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An American National Standard

Standard Specification for Aviation Gasolines[1]

This standard is issued under the fixed designation D910; 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 formulating specifications for purchases of aviation gasoline under contract and is intended primarily for use by purchasing agencies.

1.2 This specification defines specific types of aviation gasolines for civil use. 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 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]

D86 Test Method for Distillation of Petroleum Products 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[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[3]

D873 Test Method for Oxidation Stability of Aviation Fuels (Potential Residue Method)

D909 Test Method for Supercharge Rating of Spark-Ignition Aviation Gasoline

D1094 Test Method for Water Reaction of Aviation Fuels

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

D1948 Method of Test for Knock Characteristics of Motor Fuels Above 100 Octane Number by the Motor Method[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

D3341 Test Method for Lead in Gasoline—Iodine Monochloride Method

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

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

[1] This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.J0.02 on Aviation Gasoline.

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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.**

D5059 Test Methods for Lead in Gasoline by X-Ray Spectroscopy
D5190 Test Method for Vapor Pressure of Petroleum Products (Automatic Method)
D5191 Test Method for Vapor Pressure of Petroleum Products (Mini Method)
D6469 Guide for Microbial Contamination in Fuels and Fuel Systems
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

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*—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 *Abbreviations:*

3.2.1 *LL*—low lead

3.2.2 *VLL*—very low lead

4. General

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

5. Classification

5.1 Five grades of leaded aviation gasoline are provided, known as:

Grade 80
Grade 91
Grade 100
Grade 100LL
Grade 100VLL

NOTE 1—The above grade names are based on their octane/performance numbers as measured by the now obsolete Test Method D614 (Discontinued 1970). A table for converting octane/performance numbers obtained by Test Method D2700 motor method into aviation ratings was last published in Specification D910–94 in the 1995 *Annual Book of ASTM Standards*, Vol 05.01.

5.2 Grades 100, 100LL, and 100VLL represent aviation gasolines identical in minimum antiknock quality but differing in maximum lead content and color. The color identifies the difference for engines that have a low tolerance to lead.

NOTE 2—Listing of, and requirements for, Avgas Grades 91/98, 108/135 and 115/145 appeared in the 1967 version of this specification. U.S. Military Specification MIL-G-5572F, dated January 24, 1978 (withdrawn March 22, 1988), also covers grade 115/145 aviation gasoline, and is available as a research report.[4]

5.3 Although the grade designations show only a single octane rating for each grade, they shall meet a minimum lean mixture motor rating and a minimum rich mixture supercharge rating (see X1.2.2).

6. Materials and Manufacture

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 synthetic hydrocarbons or aromatic hydrocarbons, or both.

6.2 *Additives—Mandatory*, shall be added to each grade of aviation gasoline in the amount and of the composition specified in the following list of approved materials.

6.2.1 *Tetraethyl Lead*, shall be added in the form of an antiknock mixture containing not less than 61 mass % of tetraethyl lead and sufficient ethylene dibromide to provide two bromine atoms per atom of lead. The balance shall contain no added ingredients other than kerosine, an approved oxidation inhibitor, and blue dye, as specified herein. The maximum concentration limit for each grade of gasoline is specified in Table 1.

6.2.1.1 If mutually agreed upon by the fuel producer and additive vendor, tetraethyl lead antiknock mixture may be diluted with 20 mass % of a mixed aromatic solvent having a minimum flash point of 60°C according to Test Methods D93 when the product is to be handled in cold climates. The TEL content of the dilute product is reduced to 49 mass %, so that the amount of antiknock additive must be adjusted to achieve the necessary lead level. The dilute product still delivers two bromine atoms per atom of lead.

6.2.2 *Dyes*—The maximum concentration limits in each grade of gasoline are specified in Table 1.

6.2.2.1 The only blue dye that shall be present in the finished gasoline shall be essentially 1,4-dialkylaminoanthraquinone.

6.2.2.2 The only yellow dyes that shall be present in the finished gasoline shall be essentially p-diethylaminoazobenzene (Color Index No. 11021) or 1,3-benzenediol 2,4-bis [(alkylphenyl)azo-].

6.2.2.3 The only red dye that shall be present in the finished gasoline shall be essentially alkyl derivatives of azobenzene-4-azo-2-naphthol.

6.2.2.4 The only orange dye that shall be present in the finished gasoline shall be essentially benzene-azo-2-napthol (Color Index No. 12055).

