



# Standard Specification for Commercial Boiler Fuels With Used Lubricating Oils<sup>1</sup>

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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 four grades of fuel oil made of at least 25 % used lubricating oils. The four grades of fuel are intended for use in various types of fuel-oil-burning industrial equipment and commercial boilers under various climatic and operating conditions. These fuels are not intended for use in residential heaters.

1.1.1 Grades RFC4, RFC5L, RFC5H and RFC6 are used lubricating oil blends of increasing viscosity, with or without middle distillate or residual fuel oil, or both, that are intended for use in industrial burners and commercial boilers equipped to handle these types of fuels. This specification is for applications where Specification D6448 would not meet the performance or other requirements of the burner or boiler in question.

NOTE 1—For information on the significance of the terminology and test methods used in this specification, see Appendix X1.

1.2 This specification is for use in contracts for the purchase of fuel oils derived from used lubricating oil and for the guidance of consumers of such fuels. This specification does not address the frequency with which any particular test must be run.

1.3 Nothing in this specification shall preclude observance of national or local regulations which can be more restrictive. In some jurisdictions, used oil is considered a hazardous waste and fuels derived from used oil are required to meet certain criteria before use as a fuel.

NOTE 2—For United States federal requirements imposed on used oil generators, transporters and transfer facilities, reproprocessors, marketers, and burners, see 40 CFR Part 279.

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

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

1.4.1 *Exception*—Table 1 and Table X1.1 include inch-pound values in parentheses for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- D56 Test Method for Flash Point by Tag Closed Cup Tester
- D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
- D95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation
- D97 Test Method for Pour Point of Petroleum Products
- D129 Test Method for Sulfur in Petroleum Products (General High Pressure Decomposition Device Method)
- D240 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter
- D396 Specification for Fuel Oils
- D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
- D473 Test Method for Sediment in Crude Oils and Fuel Oils by the Extraction Method
- D482 Test Method for Ash from Petroleum Products
- D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
- D974 Test Method for Acid and Base Number by Color-Indicator Titration
- D1266 Test Method for Sulfur in Petroleum Products (Lamp Method)
- D1298 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
- D1552 Test Method for Sulfur in Petroleum Products (High-Temperature Method)
- D1796 Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)
- D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

**TABLE 1 Detailed Requirements for Non-Industrial Burner Fuels from Used Lubricating Oils**

Properties	Test Method <sup>A</sup>	Limits <sup>B</sup>			
		RFC4	RFC5L	RFC5H	RFC6
Physical					
Viscosity at 100°C mm <sup>2</sup> /s <sup>C</sup>	<b>D445</b>				
min	...	...	5.0	9.0	15.0
max	...	<5.0	8.9	14.9	50.0
Flash point, °C (°F), min	<b>D93</b> , Procedure B	38 (100)	55 (130)	55 (130)	60 (140)
Water and sediment, <sup>D</sup> % volume max	<b>D1796</b>	1.0	1.0	2.0	2.0
Pour point, °C (°F), max	<b>D97</b>	-6 (21)	<sup>E</sup>	<sup>E</sup>	<sup>E</sup>
Density, kg/m <sup>3</sup> at 15°C <sup>F</sup>	<b>D1298</b>	Report	Report	Report	Report
Chemical					
Acid no., mg KOH/g, max	<b>D664</b>	0.15	0.15	0.30	0.30
Ash, % mass, max <sup>G</sup>	<b>D482</b>	0.2	0.3	0.3	Report
Sulfur, % mass <sup>H</sup>	<b>D129</b>	Report	Report	Report	Report
Performance					
Gross heating value, MJ/kg (BTU/gal), <sup>I</sup> min	<b>D240</b>	40.0 (130 000)	41.5 (135 000)	41.5 (135 000)	43.0 (140 000)
Contaminants <sup>J</sup>					
Arsenic, ppm, max.	<sup>K</sup>			5	
Cadmium, ppm, max	<sup>K</sup>			2	
Chromium, ppm, max	<b>D5185</b> <sup>K</sup>			10	
Lead, ppm, max	<b>D5185</b> <sup>K</sup>			100	
Total halogens, ppm, max	<b>D5384</b> <sup>K</sup>			1000	
PCBs, ppm, max	<b>D6160</b>			50 <sup>L</sup>	

<sup>A</sup> See Section 8 for details and additional test methods.

