Designation: D6227 – 17

An American National Standard

Standard Specification for Unleaded Aviation Gasoline Containing a Non-hydrocarbon Component[1]

This standard is issued under the fixed designation D6227; 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 Grades UL82 and UL87 unleaded aviation gasolines, which are defined by this specification and are only for use in engines and associated aircraft that are specifically approved by the engine and aircraft manufacturers, and certified by the National Certifying Agencies to use these fuels. Components containing hetro-atoms (oxygenates) may be present within the limits specified.

1.2 A fuel may be certified to meet this specification by a producer as Grade UL82 or UL87 aviation gasoline only if blended from component(s) approved for use in these grades of aviation gasoline by the refiner(s) of such components, because only the refiner(s) can attest to the component source and processing, absence of contamination, and the additives used and their concentrations. Consequently, reclassifying of any other product to Grade UL82 or Grade UL87 aviation gasoline does not meet this specification.

1.3 Appendix X1 contains an explanation for the rationale of the specification. Appendix X2 details the reasons for the individual specification requirements.

1.4 The values stated in SI units are to be regarded as the standard.

1.4.1 *Exception*—The values given in parentheses are provided for information only.

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D86 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
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of Test for Knock Characteristics of Motor Fuels Below 100 Octane Number by the Motor Method; Replaced by D 2700 (Withdrawn 1969)[3]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
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
D1266 Test Method for Sulfur in Petroleum Products (Lamp Method)
D1298 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
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
D2699 Test Method for Research Octane Number of Spark-Ignition Engine Fuel
D2700 Test Method for Motor Octane Number of Spark-Ignition Engine Fuel
D3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry
D3231 Test Method for Phosphorus in Gasoline

[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 May 1, 2017. Published May 2017. Originally approved in 1998. Last previous edition approved in 2014 as D6227 – 14. DOI: 10.1520/D6227-17.

[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.

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

D3237 Test Method for Lead in Gasoline by Atomic Absorption Spectroscopy
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
D4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry
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)
D4815 Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C_1 to C_4 Alcohols in Gasoline by Gas Chromatography
D4953 Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)
D5059 Test Methods for Lead in Gasoline by X-Ray Spectroscopy
D5191 Test Method for Vapor Pressure of Petroleum Products (Mini Method)
D5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
D5482 Test Method for Vapor Pressure of Petroleum Products (Mini Method—Atmospheric)
D5599 Test Method for Determination of Oxygenates in Gasoline by Gas Chromatography and Oxygen Selective Flame Ionization Detection
D5845 Test Method for Determination of MTBE, ETBE, TAME, DIPE, Methanol, Ethanol and *tert*-Butanol in Gasoline by Infrared Spectroscopy
D5983 Specification for Methyl Tertiary-Butyl Ether (MTBE) for Downstream Blending for Use in Automotive Spark-Ignition Engine Fuel
D6469 Guide for Microbial Contamination in Fuels and Fuel Systems
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *Military Standard:*[4]
MIL-PRF-25017F Performance Specification for Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble
QPL-25017 Qualified Products List of Products Qualified Under Performance Specification MIL-PRF-25017F

3. Terminology

3.1 *Definitions:*

3.1.1 *aviation gasoline, n*—gasoline possessing specific properties suitable for fueling aircraft powered by reciprocating spark ignition engines.

3.1.1.1 *Discussion*—The principal properties of aviation gasoline include volatility limits, stability, detonation-free performance in the engine for which it is intended, and suitability for low temperature performance.

3.1.2 *non-hydrocarbon, n*—compound or compounds composed of carbon, hydrogen and other elements such as O, N, S, and P.

3.1.3 *oxygenate, n*—an oxygen-containing ashless organic compound, such as an alcohol or ether, which may be used as fuel or fuel supplement.

4. Grades

4.1 The specification covers two grades of unleaded aviation gasoline designated Grade UL82 and Grade UL87.

5. General

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

6. Material

6.1 Aviation gasoline, except as otherwise specified in this specification, shall consist of blends of refined hydrocarbons derived from crude petroleum, natural gasoline or blends, thereof, with specific aliphatic ethers, synthetic hydrocarbons, or aromatic hydrocarbons. When applicable, methyl *tertiary* -butyl ether (MTBE) shall conform to the requirements of Specification D5983. Types and quantities of trace alcohols shall meet the requirements of Table 1 and 6.2.4.2.