6.3 *Additives*—These may be added to each grade of aviation gasoline in the amount and of the composition specified in the following list of approved materials.[5] The quantities and types shall be declared by the manufacturer. Additives added after the point of manufacture shall also be declared.

6.3.1 *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.

6.3.1.1 2,6-ditertiary butyl-4-methylphenol.

6.3.1.2 2,4-dimethyl-6-tertiary butylphenol.

6.3.1.3 2,6-ditertiary butylphenol.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1255.

[5] Supporting data (guidelines for the approval or disapproval of additives) have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1125.

TABLE 1 Detailed Requirements for Aviation Gasolines[A]

		Grade 80	Grade 91	Grade 100VLL	Grade 100LL	Grade 100	ASTM Test Method[B]
Octane Ratings							
Knock value, lean mixture[C]							
Motor Octane Number	min	80.7	90.8	99.6	99.6	99.6	D2700
Aviation Lean Rating	min	80.0	91.0	100.0	100.0	100.0	D2700
Knock value, rich mixture							
Octane number	min	87	98				D909
Performance number[D,E]	min			130.0	130.0	130.0	D909
Tetraethyl lead, mL							D3341 or D5059
TEL/L	max	0.13	0.53	0.43	0.53	1.06	
gPb/L	max	0.14	0.56	0.45	0.56	1.12	
Color		red	brown	blue	blue	green	D2392
Dye content[F]							
Blue dye, mg/L	max	0.2	3.1	2.7	2.7	2.7	
Yellow dye, mg/L	max	none	none	none	none	2.8	
Red dye, mg/L	max	2.3	2.7	none	none	none	
Orange dye, mg/L	max	none	6.0	none	none	none	

Requirements for All Grades

			ASTM Test Method
Density at 15°C, kg/m^3		Report	D1298 or D4052
Distillation			D86
Initial boiling point, °C		Report	
Fuel Evaporated			
10 volume % at °C	max	75	
40 volume % at °C	min	75	
50 volume % at °C	max	105	
90 volume % at °C	max	135	
Final boiling point, °C	max	170	
Sum of 10 % + 50 % evaporated temperatures, °C	min	135	
Recovery volume %	min	97	
Residue volume %	max	1.5	
Loss volume %	max	1.5	
Vapor pressure, 38°C, kPa	min	38.0	D323 or D5190
	max	49.0	or D5191[G]
Freezing point, °C	max	−58[H]	D2386
Sulfur, mass %	max	0.05	D1266 or D2622
Net heat of combustion, MJ/kg[I]	min	43.5	D4529 or D3338
Corrosion, copper strip, 2 h at 100°C	max	No. 1	D130
Oxidation stability (5 h aging)[J,K]			D873
Potential gum, mg/100 mL	max	6	
Lead precipitate, mg/100 mL	max	3	
Water reaction			D1094
Volume change, mL	max	±2	
Electrical conductivity, pS/m	max	450[L]	D2624

[A] For compliance of test results against the requirements of Table 1, see 7.2.
[B] The test methods indicated in this table are referred to in Section 11.
[C] Both Motor Octane Number (MON) and Aviation Lean Mixture values shall be reported.
[D] A performance number of 130.0 is equivalent to a knock value determined using *iso*-octane plus 0.34 mL TEL/L.
[E] Knock ratings shall be reported to the nearest 0.1 octane/performance number.
[F] The maximum dye concentrations shown do not include solvent in dyes supplied in liquid form.
[G] Test Method D5191 shall be the referee vapor pressure method.
[H] If no crystals have appeared on cooling to −58°C, the freezing point may be reported as less than −58°C.
[I] 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.
[J] If mutually agreed upon between the purchaser and the supplier, a 16 h aging gum requirement may be specified instead of the 5 h aging gum test; in such case the gum content shall not exceed 10 mg/100 mL and the visible lead precipitate shall not exceed 4 mg/100 mL. In such fuel the permissible antioxidant shall not exceed 24 mg/L.
[K] Test Method D381 existent gum test can provide a means of detecting quality deterioration or contamination, or both, with heavier products following distribution from refinery to airport. Refer to X1.7.1.
[L] 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 pS/m.
The supplier shall report the amount of additive added.

6.3.1.4 75 % minimum 2,6-ditertiary butylphenol plus 25 % maximum mixed *tertiary* and *tritertiary* butylphenols.

