Designation: D2880 – 15

Standard Specification for Gas Turbine Fuel Oils[1]

This standard is issued under the fixed designation D2880; 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 the selection of fuels for gas turbines, excepting gas turbines used in aircraft, for the guidance of interested parties such as turbine manufacturers and the suppliers and purchasers of fuel oils. The specification sets forth the properties of fuels at the time and place of custody transfer to the user.

1.2 Three appendixes are provided for informational purposes only and do not constitute a requirement of this specification unless mutually agreed upon between the interested parties.

1.2.1 Appendix X1 describes the five grades of gas turbine fuels covered by this specification. Further, it states the significance of various test methods used in inspecting the fuels.

1.2.2 Appendix X2 discusses the sources of fuel contaminants and notes the significance of such contaminants in the operation of gas turbines and gas turbine fuel systems. The particular significance of trace metals in gas turbine fuels is noted. Upper limits of trace metals are recommended for the various grades of gas turbine fuels, but these recommended limits do not constitute a requirement of the specification unless mutually agreed upon by the interested parties. Limitations due to the use of used or recycled oil are also noted.

NOTE 1—The gas turbine operator should consult Practice D4418 for methods of ensuring fuels of adequate cleanliness and for guidance on long-term storage of distillate fuels and on liquids from non-petroleum sources as gas turbine.

NOTE 2—Nothing in this specification shall preclude observance of federal, state, or local regulations which may be more restrictive.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D56 Test Method for Flash Point by Tag Closed Cup Tester
D86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure
D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
D97 Test Method for Pour Point of Petroleum Products
D129 Test Method for Sulfur in Petroleum Products (General High Pressure Decomposition Device Method)
D396 Specification for Fuel Oils
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
D975 Specification for Diesel Fuel Oils
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)
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
D3605 Test Method for Trace Metals in Gas Turbine Fuels by Atomic Absorption and Flame Emission Spectroscopy
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

[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, Non-Aviation Gas Turbine, and Marine Fuels.

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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.

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

D4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry
D4418 Practice for Receipt, Storage, and Handling of Fuels for Gas Turbines
D4865 Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems
D5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
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)
D5985 Test Method for Pour Point of Petroleum Products (Rotational Method)
D6469 Guide for Microbial Contamination in Fuels and Fuel Systems
D6728 Test Method for Determination of Contaminants in Gas Turbine and Diesel Engine Fuel by Rotating Disc Electrode Atomic Emission 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
D7346 Test Method for No Flow Point and Pour Point of Petroleum Products

2.2 *Other Documents:*[3]

26 CFR Part 48 Diesel Fuel Excise Tax; Dye Color and Concentration
40 CFR Part 80 Regulation of Fuels and Fuel Additives

3. Terminology

3.1 *Definitions:*

3.1.1 *contamination, n*—any process which introduces contaminants into the fuel.

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

3.1.2.1 *Discussion*—Contaminants, which can be soluble in the fuel or insoluble (suspended liquid droplets or solid or semi-solid 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 microbial growth.

3.1.2.2 *Discussion*—Solid or semisolid contaminants can be referred to as silt or sediment.

3.1.3 *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.

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

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

3.1.3.3 *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 X3 discusses some matters for consideration regarding the use of fuel oils from feedstocks other than petroleum.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *fuel entering the combustor(s)*—the fuel that is actually burned in the gas turbine. Fuel may be sampled at a point upstream from the point of entry into the combustor(s), provided the sample is representative of the fuel actually entering the combustor(s).

4. General Requirements

4.1 The grades of gas turbine fuels herein specified shall be hydrocarbon oils with the use of additives to enhance performance properties, if required. The hydrocarbon oils shall be free of inorganic acid, and free of excessive amounts of solid or fibrous foreign matter likely to make frequent cleaning of suitable strainers necessary.

NOTE 4—Additives are generally included in finished gas turbine fuel oil to improve performance properties (corrosion and anti-corrosion, and so forth).

