Designation: D7666 – 12

Standard Specification for Triglyceride Burner Fuel[1]

This standard is issued under the fixed designation D7666; 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 two grades of burner fuel consisting of triglycerides and naturally occurring constituents of triglycerides including monoglycerides, diglycerides, and free fatty acids and distinguished by the pour point. The grade designation (TBF) identifies them as triglyceride burner fuels.

1.2 The triglyceride burner fuels specified are intended for use in commercial or industrial air or steam-atomized fuel oil burning equipment manufactured from materials compatible with fuels having an acid number as specified in Table 1 and under various climatic and operating conditions for the purposes of heat generation. The fuels specified herein are not intended for blending with conventional fuel oils for this purpose. They are not intended for use in burners <0.32 GJ/h (0.3×10^6 BTU/h) such as residential burners or small pressure atomization burners nor are they intended for use in internal combustion engines or marine applications.

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

1.3 This specification does not address the frequency with which any particular test shall be run.

1.4 Nothing in this specification shall preclude observance of national or local regulations, which can be more restrictive.

1.5 The *text* of this standard references notes and footnotes that provide explanatory material and shall not be considered as requirements of the standard. The *table* in this standard references footnotes, and these are to be considered as requirements of the standard.

1.6 The values given in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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
D128 Test Methods for Analysis of Lubricating Grease
D240 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter
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 by High Temperature Combustion and IR Detection
D1796 Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)
D1982 Test Method for Titer of Fatty Acids
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

[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.

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[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.

TABLE 1 Detailed Requirements for Triglyceride Burner Fuels

Properties	Test Method[A]	Limits[B]	
		TBF5	TBF6
Physical:			
Pour point °C (°F)	D97	<21 (70)	≥21 (70)
Flash point, °C (°F), min	D93	93 (200)	93 (200)
Water and sediment, % vol, max	D1796	2.0	2.0
Kinematic viscosity at 100°C, mm^2/s[C]	D445	Report	Report
Density, kg/m^3 @ 15°C[D]	D1298	Report	Report
Titer, °C	D1982	Report	Report
Chemical:			
Acid Number, mg KOH/g, max	D664	30.0	30.0
Ash, wt %, max	D482	0.15	0.15
Sulfur, wt %[E]	D4294	Report	Report
Insolubles, %mass	D128	2	2
Performance:			
Gross heating value, MJ/kg (BTU/lb[F]), min	D240	36.1 (15 500)	36.1 (15 500)

[A] The test methods indicated are the approved referee methods. Other acceptable methods are indicated in Section 8.
[B] Units given in parentheses are for informational purposes only.
[C] 1 mm^2/s = 1 cSt.
[D] Density in kg/L at 15°C multiplied by 1000 = kg/m^3.
[E] Local jurisdictions may limit the sulfur content in burner fuels.
[F] Assumes 7.6 lb/US gal.

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)[3]
D3339 Test Method for Acid Number of Petroleum Products by Semi-Micro Color Indicator Titration
D3828 Test Methods for Flash Point by Small Scale Closed Cup Tester
D4007 Test Method for Water and Sediment in Crude Oil by the Centrifuge Method (Laboratory Procedure)
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
D5185 Test Method for Multielement Determination of Used and Unused Lubricating Oils and 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
D5347 Test Method for Determination of the Ash Content of Fats and Oils
D5355 Test Method for Specific Gravity of Oils and Liquid Fats
D5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
D5854 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products
D5949 Test Method for Pour Point of Petroleum Products (Automatic Pressure Pulsing Method)
D5950 Test Method for Pour Point of Petroleum Products (Automatic Tilt Method)
D6448 Specification for Industrial Burner Fuels from Used Lubricating Oils
D6823 Specification for Commercial Boiler Fuels With Used Lubricating Oils
D6892 Test Method for Pour Point of Petroleum Products (Robotic Tilt Method)
D7042 Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)

2.2 *American Oil Chemists' Society:*[4]
Cd 22–91 Determination of Polymerized Triglycerides by Gel-Permeation HPLC

3. Terminology

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

3.2 *Definitions:*

3.2.1 *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 0.32 to 10.5 GJ/h (0.3 to 10 × 10^6 BTU/h). **D6823**

3.2.2 *industrial burner, n*—device that produces heat for industrial use through the combustion of fuel.

