Designation: D4054 – 21

An American National Standard

Standard Practice for Evaluation of New Aviation Turbine Fuels and Fuel Additives[1]

This standard is issued under the fixed designation D4054; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This standard practice provides procedures to develop data for use in research reports for new aviation turbine fuels, changes to existing aviation turbine fuels, or new aviation turbine fuel additives. These research reports are intended to support the development and issuance of new specifications or specification revisions for these products. This standard practice has also been used to evaluate the effect of incidental materials on jet fuel properties and performance.

1.2 The procedures, tests, and selection of materials detailed in this practice are based on industry expertise to provide the necessary data to determine if the new or changed fuel or additive is suitable for use on existing aircraft and engines and for use in the current aviation operational and supply infrastructure. As such, it is primarily intended for the evaluation of drop-in fuels, but it can also be used for the evaluation of other fuels.

1.3 Because of the diversity of aviation hardware and potential variation in fuel/additive formulations, not every aspect may be fully covered and further work may be required. Therefore, additional data beyond that described in this practice 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.

1.4 Units of measure throughout this practice are stated in International System of Units (SI) unless the test method specifies non-SI units.

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

1.6 *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]

A240/A240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

B36/B36M Specification for Brass Plate, Sheet, Strip, And Rolled Bar

B93/B93M Specification for Magnesium Alloys in Ingot Form for Sand Castings, Permanent Mold Castings, and Die Castings

D56 Test Method for Flash Point by Tag Closed Cup Tester

D86 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure

D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

D257 Test Methods for DC Resistance or Conductance of Insulating Materials

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

D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

D924 Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.J0.04 on Additives and Electrical Properties.

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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**

D1002 Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)
D1298 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
D1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
D1331 Test Methods for Surface and Interfacial Tension of Solutions of Paints, Solvents, Solutions of Surface-Active Agents, and Related Materials
D1405 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
D1414 Test Methods for Rubber O-Rings
D1655 Specification for Aviation Turbine Fuels
D2240 Test Method for Rubber Property—Durometer Hardness
D2386 Test Method for Freezing Point of Aviation Fuels
D2425 Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry
D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
D2624 Test Methods for Electrical Conductivity of Aviation and Distillate Fuels
D2717 Test Method for Thermal Conductivity of Liquids (Withdrawn 2018)[3]
D2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
D3114 Method of Test for D-C Electrical Conductivity of Hydrocarbon Fuels (Withdrawn 1985)[3]
D3241 Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels
D3242 Test Method for Acidity in Aviation Turbine Fuel
D3338 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
D3359 Test Methods for Rating Adhesion by Tape Test
D3363 Test Method for Film Hardness by Pencil Test
D3701 Test Method for Hydrogen Content of Aviation Turbine Fuels by Low Resolution Nuclear Magnetic Resonance Spectrometry
D3703 Test Method for Hydroperoxide Number of Aviation Turbine Fuels, Gasoline and Diesel Fuels
D3828 Test Methods for Flash Point by Small Scale Closed Cup Tester
D3948 Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer
D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
D4066 Classification System for Nylon Injection and Extrusion Materials (PA)
D4529 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
D4629 Test Method for Trace Nitrogen in Liquid Hydrocarbons by Syringe/Inlet Oxidative Combustion and Chemiluminescence Detection
D4809 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)
D5001 Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
D5291 Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants
D5304 Test Method for Assessing Middle Distillate Fuel Storage Stability by Oxygen Overpressure
D5363 Specification for Anaerobic Single-Component Adhesives (AN)
D5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
D5972 Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)
D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
D6378 Test Method for Determination of Vapor Pressure (VP_X) of Petroleum Products, Hydrocarbons, and Hydrocarbon-Oxygenate Mixtures (Triple Expansion Method)
D6379 Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection
D6732 Test Method for Determination of Copper in Jet Fuels by Graphite Furnace Atomic Absorption Spectrometry
D6793 Test Method for Determination of Isothermal Secant and Tangent Bulk Modulus (Withdrawn 2021)[3]
D6890 Test Method for Determination of Ignition Delay and Derived Cetane Number (DCN) of Diesel Fuel Oils by Combustion in a Constant Volume Chamber
D7042 Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
D7111 Test Method for Determination of Trace Elements in Middle Distillate Fuels by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D7153 Test Method for Freezing Point of Aviation Fuels (Automatic Laser Method)
D7154 Test Method for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)
D7171 Test Method for Hydrogen Content of Middle Distillate Petroleum Products by Low-Resolution Pulsed Nuclear Magnetic Resonance Spectroscopy
D7359 Test Method for Total Fluorine, Chlorine and Sulfur in Aromatic Hydrocarbons and Their Mixtures by Oxidative Pyrohydrolytic Combustion followed by Ion Chromatography Detection (Combustion Ion Chromatography-CIC)
D7566 Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

[3] The last approved version of this historical standard is referenced on www.astm.org.

D7945 Test Method for Determination of Dynamic Viscosity and Derived Kinematic Viscosity of Liquids by Constant Pressure Viscometer

E411 Test Method for Trace Quantities of Carbonyl Compounds with 2,4-Dinitrophenylhydrazine

E659 Test Method for Autoignition Temperature of Chemicals

E681 Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases)

E1269 Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry

2.2 *Federal Specifications:*[4]

FED-STD-791 Testing Method of Lubricants, Liquid Fuels, and Related Products

2.3 *Department of Defense Specifications:*[4]

DOD-L-85645 Lubricant, Dry Film, Molecular Bonded

MIL-A-8625 Anodic Coatings for Aluminum and Aluminum Alloys

MIL-C-83019 Coating, Polyurethane, for Protection of Integral Fuel Tank Sealing Compound

MIL-DTL-5541 Chemical Conversion Coatings on Aluminum and Aluminum Alloys

MIL-DTL-5624 Turbine Fuel, Aviation, Grades JP-4 and JP-5

MIL-DTL-24441 Paint, Epoxy-Polyamide, General Specification for

MIL-PRF-25017 Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble (NATO S-1747)

MIL-DTL-25988 Rubber, Fluorosilicone Elastomer, Oil- and Fuel-Resistant, Sheets, Strips, Molded Parts, and Extruded Shapes

MIL-DTL-26521 Hose Assembly, Nonmetallic, Fuel, Collapsible, Low Temperature with Non-Reusable Couplings

MIL-DTL-83054 Baffle and Inerting Material, Aircraft Fuel Tank

MIL-DTL-83133 Turbine Fuel, Aviation, Kerosene Type, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37)

MIL-H-4495 Hose Assembly, Rubber, Aerial Refueling

MIL-DTL-17902 Hose, End Fittings and Hose Assemblies, Synthetic Rubber, Aircraft Fuels

MIL-HDBK-510 Aerospace Fuels Certification

MIL-P-25732 Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Limited Service at 275 °F (135 °C)

MIL-PRF-370 Hose and Hose Assemblies, Nonmetallic: Elastomeric, Liquid Fuel

MIL-PRF-6855 Rubber, Synthetic, Sheets, Strips, Molded or Extruded Shapes, General Specification for

MIL-PRF-8516 Sealing Compound, Synthetic Rubber, Electric Connectors and Electric Systems, Chemically Cured

MIL-PRF-46010 Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting, NATO Code S-1738

MIL-PRF-81298 Dye, Liquid for the Detection of Leaks in Aircraft Fuel Systems

MIL-PRF-81733 Sealing and Coating Compound, Corrosion Inhibitive

MIL-PRF-87260 Foam Material, Explosion Suppression, Inherently Electrostatically Conductive, for Aircraft Fuel Tanks

MIL-S-85334 Sealing Compound, Noncuring, Low Consistency, Silicone, Groove Injection, for Integral Fuel Tanks

