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Standard Specification for Diesel Fuel Oils¹

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers seven grades of diesel fuel oils suitable for various types of diesel engines. These grades are described as follows:

1.1.1 *Grade No. 1-D S15*—A special-purpose, light middle distillate fuel for use in diesel engine applications requiring a fuel with 15 ppm sulfur (maximum) and higher volatility than that provided by Grade No. 2-D S15 fuel.²

1.1.2 *Grade No. 1-D S500*—A special-purpose, light middle distillate fuel for use in diesel engine applications requiring a fuel with 500 ppm sulfur (maximum) and higher volatility than that provided by Grade No. 2-D S500 fuel.²

1.1.3 *Grade No. 1-D S5000*—A special-purpose, light middle distillate fuel for use in diesel engine applications requiring a fuel with 5000 ppm sulfur (maximum) and higher volatility than that provided by Grade No. 2-D S5000 fuels.

1.1.4 *Grade No. 2-D S15*—A general purpose, middle distillate fuel for use in diesel engine applications requiring a fuel with 15 ppm sulfur (maximum). It is especially suitable for use in applications with conditions of varying speed and load.²

1.1.5 *Grade No. 2-D S500*—A general-purpose, middle distillate fuel for use in diesel engine applications requiring a fuel with 500 ppm sulfur (maximum). It is especially suitable for use in applications with conditions of varying speed and load.²

1.1.6 *Grade No. 2-D S5000*—A general-purpose, middle distillate fuel for use in diesel engine applications requiring a fuel with 5000 ppm sulfur (maximum), especially in conditions of varying speed and load.

1.1.7 *Grade No. 4-D*—A heavy distillate fuel, or a blend of distillate and residual oil, for use in low- and medium-speed diesel engines in applications involving predominantly constant speed and load.

NOTE 1—A more detailed description of the grades of diesel fuel oils is given in X1.2.

NOTE 2—The Sxxx designation has been adopted to distinguish grades by sulfur rather than using words such as “Low Sulfur” as previously because the number of sulfur grades is growing and the word descriptions were thought to be not precise. S5000 grades correspond to the so-called “regular” sulfur grades, the previous No. 1-D and No. 2-D. S500 grades correspond to the previous “Low Sulfur” grades. S15 grades were not in the previous grade system and are commonly referred to as “Ultra-Low Sulfur” grades or ULSD.

1.2 This specification, unless otherwise provided by agreement between the purchaser and the supplier, prescribes the required properties of diesel fuels at the time and place of delivery.

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

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

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

2. Referenced Documents

2.1 ASTM Standards:³

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

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

D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test

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² This fuel complies with 40 CFR Part 80—Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engines and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements: Final Rule. Regulation of Fuels and Fuel Additives: Fuel Quality Regulations for Highway Diesel Fuel Sold in 1993 and Later Calendar Years.

³ 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.

- D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
 - D482 Test Method for Ash from Petroleum Products
 - D524 Test Method for Ramsbottom Carbon Residue of Petroleum Products
 - D613 Test Method for Cetane Number of Diesel Fuel Oil
 - D1266 Test Method for Sulfur in Petroleum Products (Lamp Method)
 - D1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
 - D1552 Test Method for Sulfur in Petroleum Products (High-Temperature Method)
 - D1796 Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)
 - D2274 Test Method for Oxidation Stability of Distillate Fuel Oil (Accelerated 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
 - D2624 Test Methods for Electrical Conductivity of Aviation and Distillate Fuels
 - D2709 Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge
 - D2880 Specification for Gas Turbine Fuel Oils
 - D2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
 - D3117 Test Method for Wax Appearance Point of Distillate Fuels
 - D3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry
 - D3828 Test Methods for Flash Point by Small Scale Closed Cup Tester
 - 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
 - D4539 Test Method for Filterability of Diesel Fuels by Low-Temperature Flow Test (LTFT)
 - D4737 Test Method for Calculated Cetane Index by Four Variable Equation
 - D4865 Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems
 - D5304 Test Method for Assessing Middle Distillate Fuel Storage Stability by Oxygen Overpressure
 - D5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
 - D5771 Test Method for Cloud Point of Petroleum Products (Optical Detection Stepped Cooling Method)
 - D5772 Test Method for Cloud Point of Petroleum Products (Linear Cooling Rate Method)
 - D5773 Test Method for Cloud Point of Petroleum Products (Constant Cooling Rate Method)
 - 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
 - D6078 Test Method for Evaluating Lubricity of Diesel Fuels by the Scuffing Load Ball-on-Cylinder Lubricity Evaluator (SLBOCLE)
 - D6079 Test Method for Evaluating Lubricity of Diesel Fuels by the High-Frequency Reciprocating Rig (HFRR)
 - D6217 Test Method for Particulate Contamination in Middle Distillate Fuels by Laboratory Filtration
 - D6371 Test Method for Cold Filter Plugging Point of Diesel and Heating Fuels
 - D6468 Test Method for High Temperature Stability of Middle Distillate Fuels
 - D6469 Guide for Microbial Contamination in Fuels and Fuel Systems
 - D6751 Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels
 - D6890 Test Method for Determination of Ignition Delay and Derived Cetane Number (DCN) of Diesel Fuel Oils by Combustion in a Constant Volume Chamber
 - D6898 Test Method for Evaluating Diesel Fuel Lubricity by an Injection Pump Rig
 - D7039 Test Method for Sulfur in Gasoline and Diesel Fuel by Monochromatic Wavelength Dispersive X-ray Fluorescence Spectrometry
 - D7170 Test Method for Determination of Derived Cetane Number (DCN) of Diesel Fuel Oils Fixed Range Injection Period, Constant Volume Combustion Chamber Method
 - D7371 Test Method for Determination of Biodiesel (Fatty Acid Methyl Esters) Content in Diesel Fuel Oil Using Mid Infrared Spectroscopy (FTIR-ATR-PLS Method)
 - E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- 2.2 *Other Documents:*
- 26 CFR Part 48 Manufacturers and Realtors Excise Taxes⁴
 - 40 CFR Part 80 Regulation of Fuels and Fuel Additives⁴

