INTERNATIONAL

Designation: ~~D4054 – 19~~ D4054 – 20

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 practice covers and provides a framework for the Original Equipment Manufacturer (OEM) evaluation and approval of new fuels and new fuel additives for use in commercial and military aviation gas turbine engines. The practice was developed as a guide by the aviation gas-turbine engine Original Equipment Manufacturers (OEMs) with ASTM International member support. The OEMs are solely responsible for approval of a fuel or additive in their respective engines and airframes. Standards organizations such as ASTM International (Subcommittee D02.J0), United Kingdom Ministry of Defence, and the U.S. Military list only those fuels and additives that are mutually acceptable to all OEMs. ASTM International and OEM participation in the evaluation procedure does not constitute an endorsement of the fuel or additive.

1.2 The OEMs will consider a new fuel or additive based on an established need or benefit attributed to its use. Upon OEM approval, the fuel or fuel additive may be listed in fuel specifications such as Pratt & Whitney (P&W) Service Bulletin No. 2016; General Electric Aviation (GE) Specification No. D50TF2; and Rolls Royce (RR) engine manuals. Subsequent to OEM approval and industry review and ballot, the fuel or fuel additive may be listed in fuel specifications such as Specification D1655, DEF STAN 91–091, United States Air Force MIL-DTL-83133, and the United States Navy MIL-DTL-5624. This OEM evaluation and approval process has been coordinated with airworthiness and certification groups within each company, the Federal Aviation Administration (FAA), and the European Aviation Safety Agency (EASA).

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

1.4 *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.*

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

[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.

Current edition approved ~~May 1, 2019~~May 15, 2020. Published ~~May 2019~~July 2020. Originally approved in 1981. Last previous edition approved in ~~2017~~2019 as ~~D4054 – 17.~~D4054 – 19. ~~DOI:10.1520/D4054-19.~~DOI:10.1520/D4054-20.

[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**

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
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 (Withdrawn 2020)[3]
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

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

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
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)

[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

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 – 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

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 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

[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.
[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.

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 of Terms Specific to This Standard:*

3.1.1 *approve, n*—permission to use; not an endorsement of the new fuel or new fuel additive.

4. Significance and Use

4.1 The intent of this document is to permit a new fuel or additive to be evaluated and transitioned into field use in a cost effective and timely manner.

4.2 Its purpose is to guide the sponsor of a new fuel or new fuel additive through a clearly defined evaluation process that includes the prerequisite testing and required interactions with the engine and airframe manufacturers; standards organizations; and airworthiness agencies such as the FAA and EASA. 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 clear path forward for introducing a new technology for the benefit of the aviation community.

4.3 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 assessment of incidental materials on fuel properties. In the context of Practice D4054, incidental materials shall be considered as an additive.

