CRC Project No. AV-23-15/17

Review of Existing Test Methods Used for Aviation Jet Fuel and Additive Property Evaluations with Respect to Alternative Fuel Compositions

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COORDINATING RESEARCH COUNCIL, INC.
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Prepared by M. Thom for the Coordinating Research Council, Inc., Contract No. AV-23-15/17 May 2018

Abstract

This document covers the findings and analyses of the specifications and standards referenced in the three primary parent documents used by the U.S. aviation industry. The three parent documents guide offerors in the generation of data for the review of alternatively prepared jet fuel, new additives, and properties for quality control, purchase, and contracting. The three parent documents reviewed were ASTM D1655, Standard Specification for Aviation Turbine Fuels, ASTM D7566, Standard Specification for Aviation Turbine Fuels Containing Synthesized Hydrocarbons, and ASTM D4054, Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives. During the standards review, an additional document, Military Handbook 510 (MIL-HDBK-510) was also included as a parent document. A subsequent review was made of the E.U. Specification Defence Standard 91-091 and standards it referenced. The purpose of the study was to assess the potential impact on the referenced test specifications with fuels prepared in manners other than from traditional petroleum crude, D7566 blendstocks which may not be fluids meeting the traditional kerosene distillation profile, and additives. It was considered beyond the scope of the program to assess how potential issues and concerns were evaluated or addressed, and it was beyond the scope of the project to evaluate the constraints provided by the parent documents on quantitative results. Information on OEM considerations for testing is discussed. A review of sources for executing the listed test procedures is provided.

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Summary

This document covers the analyses of the specifications and standards referenced in the three primary parent documents used by the U.S. aviation industry. A subsequent review was made of the standards referenced in the E.U. specification, Defence Standard 91-091. These documents are used to guide offerors in the generation of data for the review of alternatively prepared jet fuel, new additives, blendstocks, and properties for quality control, purchase, and contracting. All reviewed documents were the latest revision at the time of revision. Interested parties should confirm latest revision of the standard at the time of use.

U.S. Document Review Summary

- A total of 348 documents were reviewed during the course of the project.
    - 318 test methods, guides, materials and processes were in the parent standards (including the 3 parent documents themselves)
    - 30 additional test standards were added during the project reviews
- A preliminary review assigned a category to the original 318 documents.
    - 107 standards were not a test
    - 4 were withdrawn
    - 5 were inactive
    - 68 were out of scope
    - 130 were a test
    - 3 were the parent documents

Document Conventions

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Parent Specification – Term used to reference the four documents reviewed for the project

Table Order - Because of the way Excel sorts entries, some tables display the specs based on each number in the spec identification as opposed to pure numerical order.

Discussions related to European reviews – In sections discussing U.K or E.U. related documents, the use of the Queen's English will be maintained.

- A total of 149 standards were reviewed during a second review.
    - 98 standards were identified as documents of interest
    - 32 standards were identified as not being of interest
    - 17 standards were for tests not related to fuel
    - 2 documents were unclear
- Following a second review, an additional 30 standards were added as important for evaluation but unreferenced in the parent documents
- A total of 140 standards were reviewed in depth during a third and final review
    - 27 standards were determined not be applicable to the review
    - 10 entries were relational reports
    - 70 standards were identified as having no anticipated impact based on the application, scope, or precision and bias statement limitations ("green").
    - 6 standards were identified as having a noticeable question or limitation ("red").
        - ASTM D924 Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
        - ASTM D976 Calculated Cetane Index
        - ASTM D1250 Guide for Use of the Petroleum Measurement Tables
        - ASTM D1405 Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
        - ASTM D2425 Standard Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry
        - ASTM D4529 Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
    - 27 standards were identified as having a concern and warranted further reviews ("yellow"). Most of the concerns are related to the precision and bias statements, potential deviations in software interpretations, or subsequent application of the data.
        - ASTM D130 Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
        - ASTM D240 Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter
        - ASTM D341 Standard Practice for Viscosity-Temperature Charts for Liquid Petroleum Products
        - ASTM D445 Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
        - ASTM D1298 Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
        - ASTM D1319 Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
        - ASTM D1740 Standard Test Method for Luminometer Numbers of Aviation Turbine Fuel

- ASTM D2624 Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels
- ASTM D3240 Standard Test Method for Undissolved Water In Aviation Turbine Fuels
- ASTM D3241 Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels
- ASTM D3338 Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
- ASTM D3343 Standard Test Method for Estimation of Hydrogen Content of Aviation Fuels
- ASTM D3701 Standard Test Method for Hydrogen Content of Aviation Turbine Fuels by Low Resolution Nuclear Magnetic Resonance Spectrometry
- ASTM D3948 Standard Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer
- ASTM D4308 Standard Test Method for Electrical Conductivity for Liquid Hydrocarbons by Precision Meter
- ASTM D5001 Standard Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
- ASTM D5190 Standard Test Method for Vapor Pressure of Petroleum Products (Automatic Method)
- ASTM D5191 Standard Test Method for Vapor Pressure of Petroleum Products (Mini Method)
- ASTM D5482 Standard Test Method for Vapor Pressure of Petroleum Products (Mini-Method - Atmospheric)
- ASTM D5972 Standard Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)
- ASTM D6379 Standard Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection
- ASTM D7153 Standard Test Method for Freezing Point of Aviation Fuels (Automatic Laser Method)
- ASTM D7154 Standard Test Method for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)
- ASTM D7524 Standard Test Method for Determination of Static Dissipater Additives (SDA) in Aviation Turbine Fuel and Middle Distillate Fuels—High Performance Liquid Chromatograph (HPLC) Method
- ASTM D7797 Standard Test Method for Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy—Rapid Screening Method
- ASTM E411 Standard Test Method for Trace Quantities of Carbonyl Compounds with 2,4-Dinitrophenylhydrazine
- ASTM E2071 Standard Practice for Calculating Heat of Vaporization or Sublimation from Vapor Pressure Data

Review of Test Sources

- Following a review of available testing sources, 8 test referenced test methods do not have immediately identifiable sources for procurement of data.
    - ASTM D2879 Standard Test Method for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope
    - ASTM D6866 Standard Test Method for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples using Radiocarbon Analysis
    - ASTM D7345 Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure (Microdistillation Method)
    - ASTM D7524 Standard Test Method for Determination of Static Dissipater Additives (SDA) in Aviation Turbine Fuel and Middle Distillate Fuels
    - ASTM D7797 Standard Test Method for Determination of the FAME Content of Aviation Turbine Fuel using Flow Analysis
    - ASTM D7872 Standard Test Method for Determining the Concentration of Pipeline Drag Reducer Additive in Aviation Turbine Fuels
    - ASTM D7945 Standard Test Method for Determination of Dynamic Viscosity and Derived Kinematic Viscosity of Liquids by Constant Pressure Viscometer
    - ASTM E2071 Standard Practice for Calculating Heat of Vaporization or Sublimation from Vapor Pressure Data (references ASTM D2879)

Additional Findings

- Both a technology and a needs gap was identified regarding the measurement and requirements of bulk modulus testing suggesting that while there is no obvious issue with ASTM D6793 as a test method for static bulk modulus, it appeared that D6793 was not sufficient for developing the desired dynamic bulk modulus.
- Both a technology and a needs gap was identified regarding the measurement and requirements of dielectric constant suggesting that not only is there a technology gap with ASTM D924 but that D924 may not be sufficient for jet fuel testing.
- Most of the relational data collection requirements were found in MIL-HDBK-510. While some specific additional data points at other test conditions may be requested by the hardware manufacturers, such as determining viscosity at additional temperatures, only MIL-HDBK-510 contained overt relational testing requirements such as testing a fuel property versus temperature. However, what those additional test conditions should cover, for example at what specific temperatures the additional testing should be performed, frequently was not provided.

Defence Standard 91-091 Document Review Summary

- A total of 115 documents were reviewed during the course of the project
    - 101 test methods, material specifications, guides, and processes were collected from Def Stan 91-091
    - 3 test methods were identified and added during the document review
    - 11 test methods identified during the U.S. analysis were collected during the E.U. review
        - 6 were also referenced by Def Stan 91-091
        - 5 were added to the review list

- A preliminary review assigned a category to the original 101 documents
  - 2 were identified as not being a test
  - 2 were withdrawn
  - 5 were deemed out of scope
  - 17 were IP standards with equivalency to an ASTM standard reviewed during the U.S. review
  - 46 were ASTM standards
    - 42 of these ASTM specifications had been reviewed during the U.S. review
    - 4 required no further review
  - 2 were not ASTM standards, but had been reviewed during the U.S. review
  - 27 required further review
- A total of 32 documents (27 from Def Stan 91-091 and 5 IP standards from U.S. review) were reviewed in-depth during a third and final review
  - 6 were not test methods required no further assessment
  - 1 was withdrawn (IP 355)
  - 21 were assessed as having no impact based on the application, scope, or precision and bias statement limits (green)
  - 1 was assessed as having a notable concern (red)
    - IP 381 Aviation fuels – Estimation of net specific energy
  - 3 were assessed as having a concern (yellow)
    - 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
    - IP 590 Determination of fatty acid methyl esters (FAME), derived from bio-diesel fuel, in aviation turbine fuel – HPLC evaporative light scattering detector method
    - IP 599 Determination of Fatty Acid Methyl Esters (FAME) in Aviation Turbine Fuel by Gas Chromatography using Heart-cut and Refocusing

Contents

List of Figures

List of Tables

List of Acronyms

Acronym	Definition
API	American Petroleum Industry
BOCLE	Ball-on-Cylinder Lubricity Evaluator
BSI	British Standards Institution
CHN	Carbon, Hydrogen, and Nitrogen
CIC	Combustion Ion Chromatography
CN	Carbon number
CRC	Coordinating Research Council
DoD	Department of Defense
DVPE	Dry vapor pressure equivalent
ECHA	European Chemical Agency
EIA	US Energy Information Administration
FTM	Federal Test Method
GC/MS	Gas Chromatography/Mass Spectrometry
HPLC	High Performance Liquid Chromatography
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectrometry
ILS	Interlaboratory Study
IP	International Petroleum
JIG	Joint Inspection Group
SwRI	Southwest Research Institute
LP	Liquefied petroleum
LPG	Liquefied petroleum gas
MIE	Minimum Spark Ignition Energy
NMR	Nuclear Magnetic Resonance
OEM	Original Equipment Manufacturer
RVP	Reid Vapor Pressure
SDA	Static Dissipater Additive
SME	Subject Matter Expert
STM	Standard Test Method

1 Background

1.1 Why Review the Standards

Over the last 75 years, there has been an evolution in three areas of fuel testing: changes in the needs of the aircraft hardware, changes in the technology of the test methods, and changes in the fuel chemistry.

Because of the interrelationship of the fuel with the hardware, changes in the hardware meant different specific types of data and related fuel properties are required from the fuel. The result has been viewed over time as changes in the ASTM D1655 Table 1 properties, both in absolute values and in the properties specified. Hardware has been and continues to be designed around the fluid it uses.

Secondly, analytical chemistry has evolved over time as well. Advances in solid state electronics, micro-sample capabilities, computer processing capabilities, and new methodologies have led to changes in the testing equipment and procedures. Recognition and remediation of safety hazards, for example the elimination of mercury and pyridine, have resulted in changes to the methods. Improvements to throughput due to the introduction of autosamplers, advances in technology, and completely new methods mean that different data types have histories over time. However, to evolve a methodology or to be able to provide software analyses means there are fundamental assumptions of correlation between the original method and the new method. How the correlations are created and applied could be affected by the base chemistry of the fuel.

The third area where change has occurred is the evolution of the test methods and the Table 1 properties those methods were specifically designed to control. This means a specific property or value is needed to control the refining or distribution of a petroleum-based fuel itself. It is not well understood which of the standards are legacy testing requirements that imply control over other properties not specifically measured, but are inherently controlled by the test only when the fuel is a conventional petroleum product. This may result in exposure to a lack of surrogate control and a different test method may be required to control other fuel chemistries. Examples of this evolution are distillation ranges that control the percentage of a heavy end hydrocarbon or to control carbon number distribution. This means that a requirement for the purpose of controlling a traditional petroleum refining process may make no sense for a fuel prepared from an alternative chemistry or different production methods.

As a result of these changes over time, there are three types of potential data gaps.

1. The test method and accuracy statements were developed specifically for petroleum-based chemistry and the validity of the application to non-petroleum chemistries is unknown.
2. The test method is a new technology based on test parameter assumptions from original test performance with petroleum-based chemistries. The applicability of the parameter assumptions to non-petroleum based chemistries is unknown.
3. The industry infers behavior in use based on an absolute value from a test that may or may not correspond to the behavior of that absolute value with alternative fuel chemistries. This may

occur because the actual value only corresponds to a specific chemistry or because the single value is assumed to be a predictor of test performance across a data set that it no longer predicts, i.e. a viscosity curve.

As fuel technology has evolved, the emerging situation is a state where the OEM's using the fuel in their hardware do not necessarily know what is needed from the fuel specifically, only that the fuel needs to do what it has always done. Because it is not known which of those requirements are primary, relating to performance and which are secondary relationships, like controlling refining, compliance to all the properties has been required. These restrictions may have constrained technology change. Furthermore, a fluid is required to give the same data on all the tests even if the result is non-applicable, non-valid or makes no sense. The first step in stretching into new technologies is to relearn what the data are capable of telling us and why it should be considered.

1.1.1 Originally Proposed Deliverables

- List of test standards referenced in the three target fuel documents
- A list of standards that are/imminently obsoleted by the industry
- List of any identified industry standards not specified in the three target standards
    - OEM internal, other industry standards, other
- A list of standards that display a technology gap
- A short summary on each standard to review
    - History
    - Goal or purpose
    - General status – obsolescence, access, source
    - Any documented industry equivalence
    - Issues, findings, and recommendations
- Where possible, a list of how data are used by OEM's, especially when the use diverges from the goal/purpose of the test
- List of references used, including previous surveys

The review was made considering three potential end products; 1) a final, fully formulated jet fuel that would still be a kerosene boiling range fuel; 2) a blendstock for use in a fully formulated jet fuel or a final fuel that met fit-for-purpose but could be measurably different than a normal kerosene boiling range fuel in some way; 3) testing as a result of additive approval.

It was determined that, with the exception of the standards grouped in a topic (see Section 4.1) and the critically impacted tests (see Section 3.3.2), it was impractical within the time and resource limits of the program to develop historical discussions on all of the reviewed standards. Additionally, there are several ASTM monographs, listed in the reference section, which provide comprehensive discussions on a measurable subset of the standards reviewed, making these discussions here less value-added.

1.1.2 Final Deliverables

- List of test standards referenced in the three target fuel standards
    - See Appendix 11.1, Standard List
- A list of standards that are/will be imminently obsoleted by the industry
    - See Table 1 – Referenced Withdrawn Standards and Inactivated
- List of any identified industry standards not specified in the three target standards
    - See Table11.2, Added Standards
- A list of standards that display a technology gap
    - See Sections 0 and 3.3.2; Yellow and Red Reviews
- A short summary on each standard reviewed
    - See Appendix 0, Individual Review Sheets
- Where possible, a list of how data are used by OEM's, especially when the use diverges from the goal/purpose of the test
    - See Section 5, Original Equipment Testing
- Identification of Testing Access
    - See Section 6, Testing Locations
- List of references used, including previous surveys
    - See Section **Error! Reference source not found.**, References

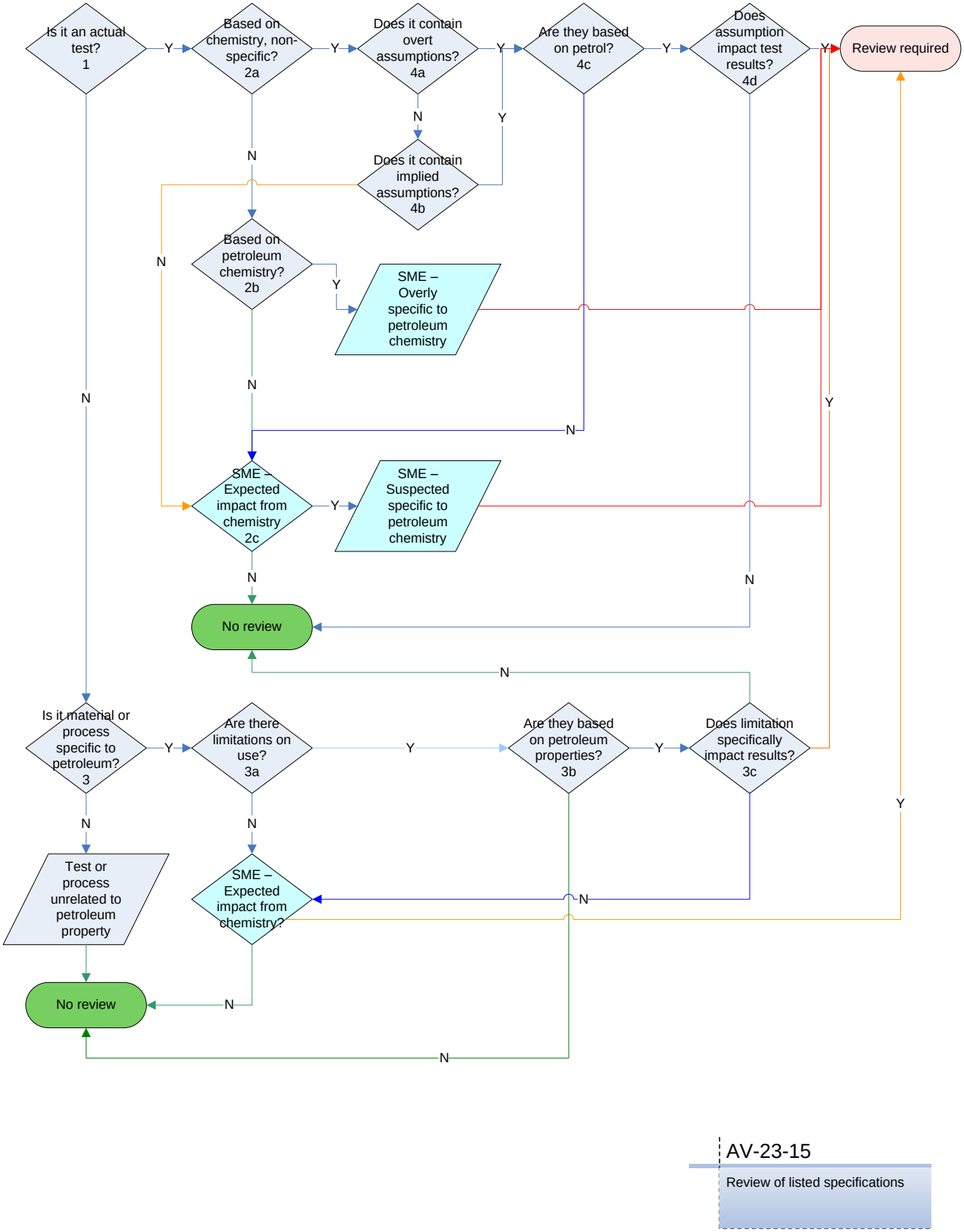
1.2 Methodology

1.2.1 Proposed Methodology

To understand where the technology gaps were, it was necessary to understand what each test method was for, why it was run, and what the data were purported to indicate. To collect this information, the following process was proposed.

- Review all the test methods and procedures referenced in ASTM D1655, D7566, and D4054.
    - What were they ostensibly to do?
    - Why did they exist in the standard?
        - For example: Are they controlling a process, were they installed to address a specific challenge in production or use, or were they to address a hardware issue?
    - Were they or could they be run at an average testing laboratory?
    - Were there indications that the test was no longer available, or required measurable effort to procure?
    - Were they built on any technical assumptions, or did the answer require a correction based on the use?
        - Was the assumption built specifically on petroleum-based chemistry or did it have specific restrictions?
        - Could the assumptions be validated for contemporary fuel chemistries?
    - What/how were other test methods being used in design?
        - Were they being used in coordination or in spite of ASTM test methods?
        - Were they manufacturer specific; and with or without standard?
    - Were there similar methods used in related industries?

A graphical representation of the proposed process for assessing each referenced standard is shown in Figure 1.



AV-23-15

Review of listed specifications

Figure 1 - Flowchart of Proposed Data Review Process

1.2.2 Actual Methodology

The basic flowchart was used for the review of the standards and the method discussed below. References to "Box #" below correspond to a box in the flowchart in Figure 1.

Originally it was believed there would be approximately 100 standards to review. Ultimately, between the four parent documents, there were a total of 318 individual standards to be reviewed. The first downselect was to determine whether a referenced document was actually a test (Box 1). Based on the content or title the standards were segregated by type (Figure 2). The categories were Practice, Guide, Specification, Method, and Unidentified. Unidentified included all other types of documents, for example, relational evaluations. The standards were also categorized by the source type (Figure 3). The four primary designations were ASTM, Energy Institute, SAE, and DoD (US military). The remaining 15% included a variety of single sources, such as EPA and UOP specifications. Following the review, 41% or 130 standards were determined to be actual test methods (Figure 4).

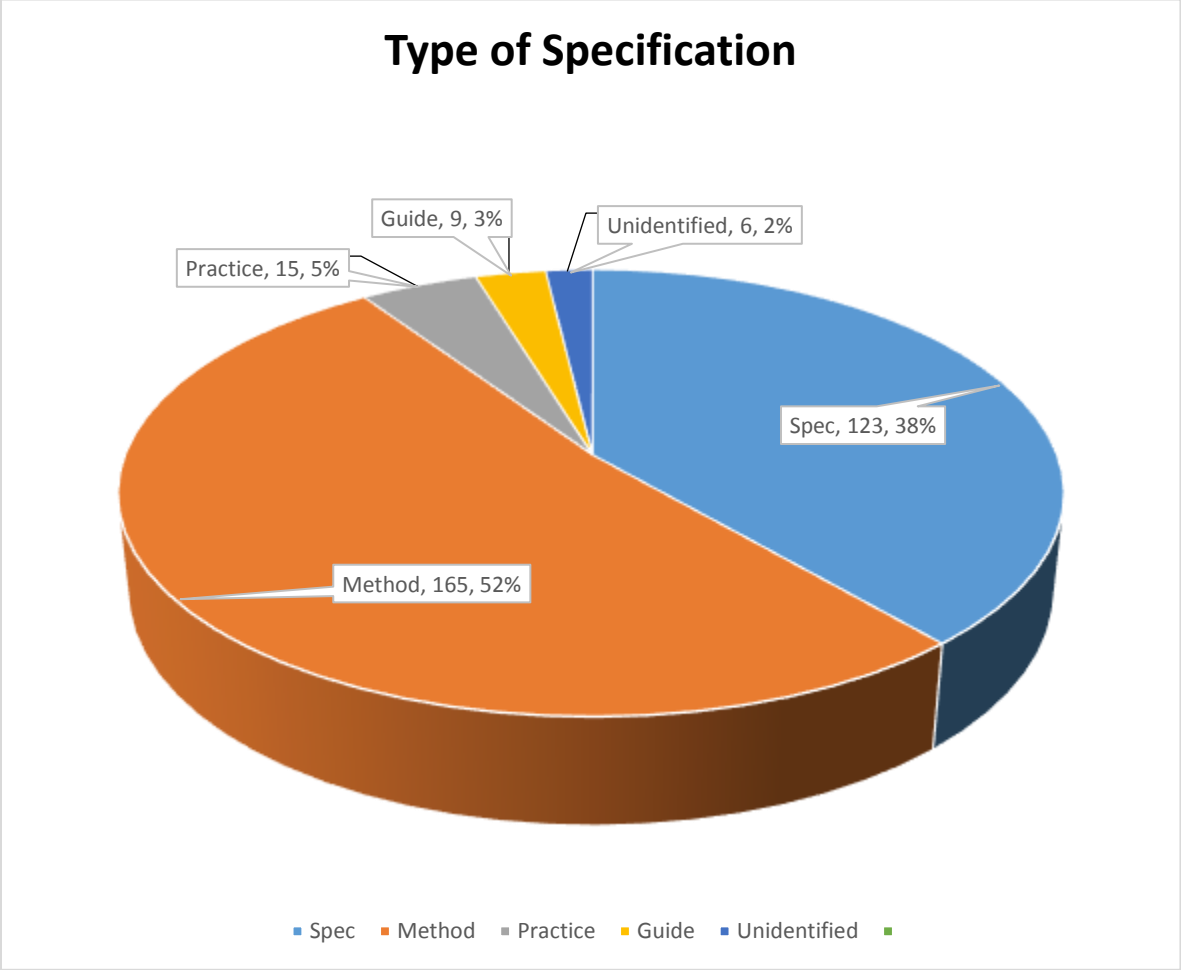


Figure 2 - Breakdown of Standard Type

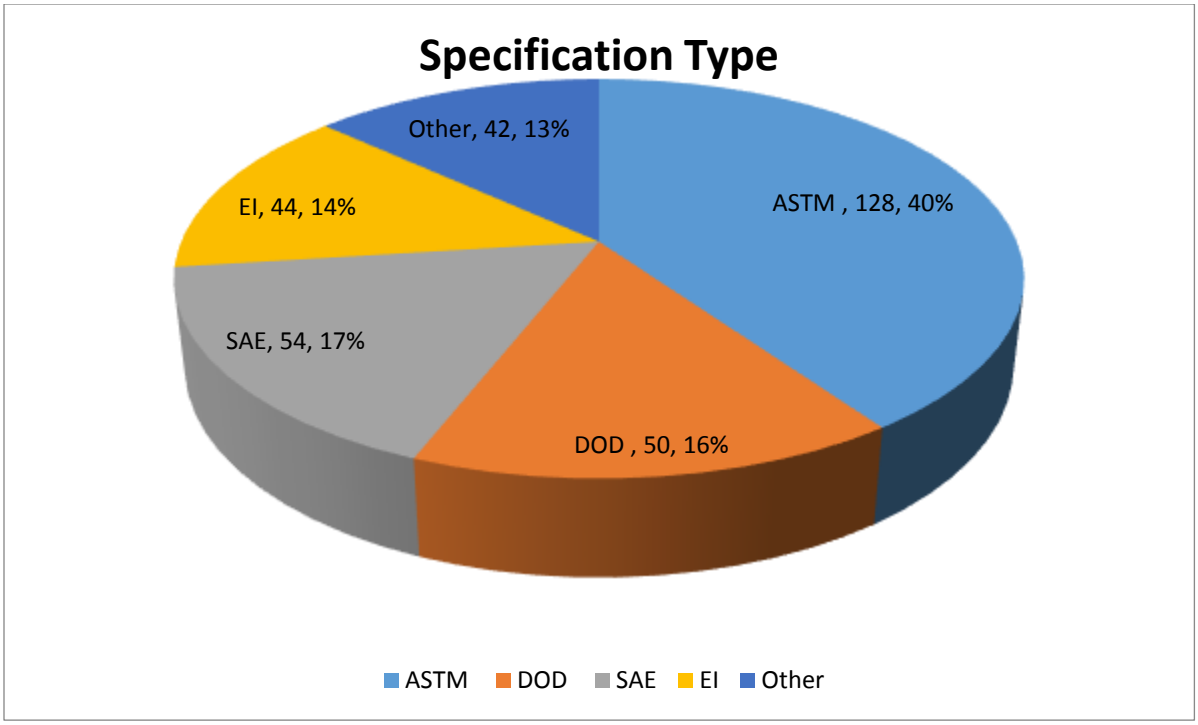


Figure 3 - Standard by Source

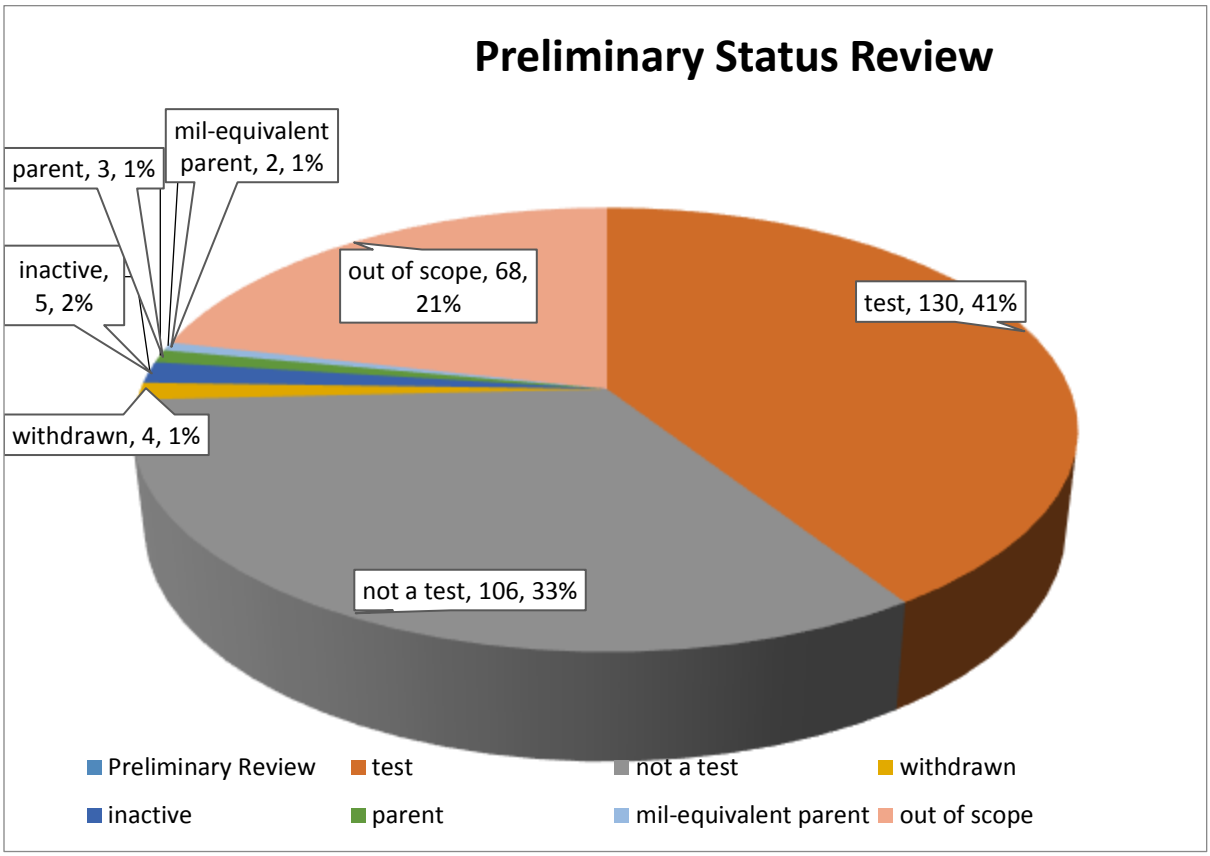


Figure 4 - First Downselect from All Referenced Standards

The entire list of standards was then sorted for top level interest. Standards that were withdrawn or inactive (Table 1), out of scope, or not a test were removed from the list (Figure 4). Following the first downselect, 148 individual standards were reviewed by the subject matter expert (SME). No Energy Institute standards were reviewed during this process (see Section 7). One standard, ASTM D3701, (green highlight) was still active, but was obsolete technology.

During the final review of the report document, an additional standard was suggested; ASTM D4305 (blue highlight) which was withdrawn in 2012 because it was no longer called out in ASTM D1655. The rationale for its removal was that it was not useful in detecting contamination.

Table 1 – Referenced Withdrawn Standards and Inactivated Specifications

Standard	Title	Status
ASTM D1660	Method of Test for Thermal Stability of Aviation Turbine Fuels (Withdrawn 1992) *AKA CRC Coker*	W
ASTM D1740	Standard Test Method for Luminometer Numbers of Aviation Turbine Fuel (Withdrawn 2006)	W
ASTM D3114	Method of Test for D-C Electrical Conductivity of Hydrocarbon Fuels (Withdrawn 1985)	W
ASTM D5190	Standard Test Method for Vapor Pressure of Petroleum Products (Automatic Method) (Withdrawn 2012)	W
DOD-L-85645	Lubricant, Dry Film, Molecular Bonded	I
MIL-C-83019	Coating, Polyurethane, for Protection of Integral Fuel Tank Sealing Compound	I
MIL-DTL-83054	Baffle and Inerting Material, Aircraft Fuel Tank	I
MIL-P-25732	Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Limited Service at 275 °F (135 °C)	I
MIL-S-85334	Sealing Compound, Noncuring, Low Consistency, Silicone, Groove Injection, for Integral Fuel Tanks	I
ASTM D3701	Method for Hydrogen Content of Aviation turbine Fuels by Low Resolution Magnetic Resonance Spectroscopy	Obsolete technology
ASTM D4305	Standard Test Method for Filter Flow of Aviation Fuels at Low Temperatures	W

This review was a more in-depth evaluation of the content. This review was Box 2a and Box 2b. Some of the standards that were test methods could be eliminated for further review because they were not related to or impacted by the fuel, for example test methods for testing braze. These were designated as not a fuel test. Other standards were reviewed and identified as not having any content specific to petroleum (Box 3). These were designated as "not a Standard of Interest (SoI)". After this interim review, 98 standards were downselected for SME review (Figure 5).

During this first SME review, an additional 30 standards were identified that were either called out by a referenced document or were recognized by the SME as standards used for evaluation of fuels and additives, even though they were not directly referenced by the parent standards. It was at this point that the references in Military Handbook 510 (MIL-HDBK-510) were also included. This was done because MIL-HDBK-510 included the information on relational evaluations and was assessed as being important to the evaluation of fuels. These relational considerations also included additional individual standards which were part of the added standards (Section 11.2).

Further discussion of the inclusion of MIL-HDBK-510 is included in Section 1.3.

Ideally the identification of the reasoning for a test method's inclusion would have also been performed at this point. Attempting to separate the reason for a test method inclusion between processing requirements and use requirements became more complex than could be supported by the scope of the project.

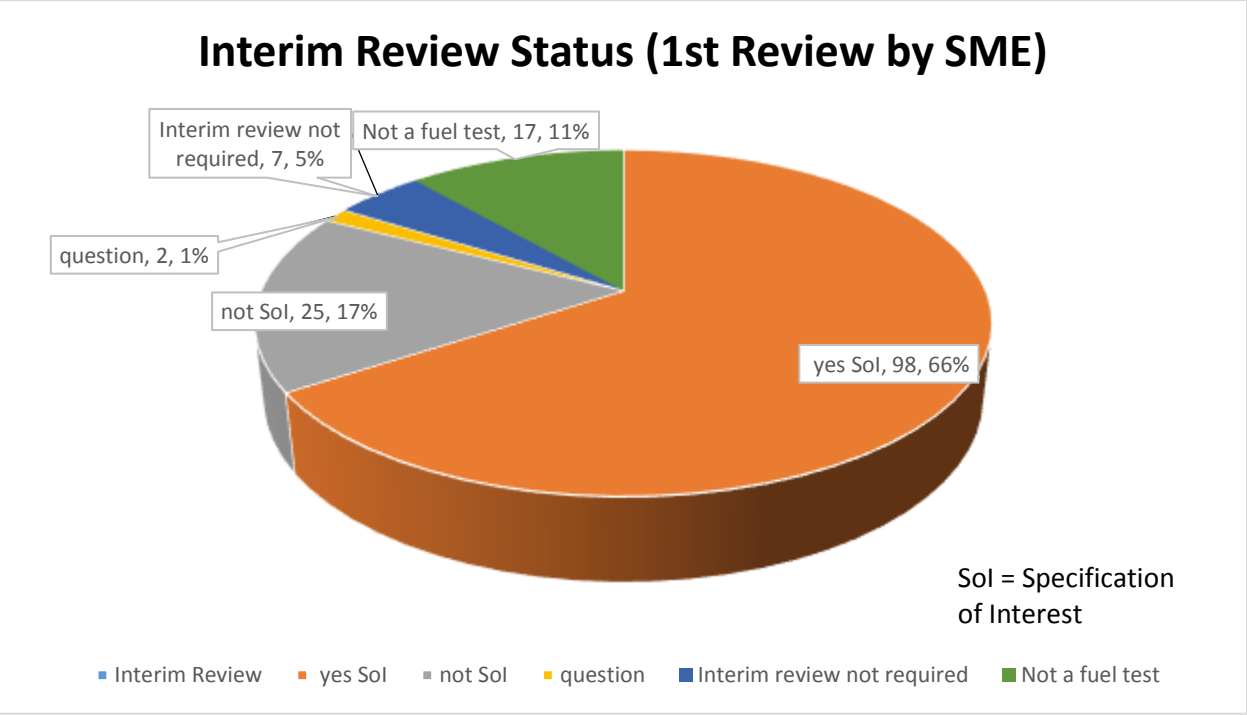


Figure 5 - Results of First SME Review

Once the standards were sorted into standards of interest, 140 standards received the final, in-depth review. This examination was essentially the review covered by Boxes 2a, 2b, 4a, 4b, 4c, and 4d of the flow chart. This review determined that another 27 standards were not applicable to the goals of the program and these documents were also removed from the evaluation. Ten of the documents were actually relational content and are discussed in Section 4.1. A total of 113 standards were evaluated and are the focus of the remainder of this report.

1.3 Addition of Military Handbook 510

This project was originally to evaluate the standards called out in the three guiding documents, ASTM D1655, ASTM D4054, and ASTM D7566. These three standards, referred to in this study as the parent standards, were selected as the source of guidance on fuel and fuel additive testing. During the course of the review, it became evident that Military Handbook 510 (MIL-HDBK 510) should also be included. While the handbook was a military controlled document containing military specific requirements, attempts were made to keep MIL-HDBK 510 aligned with ASTM D4054. It was also observed that many of the relational requirements were only discussed in MIL-HDBK-510 and not in any of the commercial guidance. The addition of the handbook did result in the addition of ASTM standards to the review list. No attempts were made to review Defence Standard 91-091. The military handbook makes use of Criteria levels which are not discussed here.

It is noted that while MIL-HDBK-510 is listed as active, as opposed to inactive or cancelled, the last revision in 2014 was for the purpose of updating it before "moth-balling" it. This means that the document may contain information that has become outdated.

1.3.1 Additional Tests

The addition of MIL-HDBK-510 resulted in the overt addition of seven ASTM standards and two inferred standards shown in yellow (Table 2). The military standard MIL-STD-3004 was the source of storage stability requirements. While ASTM D5304 is the suggested test method for storage stability testing of jet fuel, ASTM D2274 was also referenced in MIL-STD-3004. This guidance was specifically for testing F76 diesel fuels, and was not indicated for use with aviation fuels. Given the possibility of attempting to use the test method in the absence of other guidance, the standard was added to the review list.

Table 2 - Standards Added by Military Handbook 510

ASTM D97	STM for Pour Point of Petroleum Products
ASTM D613	STM for Cetane Number of Diesel Fuel Oil
ASTM D971	STM for Interfacial Tension of Oil Against Water by the Ring Method
ASTM D976	STM for Calculated Cetane Index of Distillate Fuels
ASTM D1903	Standard Practice for Determining the Coefficient of Thermal Expansion of Electrical Insulating Liquids of Petroleum Origin, and Askarels
ASTM D2274	STM for Oxidation Stability of Distillate Fuel Oil (Accelerated Method)
ASTM E2071	Standard Practice for Calculating Heat of Vaporization or Sublimation from Vapor Pressure Data
ASTM E582	STM for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures
ASTM E2253	STM for Temperature and Enthalpy Measurement Validation of Differential Scanning Calorimeters

1.3.2 Testing without References

In addition to the ten ASTM standards in Table 2, three tests were recommended without reference: flame speed, spark energy, and the speed (velocity) of sound. Research into the topics resulted in identifying a potential ASTM standard for spark energy measurements, ASTM E82 STM for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures, which was also added to the review list.

Whether this method is appropriate will require further investigations. Measuring flame speed is routinely performed in engine studies, and while discussions related to the use of ion sensors and optical sensors do exist, no published standards are immediately evident. The MIL-HDBK-510 requirement is that it be "no easier to ignite than Jet A/JP-8".

Discussions regarding the measurement of speed of sound focused on the relationships with density and no published standards or test methods were located. This lack was also noted during the OEM interviews.

1.4 Limits on Scope

To permit a reasonable review in the time available, and in consideration of the available resources, originally only the U.S. standards were reviewed in depth. A correspondence between the primarily U.S. ASTM standards and the European standards managed by the Energy Institute was developed. The IP standards were separately reviewed under a subsequent analysis and are reported in Section 9. For those standards with direct equivalency to ASTM standards, similar levels of sensitivity were assumed likely, and the ASTM document was reviewed.