⁴ Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

API RP 2003 Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents⁵

EN 14078 Liquid petroleum products - Determination of fatty acid methyl esters (FAME) in middle distillates - Infrared spectroscopy method⁶

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 diesel fuel oils.

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

3.1.3 *switch loading, n*—in the liquid petroleum fuels industry, the act of loading an empty or near-empty tank or cargo compartment, such as a tanker truck, rail car or barge with a middle distillate fuel without prior compartment cleaning treatment, when the prior cargo was a high volatility, low flash point flammable fuel such as gasoline. The reverse procedure, that is, loading gasoline after a prior load of diesel is also called switch loading.—of liquid fuels, the practice of loading low vapor pressure product (e.g., diesel fuel) into an empty or near-empty fixed or portable container that previously held a high or intermediate vapor pressure product (such as gasoline or solvent) without prior compartment cleaning treatment and inert gas purging; and the reverse procedure where a high vapor pressure product is added to a container that previously held a low vapor pressure product.

3.1.3.1 *Discussion*—Since middle distillate fuels have flash points above 38°C, during normal distribution of these fuels, the atmosphere above the fuels in the compartment a container such as a tanker truck, rail car, or barge, is normally below the lower explosive limit, so there is low risk of fire or explosion should an electrostatic discharge (spark) occur. However, when the previous load in the compartment was a volatile, flammable fuel such as gasoline, and if some residual gasoline fuel vapor or mist remains in the compartment, and the compartment is full container has a mixture of air and fuel vapor or mist (that is, not purged with an inert gas), then there is a risk that the atmosphere in the container being filled could be in the explosive range creating a hazard should an electrostatic discharge occur. Switch loading also refers to the reverse situation when light distillate (for example, gasoline) is loaded into a compartment with a prior cargo of middle distillate fuel (for example, diesel), although the former situation presents a possibly greater hazard.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *S(numerical specification maximum)*—indicates the maximum sulfur content, in weight ppm (µg/g), allowed by this specification in a diesel fuel grade.

3.2.1.1 *Discussion*—Of the seven diesel fuel grades specified in this standard, six have important distinguishing maximum sulfur regulatory requirements. These are Grades No. 1-D S15, No. 1-D S500, No. 1-D S5000, No. 2-D S15, No. 2-D S500 and No. 2-D S5000. The seventh grade, No. 4-D, is distinguished from these other grades by many major properties in addition to sulfur (unregulated maximum), and therefore is not included in this designation system. Thus, Grade No. 4-D does not have the designation S20000 as part of its grade name.

4. Sampling, Containers, and Sample Handling

4.1 It is strongly advised to review all test methods prior to sampling to understand the importance and effects of sampling technique, proper containers, and special handling required for each test method.

4.2 Correct sampling procedures are critical to obtaining a representative sample of the diesel fuel oil to be tested. Refer to Appendix X2 for recommendations. The recommended procedures or practices provide techniques useful in the proper sampling or handling of diesel fuels.

5. Test Methods

5.1 The requirements enumerated in this specification shall be determined in accordance with the following methods:

5.1.1 *Flash Point*—Test Methods D93, except where other methods are prescribed by law. For all grades, Test Method D3828 may be used as an alternate with the same limits. For Grades No. 1-D S15, No. 1-D S500, No. 1-D S5000, No. 2-D S15, No. 2-D S500, and No. 2-D S5000, Test Method D56 may be used as an alternate with the same limits, provided the flash point is below 93°C and the viscosity is below 5.5 mm²/s at 40°C. This test method will give slightly lower values. In cases of dispute, Test Methods D93 shall be used as the referee method. Test Method D56 may not be used as the alternate method for Grade No. 4-D because its minimum viscosity limit is 5.5 mm²/s at 40°C.