3.2.2.1 *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 that transfer thermal energy to water or other fluids or gases for use in heating in industrial settings and manufacturing processes. These boilers can be classified as utility/large industrial boilers with a heat input greater than 105 GJ/h (100 × 10^6 BTU/h) or small industrial boilers with a heat

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

[4] Available from American Oil Chemists' Society (AOCS), 2710 S. Boulder, Urbana, IL 61802-6996, USA. www.aocs.org/goto/methods/

input of between 10.5 to 105 GJ/h (10 to 100 × 10^6 BTU/h). D6448

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *triglyceride burner fuel, n*—any triglyceride, including recycled and unused cooking oil, greases, animal fats, and naturally occurring constituents of triglycerides including monoglycerides, diglycerides, and free fatty acids, suitable for the generation of heat by combustion in a furnace or firebox as a vapor or a spray or a combination of both with little or no preconditioning other than preheating.

4. Significance and Use

4.1 This specification specifies the properties and limits for triglyceride burner fuels to provide acceptable performance in liquid fuel burning equipment. It is for use in contracts for the purchase of triglyceride burner fuels and for the guidance of consumers of such fuels. It may also be used by third-party testing agencies in evaluating burner equipment for the purposes of verifying performance and safety of the oil-burning appliances and by regulators of such fuel and equipment use.

5. Requirements

5.1 The triglyceride burner fuels shall be homogeneous, consisting primarily of triglycerides and naturally occurring constituents of triglycerides and shall conform to the limiting requirements in Table 1.

5.2 Buyer and seller may agree to modifications of limiting requirements to meet special operating conditions provided the modifications fall within the limits specified in Table 1 for each grade.

NOTE 2—The grades specified may or may not correlate directly with similar grades in other ASTM standards. The usage descriptions of each grade may not describe all the uses but are included as general information.

5.3 The triglyceride burner fuel grades are described as follows:

5.3.1 *Grade TBF5*—A burner fuel comprised of commercial recycled and unused cooking oils, greases and rendered animal fats having a pour point below 21°C in accordance with Test Method D97. The requirements for this type of triglyceride burner fuel are presented in Table 1. This grade is intended for use in industrial burners and commercial boilers equipped with devices that use steam or compressed air to atomize fuel oil of higher viscosity. Preheating may be necessary in some types of equipment for burning this fuel and in colder climates for ease of handling.

5.3.2 *Grade TBF6*—A burner fuel comprised of commercial recycled and unused cooking oils, greases and rendered animal fats having a pour point equal to, or higher than, 21°C in accordance with Test Method D97. The requirements for this type of triglyceride burner fuel are presented in Table 1. This grade is intended for use in industrial burners and commercial boilers equipped with devices that use steam or compressed air to atomize fuel oil of higher viscosity. The use of this grade 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 grade may preclude its use in small or unattended installations, or both.

5.4 Triglyceride burner fuels shall remain homogeneous and uniform in storage and shall not separate by gravity or aging into layers under normal operating conditions.

NOTE 3—Prolonged storage or equipment downtime may necessitate circulation of the fuel oil in tank to prevent such separation.

5.5 The triglyceride burner fuel shall be free of solid or fibrous matter that could cause system handling or maintenance problems.

6. Sample Collection and Handling

6.1 Inspection of the material shall be agreed upon between the purchaser and the supplier as part of the purchase order or contract.

6.2 Unless otherwise specified, take a representative sample in accordance with Practice D4057, D4177 or other comparable sampling practices using a clean and appropriate sample container. Containers previously holding a sample or any other type of fluid are not considered appropriate containers.

NOTE 4—In case of dispute, Practice D4057 is recommended as the referee method.

6.3 A minimum sample size of 1 L is recommended for each sample taken before compositing.

6.4 Sample handling and mixing shall comply with Practice D5854.

7. Test Properties

7.1 The properties listed in this specification are those of greatest significance in obtaining acceptable performance of the burner.

NOTE 5—See X1.4 for the significance of test requirements.

8. Test Methods

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

8.1.1 *Pour Point*—Test Method D97. Test Methods D5949, D5950, or D6892 may alternatively be used with the same limits. In case of dispute, Test Method D97 shall be used as the referee method.

8.1.2 *Flash Point*—Test Method D93, Procedure B, except when other methods may be prescribed by law. For both grades, Test Method D3828 may alternatively be used with the same limits. In case of dispute, Test Method D93, Procedure B, shall be used as the referee method.