1.4.1 Defence Standard 91-091 Review

Following the completion of the original U.S. review, a request was made to review the documents, including Energy Institute standards, referenced in Defence Standard (Def Stan) 91-091 *Turbine Fuel, Aviation Kerosine Type, JET A-1*. This review was executed and the results presented in Section 9 of this document. No changes were made to the U.S. review results reported in Sections 2-8.

2 Standard Review

Once the standards list was downselected to the tests which were specific to testing the fuel (for additives, blendstocks, or kerosene distillation range fuels), several criteria were used to review and rate the standards. These criteria included, a) is the test based on a defined chemical composition or type, or on fundamental physics, b) are there any overt or implied limitations on the applicability of the test, c) are there any assumptions, conversion, calculations or other modifications to the results to make them correlate with other tests, d) are the results reported directly, related to a calibration curve, or mathematically converted to a reportable result.

When reviewing the standards, one of the first items considered was restrictions, exclusions, or limitations either directly presented or implied by the scope of the standard. One of the implied limitations to be considered was the material on which the standard could be used, i.e. "petroleum

products" or "jet fuel". The terms brought implied limitations based on the term's definition. It became necessary to consider what the industry definition of the term was at the time of the individual standard's development.

2.1 Historical Considerations on Terminology

The first individual test standards, for example ASTM D86, were developed from test methods already in use with petroleum products before there was an American Society of Testing and Materials (changed to "ASTM International" in 2001) Committee D02. Controlled test methods such as density, distillation, and flash point were used by the petroleum industry soon after the industry's inception just before the turn of the 20th century.

When an industry is older than the standards which control it, it is important to understand the foundational terminology. ASTM standards have a scope which defines applicability for the standard. Common terms in the scope of standards in this program are the terms "petroleum", "petroleum products", "distillate" and "hydrocarbon". These terms are defined and have meaning to the developer and user of the standard. It is therefore important to understand the accepted definition of a term *at the time of development*. This is important in this review because the accepted definitions of the terms may evolve but it does not mean the applicability of the content of the standard is unaffected by the change.

2.1.1 Industry Specific Terminology

The term **petroleum** first appeared in literature as early as the 10th century and came from the fundamental property of the crude. From the Greek, "petra" meaning rock, and Latin, "oleum" meaning oil, petroleum described the oily material that came from the rocks and would burn. Early uses of the material were primarily for lubrication, lighting, and heating. When the U.S. petroleum industry was born in 1859, it was concomitant with the transportation industry and it became necessary to control the production of petroleum products. In 1904, the American Society of Testing and Materials formed Committee N, for Standard Tests for Lubricants. In 1918, Committee N issued its first standard, D56, Method for Flash Point by Tag Closed Tester. In 1920, Committee N became D02 for Petroleum Products and Lubricants.

What does "petroleum" or "petroleum product" mean? First, it is important to recognize that "petroleum product" is not the same thing as "petrochemical". The first is a material comprised of a complex combination of molecules sourced from crude. The second is a pure chemical produced from petroleum. The U.S. Energy Information Administration (EIA) in their glossary defines petroleum as a "…broadly defined class of liquid hydrocarbon mixtures. Included are crude oil, lease condensate, unfinished oils, refined products obtained from the processing of crude oils, and natural gas plant liquid." BusinessDictionary.com defines petroleum products as "Those obtained from crude oil and natural gas processing, including (among many others) asphalts, automotive gasoline, aviation gasoline, fuel oil, kerosene, LPG, lubricants, naphthas, and waxes." The dictionary, dictionary.sensAgent.com defines petroleum products as "products derived from crude oil processed by a refinery." Even

definitions from D02 defined petroleum products as "liquid fuels derived from petroleum or liquefaction of coal, shale, oil sands, or other naturally occurring materials". Throughout the majority of the 20th century, petroleum and petroleum products were understood to be the result of manipulating crude oil and natural gas.

The second term to consider, **distillate**, is equally rooted in the origins of the industry. The term distillate refers to a liquid product condensed from vapor during distillation. Thus, any material that is vaporized, condensed and collected is a distillate. The term is further modified specific to the petroleum industry, i.e. *petroleum distillate*. This term refers to any liquid condensed and collected from the vaporization of petroleum. The term is further modified, such as middle distillate, a term that defines a specific temperature range for the vaporization and condensation of the liquid, in this case a boiling range between 150 °C and 370°C (300 °F to 700°F). The U.S. Office of Policy and Management in section 16a-22c, published March 12, 1987 defined middle distillate to be "General classification of one or more distilled petroleum fractions, including kerosene, fuel oil, diesel fuel oil, resid fuel oil, LP, propane, butane, motor gasoline, gasohol, aviation gasoline (D910), and aviation turbine fuel (Jet A and Jet B)." Thus the term distillate, including modifiers, is related to the function of vaporizing, condensing and collecting a liquid. As used by this industry, it means "petroleum distillate."

2.1.2 ASTM D4175, Standard Terminology

To address specific industry and test method definitions, ASTM published ASTM D4175, Standard Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants. First published in 1983, the goal of the document was to provide definitions to terms specific to ASTM standards. It stated that these definitions were unique to petroleum, petroleum products, lubricants and certain products from biomass and chemical synthesis. The document was not to be used to define terms that did not have definitions unique to the subject matter of D02. This suggested any definition found in D4175 could be considered unique to the petroleum industry and even more specifically to the standard or subcommittee with jurisdiction over the application of the specific definition.

In 1998, ASTM D4175 defined petroleum as a naturally occurring mixture of hydrocarbons that could contain compounds of sulfur, nitrogen, oxygen, metals, and other elements. In 2002, there was no definition for petroleum or petroleum product, no definition for middle distillate and jet fuel was defined as "Any liquid suitable for the generation of power by combustion in jet engines." Under the discussion, jet fuel was further described as being distinguished by its volatility and freeze point. In 2005, there was no definition for "distillate" but the term "middle distillate" appeared. The definition of middle distillate was "A generic refinery/supplier term that usually denotes a fuel primarily intended for use in compression ignition/diesel engine applications, and also in non-aviation gas turbine or other non-automotive applications such as burners."

In 2008, the term petroleum distillate appeared with the statement "synonymous with "distillate". Distillate was defined as an overhead or side stream liquid from distillation process. Further information

included the clarification that distillates could be produced either directly from crude oil (called straight run distillates) or from distillation after processing crude oil by cracking, coking, hydrocracking or other conversion processes. Modifiers were used, such as cracked distillate to define different liquids further. The ASTM definition warned, "The term distillate is sometimes used to mean middle distillate. The practice is discouraged." Additionally, a second definition, specific to the petroleum industry was included that defined a middle distillate to be a distillate whose boiling range lies between 150 °C and 370°C. Definitions of distillates continued to be added and changed throughout 2009.

In 2016, there is still the general definition for distillate, "synonymous with petroleum distillate", but also four separate definitions for middle distillates.

> **middle distillate,** *n*—a generic refinery/supplier term that usually denotes a fuel primarily intended for use in compression ignition/diesel engine applications, and also in non-aviation gas turbine engines and other non-automotive applications such as a burner fuel. **[D02.E0] D6985**

> **middle distillate,** *n*—*in the petroleum industry*, a distillate whose boiling range lies between about 150 °C and about 370 °C (about 300 °F and about 700 °F).
> DISCUSSION—Typical middle distillates, such as diesel fuels, kerosine, aviation turbine fuels (Jet A and Jet A-1) and home heating oils, will have flash points above 38 °C (100 °F). The 10 % to 90 % boiling temperatures will tend to lie between about 200 °C and 350 °C (about 400 °F and 660 °F).
> DISCUSSION—The term *light* middle distillate has been used to indicate products like kerosine and aviation turbine fuel (Jet A and Jet A-1) that are at the lighter end of the middle distillate distillation range of about 150 °C to about 300 °C (about 300 °F to about 570 °F).
> DISCUSSION—The term distillate is sometimes used to mean middle distillate. This practice is discouraged.

> **middle distillate fuel,** *n*—kerosines and gas oils boiling between approximately 150 °C and 400 °C at normal atmospheric pressure and having a closed-cup flash point above 38 °C. **[D02.E0] D6751**

> **middle distillate fuels,** *n*—generic refinery/supplier term that usually denotes a fuel primarily intended for use in compression ignition/diesel engine applications, and also in non-aviation gas turbine engines and other non-automotive applications such as a burner fuel. **[D02.04] D7524**

ASTM D4175-16c also makes the first observed change to the definition of jet fuel. The definition is now, "Common language for aviation turbine fuel as defined by specifications of national and international standards organizations and accepted by the aviation industry."

Also in D4175-16c, the only reference to "synthetic" is specific to lubricants and means originating from the chemical synthesis of relatively pure organic compounds from one or more of a wide variety of raw materials.

2.1.3 Commercial Jet Fuel

Commercial jet fuel per ASTM D1655 was first specified in 1959. Per the specification, the fuel was to be comprised of refined hydrocarbons from conventional sources. In the late 1990s, the first use of hydrocarbons from the Fischer Tropsch conversion of the coal was permitted, originating in the DEF STAN 91-091 specification for Jet A-1. It was recognized that it was impractical to try and modify D1655 with changes in fuel chemical composition. To address the burgeoning alternative sources of hydrocarbon liquids, ASTM D7566 was successfully released in 2009. This document specifically addressed non-conventional sources of feed stock and non-traditional formulations of liquid fuel. The D4175 standard definition did not offer any definition related to the constraint of the material that was called jet fuel.

2.1.4 Conclusions Related to Terminology

Petroleum and petroleum products are those materials processed from naturally occurring complex hydrocarbonaceous crude. This crude may be from a well or reservoir, tar sands, shale, or other oil bearing geological structures.

Distillates are liquids collected by vaporizing and then condensing at defined ranges of temperatures. When collected from the vaporization of petroleum, they are petroleum distillates. They may also be produced from processed crude, such as hydrotreated or cracked petroleum. Modifiers may be used to define the range of the petroleum distillate production further such as light or middle. In all cases, the source of the hydrocarbons is naturally occurring crude. The term "middle distillate" is a definition specific to a date and the definition must be taken in time context.

The term jet fuel originally conveyed an understanding of being a petroleum distillate, but no such understanding can still be assumed.

3 Study Results

3.1 Data Collection

Following the down-select of the standard list to the final 138 for in-depth review, each individual standard was reviewed to determine what, if any, impact changing the fuel chemistry could make on the results of the test method. To facilitate uniform evaluations, a data collection form was prepared (

Figure 6).

The following item numbers refer to the items in

Figure 6. The individual entries included:

1) the standard number including the revision indicator. For standards reauthorized, a date for the reauthorization was included in parentheses. The revision indicated was the latest revision at the time of the review.
2) The standard title. In most cases the document was a standard test method and was entered as STM.
3) The original publication date. This was considered an important datum when considering the industry accepted definitions and expectations at the time of development.
4) A summary of the test method scope. This included information provided in the standard scope section and information related to references gleaned throughout the STM text.

One of the topics of information that was requested by the CRC steering committee members was information on the precision and variability of the test methods. An in-depth statistical review of each standard was beyond the scope of this effort; however, to facilitate future reviews and to provide the published precision information in one place for the reader.

5) any provided precision and bias information was collected.
6) any reports related to research and the precision and statement were collected.
7) The results of the review were summarized and provided the basis for the final subject matter expert assessment of impact.
8) a general collection field, where other information gathered from the standard that was deemed important, provided background information, or aided in the SME review was collected. Where applicable, text was marked with yellow highlighting or red text, indicating information that was contributory to determining the final impact assessment.
9) Once this assessment was completed, Red, Yellow, or Green was selected in the impact assessment box at the top of the form.

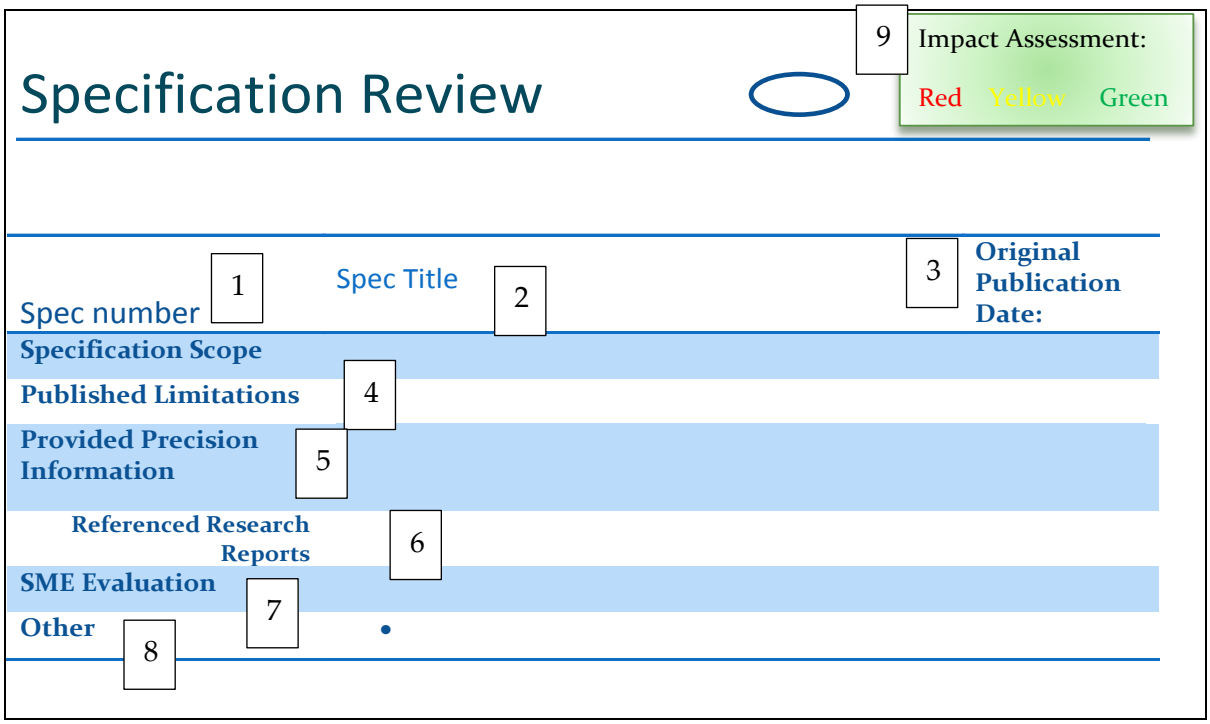


Figure 6 - Data Collection Form

To categorize the standards, a system was developed with the following criteria.

Green – There were no limitations or restrictions, either overt or implied, which directly prevented the use of the test method related to the sample composition. This did not negate the value of confirming data, particularly related to the precision and bias statement, but there was nothing about the test method that the process, chemistry, or physics would suggest a concern.

Yellow - There was something in the test method that suggested a concern. While the method did not overtly restrict the use based on the chemistry of the sample, there was content which, based on the method or based on the SME evaluation, suggested a reason that the offeror should perform additional work to document the method was acceptable for use. This included items such as changes to the precision and bias statement, a conversion of data to an output, or an assumption of correlation. This also included concerns of limitations on the fundamental test based on subject matter expertise, including in some cases how the data were used. With the exception of specific restrictions from the standard, these concerns are not likely to be observed with kerosene boiling range fuels even though they are semi or fully synthetic in origin.

Red -- There was a reason to believe the test method would not work, would not work appropriately, had limitations or restrictions that would prohibit its use, or was based on a fundamental assumption that was not valid for different chemical compositions. While

precision and bias statement inadequacies contributed to a "red" assessment, more than just a concern for the precision and bias statement was required. More significant validation of the method for use with non-traditional samples was encouraged.

N/A - Standards that were deemed to be not of interest during the final review.

Report Entries in the final review deemed to be more appropriately served by a discussion. These are primarily relational entries (see Section 4.4)

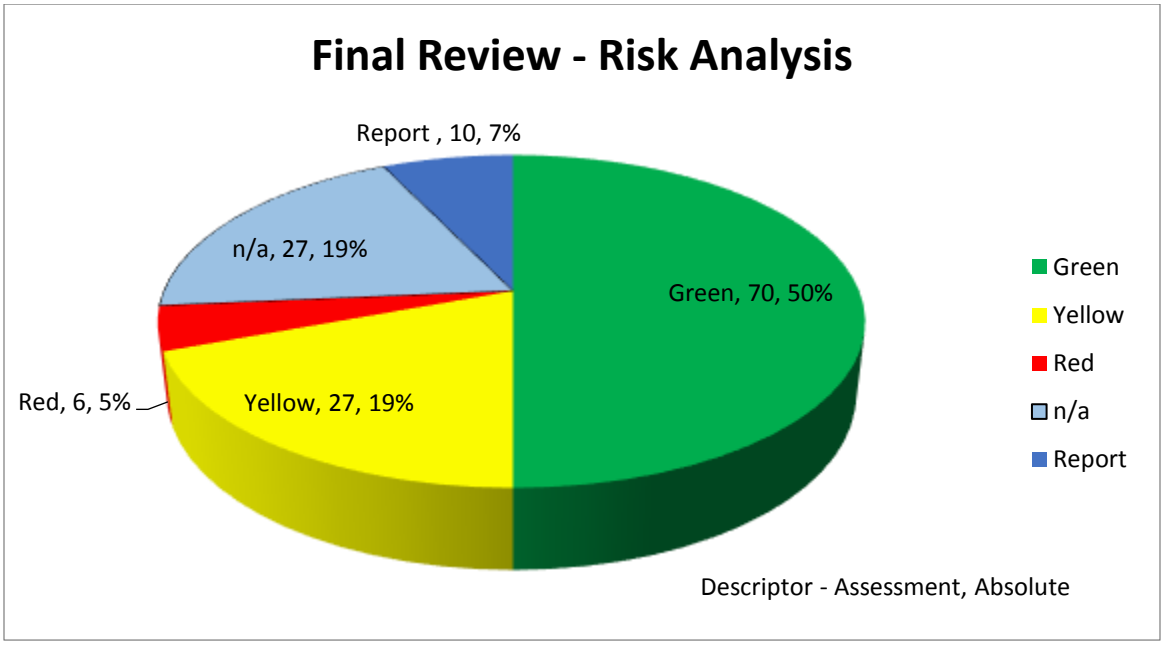


Figure 7 - Final Review Breakdown by Impact

Note that in the following tables, colored highlighting indicates additional standards not gleaned from the parent standards. Beige was added based on standard review or subject matter expertise. Reddish highlighting indicates the standard was added from Military Handbook 510.

3.2 Assessment

3.2.1 Green - No Affect

Following the in-depth review 70 or 50%, of the ASTM standards are assessed as being "green" or not affected by the chemical composition (Table 3). Highlighted entries indicate standards added during the review process. In addition to the ASTM standards, the three Environmental Protection Agency (EPA) specifications were also assessed as green. A green assessment does not mean there are no requirements for validation, for example validation of the precision and bias statements. Nor does it imply there are not considerations in the subsequent use of the data. It means there is nothing about the method development, the test execution, or the handling of the data that suggests a concern.

All information on "Green" standards is included on the individual review sheets. No further discussion on individual standards is necessary. Items noted with "*" suggest there is industry data in addition to the reviewed method which should be considered even though there is nothing specific about the method itself suggesting a concern. For example, a test which is difficult to run may be assessed as "green" due to an absence of specific composition concern, but may warrant additional consideration for other reasons.

Table 3 - Reviewed Standards - Green, No Impact

Green Standards	
ASTM D1094	Standard Test Method for Water Reaction of Aviation Fuels
ASTM D1266	Standard Test Method for Sulfur in Petroleum Products (Lamp Method)
ASTM D129	Standard Test Method for Sulfur in Petroleum Products (General High Pressure Decomposition Device Method)
ASTM D1322	Standard Test Method for Smoke Point of Kerosine and Aviation Turbine Fuel
ASTM D1331	Standard Test Methods for Surface and Interfacial Tension of Solutions of Paints, Solvents, Solutions of Surface-Active Agents, and Related Materials
ASTM 1500	Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
ASTM D156	Standard Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method
ASTM D1840	Standard Test Method for Naphthalene Hydrocarbons in Aviation Turbine Fuels by Ultraviolet Spectrophotometry
ASTM D1903	Standard Practice for Determining the Coefficient of Thermal Expansion of Electrical Insulating Liquids of Petroleum Origin, and Askarels
ASTM D2276	Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling
ASTM D2386	Standard Test Method for Freezing Point of Aviation Fuels
ASTM D2622	Standard Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
ASTM D2549	Standard Test Method for Separation of Representative Aromatics and Nonaromatics Fractions of High-Boiling Oils by Elution Chromatography
ASTM D2710	Standard Test Method for Bromine Index of Petroleum Hydrocarbons by Electrometric Titration
ASTM D2717 **(*)**	Standard Test Method for Thermal Conductivity of Liquids
ASTM D2779	Standard Test Method for Estimation of Solubility of Gases in Petroleum Liquids
ASTM D287	Standard Test Method for API Gravity of Crude Petroleum and Petroleum Products

Green Standards	
ASTM D2879	Standard Test Method for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope
ASTM D2887	Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
ASTM D2892	Standard Test Method for Distillation of Crude Petroleum (15-Theoretical Plate Column)
ASTM D3120	Standard Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry
ASTM D3227	Standard Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosine, Aviation Turbine, and Distillate Fuels (Potentiometric Method)
ASTM D323	Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)
ASTM D3242	Standard Test Method for Acidity in Aviation Turbine Fuel
ASTM D3703	Standard Test Method for Hydroperoxide Number of Aviation Turbine Fuels, Gasoline and Diesel Fuels
ASTM D381	Standard Test Method for Gum Content in Fuels by Jet Evaporation
ASTM D3828	Standard Test Methods for Flash Point by Small Scale Closed Cup Tester
ASTM D4045	Standard Test Method for Sulfur in Petroleum Products by Hydrogenolysis and Rateometric Colorimetry
ASTM D4052	Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
ASTM D4057	Practice for Manual Sampling of Petroleum and Petroleum Products
ASTM D4176	Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
ASTM D4294	Standard Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry
ASTM D4306	Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
ASTM D4625	Standard Test Method for Middle Distillate Fuel Storage Stability at 43 °C (110 °F)
ASTM D4809	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)
ASTM D4952	Standard Test Method for Qualitative Analysis for Active Sulfur Species in Fuels and Solvents (Doctor Test)
ASTM D4953	Standard Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)
ASTM D5006	Standard Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels
ASTM D5291	Standard Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants

Green Standards	
ASTM D5304	Standard Test Method for Assessing Middle Distillate Fuel Storage Stability by Oxygen Overpressure
ASTM D5452	Standard Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration
ASTM D5453	Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
ASTM D56	Standard Test Method for Flash Point by Tag Closed Cup Tester
ASTM D5842	Practice for Sampling and Handling of Fuels for Volatility Measurement
ASTM D6045	Standard Test Method for Color of Petroleum Products by the Automatic Tristimulus Method
ASTM D613	Standard Test Method for Cetane Number of Diesel Fuel Oil
ASTM D6304 **(*)**	Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
ASTM D6378	Standard Test Method for Determination of Vapor Pressure (VPX) of Petroleum Products, Hydrocarbons, and Hydrocarbon-Oxygenate Mixtures (Triple Expansion Method)
ASTM D6732	Standard Test Method for Determination of Copper in Jet Fuels by Graphite Furnace Atomic Absorption Spectrometry
ASTM D6793	Standard Test Method for Determination of Isothermal Secant and Tangent Bulk Modulus
ASTM D6866	Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis
ASTM D7042	Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
ASTM D7111	Standard Test Method for Determination of Trace Elements in Middle Distillate Fuels by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
ASTM D7171	Standard Test Method for Hydrogen Content of Middle Distillate Petroleum Products by Low-Resolution Pulsed Nuclear Magnetic Resonance Spectroscopy
ASTM D7345	Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure (Micro Distillation Method)
ASTM D7359	Standard 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)
ASTM D7872	Standard Test Method for Determining the Concentration of Pipeline Drag Reducer Additive in Aviation Turbine Fuels
ASTM D7945	Standard Test Method for Determination of Dynamic Viscosity and Derived Kinematic Viscosity of Liquids by Constant Pressure Viscometer
ASTM D86	Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure

Green Standards	
ASTM D873	Standard Test Method for Oxidation Stability of Aviation Fuels (Potential Residue Method)
ASTM D93	Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
ASTM D97	Standard Test Method for Pour Point of Petroleum Products
ASTM D971	Standard Test Method for Interfacial Tension of Oil Against Water by the Ring Method
ASTM E1269	Standard Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry
ASTM E2253	Standard Test Method for Temperature and Enthalpy Measurement Validation of Differential Scanning Calorimeters
ASTM E582	Standard Test Method for Minimum Ignition Energy and quenching Distance in Gaseous Mixtures
ASTM E659	Standard Test Method for Autoignition Temperature of Chemicals
ASTM E681	Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases)
EPA Method 8015	Nonhalogenated Organics by Gas Chromatography
EPA Method 8260	Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)
EPA Method 8270	Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)

3.2.2 *Yellow – Possible Impact*

Following the review, 27 individual standards or 19% of the total were identified as being of concern, or yellow. These were standards which had some content which raised a concern about the potential impact of the fuel composition on either the method or the results of the test. Standards which covered methods that were not themselves likely to be sensitive to the chemical composition but which had post-data usage which could be sensitive were also designated as Yellow.

A list of the standards assessed as potentially affected is provided in

Table 4.

Table 4 - Reviewed Standards - Yellow, Possible Impact

Yellow Standards	
ASTM D1298	Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
ASTM D130	Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
ASTM D1319	Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
ASTM D1740	Standard Test Method for Luminometer Numbers of Aviation Turbine Fuel
ASTM D240	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter
ASTM D2624	Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels
ASTM D3240	Standard Test Method for Undissolved Water In Aviation Turbine Fuels
ASTM D3241	Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels
ASTM D341	Standard Practice for Viscosity-Temperature Charts for Liquid Petroleum Products
ASTM D3701	Standard Test Method for Hydrogen Content of Aviation Turbine Fuels by Low Resolution Nuclear Magnetic Resonance Spectrometry
ASTM D3948	Standard Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer
ASTM D3338	Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
ASTM D3343	Standard Test Method for Estimation of Hydrogen Content of Aviation Fuels
ASTM D4308	Standard Test Method for Electrical Conductivity for Liquid Hydrocarbons by Precision Meter
ASTM D445	Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
ASTM D5001	Standard Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
ASTM D5190	Heat of Vaporization, Latent
ASTM D5191	Standard Test Method for Vapor Pressure of Petroleum Products (Mini Method)
ASTM D5482	Standard Test Method for Vapor Pressure of Petroleum Products (Mini-Method - Atmospheric)
ASTM D5972	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)
ASTM D6379	Standard Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection
ASTM D7153	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Laser Method)

Yellow Standards	
ASTM D7154	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)
ASTM D7524	Standard Test Method for Determination of Static Dissipater Additives (SDA) in Aviation Turbine Fuel and Middle Distillate Fuels—High Performance Liquid Chromatograph (HPLC) Method
ASTM D7797	Standard Test Method for Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy—Rapid Screening Method
ASTM E411	Standard Test Method for Trace Quantities of Carbonyl Compounds with 2,4-Dinitrophenylhydrazine
ASTM E2071	Calculating Heat of Vaporization from Vapor Pressure data

3.2.3 Red – Likely Impact

Following the review, six individual standards or 5% of the total were identified as having probable impact, or red. These were standards which had a high probability of impact by the chemical composition of the material. These standards had a direct limitation or prohibition on the chemistry, presented a methodology or other developmental restriction, or used post collection data modification, formulaic or correlational, that suggested a limitation.

A list of the standards assessed as likely to be affected is provided in Table 5.

Table 5 - Reviewed Standards - Red, Probable Impact

Red Standards	
ASTM D1250	Guide for Use of the Petroleum Measurement Tables
ASTM D1405	Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
ASTM D2425	Standard Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry
ASTM D4529	Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
ASTM D924	Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
ASTM D976	Standard Test Method for Calculated Cetane Index of Distillate Fuels

3.3 U.S. Standards Discussion

The discussions below summarize the reviews. For full information, including scope of purpose, limitations, and precision and bias statements, see the individual review sheets in Appendix 10.5.

When the scope limits the method to petroleum, petroleum products or distillates, it is assumed that the method was developed from traditional crude oil petroleum (see Section 2.1.4). This means that the more the chemical composition diverges from a traditional hydrocarbonaceous formula, including being more petrochemical like, the greater the potential for divergences from the data used to create the method, the precision and bias statements, or the handling of the results.

The term "aviation turbine fuel" should be considered with care. Depending on the date when the method was developed, the industry accepted definition meant fuel from traditional petroleum resources. When considering standards contemporarily, care must be taken not to assume "aviation turbine fuel" implies no chemical composition sensitivity.

3.3.1 Yellow Standards

3.3.1.1 ASTM D130-12 – Copper Strip Test from Petroleum Products

Use: Petroleum products

Concern:
- Uses a color chart developed using traditional petroleum. If new fuels/additives result in changes to the surface appearance, the color chart may have limitations.
- Assumes the sample can be dried using filter paper.
- Test times and temperatures of the method are specific to traditional petroleum.

3.3.1.2 ASTM D240-14 – Heat of Combustion by Calorimeter

Use: Liquid fuels, light distillates to residual fuels

Concern:
- If the fuel composition contains any other elements, the thermochemical corrections may be incomplete.
- Uses an estimation developed from data from 1945 to 1953. Estimation affected by chemical composition.
- This method makes a correction for the amount of water vapor that is theoretically formed based on research and analysis. As the chemical composition changes the potential amount of water vapor formed, either due to changes in hydrogen content or due to other thermal chemical reactions taking place during combustion, the correction for the latent heat of vaporization of water vapor may be effected. While this is unlikely to be an issue with kerosene boiling range materials, it may be an issue for additives or blendstocks.

3.3.1.3 ASTM D341-09 (2015) – Viscosity-Temperature Charts

Use: Petroleum products

Concern:
- Original charts had a formula with a single constant was developed from historical petroleum data.

  Current charts were derived from analysis of additional, more modern *petroleum* data and there are now two constants.
- There have been occurrences that suggest that at the extremes of low temperature, the data can show measurable deviations from linearity.

  Currently used to predict 12 cSt temperature, at the extremes of temperature.
- Per the standard, high boiling (280 °C) materials also show deviation from linearity at the high end of the chart. This may cause deviations in reported values for extrapolated or strictly numerically generated values at the upper and lower ranges.

3.3.1.4 ASTM D445-15a – Kinematic Viscosity

Use: Newtonian Liquids

Concern:
- Uses the petroleum charts from D341 (the formulae that the charts graph).
- While the test method itself is NOT likely to be sensitive to chemical composition, it is the subsequent handling of the viscosity data for fuel testing that may be sensitive.
- Users of D4054 should be generating viscosity data at multiple temperatures. They should be far enough apart to determine the viscosity data slope.

3.3.1.5 ASTM D1298-12b – Density, Relative Density or API Gravity by Hydrometer

Use: Petroleum, crude and petroleum mixtures

Concern:
- The fundamental calculations used to convert between measurements at a given temperature or between units may be affected by chemical composition. See the review of D1250 Petroleum Measurement tables for further discussion on the concern.
- The calculations used to convert to API Gravity from density or relative density has a consideration for the thermal expansion coefficient which could be chemistry dependent and are based on assumed density and viscosity relationships. As the chemistry diverges from traditional petroleum, these relationships may change. This is more likely to be seen in the blendstocks than in the final kerosene boiling range fuel.

3.3.1.6 ASTM D1319-15 – Hydrocarbon Type by Fluorescent Indicator Adsorption

Use: Petroleum products

Concern:
- Coloration may interfere with seeing the color bands formed by the dye.
- "Method has not been tested on coal, shale, or tar sand based fuels and the precision statement may not apply". Per the standard there is a concern for non-traditionally sourced petroleum products. This concern is expected to be true for those fuels not sourced from petroleum crude at all.
- Use of the method with cracked fuels did cause issues that were not fully discussed.

3.3.1.7 ASTM D1740-01 – Luminometer Number - WITHDRAWN

Use: Aviation Turbine Fuel

Concern:
- Although the standard has been withdrawn, the method may be impacted by chemical composition due to a sensitivity to the amount and type of aromatics present. This is especially true for the blendstocks and as the amount of aromatic and cyclic materials is varied. This means that any reverse correlations to luminometer number may not be accurate.

3.3.1.8 ASTM D2624-15 – Electrical Conductivity

There is currently work underway regarding electrical conductivity and the instruments. This effort is not considered during this review and may ultimately change the standard assessment.

Use: Aviation fuel and Distillate fuels

Concern:
- Each laboratory must establish temperature versus conductivity for fuels of interest.
- Any site generated correction factors would have to be reviewed for sensitivity to the fuel composition.
- May need to demonstrate the environmental factors display impacts similar to those seen with traditionally prepare jet fuel.
- May impact correlations between instrument types. These are mathematical correlations to make the results from different instruments the "same".

3.3.1.9 ASTM D3240-15 – Undissolved Water in Aviation Turbine Fuel (Aqua Glo)

Use: Aviation Turbine Fuel

Concern:
- Are there any other components in the alternative composition that may react with uranine, or are there any components that may also be collected on the pad and either fluoresce or interfere with fluorescence?
- Method is not a direct measure; continued validity of the correlation may need to be demonstrated.

3.3.1.10 ASTM D3241-16a – Thermal Oxidation Stability of Aviation Turbine Fuels (JFTOT™)

Use: Aviation Turbine Fuel

Concern:
- Given the extent of interpretation issues being reviewed regarding the JFTOT™, its applicability, and the precision and bias of the method with respect to both conventional and alternatively produced jet fuels, a true SME evaluation is beyond the scope of the program at hand. I defer to the limits, concerns, and ongoing research as to the extent and applicability of the method to chemical composition. However, the extent of the research activity is sufficient to suggest caution as to what impact chemical composition may have on the method.

3.3.1.11 ASTM D3338-09 (2014) – Estimation of Net Heat of Combustion

Use: Aviation gasoline and Aviation Turbine Fuel

Concern:
- The estimation is based on correlations created from actual data between density, aromatics, sulfur and distillation. The further from norm the chemical composition moves, the more risk involved in using the formulae.
- This method has the potential to be significantly affected by the fuel composition because of the number of assumptions of correlations between physical properties and heat of combustion.

3.3.1.12 ASTM D3343-16 – Estimation of Hydrogen Content

Use: Aviation Fuels

Concern:
- Relationships in the method were developed for the listed jet fuels at the time of the method's development, therefore petroleum from traditional petroleum sources. How changes in the chemical composition might affect the relationships is unknown.
- The results are reported to the nearest 0.01% hydrogen. This suggests a level of sensitivity in the method that is likely to be affected by changes in chemical composition.
- The empirical formulae are from known hydrocarbon behavior based on expected types and ratios of aromatics, cyclics and olefins. If an alternatively produced fuel has a chemical composition that significantly deviates in these ratios or types of hydrocarbons the formulae may no longer be valid, at least to the reported level of significance.
- "The estimation of the hydrogen content of a hydrocarbon fuel is justifiable only when the fuel belongs to a well-defined class for which a relationship among the hydrogen content and the distillation range, density, and aromatic content has been derived from accurate experimental measurements on representative samples of that class. Even in this case, the possibility that the estimates may be in error by large amounts for individual fuels should be recognized."

3.3.1.13 ASTM D3701-01 (2012) – Hydrogen by Low Res NMR (nuclear magnetic resonance)

Use: Aviation Turbine Fuels

Concern:
- Method measures the alignment of the hydrogen atoms. Method states it is biased as compared to pure hydrocarbons. In general technology has obsoleted this type of continuous wave NMR. The method recommends using D4808 for petroleum products other than aviation turbine fuel.

  Determine if it would be better suited to use one of the procedures described in ASTM D4808 or D7171 rather than D3701, particularly as the chemical composition becomes more like a pure hydrocarbon, or blends of a few discrete moieties.

3.3.1.14 ASTM D3948-14 – Water Separation Characteristics (MSEP rating)

Use: Aviation Turbine Fuels

Concern:
- Could there be a case where the instrument sees the sample as 'turbid' even after the water has been removed? This should be caught by performing the background check, but this should be confirmed. This is more likely to occur with additive studies and should be caught during the review process.
- Precision and bias statement is likely to be affected by the composition.
- Because the alternatively produced fuel chemistries have not been analyzed using the withdrawn D3602 method, it would be unwise to assume continued formulaic correlation without actual data.

3.3.1.15 ASTM D4308-13 – Electrical Conductivity (Precision Meter)

Use: Liquid Hydrocarbons

Concern:
- Each laboratory must establish temperature versus conductivity for fuels of interest.
- The test method is not likely to be affected by the chemical composition, but any site generated correction factors would need to be reviewed for sensitivity to the fuel composition.
- May need to demonstrate the environmental factors display impacts similar to those seen with traditionally prepared jet fuel.
- May impact correlations between instrument types. These are mathematical correlations to make the results from different instruments the "same".

3.3.1.16 ASTM D5001-10 (2014) – Lubricity (BOCLE)

Use: Aviation Turbine Fuels

Concern:
- The manifestation of a scar is predictive of chemical composition, so the execution of the test would not be affected by composition. However, the changes in chemical composition may have significant impact on the size of resulting scar, which may not be predictive of the actual performance in use. Thus, the interpretation of the results could be affected by composition. Historically, concerns that the large wear scars generated by synthetic fuels may not necessarily correspond to hardware failures have been discussed. Similarly, there are suggestions that changes to the measured lubricity of a fuel may impact different hardware differently, resulting in discussions related to different test methods being needed to predict performance on different hardware. In general, changes in wear scar due to composition changes require further review by the OEM's.
- Impacts to the precision and bias statement would need to be evaluated.

3.3.1.17 ASTM D5190-07 – Vapor Pressure, Automatic Method

Withdrawn 2012.

Use: Petroleum products

Concern:
- The method uses a bias correction to convert to DVPE. This bias correction could be sensitive to chemical composition.

3.3.1.18 ASTM D5191-15 – Vapor Pressure, Vacuum Method

Use: Petroleum Products

Concern:
- Dissolved water is not considered by the method, so the water capacity of the fuel, if it is related to the chemical composition, could affect the method.
- The reference tests were performed with high vapor pressure chemicals. This raises concerns for the applicability of the method precision and bias statements, and possibly the correlation for lower vapor pressure fluids like jet fuel, especially as the dissolved water content increases. The instruments are undoubtedly well programmed for traditional aviation turbine fuel, but how the software handles deviations from known is unclear.

3.3.1.19 ASTM D5482-15 – Vapor Pressure (Mini-Method Atmospheric)

Use: Petroleum Products

Concern:
- Dissolved water is not considered by the method, so the water capacity of the fuel, if it is related to the chemical composition, could affect the method. Should confirm continued accuracy in the correlation to DVPE.
- The reference tests were performed with high vapor pressure chemicals. This raises concerns for the applicability of at least the method precision and bias statements, and possibly the correlation for lower vapor pressure fluids like jet fuel, especially as the dissolved water content increases. The instruments are undoubtedly well programmed for traditional aviation turbine fuel, but how the software handles deviations from known is unclear.

3.3.1.20 ASTM D6379-11 – Aromatic Content by HPLC

Use: Aviation Fuels and Petroleum Distillates

Concern:
- Conjugated di and poly alkenes are interferents. Confirmation that the chemical composition does not include di or poly alkenes is recommended. These materials are highly reactive and should be prevented by the thermal stability requirement.

3.3.1.21 ASTM D5972-16 – Freezing Point (Phase Transition)

It is recognized that the industry is currently researching the impacts of different types of freeze point instruments. That work is not considered here. Outcomes of those efforts may negate the concerns expressed below.