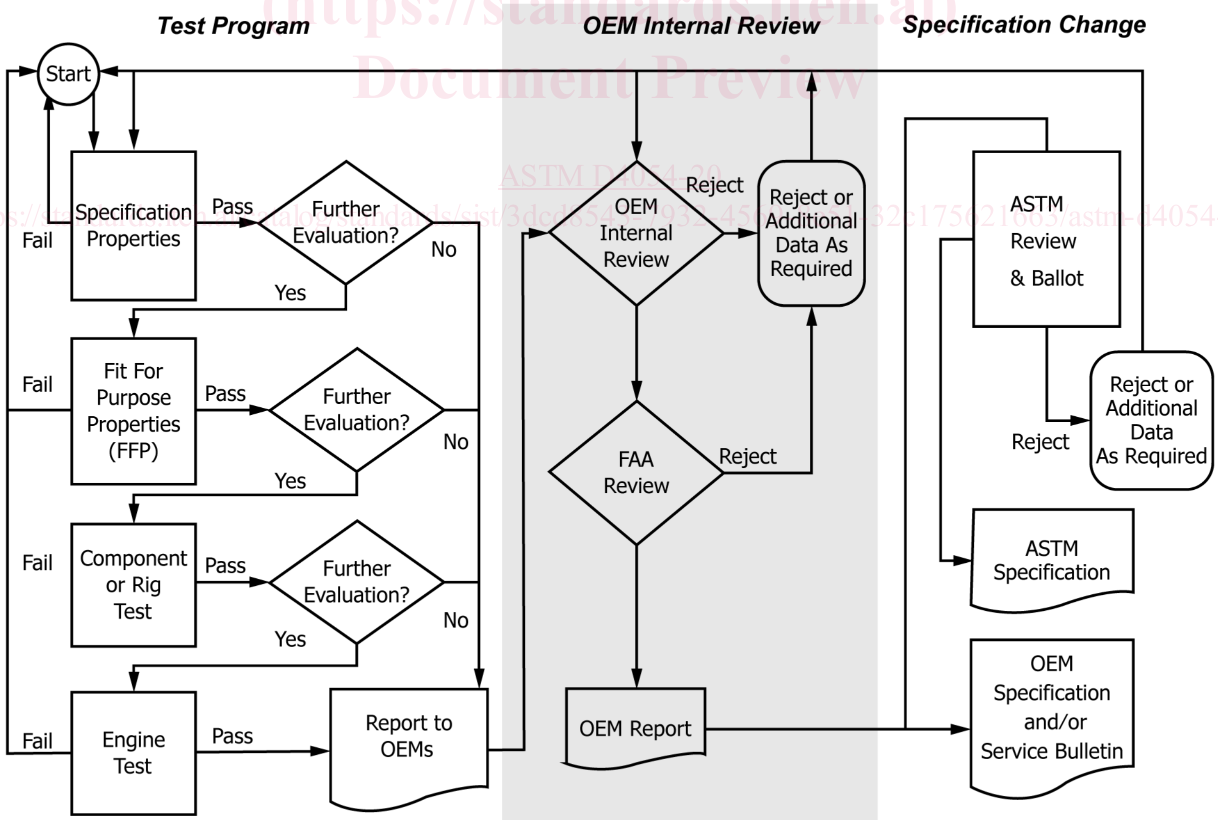


FIG. 1 Overview Fuel and Additive Approval Process

[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.

5. Overview of the OEM Qualification and Approval Process

5.1 An overview of the OEM approval process is shown in Fig. 1. The OEM approval process is comprised of three parts: *(1)* Test Program, *(2)* OEM Internal Review, and *(3)* Specification Change Determination.

5.1.1 *Test Program*—The purpose of the test program is to ensure that the candidate fuel or additive will have no negative impact on engine safety, durability, or performance. This is accomplished by investigating the impact of the candidate fuel or additive on fuel specification properties, fit-for-purpose properties, component rig tests, or engine tests. Fig. 2 lists elements of the test program; it should be considered a guideline. It is unlikely that all of the tests shown in Fig. 2 will need to be performed. The OEMs should be consulted and will provide guidance on which tests are applicable. Applicability will be based on chemical composition of the new fuel or additive, similarity to approved fuels and additives, and engine/airframe manufacturer experience. Departure from engine or airframe manufacturer experience requires more rigorous testing. The product of the test program is a research report submitted by the fuel or additive sponsor to the engine and airframe manufacturers. The research report facilitates a comprehensive review of the test data by the engine and airframe manufacturers, specification writing organizations, and regulatory agencies.

5.1.2 *OEM Internal Review*—During the OEM review, results of the test program are carefully studied by the respective OEM chief engineers and their discipline chiefs. An OEM airworthiness representative interfaces with the appropriate airworthiness authority, for example, the FAA and EASA, to determine extent of ~~FAA/ EASA~~ FAA/EASA involvement. Discipline Chiefs and their staff engineers from organizations responsible for combustion, turbine, fuel system hardware, performance system analysis, system integration, and airworthiness engage in iterative meetings and reviews until the concerns and potential impacts on the engine have been explored and satisfactorily addressed. This exercise can result in requests for additional information or testing. Final approval is made at the executive level based on the recommendation of the chief engineer. The product of the OEM internal review is a document or report that either rejects or approves the new fuel or additive for that specific OEM. After the approval of the new fuel or additive, there may be a requirement for a Controlled Service Introduction (CSI). Under a CSI, engines in the field that are exposed to the new fuel or additive are monitored for an increased level of fair wear and tear. The CSI is directed at identifying possible long-term maintenance effects.