8.1.3 *Water and Sediment*—Test Method D1796. Test Methods D2709 or D4007 may be used with the same limit. For non-emulsified samples, Test Methods D95 and D473 may also be used with the same limits. In case of dispute, Test Method D1796 shall be the referee method.

8.1.4 *Viscosity*—Test Method D445. For quality control, dynamic viscosity by Test Method D7042 may be used.

NOTE 6—Information on the significance of viscosity and viscosity ranges of triglyceride fuels and details for converting dynamic viscosity test results to kinematic viscosity may be found in X1.4.4.4.

8.1.5 *Density*—Test Methods D1298, D4052, D5355, or D7042.

8.1.6 *Titer*—Test Method D1982.

8.1.7 *Acid Number*—Test Method D664. Test Methods D974 or D3339 may be used with the same limits. Test Method D664 shall be used as the referee test method.

8.1.8 *Ash*—Test Method D482. Test Method D5347 may be used with the same limits. In case of dispute, D482 shall be the referee method.

8.1.9 *Sulfur*—Test Method D4294. Alternatively, Test Methods D1266, D1552, D2622, D5185 or D5453 may be used with the same limits.

8.1.10 *Insolubles (Grade TBF5 and Grade TBF6)*—Test Method D128, Section 12, Method 1.

8.1.11 *Heating Value (Heat of Combustion)*—Test Method D240.

8.2 One or more of the parameters listed in Table 1 may be used as an indicator of the need for more extensive testing. For example, a borderline flash point may be indicative of contamination with low flash point material such as methanol or gasoline.

9. Keywords

9.1 biofuel; boiler; cooking oil; crude glycerin; fats; fatty acid; fuel; glycerin; heating fuel; industrial burner; recycled oil; rendered animal fat; TBF; triglyceride; triglyceride fuel; used fuel; used oil; used vegetable oil; vegetable oil; yellow grease

APPENDIX

(Nonmandatory Information)

X1. SIGNIFICANCE OF ASTM SPECIFICATION FOR TRIGLYCERIDE BURNER FUELS

X1.1 Rationale

X1.1.1 This specification is the result of a request from the Used Oil Management Association (a United States trade group) to develop a specification that defines and classifies triglyceride burner fuels. At the time of the request, high energy prices and demand for renewable burner fuels were driving the increased use of innovative fuels intended for use in small industrial and commercial heating systems and for which standards did not exist. In particular, industrial users were rewriting air permits to include yellow grease as a fuel, and small commercial operations were using triglycerides for fuel.

X1.1.2 This specification is intended to define triglyceride fuels for regulators, provide a trading standard for fuel processors, buyers, and sellers, and to standardize these fuel types for heating and other equipment manufacturers.

X1.2 Classification and Use

X1.2.1 This specification separates triglyceride burner fuel into grades based upon pour point. It places limiting values on the properties of the triglyceride fuel oils in each grade believed to be of the greatest significance in determining the performance characteristics of the triglyceride fuel oils in the types of burners, storage, and delivery systems in which they are most commonly used.

X1.2.2 The type of system used to deliver triglyceride fuel oil to the burner nozzle depends largely on the variability of the triglyceride fuel viscosity in the temperature range expected during burner operation, but triglyceride burner fuels are generally for use in burners with air- or steam-assisted atomizing and constant flow fuel delivery systems. Users should pay particular attention to X1.4.1 on pour point and X1.4.4 on viscosity for information related to the cold flow characteristics of this fuel.

X1.3 Terminology

X1.3.1 The following definitions are intended to be helpful in understanding some of the basic terminology associated with triglyceride burner fuels that may be different from conventional petroleum-based fuel oil. These terms are not part of the ASTM consensus lexicon in Terminology D4175, but they are in common use in the marketplace.

X1.3.1.1 *brown grease*—waste vegetable oil, animal fat, grease, etc. recovered from a wastewater component called a grease trap. The grease is removed from wastewater sent down a restaurant's sink drain.

X1.3.1.2 *fatty acids*—monobasic acids containing only the elements carbon, hydrogen, and oxygen and consisting of an alkyl chain attached to a carboxyl group.

X1.3.1.3 *rendering*—a process of both physical and chemical transformation involving the application of heat, the extraction of moisture and the separation of fat.

X1.3.1.4 *tallow*—the melted fat from rendered animal bones and soft tissue.

