Designation: D396 – 17

Standard Specification for Fuel Oils[1]

This standard is issued under the fixed designation D396; 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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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. 1 S15, No. 2 S5000, No. 2 S500, and No. 2 S15 are middle distillate fuels for use in domestic and small industrial burners. Grades No. 1 S5000, No. 1 S500, and No. 1 S15 are particularly adapted to vaporizing type burners or where storage conditions require low pour point fuel.

1.1.2 Grades B6–B20 S5000, B6–B20 S500, and B6–B20 S15 are middle distillate fuel/biodiesel blends for use in domestic and small industrial burners.

1.1.3 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.

1.1.4 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.

1.4.1 Non-SI units are provided in Table 1 and in 7.1.2.1/7.1.2.2 because these are common units used in the industry.

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.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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 and Liquid Fuels 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
D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
D975 Specification for Diesel Fuel Oils

[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.

Current edition approved July 1, 2017. Published July 2017. Originally approved in 1934. Last previous edition approved in 2016 as D396 – 16ε1. DOI: 10.1520/D0396-17.

[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**

TABLE 1 Detailed Requirements for Fuel Oils[A,B]

Property	ASTM Test Method[C]	No. 1 S15[C]	No. 1 S500[C]	No. 1 S5000[C]	No. 2 S15[C]	No. 2 S500[C]	No. 2 S5000[C]	B6–B20 S15[C]	B6–B20 S500[C]	B6–B20 S5000[C]	No. 4 (Light)[C]	No. 4	No. 5 (Light)	No. 5 (Heavy)	No. 6
Flash Point, °C, min	D93 – Proc. A	38	38	38	38	38	38	38	38	38	38	...	...	...	...
	D93 – Proc. B	...	...	...	...	...	...	...	...	...	...	55	55	55	60
Water and sediment, percent by volume, max	D2709	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	...	...	...	...	...
	D95 + D473	...	...	...	...	...	...	...	...	...	(0.50)[D]	(0.50)[D]	(1.00)[D]	(1.00)[D]	(2.00)[D]
Distillation Temperature, °C	D86														
10 % volume recovered, max		215	215	215	...	...	...	...	...	...					
90 % volume recovered, min		...	...	...	282	282	282	282	282	282					
90 % volume recovered, max		288	288	288	338	338	338	343	343	343					
Kinematic viscosity at 40 °C, mm^2/s	D445														
min		1.3	1.3	1.3	1.9	1.9	1.9	1.3	1.3	1.3	1.9	>5.5	...	...	...
max		2.4	2.4	2.4	4.1	4.1	4.1	4.1	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 percent by mass, max	D524	0.15	0.15	0.15	0.35	0.35	0.35	0.35	0.35	0.35	...	...	...	...	...
Ash, percent by mass, max	D482	...	...	...	...	...	...	...	...	...	0.05	0.10	0.15	0.15	...
Sulfur, percent by mass max[F]	D2622	...	0.05	0.5	...	0.05	0.5	...	0.05	0.5					
	D5453	0.0015	...	...	0.0015	...	...	0.0015	...	...					
Lubricity, HFRR @ 60 °C, micron, max	D6079/D7688	520	520	520	520	520	520	520[K]	520[K]	520[K]					
Copper strip corrosion rating, max, 3 h at a minimum control temperature of 50 °C	D130	No. 3	No. 3	No. 3	No. 3	No. 3	No. 3	No.3	No. 3	No. 3	...	...	...	...	...
Density at 15 °C, kg/m^3	D1298														
min		...	...	...	...	...	...	...	...	...	>876[G]	...	...	...	...
max		850	850	850	876	876	876	876	876	876	...	...	...	...	...
Pour Point °C, max[H]	D97	–18	–18	–18	–6	–6	–6	–6	–6	–6	–6	–6	...	...	[I]
Oxidation Stability, hours, min	EN 15751	...	...	...	...	...	...	6	6	6					
Acid Number, mg KOH/g, max	D664	...	...	...	...	...	...	0.3	0.3	0.3					
Biodiesel Content, percent (V/V)[J]	D7371	...	...	...	...	...	...	6 – 20.	6 – 20.	6 – 20.	...				
Conductivity (pS/m) or Conductivity Units (C.U.), min	D2624/D4308	25[L]	25[L]	25[L]	25[L]	25[L]	25[L]	25[L]	25[L]	25[L]					