6.2 Only additives approved by this specification are permitted. In addition to identification dyes, corrosion inhibitors, antioxidants, and metal deactivators, fuel system icing inhibitor additives are permitted under 6.2.4. Permitted additives may be added to aviation gasoline 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 *Antioxidants*—The following oxidation inhibitors may be added to the gasoline separately or in combination in total concentration not to exceed 12 mg of inhibitor (not including weight of solvent) per litre of fuel.

6.2.1.1 2,6-ditertiary-butyl-phenol.

6.2.1.2 2,6-ditertiary-butyl-4-methyl-phenol.

6.2.1.3 2,4-dimethyl-6-tertiary-butyl-phenol.

6.2.1.4 2,6-ditertiary-butyl-phenol, 75 % minimum.

Tertiary and tritertiary-butyl-phenols, 25 % maximum.

6.2.1.5 2,4-dimethyl-6-tertiary-butyl-phenol, 55 % minimum; 4-methyl-2,6-ditertiary-butyl phenol 15 % minimum; the remainder as a mixture of monomethyl and dimethyl-tertiary-butyl-phenols.

6.2.1.6 2,4-dimethyl-6-tertiary-butyl-phenol, 72 % minimum.

Mixture of tertiary-butyl-methyl-phenols and tertiary-butyl-dimethyl-phenols, 28 % maximum.

6.2.1.7 2,6-ditertiary-butyl-4-methyl-phenol, 35 % minimum.

[4] Available from Standardization Document Order Desk, 700 Robbins Ave., Bldg. 4D, Philadelphia, PA 19111–5094 Attn: NPODS.

TABLE 1 Requirements for Grades UL82 and UL87 Aviation Gasoline[A]

		Grade UL82	Grade UL87	ASTM Test Method[B]
Octane Ratings				
Knock value, lean mixture, Motor method octane number	min	82.0	87.0	D2700
Knock value, Research method octane number	min	...	95.0	D2699
Color		undyed	undyed	D2392
Dye content[C]				
Blue dye,[D] mg/L	max	none	none	
Red dye,[E] mg/L	max	none	none	
Yellow dye,[F] mg/L	max	none	none	
		Requirements for All Grades		
Density at 15°C, kg/m^3		Report		D1298 or D4052
Distillation				D86
Fuel Evaporated				
10 volume % at °C	max	70		
50 volume % at °C	min	66		
	max	121		
90 volume % at °C	max	190		
End point, °C	max	225		
Recovery, volume %	min	95.0		
Residue, volume %	max	2.0		
Loss, volume %	max	3.0		
Vapor pressure 38°C, kPa	min	38		D4953, D5191, D5482
	max	62[G]		
Freezing point, °C	max	–58		D2386
Sulfur, mass %	max	0.07		D1266, D2622, D3120, D4294, D5453
Lead content, g/L		0.013[H]		D3237 or D5059
Net heat of combustion, MJ/kg		40.8		D3338,[I]D4529,[I] or D4809[I]
Corrosion, copper strip (3 h at 50°C)	max	No. 1		D130
Potential gum (5–h aging) mg/100 mL[J]	max	6		D873
Alcohols and ether content[K,L]				D4815, D5599, or D5845
Total combined methanol and ethanol, mass %, max		0.3		
Combined aliphatic ethers, methanol, and ethanol, as mass % oxygen, max		2.7		
		0.3		

[A] The requirements stated herein are subject to rounding in accordance with Practice E29 and are not subject to correction for tolerance of the test method.
[B] The test methods indicated in this table are referred to in Section 10.
[C] The maximum dye concentrations shown do not include solvent in dyes supplied in liquid form.
[D] Essentially 1,4-dialkylamino-anthraquinone.
[E] Essentially alkyl derivatives of azobenzene-4-azo-2-naphthol.
[F] Essentially p-diethylaminoazobenzene or 1,3 benzenediol 2, 4–bis[(alkylphenyl) azo-.
[G] Fuel with a vapor pressure greater than 62 kPa (9.0 psi) but not exceeding 93 kPa (13.5 psi) is permissible, if the ambient temperature is not more than 29°C (85°F) at the time and place of delivery and all federal and local regulations are met. The vapor pressure of permissible fuel exceeding 62 kPa (9.0 psi) shall be shown on all product transfer documents, *including the delivery document to the aircraft*.
[H] See X2.10.1 for maximum limits for lead and phosphorus in unleaded gasoline.
[I] Use either Eq 1 or Table 1 in Test Method D4529, or Eq 2 in Test Method D3338. See X2.7.2 for limitations and oxygen corrections required when Test Methods D3338 and D4529 are applied to fuels blended with aliphatic ethers.
[J] Test Method D381 existent gum test can provide a means of detecting deteriorated quality or contamination, or both, with heavier products following distribution from refinery to airport; refer to X2.9.1.
[K] No deliberate addition of alcohols is allowed except for isopropyl alcohol, which is allowed as an additive (see 6.2.4.2)
[L] For additional information and limitations, see X2.8

