Designation: D1655 – 10

An American National Standard

Standard Specification for Aviation Turbine Fuels[1]

This standard is issued under the fixed designation D1655; 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 Department of Defense.

1. Scope*

1.1 This specification covers the use of purchasing agencies in formulating specifications for purchases of aviation turbine fuel under contract.

1.2 This specification defines specific types of aviation turbine fuel for civil use in the operation and certification of aircraft and describes fuels found satisfactory for the operation of aircraft and engines. The specification can be used as a standard in describing the quality of aviation turbine fuels from the refinery to the aircraft.

1.3 This specification does not include all fuels satisfactory for aviation turbine engines. Certain equipment or conditions of use may permit a wider, or require a narrower, range of characteristics than is shown by this specification.

1.4 Aviation turbine fuels defined by this specification may be used in other than turbine engines that are specifically designed and certified for this fuel.

1.5 This specification no longer includes wide-cut aviation turbine fuel (Jet B). FAA has issued a Special Airworthiness Information Bulletin which now approves the use of Specification D6615 to replace Specification D1655 as the specification for Jet B and refers users to this standard for reference.

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

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

D129 Test Method for Sulfur in Petroleum Products (General Bomb Method)

D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test

D156 Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)

D240 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter

D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)

D381 Test Method for Gum Content in Fuels by Jet Evaporation

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

D1266 Test Method for Sulfur in Petroleum Products (Lamp Method)

D1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

D1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption

D1322 Test Method for Smoke Point of Kerosine and Aviation Turbine Fuel

D1405 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels

D1660 Method of Test for Thermal Stability of Aviation Turbine Fuels[3]

D1840 Test Method for Naphthalene Hydrocarbons in Aviation Turbine Fuels by Ultraviolet Spectrophotometry

D2276 Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling

D2386 Test Method for Freezing Point of Aviation Fuels

D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry

D2624 Test Methods for Electrical Conductivity of Aviation and Distillate Fuels

D2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography

D2892 Test Method for Distillation of Crude Petroleum

[1] This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.J0.01 on Jet Fuel Specifications.

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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.

[3] Withdrawn. 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.**

(15-Theoretical Plate Column)
D3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry
D3227 Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosine, Aviation Turbine, and Distillate Fuels (Potentiometric Method)
D3240 Test Method for Undissolved Water In Aviation Turbine Fuels
D3241 Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels
D3242 Test Method for Acidity in Aviation Turbine Fuel
D3338 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
D3343 Test Method for Estimation of Hydrogen Content of Aviation Fuels
D3701 Test Method for Hydrogen Content of Aviation Turbine Fuels by Low Resolution Nuclear Magnetic Resonance Spectrometry
D3828 Test Methods for Flash Point by Small Scale Closed Cup Tester
D3948 Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer
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
D4171 Specification for Fuel System Icing Inhibitors
D4176 Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
D4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry
D4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
D4529 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
D4809 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)
D4865 Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems
D4952 Test Method for Qualitative Analysis for Active Sulfur Species in Fuels and Solvents (Doctor Test)
D4953 Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)
D5001 Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
D5006 Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels
D5190 Test Method for Vapor Pressure of Petroleum Products (Automatic Method)
D5191 Test Method for Vapor Pressure of Petroleum Products (Mini Method)
D5452 Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration
D5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
D5972 Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)
D6045 Test Method for Color of Petroleum Products by the Automatic Tristimulus Method
D6379 Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection
D6469 Guide for Microbial Contamination in Fuels and Fuel Systems
D6615 Specification for Jet B Wide-Cut Aviation Turbine Fuel
D6751 Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels
D7153 Test Method for Freezing Point of Aviation Fuels (Automatic Laser Method)
D7154 Test Method for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)
D7566 Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *Energy Institute Standards:*[4]

IP 225 Copper Content of Aviation Turbine Fuel
IP 227 Silver Corrosion of Aviation Turbine Fuel
IP 540 Determination of the existent gum content of aviation turbine fuel — Jet evaporation method
IP 585 Determination of fatty acid methyl esters (FAME), derived from bio-diesel fuel, in aviation turbine fuel — GC-MS with selective ion monitoring/scan detection method

2.3 *ANSI Standard:*[5]

ANSI 863 Report of Test Results

2.4 *Other Standards:*

Defence Standard (Def Stan) 91-91 Turbine Fuel, Aviation Kerosine Type, Jet A-1[6]
IATA Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks Ref. No: 9680-02[7]
EN14214 Automotive fuels - Fatty acid methyl esters (FAME) for diesel engines - Requirements and test methods[8]

[4] Available from Energy Institute, 61 New Cavendish St., London, WIG 7AR, U.K., http://www.energyinst.org.uk.
[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.
[6] Available from Procurement Executive DFS (Air), Ministry of Defence, St. Giles Court 1, St. Giles High St., London WC2H 8LD.
[7] Available from International Air Transport Association (IATA), (Head Office) 800 Place Victoria, PO Box 113, Montreal, H4Z 1M1, Quebec, Canada. www.iata-online.com.
[8] Available from European Committee for Standardization (CEN), 36 rue de Stassart, B-1050, Brussels, Belgium, http://www.cenorm.be.

3. General

3.1 This specification, unless otherwise provided, prescribes the required properties of aviation turbine fuel at the time and place of delivery.

4. Classification

4.1 Two types of aviation turbine fuels are provided, as follows:

4.1.1 *Jet A and Jet A-1*—Relatively high flash point distillates of the kerosine type.

4.2 Jet A and Jet A-1 represent two grades of kerosine fuel that differ in freezing point. Other grades would be suitably identified.

4.3 This specification previously cited the requirements for Jet B. Requirements for Jet B fuel now appear in Specification D6615.

5. Materials and Manufacture

5.1 Aviation turbine fuel is a complex mixture predominantly composed of hydrocarbons and varies depending on crude source and manufacturing process. Consequently, it is impossible to define the exact composition of Jet A/A-1. This specification has therefore evolved primarily as a performance specification rather than a compositional specification. It is acknowledged that this largely relies on accumulated experience; therefore the specification limits aviation turbine fuels to those made from conventional sources or by specifically approved processes.

5.1.1 Aviation turbine fuel, except as otherwise specified in this specification, shall consist predominantly of refined hydrocarbons (see Note 1) derived from conventional sources including crude oil, natural gas liquid condensates, heavy oil, shale oil, and oil sands. The use of jet fuel blends containing components from other sources is permitted only in accordance with Annex A1.

NOTE 1—Conventionally refined jet fuel contains trace levels of materials that are not hydrocarbons, including oxygenates, organosulfur, and nitrogenous compounds.

5.1.2 Fuels used in certified engines and aircraft are ultimately approved by the certifying authority subsequent to formal submission of evidence to the authority as part of the type certification program for that aircraft and engine model. Additives to be used as supplements to an approved fuel must also be similarly approved on an individual basis (see X1.2.4 and X1.15.1).

5.2 *Additives*—May be added to each type of aviation turbine fuel in the amount and of the composition specified in Table 2 or the following list of approved material:

5.2.1 Other additives are permitted under 5.1 and 7.1. These include fuel performance enhancing additives and fuel handing and maintenance additives as found under Table 2. The quantities and types must be declared by the fuel supplier and agreed to by the purchaser. Only additives approved by the aircraft certifying authority are permitted in the fuel on which an aircraft is operated.

5.2.1.1 Biocidal additives are available for controlled usage. Where such an additive is used in the fuel, the approval status of the additive and associated conditions must be checked for the specific aircraft and engines to be operated.

5.2.1.2 *Fuel System Icing Inhibitor*:

(1) Diethylene Glycol Monomethyl Ether (DiEGME), conforming to the requirements of Specification D4171, Type III, may be used in concentrations of 0.10 to 0.15 volume %.

(2) Test Method D5006 may be used to determine the concentration of DiEGME in aviation fuels.

5.3 *Incidental Materials*—Incidental materials are chemicals and compositions that can occur in turbine fuels as a result of production, processing, distribution, or storage. Table 3 lists specific materials that have an agreed limit. Specification D1655 does not require that each batch of fuel be analyzed for incidental materials. Further guidance concerning these materials is presented in X1.16.

5.4 Guidance material is presented in Appendix X2 concerning the need to control processing additives in jet fuel production.

6. Detailed Requirements

6.1 The aviation turbine fuel shall conform to the requirements prescribed in Table 1.

6.2 Test results shall not exceed the maximum or be less than the minimum values specified in Table 1. No allowance shall be made for the precision of the test methods. To determine conformance to the specification requirement, a test result may be rounded to the same number of significant figures as in Table 1 using Practice E29. Where multiple determinations are made, the average result, rounded in accordance with Practice E29, shall be used.