4.2 All grades containing residual components shall remain homogeneous in normal storage and not separated by gravity into light and heavy oil components outside the viscosity limits for the grade.

5. Detailed Requirements

5.1 The various grades of gas turbine fuel oil shall conform to the limiting requirements shown in Table 1. As noted in the supplementary footnotes to Table 1, the requirements for Grade Nos. 1-GT and 2-GT conform in most respects to corresponding Grade Nos. 1 and 2 fuels in Specification D396, and to Grade Nos. 1-D and 2-D in Specification D975. The viscosity range of Grade Nos. 3-GT and 4-GT fuel brackets the Grade Nos. 4, 5, and 6 of Specification D396 and Grade No. 4-D of Specification D975. It is the intent that fuels meeting Specification D396 and D975 requirements may also be supplied under these specifications provided they meet the requirements listed in Table 1.

5.2 Modifications of limiting requirements and the inclusion of fuel additives to meet special operating conditions may be agreed upon between the interested parties.

5.3 The properties listed in this specification are those of greatest significance in obtaining acceptable performance of the turbine. However, trace metals, even in fractional parts per million, are detrimental to gas turbine service life. Information on the maximum concentration of critical metallic elements in the fuel as it enters the turbine combustor(s) is provided in

[3] Available from Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.

TABLE 1 Detailed Requirements for Gas Turbine Fuel Oils at Time and Place of Custody Transfer to User[A,B,C]

Property	ASTM Test Method[D]	Grade[E]				
		No. 0-GT	No. 1-GT[F]	No. 2-GT[F]	No. 3-GT	No. 4-GT
Flash point °C (°F) min	D93	[G]	38 (100)	38 (100)	55 (130)	66 (150)
Water and sediment % vol max	D2709	0.05	0.05	0.05	...	...
	D1796	...	...	...	1.0	1.0
Distillation Temperature °C (°F)	D86					
90 % volume recovered min		...	...	282	...	...
max		...	288	338	...	...
Kinematic viscosity 2 mm/s[H]	D445					
AT 40°C (104°F) min		[G]	1.3	1.9	5.5	5.5
max			2.4	4.1	...	...
AT 100 °C (212 °F) max			...	...	50.0	50.0
Ramsbottom Carbon residue on 10 % distillation Residue % mass, max	D524	0.15	0.15	0.35	...	...
Ash % mass, max	D482	0.01	0.01	0.01	0.03	...
Density at 15 °C kg/m^3 max	D1298	...	850	876	...	...
Pour point[H] °C (°F) max	D97	...	−18	−6	...	...

[A] To meet special operating conditions, modifications of individual limiting requirements may be agreed upon between purchaser, seller, and manufacturer.
[B] Gas turbines with waste heat recovery equipment may require fuel sulfur limits to prevent cold end corrosion. Environmental limits may also apply to fuel sulfur in selected areas in the United States and in other countries.
[C] See Section 4 and 5 for further statements on gas turbine fuel oil requirements.
[D] The test methods indicated are the approved referee methods. Other acceptable methods are indicated in 6.1.
[E] No. 0-GT includes naphtha, Jet B fuel and other volatile hydrocarbon liquids. No. 1-GT corresponds in general to specification D396 Grade No. 1 fuel and D975 Grade 1-D diesel fuel in physical properties. No. 2-GT corresponds in general to Specification D396 No. 2 fuel and D975 Grade 2-D diesel fuel in physical properties. No. 3-GT and No. 4-GT viscosity range brackets specification D396 Grades No. 4, No. 5 (light), No. 5 (heavy), and No. 6, and D975 Grade No. 4-D diesel fuel in physical properties.
[F] Under United States regulations, Grades No. 1-GT and No. 2-GT are required by 40 CFR Part 80 to contain a sufficient amount of dye Solvent Red 164 so its presence is visually apparent. At or beyond terminal storage tanks, they are required by 26 CFR Part 48 to contain the dye Solvent Red 164 at a concentration spectrally equivalent to 3.9 lb per thousand barrels of the solid dye standard Solvent Red 26.
[G] When the flash point is below 38 °C (100 °F) or when kinematic viscosity is below 1.3 mm^2/s at 40 °C (104 °F) or when both conditions exist, the turbine manufacturer should be consulted with respect to safe handling and fuel system design.
[H] For cold weather operation, the pour point should be specified 6 °C below the ambient temperature at which the turbine is to be operated except where fuel heating facilities are provided. When a pour point less than −18 °C is specified for Grade No. 2-GT, the minimum viscosity shall be 1.7 mm^2/s and the minimum 90 % recovered temperature shall be waived.

