Designation: D6448 – 16

Standard Specification for Industrial Burner Fuels from Used Lubricating Oils[1]

This standard is issued under the fixed designation D6448; 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.

1. Scope*

1.1 This specification covers four grades of fuel oil made in whole or in part with hydrocarbon-based used or reprocessed lubricating oil or functional fluids, such as preservative and hydraulic fluids. The four grades of fuel are intended for use in various types of fuel-oil-burning industrial equipment under various climatic and operating conditions. These fuels are not intended for use in residential heaters, small commercial boilers, combustion engines, or marine applications,

1.1.1 Grades RFO4, RFO5L, RFO5H, and RFO6 are used lubricating oil blends, with or without distillate or residual fuel oil, or both, of increasing viscosity and are intended for use in industrial burners equipped to handle these types of recycled fuels.

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 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, reprocessors, marketers, and burners, see 40 CFR 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; non-SI units, when given, are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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
D96 Test Method for Water and Sediment in Crude Oil by Centrifuge Method (Field Procedure) (Withdrawn 2000)[3]
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
D1217 Test Method for Density and Relative Density (Specific Gravity) of Liquids by Bingham Pycnometer
D1250 Guide for Use of the Petroleum Measurement Tables
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
D1480 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Bingham Pycnometer
D1481 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Lipkin Bicapillary Pycnometer
D1552 Test Method for Sulfur in Petroleum Products by High Temperature Combustion and IR Detection

[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.P0 on Recycled Products.

Current edition approved April 1, 2016. Published April 2016. Originally approved in 1999. Last previous edition approved in 2014 as D6448 – 14ε1. DOI: 10.1520/D6448-16.

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

[3] The last approved version of this historical standard is referenced on www.astm.org.

***A Summary of Changes section appears at the end of this standard**

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
D2709 Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge
D2983 Test Method for Low-Temperature Viscosity of Lubricants Measured by Brookfield Viscometer
D3245 Test Method for Pumpability of Industrial Fuel Oils (Withdrawn 2010)[3]
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 Products, Liquid Fuels, 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
D4377 Test Method for Water in Crude Oils by Potentiometric Karl Fischer Titration
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
D4980 Test Methods for Screening of pH in Waste (Withdrawn 2009)[3]
D5185 Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D5854 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products
D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration (Withdrawn 2016)[3]
D6450 Test Method for Flash Point by Continuously Closed Cup (CCCFP) Tester
D6822 Test Method for Density, Relative Density, and API Gravity of Crude Petroleum and Liquid Petroleum Products by Thermohydrometer Method
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

2.2 *U.S. Environmental Protection Agency Standards:*[4]
EPA 600/4-79-020 Determination of Inorganic Anions by Ion Chromatography
EPA SW-846 Method 9000 Determination of Water in Waste Materials by Karl Fisher Titration
EPA SW-846 Method 9001 Determination of Water in Waste Lubricants by Quantitative Calcium Hydride Reaction
EPA SW-846 Method 9056 Determination of Inorganic Anions by Ion Chromatography

2.3 *Federal Code of Regulations Standards:*[5]
40 CFR 279 Standards for the Management of Used Oil

3. Terminology

3.1 *Definitions:*

3.1.1 *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.

3.1.1.1 *Discussion*—Different grades are characterized primarily by viscosity ranges.

3.1.2 *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.

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

3.1.4 *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 one or more of the following: distillation, hydrotreating, or treatments employing acid, caustic, solvent, clay, or other chemicals, or combination thereof.

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

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

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

3.3 *Definitions of Terms Specific to This Standard:*

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

3.3.1.1 *Discussion*—Industrial burners are typically designed for one of two applications:

(a) 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.

(b) industrial boilers—large indirect heating units that transfer thermal energy to water or other fluids or gases for use in heating in industrial settings and in manufacturing processes

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

[4] Available from United States Environmental Protection Agency (US-EPA), Ariel Rios Bldg., Pennsylvania Ave., NW, Washington D.C. 20460. (www.epa.gov/epaoswer/hazwaste/test/main.htm.

[5] National Archives and Records Administration, Code of Federal Regulations (CFR), Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401. www.gpoaccess.gov/cfr/index.html.