Mixed methyl, ethyl, and dimethyl tertiary-butyl-phenols, 65 % maximum.

6.2.1.8 2,4-di-tertiary butyl-phenol, 60 % minimum.

Mixed tertiary-butyl-phenol, 40 % maximum.

6.2.1.9 Butylated ethyl-phenols, 55 % minimum.

Butylated methyl and dimethyl-phenols, 45 % maximum.

6.2.1.10 Mixture of a di- and tri-isopropyl-phenols, 75 % minimum.

Mixture of di- and tri-tertiary butyl-phenols, 25 % maximum.

6.2.1.11 N,N' di-secondary butyl-para phenylenediamine.

6.2.1.12 N,N' di-isopropyl-para-phenylenediamine.

6.2.1.13 N-secondary butyl, N'-phenyl ortho-phenylenediamine.

6.2.2 *Metal Deactivators*—A metal deactivator, N,N'-disalicylidene-1,2-propanediamine may be added to the gasoline in an amount not to exceed 3.0 mg/L.

6.2.3 *Corrosion Inhibitors*—Corrosion inhibitors that conform to MIL-PRF-25017F may be added to the gasoline in amounts not exceeding the maximum allowable concentrations listed in the latest revision of QPL-25017.

6.2.4 *Fuel System Icing Inhibitor:*

6.2.4.1 Diethylene glycol monomethyl ether, conforming to the requirements of Specification D4171 (Type III), may be used in concentrations of 0.10 to 0.15 volume %.

6.2.4.2 Isopropyl alcohol conforming to the requirements of Specification D4171 (Type II) may be used in concentrations recommended by the aircraft manufacturers when required by the aircraft owner operator.

7. Detailed Requirements

7.1 The aviation gasoline shall conform to the requirements in Table 1.

8. Workmanship

8.1 The finished fuel shall be visually free of water, sediment, and suspended matter.

NOTE 1—See Practice D4057 for appropriate sampling procedures.

9. Reports

9.1 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 aviation gasoline.

10. Test Methods

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

10.1.1 *Research Octane*—Test Method D2699.

10.1.2 *Motor Octane*—Test Method D2700.

10.1.3 *Color*—Test Method D2392.

10.1.4 *Distillation*—Test Method D86.

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

10.1.6 *Freezing Point*—Test Method D2386.

10.1.7 *Vapor Pressure*—Test Method D4953, D5191 or D5482.

10.1.8 *Lead Content*—Test Method D3237 or D5059 (Test Method C).

10.1.9 *Copper Strip Corrosion*—Test Method D130 (3 h at 50°C (122°F)).

10.1.10 *Sulfur*—Test Method D1266, D2622, D3120, D4294, or D5453.

10.1.11 *Potential Gum*—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.

10.1.12 *Alcohols/Ethers Detection*—Test Method D4815, D5599, or D5845.

11. Keywords

11.1 aviation gasoline; ether, fuel; gasoline/alcohol blends; gasoline/ether blends; gasoline/oxygenate blends, octane requirement; unleaded aviation gasoline

APPENDIXES

(Nonmandatory Information)

X1. REASONS FOR SPECIFICATION

X1.1 *Introduction* —Aviation gasoline defined by this specification is for use only in engines and associated aircraft specifically designed or approved to operate on Grade UL82 or Grade UL87 defined by this specification.

X2. SIGNIFICANT FACTORS FOR UNLEADED AVIATION GASOLINE

X2.1 Introduction

X2.1.1 This specification was developed to identify broad distillation range refinery products, including refined hydrocarbons derived from crude petroleum, or blends thereof, with synthetic hydrocarbons and specific aliphatic ether blends, suitable for low octane unleaded aviation gasoline applications. The requirements of Table 1 are quality limits established on the basis of development and certification tests performed on airframes and engines specifically designed to use these fuels.

