Designation: D975 – 20c

Standard Specification for Diesel Fuel[1]

This standard is issued under the fixed designation D975; 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 covers seven grades of diesel fuel 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 fuels 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 fuels. 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.

1.4 *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:*[3]

D56 Test Method for Flash Point by Tag Closed Cup Tester

D86 Test Method for Distillation of Petroleum Products and

[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 and Non-Aviation Gas Turbine Fuels.

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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**

Liquid Fuels at Atmospheric Pressure
D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
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)
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 by High Temperature Combustion and Infrared (IR) Detection or Thermal Conductivity Detection (TCD)
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 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
D2880 Specification for Gas Turbine Fuel Oils
D2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
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
D4176 Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
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 and Liquid Fuels (Optical Detection Stepped Cooling Method)
D5772 Test Method for Cloud Point of Petroleum Products and Liquid Fuels (Linear Cooling Rate Method)
D5773 Test Method for Cloud Point of Petroleum Products and Liquid Fuels (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
D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
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, 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
D7344 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure (Mini Method)
D7345 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure (Micro Distillation 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)
D7467 Specification for Diesel Fuel Oil, Biodiesel Blend (B6 to B20)
D7545 Test Method for Oxidation Stability of Middle Distillate Fuels—Rapid Small Scale Oxidation Test (RSSOT)
D7619 Test Method for Sizing and Counting Particles in Light and Middle Distillate Fuels, by Automatic Particle Counter
D7668 Test Method for Determination of Derived Cetane Number (DCN) of Diesel Fuel Oils—Ignition Delay and Combustion Delay Using a Constant Volume Combustion Chamber Method
D7683 Test Method for Cloud Point of Petroleum Products and Liquid Fuels (Small Test Jar Method)
D7688 Test Method for Evaluating Lubricity of Diesel Fuels by the High-Frequency Reciprocating Rig (HFRR) by Visual Observation
D7689 Test Method for Cloud Point of Petroleum Products and Liquid Fuels (Mini Method)
D7861 Test Method for Determination of Fatty Acid Methyl Esters (FAME) in Diesel Fuel by Linear Variable Filter (LVF) Array Based Mid-Infrared Spectroscopy
D7945 Test Method for Determination of Dynamic Viscosity and Derived Kinematic Viscosity of Liquids by Constant Pressure Viscometer
D8183 Test Method for Determination of Indicated Cetane Number (ICN) of Diesel Fuel Oils using a Constant Volume Combustion Chamber—Reference Fuels Calibration Method
D8148 Test Method for Spectroscopic Determination of Haze in Fuels
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E1064 Test Method for Water in Organic Liquids by Coulometric Karl Fischer Titration

2.2 *Other Documents:*
26 CFR Part 48 Manufacturers and Realtors Excise Taxes[4]
40 CFR Part 80 Regulation of Fuels and Fuel Additives[4]
API RP 2003 Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents[5]
EN 14078 Liquid petroleum products—Determination of fatty acid methyl esters (FAME) in middle distillates—Infrared spectroscopy method[6]
EN 15751 Automotive fuels—Fatty acid methyl ester (FAME) fuel and blends with diesel fuel—Determination of oxidation stability by accelerated oxidation method[6]
IP 156 Determination of hydrocarbon types in petroleum products—Fluorescent indicator adsorption method[7]
ISO 4406 Hydraulic fluid power—Fluids—Method for coding the level of contamination by solid particles[5]
ISO 16889 Hydraulic fluid power—Filters—Multi-pass method for evaluating filtration performance of a filter element[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *additive, n—in diesel fuels,* a substance added to diesel fuel 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 diesel fuel to enhance performance properties (for example, cetane number, lubricity, cold flow, etc.).

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 additive in 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. Similar fouling is expected in diesel engine applications and triglycerides are therefore not allowed as additives or components of additives.