<sup>B</sup> Units given in parentheses are for informational purposes only.

<sup>C</sup> 1 cSt = 1 mm<sup>2</sup>/s.

<sup>D</sup> Solids content shall not exceed 0.5 %. Filtration may be required to obtain appropriate particle size for use. A deduction in quantity shall be made for all water and sediment in excess of 1.0 mass % for Grades RFC5H and RFC6.

<sup>E</sup> Buyer and seller to agree.

<sup>F</sup> Density in kg/L at 15°C multiplied by 1000 = kg/m<sup>3</sup>.

<sup>G</sup> Buyer and seller may agree on a higher ash content.

<sup>H</sup> Local jurisdictions may limit the sulfur content in burner fuels.

<sup>I</sup> Assumes 7.5 lb/US gal.

<sup>J</sup> These are US EPA current limits (40 CFR Part 279 and 40 CFR Part 761). If state or local requirements for used oil are more stringent, the burner fuel offered shall comply with the more stringent requirements.

<sup>K</sup> US EPA SW-846 6010. Where Test Method **D5185** is listed, Test Method **D5185** will be the referee test method.

<sup>L</sup> In the United States, current unrestricted use IAW 40 CFR Part 279 is <2 ppm. PCBs are permitted in qualified incinerators as defined in 40 CFR Part 761. US EPA prohibits blending down oils of >50 ppm to <50 ppm and oils <50 ppm to less than 2 ppm.

**D2983** Test Method for Low-Temperature Viscosity of Lubricants Measured by Brookfield Viscometer

**D3228** Test Method for Total Nitrogen in Lubricating Oils and Fuel Oils by Modified Kjeldahl Method

**D3245** Test Method for Pumpability of Industrial Fuel Oils (Withdrawn 2010)<sup>3</sup>

**D3828** Test Methods for Flash Point by Small Scale Closed Cup Tester

**D4052** Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter

**D4057** Practice for Manual Sampling of Petroleum and Petroleum Products

**D4175** Terminology Relating to Petroleum, Petroleum Products, and Lubricants

**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

**D4629** Test Method for Trace Nitrogen in Liquid Petroleum Hydrocarbons by Syringe/Inlet Oxidative Combustion and Chemiluminescence Detection

**D4865** Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems

**D4868** Test Method for Estimation of Net and Gross Heat of Combustion of Burner and Diesel Fuels

**D5185** Test Method for Determination of Additive Elements, Wear Metals, and Contaminants in Used Lubricating Oils and Determination of Selected Elements in Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

**D5291** Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants

**D5384** Test Methods for Chlorine in Used Petroleum Products (Field Test Kit Method)

**D5854** Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products

**D6160** Test Method for Determination of Polychlorinated Biphenyls (PCBs) in Waste Materials by Gas Chromatography

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

**D6448** Specification for Industrial Burner Fuels from Used Lubricating Oils

**D6450** Test Method for Flash Point by Continuously Closed Cup (CCCFP) Tester

**D7042** Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)

2.2 *ISO Standard*:<sup>4</sup>

**ISO 8217** Petroleum Products—Fuel (Class F)—Specifications for Marine Fuels

2.3 *U.S. Code of Federal Regulations*:<sup>5</sup>

**40 CFR Part 761** Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions

**40 CFR Part 279** Standards for the Management of Used Oil

2.4 *US EPA Standards*:<sup>6</sup>

**SW-846** Test Methods for Evaluating Solid Wastes Physical/Chemical Methods

**SW-846 5050** Bomb Preparation Method for Solid Waste

**SW-846 6010** Inductively Coupled Plasma-Atomic Emission Spectrometry

**SW-846 9056A** Determination of Inorganic Anions by Ion Chromatography

**SW-846 9075** Test Method for Total Chlorine in New and Used Petroleum Products by X-Ray Fluorescence Spectrometry (XRF)