MIL-DTL-5578 Tanks, Fuel, Aircraft, Self-Sealing

MMM-A-132 Adhesives, Heat Resistant, Airframe Structural, Metal to Metal

QPL-25017 Qualified Products List for MIL-PRF-25017 (Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble) (NATO S-1747)

2.4 *SAE International:*[5]

SAE-AMS-2410 Plating, Silver Nickel Strike, High Bake

SAE-AMS-2427 Aluminum Coating, Ion Vapor Deposition

SAE-AMS-3215 Acrylonitrile Butadiene (NBR) Rubber Aromatic Fuel Resistant 65–75

SAE-AMS-3265 Sealing Compound, Polysulfide (T) Rubber, Fuel Resistant, Non-Chromated Corrosion Inhibiting for Intermittent Use to 360 °F (182 °C)

SAE-AMS-3276 Sealing Compound, Integral Fuel Tanks and General Purpose, Intermittent Use to 360 °F (182 °C)

SAE-AMS-3277 Sealing Compound, Polythioether Rubber Fast Curing Integral Fuel Tanks and General Purpose, Intermittent Use to 360 °F (182 °C)

SAE-AMS-3278 Sealing and Coating Compound: Polyurethane (PUR) Fuel Resistant High Tensile Strength/Elongation for Integral Fuel Tanks/Fuel Cavities/General Purpose

SAE-AMS-3279 Sealing Compound, Sprayable, for Integral Fuel Tanks and Fuel Cell Cavities, for Intermittent Use to 350 °F (177 °C)

SAE-AMS-3281 Sealing Compound, Polysulfide (T) Synthetic Rubber for Integral Fuel Tank and Fuel Cell Cavities Low Density for Intermittent Use to 360 °F (182 °C)

SAE-AMS-3283 Sealing Compound, Polysulfide Non-Curing, Groove Injection Temperature and Fuel Resistant

SAE-AMS-3361 Silicone Potting Compound, Elastomeric, Two-Part, General Purpose, 150 to 400 Poise (15 to 40 Pa·s) Viscosity

SAE-AMS-3375 Adhesive/Sealant, Fluorosilicone, Aromatic Fuel Resistant, One-Part Room Temperature Vulcanizing

SAE-AMS-3376 Sealing Compound, Non-Curing, Groove Injection Temperature and Fuel Resistant

SAE-AMS-4017 Aluminum Alloy Sheet and Plate, 2.5Mg – 0.25Cr (5052–H34) Strain-Hardened, Half-Hard, and Stabilized

SAE-AMS-4027 Aluminum Alloy, Sheet and Plate 1.0Mg – 0.60Si – 0.28Cu – 0.20Cr (6061; –T6 Sheet, –T651 Plate) Solution and Precipitation Heat Treated

SAE-AMS-4029 Aluminum Alloy Sheet and Plate 4.5Cu –

[4] Copies of these documents are available online at http://quicksearch.dla.mil/ or http://assist.dla.mil.

[5] Available from SAE International, 400 Commonwealth Dr., Warrendale, Pennsylvania 15096, http://www.sae.org/servlets/index

0.85SI – 0.80Mn – 0.50Mg (2014; –T6 Sheet, –T651 Plate) Solution and Precipitation Heat Treated

SAE-AMS-4037 Aluminum Alloy, Sheet and Plate 4.4Cu – 1.5Mg – 0.60 Mn (2024; –T3 Flat Sheet, –T351 Plate) Solution Heat Treated

SAE-AMS-4107 Aluminum Alloy, Die Forgings (7050–T74) Solution Heat Treated and Overaged

SAE-AMS-4260 Aluminum Alloy, Investment Castings 7.0Si – 0.32Mg (356.0–T6) Solution and Precipitation Heat Treated

SAE-AMS-4750 Solder, Tin–Lead 45Sn – 55Pb

SAE-AMS-4751 Tin–Lead Eutectic 63Sn – 37Pb

SAE-AMS-4901 Titanium Sheet, Strip, and Plate Commercially Pure Annealed, 70.0 ksi (485 MPa)

SAE-AMS-4915 Titanium Alloy Sheet, Strip, and Plate 8Al –1V – IMo Single Annealed

SAE-AMS-5330 Steel Castings, Investment, 0.80Cr – 1.8Ni – 0.35Mo (0.38–0.46C) (SAE 4340 Modified) Annealed

SAE-AMS-5338 Steel, Investment Castings 0.95Cr – 0.20Mo (0.35–0.45C) (SAE 4140 Mod) Normalized or Normalized and Tempered

SAE-AMS-5504 Steel, Corrosion and Heat–Resistant, Sheet, Strip, and Plate 12.5Cr (SAE 51410) Annealed

SAE-AMS-5525 Steel, Corrosion and Heat Resistant, Sheet, Strip, and Plate 15Cr – 25.5Ni – 1.2Mo – 2.1Ti – 0.006B –0.30V 1800 °F (982 °C) Solution Heat Treated

SAE-AMS-5604 Steel, Corrosion Resistant, Sheet, Strip, and Plate 16.5Cr – 4.0Ni – 4.0Cu – 0.30 Solution Heat Treated, Precipitation Hardenable

SAE-AMS-5613 Steel, Corrosion and Heat Resistant, Bars, Wire, Forgings, Tubing, and Rings 12.5Cr (SAE 51410) Annealed

SAE-AMS-5643 Steel, Corrosion Resistant, Bars, Wire, Forgings, Tubing, and Rings 16Cr – 4.0Ni – 0.30Cb – 4.0Cu Solution Heat Treated, Precipitation Hardenable

SAE-AMS-5688 Steel, Corrosion–Resistant, Wire 18Cr–9.0Ni (SAE 30302) Spring Temper

SAE-AMS-5737 Steel, Corrosion and Heat–Resistant, Bars, Wire, Forgings, and Tubing 15Cr – 25.5Ni – 1.2Mo – 2.1Ti – 0.006B – 0.30V Consumable Electrode Melted, 1650 °F (899 °C) Solution and Precipitation Heat Treated

SAE-AMS-6277 Steel Bars, Forgings, and Tubing 0.50Cr – 0.55Ni – 0.20Mo (0.18–0.23C) (SAE 8620) Vacuum Arc or Electroslag Remelted

SAE-AMS-6345 Steel, Sheet, Strip and Plate 0.95Cr – 0.20Mo (0.28–0.33C) (SAE 4130) Normalized or Otherwise Heat Treated

SAE-AMS-6415 Steel, Bars, Forgings, and Tubing, 0.80Cr – 1.8Ni –0.25Mo (0.38–0.43C) (SAE 4340)

SAE-AMS-6444 Steel, Bars, Forgings, and Tubing 1.45Cr (0.93–1.05C) (SAE 52100) Premium Aircraft-Quality, Consumable Electrode Vacuum Remelted

SAE-AMS-6470 Steel, Nitriding, Bars, Forgings, and Tubing 1.6Cr – 0.35Mo – 1.13Al (0.38–0.43C)

SAE AMS 6472 Steel, Bars and Forgings, Nitriding 1.6Cr – 0.35Mo – 1.1Al (0.38-0.43C) Hardened and Tempered, 112 ksi (772 MPa) Tensile Strength

SAE-AMS-7257 Rings, Sealing, Perfluorocarbon (FFKM) Rubber High Temperature Fluid Resistant 70 – 80

SAE-AMS-7271 Rings, Sealing, Butadiene-Acrylonitrile (NBR) Rubber Fuel and Low Temperature Resistant 60 – 70

SAE-AMS-7276 Rings, Sealing, Fluorocarbon (FKM) Rubber High-Temperature-Fluid Resistant Low Compression Set 70–80