5.1.3 *Specification Change Determination*—Approval by the OEMs of a new fuel or additive may only effect OEM internal service bulletins and engine manuals and have no impact on Specification D1655. If the OEM proposes changes to Specification D1655, then the proposed changes must be reviewed and balloted by ASTM D02.J0. Changes to Specification D1655 could include listing the additive or fuel as acceptable for use, changes to published limits, special restrictions, or additional precautions. Fig. 1 includes an overview of the ASTM review and balloting process, which is quite rigorous and typically goes through several iterations before a ballot is successful, culminating in a change to Specification D1655. The OEMs and the regulatory agencies regard the ASTM review and balloting process, and the subsequent scrutiny of industry experts, as an additional safeguard to ensure that issues relating safety, durability, performance, and operation have been adequately addressed. Although not a requirement, the OEMs typically wait for a successful ASTM ballot before changing their service bulletins and engine manuals to accommodate the new fuel or additive.

5.2 The process described in 5.1 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 meet strict compositional and performance criteria specified to ensure the blendstock and final blend fall within the typical range of current OEM-approved blendstocks and kerosine jet fuels respectively. The fast track process is described in Annex A4 of this standard 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.

6. Key Participants and Request for Qualification

6.1 *OEMs*—Engine OEMs include but are not limited to Pratt & Whitney (P&W), GE Aviation (GE Av), Rolls Royce (RR), and Honeywell. Airframe OEMs include but are not limited to Boeing, Airbus, Bombardier, and Lockheed. OEM approval is required for use of a new fuel or additive in aviation gas-turbine engines. OEM review and approval is required to ensure safety of flight, engine operability, performance, and durability requirements are not impacted by the new fuel or additive.

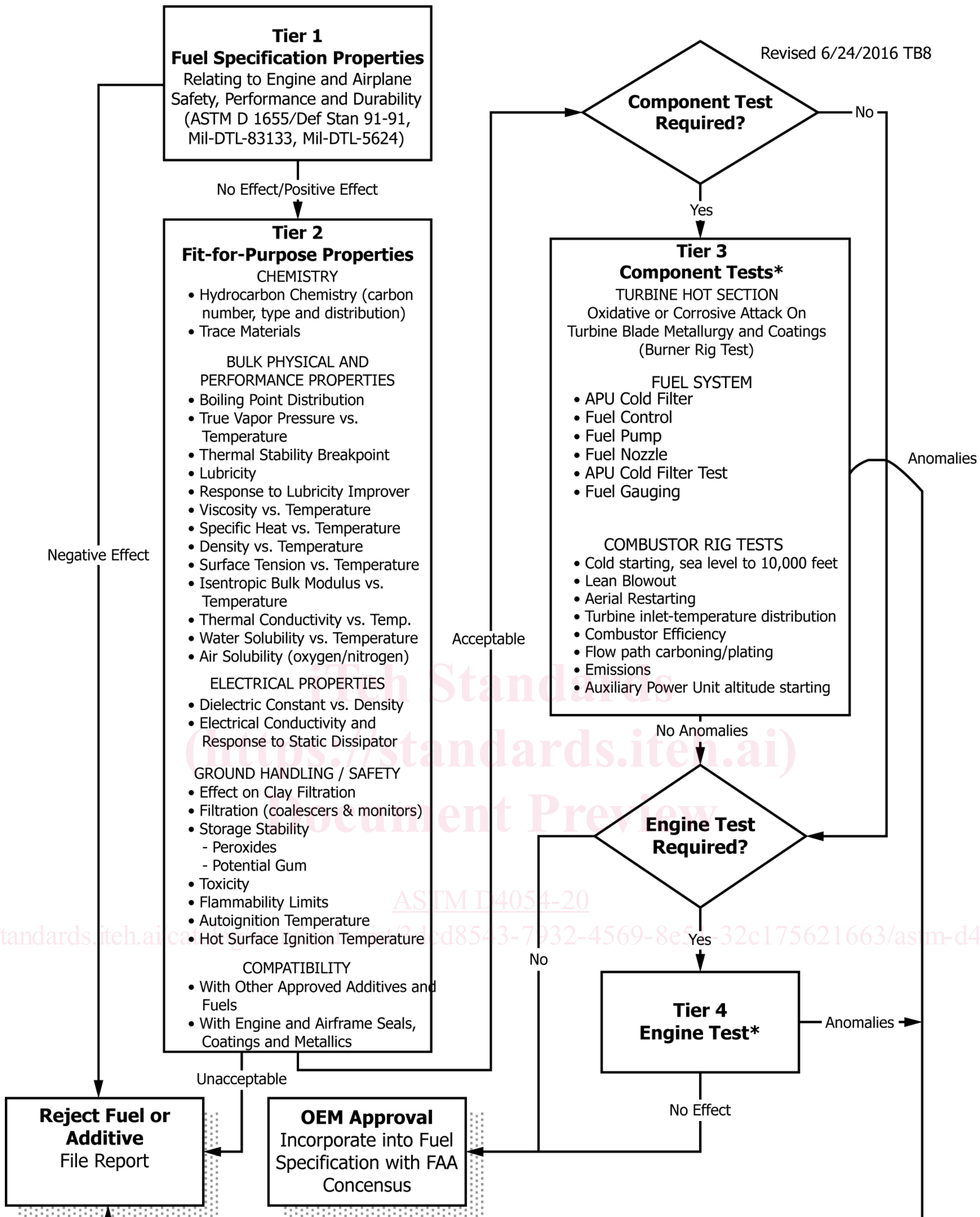
6.2 *Regulatory Authorities*—While approval of a new fuel or additive is at the discretion of the OEMs, regulatory organizations such as the FAA and EASA participate in the process. Oversight by the regulatory authorities is necessary under the following conditions:

