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An American National Standard

Standard Guide for Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives[1]

This standard is issued under the fixed designation D7826; 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 guide provides procedures to develop data for use in research reports for new aviation gasolines or new aviation gasoline additives.

1.2 This data is intended to be used by the ASTM subcommittee to make a determination of the suitability of the fuel for use as an aviation fuel in either a fleet-wide or limited capacity, and to make a determination that the proposed properties and criteria in the associated standard specification provide the necessary controls to ensure this fuel maintains this suitability during high-volume production.

1.3 These research reports are intended to support the development and issuance of new specifications or specification revisions for these products. Guidance to develop ASTM International standard specifications for aviation gasoline is provided in Subcommittee J on Aviation Fuels Operating Procedures, Annex A6, "Guidelines for the Development and Acceptance of a New Aviation Fuel Specification for Spark-Ignition Reciprocating Engines."

1.4 The procedures, tests, selection of materials, engines, and aircraft detailed in this guide are based on industry expertise to give appropriate data for review. Because of the diversity of aviation hardware and potential variation in fuel/additive formulations, not every aspect may be encompassed and further work may be required. Therefore, additional data beyond that described in this guide may be requested by the ASTM task force, Subcommittee J, or Committee D02 upon review of the specific composition, performance, or other characteristics of the candidate fuel or additive.

1.5 While it is beyond the scope of this guide, investigation of the future health and environmental impacts of the new aviation gasoline or new aviation gasoline additive and the requirements of environmental agencies is recommended.

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

1.6.1 *Exception*—Some industry standard methodologies utilize imperial units as their primary system (permeability; Table A2.1).

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

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D86 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
D97 Test Method for Pour Point of Petroleum Products
D156 Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)
D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)
D381 Test Method for Gum Content in Fuels by Jet Evaporation
D395 Test Methods for Rubber Property—Compression Set
D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
D471 Test Method for Rubber Property—Effect of Liquids
D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
D873 Test Method for Oxidation Stability of Aviation Fuels (Potential Residue Method)

[1] This guide 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.

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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.

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

D892 Test Method for Foaming Characteristics of Lubricating Oils
D909 Test Method for Supercharge Rating of Spark-Ignition Aviation Gasoline
D910 Specification for Leaded Aviation Gasolines
D924 Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
D943 Test Method for Oxidation Characteristics of Inhibited Mineral Oils
D1002 Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)
D1056 Specification for Flexible Cellular Materials—Sponge or Expanded Rubber
D1094 Test Method for Water Reaction of Aviation Fuels
D1298 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
D1331 Test Methods for Surface and Interfacial Tension of Solutions of Paints, Solvents, Solutions of Surface-Active Agents, and Related Materials
D1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
D1621 Test Method for Compressive Properties of Rigid Cellular Plastics
D2240 Test Method for Rubber Property—Durometer Hardness
D2344/D2344M Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates
D2386 Test Method for Freezing Point of Aviation Fuels
D2500 Test Method for Cloud Point of Petroleum Products and Liquid Fuels
D2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor
D2624 Test Methods for Electrical Conductivity of Aviation and Distillate Fuels
D2700 Test Method for Motor Octane Number of Spark-Ignition Engine Fuel
D2717 Test Method for Thermal Conductivity of Liquids
D2896 Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration
D3339 Test Method for Acid Number of Petroleum Products by Semi-Micro Color Indicator Titration
D3359 Test Methods for Rating Adhesion by Tape Test
D3525 Test Method for Gasoline Diluent in Used Gasoline Engine Oils by Gas Chromatography
D3652 Test Method for Thickness of Pressure-Sensitive Tapes
D3762 Test Method for Adhesive-Bonded Surface Durability of Aluminum (Wedge Test)
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
D4308 Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter
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
D5188 Test Method for Vapor-Liquid Ratio Temperature Determination of Fuels (Evacuated Chamber and Piston Based Method)
D5191 Test Method for Vapor Pressure of Petroleum Products (Mini Method)
D5762 Test Method for Nitrogen in Petroleum and Petroleum Products by Boat-Inlet Chemiluminescence
D5972 Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)
D6053 Test Method for Determination of Volatile Organic Compound (VOC) Content of Electrical Insulating Varnishes
D6227 Specification for Unleaded Aviation Gasoline Containing a Non-hydrocarbon Component
D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
D6424 Practice for Octane Rating Naturally Aspirated Spark Ignition Aircraft Engines
D6469 Guide for Microbial Contamination in Fuels and Fuel Systems
D6812 Practice for Ground-Based Octane Rating Procedures for Turbocharged/Supercharged Spark Ignition Aircraft Engines
D7096 Test Method for Determination of the Boiling Range Distribution of Gasoline by Wide-Bore Capillary Gas Chromatography
D7547 Specification for Hydrocarbon Unleaded Aviation Gasoline
E659 Test Method for Autoignition Temperature of Chemicals
E1259 Practice for Evaluation of Antimicrobials in Liquid Fuels Boiling Below 390°C

2.2 *EI Standards:*[3]
EI 1529 Aviation fuelling hose and hose assemblies
EI 1581 Specification and qualification procedures for aviation jet fuel filter/separators
EI 1583 Laboratory tests and minimum performance levels for aviation fuel filter monitors
EI 1590 Specifications and qualification procedures for aviation fuel microfilters

2.3 *MODUK Standard:*[4]
MODUK DEF STAN 80-97 Paint System, for the Interior of Bulk Fuel Tank and Fittings, Multi-Pack

2.4 *ISO Standards:*[5]
ISO 1825 Rubber hoses and hose assemblies for aircraft ground fuelling and defuelling—Specification

[3] Available from Publications Team, Energy Institute, 61 New Cavendish St., London W1G 7AR, UK, http://www.energyinst.org.
[4] Available from UK Defence Standardization, Kentigern House, Rm. 1138, 65 Brown St., Glasgow G2 8EX.
[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

ISO 20823 Determination of the flammability characteristics of fluids in contact with hot surfaces—Manifold ignition test

2.5 *UL Standard:*[6]

UL 94 Standard for Safety of Flammability of Plastic Materials for Parts in Devices and Appliances Testing

2.6 *Federal Standards:*[7]

DOT/FAA/AR-03/21 Characterization of In-Plane, Shear-Loaded Adhesive Lap Joints: Experiments and Analysis

DOT/FAA/AR-06/10 Guidelines and Recommended Criteria for the Development of a Material Specification for Carbon Fiber/Epoxy Fabric Prepregs

14 CFR Part 33:49 Block Tests; Reciprocating Aircraft Engines—Endurance Test

Fed-Std-791 Testing Method of Lubricants, Liquid Fuels, and Related Products

MIL-S-8802 Sealing Compound, Temperature-Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High-Adhesion

2.7 *SAE Standards:*[8]

SAE AMS-C-6183 Cork and Rubber Composition Sheet; for Aromatic Fuel and Oil Resistant Gaskets

SAE AS4842 Fittings and Bosses, Pipe Threaded, Fluid Connection

SAE AMS 7276 Rubber: Fluorocarbon (FKM) High-Temperature-Fluid Resistant Low Compression Set for Seals in Fuel systems and Specific Engine Oil Systems

2.8 *IP Standards:*[9]

IP 12 Determination of Specific Energy

IP 15 Determination of Pour Point

IP 16 Determination of Freezing Point of Aviation fuels—Manual Method

IP 69 Determination of Vapour Pressure—Reid Method

IP 71 Transparent and Opaque Liquids—Determination of Kinematic Viscosity and Calculation of Dynamic Viscosity

IP 119 Knock Characteristics of Aviation Gasolines by the Supercharged Method

IP 123 Determination of Distillation Characteristics at Atmospheric Pressure

IP 138 Determination of Oxidation Stability of Aviation Fuel Potential Residue Method

IP 160 Crude Petroleum and Liquid Petroleum Products—Laboratory Determination of Density— Hydrometer Method

IP 196 Determination of Colour (ASTM scale)

IP 219 Determination of Cloud Point

IP 236 Determination of Knock Characteristics of Motor and Aviation Fuels—Motor Method

IP 274 Determination of Electrical Conductivity of Aviation and Distillate Fuels

IP 365 Crude Petroleum and Petroleum Products—Determination of Density—Oscillating U-tube Method

IP 394 Liquid Petroleum Products—Vapour Pressure—Part 1: Determination of Air Saturated Vapour Pressure (ASVP) and Calculated Dry Vapour Pressure Equivalent (DVPE)

IP 435 Determination of the Freezing Point of Aviation Turbine Fuels by the Automatic Phase Transition Method

3. Terminology

3.1 *Definitions:*

3.1.1 *additive, n—in aviation gasoline,* substance added to a base aviation gasoline in relatively small amounts that either enables that base aviation gasoline to meet the applicable specification properties or does not alter the applicable specification properties of that base aviation gasoline beyond allowable limits.

3.1.2 *aviation gasoline, n*—fuel derived from petroleum or non-petroleum materials possessing specific properties suitable for operating aircraft powered by spark-ignition piston engines.

3.1.2.1 *Discussion*—Principal properties include combustion, fluidity, volatility corrosion, stability, water shedding, and detonation-free performance in the engine (or engines) for which it is intended. In the context of this guide, the terms fuel and gasoline are interchangeable.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *critical altitude, n*—maximum altitude at which, in standard atmosphere, it is possible to maintain at a specific engine revolutions per minute (RPM), a specified power, or a specified manifold pressure.

3.2.1.1 *Discussion*—Unless otherwise stated, the critical altitude is the maximum altitude at which it is possible to maintain, at the maximum engine RPM, one of the following:

(1) The maximum continuous power, in the case of engines for which this power rating is the same, at sea level and at the rated altitude, or

(2) The maximum continuous rated manifold pressure, in the case of engines, the maximum continuous power of which is governed by a constant manifold pressure.

3.2.2 *fit-for-purpose (FFP), adj—in aviation gasoline*, describes a condition of acceptance of an aviation fuel or aviation fuel additive that signifies acceptable performance in existing and future aircraft and aircraft engines, but not necessarily all existing or future aircraft and engines.

3.2.3 *fit-for-purpose properties, n*—characteristics of an aviation fuel or aviation fuel additive in the fuel that are not controlled by the fuel specification or specification properties but that are specified for evaluation in addition to the specification properties to provide a comprehensive assessment of the suitability of an aviation fuel for use on existing or future aircraft and aircraft engines, but not necessarily all existing or future aircraft and engines.

3.2.4 *sponsor, n*—entity submitting a new fuel or new fuel additive for review.

4. Summary of Practice

4.1 This guide gives sponsors of a new aviation gasoline or aviation gasoline additive guidance on evaluation procedures

[6] Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, http://www.ul.com.

[7] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

[8] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

[9] Available from Energy Institute, 61 New Cavendish St., London, W1G 7AR, U.K., http://www.energyinst.org.

using both laboratory and aircraft equipment. This guide includes requirements that address the following subjects:

4.1.1 Basic specification properties;

4.1.2 Fit-for-purpose properties, including compatibility with other aviation gasolines and aviation piston-engine lubricants;

4.1.3 Materials compatibility;

4.1.4 Aircraft component bench or rig testing;

4.1.5 Engine test cell evaluation; and

4.1.6 Aircraft flight test evaluation.

4.2 The procedure for new aviation gasolines is organized into Phase 1 and Phase 2. Details of the two phases are described below:

4.2.1 Phase 1 is intended to provide data and information sufficient to provide an initial understanding of the performance and properties of the candidate new aviation gasoline and to help guide the subsequent Phase 2 testing. A preliminary data package produced in accordance with 6.2 of this guide and an associated draft specification should be prepared to support the initial ASTM task force and subcommittee review. The preliminary data package and the draft specification should be submitted for subcommittee review in an initial ballot.

