



## Standard Specification for Aviation Gasolines<sup>1</sup>

This standard is issued under the fixed designation D 910; 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 ( $\epsilon$ ) 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 is intended primarily for use by purchasing agencies in formulating specifications for purchases of aviation gasoline under contract.

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.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- D 86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure<sup>2</sup>
- D 93 Test Methods for Flash-Point by Pensky-Martens Closed Cup Tester<sup>2</sup>
- D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test<sup>2</sup>
- D 156 Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)<sup>2</sup>
- D 323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)<sup>2</sup>
- D 357 Method of Test for Knock Characteristics of Motor Fuels Below 100 Octane Number by the Motor Method<sup>3</sup>
- D 381 Test Method for Gum Content in Fuels by Jet Evaporation<sup>2</sup>
- D 614 Method of Test for Knock Characteristics of Aviation Fuels by the Aviation Method<sup>4</sup>
- D 873 Test Method for Oxidation Stability of Aviation Fuels (Potential Residue Method)<sup>2</sup>
- D 909 Test Method for Knock Characteristics of Aviation Gasolines by the Supercharge Method<sup>5</sup>
- D 1094 Test Method for Water Reaction of Aviation Fuels<sup>2</sup>

- D 1266 Test Method for Sulfur in Petroleum Products (Lamp Method)<sup>2</sup>
- D 1298 Practice for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method<sup>2</sup>
- D 2386 Test Method for Freezing Point of Aviation Fuels<sup>2</sup>
- D 2392 Test Method for Color of Dyed Aviation Gasolines<sup>2</sup>
- D 2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-Ray Fluorescence Spectrometry<sup>2</sup>
- D 2624 Test Method for Electrical Conductivity of Aviation and Distillate Fuels<sup>2</sup>
- D 2700 Test Method for Motor Octane Number of Spark-Ignition Engine Fuel<sup>5</sup>
- D 3338 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels<sup>6</sup>
- D 3341 Test Method for Lead in Gasoline—Iodine Monochloride Method<sup>6</sup>
- D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter<sup>6</sup>
- D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products<sup>6</sup>
- D 4171 Specification for Fuel System Icing Inhibitors<sup>6</sup>
- D 4306 Practice for Aviation Fuel Sampling Containers for Tests Affected by Trace Contamination<sup>6</sup>
- D 4529 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels<sup>6</sup>
- D 4809 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)<sup>6</sup>
- D 4865 Guide for the Generation and Dissipation of Static Electricity in Petroleum Fuel Systems<sup>6</sup>
- D 5006 Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels<sup>6</sup>
- D 5059 Test Methods for Lead in Gasoline by X-Ray Spectroscopy<sup>6</sup>
- D 5190 Test Method for Vapor Pressure of Petroleum Products (Automatic Method)<sup>6</sup>
- D 5191 Test Method for Vapor Pressure of Petroleum Products (Mini Method)<sup>6</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.J0 on Aviation Fuels.

Current edition approved June 10, 2002. Published September 2002. Originally published as D 910–47T replacing former D 615. Last previous edition D 910–01.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 05.01.

<sup>3</sup> Discontinued 1969. Replaced by D 2700.

<sup>4</sup> Discontinued; see 1970 *Annual Book of ASTM Standards*.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 05.05.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 05.02.

D 6469 Guide for Microbial Contamination in Fuels and Fuel Systems<sup>7</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>8</sup>

### 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.

### 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 Four grades of aviation gasoline are provided, known as:

Grade 80  
Grade 91  
Grade 100  
Grade 100LL

NOTE 1—The above grade names are based on their octane/performance numbers as measured by the now obsolete Test Method D 614 Knock Characteristics of Aviation Fuels by the Aviation Method (Discontinued 1970). A table for converting octane/performance numbers obtained by the Test Method D 2700 Motor Method into aviation ratings was last published in Specification D 910–94 in the 1995 *Annual Book of ASTM Standards*, Vol 05.01.

5.2 Grades 100 and 100LL represent two aviation gasolines identical in anti-knock 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 91/96, 108/135 and 115/145 appeared in the 1967 version of this specification. US 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.<sup>9</sup>

5.3 Although the grade designations show only a single octane rating for each grade, each grade must meet a minimum lean mixture motor rating and a minimum rich mixture super-charge 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 m % 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 m % of a mixed aromatic solvent having a minimum flash point of 60°C according to Test Method D 93 when the product is to be handled in cold climates. The TEL content of the dilute product is reduced to 49 m%, 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 which shall be present in the finished gasoline shall be essentially 1,4-dialkylaminoanthraquinone.