7. Workmanship, Finish and Appearance

7.1 The aviation turbine fuel specified in this specification shall be visually free of undissolved water, sediment, and suspended matter. The odor of the fuel shall not be nauseating or irritating. If the fuel has an odor similar to that of "rotten egg," please refer to X1.12.5 for further discussion. No substance of known dangerous toxicity under usual conditions of handling and use shall be present, except as permitted in this specification.

8. Sampling

8.1 Because of the importance of proper sampling procedures in establishing fuel quality, use the appropriate procedures in Practice D4057 to obtain a representative sample from the batch of fuel for specification compliance testing. This requirement is met by producing fuel as a discrete batch then testing it for specification compliance. This requirement is not satisfied by averaging online analysis results.

8.2 A number of jet fuel properties, including thermal stability, water separation, electrical conductivity, and others, are very sensitive to trace contamination, which can originate from sample containers. For recommended sample containers, refer to Practice D4306.

TABLE 1 Detailed Requirements of Aviation Turbine Fuels[A]

Property		Jet A or Jet A-1	ASTM Test Method[B]
COMPOSITION			
Acidity, total mg KOH/g	max	0.10	D3242
1. Aromatics, vol %	max	25	D1319
2. Aromatics, vol %	max	26.5	D6379
Sulfur, mercaptan,[C] mass %	max	0.003	D3227
Sulfur, total mass %	max	0.30	D1266, D2622, D4294, or D5453
VOLATILITY			
Distillation temperature, °C:			D86,[D]D2887[E]
10 % recovered, temperature	max	205	
50 % recovered, temperature		report	
90 % recovered, temperature		report	
Final boiling point, temperature	max	300	
Distillation residue, %	max	1.5	
Distillation loss, %	max	1.5	
Flash point, °C	min	38[F]	D56 or D3828[G]
Density at 15°C, kg/m^3		775 to 840	D1298 or D4052
FLUIDITY			
Freezing point, °C	max	–40 Jet A[H] –47 Jet A-1[H]	D5972, D7153, D7154, or D2386
Viscosity –20°C, mm^2/s[I]	max	8.0	D445
COMBUSTION			
Net heat of combustion, MJ/kg	min	42.8[J]	D4529, D3338, or D4809
One of the following requirements shall be met:			
(*1*) Smoke point, mm, or	min	25	D1322
(*2*) Smoke point, mm, and	min	18	D1322
Naphthalenes, vol, %	max	3.0	D1840
CORROSION			
Copper strip, 2 h at 100°C	max	No. 1	D130
THERMAL STABILITY			
(2.5 h at control temperature of 260°C min)			
Filter pressure drop, mm Hg	max	25[K]	D3241
Tube deposits less than		3[L]	
		No *Peacock* or *Abnormal* Color Deposits	
CONTAMINANTS			
Existent gum, mg/100 mL	max	7	D381, IP 540
Microseparometer,[M] Rating			D3948
Without electrical conductivity additive	min	85	
With electrical conductivity additive	min	70	
ADDITIVES		See 5.2	
Electrical conductivity, pS/m		[N]	D2624

[A] For compliance of test results against the requirements of Table 1, see 6.2.

[B] The test methods indicated in this table are referred to in Section 10.

[C] The mercaptan sulfur determination may be waived if the fuel is considered sweet by the doctor test described in Test Method D4952.

[D] D86 distillation of jet fuel is run at Group 4 conditions, except Group 3 condenser temperature is used.

[E] D2887 results shall be converted to estimated D86 results by application of the correlation in Appendix X5 on Correlation for Jet and Diesel Fuel in Test Method D2887. Distillation residue and loss limits provide control of the distillation process during the use of Test Method D86, and they do not apply to Test Method D2887. Distillation residue and loss shall be reported as "not applicable" (N/A) when reporting D2887 results.

[F] A higher minimum flash point specification may be agreed upon between purchaser and supplier.

[G] Results obtained by Test Methods D3828 may be up to 2°C lower than those obtained by Test Method D56, which is the preferred method. In case of dispute, Test Method D56 will apply.

[H] Other freezing points may be agreed upon between supplier and purchaser.

[I] 1 mm^2/s = 1 cSt.

[J] For all grades use either Eq 1 or Table 1 in Test Method D4529 or Eq 2 in Test Method D3338. Test Method D4809 may be used as an alternative. In case of dispute, Test Method D4809 shall be used.

[K] Preferred SI units are 3.3 kPa, max.

[L] Tube deposit ratings shall always be reported by the Visual Method.

[M] At point of manufacture.

[N] If electrical conductivity additive is used, the conductivity shall not exceed 600 pS/m at the point of use of the fuel. When electrical conductivity additive is specified by the purchaser, the conductivity shall be 50 to 600 pS/m under the conditions at point of delivery.

$$1 \text{ pS/m} = 1 \times 10^{-12}\ \Omega^{-1}\ m^{-1}$$

TABLE 2 Detailed Information for Additives for Aviation Turbine Fuels

Additive	Dosage
Fuel Performance Enhancing Additives	
Antioxidants[A,B]	24.0 mg/L max[C]
One of the following:	
2,6 ditertiary-butyl phenol	
2,6 ditertiary-butyl-4-methyl phenol	
2,4 dimethyl-6-tertiary-butyl-phenol	
75 % minimum, 2,6 ditertiary-butyl phenol plus	
25 % maximum mixed tertiary and tritertiary butyl-phenols	
55 % minimum 2,4 dimethyl-6-tertiary-butyl phenol plus	
15 % minimum 2,6 ditertiary-butyl-4-methyl phenol,	
remainder as monomethyl and dimethyl tertiary-butyl phenols	
72 % minimum 2,4 dimethyl-6-tertiary-butyl phenol plus	
28 % maximum monomethyl and dimethyl-tertiary-butyl-phenols	
Metal Deactivator[A]	
N,N-disalicylidene-1,2-propane diamine	
On initial blending	2.0 mg/L max[C,D]
After field reblending cumulative concentration	5.7 mg/L max
Fuel System Icing Inhibitor[E]	0.10 vol % min
Diethylene Glycol Monomethyl Ether (see Specification D4171)	0.15 vol % max
Fuel Handling and Maintenance Additives	
Electrical Conductivity Improver[F]	
Stadis 450[G]	
On initial blending	3 mg/L max
After field reblending, cumulative concentration	5 mg/L max
If the additive concentration is unknown at time of retreatment, additional concentration is restricted to 2 mg/L max	
Leak Detection Additive	1 mg/kg max
Tracer A (LDTA-A)[H]	
Biocidal Additives[E,I,J]	
Biobor JF[K]	
Kathon FP1.5[L]	
Corrosion Inhibitor/Lubricity Improvers[M]	
One of the following:	
HiTEC 580	23 mg/L max
Innospec DCI-4A	23 mg/L max
Nalco 5403	23 mg/L max

[A] The active ingredient of the additive must meet the composition specified.
[B] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1125.
[C] Active ingredient (not including weight of solvent).
[D] If copper contamination is suspected, initial treatment may exceed 2.0 mg/L but cumulative total must be below 5.7 mg/L.
[E] The quantity must be declared by the fuel supplier and agreed to by the purchaser.
[F] If electrical conductivity improver is used, the conductivity shall not exceed 600 pS/m at the point of use of the fuel. When electrical conductivity additive is specified by the purchaser, the conductivity shall be 50 to 600 pS/m under the conditions at point of delivery.

$$1\ \text{pS/m} = 1 \times 10^{-12}\ \Omega^{-1} m^{-1}$$

[G] Stadis 450 is a registered trademark marketed by Innospec Inc., Innospec Manufacturing Park, Oil Sites Road, Ellesmere Port, Cheshire, CH65 4EY, UK.
[H] Tracer A (LDTA-A) is a registered trademark of Tracer Research Corp., 3755 N. Business Center Dr., Tucson, AZ 85705.
[I] Biocidal additives are available for controlled usage. Where such an additive is used in the fuel, the approval status of the additive and associated conditions must be checked for the specific aircraft and engines to be operated.
[J] Refer to the Aircraft Maintenance Manual (AMM) to determined if either biocide is approved for use and for their appropriate use and dosage.
[K] Biobor JF is a registered trademark of Hammonds Technical Services, Inc. 910 Rankin Rd., Houston, TX 77073.
[L] Kathon FP1.5 is a registered trademark of Fuel Quality Services, Inc., P.O. Box 1380, Flowery Branch, GA 30542.
[M] More information concerning minimum treat rates of corrosion inhibitor/lubricity improver additives is contained in X1.10.2.