5.1.2 *Cloud Point*—Test Method D2500. For all fuel grades in Table 1, the automatic Test Methods D5771, D5772, or D5773 can be used as alternates with the same limits. Test Method D3117 can also be used since it is closely related to Test Method D2500. In case of dispute, Test Method D2500 shall be the referee method.

5.1.3 *Water and Sediment*—Test Method D2709 is used for fuel Grades No. 1-D S15, No. 1-D S500, No. 1-D S5000, No. 2-D S15, No. 2-D S500, and No. 2-D S5000. Test Method D1796 is used for Grade No. 4-D.

⁵ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁶ 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 Diesel Fuel Oils^A

Property	ASTM Test Method ^B	Grade						
		No. 1-D S15	No. 1-D S500 ^C	No. 1-D S5000 ^D	No. 2-D S15 ^E	No. 2-D S500 ^{C,E}	No. 2-D S5000 ^{D,E}	No. 4-D ^D
Flash Point, °C, min.	D93	38	38	38	52 ^E	52 ^E	52 ^E	55
Water and Sediment, % vol, max	D2709	0.05	0.05	0.05	0.05	0.05	0.05	...
Distillation Temperature, °C90 %, % vol recovered	D1796	...	...	...	...	...	...	0.50
	D86	...	...	...	282 ^E	282 ^E	282 ^E	...
Kinematic Viscosity, mm ² /S at 40°C	D445	288	288	288	338	338	338	...
		min	1.3	1.3	1.3	1.9 ^E	1.9 ^E	1.9 ^E	5.5
max	...	2.4	2.4	2.4	4.1	4.1	4.1	24.0
Ash % mass, max	D482	0.01	0.01	0.01	0.01	0.01	0.01	0.10
Sulfur, ppm (µg/g) ^F max	D5453	15	...	...	15	...	...	...
% mass, max	D2622 ^G	...	0.05	...	...	0.05	...	...
% mass, max	D129	...	...	0.50	...	...	0.50	2.00
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	...
Cetane number, min ^H	D613	40 ^I	40 ^I	40 ^I	40 ^I	40 ^I	40 ^I	30 ^I
One of the following properties must be met:								
(1) Cetane index, min.	D976–80 ^G	40	40	...	40	40	...	...
(2) Aromaticity, % vol, max	D1319 ^G	35	35	...	35	35	...	...
Operability Requirements								
Cloud point, °C, max	D2500	J	J	J	J	J	J	...
or								
LTFT/CFPP, °C, max	D4539/ D6371							
Ramsbottom carbon residue on 10 % distillation residue, % mass, max	D524	0.15	0.15	0.15	0.35	0.35	0.35	...
Lubricity, HFRR @ 60°C, micron, max	D6079	520	520	520	520	520	520	...
Conductivity, pS/m or Conductivity Units (C.U.), min	D2624/D4308	25 ^K	25 ^K	25 ^K	25 ^K	25 ^K	25 ^K	...

^A To meet special operating conditions, modifications of individual limiting requirements may be agreed upon between purchaser, seller, and manufacturer.

^B The test methods indicated are the approved referee methods. Other acceptable methods are indicated in 5.1.

^C Under United States regulations, if Grades No. 1–D S500 or No. 2–D S500 are sold for tax exempt purposes then, 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, or the tax must be collected.

^D Under United States regulations, Grades No. 1–D S5000, No. 2–D S5000, and No. 4–D 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.

^E When a cloud point less than –12°C is specified, as can occur during cold months, it is permitted and normal blending practice to combine Grades No. 1 and No. 2 to meet the low temperature requirements. In that case, the minimum flash point shall be 38°C, the minimum viscosity at 40°C shall be 1.7 mm²/s, and the minimum 90 % recovered temperature shall be waived.

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

^G These test methods are specified in 40 CFR Part 80.

^H Where cetane number by Test Method D613 is not available, Test Method D4737 can be used as an approximation.

^I Low ambient temperatures as well as engine operation at high altitudes may require the use of fuels with higher cetane ratings.

^J It is unrealistic to specify low temperature properties that will ensure satisfactory operation at all ambient conditions. In general, cloud point (or wax appearance point) Low Temperature Flow Test, and Cold Filter Plugging Point Test may be used as an estimate of operating temperature limits for Grades No. 1–D S500; No. 2–D S500; and No. 1–D S5000 and No. 2–D S5000 diesel fuel oils. However, satisfactory operation below the cloud point (or wax appearance point) may be achieved depending on equipment design, operating conditions, and the use of flow-improver additives as described in X5.1.2. Appropriate low temperature operability properties should be agreed upon between the fuel supplier and purchaser for the intended use and expected ambient temperatures. Test Methods D4539 and D6371 may be especially useful to estimate vehicle low temperature operability limits when flow improvers are used. Due to fuel delivery system, engine design, and test method differences, low temperature operability tests may not provide the same degree of protection in various vehicle operating classes. Tenth percentile minimum air temperatures for U.S. locations are provided in Appendix X5 as a means of estimating expected regional temperatures. The tenth percentile minimum air temperatures can be used to estimate expected regional target temperatures for use with Test Methods D2500, D4539, and D6371. Refer to X5.1.3 for further general guidance on test application.