Appendix X2. Distillate fuels are usually of satisfactory purity as refined, but suppliers rarely have control over possible contamination by trace metals in distribution and storage. The limits in Appendix X2, although required as the fuel enters the combustor(s), do not apply to the fuel as delivered unless mutually agreed upon by the interested parties. Fuels may, therefore, require on-site clean-up, quality control procedures, special handling, or other arrangements.

6. Test Methods

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

6.1.1 *Flash Point*—Test Methods D93, except where other methods are prescribed by law. For all grades, Test Method D3828 and D7094 may be used as an alternative with the same limits. For Grades No. 1-GT and No. 2-GT, Test Method D56[4] 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.

6.1.2 *Pour Point*—Test Method D97. For all grades, the automatic Test Methods D5949, D5950, D5985 or D7346 may be used as alternates with the same limits. In case of dispute, Test Method D97 shall be used as the referee method.

6.1.3 *Water and Sediment*—Test Method D2709 is used for Grades 0-GT, 1-GT, and 2-GT. Test Method D1796 is used for Grades 3-GT and 4-GT.

6.1.4 *Carbon Residue*—Test Method D524.

6.1.5 *Ash*—Test Method D482.

6.1.6 *Distillation*—Test Method D86.

6.1.7 *Viscosity*—Test Method D445. Bias-corrected values from Test Method D7042 may be used as alternative results for Test Method D445 on Grades No. 1-GT and No. 2-GT with the same limits. Section 15, Precision and Bias, of Test Method

[4] Other mutually acceptable methods may be used.

D7042 contains bias-correction information. In case of dispute, Test Method D445 shall be used as the referee method.

6.1.8 *Density*—Test Method D1298 or D4052.

6.1.9 *Sulfur*—Test Method D129, Test Methods D1552,[5] D2622, and D4294 can also be used for all grades. In addition, Test Method D1266 can be used for Grades No. 0 and No. 1, but only with samples having sulfur contents of 0.4 mass percent and less (down to 0.01 %). Test Method D5453 can be used for Grades 0, 1, and 2 GT oils, but only with samples having sulfur contents of 0.8 mass % and less (down to 0.001 %). Test Method D7220 may be used for Grades 0, 1, and 2 GT oils, but only with samples having sulfur contents of 0.942 mass % and less (down to 0.0003 %). Test Method D129 is the referee sulfur test method for Specification D2880.

[5] For information on the precision of the ASTM methods of test for fuel oils refer to "An Evaluation of Methods for Determination of Sulfur in Fuel Oils" by A. R. Crawford and G. V. Dyroff (1969). This document is available from the Publications Section, American Petroleum Institute, 1220 L St., N.W., Washington, DC 20005.

7. Keywords

7.1 fuel oils; gas turbine; petroleum and petroleum products

APPENDIXES

(Nonmandatory Information)

X1. SIGNIFICANCE OF ASTM SPECIFICATIONS FOR GAS TURBINE FUEL OILS

X1.1 Scope

X1.1.1 This specification divides the fuel oils encompassed by Specifications D396 and D975 into four grades, based upon their applicability for use in gas turbines. Also there is a No. 0-GT grade to cover low-flash naphthas. The specification does not include fuels primarily intended for aircraft use. It places limiting values on a number of the properties of the fuels in each grade. The properties selected for limitation are those that are believed to be of the greatest significance in determining performance characteristics of the oils in the various gas turbine applications.