TABLE 3 Incidental Materials

Material	Permitted Level	Test Method
Fatty Acid Methyl Ester (FAME)[A]	<5 mg/kg max[B]	IP 585–10

[A] For the purpose of meeting this requirement FAME is defined as material meeting the limits of EN14214 or Specification D6751. Fatty acid methyl esters that fail to meet the biodiesel quality standards are not permitted in aviation turbine fuel.
[B] FAME is not approved as an additive for jet fuel. This level is accepted by approval authorities as the functional definition of "nil addition." The aviation industry is currently applying the additive approval process to evaluate the possible allowance of the presence of up to 100 mg/kg of FAME in aviation turbine fuel to facilitate the distribution of aviation turbine fuel in systems containing multiple products.

9. Report

9.1 The type and number of reports to ensure conformance with the requirements of this specification shall be mutually agreed upon by the seller and the purchaser of the aviation turbine fuel.

9.2 A suggested form for reporting inspection data on aviation turbine fuels is given in Appendix X3.

10. Test Methods

10.1 Determine the requirements enumerated in this specification in accordance with the following ASTM test methods.

10.1.1 *Density*—Test Method D1298 or D4052.

10.1.2 *Distillation*—Test Method D86. For Jet A and Jet A-1, Test Method D2887 can be used as an alternate. Results from Test Method D2887 shall be reported as estimated D86 results by application of the correlation in Appendix X5 on Correlation for Jet and Diesel Fuel in Test Method D2887. In case of dispute, Test Method D86 shall be the referee method (see X1.6.1.1).

10.1.3 *Flash Point*—Test Method D56 or D3828.

10.1.4 *Freezing Point*—Test Method D5972, D7153, D7154, or D2386. Any of these test methods can be used to certify and recertify jet fuel. However, Test Method D2386 is the referee method. An interlaboratory study (RR: D02–1572[9]) that evaluated the ability of freezing point methods to detect jet fuel contamination by diesel fuel determined that Test Methods D5972 and D7153 provided significantly more consistent detection of freeze point changes caused by contamination than Test Methods D2386 and D7154. It is recommended to certify and recertify jet fuel using either Test Method D5972 or Test Method D7153, or both, on the basis of the reproducibility and cross-contamination detection reported in RR:D02-1572.[9] The cause of freezing point results outside specification limits by automated methods should be investigated, but such results do not disqualify the fuel from aviation use if the results from the referee method (Test Method D2386) are within the specification limit.

10.1.5 *Viscosity*—Test Method D445.

10.1.6 *Net Heat of Combustion*—Test Method D4529, D3338, or D4809.

10.1.7 *Corrosion (Copper Strip)*—Test Method D130.

10.1.8 *Total Acidity*—Test Method D3242.

10.1.9 *Sulfur*—Test Method D1266, D2622, D4294, or D5453.

10.1.10 *Mercaptan Sulfur*—Test Method D3227.

10.1.11 *Water Separation*—Test Method D3948.

10.1.12 *Existent Gum*—Test Method D381 or IP 540. Test Method D381, using steam jet operating conditions, shall be the referee test method.

10.1.13 *Thermal Stability*—Test Method D3241.

10.1.14 *Aromatics*—Test Method D1319 or D6379. Test Method D1319 shall be the referee test method.

10.1.15 *Smoke Point*—Test Method D1322.

10.1.16 *Naphthalene Content*—Test Method D1840.

10.1.17 *Electrical Conductivity*—Test Method D2624.

11. Keywords

11.1 aviation turbine fuel; avtur; Jet A; Jet A-1; jet fuel; turbine fuel

[9] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1572.

ANNEX

(Mandatory Information)

A1. FUELS FROM NON-CONVENTIONAL SOURCES

A1.1 Introduction

A1.1.1 Jet fuel has contained synthesized hydrocarbons since the inception of Specification D1655. However, these synthesized materials are generated from petroleum, oil sand or shale derived feedstocks in the refinery and exhibit properties substantially similar to historically refined kerosine. The fuel property requirements defined in Specification D1655, Table 1 are batch-to-batch quality control tests which historically have provided fit-for-purpose jet fuel but assume that the jet fuel has a composition that is substantially similar to historical compositions. There is no basis to assume that fuels having novel compositions provide fit-for-purpose performance in current aviation hardware even if they appear to satisfy Specification D1655, Table 1 requirements. While the use of synthesized hydrocarbons is known and an acceptable practice, the use of synthesized hydrocarbons from new sources requires specific guidance that is currently outside the scope of Specification D1655. This guidance is found in Specification D7566.

A1.1.2 Specification D7566 was developed by Subcommittee D02.J0 to provide control for jet fuel produced with non-petroleum, non-shale, non-oil sands derived synthesized components. This specification guides the preparation of fuel blends that are compositionally similar to the refined fuels generated to Specification D1655 and can be controlled thereby in the distribution system. Aviation turbine fuels with synthetic components produced in accordance with Specification D7566 meet the requirements of Specification D1655. Specification D7566 does not yet include all fuels from non-conventional sources, so as an interim solution, it has been deemed necessary to recognize, on an individual basis, fuels from non-conventional sources whose performance complies with the intent of this specification and that have been approved by a coordinated specification authority.

A1.2 Acceptable Fuels from Non-Conventional Sources

A1.2.1 The SASOL semi-synthetic fuel, a blend of conventionally produced kerosine and a synthetic kerosine and specified in Defence Standard (Def Stan) 91-91, is recognized as meeting the requirements of Specification D1655.

A1.2.2 The SASOL fully synthetic fuel, a blend of up to five synthetic streams, specified in D.4.2 of Defence Standard (Def Stan) 91-91, is recognized as meeting the requirements of Specification D1655.

APPENDIXES

(Nonmandatory Information)

X1. PERFORMANCE CHARACTERISTICS OF AVIATION TURBINE FUELS

X1.1 Introduction

X1.1.1 This appendix describes the performance characteristics of aviation turbine fuels. A more detailed discussion of the individual test methods and their significance is found in ASTM Manual No. 1.[10] Additional information on aviation turbine fuel and its properties is found in ASTM's MNL 37, *Fuels and Lubricants Handbook: Technology, Properties, Performance, and Testing*[11] and the *Handbook of Aviation Fuel Properties*.[12]

X1.2 Significance and Use

X1.2.1 Specification D1655 defines two grades of jet fuel for civil use. Limiting values for the two grades of fuel covered are placed on fuel properties believed to be related to the performance of the aircraft and engines in which they are most commonly used.

X1.2.2 The safe and economical operation of aircraft requires fuel that is essentially clean and dry and free of any contamination prior to use. It is possible to measure a number of jet fuel characteristics related to quality.

X1.2.3 The significance of standard tests for fuel properties may be summarized for convenience in terms of the technical relationships with performance characteristics as shown in Table X1.1.

X1.2.4 The acceptability of additives for use must ultimately be determined by the engine and aircraft type certificate holder and must be approved by his certifying authority. In the United States of America, the certifying authority is the Federal Aviation Administration.

X1.3 Thermal Stability

X1.3.1 Stability to oxidation and polymerization at the operating temperatures encountered in certain jet aircraft is an important performance requirement. The thermal stability measurements are related to the amount of deposits formed in the engine fuel system on heating the fuel in a jet aircraft. Commercial jet fuels should be thermally stable at a fuel temperature as high as 163°C (325°F). Such fuels have been demonstrated to have inherent storage stability.

X1.3.2 In 1973, Test Method D3241 replaced Method of Test D1660, known as the ASTM Coker, for the determination of oxidative thermal stability. (See CRC Report 450, dated 1969 and revised in 1972. See also Bert and Painter's SAE

[10] *Manual on Significance of Tests for Petroleum Products* , MNL 1, ASTM International, 2003.

[11] MNL 37, *Fuels and Lubricants Handbook: Technology, Properties, Performance, and Testing*, Eds., Totten, George E., Westbrook, Steven R., and Shah, Rajesh J., ASTM International, W. Conshohocken, PA, 2003.

[12] *Handbook of Aviation Fuel Properties*, Third Edition, *CRC Report 635*, Coordinating Research Council, Atlanta, GA, 2004.