Use: Aviation Fuels

Concern:
- Contemporary challenges with the use of automatic equipment suggest a sensitivity to fuel composition that warrants further investigations. (See discussion on freeze point measurements, Section 4.1.2).
- There is a concern related to issues being observed in contemporary data that the instrument may register materials that melt at unreasonably high temperatures and are not representative of the actual freeze point of the fuel.
- If the fuel composition deviates enough from the composition used to develop the instrument and method, it is possible the instrument may generate/optically register materials that are not indicative of freeze point, or are registered erroneously as contaminate. Depending on the nature of these 'other' crystals, the instrument may report skewed results either artificially high or inappropriately low.
- The precision and bias statement may be impacted by changes in chemical composition

3.3.1.22 ASTM D7153-15 – Freeze Point, Laser Method

Use: Aviation Fuels

Concern:
- Contemporary challenges with the use of automatic equipment suggest a sensitivity to fuel composition that warrants further investigations. (See discussion on freeze point, Section 4.1.2).
- There is a concern related to issues being observed in contemporary data that the instrument may register materials that melt at unreasonably high temperatures and are not representative of the actual freeze point of the fuel.
- If the fuel composition deviates enough from the composition used to develop the instrument and method, it is possible the instrument may generate/optically register materials that are not indicative of freeze point, or are registered erroneously as contaminate. Depending on the nature of these 'other' crystals, the instrument may report skewed results either artificially high or inappropriately low.
- The precision and bias statement may be impacted by changes in chemical composition

3.3.1.23 ASTM D7154-15 – Freeze Point, Fiber Optic Method

Use: Aviation Fuels

Concern:
- Contemporary challenges with the use of automatic equipment suggest a sensitivity to fuel composition that warrants further investigations. (See discussion on freeze point measurements, Section 4.1.2).
- There is a concern related to issues being observed in contemporary data that the instrument may register materials that melt at unreasonably high temperatures and are not representative of the actual freeze point of the fuel.
- If the fuel composition deviates enough from the composition used to develop the instrument and method, it is possible the instrument may generate/optically register materials that are not indicative of freeze point, or are registered erroneously as contaminate. Depending on the nature of these 'other' crystals, the instrument may report skewed results either artificially high or inappropriately low.
- The precision and bias statement may be impacted by changes in chemical composition
- The study in which 14% of the samples were incorrectly identified as contaminated suggests the method may be sensitive to chemical composition (RR:D02-1572)

3.3.1.24 ASTM D7524-10 (2015) – Static Dissipater Additive by HPLC

Use: Aviation Turbine Fuel and Middle Distillate Fuels

Concern:

- The solid phase extraction (SPE) step is based on polarity and assumes that there is nothing else separated from the fuel at this step. It is possible any component collected during the solid phase extraction would elute from the HPLC at a different retention time than the sulfonic acid (the SDA). It would be necessary to know which peak was the sulfonic acid peak if other materials are eluted. Further method development would be required.
- Until it can be demonstrated an alternative fuel preparation method does not contain either naturally occurring sulfonic acid compounds eluting at the same time as the target material, or other compounds that will act as an interferent to the HPLC analysis are not removed by the SPE step, the method could be fuel chemistry sensitive.

3.3.1.25 ASTM D7797-16 – FAME Concentration by FTIR

Use: Aviation Turbine Fuel

Concern:

- The extensive testing performed with the method for the PLS-1 model was performed on an extensive suite of traditional kerosene jet fuels of a number of production types. This testing did confirm a need to verify the composition of a fuel did not impact the measurement.

  The FT-IR instrument only reports a chemometrics modeled derived value from an FT-IR signal response at a wave number, regardless of the source of the signal. Therefore, deviation errors may occur due to the removal of a species that is not FAME during filtration, or the presence of an absorbing species that occurs at or near the wavelength of interest. While chemometrics have moved beyond simple Beer's Law considerations, impacts to changes in what appears in the spectra must be considered. This suggests there is a potential to be sensitive to the chemical composition. It would be prudent to validate the pre and post sorbent results of a clean fuel. The use of chemometrics caused refinery specific biases that were described in the FIJI world survey report as ranging from ±20 ppm.

3.3.1.26 ASTM E411-12 – Trace Carbonyl Compounds

Use: No overt listing

Concern:
- Aldehydes and ketones, and acetals that only partially hydrolyze will interfere.
- Given the number of potential undesirable reactions or incomplete reactions that could occur, the use of this standard should be done with consideration.

3.3.1.27 ASTM E2071-00 (2015) – Heat of Vaporization from Vapor Pressure Data

Use: Liquids

Concern:
- The method is not generally applicable to mixtures as the composition changes with vaporization.
- When considering the impact of alternatively produced jet fuel chemical composition, the accuracy will be reflected in the amount of convergence or divergence on a single chemical moiety. In the extreme, for compositions of components with measurably different heat of vaporizations, the accuracy is likely to be poor.

3.3.2 Red Standards

3.3.2.1 ASTM D924-15 – Dielectric Constant

Use: Electrical Insulating Liquids

Concern:
- The precision and bias statement was developed using mineral oil and as such may not be applicable to traditional aviation turbine fuel, much less to alternatively prepared fuels.
- The dielectric constant is related to density and the speed at which the atoms respond to the electric field. The first becomes part of the analysis. The second can be foundational to the results.
- The method was not originally developed for measuring fuel capacitance. The data were determined to provide a useful means of measuring fuel volume and by relationship calculation, determining density, and therefore mass of fuel. As such there are a number of testing variables that are points of discussion within the industry: the K-cell vs. a 3 terminal cell; the frequency at which the test is run; the relative density terms used for calculations (vacuum or air, dry or ambient, matched temperature or ambient).
- While capacitance and its measurement are foundational physics properties, the testing parameters and how the data are used ARE fuel chemistry dependent. This is because how the atoms respond in the electric field under different test conditions will be affected by the fuel chemistry. The method, as written, was developed for mineral oil. Discussions with the OEMs and with researchers performing the test indicated that kerosene boiling range fuels need different testing parameters because of differences in chemical composition as compared to mineral oil.

- There are enough variables and calculations involved to suggest that the test method is sensitive to chemical composition. See full discussion on dielectric constant in Section 4.2.

3.3.2.2 ASTM D976-06 (2016) – Calculated Cetane Index

Use: Distillate Fuels

Concern:
- Published limitation that the method is not applicable to pure hydrocarbons, synthetic fuels, alkylates or coal tar products. This suggests compositional sensitivity.
- This method is NOT applicable to jet fuel and is specifically invalid by the published property range limitations. The results will be affected by the chemical composition of the sample.

3.3.2.3 ASTM D1250-08 (2013) – Use of Petroleum Measurement Tables

Use: Petroleum Products

Concern:
- Note: these concerns are less likely to be encountered for fuels in the normal kerosene boiling range. However, as chemical composition, especially of the blendstocks diverge from normal kerosene, the following concerns should be considered.
- The use of the Petroleum Tables is no longer in the hands of the analyst. It is completely a software exercise requiring inputting the "correct" values. It assumes that all petroleum products follow the same correlations, and it assumes that the analyst selects the appropriate "class" to access the correct equation.
- Given the dependence on data from naturally occurring petroleum products to generate the software, there is a concern that the correlations may not be the same for synthetically or alternatively produced hydrocarbon fuels or for the blendstocks used to prepare final fuels. These variations may actually be small; however, there is a natural predilection to ascribe inappropriate accuracy and precision to a value reported from computer-based output that may be at odds with the precision and accuracy of the actual correlations.
- Because volume changes are part of the calculations to convert from °API or relative density at one temperature to another, especially with the use of a hydrometer, there is a potential for diversion from historical data if the rate of volume change is different.
- These diversions from historical are potentially even more problematic for other outputs of the Petroleum Tables, such as volume vs weight calculations, and thermal expansion calculations used by the fuel handling and distribution industries.
- The table for conversion of observed gravity to the gravity at 60/60 has already accounted for the change in volume with temperature. If the chemical composition results in measurable deviations to this relationship, the conversion could be affected.

3.3.2.4 ASTM D2425-04 – Hydrocarbon Types by Mass Spectroscopy

Use: Middle Distillates with the boiling range 204 °C to 343°C (400 °F to 650°F).

Note: Standard currently being revised. Interested parties should check the latest version of the method. Concerns expressed may be addressed.

Concern:
- Per the method, the composition should be paraffinic in the C_{10} to C_{18} with an average between C_{12} and C_{16}.
- As the alternatively prepared jet fuel sources result in more skewed, narrowed, or limited carbon number ranges, and less traditional composition, concerns for the applicability of the method as developed and described increase.
- The work developing the summation scheme may be impacted by the chemical composition of the sample. Moving to new sources may require changes to the scheme due to shifts in the carbon number distributions. The way this method is designed, an analyst has to have at least some knowledge of from where one is starting to confirm a) samples are in the target carbon number range, with the expected average carbon number, and b) expected carbon mass fragments that may or should be seen.
- In addition, testing to date has shown that reproducibility error increases as the paraffinic content increases. This means it is not a good choice of method for alternatively produced fuels, many of which have a very high paraffinic composition.
- Experts in the field have expressed concern the equipment is obsolete, is hard to run well, and is hard to find a source to run it.

3.3.2.5 ASTM D1405-08 – Estimation of Net Heat of Combustion

Use: Aviation Fuels

Concern:
- Per the stated limitations, the method is only valid for liquid hydrocarbon fuels derived by normal refining processes from conventional crude oil. It is not valid for synthetic or other petrochemical compositions.
- Per the stated limitations, the method is not applicable to pure hydrocarbons. This means that the results reported for fuel chemistries based on pure hydrocarbons will be incorrect.

3.3.2.6 ASTM D4529-01 (2011) – Estimation of Net Heat of Combustion (Constant Pressure)

Use: Aviation fuels

Concern:
- Per the standard, the method is purely empirical, and is applicable only to liquid hydrocarbon fuels derived by normal refining processes from conventional crude oil.
- "The estimation of the net heat of combustion of a hydrocarbon fuel from its aniline point temperature and density is justifiable only when the fuel belongs to a well-defined class for which a relationship between these quantities has been derived from accurate experimental measurement on representative samples of that class."
  - The aniline point, density and sulfur contents are determined experimentally and correlations are based on articles from the 1950s and 60s.

4 Special Discussions

4.1 Groups of Standards on Topic

One of the observations made during the review was an evolution of test methods for an individual data class. Where multiple methods were referenced, reviews of the individual standards suggested value in discussing the standards as a group. There were four primary data areas suggested; vapor pressure, freeze point, heat of combustion, and hydrogen content. The different standards in a group were present for two primary reasons, they measured a property at different conditions using different parameters, or they were an evolution of how a property could be analytically measured. Each of the groups is further discussed below.

4.1.1 Vapor Pressure

Vapor pressure is the pressure exerted by a vapor in equilibrium with its liquid at a given temperature. It is a physical phenomenon that is dependent on the molecules that compose the material. It is related to how easily a material will evaporate and the vapor pressure of a mixture will continue to change as evaporation occurs. This is the reason for the stringent control on the sampling and the test execution. This also makes running the test correctly challenging.

For aviation fuel there are seven methods referenced by the parent documents for determining the vapor pressure of the fuel. Each measure something slightly different and not all of the values are directly related. Additional standardized test methods for vapor pressure measurement do exist but are not discussed in this document. It may be worth noting that all standard methods tend to measure or correct to a V/L of 4:1 to correspond to the original Reid Vapor pressure test method. No test method currently exists for determining total vapor pressure at a zero vapor volume, the onset of vaporization. This value will be higher than the RVP because of the loss of lighter fractions when the V/L is 4:1.

Table 6 – Standards Involving Vapor Pressure

Test	Title	Primary Function
ASTM D323	Reid Vapor Pressure	Includes atmospheric air and entrained moisture. Moisture makes it slightly different from true vapor pressure.
ASTM D2879	Vapor Pressure by Isoteniscope	The true vapor pressure of the petroleum product without atmospheric air or entrained moisture.
ASTM D4953	Vapor Pressure of Gasoline Dry Method	Includes atmospheric air and entrained moisture. Moisture makes it slightly different from true vapor pressure. The apparatus interior is kept dry to prevent external moisture from contacting the sample. Method was designed specifically for gasolines containing oxygenates.
ASTM D5190	Vapor Pressure of Petroleum Products Automatic Method (Withdrawn)	Similar to D4953 except the sample is automatically forced into the second chamber instead of being manually connected.
ASTM D5191	Vapor Pressure of Petroleum Products Mini-Method (Vacuum)	Measures the vapor pressure under a vacuum as opposed to atmospheric conditions.
ASTM D5482	Vapor Pressure of Petroleum Products Mini-Method (Atmospheric)	Measures the vapor pressure under atmospheric conditions as opposed to a vacuum.
ASTM D6378	Vapor Pressure of Petroleum Products Triple Expansion Method	Determines partial pressure of entrained air by performing three separate expansions. Highly volatile components will be mistakenly included in air partial pressure. Eliminates the need to saturate the sample with air.

4.1.1.1 Reid Vapor Pressure D323

Reid vapor pressure (RVP) was first published in 1930 and is sometimes referred to as the absolute vapor pressure or "wet REID". The measured pressure is relative to atmospheric pressure because the gauge measures the pressure of the vapor in equilibrium with the liquid in a non-evacuated chamber. Thus, RVP is not a true vapor pressure. Note, referring to a vapor pressure as "the RVP" means specifically testing per ASTM D323 and should not be confused with "vapor pressure", "true vapor pressure", or "dry vapor pressure equivalent".

ASTM D323-15 provides testing information for four classes of petroleum products, but specifically excludes liquefied petroleum gases (LP) or fuels with oxygenates other than methyl t-butyl either (MTBE). The four classes are A) liquids with a vapor pressure less than 26 psi; B) gasoline; C) liquids with a vapor pressure greater than 26 psi; and D) Aviation gasoline. Briefly, chilled sample placed in a chilled chamber is connected to an empty heated chamber and the vapor is allowed to expand. The test temperature is 100 °F (37.8 °C) and the vapor pressure is measured using a Bourdon spring gauge. This is a routine petroleum test and multiple laboratories capable of running the method were identified.

4.1.1.2 Dry Method for Gasoline and Oxygenates D4953

Because ASTM D323 specifically excludes gasoline containing oxygenates which must be kept dry, a second test method, ASTM D4953 was developed in 1989. The method is a modification to ASTM D323 RVP because all of the interior surfaces of the apparatus are kept completely free of water, not a requirement in D323. It does have air in the chamber, and as such is not a true vapor pressure either. Unlike Reid vapor pressure, D4953 refers to dry vapor pressure equivalent and is sometimes referred to as "dry REID".

Briefly, chilled sample placed in a dry, chilled chamber is connected to an empty, dry, heated chamber and the vapor is allowed to expand. The test temperature is 100 °F (37.8 °C) and the vapor pressure is measured using a Bourdon spring gauge. A second method is also covered which has a semi-automatic unit. While there is nothing about the method to prohibit its use on aviation fuels, it is not the traditional test method and is designed for fuels that must be kept dry. Additionally, the precision and bias statement is not applicable to aviation turbine fuel. This is a routine petroleum test and multiple laboratories capable of running the method were identified.

4.1.1.3 Automatic Method D5190

The automatic method developed in 1991 was designed for petroleum products, including fuels containing oxygenates. It was subsequently withdrawn in 2012. The method did not take any dissolved water into account, so it would give vapor pressure numbers slightly different from the true vapor pressure. It was, however, a dry vapor pressure measure. The instrument would use a bias correction factor DVPE = (0.954 X) + A where A = 1.94 kPa, to match the reported DVPE value from the test instrument to that of ASTM D4953.

Briefly, the chilled fuel is placed into a chilled sample cup and the sample is automatically forced into the expansion chamber where it is brought to thermal equilibrium at 100 °F (37.8 °C). This is done in a manner to assure a 4:1 vapor to liquid ratio, and the final pressure is measured by a pressure transducer.

Method D5190 is still referenced in ASTM D7566. The equipment is a standard instrument and multiple laboratories capable of running the method were identified. Further research suggests it is run as a software option on equipment referenced below.

4.1.1.4 Mini-Method in a Vacuum D5191

At the same time as the automatic method was being developed, the Mini-Method was developed. This method was based on the same principle as D5190 but used an evacuated expansion chamber and the sample was specifically described as being air-saturated.

Briefly, a controlled volume of chilled, air-saturated sample is automatically introduced into the evacuated chamber and the sample expanded three times. By measuring the change in pressure, the partial pressure of the air and the sample are determined. The entire process is tightly controlled by the instrument. On-board software is used to calculate and report DVPE measurements based on the physical pressure measures made by the equipment. Within the standard, indications are the precision and bias statements were prepared using primarily spark ignition fuel. The equipment is a standard instrument and multiple laboratories capable of running the method were identified.

4.1.1.5 Mini-Method in Atmosphere D5482

In 1993, the mini-method in atmosphere was developed. This method was essentially equivalent to ASTM D5191, except that instead of a vacuum environment the sample was injected into a chamber under atmospheric conditions. There was still no account made for the dissolved water in the sample. In all other ways, the sample, method, and presumably the equipment, was equivalent.

Briefly, a controlled volume of chilled, air-saturated sample is automatically introduced into the chamber under atmospheric conditions and the sample expanded three times. By measuring the change in pressure, the partial pressure of the air and the sample are determined. The entire process is tightly controlled by the instrument. On-board software is used to calculate and report DVPE measurements based on the physical pressure measures made by the equipment. It was noted that the correlation factor is specific to the manufacturer of the equipment. This suggests that as the fuel composition moves further from traditional, there is a potential for divergence in the reported DVPE values. The equipment is standard and multiple laboratories capable of running the method were identified.

4.1.1.6 Triple Expansion Method D6378

In 1999, an automated method was developed specifically for aviation turbine fuels. The method is similar to the previous automated method in that there are multiple expansion steps, but the sample does not require air saturation. The test may also be run at a variety of temperatures. The sample size is determined by the vapor/liquid ratio of the individual sample. The method can report DVPE for gasoline, but specifically does not report DVPE for aviation turbine fuel.

Briefly, a known volume of sample is drawn into the temperature controlled sample chamber that is at a temperature of 20 °C or higher. Once drawn into the sample chamber, the temperature is increased to the target test temperature and allowed to expand. Once stable, the chamber volume is increased and the sample is allowed to expand again. After stabilizing, the volume is increased once more and the sample is allowed to expand a third time. The partial pressure of the air and the solubility of the air in the sample are determined from the three pressure measurements. The total pressure of the sample is

then mathematically determined by removing the partial pressure of the air. The major caveat is related to errors due to the presence of high vapor pressure constituents that will be lost with the air. The equipment is a standard instrument and multiple laboratories capable of running the method were identified.

4.1.1.7 Isoteniscope D2879

The isoteniscope is a fundamental physical measurement based on a constant volume. The material which has had the entrained air and moisture removed is drawn into a manometer. The sample is completely surrounded by the bath and it is brought to a temperature above boiling. The sample will balance against a pressure exerted by a known inert gas. The gauge reads the pressure of the inert gas which is now equal to the pressure exerted by the sample. While the method is better suited for pure chemicals, with care mixtures can also be measured because changes in the composition over the course of the measurement are minimized.

First published in 1970, ASTM D2879-10 determines the vapor pressure and decomposition temperature of a sample using an isoteniscope. The data are reported as the logarithm of the rate of pressure rise plotted versus the reciprocal of the absolute temperature. This is the method referenced by ASTM E2071, the procedure for calculating the heat of vaporization from vapor pressure data referenced by MIL-HDBK-510. It is not a routine test method and no source for laboratory testing was identified. It was noted the automatic vapor pressure equipment suggests the ability of the equipment to provide isoteniscope data, although the method would not be in compliance with ASTM D2879.

4.1.1.8 Summary

The primary value of moving from the traditional ASTM D323 Reid vapor pressure to more contemporary vapor pressure testing instruments is the reduction is sample size and greater control over sample introduction and measurement. A probable consequence of this is greater precision in test execution. However, the instruments all use on-board software to convert the direct pressure measurements to a dry vapor pressure equivalent, with the exception of ASTM D6378 triple point. There are two caveats to this shift. First, because of on-board software performing correlation corrections to provide the data "equivalent to ASTM D323 and ASTM D4953" there is a potential for a loss in accuracy as the fuel composition deviates from traditional aviation turbine fuel. The second caveat is that a single instrument can execute and report "different" values, i.e. wet Reid versus dry Reid or DVPE measured in a vacuum or under atmospheric conditions. This makes it important and incumbent on the user of the data to be clear as to how the data were actually collected, and what correlations were used on the data before they were reported. Furthermore, as fuel chemistry diverges from traditional, precision and accuracy statements will require review.

4.1.2 Freezing Point

Freezing point is the description of a thermodynamic point at which the liquid and solid phases of a sample are in equilibrium. The freezing point of a liquid is also the melting point of the solid. A material

is solid when the bonds between the molecules are strong enough to prevent movement of the individual molecules. When heat is applied to a solid, the temperature of the solid will rise until the bonds begin to break. This temperature will remain constant until the last bond between the molecules has broken. In a liquid form, the strength of the bonds between the molecules is such that they continuously break and reform. In the case of aviation fuels, the liquid is cooled until solids can be seen to form and then the mixture is heated until the last observable crystal is observed to melt. This is reported as the freeze or freezing point.

For petroleum products in general, and aviation fuel in particular, four freezing point methods were identified. Each method is an evolution primarily in technology to observe the phase changes. In all four cases, it is assumed that there are two materials formed during the process, a water haze due to dissolved water, and the formation of the hydrocarbon crystals.

Table 7 – Standards Involving Freeze Points

Test	Title	Primary Function	Mix and heat rates
ASTM D2386	Freezing Point of Aviation Fuels (Manual)	Cool the sample until solids are visually observed to form and then heat until the last observable particle melts.	Stir at 1 cycle/s with loop, up and down. No specified cooling rate. No specified heating rate.
ASTM D5972	Freezing point of Aviation Fuels (Automatic Phase Transition)	Cool the sample until the optical detectors sense the formation of solids and then heat until the detectors sense the last observable particle melts.	No stirring specified. Cooling rate – 15 °C/min Heating rate – 10 °C/min
ASTM D7153	Freezing Point of Aviation Fuels (Automatic Laser)	Cool the sample until the optical and laser detectors sense the formation of solids and then heat until the crystal detector senses the last observable particle melts.	No stirring specified. Cooling rate – 10 °C/min Heating rate – 3 °C/min
ASTM D7154	Freezing Point of Aviation Fuels (Automatic Fiber Optical)	Cool the sample until the fiber optics sense the formation of solids and then heat until the crystal detector senses the last observable particle melts.	Stir at 1 cycle/s with loop, up and down. No specified cooling rate. No specified heating rate.

4.1.2.1 Manual Method D2386

Originally developed in 1965, the manual method is based on the assumption that two materials will be observed to form during the test; one the potential for a haze of ice crystals due to the dissolved water naturally occurring in jet fuel and the second, the formation of hydrocarbon crystals. The method makes no consideration for molecules that are not part of the traditional hydrocarbon fluid.

Briefly, a sample of the fuel is placed into a jacketed sample tube fitted with a collar that prevents the introduction of atmospheric moisture and condensate. A stirrer comprised of a loop that is free to move up and down around the thermometer, and the thermometer both pass through this collar. The entire sample assembly is then placed into a cooling bath capable of chilling the sample to below the expected freezing point of the fuel. The temperature is visually monitored and the sample is visually monitored for the formation of crystalline/waxy particles. This temperature is noted and the cooling bath is removed. Stirring continues, and the sample is visually monitored until the last of the crystals are observed to melt. This is reported as the freezing point. It should not be more than 6 °C different from the temperature at which crystal formation was observed.

The method is dependent on the visual acuity of the test operator and the ability to see the formation of the crystalline/waxy material. Similarly, it is dependent on the ability of the operator to see the crystals disappear. A reported accuracy of 1.5 °C suggests that the method has reasonable precision but that may no longer be sufficient as modern systems operate on tighter tolerances of freezing point. The equipment is a standard instrument and multiple laboratories capable of running the method were identified.

4.1.2.2 Automatic Phase Transition D5972

In 1996, an automatic freezing point tester was developed. This method covered an instrument that used optical sensors to monitor the formation of crystals and a Peltier heating device (uses electrical current to transfer heat to and from an item). The goal was to improve the sensitivity of sensing the formation of crystals, thus increasing the precision. Based on an interlaboratory studies (ILS) done in 1994 and 2003 with jet fuel, no bias between the automatic method and the manual method were observed. A possible bias with Jet B/JP-4 may have been observed.

Briefly, a sample of the liquid is placed into a sample chamber with a highly polished bottom. Light of a known wavelength impinges through the liquid onto the polished bottom where it is reflected. The fuel is cooled at a rate of 15 °C/min ± 5 °C until the optical sensors detect the formation of crystals. As long as the sample is liquid, the light bounces off the bottom at the same incident angle it struck. Once the liquid begins to form hydrocarbon crystals, the light is reflected upward, towards the optical sensor. The instrument then reverses the electric current on the Peltier device and heats the sample at 10 °C/min ±0.5 °C until the crystals melt. When the crystals melt, the impinging light returns to a normal incident reflection.

The method provides no agitation of the sample during the test due to the small sample size and likely because agitation would interfere with the reflection of the light by particles. The instrument makes no distinction as to what is forming the crystals that deflect the incident light. Published literature indicates the system is sensitive in detecting fuel contamination, suggesting any solid formed will be registered by the instrument. The ILS suggests there is no bias between the instruments so the freezing point reported is the temperature measured by the temperature sensor integral to the bottom of the sample cup. The

equipment is a standard instrument and multiple laboratories capable of running the method were identified.

4.1.2.3 Automatic Laser D7153

An instrument that replaced the light used in the automatic tester with a laser was developed in 2005. It is likely that the use of a laser permitted greater control over the ability to polarize and detect the incident light. The method also used different cooling and heating rates than the previous automatic method. The reason for the difference is not immediately known.

Briefly, a sample is placed into the sample tube and cooled at 10 °C/min ±5 °C until both the optical detectors and the opacity detectors register the formation of crystals. Until crystals form, the light is not scattered and the detectors do not register light. Once both detectors sense the presence of crystals, the sample is heated at 3 °C/min ±0.5 °C. The last crystal to melt is indicated by the optical detector no longer registering any light. With the use of a process chart, multiple peaks indicating potential contamination can be observed. Based on interpretation, non-traditional fuel composition might display similar multi-peak behavior.

The method provides no agitation of the sample during the test, most likely because agitation would interfere with the reflection of the laser by the particles. The instrument makes no distinction as to what is forming the crystals that deflect the incident light. The instrument did display a systemic bias relative to the manual method of approximately 0.347 °C high but the bias was assessed as being within the reproducibility of both methods. The ILS study was performed in 2003 at the same time as the ILS for D5972. The equipment is a standard instrument and multiple laboratories capable of running the method were identified.

4.1.2.4 Automatic Fiber Optic D7154

Of the three automatic methods, D7154 is most like the original manual method. It uses a convective cooling bath and permits the cooling and heating to take place unrestricted. It also provides agitation throughout the test in the same manner and rate as the manual method. This method is also listed as being equivalent to ASTM D5901 except for the algorithm used by the software. ASTM 5901, withdrawn in 2010, is not a referenced standard in this study.

The method is the same in all ways as D2386 manual method with the exception of the use of a fiber optic detector that transmits from the center of the sample through the stir loops to a detector at the base of the instrument. Research results attempting to locate an instrument specific to D7154 were confusing at best with the equipment appearing to use the fiber optic sensor referencing D2386. Dixie Services did respond they provide testing per ASTM D7154.

4.1.2.5 Summary

As early as the 1990s, observations related to different values being reported between the manual and the automatic methods were being reported. Samples with freezing points as different as 10 °C to 30 °C

between the two methods were observed. Furthermore, the reported freezing points were reported to be as high as -10 °C to 10 °C for samples measured with the automatic method, temperatures that were inconsistent with physical observations. The sources of these differences were questioned. Continuing over a decade, evaluations by the JIG ILS suggested measurable divergences in the reported freezing points for test samples, although in recent years this may be improving. Even in the open forum of the industry, questions are seen where the automatic test equipment gives erratic freezing point values for fuels with elevated gum content.

With the introduction of alternatively prepared jet fuel and jet fuel of non-traditional chemical composition, questions have been raised regarding what is actually being observed by the instruments. The automated instruments are designed to be more sensitive and "see" crystals even when they might not be visible to the human eye. This is part of what allows the higher precision in the measurements.

There is growing evidence to suggest that the three automated methods do not all "see" the same thing. One hypothesis is that because they do not provide the same testing conditions different types of crystal formation may occur. Hypotheses include steric interactions, and chemical bonding differences related to cooling and heating rates. For traditional hydrocarbon fuels, these differences may have been small enough to be insignificant. However, as the fuel chemistry changes, these differences may result in different phase change behaviors in the samples between the methods, the result being different reported freezing point values depending on the method used.

The manual method does have the benefit of operator experience in recognizing materials that may not be consistent with traditional hydrocarbon crystal formation. Examples include different shape/color/consistency of the crystals, smaller than normal numbers of crystals formed, or unusual phase change behavior. One school of thought is that the formation of any amount of any material is an issue and it is not important to know if it is or is not hydrocarbon or whether there is or is not measurable quantities of the particulates. The thought is that even if it is a contaminant or something new in the fuel composition, the temperature at which any material forms is critical. However, because of other physical contributions such as heating rates and agitation potentially resulting in different biases in the reported results, further understanding of how the methods respond to changes in chemical composition may be value added.

4.1.3 Heat of Combustion

Three of the five standards assessed as having a measurable concern related to the chemical compositions (red) as well as one with a concern (yellow) were related to heat of combustion. It should be noted that the other terms often used in relationship to fuel and related to heat energy include specific heat (heat required to raise the temperature of one gram one degree Kelvin) and heat capacity (the amount of heat required to raise the temperature of the entire mass involved one degree Kelvin). The heating value is the heat released when one unit of fuel is completely combusted.

The heat of combustion of a substance is the total energy released when the substance undergoes complete combustion with oxygen under standard conditions. In physical chemistry this is referred to as an enthalpy change. The conventional method for determining a heat of combustion is to stoichiometrically combust a sample in a bomb calorimeter with oxidizer and measure the temperature change. There are errors due to composition, for example the presence of sulfur and nitrogen compounds in the fuel. It becomes necessary to know how much sulfur and nitrogen are present and correct for their heat of combustion. Because there is also heat moving to and from the water bath around the calorimeter, the radiation errors must also be corrected for and are values generally supplied by the manufacturer.

Traditional hydrocarbons have been well characterized and as such reasonably accurate empirical formulae exist for computing the heating values of hydrocarbon mixtures. Most are variations on the Sherman & Kropff equation. For kerosene, the formula for the heating value (BTU/lb) = 18440 + 40 (API – 10), where API is the API gravity of the hydrocarbon. This formula becomes less accurate for heavy, cracked fuel oils. In Popovich (1959), the author comments, "It should be understood that the results from the foregoing equations are not so sufficiently precise that heating values calculated for them are accurate for a particular temperature or pressure. Nevertheless, calculated results are probably more accurate than those which would be obtained by an inexperience operator using a bomb calorimeter."

The other thing to be considered when measuring the heat of combustion is the water formed by the combustion. The presence of this water is part of the explanation of the difference between the higher heating value and the lower heating values. To compute the net or lower heating value from the higher heating value, the amount of water in the combustion products is determined from the hydrogen content. For most hydrocarbons, the lower heating value in BTU/lb = 17944.9 + 0.1043B, where B = the aniline constant determined by ASTM D1405.

The net heating value or lower heating value is the heat released by combusting the specified quantity of fuel from an initial temperature of 25 °C and then allowing the combustion products to cool to 150 °C. In this case the latent heat of vaporization of the water in the reaction products is not recovered. The higher heating value or gross heating value is the amount of heat released when the specified quantity of fuel starting at 25 °C is combusted and then the combustion products are allowed to cool all the way back to 25 °C. This value DOES consider the latent heat of vaporization of the water created by the combustion reaction.

Because traditional hydrocarbon jet fuels have been well characterized, the relationships to density and aniline number are well understood, and the variations in heating values have been relatively small in comparison to the accuracy challenges in operating a bomb calorimeter, it has been quite reasonable to determine the heating value of jet fuel empirically. However, as fuel chemistry begins to diverge from the traditional composition, the potential for errors may result in expectations of significance to the calculated values that is not warranted, and breaking down of the assumptions that made Sherman & Kropff's equations sufficient.

Table 8 – Standards Involving Heat of Combustion

Test	Title	Primary Function
ASTM D240	Heat of Combustion by Bomb Calorimetry	Measure heat change during combustion of a sample under standard conditions in a bomb calorimeter.
ASTM D1405	Estimation of Net Heat of Combustion of Aviation Fuels (Aniline and API gravity)	Determine net heat of combustion at constant pressure based on aniline constant using one of four formulae.
ASTM D3338	Estimation of Net Heat of Combustion of Aviation Fuels (Density, aromatics, and distillation)	Determine net heat of combustion using relationships between density, aromatic content, sulfur content, and distillation values in one formula.
ASTM D4529	Estimation of Net Heat of Combustion of Aviation Fuels (Aniline, and density)	Determine net heat of combustion based on aniline constant, density, and sulfur content using one formula.
ASTM D4809	Heat of Combustion by Bomb Calorimetry (Precision method)	Measure heat change during combustion of a sample under standard conditions in a bomb calorimeter. Designed specifically for traditional turbine fuels. More accurate and precise than D240

4.1.3.1 Bomb Calorimeter D240

This method for calculating the heat of combustion is a fundamental analytical method developed in 1957 in which a sample is combusted stoichiometrically with an oxidizer. The gross heat of combustion is determined by measuring the bomb temperature before and after combustion.

Because of the creation of water due to combustion, it is necessary to use the hydrogen content to determine the water formed, and then to correct the measured value Q_{gross} to obtain the net heat of combustion. If the mass % of hydrogen is not determinable, then the heat of combustion, Q_{net}, is calculated by using the equation $Q_{net} = 10.025 + 0.7195\ Q_{gross}$. This formula is based on experimental data developed in 1953. Furthermore, the results must also be corrected for thermochemical reactions from other contributors (i.e. sulfur or nitrogen).

This is a standard analytical test method and is routinely available although testing is usually done as a research test, not bulk lab test. The equipment is a standard instrument and multiple laboratories capable of running the method were identified.

4.1.3.2 Estimation of Net Heat of Combustion (Aniline and API) D1405

Years of experience with traditional crude sourced petroleum product has determined there is a strong correlation between the net heat of combustion of petroleum products and the aniline gravity although there may still be large errors in the calculation. The correlations in this method are the result of analyzing actual data and were first released in 1956. The correlations assume that the relationships have already been well established for a product before the estimation is made. The method is not applicable to pure hydrocarbons and ASTM D4529 is recommended for aviation turbine fuels.

Briefly, the HoC for a fuel in one of four defined classes (aviation gasoline, JP-4, JP-5 or Jet A, A-1) is calculated empirically using the measured aniline point and the API gravity. If the fuel is known to contain sulfur, the final HoC is corrected using the mass percent of sulfur in an additional formula. The less like traditional crude sourced hydrocarbons the product is, the less accurate the estimation will be. The method requires data from three other methods, all of which are standard tests and testing laboratories for the three data methods and the estimation were identified.

4.1.3.3 Estimation of Net Heat of Combustion (Density and Aromatics) D3338

Similar to ASTM D1405, ASTM D3338 was developed in 1974 with the goal of creating relationships that did not require the determination of an aniline number. The correlations in this method are the result of analyzing actual data and provide a single equation for use with all aviation fuels. Note that this method was developed using a wide variety of fuels. It also included many pure hydrocarbons, so it goes beyond traditional fuel compositions.

Briefly, the heat of combustion for any aviation fuel is calculated empirically using the measured aromatics, API gravity and volatility (distillation) properties. If the fuel is known to contain sulfur, the estimated net heat of combustion is further corrected for mass percent sulfur content using a second formula. The less like traditional crude sourced aviation fuel the product is, the less accurate the estimation will be. The method also requires data from four other methods, all of which are standard tests and laboratories capable of running the four data methods and the estimation determination were identified.

4.1.3.4 Estimation of Net Heat of Combustion (Aniline, Density and Sulfur) D4529

Similar to ASTM D1405, ASTM D4529 was developed in 1985 to estimate the net heat of combustion (HoC) based on relationships between HoC and aniline point and density as opposed to API gravity. Unlike D1405, all aviation fuels are estimated using the same formula. The correlations are based on research and data from the 1950s and fuels must be well described by those original relationships for the estimation to be used.

Briefly, the HoC for any aviation fuel is calculated empirically using the measured aniline point and density. If the fuel is known to contain sulfur, the final HoC is corrected using the mass percent of sulfur in an additional formula. The less like traditional crude sourced hydrocarbons the product is, the less accurate the estimation will be. The method requires data from three other methods, all of which are standard tests and laboratories capable of running the three data methods and the estimation were identified.

4.1.3.5 Bomb Calorimeter (Precision) D4809

This bomb calorimeter method was developed in 1988 specifically for evaluating liquid hydrocarbon fuels, specifically aviation turbine fuel. The method was improved over D240 by the use of better temperature controls. Pure hydrocarbons and hydrocarbons not part of the data set used to develop the method require additional thermodynamic corrections not provided by the method. Thermodynamic corrections for traditional hydrocarbon fuels are provided.

The method is run using a calorimeter and both isothermal (isoperibol) and adiabatic methods are provided. Corrections for thermodynamic contributions of nitrogen, sulfur, the pressure sensitive tape, the firing wire, and the mass percent of hydrogen are all provided. From these calculations, the final net heat of combustion is determined. This is a standard analytical test method and is routinely available although testing is usually done as a research test, not a bulk lab test. The equipment is a standard instrument and laboratories capable of running the method were identified.

4.1.3.6 Summary

Determining the net heat of combustion of a liquid is an analytical process based on fundamental physical chemistry. As such, analytically determining the value, although not trivial, is not an unusual activity. Because of the challenges in measuring the actual heat of combustion, and the strong correlations between physical properties of traditional crude sourced hydrocarbons, it was relatively straight forward to generate formulae that could estimate the value with acceptable accuracy. This is predicated on the estimates having been developed from sufficient data of sufficient quality to provide reliable estimates.

The most notable caveat is the requirement for estimates to be made for a fuel from a traditional crude source. As the fuel composition diverges from traditional hydrocarbons, the correlation to the measured HoC values may also begin to diverge. The methods specifically exclude pure hydrocarbons from the estimation methods and many of the alternatively prepared fuels are more like pure hydrocarbons than traditional crude.

4.1.4 Hydrogen content

The hydrogen content of a fuel is important to the determination of the HoC of the fuel as well as determination of other combustion properties. Instead of measuring the luminometer number, the hydrogen content is considered. Knowing the amount of hydrogen and the amount of aromatics also helps predict the paraffinic content and thereby the combustion quality.

Table 9 – Standards Involving Hydrogen Content

Test	Title	Primary Function
ASTM D3343	Estimation of Hydrogen Content of Aviation Fuels	Uses relationship between API gravity, distillation range, aromatics and relative density to estimate hydrogen content
ASTM D3701	Hydrogen Content of Aviation Fuels by Low Res NMR	NMR response of sample is compared to the NMR response of a known, pure hydrocarbon to report hydrogen content
ASTM D5291	Determination Of Carbon Hydrogen and Nitrogen in Petroleum Products	Measure the carbon, hydrogen and nitrogen content of a sample using a LECO/Flash EA CHN analyzer
ASTM D7171	Hydrogen Content of Petroleum Products by Low Res, Pulsed NMR	Similar to D3701 except the NMR is pulsed instead of continuous

4.1.4.1 Hydrogen Content Estimation D3343

Originally, actual hydrogen content was determined by burning the petroleum product in purified air (ASTM D1018 originally published in 1949). In 1974 it was recognized that a reasonable estimation of the mass percent of hydrogen in aviation fuels could be made using the relationships between the API gravity, the distillation range, the aromatic content and the relative density (specific gravity). The method is specifically for well-defined classes of hydrocarbons and even then may have measurable inaccuracies. In 1998 the hydrocarbon range was defined as C_6 to C_{10}.

Briefly, an estimation is made using the formula %H = 0.063 17G – 0.041 089A + 0.000 072 135AV + 0.000 023 84GV – 0.000 496 0GA + 10.56, where G is the API gravity, A is the volume % aromatics, V is the average of the distillation data, and D is the relative density. The formula was empirically derived from accurate data collected on fuels. The hydrogen value is reported to the nearest 0.01%.

