Designation: D 1655 – 01

An American National Standard

Standard Specification for Aviation Turbine Fuels[1]

This standard is issued under the fixed designation D 1655; 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. It 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.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 56 Test Method for Flash Point by Tag Closed Tester[2]

D 86 Test Method for Distillation of Petroleum Products[2]

D 93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester[2]

D 129 Test Method for Sulfur in Petroleum Products (General Bomb Method)[2]

D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test[2]

D 156 Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)[2]

D 240 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter[2]

D 323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)[2]

D 381 Test Method for Existent Gum in Fuels by Jet Evaporation[2]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)[2]

D 1094 Test Method for Water Reaction of Aviation Fuels[2]

D 1266 Test Method for Sulfur in Petroleum Products (Lamp Method)[2]

D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[2]

D 1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption[2]

D 1322 Test Method for Smoke Point of Aviation Turbine Fuels[2]

D 1405 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels[2]

D 1552 Test Method for Sulfur in Petroleum Products (High-Temperature Method)[2]

D 1660 Test Method for Thermal Stability of Aviation Turbine Fuels[3]

D 1840 Test Method for Naphthalene Hydrocarbons in Aviation Turbine Fuels by Ultraviolet Spectrophotometry[2]

D 2276 Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling[2]

D 2386 Test Method for Freezing Point of Aviation Fuels[2]

D 2622 Test Method for Sulfur in Petroleum Products by X-Ray Spectrometry[4]

D 2624 Test Methods for Electrical Conductivity of Aviation and Distillate Fuels[4]

D 2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography[4]

D 3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry[4]

D 3227 Test Method for Mercaptan Sulfur in Gasoline, Kerosine, Aviation Turbine, and Distillate Fuels (Potentiometric Method)[4]

D 3240 Test Method for Undissolved Water in Aviation Turbine Fuels[4]

D 3241 Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels (JFTOT Procedure)[4]

D 3242 Test Method for Acidity in Aviation Turbine Fuel[4]

D 3338 Test Method for Estimation of Heat of Combustion of Aviation Fuels[4]

D 3343 Test Method for Estimation of Hydrogen Content of Aviation Fuels[4]

[1] This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.J on Aviation Fuels.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] Discontinued—Replaced by D 3241—See *1993 Annual Book of ASTM Standards*, Vol 05.02.

[4] *Annual Book of ASTM Standards*, Vol 05.02.

D 3701 Test Method for Hydrogen Content of Aviation Turbine Fuels by Low Resolution Nuclear Magnetic Resonance Spectrometry[4]
D 3828 Test Methods for Flash Point by Small Scale Closed Tester[4]
D 3948 Test Methods for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer[4]
D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter[4]
D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products[4]
D 4171 Specification for Fuel System Icing Inhibitors[4]
D 4176 Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)[4]
D 4294 Test Method for Sulfur in Petroleum Products by Energy-Dispersive X-Ray Fluorescence Spectroscopy[4]
D 4305 Test Method for Filter Flow of Aviation Fuels at Low Temperatures[4]
D 4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination[4]
D 4529 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels[4]
D 4809 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)[5]
D 4865 Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems[5]
D 4952 Test Method for Qualitative Analysis for Active Sulfur Species in Fuels and Solvents (Doctor Test)[5]
D 4953 Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)[5]
D 5001 Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-On-Cylinder Lubricity Evaluator (BOCLE)[5]
D 5006 Test Method for Determination of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels[5]
D 5190 Test Method for Vapor Pressure of Petroleum Products (Automatic Method)[5]
D 5191 Test Method for Vapor Pressure of Petroleum Products (Mini Method)[5]
D 5452 Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration[5]
D 5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Motor Fuels and Oils by Ultraviolet Fluorescence[5]
D 5901 Test Method for Freezing Point of Aviation Fuels (Automated Optical Method)[5]
D 5972 Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)[5]
D 6045 Test Method for Color of Petroleum Products by the Automatic Tristimulus Method[6]
D 6469 Guide for Microbial Contamination in Fuels and Fuel Systems[6]
E 29 Practice for Using Significant Digits In Test Data to Determine Conformance with Specifications[7]

2.2 *IP Standards:*[8]
225 Copper Content of Aviation Turbine Fuel
227 Silver Corrosion of Aviation Turbine Fuel

2.3 *ANSI Standard:*[9]
ANSI 863 Report of Test Results

2.4 *Other Standard:*
Defence Standard 91-91 Issue 3 (DERD 2494) Turbine Fuel, Aviation Kerosine Type, Jet A-1.[10]

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 Three 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.