3.1.2 *alternative blendstock, n—in diesel fuels and fuel oils,* a non-hydrocarbon oil substance added to diesel fuel and 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 X7 for guidance regarding new materials for #1-D and #2-D grades of diesel fuels.

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 diesel fuels and 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 *fuel contaminants, n*—material not intended to be present in a fuel, whether introduced during or subsequent to manufacture, handling, distribution or storage, that makes the fuel less suitable for the intended use.

3.1.5.1 *Discussion*—Fuel contaminants include materials introduced subsequent to the manufacture of fuel and fuel degradation products. Contaminants, which can be soluble in the fuel or insoluble (suspended liquid droplets or solid or semisolid particles), can be the result of improper processing or contamination by a wide range of materials including water, rust, airblown dust, deterioration of internal protective coatings on pipes or vessels and products of fuel degradation and biological growth. Solid or semisolid contaminants can be referred to as silt or sediment.

3.1.6 *fuel-degradation products, n*—those materials that are formed in fuel during storage, usage, or exposure to high temperatures and pressures.

3.1.6.1 *Discussion*—Insoluble degradation products can

[4] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.
[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).
[7] Available from Energy Institute, 61 New Cavendish St., London, W1G 7AR, U.K., http://www.energyinst.org.

combine with other fuel contaminants to enhance deleterious effects. Soluble degradation products (soluble gums) are less volatile than fuel and can carbonize to form deposits due to complex interactions and oxidation of small amounts of olefinic or sulfur-, oxygen-, or nitrogen-containing compounds present in fuels. The formation of degradation products can be catalyzed by dissolved metals, especially copper and zinc. When dissolved copper and zinc are present it can be deactivated with metal deactivator additives.

3.1.7 *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.

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

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

3.1.7.3 *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 X7 discusses some matters for consideration regarding the use of diesel fuels from feedstocks other than petroleum.

3.1.8 *S(numerical specification maximum), n*—a part of the grade name that states the maximum sulfur content, in ppm by mass (mg/kg), allowed by this specification and formatted as S followed with no space by the numerical sulfur maximum.

3.1.8.1 *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.

3.1.8.2 *Discussion*—mg/kg is equivalent to µg/g, 1×10^{-4} % by mass, and mass fraction 0.000001.

3.1.8.3 *Discussion*—Most, but not all, test methods to determine sulfur content mentioned in this specification produce results in units of mg/kg. Consult the test method in use to determine units for a particular result.

3.1.9 *severe use, n*—use of the fuel in applications where engines operating under high load conditions can cause the fuel to be exposed to excessive heat and pressure.

3.1.10 *switch loading, n—of liquid fuels*, the practice of loading low vapor pressure product (for example, 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.

3.1.10.1 *Discussion*—Since middle distillate fuels have flash points above 38 °C, during normal distribution of these fuels, the atmosphere above the fuels in 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 fuel vapor or mist remains in the compartment, and the 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.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bulk fuel, n*—fuel in a vessel exceeding 400 L.

3.2.2 *long-term storage, n*—storage of fuel for longer than 12 months after it is received by the user.

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 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 Methods D3828 and D7094 may be used as alternatives 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 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 Methods D93 shall be used as the referee method. Test Method D56 may not be used as the alternative method for Grade No. 4-D because its minimum viscosity limit is 5.5 mm^2/s at 40 °C.

5.1.2 *Cloud Point*—Test Method D2500. For all fuel grades in Table 1, bias-corrected results from the automatic Test Methods D5771, D5772, D5773, D7683, or D7689 may be used as alternatives with the same limits. Bias-correction equations are noted in the respective precision sections of each automatic test method. 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. See Appendix X8 for additional guidance on water and sediment in Grades No. 1-D and 2-D diesel fuels.