The caveat to the method is that the formula was derived from actual petroleum based fuel data and is based on expected types and ratios of aromatics, cyclics, and olefins. As the types and ratios of hydrocarbons diverge from the traditional, it is probable that estimates to the nearest 0.01% will become less accurate. All of the required data to perform the computations are routinely available tests and testing laboratories were identified.

4.1.4.2 Hydrogen Content by Continuous Wave NMR D3701

In the 1950s, nuclear magnetic resonance (NMR) equipment was developed. Low resolution NMR or time domain NMR worked by generating a magnetic field and measuring the response of protons aligning in the field. The instrument irradiated the sample with a range of frequencies in a continuous

wave, broadcasting each frequency in order. The method was a fundamental analytical chemistry method and was routinely used for analyses. In 1978, ASTM D3701 was published which used the NMR instrument to measure the hydrogen content of aviation turbine fuels. Note, in 1988, a separate method, ASTM D4808, was developed for petroleum products other than aviation fuel using the same methodology and equipment. This method did not show the same bias to pure hydrocarbons that D3701 displayed. D4808 is not a referenced standard in this project.

Briefly, a sample of the fuel is introduced into the NMR equipment and is irradiated in a magnetic field. The response of the protons (hydrogen) spinning in the field is measured. By comparing the resultant spectrum with that of a known, pure hydrocarbon, the mass % of hydrogen is determined. The method was faster and more precise than combusting the sample (D1018) or estimating the content from other properties.

As technologies have evolved, this continuous wave NMR has been obsoleted, but owners of the equipment may continue to use the method as long as accurate operation continues to be statistically demonstrated. Currently Southwest Research Institute still provides testing to D3701.

4.1.4.3 Hydrogen Content by Pulsed NMR D7171

As technology has evolved, so has the NMR. Better magnets and software algorithms have resulted in the introduction of pulsed NMR. This NMR instrument irradiates the sample with all of the desired frequencies at the same time. In 2005, ASTM D7171 was released, essentially replacing ASTM D3701. This method is not specifically for aviation fuel, but as long as the sample is within the boiling range of 150 °C to 390 °C, the method is valid.

The method works in the same way as D3701, aligning the protons in a magnetic field, but the instrument has better magnets, resulting in a more homogeneous field, and all of the frequencies can be used at once, instead of sequentially as in the continuous wave instrument. The resulting spectrum is compared to a reference spectrum of a known pure hydrocarbon and the mass % hydrogen determined. The equipment is a standard instrument and testing laboratories were identified.

4.1.4.4 Hydrogen Content by CHN Analyzers D5291

Hydrogen can be determined instrumentally as part of a carbon, hydrogen, nitrogen analysis. Instruments, referred to collectively as CHN analyzers, work on the general concept of converting the sample into carbon dioxide, water vapor and elemental nitrogen by combustion. In 1992, ASTM D5291 for instrumental determination of carbon, hydrogen and nitrogen was released. While the nitrogen content in jet fuel cannot be determined using this method due to the low absolute content, carbon and hydrogen can.

Specifics are instrument dependent, but generically a weighed sample is introduced into the instrument where the chamber is purged and then pure oxygen provided. The sample is combusted in the oxygen. The resulting combustion gases may be scrubbed, or reduced with copper, or adsorbed, or treated with

calcium oxide, depending on the specific instrument, to generate elemental gases. The resulting elemental gases are generally then carried through a separation column, like a gas chromatography column, generally using helium, to a detector. The resulting peak areas are compared to a calibration graph and the mass percent of each carbon, hydrogen, nitrogen (if not fuel) and sulfur can be determined.

The methodology uses a standard analytical instrument with well documented precision and accuracy capabilities. While results are dependent on operator experience, the method is reliable. The equipment is standard instrumentation and testing laboratories were identified.

4.1.4.5 Summary

All of the direct measurement methods are sufficient and robust for determining the hydrogen content of fuel experimentally. While the continuous wave NMR has been obsoleted in favor of the more technologically advanced pulsed NMR, none of the methods should present a problem. It is noted that the method for estimating hydrogen content from physical properties is subject to lack of accuracy that is likely to become more noticeable as the fuel chemistry diverges from traditional petroleum sources.

4.2 Dielectric Testing

One of the topics that developed as a critical property during the program with a potentially large testing gap was related to capacitance type fuel gauging. This became visible during the review of OEM requirements (see Section 5.2). To understand the testing gap, a review of the technology goals and the identified testing was determined to be warranted.

4.2.1 Background

Current aircraft fuel gauging systems are based on a capacitance type fuel gauge system. In its most basic form, an electrical circuit in which the fuel is the bridge is monitored. As the fuel level changes, the balance between the test capacitor and the reference capacitor changes, resulting in a signal change.

The contributors to changes in the circuit are the area of the capacitor plates, the distance between the two plates, and the dielectric constant of the material between the two plates. In the aircraft the two capacitor plates are two tubes, mounted concentrically with a narrow air gap between them. The tubes are the entire depth of the fuel tank at the point they are mounted. In a fuel gauge, the area of the plates and the distance between them is fixed. The only variable that changes is the dielectric constant because the "material" between the two plates is a changing ratio of fuel and air. The aircraft system measures the dielectric constant. The software uses the fuel depth and a computed "density" that gives the pilot mass of the on-board fuel. Changes to the temperature of the fuel changes the fuel's volume, density, and dielectric constant, all of which must be accounted for by the fuel gauging system. Compensators, capacitance gauges that are completely submerged, and densitometers, vibratory gauges, determine the density of the fuel at the current temperature and correct the fuel tank gauges.

According to Maxwell Smith (p. 288), "the variation of permittivity of hydrocarbon fuels with temperature is linear and is compensated for in normal capacitance gauges. *Fuels which have different*

densities at a given temperature require special consideration (emphasis added). Variations in the capacitance of tank probes due to variation in the amount of free or dissolved water in the fuel, or to changes in air or vapour pressure, are negligible."

4.2.2 Terms

When discussing capacitance as a physical property, multiple terms are encountered. All of the following are used when discussing capacitance; dielectric constant, specific inductive capacity, and relative permittivity. These terms all relate to the force between two electric charges separated by a distance. Relative permittivity indicates to what medium the measurement is relative, for example relative to air or to fuel. The relative dielectric constant or permittivity, ε_r, is measured in farads/m^2. Note that a farad is defined as the capacitance across which, when charged with one coulomb, there is a potential difference of one volt. When the permittivity is relative to a vacuum, κ, the value is dimensionless.

4.2.3 Contributors to Variations

Not only temperature affects the measured permittivity. Because the measurement is related to the application of an electrical field, the frequency, aka the application time of the field, and the wavelength, aka amount of energy applied, can impact the measured value. As the frequency increases, the absolute time the field is applied decreases, thus decreasing the measured permittivity. An increased frequency also means the energy (wavelength) can be applied more times per unit time. Another contributor to variations is the polarity of the material being tested. As the polarity of the dielectric material increases, the rate at which the charges can change direction in the changing field decreases due to molecular forces. If the field changes direction too quickly, the material cannot respond; the ions in the fluid cannot change orientation fast enough.

4.2.4 Dielectric Constant ASTM D924

Currently, the dielectric constant of jet fuel is measured using ASTM D924, Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant of Electrical Insulating Liquids.

During the standard review, this document was assessed as having measurable impact (see Section 3.3.2.1) primarily because the standard was designed for insulating liquids used in cables, transformers, oil circuit breakers and "other electrical apparatus". While it could be argued that the aircraft capacitance gauge was an "electrical apparatus", it was clear the methodology was for insulator fluids as opposed to changing conditions in a measurement device. The reported precision statement was generated using mineral oil as the test fluid. The test method leaves the test temperature up to the tester, "generally 25, 90 or 100 °C", and the frequency chosen related to the density of the fluid, typically 45 and 65 Hz.

4.2.4.1 Summary of D924

Given the original intended application of the method, the lack of guidance on the test parameters, potential reinterpretation of the application of "electrical apparatus" and the development of the

reported precision statement on mineral oil, there is measurable concern with the standard related to changing the chemical composition of the test fluid.

4.2.5 Contemporary Testing

As is discussed in Section 5.2, contemporary testing of the dielectric constant on jet fuel is no longer convergent on ASTM D924, if it ever were. Depending on the requester, dielectric constant testing is performed per D924 as written, per D924 with frequency and temperature modifications, or not performed to D924 at all.

When testing was performed in 2011 for the USAF for the synthetic fuel development, testing was performed by Southwest Research Institute (SwRI) using a "K-cell on loan from Goodrich." Testing was performed at 400 Hz, the historical frequency, although SwRI researchers recommended 1 KHz. The test method performed was to measure the permittivity of the clean, dry K-cell. The K-cell was submerged in the fuel and allowed to equilibrate to temperature, the fuel capacitance was measured and the permittivity of the jet fuel was calculated. SwRI used air capacitance at ambient conditions for all of the calculations even when the fuel temperature was not at ambient.

Other testing, performed by the OEM's themselves was run under entirely different conditions. One of the companies reported they ran the test using a three terminal cell instead of the two terminal cell used by D924 and SwRI. They also ran the test using a vacuum instead of air because of observed fluctuations in the capacitance of air. The test frequency recommended was 3 to 20 KHz, much higher than the 45 and 65 Hz specified in D924 or the 400 Hz reported as the historical frequency. A second OEM enlisted their hardware manufacturer for testing and also indicated the need for a more representative frequency for the testing, and better defined environmental conditions.

The second difference from ASTM D924 testing was a recognition and desire to better link changes in the fuel density with temperature to the fuel's permittivity changes with temperature.

4.2.6 Conclusion

The current requirement for understanding the dielectric constant, especially versus temperature, and potentially in relation to density changes with temperature creates a critical technology gap, both in the lack of suitable test method and property requirements. The current test method is not designed for the jet fuel application, nor is the test condition consistent with the fuel gauging application. Variations in the testing modifications and a lack of standardization of the conditions and equipment are confounding the analysis of data by the OEMs. Furthermore, the OEMs have a high dependency on the gauging equipment manufacturers for operation validation with fuel chemistry which further confounds the interpretation of research data.

4.3 Bulk Modulus

Bulk modulus is a fundamental physical chemical property that is a measure of how compressible a substance is when a force is applied. Through derivations starting with the ideal gas law, PV=nRT, bulk

modulus can be described as the reciprocal of compressibility. This is because a change in pressure will result in a change in volume; increase pressure, decrease volume. The change in pressure would be proportional to the density. The larger the bulk modulus is, the less compressible the fluid is. Again, with an ideal gas, this process can be performed isothermally, that is there is a change to the volume when the pressure is applied but no change to the temperature. The bulk modulus in this case would be the static bulk modulus.

In actual application, the heat diffusion, that is the ability to keep the temperature fixed in the system by letting it escape/enter, is too slow and there is a change to temperature. The compression is actually at constant entropy (isentropic) as opposed to isothermal, so when the volume is decreased the pressure increases and so does the temperature. The temperature does not diffuse away, so a compression causes the medium to heat up and a reduction causes the medium to cool down. The bulk modulus in this case is the dynamic bulk modulus. Static bulk modulus is related to dynamic bulk modulus by the ratio of the medium's heat capacity at constant pressure, C_P, to the medium's heat capacity at constant volume, C_v, or $\gamma = {C_P}/{C_v}$.

Using Hooke's law and further derivations, the bulk modulus is related to the speed of sound and the density of the fluid by the relationship, $c^2 = \frac{B}{\rho}$ *or* $c = \sqrt{\frac{B}{\rho}}$ where c is the speed of sound, B is the bulk modulus and ρ is the density. If the density at a given temperature is known, and the speed of sound is measured in the medium at that temperature, then the dynamic bulk modulus at that temperature can be determined. In application, at a given temperature it is possible to measure the speed of sound, and knowing the bulk modulus at that temperature, to determine the density at that temperature. This then becomes a densiometer, where $\rho = \frac{B}{c^2}$.

4.3.1.1 Tangent Bulk Modulus D6793 versus Speed of Sound

The bulk modulus test method referenced in the parent documents is ASTM D6793, Determination of Isothermal Secant and Tangent Bulk Modulus. The method is used to determine the compressibility or static bulk modulus of a medium under isothermal conditions. A known change in volume applied to bulk modulus standard and a V/ΔV constant for the test apparatus is determined. A liquid in a chamber is compressed by the insertion of a piston and the resulting pressure change is measured.

A plot of bulk modulus with pressure is not linear, so two mathematical methods are used to define the slope of the line at a point, the secant bulk modulus and the tangent bulk modulus. Isothermal secant bulk modulus is a linear function of pressure between ambient to 10,000 psig, and extrapolation is possible. The isothermal secant is determined by calculation, $B_i = (\overline{P_n} - P_0)({V}/{\Delta V})$. Isothermal tangent bulk modulus and density as a function of pressure may be calculated from the measured secant bulk modulus as a function of pressure.

Method D6793 is used to determine isothermal secant and tangent bulk moduli, but the data cannot be used to determine the dynamic bulk modulus. Per the method, dynamic bulk modulus is usually determined from speed of sound measurements.

4.3.1.2 Method Summary

The test method is an analytical method based on physics. As long as the equipment is functional and the V/ΔV has been appropriately determined, the method is not dependent on the material being tested. However, it only provides isothermal or static bulk modulus. If dynamic bulk modulus is desired, this method will not provide it.

4.3.2 Summary

As is discussed in Section 5.2, the OEMs do not currently have a standardized test where the speed of sound is used to determine the dynamic bulk modulus with temperature when function of density with temperature is known. In January 2016, Scott Hutzler of SwRI provided an interim report where he described efforts to develop a Federal Test Method to measure isentropic bulk modulus. The efforts were showing promise, but more work was recommended. Mr. Hutzler indicated the additional testing had been done and there were positive results. An FTM draft was provided to the US Army, the client, but he did not know what they intended to do. A search of the literature did not locate an FTM test method. Additional input suggested there may be intent to add the method to FED-STD-791 in the future, but to date that had not occurred.

If the OEMs do indeed wish to use isentropic bulk modulus to determine density at temperature and pressure, then a method such as the proposed FTM has value. Because the referenced ASTM D6793 standard is for static bulk modulus and it appears the OEMs wish to use dynamic bulk modulus, then the ASTM method is insufficient and there is a technology gap.

4.4 Special Data Discussions

ASTM D1655 is a specification that is primarily a quality and purchase control document. The primary goal of the limits provided in the document is to assure the continued compliance of the produced commodity to an expected set of properties and to provide a quality control mechanism throughout the delivery and use of the fuel. Over time, the Table 1 properties have come to be accepted as the minimum properties to define a fuel that continues to provide the same expected behavior in use. These properties have come to be the minimum parameters necessary to "draw the box" that describe an acceptable commodity.

One of the most noticeable divergences from the use of Table 1 as a description of a commodity to the evaluation of alternative production sources and end products is the understanding that Table 1 properties are not necessarily sufficient to evaluate alternative chemical compositions. It is necessary to understand the alternative compositions' behavior in a relational nature as opposed to individual data points. How does a physical property change with temperature? What is the relationship between two physical properties and how does that relationship compare to traditional petroleum derived jet fuel?

At the most basic level is the requirement for additional data points for a physical property regularly considered, for example viscosity or surface tension at multiple temperatures to assess similarity to norm. At a higher level is the preparation of full relational charts such as thermal expansion versus density. Because these relationships have not been evaluated in some time, do not have specified values, and in some cases, do not have a consensus on acceptable testing parameters, they provide a greater interpretive challenge.

Similarly, D4054 and MIL-HDBK-510 have test requirements for properties deemed important for evaluation but which are not typical Table 1 properties. Some of these properties have not been evaluated in some time, others are items identified as important but which may not have any specified or even expected values. As indicated in Section 5.1, the original equipment manufacturers indicated they generally used ASTM D4054 and ASTM D7566 as published with the exception of potentially requesting additional test conditions for data collection.

While the individual test standards have been reviewed and are discussed in Section 3.2, it was deemed value added to discuss the relationships and unique tests further.

4.4.1 Thermal Conductivity vs Temperature

Thermal conductivity is the property of a material to be able to conduct heat and refers to the fuel's effectiveness as a primary heat sink. The higher the thermal conductivity a material has the higher the rate at which heat transfer can occur. Thermal conductivity of jet fuel is not a measured property for ASTM D1655 or D7566. It is referenced in ASTM D4054 and MIL-HDBK-510 as a relational requirement. Offerors are instructed to use ASTM D2717 to test the fuel. The requirement is listed without limits and with instructions to "conform". A chart of typical thermal conductivity vs temperature is provided for guidance. Neither D4054 nor MIL-HDBK-510 provides recommendations for test temperatures. A review of the D4054 user's guide recommends the test be run at 0 °C, 30 °C, and 60 °C. It is assumed the relationship between thermal conductivity and temperature is linear.

4.4.1.1 ASTM D2717

The method is designed to measure the thermal conductivity of liquids by measuring the temperature gradient of the liquid, equilibrated to the test temperature, when a known amount of energy is introduced into the liquid via an electrically heated platinum element. The test method indicates there has been no ILS performed because the equipment is expensive and few people run the test. The reported precision and bias statement is a repeatability of ~10% of the mean value. In the US the test is run at SwRI and at Texas Oil Tech Laboratories. The method is based on fundamental physics and is not impacted by the chemical composition of the liquid.

4.4.1.2 Summary

The method provided, ASTM D2717, appears to be sufficient and the suggested temperatures provided in the D4054 guide provide three points for determining the relational line. Assuming that the thermal

conductivity of the material is reasonably linear over the entire operating temperature range, then the three suggested temperatures are likely sufficient.

It is noted both within D2717 and within the literature that the specified method is expensive and difficult to execute. While no other ASTM methods for measuring the thermal conductivity of liquids are identified, other methods for determining thermal conductivity of liquids exist, several with ISO specifications. Using other methods would lose the relationship to existing data; a concern given the only assessment is by similarity of values. Alternatively, the requirement is a relational assessment as opposed to a Table 1 required property and new values could be developed. In an April 2015 Research Report, SwRI noted "Thermal conductivity has proved to be very difficult to measure on liquids. Over the last 17 years since the first Sasol IPK evaluation, it has been difficult to find laboratories that can perform the D2717 method. SwRI now uses the new ASTM D7896 test method, a transient hot-wire method." There may be value in considering more user-friendly methods, especially if increases in precision and accuracy, and an increased temperature test range could be realized.

4.4.2 Energy Change with Temperature

During the course of the study, several different energy change requirements were identified across the parent documents; enthalpy vs temperature, specific heat vs temperature, latent heat of vaporization, heat of combustion, and heating value. Enthalpy is the heat energy required to bring a fuel from one reference state to another state. It is a function of the integral of the specific heat between the two states, and any latent heat of vaporization that was required in the interval. In an enthalpy graph, the saturated liquid curve represents the heat that can be absorbed in the liquid phase alone, and the saturated vapor curves depict the heat absorbed to vaporize the fuel completely. The intermediate area denotes partial vaporization, while the curves above this saturated vaporization line indicate super-heated vapor. The line of constant pressure provides the pressure relationship to determine the state of vaporization of the fuel for the addition of a given amount of heat. The specific heat of a fuel is the amount of heat-energy transferred into or out of a unit mass of the fuel when increasing or decreasing its temperature. In fuel system analysis, specific heats are used in the calculation of heat transfer when using the fuel as a coolant or as a heat sink. MIL-HDBK-510 has a reference for specific heat, ASTM E1269 Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry.

While the two relationships referenced in MIL-HDBK-510, enthalpy vs temperature and specific heat vs temperature are listed as having no referenced test methods, multiple methods are provided for other energy change descriptions.

4.4.2.1 Enthalpy vs Temperature

The handbook indicates that enthalpy versus temperature is a Criteria 3 requirement. They are interested in the enthalpy from 0 °C to 250 °C. While the handbook does not provide guidance on how to perform the testing, determining enthalpy from calorimetry data are a fundamental physics calculation.

4.4.2.2 Specific Heat vs Temperature

The handbook recognizes that specific heat is related to enthalpy as a measure of the heat that moves into or out of the test material. No specific requirements for the relationship are provided, only a reference to the charts prepared by the CRC. The CRC Aviation Fuel Properties handbook does not provide a test method, only a reference to use of a differential scanning calorimeter to develop data.

4.4.2.3 Heat of Vaporization, Latent

Latent heat of vaporization is the heat (ν) per kilogram needed to change between the liquid and gas phase; ΔQ = change in heat. Alternatively, ΔQ = m (mass) x L (latent heat). Rearranging the terms, L = ΔQ/m. At the same time ΔH_{vap} = the enthalpy of vaporization, which is affected by the pressure at the time of the measurement. There is a strong relationship between the volatility of a material and its change in heat (ΔQ). Volatility can be measured using the material's vapor pressure. Therefore from the Clausius-Clapeyron equation, $\ln(P) = \frac{-\Delta Hvap}{RT} + constant$ or $\frac{dP}{dt} = \frac{L}{T\Delta V}$, where R is the molar constant 8.314 J/K mol, T is in degrees Kelvin and L is the latent heat. By graphing the log (P) vs 1/T, a straight-line results, with mass related to the ΔH_{vap}.

In order to evaluate the change in heat of vaporization with temperature, the relational analysis requires the vapor pressure of the material with temperature. To obtain this information, offerors are suggested to develop vapor pressure with temperature using either ASTM D323 RVP or ASTM D5190 DVPE by the automatic method. ASTM D5190 was withdrawn in 2012 but the instrument and method could still be used to develop the vapor pressure data. Because the graph is of the log (P), it is important to have the correct vapor pressure as errors will grow exponentially.

Only the military handbook discusses the need for determining the heat of vaporization but does not offer any data requirements. It does provide information regarding the calculation of heat of vaporization using ASTM E2071 from the vapor pressure data.

4.4.2.4 Summary

Multiple types of energy change data are identified in the four parent standards, all different and all related. It may be possible to reduce the complexity of the data collection by better coordinating the data collected and the information required.

4.4.3 Density vs Temperature and Thermal Expansion vs Temperature

MIL-HDBK-510 specifically requires the development of a density versus temperature relationship because of the importance of density measurements to the aircraft. Knowing the variations in the density with temperature and how the variations compare to traditional jet fuel is critical to the data evaluation. Related to density is the thermal expansion or volume change experienced by the fuel.

Thermal expansion is a derived property from temperature and density data. A temperature has to be established to set a reference volume and the corresponding volume change. The volume change may be reported as a multiple of volume with the reference temperature being 1.0 or it may be reported as a

percent change. The fact that the density-versus-temperature of different fuels may be parallel does not imply that the coefficient of thermal expansion is the same - the volume expansion is inversely related to density.

The handbook provides two ASTM methods for the determination of density, ASTM D1298 and ASTM D4052. Both of these standards are included in the parent documents. The handbook also suggests that there is no standard test method for determining thermal expansion, but does provide reference to ASTM D1903, Determining the Coefficient of Thermal Expansion of Electrical Insulating Liquids of Petroleum Origin. This method formally describes determining the thermal expansion by measuring the density at any two temperatures and calculating the coefficient of thermal expansion; $\alpha = \frac{(\rho - \rho_1)}{\rho\,(T_1 - T)}$ where ρ is the relative gravity at the lower temperature, T, and ρ_1 is the relative gravity at the higher temperature, T_1. By repeating the calculation at multiple temperature sets, an average coefficient of thermal expansion can be determined.

4.4.4 Storage Stability

Traditionally, the storage stability of commercial jet fuels is neither routinely measured nor do limits exist. However, it is recognized that significant changes in chemical composition could result in changes to the storage stability of the fuel and should be evaluated in comparison to existing traditional aviation turbine fuel. Without specified guidance, the potential is to make use of test methods already existing, even if not specified for use with jet fuel.

MIL-HDBK-510 calls out MIL-STD-3004 Storage Stability testing which references ASTM D5304 and ASTM D2274. Per the US Air Force, 1) in the absence of storage stability guidance for aviation turbine fuels, MIL-HDBK-510 references the storage stability requirement in MIL-DTL-16884 (F-76 marine diesel fuel specification) by D5304 which is reflected in MIL-STD-3004. MIL-HDBK-510 also acknowledges the reference to D5304 in Practice D4054. MIL-HDBK-510 mentions the reference of D3703 in D4054 to check for peroxides. 2) There is no reference to D2274 in MIL-HDBK-510. There is a reference to D2274 in MIL-STD-3004 but only applicable to marine diesel fuels (mirroring the requirements in MIL-DTL-16884). At no point is D2274 made applicable to jet fuels. ASTM D2274 is specifically for distillate fuel oil (diesel fuel) and is not applicable to jet fuel. MIL-HDBK-510 indicates that D5304, Assessing Middle Distillate Fuel Storage Stability by Oxygen Overpressure, was developed to evaluate the storage stability of fuel. The test method measures the formation of fuel insoluble products (potential gums) following heating in an oxygen environment. There is no other guidance on testing requirements.

ASTM D4054 references ASTM D3703 (peroxides) and ASTM D5304 (potential gums) for evaluation of storage stability. Offerors are told to run D3703 for 6 weeks at 65 °C and measure the formation of peroxides which should not exceed 8ppm. ASTM D5304 is to be run for 16 hours at 100°C (higher than the temperature specified in the method) and the formation of potential gums should not exceed 7 mg/100ml. The D4054 users guide lists as the suggested source for storage stability evaluation ASTM D4625, Middle Distillate Fuel Storage Stability at 43 °C, with no requirements. D4625 is not a referenced

standard in the parent documents, although contemporary jet fuel may be the transportation fuel closest to those used to develop D4625 originally.

4.4.4.1 Hydroperoxide Number D3703

This method is not a storage test, but rather measures the ability of a fuel to form peroxides. A sample of fuel dissolved in 2,2,4-trimethylpentane is reacted with potassium iodide solution. Any hydroperoxides present are reduced by the potassium and iodine is liberated. This iodine is reacted with sodium thiosulfate in a titration and the milligrams of hydroperoxide per kilogram of sample are reported. High levels of peroxides are considered to be an indication of the oxidizing moieties present in the fuel and by extension a prediction of the propensity of a fuel to oxidize. The test is an oxidation stability indicator and is not directly related to storage stability.

4.4.4.2 Storage Stability by Oxygen Overpressure (Potential gums) D5304

The test method has a 100 ml aliquot of the fuel placed in a borosilicate glass container which is in turn placed into a pressure vessel. The pressure vessel is then pressurized with oxygen to assure an oxygen environment throughout the test. In other words, oxygenation of the sample will not be able to consume all of the oxygen before the end of the test. The test is run for 16 hours at 90 °C. At the end of the test, the cooled sample is filtered through weighed filter paper and the amount of material formed and filterable is determined gravimetrically. While the method did show some relationship between 40 hours at 40 °C to 40 months at 20 °C for the F-76 fuel samples originally tested, the method is not designed to be predictive for jet fuel. The method does provide comparative information.

4.4.4.3 Storage Stability at 43 °C D4625

The test method is not referenced in any of the parent documents, but is called out in the ASTM D4054 Users guide as a special case beyond the discussed D3703 and as such is considered here. The test method involves preparing two 400 ml samples for each of six sample durations. The samples are placed in borosilicate glass bottles which are vented. The sample bottles are stored at 43 °C with a sample bottle removed at each of 0, 4, 8, 12, 18, and 24 weeks. Two of the samples are removed at each date, allowed to cool to room temperature. The 400 ml sample is filtered through weighed filter paper. The bottle is flushed with filtered flushing fluid. The filter paper is dried and weighed. This is the filterable insolubles. After completing the filterable insolubles, the sample bottle is rinsed with solvent and the rinsings are placed into a weighed 100 ml beaker. The solvent is evaporated at 160 °C until completely evaporated and the beaker is cooled and reweighed. This is the adherent insoluble content. Repeat with the second sample and average the results. The results are entirely comparative and have no relationship to actual storage stability rates.

4.4.4.4 Summary

Storage stability is a complicated process and none of the test methods directly predict storage stability. However, all three data are indicative of a propensity to oxidize and form insoluble materials. By

running these tests, an evaluator has some level of ranking, although the results should not be considered absolute or predictive.

It is noted that the standard D4054 and the D4054 users guide do not reference the same storage stability test, potentially resulting in confusion by either the offeror or the interpreter. One method is a much shorter test run at elevated temperatures and providing only filterable solids information. The other is a much longer test method (24 weeks minimum) but provides both rate and quantitative filterable solids formation. Whether both test methods are necessary should be considered. In either case, both documents should refer to the same test requirements.

4.4.5 Flame Speed

Flame speed provides information related to both combustion and safety. With respect to combustion, flame speed is an indication of the "laminar flame speed, the speed of a flame propagating through jet fuel vapor/air mixtures. This is about ~157 feet/minute (~2.6 feet/second). With respect to safety, flame speed is a measure of the rate of time it takes a flame to cross a liquid pool of fuel. This speed may be related to a safety issue such as a spill on the ground – how fast will the fire spread under ambient conditions. Review of ASTM and investigations with aerospace combustion engineers suggests there is no published industrial specification or standard although there are generally accepted practices. The MIL-HDBK-510 does provide a test procedure. The requirement provided by MIL-HDBK-510 is for a baseline value of between 0.3 and 0.6 meters/second (~1 foot/second and ~2 feet/second) in Table C-XLII and in Table F-I as, "Varies by fuel temperature. Typically, less than 5 inches/second below the flash point and up to 70 inches/second above the flash point."

4.4.6 Minimum Spark Ignition Energy

The minimum spark ignition energy (MIE) is a measure of the energy required to ignite a combustible fuel/air mixture. Note that the minimum ignition energy is not the same thing as the flash point (temperature at which sufficient vapor exists for ignition) or the lower flammability limit, (lowest fuel/air mixture that will support combustion). The primary reason for considering the MIE is safety considerations. MIL-HDBK-510 lists a requirement for determining the minimum ignition energy saying it should be no less than that of existing jet fuel.

In one section, the handbook suggests using the test method ASTM E582, Standard Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures, and in a second section, the handbook suggests the test method is 'TBD' and a Criteria 2 requirement. MIL-HDBK-510 provides CRC data for comparison, but the test method used to generate the CRC data are not indicated. The provided charts and research indicates that the MIE is temperature and pressure dependent, given its relationship to vapor pressure. However, E582 is at ambient conditions with a fuel/air ratio matched to the test conditions. MIL-HDBK-510 does not provide test conditions, nor is determination of the relational results, i.e. MIE vs temperature, overtly requested.

4.4.6.1 Minimum Ignition Energy E582

The ASTM test method covers determining the minimum energy required for ignition of the gaseous mixture and the flat-plate quenching distance of alkane and alkene fuels mixed with air at ambient temperature and pressure. Fuel/air vapor expected for the ambient test conditions is placed into a spherical reaction vessel fitted with ignition electrodes. The voltage introduced by the ignition electrodes is increased until the fuel air vapor in the reaction vessel ignites.

According to the precision and bias statement, the reproducibility and repeatability of the method are ±10% the measured minimum ignition energy. Research suggests that the method has measurable variability in practice. Considerations include variability of the spark shape and position, carbon formation in the spark zone, changes in fuel/air ratio at the upper flammability limit as ignition initiates, and the size and shape of the reaction vessel.

4.4.6.2 Summary

It is unclear whether the handbook is or is not recommending the use of E582 to measure the minimum spark ignition energy. Determination of ignition energy or reference to E582 is not required in the other parent documents. Research suggests that the methodology presented in E582 is consistent with other generally accepted practices, even where those practices are not formal standards. All suggests the method is appropriate, but further confirmation should be considered. Additionally, inclusion of the required test conditions, whether it be a single data point at ambient conditions or the development of relational data, should be considered.

4.4.7 Water Measurements

During the review, it was noted that during research and development of synthetic fuels, it had been reported that there were issues encountered with the fuels' abilities to shed water. These observations were made in relation to the use of standard test method, ASTM D6304, Coulometric Karl Fischer Titration. In the ATJ Research Report, Version 1.4, dated March 2014, researchers reported that there were issues with the maximum amount of water which the fuel could pick up when exposed to excess water. SwRI developed a specialized test to look at this saturation level of dissolved water. The test utilized the standard coulometric Karl Fischer water titrator, but the sample preparation was unique.

The implications of the report were not that the test method itself was performing incorrectly due to the composition of the fuel, but that there were concerns related to the saturation performance of the fuels when exposed to water. This performance was related to the composition of the fuel and is an important consideration for fuel developers.

4.4.8 Existent Gums Measurements

It was observed during the standard review process that the standard test method for gum contact, ASTM D381 does contain a statement warning the user that it is possible for there to be materials that do not evaporate during the testing, typically due to their molecular weight. These materials are not, however, related to the existent gum content. Where appropriate, these materials are removed using a

heptane wash, leaving only the gums. This was observed during the testing of HFP-HEFA (green diesel) and reported in the HFP-HEFA Research Report, Version 3, April 2017 that the modification using the heptane wash was employed.

Because this limitation regarding composition has already been noted and captured in the existing text, the method was deemed appropriate (green), but it was deemed important for researchers to recognize and understand how this limitation might apply to a presented fuel composition.

4.4.9 Flash Point Testing

After the U.S. and E.U. reviews, it was noted there were a number of test methods for flash point in use related to aviation turbine fuel. Given the diversity of test methods, it was deemed pertinent to point out the differences in this report. Flash point is not a physio-chemical property intrinsic to the material being tested. Instead it is a property that is defined by the test method used to measure it. Because the results are specific to the method and procedures used to determine the value, it is not possible to correlate between the methods. This does not negate the usefulness of the property in giving information regarding the potential flammability characteristics of a material, but rather points out the care needed in noting the method used to generate the value.

ASTM maintains an in-depth monograph on the topic, Manual 74 "*The Practice of Flash Point Determination*", which covers all of the methods in much greater depth and the following is only a brief discussion on the general differences in the methods. At the time of this writing, there were eleven ASTM flash point methods and at least three IP flash point methods. Of these 14 methods, 6 are referenced in the aviation fuel standards.

In general, flash point testing falls into one of two types; equilibrium or dynamic, and one of three principles; closed cup, open cup and other. Equilibrium means that the heat source, the fuel and the vapor are all essentially at the same temperature. Dynamic means there is a rate related to the movement of heat from the source, to the fuel, and then the vapor. The result is the liquid and the vapor are not at the same temperature and the temperature is continuously changing.

Closed cup methods use a sample cup that is closed during heating until the ignition source is introduced, simulating a spill in a confined space. Because of the confined environment, the results are more like real world closed vessels, for example tanks. The closed environment means that the heat and vapors are contained within the sample cup, resulting on average in lower flash point temperatures than open cup methods. The three main types of closed cup flash point tests are Tag Closed Cup, Pensky Martens, and Abel.

Open cup methods have the fluid sample exposed to the outside air during the test and the ignition source is passed over the top of the cup, simulating a spill in an open environment. In open cup methods flash points will be affected by the distance between the sample and the ignition source. The most

common open cup methods are the Cleveland Open Cup method and the Tag Open Cup. Neither open cup method is referenced in the aviation fuel standards.

Other methods include the continuously closed cup method where the sample is in a cup that is never opened. The ignition source may be a high voltage arc and the flash is measured by either a pressure rise or a change in ionization in the vapor.

4.4.9.1 Tag Closed Cup – ASTM D56

The Tag flash point test method is a closed cup test method and a dynamic method. It is the current referee method for ASTM D1655. Neither the fluid nor the vapor space is agitated. Observation of flash is visual. The thermal source is external and cools/heats a water bath, permitting lower than room temperature testing. Sample size is 50 ml ±0.5 ml and the sample cup is partially submerged in the water bath. The cup and bath temperatures are measured. The ignitor flame is introduced through a shuttered opening.

4.4.9.2 Pensky-Martens Closed Cup – ASTM D-93 and IP-34

The Pensky-Martens flash point test method is a dynamic test method. Both the fluid in the cup and the vapor space over the fluid are agitated by the presence of rotating mixers. Observation of a flash is visual. The heat source is in direct contact with the sample cup. Sample size is approximately 70 ml and the thermometer measures the vapor. The ignitor flame is introduced through a shuttered opening.

4.4.9.3 Abel Closed Cup – IP 170

The Abel flash point test method is commonly used in the European markets and is the referee method for Def Stan 91-091. It is a closed cup test and a dynamic test method. Only the fluid is agitated by the presence of a rotating mixer. Observation of a flash is visual. An external thermal source cools/heats a water jacket, permitting lower than room temperature testing. Sample size is approximately 78 ml and the thermometer measures the vapor. The ignitor flame is introduced through a shuttered opening.

4.4.9.4 Small Scale Rapid Flash Point – ASTM D3828, IP 523 and IP 524

These methods are all very similar. The methods are equilibrium test methods, meaning the liquid and vapor are at the same temperature. Either 2 or 4 ml, depending on method are injected into a sample chamber at a set temperature and the presence of flash is measured. If a flash is not measured, the aliquot is removed and a new aliquot is introduced at a new temperature. There is no stirring and heat is supplied by an electric heater through an aluminum block. The ignitor is a small test flame.

4.4.9.5 Modified Continuously Closed Cup Flash Point (MCCCFP) – ASTM D7094

In 2004, ASTM approved the MCCCFP test. Based on a completely closed cup, the lid is never opened. This method is not currently called out by any of the aviation turbine fuel standards, but has been presented and used as an equivalent to the Pensky-Marten closed cup flash point test. The sample in the sample cup is stirred with a magnetic stir bar and the flash is measured as a pressure rise in the chamber.

Sample size is 2 ml and there is a temperature ramp. The ignition source is internal to the sample chamber and provided by a high voltage arc.

4.4.9.6 Cleveland Open Cup – ASTM D-92 and IP 36

While not called out in any of the documents reviewed, the Cleveland Open Cup is also a commonly used dynamic flash point test method. Observation of flash is visual. This test method has a heating mantle and external gas flame heat source. Sample size is 75 ml. The ignitor flame is moved over the surface of the sample in a radial arc.

4.4.9.7 Tag Open Cup – ASTM D1310

Also not called out in any of the documents reviewed, the Tag Open Cup is a dynamic test method. The observation of flash is visual. The method has a liquid bath with external heat source and is capable of running temperatures below room temperature. Sample size is approximately 90 ml. The ignitor flame is moved over the surface of the sample in a radial arc.

4.4.9.8 Other Flash Point Test Methods

While not currently called out by any of the jet fuel standards, other ASTM flash point test methods at the time of this report include:

- ASTM D3278 - small scale closed cup (as opposed to the small scale rapid flash point above)
- ASTM D3934 – flash/no flash equilibrium closed cup
- ASTM D3941 – flash point equilibrium closed cup
- ASTM D6450 – continuous closed cup
- ASTM D7236 – small scale closed cup with ramp

5 Original Equipment Manufacturer Review

5.1 General Tests

By interview of original equipment manufacturers (OEMs) and by review of offerors' existing reported studies, an assessment of testing requirements by original equipment manufacturers was performed. The invited companies were both US and international based companies and included six engine companies, seven airframe companies and two equipment manufactures. The companies were asked to comment on any additions in testing requirements from those expressed in the parent documents, whether there were any testing requirements specific to the individual companies (in-house), and if there were any modifications made to the specified testing. Airframers were also asked to comment specifically on any gauging testing. Of the companies polled, four engine, five airframe, and two equipment manufacturers responded at some level. Invited companies are listed in Appendix 11.4.

The results indicated that in general, all of the responding companies used primarily to exclusively the three parent documents (D1655, D4054, and D7566) as their list of required test information. Furthermore, the testing was typically requested to be performed to the requirements of D1655/D7566 with no company specific modifications. Representatives of the responding companies did indicate that

there were occasions where additional data points were required as compared to the Table 1 requirements, for example the addition of -40 °C viscosity testing. One engine company indicated they not only requested a more extensive viscosity versus temperature testing profile, the company actually calculated the viscosity coefficient for each fuel tested. Other specifically noted requests were surface tension at multiple temperatures, and actual break point determination. Engine manufacturers noted a more extensive thermal degradation testing program, usually involving in-house test rigs.

Based on a review of data reports, requests have been made for thermal cycle tests where the fuel was thermally stressed and then the physical properties measured. Other tests identified included, differential scanning calorimetry (DSC) studies of the triple point, DSC studies of the samples with FAME contamination, ion exchange studies with a variety of water, salts, acid, and base combinations, and water diffusion tests. In one instance, modifications to ASTM D665 corrosion testing using a greater variety of salts were requested. Hot surface ignition testing per FED-STD-791, method 6053 (sometimes listed as FTM 791-6053) with modifications to the method to bracket actual ignition temperatures was noted. In another case water solubility studies using modifications to the Karl Fischer test preparation and use of U.S. Navy tests were noted.