X2.1.2 Engines certified for low octane fuels and their associated aircraft operate within a variety of mechanical, physical, and chemical environments. The properties of unleaded aviation gasoline (Table 1) must be properly balanced to give satisfactory engine performance over a wide range of conditions.

TABLE X2.1 Significant Factors for Unleaded Aviation Gasoline

Factors of Significance	Test Method	Sections
Introduction		X2.1
Antiknock quality	motor and research methods	X2.2
Fuel metering and volatility	vapor pressure	X2.4.1
	distillation	X2.4.2
Corrosion of fuel system and engine parts	copper strip	X2.5.1
	sulfur	X2.5.2
Low temperature performance	fuel icing inhibitor	X2.6.1
	fuel freezing point	X2.6.2
Heat of combustion	net heat of combustion	X2.7
Oxygenates	ethers	X2.8.2
	alcohols	X2.8.3
Cleanliness, handling, and storage stability	existent gum	X2.9.1
	potential gum	X2.9.2
	dyes	X2.9.3
Miscellaneous	lead content	X2.10.1

X2.2 Antiknock Quality

X2.2.1 The fuel-air mixture in the cylinder of a spark-ignition engine will, under certain conditions, spontaneously ignite ahead of the flame front. This will cause a knock, which is usually inaudible in aircraft engines. This knock, if permitted to continue, may result in serious loss of power and damage to the aircraft engine.

X2.2.2 Traditional leaded aviation gasolines have been defined by both lean and rich mixture ratings. A minimum lean mixture rating of 82.0 determined by the motor method (Test Method D2700) provides satisfactory antiknock properties on engines certified for low octane fuels. Rich mixture ratings by Test Method D909 were developed for older large displacement, high output engines for which this fuel is not suitable. A research program has investigated the octane satisfaction of engines designed to operate on mid-octane fuel within the scope of this specification. A lean mixture rating of 87.0 by the motor method (Test Method D2700) combined with a research rating of 95.0 determined by the research method (Test Method D2699) was found to provide satisfactory antiknock properties.[5]

X2.2.3 The motor Test Method D2700 is an engine method for determining the knock characteristics at a lean fuel-air ratio of fuels for use in spark-ignition engines. It was originally developed (as Test Method D357) to test motor gasolines for motor octane number, but an extensive program revealed that the octane number rating of current aviation gasolines could also be determined by the motor method. The research Test Method D2699 is an engine method for determining the knock characteristics of fuels for use in automotive spark-ignition engines, but work has demonstrated the method suitable to determine the octane number ratings of Grade UL87 fuel in this specification. Knock characteristics of a test fuel are established by comparing its knocking tendency with those for blends of ASTM reference fuels of known octane number under prescribed operating conditions.

X2.3 Fuel Metering and Vaporization—General Comments

X2.3.1 In most spark-ignition engines, the aviation gasoline is metered in liquid form through carburetors or low pressure injectors. Fuel vaporization starts in the carburetor or downstream of the injector and continues in the intake manifold from which the fuel-air enters the cylinders of the engine. The volatility, the tendency to evaporate or change from a liquid to a gaseous state, is an extremely important characteristic of aviation fuel.

X2.3.2 Gasolines that vaporize too readily may boil in fuel lines or in fuel metering devices, particularly as altitude increases, and cause vapor lock with resultant power loss. Conversely, fuels that do not completely vaporize may cause engine malfunctioning of other sorts. Therefore, a proper balance of the volatility of the various hydrocarbon and oxygenated components is essential to satisfactory performance of the finished fuel.

X2.4 Volatility

X2.4.1 *Vapor Pressure*—The vapor pressure of an aviation gasoline is the measure of the tendency of the more volatile components to evaporate. Fuels having a vapor pressure no higher than 93 kPa (13.5 psi) will be free of vapor-locking tendencies under operating conditions of the aircraft developed for such fuels. The minimum vapor pressure of 38 kPa (5.5 psi) adopted in this specification is consistent with the requirements of other aviation gasolines.

X2.4.2 *Distillation*—Gasoline is made up of a broad range of hydrocarbon components. Distillation temperatures are a measure of a fuel's volatility. The method of measuring distillation temperatures is useful in comparing fuels, but is not intended to separate or identify quantitatively the individual hydrocarbons present.