[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. 1 S15, No. 2 S5000, No. 2 S500, No. 2 S15, B6–B20 S5000, B6–B20 S500, B6–B20 S15, 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 at least 3.9 lb of the solid dye standard Solvent Red 26 per thousand barrels of fuel oil.

[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 % by mass, and a deduction in quantity shall be made for all water and sediment in excess of 1.0 % by 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 mm^2/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.

[J] See subsection 4.3.1.3 on biodiesel content for grades other than B6–B20.

[K] If the fuel oil is qualified under Table 1 of Specification D396 for lubricity, it is not necessary to measure the lubricity of the blend because the lubricity of the individual blend components will be less than 520 µm so the resulting blend will also be less than 520 µm.

[L] The electrical conductivity of the fuel oil is measured at the time and temperature of the fuel at delivery. The 25 pS/m minimum conductivity requirement applies at all instances of high velocity transfer (7 m/s) but sometimes lower velocities, (see 8.1 for detailed requirements) into mobile transport (for example, tanker trucks, rail cars, and barges).

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 by High Temperature Combustion and Infrared (IR) Detection or Thermal Conductivity Detection (TCD)
D2500 Test Method for Cloud Point of Petroleum Products and Liquid Fuels
D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
D2624 Test Methods for Electrical Conductivity of Aviation and Distillate Fuels
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
D4308 Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter
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)
D6079 Test Method for Evaluating Lubricity of Diesel Fuels by the High-Frequency Reciprocating Rig (HFRR)
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
D7346 Test Method for No Flow Point and Pour Point of Petroleum Products and Liquid Fuels
D7371 Test Method for Determination of Biodiesel (Fatty Acid Methyl Esters) Content in Diesel Fuel Oil Using Mid Infrared Spectroscopy (FTIR-ATR-PLS Method)
D7688 Test Method for Evaluating Lubricity of Diesel Fuels by the High-Frequency Reciprocating Rig (HFRR) by Visual Observation
D7861 Test Method for Determination of Fatty Acid Methyl Esters (FAME) in Diesel Fuel by Linear Variable Filter (LVF) Array Based Mid-Infrared Spectroscopy
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *Other Documents:*

26 CFR Part 48 Diesel Fuel Excise Tax; Dye Color and Concentration[3]
40 CFR Part 80 Regulation of Fuel and Fuel Additives[3]
EN 14078 Determination of Fatty Acid Methyl Ester (FAME) Content in Middle Distillates — Infrared Spectrometry Method[4]
EN 15751 Automotive Fuels—Fatty Acid Methyl Ester (FAME) Fuel and Blends with Diesel Fuel—Determination of Oxidation Stability by Accelerated Oxidation Method[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *additive, n—in fuel oils*, a substance added to fuel oil at a blend level not greater than 1 % by volume of the finished fuel.

3.1.1.1 *Discussion*—Additives are generally included in finished fuel oil to enhance performance properties (for example, stability, pour point, and so forth)

3.1.1.2 *Discussion*—Additives that contain hydrocarbon oil blended with other substances may exclude the hydrocarbon oil portion for determination of the volume percent of the finished fuel.

3.1.1.3 *Discussion*—Triglycerides (for example, vegetable oils, animal fats, greases, and so forth) have been found to cause fouling of fuel oil burning equipment, and triglycerides are therefore not allowed as additives or components of additives.

[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 *alternative blendstock, n—in fuel oils*, a non-hydrocarbon oil substance added to fuel oil at blend levels greater than 1 % by volume of the finished fuel.