4.1.2 *Jet B*—A relatively wide boiling range volatile distillate.

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.

5. Materials and Manufacture

5.1 Aviation turbine fuel, except as otherwise specified herein, shall consist of refined hydrocarbons 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 are only permitted on a specific, individual basis (see Annex A1).

5.1.1 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 X1.11.1).

5.2 *Additives*—May be added to each type of aviation turbine fuel in the amount and of the composition specified in the following list of approved material:[11]

5.2.1 *Antioxidants*—In amounts not to exceed 24.0 mg/L active ingredients (not including weight of solvent):

5.2.1.1 2,6-ditertiary-butyl phenol.

5.2.1.2 2,6-ditertiary-butyl-4-methyl phenol.

5.2.1.3 2,4-dimethyl-6-tertiary-butyl phenol.

[5] *Annual Book of ASTM Standards*, Vol 05.03.

[6] *Annual Book of ASTM Standards*, Vol 05.04.

[7] *Annual Book of ASTM Standards*, Vol 14.02.

[8] Available from Directorate of Standardization, Stan 1, Room 5131, Kentigern House, 65 Brown St., Glasgow, G2 8EX, United Kingdom.

[9] Available from American National Standards Institute, 11 W 42nd St., 13th Floor, New York, NY 10036.

[10] Available from Procurement Executive DFS (Air), Ministry of Defence, St. Giles Court 1, St. Giles High St., London WC2H 8LD.

[11] Guidelines for Approval or Disapproval of Additives are available from ASTM, Headquarters. Request RR: D02-1125.

5.2.1.4 75 % minimum 2,6-ditertiary-butyl phenol, plus 25 % max. mixed tertiary and tritertiary-butyl phenols.

5.2.1.5 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.

5.2.1.6 72 % minimum 2,4-dimethyl-6tertiary-butyl phenol, 28% maximum monomethyl and dimethyl-tertiary-butyl phenols.

5.2.2 *Metal Deactivator Additive (MDA)*, in amount not to exceed 2.0 mg/L (not including weight of solvent) on initial fuel manufacture at the refinery. Higher initial concentrations are permitted in circumstances where copper contamination is suspected to occur during distribution. Cumulative concentration of MDA when retreating the fuel shall not exceed 5.7 mg/L.

5.2.2.1 *N,N* -disalicylidene-1,2-propane diamine.

5.2.3 *Electrical Conductivity Additive*—Stadis 450[12] not to exceed 3 mg/L.

5.2.3.1 When loss of fuel conductivity necessitates retreatment with electrical conductivity additive, the following concentration limits apply:

At Manufacture:	
Stadis 450	3 mg/L, max
Retreatment	
Stadis 450	cumulative total 5 mg/L, max

5.2.4 *Leak Detection Additive*—Tracer A (LDTA-A)[13] may be added to the fuel in amounts not to exceed 1 mg/kg.

5.2.5 Other additives are permitted under 5.1 and Section 7.1. These include fuel system icing inhibitor, other anti-oxidants, inhibitors, and special purpose additives. 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.

5.2.5.1 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.

5.2.5.2 *Fuel System Icing Inhibitor*:

(a) Diethylene Glycol Monomethyl Ether (DIEGME), conforming to the requirements of Specification D 4171, Type III, may be used in concentrations of 0.10 to 0.15 volume %.

(b) Test Method D 5006 may be used to determine the concentration of DIEGME in aviation fuels.

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 E 29. Where multiple determinations are made, the average result, rounded in accordance with Practice E 29, shall be used.

7. Workmanship, Finish, and Appearance

7.1 The aviation turbine fuel herein specified shall be visually free of undissolved water, sediment, and suspended matter. The odor of the fuel shall not be nauseating or irritating. No substance of known dangerous toxicity under usual conditions of handling and use shall be present, except as permitted herein.

8. Sampling

8.1 Because of the importance of proper sampling procedures in establishing fuel quality, use the appropriate procedures in Practice D 4057.

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 D 4306.

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 D 1298 or D 4052.

10.1.2 *Distillation*—Test Method D 86.

10.1.3 *Vapor Pressure*—Test Method D 323 or D 5191. Test Method D 5191 shall be the referee test method.