X1.3.1.5 *triglyceride*—a chemical combination of fatty acids (mainly oleic, palmitic, and stearic) and glycerol. Animal fats and vegetable oils are triglycerides. They consist of three fatty acids attached to a glycerin backbone.

X1.3.1.6 *yellow grease*—a grease made from used restaurant greases (fats and oils from cooking) or from rendering facility material.

X1.4 Physical Properties

X1.4.1 *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 triglyceride burner fuels are designated as TBF6 and are permissible where heated storage and adequate piping facilities are provided. An increase in pour point can occur when

triglyceride burner fuel is subjected to cyclic temperature variations that can occur in the course of storage. In these circumstances, it may be necessary to heat the stored fuel well above the pour point to return the triglyceride burner fuel to desired properties. To predict these properties, Test Method D3245 may be required.

X1.4.2 *Flash Point*—The flash point of a triglyceride burner fuel 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. Flash points lower than the limits listed in Table 1 indicate contamination of the triglyceride burner fuel.

X1.4.3 *Water and Sediment*—Appreciable amounts of water and sediment in a triglyceride burner fuel tend to cause fouling of fuel-handling facilities and give trouble in burner mechanisms. Sediment is likely to accumulate in storage tanks and on strainer screens or burner parts resulting in obstruction to the flow of oil from the tank to the burner. For this reason, triglyceride burner fuel storage tanks should be fitted with access to allow periodic sludge removal and cleaning. Water in triglyceride burner fuel can cause corrosion of tanks and equipment, and it may cause an interphase layer. 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) because of the rapid expansion of water as water vapor at a hot nozzle tip. Excessive water in triglyceride burner fuel can extinguish the flame, leading to flame-out. For this reason, storage tanks should be fitted with bottom water valves to allow periodic removal of any water that may have accumulated. Emulsified test specimens can produce gross negative test results if water is determined by a distillation method. In some instances, determining the water content by evaporative means is more useful.

X1.4.4 *Viscosity*—Viscosity is the measure of a fluid's resistance to flow. In the use of triglyceride burner fuel, it is more significant than in the use of conventional petroleum-based fuel oil, in which it is highly significant. It indicates both the relative ease with which the fuel will flow, or can be pumped, and the ease of atomization. Table 1 requires reporting kinematic viscosity values in mm^2/sec at 100°C. To obtain viscosity over an extended temperature range, viscosity may be measured at other temperatures or quoted in other units.

X1.4.4.1 *Converting Dynamic Viscosity to Kinematic Viscosity*—Viscosity may also be determined using rotational or dynamic viscosity test methods. 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^3. The density used should be at the same temperature as the temperature of the desired kinematic viscosity.

X1.4.4.2 *Viscosity/Temperature Range Data*—TBF6 fuels can be solid or semi-solid at room temperatures and so may require appropriate preheating facilities to permit the product to be pumped to the burner and for good atomization.

X1.4.4.3 The viscosity of both TBF5 and TBF6 fuel oils can change significantly with relatively small temperature differences in the range of temperatures at which the burner operates. For this reason, burner manufacturers and triglyceride fuel users should consider the viscosity characteristics of the range of potential triglyceride burner fuels very carefully. It is recommended that a constant flow system (as opposed to a conventional constant pressure system) be used to deliver triglyceride burner fuels to the burner nozzle.

X1.4.4.4 Fig. X1.1 gives approximate kinematic viscosities at temperatures below 100°C for various materials that may be used as triglyceride burner fuels.

X1.4.4.5 In general, the viscosity increases substantially below 100°C for all materials shown. These values are for reference only. The data should be used with caution, since (a) the precision of measurements at temperatures other than 100°C may differ and, (b) the variability of composition of these fuels may cause variations in viscosity-temperature relationships. Yellow grease, in particular, can be problematic in burning applications due to its inconsistent viscosity.

X1.4.4.6 *Density*—Density alone is of little significance as an indication of the burning characteristics of triglyceride burner fuel. When used in conjunction with other properties, it is of value in mass-volume relationships and calculating the specific energy (heating value per unit volume) of a triglyceride burner fuel. A typical density for Grade TBF5 is in the order of 0.91 kg/m^3.

X1.4.4.7 *Titer*—The titer of a fat is the temperature at which it solidifies. The higher the titer, the harder the fat. Traditionally titer is used in determining whether an animal fat is considered tallow (titer higher than 40°C) or grease (titer below 40°C), but it may also be useful in determining the operating temperature range of triglyceride burner fuels.