3.1.2.1 *Discussion*—An alternative blendstock should normally have an industry consensus standard or an annex in this specification that defines its physical and chemical properties.

3.1.2.2 *Discussion*—See Appendix X3 for guidance regarding new materials for No. 1 and No. 2 grades of fuel oils.

3.1.3 *biodiesel, n*—fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100.

3.1.4 *biodiesel blend (BXX), n*—blend of biodiesel fuel with fuel oils.

3.1.4.1 *Discussion*—In the abbreviation BXX, the XX represents the volume percentage of biodiesel fuel in the blend.

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

3.1.5.1 *Discussion*—Neither macro nor micro emulsions are included in this definition since neither are homogeneous mixtures.

3.1.5.2 *Discussion*—Examples of excluded oxygenated materials are alcohols, esters, ethers, and triglycerides.

3.1.5.3 *Discussion*—The hydrocarbon oil may be manufactured from a variety of raw materials, for example, petroleum (crude oil), oil sands, natural gas, coal, and biomass. Appendix X3 discusses some matters for consideration regarding the use of fuel oils from feedstocks other than petroleum.

3.1.6 *S(numerical specification maximum), n*—indicates the maximum sulfur content in µg/g (ppm by mass) allowed by this specification in a fuel.

3.1.6.1 *Discussion*—Of the fourteen fuel oil grades specified in this specification, nine have important distinguishing maximum sulfur regulatory requirements: Grades No. 1 S5000, No. 1 S500, No. 1 S15; No. 2 S5000, No. 2 S500, and No. 2 S15; B6-B20 S5000, B6-B20 S500, and B6-B20 S15. The remaining grades are distinguished from these grades by other major properties in addition to sulfur (unregulated maximum), and therefore are not included in this designation system.

4. General Requirements

4.1 The grades of fuel oil specified herein shall be hydrocarbon oils, except as provided in 4.3, free from inorganic acid, and free from excessive amounts of solid or fibrous foreign matter. The inclusion of additives to enhance performance properties, if required, is allowed.

NOTE 4—Additives are generally included in finished fuel oil to improve performance properties (stability, pour point, and so forth).

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 *Alternative Blendstocks:*

4.3.1 *Fuels Blended with Biodiesel*—The detailed requirements for fuels blended with biodiesel shall be as follows:

4.3.1.1 *Biodiesel for Blending*—If biodiesel is a component of any fuel oil, the biodiesel shall meet the requirements of Specification D6751.

4.3.1.2 The remainder of the fuel oil shall be fuel oil conforming to Specification D396 Grades No. 1 or No. 2 of any sulfur level specified, with the exception that fuel oil whose sulfur level falls outside of Specification D396 may be blended with biodiesel meeting Specification D6751, provided the finished mixture meets this specification.

4.3.1.3 Fuel oil containing up to 5 % by volume biodiesel shall meet the requirements for the appropriate grade No. 1 or No. 2 fuel as listed in Table 1.

4.3.1.4 Fuel oil containing 6 % to 20 % by volume biodiesel shall meet the requirements for the appropriate grade B6 to B20 as listed in Table 1.

4.3.1.5 Test Methods D7371, D7861, and EN 14078 may be used for determination of the percent by volume biodiesel in a biodiesel blend. In cases of dispute, Test Method D7371 shall be the referee test method. See Practice E29 for guidance on significant digits.

4.3.1.6 Fuel oils containing more than 20 % by volume biodiesel component are not included in this specification.

4.3.1.7 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.

[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.

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 mm^2 /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, D6892, and D7346 may be used as alternatives 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 gal) 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 gal 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 alternative test method) or by Test Method D97 Pour Point (or an approved alternative 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 X4 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 alternative 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 Methods D2622 for all grades except S15 and D5453 for S15 grades. See Table 3 for alternative test methods for sulfur and the corresponding fuel grades.

7.1.11 *Lubricity*—Test Methods D6079 or D7688. Test Method D6079 shall be the referee method.