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

4. Classification

4.1 There are four grades of industrial 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 RFO designation identifies them as Reprocessed Fuel Oils. 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:

4.1.1 *Grade RFO4*—Primarily a blend of used lubricating oils and distillate or a reprocessed distillate product derived from used oil. It is intended for use in pressure atomizing industrial burners with no preheating. This grade of recycled oil fuel is used in many medium capacity industrial burners where ease of handling justifies the higher cost over the heavier used oil fuels.

4.1.2 *Grade RFO5L*—A straight (100 %) used lubricating oil blend or a used lubricating oil and distillate blend fuel of intermediate viscosity, heavier than Grade RFO4. It is intended for use both in pressure-atomizing industrial burners not requiring higher cost distillates and in burners equipped to atomize oils of higher viscosity with or without pre-heating. Its permissible viscosity range allows it to be pumped and atomized at relatively low-storage temperatures.

4.1.3 *Grade RFO5H*—A straight (100 %) used lubricating oil blend or a used lubricating oil and residual blend fuel, heavier than Grade RFO5L. It is intended for use in industrial burners equipped with devices that atomize oil of higher viscosity than domestic burners can handle. Preheating may be necessary in some types of equipment for burning and in colder climates for handling.

4.1.4 *Grade RFO6*—A high-viscosity used lubricating oil and residual blend fuel, heavier than Grade RFO5H. It is intended for use in large industrial heaters 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.

5. General Requirements

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

5.2 The fuel oils shall be homogeneous fluids consisting primarily of hydrocarbons. Fuel oils containing residual components shall remain uniform in storage and shall not separate by gravity or aging 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.

5.3 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 only for burners capable of handling and combusting fuels with potentially higher metals and ash content.

6. Detailed Requirements

6.1 *Grade RFO4*—The requirements for this type of fuel are presented in Table 1 and include fuels in the viscosity range below 5 mm^2/s (cSt) at 100 °C in accordance with Test Method D445.

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

Properties	Method[A]	Proposed Limits[B]			
		RFO4	RFO5L	RFO5H	RFO6
Physical:					
Viscosity @ 100 °C mm^2/s[C]	D445				
minimum	. . .	. . .	5.0	9.0	15.0
maximum	. . .	<5.0	8.9	14.9	50.0
Flash point, °C (°F), min	D93	38 (100)	55 (130)	55 (130)	60 (140)
Water & sediment,[D] percent by volume max	D95 and D473	2.0	3.0	3.0	3.0
Pour point, °C (°F), max	D97	−6 (21)	NA	NA	NA
Density, kg/m^3 @ 15 °C[E]	D1298	Report	NA	NA	NA
Chemical:					
Ash, percent by mass, max	D482	0.7	0.8	0.8	Report
Sulphur, percent by mass[F]	D129	Report	Report	Report	Report
Extracted pH, min	D4980	4.0	4.0	4.0	4.0
Performance:					
Gross heating value, MJ/kg (BTU/US gal),[G] min	D240	40.0 (130 000)	41.5 (135 000)	41.5 (135 000)	43.0 (140 000)

[A] See Section 7 for details and additional methods.
[B] Units given in parentheses are for informational purposes only.
[C] 1 cSt = 1 mm^2/s.
[D] Solids content should not exceed 1.0 % for RFO4 and 5; 2.0 % for RFO 6; Filtration may be required to obtain appropriate particle size for use.
[E] Density in kg/L at 15 °C multiplied by 1000 = kg/m^3.
[F] Local jurisdictions may limit the sulphur content in burner fuels.
[G] Assumes 7.5 lb/U.S. gal.

6.2 *Grade RFO5L*—The requirements for this type of fuel are presented in Table 1 and include fuels in the viscosity range 5.0 mm^2/s to 8.9 mm^2/s (cSt) at 100 °C in accordance with Test Method D445.

6.3 *Grade RFO5H*—The requirements for this type of fuel are presented in Table 1 and include fuels in the viscosity range 9.0 mm^2/s to 14.9 mm^2/s (cSt) at 100 °C in accordance with Test Method D445.

6.4 *Grade RFO6*—The requirements for this type of fuel are presented in Table 1 and include fuels in the viscosity range 15.0 mm^2/s to 50.0 mm^2/s (cSt) at 100 °C in accordance with Test Method D445.