X1.4.4.8 Saturated fatty acids solidify at a higher temperature than unsaturated fatty acids. Test Method D1982 provides a means of measuring the solidification temperature of a sample containing both unsaturated and saturated fatty acids by cooling the specimen and measuring the temperature at which solidification occurs. Water present in the sample will raise the titer, so provisions are made in the test method to remove traces of moisture.

X1.5 Chemical Properties

X1.5.1 *Acid Number*—Acid number is used to determine the level of free fatty acids, processing, or degradation by-products that may be present in triglyceride fuel. A high acid number has been shown to accelerate fueling system deposits, increase filter-plugging potential, and it may increase the likelihood for corrosion. Burner materials such as copper, brass, bronze, or light gage carbon steel may have reduced service life due to corrosion when exposed to triglyceride burner fuels.

X1.5.2 *Ash*—Ash is the amount of noncombustible material in fuel oil. Ash-forming materials may be present in triglyceride burner fuel in two forms: solid particles, or triglyceride- 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

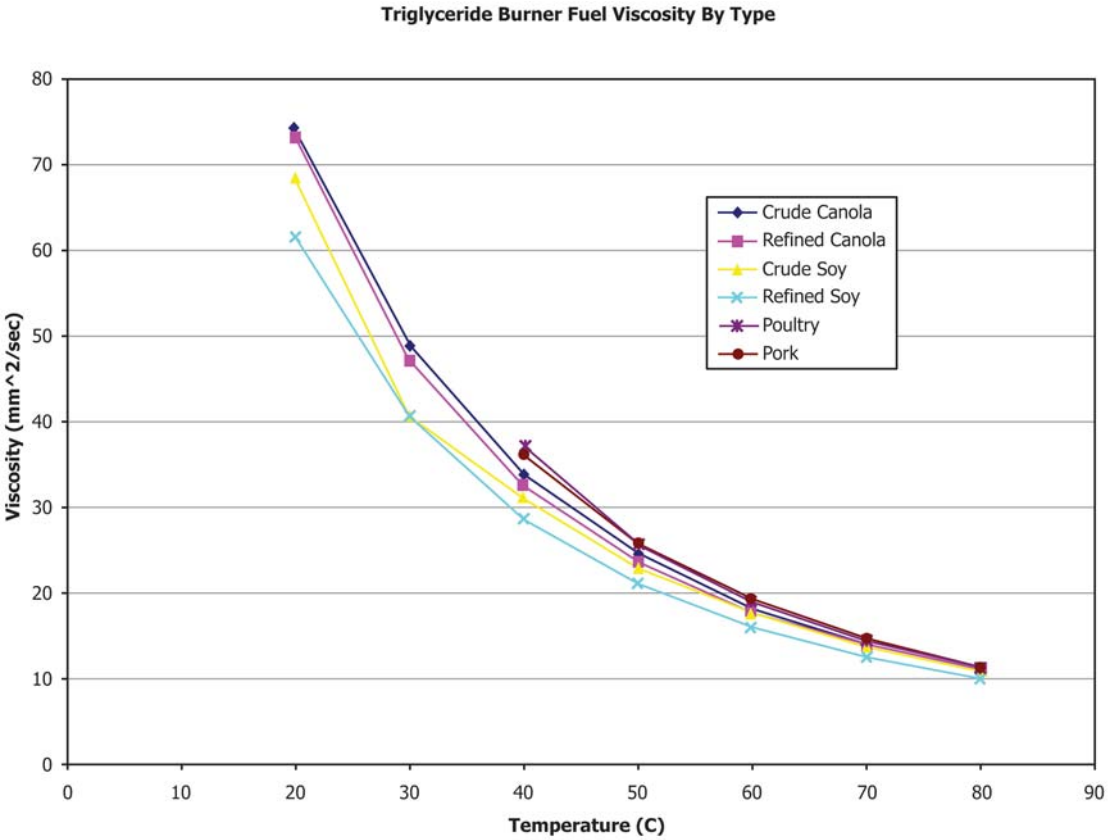

FIG. X1.1 Triglyceride Burner Fuel Viscosity By Type

they can contain elements that produce corrosion and deposits on boiler heating surfaces. Excessive amounts of ash may also indicate contamination of the fuel and may result in violation of national or local air emission regulations.