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

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

Property	ASTM Test Method[C]	Grade						
		No. 1-D S15	No. 1-D S500[D]	No. 1-D S5000[E]	No. 2-D S15[F]	No. 2-D S500[D,F]	No. 2-D S5000[E,F]	No. 4-D[E]
Flash Point, °C, min.	D93	38	38	38	52[F]	52[F]	52[F]	55
Water and Sediment, percent volume, max	D2709	0.05	0.05	0.05	0.05	0.05	0.05	...
	D1796	...	...	...	...	...	...	0.50
Distillation Temperature, °C 90 %, percent volume recovered	D86							
min		...	...	...	282[F]	282[F]	282[F]	...
max		288	288	288	338	338	338	...
Kinematic Viscosity, mm^2/S at 40 °C	D445							
min		1.3	1.3	1.3	1.9[F]	1.9[F]	1.9[F]	5.5
max	...	2.4	2.4	2.4	4.1	4.1	4.1	24.0
Ash percent mass, max	D482	0.01	0.01	0.01	0.01	0.01	0.01	0.10
Sulfur, ppm (µg/g)[G] max	D5453	15	...	...	15	...	...	...
percent mass, max	D2622[H]	...	0.05	0.50	...	0.05	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[I]	D613	40.[J]	40.[J]	40.[J]	40.[J]	40.[J]	40.[J]	30.[J]
One of the following properties must be met:								
(1) Cetane index, min.	D976–80[H]	40	40	...	40	40	...	...
(2) Aromaticity, percent volume, max	D1319[H,K]	35	35	...	35	35	...	...
Operability Requirements								
Cloud point, °C, max	D2500	[L]	[L]	[L]	[L]	[L]	[L]	...
or								
LTFT/CFPP, °C, max	D4539/D6371							
Ramsbottom carbon residue on 10 % distillation residue, percent mass, max	D524	0.15	0.15	0.15	0.35	0.35	0.35	...
Lubricity, HFRR @ 60 °C, micron, max	D6079/D7688	520	520	520	520	520	520	...
Conductivity, pS/m or Conductivity Units (C.U.), min	D2624/D4308	25[M]	25[M]	25[M]	25[M]	25[M]	25[M]	...

[A] To meet special operating conditions, modifications of individual limiting requirements may be agreed upon between purchaser, seller, and manufacturer.
[B] See Sections 6 and 7 for further statements on diesel fuel requirements.
[C] The test methods indicated are the approved referee methods. Other acceptable methods are indicated in 5.1.
[D] Unless otherwise exempted under United States regulations, if Grades No. 1–DS15, No. 1–D S500, No. 2–D S15, 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 of the solid dye standard Solvent Red 26 per thousand barrels of diesel fuel or kerosine, or the tax must be collected.
[E] 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 of the solid dye standard Solvent Red 26 per thousand barrels of diesel fuel or kerosine.
[F] 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 mm^2/s, and the minimum 90 % recovered temperature shall be waived.
[G] Other sulfur limits can apply in selected areas in the United States and in other countries.
[H] These test methods are specified in 40 CFR Part 80 for S500 grades.
[I] Where cetane number by Test Method D613 is not available, Test Method D4737 can be used as an approximation. Although biodiesel blends are excluded from the scope of Test Method D4737, the results of Test Method D4737 for up to B5 blends can be used as an approximation.
[J] Low ambient temperatures as well as engine operation at high altitudes may require the use of fuels with higher cetane ratings.
[K] See 5.1.12.
[L] It is unrealistic to specify low temperature properties that will ensure satisfactory operation at all ambient conditions. In general, cloud 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 S15; No. 2–D S15; No. 1–D S500; No. 2–D S500; and No. 1–D S5000 and No. 2–D S5000 diesel fuel. However, satisfactory operation below the cloud 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.
[M] 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).