TABLE X1.1 Performance Characteristics of Aviation Turbine Fuels

Performance Characteristics	Test Method	Sections
Engine fuel system deposits and coke	Thermal stability	X1.3
Combustion properties	Smoke point	X1.4.2.1
	Aromatics	X1.4.2.2
	Percent naphthalenes	X1.4.2.3
Fuel metering and aircraft range	Density	X1.5.1
	Net heat of combustion	X1.5.2
Fuel atomization	Distillation	X1.6.1
	Viscosity	X1.6.2
Fluidity at low temperature	Freezing point	X1.7.1
Compatibility with elastomer and the metals in the fuel system and turbine	Mercaptan sulfur	X1.8.1
	Sulfur	X1.8.2
	Copper strip corrosion	X1.8.3
	Acidity	X1.8.4
Fuel storage stability	Existent gum	X1.9.1
Fuel handling	Flash point	X1.11.1
	Static Electricity	X1.11.2
	Water separation characteristics	X1.13.2
	Free water and particulate contamination	X1.12.3
	Particulate matter	X1.12.4
	Membrane color ratings	X1.12.4.1
	Undissolved water	X1.12.2
Fuel lubricating ability (lubricity)	Fuel lubricity	X1.10
Miscellaneous	Additives	X1.15.1
	Sample containers	X1.15.3

paper 730385.[13]). Today, a single pass/fail run with the tube temperature controlled at 260°C is used to ensure compliance with the specification minimum requirements. For a more complete characterization of a fuel's thermal stability, a *breakpoint* can be obtained. The breakpoint is the highest tube temperature at which the fuel still passes the specification requirements of tube deposit color and pressure differential. Normally, obtaining a breakpoint requires two or more runs at differing tube temperatures. Breakpoints are therefore not used for quality control, but they serve mostly for research purposes.

X1.4 Combustion

X1.4.1 Jet fuels are continuously burned in a combustion chamber by injection of liquid fuel into the rapidly flowing stream of hot air. The fuel is vaporized and burned at near stoichiometric conditions in a primary zone. The hot gases produced are continuously diluted with excess air to lower their temperature to a safe operating level for the turbine. Fuel combustion characteristics relating to soot formation are emphasized by current specification test methods. Other fuel combustion characteristics not covered in current specifications are burning efficiency and flame-out.

X1.4.2 In general, paraffin hydrocarbons offer the most desirable combustion cleanliness characteristics for jet fuels. Naphthenes are the next most desirable hydrocarbons for this use. Although olefins generally have good combustion characteristics, their poor gum stability usually limits their use in aircraft turbine fuels to about 1 % or less. Aromatics generally have the least desirable combustion characteristics for aircraft turbine fuel. In aircraft turbines they tend to burn with a smoky flame and release a greater proportion of their chemical energy as undesirable thermal radiation than the other hydrocarbons. Naphthalenes or bicyclic aromatics produce more soot, smoke, and thermal radiation than monocyclic aromatics and are, therefore, the least desirable hydrocarbon class for aircraft jet fuel use. All of the following measurements are influenced by the hydrocarbon composition of the fuel and, therefore, pertain to combustion quality: smoke point, percent naphthalenes, and percent aromatics.[14]

X1.4.2.1 *Smoke Point*—This method provides an indication of the relative smoke-producing properties of jet fuels and is related to the hydrocarbon-type composition of such fuels. Generally, the more highly aromatic the jet fuel, the more smoky the flame. A high smoke point indicates a fuel of low smoke-producing tendency.

X1.4.2.2 *Aromatics*—The combustion of highly aromatic jet fuels generally results in smoke and carbon or soot deposition, and it is therefore desirable to limit the total aromatic content as well as the naphthalenes in jet fuels.

X1.4.2.3 *Percent Naphthalenes*—This method covers measurement of the total concentration of naphthalene, acenaphthene, and alkylated derivatives of these hydrocarbons in jet fuels containing no more than 5 % of such compounds and having boiling points below 600°F (316°C).

X1.5 Fuel Metering and Aircraft Range

X1.5.1 *Density*—Density is a property of a fluid and is of significance in metering flow and in mass-volume relationships for most commercial transactions. It is particularly useful in empirical assessments of heating value when used with other parameters, such as aniline point or distillation. A low density may indicate low heating value per unit volume.

X1.5.2 *Net Heat of Combustion*—The design of aircraft and engines is based on the convertibility of heat into mechanical energy. The net heat of combustion provides a knowledge of the amount of energy obtainable from a given fuel for the performance of useful work; in this instance, power. Aircraft design and operation are dependent upon the availability of a certain predetermined minimum amount of energy as heat. Consequently, a reduction in heat energy below this minimum is accompanied by an increase in fuel consumption with corresponding loss of range. Therefore, a minimum net heat of combustion requirement is incorporated in this specification. The determination of net heat of combustion is time consuming and difficult to conduct accurately. This led to the development and use of the aniline point and density relationship to estimate the heat of combustion of the fuel. This relationship is used along with the sulfur content of the fuel to obtain the net heat of combustion by Test Method D4529 for the purposes of this specification. An alternative calculation, Test Method D3338, is based on correlations of aromatics content, gravity, volatility, and sulfur content. This method may be preferred at refineries where all these values are normally obtained and the necessity to obtain the aniline point is avoided. The direct measurement method, Test Method D4809, is normally used only as a referee method in cases of dispute.

X1.6 Fuel Atomization

X1.6.1 *Distillation*—The fuel volatility and ease of vaporization at different temperatures are determined by distillation. The 10 % distilled temperatures are limited to ensure easy starting. The Final Boiling Point limit excludes heavier fractions that would be difficult to vaporize.

X1.6.1.1 Test Method D86 is the referee method for measuring distillation properties; Test Method D2887 is approved as an alternate method. Test Method D86 and Test Method D2887 do not give the same numerical results. Test Method D2887 always starts at a lower temperature and ends at a higher temperature than Test Method D86 because Test Method D2887 gives true boiling point distribution (similar to Test Method D2892), as opposed to Test Method D86, which is a low efficiency distillation. To avoid confusion, it is required that Test Method D2887 results be reported as estimated D86 results by applying the correlation in Appendix X5 of Test Method D2887.

X1.6.1.2 Caution should be used when using distillation properties to estimate other fuel properties. A correlation equation giving a quantitative estimate of a fuel property based on Test Method D86 data should not be used with unconverted Test Method D2887 results without validation. Further, Test

[13] Bert, J. A., and Painter, L., "A New Fuel Thermal Stability Test (A Summary of Coordinating Research Council Activity)," SAE Paper 730385, Society of Automotive Engineers, Warrendale, PA, 1973.

[14] A task force studied the possible use of hydrogen content as an alternative to aromatics content. Supporting data (a report of these studies completed in 1989) have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1258.

Method D2887 results converted into a form compatible with Test Method D86 might not be suitable for some property correlations because of the accumulation of errors from each correlation step.

X1.6.2 *Viscosity*—The viscosity of a fuel is closely related to pumpability over the temperature range and consistency of nozzle spray patterns. The ability of fuel to lubricate a pump may also be related to the viscosity.

X1.7 Fluidity at Low Temperatures

X1.7.1 *Freezing Point*—The freezing point is particularly important and must be sufficiently low to preclude interference with flow of fuel through filter screens to the engine at temperatures prevailing at high altitudes. The temperature of fuel in an aircraft tank decreases as the outside temperature decreases. The minimum temperature experienced during a flight depends mostly on the outside air temperature, flight duration, and aircraft speed. For example, long duration flights would require fuel of lower freezing point than would short duration flights.

X1.7.1.1 The manual freezing point method, Test Method D2386, has a long history of providing results sufficient to support safe aviation operations, so it is designated the referee method. As shown by the results in RR:D02-1572[9], automated methods often provide greater precision in determining freezing point and more sensitivity to cross-product contamination than the manual method, so their use is recommended in certifying and recertifying jet fuel. Recent experience has shown, however, that automated methods sometimes give unreliable freezing points or freezing points significantly warmer than the manual method. In such cases, in the absence of cross-product contamination, the fuel may be certified/recertified by the manual method.

X1.7.1.2 Because of the advantages of automated freezing point methods, many laboratories no longer run the manual freezing point method on a routine basis. It is recommended, when requesting manual freezing point measurements, that requestors ensure that the method is being conducted properly.

NOTE X1.1—Absence of cross-product contamination is intended to set an expectation that the possibility and ramifications of cross-product contamination are considered before the fuel is released, hence this decision should not be made solely on the manual freezing point result.

X1.8 Compatibility with Elastomer and the Metals in the Fuel System and Turbine

X1.8.1 *Mercaptan Sulfur*—Mercaptans are known to be reactive with certain elastomers. A limitation in mercaptan content is specified to preclude such reactions and to minimize the unpleasant mercaptan odor.