10.1.4 *Flash Point*—Test Method D 56 or D 3828.

10.1.5 *Freezing Point*—Test Method D 2386, D 4305, D 5901, or D 5972. Test Method D 2386 shall be the referee test method.

10.1.6 *Viscosity*—Test Method D 445.

10.1.7 *Net Heat of Combustion*—Test Method D 4529, D 3338, or D 4809.

10.1.8 *Corrosion (Copper Strip)*—Test Method D 130.

10.1.9 *Total Acidity*—Test Method D 3242.

10.1.10 *Sulfur*—Test Method D 1266, D 1552, D 2622, D 4294, or D 5453.

10.1.11 *Mercaptan Sulfur*—Test Method D 3227.

10.1.12 *Water Reaction*—Test Method D 1094.

10.1.13 *Existent Gum*—Test Method D 381.

10.1.14 *Thermal Stability*—Test Method D 3241.

NOTE 1—Table 1 requires the measurement of thermal stability at a tube temperature of 260°C, but permits a retest at 245°C if the first test fails. This two tier system was developed to resolve a dispute over the equivalence of results by Test Method D 3241 compared to Test Method D 1660, the original thermal stability method. A more detailed discussion of test conditions is found in X1.3.2.

10.1.15 *Aromatics*—Test Method D 1319.

10.1.16 *Smoke Point*—Test Method D 1322.

[12] Stadis 450 is a registered trademark marketed by Octel America, 200 Executive Dr., Newark, DE 19702.

[13] Tracer A (LDTA-A) is a registered trademark of Tracer Research Corp., 3755 N. Business Center Dr., Tucson, AZ 85705.

TABLE 1 Detailed Requirements of Aviation Turbine Fuels[A]

Property		Jet A or Jet A-1	Jet B	ASTM Test Method[B]
COMPOSITION				
Acidity, total mg KOH/g	max	0.10	...	D 3242
Aromatics, vol %	max	25	25	D 1319
Sulfur, mercaptan,[C] weight %	max	0.003	0.003	D 3227
Sulfur, total weight %	max	0.30	0.3	D 1266, D 1552, D 2622, D 4294, or D 5453
VOLATILITY				
Distillation temperature, °C:				
10 % recovered, temperature	max	205	...	D 86
20 % recovered, temperature	max	...	145	
50 % recovered, temperature	max	report	190	
90 % recovered, temperature	max	report	245	
Final boiling point, temperature	max	300	...	
Distillation residue, %	max	1.5	1.5	
Distillation loss, %	max	1.5	1.5	
Flash point, °C	min	38[D]	...	D 56 or D 3828[E]
Density at 15°C, kg/m^3		775 to 840	751 to 802	D 1298 or D 4052
Vapor pressure, 38°C, kPa	max	...	21	D 323 or D 5191[F]
FLUIDITY				
Freezing point, °C	max	−40 Jet A[G] −47 Jet A-1[G]	−50[G]	D 2386, D 4305[H], D 5901, or D 5972[I]
Viscosity − 20°C, mm^2/s[J]	max	8.0		D 445
COMBUSTION				
Net heat of combustion, MJ/kg	min	42.8[K]	42.8[K]	D 4529, D 3338, or D 4809
One of the following requirements shall be met:				
(*1*) Smoke point, mm, or	min	25	25	D 1322
(*2*) Smoke point, mm, and	min	18	18	D 1322
Naphthalenes, vol, %	max	3.0	3.0	D 1840
CORROSION				
Copper strip, 2 h at 100°C	max	No. 1	No. 1	D 130
THERMAL STABILITY				
JFTOT (2.5 h at control temperature of 260°C min)[L]				
Filter pressure drop, mm Hg	max	25[M]	25[M]	D 3241[L]
Tube deposits less than		3[N]	3[N]	
		No *Peacock* or *Abnormal* Color Deposits		
CONTAMINANTS				
Existent gum, mg/100 mL	max	7	7	D 381
Water reaction:				
Interface rating	max	1b	1b	D 1094
ADDITIVES		See 5.2	See 5.2	
Electrical conductivity, pS/m		[O]	[O]	D 2624

[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 D 4952.

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

[E] Results obtained by Test Methods D 3828 may be up to 2°C lower than those obtained by Test Method D 56, which is the preferred method. In case of dispute, Test Method D 56 will apply.