4.2.2 Phase 2 consists of the development of the final data set and the balloting of the ASTM Research Report and proposed specification to the subcommittee and/or committee. Based on feedback from the subcommittee in response to the initial ballot, the preliminary data should be supplemented with data developed in accordance with 6.3 of this guide. The entire data set should then be compiled in an ASTM Research Report and balloted along with the proposed specification to the subcommittee and/or committee.

4.3 The procedure to evaluate new aviation gasolines or aviation gasoline additives is progressive and iterative in nature with the extent of continued testing determined by the fuel properties, characteristics, and test results revealed at each successive stage. The extent of testing can be expected to grow with increasing degree of divergence from the properties, performance, and experience with existing aviation gasolines. This degree of divergence and its consequences are evaluated during the analysis of data provided in the preliminary data package or the research report.

4.4 The procedure for new aviation gasoline additives consists of test specification, Fit For Purpose 1 (FFP-1) and, where appropriate, Fit for Purpose 2 (FFP-2) testing.

5. Significance and Use

5.1 This guide is intended for the developers or sponsors of new aviation gasolines or additives to describe the data requirements necessary to support the development of specifications for these new products by ASTM members. The ultimate goal of the data generated in accordance with this guide is to provide an understanding of the performance of the new fuel or additive within the property constraints and compositional bounds of the proposed specification criteria.

5.2 This guide is not an approval process. It is intended to describe test and analysis requirements necessary to generate data to support specification development. This guide does not address the approval process for ASTM International standards.

5.3 This guide will reduce the uncertainty and risk to developers or sponsors of new aviation gasolines or additives by describing the test and analysis requirements necessary to proceed with the development of an ASTM International specification for aviation gasoline or specification revision for an aviation gasoline additive.

5.4 This guide does not purport to specify an all-inclusive listing of test and analysis requirements to achieve ASTM International approval of a specification or specification revision. The final requirements will be dependent upon the specific formulation and performance of the candidate fuel and be determined by the ASTM International task forces and committees charged with overseeing the specification development.

5.5 This guide is intended to describe data to be used to make a determination of the suitability of the proposed fuel or additive for use on existing or future aircraft and engines, but not necessarily for use on all existing or future aircraft and engines.

5.6 This guide does not describe data requirements of other approving authorities, such as national aviation regulatory authorities, or of other organizations or industry associations. However, the data generated in the conduct of the procedure may be useful for other purposes or other organizations.

5.7 Over 200 000 piston-engine aircraft rely on Specification D910 lead-containing aviation gasoline (avgas) for safe operation. There has been an increase in the research and development of alternatives to Specification D910 gasolines as a result of environmental and economic concerns.

6. Procedure

6.1 *Special Considerations for Additives*—The following procedure is applicable to both aviation gasolines and aviation gasoline additives. Therefore, the terms "aviation gasoline," gasoline," and "fuel" will only be used to describe the test product unless special considerations exist for additives. When these special considerations for additives exist, they will be specified in the appropriate section of the procedure.

6.1.1 The additive's final chemistry, carrier solvent, recommended treatment level, location in the production or supply chain for treatment, and conditions for retreatment should be identified.

6.1.2 Complete information on the base fuel into which the additive is to be added should be provided. If the base fuel is fuel approved to current major aviation gasoline specifications such as Specifications D910, D7547, or D6227, this shall be noted and all further testing shall be done on fuel samples blended with locally available fuel.

6.1.3 All testing of additives, unless otherwise noted, should be conducted with base fuel containing 400 % (4×) of the maximum additive dosage.

6.2 *Phase 1: Draft Specification and Preliminary Data Package*—The tests and analysis in Table 1 should be conducted and the resulting data should be compiled for review by the task force and subcommittee.

6.2.1 *Pilot Production Report*—A report describing the simulated production, pilot plant ramp up, and/or production capability to confirm that adequate production capacity is available to support the test and analyses of this procedure. Ideally, several batches of fuel should be produced to reflect a range of specification properties to support "worst-case" testing of fuel for the below requirements.

6.2.2 *Basic Specification Properties*—These should be based on, but not be limited to Specification D910 Table 1 or Specification D7547 Table 1 properties. The basic specification property results for evaluation of additives should be compared to the corresponding data for the base fuel. Special focus should be provided for the following properties:

6.2.2.1 *Octane*—This requirement should consider the variations in the correlation between the motor octane test (Test Method D2700) and the rich rating test (Test Method D909) with actual engine anti-knock capability for unleaded fuels.

6.2.2.2 *Freezing Point*—Critical for flight safety (Test Method D2386).

6.2.2.3 *Distillation Curve*—Critical for adequate engine performance throughout the entire operability range, including engine starting. Provide distillation points of Specification D910, Table 1 or D7547, Table 1 (Test Method D86).

6.2.2.4 *Vapor Pressure*—Important for vapor lock and engine starting. Test at 38 °C (Test Method D5191).

6.2.2.5 *Net Heat of Combustion*—Determines aircraft range (Test Method D4809).

6.2.2.6 *Density*—Determines aircraft range, possible impact on structure, weight, and balance and its impact under different flight attitudes. Note that traditional density/range relationships are based on traditional hydrocarbon fuels. The relationships may change with different base compositions. Test at 15 °C (Test Method D4052).

6.2.2.7 *Water Reaction and Separation*—Important for control of water in fuel and confirm the absence of significant quantities of alcohol (Test Method D1094).

6.2.2.8 *Electrical Conductivity*—Fire safety (Test Methods D2624).

6.2.3 *Fuel Composition*—Detailed chemical analysis of hydrocarbons and trace materials. The composition of additives should be defined to the extent necessary to establish conformance of the products used for testing (GC X GC).

6.2.4 *Fit-For-Purpose Properties, Part 1 (FFP-1)*—The following FFP-1 tests should be performed to evaluate the fuel properties. The test results should be compared to the corresponding data for Specification D910 100LL or D7547 unleaded fuels. The FFP-1 results for evaluation of additives should be compared to the corresponding data for the base fuel.

6.2.4.1 *Distillation Characteristics*—A complete boiling point distribution and comparison of the distillation curve, residue, and loss with Specification D910 100LL per Test Method D86. Include simulated distillation to Test Method D7096.

TABLE 1 Phase 1—Summary of the Testing Required for the Preliminary Data Package and Draft Specification

Manufacturing Documentation		
Documentation covering manufacture, pilot plant or full scale, quality control, typical and "worst case" analysis.		
Laboratory Tests – Basic Specification Properties		
Test	Premise	ASTM Test Method
MON	Combustion anti-detonation quality	D2700/IP 236
Supercharge	Combustion anti-detonation quality	D909/IP 119
Freeze Point	Fluidity at low temperature/altitude	D2386/IP 16
Distillation	Engine starting and operability	D86/IP 123
Vapor Pressure	Combustion performance	D5191/IP 394
Net Heat of Combustion	Determines aircraft range	D4809/IP 12
Density	Aircraft range and structural considerations	D4052/IP 365
Water Reaction	Control of water in fuel	D1094
Electrical Conductivity	Fire safety	D2624/IP 274
Fuel Composition	Describes fuel composition	GC X GC
Laboratory Tests – Fit For Purpose Properties – Part 1		
Test	Premise	ASTM Test Method
Distillation Curve	Engine operability	D86/IP 123 and D7096
Liquid/Vapor Ratio	Fuel vaporization characteristics	D5188
Vapor Pressure	Fuel vaporization characteristics	D323/IP 69, or D5191
Viscosity	Fluidity at low temperature/altitude	D445/IP 71
Density	Aircraft range and structural considerations	D1298 or D4052
Water Solubility	Control of water in fuel	D6304/IP 160
Cloud Point	Fluidity at low temperature/altitude	D2500/IP 219
Pour Point	Fluidity at low temperature/altitude	D97/IP 15
Additional Tests		
Test	Premise	Refer to Sections
Preliminary Materials Compatibility	To ensure compatibility with aviation fuel handling, aircraft and engine components.	6.2.5
Optional Tests[A]		
Engine test[A]	To support laboratory data and demonstrate fuel performance in full size engine.	6.2.6
Flight test[A]	To support operational performance.	6.2.7

[A] These tests are not mandatory but may offer useful supporting data.

6.2.4.2 *Fuel Vaporization Properties*—Liquid/vapor ratio per Test Methods D5188 and vapor pressure per Test Methods D323 or D5191. Temperature for a vapor-liquid ratio of 20 should be reported. Temperatures of other vapor-liquid ratios may be requested.

6.2.4.3 *Viscosity*—Measure from freezing point to room temperature per Test Method D445.

6.2.4.4 *Density*—Measure over operating temperature range per Test Methods D1298 or D4052.

6.2.4.5 *Water Solubility*—Measure over operating temperature range per Test Method D6304.

6.2.4.6 *Low-Temperature Fuel Characterization*—Phase transition to freezing as compared to Specification D910 100LL freeze point per Test Method D2386/IP 16 or Test Method D5972/IP 435, cloud point per Test Method D2500 (IP 219), and pour point per Test Method D97 (IP 15).

6.2.5 *Preliminary Materials Compatibility*—Perform soak testing of two metallic materials from Table A2.1 (5052-0 aluminum, tube and AMS 4505 brass) and three nonmetallic materials from Table A2.2 (Buna – N (nitrile), fluorosilicone, and SAE AMS 7276 Viton) in accordance with the procedures described in Annex A2 to measure property changes such as percent volume change, hardness, tensile strength, and so forth.

6.2.6 *Engine Testing*—The basic specification property data and FFP-1 data should be compared to similar data for known aviation gasolines such as Specification D910 100LL. This analysis should be used to determine the engine model to be used for these tests.

6.2.6.1 New production or newly overhauled engines that have not been operated on any fuel other than the test fuel should be used for this testing. The engine should be broken in and exclusively operated on only the test fuel. Limited operation with other fuels may be permitted under controlled conditions if accompanied by purging run periods of acceptable duration.

6.2.6.2 *Performance and Operability Testing*—Engine-rated power, steady-state performance, transient performance, and starting should be evaluated on a dynamometer-equipped engine test stand that meets industry standards for facility configuration and instrumentation calibration. Performance data should be compared to the engine manufacturer's published performance data.

6.2.6.3 *Detonation Testing*—Detonation testing should be conducted in accordance with the procedures described in ASTM International Specifications D6424 and D6812. A detonation measurement system that uses piezoelectric sensors that are flush mounted in the combustion chamber, or a system found to be equivalent, should be used for this testing. Detonation threshold levels and measurement accuracy and sensitivity should be correlated to known systems.

6.2.7 The preliminary data package should provide data and summarize results of above fuel and engine testing. It should include the draft specification properties that are sufficient to control the performance of the fuel for testing in the next phase of this procedure. Both the draft specification and preliminary data package should be submitted as an initial ballot for determination of the additional testing required to support the eventual balloting of the new specification.

6.3 *Phase 2*—Upon completion of Phase 1, the following tests and analysis should be conducted and the resulting data should be compiled in an ASTM Research Report (see Table 2).

6.3.1 *Production Report*—A report describing the pilot plant or, preferably, a refinery/chemical plant production process. The fuel used in the following testing should be produced from representative production processes, including the fuel's blending components. Fuel produced for this phase should be derived from an integrated process from feedstock to finished fuel. Chemical facsimiles of production fuel or fuel produced in a manner not representative of finished production routes are not acceptable for development of an ASTM production specification.

6.3.2 *Fit-For-Purpose Properties, Part 2 (FFP-2)*—FFP-2 includes additional properties relating to engine and aircraft operability and performance and also includes properties relating to fuel handling and distribution. The data generated during this testing should be compared to corresponding data for Specification D910 100LL fuel properties. Differences from Specification D910 FFPs should be reconciled in the research report. The FFP-2 results for evaluation of additives should be compared to the corresponding data for the base fuel.

6.3.2.1 *Carburetor Icing*—A simulated or actual flight test evaluation of carburetor icing propensity of the candidate fuel. An example of carburetor testing may be seen in Coordinating Report No. AV-17-13.[10]

6.3.2.2 *Fuel Gauging and Capacitance*—Comparative analysis to 100LL per Test Methods D2624 or D4308.