SAE-AMS-7902 Beryllium, Sheet and Plate, 98Be

SAE-AMS-C-27725 Coating, Corrosion Preventative, Polyurethane for Aircraft Integral Fuel Tanks for Use to 250 °F (121 °C)

SAE AMS-I-7444 Insulation Sleeving, Electrical, Flexible

SAE-AMS-DTL-23053/5 Insulation Sleeving, Electrical, Heat Shrinkable, Polyolefin, Flexible, Crosslinked

SAE-AMS-P-5315 Butadiene–Acrylonitrile (NBR) Rubber for Fuel- Resistant Seals 60 to 70

SAE-AMS-P-83461 Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Improved Performance at 275 °F (135 °C)

SAE-AMS-QQ-A-250/12 Aluminum Alloy 7075, Plate and Sheet

SAE-AMS-QQ-P-416 Plating, Cadmium (Electrodeposited)

SAE-AMS-R-25988 Rubber, Fluorosilicone Elastomer, Oil-and-Fuel-Resistant, Sheets, Strips, Molded Parts, and Extruded Shapes

SAE-AMS-R-83485 Rubber, Fluorocarbon Elastomer, Improved Performance at Low Temperatures

SAE-AMS-S-4383 Sealing Compound, Topcoat, Fuel Tank, Buna-N Type

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

SAE AS5127/1 Aerospace Standard Test Methods for Aerospace Sealants Two-Component Synthetic Rubber Compounds

2.5 *American Welding Society (AWS):*[6]

AWS C3.4 Specification for Torch Brazing

AWS C3.5 Specification for Induction Brazing

AWS C3.6 Specification for Furnace Brazing

AWS C3.7 Specification for Aluminum Brazing

2.6 *IPC:*[7]

J-STD-004 Requirements for Soldering Fluxes

J-STD-005 Requirements for Soldering Pastes

J-STD-006 Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications

2.7 *Boeing Material Specifications (BMS):*[8]

BMS 5-267 Fuel Tank Coating

BMS 10-20 Corrosion Resistant Finish for Integral Fuel Tanks

BMS 10-39 Fuel and Moisture Resistant Finish for Fuel Tanks

[6] Available from American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33126; http://www.aws.org/

[7] Available from IPC, 3000 Lakeside Drive, Suite 309S, Bannockburn, Illinois 60015; http://www.ipc.org

[8] Available from Boeing.

2.8 *International Organization for Standardization (ISO):*[9]

ISO 20823 Petroleum and related products determination of the flammability characteristics of fluids in contact with hot surfaces manifold ignition test

2.9 *United Kingdom Ministry of Defence (UK MOD):*[10]

DEF STAN 91–091 Turbine Fuel, Kerosine Type, Jet A-1, NATO Code: F-35 Joint Service Designation: AVTUR

2.10 *Environmental Protection Agency (EPA):*[11]

Method 8015 Nonhalogenated Organics by Gas Chromatography

Method 8260 Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)

Method 8270 Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)

2.11 *American Petroleum Institute (API)*[12]

API/EI 1581 Specifications and qualification procedures for aviation jet fuel filter/separators, Fifth Edition

2.12 *Energy Institute Standards:*[13]

EI 1581 Specifications and qualification procedures for aviation jet fuel filter/separators

IP 16 Determination of the freezing point of aviation fuels—Manual method

IP 71 Section 1 Petroleum Products—Transparent and opaque liquids—Determination of kinematic viscosity and calculation of dynamic viscosity

IP 123 Petroleum products—Determination of distillation characteristics at atmospheric pressure

IP 160 Crude petroleum and liquid petroleum products—Laboratory determination of density—Hydrometer method

IP 170 Determination of flash point—Abel closed-cup method

IP 323 Jet fuel thermal oxidation tube rating training guidelines

IP 354 Determination of the acid number of aviation turbine fuels—Colour-indicator titration method

IP 365 Crude petroleum and petroleum products—Determination of density—Oscillating U-tube method

IP 379 Determination of organically bound trace nitrogen—Oxidative combustion and chemiluminescence method

IP 406 Petroleum products—Determination of boiling range distribution by gas chromatography

IP 435 Determination of the freezing point of aviation turbine fuels by the automatic phase transition method

IP 438 Petroleum products—Determination of water—Coulometric Karl Fischer titration method

IP 523 Determination of flash point—Rapid equilibrium closed cup method (ISO 3679:2004)

IP 528 Determination of the freezing point of aviation turbine fuels—Automated fibre optic method

IP 529 Determination of the freezing point of aviation fuels—Automatic laser method

IP 585 Determination of fatty acid methyl esters (FAME), derived from bio-diesel fuel, in aviation turbine fuel—GC-MS with selective ion monitoring/scan detection method

2.13 *University of Dayton Research Institute (UDRI):*[14]

UDRI Method FC-M-101 Flow Modulation GCXGC for Hydrocarbon Type Analysis of Conventional and Alternative Aviation Fuels

UDRI Method FC-M-102 Identification and Quantitation of Polar Species in Conventional and Alternative Aviation Fuels Using SPE-GCXGC

2.14 *UOP Test Methods:*[15]

UOP 389 Trace Metals in Oils by Wet Ash/ICP-AES

3. Terminology

3.1 *Definitions:*

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

3.1.2 *task group, n*—an ad-hoc group operating in an unofficial capacity for the subcommittee for a specific activity.

3.1.2.1 *Discussion*—If appropriate, a timetable for completion may be established. Society or Committee membership is not required, but the task group is encouraged to represent a balance of interests wherever possible and appropriate. Formal balloting is not required at the task group level. Discharge may occur with completion or cause to abandon the activity.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aviation regulatory authorities, n*—governmental organizations such as agencies or departments that are empowered by statute to oversee and enforce compliance to a nation's airworthiness regulations.

3.2.1.1 *Discussion*—Aviation regulatory authorities such as the U.S. Federal Aviation Administration (FAA) and the European Union Aviation Safety Agency (EASA) typically participate in the task force activities and review the submitted data. These authorities work very closely with the OEMs to support certification activities that may be necessary to accommodate the new aviation turbine fuel, the change to an existing aviation turbine fuel, or the new aviation turbine fuel additive.

3.2.2 *drop-in, adj—as applied to a substance*, possessing essentially identical physical and performance properties and chemical composition as an existing substance and intended for use as an alternative to that existing substance.

[9] Available from ISO, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland; http://www.iso.org/

[10] Available from Defence Equipment and Support, UK Defence Standardization, Kentigern House, 65 Brown Street, Glasgow, G2 8EX; http://www.dstan.mod.uk

[11] Available from US EPA, Office of Resource Conservation and Recovery (5305P), 1200 Pennsylvania Avenue, NW, Washington, DC 20460; http://www.epa.gov/

[12] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org or Energy Institute (EI), 61 New Cavendish St., London, W1G 7AR, U.K., http://www.energyinst.org.

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

[14] Available from University of Dayton Research Institute (UDRI), 300 College Park, Dayton, OH 45469-0043, https://udayton.edu/udri.

[15] Available from ASTM International, www.astm.org, or contact ASTM Customer Service at service@astm.org.

3.2.2.1 *Discussion*—Drop-in alternative fuels exhibit essentially identical composition, performance, and physical properties as existing petroleum-derived fuels and require no special handling or unique operating procedures.

3.2.3 *fit-for-purpose, adj*—describes a condition of acceptance of an aviation fuel or aviation fuel additive that signifies acceptable performance in aircraft and aircraft engines.

3.2.3.1 *Discussion*—Fit-for-purpose properties are characteristics of an aviation fuel or aviation fuel additive in the fuel that are not listed in the specification criteria but are inherent in petroleum-derived jet fuel. These properties are specified for evaluation in addition to the specification properties to provide a comprehensive assessment of the suitability of an aviation fuel for use in aircraft and aircraft engines.

