Designation: ~~D7960 – 18~~ D7960 – 21

An American National Standard

Standard Specification for Unleaded Aviation Gasoline Test Fuel Containing Non-hydrocarbon Components[1]

This standard is issued under the fixed designation D7960; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers formulating specifications for purchases of a UL102 unleaded aviation gasoline test fuel under contract and is intended solely for use by purchasing agencies for testing purposes.

1.2 This specification defines a specific type of aviation gasoline for use as an aviation spark-ignition engine test fuel. It does not include all gasolines satisfactory for reciprocating aviation 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 The D7960 test fuel defined by this specification may not exhibit identical performance to those leaded fuels with which the existing aircraft and ground-based fuel handling equipment have been designed to operate. Therefore, the suitability of this fuel for use on any specific aircraft, aircraft engine, or ground-based fuel handling equipment should be evaluated before use on that equipment.

1.4 Issuance of this specification does not constitute approval to operate certificated aircraft with this fuel. 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 certification program for that aircraft and engine model.

1.5 This specification, unless otherwise provided, prescribes the required properties of unleaded D7960 test fuel at the time and place of delivery.

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

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

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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[1] This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.J0.02 on Spark and Compression Ignition Aviation Engine Fuels.

Current edition approved ~~Oct. 1, 2018~~May 1, 2021. Published ~~October 2018~~June 2021. Originally approved in 2014. Last previous edition approved in ~~2017~~2018 as ~~D7960 – 17.~~D7960 – 18. DOI: ~~10.1520/D7960-18.~~10.1520/D7960-21.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D86 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)
D357 Method of Test for Knock Characteristics of Motor Fuels Below 100 Octane Number by the Motor Method; Replaced by D 2700 (Withdrawn 1969)[3]
D381 Test Method for Gum Content in Fuels by Jet Evaporation
D614 Method of Test for Knock Characteristics of Aviation Fuels by the Aviation Method; Replaced by D 2700 (Withdrawn 1970)[3]
D873 Test Method for Oxidation Stability of Aviation Fuels (Potential Residue Method)
D909 Test Method for Supercharge Rating of Spark-Ignition Aviation Gasoline
D910 Specification for Leaded Aviation Gasolines
D1094 Test Method for Water Reaction of Aviation Fuels
D1298 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
D1948 Method of Test for Knock Characteristics of Motor Fuels Above 100 Octane Number by the Motor Method; Replaced by D 2700 (Withdrawn 1968)[3]
D2386 Test Method for Freezing Point of Aviation Fuels
D2392 Test Method for Color of Dyed Aviation Gasolines
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
D2700 Test Method for Motor Octane Number of Spark-Ignition Engine Fuel
D3338 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
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
D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products
D4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry
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
D5006 Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels
D5059 Test Methods for Lead and Manganese in Gasoline by X-Ray Fluorescence Spectroscopy
D5191 Test Method for Vapor Pressure of Petroleum Products and Liquid Fuels (Mini Method)
D5972 Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)
D6227 Specification for Unleaded Aviation Gasoline Containing a Non-hydrocarbon Component
D6469 Guide for Microbial Contamination in Fuels and Fuel Systems
D7220 Test Method for Sulfur in Automotive, Heating, and Jet Fuels by Monochromatic Energy Dispersive X-ray Fluorescence Spectrometry
D7719 Specification for High Aromatic Content Unleaded Hydrocarbon Aviation Gasoline
D7826 Guide for Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *Other Documents:*

MIL-PRF-25017 Lubricity Improver, Fuel Soluble[4]
GOST 1012–72 Aviation Petrols, Specifications[5]

3. Terminology

3.1 *Definitions:*

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.
[3] The last approved version of this historical standard is referenced on www.astm.org.
[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.
[5] Available from Technormativ LLC (Runorm), 19 Shosse Entuziastov, Moscow, 111024, Russia, http://www.runorm.com.