Depending on the target material being evaluated, specific tests such as SAP migration, full microbial testing, Scuffing BOCLE and specialized water diffusion testing were also requested.

5.2 Dielectric Tests/Speed of Sound

Because of existing concerns, the OEMs were asked to comment specifically on the dielectric testing. This testing was required to evaluate impacts to the fuel gauging systems on aircraft.

A review of the existing test method, ASTM D924 (dielectric), raised concerns for a technology gap related to the precision and bias statement, interpretation of the data, and a lack of testing parameters specific to hydrocarboneous fuels. Two additional references cited by the OEMs for testing were ARINC 611 (Guidance for the Design and Installation of Fuel Quantity Systems) and CRC 635 (Handbook of Aviation Fuel Properties). Two companies indicated they used compensators and densitometers for evaluating the potential effects on gauging as opposed to ASTM testing. Based on recent discussions in open fora and based on the responses to the surveys of the OEMs, there is a fundamental concern related to the measurement of dielectric constants.

The first and foremost concern is the noticeable variability in how the tests are performed, including the number of electrodes, the frequencies at which the tests are run, the test temperature, and whether the test is run through air or vacuum (see Section 4.2). The offerors use ASTM D924 as written, while the OEMs with specified parameters each have their own individual requirements. Other OEMs collect the data from the offerors, but find a lack of commonality between the data depending on how the fluid is tested. This lack of a unified test method and of specified testing parameters results in difficulties in interpreting the results and assessing potential effects.

When asked questions regarding the dielectric constant, the topic of the speed of sound through the fuel and bulk modulus was also raised. Because there is no established or standardized test for speed of sound, it is calculated from the isentropic bulk modulus; $\beta = p * c^2$. References to actually measuring speed of sound only noted "measured with the SwRI device". Other locations in the U.K. such as University of Sheffield were also noted for testing speed of sound. Research results in comparison to the OEM responses suggest that it is the dynamic bulk modulus being determined by measuring the speed of sound, not determining the speed of sound itself. Measuring isentropic bulk modulus is further discussed in Section 4.3.

5.2.1 Summary of OEM Comments (C. Lewis)

Common threads/answers:

- Gauge compensator read out (aka K Cell) is used to measure fuel properties.
- High reliance on gauge vendors.
- No knowledge of lab test methodology in many cases.
- Lack of concern regarding this issue for some OEMs vs "industry engaged" OEMs who realise that:
    - Dielectric constant and relationship to fuel density may change.
    - This change, if extreme, could impact gauge accuracy.
    - This could be caused by out-of-experience synthetic blends in the future.

Clearly there is a dis-joint in the standard where dielectric constant and its relationship to density is a fuel property requirement, but it is not controlled within the standard currently. This has been a satisfactory situation prior to the introduction of synthetic blends since conventional fuels have been within acceptable limits. The increasing use of synthetic blends creates the risk of these properties being outside experience and therefore must be addressed. There is also an element of the fact that these properties and the impact of fuel composition on them has been scrutinised to a higher degree than previously. This scrutiny has identified a potential shortfall in the standard and/or test methodology in a similar way that minimum aromatics and maximum viscosity are now being examined.

6 Testing Access

One of the concerns in the industry is access to testing given the list of tests to execute. To gain insight into test access, a study was performed to determine if there were any tests that could not be run in the open market. To reflect more accurately the state of the industry, a researcher was identified with reasonable search skills, a basic understanding of the industry, and experience in researching and locating purchase sources. This researcher was provided with the list of test standards and was instructed to find test facilities capable of providing the requested services. The list only included the ASTM standards located in the final list. The researcher was instructed to limit their searches at this time to U.S. testing locations, although Canadian sources were later included. The researcher was to use typical internet sources as well as being provided with a short list of known test houses in petroleum testing. Sources were reviewed using posted test lists, email requests, and by telephone.

Once a testing location was identified, duplicate sources were not required. In some cases, the only identified source was Southwest Research Institute (SwRI) which is recognized to have greater reach due to being more than just a test house. A lack of identification does not mean no source is available, only that with reasonable effort, a source on the open market was not immediately identifiable. No consideration was made during the review for acceptable alternative methods, specifically where test houses had chosen one test standard over another to run a specific test. Each test was researched as a separate requirement.

6.1 Sourced Testing

Individual test locations are indicated in the Excel spreadsheet with the individually referenced ASTM standard tests. Referenced ASTM testing was found to be available at the following locations (Table 10). Note that the EPA methods are standard methods available at any EPA test facility but they are not á la carte type tests.

Table 10 - Identified ASTM Testing Sources

Facility	Location
Analytical Testing Services	Franklin, PA
Beta Analytic	Miami, FL
Chilworth	Princeton, NJ
Dixie Services	Galena Park, TX
IMR Test Labs (Curtis Wright)	Ithaca, NY; Louisville, KY; Portland, OR
InnoTech Alberta	Edmonton, Alberta
Intertek	Multiple
Nobil	Elizabeth, NJ
Safety Consulting Engineers	Schaumburg, IL
Savant Labs	Midland, MI
Saybolt	Multiple
Smithers Rapra	Akron, OH; Lansing MI
Southwest Research Institute	San Antonio, TX
Texas Oil Tech Labs	Houston, TX

6.2 Unsourced Tests

Of the 127 reviewed ASTM standards and the 9 relational tests identified from MIL-HDBK-510, sources were identified for all but 8 ASTM tests. Tests with no immediately identifiable testing locations within the search limitations are shown in Table 11.

Table 11 - Tests with No Identified Testing Source

Test	Title
ASTM D6866	STM for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples using Radiocarbon Analysis
ASTM D7345	STM for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure (Microdistillation Method)
ASTM D7524	STM for Determination of Static Dissipater Additives (SDA) in Aviation Turbine Fuel and Middle Distillate Fuels
ASTM D7797	STM for Determination of the FAME Content of Aviation turbine Fuel using Flow Analysis
ASTM D7872	STM for Determining the Concentration of Pipeline Drag Reducer Additive in Aviation Turbine Fuels
ASTM D7945	STM for Determination of Dynamic Viscosity and Derived Kinematic Viscosity of Liquids by Constant Pressure Viscometer
ASTM E2071	Standard Practice for Calculating Heat of Vaporization or Sublimation from Vapor Pressure Data (references ASTM D2879)
ASTM D2879	STM for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope

7 ASTM and IP

To complete the program rapidly, and because of the focus being primarily on U.S. fuel requirements at this point, the scope of the program was limited to primarily U.S. sourced standards. It was recognized that there are measurable activities taking place to facilitate a more global development of liquid fuels for aviation. However, given the available resources for this study, it was not practical at this point in time to review DEF-STAN 091-091, the Energy Institute standards or other global test methods.

An effort was made to develop a full list of IP standards and to match them to equivalent or similar ASTM standards. The list of Energy Institute IP standards was generated from four different sources; 1) specifically referenced in the parent standards, 2) provided as an equivalent in an individual standard, 3) provided as an equivalent in ASTM Manual 44, or 4) provided in a reverse review by a U.K. reviewer.

During the initial review of the parent standards, 42 individual IP standards were referenced. Following the development of the list, the items were evaluated for correspondence between the IP and the ASTM standards. Thirty-three standards were referenced, 22 of which had an ASTM equivalent and 11 of which did not. During the review, the list of ASTM standards was compared to ASTM Manual 44 and any equivalence not indicated by the individual standard entered. This resulted in an additional 11 standards not referenced by the parent document and are indicated by green highlighting in the Appendix in Section 11.3.

7.1 Additional IP Document Review

During the analysis of the Defence Standard 91-091 the eleven IP documents not evaluated during the U.S. review were considered. Of the eleven documents, six were reviewed as part of the E.U. analysis.

Table 12 - IP Documents Referenced in ASTM D1655 and Def Stan 91-091

IP 170	Petroleum Products and other Liquids– Determination of Flash Point – Abel Closed Cup Method
IP 475	Petroleum Liquids – Manual Sampling (ISO 3170:2004)
IP 523	Determination of Flash Point – Rapid Equilibrium Closed Cup 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
IP 590	Determination of fatty acid methyl esters (FAME), derived from bio-diesel fuel, in aviation turbine fuel – HPLC evaporative light scattering detector method
IP 599	Determination of Fatty Acid Methyl Esters (FAME) in Aviation Turbine Fuel by Gas Chromatography using Heart-cut and Refocusing

The remaining five documents were not reference by Def Stan 91-091 but were reviewed as a stand-alone set of IP documents supporting the U.S. document review.

Table 13 - IP Documents Referenced in D1655 but Not Def Stan 91-091

IP 225	Determination of Copper in Light Petroleum Distillates—Spectrophotometric Method	Method						Yes	Green
IP 227	Corrosiveness to Silver of Aviation Turbine Fuels—Silver Strip Method	Method	cancelled or withdrawn					Yes	No Assessment Req'd
IP 379	Determination of Organically Bound Trace Nitrogen—Oxidative Combustion and Chemiluminescence Method	Method						Yes	Green
IP 438	Determination of Water—Coulometric Karl Fischer Titration Method	Method						Yes	Green
IP 524	Determination of Flash/No Flash—Rapid Equilibrium Closed Cup Method	Method						Yes	Green

The final assessment of the eleven documents was seven green, three yellow, no red and one withdrawn as obsolete. A discussion of the three yellow documents may be found in Section 0. The review sheets for the eleven IP specifications are located in Section 11.7.

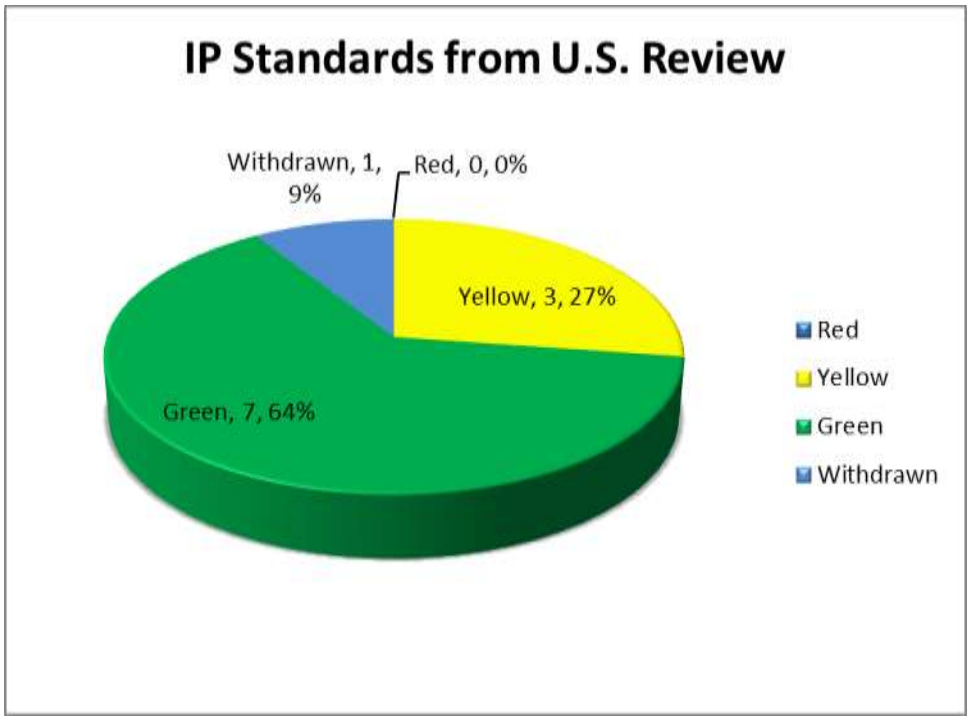


Figure 8 - Distribution of IP Documents from U.S. Review

8 Recommendations

8.1 Items that were Beyond Scope

8.1.1 Precision Statement Considerations

There was a request to consider the variability of an individual test method and comment on how precise was a method. This is separate from a consideration of the accuracy of the test method which is assumed to have been addressed by the process resulting in an approval of the method. Ideally, the desire was to assess the standards related to how variable the results from a test might be with respect to the absolute size of the value. Initially, the intent here was to attempt to make broad comments on the precision of each of the reviewed test methods. During the review process it became clear that this was an activity that would require more resources, especially in time and access to appropriate statistical experts, than was included in the original scope.

It was decided that while a statistical review of precision was beyond the scope of the program, it would be imprudent not to collect provided precision and bias information during the review. This was done to facilitate future assessments, eliminating the need to recollect and reread the individual standards for provided precision information. It also provided a single location to gather pertinent ASTM Research Report references.

It is recommended that a future study be considered to review the precision and bias statements, especially in concert with the absolute size of the results to assess how variable the values collected are actually.

8.1.2 Data Value Limits versus Control

It was beyond the scope of the program to evaluate whether the specified limits on various properties were necessary for describing an operational need or whether they were necessary for controlling a production or quality property of traditional petroleum based aviation fuel. Longer term, and most likely in stages, investigations into the actual purpose of each property's limit and whether the limit is an actual requirement of the hardware, may be warranted. It is recommended that the effort begin with Table 1 properties, then fit for purpose, and then special request. It was noted that many of the special request tests did not even have a limit but rather offerors were advised to target values no more/less than the jet fuel values.

8.2 Dielectric Constant

One of two notable technology and testing gaps identified during the project, was the lack of uniformity in method, conditions, and requirements of dielectric constant testing. While the research suggested it was a widely used property by the airframers and fuel gauging manufacturers, there was a noticeable lack of uniformity in how the data were measured, at what conditions the test was performed, or how the data were reported. This resulted in complexity and confusion both for the offerors and for the interpreters of the data.

It is recommended that a program to evaluate modifications to the existing ASTM standard ASTM D924, Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids, development of a new ASTM standard, or provision of standardized testing and conditions as generally accepted industry practices be considered by the CRC.

8.3 Bulk Modulus

The second notable technology and testing gap was the lack of test method for dynamic bulk modulus or speed of sound. It was determined that SwRI had been working to develop a formal test method which had shown promise, but no formal test method appeared to have been published. It was believed the effort to develop a Federal Test Method was in the hands of the U.S. Army, but there was no indication it had been pursued.

Given the ubiquity of the references to dynamic bulk modulus or using the speed of sound to measure dynamic bulk modulus, it is recommended that further inquiries and potentially championing of a test method be considered.

8.4 Addressing "Red" Standards

Following the review, six standards were identified with significant concerns for being sensitive to fuel chemistry. One of the standards, dielectric constant, has already been discussed. One standard was of concern because it was for performing estimates and the continued validity of the assumptions was unknown. One was related to the use of petroleum measurement tables. One was related to interpretation of mass spectrometry. One was the use of calculated cetane index.

8.4.1 Estimates

The three (one rated red and two yellow) standards regarding estimates each has assumptions regarding the relationships between the contributing properties. It is recommended those three standards' actual sensitivity to chemical composition be investigated. This will most likely require a new precision and bias study for each of ASTM D1405 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels, ASTM D3338, Test Method for Estimation of Net Heat of Combustion of Aviation Fuels, and ASTM D4529, Test Method for Estimation of Net Heat of Combustion of Aviation Fuels.

8.4.2 Hydrocarbon Typing by Mass Spec

ASTM D2425, Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry has as a caveat in the methodology that that the carbon distribution should be paraffins with carbon numbers distributed from C_{10} to C_{16}. Mass spectroscopy fragments the hydrocarbons and does not assess from what moieties the fragments originated. The work that contributed to the creation of the summation scheme could be impacted by the chemical composition. The method itself indicates that the reproducibility error increases as the paraffinic content increases, suggesting that highly paraffinic compositions may result in skewed results.

All of these concerns do not mean that the method is not applicable, only that further work to validate the method on non-traditional hydrocarbon distributions should be considered. Alternatively, new methods better suited for determine hydrocarbon speciation such as GCxGC could be considered.

8.4.2.1 Cetane Calculations

The industry recognizes the desire to understand the cetane value of the jet fuels better for use by sister industries, even if the value is not going to be overtly controlled. However, the military handbook has chosen ASTM D976, Calculated Cetane Index as their recommended test method. Work by the community has resulted in agreement that D976 is not a good choice for determining cetane on jet fuel, and the results are impacted by chemical composition. Other measurements for cetane, for example the ignition quality test and derived cetane by ASTM D6890, are more appropriate.

8.4.3 Petroleum Measurement Tables

During the review, it came to the author's attention that the use of ASTM D1250, Guide for Use of the Petroleum Measurement Tables raised notable concerns. ASTM D1250 is not called out by any of the parent documents. However, these tables are foundational to conversions between density units, conversions between data at different temperatures, and determinations of loads, weights, and volumes related to jet fuel. These tables are now incorporated into analytical equipment as part of the on-board software that converts the physical measurements into reportable measurements. During the review it appeared that two things had occurred which raised concerns with D1250. The first is that D1250 is now entirely a software exercise based on assumptions of traditional petroleum relationships. The second is that no consideration for volume change is made, so conversions from values at one temperature to another by analytical equipment such as densitometers may be affected by chemical composition changes.

The concerns with D1250 are foundational and far reaching and the development of a recommendation may be the first step for addressing a) IF there is a legitimate concern, and b) WHAT would be the best recommendation for addressing the concern.

8.5 Addressing "Yellow" Concerns

During the review, 27 standards were identified as having content that raised a concern related to changing the fuel chemistry. This review should not be considered the conclusion of the assessment but rather the starting point for discussions to determine if there were concerns requiring further inquiry. In the majority of the methods, the concern was related to precision and bias statements. This occurred when the precision and bias statement was based on a specified chemical composition, i.e. "petroleum" or the data analyzed was from a specific fluid, i.e. iso-octane. In other cases, the concerns were specific to a step in the method that may have other considerations when chemistries change, i.e. the fuel would be dried by filtering with paper filter paper, or color ratings would continue to be related to the same chemical process. In a very few cases the concern related to how the data were subsequently interpreted, i.e. an ASTM color rating.

It is not value added to reproduce each of the 27 concerns here as they are listed in Section 0. The recommendation is that each of these concerns is individually reviewed and an appropriate remediation be considered. In most cases, the remediation will be related to determining the continued validity of the precision and bias statement and potentially a new precision and bias study of available data. Other standards may benefit from a coordinated review with the standard technical content owner. In other cases, a review by a panel of experts in each of the methods to answer questions may determine a concern is unwarranted.

9 Defence Standard 91-091 Review

It should be noted that throughout the Defence Standard review, the Queen's English spelling will be maintained.

9.1 Why Review the Standards

Following the completion of the U.S. assessment of the standards referenced in ASTM D1655, ASTM D7566, and Mil Handbook 510 and reported in Sections 2 to 8 of this document, a subsequent request was made to review Defence Standard 91-091 Turbine Fuel, Aviation Kerosine Type, JET A-1. This work was to be done as a follow-on effort to address the original scope limitations.

The same reasoning and methodology discussed in Sections 1.1 and 1.2 were used and the same researchers executed the reviews. This was done to maintain commonality of the process. The commonality facilitated direct comparisons of the U.S. documents already reviewed and the E.U. documents under the subsequent review.

The referenced documents were collected from Def Stan 91-091 and entered into a new spreadsheet. The original document lists contained 101 documents. The first downselect was to categorize each document by type. The same identifiers of Method, Guide, Practice, and Specification were used. An additional category of "Report" replaced the category "Unidentified" (Figure 9). The documents were also identified by source type; ASTM, Energy Institute, SAE, Defence Standard, and other (Figure 10).

Following the preliminary review, one standard was found to have been cancelled, STANAG 3583 Ed 4 "Standards of Accuracy for Differential Pressure Gauges Used on Aviation Fuel Filters and Filter Water Separator Vessels". Additionally, the referenced standard BS EN 14214:2008 was found to have been replaced by EN 14214:2012 "Automotive Fuels. Fatty Acid Methyl Esters (FAME) for Diesel Engines. Requirements and Test Methods". Lastly, IP 355 "Estimation of Net Specific Energy of Aviation Turbine Fuels, using Hydrogen Content Data" was found to have been withdrawn. STANAG 3583 and IP 355 were removed from the review list. The updated revision of EN 14214 was reviewed. Also during this preliminary review, a comparison was made to identify the documents already assessed, and any documents that had been assessed either directly, or as the equivalent ASTM. Per the agreement for the E.U. review, those documents having an U.S. equivalent would be evaluated based on the U.S. document.

This equivalency was found to be ASTM equivalents for IP standards in all cases. The results of this preliminary assessment are shown in Figure 11.

A total of 31 documents were passed on for the first subject matter expert (SME) level review. This review was a more in-depth evaluation of the content (see Figure 1, Box 2a and 2b). This review further down-selected to 23 documents from Def Stan 91-091 plus an additional three documents identified within the reviewed documents during the first review. This in-depth review was that covered by boxes 2a, 2b, 4a, 4b, 4c and 4d of the flow chart. After this analysis, 25 standards were passed on for full SME evaluation and are the focus of the remainder of this section.

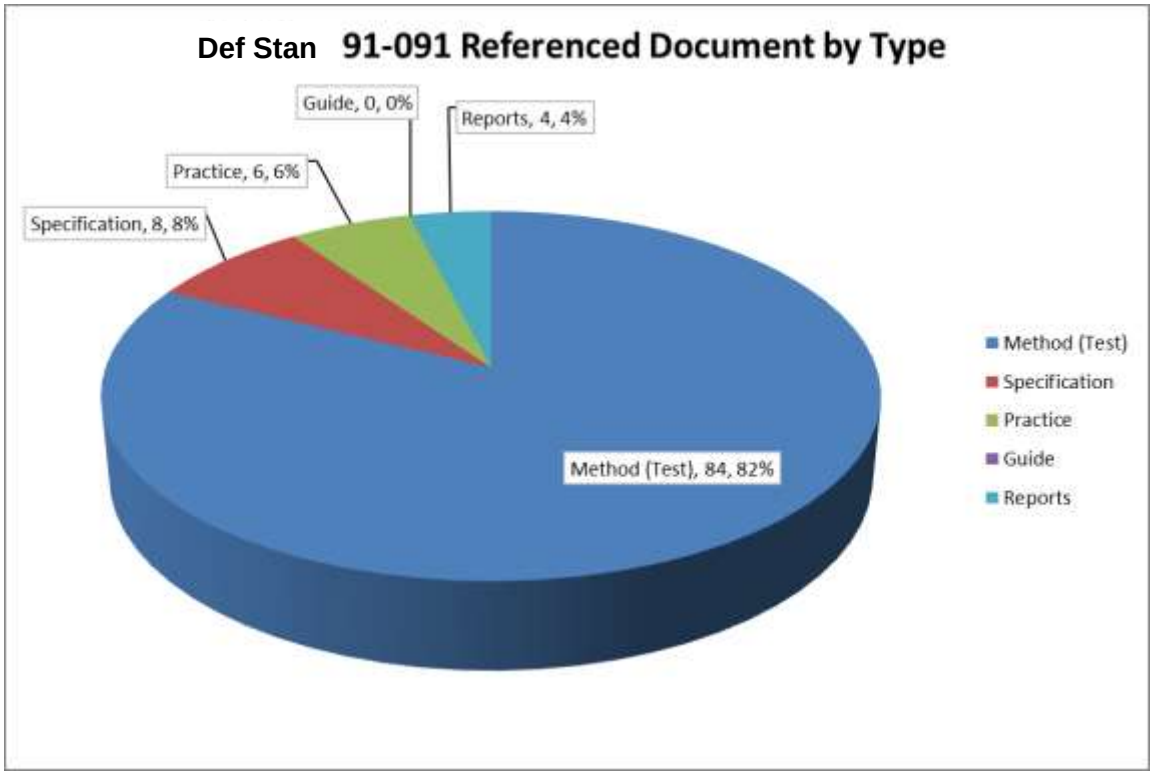


Figure 9 - Def Stan 91-091 Referenced Documents Broken Down by Type

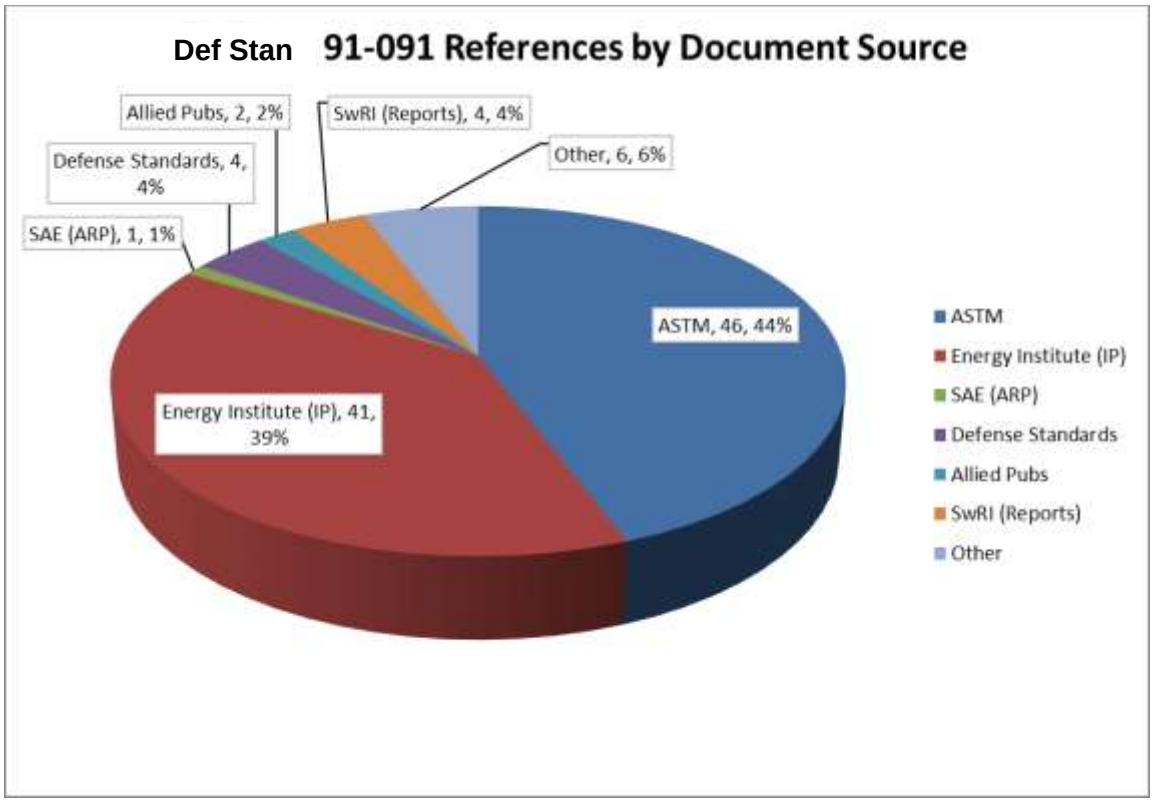


Figure 10 - Def Stan 91-091 Referenced Documents by Source

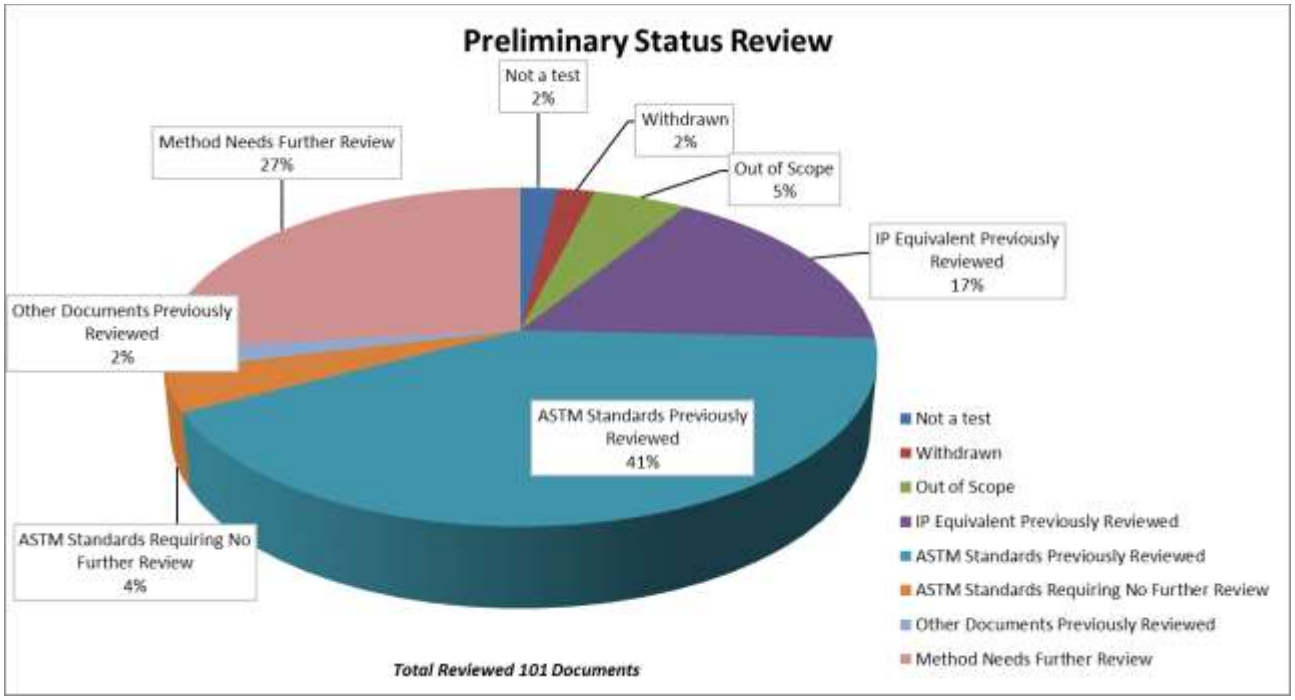


Figure 11 - First Document Review

9.2 Standard Review

All of the considerations developed during the U.S. review were used for the Def Stan 91-091 review. The review was made considering three potential end products; 1) a final, fully formulated jet fuel that would still be a kerosene boiling range fuel; 2) a blendstock for use in a fully formulated jet fuel or a final fuel that met fit-for-purpose but could be measurably different than a normal kerosene boiling range fuel in some way; 3) testing as a result of additive approval. The criteria considered included; a) is the test based on a defined chemical composition or type? b) are there any overt or implied limitations on the applicability of the test? c) are there any assumptions, conversions, calculations, or other modification to the results to make them correlate to other test results? d) are the results reported directly, related to a calibration curve or mathematically converted to a reportable result?

9.2.1 Standard Terminology

With respect to the terminology used, a similar exercise to that reported in Section 2.1 was performed. The results were less historical than the results obtained during the U.S. review. The Energy Institute did not appear to have a terminology document similar to ASTM D4175 nor could anyone contacted provide a source of definitions. Because of the numbering system used, it was not possible to determine an IP standard's original publication date (see discussion below) and attempts to procure past revisions of the standards were unsuccessful. Due to the scope limitations on procuring IP standards, only limited attempts were made to locate past versions of the documents.

Given the European Union's requirements for definitions on products, a limited investigation into contemporary definitions was undertaken. After several failed attempts within the industry standards, definitions for petroleum, hydrocarbon and jet fuel were located under the jurisdiction of the European Chemicals Agency (ECHA). Petroleum was defined as

> A complex combination of hydrocarbons. It consists predominantly of aliphatic, alicyclic and aromatic hydrocarbons. It may also contain small amounts of nitrogen, oxygen and sulfur compounds. This category encompasses light, medium, and major chemical changes for their recovery or conversion to petroleum refinery feedstocks such as crude shale oils, upgraded shale oils and liquid coal fuels are not included in this definition. (ECHA, 2018)

Based on the entries, the term "petroleum" is used interchangeably with "crude oil" and "petroleum oil".

One definition of crude oil (petroleum) was defined as including recycled naphtha and being distilled, cracked, hydrotreated and hydrodesulfurized. The definition provided for distillates (petroleum), was hydrotreated lightly and defined as

> A complex combination of hydrocarbons obtained by treating a petroleum fraction with hydrogen in the presence of a catalyst. It consists of hydrocarbons having carbon numbers predominantly in the range of C9 through C16 and boiling in the range of approximately 150°C to 290°C (302°F to 554°F (ECHA, 2018).

An attempt to determine the generic definition of "hydrocarbon" was less successful. Based on the ECHA database, each individual hydrocarbon,(C_4, C_5, C_6, etc.) and the means of producing it, i.e. chemical conversion of polyethylene, had a separate entry. It was assumed this was because ECHA's primary role is supporting environmental regulations.

Three different definitions for jet fuel were located. 1) Kerosine (petroleum), "A complex combination of hydrocarbons produced by the distillation of crude oil. It consists of hydrocarbons having carbon numbers predominantly in the range of C9 through C16 and boiling in the range of approximately 150°C to 290°C (320°F to 554°F)." 2) Kerosine (petroleum), hydrodesulfurized, "A complex combination of hydrocarbons obtained from a petroleum stock by treating with hydrogen to convert organic sulfur to hydrogen sulfide which is removed. It consists of hydrocarbons having carbon numbers predominantly in the range of C9 through C16 and boiling in the range of approximately 150°C to 290°C (302°F to 554°F)." 3) Kerosine (petroleum), sweetened "A complex combination of hydrocarbons obtained by subjecting a petroleum distillate to a sweetening process to convert mercaptans or to remove acidic impurities. It consists predominantly of hydrocarbons having carbon numbers predominantly in the range of C9 through C16 and boiling in the range of 130°C to 290°C (266°F to 554°F)." All three definitions come from ECHA (2018) and all three had as their IUPAC name "kerosine".

Again, it is assumed these definitions are related to the ECHA's regulatory support role. However, without any other guidance, these are the only specific definitions for the terms within the E.U. that could be located. These definitions are not materially different from the U.S. understanding so the same terminology considerations used during the U.S. document review are accepted as valid.

9.2.2 *European Document Format*

The majority of the reviewed standards subjected to the full SME analysis were Energy Institute IP standards and ISO standards. Whereas the ASTM document format maintains the original publication date of the standard, the IP and ISO format do not. A third primary specification organization, the British Standards Institute (BSi) was encountered. The BSi format also did not maintain an original publication date.

Currently the Energy Institute has responsibility for the IP standards. An IP standard is formatted similarly to an ASTM document. The numbering format has the document number, i.e. IP **336**, followed by the last revision date, i.e. IP 336/**04**, and if present a review without revision date, i.e. IP 336/04 **(2014).** The document shows any equivalent specifications across the top. This includes ASTM, BSi and ISO. In some cases, the IP document is actually converted to the equivalent ISO standard and ISO then has responsibility for the document's maintenance. The document will have the ISO standard number and the style and format of an ISO document. Because the Energy Institute no longer has the primary responsibility for the document, it no longer has the ability to make changes to the document. The Energy Institute provides a technical note page in front of the ISO document that captures any changes that are recommended for incorporation at the time of the next ISO review. For example, changes made to

maintain equivalency to an ASTM document are recorded on the technical note page. ISO then considers the inclusion of the recommended changes during the document's routine five-year review and update.

The British Standards Institute (BSi) is an organization originally established in 1901 as the Engineering Standards Committee. The BSi has a memorandum of Understanding with the UK government which establishes the position of BSi as the recognized UK National Standards body and making BSi responsible for the English language version of ISO documents. In some cases, the BSi reference indicates the national body to which the method reports, for example BSi **2000**. The standard number is typically the same as either the IP document, i.e. BSi 2000: Part **336**, or the ISO number.

Another observation made was that the IP standard may have a version specific equivalence to an ASTM standard. For example, IP 160/99 has an equivalency listed to ASTM D1298-99 (2005). A check of the ASTM database finds that ASTM D1298-99 (2005) does have the IP equivalency listed. However, the latest or current version of ASTM D1298 is D1298-12b, and it does not have an IP equivalency. This means any changes made to D1298 since 2005, and there were two revisions, have not been included in the current version of IP 160. Thus, organizations working to compliance to both the U.S. fuel specifications and the Defence Standard fuel specification need to consider the differences between the IP and ASTM methods, especially when specific versions are not synchronized.

9.3 Study Results

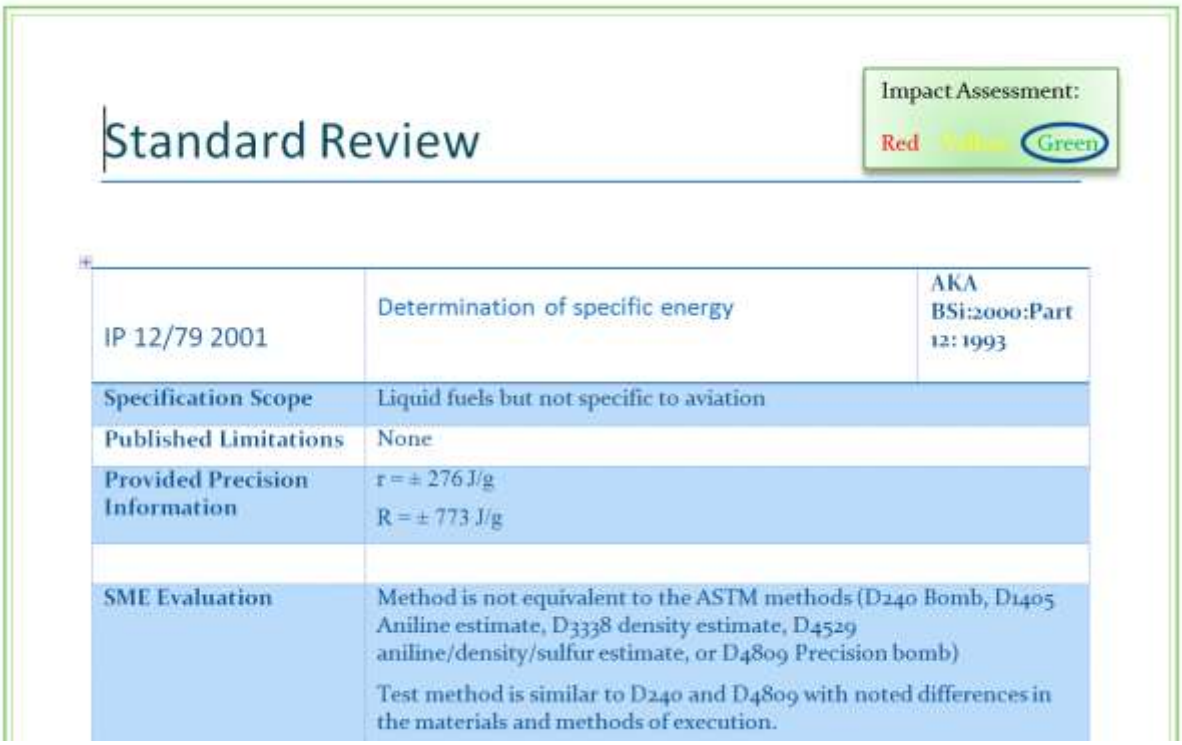
9.3.1 Data Collection

To evaluate each of the 25 documents and to facilitate commonality with the U.S. review, the same review sheet described in Section 3.1 and

Figure 6 - Data Collection Form was used. There were three major changes. Due to the inability to determine the original publication date, this box was eliminated (see 3 in

Figure 6). This area was changed to capture any equivalent specifications listed on the document being reviewed. In addition, IP documents do not reference Research Reports in most cases and this box was eliminated (see 6 in

Figure 6). This box was used instead to record any equivalent standards listed in the IP document. All other entries were used in the same way as described in Section 3.1. An example of the Def Stan 90-091 review sheet is shown in Figure 12.



Standard Review

Impact Assessment:
Red Green

IP 12/79 2001	Determination of specific energy	AKA BSi:2000:Part 12: 1993
Specification Scope	Liquid fuels but not specific to aviation	
Published Limitations	None	
Provided Precision Information	r = ± 276 J/g R = ± 773 J/g	
SME Evaluation	Method is not equivalent to the ASTM methods (D240 Bomb, D1405 Aniline estimate, D3338 density estimate, D4529 aniline/density/sulfur estimate, or D4809 Precision bomb) Test method is similar to D240 and D4809 with noted differences in the materials and methods of execution.	