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, D7344, or D7345 can be used as an alternative. Results from Test Method D2887 shall be reported as "Predicted D86" results by application of the correlation in Appendix X4 of Test Method D2887 to convert the values. Results from Test Methods D7344 and D7345 shall be reported as "Predicted D86" results by application of the corrections described in Test Methods D7344 and D7345 to improve agreement with D86

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 and D7945 may be used for all fuel grades in Table 1 with the same limits. Bias-corrected values from Test Method D7042 may be used as alternative results for Test Method D445 on Grades No. 1-D and No. 2-D with the same limits. Section 15, Precision and Bias, of Test Method D7042 contains bias-correction information. In case of dispute, Test Method D445 shall be used as the referee method.

5.1.8 *Sulfur*—The following list shows the referee test methods and alternative test methods for sulfur and the corresponding fuel grades to which each applies.

Sulfur Test Method	Grades
D129	No. 1-D S5000, No. 2-D S5000, No. 4-D
D1266	No. 1-D S500, No. 2-D S500
D1552	No. 1-D S5000, No. 2-D S5000, No. 4-D
D2622 (referee for S500, S5000, and No. 4 Grades)	All Grades
D3120	No. 1-D S15, No. 2-D S15 No. 1-D S500, No. 2-D S500 (If the fuel contains biodiesel, this method may not be applicable as it is limited to oxygenates with a boiling range of 26 °C to 274 °C)
D4294	No. 1-D S500, No. 2-D S500 No. 1-D S5000, No. 2-D S5000, No. 4-D
D5453 (referee for S15 grades)	All Grades
D7039	No. 1-D S15, No. 2-D S15 No. 1-D S500, No. 2-D S500
D7220	No. 1-D S15, No. 1-D S500 No. 2-D S15, No. 2-D S500

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 Methods D6890, D7668 (see Note 4), or D8183 (see Note 5) may be used for all No. 1-D and No. 2-D grades with the DCN or ICN (D8183) result being compared to the cetane number specification requirement of 40. Test Method D613 shall be the referee method.

NOTE 4—Precision from Test Method D7668 were obtained from results produced by laboratories using externally obtained pre-blended calibration reference material.

NOTE 5—Precision from Test Method D8183 were obtained from results produced by laboratories using pre-blended calibration reference materials from a single source.

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. The supplier of the fluorescent indicator dyed gel used in Test Method D1319 (and IP 156) is no longer able to supply the dye needed for the method to work with diesel fuel. Lot numbers 3000000975 and above will not provide correct aromatics values.

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

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.

6.2 The diesel fuel shall also be free of any adulterant or contaminant that can render the fuel unacceptable for its commonly used applications.

7. Requirements

7.1 The grades of diesel fuels herein specified shall be hydrocarbon oils, except as provided in 7.3, with the inclusion of additives to enhance performance, if required, conforming to the detailed requirements shown in Table 1 and as provided in 7.1.1.

7.1.1 Additives may be included in diesel fuel at a blend level not greater than 1 % by volume of the finished fuel.

7.1.1.1 Additives are generally included in finished diesel fuel to enhance performance properties (for example, cetane number, lubricity, cold flow, and so forth).

7.1.1.2 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.

7.1.1.3 Triglycerides (for example, vegetable oils, animal fats, greases, and so forth) have been found to cause fouling of fuel oil burning equipment. Similar fouling is expected in diesel engine applications, and triglycerides are therefore not allowed as additives or components of additives.

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 mm^2/s, and the minimum 90 % recovered temperature shall be waived.

7.3 *Alternative Blendstocks:*

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 containing up to 5 % volume 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 volume percent biodiesel in a biodiesel blend. Test Method EN 14078 or Test Method D7861 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 % volume 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).

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 ≥ 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

9. Keywords

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

APPENDIXES

(Nonmandatory Information)

X1. SIGNIFICANCE OF ASTM SPECIFICATION FOR DIESEL FUELS

X1.1 Introduction

X1.1.1 The properties of commercial fuel oils and diesel fuels 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 °C 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 fuels. Limiting values of significant properties are prescribed for seven grades of diesel fuels. 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 diesel fuels 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 diesel fuels 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 diesel fuels 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 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 diesel fuel 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.