6.3.2.3 *Conductivity and Static Charge Dissipation*—Comparative analysis to 100LL over the operating temperature range per Guide D4865.

6.3.2.4 Surface tension versus temperature compared to baseline test fluid per Test Method D1331.

6.3.2.5 Thermal conductivity versus temperature compared to baseline test fluid per Test Method D2717.

6.3.2.6 Dielectric constant versus density compared to baseline test fluid per Test Method D924. Users should be aware this test method includes the capacitance of the air which may contribute to variability in resulting test values.

6.3.2.7 Hot surface ignition temperature compared to baseline test fluid using FED-STD-791, Test Method D6053 Manifold Ignition Test, or ISO 20823.

6.3.2.8 Gum formation per Test Method D873.

6.3.2.9 *Potential Gums*—Test Method D873.

6.3.2.10 Water reaction per Test Method D1094.

6.3.2.11 *Microbial Contamination Susceptibility per Guide D6469 and Test Method E1259*—Since alkyl lead compounds are biocides, microbial growth has not generally been an issue in aviation gasoline containing lead compounds. However, microbial growth in lead-free aviation gasoline could become a concern. Microbial growth should be compared with Specification D910 fuels or suitably identified test fluid over ambient operating range and fuel compositional range.

6.3.2.12 Electrical conductivity per Test Methods D2624.

[10] Available from Coordinating Research Council, 5755 North Point Parkway, Suite 265, Alpharetta, GA 30022, www.crcao.org.

TABLE 2 Phase 2—Summary of Testing Required for the ASTM Research Report

Preliminary Data Package
Include all test data from Table 1 in the final ASTM Research Report.
Manufacturing Documentation
Documentation covering manufacture, pilot plant or full scale, quality control, typical and "worst case" analysis.

Laboratory Tests – Fit For Purpose Properties – Part 2

Test	Premise	ASTM Test Method
Carburetor Icing	Cold weather fuel system operation	Refer to 6.3.2.1
Fuel Gauging and Capacitance	Aircraft range measurement	D2624/IP 274 or D4308
Conductivity and Static Charge Dissipation	Fire safety	D4865
Surface Tension	Fuel system operation	D1331
Thermal Conductivity	Engine cooling	D2717
Dielectric Constant	Aircraft range measurement	D924
Hot Surface Ignition Temp	Engine durability	FED-STD-791 or ISO 20823
Gum Formation	Storage stability	D873/IP 138
Potential Gums	Storage stability	D873/IP 138
Water Reaction	Water control	D1094
Microbial Contamination	Contamination control	D6469
Electrical Conductivity	Fire safety	D2624
Fuel Weathering	Long-term fuel performance	User defined
Test Method Validation	Fuel performance control	Refer to 6.3.2.14
Additive Response and Compatibility	Fuel property control	Refer to 6.1 and Annex A1
100LL Fuel Compatibility	Fuel property control	Refer to 6.3.2.16
Lube Oil Compatibility	Engine durability	Refer to 6.3.2.17
Fuel Coloration	Mis-fueling control	D156 or D1500/IP 196
Health, Safety, and Environmental	Personnel health	Refer to 6.3.2.19
Toxicity		Refer to 6.3.2.20
Long Term Fuel Storage Stability	Storage stability	D873/IP 138
Laboratory Tests	Fuel property control	Refer to 6.3.2.22
Fuel Distribution System	Fuel quality control	Refer to 6.3.2.23
Component Compatibility		User defined
Emissions	Environmental impact	Refer to 6.3.2.24

Additional Tests

Test	Premise	Refer to Sections
Final Materials Compatibility	To ensure compatibility with aviation fuel handling, aircraft and engine components.	6.3.3
Component Testing		6.3.4
Aircraft Operation and Safety Tests		
Engine Test	To support laboratory data and demonstrate fuel performance in full size engine.	6.3.5
Flight Test	To support operational performance.	6.3.6

6.3.2.13 *Fuel Stability Over Time (Weathering)*—Evaluate for impact on fuel performance over long-duration storage, include anti-knock capability, cold starting, and so forth. The method for weathering the fuel and selection of data collected is user defined. The offeror is encouraged to obtain industry input on the weathering plan prior to execution.

6.3.2.14 *Test Method Validation*—Test methods and associated criteria are based on Specification D910. They need to be validated for applicability and accuracy with the new fuel. Additional and or replacement methods should be provided.

6.3.2.15 *Additive Response and Compatibility*—The new fuel should respond to currently approved additives in the same manner as existing fuels, such as Specification D910 100LL fuel. Typical additives are antioxidants, fuel system icing inhibitor (FSII), electrical conductivity, and corrosion inhibitor. Refer to Annex A1.

(1) New additives should be evaluated for compatibility with additives approved for the base fuel in accordance with Annex A1 and Annex A2.

6.3.2.16 *100LL Fuel Compatibility*—Data indicates that MON and other fuel properties may not vary linearly when mixing 100LL with other liquid fuels. Fuel blends need to be prepared representing the range of blend ratios with 100LL of 20:80, 30:70, 50:50, 70:30, and 80:20. Table 1 properties from Specifications D910, D7547, or D6227 as appropriate shall be confirmed at each blend ratio.

6.3.2.17 *Lubricating Oil Compatibility*—Assessment of the fuel's compatibility with lubricating oils approved for use with aviation piston engines. It is recommended the assessment to be accomplished by evaluating the oil from the engine Durability and Operability test (see 6.3.2*(1)*).

(1) Data from engine durability testing may be used to support this analysis. Sample the oil before (virgin sample for baseline), every 25 h during testing, and after the engine test using industry standard practices (Practice D4057). Execute a standard oil analysis including a spectrometric oil analysis program (SOAP) test for wear materials, physical properties changes including acid number (Test Methods D664 or D3339), base number (Test Method D2896), viscosity (Test Method D445), density (Test Methods D1298 or D4052), oil dilution with fuel (Test Method D3525), nitrogen (Test Method D5762), foaming (Test Method D892), oxidation (Test Method D943), and moisture content (Test Method D6304).

6.3.2.18 *Fuel Coloration*—Dyes need to be specified to produce fuel color. Variations in color need to be evaluated. If, by choice or availability, none of the current approved Specification D910 dyes are to be used, any proposed new dye should be evaluated in both Phase 1 and Phase 2.

6.3.2.19 *Health, Safety, and Environmental*—The fuel should meet health, safety, and environmental (HSE) criteria for sale to the general public. Examples include vapor exposure, skin exposure cancer risk, and spill/water table contamination (that is, methyl tertiary butyl ether (MTBE) issue). Additional information may be available from the Environmental Protection Agency (EPA). Other HSE requirements include the following:

(1) Flammability—Acceptable flammability range. Products with very broad range (for example, hydrogen) represent additional handling risk/explosive atmosphere. Visible flame on combustion, for example, alcohol fire may not be visible.

(2) Ignition Energy—Appropriate ignition energy. Very low ignition energy represents additional hazard from friction and so forth, for example, hydrogen.

(3) Autoignition Temperature—Suitable autoignition temperature and not unstable in storage (for example, peroxide risk). Compare to Specification D910 fuel, Test Method E659.

(4) Firefighting Media—Current firefighting media need to be effective.

(5) Static/Conductivity—Similar/better than current product. Risk of excessive static being generated/charge dissipation rate—hazard for over-wing refueling.

6.3.2.20 *Toxicity*—Does the fuel possesses mutagenic properties, is it classified as an irritant, and so forth? See MIL-HNDBK-510-1.[11]

(1) Combustion Products—Should be analyzed and compared to existing fuels such as Specification D910 100LL.

6.3.2.21 *Long-Term Fuel Storage Stability:*

(1) Long-term storage stability is covered by Test Method D873 tested as part of Specification D910 Table 1 and D7547 Table 1 properties.

(2) Dirt/Water Dropout—Allows dirt/water to partition from fuel at a similar rate to current product.

(3) Density—Density appropriate for storage/manual handling (drums).

6.3.2.22 *Laboratory Tests*—The fuel properties and quality should be controlled by laboratory tests, which are readily available. Currently available personal protective equipment (for example, flame-resistant meta-aramid material coats, gloves) should be appropriate for conducting specified laboratory tests.

6.3.2.23 *Fuel Distribution System Component Compatibility*—In addition to the fuel-wetted components in the aircraft (6.2.5), it is recommended that the fuel sponsor also consider the compatibility of the fuel with the fuel-wetted components present in the aviation gasoline fuel supply distribution system. The new fuel should not negatively impact the fuel-wetted materials. Negative effects include, but are not limited to, unacceptable swelling/shrinkage, unacceptable hardening or softening of components, corrosion or unacceptable impact on fuel delivery rates, and filter media or storage.

(1) A typical tank lining system such as the three-coat epoxy/amine adduct system should be tested.

(2) Filtration Compatibility—The performance of coalescer filters and monitors should be compared to performance with existing fuels such as Specification D910 100LL (see Annex A4).

6.3.2.24 *Emissions*—CO_2, CO, NOX, PM, benzene, polyaromatic hydrocarbons, total hydrocarbons (THC), vapor emissions and combustion products, by comparison with existing fuels such as D910 100LL under similar test conditions.

6.3.3 *Final Materials Compatibility*—Engine and aircraft fuel system polymer and metallic materials that are exposed to fuel should be evaluated for compatibility with the new fuel. The results of the compatibility testing should be compared to corresponding results or service experience of existing fuels, and any deviations from current material behavior should be reconciled.

6.3.3.1 Incompatibility may be indicated by unacceptable swelling or shrinkage, delamination, unacceptable hardening or softening, corrosion, or embrittlement.

6.3.3.2 Procedures for materials compatibility testing of aviation gasolines and aviation gasoline additives are provided in Annex A2.

6.3.3.3 A representative listing of piston engine aircraft materials is provided in Annex A3. Those materials tested for the preliminary materials compatibility requirement need not be retested for final materials compatibility.

6.3.3.4 An example procedure for compatibility testing of aircraft composite fuel tank materials may be found in Annex A5.

6.3.3.5 An example procedure for permeability testing of aircraft fuel tank bladder materials may be found in Annex A6.

6.3.4 *Component Testing:*

6.3.4.1 *Flame Speed*—Flame speed effects should be evaluated with a representative engine cylinder assembly. Particular attention shall be given to exhaust valve temperature, turbocharger inlet temperature, and exhaust valve seat condition in a worst-case engine or cylinder assembly. A determination of exhaust valve creep life response shall be made. In addition, changes in engine cooling demands, fuel consumption, effective ignition timing, performance, power train stresses, and vibration shall be determined in worst-case engine(s).

6.3.4.2 *Fuel-Gauging Equipment:*

(1) Modern aircraft use capacitance fuel gauges for reporting the fuel quantity. The gauge operates by using a low-voltage capacitor probe where the fuel acts as the dielectric. A low voltage current is applied to the sensing capacitor and the resulting charge is compared to a reference probe. As the fuel level increases, the charge on the senor probe increases. The difference between the sensing probe and the reference probe is measured using a voltmeter. The voltages are calibrated to fuel load, which is reported on the gauge.

(2) If the dielectric properties of the fuel are different, then the measured voltages will be different resulting in an incorrect fuel load reading. It is known, for example, that the presence of ethanol in the fuel load results in an incorrect fuel reading because the dielectric behavior of the fuel has been changed. Test fuel dielectric constant using Test Method D924 and compare to 100LL baseline.

[11] Available from the U.S. Government Printing Office, Superintendent of Documents, 732 N. Capital St., NW, Washington, DC 20402-0001.

6.3.5 *Fuel Performance Evaluation on Aircraft and Engines:*

6.3.5.1 A recommended portfolio of tests to be conducted on specific engine and aircraft models has been developed to evaluate the performance of the candidate fuel under actual operating conditions.

