openings or passageways, that is, oil-line filters, burner nozzles, and pump strainers. The plugging is reversible when the fuel is warmed.

X1.5.1.3 *Water and Sediment*—Appreciable amounts of water and sediment in a fuel oil tend to cause fouling of facilities for handling it, and to give trouble in burner mechanisms. Sediment may accumulate in storage tanks and on filter screens or burner parts, resulting in obstruction to flow of oil from the tank to the burner. Water in distillate fuels can cause corrosion of tanks and equipment and it can cause emulsions in residual fuels.

X1.5.1.4 *Carbon Residue*—The carbon residue of a fuel is a measure of the carbonaceous material left after all the volatile components are vaporized in the absence of air. It is a rough

approximation of the tendency of a fuel to form deposits in vaporizing burners, such as pot-type and sleeve-type burners, where the fuel is vaporized in an air-deficient atmosphere.

X1.5.1.4.1 To obtain measurable values of carbon residue in the lighter distillate fuel oils, it is necessary to distill the oil to remove 90 % of it in accordance with Section 9 of Test Method **D524**, and then determine the carbon residue concentrated in the remaining 10 % bottoms.

X1.5.1.5 *Ash*—The amount of ash is the quantity of non-combustible material in an oil. Excessive amounts can indicate the presence of materials that cause high wear of burner pumps and valves, and contribute to deposits on boiler heating surfaces.

X1.5.1.6 *Distillation*—The distillation test shows the volatility of a fuel and the ease with which it can be vaporized. The test is of greater significance for oils that are to be burned in vaporizing type burners than for the atomizing type. For example, the maximum 10 % and 90 % distilled temperatures are specified for grade No. 1 fuel. The limiting 10 % value ensures easy starting in vaporizing type burners and the 90 % limit excludes heavier fractions that would be difficult to vaporize.

(1) The limits specified for grade No. 2 heating oil define a product that is acceptable for burners of the atomizing type in household heating installations. Distillation limits are not specified for fuel oils of grades Nos. 4, 5, and 6.

X1.5.1.7 *Viscosity Limits for Grades Nos. 1 and 2*—The viscosity of an oil is a measure of its resistance to flow. In fuel oil it is highly significant since it indicates both the relative ease with which the oil will flow or can be pumped, and the ease of atomization.

(1) Viscosity limits for No. 1 and No. 2 grades are specified to help maintain uniform fuel flow in appliances with gravity flow, and to provide satisfactory atomization and constant flow rate through the small nozzles of household burners. For the

heavier grades of industrial and bunker fuel oils, viscosity is of major importance, so that adequate preheating facilities can be provided to permit them to be pumped to the burner and to provide good atomization. However, it is equally important that the maximum viscosity under the existing conditions be such that the oil can be pumped satisfactorily from the storage tank to the preheater.

X1.5.1.8 *Density*—Density alone is of little significance as an indication of the burning characteristics of fuel oil. However, when used in conjunction with other properties, it is of value in mass-volume relationships and in calculating the specific energy (heating value) of an oil.

X1.5.1.9 *Corrosion*—The corrosion test serves to indicate the presence or absence of materials that could corrode copper, brass, and bronze components of the fuel system. This property is specified only for Nos. 1 and 2 distillate fuel oils.

X1.5.1.10 Limited sulfur content of fuel oil can be required for special uses in connection with heat treatment, nonferrous metal, glass, and ceramic furnaces or to meet federal, state, or local legislation or regulations.

X1.5.1.11 *Nitrogen*—Nitrogen oxide emission regulations have been imposed on certain combustion facilities as a function of fuel nitrogen content. For purposes of these regulations, distillate fuels, low nitrogen residual fuels, and high nitrogen residual fuels have been defined by their nitrogen content. Installations are required to meet different emission standards according to the classification of the fuel being used. When regulations require such a distinction to be made, fuel nitrogen specifications can be needed in the contractual agreement between the purchaser and the supplier.

X1.6 Other

X1.6.1 *Microbial Contamination*—Refer to Guide **D6469** for a discussion of this form of contamination.

X2. TENTH PERCENTILE MINIMUM AMBIENT AIR TEMPERATURES FOR THE UNITED STATES (EXCEPT HAWAII)

X2.1 Introduction

X2.1.1 The tenth percentile minimum ambient air temperatures shown in **Table 2** were derived from an analysis of historical hourly temperature readings recorded over a period of 15 to 21 years from 345 weather stations in the United States. This study⁷ as conducted by the U.S. Army Mobility Equipment Research and Development Center (USAMERDC), Coating and Chemical Laboratory, Aberdeen Proving Ground, MD 21005. The tenth percentile minimum ambient air temperature is defined as the lowest ambient air temperature which will not go lower on average more than 10 % of the time. In other words, the daily minimum ambient air temperature would on average not be expected to go below the monthly tenth percentile minimum ambient air temperature more than 3 days for a 30-day month. See **Table 2**.