6.2.2.2 The only yellow dyes which 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 which 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-naphthol (Color Index No. 12055).

6.3 *Additives—Optional*, may be added to each grade of aviation gasoline in the amount and of the composition specified in the following list of approved materials.<sup>10</sup> The quantities and types must be declared by the manufacturer and agreed to by the purchaser.

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.

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

6.3.1.5 75 % min di- and tri-isopropyl phenols plus 25 % max di- and tri-*tertiary* butylphenols.

6.3.1.6 72 % min 2,4-dimethyl-6-tertiary butylphenol plus 28 % max 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.

<sup>7</sup> *Annual Book of ASTM Standards*, Vol 05.04.

<sup>8</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>9</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1255.

<sup>10</sup> 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<sup>A</sup>**

		Grade 80	Grade 91	Grade 100LL	Grade 100	ASTM Test Method <sup>B</sup>
Knock value, lean mixture						
Motor Method						D 2700
Octane number	min	80.0	91.0	99.5	99.5	
Knock value, rich mixture						
Supercharge rating						D 909
Octane number	min	87.0	98.0			
Performance number <sup>CD</sup>	min			130.0	130.0	
Tetraethyl lead, mL TEL/L	max	0.13	0.53	0.53	1.06	D 3341 or D 5059
gPb/L	max	0.14	0.56	0.56	1.12	
Color		red	brown	blue	green	D 2392
Dye content <sup>E</sup>						
Blue dye, mg/L	max	0.2	3.1	2.7	2.7	
Yellow dye, mg/L	max	none	none	none	2.8	
Red dye, mg/L	max	2.3	2.7	none	none	
Orange dye, mg/L	max	none	6.0	none	none	
Requirements for All Grades						
Density at 15°C, kg/m <sup>3</sup>				Report		D 1298 or D 4052
Distillation						D 86
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		D 323 or D 5190
	max			49.0		or D 5191 <sup>F</sup>
Freezing point, °C	max			-58		D 2386
Sulfur, m %	max			0.05		D 1266 or D 2622
Net heat of combustion, MJ/kg <sup>G</sup>	min			43.5		D 4529 or D 3338
Corrosion, copper strip, 2 h at 100°C	max			No. 1		D 130
Oxidation stability (5 h aging) <sup>H,I</sup>						D 873
Potential gum, mg/100 mL	max			6		
Lead precipitate, mg/100 mL	max			3		
Water reaction						D 1094
Volume change, mL	max			±2		
Electrical conductivity, pS/m	max			450 <sup>J</sup>		D 2624

<sup>A</sup> For compliance of test results against the requirements of Table 1, see 7.2.

<sup>B</sup> The test methods indicated in this table are referred to in Section 11.

<sup>C</sup> A performance number of 130.0 is equivalent to a knock value determined using *iso*-octane plus 0.34 mL TEL/L.

<sup>D</sup> Knock ratings shall be reported to the nearest 0.1 octane/performance number.

<sup>E</sup> The maximum dye concentrations shown do not include solvent in dyes supplied in liquid form.

<sup>F</sup> Test Method D 5191 shall be the referee vapor pressure method.

<sup>G</sup> For all grades use either Eq 1 or Table 1 in Test Method D 4529 or Eq 2 in Test Method D 3338. Test Method D 4809 may be used as an alternative. In case of dispute, Test Method D 4809 shall be used.

<sup>H</sup> 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.

<sup>I</sup> Test Method D 381 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.

<sup>J</sup> 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.

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

**6.3.2.1 Isopropyl Alcohol (IPA, propan-2-ol)**, conforming to the requirements of Specification D 4171 (Type II). May be used in concentrations recommended by the aircraft manufacturer when required by the aircraft owner/operator.

below minimum specification values (see X1.2.4).<sup>11</sup>

**6.3.2.2 Di-Ethylene Glycol Monomethyl Ether (Di-EGME)**, conforming to the requirements of Specification D 4171 (Type III). May be used in concentrations of 0.10 to 0.15 volume %

<sup>11</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02-1526.

NOTE 3—Addition of isopropyl alcohol (IPA) may reduce knock ratings

when required by the aircraft owner/operator.