6.3.5.2 Each test is designed to evaluate specific performance characteristics of the candidate fuel but not all tests will necessarily be required for all candidate fuels. The tests to be conducted will be determined based on the properties of the candidate fuel under evaluation. In Table 3, a summary of these tests and the associated fuel performance characteristics the test is intended to address are provided. In the table, the E-series reference engine tests, and the A-series reference aircraft tests. A description of each of these tests and test articles to be used for the tests is provided in the following sections.

6.3.6 *Engine Testing*—Acceptable engine performance, durability, and operability, when operating with the new aviation gasoline, should be demonstrated on the aircraft piston engines identified in this section.

6.3.6.1 *General:*

(1) The testing should be performed on a dynamometer-equipped engine test stand that meets industry standards for facility configuration and instrumentation calibration unless otherwise noted.

(2) New production or newly overhauled engines that have not been operated on any fuel other than the test fuel should be used for Test E-1. Test E-2 should be performed with a new engine or an engine remanufactured to new engine specifications. For both tests, the engine should be broken in and exclusively operated on only the test fuel. Limited operation with other fuels may be permitted under controlled conditions if accompanied by purging run periods of acceptable duration.

(3) Each test engine should undergo a performance calibration before conducting the tests specified in the following.

6.3.6.2 *Engine Tests and Test Articles*—Engine models and the engine tests to be conducted on those models are shown in Table 4.

(1) Test E-1: Performance and Detonation

(a) A complete performance characterization of each engine should be performed on a dynamometer-equipped engine test stand to measure brake horsepower, exhaust gas temperature, RPM, and mixture strength relative to the performance charts published in the engine operating instructions.

(b) Detonation testing should be conducted in accordance with the procedures described in Specifications D6424 and D6812. A detonation measurement system that uses piezoelectric sensors that are flush mounted in the combustion chamber, or a system found to be equivalent, should be used for this testing. Detonation threshold levels and measurement accuracy and sensitivity should be correlated to known systems.

(c) Sea level detonation tests should be performed at rated engine power and engine settings defined by the manufacturer such as recommended climb power, maximum best cruise power, and maximum best economy power. Sea level detonation should be performed on naturally aspirated and turbocharged/supercharged engines.

(d) Detonation tests should be performed at critical altitude for 100 %, 75 % power for turbocharged or supercharged engines.

NOTE 1—Testing is performed based on where the engine is most likely to detonate. For normally aspirated engines, this is at sea level at which the highest manifold air pressure is achieved. For turbo/supercharged engines, this may be a critical altitude. The critical altitude is the highest altitude at which the stated power is attained. This is where the turbo/supercharger works the hardest and therefore produces the highest manifold air temperature. Sea level testing is required for both normally aspirated and turbo/supercharged engines.

(2) Test E-2: Durability and Operability Test—This is a long-duration engine test to evaluate the candidate fuel relative to durability, operability, deposit formation, starting, cooling, mixture distribution, and valve-train operation. The test should evaluate the fuel over the complete range of temperature and altitude conditions specified in the manufacturer's operating instructions. The following requirements apply to this test:

(a) This test may be performed in a propeller test stand only if evidence of acceptable performance calibration is provided.

(b) The test duration should be at least 300 h and include throttle transients, cruise conditions, and cold and hot starts. The specific duty cycle should be defined by the fuel sponsor and reviewed with the task force members for acceptability.

(c) Do not switch between unleaded and leaded fuels during the test.

(d) The test should address the ability of the fuel to form a combustible mixture under all operating conditions.

(e) The impact of the candidate fuel on engine cooling should be evaluated during the test.

TABLE 3 Fuel Tests and Associated Test Characteristics

	Test E-1 Performance and Detonation	Test E-2 Operability and Durability	Test A-1 Performance, Operability, and Durability	Test A-2 Hot Weather Operation	Test A-2b Cold Weather Operation	Test A-3 Detonation and Range
Volatility		X	X	X	X	
Fluidity		X	X		X	
Combustion	X	X		X	X	X
Corrosion		X	X			
Stability		X				
Lubricity		X	X			
Fuel/oil interaction (fuel dilution, CRC sludge rating)		X				

TABLE 4 Engine Tests and Test Articles

Test	Description	Lycoming TIO-540-J2BD Engine	Continental O-470-U Engine	Lycoming IO-540-K Engine	Rotax 912S
	Engine Model Key Characteristics	Turbocharged, nonintercooled, fuel injected, large displacement	Normally aspirated, carbureted, high compression, large displacement	Normally aspirated, fuel injected, high compression, large displacement	Normally aspirated, small displacement, High RPM, High compression, autogas approved
E-1	Performance and detonation	X	X	X	
E-2	Durability and operability		X		X

(f) The test should evaluate the impact of fuel deposits from the new fuel on the octane demand of the engine and pre-ignition tendency of the engine. Periodic detonation measurements with a leaded reference or baseline fuel at 50 h intervals should be included.

(g) Combustion (including peak cylinder pressure) may impact structural loading of critical engine components. If combustion pressure is different or ignition timing shall be adjusted or both, the resulting effect on both crankshaft torsional vibration and bottom end loading (crankcase, main bearings, and crankshaft) shall be addressed to document resulting loads and stresses are within allowable engine limits.

(h) Upon completion of the test, a comparison of pre- and post-test engine hardware condition and measurements should be conducted. Recommended measurements are shown in Table 5. For locations and direction of measurements, refer to the original equipment manufacturer (OEM) engine overhaul manual. The engine should be examined for evidence of discoloration of fuel- and oil-wetted parts, valve sticking, combustion chamber deposits, fuel system deposits, oil system deposits, exhaust system deposits, turbocharger deposits, carburetor deposits, and induction system.

6.3.7 *Aircraft Flight Testing*—Aircraft performance, operability, and range when operating with the new aviation gasoline should be demonstrated on the aircraft identified in this section.

TABLE 5 Engine Durability Measurements

Part/System/Component	Recommended Measurements/Inspections
Valve Train (exhaust and intake)	Stems, guides, stem-to-guide clearance, valve face runout, valve stem height, tappets, tappet bores, tappet-to-bore clearance, tappet hydraulic leak down. Inspect cam lobes, pushrods, rocker surfaces, rocker shaft to bearing clearance, and deposits.
Camshaft	Journals, bearings, journal-to-bearing clearances, and lobes.
Crankshaft	Main and crankpin journals, bearings, and journal-to-bearing clearances.
Piston and Cylinder	Bores, ring-side clearance and end gap, piston-to-cylinder clearance, pin hole, bushing, connecting rod, and deposits.
Fuel System	Nozzle, manifold, intake, carburetor deposits or coatings, and pumps.
Oil System	Deposits, sludge, and gear-driven pumps.

6.3.7.1 *General*—The aircraft fuel system should be flushed with a solvent-acting solution or fuel before initiation of flight testing. When operating with two fuels, the new fuel should be kept segregated from the reference fuel.

6.3.7.2 *Aircraft Tests and Test Articles*—Aircraft models and the flight tests to be conducted on those models are shown in Table 6.

6.3.7.3 *A-1 Performance, Operability, and Durability Test*—Aircraft flight testing should be conducted to evaluate the impact of the new fuel on aircraft performance, operability, and durability. The aircraft should be operated at conditions representing the extreme corners of the operational envelope specified by the OEM in the aircraft flight manual or pilot's operating handbook. The aircraft should be tested for a duration long enough to address the following items in a wide range of temperature conditions, including sufficient operation to identify trends in engine performance with accumulated operating time:

(1) Evaluate impact on fuel system materials;

NOTE 2—Non-operating time may be more important to evaluate compatibility than operating time.

(2) Demonstrate starting with hot fuel and demonstrate cold fuel altitude relights;

(3) Demonstrate smooth throttle transients at most severe operating envelope conditions;

(4) Comparison of induction system icing susceptibility between the new fuel and a reference fuel;

(5) Evaluate for normal engine operation during all approved aircraft maneuvers, for example, takeoff and landing, balked landing, and so forth;

(6) Measure and document the power produced during flight operation;

(7) Document any changes to equipment calibration that is required for the new fuel;

(8) Measure and document take off and cruise fuel consumption;

(9) Monitor and record any effects on engine cooling (CHT);

(10) Monitor and record any effects on exhaust gas temperature (EGT); and

(11) Monitor and record any effects on turbocharger performance.

6.3.7.4 *A-2 Hot Weather Operation Test*—Aircraft flight testing should be conducted to evaluate aircraft performance under high-temperature conditions. The following should be addressed during this testing:

TABLE 6 Aircraft Tests and Test Articles

Test	Description	Cessna 210 with TCM 520 Series Engine	Cessna 182 with Continental O-470 Series Engine	Piper Navajo Chieftain PA-31 with Twin TIO-540-J2B engines	Diamond DA-20- A1 with Rotax 912S3
	Aircraft Model Key Characteristics	High-wing, single-engine, high performance	High-wing, single-engine, moderate performance	Low-wing, twin-engine, high performance, turbocharged, non-intercooled	Low-wing, low-performance, fixed-pitch prop, autogas approved
A-1	Performance, operability, and durability		X		X
A-2a	Hot-day conditions	X			
A-2b	Cold-day conditions		X		
A-3	Detonation and range			X	

(1) Hot Fuel Test—Evaluate the performance of the aircraft with hot fuel during taxiing, takeoff, and climb.

(2) Vapor Lock Test—Demonstrate fuel system pumping capability in hot weather conditions.

6.3.7.5 *A-2b Cold Weather Operation Test*—Aircraft flight testing should be conducted to evaluate aircraft performance under low-temperature conditions. The following should be addressed during this testing:

(1) Starting and operability with cold fuel under cold weather conditions.

(2) Restarting at altitude with cold fuel under cold weather conditions.

6.3.7.6 *A-3 Detonation and Range Test*—Aircraft flight testing should be conducted to demonstrate adequate anti-knock capability of the new fuel and evaluate any impact on aircraft range when operating with the new fuel. The following should be addressed during this testing:

(1) Detonation testing should be conducted at high altitude under worst-case ambient conditions. The type, make, and accuracy of the detonation test instrumentations should be reviewed with the task force for acceptability.

6.3.8 *ASTM Research Report and ASTM Specification*—The research report should provide data and summarize results of above fuel and engine testing. The specification should be sufficient to control the performance of the fuel as a finished product. Both the research report and specification should be balloted to the ASTM subcommittee and committee for approval.

7. Keywords

7.1 additive evaluations; additive qualifications; alternative fuels; approval protocols; ASTM International; aviation gasolines; fuel additives; fuel evaluations; fuel qualifications; material compatibility

ANNEXES

(Mandatory Information)

A1. COMPATIBILITY OF CANDIDATE ADDITIVE WITH ADDITIVES CURRENTLY PERMITTED IN SPECIFICATIONS D910, D7547, D6227, OR OTHER APPROPRIATE AVIATION GASOLINE SPECIFICATIONS

A1.1 *Scope*—The following test program is required to determine the compatibility of a new additive with additives previously approved for use in aviation gasoline. Tests are conducted with aviation gasoline at four times the maximum additive concentration as recommended by the supplier or maximum level plus 10 % as appropriate.

A1.2 *Preparation of the Test Fuel*—Blend the candidate additive into 200 mL of the additive free blendstock of known properties, sourced from a manufacturing refinery, at four times the maximum recommended concentration or maximum blend level plus 10 % as appropriate. Blend each of the approved additives into the test fuel at two times the maximum recommendation concentration permitted by Specifications D910, D7547, D6227, or other appropriate base fuel specifications.

A1.3 *Test Procedure*:

A1.3.1 Prepare duplicate test blends by dividing the additive mixtures into two 100 mL, clear, tall glass containers.

A1.3.2 Place the duplicate samples into dark, cold storage at –17.8 °C for 24 h. At the conclusion of the 24 h storage period, remove the duplicate samples from cold storage and immediately inspect for indication of precipitation. Indications of precipitation include cloudiness, darkening, or other visible evidence of incompatibility. Document results by photographing the sample container.