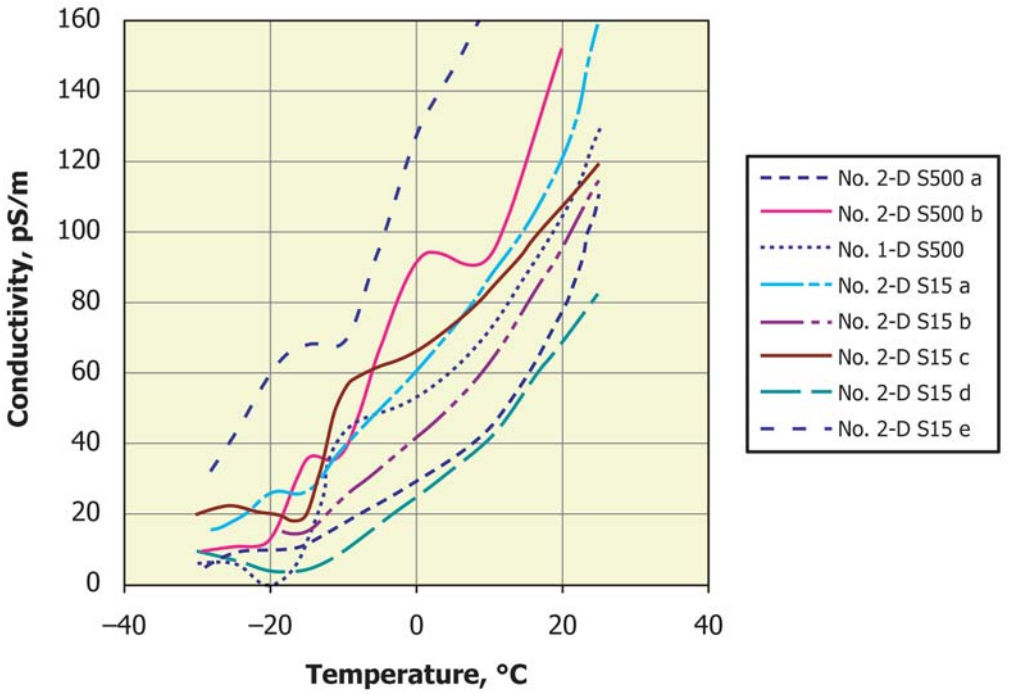

FIG. X1.1 Conductivity Varies with Temperature

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 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.[8]

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, 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

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

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 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 fuels. As diesel fuel 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 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 equipment manufacturer or by federal, state, or local government regulations. Although they cannot replace 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.

X3.1.4 Thermal stability test method, Test Method D6468, was established and successfully used for many years to evaluate Grade No. 2-D S5000 and S500 diesel fuels. Reflectance levels of 70 % at 90 min and 80 % at 180 min were suggested by studies and experience for acceptable and premium performance. The National Conference on Weights and Measures (NCWM) adopted 80 % reflectance at 180 min as one requirement for the definition of premium diesel.

X3.1.5 Nearly all S15 fuel samples, when tested, result in reflectance levels greater than 90 %. Some experts were concerned about the formation of peroxides as the next category of stability concern for S15. If formed, peroxides could affect certain elastomers in equipment adversely.

X3.1.6 Despite high thermal stability as defined by Test Method D6468 and a lack of incidents regarding peroxide formation, the stability of diesel fuel remains a concern because a number of elements have changed. A high reflectance from the Test Method D6468 test may no longer be a clear indication of sufficiently high diesel stability.

X3.1.6.1 Diesel common-rail fuel injection systems with high pressure and high temperature were introduced.

X3.1.6.2 Fuels may be stressed more severely than before in production and usage.

X3.1.6.3 Finer filters are required in some applications to remove particulates from fuel.