NOTE 6—In the United States, fuel must also meet Environmental Protection Agency on-specification parameters for recycled used oil fuels as defined under 40 CFR 279.11.

6.5 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 7 for alternative test methods and Appendix X1 for significance of test requirements).

6.6 A representative sample shall be obtained for testing. Practice D4057 or 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 (1 U.S. qt) is recommended.

6.7 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 7—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.

7. Test Methods

7.1 The requirements enumerated in this specification shall be determined in accordance with the following test methods, except as noted:

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

7.1.1.1 Kinematic viscosity may be calculated from dynamic viscosity measurement by dividing the dynamic viscosity in millipascal second (mPa-s) by the density of the sample in kilogram per meter cubed (kg/m^3).

7.1.1.2 The density used shall be at the same temperature as the temperature of the desired kinematic viscosity. As density values are commonly referenced at 15 °C, the ASTM Petroleum Measurement Tables may be used to provide the value at different temperatures. Guide D1250 provides a description of the tables and their proper use.

7.1.1.3 Alternatively, the density of the sample can be determined at the test temperature of the kinematic viscosity determination by an appropriate method such as Test Methods D1217, D1480, or D1481.

7.1.2 *Flash Point*—Test Method D93, except where other test methods are prescribed by law. For all grades, Test Methods D3828, D6450, and D7094 may be used as alternative test methods with the same limits. For Grade RFO4 fuel oils, 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 case of dispute, Test Method D93 shall be used as the referee method.

7.1.3 *Water and Sediment*—Test Method D95 for water and Test Method D473 for sediment. A density of 1.0 kg/L shall be used for Test Method D95. Test Methods D96 for water and sediment, D1796 for water and sediment, and D4377 for water and EPA SW-846 Method 9000 for water and EPA SW-846 Method 9001 for water may be used as alternative test methods with the same limits. For all grades, Test Method D6304 for water may be used as an alternative with the same limits provided the mercapatan and the sulfide in the fuel is under 500 mg/kg. For Grade RFO4 fuel oils, Test Method D2709 may be used as an alternative with the same limits, provided the viscosity is in the range from 1.0 mm^2/s to 4.1 mm^2/s (1.0 cSt to 4.1 cSt) at 40 °C and the density is in the range from 0.870 kg/L to 0.900 kg/L at 15 °C. In case of dispute, Test Methods D95 and D473 shall be the referee test methods.

7.1.4 *Pour Point*—Test Method D97.

7.1.5 *Density*—Practice D1298. Test Methods D4052 or D6822 may be used as alternative test methods with the same limits. In case of dispute, Practice D1298 shall be the referee method.

7.1.6 *Ash*—Test Method D482.

7.1.7 *Sulfur*—Test Method D129. Test Methods D1266, D1552, D2622, D4294, and D5185 and EPA 600/4-79-020 and EPA SW-846 Method 9056 may also be used for all grades with the same limits. For Grade RFO4 fuels having a mass sulphur content below 0.4 %, Test Method D1266 may be used as an alternative with the same limits. In case of dispute, Test Method D129 shall be the referee method.

7.1.8 *Extracted pH*—Test Method D4980.

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

8. Keywords

8.1 burner fuels; fuel oils; furnace oils; petroleum and petroleum products; specifications; used oils; viscosity

APPENDIX

(Nonmandatory Information)

X1. SIGNIFICANCE OF ASTM SPECIFICATION FOR INDUSTRIAL BURNER FUELS FROM 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*—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*—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 can 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 *pH*—An indication of potentially hazardous levels of acidity or alkalinity.

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, and Table X1.1 gives approximate relationships. The data should be used with caution, firstly since the precision of measurements at temperatures other than 100 °C may differ, and secondly because the variability of composition of these fuels may cause variations in viscosity-temperature relationships.

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

Kinematic Viscosity, mm^2/s at 100 °C	Approximate Kinematic Viscosity at 40 °C	Approximate Kinematic Viscosity at 50 °C	Approximate Saybolt Universal Seconds at 100 °F	Approximate Saybolt Furol Seconds at 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

SUMMARY OF CHANGES

Subcommittee D02.P0 has identified the location of selected changes to this standard since the last issue (D6448 – $14^{\varepsilon 1}$) that may impact the use of this standard. (Approved April 1, 2016.)

(1) Revised 7.1.1 and Section 8.