6.3.1.5 75 % minimum di- and tri-isopropyl phenols plus 25 % maximum di- and tri-*tertiary* butylphenols.

6.3.1.6 72 % minimum 2,4-dimethyl-6-tertiary butylphenol plus 28 % maximum monomethyl and dimethyl *tertiary* butylphenols.

6.3.1.7 N,N′-di-isopropyl-para-phenylenediamine.

6.3.1.8 N,N′-di-secondary-butyl-para-phenylenediamine.

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

6.3.2.1 *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.

NOTE 3—Addition of isopropyl alcohol (IPA) may reduce knock ratings below minimum specification values (see X1.2.4).[6]

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

6.3.2.3 Test Method D5006 can be used to determine the concentration of Di-EGME in aviation fuels.

6.3.3 *Electrical Conductivity Additive*—Stadis 450[7] 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.

6.3.4 *Corrosion Inhibitor Additive*—The following corrosion inhibitors may be added to the gasoline in concentrations not to exceed the maximum allowable concentration (MAC) listed for each additive.

DCI-4A	MAC = 22.5 g/m^3
DCI-6A	MAC = 9.0 g/m^3
HITEC 580	MAC = 22.5 g/m^3
NALCO 5403	MAC = 22.5 g/m^3
NALCO 5405	MAC = 11.0 g/m^3
PRI-19	MAC = 22.5 g/m^3
UNICOR J	MAC = 22.5 g/m^3
SPEC-AID 8Q22	MAC = 24.0 g/m^3
TOLAD 351	MAC = 24.0 g/m^3
TOLAD 4410	MAC = 22.5 g/m^3

7. Detailed Requirements

7.1 The aviation gasoline 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 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 aviation gasoline specified in this specification shall be free from undissolved water, sediment, and suspended matter. The odor of the fuel shall not be nauseating or irritating. 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 refinery specification compliance testing shall be performed on a sample taken following procedures in Practice D4057.

9.2 A number of aviation gasoline 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 aviation gasoline.

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 *Knock Value (Lean Rating)*—Test Method D2700.

11.1.2 *Knock Value (Rich Rating)*—Test Method D909.

11.1.3 *Tetraethyllead*—Test Methods D3341 or D5059.

11.1.4 *Color*—Test Method D2392.

11.1.5 *Density*—Test Methods D1298 or D4052.

11.1.6 *Distillation*—Test Method D86.

11.1.7 *Vapor Pressure*—Test Methods D323, D5190, or D5191.

11.1.8 *Freezing Point*—Test Method D2386.

11.1.9 *Sulfur*—Test Methods D1266 or D2622.

11.1.10 *Net Heat of Combustion*—Test Methods D4529 or D3338.

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

11.1.12 *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.

11.1.13 *Water Reaction*—Test Method D1094.

11.1.14 *Electrical Conductivity*—Test Methods D2624.

12. Keywords

12.1 Avgas; aviation gasoline; gasoline

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1526.

[7] Stadis is a registered trademark marketed by Octel America, Inc., Newark, DE 19702.

APPENDIX

(Nonmandatory Information)

X1. PERFORMANCE CHARACTERISTICS OF AVIATION GASOLINES

X1.1 Introduction

X1.1.1 Aviation gasoline is a complex mixture of relatively volatile hydrocarbons that vary widely in their physical and chemical properties. The engines and aircraft impose a variety of mechanical, physical, and chemical environments. The properties of aviation gasoline (Table X1.1) must be properly balanced to give satisfactory engine performance over an extremely wide range of conditions.

X1.1.2 The ASTM requirements summarized in Table 1 are quality limits established on the basis of the broad experience and close cooperation of producers of aviation gasoline, manufacturers of aircraft engines, and users of both commodities. The values given are intended to define aviation gasoline suitable for most types of spark-ignition aviation engines; however, certain equipment or conditions of use may require fuels having other characteristics.

X1.1.3 Specifications covering antiknock quality define the grades of aviation gasoline. The other requirements either prescribe the proper balance of properties to ensure satisfactory engine performance or limit components of undesirable nature to concentrations so low that they will not have an adverse effect on engine performance.