^K The electrical conductivity of the diesel fuel 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).

5.1.4 *Carbon Residue*—Test Method D524 is used for fuel Grades No. 1-D S15, No. 1-D S500, No. 1-D S5000, No. 2-D S15, No. 2-D S500 and No. 2-D S5000. Grade No. 4-D does not have a limit for carbon residue.

5.1.5 *Ash*—Test Method D482 is used for all grades in Table 1.

5.1.6 *Distillation*—Test Method D86 is used for Grades No. 1-D S15, No. 1-D S500, No. 1-D S5000, No. 2-D S15, No. 2-D S500, and No. 2-D S5000. For all grades, Test Method D2887 can be used as an alternate. Results from Test Method D2887 shall be reported as “Predicted D86” results by application of the correlation in Appendix X5 of Test Method D2887 to convert the values. In case of dispute, Test Method D86 shall be the referee method. Grade No. 4-D does not have distillation requirements.

5.1.7 *Viscosity*—Test Method D445 is used for all fuel grades in Table 1.

5.1.8 *Sulfur*—The following list shows the referee test methods and alternate test methods for sulfur, the range over which each test method applies and the corresponding fuel grades.

Sulfur Test Method	Range	Grades
D129 (referee)	>0.1 mass %	No. 1-D S5000, No. 2-D S5000, No. 4-D
D1266	0.0005 to 0.4 mass % 5 to 4000 mg/kg (wt ppm)	No. 1-D S500, No. 2-D S500
D1552	>0.06 mass %	No. 1- D S5000, No. 2-D S5000, No. 4-D
D2622 (referee for S500 Grades)	0.0003 to 5.3 mass % 3 to 53 000 mg/kg (wt ppm)	All Grades
D3120	3.0 to 100 mg/kg (wt ppm)	No. 1-D S15, No. 2-D S15 No. 1-D S500, No. 2-D S500 (S500 grades must be diluted before testing)
D4294	0.0150 to 5.00 mass % 150 to 50 000 mg/kg (wt ppm)	No. 1- D S5000, No. 2-D S5000, No. 4-D
D5453 (referee for S15 grades)	0.0001 to 0.8 mass % 1.0 to 8000 mg/kg (wt ppm)	All Grades
D7039	4 to 17 mg/kg	No. 1–D S15, No. 2–D S15

NOTE 4—The units used to report results in the above test methods are:

D129	mass %
D1266	mass %
D1552	mass %
D2622	mass %
D3120	ppm (µg/g)
D4294	mass %
D5453	ppm (µg/g)
D7039	mg/kg

Results reported in mg/kg and in ppm (µg/g) are numerically the same. The units used in Table 1 for the sulfur requirements are the units in which results for the referee test are reported.

5.1.9 *Copper Corrosion*—Test Method D130, 3-h test at a minimum control temperature of 50°C. This test method is used for fuel Grades No. 1-D S15, No. 1-D S500, No. 1-D S5000, No. 2-D S15, No. 2-D S500 and No. 2-D S5000. Grade No. 4-D does not have a copper corrosion requirement.

5.1.10 *Cetane Number*—Test Method D613 is used for all fuel grades in Table 1. Test Method D6890 or Test Method D7170 may be used for all No. 1-D and No. 2-D grades with the DCN result being compared to the cetane number specification requirement of 40. Test Method D613 shall be the referee method.

5.1.11 *Cetane Index*—Test Methods D976–80 is used for fuel Grades No. 1-D S15, No. 1-D S500, No. 2-D S15 and No. 2-D S500. Grades No. 1-D S5000, No. 2-D S5000 and No. 4-D do not have an aromatics content requirement, so do not use this test method as a surrogate for aromatics content.

5.1.12 *Aromaticity*—Test Method D1319. This test method provides an indication of the aromatics content of fuels. For fuels with a maximum final boiling point of 315°C, this method is a measurement of the aromatic content of the fuel. This test method is used for fuel Grades No. 1-D S15, No. 1-D S500, No. 2-D S15 and No. 2-D S500. Grades No. 1-D S5000, No. 2-D S5000 and No. 4-D do not have an aromatics content requirement.

5.1.13 *Lubricity*—Test Method D6079.

5.1.14 *Conductivity*—Both conductivity test methods, Test Methods D2624 and D4308 are allowed for all grades of No. 1 and No. 2 diesel fuels. There is no conductivity requirement for No. 4 diesel fuel. For conductivities below 1 pS/m, Test Method D4308 is preferred.