**SW-846 9076** Test Method for Total Chlorine in New and Used Petroleum Products by Oxidative Combustion and Microcoulometry

**SW-846 9077** Test Methods for Total Chlorine in New and Used Petroleum Products (Field Test Kit Methods)

### 3. Terminology

3.1 For definitions of other terms used in this specification, refer to Terminology **D4175**.

#### 3.2 Definitions:

3.2.1 *burner fuel oil, n*—any petroleum liquid suitable for the generation of heat by combustion in a furnace or firebox as a vapor or a spray, or a combination of both.

3.2.1.1 *Discussion*—Different grades are characterized primarily by viscosity grades.

3.2.2 *reclaiming, n*—the use of cleaning methods during recycling primarily to remove insoluble contaminants, thus making the oil suitable for further use. The methods may include settling, heating, dehydration, filtration, and centrifuging.

3.2.3 *recycling, n—in petroleum technology*, the acquisition of oil that has become unsuitable for its intended use, and processing it in order to regain useful materials.

3.2.4 *re-refining, n*—the use of refining processes during recycling to produce high quality base stocks for lubricants or other petroleum products. Re-refining may include distillation, hydrotreating, or treatments employing acid, caustic, solvent, clay, or both, or other chemicals, or a combination thereof.

3.2.5 *used oil, n—in petroleum product recycling*, oil whose characteristics have changed since being originally manufactured, and which is suitable for recycling.

3.2.6 *waste oil, n—in petroleum technology*, oil having characteristics making it unsuitable either for further use or for economic recycling.

#### 3.3 Definitions of Terms Specific to This Standard:

3.3.1 *commercial boiler, n*—indirect heating units which transfer thermal energy to water or other fluids or gases for use in heating and having a heat input between  $0.3$  to  $10 \times 10^6$  BTU/h.

3.3.2 *industrial burner, n*—a device which produces heat for industrial use through the combustion of liquid hydrocarbon fuels.

3.3.2.1 *Discussion*—Industrial burners are typically designed for one of two applications: (1) *industrial furnaces*—integral components of manufacturing processes that provide direct heating; for example, in aggregate, cement, lime, or phosphate kilns; coke ovens; or blast, smelting, melting, refining, or drying ovens and (2) *industrial boilers*—large indirect heating units which transfer thermal energy to water or other fluids or gases for use in heating in industrial settings and in manufacturing processes. These boilers can be classified as utility/large industrial boilers with a heat input greater than  $100 \times 10^6$  BTU/h or small industrial boilers with a heat input of between  $10$  to  $100 \times 10^6$  BTU/h.

3.3.3 *reprocessing, n—in petroleum product recycling*, the preparation of used oil to be suitable as a fuel.

3.3.3.1 *Discussion*—Reprocessing includes procedures such as settling, filtration, blending, distillation, or chemical treatment.

#### 3.4 Acronyms:

3.4.1 *ISO*—International Organization for Standardization.

3.4.2 *RCRA*—Resource Conservation and Recovery Act (United States).

3.4.3 *US EPA*—United States Environmental Protection Agency.

#### 3.5 Abbreviations:

3.5.1 *CFR*—Code of Federal Regulations.

3.5.2 *IAW*—in accordance with.

3.5.3 *RFC4*—recycled fuel, commercial boilers, grade number 4.

3.5.4 *RFC5L*—recycled fuel, commercial boilers, grade number 5 light.

3.5.5 *RFC5H*—recycled fuel, commercial boilers, grade number 5 heavy.