X1.2 Combustion Characteristics (Antiknock Quality and Antiknock Compound Identification)

X1.2.1 The fuel-air mixture in the cylinder of a spark-ignition engine will, under certain conditions, ignite spontaneously in localized areas instead of progressing from the spark. This may cause a 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. When aviation gasoline is used in other types of aviation engines, for example, in certain turbine engines where specifically permitted by the engine manufacturers, knock or detonation characteristics may not be critical requirements.

TABLE X1.1 Performance Characteristics of Aviation Gasoline

Performance Characteristics	Test Methods	Sections
Combustion characteristics	knock value (lean mixture)	X1.2.4
Antiknock quality and antiknock compound identification	knock value (rich mixture)	X1.2.5
	isopropyl alcohol	X1.2.6
	tetraethyllead	X1.2.7
	dyes	X1.2.8
Fuel metering and aircraft range	density	X1.3.1
	net heat of combustion	X1.3.2
Carburetion and fuel vaporization	vapor pressure	X1.4.1
	distillation	X1.4.2
Corrosion of fuel system and engine parts	copper strip corrosion	X1.5.1
	sulfur content	X1.5.2
Fluidity at low temperatures	freezing point	X1.6
Fuel cleanliness, handling, and storage stability	existent gum	X1.7.1
	potential gum	X1.7.2
	visible lead precipitate	X1.7.3
	water reaction	X1.7.5

X1.2.2 Aviation gasoline grades are also identified by two numbers separated by a slant line (/). The first number is called the lean mixture rating and the second number is called the rich mixture rating. This specification describes five grades of aviation gasoline as follows: 80/87, 91/98, 100/130, 100/130LL, and 100/130VLL. Numbers below 100 are octane numbers, while numbers above 100 are performance numbers. At 100, octane number and performance number are equal. The suffix LL describes a grade containing lower tetraethyllead than a second grade of identical lean and rich mixture ratings. The suffix VLL designates a grade containing lower tetraethyllead than grade 100/130LL of identical lean and rich mixture ratings.

X1.2.3 Both the lean mixture rating and the rich mixture rating are determined in standardized laboratory knock test engines that are operated under prescribed conditions. Results are expressed as octane numbers up to 100 and above this point as quantities of tetraethyllead added to *iso*octane (2,2,4-trimethylpentane). Octane number is defined arbitrarily as the percentage of *iso*octane in that blend of *iso*octane and *n*-heptane that the gasoline matches in knock characteristics when compared by the procedure specified. The quantities of tetraethyllead added to *iso*octane that the gasoline matches in knock characteristics when compared by the procedure specified may be converted to performance numbers by a chart. The performance number is an indication of the relative power obtainable from an engine as compared with operation of the same engine with leaded *iso*octane, operating at equal knocking intensity. The lean mixture rating together with the rich mixture rating can be used as a guide to the amount of knock-limited power that may be obtained in a full-scale engine under cruise (lean) and take-off (rich) conditions.

X1.2.4 It has been observed that when isopropyl alcohol (IPA) is added to a Grade 100, Grade 100LL, or Grade 100VLL aviation gasoline as a fuel system icing inhibitor, the antiknock rating of the fuel can be reduced. Since isopropyl alcohol is normally added in the field at the point of use, the operator is cautioned that performance numbers on the alcohol-fuel blend may not meet specification minimums. Typical performance number reductions with addition of one volume % IPA has been 0.5 motor octane number on the lean rating and 3.0 to 3.5 performance number on the rich rating. Thus a Grade 100, 100LL, or 100VLL aviation gasoline rated in the knock test engines at the point of manufacture to be 99.5/130 octane/performance number might, with the addition of one volume % alcohol, be about 99/127 octane/performance number. At three volume %, the reductions are about 1.5 octane number and 7.5 performance number for lean and rich ratings, respectively. It should be noted that a survey conducted by the General Aviation Manufacturers Association failed to find field evidence or experience to suggest that these reductions have caused engine distress, that is, knocking or power loss at their recommended 1 % maximum level. On Grade 80 aviation gasoline, addition of the IPA additive can increase the octane rating.