6. Workmanship

6.1 The diesel fuel shall be visually free of undissolved water, sediment, and suspended matter.

7. Requirements

7.1 The grades of diesel fuel oils herein specified shall be hydrocarbon oils, except as provided in 7.3.1, conforming to the detailed requirements shown in Table 1.

TABLE 2 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 \geq 4.9 m/s	fuel velocity \geq 7.0 m/s	fuel velocity \geq 7.0 m/s
0.1541 m	fuel velocity \geq 3.24 m/s	fuel velocity \geq 5.20 m/s	fuel velocity \geq 7.0 m/s
0.2027 m	fuel velocity \geq 2.47 m/s	fuel velocity \geq 3.90 m/s	fuel velocity \geq 7.0 m/s
0.2545 m	fuel velocity \geq 1.96 m/s	fuel velocity \geq 3.14 m/s	fuel velocity \geq 7.0 m/s

7.2 *Grades No. 2-D S15, No. 2-D S500 and No. 2-D S5000*—When a cloud point less than -12°C is specified, as can occur during cold months, it is permitted and normal blending practice to combine Grades No. 1 and No. 2 to meet the low temperature requirements. In that case, the minimum flash point shall be 38°C , the minimum viscosity at 40°C shall be $1.7\text{ mm}^2/\text{s}$, and the minimum 90 % recovered temperature shall be waived.

7.3 *Alternative Fuels and Blend Stocks:*

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

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

7.3.1.2 Diesel fuel oil containing up to 5 vol% biodiesel shall meet the requirements for the appropriate grade No. 1-D or No. 2-D fuel, as listed in Table 1.

7.3.1.3 Test Method D7371 shall be used for determination of the vol% biodiesel in a biodiesel blend. Test Method EN 14078 may also be used. In cases of dispute, Test Method D7371 shall be the referee test method. See Practice E29 for guidance on significant digits.

7.3.1.4 Diesel fuels containing more than 5 vol% biodiesel component are not included in this specification.

7.3.1.5 Biodiesel blends with No. 4-D fuel are not covered by this specification.

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 2 exist for the delivery into a mobile transport container (for example, tanker trucks, railcars, and barges).

9. Keywords

9.1 biodiesel; biodiesel blend; diesel; fuel oil; petroleum and petroleum products

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APPENDIXES

(Nonmandatory Information)

X1. SIGNIFICANCE OF ASTM SPECIFICATION FOR DIESEL FUEL OILS

X1.1 Introduction

X1.1.1 The properties of commercial fuel oils depend on the refining practices employed and the nature of the crude oils from which they are produced. Distillate fuel oils, for example, can be produced within the boiling range of 150 and 400°C having many possible combinations of various properties, such as volatility, ignition quality, viscosity, and other characteristics.

X1.2 Grades

X1.2.1 This specification is intended as a statement of permissible limits of significant fuel properties used for specifying the wide variety of commercially available diesel fuel oils. Limiting values of significant properties are prescribed for seven grades of diesel fuel oils. These grades and their general applicability for use in diesel engines are broadly indicated as follows:

X1.2.2 *Grade No. 1-D S15*—Grade No. 1-D S15 comprises the class of very low sulfur, volatile fuel oils from kerosine to the intermediate middle distillates. Fuels within this grade are applicable for use in (1) high-speed diesel engines and diesel engine applications that require ultra-low sulfur fuels, (2) applications necessitating frequent and relatively wide variations in loads and speeds, and (3) applications where abnormally low operating temperatures are encountered.

X1.2.3 *Grade No. 1-D S500*—Grade No. 1-D S500 comprises the class of low-sulfur, volatile fuel oils from kerosine to the intermediate middle distillates. Fuels within this grade are applicable for use in (1) high-speed diesel engines that require low sulfur fuels, (2) in applications necessitating frequent and relatively wide variations in loads and speeds, and (3) in applications where abnormally low operating temperatures are encountered.

X1.2.4 *Grade No. 1-D S5000*—Grade No. 1-D S5000 comprises the class of volatile fuel oils from kerosine to the intermediate middle distillates. Fuels within this grade are applicable for use in high-speed diesel engines applications necessitating frequent and relatively wide variations in loads and speeds, and also for use in cases where abnormally low operating temperatures are encountered.

X1.2.5 *Grade No. 2-D S15*—Grade No. 2-D S15 includes the class of very low sulfur, middle distillate gas oils of lower volatility than Grade No. 1-D S15. These fuels are applicable for use in (1) high speed diesel engines and diesel engine applications that require ultra-low sulfur fuels, (2) applications necessitating relatively high loads and uniform speeds, or (3) diesel engines not requiring fuels having higher volatility or other properties specified in Grade No. 1-D S15.