3.5.6 *RFC6*—recycled fuel, commercial boilers, grade number 6.

<sup>4</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

<sup>5</sup> Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401 ([www.gpoaccess.gov](http://www.gpoaccess.gov)).

<sup>6</sup> Available from Environmental Protection Agency, Ariel Rios Bldg., 1200 Pennsylvania Ave., N.W., Washington, DC 20460 ([www.epa.gov](http://www.epa.gov)). Downloadable files available at <http://www.epa.gov/epawaste/hazard/testmethods/sw846/index.htm>.

3.5.7 *SW*—solid waste, SW-846SW-846 **Test Methods for Evaluating Solid Wastes Physical/Chemical Methods** is US EPA Office of Solid Waste’s official compendium of analytical and sampling methods for use in complying with the RCRA regulations.

#### 4. Significance and Use

4.1 The intention of this specification is to cover fuel oil used in industrial equipment and commercial boilers as stated in the Scope section. The use of used lube oil in marine and industrial diesel engines is a contentious issue. A major marine fuel oil specification is ISO 8217. Fuel oils manufactured against this standard may also meet the requirements of ISO 8217 and can be used in marine diesel engine operations provided compliance to ISO 8217 is demonstrated.

#### 5. Classification

5.1 There are four grades of burner fuel containing recycled lubricating oils covered by this specification. These grades may or may not correlate directly with similar grades in other ASTM standards. The RFC designation identifies them as recycled fuel oil, commercial boilers. The usage descriptions of each grade may not describe all the uses, but are included as general information. The four grades are described as follows:

5.1.1 *Grade RFC4*—Primarily a blend of used lubricating oils and middle distillate or a reprocessed distillate product derived from used oil. It is intended for use in pressure atomizing industrial burners or commercial boilers with no pre-heating. This grade of recycled oil fuel is used in many medium capacity industrial burners and commercial boilers where ease of handling justifies the higher cost over the heavier used oil fuels.

5.1.2 *Grade RFC5L*—A blend of a used lubricating oil or a reprocessed product from used oil and middle distillate or residual fuel of intermediate viscosity heavier than RFC4. It is intended for use both in pressure-atomizing industrial burners and commercial boilers not requiring higher cost middle distillates and in burners and commercial boilers equipped to atomize fuel oils of higher viscosity with or without preheating. Its permissible viscosity range allows it to be pumped and atomized at relatively low-storage temperatures.

5.1.3 *Grade RFC5H*—A used lubricating oil and residual blend fuel, heavier than Grade RFC5L. It is intended for use in industrial burners and commercial boilers equipped with devices that atomize fuel oil of higher viscosity. Preheating may be necessary in some types of equipment for burning and in colder climates for handling.

5.1.4 *Grade RFC6*—A high-viscosity used lubricating oil and fuel heavier than Grade RFC5H. It is intended for use in large industrial heaters and boilers and may require preheating in the storage tank to permit pumping. Additional preheating at the burner may be necessary to permit satisfactory atomization. The extra equipment and maintenance required to handle this fuel usually preclude its use in small installations.

#### 6. General Requirements

6.1 The fuel oils specified herein shall contain a minimum of 25 % volume of used lubricating oil-derived products, the balance being a Specification **D396** fuel oil or suitable refinery stocks.

6.2 The fuel oils shall be homogeneous fluids consisting primarily of hydrocarbons. RFC shall remain homogeneous and uniform in storage and shall not separate by gravity into layers in normal operating conditions.

NOTE 4—Prolonged storage or equipment down time may necessitate circulation of the fuel oil in-tank to prevent such separation. The buyer and seller should agree on any requirements for long-term homogeneity.

6.3 The fuel oil shall not contain excessive amounts of organic or inorganic acids, or both, and shall be free of solid or fibrous matter that could cause system handling or maintenance problems. The buyer and seller should agree on any requirements for particle size.