6.3.2.3 Test Method D 5006 can be used to determine the concentration of Di-EGME in aviation fuels.

6.3.3 *Electrical Conductivity Additive*—Stadis 450<sup>12</sup> 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 <sup>3</sup>
DCI-6A	MAC = 9.0 g/m <sup>3</sup>
HITEC 580	MAC = 22.5 g/m <sup>3</sup>
MOBILAD F800	MAC = 22.5 g/m <sup>3</sup>
NALCO/EXXON 5403	MAC = 22.5 g/m <sup>3</sup>
NALCO/EXXON 5405	MAC = 11.0 g/m <sup>3</sup>
PRI-19	MAC = 22.5 g/m <sup>3</sup>
UNICOR J	MAC = 22.5 g/m <sup>3</sup>
SPEC-AID 8Q22	MAC = 24.0 g/m <sup>3</sup>

## 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 E 29. Where multiple determinations are made, the average result, rounded according to Practice E 29, shall be used.

## 8. Workmanship, Finish and Appearance

8.1 The aviation gasoline herein specified 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 herein.

<sup>12</sup> Stadis is a registered trademark marketed by Octel America, Inc., Newark, DE 19702.

## 9. Sampling

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

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 D 4306.

## 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 D 2700.

11.1.2 *Knock Value (Rich Rating)*—Test Method D 909.

11.1.3 *Tetraethyllead*—Test Methods D 3341 or D 5059.

11.1.4 *Color*—Test Method D 2392.

11.1.5 *Density*—Test Methods D 1298 or D 4052.

11.1.6 *Distillation*—Test Method D 86.

11.1.7 *Vapor Pressure*—Test Methods D 323, D 5190, or D 5191.

11.1.8 *Freezing Point*—Test Method D 2386.

11.1.9 *Sulfur*—Test Methods D 1266 or D 2622.

11.1.10 *Net Heat of Combustion*—Test Methods D 4529 or D 3338.

11.1.11 *Corrosion (Copper Strip)*—Test Method D 130, 2 h test at 100°C in bomb.

11.1.12 *Potential Gum and Visible Lead Precipitate*—Test Method D 873 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 D 1094.

11.1.14 *Electrical Conductivity*—Test Method D 2624.

## 12. Keywords

12.1 Avgas; aviation gasoline; gasoline

## 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;

**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

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.

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 four grades of aviation gasoline as follows: 80/87, 91/98, 100/130 and 100/130LL. 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.

X1.2.3 Both the lean mixture rating and the rich mixture rating are determined in standardized laboratory knock test engines which are operated under prescribed conditions. Results are expressed as octane numbers up to 100 and above this point as quantities of tetraethyllead added to *isooctane* (2,2,4-trimethylpentane). Octane number is defined arbitrarily as the percentage of *isooctane* in that blend of *isooctane* and *n*-heptane which the gasoline matches in knock characteristics when compared by the procedure specified. The quantities of tetraethyllead added to *isooctane* which 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 *isooctane*, 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 or Grade 100LL aviation gasoline as a fuel system icing inhibitor, the anti-knock rating of the fuel may 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 1 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 or 100LL 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 may increase the octane rating.

X1.2.5 *Lean Mixture Rating (Motor Test Method D 2700)*—Test Method D 2700 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 D 357 (Discontinued 1969, replaced by Test Method D 2700) 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.

X1.2.6 *Rich Mixture Rating (Supercharge Test Method D 909)*—This test method uses a laboratory engine which 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 D 3338 is based on correlations of aromatics content, density, volatility, and sulfur content. This method may be preferred at refineries where all these values are normally obtained and the necessity to obtain the aniline point is avoided. The direct measurement method 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 which 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 or 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 in 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.<sup>13</sup>

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

<sup>13</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting, *Autogas for Avgas and the Related Problem of Vapor Lock*, Research Report RR: D02-1146.

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 conform to the requirements shown in Specification D 4171.

### **X1.7 Fuel Cleanliness, Handling and Storage Stability**

**X1.7.1 Existent Gum**—Gum is a non-volatile residue left on 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 con-

tribute 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 D 4865 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 D 6469 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 D 910 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  $-58^{\circ}\text{C}$ , 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  $138^{\circ}\text{C}$ ) 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.<sup>14</sup>

<sup>14</sup> *Manual on Significance of Tests for Petroleum Products*, MNL 1, ASTM International, W. Conshohocken, PA.

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