X1.2.6 *Grade No. 2-D S500*—Grade No. 2-D S500 includes the class of low-sulfur, middle distillate gas oils of lower volatility than Grade No. 1-D S500. These fuels are applicable for use in (1) high-speed diesel engine applications that require low sulfur fuels, (2) applications necessitating relatively high loads and uniform speeds, or (3) diesel engines not requiring fuels having higher volatility or other properties specified for Grade No. 1-D S500.

X1.2.7 *Grade No. 2-D S5000*—Grade No. 2-D S5000 includes the class of middle distillate gas oils of lower volatility than Grade No. 1-D S5000. These fuels are applicable for use in (1) high-speed diesel engines in applications necessitating relatively high loads and uniform speeds, or (2) in diesel engines not requiring fuels having higher volatility or other properties specified for Grade No. 1-D S5000.

X1.2.8 *Grade No. 4-D*—Grade No. 4-D comprises the class of more viscous middle distillates and blends of these middle distillates with residual fuel oils. Fuels within this grade are applicable for use in low- and medium-speed diesel engines in applications necessitating sustained loads at substantially constant speed.

X1.3 Selection of Particular Grade

X1.3.1 The selection of a particular diesel fuel oil from one of these seven ASTM grades for use in a given engine requires consideration of the following factors:

X1.3.1.1 Fuel price and availability,

X1.3.1.2 Maintenance considerations,

X1.3.1.3 Engine size and design,

X1.3.1.4 Emission control systems,

X1.3.1.5 Speed and load ranges,

X1.3.1.6 Frequency of speed and load changes, and

X1.3.1.7 Atmospheric conditions. Some of these factors can influence the required fuel properties outlined as follows:

X1.4 Cetane Number

X1.4.1 Cetane number is a measure of the ignition quality of the fuel and influences combustion roughness. The cetane number requirements depend on engine design, size, nature of speed and load variations, and on starting and atmospheric conditions. Increase in cetane number over values actually required does not materially improve engine performance. Accordingly, the cetane

number specified should be as low as possible to assure maximum fuel availability.

X1.5 Distillation

X1.5.1 The fuel volatility requirements depend on engine design, size, nature of speed and load variations, and starting and atmospheric conditions. For engines in services involving rapidly fluctuating loads and speeds as in bus and truck operation, the more volatile fuels can provide best performance, particularly with respect to smoke and odor. However, best fuel economy is generally obtained from the heavier types of fuels because of their higher heat content.

X1.6 Viscosity

X1.6.1 For some engines it is advantageous to specify a minimum viscosity because of power loss due to injection pump and injector leakage. Maximum viscosity, on the other hand, is limited by considerations involved in engine design and size, and the characteristics of the injection system.

X1.7 Carbon Residue

X1.7.1 Carbon residue gives a measure of the carbon depositing tendencies of a fuel oil when heated in a bulb under prescribed conditions. While not directly correlating with engine deposits, this property is considered an approximation.

X1.8 Sulfur

X1.8.1 The effect of sulfur content on engine wear and deposits appears to vary considerably in importance and depends largely on operating conditions. Fuel sulfur can affect emission control systems performance. To assure maximum availability of fuels, the permissible sulfur content should be specified as high as is practicable, consistent with maintenance considerations.

X1.9 Flash Point

X1.9.1 The flash point as specified is not directly related to engine performance. It is, however, of importance in connection with legal requirements and safety precautions involved in fuel handling and storage, and is normally specified to meet insurance and fire regulations.

X1.10 Cloud Point

X1.10.1 Cloud point is of importance in that it 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.

X1.11 Ash

X1.11.1 Ash-forming materials can be present in fuel oil in two forms: (1) abrasive solids, and (2) soluble metallic soaps. Abrasive solids contribute to injector, fuel pump, piston and ring wear, and also to engine deposits. Soluble metallic soaps have little effect on wear but can contribute to engine deposits.

X1.12 Copper Strip Corrosion

X1.12.1 This test serves as a measure of possible difficulties with copper and brass or bronze parts of the fuel system.

X1.13 Aromaticity

X1.13.1 This test is used as an indication of the aromatics content of diesel fuel. Aromatics content is specified to prevent an increase in the average aromatics content in Grades No. 1-D S15, No. 1-D S500, No. 2-D S15 and No. 2-D S500 fuels and is required by 40 CFR Part 80. Increases in aromatics content of fuels over current levels can have a negative impact on emissions.

X1.14 Cetane Index

X1.14.1 Cetane Index is specified as a limitation on the amount of high aromatic components in Grades No. 1-D S15, No. 1-D S500, No. 2-D S15 and No. 2-D S500.

X1.15 Other

X1.15.1 *Microbial Contamination*—Refer to Guide D6469 for a discussion of this form of contamination.