3.1.1 *unleaded aviation gasoline, n*—gasoline intended for use in aircraft powered by reciprocating spark ignition engines, where lead is not intentionally added for the purpose of enhancing octane performance.

3.1.1.1 *Discussion*—

Principal properties include volatility limits, stability, detonation-free performance in the engine for which it is intended, and suitability for low temperature performance.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *non-hydrocarbon, adj*—compound composed of carbon and hydrogen and one or more of the elements oxygen, nitrogen, and sulfur, and any combination of these elements.

3.2.1.1 *Discussion*—

Some examples of non-hydrocarbon components that may be used in D7960 aviation gasoline are aniline, t-butyl acetate, 2,6 ditertiarybutyl phenol, 2,4-dimethyl-6-tertiarybutylphenol.

4. General

4.1 This specification, unless otherwise provided, prescribes the required properties of unleaded aviation gasoline test fuel at the time and place of delivery.

5. Classification

5.1 One grade of unleaded aviation gasoline is described, UL102 aviation gasoline test fuel.

NOTE 1—The above grade name is based on the fuel's motor octane as measured by Test Method D2700.

6. Materials and Manufacture

6.1 D7960 test fuel, except as otherwise specified in this specification, shall consist of blends of refined hydrocarbons derived from crude petroleum, natural gasoline, biomass or blends thereof, with synthetic hydrocarbons or aromatic hydrocarbons, or both; with hetero-molecules such as amines, alcohols, carboxylic acids, esters and ethers.

6.1.1 See Appendix X1 for a representative composition that meets the parameters of Table 1.

6.2 *Additives*—These may be added to D7960 test fuel in the amount and of the composition specified in the following list of approved materials:

6.2.1 *Other Additives*—These may be added in the amount and of the composition specified in the following list of approved materials. The quantities and types shall be declared by the manufacturer. Additives added after the point of manufacture shall also be declared.

6.2.1.1 *Antioxidants*—The following oxidation inhibitors may be added to the fuel separately, or in combination, in total concentration not to exceed 12 mg of inhibitor (not including mass of solvent) per liter of fuel.

(1) 2,6-ditertiary butyl-4-methylphenol.
(2) 2,4-dimethyl-6-tertiary butylphenol.
(3) 2,6-ditertiary butylphenol.
(4) 75 % minimum 2,6-ditertiary butylphenol plus 25 % maximum mixed tertiary and tritertiary butylphenols.
(5) 75 % minimum di- and tri-isopropyl phenols plus 25 % maximum di- and tri-tertiary butylphenols.
(6) 72 % minimum 2,4-dimethyl-6-tertiary butylphenol plus 28 % maximum monomethyl and dimethyl tertiary butylphenols.
(7) N,N'-di-isopropyl-para-phenylenediamine.
(8) N,N'-di-secondary-butyl-para-phenylenediamine.

6.2.1.2 *Fuel System Icing Inhibitor (FSII)*—One of the following may be used:

(1) Isopropyl Alcohol (IPA, propan-2-ol), in accordance with the requirements of Specification D4171 (Type II). May be used in concentrations recommended by the aircraft manufacturer when required by the aircraft owner/operator.