A1.3.3 Allow the sample to warm to ambient temperature. Inspect for indication of precipitation. Document results by photographing the sample container.

A1.3.4 Shake the sample to remix any separated components. Heat the sample to 38 °C and maintain temperature for 24 h. At the conclusion of the 24 h storage period, allow the samples to cool to ambient temperature. Inspect for indication of precipitation. Document results by photographing the sample container.

NOTE A1.1—Keep the fuel samples in dark storage during conditioning and between inspections.

A2. EVALUATING COMPATIBILITY OF ADDITIVES OR FUELS WITH FUEL SYSTEM MATERIALS

A2.1 *Scope*—The following procedure is recommended to determine compatibility of a new fuel or new fuel additive with fuel-wetted nonmetallic materials, metals present in engine, and aircraft fuel systems.

A2.2 *Test Program*:

A2.2.1 *Entrance Criteria*—A complete chemical description of the candidate fuel or additive is required for defining the test program. If the new material is an additive, its carrier solvent and recommended concentration shall also be provided.

A2.2.2 *Blend Concentration if Evaluating a New Fuel Additive*—Fuel additive concentration for the material compatibility tests shall be tested at 4× the concentration being sought or the maximum concentration plus 10 % as appropriate. The additive shall be blended into at least one of the two baseline reference fluids described in A2.2.3. Back-to-back tests shall be performed on the additive blend and a control sample consisting of the baseline reference fuel without the additive. The purpose of the control sample is to provide a baseline for comparison.

A2.2.3 *Baseline Test Fluids*—Testing should be performed in a fully characterized comparative base fluid. This could be a locally procured aviation gasoline per Specification D910 that has a full CoA or that has been fully characterized by a laboratory. Regardless of the choice of baseline fuel, the fuel needs to be fully characterized before use in testing.

A2.2.4 *Test Materials:*

A2.2.4.1 Table A2.1 is a list of fuel-wetted metallic materials and Table A2.2 is a list of fuel wetted nonmetallic materials. Table A2.3 lists materials found in aircraft fuel tanks and ground supply vehicles. Table A2.4 contains part numbers representative of the materials used in Cessna aircraft fuel systems with both Lycoming and Continental engine installations. Tables A2.5 and A2.6 contain part numbers representative of the materials used in Continental engines.

A2.2.4.2 *Composition of the Materials List*—This list contain examples of classes of materials for testing, not necessarily every individual material. For example, many different polysulfide sealants are used in fuel tanks. Rather than test them all, a representative manganese dioxide cured product and a representative chromate cured product were selected. The engine manufacturers and airplane manufacturers have agreed to these generic classes of materials for the purpose of evaluating compatibility with fuels and fuel additives. Materials known to be sensitive to a specific fuel or additive chemistry should be tested first.

TABLE A2.1 Metallic Materials

Material	Size
1100 aluminum	⅛ in., 1 in. × 3 ft
2017 aluminum	¾ in. aluminum fitting
2024-T3 aluminum	¼ in., 12 in. × 12 in.
2024-T351 aluminum, hard anodize	1 in. × 12 ft
2024-T4 aluminum, hard anodize and dry film lubricant coated	1 in. × 12 ft
5052-0 aluminum	⅛ in., 1 in. × 3 ft
6061-T6 aluminum anodized	1⁄16 in., 12 in. × 12 in.
7075 aluminum	¼ in., 1 in. × 3 ft
AMS 4505 brass (~C260)	1⁄16 in., 12 in. × 12 in.
AMS 4610 brass (~C360)	1⁄16 in., 1 in. × 3 ft
CA122 (ASTM B187) brass	1 in. × 12 ft
C46400 brass	1 in. × 12 ft
Phosphor bronze 510	1⁄16 in., 12 in. × 12 in.
Copper	1⁄16 in., 1 ft × 3 ft
Lead	⅛ in., 12 in. × 12 in.
Monel	1⁄16 in., 12 in. × 12 in.
Nickel plating, electro, QQ-N-290A over cold rolled steel	1 in. dia washers
Chrome plate, over steel	1 in. dia washers
Tin plate, ASTM B545, Class B (Bright) over cold rolled steel	1 in. dia washers
Zinc plate ASTM B633 SC2, Type 2 over cold rolled steel	1 in. dia washers
1010 Steel, cadmium plate	1 in. dia washers
17-4 PH steel, passivate	¼ in., 1 in. × 3 ft
303 steel	⅛ in., 1 in. × 3 ft
316 steel, passivate	1 in. dia × 1 ft
321 steel, passivate (stainless)	0.032 in., 12 in. × 12 in.
416 stainless steel	1 in. × 1 ft
440C steel	¼ in., 1 in. × 3 ft
Chrome steel (4140 Alloy)	¼ in., 1 in. × 3 ft
52100 bearing steel	1 in. dia × 1 ft
AMS 4750, QQ-S-571-SN63 lead tin solder	0.125 in. diam
Silver braze	1⁄16 in., 18 in. rod
Plated music wire (springs) RSA Carburetor P/N CF24-A10	Each

A2.2.5 *Test Temperatures*—Materials are to be tested at the highest temperature to which they will be subjected for their specific application within an aircraft and engine fuel system. Testing at temperatures beyond these maximums results in diminished baseline material performance and significantly reduces test sensitivity. Some appropriate test temperatures for the nonmetallic materials are provided in Table A2.2.

A2.2.6 *Screening Tests:*

A2.2.6.1 Laboratory-scale soak tests shall be performed on the list of materials compiled in Table A2.1 and Table A2.2. Soak temperatures, test methods, and acceptance criteria are called out in the respective tables. The soak period is 28 days. The test fluid shall be changed out every 14 days with fresh test fluid.

A2.2.6.2 The tests called out in Table A2.2 compare changes in properties, for example, tensile strength, of materials soaked in the new fuel (or new fuel additive blend) to that of materials soaked in a baseline reference fuel(s). The tests are intended to be a first-level screening to identify potential compatibility problems. If tests results are within allowable variation as defined in the evaluation criteria for each material, then the risk level of the new fuel or fuel additive is considered minimal.

A2.2.7 *Procedure for Soaking (Aging) Test Materials in Fuel:*

A2.2.7.1 *Material Procurement for the Soak Procedure:*

(1) Sealant, coating, composite, and adhesive materials are typically procured in their raw (uncured) form. This often consists of a two-part mixture, prepreg, or film. This then relies on the expertise of the laboratory performing the testing to be able to fabricate the specimens required for the various tests. For example, once prepared, sealant specimens are required to be cured in environmentally controlled rooms (23.8 °C and 50 % relative humidity) and the composites are cured in an autoclave.

(2) Adhesive lap shear testing is done using aluminum adherents with the manufacturer's recommended surface preparation and cure cycle.

(3) Bladder, hose, foam, and wire insulation materials are procured as a sheet of the material from the applicable vendor. These sheets are then used to die out (cut out) the specimens required for the testing. For example, an ASTM specified dog-bone shaped cutter is used to obtain dog-bone specimens for tensile and elongation testing.

(4) O-rings are also obtained directly from the vendors that manufacture materials meeting the various specifications.

(5) Metallic specimens are obtained from various sources who can certify the materials to meet the applicable specifications. Typically, three specimens of each material are used in the aging of the metallic specimens. These specimens are roughly 2.5 cm by 5 cm where practical. Thickness is not relevant as only surface effects are being evaluated. Samples may have a hole drilled into them prior to test to facilitate hanging samples. Samples procured as parts may be used as received.

A2.2.7.2 *Fuel Soak:*

(1) Materials are typically exposed to the fuel in separate glass mason jars (0.946 L, quart size). For example, the tensile and elongation and volume swell specimens of the AMS-S-8802 polysulfide sealant are aged in a separate jar from the AMS-3281 lightweight polysulfide tensile and elongation and volume swell specimens. Specimens of different materials are not aged in the same container because it is possible that components may leach out into the fuel and react with other material specimens or components.

(2) Tensile and elongation, volume swell, and hardness specimens shall be suspended in the fuel and not just laid in the bottom of the jar. This can be done by using a rack and wires to hang the specimens and then place in the jar.

(3) A piece of foil is placed over the mouth of the jar and then the lid is screwed into place to prevent evaporation of the fuel while aging. The foil should extend roughly 2.5 cm over all sides of the mouth of the jar. The heating of the quart jars is done using explosion-proof ovens. These ovens can hold a large number of jars, so many specimens requiring the same temperature can be aged simultaneously.

(4) Fuel change out, that is, replacement of old fuel with fresh fuel, shall be performed after 14 days for the 28 day aging of nonmetallic specimens and after 7 days for the metallic specimens. Change out of the fuel is necessary because properties of the fuel can change significantly when exposed to high temperatures for an extended period of time.

A2.2.8 *Types of Tests to be Performed after 28-Day Soak Period:*

TABLE A2.2 Nonmetallics

Material	Size (inches)	Test[A]	Temperature, °C
Buna-N/vinyl (white)	⅛ in. thick, 12 in. × 12 in.	(T, D, DC, S, V)	71
BunaN (Nitrile) Abrasion resistant (orange)	18 in., 12 × 12, 52A duro	(T, D, DC, S, V)	71
BunaN (Nitrile) Med (black)	⅛ in., 12 in. × 12 in.	(T, D, DC, S, V)	71
Nitrile (foam)	⅛ in., 40 in. × 68 in.	(T, D, DC, S, V)	71
Phenolic	⅛ in., 24 in. × 48 in.	(T, D, DC, S, V)	71
ABS Thermoplastic (Acrylonitrile Butadiene styrene)	⅛ in., 12 in. × 12 in.	(T, D, DC, S, V)	71
Cork, plain back	⅛ in., 12 in. × 36 in.	(T, D, DC, S, V)	71
Cork, neoprene	⅛ in., 12 in. × 36 in.	(T, D, DC, S, V)	71
Nyon 6/6	⅛ in., 6 in. bar	(D, DC, S, V)	71
Glass-filled Nylon 6	¼ in., 12 in. × 12 in.	(D, DC, S, V)	71
Leather	RSA Carb leather seal	(D, DC, S, V)	71
Safety Foam	1 in., 12 in. × 12 in.	(D, DC, S, V)	71
PR 1440 B-2 Polysulfide AMS-S-8802 CL B2	Comes in tubes, needs to be specialty cured	(T, D, DC, S, V)	71
PR-1773 B-2 Polysulfide AMS 3284	Comes in tubes, needs to be specialty cured	(T, D, DC, S, V)	71
P/S 890 A-2 Polysulfide, AMS 8802	Comes in tubes, needs to be specialty cured	(T, D, DC, S, V)	71
Aerospace Sealant AC-350 B-2 Polysulfide, AMS 3276	Comes in tubes, needs to be specialty cured	(T, D, DC, S, V)	71
Fairprene RSA carb seal P/N 626536 fuel manifold valve	Each	(D, DC, S, V)	71
Fluorosilicone	⅛ in., 12 ft × 12 in.	(T, D, DC, S, V)	93
Polyester sheet	¼ in. thick, 6 in. × 6 in.	(T, D, DC, S, V)	93
Neoprene	⅛ in., 12 × 12, 60A duro	(T, D, DC, S, V)	93
Viton A (FKM)	⅛ in., 12 × 12, 75A duro	(T, D, DC, S, V)	93
Polyester film (Mylar)	0.010 in., 40 in. × 10 ft	(T, D, DC, S, V)	93
Silicone	0.040 in., 12 in. × 12 in., 55A	(T, D, DC, S, V)	93
Teflon (adhesive ready)	⅛ in., 12 in. × 12 in.	(T, D, DC, S, V)	93
Polypropylene (flame retardant	¼ in., 6 in. × 6 in.	(T, D, DC, S, V)	93
Fiberglass Fabric reinforced silicone	⅛ in., 12 in. × 12 in.	(T, D, DC, S, V)	93
Epichlorohydrin - foam	⅛ in., 35 in. × 45 in.	(T, D, DC, S, V)	93
ASTM D710 vulcanized fibre (red)	0.125 in. thick, 4.5 ft × 7 ft	(T, D, DC, S, V)	93
Polyurethane	⅛ in., 12 in. × 24 in.	(T, D, DC, S, V)	93
Fuel Bladders	See bladder test	(D, DC, S, V)	93
Low Pressure Rubber hose (MIL-H-6000)(feet)	½ in. O.D., 24 in.	(D, DC, S, V)	71
Med. Pressure Metal Braided hose (MIL-H-8794) (feet)	½ in. O.D., 24 in.	(D, DC, S, V)	71
Med. Pressure PTFE hose (MIL-DTL-27267)	½ in. O.D., 24 in.	(D, DC, S, V)	71
Epoxy carb floats	Set	(D, DC, S, V)	71
3M Scotch Weld Epoxy adhesive, EC2216	Each	(L, V)	93
Hysol EA9628 Epoxy adhesive	36 in. × 167 in.	(L, V)	93
BMS fuel tank epoxy primer	12 in. × 12 in.	Adhesion cohesion	93
Akzo fuel tank epoxy primer	12 in. × 12 in.	Adhesion cohesion	93
Loctite 290	Each	Breaking torque	93
Loctite 569 (dimethacrylate ester)	Each	Pipe thread	93