X1.16 Conductivity

X1.16.1 Electrical conductivity of fuels is an important consideration in the safe handling characteristics of any fuel. The risk associated with explosions due to static electrical discharge depends on the amount of hydrocarbon and oxygen in the vapor space and the energy and duration of a static discharge. There are many factors that can contribute to the high risk of explosion. For Ultra Low Sulfur Diesel (ULSD) fuels in particular, electrical conductivity can likely be very low before the addition of static dissipater additive (SDA). The intent of this requirement is to reduce the risk of electrostatic ignitions while filling tank trucks, barges, ship

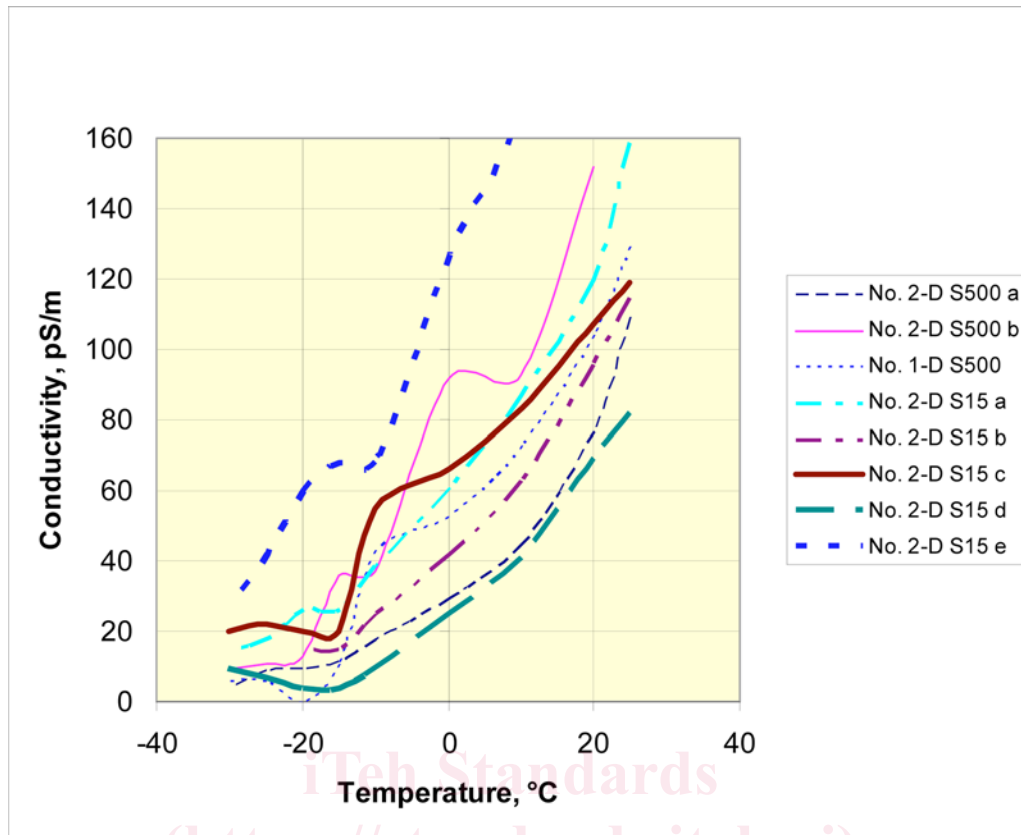


FIG. X1.1 Conductivity Varies with Temperature

compartments, and rail cars, where flammable vapors from the past cargo can be present. Generally, it does not apply at the retail level where flammable vapors are usually absent. Those parties handling any fuel are advised to review Guide D4865 as well as API RP 2003 and ISGOTT.⁷

X1.16.2 Conductivity is known to be highly dependent on temperature. The conductivity requirement in Table 1 will decrease the risk, but it will not eliminate it.

X1.16.3 Fig. X1.1 presents the response of conductivity to temperature for some typical diesel fuels.

X1.16.4 Due to the normal depletion of fuel conductivity additive during commingling, storage, and distribution, or reduction of conductivity, or a combination thereof, at low temperatures, the fuel should be sufficiently treated, if needed with conductivity improver additives (also called static dissipater additives (SDA)) to ensure that the electrical conductivity requirement is met. The method of fuel distribution and temperature at the point of delivery into mobile transport can require a substantially greater conductivity level than 25 pS/m at the point of additive treatment. If a static dissipater additive is needed to meet the minimum conductivity requirement, then initial additive treatment should allow for temperature, commingling, distribution, and adequate mixing effects to ensure the minimum conductivity is attained at the point of delivery into mobile transport. For more information on this subject, please refer to Guide D4865 and Test Method D2624.

X1.16.5 Fuel handlers should not be lulled into a false sense of security if the fuel meets or exceeds the minimum conductivity requirement. Improved fuel conductivity will accelerate the dissipation of electric charge but not eliminate the risks associated with handling combustible or flammable fuels. Fuel handlers should be aware of the increased static electricity production when diesel fuels are filtered through fine-mesh strainers and filters. Fuel handlers are encouraged to use industry-recommended safety practices to minimize the risk associated with handling fuel. One such safe operating practice recommends lower maximum flowrates upon initial loading procedures. Loading operations involving “switch-loading” of tanker trucks and other vessels pose increased risks.