TABLE 1 Detailed Requirements for UL102 Aviation Gasoline Test Fuel

Property	Test Method	Min/Max	Test Gasoline
Motor Octane Number[A]	ASTM D2700	Min	102.5
Pb, g/L	ASTM D5059	Max	0.013[B]
density @ 15 °C, kg/m^3	ASTM D1298 or D4052[C]	Report	Report
IBP, °C	ASTM D86	Report	Report
10 % by volume at °C	ASTM D86	Max	75
40 % by volume at °C	ASTM D86	Min	75
50 % by volume at °C	ASTM D86	Max	105
90 % by volume at °C	ASTM D86	Max	135
Final boiling point, °C	ASTM D86	Max	210
Sum of 10 % and 50 % evaporated, °C	ASTM D86	Min	135
Recovery, % by volume	ASTM D86	Min	97
Residue, % by volume	ASTM D86	Max	1.5
Loss, % by volume	ASTM D86	Max	1.5
Vapor pressure, 38 °C, kPa	ASTM D323, ASTM D5191[C]	Min	38.0
		Max	49.0
Freezing Point, °C[D]			
Freezing Point, °C	ASTM D2386		REPORT[E]
Freezing Point, °C	ASTM D5972		REPORT[F]
Sulfur, % by mass	ASTM D2622, D4294, or D7220	Max	0.05
Net Heat of Combustion, MJ/kg	ASTM D4809	Min	42
Corrosion, copper strip, 2 h at 100 °C	ASTM D130	Max	No. 1
Oxidation stability (5 h aging), potential gum, mg/100 mL	ASTM D873	Max	6
Existent Gum, mg/100 mL	ASTM D381	Max	1
Water reaction, volume change, mL	ASTM D1094	Max	±2
~~Electrical Conductivity, pS/m~~	~~ASTM D2624~~	~~Min~~	~~50[G]~~
		~~Max~~	~~450[G]~~
Electrical Conductivity, pS/m	ASTM D2624	Min	50[G]
		Max	600[G]

[A] MON is reported without any corrections applied.
[B] Lead content is applicable at the point of manufacture and the point of fit for purpose testing.
[C] ASTM Test Methods D4052 and D5191 will be used as referee methods.
[D] Caution in the use of this fuel and further investigation may be warranted when results are > –58 °C.
[E] This is the standard method used for aviation gasolines; its applicability with this new fuel formulation is under evaluation.
[F] This method is currently not applicable for aviation gasolines and is under evaluation for applicability.
[G] Applies only when an electrical conductivity additive is used; when a customer specifies fuel containing conductivity additive, the following conductivity limits shall apply under the condition at point of use:
Minimum 50 pS/m
Maximum ~~450~~ 600 pS ~~pS/m~~/m
The supplier shall report the amount of additive added.

NOTE 2—Addition of isopropyl alcohol (IPA) may reduce knock ratings below minimum specification values.[6]

(2) Di-Ethylene Glycol Monomethyl Ether (Di-EGME),[7] conforming to the requirements of Specification D4171 (Type III). May be used in concentrations of 0.10 % to 0.15 % by volume when required by the aircraft owner/operator.

6.2.1.3 *Corrosion Inhibitor Additive*—Corrosion inhibitors that conform to the latest issue of MIL-PRF-25017 may be added to the D7960 test fuel in amounts not exceeding the maximum allowable concentrations listed in the latest revision of QPL-25017.

6.2.1.4 *Electrical Conductivity Additive*—Stadis® 450[8] in concentrations up to 3 mg/L is permitted. When loss of fuel conductivity necessitates retreatment with electrical conductivity additive, further addition is permissible up to a maximum cumulative level of 5 mg/L of Stadis® 450.

7. Detailed Requirements

7.1 The D7960 test fuel shall conform to the requirements prescribed in Table 1.

7.2 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 the conformance to the specification requirement, a test result may be

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1526. Contact ASTM Customer Service at service@astm.org.
[7] Test Method D5006 can be used to determine the concentration of Di-EGME in aviation fuels.
[8] Stadis® 450 is a registered trademark marketed by Innospec, Inc., Innospec Manufacturing Park, Oil Sites Road, Ellesmere Port, Cheshire, CH65 4EY, UK.

rounded to the same number of significant figures as in Table 1 using Practice E29. Where multiple determinations are made, the average result, rounded according to Practice E29, shall be used.

8. Workmanship, Finish, and Appearance

8.1 The D7960 test fuel specified in this specification shall be free from undissolved water, sediment, and suspended matter. No substances of known dangerous toxicity under usual conditions of handling and use shall be present except as permitted in this specification.