X1.2.5 *Knock Value, Lean Mixture Rating (Test Method D2700)*—The specification parameter knock value, lean value mixture lists both "Motor Octane Number" (MON) and "Aviation Lean," as determined by Test Method D2700. Historically, aviation lean ratings were determined (from 1941 through 1970) by Test Method D614. An extensive comparison of National Exchange Group data from 1947 through 1964 established that motor octane numbers as determined by Test Methods D357 and D1948 could be converted to equivalent Test Method D614 ratings. A table to convert MON to the corresponding aviation lean rating was included in Test Method D2700, which was first issued in 1968 as a revision, consolidation and intended eventual replacement of Test Methods D357 (Withdrawn 1969), D614 (Withdrawn 1970), and D1948 (Withdrawn 1968). Currently "Aviation Lean" ratings are only determinable from the MON conversion table in Test Method D2700. However, the equivalent "Aviation Lean" rating is maintained as a specified parameter in Table 1 to ensure aircraft compliance with historical type certification data sheets.

X1.2.6 *Rich Mixture Rating (Supercharge Test Method D909)*—This test method uses a laboratory engine that is capable of being operated at varying air-fuel mixtures and through a range of supercharge manifold pressures. The rating of a fuel is determined by comparing its knock-limited power with those for bracketing blends of reference fuels under standard operating conditions. The rating is made at the rich peak of the mixture response curve (about 0.11 fuel-air ratio) of the lower bracketing reference fuel.

X1.2.7 *Tetraethyllead*—Tetraethyllead offers the most economical means of providing high antiknock value for aviation gasoline. It is added to aviation gasoline in the form of a fluid which, in addition to tetraethyllead, contains an organic halide scavenging agent and an identifying blue dye. The scavenging agent is needed to keep the tetraethyllead combustion products volatile so that they will theoretically be completely discharged from the cylinder. Actually, lead compounds are deposited in the combustion chamber and some find their way into the lubricating oil. The products of combustion of tetraethyllead fluid are also known to be corrosive. Since deposition and corrosive tendencies are undesirable, the quantity of tetraethyllead in aviation gasoline is limited by specification commensurate with economic considerations.

X1.2.8 *Dyes*—The law provides that all fuels containing tetraethyllead must be dyed to denote the presence of the poisonous component. Colors are also 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 names of the approved dyes are specified as well as the maximum quantity of each permissible in each grade.

X1.3 Fuel Metering and Aircraft Range

X1.3.1 *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.

X1.3.2 *Net Heat of Combustion*—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 the 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 for the purposes of this specification. An alternative calculation, Test Method D3338, is based on correlations of aromatics content, density, volatility, and sulfur content. This test 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 is normally used only as a referee method in cases of dispute.

X1.3.3 No great variation in density or heat of combustion occurs in modern aviation gasolines, since they depend on hydrocarbon composition that is already closely controlled by other specification properties.

X1.4 Carburetion and Fuel Vaporization

X1.4.1 In many spark-ignition aviation engines, the gasoline is metered in liquid form through the carburetor where it is mixed with air and vaporized before entering the supercharger from which the fuel-air mixture enters the cylinder of the engine. In other types of engines, the fuel may be metered directly into the supercharger, the cylinder, or the combustor. The volatility, the tendency to evaporate or change from a liquid to a gaseous state, is an extremely important characteristic of aviation fuel.

X1.4.2 Gasolines that vaporize too readily may boil in fuel lines or carburetors, particularly as altitude increases, and cause vapor lock with resultant stoppage of fuel flow to the engine. 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 components is essential to satisfactory performance of the finished fuel.

X1.4.3 *Vapor Pressure*—The vapor pressure of an aviation gasoline is the measure of the tendency of the more volatile components to evaporate. Experience has shown that fuels having a Reid vapor pressure no higher than 49 kPa will be free of vapor-locking tendencies under most conditions of aircraft usage. A research report is available.[8]

X1.4.4 *Distillation*—The relative proportions of all the hydrocarbon components of a gasoline are measured in terms

[8] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1146.

of volatility by the range of distillation temperatures. The method is empirical and useful in comparing fuels, but is not intended to separate or identify quantitatively the individual hydrocarbons present in the fuel.

X1.4.4.1 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. To guard against too high a volatility that might lead to carburetor icing or vapor lock, or both, (also protected against by the vapor pressure test) a minimum value is set for the sum of the 10 and 50 % evaporated points.

X1.4.4.2 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.

X1.4.4.3 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 excessive leanness in some cylinders with consequent engine roughness, perhaps accompanied by knocking and damage to the engine. Lowered fuel economy and excessive dilution of the lubricating oil may result from too high a 90 % evaporated point.