6.2.1 The new fuel or additive impacts specification properties to the extent that the fuel does not conform to Specification D1655,

6.2.2 A new specification must be written to accommodate the new fuel or additive, or

6.2.3 Recertification of the engine or aircraft and aircraft operating limitations is required.

6.3 *Airlines*—Airline advocacy for the candidate fuel or additive is important to warrant consideration for qualification. The OEMs need strong support from the airlines to justify committing internal resources to evaluating a new fuel or new fuel additive



* 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

for use in an aircraft. Interested airlines or other users (for example, U.S. Military and air cargo) must submit formal written requests to the OEM customer service groups expressing a need and requesting that the fuel or additive be evaluated for OEM qualification and approval. Requests from the airlines facilitate OEM management support, resulting in multi-discipline (combustor, turbine, fuel system hardware, materials, etc.) involvement in assessing impact on engine and aircraft operation.

6.4 *Military*—Military participation in the evaluation process is important because many commercial engines have military derivatives. The U.S. Air Force and U.S. Navy, respectively, have an approval protocol that is specific to the unique considerations of military engines. The protocols are based largely on this practice. Every effort is made to harmonize the commercial and military protocols such that they complement each other.

6.5 *ASTM International:*

6.5.1 ASTM Subcommittee D02.J0 on Aviation Fuels promotes the knowledge of aviation fuels by the development of specifications, test methods, and other standards relevant to aviation fuels. Issuance of an aviation fuel specification or test method by ASTM International represents the culmination of a comprehensive evaluation process conducted by ASTM members representing the petroleum industry, aerospace industry, government agencies, and the military. ASTM members are classified as producers (petroleum, additive and other fuel companies); users (aircraft or engine manufacturers, airlines); consumers (pilot or aerospace representative organizations); or general interest (government agencies and other parties). All such organizations or individuals showing ability and willingness to contribute to the work of Subcommittee D02.J0 are eligible for membership and participation in standards development.

6.5.2 The process for evaluating a fuel or additive is initiated by a sponsor who acts as an advocate for promotion of the new aviation fuel. The sponsor approaches the ASTM aviation fuels subcommittee and solicits their support. ASTM members are volunteers and there is no obligation on the part of ASTM members to participate in the specification development activity. Participation of ASTM will be influenced by the quality of the presented material.