X1.8.2 *Sulfur*—Control of sulfur content is significant for jet fuels because the sulfur oxides formed during combustion may be corrosive to turbine metal parts.

X1.8.3 *Copper Strip Corrosion*—A requirement that jet fuel must pass the copper strip test ensures that the fuel will not corrode copper or any copper-base alloys in various parts of the fuel system.

X1.8.4 *Total Acidity*—Some petroleum products are treated with mineral acid or caustic, or both, as part of the refining procedure. Any residual mineral acid or caustic is undesirable. Neither impurity is likely to be present. However, a determination of acidity confirms this when inspecting new or unused fuel. It also measures organic acids if present.

X1.9 Fuel Storage Stability

X1.9.1 *Existent Gum*—Gum is a nonvolatile residue left on evaporation of fuel. Steam or air is used as an evaporating agent for fuels that are to be used in aircraft equipped with turbine engines. The amount of gum present is an indication of the condition of the fuel at the time of test only. Large quantities of gum are indicative of contamination of fuel by higher boiling oils or particulate matter and generally reflect poor fuel handling practices.

X1.10 Fuel Lubricity

X1.10.1 Aircraft/engine fuel system components and fuel control units rely on the fuel to lubricate their sliding parts. The effectiveness of a jet fuel as a lubricant in such equipment is referred to as its *lubricity*. Differences in fuel system component design and materials result in varying degrees of equipment sensitivity to fuel lubricity. Similarly, jet fuels vary in their level of lubricity. In-service problems experienced have ranged in severity from reductions in pump flow to unexpected mechanical failure leading to in-flight engine shutdown.

X1.10.2 The chemical and physical properties of jet fuel cause it to be a relatively poor lubricating material under high temperature and high load conditions. Severe hydroprocessing removes trace components resulting in fuels that tend to have lower lubricity than straight-run or wet-treated fuels. Corrosion inhibitor/lubricity improver additives (see Table 2) are routinely used to improve the lubricity of military fuels and may be used in civil fuels. These additives vary in efficacy and may be depleted by adsorption on tank and pipe surfaces, so treat rates should be set with care. Because of their polar nature, these additives can have adverse effects on fuel filtration systems and on fuel water separation characteristics. For this reason, it is preferable to avoid adding more of these additives than needed. When adequate jet fuel lubricity performance is achieved solely by additive use (without BOCLE testing or commingling with higher lubricity fuels), the additive concentration should be used at no less than its Minimum Effective Concentration (MEC) from the military Qualified Products List (QPL-25017). These levels are:

CI/LI Additive	MEC
HiTEC 580	15 g/m^3
Innospec DCI-4A	9 g/m^3
Nalco 5403	12 g/m^3

X1.10.3 Most modern aircraft fuel system components have been designed to operate on low lubricity fuel (Test Method D5001 (BOCLE) wear scar diameter up to 0.85 mm). Other aircraft may have fuel system components that are more sensitive to fuel lubricity. Because low lubricity fuels are commingled with high lubricity fuels in most distribution systems, the resultant fuels no longer have low lubricity. However, problems have occurred when severely hydroprocessed fuel from a single source was the primary supply for sensitive aircraft. Where there are concerns about fuel lubricity,

the air frame manufacturer can advise precautionary measures, such as the use of an approved lubricity additive to enhance the lubricity of the fuel.

X1.10.4 Test Method D5001 (BOCLE) is a test for assessing fuel lubricity where lower lubricity fuels give larger BOCLE wear scar diameters. BOCLE is used for in-service trouble shooting, lubricity additive evaluation, and in the monitoring of low lubricity test fluid during endurance testing of equipment. However, because the BOCLE may not accurately model all types of wear that cause in-service problems, other methods may be developed to better simulate the type of wear most commonly found in the field.

X1.10.5 Regulations are requiring increased production and distribution of ultralow sulfur diesel fuel (15 ppm maximum sulfur content). Diesel fuels are desulfurized to these low levels by severe hydroprocessing, sometimes resulting in very low lubricity fuels. Jet fuel lubricity may be impacted by the increased use of low sulfur diesel fuel, because batches of jet fuel may be made to these ultralow sulfur levels to maintain efficient production and distribution.

X1.11 Fuel Handling

X1.11.1 *Flash Point*—The flash point is an indication of the maximum temperature for fuel handling and storage without serious fire hazard. The shipment, storage, and handling precautions regulated by municipal, state, or federal laws and insurance requirements are a function of the flash point for the particular fuel being utilized.

X1.11.2 *Static Electricity*—The generation and dissipation of static electricity can create problems in the handling of aviation fuels. Electrical conductivity additives can be added to dissipate charge more rapidly. This is most effective when the fuel conductivity is in the range from 50 to 600 pS/m. Studies have shown that when fuels treated with conductivity additive are commingled with non-additized fuel resulting in a low conductivity fuel, that fuel blend does not exhibit unusual static behavior. For more information on this subject, see Guide D4865.

X1.12 Fuel Cleanliness and Contamination

X1.12.1 *Introduction*:

X1.12.1.1 Unlike most other fuel properties, fuel cleanliness is dynamic; constantly changing during transportation and distribution. Jet fuel should be maintained in as clean a condition as possible right up to and in airport storage to ensure that possible failures of individual filtration components will not result in an unsafe condition. Airport control of cleanliness should be such as to ensure that only fuel relatively absent of free water and solid particulates is delivered into aircraft.

X1.12.1.2 The cleanliness of aviation turbine fuel is an essential performance requirement. Cleanliness requires the relative absence of free water and solid particulates. Water or dirt contamination, or both, in fuel onboard an aircraft represents a threat to flight safety and can cause long–term problems in areas such as wear, corrosion, and plugging of filters and other narrow tolerance parts.

X1.12.1.3 The cleanliness of aviation turbine fuel is protected in part by allowing time for dirt and water to settle during fuel distribution and by the routine use of effective filtration that removes both dirt and water. Generally the fuel handling system filters the fuel several times between manufacture and use with the final filtration occurring as the fuel is loaded onto an aircraft.

X1.12.2 *Undissolved Water*—The test method for undissolved water provides a quantitative means for measuring the amount of undissolved or free water in flowing fuel streams without exposing the sample to the atmosphere or to a sample container. It also provides a means for checking the performance of fuel filter-separators. Test Method D3240 describes this test method.

X1.12.3 *Free Water and Particulate Contamination in Distillate Fuels (Clear and Bright Pass/Fail Procedures)*—The procedures in Test Method D4176 provide rapid but nonquantitative methods for detecting contamination in a distillate fuel. Other following methods permit quantitative determinations.

X1.12.4 *Particulate Matter*—The presence of adventitious solid particulate contaminants such as dirt and rust may be detected by filtration of the jet fuel through membrane filters under prescribed conditions. Test Methods D2276 and D5452 describe a suitable technique.

X1.12.4.1 *Membrane Color Ratings*—Filtering the fuel through a membrane and rating the color of the deposits against a standard color scale offers a qualitative assessment of particulate contaminant levels in fuels or of changes in fuel contaminant levels at a particular location. Appendix XI on Filter Membrane Color Ratings for Fuels of Test Method D2276 describes a suitable technique.

X1.12.5 *Microbial Contamination*—Uncontrolled microbial contamination in fuel systems can cause or contribute to a variety of problems including corrosion, odor, filter plugging, decreased stability, and deterioration of fuel/water separation characteristics. In addition to system component damage, off-specification fuel can result.

X1.12.5.1 Microorganisms (that is, bacteria, yeast, and mold) that have become established in a fuel system can present the fuel manufacturer, distributor, or user with a unique set of operational and maintenance challenges. Unlike inanimate material such as dirt, rust, or chemicals, microorganisms are living organisms that are ubiquitous in the environment, can reproduce from a single cell into a great number ($>10^9$) of cells, are transported during fuel movement, need only small amounts of water to remain viable and utilize aviation fuel as a food source. Gross evidence of the presence of microbial contamination can include suspended matter in the fuel or at the fuel water interface and/or the smell of “rotten egg” which is due to the presence of hydrogen sulfide a typical metabolite of sulfate reducing bacteria. There are a number of semi-quantitative and quantitative techniques available when gross observation proves inconclusive to rule out the presence of microorganisms. These techniques include nutrient/growth media, bioluminescence and immunoassay. As a result of uncontrolled microbial growth, structural components that make up the aviation fuel storage and distribution network such as product pipeline, tankers, storage tanks and airport fueling hydrant systems can experience accelerated forms of corrosion thereby compromising the integrity and operation of the fuel

network as well as acting as a conduit to introduce microorganisms into aircraft fuel systems.