X2.1.2 These data can be used to estimate low temperature operation and handling requirements for fuel oil/heating oil systems. In establishing low temperature requirements, consideration should be given to the following. These factors, or any combination, can make low temperature operations more or less severe than normal. Pour point is a directional indicator of low temperature mobility of fuel, but, due to the nature of the lab test, fuel stored at or above the Pour Point for extended periods can gel and prevent flow to the fuel oil burner with or without cold flow additives.

X2.1.2.1 Long term weather patterns. (Average winter low temperatures will be exceeded on occasion.)

X2.1.2.2 Short term local weather conditions. (Unusual cold periods do occur.)

X2.1.2.3 Elevation. (High locations are usually colder than surrounding lower areas.)

X2.1.2.4 Fuel delivery system design. (Fuel delivery line diameter, filter location, filter capacity, filter porosity, and so forth.)

⁷ Doner, John P., "A Predictive Study for Defining Limiting Temperatures and Their Application in Petroleum Product Specifications," CCL Report No. 316.

- X2.1.2.5 Fuel viscosity at low temperatures.
- X2.1.2.6 Equipment add-ons (that is, fuel line and fuel filter heaters).
- X2.1.2.7 Types of operation. (Fuel turn over rate, continuous operation, or unusual operation.)
- X2.1.2.8 Low temperature flow improver additives in fuel.
- X2.1.2.9 Geographic area for fuel use.
- X2.1.2.10 General housekeeping. (Dirt or water, or both, in fuel or fuel supply system.)
- X2.1.2.11 Consequences of failure to start or operate. (Critical vs. non-critical application.)
- X2.1.2.12 Fuel tank location.

X2.1.3 *Current Practices*—It is recognized that fuel distributors, producers, and end users commonly use pour point to estimate low temperature operation and handling limits for fuel oil. No independent data has been published in recent years to determine test applicability for today's fuel oils. It is also well known that smaller volumes will cool down faster under outside storage conditions making the 275 and 550 gal storage tanks commonly used in home heating oil applications

more susceptible to wax precipitation and fuel gelling. Colder than normal temperatures and extended periods of normal low temperatures significantly increase the chances for field problems even in the larger terminal and distributor tanks.

X2.1.4 *Pour Point and Cloud Point*—Cloud Point may be used to meet the low temperature recommendations, or Pour Point may be used as long as the Cloud Point was not more than 10°C above the low temperature recommendation from Table 2. For example, if the low temperature guidance in January is –24°C, then the Pour Point could be –24°C or lower as long as the Cloud Point did not exceed –14°C. The reason for this guidance is that at 10°C below the Cloud Point of a fuel between 2 and 3% wax is out of solution in a typical United States fuel and it is quite manageable. 3% wax out of solution appears to be a critical limit for most filterability tests. Higher levels of wax have been found to overwhelm filters and produce less reliable results in laboratory test results which is why general confidence limits of 10°C below Cloud Point are placed upon those tests.

SUMMARY OF CHANGES

Subcommittee D02.E0 has identified the location of selected changes to this standard since the last issue (D396 – 13b) that may impact the use of this standard. (Approved Dec. 1, 2013.)

- (1) An alternative test method for viscosity (Test Method **D7042**) was added to Sections **2** and **7.1.7**.

Subcommittee D02.E0 has identified the location of selected changes to this standard since the last issue (D396 – 13a) that may impact the use of this standard. (Approved Nov. 15, 2013.)

- (1) An alternative test method for the determination of flash point was added to Sections **2** and **7.1.1**.

Subcommittee D02.E0 has identified the location of selected changes to this standard since the last issue (D396 – 13) that may impact the use of this standard. (Approved June 15, 2013.)

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| <p>(1) Revised 7.1.10 to show Test Method D2622 as referee sulfur method for all grades and to modify references to Table 3.</p> <p>(2) Revised Table 1 to show Test Method D2622 as referee sulfur method for all grades.</p> | <p>(3) Revised Table 3 to show changes in referee and alternate sulfur test methods.</p> |
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Subcommittee D02.E0 has identified the location of selected changes to this standard since the last issue (D396 – 12) that may impact the use of this standard. (Approved May 1, 2013.)

- (1) An alternative test method for the determination of sulfur was added to Sections **2** and **7**.

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