X1.4.4.4 A minimum value is stipulated for the 40 % evaporated temperature in an effort to control, indirectly, specific gravity and, consequently, carburetor metering characteristics.

X1.4.4.5 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 that may lead to maldistribution, spark plug fouling, power loss, lowered fuel economy, and lubricating oil dilution.

X1.4.4.6 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.

X1.4.4.7 A maximum value is specified for the distillation residue to prevent the inclusion of undesirable high-boiling components essentially impossible to burn in the combustion chamber, the presence of which 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.

X1.5 Corrosion of Fuel System and Engine Parts

X1.5.1 *Copper Strip*—The requirement that gasoline must pass the copper strip corrosion test provides assurance that the product will not corrode the metal parts of fuel systems.

X1.5.2 *Sulfur*—Total sulfur content of aviation fuels is significant because the products of combustion of sulfur can cause corrosive wear of engine parts.

X1.6 Fluidity at Low Temperatures

X1.6.1 A freezing point requirement is specified to preclude solidification of any hydrocarbon components at extremely low temperatures with consequent interference with fuel flow to the engine.

X1.6.2 *Fuel System Icing Inhibitor*—Isopropyl alcohol (IPA), approved in 6.3.2.1, and diethyleneglycol monomethyl ether (Di-EGME), approved in 6.3.2.2, shall be in accordance with the requirements shown in Specification D4171.

X1.7 Fuel Cleanliness, Handling and Storage Stability

X1.7.1 *Existent Gum*—Gum is a non-volatile residue left by evaporation of fuel. 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.

X1.7.2 *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 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, whereas a 16-h period is desirable to provide stability assurance for long periods and severe conditions, such as storage in tropical climates.

X1.7.3 *Visible Lead Precipitate*—The formation of a lead precipitate during the aging period of the potential gum test under the accelerated oxidation conditions used in this determination indicates a potential instability. Since even small amounts of insoluble material may foul the induction system and plug filters, it is necessary to place a limit on the amount of precipitate formed in this determination.

X1.7.4 *Permissible Oxidation Inhibitors and Oxidation Inhibitor Content*—Antioxidants are used to prevent the formation of gum in fuel during storage. The efficacy of a given inhibitor determined by the apparent oxidation stability of a fuel does not completely establish its suitability for use in an aircraft engine. Oxidation inhibitors have been found to contribute to excessive induction system deposits; therefore, their acceptability for use must ultimately be determined in the full-scale aircraft engine.

X1.7.4.1 The chemical names of approved inhibitors and the maximum quantities permitted are shown in this specification.

X1.7.5 *Water Reaction*—The water reaction method provides a means of determining the presence of materials readily extractable by water or having a tendency to absorb water. When the fuel consists essentially of hydrocarbon components, there is no measurable change in the volume of the water layer.

X1.7.6 *Electrical Conductivity*—The generation of static electricity can create problems in the handling of aviation gasolines. Addition of a conductivity improver may be used as an additional precaution to reduce the amount of static electrical charge present during fuel handling. See Guide D4865 for more information.

X1.7.7 *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.

X1.7.8 Guide D6469 provides personnel with limited microbiological background and an understanding of the symptoms, 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.

X1.8 Miscellaneous Tests

X1.8.1 *Aromatics Content*—Low boiling aromatics, which are common constituents of aviation gasolines, are known to affect elastomers to a greater extent than other components in aviation gasoline. Although Specification D910 does not include an explicit maximum aromatic limit, other specification limits effectively restrict the aromatic content of aviation gasolines. Benzene is virtually excluded by the maximum freezing point of −58°C, while other aromatics are limited by the minimum heating value and the maximum distillation end point. Thus, the heating value limits toluene to about 24 %. Xylenes have a slightly higher heating value and, therefore, would permit somewhat higher aromatic concentrations; however, their boiling points (above 138°C) limit their inclusion at levels not higher than 10 %. Total aromatic levels above 25 % in aviation gasoline are, therefore, extremely unlikely.

X1.9 General

X1.9.1 Further detailed information on the significance of all test methods relevant to aviation gasoline is provided in Manual MNL 1.[9]

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

SUMMARY OF CHANGES

Subcommittee D02.J0 has identified the location of selected changes to this standard since the last issue (D910–07a) that may impact the use of this standard.

(*1*) Included provisions for Grade 100/130VLL (very low lead) aviation gasoline throughout the standard.