Figure 12 - Example IP Document Review Sheet

The original scope of work for the additional E.U. review was to review the ASTM document in cases of equivalency. Where direct equivalency was identified, the document was categorized by the U.S. assessment and was noted as "previous", i.e. "green previous". During the in-depth review of the 24 European standards, 12 were found to be essentially equivalent in content to an ASTM standard even though they were not linked and a comparative analysis of the two documents was performed. The final assessment of all 104 documents is shown in Figure 13.

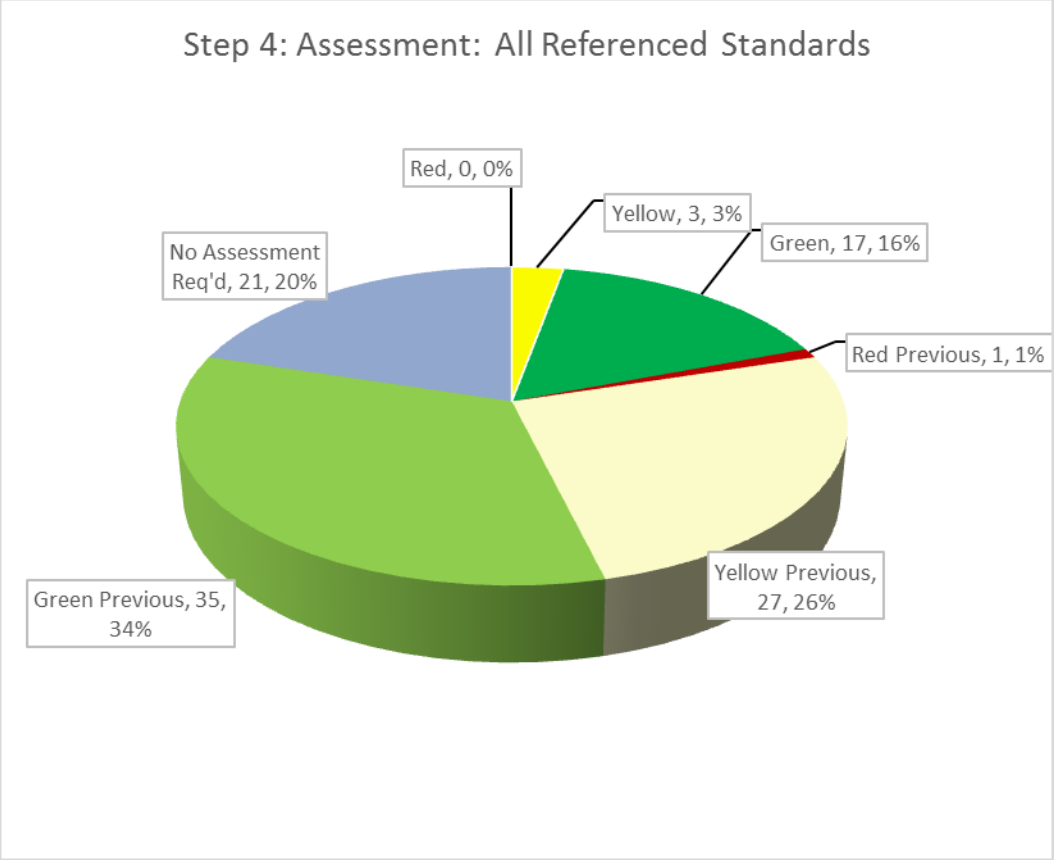


Figure 13 - Final Assessment of All Referenced Documents

9.4 Assessment Results

Assessment results should not be considered the final analysis of the standards, but rather the beginning of conversations. Items assessed as yellow or red do not mean there is an issue with the test, only that there is some aspect of the test which raises a concern and may warrant further investigation. An assessment of a method being sensitive to chemical composition considers the potential for significant compositional deviations in additives and blendstocks; and the use of a different composition as a blendstock does not necessarily mean there is an issue with the method when testing the final fuel composition.

9.4.1 Green - No Affect

A green assessment does not mean there are no requirements for validation, for example validation of precision and bias statements. Nor does it imply there are not considerations for the subsequent use of the data. It means there is nothing about the method development, test execution or the handling of the data that suggests a concern.

9.4.1.1 Documents Assessed Previously as "Green"

Following the review 36, or 35%, of the referenced documents were assessed as being "green – previous" or determined not be affected by the chemical composition based on a previous review of the equivalent ASTM method. All information on "green – previous" documents is included on the individual review

sheets located in Section 11.6.1 and no further discussion is necessary. The standards referenced in Def Stan 91-091 and assessed as "green – previous" are listed in Table 14

Table 14 - Documents Identified as Previously Reviewed as "Green"

IP 16	Petroleum Products – Determination of the Freezing Point of Aviation Fuels
IP 30	Detection of Mercaptans, Hydrogen Sulfide, Elemental Sulfur and Peroxides – Doctor Test Method
IP 107	Determination of Sulfur – Lamp Combustion Method
IP 336	Petroleum Products – Determination of Sulfur Content – Energy-Dispersive - X-Ray Fluorescence Method
IP 342	Petroleum Products – Determination of Thiol (Mercaptan) Sulfur in Light and Middle Distillate Fuels – Potentiometric Method
IP 354	Determination of the Acid Number of Aviation Turbine Fuels – Colour-Indicator Titration Method
IP 406	Petroleum Products – Determination of Boiling Range Distribution by Gas Chromatography
IP 423	Determination of Particulate Contaminant in Aviation Turbine Fuels by Laboratory Filtration
IP 598	Determination of the smoke point of kerosene, manual and automated procedures.
EI/JIG 1530	Quality assurance requirements for the manufacture, storage and distribution of aviation fuels to airports.
ASTM D56	Standard Test Method for Flash Point by Tag Closed Cup Tester
ASTM D86	Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
ASTM D156	Standard Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)
ASTM D381	Standard Test Method for Gum Content in Fuels by Jet Evaporation
ASTM D1266	Standard Test Method for Sulfur in Petroleum Products (Lamp Method)
ASTM D1322	Standard Test Method for Smoke Point of Kerosene and Aviation Turbine Fuel
ASTM D1840	Standard Test Method for Naphthalene Hydrocarbons in Aviation Turbine Fuels by Ultraviolet Spectrophotometry
ASTM D2386	Standard Test Method for Freezing Point of Aviation Fuels
ASTM D2622	Standard Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-Ray Fluorescence Spectrophotometry
ASTM D2887	Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
ASTM D3227	Standard Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosene, Aviation Turbine, and Distillate Fuels (Potentiometric Method)
ASTM D3242	Standard Test Method for Acidity in Aviation Turbine Fuel
ASTM D3828	Standard Test Methods for Flash Point by Small Scale Closed Cup Tester

ASTM D4052	Standard Test Method for Density, Relative Density and API Gravity of Liquids by Digital Density Meter
ASTM D4057	Standard Practice for Manual Sampling of Petroleum and Petroleum Products
ASTM D4176	Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
ASTM D4294	Standard Test Method for Sulfur in P e t r o l e u m a n d Petroleum Products by Energy- Dispersive X- Ray Fluorescence Spectrometry
ASTM D4809	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)
ASTM D4952	Standard Test Method for Qualitative Analysis for Active Sulfur Species in Fuels and Solvents (Doctor Test)
ASTM D5006	Standard Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels
ASTM D5452	Standard Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration
ASTM D5453	Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel and Engine Oil by Ultraviolet Fluorescence
ASTM D6045	Standard Test Method for Color of Petroleum Products by the Automatic Tristimulus Method
ASTM D7042	Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
ASTM D7345	Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure (Micro Distillation Method)

9.4.1.2 Documents Assessed as "Green"

Following the in-depth review of the documents without U.S. equivalents, an additional 16, or 15%, of the referenced documents were assessed as "green". These documents are listed in Table 15. All information on "green" standards is included on the individual review sheets located in Section 11.7.1 and no further discussion is necessary.

Table 15 - Documents Assessed as "Green"

IP 12	Determination of Specific Energy
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	Petroleum Products and other Liquids– Determination of Flash Point – Abel Closed Cup Method
IP 243	Petroleum Products and Hydrocarbons – Determination of Sulfur Content – Wickbold Combustion Method
IP 365	Crude Petroleum and Petroleum Products – Determination of Density – Oscillating U-tube Method
IP 367	Petroleum Products – Determination and Application of Precision Data in Relation to Methods of Test
IP 373	Determination of Sulfur Content of Light and Middle Distillates by Oxidative Microcoulometry
IP 424	Determination of Fuel System Icing Inhibitor Content of Aviation Turbine Kerosenes by High Performance Liquid Chromatography
IP 447	Petroleum Products – Determination of Sulfur Content – Wavelength-Dispersive X-Ray Fluorescence Spectrometry
IP 475	Petroleum Liquids – Manual Sampling (ISO 3170:2004)
IP 523	Determination of Flash Point – Rapid Equilibrium Closed Cup Method
IP 540	Determination of the Existent Gum Content of Aviation Turbine Fuel – Jet Evaporation Method
IP 564	Determination Of The Level Of Cleanliness Of Aviation Turbine Fuel – Laboratory Automatic Particle Counter Method
IP 565	Determination of the level of cleanliness of aviation turbine fuels - Portable automatic particle counter method
IP 577	Determination of the level of cleanliness of aviation turbine fuel – Automatic particle counter method using light extinction
SAE ARP 1797	Aircraft and Aircraft Engine Fuel Pump Low Lubricity Fluid Endurance Test

9.4.1.3 Scheduled for Withdrawal

It was noted during the review process that IP 243, Determination of sulfur content by Wickbold Combustion has been slated for withdrawal by the Energy Institute in 2019.

9.4.2 Yellow - Possible Impact

A yellow assessment resulted when a standard had some content that raised a concern about the potential impact of the fuel composition on either the method or the results of the test. Standards which

covered methods that were not themselves likely to be sensitive to the chemical composition but which had post-data usage which could be sensitive were also designated as "yellow".

9.4.2.1 Documents Assessed Previously as "Yellow"

Following the initial review, 27, or 26%, of the standards were assessed as "yellow – previous" or a concern was identified in a standard that had been assessed during the U.S. review. These documents are listed in Table 16. All information on "yellow – previous" standards is included on the individual ASTM review sheets in Section 11.6.2 and discussed in Section 0.

Table 16 - Documents Identified as Previously Reviewed as "Yellow"

IP 71	Petroleum Products – Transparent and Opaque Liquids – Determination of Kinematic Viscosity and Calculation of Dynamic Viscosity
IP 154	Petroleum Products – Corrosiveness to Copper – Copper Strip Test
IP 156	Determination of Hydrocarbon Types in Petroleum Products – Fluorescent Indicator Adsorption Method
IP 274	Petroleum Products – Aviation and Distillate Fuels - Determination of Electrical Conductivity
IP 323	Petroleum Products - Determination of Thermal Oxidation Stability of Gas Turbine Fuels
IP 435	Determination of the Freezing Point of Aviation Turbine Fuels by the Automated Phase Transition Method
IP 436	Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates – High Performance Liquid Chromatography Method with Refractive Index Detection
IP 528	Determination of the Freezing Point of Aviation Turbine Fuels – Automated Fiber Optic Method
IP 529	Determination of the Freezing Point of Aviation Fuels – Automatic Laser Method
IP 568	Determination of the static dissipater additives (SDA) in aviation turbine fuel and middle distillate fuels - HPLC Method
IP 583	Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy - Rapid Screening Method
ASTM D130	Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
ASTM D445	Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)
ASTM D1298	Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

ASTM D1319	Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
ASTM D2624	Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels
ASTM D3241	Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels
ASTM D3338	Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
ASTM D3948	Standard Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer
ASTM D5001	Standard Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
ASTM D5972	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)
ASTM D6379	Standard Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates High Performance Liquid Chromatography Method with Refractive Index Detection
ASTM D7153	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Laser Method)
ASTM D7154	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)
ASTM D7524	Standard Test Method for Determination of Static Dissipater Additives (SDA) in Aviation Turbine Fuel and Middle Distillate Fuels—High Performance Liquid Chromatograph (HPLC) Method
ASTM D7797	Standard Test Method for Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy - Rapid Screening Method

9.4.2.2 Documents Assessed as "Yellow"

Following the in-depth review of the standards without U.S. equivalents, an additional 3, or 3%, of the referenced documents were assessed as "yellow". These documents are listed in Table 177. The individual review sheets are located in Section 11.7.2. A discussion of each of the three documents follows in Section 9.5.1.

Table 17 - Documents Assessed as "Yellow"

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
IP 590	Determination of fatty acid methyl esters (FAME), derived from bio-diesel fuel, in aviation turbine fuel – HPLC evaporative light scattering detector method
IP 599	Determination of Fatty Acid Methyl Esters (FAME) in Aviation Turbine Fuel by Gas Chromatography using Heart-cut and Refocusing

9.4.3 Red - Likely Impact

An assessment of "red" resulted when a standard was found to have a notable concern for a limitation due to the chemical composition of the material. These standards had a direct limitation or prohibition on the chemistry, or used a post collection data modification, either formulaic or correlational, which suggested a limitation on the method's use. While a concern with the precision and bias statement may have existed, a concern only with the precision statement was not sufficient for an assessment of "red".

9.4.3.1 Documents Assessed Previously as "Red"

Following the initial review, one standard was found to be assessed as "red – previous", IP 381 Aviation Fuels – Estimation of Net Specific Energy. IP 381 was equivalent to ASTM D4529-02. The document was not directly called out by Def Stan 91-091, but was added based on the Def Stan document review. ASTM D4529-02 is discussed in Sections 0 and 4.1.3.4.

9.4.3.2 Documents Assessed as "Red"

Following the in-depth review of the referenced documents, no additional IP documents were assessed as "Red".

9.5 Def Stan 91-091 Standards Discussion

The discussions below summarize the reviews of the referenced standards that did not have equivalence to any documents assessed during the U.S. document review. For full information including scope of purpose, limitations, and precision and bias statements, see the individual review sheets in Section 11.7.

When the scope limited the method to petroleum, petroleum products or distillates, it was assumed the method was developed using traditional crude oil petroleum. This means the more the chemical composition diverged from a traditional hydrocarbonaceous formula, including being more petrochemical-like, the greater the potential for the data to diverge from the data originally used to create the method, the precision statements, or the handling of the results. The reviews consider test materials that may be a finished fuel, a blend stock, or an additive.

Because of the numbering system of the documents used, there was no reliable means of determining the definition of turbine fuel or jet fuel in place at the time the methods were developed.

9.5.1 Yellow Standards

All three of the IP standards assessed as "yellow" or having a potential to be affected by composition, involved the measurement of FAME content. On one hand, these methods were developed relatively recently meaning a greater likelihood the developers had a broad range of fuel compositions available. On the other hand, the methods are attempting to isolate and identify very low levels of FAME, meaning the sensitivity of the method is very high. Based on analytical principles, the high sensitivity would correspondingly increase the risk that small changes in chemical composition would potentially impact the method.

9.5.1.1 IP 585/10 – Determination of fatty acid methyl esters (FAME) derived from biodiesel, in Aviation turbine fuel – GC-MS with selective ion monitoring/scan detection method

Use: Aviation Turbine Fuel (AVTUR)

Concern:
- Method specifically notes the potential for some FAME to be difficult to separate from jet fuel components. It is possible that if the chemical moieties present are enough like target FAME isomers in other molecular weight ranges, similar interference could be experienced.
- Depending on how the composition is different and how much of the volume is comprised of the changed composition, the precision and bias statements may require validation.

9.5.1.2 IP 590/10 Determination of fatty acid methyl ester (FAME) in aviation turbine fuel – HPLC evaporative light scattering detector method

Use: Aviation turbine fuel (AVTUR)

Concern:
- As the chemical composition of the test fluid diverges from traditional petroleum, the ability of the silica column to sufficiently separate the fuel matrix from the FAME matrix may need to be validated because the precision and bias statement was developed using traditional petroleum derived fuel and existing synthetic fuel blends, continued accuracy and precision of the method should be confirmed.
- It was noted that some jet fuels cause high noise in the detector for which diversion of the hydrocarbon fraction ahead of the FAME is permitted. This is another area where sufficient separation of the fuel.

9.5.1.3 IP 599/14 Determination of fatty acid methyl ester (FAME) in aviation turbine fuel – Gas chromatography using heart-cut and refocusing

Use: Aviation turbine fuel (AVTUR)

Concern:
- The risk of impact by chemical composition is relatively low. It should be sufficient to validate a divergent chemical composition does not have interferences as described by the method.
- This method could be assessed as green except for concerns related to the low concentration of FAME versus sensitivity.

9.6 Special Discussion Related to U.K. Methods

9.6.1 Similar but not directly equivalent standards

During the review, several of the Energy Institute documents were reviewed that were observed to be nearly equivalent to an ASTM standard but without a direct equivalency linkage, or having a statement of equivalency that was not reflected in the current revision of the ASTM standard. In those cases where there was similarity without equivalency, attempts were made to provide comparative information. All of standards were assessed as "green" so there is no indicated concern related to the use of the methods. This information is provided as a service to the reader and to reiterate the importance of noting the revision number of a document in use or in reference.

9.6.1.1 IP 123/11 (2014) Distillation characteristics at atmospheric pressure

Equivalency to ASTM: None

Similar ASTM standard: D86

ASTM D86 references IP 123 in the reference list. IP method is for both the manual and the automated distillation method while D86 if for the manual method only.

Comparative Comments: The manual methodology is essentially equivalent. Fluid group categories are the same. There is a difference in the barometric pressure corrections. The IP method includes a correction for latitude. Both the repeatability and reproducibility values are different. Both methods used the same research report.

9.6.1.2 IP 156/08 Determination of hydrocarbon types – Fluorescent indicator adsorption method

Equivalency to ASTM: None

Similar ASTM standard: D1319

ASTM D1319 is listed as equivalent to IP 1319 in ASTM Manual 44

Comparative Comments: Both methods use the same scope, the same dye and the same equipment. Both methods have the same repeatability and reproducibility values.

9.6.1.3 IP 160/99 Laboratory determination of density - Hydrometer

Equivalency to ASTM: Listed as equivalent to ASTM D1298-99 (2005)

Current ASTM Revision: ASTM D1298-12a; revision does not contain a link to the IP method

Comparative Comments: Current ASTM revision is two iterations from the IP linked method revision. The changes from the -99 (2005) method included the addition of a thermal glass correction and updates/corrections to the procedure, the precision statement and the reporting requirements. There was also the addition of a discussion on terminology of hydrometer reading which did not exist in -99 (2005) and the addition of a discussion on testing opaque fluids.

The IP method contains only the hydrometer method while the ASTM method considers the use of the Manual of Petroleum Measurement Standards (MPMS), Chapter 9.1.

None of the updates fundamentally change the actual method of using the hydrometer and do not fundamentally change the SME review. Both standards acknowledge the requirement to apply a hydrometer correction factor and require the operator to use correctly a computer program. For the IP method this is ISO 91-1:1992.

In either case, concerns with the method are not related to the chemical composition of the test fluid.

9.6.1.4 IP 336/04 (2014) Determination of sulfur content – Energy-dispersive X-ray fluorescence spectrometry

Equivalency to ASTM: None

Similar ASTM Standard: ASTM D4294

Comparative Comments: IP range is not as low as ASTM but the upper range is slightly higher.

IP method is not specific to aviation turbine fuel while the ASTM method does specifically reference aviation turbine fuel.

Similar interferents – water, elements, halides. ASTM method also recognizes FAME as an interferent.

IP has more calibrant preparation information.

IP has fewer instrument related instructions, relying instead on the instrument manufacturer instructions.

Slightly different precision statements; the IP method includes a high and low sulfur content precision value.

9.6.1.5 IP 365/97 Determination of density – Oscillating U-tube method

Equivalency to ASTM: None

Similar ASTM standard: D4052

ASTM D4052 is listed as equivalent to IP 365 in ASTM Manual 44.

Comparative Comments: Methods use similar equipment and procedures.

The precision statements are not equivalent.

IP method does not appear to have any corrections, only a direct conversion of frequency to density through the use of the calibration fluids. The instrument in the IP method is calibrated with a test fluid, in the same density range as the test fluid. The ASTM method has a calibration but not specific to the test fluid.

9.6.1.6 IP 373/11 Determination of sulfur content oxidative microcoulometry

Equivalency to ASTM: None

Similar ASTM standard: D3120

Comparative Comments: The operational sulfur range of the IP method is smaller than the ASTM.

Lists similar interferents but effect amounts are different.

Uses the same drawing of the apparatus.

There are no calibration standards provided by the method.

The calculations are mathematically equivalent.

The precision statements have a different presentation and different values. The ASTM method includes values specific to the test fluids in addition to the simple repeatability and reproducibility values.

Because matching of standards to sample are not considered by the IP method, there may be a potential for greater variability in the results. This would not be a compositional effect.

9.6.1.7 IP 447/08 Determination of sulfur content – XRF

Equivalency to ASTM: None

Similar ASTM standard: D4294

Comparative Comments: IP method has a slightly smaller effective range of sulfur.

IP method uses an internal reference of zirconium.

There is no matrix guidance in the IP method and uses different calibrants.

IP method has different precision data.

Methods are fundamentally the same.

9.6.1.8 IP 475/05 Method for manual sampling

Equivalency to ASTM: None

Similar ASTM standard: D4057

Comparative Comments: Similarities and differences determined to be beyond the scope of this effort and were not specifically valuable to this discussion.

9.6.1.9 IP 523/15 Determination of flash point – Rapid equilibrium closed-cup method

Equivalency to ASTM: None

Similar ASTM standard: D3828

Comparative Comments: Same functional range.

IP method is less specific on procedures, referring instead to equipment manufacturer instructions.

ASTM method B references IP ***583B***, method B.

Same precision statements.

9.6.1.10 IP 524/05 Determination of flash/no flash – Rapid equilibrium closed cup method

Equivalency to ASTM: None

Similar ASTM standard: D3828; ASTM references IP524 for Method A, flash/no flash.

Comparative Comments: Same apparatus as presented in IP 523.

Uses a 5 ml syringe whereas IP 523 uses a 2 ml syringe or a 2 ml syringe injected twice.

Same sampling method as IP 523.

IP 524 has only the flash/no flash method whereas IP 523 has both the flash/no flash method and the flash point determination method.

IP methods have different precision statements.

It is not clear what the difference in the two IP methods is addressing nor how the end user selects the method.

9.6.1.11 IP 540/08 Existent gum by jet evaporation

Equivalency to ASTM: None

Similar ASTM standard: D381

ASTM D381 references IP 540. ASTM manual 44 gives equivalence to IP ***131***.

Comparative Comments: IP 540 is only for aviation fuel whereas ASTM D381 is for all fuels.

Both methods use the same equipment and calibration procedures.

Precision statements are different.

9.6.1.12 IP 564/13 Laboratory Particle Counter

Equivalency to ASTM: None

Similar ASTM standard: D7619; not used in D1655.

Comparative Comments: ASTM method uses a smaller sample chamber (125ml) and a smaller sample (100ml) as compared to the IP method which uses a 500ml chamber and a 450 ml sample.

9.7 Sourced Testing of IP Methods

In the same manner used for the U.S. assessment, locations for the IP test methods that had not been assessed previously were identified. All but one of the referenced IP tests was found to be available at least at the following locations (Table 18). Individual test locations are indicated in the spreadsheet below for the individually referenced IP standard tests (Table 19).

Table 18 - Testing Facilities for IP Testing

Facility	Location
INEOS Laboratory	Multiple U.S. and E.U.
Intertek	Multiple U.S. and E.U.
SGS	Multiple U.S. and E.U.

Table 19 - Identification of Testing Location By Test Method

Standard Test Methods		Company Name
IP 12	Determination of Specific Energy	Intertek
IP 123	Petroleum Products-Determination of distillation characteristics at atmospheric pressure	INEOS Holdings Limited
IP 160	Crude petroleum and liquid petroleum products-laboratory determination of density-Hydrometer Method	INEOS Holdings Limited
IP 170	Petroleum products and other liquids-determination of flash point-Abel closed cup method	INEOS Holdings Limited
IP 225	Determination of copper in light petroleum distillates-spectrophotometric method	Intertek
IP 227	Silver Corrosion Test	Intertek
IP 243	Petroleum products and hydrocarbons- determination of sulfur content-wickbold combustion method	Intertek
IP 365	Crude petroleum and petroleum products-determination of density-oscillating U-tube method	INEOS Holdings Limited OR Intertek
IP 373	Determination of sulfur content of light and middle distillates by oxidative microcouluometry	**ASTM D3246 offered by Intertek
IP 379	Determination of organically bound trace nitrogen-oxidative combustion and chemiluminescence method	INEOS Holdings Limited OR Intertek
IP 424	Determination of fuel system icing inhibitor content of aviation turbine kerosenes by high performance liquid chromatography	
IP 438	Petroleum products-determination of water-coulometric Karl Fischer titration method	INEOS Holdings Limited
IP 447	Petroleum products-determination of sulfur content-wavelength-dispersive X-ray Fluorescence Spectrometry	SGS
IP 524	Determination of flash/no flash-rapid equilibrium closed cup method ISO 3680:2004	Intertek
IP 540	Determination of the existent gum of content of aviation turbine fuel-jet evaporation method	INEOS Holdings Limited OR Intertek

Standard Test Methods		Company Name
IP 564	Determination of the level of Cleanliness of aviation turbine fuel-laboratory automatic particle counter method	SGS
IP 565	Determination of the level of cleanliness of aviation turbine fuels-portable automatic particle counter method	INEOS Holdings Limited OR Intertek
IP 577	Determination of the level of cleanliness of aviation turbine fuel-automatic particle counter method using light extinction	Possibly SGS
IP 585	Determination of faty acid methyl esters (FAME), derived from bio-diesel fuel, in aviation turbine fuel-GC-MS with selective ion monitoring/scan detection method	INEOS Holdings Limited OR Intertek
IP 590	Determination of fatty acid methyl esters (FAME), derived from bio-diesel fuel, in aviation turbine fuel – HPLC evaporative light scattering detector method	SGS
IP 599	Determination of Fatty Acid Methyl Esters (FAME) in Aviation Turbine Fuel by Gas Chromatography using Heart-cut and Refocusing	SGS runs IP 585 for the same parameters

9.8 Unsourced Testing of IP Methods

Of the 22 individual test methods that were not assessed during the U.S. review, sources were found for all but one test. IP 424, Determination of FSII content did not have a testing location identified. While the equipment is available for purchase, a test house offering the test was not identified with reasonable search effort.

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11 *APPENDICES*

11.1 U.S. Standards List

Guides

Document Number	Referenced Document Title
9680–04	IATA Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks
AFRL-RQ-WP-TR-2013-0271	Determination of the Minimum Use Level of Fuel System Icing Inhibitor (FSII) in JP-8 that will Provide Adequate Icing Inhibition and Biostatic Protection for Air Force Aircraft
API 1543	Documentation, Monitoring and Laboratory Testing of Aviation Fuel During Shipment from Refinery to Airport
API 1595	Design, Construction, Operation, Maintenance, and Inspection of Aviation Pre-Airfield Storage Terminals
ASTM D4865	Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems
ASTM D6469	Guide for Microbial Contamination in Fuels and Fuel Systems
JIG Bulletin Number 65	MSEP Protocol
EI/JIG 1530	Quality Assurance Requirements for the Manufacture, Storage and Distribution of Aviation Fuels to Airports
IATA Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks	Ref. No: 9680-029

Methods

Document Number	Referenced Document Title
ASTM D1002	Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)
ASTM D1094	Test Method for Water Reaction of Aviation Fuels
ASTM D1266	Test Method for Sulfur in Petroleum Products (Lamp Method)
ASTM D129	Test Method for Sulfur in Petroleum Products (General High Pressure Decomposition Device Method)
ASTM D1298	Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
ASTM D130	Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
ASTM D1319	Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
ASTM D1322	Test Method for Smoke Point of Kerosine and Aviation Turbine Fuel
ASTM D1331	Test Methods for Surface and Interfacial Tension of Solutions of Paints, Solvents, Solutions of Surface-Active Agents, and Related Materials
ASTM D1405	Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
ASTM D1414	Test Methods for Rubber O-Rings
ASTM 1500	Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
ASTM D156	Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method
ASTM D1660	Method of Test for Thermal Stability of Aviation Turbine Fuels (Withdrawn 1992) *AKA CRC Coker*
ASTM D1740	Standard Test Method for Luminometer Numbers of Aviation Turbine Fuel
ASTM D1840	Test Method for Naphthalene Hydrocarbons in Aviation Turbine Fuels by Ultraviolet Spectrophotometry
ASTM D2240	Test Method for Rubber Property—Durometer Hardness
ASTM D2276	Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling
ASTM D2386	Test Method for Freezing Point of Aviation Fuels

Document Number	Referenced Document Title
ASTM D240	Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter
ASTM D2425	Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry
ASTM D2549	Test Method for Separation of Representative Aromatics and Nonaromatics Fractions of High-Boiling Oils by Elution Chromatography
ASTM D257	Test Methods for DC Resistance or Conductance of Insulating Materials
ASTM D2622	Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
ASTM D2624	Test Methods for Electrical Conductivity of Aviation and Distillate Fuels
ASTM D2710	Test Method for Bromine Index of Petroleum Hydrocarbons by Electrometric Titration
ASTM D2717	Test Method for Thermal Conductivity of Liquids
ASTM D2779	Test Method for Estimation of Solubility of Gases in Petroleum Liquids
ASTM D287	Test Method for API Gravity of Crude Petroleum and Petroleum Products
ASTM D2887	Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
ASTM D2892	Test Method for Distillation of Crude Petroleum (15-Theoretical Plate Column)
ASTM D3114	Method of Test for D-C Electrical Conductivity of Hydrocarbon Fuels (Withdrawn 1985)3
ASTM D3120	Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry
ASTM D3227	Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosine, Aviation Turbine, and Distillate Fuels (Potentiometric Method)
ASTM D323	Test Method for Vapor Pressure of Petroleum Products (Reid Method)
ASTM D3240	Test Method for Undissolved Water In Aviation Turbine Fuels
ASTM D3241	Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels
ASTM D3242	Test Method for Acidity in Aviation Turbine Fuel
ASTM D3338	Test Method for Estimation of Net Heat of Combustion of Aviation Fuels

Document Number	Referenced Document Title
ASTM D3343	Test Method for Estimation of Hydrogen Content of Aviation Fuels
ASTM D3359	Test Methods for Measuring Adhesion by Tape Test
ASTM D3363	Test Method for Film Hardness by Pencil Test
ASTM D3701	Test Method for Hydrogen Content of Aviation Turbine Fuels by Low Resolution Nuclear Magnetic Resonance Spectrometry
ASTM D3703	Test Method for Hydroperoxide Number of Aviation Turbine Fuels, Gasoline and Diesel Fuels
ASTM D381	Test Method for Gum Content in Fuels by Jet Evaporation
ASTM D3828	Test Methods for Flash Point by Small Scale Closed Cup Tester
ASTM D3948	Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer
ASTM D395	Test Methods for Rubber Property—Compression Set
ASTM D4045	Standard Test Method for Sulfur in Petroleum Products by Hydrogenolysis and Rateometric Colorimetry
ASTM D4052	Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
ASTM D412	Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
ASTM D4176	Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
ASTM D4294	Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry
ASTM D4308	Test Method for Electrical Conductivity for Liquid Hydrocarbons by Precision Meter
ASTM D445	Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
ASTM D4529	Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
ASTM D471	Test Method for Rubber Property—Effect of Liquids
ASTM D4809	Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)

Document Number	Referenced Document Title
ASTM D4952	Test Method for Qualitative Analysis for Active Sulfur Species in Fuels and Solvents (Doctor Test)
ASTM D4953	Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)
ASTM D5001	Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
ASTM D5006	Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels
ASTM D5190	Heat of Vaporization, Latent - See ASTM D323 (RVP) or ASTM D5190 Vapor Pressure
ASTM D5191	Test Method for Vapor Pressure of Petroleum Products (Mini Method)
ASTM D5291	Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants
ASTM D5304	Test Method for Assessing Middle Distillate Fuel Storage Stability by Oxygen Overpressure
ASTM D5452	Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration
ASTM D5453	Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
ASTM D5482	Test Method for Vapor Pressure of Petroleum Products (Mini-Method - Atmospheric)
ASTM D56	Test Method for Flash Point by Tag Closed Cup Tester
ASTM D5972	Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)
ASTM D6045	Test Method for Color of Petroleum Products by the Automatic Tristimulus Method
ASTM D6304	Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
ASTM D6378	Test Method for Determination of Vapor Pressure (VPX) of Petroleum Products, Hydrocarbons, and Hydrocarbon-Oxygenate Mixtures (Triple Expansion Method)

Document Number	Referenced Document Title
ASTM D6379	Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection
ASTM D6732	Test Method for Determination of Copper in Jet Fuels by Graphite Furnace Atomic Absorption Spectrometry
ASTM D6793	Test Method for Determination of Isothermal Secant and Tangent Bulk Modulus
ASTM D6866	Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis
ASTM D7042	Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
ASTM D7111	Test Method for Determination of Trace Elements in Middle Distillate Fuels by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
ASTM D7153	Test Method for Freezing Point of Aviation Fuels (Automatic Laser Method)
ASTM D7154	Test Method for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)
ASTM D7171	Test Method for Hydrogen Content of Middle Distillate Petroleum Products by Low-Resolution Pulsed Nuclear Magnetic Resonance Spectroscopy
ASTM D7345	Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure (Micro Distillation Method)
ASTM 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)
ASTM D7524	Test Method for Determination of Static Dissipater Additives (SDA) in Aviation Turbine Fuel and Middle Distillate Fuels—High Performance Liquid Chromatograph (HPLC) Method
ASTM D7797	Test Method for Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy—Rapid Screening Method

Document Number	Referenced Document Title
ASTM D7872	Test Method for Determining the Concentration of Pipeline Drag Reducer Additive in Aviation Turbine Fuels
ASTM D790	Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D7945	Test Method for Determination of Dynamic Viscosity and Derived Kinematic Viscosity of Liquids by Constant Pressure Viscometer
ASTM D7974	Test Method for Determination of Farnesane, Saturated Hydrocarbons, and Hexahydrofarnesol Content of Synthesized Iso-Paraffins (SIP) Fuel for Blending with Jet Fuel by Gas Chromatography
ASTM D86	Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
ASTM D873	Test Method for Oxidation Stability of Aviation Fuels (Potential Residue Method)
ASTM D924	Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
ASTM D93	Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
ASTM E1269	Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry
ASTM E411	Test Method for Trace Quantities of Carbonyl Compounds with 2,4-Dinitrophenylhydrazine
ASTM E659	Test Method for Autoignition Temperature of Chemicals
ASTM E681	Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases)
EN14214	Automotive Fuels—Fatty Acid Methyl Esters (FAME) for Diesel Engines—Requirements and Test Methods
FED-STD-791	Testing Method of Lubricants, Liquid Fuels, and Related Products
IP196	ASTM Color of Petroleum Products(ASTM color scale)
IP 107	Determination of Sulfur – Lamp Combustion Method
IP 12	Determination of Specific Energy
IP 123	Petroleum Products—Determination of Distillation Characteristics at Atmospheric Pressure

Document Number	Referenced Document Title
IP 131	Petroleum products - Gum content of light and middle distillate fuels - Jet evaporation method
IP 138	Determination of oxidation stability of aviation fuel Potential residue method
IP 154	Petroleum Products—Corrosiveness to Copper—Copper Strip Test
IP 156	Petroleum Products and Related Materials—Determination of Hydrocarbon Types—Fluorescent Indicator Adsorption Method
IP 16	Determination of Freezing Point of Aviation Fuels—Manual Method
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 216	Particulate Contaminant in Aviation Fuel
IP 225	Determination of Copper in Light Petroleum Distillates—Spectrophotometric Method
IP 227	Corrosiveness to Silver of Aviation Turbine Fuels—Silver Strip Method
IP 274	Determination of Electrical Conductivity of Aviation and Distillate Fuels
IP 289	Determination of water reaction of aviation fuels
IP 299	Determination of Bromine Index—Electrometric Titration Method
IP 30	Detection of Mercaptans, Hydrogen Sulfide, Elemental Sulfur and Peroxides—Doctor Test Method
IP 303	*Obsolete? Not listed in IP current methods but cited by Stanhope Seta Small Scale Closed Cup Flash Point. (IP534 replaces?)*
IP 323	Determination of Thermal Oxidation Stability of Gas Turbine Fuels
IP 336	Petroleum Products—Determination of Sulfur Content—Energy-Dispersive X-ray Fluorescence Spectrometry
IP 34	Determination of Flash Point—Pensky-Martens Closed Cup Method
IP 342	Petroleum Products—Determination of Thiol (Mercaptan) Sulfur in Light and Middle Distillate Fuels—Potentiometric Method

Document Number	Referenced Document Title
IP 354	Determination of the Acid Number of Aviation 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 381	Aviation fuels - Estimation of net specific energy (aniline point, density and sulfur content)
IP 394	Liquid Petroleum Products—Vapour Pressure—Part 1: Determination of Air Saturated Vapour Pressure (ASVP) and Calculated Dry Vapour Pressure Equivalent (DVPE)
IP 406	Petroleum Products—Determination of Boiling Range Distribution by Gas Chromatography
IP 423	Determination of Particulate Contaminant in Aviation Turbine Fuels by Laboratory Filtration
IP 435	Determination of the Freezing Point of Aviation Turbine Fuels by the Automatic Phase Transition Method
IP 436	Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection
IP 438	Determination of Water—Coulometric Karl Fischer Titration Method
IP 475	Petroleum Liquids—Manual Sampling
IP 523	Determination of Flash Point—Rapid Equilibrium Closed Cup Method
IP 524	Determination of Flash/No Flash—Rapid Equilibrium Closed Cup Method
IP 528	Determination for the Freezing Point of Aviation Turbine Fuels—Automatic Fibre Optic Method
IP 529	Determination of the Freezing Point of Aviation Turbine Fuels—Automatic Laser Method
IP 540	Determination of the Existent Gum Content of Aviation Turbine Fuel—Jet Evaporation Method
IP 568	Determination of the static dissipater additives (SDA) in aviation turbine fuel and middle distillate fuels - HPLC Method

Document Number	Referenced Document Title
IP 583	Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy—Rapid Screening 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
IP 590	Determination of Fatty Acid Methyl Esters (FAME) in Aviation Turbine Fuel—HPLC Evaporative Light Scattering Detector Method
IP 596	Petroleum products - Determination of distillation characteristics of petroleum products - Micro distillation method
IP 598	Petroleum Products—Determination of the Smoke Point of Kerosine, Manual and Automated Method
IP 599	Determination of Fatty Acid Methyl Esters (FAME) in Aviation Turbine Fuel by Gas Chromatography using Heart-cut and Refocusing
IP 61	Determination of sulfur - High pressure combustion method
IP 69	Vapour Pressure-Reid Method (St-B-9)
IP 71, Section 1	Petroleum Products—Transparent and Opaque Liquids—Determination of Kinematic Viscosity and Calculation of Dynamic Viscosity
ISO 20823	Petroleum and Related Products Determination of the Flammability Characteristics of Fluids in Contact with Hot Surfaces Manifold Ignition Test
UOP 389	Trace Metals in Oils by Wet Ash/ICP-AES
ASTM D1903	Density (versus temperature - subset 1, thermal expansion -subset 2)
ASTM D97	Pour Point
ASTM D971	Surface Tension versus Temperature
ASTM D976	Calculated Cetane Index
ASTM E2071	Calculating Heat of Vaporization from Vapor Pressure data

Practices

Document Number	Referenced Document Title

ASTM D1250	Guide for Use of the Petroleum Measurement Tables
ASTM D341	Standard Practice for Viscosity-Temperature Charts for Liquid Petroleum Products
ASTM D4054	Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D4057	Practice for Manual Sampling of Petroleum and Petroleum Products
ASTM D4306	Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
ASTM D5842	Practice for Sampling and Handling of Fuels for Volatility Measurement
ASTM E29	Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications 2.2 Energy Institute Standards:4