6.5.3 The new fuel or additive formulation must be well defined prior to approaching ASTM. Compositional changes cannot be accommodated during the review process without written approval by the OEMs. The additive or fuel shall be identified by its specific chemical name or trade name. A chemical description of the fuel or additive shall be provided. If qualification is being sought for an additive, the carrier solvent and recommended concentration shall be provided. If the additive chemistry is proprietary, a generic description shall be provided. If merited, nondisclosure agreements can be placed between the additive manufacturer, the OEMs, and any task force member organization assisting in the investigation. ASTM and the Coordinating Research Council (CRC)[16] cannot enter into nondisclosure agreements or guarantee confidentiality.

6.5.4 A producer's specification for the fuel or additive shall be agreed upon by the OEMs. The specification shall define appropriate limits in sufficient detail that the purchaser can use it to ensure the receipt of the approved material. In cases where the approved material is a single named chemical, the specification shall, at a minimum, define the purity level of the approved chemical.

6.5.5 A technical case shall be presented to the OEMs and Subcommittee D02.J0 establishing need for the fuel or additive. Verifiable data performed by an industry-recognized laboratory shall be presented supporting performance for the specified application. The OEM/ASTM technical body will assess value and need based on the technical case. The assessment will consider scientific approach, source, and credibility of the data presented. The sponsor or investigating body shall submit a written report containing nonproprietary information to the OEMs.

6.6 *Coordinating Research Council (CRC)*—The CRC Aviation Fuels Committee has a mission to foster scientific cooperative aviation fuels research. The vision is to be a worldwide forum for the aviation fuel technical community and the leader in cooperatively funded aviation fuel research. CRC typically will respond to a request from ASTM to investigate a fuel-related issue. A fuel or additive will be considered for qualification if the OEMs and Subcommittee D02.J0 determines that the fuel or additive fulfills a need or provides a significant benefit to the aviation industry. If additional data or research is required, ASTM may request CRC or other cooperative research group investigate the fuel or candidate additive in more detail. Involvement of CRC or other cooperative research group can range from a review of data presented by the additive manufacturer or sponsor to actual testing and research performed by CRC task force members. The acceptance by the CRC to carry out the requested research is independent of the ASTM process and contingent on CRC steering committee approval.

7. Funding the Investigation and Qualification Process

7.1 The organization (for example, the additive manufacturer or refiner) seeking permission to use a new fuel or fuel additive is responsible for funding all aspects of the fuel or additive qualification process. Costs include laboratory, rig, or engine tests, if required, as well as interpreting, communicating, and reporting data. Depending on how beneficial the fuel or additive is considered to be to the aviation industry, CRC may organize task forces and may solicit its members to perform work using available funding within their organizations. The U.S. military or other government organizations will sometimes consider participating in a Cooperative Research Program if the fuel or additive is deemed to be of significant benefit to the military.

[16] Coordinating Research Council, Inc., 5755 North Point Pkwy, Suite 265, Alpharetta, GA 30022. www.crcao.org

8. Elements of the Test Program

8.1 Elements of the test program to be performed are shown in Fig. 2. The purpose of the test program 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 of a petroleum-derived fuel and assumed to be within a given range of experience. Fit-for-Purpose Properties are not controlled by specification but are considered critical to engine and airframe fuel system design. Examples include fuel lubricity, seal swell, and dielectric constant. During the course of the test program, special considerations may be identified and investigated to resolve anomalies. Examples include minimum aromatic level, maximum flash point, and minimum lubricity.

8.2 A complete chemical description of the candidate fuel or additive is required for defining the test program. Additionally, a description of the manufacturing process is required for a new fuel. This information can be provided under a non-disclosure agreement (NDA) with the OEMs. 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 that the tests should be performed. The chemical nature of the fuel or additive defines criticality of the following issues:

8.2.1 Compatibility with fuel system seals and metallics.

8.2.2 Hot section compatibility.

8.2.3 Cold flow properties.

8.2.4 Thermal stability.

8.2.5 Rig tests for performance and operability.

8.2.6 Emissions.

8.2.7 Fuel handling.

8.3 It is important to note that during the evaluation process or subsequent OEM approval, 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 OEMs and ASTM Task Force. It is possible that such changes will render data collected previously invalid and require the qualification process be started anew.