3.2.4 *identified incidental materials, n*—chemicals and compositions that have defined upper content limits in an aviation fuel specification but are not approved additives.

3.2.5 *original equipment manufacturers (OEMs), n*—manufacturers of aircraft and aircraft engines.

3.2.5.1 *Discussion*—Engine OEMs include but are not limited to Pratt & Whitney (P&W), GE Aviation (GE), Rolls Royce (RR), SAFRAN, and Honeywell. Airframe OEMs include but are not limited to Boeing, Airbus, Embraer, Bombardier, Dassault, and Lockheed. OEM review and evaluation of new fuels and new additives is required to ensure that safety of flight, engine operability, performance, and durability requirements are not impacted by the new fuel or additive.

4. Summary of Practice

4.1 This practice provides a procedure and associated laboratory and aircraft equipment test methods to evaluate a new aviation turbine fuel, a change to an aviation turbine fuel, or a new or changed aviation turbine fuel additive.

4.2 The practice is an iterative process that relies on the generation of data and periodic review by the OEMs, task group, and subcommittee members to determine subsequent testing recommendations. As such, the practice should not be considered prescriptive, and it should be recognized that test requirements may be added or removed based upon the specific characteristics of the new fuel, changed fuel, or new additive, and upon the review of the test data generated at each phase in the process.

4.3 An overview of the practice is shown in Fig. 1. The practice consists of four tiers of testing, with a review after the second tier to determine the recommended scope of testing for the final two tiers.

4.3.1 Tier 1 consists of testing a small sample of the new fuel (approximately 10 U.S. gallons (37.8 L), or of existing jet fuel with the new additive, to the existing properties specified in the most referenced global aviation turbine fuel specifications.

4.3.2 Tier 2 consists of testing a larger volume of fuel (approximately 80 U.S. gallons (302.8 L) to an expanded set of properties that have been defined by the aviation fuel subcommittee. These properties are called Fit-for-purpose (FFP)

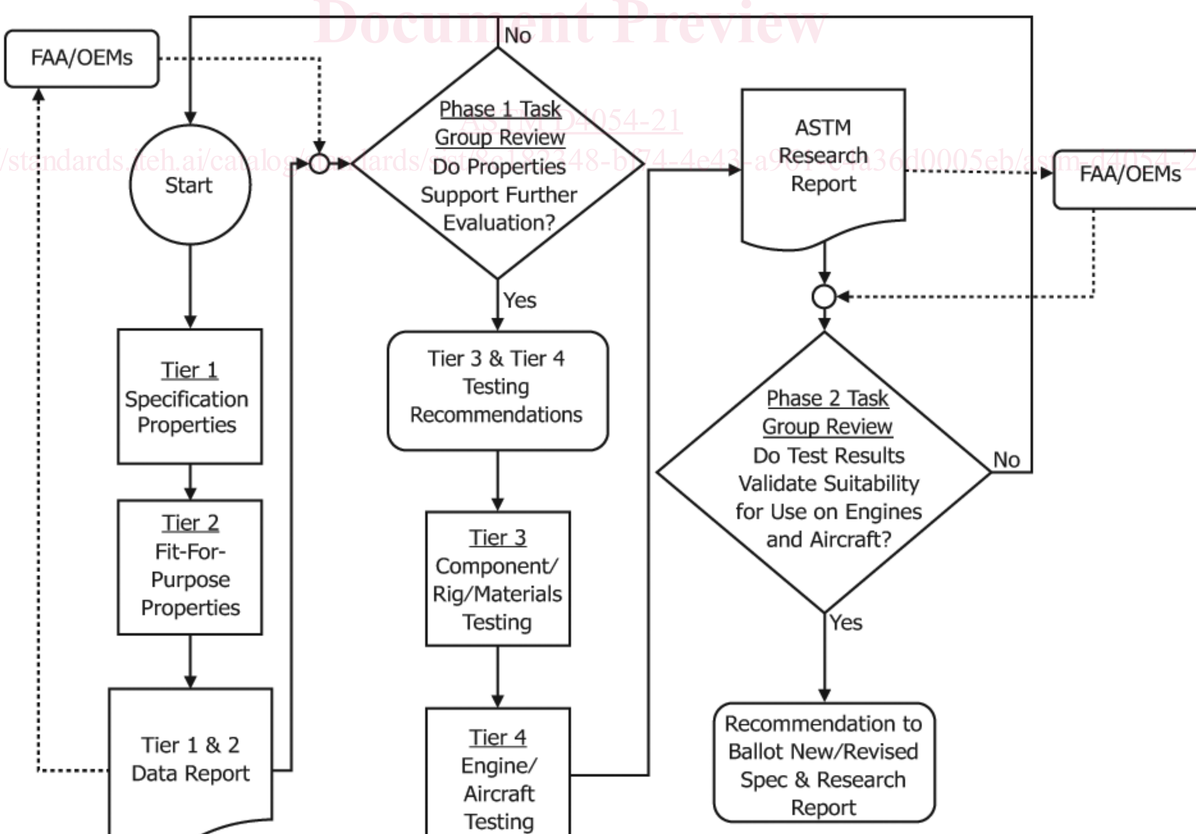


FIG. 1 Overview Fuel and Additive Approval Process

properties, and they address properties that are not listed in the specification criteria but are inherent in petroleum-derived jet fuel.

4.3.3 Upon completion of Tier 1 and 2, the data are reported to the subcommittee task group for Phase 1 review. The subcommittee task group relies on the recommendations of the engine and aircraft manufacturers (OEMs) and the Federal Aviation Administration (FAA) to determine if the initial property data indicates that the fuel or additive is acceptable for further evaluation. A Phase 1 data report is provided to the FAA and OEMs for this purpose. If the data is found to be acceptable, then the fuel or additive is ready for Tier 3 and 4 testing. Because these final two tiers involve testing of the fuel or additive with unique aerospace materials, and on specialized aircraft or engine component rigs, complete engines, or aircraft flight testing, the subcommittee task group solicits recommendations for Tier 3 and 4 testing from the FAA and the OEMs. The FAA and each of the OEMs will conduct their own internal review of the data to determine the acceptability of the fuel or additive for use on their aircraft and engines and to identify the Tier 3 and 4 testing recommendations (see Appendix X2). These determinations and recommendations will be based on a comparison of the data with the fuel properties scope of experience described in Annex A1.

4.3.4 Tier 3 consists of testing the fuel or additive on specialized engine or aircraft rigs or test benches, and of testing the compatibility of the fuel or additive with fuel system materials. This testing can require up to 10 000 U.S. gallons (37 854 L) of test fuel to complete.

4.3.5 Tier 4 consists of testing the fuel or additive on aircraft engines in ground test cells, or on aircraft in flight. This testing can require up to 225 000 U.S. gallons (851 718 L) of test fuel depending on the equipment recommended for testing.

4.3.6 Upon completion of Tier 3 and 4 testing, which will vary from candidate to candidate, the data for all four tiers is reported to the subcommittee task group. A final ASTM Research Report is submitted to the OEMs and FAA for Phase 2 review. The subcommittee relies on the recommendations of the OEMs and the FAA to determine if data contained in the research report validates that the fuel or additive is acceptable for use on aircraft and engines. As with the Phase 1 review described in 4.3.3 above, the OEMs conduct their own internal review to make this final recommendation (see Appendix X2). If acceptable, then a motion is made to ballot the research report, and the associated new specification, or specification revision to the subcommittee.