[A] Test Key:

(T)	Tensile ⁄elongation	D412, Section 12
(D)	Durometer—Shore A	D2240
(DC)	Density change	D471
(S)	Volume swell/dimensional change	D471
(V)	Visual inspection	None
(L)	Lap shear	D1002

TABLE A2.3 Distribution System Materials

Material	Manufacturer	Product Name
Distribution tank sealant	Hempel Marine Paint	Hempadour 1540 systems
Storage tank internal lining		Epoxy to MODUK 80-97
Aircraft fueling hose		EI 1529/ISO 1825 types
Fuel filters		Microfilters to EI 1590
Water separators		Filter water separators to EI 1581
Filter monitors		Filter monitors to EI 1583

A2.2.8.1 *Nonmetallic Materials*—Examples of the tests to be performed on the nonmetallic materials listed in Table A2.2 include the following:

(1) Lap Shear—Test Method D1002;

(2) Cohesion;

(3) Volume swell—Test Method D471, Section 12;

(4) Tensile—Test Methods D412, Section 12;

(5) Elongation—Test Methods D412, Section 12;

(6) Tape adhesion—Test Methods D3359;

(7) Hardness—Test Method D2240;

(8) Peel strength;

(9) Laminar shear;

(10) Compression set;

(11) Resistivity; and

(12) Visual inspection.

A2.2.8.2 *Metals*—Exemplar test soak temperature shown in Table A2.7. Tests to be performed are described in A2.2.8.3 and A2.2.8.4.

TABLE A2.4 Cessna Materials

NOTE 1—Table contains full parts lists. The sponsor should only be concerned with those that are actually fuel-wetted.

Cessna Part Number	Description	Material	Finish
0522644	Structure and Equipment Fuel		
	Wing Skins	Alclad 2024-T3 aluminum	Epoxy primer
NAS680A3	Nut plates	Alloy steel	Cadmium plate
MS20470AD	Rivets	2117-T3 aluminum	Clear anodize or chemical film
847	3M Scotch-Grip	Acrylonitrile-butadiene polymer	
S3331–1	Fuel Quantity		
	Body	380 aluminum die casting	
	Float Rod	Tempered aluminum	
	Float	Nitrophyl	
	Electrical	Brass/copper	
C156003–0101	Fuel Cap		
	Body	Die cast zinc	Red epoxy paint (exterior only)
	Shim	Nylon sheet	
	Seal	Neoprene rubber	
	Locking Tab	4130 steel	Cadmium plate
	Sniffle Valve	2024-T3 aluminum	
	Sniffle Valve	Silicone rubber	
0716614–9	Vent Tube	Nylon tube	
0726012–10	Welded Vent	5052-0 aluminum	Chemical film and epoxy primer
0726012–1	Fuel Strainer		
0726012–3	Tube and	5052-0 aluminum	Chemical film and epoxy primer
1526007–5	Screen	0.018-12 mesh monel or 304 stainless wire screen	
S2359–1	Swing Check		
	Body and Seal	Aluminum	Anodize
	Hinge, Pin, and	Stainless steel	Passivate
	Seal	Flurosilicone	
0523554	Gaskets	MIL-C-6183 cork/rubber	
1726048–2	Boss-Fuel	2024-T351 aluminum	Chemical film and epoxy primer
S2020–2	Fuel Drain Valve		
	Body and	Alloy steel	Cadmium plate
	Spring	Alloy steel	Cadmium plate
NA51593	"O" ring seals	Parker V747–75 or V884–75 fluorocarbon	
PR-1440	Tank Sealant-B2	Courtoulds Aerospace—Polysulfide sealant per MIL-S-8802	
0500423 and 2400010	Line Assemblies		
	Tube (0.375	5052–0 aluminum	
	End Fittings (AN	Aluminum (ref proc Spec SAE AS4842)	Anodize
AN and MS Style	Fluid Fittings	Aluminum (ref proc Spec SAE AS4842)	Anodize
S1495–6	Hose	Buna-N inner tube, rayon braid, and neoprene outer cover	
S1891–6	Clamp	302 (1808) stainless steel	Passivate
9851096–5	Fuel Selector		
9851066–2	Cover	Nylon	
9851094–1	Rotor	2024-T351 aluminum	Hard anodize
9851095–1	Body	2024-T4 aluminum	Hard anodized and dry film lubricant
9851097–1	Seal	CCM100 Type II polyester	
S1358–2	Washer—Shim	Type A "Mylar" polyester film	
S2385–5	Washer	AMS-4045 brass	
LCO-045G1	Spring	Steel music wire	Cadmium plate
NAS1593	"O" Ring	Parker V747–75 or V884–75	
NAS1596	"O" Ring	Parker V747–75 or V884–75	
S2485–1	Drain Valve		
	Body	Aluminum	Anodize
	Stem	Brass	Cadmium plate
	Spring	Stainless steel	Passivate
	Seal	Parker N406–60 nitrile rubber	
ULA-022	Fuel Reservoir Assembly		
ULA-022-7	Fuel Reservoir Assembly Pump module	5052–0 and 6061–T6 aluminum	
ULA-022-6	Body	356–T6 aluminum casting	
3405-XX	Bypass Valve		
	Body and Seal	Aluminum	Anodize
	Hinge Pin and	Stainless steel	Passivate
	Seal	Fluorosilicone	
532A-6 D·32	Relief Valve		
	Body, Poppet, and	2024–T4 aluminum	Anodize
	Spring	Stainless steel	Passivate
	Seal	SAE AMS 7276 viton (fluorocarbon)	
ULA-022	Fuel Reservoir and Pump		
ULA-022-12	Fuel Pick-up		
	Tube and Pick	5052–0 and 6061-T6 Aluminum	

TABLE A2.4 *Continued*

	End Fittings (AN	Aluminum (ref proc SAE AS4842)	Anodize
	Fitting—Pump	Brass	
P-88	Fuel Pump (Borg-Warner)	Standard automotive in-tank fuel pump used for base-line development tests	
SAE30R5Kx	Hose—Pump to Fitting	Buna N inner tube, rayon braid, and neoprene outer cover	
S2357–1	Clamp	Stainless steel	
AN815–8D	Union—Outlet Port	Aluminum (ref proc SAE AS4842)	
NAS1593	"O" Rings	Parker V747–75 or V884–75 fluorocarbon	
S2106–2	Drain Valve		
	Body and Stem	Alloy steel	Cadmium plate
	Spring	Stainless steel	Passivate
	Seal	Parker N406–60 nitrile	
S1903–2 (0716111–	Fuel Shut-off		
	Body	2024-T4 aluminum	Chemical film
	Rotor	17–4 PH stainless steel Cond H900	Passivate
	Seal	Nylon	
	Cover	1010 steel	Cadmium plate
	Spring	Steel music wire	Cadmium plate
	"O" Rings	Parker V747–75 or V884–75 fluorocarbon	
AE7010000H0120	Hose Assembly		
	Hose	Aeroquip AE701 (AQP) hose with synthetic rubber inner liner and stainless steel wire braid outer reinforcement	
	Swivel End	6061-T6 aluminum	Anodize
0516029–1	Fitting—Firewall	321 stainless steel	Passivate
0756039–7	Fuel strainer		
0756006–5	Top assembly		
0756006–498	Casting	380 aluminum die casting	
0756016–4	Insert	AMS-461 O brass	
0756007–3 and –4	Tubes	5052–0 aluminum tube	
0756036–2	Standpipe	6061-T6 aluminum	Anodize
0756037–1	Bowl	6061-T6 aluminum	Chemical film
0756038–1	Filter assembly	321 stainless steel sheet and 304 stainless steel 20 and 100 mesh screen	Passivate
0756041–1	Gasket	ASTM D1056, Grade SBE41 Nitrile sponge rubber	
NAS1593	"O" Rings	Parker V747–75 or V884–75 fluorocarbon	
2526028–3	Extension Nut	4130 steel	Cadmium plate
S2485–1	Drain Valve		
	Body	Aluminum	Anodize
	Stem	Brass	Cadmium plate
	Spring	Stainless steel	Passivate
	Seal	Parker V747–75 or V884–75 fluorocarbon	
MS20822–6–6D	Elbow—strainer outlet	Aluminum (ref proc SAE AS4842)	Anodize
AE3663161G0164	Hose Assembly		
	Pump		
	Hose	Aeroquip 666 hose with Teflon inner liner and stainless steel wire braid outer reinforcement and silicone rubber firesleeve	
	Swivel End	304 stainless steel	Passivate
LW15473	Engine Driven Fuel Injection	Material information not available from Textron Lycoming. Note—An FAA approved alternate pump (P/N 40296) supplied by Aero Accessories. Inc. reportedly incorporates diaphragms/seals made from nylon fabric reinforced Buna N compound.	
AN815–6	Union—Pump Inlet	Steel (ref proc SAE AS4842)	
AN833–6	Elbow—Pump Outlet	Steel (ref proc SAE AS4842)	
NAS1596–6	"O" Rings	Parker V747–75 or V884–75 fluorocarbon	
LW-12799-6S180	Hose Assembly		
	Injection Unit		
	Hose	Teflon inner liner and stainless steel wire braid outer reinforcement and silicone impregnated fiberglass cloth firesleeve.	
	Swivel end	303 and 321 stainless steel	Passivate
AE7013106G0180	Hose Assembly		
	Hose	Aeroquip AE701 (AQP) hose with synthetic rubber inner liner and stainless steel wire braid outer reinforcement and integral silicone rubber firesleeve.	
	Swivel End	2024-T4 aluminum	Anodize
2400010	Line Assemblies		
	Tube (0.375	5052-0 aluminum	
	End Fittings (AN	Aluminum (ref proc SAE AS4842)	Anodize
AN and MS Style	Fluid Fittings	Aluminum (ref proc SAE AS4842)	Anodize
RSA-5AD1	Precision Airmotive Fuel		