X3.1.6.4 Fuel characteristics have changed and new fuel blends, such as with biodiesel, were introduced.

X3.1.7 Therefore, it has been shown that the existing test methods, suggested levels, and practices may not be compatible or adequate to describe diesel fuel stability and its effect in current and future diesel injection equipment. New test methods such as Rancimat (EN 15751) and PetroOxy (D7545) have been introduced and are used, if appropriate for the fuel type.

X3.2 Fuel Selection

X3.2.1 The stability properties of middle distillates are highly dependent on the crude oil sources, severity of processing, use of additives, and whether additional refinery treatment has been carried out.

X3.2.2 The composition and stability properties of middle distillate fuels produced at different refineries can vary. Any special requirements of the user, such as long-term storage or severe service, should be discussed with the supplier.

X3.2.3 Blends of S15, S500, and S5000 diesel fuels from various sources can interact to give stability properties worse than expected based on the characteristics of the individual fuels.

X3.3 Fuel Additives

X3.3.1 Fuel additives can improve the suitability of marginal fuels for long-term storage and thermal stability, but can be unsuccessful for fuels with markedly poor stability properties. Most stability additives should be added at the refinery or as soon after manufacture as possible (no more than a few weeks) to obtain maximum benefits.

X3.3.2 Biocides or biostats kill or inhibit, respectively, the growth of fungi and bacteria, which can grow at fuel-water interfaces to give high particulate concentrations in the fuel. Most available biocides and biostats are soluble in both the fuel and water or in the water phase only.

X3.4 Tests for Fuel Quality

X3.4.1 The storage stability of fuel may be assessed using Test Method D2274 or D5304. However, these accelerated stability tests may not correlate well with field storage stability due to varying field conditions and to fuel composition. Also, these test methods were developed for S5000 and S500 fuels and may not show potential instability of S15 fuels and biodiesel blends of S15 fuels. More recently developed accelerated stability Test Method D7545 has been shown to be suitable for assessing the potential instability of S15 fuels and biodiesel blends of S15 fuels. EN 15751 is used in Specification D7467 for B6-B20 Biodiesel blends and has been shown to be suitable for assessing the potential instability of S15 biodiesel blends of 2 % biodiesel or greater. The presence of cetane improver (2-ethylhexyl nitrate) in diesel fuel can degrade Test Method D7545 performance. While Test Method D7545 can be used to assess the potential instability of fuels, there is no current limit for its use within a specification.

X3.4.2 Performance criteria for accelerated stability tests that assure satisfactory long-term storage of fuels have not been established.

X3.4.3 Test Method D6468, developed for S5000 and S500 fuels, does not show potential thermal instability of S15 fuels and biodiesel blends of S15 fuels very well. Typical S15 diesel fuel almost always results in greater than 90 % reflectance.

X3.5 Fuel Monitoring

X3.5.1 A plan for monitoring the quality of bulk fuel during prolonged storage is an integral part of a successful fuel quality program. A plan to replace aged fuel with fresh product is also desirable.

X3.5.2 Stored fuel should be periodically sampled and its quality assessed. Practice D4057 provides guidance for sampling. Fuel contaminants and degradation products will usually settle to the bottom of a quiescent tank. A “Bottom” or “Clearance” sample, as defined in Practice D4057, should be included in the evaluation along with an “All Level” sample.

X3.5.3 The quantity of insoluble fuel contaminants present in fuel can be determined using Test Method D6217.

X3.5.4 Test Method D6468, can be used for investigation of operational problems that might be related to fuel thermal stability of S500 and S5000 fuels. Test Method D6468 does not show potential thermal stability of S15 fuels and biodiesel blends of S15 fuels very well. Use EN 15751 or Test Method D7545 for oxidative stability assessment instead. Testing samples from the fuel tank or from bulk storage may give an indication as to the cause of filter plugging. It is more difficult to monitor the quality of fuels in vehicle tanks since they may contain fuels from multiple sources.