X1.12.5.2 Once microorganisms have established a presence in an aircraft fuel system a variety of operational and maintenance issues can occur that could affect the safe and economic operation of the aircraft. For example, uncontrolled microbial contamination can lead to the corrosion of metallic structures such as wing tanks; degradation of protective coatings, alloys, and electrical insulation; erratic readings in the Fuel Quantity Indication System (FQIS); blocking of the scavenge systems; and blocking of engine fuel filters. The two biocide additives that are generally approved for use by the airframe and engine manufacturers are Biobor JF[15] and KATHON FP1.5.[16] These biocide additives may be used in aviation fuel only in accordance with local regulations, aircraft engine guidelines and airframe manufacturer guidelines. The ultimate user shall be informed and agree to the presence of biocide additive in their jet fuel supply. Consult with the appropriate Aircraft Maintenance Manual (AMM) for instructions.

X1.12.5.3 Guide D6469 provides individuals with a limited background in microbiology an understanding of the occurrence, symptoms, and consequences of chronic microbial contamination. The guide also suggests means for detection and remediation of microbial contamination in fuels and fuel systems. IATA Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks also provides guidance for determining the potential source, detection and remediation of the potential microbial contamination.

X1.13 Surfactants

X1.13.1 A key element in preventing contamination is to minimize or eliminate surfactants, which can compromise the ability of fuel handling systems to remove dirt and water. For example, surfactants can reduce the particle size of suspended solid and water droplets, which slows removal by settling. Surfactants can disperse dirt and water so finely that they pass through filters. Surfactants can adsorb on the surfaces of filter/coalescers interfering with water removal. Surfactants can also lift rust from surfaces, thus increasing the solids level in the fuel.

X1.13.2 *Water Separation Characteristics*—The ease of coalescence of water from fuels as influenced by surface active agents (surfactants) is assessed by Test Methods D3948 and is designed to be used as a field or laboratory method. A high rating suggests a fuel free of surfactants; a low rating indicates that surfactants are present. Surfactants, which may be contaminants or deliberately added materials, may gradually disarm filter coalescers, allowing fine water droplets and particulate contaminants to pass separators in ground handling equipment.

X1.13.2.1 *Water Separation Characteristics at Point of Manufacture*—The presence of surfactants in aviation turbine fuel specified by Specification D1655 is controlled at the point of manufacture by the Test Method D3948 performance requirement listed in Table 1. To determine if surfactant contamination occurs during transportation the fuel should also be tested downstream of the point of manufacture as appropriate.

X1.13.2.2 *Water Separation Characteristics at Points Downstream*—Results of downstream Test Method D3948 testing are not to be used as the sole reason for rejection of fuel, but they can indicate a mandatory need for further diligent investigation or remedial action, or both, such as passing the fuel through a clay adsorption unit to remove surfactants. However, the fuel may be rejected in the absence of satisfactory Test Method D3948 testing results if no documented evidence is presented that a detailed investigation was carried out demonstrating that the fuel was free of excess water and dirt and could be delivered into aircraft in a clean condition.

X1.13.2.3 *Water Separation Assessment*—Because distribution systems can be complex and employ a variety of methods of transporting the fuel, sampling points and methodologies should be established as a result of a technical assessment designed to ensure that fuel cleanliness is maintained throughout the system to the point of delivery into aircraft. Since transport systems vary in their basic nature, for example, a multi-product pipeline versus a dedicated pipeline, and also in their detailed operating conditions, the parties assuming custody of the fuel should evaluate their particular systems and establish suitable testing requirements.

X1.14 Cleanliness at Time of Fuel Custody Transfer at Airport

X1.14.1 Airport fueling is the most critical location for controlling dirt and water cleanliness. Into-airport storage is thus an important point for controlling surfactant contamination so as to protect out-of-storage and into-plane dirt and water filtration.

X1.15 Miscellaneous

X1.15.1 *Additives*—Antioxidants and metal deactivators are used to prevent the formation of oxidation deposits in aircraft engine fuel systems, to counteract the catalytic effects of active metals in fuel systems, and to improve the oxidation stability of fuels in storage. Other additives are available to inhibit the corrosion of steel in fuel systems, to improve the fuel lubricity, to increase the electrical conductivity of fuel, to combat microbiological organisms, to prevent the formation of ice in fuel systems containing water, and to assist in detecting leaks in fuel storage, delivery, and dispensing systems. The chemical names or registered trade names of approved additives and the maximum quantities permitted are shown in the specifications.

X1.15.1.1 *Fuel System Icing Inhibitor*, diethylene glycol monomethyl ether approved in 5.2.1.2 shall conform to the requirements shown in Specification D4171.

X1.15.2 *Leak Detection Additive*—Addition of leak detection additive, approved in 5.2, should be added to the fuel in accordance with the Tracer Tight[17] methodology.

[15] Biobor JF is a registered trademark of Hammonds Technical Services, Inc. 910 Rankin Rd., Houston, TX 77073.

[16] Kathon FP1.5 is a registered trademark of Fuel Quality Services, Inc., P.O. Box 1380, Flowery Branch, GA 30542.

[17] Tracer Tight is a registered trademark of Tracer Research Corp., 3755 N. Business Center Dr., Tucson, AZ 85705.

X1.15.3 *Sample Containers*—A practice for sampling aviation fuel for tests affected by trace contamination can be found in Practice D4306.

X1.15.4 *Color*—While this specification does not have a color requirement, color can be a useful indicator of fuel quality. Normally fuel color ranges from water white (colorless) to a straw/pale yellow. Other fuel colors may be the result of crude oil characteristics or refining processes. Darkening of fuel or a change in fuel color may be the result of product contamination and may be an indicator that the fuel is off-specification, which could render it unfit and not acceptable for aircraft/engine use. Fuel having various shades of color, that is, pink, red, green, blue, or a change in color from the supply source should be investigated to determine the cause of color change to ensure suitability for aircraft/engine use and should be documented prior to final delivery to airport storage.

X1.16 Incidental Materials

X1.16.1 Incidental materials are chemicals and compositions that can occur in turbine fuel as a result of production, processing, distribution or storage (see Table 3). Incidental materials are unavoidable from a practical view point. Table 3 lists specific materials that have an agreed limit. Turbine fuel containing an incidental material in excess of the limit listed in Table 3 may not comply with the operating limitations approved by aircraft regulatory authorities for use on commercial aircraft.

X1.16.2 It is not necessary to test each batch of turbine fuel for compliance with Table 3. The implementation of control or management of change schemes that satisfy the expectation that Table 3 limits are not exceeded is adequate to meet the requirements of this specification.

X1.16.3 Additional test methods for FAME content analysis are being developed by the Energy Institute and will be cited when complete.

X2. CONTROL OF PROCESSING ADDITIVES

X2.1 Experience has shown that refinery processing additives, such as corrosion inhibitors, might be carried over in trace quantities into aviation fuel during refinery production. In some cases, this has resulted in operational problems in aircraft fuel systems. Moreover, these additives can cause problems at levels which may not be detected by the standard specification testing detailed in Table 1. While the specification (5.1.2) requires that only approved additives are used, confirming that non-approved additives are absent is difficult, because it is unclear what analytical method to apply, given that:

X2.1.1 The analytical target may be uncertain, since there is a wide range of (often proprietary) materials involved.

X2.1.2 There is no industry-agreed basis for determining the required analysis sensitivity.

X2.1.3 There usually are no available data, relating to processing additive concentration to aircraft system performance, to set no-harm levels (to define analysis sensitivity).

X2.2 It is therefore not practical for this specification to require detailed chemical analysis of each production batch of aviation fuel beyond the requirements listed in Table 1. Instead, each manufacturing location should ensure that procedures are in place to control processing additive use and impact on product performance. One acceptable approach to do this is to implement a management of change procedure that evaluates the impact of processing changes (including process additives) on finished product quality. Other approaches may also be acceptable.

X3. FORM FOR REPORTING INSPECTION DATA ON AVIATION TURBINE FUELS

X3.1 Introduction

X3.1.1 Many airlines, government agencies, and petroleum companies make detailed studies of inspection data provided on production aviation turbine fuels. Because a large number of inspections or inspection locations, or both, is generally involved, these studies are frequently made with the aid of a computer. Without a standardized form for reporting data from different sources, transcribing the reported data for computer programming is laborious. An individual must search each different data sheet for desired information because of the random ordering of results by different reporting laboratories. One objective, therefore, of a standard reporting form is to provide a precise ordering of inspection test data being reported.