NOTE 5—The fuels defined by this specification are appropriate for burners capable of handling and combusting fuels with potentially high metals and higher ash content than Specification **D396** fuels.

#### 7. Detailed Requirements

7.1 *Grade RFC4*—The requirements for this type of fuel are presented in **Table 1** and include fuels in the viscosity range below 5 mm<sup>2</sup>/s (cSt) at 100°C according to Test Method **D445**.

7.2 *Grade RFC5L*—The requirements for this type of fuel are presented in **Table 1** and include fuels in the viscosity range 5.0 to 8.9 mm<sup>2</sup>/s (cSt) at 100°C according to Test Method **D445**.

7.3 *Grade RFC5H*—The requirements for this type of fuel are presented in **Table 1** and include fuels in the viscosity range 9.0 to 14.9 mm<sup>2</sup>/s (cSt) at 100°C according to Test Method **D445**.

7.4 *Grade RFC6*—The requirements for this type of fuel are presented in **Table 1** and include fuels in the viscosity range 15.0 to 50.0 mm<sup>2</sup>/s (cSt) at 100°C according to Test Method **D445**.

NOTE 6—Refer to **X1.3**. Viscosity measurements may be provided/agreed to other than the above listed temperatures.

NOTE 7—In the U.S., RFC must also meet US EPA on-specification parameters for recycled used oil fuels as defined under 40 CFR Part 279, 40 CFR Part 761, and air quality regulations for particulate matter.

7.5 The properties listed in this specification are those of greatest significance in obtaining acceptable performance of the burner. Only referee test methods are shown in **Table 1**. (See Section 8 for alternate test methods and **Appendix X1** for significance of test requirements.)

7.5.1 *Ash Content*—Specific burners/boilers may be able to handle higher ash contents without increasing maintenance. Buyer/seller may agree on an alternate ash content based on specific equipment capabilities.

7.6 A representative sample shall be obtained for testing. Practices **D4057**, **D4177**, or other comparable sampling standards should be followed. In case of dispute, Practice **D4057**

shall be the referee practice. A minimum sample size of about 1 L is recommended for each sample taken (before compositing). Sample handling and mixing shall comply with Practice **D5854**.

7.7 Testing frequency and any modifications of limiting requirements to meet special operating conditions shall be agreed upon by both the buyer and the seller.

NOTE 8—It is possible that one or more of the parameters listed in **Table 1** may be used as an indicator of when more extensive testing is required.

## 8. Test Methods

8.1 The requirements enumerated in this specification shall be determined in accordance with the following ASTM methods except as noted:

8.1.1 *Viscosity*—Test Method **D445**. For quality control, Test Method **D7042** or a Brookfield rotary viscometer (Test Method **D2983**) may be used. In case of dispute, Test Method **D445** shall be used as the referee method.

8.1.2 *Flash Point*—Test Methods **D93** Procedure B, manual method, except where other methods are prescribed by law. For all grades, Test Methods **D3828** and **D6450** may be used as an alternative method with the same limits. For RFC4 fuel oils, 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 mm<sup>2</sup>/s at 40°C. This test method will give slightly lower values. In case of dispute, Test Methods **D93** Procedure B, manual method, shall be used as the referee method.

8.1.3 *Water and Sediment*—Test Method **D1796** for water and sediment, Test Methods **D95** and **D473** may be used as an alternate with the same limits if agreed. The volume percents are added to obtain the percent of total water and sediment. In case of dispute, Test Method **D1796** shall be used as the referee method.

8.1.4 *Pour Point*—Test Method **D97**.

8.1.5 *Density*—Test Method **D1298**. Test Method **D4052** may be used as an alternate with the same limits. In case of dispute, Test Method **D1298** shall be the referee method.

8.1.6 *Acid Number*—Test Methods **D974** and **D664** are acceptable. Test Method **D664** shall be used as the referee test method.

8.1.7 *Ash*—Test Method **D482**.