X2.4.2.1 A maximum value is set on the 10 % evaporated point to ensure ease of starting and a reasonable degree of flexibility during the warm-up period.

X2.4.2.2 To guard against too high a volatility, which might lead to carburetor icing or vapor lock, or both, (also protected against by the vapor pressure), a minimum value is set for the 50 % evaporated points.

X2.4.2.3 A maximum value is specified for the 50 % evaporated temperature to ensure average volatility sufficient to permit adequate evaporation of the fuel in the engine induction system. Insufficient evaporation may lead to loss of power.

X2.4.2.4 A maximum temperature is prescribed for the 90 % evaporated point to prevent too much liquid fuel being delivered to the cylinders, resulting in power loss, and to prevent poor distribution to the various cylinders. Such a condition might lead to engine roughness, perhaps accompanied by knocking and damage to the engine. Excessive dilution of the lubricating oil may result from too high a 90 % evaporated point.

X2.4.2.5 A maximum is placed on the final boiling point (end point), which together with the maximum prescribed for the 90 % evaporated point, is used to prevent incorporation of excessively high boiling components in the fuel, which may lead to mal-distribution, spark plug fouling, power loss, and lubricating oil dilution.

X2.4.2.6 A maximum value is specified for the distillation residue to prevent the inclusion of undesirable high-boiling components essentially impossible to burn in the chamber. The presence of such residue may reflect the degree of care with which the product is refined or handled. The amount of residue, along with the end-point temperature, can be used as an indication of contamination with high-boiling materials.

X2.4.2.7 The stipulation of a minimum recovery and a maximum loss in this specification in conjunction with the vapor pressure requirement is intended to protect against excessive losses by evaporation in storage, handling, and in the aircraft tank. It is also a check on the distillation test technique.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1709.

X2.5 Corrosion of Fuel System and Engine Parts

X2.5.1 *Copper Strip*—The requirement that aviation gasoline must pass the copper strip corrosion test provides assurance that copper components of the fuel system will not be corroded by sulfur compounds in the fuel.

X2.5.2 *Sulfur*—Total sulfur content of aviation fuels is significant because the products of combustion of sulfur can cause corrosive wear of engine parts.

X2.6 Low Temperature Performance

X2.6.1 *Fuel System Icing Inhibitor*—Diethylene glycol monomethyl ether, approved in 6.2.4.1, and isopropyl alcohol, approved in 6.2.4.2, shall be in accordance with the requirements shown in Specification D4171.

X2.6.2 *Fuel Freezing Point*—A freezing point requirement is specified to preclude solidification of any of the materials cited in 6.1 and 6.2 at extremely low temperatures with the consequent interference with fuel flow to the engine.

X2.7 Heat of Combustion

X2.7.1 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, reductions in heat energy are accompanied by an increase in fuel consumption with corresponding loss of range. Therefore, a minimum net heat of combustion requirement is incorporated in the specification.

X2.7.2 The calculation method presented here provides a correction for oxygen content when Test Methods D3338 and D4529 are adopted to determine the net heat of combustion of oxygenated blends.

$$Q = W_1(QP_1) + W_2(QP_2) + W_3(QP_3) + W_4(QP_4) + W_5(QP_5) \quad \text{(X2.1)}$$

where:

Q = net heat of combustion, MJ/kg (BTU/lb) of the gasoline - ether blend,
W_1 = oxygenate-free hydrocarbon mass fraction (or mass % ÷ 100),
QP_1 = net heat of combustion, MJ/kg (BTU/lb) of oxygenate-free hydrocarbon fraction, calculated from measured properties of the fuel,
W_2 = MTBE mass fraction (or mass % ÷ 100),
QP_2 = net heat of combustion of MTBE listed in the research report,[6] which is 35.12 MJ/kg (15 100 BTU/lb),
W_3 = TAME mass fraction (or mass % ÷ 100),
QP_3 = net heat of combustion of TAME listed in the research report,[6] which is 36.49 MJ/kg (15 690 BTU/lb),
W_4 = ETBE mass fraction (or mass % ÷ 100),
QP_4 = net heat of combustion of ETBE listed in the research report,[6] which is 36.36 MJ/kg (15 635 BTU/lb),
W_5 = DIPE mass fraction (or mass % ÷ 100), and
QP_5 = net heat of combustion of DIPE listed in the research report, which is 38.13 mJ/kg (16 393 BTU/lb).

and where:

$W_1 + W_2 + W_3 + W_4 + W_5 = 1$

X2.7.3 If the properties of the oxygenate-free hydrocarbon fraction of the fuel are not known or if only the gasoline-ether blend properties are available, it is not possible to calculate the net heat of combustion of the gasoline-ether blend using Test Method D3338 or D4529. Under these circumstances, the net heat of combustion should be measured using Test Method D4809. See SAE J1498, for further discussion.[7]

X2.7.4 The research report[6] establishes the practical minimum value of net heat of combustion of 40.8 MJ/kg (17 540 BTU/lb) adopted in this specification. However, the value includes the maximum anticipated ether concentrations, and in most cases, actual net heating values will exceed this minimum.