X1.1.2 The physical properties of commercial fuel oils that are important in gas turbine operation are generally the same as those specified by Specifications D396 and D975. In addition, gas turbine operating experience has shown that certain chemical properties of the fuel oil ash must be controlled since slag-forming substances present in the oil ash can cause corrosion and deposits on those turbine parts that must operate at surface temperatures of 593 °C and above. This specification includes the applicable physical properties from Specifications D396 and D975. Appendix X2 lists restrictions required to control high temperature corrosion and deposits.

X1.2 Grades

X1.2.1 Grade 0-GT includes naphtha, Jet B, and other light hydrocarbon liquids that characteristically have low flash point and low viscosity as compared with kerosine and fuel oils.

X1.2.2 Grade 1-GT is a light distillate fuel oil suitable for use in nearly all gas turbines.

X1.2.3 Grade 2-GT, which is a heavier distillate than Grade 1-GT, can be used by gas turbines not requiring the clean burning characteristics of Grade 1-GT. Fuel heating equipment may be required by the gas turbine depending on the fuel system design or ambient temperature conditions, or both.

X1.2.4 Grade 3-GT may be a heavier distillate than Grade 2-GT, a residual fuel oil that meets the low ash requirements, or a blend of distillate with a residual fuel oil. Fuel heating will be required by the gas turbine in almost every installation.

X1.2.5 Grade 4-GT includes most residuals and some topped crudes. Because of the wide variation and lack of control of properties, the gas turbine manufacturer should be consulted with regard to acceptable limits on properties.

NOTE X1.1—Fuels prepared to different specifications and sold under different names may meet the requirements of fuels specified under Specification D2880. However, specification tests would normally have to be run to ensure compliance with the requirements of Specification D2880 as other fuels are not necessarily interchangeable with D2880 fuels throughout the range permitted by the other specifications.

X1.3 Selection of Particular Grade

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

X1.3.1.1 Availability of the fuel,

X1.3.1.2 Design of the gas turbine and fuel handling system,

X1.3.1.3 Maintenance of the gas turbine, and

X1.3.1.4 Operating requirements for the gas turbine.

X1.4 Significance of Test Methods

X1.4.1 The significance of the properties of fuel oil on which limitations are placed by the specifications is as follows:

X1.4.1.1 Flash point is an indication of the maximum temperature at which a fuel oil can be stored and handled without serious fire hazard. The minimum permissible flash point is usually regulated by federal, state, or municipal laws and is based on accepted practice in handling and use.

X1.4.1.2 Pour point is an indication of the lowest temperature at which a fuel oil can be stored and still be capable of flowing under gravitational forces. The pour point is prescribed in accordance with the conditions of storage and use. Fuels with higher pour point are permissible where heated storage and adequate piping facilities are provided.

X1.4.1.3 *Water and Sediments*—Appreciable amounts of water and sediment in a fuel oil tend to cause fouling of the fuel-handling facilities and to give trouble in the fuel system of the gas turbine. An accumulation of sediment in storage tanks and on filter screens may obstruct the flow of oil from the tank

to the combustor of the gas turbine. Water in distillate fuels may cause corrosion of tanks and equipment, and water in residual fuel may cause emulsions.

X1.4.1.4 Carbon residue is a measure of the carbonaceous material left in a fuel after all the volatile components are vaporized in the absence of air. It is a rough approximation of the tendency of a fuel to form carbon deposits in the combustor of the gas turbine. Combustion systems designed for use on Grades 3-GT and 4-GT are insensitive to this property, but other gas turbines may require a limit on the carbon residue. To obtain measurable values of carbon residue in the lighter distillate fuel oils, it is necessary to remove 90 % of the oil by distillation in accordance with Test Method D86, and then determine the carbon residue concentrated in the remaining 10 % bottoms.