4.4 *Fast Track Annex A4*—The process described in 4.3.1 through 4.3.6 is a rigorous and comprehensive evaluation of alternative jet fuels that requires a significant level of resources to accomplish. This was intentional because of the critical role that aviation fuel plays in the safe conduct of air transportation. However, extensive testing and evaluation of alternative jet fuels has provided a sufficient experience base to allow the establishment of a fast track process with reduced testing requirements. This fast track process may only be used for new alternative jet fuel blending components that fall within compositional and performance criteria that reflect the typical range of current OEM-approved blendstocks and kerosine jet fuels. Target values are provided as a guideline and starting point for the evaluation of candidate alternative jet fuels for acceptability for the fast track process. The fast track process is described in Annex A4 of this practice and is available for consideration by sponsors of new alternative jet fuel blending components. It is not applicable to the OEM qualification and approval of aviation turbine fuel additives.

5. Significance and Use

5.1 This practice is intended to describe the data requirements necessary to support the review of new aviation turbine fuels or additives by ASTM members for the developers or sponsors of these new products.

5.2 Its purpose is to guide the sponsor of a new fuel or new fuel additive through a defined evaluation process that includes the prerequisite testing and required periodic reviews with the subcommittee members. This practice provides a basis for calculating the volume of additive or fuel required for assessment, insight into the cost associated with taking a new fuel or new fuel additive through the evaluation process, and a defined path forward for introducing a new technology for the benefit of the aviation community.

5.3 The allocation of resources necessary to support the full scope of the evaluation process is the responsibility of the sponsor of the new fuel or fuel additive. This will include laboratory, rig, or engine tests, if required, as well as support of OEM activities such as the Phase 1 and 2 reviews.

5.4 This process may also be used to assess the impact of changes to fuels due to changes in production methods and/or changes during transportation. An example is the assessment of the impact of incidental materials on fuel properties. In the context of Practice D4054, incidental materials shall be considered as an additive.

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

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

5.7 Neither the generation of data and issuance of a research report described in this practice, nor the ultimate issuance of a new or revised ASTM fuel specification based on that data, constitutes approval to use the new or changed fuel or new additive on civil aircraft. As described in Appendix X2, the OEMs will conduct an internal review process in coordination with their aviation regulatory authorities to determine if the new fuel or additive is acceptable for use on each of their respective products. Only upon successful completion of this OEM internal review will the new fuel or additive be permitted for use on civil aircraft.

5.8 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, it is expected that the data generated in the conduct of the procedure will be used by the OEMs and national aviation regulatory authorities to support their internal approval processes (see Appendix X2) and may be useful for other purposes or other organizations.

6. Procedure

6.1 *General:*

6.1.1 The scope of properties that could be tested are shown in Fig. 2. The purpose of the testing is to investigate the impact of the candidate fuel or additive on fuel specification properties, fit-for-purpose properties, fuel system materials, turbine materials, fuel system components, other approved additives, and engine operability, durability, and emissions. "Fit-for-Purpose properties" refers to properties inherent in a petroleum-derived fuel and assumed to be within a given range of experience. Fit-for-Purpose Properties are not controlled explicitly by specification but are considered critical to engine and airframe fuel system design. Examples include fuel surface tension, seal swell, and dielectric constant. During the testing, special considerations may be identified and investigated to resolve anomalies. Examples include minimum aromatic level, maximum flash point, and minimum lubricity.

6.1.2 A complete chemical description of the candidate fuel or additive is required at the start of the testing. Additionally, a description of the manufacturing process is required for a new fuel. If the new material is an additive, its carrier solvent and recommended concentration must also be provided. This information is important for determining test requirements and the order in which the tests should be performed. Because the OEMs require this information to support their internal approval process with the aviation regulatory authorities (see Appendix X2), they have been designated by the subcommittee for receipt of any proprietary compositional information. This information can be provided under a non-disclosure agreement (NDA). The chemical nature of the fuel or additive plays a critical role in the following elements of the evaluation.

(1) Compatibility with fuel system seals and metallics.

(2) Hot section compatibility.

(3) Cold flow properties.

(4) Thermal stability.

(5) Rig tests for performance and operability.

(6) Emissions.

(7) Fuel handling.

6.1.3 It is important to note that during the evaluation process, any change in the formulation of the fuel or additive, method of manufacture, or the way it is to be used, must be brought to the attention of the recipients of the compositional data (i.e., OEMs) and the ASTM task group. It is possible that such changes will render invalid any data collected previously and require the qualification process be started anew.

6.1.4 Conduct of the D4054 evaluation of a new fuel may involve several separate and distinct batches of test fuel. It is important that each batch of test fuel is clearly identified and that the presented test data is clearly associated with the batch of fuel used for that particular test.

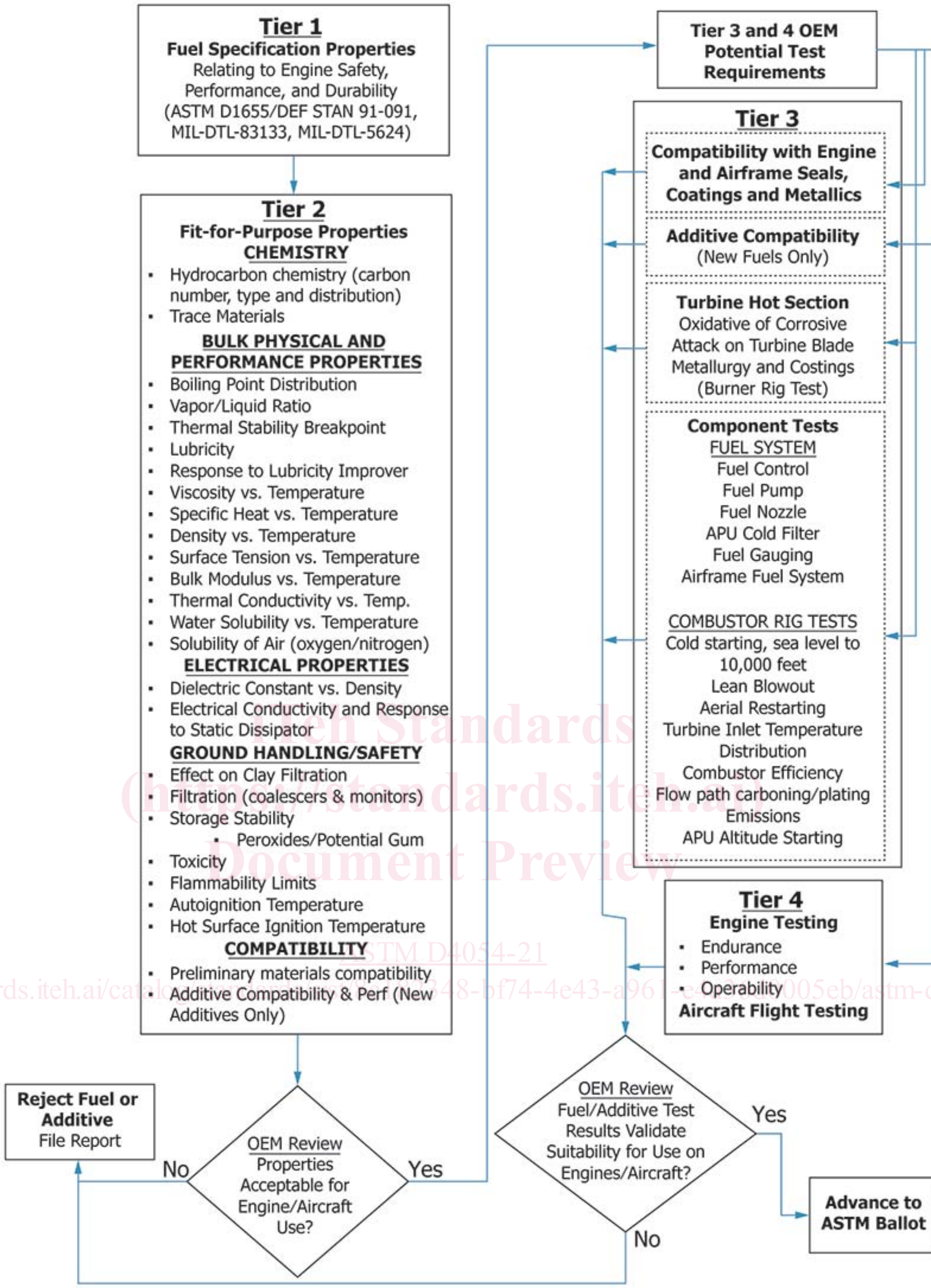
6.1.5 Much experience has been garnered from past industry and military efforts directed at investigating fuels and fuel additives. Additive investigations have been conducted on biocides, leak-detectors, thermal oxidative stability improvers, pipeline drag reducers, anti-static additives, and a water solubilizer for use in jet fuel. Fuel evaluations have included oil sands, shale oil, Fischer-Tropsch synthetic kerosines and biofuels. Lessons learned include the importance of prioritizing testing and performing first those tests that have the greatest potential to be cause for rejection.