X2.8 Oxygenates

X2.8.1 Oxygenates are oxygen-containing, ashless compounds, such as alcohols and ethers, which can be used as a fuel supplement.

X2.8.2 Aliphatic ethers allowed up to the specification limit include methyl *tertiary*-butyl ether (MTBE), *tertiary*-amyl methyl ether (TAME), ethyl *tertiary*-butyl ether (ETBE), and diisopropyl ether (DIPE).

X2.8.3 The deliberate addition of alcohols is prohibited by this specification, except that isopropyl alcohol is allowed as a fuel system icing inhibitor field additive (see 6.2.4.2) and is limited by aircraft manufacturers to a maximum concentration of 1.0 volume %. Alcohols are prohibited because of their excessive water solubility, increase in vapor pressure, material incompatibility, and in addition for methanol, corrosivity. Low concentrations of methanol and ethanol are only permitted by this specification because they are unreacted components from the manufacturing of aliphatic ethers. The total of the combination of methanol and ethanol shall not exceed 0.3 mass % oxygenate as determined by Test Method D4815, D5599, or D5845.

X2.9 Fuel Cleanliness, Handling, and Storage Stability

X2.9.1 *Existent Gum*—The amount of non-volatile residue remaining after evaporation by a high temperature air jet. This residue may represent solid or heavy liquid contaminants or insoluble residue formed by oxidation in storage.

X2.9.2 *Potential Gum*—Fuel must be usable after storage for variable periods under a variety of climatic conditions. The potential gum test, which is an accelerated oxidation method, is used to estimate fuel stability in storage and the effectiveness

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1427.

[7] *Heating Value of Fuels*, February 1998. Available from Society of Automotive Engineers, 400 Commonwealth Dr., Warrendale, PA 15096–0001.

of oxidation inhibitors. If the fuel is to be stored under relatively mild conditions for short periods, an oxidation period of 5 h is generally considered sufficient to indicate if the desired stability has been obtained.

X2.9.3 *Dyes*—Colors are used in aviation fuels to differentiate between grades. Service experience has indicated that only certain dyes and only certain amounts of dye can be tolerated without manifestation of induction system deposition. The composition of the approved dyes as well as the maximum quantity of each permissible dye is specified in Table 1. The allowable color levels are established by Test Method D2392. Both Grade UL82 and UL87 specified by this specification are current un-dyed as a reassignment of dyes for unleaded aviation gasoline is underway. However, the provision for dyes remains in the specification.

X2.9.4 *Microbial Contamination*—Uncontrolled microbial contamination in fuel systems may 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.

X2.9.5 Guide D6469 provides personnel with limited microbiological background an understanding of the systems, occurrence, and consequences of chronic microbial contamination. The guide also suggests means for detection and control. Biocides used in aviation fuels must follow engine and airframe manufacturers' approval guidelines.

X2.10 Miscellaneous

X2.10.1 *Lead Content*—A number of analytical test methods are permitted to cover the unintentional presence of lead in unleaded fuel. The intentional addition of lead or phosphorus compounds to unleaded fuel is not permitted. Industry practice currently limits maximum concentrations to 0.013 g of lead/L (0.05 g/U.S. gal) and 0.0013 g of phosphorus/L (0.005 g/U.S. gal) (see Test Method D3231), respectively.

X2.10.2 *Aromatic Content*—Low boiling aromatics, which are common constituents of aviation gasolines, are known to affect elastomers to a greater extent than other components.

SUMMARY OF CHANGES

Subcommittee D02.J0 has identified the location of selected changes to this standard since the last issue (D6227 – 14) that may impact the use of this standard. (Approved May 1, 2017.)

(1) Revised Table 1 and subsection X2.9.3.

(2) Deleted former subsection X1.2.