8.1.8 *Sulfur*—Test Method **D129**. Test Methods **D1266**, **D1552**, **D2622**, **D4294**, and **D5185**. For Grade RFC4 fuels having a sulfur content below 0.4 % mass, Test Method **D1266** may be used as an alternate with the same limits. In case of dispute, Test Method **D4294** shall be the referee method.

8.1.9 *Heating Value (Heat of Combustion)*—Test Method **D240**. Test Method **D4868**, a calculation method, may be used as an alternate, with the same limits, where precise heat determinations are not critical. In case of dispute, Test Method **D240** shall be the referee method.

8.1.10 *Metals*—Test Method **D5185** or other approved method meeting US EPA Test Method SW 846-6010 are acceptable. In case of dispute, Test Method **D5185** shall be the referee method.

8.1.11 *Halogens*—Test Method **D5384** or other approved standards meeting US EPA Test Method SW 846-5050, SW 846-9056, SW 846-9075, SW 846-9076, or SW 846-9077 are acceptable.

## 9. Keywords

9.1 burner fuels; fuel oils; petroleum and petroleum products; specifications; used oils

## APPENDIXES

### (Nonmandatory Information)

## X1. SIGNIFICANCE OF ASTM SPECIFICATION FOR COMMERCIAL BURNER FUELS WITH USED LUBRICATING OILS

### X1.1 Scope

X1.1.1 This specification divides fuel oils into grades based upon kinematic viscosity. It places limiting values on the properties of the oils in each grade believed to be of the greatest significance in determining the performance characteristics of the fuel oils in the types of burners in which they are most commonly used. The type of burner for which a fuel oil is suitable depends largely on the fuel's viscosity.

### X1.2 Significance of Test Methods

#### X1.2.1 *Physical Properties:*

X1.2.1.1 *Viscosity*—Viscosity is the measure of a fluid's resistance to flow. In fuel oil it is highly significant; it indicates both the relative ease with which the oil will flow or can be pumped, and the ease of atomization. Viscosity is particularly important for the heavier grades which may require appropriate

preheating facilities to permit the product to be pumped to the burner and for good atomization.

X1.2.1.2 *Flash Point*—The flash point of a fuel oil is an indication of the maximum temperature at which it can be stored and handled without serious fire hazard. The minimum permissible flash point is usually regulated by national or local laws and is based on accepted practice in handling and use.

X1.2.1.3 *Water and Sediment*—Appreciable amounts of water and sediment in a fuel oil tend to cause fouling of fuel-handling facilities and to give trouble in burner mechanisms. Sediment may accumulate in storage tanks and on filter screens or burner parts, resulting in obstruction to flow of oil from the tank to the burner. Water in distillate fuel can cause corrosion of tanks and equipment, and water in residual fuel may cause emulsions. The presence of water in a burner fuel can also cause *spattering* in a burner flame, and lead to damage of burner nozzles (erosion or *explosive* damage) due to the

rapid expansion of water in water vapor at a hot nozzle tip. Excessive water in burner fuel could lead to *flame out* or extinguishing the flame.

**X1.2.1.4 Pour Point**—An indication of the lowest temperature at which a fuel oil can be stored and still be capable of flowing under very low forces. The pour point is prescribed in accordance with the conditions of storage and use. Higher pour point fuels are permissible where heated storage and adequate piping facilities are provided. An increase in pour point can occur when residual fuel oils are subjected to cyclic temperature variations that can occur in the course of storage or when the fuel is preheated and returned to storage tanks. To predict these properties, Test Method **D3245** may be required.

**X1.2.1.5 Density**—Density alone is of little significance as an indication of the burning characteristics of fuel oil. However, when used in conjunction with other properties, it is of value in mass-volume relationships and in calculating the specific energy (heating value per unit mass) of an oil. Higher density burner fuels may indicate higher aromatics content, which may result in more soot or carbonaceous deposits if combustion temperatures are not hot enough for complete combustion.