6.1.6 A test program directed at evaluating a fuel or additive for use in a gas turbine engine shall contain the elements shown in the paragraphs that follow. The order of testing, as well as the tests that must be performed, may be redefined based on the specific nature and composition of the fuel or additive. Similarity to currently qualified fuels or additives is a chief consideration. In most cases, testing of a candidate fuel additive shall be performed at four times (4×) the concentration being requested for qualification. If solubility of the additive prevents blending at 4×, then the maximum level that is soluble should be used. The requirement to test at 4× is a means for assessing the impact of accidental additive overdose. It also lends itself to early detection of possible negative impacts. Additionally, testing at 4× permits more flexibility in selecting the baseline fuel to be used in the qualification process. Fuels can vary in their sensitivity to a particular additive. Testing at 4× negates the need to spend resources searching for a sensitive fuel for use as the baseline test fuel.

6.1.7 If a problem is identified with an additive at 4×, consideration will be given to assessing the impact of the additive at a lower concentration. Tests shall be performed with and without the candidate additive in the baseline test fuel. The baseline test fuel shall be Jet A or Jet A-1 conforming to the most recent revision of Specification D1655 or DEF STAN 91–091; JP-8 conforming to the most recent revision of MIL-DTL-83133 (NATO F-34); or JP-5 conforming to the most recent version of MIL-DTL-5624 (NATO F-44). The same batch of test fuel should be used in performing tests directed at impact on fuel specification properties. The same batch of test fuel should be used for as many of the Fit-for-Purpose Property tests as possible. The material compatibility tests should be performed using the same batch of test fuel. Some notable exceptions to using the same batch of test fuel might be component and engine tests.

6.1.8 A passing or failing test result is based on the type of test performed. In the case of specification testing, minimum or maximum specification requirements must be met. Some areas of investigation called out in this practice may not be amenable to a "pass" or "fail" result. For example, significant deviation from the baseline fuel or from what is judged to be the norm during the Fit-for-Purpose Tests could result in a failure. During aircraft, engine, rig, or component testing, results may be considered as failing when equipment performance or function is impacted. Further, test results that extend beyond the current range experience, such that a degree of risk is introduced to users of the fuel or additive, could result in a failure or a need for further testing.

6.2 *The Evaluation Process:*



* Testing must be performed at P&W, GE, Rolls Royce, Snecma, Honeywell, or in other locations per OEM agreement due to proprietary concerns and test methods.

NOTE 1—Additive testing to be performed at 4× the concentration being requested for approval except for filtration.

FIG. 2 Test Program

6.2.1 The test program is comprised of four tiers. Each tier consists of a distinct set of tests focused on a critical consideration that impacts engine and airplane design, safety, durability, performance, and reliability. The four tiers of testing are comprised of (*1*) Fuel Specification Properties; (*2*) Fit-for-Purpose Properties; (*3*) Component, Rig, and Materials Tests; and (*4*) Engine and Aircraft Tests.

6.2.2 The four-tier system provides an orderly approach to the evaluation of a new fuel or fuel additive. Testing is typically performed in sequence of the tier and builds upon the successful completion of each. Tiers act as a gate. Technical and financial resources should not be expended on moving to the next tier of testing if the tier just completed yields unacceptable results. In many cases, the unacceptable result can be resolved. In others, testing and evaluation of the additive or fuel should be terminated. Each successive tier tends to require more sophisticated testing and more specialized facilities. The task group will assist in directing the sponsor of the new fuel or additive to a qualified testing facility. Progressing to each tier will be accompanied by the requirement to provide greater volumes of the new fuel or additive. Table 1 shows the approximate volume of fuel required for each of the four tiers.

6.3 *Tier 1—Fuel Specification Properties*—All property tests as required in Specification D1655, DEF STAN 91–091, MIL-DTL-83133, and MIL-DTL-5624. When evaluating a new fuel, tests should be performed on the synthetic blend material as well as the final blend. The OEM team will provide guidance on which tests are appropriate for the synthetic blend material.

6.3.1 A special consideration under Tier 1 testing for a new fuel is that heat of combustion be measured using Test Method D4809. Alternative methods for determining heat of combustion such as Test Methods D1405, D3338, and D4529 are estimation methods. Test Method D3338 states in subsection 1.2: This test method is purely empirical and is applicable to liquid hydrocarbon fuels that conform to the specifications for aviation gasolines or aircraft turbine and jet engine fuels of grades Jet A, Jet A-1, Jet B, JP-4, JP-5, JP-7 and JP-8. Test Method D4529 has a similar statement. The estimation methods are not appropriate for a new fuel not yet demonstrated to be equivalent to the above conventional fuels. Subsequent to measuring heat of combustion using Test Method D4809, the fuel should be tested to D1405, D3338, and D4529 to demonstrate that estimation methods hold true for the proposed fuel.

6.4 *Tier 2—Fit-for-Purpose Properties*—When evaluating a new fuel, some of the Fit-for-Purpose Properties may be required to be performed on both the synthetic blend material as well as the final blend. The OEM team will provide guidance as to which tests will need to be performed.

6.4.1 *Accepted Test Methods and Limits*—Fit-for-Purpose Properties and associated test methods are shown in Table 2. Some Fit-for-Purpose Properties do not have well-defined limits. In these cases, the effect of the new fuel or new additive on a Fit-for-Purpose property must fall within the scope of experience of currently specified aviation turbine fuel. The basis for the scope of experience for these properties is described in Table 2.

6.4.2 *New Additive Performance and Compatibility with Additives Currently Permitted in Specification D1655*—The procedures used to determine compatibility of the new additive with additives currently approved for use in aviation fuels, and the procedures to evaluate performance of a new additive for its intended function are shown in Annex A2.

6.4.3 *New Fuel and Additive Preliminary Compatibility with Fuel System Materials*—This preliminary evaluation for compatibility includes three types of O-ring elastomers as specified in Annex A3: (*1*) Nitrile (N0602-70), Specification SAE AMS-P-5315, –70 °F to 180 °F, Black; (*2*) Fluorosilicone (L1120-70), Specification SAE AMS-R-25988, TY I, CL I, GR 70, UL listed, –100 °F to 350 °F, Blue; (*3*) Fluorocarbon (Viton) (V1226-75), Specification SAE AMS-7276, UL listed, –15 °F to 400 °F, Brown.

Aged and unaged samples should be soaked for seven days in the dark at room temperature and then tested for Shore M hardness (D2240), volume change (D1414/D471), and tensile strength (D1414/D412).

6.4.3.1 Additive concentration for the preliminary material compatibility tests shall be 4× the concentration being sought for qualification. Test temperatures shall be the highest temperature the materials are subjected to in their specific application within an aircraft or engine fuel system. The test temperature for each material is shown in Tables A3.2 and A3.3 in Annex A3 along with the standard test procedure and pass/fail criteria.