9. Sampling

9.1 Because of the importance of proper sampling procedures in establishing fuel quality, use the appropriate procedures in Practice D4057 or Practice D4177.

9.1.1 Although automatic sampling following Practice D4177 may be useful in certain situations, initial manufacturer/supplier specification compliance testing shall be performed on a sample taken following procedures in Practice D4057.

9.2 A number of D7960 properties, including copper corrosion, electrical conductivity, and others are very sensitive to trace contamination which can originate from sample containers. For recommended sample containers, refer to Practice D4306.

10. Reports

10.1 The type and number of reports to ensure conformance with the requirements of this specification shall be mutually agreed to by the purchaser and the supplier of the D7960 test fuel.

11. Test Methods

11.1 The requirements enumerated in this specification shall be determined in accordance with the following ASTM test methods:

11.1.1 *Motor Octane Number*—Test Method D2700.

11.1.2 *Tetraethyl Lead*—Test Method D5059.

11.1.3 *Density*—Test Methods D1298 or D4052.

11.1.4 *Distillation*—Test Method D86.

11.1.5 *Vapor Pressure*—Test Methods D323 or D5191.

11.1.6 *Freezing Point*—Test Method D5972 and D2386.

11.1.7 *Sulfur*—Test Method D2622, D4294, or D7220.

11.1.8 *Net Heat of Combustion*—Test Methods D4809.

11.1.9 *Corrosion (Copper Strip)*—Test Method D130, 2 h test at 100 °C in pressure vessel.

11.1.10 *Potential Gum and Visible Lead Precipitate*—Test Method D873 except that wherever the letter X occurs (referring to oxidation time) insert the number 5, designating the number of hours prescribed in this specification.

11.1.11 *Water Reaction*—Test Method D1094.

11.1.12 *Electrical Conductivity*—Test Method D2624.

12. Keywords

12.1 aviation gasoline; unleaded aviation gasoline

APPENDIXES

(Nonmandatory Information)

X1. PERFORMANCE CHARACTERISTICS OF UNLEADED AVIATION GASOLINE TEST FUEL

X1.1 Introduction

X1.1.1 This specification was developed to identify distillate range refinery products, including refined hydrocarbons derived from crude petroleum, or blends thereof, with synthetic hydrocarbons and specific heteroatom containing molecules, suitable for high octane unleaded aviation gasoline applications. The requirements of Table 1 are quality limits established on the basis of test development as well as tests performed on airframes and engines specifically designed to use these fuels.

X1.1.2 The performance requirements summarized in Table 1 are quality limits which have as their basis the Specification D910 limits supplemented with additional characterization tests where appropriate, which are themselves the result of long-term industry experience and extensive scientific and engineering literature, as well as the cooperation of certain petroleum refiners and test procedure owners. The values given are intended to define unleaded aviation gasoline suitable for most types of spark-ignition aviation engines; however, certain equipment or conditions of use may require fuels having other characteristics.

X1.2 Composition

X1.2.1 The origin of the fuel lies in balancing the synergistic effects of a number of components and compounds to achieve, as closely as possible, the performance properties of the historic ASTM D910 fuel. One example of a potential compositional space in volume percent permitted by this test specification is as follows:

15 % to 20 % isopentane
40 % to 50 % alkylate or alkylate blend
20 % to 30 % aromatic
2 % to 10 % amine
0 % to 10 % hetero-molecules in addition to any amine

X1.2.2 The precise formulation composition of any fuel tested will be recorded within a research report along with testing results with the aim of more precisely defining the composition and properties of a potential production specification.

X2. PERFORMANCE CHARACTERISTICS OF UNLEADED AVIATION GASOLINE TEST FUEL

X2.1 Introduction

X2.1.1 The unleaded aviation gasoline test fuel (hereafter referred to as “D7960 test fuel”) is a complex mixture of relatively volatile hydrocarbons that result in a narrow range of physical and chemical properties to assure an appropriate amount of power, detonation suppression, and volatility for high performance piston-engine aircraft while exhibiting the critical low temperature properties required for General Aviation (“GA”) applications. The engines and aircraft impose a variety of mechanical, physical, and chemical environments. The properties of D7960 test fuel (Table 1) must be properly balanced to give satisfactory engine performance over an extremely wide range of conditions.