X3.1.2 The inspection form shown in Fig. X3.1 incorporates the requirements of the most commonly used international fuel specifications, including Specification D1655, British specification Defence Standard (DERD 2494), and IATA Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks.

X3.1.3 Specific users of aviation turbine fuels sometimes find it necessary to specify properties that are not included in Specification D1655, which are provided as a basis for formulating their own specifications. Another objective of a standard form is to list all tests that might be included in the large number of individual aviation turbine fuel specifications. The fact that a particular test is listed in the standard reporting form does not in itself indicate that there is a universal need for a

INSPECTION DATA ON AVIATION TURBINE FUEL
(Items in **bold** type are referenced in the specification)

MANUFACTURER/SUPPLIER _____
PRODUCT CODE/GRADE_____
SPECIFICATION_____
SAMPLE NUMBER_____
DATE SAMPLED_____
SAMPLING LOCATION_____
BATCH NO._____
QUANTITY LITRES @ 15°C_____
QUANTITY U.S. GALLONS @ 60°F_____
LABORATORY_____

DATE SAMPLED_____
DATE RECEIVED AT LAB_____
CONTRACT NO._____
ORDER NO._____
TANK NO._____
DESTINATION_____
CRUDE SOURCE_____
PROCESSING METHOD_____
REMARKS_____

Method			Result
		APPEARANCE	
010	D 156	Color (Saybolt)	◊◊◊
020	D 6045	Color (Saybolt)	◊◊◊
030	D 4176	Visual ("Pass" or "Fail")	◊◊◊◊
		COMPOSITION	
100C	**D 3242**	**Acidity, Total (mgKOH/g)**	◊●◊◊◊
110	**D 1319**	**Aromatics (vol %)**	◊◊●◊
112	**D 6379**	**Aromatics (vol %)**	◊◊●◊
115	D 1319	Olefins (vol %)	◊●◊
120	**D 1840**	**Naphthalene (vol %)**	◊●◊◊
130	**D 3227**	**Sulfur, Mercaptan (mass %)**	◊●◊◊◊◊
140	D 4952	Doctor Test (P = pos, N = neg)	◊
150A	D 129	Sulfur, Total (mass %)	◊●◊◊
150B	**D 1266**	**Sulfur, Total (mass %)**	◊●◊◊
150D	**D 2622**	**Sulfur, Total (mass %)**	◊●◊◊
150E	D 3120	Sulfur, Total (ppm)	◊◊◊◊
150F	**D 4294**	**Sulfur, Total (mass %)**	◊●◊◊
150G	**D 5453**	**Sulfur, Total (ppm)**	◊◊◊◊
160A	D 3343	Hydrogen Content (mass %)	◊◊●◊◊
160B	D 3701	Hydrogen Content (mass %)	◊◊●◊◊
		VOLATILITY	
200A	**D 86**	**Distillation by Auto/Manual (°C)**	◊
200B	D 2887	Distillation by GC (°C)	◊
201		Distillation by Initial BP (°C)	◊◊◊●◊
202		Distillation by 10 % Rec (°C)	◊◊◊●◊
203		Distillation by 20 % Rec (°C)	◊◊◊●◊
204		Distillation by 50 % Rec (°C)	◊◊◊●◊
205		Distillation by 90 % Rec (°C)	◊◊◊●◊
206		Distillation by 95 % Rec (°C)	◊◊◊●◊
211		Distillation by Final BP (°C)	◊◊◊●◊
213		Residue (vol %)	◊●◊
214		Loss (vol %)	◊●◊
220A	**D 56**	**Flash Point, Tag Closed (°C)**	◊◊●◊
220B	D 93	Flash Point, PM Closed (°C)	◊◊●◊
220C	**D 3828**	**Flash Point, Setaflash (°C), Meth A**	◊◊●◊
220D	D 3828	Flash Point, Setaflash (°C), Meth B	◊◊●◊
221	D 3828	Flash Point, Setaflash (Flash/No Flash)	◊
230A	**D 1298**	**Density @ 15°C (kg/m^3)**	◊◊◊●◊
230B	**D 4052**	**Density @ 15°C (kg/m^3)**	◊◊◊●◊
231A	D 1298	API Gravity @ 60°F	◊◊●◊
240A	D 323	Vapor Pressure, Reid (kPa)	◊◊●◊
240B	D 4953	Vapor Pressure, Dry Method (kPa)	◊◊●◊
240C	D 5190	Vapor Pressure, Automatic Method (kPa)	◊◊●◊
240D	D 5191	Vapor Pressure, Mini Method (kPa)	◊◊●◊
		FLUIDITY	
300A	**D 2386**	**Freezing Point (°C)**	-◊◊●◊◊
300B	**D 5901**	**Freezing Point (°C)**	-◊◊●◊◊
300C	**D 5972**	**Freezing Point (°C)**	-◊◊●◊◊
300D	**D 4305**	**Freezing Point (°C)**	-◊◊●◊◊
300F	**D 7154**	**Freezing Point (°C)**	-◊◊●◊◊
310	**D 445**	**Viscosity @ -20°C (mm^2/s)**	◊◊●◊◊◊
311	D 445	Viscosity at other temp (mm^2/s)	◊◊●◊◊◊
312	D 445	Temp (°C) of Item 311	◊◊◊◊

Method			Result
		COMBUSTION	
400A	D 240	Net Heat of Combustion (MJ/kg)	◊◊●◊◊◊
400B	D 1405	Net Heat of Combustion (MJ/kg)	◊◊●◊◊◊
400C	**D 3338**	**Net Heat of Combustion (MJ/kg)**	◊◊●◊◊◊
400D	**D 4529**	**Net Heat of Combustion (MJ/kg)**	◊◊●◊◊◊
400E	**D 4809**	**Net Heat of Combustion (MJ/kg)**	◊◊●◊◊◊
410	**D 1740**	**Luminometer No.**	◊◊
420	**D 1322**	**Smoke Point (mm)**	◊◊●◊
		CORROSION	
500	**D 130**	**Copper Strip**	◊◊
510	IP 227	Silver Strip	◊
		STABILITY	
601A	**D 3241**	**Filter ΔP (mm Hg) @ other temp**	◊◊●◊
602A	**D 3241**	**Tube Deposit @ other temp**	◊◊◊◊
603A	**D 3241**	**TDR Spun Rating @ other temp**	◊◊
604A		**Temperature (°C) of above**	◊◊◊◊
601B	**D 3241**	**Filter ΔP (mm Hg) @ 260°C**	◊◊●◊
602B	**D 3241**	**Tube Deposit Rating @ 260°C**	◊◊◊◊
603B	**D 3241**	**TDR Spun Rating @ 260°C**	◊◊
		CONTAMINANTS	
700	IP 225	Copper Content (mg/kg)	◊●◊◊
710	**D 381**	**Existent Gum (mg/100 mL)**	◊◊◊
710A	**IP 540**	**Existent Gum (mg/100 mL)**	◊◊◊
720A	D 2276	Particulate (mg/L)	◊●◊◊
720B	D 5452	Particulate (mg/L)	◊●◊◊
730		Filtration time (minutes)	◊◊
740	**D 1094**	**Water Reaction Interferance Rating**	◊◊
750	D 3948	MSEP (With SDA)	◊◊◊
751	D 3948	MSEP (Without SDA)	◊◊◊

		ADDITIVES	**Brand**	
800		Antioxidant (mg/L)	[ ]	◊◊●◊
810		Metal Deactivator (mg/L)	[ ]	◊●◊
820		Static Dissipator Additive (mg/L)	[ ]	◊●◊
830A	(D5006)	FSII (vol%)	[ ]	◊●◊◊◊
830B	(FTM5327)	FSII (vol%)	[ ]	◊●◊◊◊
830C	(FTM5340)	FSII (vol%)	[ ]	◊●◊◊◊
840		Corrosion Inhibitor (mg/L)	[ ]	◊◊●◊
		OTHER TESTS		
900	**D 2624**	**Conductivity (pS/m)**		◊◊◊◊
901	**D 2624**	**Conductivity Test Temperature (°C)**		◊◊◊

Comments and/or Additional Tests:

_____
_____
_____
_____
_____
_____
_____

CERTIFIED BY _____

FIG. X3.1 Standard Form for Reporting Inspection Data on Aviation Turbine Fuels

specification limit. For example, a high-performance military aircraft might have fuel requirements not applicable to subsonic commercial aircraft.