X1.4.1.5 Ash is the noncombustible material in an oil. Ash-forming materials may be present in fuel oil in two forms: (*1*) solid particles and (*2*) oil- or water-soluble metallic compounds. The solid particles are for the most part the same material that is designated as sediment in the water and sediment test. Depending on their size, these particles can contribute to wear in the fuel system and to plugging of the fuel filter and the fuel nozzle. The soluble metallic compounds have little or no effect on wear or plugging, but they can contain elements that produce turbine corrosion and deposits as described subsequently.

X1.4.1.6 *Distillation*—The distillation test shows the volatility of a fuel and the ease with which it can be vaporized. Distillation temperature is not directly significant to operation of gas turbines designed for Grades 3-GT and 4-GT. In other gas turbines that are most susceptible to carbon deposition and smoke formation, the more volatile fuels may provide better performance.

X1.4.1.7 Viscosity of a fluid is a measure of its resistance to flow. In fuel oil it is highly significant since it indicates both the relative ease with which the oil will flow or may be pumped, and the ease of atomization by the fuel nozzles. Minimum viscosity is limited because some fuel pumps will not perform satisfactorily if the viscosity reaches too low a value. Maximum viscosity is limited since too high a viscosity can cause excessive pressure losses in the piping system, and poor fuel atomization.

X1.4.1.8 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 weight-volume relationships and in calculating the specific energy heating value of an oil.

X1.4.1.9 Sulfur normally burning to sulfur dioxide, also can be oxidized partially to sulfur trioxide which then can combine with sodium and potassium compounds from the ash in the fuel to form sulfates, pyrosulfates, and such compounds as sodium or potassium iron trisulfate. The pyrosulfates, and the trisulfates have melting points in the operating range of the gas turbine. Hence, the compounds produce severe corrosion of the turbine blading. In general, it has been found impractical to prevent corrosion by limiting the sulfur content of the fuel, so corrosion of this type is controlled by limiting the sodium and potassium. Gas turbines with waste heat recovery equipment may require additional sulfur control to prevent cold-end corrosion.

X2. SIGNIFICANCE OF FUEL CONTAMINANTS AND TRACE METALS IN FUEL SYSTEMS AND IN FUEL ENTERING TURBINE COMBUSTOR(S)

X2.1 Scope

X2.1.1 This appendix discusses the sources of fuel contaminants and notes the significance of such contaminants in the operation of gas turbines and gas turbine fuel systems.

X2.1.2 The particular significance of trace metals in gas turbine fuels is noted and upper limits of trace metals are recommended for the various grades of gas turbine fuels.

X2.2 Sources of Contaminants

X2.2.1 Water may be present in the fuel as dissolved water or as free (undissolved) water, or both. The free water may be fresh or saline. Fresh water may enter the fuel from steam coils in storage tanks, from condensation out of moisture-laden air, or from leaking cooling coils. Saline water can enter the fuel during transportation in barges or tankers.

X2.2.2 Microbial slimes may result when conditions are conducive to the growth of microorganisms, which are always present. The presence of free water is essential to the growth of many of these microorganisms, which grow in tank water bottoms and feed on nutrients in the water or on the hydrocarbons.

X2.2.3 A significant source of particulate solids in gas turbine fuel systems can be the degradation of the fuel to form fuel insoluble compounds. The chemical reactions that cause this degradation vary with the chemical composition of the fuel but can include oxidation, polymerization, and acid-base reactions. The use of appropriate fuel additives can often provide some control of these reactions. Particulate solids can enter a fuel from the air (suspended dirt and aerosols) or from the distribution and storage systems (rust, corrosion products, gasket debris, and so forth).