~~X1.16.6 There is some concern over excessive additization of diesel fuel with static dissipater additives. A potential concern includes failure of exposed electrical equipment immersed in over-additized fuel. Another concern is potential interference with the properties of adjacent products in pipeline. Fuel handlers using static dissipater additives should employ effective controls to prevent over-additizing diesel fuel. Fuel handlers adding SDA or other additives should be aware of possible antagonistic or~~

⁷ ISGOTT (International Safety Guide for Oil Tankers and Terminals) , 5th edition, Oil Companies International Marine Forum (OCIMF), London, England, www.ocimf.com.

synergistic effects between additives used simultaneously in diesel fuel. Consultation with the appropriate SDA additive supplier or other experts, or both, as well as conducting appropriate additive interaction studies is recommended.

X1.16.6 There is some concern over excessive additization of diesel fuel with static dissipater additives. A potential concern includes failure of exposed electrical equipment immersed in over-additized fuel. Another concern is potential interference with the properties of adjacent products in pipeline. Fuel handlers using static dissipater additives should employ effective controls to prevent over-additizing diesel fuel. Fuel handlers adding SDA or other additives should be aware of possible antagonistic or synergistic effects between additives used simultaneously in diesel fuel. Consultation with the appropriate SDA additive supplier or other experts, or both, as well as conducting appropriate additive interaction studies is recommended.

X1.16.7 For those fuel transporters that practice switch loading of fuels without container cleaning and purging after hauling high or intermediate fuels or solvents, risks are involved with that practice. Switch loading should be discouraged because of the difficulty in ensuring removal of all residual vapor-producing materials. Accidental electrostatic discharge ignition requires three elements:

- (1) Presence of a flammable atmosphere from a previous volatile cargo,
- (2) The ability of the low volatility material being loaded to accumulate an electrostatic charge because of low conductivity, and
- (3) Operating conditions during loading, which encourage charge generation and reduce charge relaxation—especially the velocity of the loading stream. Switch loading also refers to the reverse situation when light product (for example, gasoline) is loaded into a container that previously held middle distillate fuel (for example, diesel), although this mode of switch loading is generally not considered a static ignition hazard (but may be a product contamination concern).

X2. SAMPLING, CONTAINERS AND SAMPLE HANDLING

X2.1 Introduction

X2.1.1 This appendix provides guidance on methods and techniques for the proper sampling of diesel fuel oils. As diesel 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.

X2.2 Sampling, Containers and Sample Handling Recommendations

X2.2.1 Appropriate manual method sampling procedures can be found in Practice D4057 and automatic method sampling is covered in Practice D4177.

X2.2.2 The correct sample volume and appropriate container selection are also important decisions that can impact test results. Practice D4306 for aviation fuel container selection for tests sensitive to trace contamination can be useful. Practice D5854 for procedures on container selection and sample mixing and handling is recommended. For cetane number determination protection from light is important. Collection and storage of diesel fuel oil samples in an opaque container, such as a dark brown glass bottle, metal can, or a minimally reactive plastic container to minimize exposure to UV emissions from sources such as sunlight or fluorescent lamps, is recommended. According to Paragraph 8.2 of Test Method D6079, “Because of sensitivity of lubricity measurements to trace materials, sample containers shall be only fully epoxy-lined metal, amber borosilicate glass, or polytetrafluoroethylene as specified in Practice D4306.”

X2.2.3 For volatility determination of a sample, Practice D5842 for special precautions recommended for representative sampling and handling techniques may be appropriate.

X3. STORAGE AND THERMAL STABILITY OF DIESEL FUELS

X3.1 Scope

X3.1.1 This appendix provides guidance for consumers of diesel fuels who may wish to store quantities of fuels for extended periods or use the fuel in severe service or high temperature applications. Fuels containing residual components are excluded. Consistently successful long-term fuel storage or use in severe applications requires attention to fuel selection, storage conditions, handling and monitoring of properties during storage and prior to use.

X3.1.2 Normally produced fuels have adequate stability properties to withstand normal storage and use without the formation of troublesome amounts of insoluble degradation products. Fuels that are to be stored for prolonged periods or used in severe applications should be selected to avoid formation of sediments or gums, which can overload filters or plug injectors. Selection of these fuels should result from supplier-user discussions.

X3.1.3 These suggested practices are general in nature and should not be considered substitutes for any requirements imposed by the warranty of the distillate fuel equipment manufacturer or by federal, state, or local government regulations. Although they cannot replace a knowledge of local conditions or good engineering and scientific judgment, these suggested practices do provide guidance in developing an individual fuel management system for the middle distillate fuel user. They include suggestions in the operation and maintenance of existing fuel storage and handling facilities and for identifying where, when, and how fuel quality should be monitored or selected for storage or severe use.