Standard

Document Number	Referenced Document Title
ASTM A240/A240M	Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASTM B36/B36M	Specification for Brass Plate, Sheet, Strip, and Rolled Bar
ASTM B93/B93M	Specification for Magnesium Alloys in Ingot Form for Sand Castings, Permanent Mold Castings, and Die Castings
ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D4066	Classification System for Nylon Injection and Extrusion Materials (PA)
ASTM D4171	Specification for Fuel System Icing Inhibitors
ASTM D5363	Specification for Anaerobic Single-Component Adhesives (AN)
ASTM D6615	Specification for Jet B Wide-Cut Aviation Turbine Fuel
ASTM D6751	Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels
ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
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
BMS 10-20	Corrosion Resistant Finish for Integral Fuel Tanks
BMS 10-39	Fuel and Moisture Resistant Finish for Fuel Tanks
BMS 5-267	Fuel Tank Coating
Defence Standard 91-091	Turbine Fuel, Aviation Kerosine Type, Jet A-1
DOD-L-85645	Lubricant, Dry Film, Molecular Bonded
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
MIL-C-83019	Coating, Polyurethane, for Protection of Integral Fuel Tank Sealing Compound
MIL-DTL-17902	Hose, End Fittings and Hose Assemblies, Synthetic Rubber, Aircraft Fuels
MIL-DTL-24441	Paint, Epoxy-Polyamide, General Specification for

Document Number	Referenced Document Title
MIL-DTL-24441/19C	Paint, Epoxy-Polyamide, Zinc Primer, Formula 159, Type III
MIL-DTL-24441/20B	Paint, Epoxy-Polyamide, Green Primer, Formula 150, Type III
MIL-DTL-24441/21B	Paint, Epoxy-Polyamide, Haze Gray Formula 151, Type III
MIL-DTL-24441/22B	Paint, Epoxy-Polyamide, White Formula 152, Type III
MIL-DTL-24441/23B	Paint, Epoxy-Polyamide, Dark Gray RO1.8, Formula 153, Type III
MIL-DTL-24441/24B	Paint, Epoxy-Polyamide, Dark Gray, RO3.6 Formula 154, Type III
MIL-DTL-24441/25B	Paint, Epoxy-Polyamide, Dark Gray, RO6.0 Formula 155, Type III
MIL-DTL-24441/26B	Paint, Epoxy-Polyamide, Red Formula 156, Type III
MIL-DTL-24441/27B	Paint, Epoxy-Polyamide, No. 50 Gray Formula 157, Type III
MIL-DTL-24441/28B	Paint, Epoxy-Polyamide, Yellow Formula 158, Type III
MIL-DTL-24441/29B	Paint, Epoxy-Polyamide, Green Primer, Formula 150, Type IV
MIL-DTL-24441/30B	Paint, Epoxy-Polyamide, Haze Gray, Formula 151, Type IV
MIL-DTL-24441/31B	Paint, Epoxy-Polyamide, White, Formula 152, Type IV
MIL-DTL-24441/32B	Paint, Epoxy-Polyamide, Dark Gray RO1.8 Formula 153, Type IV
MIL-DTL-24441/33B	Paint, Epoxy-Polyamide, Dark Gray RO3.6, Formula 154, Type IV
MIL-DTL-24441/34B	Paint, Epoxy-Polyamide, Dark Gray, RO6.0, Formula 155, Type IV
MIL-DTL-24441/35B	Paint, Epoxy-Polyamide, Red, Formula 156, Type IV
MIL-DTL-24441/36B	Paint, Epoxy-Polyamide, No. 50 Gray, Formula 157, Type IV
MIL-DTL-24441/37B	Paint, Epoxy-Polyamide, Yellow, Formula 158, Type IV
MIL-DTL-24441/38B	Paint, Epoxy-Polyamide, Black, Formula 160, Type IV
MIL-DTL-24441/39B	Paint, Epoxy-Polyamide, Yellow, Formula 161, Type IV
MIL-DTL-24441/40B	Paint, Epoxy-Polyamide, Red, Formula 162, Type IV

Document Number	Referenced Document Title
MIL-DTL-25988	Rubber, Fluorosilicone Elastomer, Oiland 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-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-DTL-5578	Tanks, Fuel, Aircraft, Self-Sealing
MIL-DTL-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5
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-P-25732	Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Limited Service at 275 °F (135 °C)
MIL-PRF-25017	Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble
MIL-PRF-370	Hose and Hose Assemblies, Nonmetallic: Elastomeric, Liquid Fuel
MIL-PRF-46010	Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting, NATO Code S-1738
MIL-PRF-6855	Rubber, Synthetic, Sheets, Strips, Molded or Extruded Shapes, General Specification for
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-8516	Sealing Compound, Synthetic Rubber, Electric Connectors and Electric Systems, Chemically Cured
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
MMM-A-132	Adhesives, Heat Resistant, Airframe Structural, Metal to Metal
QDS-25017	Qualified Data Set for MIL-PRF-25017 (Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble)
QPL-25017	Qualified Products List for MIL-PRF-25017 (Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble)
SAE AMS-I-7444	Insulation Sleeving, Electrical, Flexible

Document Number	Referenced Document Title
SAE AS5127/1	Aerospace Standard Test Methods for Aerospace Sealants Two-Component Synthetic Rubber Compounds
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 40Pa·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

Document Number	Referenced Document Title
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

Document Number	Referenced Document Title
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-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

Document Number	Referenced Document Title
SAE-AMS-S-8802	Sealing Compound, Temperature Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High Adhesion
ANSI 863	Report of Test Results
ATA-103	Standard for Jet Fuel Quality Control at Airports
EI 1550	Handbook on Equipment Used for the Maintenance and Delivery of Clean Aviation Fuel
EI 1583	Laboratory Tests and Minimum Performance Levels for Aviation Fuel Filter Monitors
ICAO 9977	Manual on Civil Aviation Jet Fuel Supply
JIG 1	Aviation Fuel Quality Control & Operating Standards for Into-Plane Fueling Services
JIG 2	Aviation Fuel Quality Control & Operating Standards for Airport Depots & Hydrants
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)
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys
MIL-HDBK-510	Aerospace Fuels Certification
CRC Aviation Fuel Properties Handbook	Thermal Conductivity versus Temperature
MIL-STD-3004	Quality Assurance/Surveillance for Fuels, Lubricants and Related Product – Topic: Storage Stability
TBD-Enthalpy	Enthalpy versus Temperature
TBD-Flame Speed	Flame Speed
TBD-Spark Energy	Minimum Spark ignition energy (the criterion is defined as "no easier to ignite than Jet A/JP-8)
TBD-Thermal Expansion	Thermal Expansion see ASTM D1298, D4052, D1903 Density (Thermal Expansion)
TBD-Velocity of Sound	Velocity of Sound
ASTM D613	Standard Test Method for Cetane Number of Diesel Fuel Oil
IP 200	Guidelines for the use of the Petroleum Measurement Tables
TBD - Heat Vaporization	Heat of Vaporization, Latent – see ASTM D323 or ASTM D5191 Vapor Pressure
TBD - Specific Heat	Specific Heat (as a Function of Temperature) (currently calculated)

11.2 Added Standards

Document Number	Title
ASTM D1094	Test Method for Water Reaction of Aviation Fuels
ASTM D1250	Guide for Use of the Petroleum Measurement Tables
ASTM 1500	Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
ASTM D1903	Density (versus temperature - subset 1, thermal expansion D1903 - subset 2)
ASTM D2274	Test Method for Oxidation Stability of Distillate Fuel Oil (Accelerated Method)
ASTM D2549	Test Method for Separation of Representative Aromatics and Nonaromatics Fractions of High-Boiling Oils by Elution Chromatography
ASTM D2779	Test Method for Estimation of Solubility of Gases in Petroleum Liquids
ASTM D287	Test Method for API Gravity of Crude Petroleum and Petroleum Products
ASTM D2879	Test Method for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope
ASTM D341	Standard Practice for Viscosity-Temperature Charts for Liquid Petroleum Products
ASTM D4308	Test Method for Electrical Conductivity for Liquid Hydrocarbons by Precision Meter
ASTM D4625	Test Method for Middle Distillate Fuel Storage Stability at 43 °C (110 °F)
ASTM D5190	Heat of Vaporization, Latent - See ASTM D323 (RVP) or ASTM D5190 Vapor Pressure
ASTM D5482	Test Method for Vapor Pressure of Petroleum Products (Mini-Method - Atmospheric)
ASTM D5842	Practice for Sampling and Handling of Fuels for Volatility Measurement
ASTM D613	Test Method for Cetane Number of Diesel Fuel Oil
ASTM D873	Test Method for Oxidation Stability of Aviation Fuels (Potential Residue Method)
ASTM D97	Test Method for Pour Point of Petroleum Products
ASTM D971	D971 Surface Tension versus Temperature
ASTM D976	Test Method for Calculated Cetane Index of Distillate Fuels
ASTM D2717	Thermal Conductivity versus Temperature CRC Aviation Fuel Properties Handbook, (assumed D2717)
ASTM E253	Enthalpy versus Temperature Maybe E2253

ASTM E582 TBD	Minimum Spark ignition energy (the criterion is defined as "no easier to ignite than Jet A/JP-8) ?ASTM E582?
ASTM E681	Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases)
ASTM E2071	Calculating Heat of Vaporization from Vapor Pressure data
MIL-STD-3004	Storage Stability Calls out D5304 and D2274
TBD-	Flame Speed
TBD-	Velocity of Sound

11.3 IP Specifications from U.S. Review

Equivalence noted in individual ASTM Standard

Equivalence listed in ASTM Manual 44 Guide to ASTM Test Methods for the Analysis of Petroleum Products and Lubricants

Font color "red" equivalent to a "red" ASTM specification

Font color "yellow" equivalent to a "yellow" ASTM specification

Document Number	Title	ASTM Equiv
IP 107	Determination of Sulfur – Lamp Combustion Method	ASTM D1266
IP 12	Determination of Specific Energy	ASTM D240
IP 123	Petroleum Products—Determination of Distillation Characteristics at Atmospheric Pressure	ASTM D86
IP 131	Petroleum products - Gum content of light and middle distillate fuels - Jet evaporation method	ASTM D381
IP 138	Determination of oxidation stability of aviation fuel Potential residue method	ASTM D873
IP 154	Petroleum Products—Corrosiveness to Copper—Copper Strip Test	ASTM D130
IP 156	Petroleum Products and Related Materials—Determination of Hydrocarbon Types—Fluorescent Indicator Adsorption Method	ASTM D1319
IP 16	Determination of Freezing Point of Aviation Fuels—Manual Method	ASTM 2386
IP 160	Crude Petroleum and Liquid Petroleum Products—Laboratory Determination of Density—Hydrometer Method	ASTM D1298
IP 170	Determination of Flash Point—Abel Closed-Cup Method	X

Document Number	Title	ASTM Equiv
IP 196	ASTM Color of Petroleum Products(ASTM color scale)	ASTM D1500
IP 200	Guidelines for the use of the Petroleum Measurement Tables	ASTM D1250
IP 216	Particulate Contaminant in Aviation Fuel	ASTM D2276
IP 225	Determination of Copper in Light Petroleum Distillates—Spectrophotometric Method	X
IP 227	Corrosiveness to Silver of Aviation Turbine Fuels—Silver Strip Method	X
IP 274	Determination of Electrical Conductivity of Aviation and Distillate Fuels	ASTM D2624
IP 289	Determination of water reaction of aviation fuels	ASTM D1094
IP 299	Determination of Bromine Index—Electrometric Titration Method	ASTM D2710
IP 30	Detection of Mercaptans, Hydrogen Sulfide, Elemental Sulfur and Peroxides—Doctor Test Method	ASTM D4952
IP 303	*Obsolete? Not listed in IP current methods but cited by Stanhope Seta Small Scale Closed Cup Flash Point. (IP534 replaces?)*	ASTM D3828
IP 323	Determination of Thermal Oxidation Stability of Gas Turbine Fuels	ASTM D3241
IP 336	Petroleum Products—Determination of Sulfur Content—Energy-Dispersive X-ray Fluorescence Spectrometry	ASTM D4294
IP 34	Determination of Flash Point—Pensky-Martens Closed Cup Method	ASTM D93
IP 342	Petroleum Products—Determination of Thiol (Mercaptan) Sulfur in Light and Middle Distillate Fuels—Potentiometric Method	ASTM D3227
IP 354	Determination of the Acid Number of Aviation Fuels-Colour-Indicator Titration Method	ASTM D3242
IP 365	Crude Petroleum and Petroleum Products—Determination of Density—Oscillating U-tube Method	ASTM D4052
IP 378	Determination of storage stability at 43 °C of distillate fuel	ASTM D4625
IP 379	Determination of Organically Bound Trace Nitrogen—Oxidative Combustion and Chemiluminescence Method	X
IP 381	Aviation fuels - Estimation of net specific energy (aniline point, density and sulfur content)	ASTM D4529
IP 394	Liquid Petroleum Products—Vapour Pressure—Part 1: Determination of Air Saturated Vapour Pressure (ASVP) and Calculated Dry Vapour Pressure Equivalent (DVPE)	ASTM D5191

Document Number	Title	ASTM Equiv
IP 406	Petroleum Products—Determination of Boiling Range Distribution by Gas Chromatography	ASTM D2887
IP 423	Determination of Particulate Contaminant in Aviation Turbine Fuels by Laboratory Filtration	ASTM D5452
IP 435	Determination of the Freezing Point of Aviation Turbine Fuels by the Automatic Phase Transition Method	ASTM D5972
IP 436	Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection	ASTM D6379
IP 438	Determination of Water—Coulometric Karl Fischer Titration Method	X
IP 475	Petroleum Liquids—Manual Sampling	X
IP 523	Determination of Flash Point—Rapid Equilibrium Closed Cup Method	X
IP 524	Determination of Flash/No Flash—Rapid Equilibrium Closed Cup Method	X
IP 528	Determination for the Freezing Point of Aviation Turbine Fuels—Automatic Fiber Optic Method	ASTM D7154
IP 529	Determination of the Freezing Point of Aviation Turbine Fuels—Automatic Laser Method	ASTM D7153
IP 540	Determination of the Existent Gum Content of Aviation Turbine Fuel—Jet Evaporation Method	ASTM D381
IP 568	Determination of the static dissipater additives (SDA) in aviation turbine fuel and middle distillate fuels - HPLC Method	ASTM D7524
IP 583	Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy—Rapid Screening Method	ASTM D7797
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	X
IP 590	Determination of Fatty Acid Methyl Esters (FAME) in Aviation Turbine Fuel—HPLC Evaporative Light Scattering Detector Method	X
IP 596	Petroleum products - Determination of distillation characteristics of petroleum products - Micro distillation method	ASTM D7345
IP 598	Petroleum Products—Determination of the Smoke Point of Kerosine, Manual and Automated Method	ASTM D1322
IP 599	Determination of Fatty Acid Methyl Esters (FAME) in Aviation Turbine Fuel by Gas Chromatography using Heart-cut and Refocusing	X

Document Number	Title	ASTM Equiv
IP 61	Determination of sulfur - High pressure combustion method	ASTM D129
IP 69	Vapour Pressure-Reid Method (St-B-9)	ASTM D323
IP 71, Section 1	Petroleum Products—Transparent and Opaque Liquids—Determination of Kinematic Viscosity and Calculation of Dynamic Viscosity	ASTM D445

11.4 Invited Original Equipment Manufacturers

Companies invited to participate were contacted by email or phone. The companies invited included:

- Airbus
- BAE
- Boeing
- Embraer
- Fokker
- General Electric
- Gulfstream
- Hawker
- Honeywell (Engine and Accessories)
- Pratt and Whitney
- Pratt and Whitney Canada
- Rolls Royce
- Williams
- Zodiac

11.5 Def Stan 91-091 Standards List

Number	Title
05-052, Pt 1, Iss 3	Markings for the Identification of Fuels, Lubricants and Associated Products - Containers Holding 216.5 Litres or Less
68-150, Iss 2	Mixture of Fuel System Icing Inhibitor and Lubricity Improving Additive Joint Service Designation: AL-48
68-251, Iss 3	Fuel Soluble Lubricity Improving Additives for Aviation Turbine Fuels NATO Code: S- 1747 Joint Service Designation: AL-61
68-252, Iss 3	Fuel System Icing Inhibitor NATO Code: S-1745 Joint service Designation: AL-41
3583 Edition 4	Standards Of Accuracy For Differential Pressure Gauges Used On Aviation Fuel Filters And Filter Water Separator Vessels
AFLP-3583 Edition A Version 1	Standards For Differential Pressure Gauges Used On Aviation Fuel Filters And Filter Water Separator Vessels
QPL 68-251	Qualified Products List of Aircraft Materials to Def Stan 68-251
IP 12	Determination of Specific Energy
IP 16	Petroleum Products – Determination of the Freezing Point of Aviation Fuels
IP 30	Detection of Mercaptans, Hydrogen Sulfide, Elemental Sulfur and Peroxides – Doctor Test Method
IP 71	Petroleum Products – Transparent and Opaque Liquids – Determination of Kinematic Viscosity and Calculation of Dynamic Viscosity
IP 107	Determination of Sulfur – Lamp Combustion Method
IP 123	Petroleum Products – Determination of Distillation Characteristics at Atmospheric Pressure
IP 154	Petroleum Products – Corrosiveness to Copper – Copper Strip Test
IP 156	Determination of Hydrocarbon Types in Petroleum Products – Fluorescent Indicator Adsorption Method
IP 160	Crude Petroleum and Liquid Petroleum Products – Laboratory Determination of Density – Hydrometer Method
IP 170	Petroleum Products and other Liquids– Determination of Flash Point – Abel Closed Cup Method
IP 243	Petroleum Products and Hydrocarbons – Determination of Sulfur Content – Wickbold Combustion Method

IP 274	Petroleum Products – Aviation and Distillate Fuels - Determination of Electrical Conductivity
IP 323	Petroleum Products - Determination of Thermal Oxidation Stability of Gas Turbine Fuels
IP 336	Petroleum Products – Determination of Sulfur Content – Energy-Dispersive - X-Ray Fluorescence Method
IP 342	Petroleum Products – Determination of Thiol (Mercaptan) Sulfur in Light and Middle Distillate Fuels – Potentiometric Method
IP 354	Determination of the Acid Number of Aviation Turbine Fuels – Colour-Indicator Titration Method
IP 355	Estimation of Net Specific Energy of Aviation Turbine Fuels, using Hydrogen Content Data
IP 365	Crude Petroleum and Petroleum Products – Determination of Density – Oscillating U-tube Method
IP 367	Petroleum Products – Determination and Application of Precision Data in Relation to Methods of Test
IP 373	Determination of Sulfur Content of Light and Middle Distillates by Oxidative Microcoulometry
IP 381	Aviation fuels - Estimation of net specific energy
IP 406	Petroleum Products – Determination of Boiling Range Distribution by Gas Chromatography
IP 423	Determination of Particulate Contaminant in Aviation Turbine Fuels by Laboratory Filtration
IP 424	Determination of Fuel System Icing Inhibitor Content of Aviation Turbine Kerosenes by High Performance Liquid Chromatography
IP 435	Determination of the Freezing Point of Aviation Turbine Fuels by the Automated Phase Transition Method
IP 436	Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates – High Performance Liquid Chromatography Method with Refractive Index Detection
IP 447	Petroleum Products – Determination of Sulfur Content – Wavelength-Dispersive X- Ray Fluorescence Spectrometry
IP 475	Petroleum Liquids – Manual Sampling (ISO 3170:2004)
IP 523	Determination of Flash Point – Rapid Equilibrium Closed Cup Method
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 540	Determination of the Existent Gum Content of Aviation Turbine Fuel – Jet Evaporation Method
IP 564	Determination Of The Level Of Cleanliness Of Aviation Turbine Fuel – Laboratory Automatic Particle Counter Method
IP 565	Determination of the level of cleanliness of aviation turbine fuels - Portable automatic particle counter method
IP 568	Determination of the static dissipater additives (SDA) in aviation turbine fuel and middle distillate fuels - HPLC Method
IP 577	Determination of the level of cleanliness of aviation turbine fuel – Automatic particle counter method using light extinction
IP 583	Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy - Rapid Screening 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
IP 590	Determination of fatty acid methyl esters (FAME), derived from bio-diesel fuel, in aviation turbine fuel – HPLC evaporative light scattering detector method
IP 598	Determination of the smoke point of kerosene, manual and automated procedures.
IP 599	Determination of Fatty Acid Methyl Esters (FAME) in Aviation Turbine Fuel by Gas Chromatography using Heart-cut and Refocusing
BS EN 14214 :2008+A1:2009	Automotive Fuels. Fatty Acid Methyl Esters (FAME) for Diesel Engines. Requirements and Test Methods
ISO 4406:1999	Hydraulic fluid power – Fluids – Method for coding the level of contamination by solid particles.
EI HM 50	Guidelines for the cleaning of tanks and lines for marine tank vessels carrying petroleum and refined products
EI/JIG 1530	Quality assurance requirements for the manufacture, storage and distribution of aviation fuels to airports.
API 1543	Documentation, Monitoring and Laboratory Testing of Aviation Fuel During Shipment from Refinery to Airport
SAE ARP 1797	Aircraft and Aircraft Engine Fuel Pump Low Lubricity Fluid Endurance Test
SwRI – 8531	Qualification of Sasol Semi-Synthetic JET A-1 as Commercial Jet Fuel

SwRI 08-04438	Evaluation of Sasol Synthetic Kerosene for Suitability as Jet Fuel
SwRI 08-04438-2	Evaluation of Sasol Synthetic Kerosene for Suitability as Jet Fuel. Phase II, Engine and Combustion Tests.
SwRI 08-04438.04	Evaluation of Heavy Naphtha Stream from SASOL Fully Synthetic Jet Fuel to Produce Semi-Synthetic Jet Fuel
ASTM D3241	Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels (JFTOT Procedure)
ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D6751	Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels
ASTM D56	Standard Test Method for Flash Point by Tag Closed Cup Tester
ASTM D86	Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
ASTM D130	Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
ASTM D156	Standard Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)
ASTM D381	Standard Test Method for Gum Content in Fuels by Jet Evaporation
ASTM D445	Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)
ASTM D1266	Standard Test Method for Sulfur in Petroleum Products (Lamp Method)
ASTM D1298	Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
ASTM D1319	Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
ASTM D1322	Standard Test Method for Smoke Point of Kerosene and Aviation Turbine Fuel
ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D1840	Standard Test Method for Naphthalene Hydrocarbons in Aviation Turbine Fuels by Ultraviolet Spectrophotometry
ASTM D2386	Standard Test Method for Freezing Point of Aviation Fuels
ASTM D2622	Standard Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-Ray Fluorescence Spectrophotometry
ASTM D2624	Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels

ASTM D2887	Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
ASTM D3227	Standard Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosene, Aviation Turbine, and Distillate Fuels (Potentiometric Method)
ASTM D3241	Standard Test Method for Termal Oxidation Stabilit of Aviation Turbine Fuels
ASTM D3242	Standard Test Method for Acidity in Aviation Turbine Fuel
ASTM D3338	Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
ASTM D3828	Standard Test Methods for Flash Point by Small Scale Closed Cup Tester
ASTM D3948	Standard Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer
ASTM D4052	Standard Test Method for Density, Relative Density and API Gravity of Liquids by Digital Density Meter
ASTM D4057	Standard Practice for Manual Sampling of Petroleum and Petroleum Products
ASTM D4176	Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
ASTM D4294	Standard Test Method for Sulfur in P e t r o l e u m a n d Petroleum Products by Energy- Dispersive X- Ray Fluorescence Spectrometry
ASTM D4809	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)
ASTM D4952	Standard Test Method for Qualitative Analysis for Active Sulfur Species in Fuels and Solvents (Doctor Test)
ASTM D5001	Standard Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
ASTM D5006	Standard Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels
ASTM D5452	Standard Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration
ASTM D5453	Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel and Engine Oil by Ultraviolet Fluorescence
ASTM D5972	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)
ASTM D6045	Standard Test Method for Color of Petroleum Products by the Automatic Tristimulus Method

ASTM D6379	Standard Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates High Performance Liquid Chromatography Method with Refractive Index Detection
ASTM D6751	Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels
ASTM D7042	Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
ASTM D7153	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Laser Method)
ASTM D7154	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)
ASTM D7345	Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure (Micro Distillation Method)
ASTM D7524	Standard Test Method for Determination of Static Dissipater Additives (SDA) in Aviation Turbine Fuel and Middle Distillate Fuels—High Performance Liquid Chromatograph (HPLC) Method
ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesised Hydrocarbons
ASTM D7797	Standard Test Method for Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy - Rapid Screening Method

11.6 Individual Review Sheets – U.S.

Note: References to "Precision Statements" refers to any provided precision, bias, repeatability or reproducibility statements provided in the reviewed document. This is in contrast to an analysis of the statistical variation or accuracy (correctness) of a result.

Note: Specific items leading to a yellow or red assessment are colored within the review sheets. The text describing items that contributed to a concern are highlighted in yellow while text describing items contributing to assessment of red are colored red. This is done to facilitate locating specific items of concern within the review document.

It is recognized the individual forms are described as "Specification Review" sheets and in this case the term Specification refers to all Standards.

11.6.1 Green –

Specification Review

Impact Assessment:

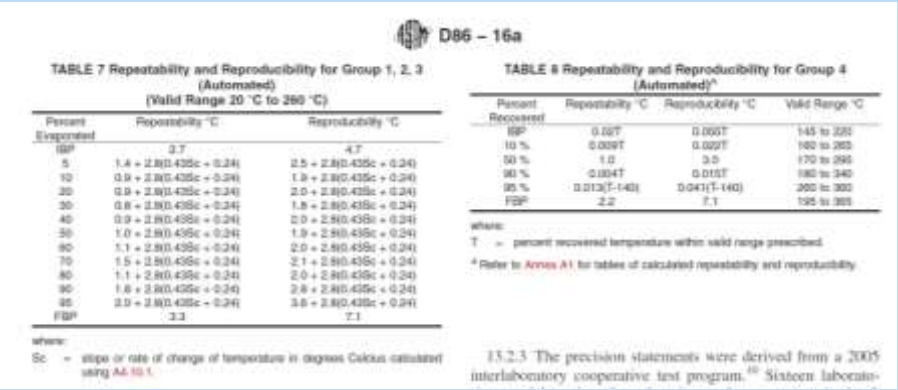
Red Yellow Green

ASTM D56-16a	STM for Flash Point by Tag Closed Cup Tester	**Original Pub Date 1918**
Specification Scope	Determination of the minimum temperature at which sufficient vapor exists over the liquid to ignite with the introduction of an ignition source	
Published Limitations	• Limited to materials with viscosity less than 9.5 mm^2/s (cSt) @ 25°C and below 5.5 mm^2/s (cSt) @ 40°C AND a flash point greater than 93°C • There can be no film formation or suspended solids • Automated and manual methods do not agree for samples which are wet (contain measurable water) or are chlorinated • The presence of an inerting component such as HFC, will mask the flash point • If the flame changes color, stopping the test is recommended. User is directed to ASTM E502	
Provide Precision Information	*Repeatibility*: +/- 1.2 °C (2°F) when FP < 60 °C (140°F) +/- 3°F when FP > 60° C (140°F) *Reproducibility:* +/- 4.3°C (8°F) when FP < 60 °C (140°F) +/- 5.8°C (10°F) when FP > 60° C (140°F)	
Referenced Research Reports	RR:515-1007	
SME Evaluation	The test method is a fundamental test method. If there are vapors present in a flammable state, the introduction of the ignition source will cause a flash. The method measures a fundamental property and as such, becomes a desirous measure of the fluid composition.	
Other	• ASTM D3941 has a slower temperature ramp and is specifically NOT equivalent to D56 • The certified reference material is specified to be a hydrocarbon or petroleum product.	

Impact Assessment:

Red Yellow Green

Specification Review

D86-16a	**STM for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure**	**Original Pub Date 1921**
Specification Scope	Determining the temperature versus proportion of a complex mixture by evaporation and condensation.	
Published Limitations	• Specification limits the method to use on "products that come from petroleum products such as … aviation gasolines, aviation turbine fuels, … naphthas, white spirits, kerosines, …" (see comment on definition of petroleum products). • Excludes any high resid materials • Limited to ≤ 100°C to >250 °C, separated into four groups	
Provided Precision Information	Precision statements were generated with gasoline and with diesel, no jet fuel precision statements were available. 	
Referenced Research Reports	RR: D02-1621 RR: D02-1807 (Updated in D86-16a)	

SME Evaluation	• Technically DISTILLATION works on any liquid material which can be evaporated and then condensed. It is a fundamental test method.
	  ○ However, the descriptions in the method, the caveats and the impacts are all petroleum specific, based on traditional definitions of "petroleum".
	  ○ This is especially true of the sample preparations, such as how to dry the sample prior to testing.
	• Aside from a barometric pressure correction to temperature, the data are read directly.
	  ○ There is no data correction except for when evaporation losses are greater than 2%	

	As long as care is taken regarding the method requirements specific to petroleum, the test is a measure of a fundamental property and should give data that are what they are. The test should be fuel composition agnostic.
Other	• Technically method is related to vapor pressure and pour point • Method is the Engler distillation

Impact Assessment:
Red Yellow Green

Specification Review

D93-16a	STM for Flash Point by Pensky-Martens Closed Cup Tester	**Original Pub Date** **1921**
Specification Scope	Determination of a dynamic flashpoint, the minimum temperature at which sufficient vapor exists over the liquid to ignite with the introduction of an ignition source. Both the fluid and the air space are continuously stirred.	
Published Limitations	For use with "petroleum products" (see comment on definition of petroleum products) with flash points 40 – 360°C for manual testers and 60 – 190°C for automatic testers (due precision statement limitations). There are three different procedures for described fluid types – A – distillate fuels, lube oils and homogeneous petroleum not in B or C B – Resid, cutback residua, used lube oil, mixtures w/ solids, petroleum w/skinning, and non-uniform heating C – Biodiesel w/ residual alcohol content (auto method) Flash point can be masked by HFC components. Mixtures with significantly different flash points can confound the data.	
Provided Precision Information	The CRM for performance validation was done with n-decane, n-undecane, n-tetradecane or n-hexadecane. Method A: r^2 and R^2 were done with 12 fuels and 4 pure chemicals. *Repeatability:* r = 8.4°C *Reproducibility:* R = 14.7°C	
Referenced Research Reports	RR:D02-1683 RR:D02-2008	
SME Evaluation	There is a step for drying free water which could be a material compatibility issue depending on the fuel composition. There is a barometric pressure temperature correction, but otherwise the data is read directly. There are no data corrections. The test measures a fundamental property and aside from the potential masking considerations gives data that are what they are. The test should be fuel composition agnostic.	
Other	• ASTM D3941 has a slower heating ramp rate and is NOT equivalent to D93	

Impact Assessment:

Red Yellow Green

Specification Review

D97-16	STM for Pour Point of Petroleum Products	**Original Publication Date: 1927**
Specification Scope	Manually determines the lowest temperature at which the sample will move when tilted.	
Published Limitations	Method was developed for "any petroleum product" (see comments about definition of petroleum)	
Provided Precision Information	Only lube oil and middle distillates & resid fuels have precision statements. *Repeatability:* r = 6 °C lube oil r = 3 °C middle distillates and resid *Reproducibility:* R = 9 °C lube oil R = 9 °C middle distillates and resid	
Referenced Research Reports	RR:D02-1499 Lube oil No research report for middle distillates and resid, based on ILS	
SME Evaluation	The method measures a fundamental physical property, whether a material flows or not. It is a visual method, so is limited by the operator's ability to recognize movement. There is no precision statement related to jet fuel, so there is no assessment of accuracy of the method for traditional petroleum-based or alternatively produced jet fuel. There is nothing about the method that suggests it should be sensitive to chemical composition. Operators would have to develop a relative repeatability for fuels.	

Other	• Method originally also contained the cloud point method. This was separated and is now ASTM D2500 which is not a referenced document in this program.
	• All automated methods for determining pour point are listed under separate ASTM designations. None of these other methods are referenced in this program.
	  ○ ASTM D5949 – Pulse method
	  ○ ASTM D5950 – Tilt method
	  ○ ASTM D5985 – Rotational Method
	  ○ ASTM D6749 – Air pressure Method
	  ○ ASTM D7346 – Lowest point of utility Method
	• Method included for resid fuels, block oils and cylinder stocks, petroleum products known to have a thermal memory; the pour point changes depending on the previous temperature exposure history.	

Specification Review

Impact Assessment:
Red Yellow Green

D129-13	STM for Sulfur in Petroleum Products (High Pressure Decomposition)	**Original Pub Date** 1922
Specification Scope	Determine the presence of sulfur in petroleum products by combusting the specimen and reacting with barium chloride and measuring the resulting barium sulfate concentration	
Published Limitations	• The method is for petroleum products (see comment on definition of petroleum products) that cannot be completely burned in a wick lamp. • The method is applicable to any material of sufficiently low volatility that it can be weighed accurately in an open boat. • Test specimen should contain at least 0.1% sulfur. Interfering elements – Fe, Al, Ca, Si, Pb, MoS_2, silica, asbestos, mica	
Provided Precision Information	R^2 and r^2 were statistically developed by the Energy Institute (EI) in 1960. *Repeatability:* r = 0.04 to 0.18 wt% depending on sulfur content *Reproducibility:* R = 0.05 to 0.27 wt% depending on sulfur content	
Referenced Research Reports	RR:D02-1007 RR:D02-1278	
SME Evaluation	Low end materials that could evaporate during weighing could impact the results. However, as long as the fuel composition is no more volatile than traditional jet fuel, it should have similar response. As long as the fuel composition does not include any of the interfering elements, the test method should be fuel composition agnostic.	
Other	•	

Sulfur, weight percent	Repeatability	Reproducibility
0.1 to 0.5	0.04	0.05
0.5 to 1.0	0.06	0.09
1.0 to 1.5	0.08	0.15
1.5 to 2.0	0.12	0.25
2.0 to 5.0	0.18	0.27

[7] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1278.

Impact Assessment:

Red Yellow Green

Specification Review

D156-15	STM for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)	**Original Publication Date: 1923**
Specification Scope	• The method is used to determine the color of a finished petroleum product by comparison to standard color filters. • The method is for lighter colored petroleum products (see comment on definition of petroleum products)and products that are darker than the maximum Saybolt Color are tested with ASTM D1500 ASTM Color	
Published Limitations	• The test method specifies suitability of its use with motor gasoline, aviation gasoline, jet fuel, naphtha, kerosene, petroleum wax and pharmaceutical white oil. • The primary reason for the development of the method was for the control of refinery production, and facilitating the recognition of contamination.	
Provided Precision Information	*Repeatability:* +/- 1 color unit *Reproducibility:* +/- 2 color units	
Referenced Research Reports	No research report provided	
SME Evaluation	The test method provides an absolute color report, that being the closest match to a color standard, and as such the reported color is composition agnostic. However, how the color value is used, especially in a comparative manner, has the potential to be specific to the chemical composition. In general, aviation turbine fuels display colors ranging from water white to straw yellow, and as such the color of the alternatively produced fuel is not likely to cause issue. If, however, the color is outside of the generally observed range, it could potentially be misinterpreted in a comparative analysis. Care is required regarding HOW the data is used. Additionally, the use of filtration with qualitative filter paper to remove entrained water could be sensitive to chemical composition. It may be necessary to confirm this method works with the target fuel composition.	
Other	• The method specifies filtering the sample until it is clear and bright, the goal being to remove entrained water and any solid contamination.	

Impact Assessment:

Red Yellow Green

Specification Review

D287-12	STM for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer)	**Original Publication Date: 1928**
Specification Scope	Determines with calculations, the API gravity from hydrometer readings.	
Published Limitations	• The material is handled as a liquid with an RVP < 14.696psi • The material is neither a non-hydrocarbon nor an essentially pure hydrocarbon, such as aromatics	
Provided Precision Information	*Repeatability:* r = 0.2 °API *Reproducibility:* R = 0.5 °API	
Referenced Research Reports	No ILS or research report referenced	
SME Evaluation	Hydrometers are a straight physics phenomenon. A weighted tube with markings is suspended in the fluid and a value is read from the stem. To that point it is what it is. As long as the restrictions of the scope, i.e. that it is not a pure hydrocarbon like an aromatic, are met, then the test should not be fuel composition sensitive. The further from this restriction the composition is, the greater the likelihood of errors. A related concern could be the formula used to move between °API and relative density being sensitive to fuel composition. Based on initial research, the likelihood of a fluid being outside of the range for which the technical concept has been developed as long as it meets the published restrictions, is believed to be low. There is a concern regarding the coefficient of thermal expansion for the hydrometer which used to be provided in the petroleum tables and is no longer provided. If a correction coefficient is not available, the hydrometer will only be useful at 60 °F.	

Other	• A hydrometer reading is not equivalent to density. It is a number on the stem of the hydrometer, corrected for temperature and if necessary meniscus height.
	  ○ °API is a special function of relative density for 60/60 °F.
	  ○ °API = [141.5 / (relative density 60/60)]-31.5
	• A hydrometer reading must be corrected for the meniscus (if it cannot be seen due to fluid color) and for the thermal expansion of the glass in the hydrometer.	

Impact Assessment:

Red Yellow Green

Specification Review

D323-15a	STM for Vapor Pressure of Petroleum Products (Reid Method)	Original Publication Date: 1930
Specification Scope	To measure the vapor pressure of the vapor of the petroleum product (see comment on definition of petroleum products) and the small amount of atmospheric water vapor when in equilibrium with the liquid phase of the petroleum product. The system is a fixed volume system.	
Published Limitations	The method is divided into four procedures related to the product's vapor pressure (A and C), and whether it is a gasoline (B) or aviation gasoline (D). The method is not applicable to LP or fuels with oxygenates other than MTBE.	
Provide Precision Information	10.1.1 *Repeatability*—The difference between successive test results obtained by the same operator with the same apparatus under constant operating conditions on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following value only in one case in twenty.	

	Range		Repeatability		
Procedure	kPa	psi	kPa	psi	
A Gasoline	35–100	5–15	3.2	0.46	Note 2
B Gasoline	35–100	5–15	1.2	0.17	Note 2
A	0–35	0–5	0.7	0.10	Note 3
A	110–180	16–26	2.1	0.3	Note 3
C	>180	>26	2.8	0.4	Note 3
D Aviation Gasoline	50	7	0.7	0.1	Note 3

10.1.2 *Reproducibility*—The difference between two, single and independent results, obtained by different operators working in different laboratories on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following value only in one case in twenty.

	Range		Reproducibility		
Procedure	kPa	psi	kPa	psi	
A Gasoline	35–100	5–15	5.2	0.75	Note 2
B Gasoline	35–100	5–15	4.5	0.66	Note 2
A	0–35	0–5	2.4	0.35	Note 3
A	110–180	16–26	2.8	0.4	Note 3
C	>180	>26	4.9	0.7	Note 3
D Aviation Gasoline	50	7	1.0	0.15	Note 3

NOTE 2—These precision values are derived from a 1987 cooperative program[4] and the current Committee D02 Statistical Method RR:D02-1007.

NOTE 3—These precision values were developed in the early 1950's, prior to the current statistical evaluation method.

Referenced Research Reports	RR:D02-1007 (on gasoline) Others predate current ASTM statistical methods.
SME Evaluation	The method is a fundamental test procedure, such that it measures the vapor pressure of the fluid. If the material is volatile, it will have vapor and the vapor will exert a pressure. This is a fundamental physics phenomenon. Therefore, the generation of the number is not specific to the chemical composition of the test fluid.

	As long as the correct procedure, in most cases either A or C is used, even the precision statement is likely to remain valid regardless of the fluid composition.
Other	• Crude oil can be measured with this method, but users are encouraged to use ASTM D6377. • An impact specific to the vapor pressure of aviation gasoline is provided. • This method is an absolute vapor pressure at 37.8 °C (100 °F) due to the presence of atmospheric air and water vapor as opposed to a true vapor pressure.

Impact Assessment:

Red Yellow Green

Specification Review

D381-12	STM for Gum Content in Fuels by Jet Evaporation	Original Publication Date: 1934
Specification Scope	Determine the amount of material, aka gum, remaining after a fuel is evaporated. For aviation fuel this is an existent gum, defined as evaporation residue. For non-aviation fuels, there are accommodations made for unwashed gum content. and solvent washed gum content which are residues remaining after a rinse with heptane.	
Published Limitations	Method is for use with aviation fuels, motor gasoline, and volatile distillates including alcohol and ether oxygenates (see comment on definition of petroleum products).	
Provided Precision Information	The precision statement specific to aviation gasoline and aviation turbine fuel: *Repeatability- AvGas:* r = 1.1 + 0.095 x where x = measured gum *AvTur:* r = 0.5882 + 0.2490 x *Reproducibility- AvGas:* R = 2.09 + 0.126 x *AvTur:* R = 2.941 + 0.2794 x	
Referenced Research Reports	RR:D02-1466	
SME Evaluation	The test will generate what it generates. The material that will evaporate at the measured test temperature is a physical phenomenon and observing differences in chemical composition are exactly for what the test method is used. The temperature at which the method is run is specific to the fuel type being analyzed but is likely defined by the usage temperature concerns. The applicability of any observed gum as compared to existing limits as the chemical composition diverged from traditional aviation turbine fuel could require further consideration. The impact of the increase in existent gum may or may not have a concomitant impact on performance due to the lack of an existing correlation between gum and turbine engine performance. There is a potential for the chemical composition of the alternatively produced fuel to contain non-volatile organic components materials similar to those requiring the heptane wash in the other fuels. The reason the heptane wash exists for the non-aviation fuels is because of the potential for materials that do not readily evaporate but which have been determined to be unimportant to the use of the fuel. If a similar component exists in the alternatively prepared jet fuel, further research could be required to determine whether a heptane wash is required and appropriate for use in aviation applications given a specific chemical composition.	