X2.2.4 Metals may be present as metallic compounds in the fuel as a natural result of the composition of the crude oil and of the refining process. However, unless special precautions are taken, additional metallic compounds can be acquired during distribution and storage. A commercial product pipeline may contain residues of lead-containing gasoline which would then be dissolved by the gas turbine fuel. Tank trucks, railroad tankcars, barges, and tankers may be inadequately cleaned and contain residues of past cargos. Acidic components in saline water salts in the fuel may react with distribution and storage equipment.

X2.3 Significance of Contaminants

X2.3.1 Contamination levels in the fuel entering the combustor(s) must be low for improved turbine life. Low contamination levels in the fuel in the turbine's in-plant fuel system is required to minimize corrosion and operating problems. To provide fuel of adequate cleanliness to the gas turbine combustor(s) may require special actions by the user. These actions might include special transportation arrangements with the fuel supplier, particular care in on-site fuel storage and quality control procedures, and establishment of on-site clean-up procedures. Each of the four classes of contaminants defined in X2.2.2 has its own significance to system operation.

X2.3.2 Water will cause corrosion of tanks, piping, flow dividers, and pumps. Corrosion or corrosion products in close tolerance devices such as flow dividers may cause plugging and may stop flow to the turbines. Free water is potentially corrosive; in sulfur-containing fuels, it may be particularly corrosive. Free water may contain dissolved salts that may be corrosive, and may encourage microbiological growth.

X2.3.3 Microbial slimes caused by microorganisms can plug filters and other close-tolerance openings. Some organisms can cause corrosion as well as produce slimes. Under anaerobic conditions, hydrogen sulfide, which may cause corrosion, can be generated by biological action. Biocides are available for controlling the growth of microorganisms, but their effect on trace metal levels and other fuel properties should be considered. Since water is required for the growth of the microorganisms, one way of controlling their growth is to eliminate the presence of water through tank-stripping operations or other separation techniques. Refer to Guide D6469 for a more complete discussion.

X2.3.4 Particulate solids may shorten the life of fuel system components. Life of fuel pumps and of various close-tolerance devices is a function of particulate levels and size distributions in the fuel. High levels of particulates can lead to short cycle times in the operation of filters, filter/separators, centrifuges, and electrostatic purifiers. Since such separation devices do not remove all the particulates, certain quantities will be present in the down-stream fuel.

X2.3.5 Trace metals refer both to those metals present as metallic compounds in solution and to metals present in particulates like rust. They are dissolved or suspended either in the fuel hydrocarbons or in free water present in the fuel. The significance of several individual trace metals with respect to hot corrosion is discussed in Appendix X1. Although lower levels of trace metals in a fuel will promote longer turbine service from a corrosion standpoint, the specification of excessively low levels may limit the availability of the fuel or materially increase its cost. Table X2.1 suggests levels of trace metals that would probably yield satisfactory service.

X2.3.6 Sodium and potassium can combine with vanadium to form eutectics which melt at temperatures as low as 566 °C and can combine with sulfur in the fuel to yield sulfates with melting points in the operating range of the gas turbine. These compounds produce severe corrosion, and for turbines operating at gas inlet temperatures above 650 °C additives are not yet in general use which control such corrosion. Accordingly, the sodium-plus-potassium level must be limited, but each element is measured separately. Some gas turbine installations incorporate systems for washing oil with water to reduce the sodium-plus-potassium level. In installations where the fuel is moved by sea transport, the sodium-plus-potassium level should be checked prior to use to ensure that the oil has not become contaminated with sea salt. For gas turbines operating at turbine inlet gas temperatures below 650 °C (1200 °F), the corrosion due to sodium compounds is of minor importance and can be further reduced by silicon-base additives. A high-sodium content is even beneficial in these turbines because it increases the water-solubility of the deposits and thereby increases the ease with which gas turbines can be water-washed to obtain recovery of the operating performance.