8.4 Much experience has been garnered from ASTM, CRC, U.S. Military and OEM past efforts directed at investigating fuels and fuel additives. Additive investigations have included 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 those tests first that have the greatest potential to be cause for rejection.

8.5 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 engine and airframe manufacturers have agreed to the order of testing. 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.

8.6 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.

8.7 A passing or failing test result is defined by 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. In these cases (such as the Fit-for-Purpose Tests), significant deviation from the baseline fuel or from what the OEMs judge to be the norm could result in a failure. Results may be considered as failing when expected levels of equipment performance are compromised, that is, not functioning optimally. Further, test results that extend beyond OEM experience, such that a degree of risk is introduced, could result in a failure or a need for further testing.

9. Performing the Test Program

9.1 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 and Rig Tests; and (*4*) Engine Test.

9.1.1 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 negative results. In many cases, the negative 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 engine and airplane OEM team 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.

9.2 *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.

9.2.1 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 drop-in fuel.

9.3 *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.

9.3.1 *Accepted Test Methods and Limits*—Fit-for-Purpose Properties as agreed upon by the engine and airplane manufacturers are shown in Table 2. Accepted test methods for evaluating the Fit-for-Purpose Properties are shown along with limits. Some Fit-for-Purpose Properties have no 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 the engine manufacturers. The basis for the engine manufacture's scope of experience for these properties is described in Table 2.

9.3.2 *Performance of and Compatibility with Additives Currently Permitted in Specification D1655*—The procedures utilized 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.

9.3.3 *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 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.

9.3.3.1 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.

9.4 *Tier 3—Component and Rig Tests:*

9.4.1 *Turbine Hot-Section Erosion and Corrosion:*

9.4.1.1 Metallurgy.

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	
Zn, Fe, V, Ca, Li, Pb, P, Na, Mn, Mg, K, Ni, Si	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					
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.

TABLE 2 *Continued*

Fuel Property	Test Method[A]	Units	Min	Max	Comments
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					
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.
With Engine and Airframe Seals, Coatings and Metallics	ASTM D4054, Annex A3				

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

9.4.1.2 Coatings.

9.4.1.3 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.

9.4.2 *Fuel System Component Testing:*

9.4.2.1 Fuel Pump.

9.4.2.2 Fuel Control.

9.4.2.3 Fuel Nozzle.

9.4.2.4 APU Cold Filter Test.

9.4.2.5 Fuel Gauging

9.4.3 *Combustor Rig Testing:*

9.4.3.1 Cold starting at sea level to 10 000 ft.

9.4.3.2 Lean blowout.

9.4.3.3 Aerial restarting after a flame-out event.

9.4.3.4 Turbine inlet-temperature distribution.

9.4.3.5 Combustor efficiency.

9.4.3.6 Flow path carboning/plating.

9.4.3.7 Emissions.

9.4.3.8 Auxiliary Power Unit (APU) altitude starting.

9.5 *Tier 4—Engine Test*—The qualification process may require an engine test. Not all fuel or additive qualifications will require an engine test. The necessity for an engine test is based on the nature and chemical composition of the fuel or additive and is at the discretion of the engine manufacturers. The elements of an endurance test, or a combination of a performance test and an endurance test, are defined by the engine manufacturer. Engine tests are engine specific 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.

10. Report

10.1 A research report shall be issued upon completion of the test program that formally documents all data and information compiled during the evaluation process. The report shall provide a conclusion regarding fit-for-purpose. The report shall include a specification of the approved material with sufficient detail and limits to permit a purchaser to confirm receipt of OEM approved material. It is the responsibility of the sponsor(s) to prepare and submit the report to the OEMs, specification authorities and ASTM. The OEMs, specification authorities and ASTM will require this report for use as supporting evidence for subsequent qualification via internal engineering groups and airworthiness authorities.

11. Keywords

11.1 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.