7.1.12 *Conductivity*—Both conductivity test methods, Test Methods D2624 and D4308 are allowed for all grades of No. 1 and No. 2 fuels. There is no conductivity requirement for No. 4, No. 5, or No. 6 grades.

8. Precautionary Notes on Conductivity

8.1 Accumulation of static charge occurs when a hydrocarbon liquid flows with respect to another surface. The electrical conductivity requirement of 25 pS/m minimum at temperature of delivery shall apply when the transfer conditions in Table 4 exist for the delivery into a mobile transport container (for example, tanker trucks, railcars, and barges).

9. Keywords

9.1 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	Grades
D2622 (referee for all grades except S15 grades))	All Grades
D129	No. 1 S5000, No. 2 S5000, No. 4 (Light), No. 5 (Heavy), No. 6
D1266	No. 1 S500, No. 2 S500
D1552	No. 1 S5000, No. 2 S5000, No. 4 (Light), No. 4, No. 5 (Light), No. 5 (Heavy), No. 6
D4294	All Grades except S15 grades
D5453 (referee for S15 grades)	All Grades
D7039	S500 grades, S5000 grades only if the sulfur result is 2822 mg/kg or less
D7220	S500 grades

TABLE 4 Transfer Conditions

Maximum Pipe Diameter (for a distance of 30 s upstream of delivery nozzle)	When Filling Tank Truck Compartments	When Filling Undivided Rail Car Compartments	When Filling Marine Vessels
0.1023 m	Fuel velocity ≥4.9 m/s	Fuel velocity ≥7.0 m/s	Fuel velocity ≥7.0 m/s
0.1541 m	Fuel velocity 3.24 m/s	Fuel velocity ≥5.20 m/s	Fuel velocity ≥7.0 m/s
0.2027 m	Fuel velocity ≥2.47 m/s	Fuel velocity ≥3.90 m/s	Fuel velocity ≥7.0 m/s
0.2545 m	Fuel velocity ≥1.96 m/s	Fuel velocity ≥3.14 m/s	Fuel velocity ≥7.0 m/s

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, No. 1 S500, and No. 1 S15* 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 grades S15 or 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, No. 2 S500, and No. 2 S15* are middle distillates somewhat heavier than grades No. 1 S5000, No. 1 S500, and No. 1 S15. 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 grades S15 or S500 may be specified by federal, state, or local regulations to reduce SOx emissions 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 *Grades B6–B20 S5000, B6–B20 S500, and B6–B20 S15* are middle distillate/biodiesel blends intended for use in atomizing type burners that spray the oil into a combustion chamber where the tiny droplets burn while in suspension. These grades of oil are intended for use in most domestic burners and in many medium capacity commercial-industrial burners, where ease of handling and ready availability sometimes justify higher cost over residual fuels. The low sulfur

grades S15 or 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.

X1.3.4 *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.

X1.3.5 *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.

X1.3.6 *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.

X1.3.7 *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.

X1.3.8 *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.

X1.3.9 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.

X1.4.2.4 *Samples for Lubricity Testing*—Because of the sensitivity of lubricity measurements to trace materials, sample containers shall be only fully epoxy-lined metal, amber borosilicate glass, or polytetrafluoroethylene (PTFE), cleaned and rinsed thoroughly at least three times with the product to be sampled before use, as specified under Containers for Lubricity Testing in Practice D4306. New sample containers are preferred, but if not available, the Containers for Lubricity Testing section of Practice D4306 gives guidance on suitable cleaning procedures for each type of container.

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 *Sulfur*—See X1.3.

X1.5.1.4 *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.

X1.5.1.5 *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.

X1.5.1.5.1 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.

X1.5.1.6 *Ash*—The amount of ash is the quantity of noncombustible 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.

X1.5.1.7 *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.

X1.5.1.8 *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.

X1.5.1.9 *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.

X1.5.1.10 *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.

X1.5.1.11 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.

X1.5.1.12 *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.