TABLE X2.1 Trace Metal Limits of Fuel Entering Turbine Combustor(s)[A,B]

Designation	Trace Metal Limits, mg/kg			
	Vanadium (V)	Sodium plus Potassium (Na + K)	Calcium (Ca)	Lead (Pb)
No. 0-GT	0.5	0.5	0.5	0.5
No. 1-GT	0.5	0.5	0.5	0.5
No. 2-GT	0.5	0.5	0.5	0.5
No. 3-GT	0.5	0.5	0.5	0.5
No. 4-GT	(Consult turbine manufacturers)			

[A] Test Method D3605 may be used for determination of vanadium, sodium, calcium, and lead.
[B] Test Method D6728 may be used for determination of vanadium, sodium, potassium, calcium, and lead.

X2.3.7 Calcium is not harmful from a corrosion standpoint; in fact, it serves to inhibit the corrosive action of vanadium. However, calcium can lead to hardbonded deposits that are not self-spalling when the gas turbine is shut down, and that are not readily removed by water washing of the turbine. The fuel washing systems used at some gas turbine installations to reduce the sodium and potassium level will also significantly lower the calcium content of fuel oil.

X2.3.8 Vanadium can form low melting compounds such as vanadium pentoxide that melts at 691 °C, and causes severe corrosive attack on all of the high temperature alloys used for gas turbine blades. If there is sufficient magnesium in the fuel, it will combine with the vanadium to form compounds with higher melting points and thus reduce the corrosion rate to an acceptable level. The resulting ash will form deposits in the turbine and will require appropriate cleaning procedures.

X2.3.8.1 When vanadium is present in more than trace amounts either in excess of 0.5 mg/kg or a level recommended by the turbine manufacturer, it is necessary to maintain a weight ratio of magnesium to vanadium in the fuel of not less than 3.0 in order to control corrosion.

X2.3.8.2 An upper limit of 3.5 is suggested since larger ratios will lead to unnecessarily high rates of ash deposition. In most cases, the required magnesium-to-vanadium ratio will be obtained by additions of magnesium-containing compounds to the fuel oil. The special requirements covering the addition of and type of magnesium-containing additive, or equivalent, shall be specified by mutual agreement between the various

interested parties. The additive will vary depending on the application, but it is always essential that there is a fine and uniform dispersion of the additive in the fuel at the point of combustion.

X2.3.8.3 For gas turbines operating at turbine inlet gas temperatures below 650 °C, the corrosion of the high-temperature alloys is of minor importance, and the use of a silicon-base additive will further reduce the corrosion rate by absorption and dilution of the vanadium compounds.

X2.3.9 Lead can cause corrosion and in addition it can spoil the beneficial inhibiting effect of magnesium additives on vanadium corrosion. Since lead is only rarely found in significant quantities in crude oils, its appearance in the fuel oil is primarily the result of contamination during processing or transportation.

X3. GUIDANCE ON EVALUATION OF NEW MATERIALS FOR No. 0-GT, No. 1-GT, AND No. 2-GT GRADES OF GAS TURBINE FUEL OILS

X3.1 The purpose of this appendix is to provide some general guidance from Subcommittee D02.E0 on evaluation of new materials or blends containing new materials intended to meet Specification D2880, Grades No. 0-GT, No. 1-GT and No. 2-GT type fuels.

X3.2 ASTM International is an organization made up of volunteers and open to all stakeholders and interested entities including users of fuels, producers of fuels, and general interests, including members of the public, and governmental and nongovernmental organizations. Technical committees and subcommittees of ASTM International do not certify, approve, reject, or endorse specific fuels. Rather, ASTM International Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and its Subcommittee D02.E0 on Burner, Diesel, Non-Aviation Gas Turbine, and Marine Fuels develop fuel specifications and, with other subcommittees, test methods for gas turbine fuel oils. These fuel specifications and test methods provide minimum requirements for properties of fuels covered by these documents in commerce and address the concerns of stakeholders, including that fuels perform appropriately in the specified application.