6.5 *Tier 1 & 2 Data Report*—The results of the Tier 1 & 2 testing should be reported to the subcommittee task group. In addition, a report containing compositional information, and any necessary descriptive information relating to the production process, source materials (i.e., feed stocks), formulation control, or batch quality control is provided to the OEMs and the FAA for the Phase 1 review. It is also recommended that proposed specification properties be included in the report.

6.6 *Phase 1 Review*—The Phase 1 review is initially conducted by the OEMs and the FAA followed by reporting to the task group and subcommittee for further review. The purpose

TABLE 1 Typical Fuel Volume Requirements to Evaluate a New Fuel or New Fuel Additive

NOTE 1—Fuel volumes shown are for a single test fuel. In most cases, a baseline fuel of equal volume will be required in addition to the new fuel blend stock, new fuel finished blend, or fuel additive blend being evaluated.

Tier	Tier Testing Description	Fuel Volume U.S. Gallons (Litres)	Note
1	Fuel Specification Properties	10 (37.8 L)	
2	Fit-for-Purpose Properties	80 (320.8 L)	
3	Component and Rig Tests	250 to 10 000 (946.3 L to 37 854.1 L)	Fuel volume depends on component type
4	Engine Test	450 to 225 000 (1703 to 851 718 L)	Fuel volume depends on engine type and whether it is a performance or endurance test

TABLE 2 Fit-for-Purpose Properties

Fuel Property	Test Method[A]	Units	Min	Max	Comments
CHEMISTRY					
Hydrocarbon Types	ASTM D2425	mass %	Report		Determines normal and iso-paraffins, cyclo-paraffins, mono-aromatics, indans, indanes, tetralins, naphthalenes, acenaphthenes, acenaphthalenes, tricyclic aromatics.
Aromatics	ASTM D1319 or ASTM D6379	Vol %	8 8.4	25 26.5	
Hydrogen	ASTM D5291 , D3701, or D7171	mass %	Report		
Trace materials					
Organics					
Carbonyls	ASTM E411	µg/g (ppm by mass)	Report		No limits established.
Alcohols	EPA Method 8015	m % or mg/L (ppm)	Report		
Esters	EPA Method 8260	mg/L (ppm)	Report		
Phenols	EPA Method 8270	mg/L (ppm)	Report		
Inorganics: N	ASTM D4629	mg/kg (ppm by mass)	Report		
Trace Elements					
Cu	ASTM D6732	µg/kg (ppb by mass)		< 20	
Al, Ca, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Pd, Pt, Si, Sn, Sr, Ti, V, Zn	ASTM D7111 or UOP 389	mg/kg (ppm by mass)	Report		
BULK PHYSICAL AND PERFORMANCE PROPERTIES					
Boiling point distribution	ASTM D86	°C			Based on CRC World Survey and Defense Logistics Agency Energy Petroleum Quality Information System survey.
Initial Boiling Point		°C	Report		
10 % Recovery (T10)		°C	150	205	
20 % Recovery		°C	Report	Report	
30 % Recovery		°C	Report	Report	Minimum and maximum values are based on Coordinating Research Council World Survey and Defense Logistics Agency Energy Petroleum Quality Information System survey.
40 % Recovery		°C	Report	Report	
50 % Recovery (T50)		°C	165	229	
60 % Recovery		°C	Report	Report	
70 % Recovery		°C	Report	Report	
80 % Recovery		°C	Report	Report	
90 % Recovery (T90)		°C	190	262	
Final Boiling Point		°C		300	
T50 - T10		°C	15	—	
T90 - T10		°C	40	—	
Simulated Distillation	ASTM D2887		Report Full Range		
Thermal Stability, JFTOT Breakpoint	ASTM D3241, Appendix X2	°C	See Comment		Additives cannot degrade breakpoint.
Deposit Thickness at Breakpoint	ASTM D3241, Annex A3 (Ellipsometer) or ASTM D3241, Annex A2 (Interferometer)	nm	Report		
Lubricity	ASTM D5001	mm WSD		0.85	Based on DEF STAN 91–091 requirements.
Response to Corrosion Inhibitor/ Lubricity Additive	ASTM D5001	mm WSD	Conform[B]		See Fig. A1.2 for typical response.
Viscosity vs. Temperature	ASTM D445 or D7042	mm^2/s	Conform[B]		Plot viscosity at –40 °C (or freezing point plus 5 °C, whichever is higher), –20 °C, 25 °C, and 40 °C. See Fig. A1.1 for typical values.
Specific Heat vs. Temperature	ASTM E1269	kJ/kg/K	Conform[B]		See Fig. A1.3 for temperature ranges, typical values, and temperature variations. Specific Heat on a dodecane standard must run and submitted along with the fuel value.
Density vs. Temperature	ASTM D4052	kg/m^3	Conform[B]		Plot density at –20 °C, 20 °C, and 60 °C. See Fig. A1.4 for typical values.
Surface Tension vs. Temperature	ASTM D1331	mN/m	Conform[B]		See Fig. A1.5 for minimum values and typical variation.
Isentropic Bulk Modulus vs. Temperature and Pressure	ASTM D6793	MPa	690 MPa (100 000 psi)		Limits not known; see Fig. A1.6 for typical values and variation.
Thermal Conductivity vs. Temperature	ASTM D2717	watts/m/K	Conform[B]		Limits not known; see Fig. A1.7 for typical values and variation.
Water Solubility vs. Temperature	ASTM D6304	mg/kg	Conform[B]		See CRC Handbook of Aviation Fuel Properties for typical values.
Air Solubility (oxygen/nitrogen)	Ostwald & Bunsen Coefficient (mm^3 of gas/mm^3 of fuel)		Conform[B]		See Fig. A1.9 for typical values. OEM experience is based on the air solubilities of TS-1 and JP-5, which is the least and most dense and volatile to which engines are currently designed.
True Vapor Pressure vs. Temperature	ASTM D6378	kPa or psi	Report –28, 12, 25, 38, 78, and 200 °C		See Fig. A1.10 for typical true vapor pressures for various jet fuel types.
Flash Point	ASTM D56, D3828, or D93	°C		68	
Freezing Point Test Methods—Response to Manual vs. Automatic Phase Transition	ASTM D2386 and D5972	°C	Conform[B]		
ELECTRICAL PROPERTIES					

TABLE 2 *Continued*

Fuel Property	Test Method[A]	Units	Min	Max	Comments
Dielectric Constant vs. Density	ASTM D924	N/A	Conform[B]		See Fig. A1.8 for typical values.
Conductivity Response	ASTM D2624	pS/m	Conform[B]		See Fig. A1.9 for typical response.
GROUND HANDLING PROPERTIES AND SAFETY					
Effect on Clay Filtration	ASTM D3948	MSEP No.	See Comment		No impact when compared to Jet A
Filtration – Coalescer Filters & Monitors (water fuses)	API/EI 1581	ppm by volume	See Comment		No impact when compared to Jet A
Storage Stability					
Peroxides	ASTM D3703	mg/kg (ppm by mass)	—	8.0	Store for 6 weeks at 65 °C.
Potential gums	ASTM D5304	mg/100 mL	—	7.0	Store for 16 h at 100 °C.
Toxicity	MSDS Review				
Flammability Limits	ASTM E681	°C	See Comment		No impact when compared to Jet A
Autoignition Temperature	ASTM E659	°C	See Comment		No impact when compared to Jet A
Hot Surface Ignition Temperature	FED-STD-791, Method 6053 or ISO 20823	°C	See Comment		No impact when compared to Jet A
COMPATIBILITY & PERFORMANCE (New Additives Only)					
Compatibility With Other Approved Additives	ASTM D4054, Annex A2	N/A	See Comment		Antioxidant, Corrosion Inhibitor/Lubricity Additive Fuel System Icing Inhibitor, Static Dissipator Additive No visible separation, cloudiness, solids, or darkening of color.
New Additive Performance	ASTM D4054, Annex A2	N/A			
PRELIMINARY MATERIALS COMPATIBILITY					
With Selected O-ring Elastomers		N/A	See 6.4.3		Nitrile, Fluorosilicone and Fluorocarbon (Viton) Elastomers