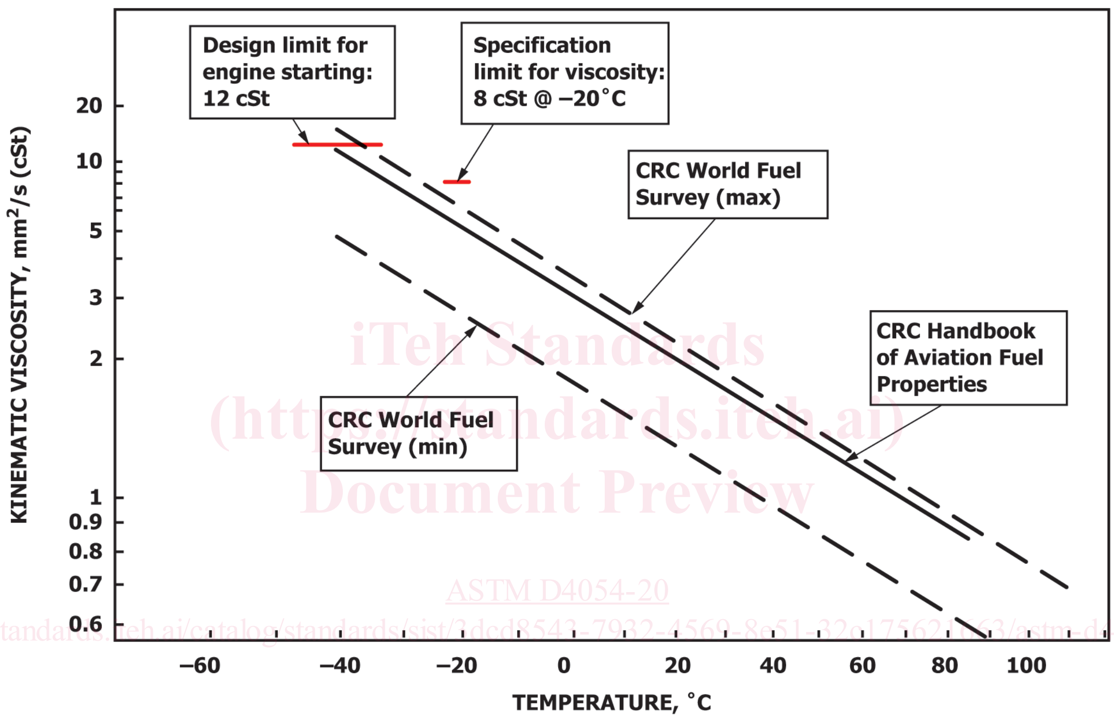


FIG. A1.1 Typical Viscosity Characteristics of Jet Fuel

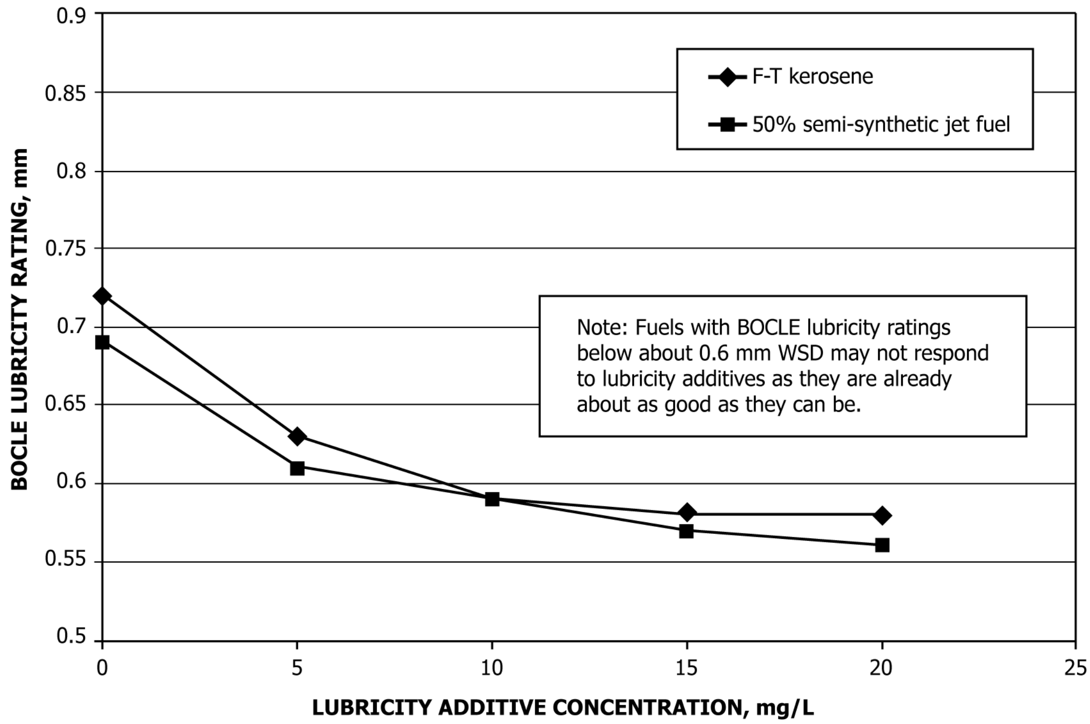