**X1.2.2 Chemical Properties:**

**X1.2.2.1 Ash**—Ash is the amount of noncombustible material in an oil. Ash-forming materials may be present in fuel oil in two forms, solid particles or oil- or water-soluble metallic compounds, or both. The solid particles are, for the most part, the same material that is designated as sediment in the water and sediment test. Depending upon their size, these particles can contribute to wear of burner pumps and valves, and decrease fuel efficiency. The soluble metallic compounds have little or no effect on wear or plugging, but they can contain elements that produce corrosion and deposits on boiler heating surfaces. Excessive amounts of ash also may cause violation of national or local air emission regulations.

**X1.2.2.2 Sulfur**—A knowledge of the sulfur content of fuel oil can be useful for special applications in connection with heat treatment, nonferrous metal, glass, and ceramic furnaces or to meet national or local legislation or regulations.

**X1.2.2.3 Contaminants**—Arsenic, cadmium, chromium, lead, and halogens are residues found in lubrication oils from additives in the lubricating oil and metal wear. These have been

found to cause health risks at levels above the permitted limits. The metals are known to increase ash and foul nozzles which affect boiler performance.

**X1.2.3 Performance Properties:**

**X1.2.3.1 Heat of Combustion**—A knowledge of the heat of combustion is useful in determining the thermal efficiency of equipment for producing either power or heat. This in turn may determine the economic value of the fuel.

**X1.3 Viscosity Conversions**

**X1.3.1** This specification specifies limiting values of kinematic viscosity at 100°C for the fuel oil categories contained in **Table 1**. In some cases, kinematic viscosity may be measured or quoted at other temperatures or in other units. **Table X1.1** gives approximate relationships. The data should be used with caution, first, since the precision of measurements at temperatures other than 100°C may differ, and second, because the variability of composition of these fuels may cause variations in viscosity-temperature relationships.

**NOTE X1.1**—Kinematic viscosity may be calculated from dynamic viscosity measurement by multiplying the dynamic viscosity in mPa.s by the density of the sample density in kg/m<sup>3</sup>. Use the density at the same temperature as the temperature of the desired kinematic viscosity.

**X1.4 Nitrogen Requirement**

**X1.4.1** When mandated by environmental or permit regulatory agencies, the nitrogen content shall be tested using Test Methods **D3228**, **D4629**, or **D5291**. The nitrogen content is used to determine nitrogen oxides (NO<sub>x</sub>) emissions from boiler systems. It is highly recommended that the buyer know whether this requirement exists and place it in the purchase request.

**TABLE X1.1 Viscosities Estimated from Those Measured at 100°C**

Kinematic Viscosity, mm <sup>2</sup> /s	Estimated Viscosity at Temperature			
	Kinematic Viscosity, mm <sup>2</sup> /s		Saybolt Universal, s	Saybolt Furol, s
	100°C	40°C	100°F	122°F
5.0	24	17	125	...
9.0	58	40	290	21
15.0	170	100	900	48
50.0	1350	640	7400	300

**X2. STABILITY OF SEDIMENT AND WATER IN FUEL OILS**

**X2.1** There are occasions when the stability of the sediment and water in a mixture is important to the buyer or seller. As a measure of the rapidity with which sediment and water settles out of the product, a stability ratio may be used. The stability ratio is defined as:

$$\text{express \% stability} = \quad (X2.1)$$

$$\frac{\text{concentration of sediment and water at the top}}{\text{concentration of sediment and water at the bottom}} \times 100$$

**X2.2** Take a 1 L sample from a homogenous source of the fuel oil.

**X2.3** Allow to settle for 24 h.

**X2.4** Take an aliquot 1 in. from the top sufficient to run the sediment and water test without disturbing the layers below the sample point. Take an aliquot 1 in. from the bottom sufficient to run the sediment and water test.

**X2.5** Perform the sediment and water test on each aliquot.

**X2.6** Calculate the express % stability.

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