X1.5.1.13 *Lubricity*—Fuel oil functions as a lubricant in fuel pumps. In limited cases, fuel with specific properties, particularly severely processed fuel to meet the S15 grade requirement, can have insufficient lubricating properties which will lead to a reduction in the normal service life and functional performance of fuel pumps. Manufacturers of fuel pumps used in new heating oil furnaces have found that S15 grades of fuel oil generally have insufficient natural lubricity, and require addition of a lubricity enhancer to meet the requirement of 520 µm maximum in the HFRR test at 60 °C, which is the same lubricity requirement as in ultra-low sulfur (S15) diesel fuel. Fuel oils containing biodiesel at or above 2 % by volume generally have excellent lubricity and do not require the addition of a lubricity additive.

X1.5.1.14 *Acid Number*—The acid number is used to determine the concentration of acids (such as free fatty acids or processing acids) that can be present in the biodiesel or fuel oil when produced, and acids which form upon aging. Biodiesel blends with an acid number outside the specification have been

shown to increase fuel system deposits and can increase the likelihood for corrosion.

X1.5.1.15 *Oxidation Stability*—Fuel oxidation can cause fuel system deposits and lead to filter clogging and fuel system malfunctions. Existing data[7] indicates the oxidation stability of B6 to B20 fuel oil blends as determined by Test Method EN 15751 should be over 6 h if the oxidation stability of the Specification D6751 biodiesel is 3 h or higher at the time of blending the fuel oil.

[7] McCormick, R. L., and Westbrook, S. R., "Empirical Study of the Stability of Biodiesel and Biodiesel Blends, Milestone Report," NREL/TP-540-41619, National Renewable Energy Laboratory, Golden, Colorado, May 2007, http://www.nrel.gov/docs/fy07osti/41619.pdf.

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 study[8] 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.)

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 gal 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. The addition of biodiesel can also affect cold flow properties, with the impacts on No. 1 type fuels being more pronounced. See Specification D6751, Appendix X3, Low Temperature Operability of Biodiesel Blends for additional information.

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.

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

X3. GUIDANCE ON EVALUATION OF NEW MATERIALS FOR No. 1 AND No. 2 GRADES OF FUEL OILS

X3.1 The purpose of this appendix is to provide some general guidance from Subcommittee D02.E0 on evaluation of new materials or blends containing new materials intended to meet Specification D396, Grades No. 1 and No. 2 type fuel oils.

X3.2 ASTM International is an organization made up of volunteers and open to all stakeholders and interested entities including users of fuels, producers of fuels, and general interests, including members of the public, and governmental and nongovernmental organizations. Technical committees and subcommittees of ASTM International do not certify, approve, reject, or endorse specific fuels. Rather, ASTM International Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and its Subcommittee D02.E0 on Burner, Diesel, Non-Aviation Gas Turbine, and Marine Fuels develop fuel specifications and with other subcommittees, test methods for diesel fuels. These fuel specifications and test methods provide minimum requirements for properties of fuels covered by these documents in commerce and address the concerns of stakeholders, including that fuels perform appropriately in the specified application.

X3.3 Historically, fuel oil has been hydrocarbon molecules refined from petroleum. As a result, Specification D396 has evolved to define performance requirements (and tests to determine if those requirements were met) for fuel oils composed of conventional hydrocarbon oils refined from petroleum. Because the specification evolved to describe this type of fuel, some of the properties necessary for use in conventional burners which are inherent in petroleum derived oils may not be addressed in Specification D396.

X3.4 Specification D396, however, does not require that fuels be derived from petroleum. Subection 4.1 reads, “The grades of fuel oil herein specified shall be hydrocarbon oils, except as provided in 4.3, free from inorganic acid, and free from excessive amounts of solid or fibrous foreign matter. The inclusion of additives to enhance performance properties, if required, is allowed.” Subsection 4.3 provides a path to include other fuels and blendstocks found by the Subcommittee to be appropriate for inclusion in Specification D396. To date, this path has been used by biodiesel, which is not refined from petroleum and is not hydrocarbon oil.