FIG. A1.2 Typical Response to Corrosion Inhibitor/Lubricity Improver (CI/LI) Additive

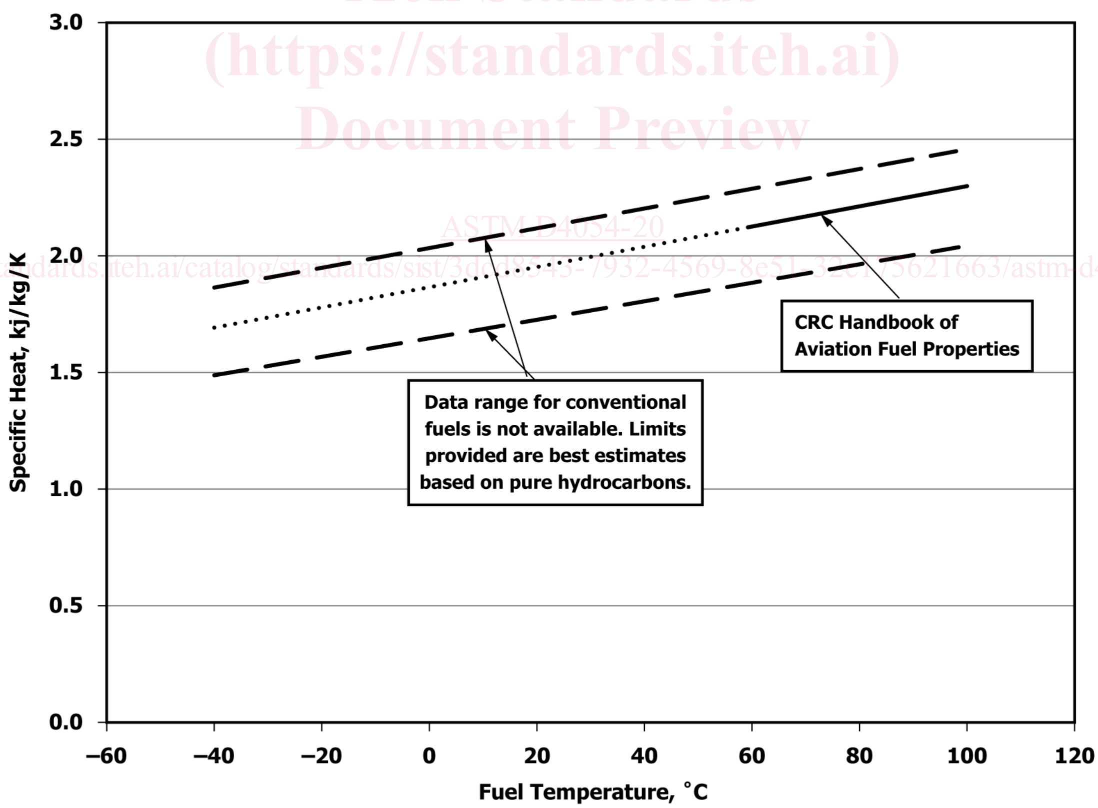


FIG. A1.3 Typical Specific Heat Characteristics of Jet Fuel