X1.5.3 *Sulfur*—Knowledge of the sulfur content of triglyceride burner fuel 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. Triglyceride burner fuels are generally low in sulfur (<0.02%).

X1.5.4 *Insolubles*—Insoluble impurities such as mineral grit, cellulosic fiber, or polymeric materials within most rendered material are known to cause operational issues in industrial burners if not pretreated. Mineral grit results in ash formation and so will be reflected in the measure of ash, but insoluble constituents such as cellulosic and polymeric materials that do not contribute to significant ash formation may also cause operational problems.

X1.5.4.1 Test Method D128 is suitable for Grades TBF5 and TBF6 fuel. Developed for the determination of insoluble material in fats used in grease, the test is ultimately conducted at 65°C and measures the mass% of the insoluble material. The limit of 2% is the American Fats and Oils Association current specification for insolubles in tallow and greases. Users of triglyceride burner fuels should consider the quantity of insoluble components very carefully since 2% of all fuel used can amount to significant quantities of materials that must be removed from storage tanks and disposed of.

X1.6 Performance Properties

X1.6.1 *Heat of Combustion*—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 triglyceride burner fuel.

X1.7 Other Considerations

X1.7.1 *Contaminants from other Oil Sources*—Arsenic, cadmium, calcium, chromium, lead, magnesium, zinc, and halogens are residues found in lubrication oils from additives in the lubricating oil and from metal wear. These have been found to cause health risks at levels above the permitted limits. Vanadium, titanium, and nickel are known to occur in crude oil and No. 6 fuel oil. The materials can increase ash and foul nozzles affecting boiler performance. These materials are not normally present in triglyceride burner fuels, so identification of these materials is an indication of contamination or adulteration of the triglyceride burner fuel.

X1.7.2 *Polymers*—Both naturally occurring polymers and those from materials introduced in the rendering process may cause both soluble and insoluble polymers to be present in triglyceride burner fuels.

X1.7.2.1 Naturally occurring polymers are formed when radicals of free fatty acids and glycerol combine with one another in various unpredictable and nondescript ways. These polymers are most frequently formed in the presence of oxygen, moisture, and heat.

X1.7.2.2 Polyethylene from the rendering of packed out-of-date supermarket meats frequently survives the rendering process. Polymers are also present in flocculent used in dissolved air flotation systems in rendering facility wastewater treatment plants. The flocculent and accumulated fats, oil, and other impurities are frequently returned to the rendering process.

X1.7.2.3 Burner nozzles are a prime location for polymer build-up to occur because of the presence of oxygen and high temperature. The accumulation of these polymers represents a maintenance issue. If polymer build-up on burner nozzles is left unattended, the flame characteristics may become erratic or the flame may fail. These naturally occurring polymers are easily removed by soaking the burner nozzles in a high pH water solution. Polyethylene residues would have to be removed mechanically by cleaning.

X1.7.2.4 Although most of the polymers that may be present are soluble and will pass through strainers and burner nozzles without affecting performance, some sources of triglyceride burner fuels may contain higher than normal concentrations of insoluble polymers. If frequent or troublesome strainer or nozzle plugging occurs it may be necessary to evaluate the fuel for the presence of polymers. American Oil Chemist Society (AOCS) Test Method Cd 22–91, may be used to quantify the presence of polymers. This test will identify the presence of, but will not differentiate, naturally occurring polymers and those from materials introduced in the rendering process. The test will not differentiate soluble and insoluble polymers. Because of this, and since the configuration of burner systems differs from manufacturer to manufacturer, no specific polymer limit is recommended, although any result over 5% by mass would be cause for concern. If fouling or plugging problems persist, it may be necessary to determine the limits appropriate for a given system by trial and error.

X1.7.3 *Combustibility*—Knowing the flash point of the triglyceride burner fuel and the fire point (the point at which a sample will sustain a flame), the density and the energy content may provide an indication of how easily the fuel will ignite and sustain combustion.

X1.7.4 *Nitrogen Requirement*—When mandated by environmental or permit regulatory agencies without the test method being specified, the nitrogen content may be tested using Test Methods D3228, D4629, or D5291. The nitrogen content is used to determine nitrogen oxides (NOx) emissions from boiler systems. It is highly recommended that the buyer know whether this requirement exists and place it in the purchase request.