X3.5 It should be noted that fuel specifications other than Specification D396 have been and are being developed for fuel oils used in burners. Specification D6751 sets specifications for alkyl esters of fatty acids (B100) to be used as an alternative blendstock. Other new specifications are currently under development. Some new materials may require new standard specifications if they are significantly different than current fuel oils and require different parameters to be controlled or different test methods to properly measure required parameters.

X3.6 Because the composition and properties of new fuels may vary, the particular path to a specification for a new fuel may vary. Some current alternative fuels are similar to traditional petroleum-refined diesel fuel while others are chemically and physically different. Future fuels may vary even more.

X3.7 Three areas for consideration when reviewing new fuels’ alignment with existing standards or developing new standards are: test methods, chemical and physical limitations of fuels in existing specifications, and chemical and physical limitations appropriate for new fuels. The test methods that have been developed for existing burner fuels may or may not be appropriate for a new fuel. Guidance on materials used to develop a test method, and its applicability, can generally be found in a test method’s scope and precision statements. The test method may also work for other materials.

X3.8 Applicability of the test method to materials outside its scope may be established by the subcommittee responsible for the method. Also, Subcommittee D02.E0, during the specification development process, may determine that a test method is applicable for specification purposes, even if the material is not in the test method’s scope. Chemical and physical limits set in existing standards may or may not be appropriate to the new fuel or components. The new material may also require chemical or physical limits that are not appropriate to fuels in existing standards. These along with other considerations may indicate the need for separate new specifications. Although each case will require a separate evaluation, logic suggests that the fewer chemical and physical differences there are between the new fuel and traditional petroleum-based fuel oils, the fewer differences in test methods and chemical or physical limits will be needed.

X3.9 If the proponent of the new fuel desires to move forward via the consensus process as described by ASTM bylaws and as implemented in Committee D02, then the proponent or a task force including the fuel manufacturer or proponent will bring forward ballot revisions to Specification D396 or a new specification appropriate for use of the new fuel or blendstock. Because D02 specifications are established based on technical data, such data should exist before the specification process moves forward. If such data does not exist, it needs to be developed.

X3.10 This guidance is not all-encompassing and cannot replace the judgment and process of a task force and subcommittee charged with evaluating a new fuel or blendstock. However it may give some guidance to proponents or fuel manufacturers who are considering participation in ASTM Committee D02 and its subcommittees to promote the inclusion of their new fuel or blendstock in ASTM standards.

SUMMARY OF CHANGES

Subcommittee D02.E0 has identified the location of selected changes to this standard since the last issue (D396 – $16^{\varepsilon 1}$) that may impact the use of this standard. (Approved July 1, 2017.)

(1) Revised Table 3 to show Test Method D2622 suitable for all grades (including S15 grades) and to restrict Test Method D4294 to all grades other than the S15 grades.
(2) Revised subsection 7.1.10 for sulfur test methods.
(3) Revised subsection X1.3.3 to include discussion of Grade B6–B20 S15.
(4) Added subsection X1.5.1.3 to include discussion reference of the significance of sulfur testing.
(5) Added subsection 3.1.2 for definition of "alternative blendstock"; revised subsections 4.3 and X3.5 to accommodate the new definition.
(6) Added subsection 3.1.1 for definition of "additives" and discussions.

Subcommittee D02.E0 has identified the location of selected changes to this standard since the last issue (D396 – 15c) that may impact the use of this standard. (Approved Oct. 1, 2016.)

(1) Added ultra-low sulfur grades No. 1 S15, No. 2 S15, and B6–B20 S15 to the specification, with changes in Scope (1.1.1), Referenced Documents, Terminology, Test Methods (new subsections 7.1.11 and 7.1.12), Table 1, Table 3, new Table 4, revised Appendix subsections X1.3.1 and X1.3.2, and new Appendix subsections X1.4.2.4 and X1.5.1.13.
(2) The title of subsection 4.3 was changed, and following subsections were renumbered to align with subsection 7.3 of Specification D975.