[A] Equivalent IP methods are acceptable.
[B] Conform = conform to typical response or values within engine/airframe manufacturers' experience. See Comment.

of the Phase 1 review is twofold. First, the tier 1 and 2 data needs to be evaluated to determine if the chemical and physical properties exhibited by the fuel or additive indicate suitability for further evaluation. Second, the specific tier 3 and 4 tests and associated test equipment necessary to evaluate the fuel or additive for use on aircraft and engines need to be defined. Because of the advanced technologies and materials used in modern gas turbine engines and aircraft, the subcommittee must rely on the expertise of the aircraft and engine OEMs and the FAA to make these determinations. The OEMs will conduct their own internal reviews of the Tier 1 & 2 Data Report (see Appendix X2) and provide their recommendations to the fuel/additive sponsor. Because many of the Tier 3 and 4 recommended tests will require the use of OEM specialized equipment, rigs, and facilities, close coordination between the sponsor and OEMs will be required to conduct this testing. While these recommendations are not mandatory, it is unlikely that the fuel or additive sponsor's proposed new or revised specification will advance through the ASTM subcommittee balloting process if an alternative testing or validation approach is applied.

6.7 *Tier 3—Component, Rig, and Compatibility Tests:*

6.7.1 *New Fuel Compatibility with Additives Currently Permitted in Specification D1655*—The procedures used to determine compatibility of the new fuel with additives currently approved for use in aviation fuels are shown in Annex A5.

6.7.2 *New Fuel and Additive Compatibility with Fuel System Materials*—A list of generic materials used in P&W, GE Av, RR, Honeywell, Boeing, Airbus, and Lockheed gas-turbine engine and airframe fuel systems is shown in Tables A3.2 and A3.3 in Annex A3. The engine and airframe manufacturers have agreed to these generic classes of materials for the purpose of evaluating compatibility with fuels and fuel additives. The generic list of materials to be tested includes 37 non-metallics and 31 metals. Materials known to be sensitive to a specific fuel or additive chemistry shall be tested first. The types of tests to be performed are defined in Tables A3.2 and A3.3 for each material. The scope of this testing will be determined based on the results of the Tier 2 preliminary materials compatibility testing described in 6.4.3.

6.7.2.1 Additive concentration for the material compatibility tests shall be 4× the concentration being sought for qualification. Test temperatures shall be the highest temperature the materials are subjected to in their specific application within an aircraft or engine fuel system. The test temperature for each material is shown in Tables A3.2 and A3.3 in Annex A3 along with the standard test procedure and pass/fail criteria.

6.7.3 *Turbine Hot-Section Erosion and Corrosion:*

6.7.3.1 Metallurgy.

6.7.3.2 Coatings.

6.7.3.3 Oxidative or corrosive attack is defined as hardware degradation of a degree and at a rate that oxidation or corrosion would likely be a primary cause of hardware failure or rejection of in-service hot section hardware.

6.7.4 *Fuel System Component Testing:*

6.7.4.1 Fuel Pump.

6.7.4.2 Fuel Control.

6.7.4.3 Fuel Nozzle.

6.7.4.4 APU Cold Filter Test.

6.7.4.5 Fuel Gauging.

6.7.4.6 Airframe Fuel System.

6.7.5 *Combustor Rig Testing:*

6.7.5.1 Cold starting at sea level to 10 000 ft.

6.7.5.2 Lean blowout.

6.7.5.3 Aerial restarting after a flame-out event.

6.7.5.4 Turbine inlet-temperature distribution.

6.7.5.5 Combustor efficiency.

6.7.5.6 Flow path carboning/plating.

6.7.5.7 Emissions.

6.7.5.8 Auxiliary Power Unit (APU) altitude starting.

6.8 *Tier 4—Engine and Aircraft Testing:*

6.8.1 *Engine Testing*—The evaluation process may require an engine test. The necessity for an engine test is based on the physical properties and chemical composition of the fuel or additive and will be determined during the Phase 1 review. The test procedures and equipment needed to conduct engine endurance, performance and operability testing will be defined based on consultation with the specific OEM entity that is conducting the testing and with the other OEM members of the subcommittee. Engine tests are unique to the specific engine model undergoing testing, and, consequently, cannot be predefined. Typically, the endurance portion of the test is a minimum of 150 h and 450 cycles. A cycle is defined as moving through a set of engine-throttle settings that include start, idle, accelerate to higher power, hold for a short period of time, decelerate to idle and stop. A typical cycle is 15 min to 20 min in duration. Operability and performance testing are typically of shorter duration, but may require special test cells or other equipment necessary to simulate in-flight operating conditions.

6.8.2 *Aircraft Flight Testing*—The evaluation process may also require an aircraft flight test. The necessity for an aircraft flight test is based on the physical properties and chemical composition of fuel or additive and will be determined during the Phase 1 review. However, most operating conditions can be simulated during engine testing so aircraft flight testing is not typically required. If required, the test procedures and equipment for conduct of aircraft flight testing will be defined based on consultation with the specific OEM entity that is conducting the testing and with the other OEM members of the subcommittee. Aircraft flight tests are unique to the specific aircraft model undergoing testing, and, consequently, cannot be predefined.

6.9 *ASTM Research Report*—A research report shall be issued upon completion of the Tier 3 and Tier 4 testing that formally documents all data and information compiled during the entire evaluation process. The report shall provide a conclusion regarding fit-for-purpose. The report shall include a proposed specification of the approved material with sufficient detail and limits to ensure formulation control within the experience base of the test data. It is the responsibility of the sponsor(s) to prepare and submit the report to the subcommittee.

6.10 *Phase 2 Review*—The purpose of the Phase 2 review is to determine if the fuel or additive is suitable for use on aircraft and engines, and based on that determination, to provide a recommendation to the subcommittee whether to ballot the new specification or revised specification to the ASTM membership. Because of the advanced technologies and materials used in modern gas turbine engines and aircraft, the subcommittee must rely on the expertise of the aircraft and engine OEMs and the FAA to make this determination. The OEMs will conduct their own internal review of the ASTM Research Report (see Appendix X2) and provide their recommendations to the fuel/additive sponsor and the subcommittee. The task group and subcommittee will then make a determination as to whether the research report data and OEM recommendations support the issuance of a ballot to incorporate the new fuel or additive into the fuel specifications. While these recommendations are not binding, it is unlikely that the fuel or additive sponsor's proposed new or revised specification will advance through the ASTM subcommittee balloting process if the OEMs determine that use of the fuel or additive is unacceptable for use on aircraft or engines. In addition, OEM internal approval in coordination with the aviation regulatory authorities is required to permit use of the fuel or additive on civil aircraft.

7. Keywords

7.1 additive evaluation; additive qualification; alternative fuels; ASTM; fuel additives; fuel evaluation; fuel qualification; jet fuel; material compatibility; OEM approval

ANNEXES

(Mandatory Information)

A1. BASIS OF ENGINE AND AIRPLANE MANUFACTURERS' EXPERIENCE

A1.1 Figs. A1.1-A1.11 describe the limits or characteristics that make up the engine manufacturers' scope of experience in evaluating the impact of a new fuel or new additive on a fit-for-purpose property that does not currently have a well-defined limit.