[F] Cyclohexane and toluene, as cited in 7.2 and 7.7 of Test Method D 5191, shall be used as calibrating reagents. Test Method D 5191 shall be the referee method.

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

[H] When using Test Method D 4305, use Procedure A only, do not use Procedure B. Test Method D 4305 shall not be used on samples with viscosities greater than 5.0 mm^2 at -20°C. If the viscosity of the sample is not known and cannot be obtained by means of the batch certificate(s), then it shall be measured. The viscosity shall be reported when reporting the Test Method D 4305 results. In case of dispute, Test Method D 2386 shall be the referee method.

[I] Test Method D 5972 may produce a higher (warmer) result than that from Test Method D 2386 on wide-cut fuels such as Jet B or JP-4. In case of dispute, Test Method D 2386 shall be the referee method.

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

[K] For all grades use either Eq 1 or Table 1 in Test Method D 4529 or Eq 2 in Test Method D 3338. Test Method D 4809 may be used as an alternative. In case of dispute, Test Method D 4809 shall be used.

[L] If the requirements of Table 1 are not met on re-testing after it leaves the refinery, the test may be conducted for 2.5 h at 245°C but results at both temperatures shall be reported in this case. This footnote shall expire on December 31, 2001.

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

[N] Tube deposit ratings shall always be reported by the Visual Method; a rating by the Tube Deposit Rating (TDR) optical density method is desirable but not mandatory.

[O] If electrical conductivity additive is used, the conductivity shall not exceed 450 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 450 pS/m under the conditions at point of delivery.

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

10.1.17 *Naphthalene Content*—Test Method D 1840.

10.1.18 *Electrical Conductivity*—Test Method D 2624.

11. Keywords

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

ANNEX

(Mandatory Information)

A1. FUELS FROM NON-CONVENTIONAL SOURCES

A1.1 Introduction

A1.1.1 Jet fuels containing synthetic hydrocarbons have been previously allowed under Specification D 1655. However, the fraction of these hydrocarbons was not limited, and there were no requirements or restrictions placed on either these hydrocarbons or the final blend. It has been recognized that synthetic blends represent a potential departure from experience and from key assumptions on which the fuel property requirements defined in Table 1 have been based.

A1.1.2 The longer term strategy is to revise Specification D 1655 to fully encompass fuels from non-conventional sources, but this has yet to be defined. 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.

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 91-91/Issue 3, dated November 12, 1999, is recognized as meeting the requirements of Specification D 1655.

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.[14]

X1.2 Significance and Use

X1.2.1 Specification D 1655 defines two types of jet fuel for civil use. Limiting values for the two types 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 fuel temperature as high as 149°C (300°F). Such fuels have been demonstrated to have inherent storage stability.

X1.3.2 Originally, thermal stability was measured by Test Method D 1660, known as the ASTM Coker. When this test was replaced by Test Method D 3241, the JFTOT, a correlation study was conducted between the two methods. (CRC Report 450, dated 1969 and revised in 1972. See also Bert and Painter's SAE paper 730385.[15]) It was concluded that, on average, a Test Method D 3241 test at 245°C was equivalent to the original Test Method D 1660 requirement of 300°F/400°F/5 lbs/h (149°C/204.5°C/2.27 kg/h). However, the data scatter about the best fit line was such that users insisted on the

[14] ASTM Manual 1, *Manual on Significance of Tests for Petroleum Products*, 1993, Available from ASTM Headquarters.

[15] 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.

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
	Vapor pressure	X1.6.2
	Viscosity	X1.6.3
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	Existant gum	X1.9.1
Fuel cleanliness, handling	Flash point	X1.10.1
	Water reaction	X1.10.2
	Water separation characteristics	X1.10.3
	Free water and particulate contamination	X1.10.4
	Particulate matter	X1.10.5
	Membrane color ratings	X1.10.6
	Undissolved water	X1.10.7
Fuel lubricating ability (lubricity)	Fuel lubricity	X1.11
Miscellaneous	Additives	X1.12.1
	Sample containers	X1.12.2

initial test of 260°C as a safety margin but permitted a retest at 245°C.

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 so 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: luminometer number, smoke point, percent naphthalenes, and percent aromatics.[16]

[16] A task force studied the possible use of hydrogen content as an alternative to aromatics content. A report of these studies completed in 1989 is available from ASTM Headquarters. Request RR:D02-1258.

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