TABLE A2.4 *Continued*

	Body	Aluminum 356-T6, also 1100, 2024, 6061-T6, AMS-4177, AMS-4129, AMS-	Anodize
	Shafts, Metering Valves, etc	Stainless steel 302, 304, 316, AMS-5516, AMS-5560, AMS-5565, AMS-5610, AMS-5613, AMS-5646, AMS-5647, AISI-440C brass C260, C360, AMS-4610, AMS-	
	Stem Seals	Teflon ASTM D3652	
	Springs	Stainless steel, see above	Passivate
	Diaphragms	Silicone rubber coated AMS-R-25988 T1 C1 G-70 Dacron polyester fabric	
	Diaphragm	Aluminum (see above)	Anodize
	"O" Rings	Viton (fluorocarbon) copolymer of vinylidene fluoride and lexaflouropropylene Fluorosilicone	
	Inlet and Outlet	Steel SAE AS4842 Silver braze AMS-4665 Solder AMS-4750, QQ-S-571–SN63 Nickel plating both electro and electroless hard coat anodize of fluoronated solder AMS-4750, QQ-S-571-SN63	Cadmium plate
RSA-5AD1	Precision airmotive		
	Body	Aluminum	Anodize
	Shafts, metering	Stainless steel or brass	
	Stem seals	Teflon	
	Springs	Stainless steel	Passivate
	Diaphragms	Silicone rubber coated Dacron polyester fabric	
	Diaphragm	Aluminum	Anodize
	"O" Rings	Viton (fluorocarbon) and fluorosilicone	
	Inlet and Outlet	Steel	Cadmium plate

TABLE A2.5 Continental Engine Materials

Engine	Airframe	Fuel Pump	Fuel Ctl Unit	Manifold Valve	Nozzles	Fuel Press Reg.
TSIO-520-VB	Cessna 402C	646210–8A1	632916–11A5	641032–17A3	632748–16A/B	n/a
TSIO-520-J	Cessna 414	646210–2A3 632818–2A3	632916–11A1	634326–11A3 634326–12A3	632748–14B/C	642100–5
TSIO-520-K	Cessna 340	646210–2A3 632818–2A3	632916–11A2	634326–6A4	632748–14B/C	642100–5
GTSIO-520-H	Cessna 421	646211–2A1 646211–2A2	633573–9A17	634326–7A8	633723D19–A/AA	642100–1A1

A2.2.8.3 *Surface Evaluation*—At the conclusion of the 28 day soak, the metal test specimens shall be removed from the test fluid, air dried, and examined visually and under low-power (<50×) optical magnification. The objective is to inspect for evidence of staining, deposits, surface pits, or gross corrosion. Staining is considered a benign surface phenomenon. Staining results in no appreciable weight loss or gain and indicates the formation of a passive layer that inhibits corrosion. Subsequent to the initial examination, the metal surfaces shall be cleaned using acetone or alcohol and reexamined for surface pits. If desired, deposits can be preserved by evaporating the solvents and then storing in a desiccator for future analysis.

A2.2.8.4 *Microstructural Evaluation*—Following surface evaluation, metal test specimens shall be cross sectioned, mounted, and polished to reveal a profile of the surface and interior. Polishing shall be conducted in accordance with procedures established by the evaluating laboratory. The procedures shall be consistent with those specified by the polishing apparatus manufacturer and appropriate for use on the metallic alloys being evaluated as described by metallographic procedures outline in the *ASM Metals Handbook*.[12] Mounted and polished specimens shall be examined at optical magnification levels between 100× and 1000× for evidence of microstructural changes, corrosion, or other effects of exposure on the surface or bulk material. A good edge retention mounting compound should be used for cross-section metallographic examination. If there is an evidence of corrosion, then further characterization should be sought using scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDAX) to analyze the corrosion products.

A2.2.9 *Evaluation Criteria*—The evaluation criterion for nonmetallic materials is shown in Table A2.2. The approach is to look for significant variations in test values between the baseline fuel and the candidate fuel or additive/baseline fuel blend. The allowable variations from the baseline fuel for nonmetallic materials are based on the precision and bias of the test method. Most of the materials have test requirements expressed as maximum or minimum values. These values are

[12] *Metals Handbook*, J. R. Davis, Ed., ASM International, Materials Park, OH, 1998.

TABLE A2.6 Continental Engine Subcomponents

Fuel Pump: Components Subjected to Fuel
(aside from aluminum housing components, stainless liner, and bronze sleeve)

Nomenclature	Relief Valve Diaphragm	End Plate Seal	Variable Body Gasket	Separator Gasket	Vanes	Shaft Seal	Aneroid Rod Seal
Part Number	642644	630979–14	653746	625548	635549	649198	639484
Composition	SAE AMS 3274G	Viton Parker Seal			Carbon-based composite	Garlock seal	

Fuel Control Unit: Components Subjected to Fuel
(aside from brass/aluminum metering housings and stainless/brass valving)

Nomenclature	O-Ring	O-Ring Packings	Washer	Seal Washer	Finger Strainer Gasket
Part Number	AN123962	630979	635835–1	538600–1	646665
Composition	Viton	Viton	Teflon	Buna	

Manifold Valve: Components Subjected to Fuel
(aside from aluminum body, stainless plunger, and brass screen)

Nomenclature	Diaphragm	Seal	Gasket	Other
Part Number	626536	631330	627124	Locktite 290
Composition	reinforced Fairprene BN		Buna	Dimethacrylate ester

Fuel Pressure Regulator: Components Subjected to Fuel
(aside from aluminum body, stainless valve)

Nomenclature	Diaphragm	Seat
Part Number	636207	636216
Composition	Reinforced Fairprene BN	Brass

Nozzle Assemblies

Nomenclature	Body	Jet	O-Rings
Part Number		627333	630979–9
Composition	Brass	Brass	Viton

TABLE A2.7 Exemplar Soak Temperatures

Material	Coating	Soak Temp, °C
2024-T3 Bare	N/A	93
2024-T351	Hard anodize	93
2024-T4	Hard anodize and dry film lubricant coated	93
2024-T42	N/A	93
6061-T6 Bare	N/A	93
346 T6 Cast Aluminum	N/A	93
SN63 Solder	N/A	93
304 Steel	Passivate	93
304A Steel	Passivate	93
17-4 pH	Passivate	93
440C	N/A	93
Monel	N/A	93
1010 Steel	Cadmium	93
Brass	Cadmium	
AMS 4665 Silver Braze	N/A	

drawn from the material specification when applicable. If there is no material specification or the specification does not have a fuel-soak requirement, then pass/fail criteria is gleaned from experience gained in previous investigations performed on similar materials.

A3. REPRESENTATIVE ENGINE AND AIRCRAFT MATERIALS

A3.1 *Scope*—The following tables are a compilation of the wetted metallic (Table A2.1) and nonmetallic (Table A2.2) materials located throughout the engine, airframe, and distribution system. Tables A2.4-A2.6 are listings of representative parts, their manufacturers, and representative part numbers and are provided to assist in identifying and procuring representative materials. If no test method or temperature range is provided, tests should be selected based on the part type and size. The temperature should be related to the maximum temperature the part would see in use.

A4. FILTER MONITOR SEPARATOR/MICROFILTER TESTING

A4.1 *Scope*—In addition to on-aircraft fuel-wetted components, the compatibility of the fuel with the fuel-wetted distribution equipment should be evaluated. In the fuel filtration specifications, a compatibility test is run in which complete filter elements are immersed in test fluids (fuels with additives and 30:70 toluene/iso-octane mixture) for a period of time after which the element is visually examined and the fuel is tested.

A4.2 The test shall be performed by selecting two representative elements from each supplier and soaking one element in a reference fluid consisting of a representative sample of Specification D910 aviation gasoline Grade 100LL and one element in 100 % of the fuel under evaluation. Separate soak containers shall be used for each element and these situated in close proximity to ensure equivalent temperatures. The volume of the liquid in the test shall be five times the volume of a solid object having the same outside dimensions as the test element. The elements shall receive two sequential 336 h soaks with a 4 h drainage period between soaks with the test temperature being monitored daily and in the range of 5 °C to 30 °C. One-litre samples of the reference aviation gasoline and test fluid shall be stored for comparative testing at the end of the period.

A4.2.1 The soak container shall be of such dimensions that the element is totally immersed in the test fluid and have a noncontaminating sealing lid. The container will be inert to the test fluid and will be thoroughly rinsed with the test fluid before use.

A4.2.2 The reference aviation gasoline and test fuel shall be tested at the start and end of the test period for existent gum (Test Method D381) and color (Test Method D156). Both elements shall be subjected to a detailed visual inspection of all component parts.

A4.2.3 Compare the condition of the glue, filter media, rubber seal, central core, and the stacking seal of the filter cartridge between exposure to the test fluid and a baseline aviation gasoline.

A4.2.4 Inspect the aviation gasoline and test fuel visually by the clear and bright procedure for gross indications of polymer extraction.

A5. MATERIALS COMPATIBILITY TESTING FOR COMMON COMPOSITE FUEL TANK MATERIALS

A5.1 Introduction

A5.1.1 In this section, a fuel's compatibility to common structural composite materials used in aircraft fuel tank areas is assessed. The results provide a general indication of the proposed fuel's composite compatibility to composite materials but do not guarantee results for a specific material system. Unlike most aviation metals, there are few standard composite material formulations. Composites can vary in fiber type, fiber sizing, core material, resin type, curing agents, toughening agents, fillers, and other modifiers. There are literally thousands of composite materials in use and their resistance to a particular chemical can vary greatly among them. It is impractical to evaluate each proposed fuel against every composite material combination so a smaller test group of representative materials is used. In down-selecting to the smaller test group of materials, the following assumptions were made:

A5.1.1.1 *Current Composite Materials in Fuel Areas are Compatible with 100LL*—Some composite materials perform poorly when exposed to 100LL. It is assumed that these materials, if used, would not be in areas where fuel contact is likely. This eliminates the need to test materials that are known to have problems with organic solvents.

A5.2 The resin and not the fiber is the primary concern for fuel compatibility. The most commonly used aviation fibers are E-Glass, S-glass, and pan-based carbon fiber. These fibers have high resistance to organic solvents so it is assumed that fiber type is not a critical variable for fuel compatibility testing. Resins do exhibit fuel compatibility differences and will require testing of multiple resin types. Test coupons will be made mostly of glass fiber to make detecting color changes easier.

A5.3 *Fiber Surface Treatment is Not Specifically Evaluated*—For structural composite applications, a fiber's surface is treated in different ways to promote adhesion to the resin system. Fibers are often coated with a sizing material that enhances bonding to a particular type of resin system. While most modern sizings for structural aerospace applications use silane chemistry, older fabrics often used chromium (III) methacrylate chemistry. Manufacturers often keep fiber surface treatment details a secret making it difficult to generalize about the effects of sizing on fuel compatibility. The fibers and fabrics for these test coupons are specified with particular surface treatments so results can be compared between different fuels. The surface treatments for the test fibers and fabrics are considered fairly standard for these types of structural applications. To demonstrate chemical resistance to a particular fiber/sizing/resin combination requires a material specific evaluation.

A5.4 *Resins with Similar Chemistry Will Have Similar Fuel Compatibility*—There are thousands of resin formulations. To reduce the number of test articles to a reasonable level, a representative resin is selected for each general chemical family of resins that is in common aircraft use. It is assumed these test materials will provide a reasonable indication of the fuel compatibility for other chemically similar resins. While this assumption is generally true, final demonstration of the chemical resistance to a particular resin system requires a material-specific evaluation.

A5.5 *Resin Systems Are Fully Cured*—The chemical resistance of most resins degrades if it is not fully cured. The processes of curing composites can vary from one manufacturer to another, but it is assumed that all resins are fully cured before they are put into service. This assumption may not hold true for some homebuilt aircraft.

A5.6 *Surface Preparation Not Specifically Evaluated*—The chemical resistance of bonds can sometimes depend on the method of surface preparation. Surface preparation can vary from one manufacturer to another. Demonstrating chemical resistance using a different surface preparation requires a material specific evaluation.

A5.7 *Composite Test Materials*—The following test materials are selected to represent the most common material types used in piston powered general aviation composite structures.

A5.7.1 *Liquid Laminating Resins*—Four laminating resins are selected to cover the most commonly used chemical families. Epoxies are the most commonly used resin systems in general aviation. Accordingly, most of the test articles are made using epoxy formulations. A vinylester system is included because there are a number of aircraft that use vinylester resins in their fuel tanks. Vinylester's chemical resistance tends to be greater than epoxy systems so there is less of a need to test many different formulations. Laminating resin coupons are made using a 7781 style E-glass fabric with BGF Industries 497A sizing. 497A is a silane finish that can undergo addition or condensation reactions with polymeric resins and is compatible with epoxy, phenolic, polyimide, and polyester resins.