X3.1.4 The third objective in meeting future electronic commerce needs is to establish the industry standard to be used to electronically transmit aviation turbine fuel quality data from one location to another. This form will serve as the template for mapping to ANSI 863 for aviation fuels.

X3.2 Dimensions of Standard Form

X3.2.1 A standard reporting form for aviation turbine fuels is shown in Fig. X3.1.

X3.2.2 Earlier versions of this form were available from ASTM as Adjunct 12-416552-00 and were sized so that the forms could be used in a standard typewriter. Because of decreased use, the form is now presented only as an example of a suitable data reporting sheet and is no longer available from ASTM as an adjunct.

X3.3 Description of Standard Form

X3.3.1 The top of the form (Header Section) provides a method for entering pertinent information regarding description and identity of the fuel being tested and the laboratory performing the tests. Items in italic print are mandatory items. Fill in only those data elements necessary to cover the individual testing situation. Explanation of non-self-explanatory Entries is provided below:

X3.3.1.1 *Manufacturer/Supplier*—Agency or activity who has possession of the fuel to be tested.

X3.3.1.2 *Product Code/Grade*—Accepted code for product being tested.

X3.3.1.3 *Sampling Location*—Place where sample was collected, as specific as possible.

X3.3.1.4 *Batch Number*—If sample was taken from the storage tank, this number should be the batch number of the product in the tank. If the sample is a composite of a shipment, this number should be the batch number or cargo number that represents the shipment.

X3.3.1.5 *Destination*—Location to which the product will be shipped. If more than one location, write *Multiple* in this block and list locations in the *Comments* block at the bottom of the form.

X3.3.1.6 *Crude Source*—If required by contract or other agreement, list the crude(s) and percentages used to refine the product. This is done in an attempt to correlate fuel properties with types of crudes.

X3.3.1.7 *Processing Method*—If required by contract or other agreement, list the crude processing technique(s) used to refine the product. Examples are hydrotreating, caustic wash, hydrocracking, merox, and so forth. (All assume atmospheric distillation.) Used in conjunction with the crude source, this information can be used to correlate fuel properties with crude processing technique.

X3.3.2 The body of the form provides for entering test results. There are four columns provided for each test.

X3.3.2.1 The first column shows the item number or code assigned to each specific test result. The number assignment for each grouping of fuel characteristics is as follows:

10–99	Appearance
100–199	Composition
200–299	Volatility
300–399	Fluidity
400–499	Combustion
500–599	Corrosion
600–699	Stability
700–799	Contaminants
800–899	Additives
900–999	Other Tests

The code designations are derived from a master list of codes assigned to tests performed for all products. Under these general categories, item numbers or codes increase either by one unit, five units, ten units, or an alpha character. For each property to be measured under a category, the code increases by five or ten units, depending on the number of characteristics that fall under that general category. The alpha codes represent the various methods allowed by specification to measure that characteristic. This may be a change of test method (see total sulfur as an example) or a change in test conditions (see D3241 as an example). When the code varies by one unit, this is intended to indicate more than one reported measurement or evaluation for that particular test method (see distillation and water reaction as examples). This system allows for the coding of test methods with their equivalents and for the introduction of newly approved methods systematically into the standardization data sheet.

X3.3.2.2 The second column lists the applicable ASTM method number. Where there is no ASTM method number, the applicable IP number (Institute of Petroleum) is shown.

X3.3.2.3 The third column presents word descriptors for each test.

X3.3.2.4 The fourth column presents diamonds for entering the results of each test with location of the decimal point shown where applicable.

X3.3.3 The lower right-hand part of the form provides space for comments or for entering other test results that are not listed in the main body of the form.

X3.4 Instructions for Executing Column 4

X3.4.1 *General Instructions*:

X3.4.1.1 This form is intended for use with both naphtha- and kerosine-based aviation fuels and provides choice of test methods. Individual laboratory analysis reports should cite only the required or relevant data for the top of the form and reference the assigned item number or code for each characteristic analyzed. Number of decimal places or significant figures, or both, is meant to reflect that which is appropriate for the test method. When determining compliance of the data reported with the requirements of the cited specification, however, the specification values (and rules cited for rounding, if any) shall prevail. If a characteristic is determined by a method not cited in the standard form, enter the method identification and result in *Comments and/or Additional Tests* section.

X3.4.2 *Detailed Instructions*:

X3.4.2.1 *Items 10 and 20, Color (Saybolt)*—Enter either a (+) or a (−) sign in the first square. *Example:* +15.

X3.4.2.2 *Item 30, Visual*—According to Test Method D4176, report result as *Pass* or *Fail*, using the criteria outlined in the test method.

X3.4.2.3 *Item 200, Distillation*—This method has both a choice of methods and more than one measurement to be made per run. Selection of *A* or *B* for item 200 selects which method is used. All of the subsequent measurements are referenced to Test Method D86. When Test Method D2887 is used, the results shall be reported as estimated D86 results by application of the correlation in Appendix X5 of Test Method D2887. Select, using an *x* in the appropriate *A* or *B* item, which test method is used, and whichever items or codes apply to the particular situation or specification being reported.

X3.4.2.4 *Items 230 and 231*—For those contracts or instances that require reporting in units of API Gravity, Item 231A reports of API Gravity using Test Method D1298, and Item 230A reports density by the same method, either as an alternate or concurrent measurement. Item 230B reports density by using Test Method D4052, which only provides for density as currently written.

X3.4.2.5 *Item 310 and 311, Viscosity*—For aviation turbine fuels, viscosity is measured at –20°C; therefore, the value for item 311 will always be -20. If the test is performed at some other temperature, use item number 311 to report this temperature.

X3.4.2.6 *Items 601 - 603,* D3241—Select the temperature at which the test was performed. The letter suffix refers to one temperature. Items 601 - 603, as appropriate, refer to the data for that specific test temperature. If results for runs at different temperatures are reported, then use the data with the appropriate suffix consistent for the temperature. In this manner, results for tests at 245°C and 275°C, for example, can be kept separate and reported simultaneously on the same report. For colors that match the Color Standards, report the color code number. If the color falls somewhere between two colors, report an L for *less than* followed by the higher code number of the two between which the color falls. If there are only abnormal or peacock deposits as defined in Test Method D3241, report an A or P, respectively. If there are both peacock and abnormal deposits, report both an A and P. If the darkest deposit on a tube matches a color code number but there is also an abnormal or peacock deposit, report the code number followed by an A or P, respectively. If the darkest deposit on a tube falls between two color code numbers and there are also abnormal or peacock deposits, or both, record the color as L, followed by the higher of the two code numbers, followed by A, P, or AP, as applicable.

X3.4.2.7 *Items 800, 810, 820, 830, and 840*—Enter the manufacturer's brand name in the square provided. If there is insufficient room in the square provided, indicate by entering asterisks and provide the information on brand name in the REMARKS section.

SUMMARY OF CHANGES

Subcommittee D02.J0 has identified the location of selected changes to this standard since the last issue (D1655–09a) that may impact the use of this standard. (Approved July 1, 2010.)

(*1*) Revised 5.1, and added 5.1.1.
(*2*) Added 5.3.
(*3*) Added Table 3.
(*4*) Added X1.16.

Subcommittee D02.J0 has identified the location of selected changes to this standard since the last issue (D1655–09) that may impact the use of this standard. (Approved Dec. 1, 2009.)

(*1*) Deleted D1094 from Referenced Documents.
(*2*) Updated IATA in Referenced Documents.
(*3*) Updated Defence Standard in Referenced Documents.
(*4*) Revised 5.2.1, 7.1, X1.12.5, 10.1.11, A1.1.2, and A1.2.2.
(*5*) Added biocides to Table 2.
(*6*) Deleted Apollo PRI-19 corrosion inhibitor from Table 2 and X1.10.2.
(*7*) Removed all instances of the acronym for Jet Fuel Thermal Oxidation Tester.

Subcommittee D02.J0 has identified the location of selected changes to this standard since the last issue (D1655–08a) that may impact the use of this standard. (Approved Aug. 1, 2009.)

(*1*) Modified 10.1.2.
(*2*) Modified Table 1 text and footnote K.
(*3*) Modified X1.6.1.1 and added X1.6.1.2.
(*4*) Modified X3.4.2.3.
(*5*) Modified 5.1 and added Note 1.
(*6*) Modified A1.1.1.
(*7*) Added Specification D7566 to text and Referenced Documents.
(*8*) Modified A1.1.2 and added A1.2.2.
(*9*) Deleted reference to RR:D02-1125.