X2.1.2 The ASTM requirements summarized in Table 1 are quality limits that have as their basis the historic limits for aviation

gasolines, which are themselves the result of long-term industry experience and extensive scientific and engineering literature, as well as the cooperation of certain petroleum refiners. Further establishment of appropriate limits for D7960 test fuel are established on the basis of Guide D7826 guidelines, which include laboratory testing, engine testing, flight testing, toxicology testing, material compatibility testing, and ongoing certification testing and close cooperation of producers of aviation gasoline, manufacturers of aircraft engines, and users of both commodities. The values given are intended to define D7960 fuel intended for most types of spark-ignition aviation engines.

X2.1.3 This specification includes only one grade of D7960 test fuel defined by its antiknock quality. The other requirements either prescribe a suite of properties to accommodate engine performance; to support production and distribution of the fuel; or to limit components of undesirable nature to concentrations so low that they will not have an adverse effect on engine performance.

X2.2 Combustion Characteristics

X2.2.1 The fuel-air mixture in the cylinder of a spark ignition engine will, under certain conditions, ignite spontaneously in localized areas instead of solely progressing as a flame front from the spark. This may cause detonation or knock, usually inaudible in aircraft engines. This knock, if permitted to continue for more than brief periods, may result in serious loss of power and damage to, or destruction of, the aircraft engine. Should D7960 test fuel be used in other types of aviation engines (for example, in certain turbine engines where specifically permitted by engine manufacturers), knock or detonation characteristics may not be critical requirements. Modifications or adjustments to avoid knock or detonation when operating with D7960 test fuel on aircraft engines originally designed to operate on other leaded aviation gasolines should consider the impacts that those modifications or adjustments may have on aircraft or engine performance.

X2.2.2 The D7960 test fuel grade rating is based on an ASTM Motor Octane Number (MON) as measured by the Test Method D2700 laboratory test. MON is a measure of how the fuel behaves when under load (stress). MON testing uses a test engine with a preheated fuel mixture, 900 r⁄min engine speed, and variable ignition timing to stress the fuel's knock resistance. The MON of the D7960 test fuel can be used as a guide to the amount of knock-limiting power that may be obtained in a full-scale engine under take-off, climb and cruise conditions. Leaded aviation gasolines also specify the Test Method D909 Supercharge Rating, but this method is not currently specified in Table 1 for D7960 test fuel because it produces an atypical response compared to the leaded reference fuels used in the method. Research is ongoing to determine if an alternative to Supercharge Rating method is necessary for D7960 test fuel.

X2.2.3 Since isopropyl alcohol (IPA) is normally added in the field at the point of sale as a fuel system icing inhibitor, the operator is cautioned that it may impact octane performance. The addition of IPA additive may decrease the MON rating.

X2.2.4 *Blends with Other Aviation Gasolines*—It is anticipated that D7960 test fuel could potentially be mixed with other existing

TABLE X2.1 Performance Characteristics of Aviation Gasoline

Performance Characteristics	Test Methods	Sections
Combustion characteristics	motor octane number	X2.2.2
	anti-icing compound	X2.2.3
Fuel metering and aircraft range	density	X2.3.1
	net heat of combustion	X2.3.2
Carburetion and fuel vaporization	vapor pressure	X2.4.3
	distillation	X2.4.4
Corrosion of fuel system and engine parts	copper strip corrosion	X2.5.1
	sulfur content	X2.5.2
Fluidity at low temperatures	freezing point	X2.6.1
Fuel cleanliness, handling, and storage	existent gum	X2.7.1
	stability potential gum	X2.7.2
	water reaction	X2.7.4