A5.7.1.1 *Material 1—Bis A Epoxy with a Fast Cycloaliphatic Amine Curing Agent (Hexion MGS 285 using MGS LH 285),* MGS 285 is liquid laminating resin system used by a number of aircraft manufacturers. The base resin in Hexion MGS 285 is diglycdyl ether of bisphenol A (DGEBPA or Bis A epoxy). DGEBPA is one of the oldest and most common epoxy base resins. To make fabric wet out easier, the DGEBPA in MGS 285 is thinned using glycerol polyglycidyl ether (GPE). The MGS 285 system has both a fast- and slow-curing agent. Manufacturers can regulate the cure rate by adjusting the ratio of the fast- and slow-curing agent. The fast-curing agent (MGS LH 285) consists mostly of isophorone diamine (IPDA), a commonly used cycloaliphatic amine curing agent. Test Material 2 uses the slow-curing agent to cover all possible mix ratios.

A5.7.1.2 *Material 2—Bis A Epoxy with a Slow Cycloaliphatic Amine Curing Agent (Hexion MGS 285 using MGS LH 287),* Material 2 uses the same epoxy base resin as Material 1 (Hexion MGS 285) but uses the slower MGS LH 287 curing agent. This is a cycloaliphatic amine curing agent consisting mostly of 4'-diaminodicyclohexylmethane (DMDC).

A5.7.1.3 *Material 3—Bis F Epoxy System with a Fast Primary Amine Curing Agent (Hexion Formulation 8014),* Hexion Formulation 8014 is a diglycdyl ether of bisphenol F (DGEBPF or Bis F) epoxy resin system. Bis F epoxies tend to have improved chemical resistance to solvents and are often used in fuel tank areas. This formulation uses neopentyl glycol diglycidyl ether (NPGDGE), a common diluent to thin the Bis-F resin. The curing agent is triethylene tetramine (TETA), a common aliphatic amine curing agent that cures at room temperature.

A5.7.1.4 *Material 4—Vinylester System on E-Glass Fabric (Dow Derakane 470-300),* Dow Derakane 470-300 represents a commonly used vinylester system for aircraft construction. It has been used both as the main structural resin in a number of airplanes and as a fuel tank sealer.

A5.7.2 *Epoxy Prepregs*—The most common type of prepreg used in piston-powered general aviation aircraft are epoxy prepregs with long room temperature out life (10 days to 30 days) and a relatively quick low-temperature cure. These characteristics limit the resin chemistry to a relatively small group of materials. The basic constituents are a mixture of Bis-A epoxies plus a dicyandiamide (Dicy) curing agent and a substituted urea accelerator like diuron. Some prepregs add toughening agents to make the system less brittle and more damage tolerant. A common toughening method is the addition of liquid butadiene-acrylonitrile polymers with terminal carboxyl groups like carboxyl-terminated butadiene-acrylonitrile (CTBN) that form small rubber regions inside the epoxy. Both a toughened and nontoughened epoxy prepreg system are tested.

A5.7.2.1 *Material 5—Nontoughened 250F Cure Prepreg System on E-Glass (TenCate BT250E-1),* TenCate BT250E-1 is a typical 250 cure prepreg system and the most common prepreg system found on piston-powered general aviation aircraft.

A5.7.2.2 *Material 6—Toughened 250F Cure Prepreg System on Carbon (ACG MTM 45-1),* MTM 45-1 is a common 250 cure CBTN-toughened prepreg system. Toughened resins are more often used with carbon composites so these test coupons will be made from a carbon fiber prepreg.

A5.7.3 *Paste Adhesives*—Low-temperature curing paste adhesives are commonly used on piston-powered general aviation aircraft to bond composite parts together. In the fuel tank areas, these adhesives not only prevent fuel from leaking out but also support structural loads. These aircraft typically have relatively thick bonds to accommodate greater bond gap tolerances. This requires the use of thick adhesive pastes for bonding instead of thin adhesive films used on military aircraft. Adhesive pastes have chemistry similar to that of the laminating resins with the addition of fillers to modify their density and performance. The two selected structural adhesives are commonly used in general aviation composite aircraft and were previously selected for FAA evaluation (DOT/FAA/AR-03/21). Adhesive test coupons are made using Appendix C instructions.

A5.7.3.1 *Material 7—Low-Temperature Cure Structural Epoxy Adhesive (PTM-W ES6292),* ES6292 is a two-component epoxy adhesive intended for use in bonding composite parts and structural assemblies. The material's thixotropy allows it to fill gaps in uneven bond lines without sagging or run out during cure. This is a fire-retardant system and meets requirements of Specification UL-94.

A5.7.3.2 *Material 8—Low-Temperature Cure Structural Epoxy Adhesive (Hysol EA 9360),* Hysol EA 9360 is a two-component toughened paste adhesive, which combines high peel strength at room temperature with tensile lap shear strength at 107 °C to 121 °C.

A5.7.3.3 *Material 9—Two-Part, Manganese Dioxide cured, Polysulfide Sealant (AMS 8802),* Polysulfide sealants are very resistant to organic solvent and retain a high degree of flexibility over a broad temperature range making them well suited for fuel tank sealing in both composite and aluminum aircraft. Polysulfide sealants are commonly used as an additional sealing layer over composite bonds because their flexibility can prevent leaks in the more brittle structural adhesive if an in-service crack forms.

A5.7.4 *Core Materials*—Composite structures often incorporate core materials. Core materials are usually not intended to be in direct contact with fuels, but field experience has shown that leak paths through the composite face sheets do occur. Because of this leak potential, closed cell foam cores are often used in fuel tank areas to prevent further fuel migration. Chemically, there are two types of foam commonly used in fuel tank areas: rigid polyvinyl chloride (PVC) structural foam and rigid flame-retardant polyurethane foam.

A5.7.4.1 *Material 10—PVC Structural Foam (Diab Divinycell HT 61—trademarked),* Structural PVC foams are produced by a number of manufacturers. The most common aircraft PVC foam is Diab's Divinycell HT line of foams.[13] This foam is capable of withstanding the higher temperatures needed for processing aerospace pregregs.

A5.7.4.2 *Material 11—Rigid Polyurethane Foam (General Plastics FR-3700 Last-A-Foam—trademarked),* Polyurethane foams have fallen out of favor in recent years but, before 2000, there were a number of aircraft using polyurethane foam cores in the fuel tanks areas. The most common polyurethane foam was General Plastics FR-3700 Last-A-Foam.[14]

A5.8 Fuel Compatibility Tests

A5.8.1 The fuel compatibility Tests 1-7 follow the recommendations in DOT/FAA/AR-06/10. Changes in materials, weight, dimensions, visual appearance, hardness, and shear strength are measured over a 500 h soak in the test fluid.

A5.8.2 These standard soak tests, in which the material is not under any load, may miss significant long-term deterioration as reported in Australian DOD Report DSTO-TR-1650.[15] This report suggests that putting the material under load while exposed to the test fluid in the form of a wedge crack test, provides a better means to detect long-term deterioration. Test 8 is a modified version of the Test Method D3762 wedge crack test for use with these test materials.

A5.8.3 Test results are compared to 100LL test results to identify areas in which the test fuel causes significantly greater material degradation.

A5.8.3.1 *Test Matrix.* See Table A5.1.

[13] Divinycell is a registered trademark of Diab, www.diabgroup.com.

[14] FR-3700 Last-A-Foam is a registered trademark of General Plastics Manufacturing Co., 4901 Burlington Way, Tacoma, WA 98409.

[15] Andrew N. Rider and Eudora Yeo, "The Chemical Resistance of Epoxy Adhesive Joints Exposed to Aviation Fuel and its Additives," Report DSTO-TR-1650, Australian Department of Defense, 2005, http://www.dsto.defence.gov.au/publications/search.php?query=DSTO-TR-1650.

TABLE A5.1 Test Matrix for Composite Testing

Tests	Laminates Materials 1–6	Adhesive Materials 7–9	Cores Materials 10, 11	Test Method
1: Weight	X	X	X	500 h soak measuring change in mass to 0.001 g
2: Dimensional	X	X	X	500 h soak measuring dimensional change to 0.02 mm
3: Visual	X	X	X	500 h soak noting color and surface change using 50× magnification
4: Hardness	X	X		500 h soak measuring change in surface hardness (ASTM D2583)
5: Shear Strength	X			500 h soak measuring change in short beam shear strength/modulus (ASTM D2344/D2344M)
6: Bond Strength		X		500 h soak measuring change in single lap bond strength/modulus (ASTM D1002)
7: Core Compression			X	500 h soak measuring change in compression strength/modulus (ASTM D1621)
8: Bond Durability	X	X		Measure change in long-term adhesive/cohesive durability (Modified ASTM D3762)

A6. PERMEABILITY OF FUEL TANK BLADDER MATERIALS

A6.1 *Scope*—The following procedure is recommended to determine permeability of a new fuel or new fuel additive in fuel with the bladder materials used in aircraft fuel tanks.

A6.2 *Material*—Bladder material can may be procured from a fuel bladder manufacturer. The tester should request a sheet of assembled bladder material.

A6.3 *Method*:

A6.3.1 Cut four (4) 2.5 in. (6.35 cm) circles from the fuel bladder (should match the top of the permeability cup).

A6.3.2 Add 100 mL of test fuel to the permeability cup.

A6.3.3 Place fuel bladder circle on top.

A6.3.4 Repeat for each fuel.

A6.3.5 Screw on the tops of the permeability cups.

A6.3.6 Leave the permeability cups will be left upright for 1 h before weighing to the nearest 0.005 g.

A6.3.7 After weighing, leave the cups will be left upright for 24 h before reweighing and inverting onto the test rack.

A6.3.8 Reweigh the cups will be reweighed on Days 3, 5, and 8 after inversion (Days 4, 6, and 9 after assembly).

A6.3.9 Any leaks are usually found by Day 3.

A6.3.10 Calculate the diffusion rate is calculated from data collected between Day 5 and Day 8

A6.3.11 K is determined by the formula:

$$K = \frac{144}{(SpGr)(29.573)(3.142)R^2} \quad (A6.1)$$

where:

$SpGr$ = specific gravity of the fluid at 77 °F (25 °C), and
R = inside radius of the test cup expressed in inches.

A6.3.12 The diffusion rate is expressed in fluid ounces per square foot per 24 h and is equal to the gram loss of the test specimen per 24 h multiplied by the factor "*K*." The weight loss in grams between Day 5 and Day 8 is divided by three to obtain a value for 24 h.

A6.3.13 Report the permeability as fluid ounces per square foot per 24 h.

SUMMARY OF CHANGES

Subcommittee D02.J0 has identified the location of selected changes to this standard since the last issue (D7826 – 16) that may impact the use of this standard. (Approved June 1, 2017.)

(1) Added Test Methods D1331, D1500, D2717, and D7096 to Referenced Documents; added IP 196 to Referenced Documents.
(2) Deleted D2887, D5304, and IP 406 from Referenced Documents.
(3) Revised Table 1 and Table 2.
(4) Revised subsections 6.2.4.1, 6.3.2.1, 6.3.2.4, 6.3.2.5, 6.3.2.6, 6.3.2.9, and 6.3.2.13.
(5) Added new subsection 1.2.
(6) Revised Sections 3 (Terminology), 4 (Summary of Practice), and 6 (Procedure) to change "test specifications" and "product specifications" to "Phase 1 and Phase 2" testing throughout.

Subcommittee D02.J0 has identified the location of selected changes to this standard since the last issue (D7826 – 15) that may impact the use of this standard. (Approved May 1, 2016.)

(1) Removed Test Method D2533 and all references to it in the text (Table 1 and subsection 6.2.4.2).
(2) Updated Table A2.1 and Table A2.2 based on more contemporary and better representative materials.