X3.3 Historically, gas turbine fuel has been hydrocarbon molecules refined from petroleum. As a result, Specification D2880 has evolved to define performance requirements (and tests to determine if those requirements were met) for gas turbine fuels composed of conventional hydrocarbon oils refined from petroleum. Because the specification evolved to describe this type of fuel, some of the properties necessary for use in a gas turbines which are inherent in petroleum derived oils may not be addressed in Specification D2880.

X3.4 Specification D2880, however, does not require that fuels be derived from petroleum. Subsection 4.1 reads, "The grades of gas turbine fuel herein specified shall be hydrocarbon oils with the use of additives to enhance performance properties, if required."

X3.5 It should be noted that fuel specifications other than Specification D2880 may be developed for fuel for gas turbines. Other new specifications are under development. Some new materials may require new standard specifications if they are significantly different than current gas turbine fuels and require different parameters to be controlled or different test methods to properly measure required parameters.

X3.6 Because the composition and properties of new fuels may vary, the particular path to a specification for a new fuel may vary. Some current alternative fuels are similar to traditional petroleum-refined fuel oil while others are chemically and physically different. Future fuels may vary more than current fuels.

X3.7 Three areas for consideration when reviewing new fuels alignment with existing standards or developing new standards are: test methods, chemical and physical limitations of fuels in existing specifications, and chemical and physical limitations appropriate for new fuels. The test methods that have been developed for existing gas turbine fuels may or may not be appropriate for a new fuel. Guidance on materials used to develop a test method, and its applicability, can generally be found in a test method's scope and precision statements. The test method may also work for other materials.

X3.8 Applicability of the test method to materials outside its scope may be established by the subcommittee responsible for the method. Also, Subcommittee D02.E0, during the specification development process, may determine that a test method is applicable for specification purposes, even if the material is not in the test method's scope. Chemical and physical limits set in existing standards may or may not be appropriate to the new fuel or components. The new material may also require chemical or physical limits that are not appropriate to fuels in existing standards. These along with other considerations may indicate the need for separate new specifications. Although each case will require a separate evaluation, logic suggests that the fewer chemical and physical differences there are between the new fuel and traditional petroleum-based gas turbine fuel, the fewer differences in test methods and chemical or physical limits will be needed.

X3.9 If the proponent of the new fuel desires to move forward via the consensus process as described by ASTM bylaws and as implemented in Committee D02, then the proponent or a task force including the fuel manufacturer or proponent will bring forward ballot revisions to Specification D2880 or a new specification appropriate for use of the new fuel or blendstock. Because D02 specifications are established based on technical data, such data should exist before the

specification process moves forward. If such data does not exist, it needs to be developed.

X3.10 This guidance is not all-encompassing and cannot replace the judgment and process of a task force and subcommittee charged with evaluating a new fuel or blendstock. However it may give some guidance to proponents or fuel manufacturers who are considering participation in ASTM Committee D02 and its subcommittees to promote the inclusion of their new fuel or blendstock in ASTM standards.

SUMMARY OF CHANGES

Subcommittee D02.E0 has identified the location of selected changes to this standard since the last issue (D2880 – 14a) that may impact the use of this standard. (Approved June 1, 2015.)

(1) Added Test Method D7346 to Section 2, Referenced Documents, and to subsection 6.1.2.

Subcommittee D02.E0 has identified the location of selected changes to this standard since the last issue (D2880 – 14) that may impact the use of this standard. (Approved Dec. 1, 2014.)

(1) Revised 3.1 by moving definition of *fuel contaminant* from 3.2; added new term *contamination*.

(2) Added new Appendix X3.

Subcommittee D02.E0 has identified the location of selected changes to this standard since the last issue (D2880 – 13b) that may impact the use of this standard. (Approved Aug. 1, 2014.)

(1) Moved definition of *hydrocarbon oil* from 3.2 to 3.1.

(2) Revised 4.1 and moved Note 4 to this subsection.

(3) Added alternative test method (D7042) to Referenced Documents and to 6.1.7, Viscosity.