	Related to this caveat, is a caveat on the precision statements. As the chemical composition diverges from the traditional petroleum aviation turbine fuel, there is a potential for changes to the precision statements.
Other	• The ASTM method specifies the use of steam for the jet evaporation where the equivalent IP 540 does not. • This test is generally a handling control for aviation turbine fuel to indicate contamination by higher boiling oils and particulates. The significance of the amount of existent gum has not been otherwise established. • The test temperature is specific to the test fluid being tested, aviation turbine fuel is tested at 232 to 246°C bath, and 229 to 235 °C test well. • From HFP-HEFA Research report, Version 3, April 2017 HFP-HEFA Research Report, Version 3, April 2017: 2.2.6 **Existent Gum** All High Freeze Point HEFA blends that satisfy freezing point and viscosity requirements passed the existent gum test (Table 2-17). Some of the neat bioderived fuels, however, did not meet the maximum requirement of 7 mg/100 ml. Heptane wash of the residue brought the existent gum below the specification requirement. This behavior can be attributed to the incomplete evaporation of the High Freeze Point HEFAs rather than to the presence of insoluble gums. It is likely that the observed difference in evaporation rates between typical jet fuels and High Freeze Point HEFAs is due to the latter having higher molecular weight.

Impact Assessment:

Red Yellow Green

Specification Review

D613-16a	STM for Cetane Number of Diesel Fuel Oil	**Original Publication Date: 1941**
Specification Scope	Determine the rating in terms of the arbitrary cetane index of diesel fuel oil	
Published Limitations	Interferences: - UV light can induce chemical reactions that affect cetane rating - "Certain gases and fumes" may measurable affect rating (what those gases/fumes are is not immediately clear) - Method is not suitable for fuels that won't flow through a gravity flow nozzle	
Provided Precision Information	*Repeatability:* r = 0.8 cetane number when cetane = 40 r = 0.9 when cetane = 44 to 52 r = 1.0 when cetane = 56 *Repeatability:* R = 2.8 cetane number when cetane = 40 R = 3.3 to 4.3 when cetane = 44 to 52 R = 4.8 when cetane = 56	
Referenced Research Reports	RR:D02-1303	
SME Evaluation	While not specifically designed for kerosene/aviation turbine fuel, the method is based on measuring actual combustion behavior. As such the method is not likely to be affected by the chemical composition. However, how the reported value may correlate to actual operation is unknown and a stated limitation of the method.	
Other	• Cetane range is 1 to 100 but typical testing is 35-65 • Measures the ignition performance, AKA ignition delay of a diesel fuel oil compared to two bracketing reference fuels • Method may be used on unconventional fuels, but there is no known relationship to how that cetane number will behave in actual use.	

Impact Assessment:

Red Yellow Green

Specification Review

D873-12	STM for Oxidation Stability of Aviation Fuels (Potential Residue Method)	**Original Publication Date: 1946**
Specification Scope	Determine the potential for aviation gasoline, aviation turbine and jet engine fuels to form soluble and insoluble gums and deposits following oxidation.	
Published Limitations	Not intended for volatile components	
Provided Precision Information	Following a 16 hour oxidation test – *Repeatability:* r = 2 mg/100ml to 5 mg /100ml *Reproducibility:* R = 4 mg/100ml to 7 mg/100ml	
Referenced Research Reports	None	
SME Evaluation	This test method determines oxidation in an oxygen environment and is what it is. There are no formulas or correction of the results for jet fuel. It is designed for aviation gasoline and kerosene, and other petroleum products (see comment on definition of petroleum products) and it is unlikely the method is sensitive to chemical composition. The only issue could be if the fuel composition is comprised of a large volatile fraction. This is more of a safety issue than a data issue. There could be issues with the precision statement for compositions noticeably different from traditional chemistry.	
References	• Schwartz, FG; Albright, CS; & Ward, CC (Dec 1968) *Bureau of Mines Report of Investigations, Storage Stability of Gasoline* • White, EW (Aug 1994) *A Fuel Stability Study Filterable & Adherent Insolubles as a Function of Time*. ACS National Meeting, pp 938-942. • White, EW (Aug 1990) *A Fuel Stability Study: Total Insolubles as a Function of Time.* Symposium on the Stability and Oxidation Chemistry of Middle Distillate Fuels, Div of Fuels and Petroleum Chemistry ACS, pp 1184-91. • Ackerman, L. (1969) *Gum Formation in Cracked Gasolines*. Polytech Chemistry Engineering, Vol 13, No. 1-2, pp 29-39. • Stavinoa, LL; Bowden JN, LePera, ME (Dec 1990) *Evaluation of Motor Gasoline Stability, Interim Report BFLRF No. 266*	

Impact Assessment:

Red Yellow Green

Specification Review

D971-12	STM for Interfacial Tension of Oil Against Water by the Ring Method	**Original Publication Date: 1948**
Specification Scope	Determines the interfacial tension between mineral oil and water. **Target system – mineral oil and water. Designed to monitor insulating oils for oxidation and polar contamination.**	
Published Limitations	None	
Provided Precision Information	*Repeatability:* r = 0.04*X *Reproducibility:* R = 0.10 * X Where X equals the mean of measured values	
Referenced Research Reports	None	
SME Evaluation	The initial observation is that this method is specific to water/oil interface and it is not clear why the MIL-HBK uses this method D1331 Surface and Interfacial Tension of Solutions of Surface Active Agents, referenced in D4054. No surface tension requirements are listed in ASTM D1655 or D7566. The method does have the advantage over D1331 in that it calculates a value for F which D1331 requires but does not provide. The method is based on fundamental physics, the amount of force required to break free from the surface of the liquid. It should not be sensitive to chemical composition as long as an interfacial layer forms between the water and fuel.	
Other	• Method uses a duNuoy ring. The surface tension of a sample of distilled water is measured. Then a layer of oil is carefully layered onto the water. Then the interfacial tension is measured.	

Specification Review

Impact Assessment:

Red Yellow Green

D1094-07	STM for Water Reaction of Aviation Fuels	**Original Publication Date: 1950**
Specification Scope	Determine the presence of water miscible components in aviation gasoline and aviation turbine fuel and the effect on the volume at the interface between fuel and water.	
Published Limitations		
Provided Precision Information	Precision statement is for aviation gasoline and is "qualitative". A qualitative test does not have a statistical precision statement.	
Referenced Research Reports	None	
SME Evaluation	The test method would identify materials that do react and might disarm the filter/separators. The question would be whether there are things present in the alternatively produced fuel that do not react in the test but would disarm the filter/separator.	
Other	• Used in aviation turbine fuel to look for surfactants and things that disarm filter/separators. • D3948 is better for looking for surfactants	

Specification Review

Impact Assessment:

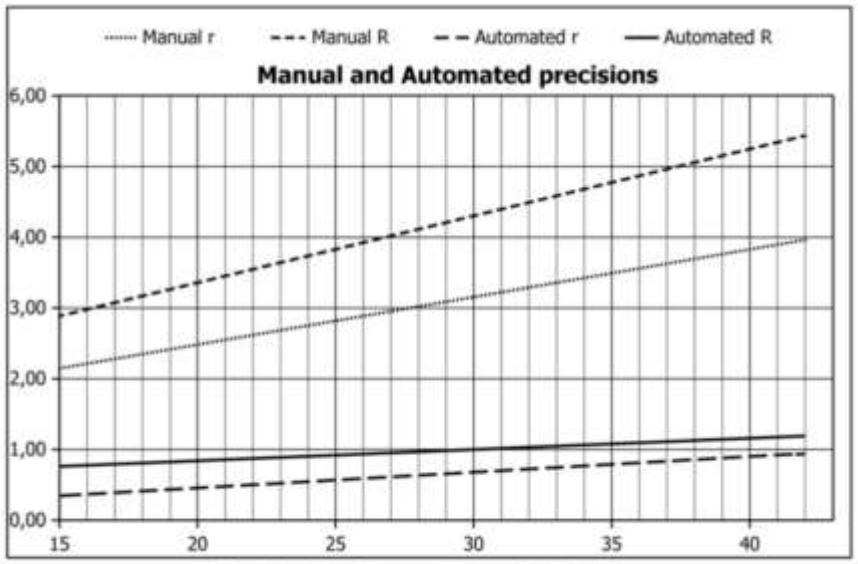
Red Yellow Green

D1266-13	STM for Sulfur in Petroleum Products (Lamp Method)	**Original Publication Date: 1953**
Specification Scope	Determine the concentration of total sulfur in a liquid petroleum by combusting the liquid and titrating the resulting sulfates.	
Published Limitations	For use in determining total sulfates from 0.01 to 0.4 mass %. For heavy products that do not completely burn, see ASTM D129, IP63, or D1552. Product must burn completely by wick. The liquid may be blended down to improve combustion. Any acid forming or base forming elements created during combustion will interfere.	
Provide Precision Information	*Repeatability:* r = 0.005 *Reproducibility:* R = 0.010 + 0.025 x (total sulfur content, mass %)	
Referenced Research Reports	No RR referenced	
SME Evaluation	While the chemistry principle on which the method is based is not affected by the composition, the peroxide and titration will react with what they react, the results may be dependent on the chemical composition. Any base or acid in the combustion products will be titrated, not just sulfates. This absence should be confirmed.	
Other	• Combusted in a controlled atmosphere, reacted with hydrogen peroxide to create sulfates, and then titrated with either sodium hydroxide or barium sulfate. • Corrections are provided for dealing with lead in leaded fuels.	

Impact Assessment:

Red Yellow Green

Specification Review

D1322-15	**STM for Smoke Point of Kerosine and Aviation Turbine Fuel**	**Original Publication Date: 1954**
Specification Scope	Determining the smoke point of a fuel using either a manual or an automatic tester by measuring how big a flame can be achieved before it smokes and compare it against known pure hydrocarbons.	
Published Limitations	Defines aviation turbine fuel "refined petroleum distillate" kerosene boiling between 140 and 300 °C. Precision statements are different between manual and automatic methods.	
Provided Precision Information	 FIG. 9 Graphical Representation of the Precisions	
Referenced Research Reports	RR:D02-1747 RR:D02-1178	
SME Evaluation	The test is based solely on the physics of flames and combustion, and is a fundamental analytical tool; it shows differences in fuel chemistry. There could be an impact on the bias calculation variables, M (manual results) and A (automated results), but not likely	
Other	• Method uses a "Diffusion flame" – a flame where the oxidizing material and fuel diffuse together as opposed to a premixed flame. It is a slow mixing. • High smoke point equates to low smoke producing fuel • It has been correlated to the presence of aromatics	

- Quantitatively related to radiant heat which impacts burner life.
- The referee method is the automatic method.
- Results are corrected for barometric pressure

Specification Review

Impact Assessment:

Red Yellow Green

D1331-14	STM for Surface and Interfacial Tension of Solutions of Paints, Solvents, Solutions of Surface-Active Agents, and Related Materials	**Original Publication Date: 1954**
Specification Scope	Determining the surface tension of aqueous and non-aqueous fluids, and the interfacial tension between two phases. Method covers both du Nouy Ring and Wilhelmy Plate	
Published Limitations		
Provided Precision Information	None provided	
Referenced Research Reports	None provided	
SME Evaluation	The test is an analytical method based on fundamental physics principles and would not be affected by chemical composition. It would be a measurement of chemical composition. The only challenge could be access to values for "F" and "d". If values are not published, the surface/interfacial tension cannot be calculated. Wilhelmy does not require corrections and could be used.	
Other	• Du Nouy method has a correction factor, "F" which is determined from the radii of the ring and V. ○ V = M/(D-d) ○ M is calculated from the readings, D is the fluid density and is measured, and d = the saturated air vapor from published data. With these three values, you go to a reference table (outside of the specification) and read off "F".	

Specification Review

Impact Assessment:

Red Yellow Green

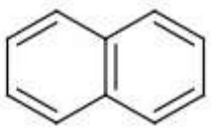
D1500-12	STM for ASTM Color of Petroleum Products (ASTM Color Scale)	**Original Publication Date: 1957**
Specification Scope	Visually determine the color of petroleum products (see comment on definition of petroleum products) with colors darker than Saybolt Colors	
Published Limitations	None	
Provided Precision Information	*Repeatability:* r = .5 color unit *Reproducibility:* R = 1 color unit	
Referenced Research Reports	RR:D02-1234	
SME Evaluation	The test gives an absolute color based on a comparison to a set of reference standards. The test becomes an indicator of chemical composition. Consideration of the method becomes important as alternative production methods result in darker colored fuels. Because the color is used as a gross indicator of quality, darker colored fuels could mean the meaning of the color becomes fuel composition specific.	
Other	• Method is for petroleum products darker than those measured using the Saybolt color scale. • Generally used for quality control and gross indication of contamination. It is not a reliable guide for composition. • Samples may be diluted with kerosine	

Impact Assessment:

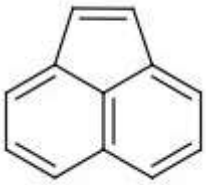
Red Yellow Green

Specification Review

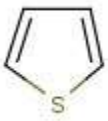
D1840-07 (2013)	**STM for Naphthalene Hydrocarbons in Aviation Turbine Fuels by UV Spectrophotometry**	**Original Publication Date: 1961**
Specification Scope	Determines the total concentration of naphthalene, acenaphthene, and alkylated derivatives of the target chemicals in jet fuel using ultraviolet spectrometry.	
Published Limitations	Limits content to a maximum of 5% of target compounds and a maximum boiling point of 315°C, with a homogeneous nature. Listed interferences – phenanthrenes, di benzothiophenes, biphenyls, benzothiophenes, and anthracenes.	
Provided Precision Information	*Repeatability:* $r = 0.0222 (1.00 + X)$ [Procedure A] $r = 0.056 (X^{0.6})$ [Procedure B] *Reproducibility:* $R = 0.0299 (1.00 + X)$ [Procedure A] $R = 0.094 (X^{0.6})$ [Procedure B] where X is the average volume % of two analyses	
Referenced Research Reports	RR:D02-1375 RR:D02-1525	
SME Evaluation	The method describes a fundamental analytical technique measuring an absorbance value of energy at a specified wavelength. It is what it is. For the method, 285 nm was selected as the value that will respond to the target compounds with enough sensitivity while limiting reactivity from other materials, for example thiophenes, pyrroles or phenolates. However, if there are other chemical compounds in the fuel that are active at 285 nm, they will cause a response even if they are not the target material. This may confound the results, especially if only the single wavelength is considered. If two fuels had the same volume % of naphthalene but it was comprised of two different isomers, the analysis could give different volume % results.	
Other	• Analysis done at a target wavenumber of 285 nm. • Example schematics of chemical moieties	



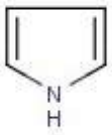
Naphthalene



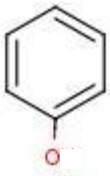
Acenaphthene



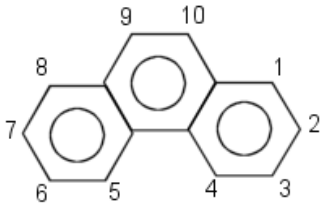
Thiophene



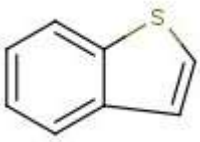
Pyrrole



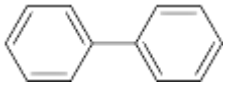
Phenolates



Phenanthrene



Benzothiophene



Biphenyl

Impact Assessment:

Red Yellow Green

Specification Review

D1903-08	Standard Practice for Determining the Coefficient of Thermal Expansion of Electrical Insulating Liquids of Petroleum Origin, and Askarels	**Original Publication Date: 1961**

Specification Scope	Determines the coefficient of thermal expansion of electrical insulating liquids containing PCBs and prepared from petroleum (see comment on the definition of petroleum).
Published Limitations	
Provided Precision Information	None
Referenced Research Reports	None
SME Evaluation	While the method is specifically designed for PCB containing insulating liquids, not for fuels, the method is based on directly measuring the expansion as measured by changes in relative density for changes in volume, both of which are used to determine CoTE (γ). Just based on the fundamental principle of the method, it is not likely the method will be impacted by changes in chemical composition. NOTE: the changes in density between the two temperatures need to be significant enough to be observed. It is recommended the applicability of the method be demonstrated.
Other	• From petroleum measurement tables in D1250, the coefficient of thermal expansion is assumed to be essentially equivalent for all petroleum oils with a density of 0.9659 to 0.8504. This method is to get higher precision than ASTM D1250. • Method calculates the CoTE by determining the observed relative densities at any two temperatures below 90 °C (194 °F) and between 5 and 14 °C (9 and 25 °F) apart. The difference may be used as the average CoTE. $$CoTE = \frac{(S - S_1)}{S\,(T_1 - T)}$$ Where S is the relative density at the lower temperature S_1 is the relative density at the higher temperature T = the lower temperature T_1 = the higher temperature • Askarels are polychlorinated biphenyl transformer oils (PCB).
Reference	Abhijit Kar Gupta, "Fundamentals of Physics I", www.scribd.com/doc/2280493/expansion of liquid, Accessed 01/2017

Specification Review

Impact Assessment:

Red Yellow Green

D2276-06 (2013)	STM for Particulate Contaminant in Aviation Fuel by Line Sampling	**Original Publication Date: 1964**
Specification Scope	In line measurement of particulates using a field monitor	
Published Limitations		
Provided Precision Information	*Repeatability:* r = 0.175x + 0.070 *Reproducibility:* R = 0.44x + 0.178 Where x = the average value of two results	
Referenced Research Reports	RR:D02-1197 The precision data was originally developed in 1966 by statistical examination of test results	
SME Evaluation	The gravimetric evaluation measures any change in mass to the filters. It is not sensitive to the chemical composition as long as the fuel is compatible with the filter. The color rating is based on a comparison to color standards. The comparison is a visual comparison and the execution of the test will not be sensitive to chemical composition. However, the interpretation of the color results may be sensitive to the chemical composition, given that there is no direct relationship between color and gravimetric measurements.	
Other	• Relates to ASTM D5452, laboratory gravimetric measurements (included in the review) • There is no relationship between gravimetric measurements and fuel color	

Specification Review

Impact Assessment:

Red Yellow Green

D2386 – 15	STM for Freezing Point of Aviation Fuels	**Original Publication Date: 1965**
Specification Scope	Manual method for determining the temperature at which the last crystal of material disappears when sample is warmed.	
Published Limitations	Test method is for aviation turbine fuel and aviation gasoline.	
Provided Precision Information	*Repeatability:* r = 1.5 °C *Reproducibility:* R = 2.5 °C	
Referenced Research Reports	RR:D02-1572 ILS was done with Jet A, Jet A-1, JP-5 and JP-8	
SME Evaluation	The method observes a fundamental physical chemical characteristic. At the most basic level, the test method provides information on chemical composition as opposed to be being sensitive to it. It is technically a melting point. However, there may be competing physical chemistry properties involved. Theoretically, thermal conductivity differences could change the cooling rates of the fuel, changing the temperature of the observed phase change. The cooling and warming rates are an important consideration when running the test and should be validated as the fuel chemistry changes. Theoretically, reactions with carbon dioxide evolved from the dry ice could cause changes in the temperature of the observed phase change.	
Other	• Method is visual and dependent on the ability of the operator to see phase changes in the sample. • Calcium sulfate or silica collars may be used to dry the samples. Entrained water can interfere with the observations	

Specification Review

Impact Assessment:

Red Yellow Green

D2549-02 (2012)	STM for Separation of Representative Aromatics and Nonaromatics Fraction of High-Boiling Oils by Elution Chromatography	**Original Publication Date: 1965**
Specification Scope	Method is used to separate hydrocarbons into aromatic and nonaromatic (polar and nonpolar) fractions.	
Published Limitations	Hydrocarbon mixtures should have a boiling range between 232 to 538 °C (450 and 1000 °F). This limit is due to steam evaporation step. *An alternative procedure for materials with an IBP < 232 °C (450 °F) but a 5% point > 178 °C (350 °F) is provided in an appendix.*	
Provided Precision Information	Alternative procedure does not have a precision statement	
Referenced Research Reports	None	
SME Evaluation	Bearing in mind the limitations of the method with respect to low-boiling fractions, the method itself is based on foundational analytical chemistry techniques. The method separates the hydrocarbon into polar and nonpolar fractions, therefore aromatic and nonaromatic fractions. Within the limits of the solvents being able to separate the chemical moieties within the sample based on this property, the method will separate the sample into polar and nonpolar fractions. This is a measurement of chemical composition, and the method execution not affected by the fuel source. Ability to separate the eluted fractions from the eluent should be confirmed.	
Other	• Separation method is called out in ASTM D2425. The limitation of boiling range may make it unsuited for jet fuel, due to the inability to separate the carrier solvent from the light ends of the jet fuel. ○ An alternative method is provide in X.1 for some lower boiling hydrocarbon mixtures. • Aromatics are desorbed with polar eluents (diethyl ether, chloroform, and ethyl alcohol). Nonaromatics eluted with n-pentane.	

Impact Assessment:

Red Yellow Green

Specification Review

D2622-16	STM for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry	**Original Publication Date: 1967**
Specification Scope	Determine the total sulfur in a liquid petroleum using XRF	
Published Limitations	Petroleum or petroleum product, single phase, and a liquid at room temperature or liquefiable, with a maximum of 4.6 mass % sulfur Interferences – phosphorus, zinc, barium, lead, calcium, chlorine, oxygen, FAME, ethanol, and methanol	
Provided Precision Information	*Repeatability:* $r = 0.1462\ X^{0.8015}$ mg/kg $r = (0.1462\ ((Y*10000)^{0.8015}) / 10000$ mass % *Reproducibility*: $R = 0.4273\ X^{0.8015}$ mg/kg $R = (0.4273\ ((Y*10000)^{0.8015}) / 10000$ mass % Where X is sulfur concentration in mg/kg and Y is sulfur concentration in mass percent.	
Referenced Research Reports	RR:D02-1622 Study of 27 samples across petroleum types. Between 1987 and 2016 a significant amount of precision work was performed. The current version of the specification has 12 pages of discussion. In 1987 there were three pages.	
SME Evaluation	XRF is a fundamental analytical principle. The instrument responds to materials fluorescing at the designated wavelength (optimally 0.537 nm). This wavelength has been determined to be sensitive to sulfur. As long as there are no constituents which also fluoresce at 0.537 nm, (see indicated interferences), the response is attributed to sulfur. It may be necessary to confirm there are no moieties present in the chemical composition that fluoresce in the sulfur range. Section 12.2 contains a correction factor for mismatched matrices and is based on a pure chemical graph of relationships of carbon/hydrogen versus sensitivity. This further suggests the relationship is hydrocarbon source agnostic.	
Other	• Method requires a calibration curve to convert measured fluorescence to a concentration. • The calibration matrix described is a white mineral oil. If necessary to match matrices, a surrogate may be prepared from laboratory solvents.	

Specification Review

Impact Assessment:

Red Yellow Green

D2710-09 (2013)	STM for Bromine Index of Petroleum Hydrocarbons by Electrometric Titration	**Original Publication Date: 1968**
Specification Scope	Measure bromine reactive species in "petroleum hydrocarbons", therefore measuring trace unsaturates.	
Published Limitations	Maximum bromine index < 1000 Only to be used for olefin free hydrocarbons (aka alkenes), free from materials lighter than isobutene (C_4), with a distillation endpoint < 288 °C (550 °F)	
Provided Precision Information	*Repeatability:* r = 14 bromine index numbers ∴14 mg/100 *Reproducibility*: R = 118 bromine index numbers ∴ 118 mg/100	
Referenced Research Reports	Precision data was not prepared in accordance with RR:D02-1007 and the source is not provided.	
SME Evaluation	This method begins with the assumption that there are no olefins present normally. If the fuel IS expected to have or might have olefins, then either don't use bromine index because it is non-probative, or use bromine number. The method is a titration to an electrically measured end point. Anything that will react with the bromide-bromate solution will be titrated. The method measures a fundamental chemistry property, so as long as the chemical composition contains only trace olefins or there are no other moieties that could react, the method should not be affected by the chemical composition of alternatively produced fuels.	
Other	• Bromine Index is mg/100, the bromine consumed by a 100g sample Bromine Number is g/100 You can go from bromine index to bromine number by dividing by 1000, but you may NOT go from bromine number to bromine index.	

Specification Review

Impact Assessment:

Red Yellow Green

D2717-95 (2009)	STM for Thermal Conductivity of Liquids	**Original Publication Date: 1968**
Specification Scope	Thermal conductivity is determined by measuring the temperature gradient produced across the liquid.	
Published Limitations	Non-metallic liquids, that are non-reactive with borosilicate and platinum, and which are moderately IR transparent or absorbent and have a vapor pressure < 200 torr (3.9 psi).	
Provided Precision Information	No ILS has been performed due to the cost of the equipment. *Repeatability:* Reported as being essentially equivalent to 10% of the mean.	
Referenced Research Reports	None	
SME Evaluation	The method is a fundamental chemistry method measuring transmission of thermal energy across a fluid. As long as the limitations of the method on the fluid are met, particularly vapor pressure, there is nothing in the method that would be constrained by the chemical composition of liquid.	
Other	• In testing reported in the IPK/A research report, SwRI indicated that thermal conductivity has proved to be very difficult to measure on liquids. Over the last 17 years since the first Sasol IPK evaluation, it has been difficult to find laboratories that can perform the D2717 method. SwRI now uses the new ASTM D7896 test method, a transient hot-wire method (not a method reviewed in this project).	

Impact Assessment:

Red Yellow Green

Specification Review

D2779-92 (2007)	**STM for Estimation of Solubility of Gases in Petroleum Liquids**	**Original Publication Date: 1969**
Specification Scope	Determine the solubility of several common gases into petroleum liquids.	
Published Limitations	Density 0.63 < ρ < 0.90 at 288 K (59 °F) Method covers -50 °F to 302 °F The Oswald coefficient values provided in the method for methane, hydrogen sulfide, ammonia, carbon dioxide, and ethylene are not valid values for highly aromatic liquids. Method assumes the material can be considered ideal within the limits of the test (not using fugacity).	
Provided Precision Information	The precision discussion is gas specific. Some are pretty extreme like xenon which has an R = 123% difference between estimated and measured values. The estimated values for the components of air as compared to measured values: R nitrogen gas = 76%, oxygen = 44%. For air, R = 28% different.	
Referenced Research Reports	RR:D02-1129	
SME Evaluation	The method is based entirely on empirical values and calculations and no actual measurements are made. The only warning is for the specific Oswald coefficients not being valid when the fluid is highly aromatic. This is a composition sensitive issue. Beyond the assumptions, (i.e. ideal gas, Oswald density corrections), the method should be insensitive to the chemical composition, as long as the composition is basically hydrocarbon in nature. The assumptions do, however, result in a measurable variability in values. Given the range of potential error in the estimates, confounding the estimate with chemistry composition that diverges from traditional composition may be a source of concern. On the other hand, the more simple nature of the chemical compositions of alternatively prepared fuels may result in less error in the estimates. In general, it is difficult to make an educated comment on the sensitivity of the method to the fluid composition but is most likely not sensitive.	

Other

- Calculations are based on Clausius-Claypeyron, Henry's Law, and the ideal gas law.

  Clausius-Claypeyron characterized discontinuous phase transition. Used to predict vapor pressure. L= latent heat, S= entropy, Δv = change in volume

  $$\frac{dP}{dT} = \frac{L}{T\Delta v} = \frac{\Delta S}{\Delta v}$$

  Henry's Law, P = partial pressure above solution, C = concentration of gas in the solution, and Henry's constant for the solution.

  $$P = K_H C$$

  Ideal gas law

  $$PV = nRT$$

  P = pressure, for non-ideal gases this is fugacity.

- Also uses the Bunsen coefficient, α (solubility of a gas as a volume in 1 liter @ 32 °F and 1 atm), and the Oswald coefficient, β (solubility of a gas dissolved in 1L of solvent at equilibrium)
  - From NACA Tech Note 3276 (1956), p23

    $$\alpha = \beta * \frac{492}{T\ °Rankin}$$

- Method takes the density of the liquid at 59 °F and the nature of the gas to obtain L (latent heat).
  - Determine ρ by ASTM D1298.
  - Determine L_o from the table in the method
  - Determine L from Figure 1 in the method
- The Oswald correction to other densities is based on a constant of 0.98. The constant is based on the intermolecular volume of hydrocarbons.

References

- (1956) NACA Technical Note 3276
- Ridenour, W., Weatherford, W., & Capell, R. (1954). Solubility of Gases in Molten Paraffin and Microcrystalline Waxes. *Industrial and Engineering Chemistry*, 46 (11), 2376-2381.

Specification Review

Impact Assessment:

Red Yellow Green

D2879-10	STM for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope	**Original Publication Date: 1970**
Specification Scope	Determining the vapor pressure and decomposition temperature of pure chemicals and mixtures This specifically includes petroleum products.	
Published Limitations	Vapor pressures must be between 1.0 and 760 torr. Test temperature should be between ambient and 748 °K (475 °C) but can be run below ambient with a suitable temperature bath.	
Provided Precision Information	No precision studies have been completed.	
Referenced Research Reports	None	
SME Evaluation	The test method is based on fundamental physics where the vapor pressure of the sample is balanced against an inert gas. The vapor pressure is corrected for reporting, but it is a mathematical relationship and not based on the chemistry of the specimen.	
Other	• None	

Impact Assessment:

Red Yellow Green

Specification Review

D2887-16	STM for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography	Original Publication Date: 1973

Specification Scope	Determine the distillation range for a liquid petroleum using gas chromatography
Published Limitations	Liquid "petroleum products" with an initial boiling point > 55 °C (100 °F) and a final boiling point < 583 °C (1000 °F). Method cannot be used with gasoline
Provided Precision Information	Procedure A and Procedure B have separate precision statements. Procedure A TABLE 5 Repeatability Note 1—x = the average of the two results in °C and y = the average of the two results in °F. Repeatability % Off / °C / °F IBP 0.011 x 0.011 (y - 32) 5 % 0.0052 (x + 100) 0.0032 (y + 146) 10 %–20 % 0.8 1.4 30 % 0.8 1.4 40 % 0.8 1.4 50 %–90 % 1.0 1.8 95 % 1.2 2.2 FBP 3.2 5.8 TABLE 6 Reproducibility Note 1—x = the average of the two results in °C and y = the average of the two results in °F. Reproducibility % Off / °C / °F IBP 0.066 x 0.066 (y - 32) 5 % 0.015 (x + 100) 0.015 (y + 146) 10 %–20 % 0.015 (x + 100) 0.015 (y + 146) 30 % 0.013 (x + 100) 0.013 (y + 146) 40 % 4.3 7.7 50 %–90 % 4.3 7.7 95 % 5.0 9.0 FBP 11.8 21.2 Procedure B **TABLE 13 Repeatability and Reproducibility, Procedure B (Accelerated D2887) Test[A,B]** % Mass / Repeatability, *r* (°C) / Repeatability, *r* (°F) / Reproducibility, *R* (°C) / Reproducibility, *R* (°F) IBP 2.94 5.29 7.97 9.52 5 %– 95 % 0.000857 (X+ 500) 0.000857(X+ 868) 0.00449(X+500) 0.00449(X+868) FBP 3.32 6 7.63 10.8
Referenced Research Reports	RR:D02-1407 RR:D02-1477 RR:D02-1761
SME Evaluation	The method does have a significant amount of calculations and correlations but they are related to the GC operation, not to the fuel characterization. Therefore, as long as the test method is followed and the test fuel does not contain any polar compounds that might not be eluted by the column, the method should be fuel chemistry agnostic. It would be prudent for a fuel offeror to demonstrate sufficient eludation in application. While it is not generally practical

	to compare the results from this method to D2892, demonstration that the method is sufficient is required by the D4054 review process. There is a correction factor for moving from Procedure B to A that was generated experimentally. There is no scientific reason to suggest this correction would be impacted by the chemical composition of alternatively prepared jet fuel. There is a known deviation for non-paraffinic boiling points. It is a chemistry behavior related to the atmospheric pressure and is also seen in D2892. Synthetic aromatics or synthetic fuels with a high non-paraffinic component should consider this deviation. The specification has a correlation study to D86 which was performed specifically for jet fuel. This is a mathematical correlation based on actual measurements. This correlation WOULD be fuel specific and should not be used on synthetic jet fuel without a repeat of the study to validate the correlation coefficients.
Other	• The IBP and FBP are based on the total GC chromatograph peak area. IBP is defined as being when 0.5% of the peak area is reached. FBP is when 99.5% of the peak area is reached. • Method uses a non-polar column heated at a linear rate • Conversion of the GC retention time to a boiling range is done by comparison to known hydrocarbon mixtures. • Results are determined to be equivalent to the true boiling point determined by ASTM D2892 but not equivalent to D86 or D1160 • Procedure A is slow. Procedure B is fast and is also designated for use with FAME and biodiesel.

Impact Assessment:

Red Yellow Green

Specification Review

D2892-15	STM for Distillation of Crude Petroleum (15-Theoretical Plate Column)	**Original Publication Date: 1970**
Specification Scope	Determine the distillation properties of a petroleum product using fractionized distillation	
Published Limitations	RVP < 82.7 kPa (12 psi) and initial boiling point < 400 °C (752 °C)	
Provided Precision Information	*Repeatability:* r = 0.6 mass % at atmospheric pressure r = 0.9 mass % at 13.33 kPa and 1.33 kPa vacuum pressure *Reproducibility:* R = 13.3 mass % at atmospheric pressure R = 1.5 mass % at 13.33 kPa vacuum pressure R = 2.0 mass % at 1.33 kPa vacuum pressure	
Referenced Research Reports	RR:D02-1705	
SME Evaluation	This is a fundamental laboratory method and is used ubiquitously with liquid petroleum products and in other industries. Therefore there should be no sensitivity in the method to the chemical composition of the alternatively produced jet fuels. The specification method itself is specifically written with the fractionation of crude oil in mind, so adjustments in operation may be required. These adjustments are unlikely to be any different than those required to use the method on traditional petroleum products and would be within a trained operator's capability. The presence of excess water can interfere with the fractionation, so if the formula had excessive water content it may require drying. This is necessary to get accurate results in the light naphtha range.	
Other	• Method uses a fractionation process to repeatedly heat and cool the rising gas to obtain more completely separated fractions. The "little bit" of fraction A that gets carried up into fraction B, gets separated out and sent back to fraction A. This as opposed to a simple distillation like ASTM D86 where the amount collected at each temperature still has the little bit of A in the B fraction. • Every time the fluid goes around, the A+B is cooled a little bit to separate A +B further, is a theoretical plate. • The pressure in the distillation rig will change with temperature so the temperature measured must be corrected to atmospheric pressure. • In 2001 the formulas related to the atmospheric equivalent temperature were corrected.	

Impact Assessment:

Red Yellow Green

Specification Review

D3120-08 (2014)	STM for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry	**Original Publication Date: 1972**
Specification Scope	Determine the amount of sulfur in the range of 3 to 1000 mg/kg (ppm) by converting sulfur to SO_2 by pyrolytic oxidation and then titrating with I_3.	
Published Limitations	Light liquid hydrocarbons and fuels with oxygenates boiling between 26 to 274 °C (80 to 525 °F) Method is designed for gasoline and diesel. Interferents: halides present at > 10x sulfur, nitrogen present at >1000x sulfur, and lead, nickel and vanadium present at > 500ppm.	
Provided Precision Information	Developed from two separate ILS. The fuel types in the first (Case I) are not provided. The second (Case II) was for low sulfur gasoline and diesel. *Repeatability:* $r = 0.2802\ X^{(0.7901)}$ for Case I $r = 0.08520\ (X + 0.65758)$ for Case II diesel *Reproducibility:* $R = 0.5793\ X^{(0.7901)}$ for Case I $R = 0.5152\ (X + 0.65758)$ for Case II diesel Where X is the average of two test results.	
Referenced Research Reports	RR:D02-1036 (Case I) RR:D02-1546 (Case II)	
SME Evaluation	The method is based on fundamental pyrolysis and titration chemistry. Care must be taken to pyrolyze the sample appropriately. As long as the solvent and calibration standards are chosen to match the fuel, the method should not be affected by the chemical composition within the limits of the interferences, and that the sulfur is not present as or converted to sulfates. Users of the method should also recognize the method was primarily developed for gasoline and diesel type products. Any modifications or considerations made would likely be the same whether the material was traditional petroleum based fuel or alternatively produced.	
Other	• Method uses a test generated calibration curve; the operator has to know the linear region of the test. • Combustion rates and incomplete oxidation are primary concern as indicated by the number of notes in the method. • Sulfate SO_3 doesn't titrate.	

Specification Review

Impact Assessment:

Red Yellow Green

D3227-13	STM for (Thiol Mercaptan) Sulfur in Gasoline, Kerosine, Aviation Turbine, and Distillate Fuels (Potentiometric Method)	**Original Publication Date: 1973**
Specification Scope	Measures mercaptan sulfur present between 0.0003 and 0.01 mass %	
Published Limitations	Elemental sulfur < 0.0005 mass % Hydrogen sulfide interferes When methyl mercaptan or heavier thiols are present, results may be erratic and running the test at 4°C (25 °F) may be required.	
Provided Precision Information	*Repeatability:* r = 0.00007 + 0.027X *Reproducibility:* R = 0.00031 + 0.042X Where X = average mercaptan sulfur, mass %	
Referenced Research Reports	Statistical analysis of an ILS but no research report referenced.	
SME Evaluation	Titration is a fundamental chemistry test and should not be affected by chemical composition, but rather will display chemical composition. As long at the test fuel does not contain species which also react with silver nitrate, the test should not be affected by the chemical composition. The data is a direct measurement of mass of silver nitrate required to titrate to a potentiometric endpoint. The test method does reference ASTM D1250 petroleum measurement tables for density. This means there must be a reasonable expectation the alternatively produced fuel has essentially equivalent thermal expansion characteristics as traditional petroleum fuels. To date there is no reason to expect different PVT behavior.	
Other	• Sample is dissolved in alcoholic sodium acetate and reacted with silver nitrate, then titrated potentiometrically. • Method suggests that peroxides may be an interferent but this may be related to the formation of peroxides in the alcohol. • Example structures  R-SH Thiophene Mercaptan	

Specification Review

Impact Assessment:

Red Yellow Green

D3242-11	STM for Acidity in Aviation Turbine Fuel	**Original Publication Date: 1973**
Specification Scope	Measure the trace acid content of an aviation turbine fuel by coulometric titration	
Published Limitations	Total acid content should be between 0.000 to 0.100 mg/KOHg	
Provided Precision Information	ILS only performed on the manual method.	
Referenced Research Reports	RR:D02-1626 RR:D02-1010	
SME Evaluation	Method is based on fundamental chemistry property of acid-base reaction, titrated to an endpoint. As long as there are no components that will react with KOH or which interfere with the reaction between the H^+ and the OH^-, the method should not be sensitive to the chemical composition	
Other	• Solvent with sample is titrated with potassium hydroxide to a color endpoint • Uses a specification specific concept of pHr which is a measure of hydrogen activity based on the indicator in the same way as pH.	

Average Acid Number	Repeatability	Reproducibility
0.001	0.0004	0.0013
0.002	0.0006	0.0018
0.005	0.0009	0.0029
0.010	0.0013	0.0041
0.020	0.0019	0.0057
0.050	0.0030	0.0091
0.100	0.0042	0.0128

[A] These precision data were derived as follows:

Repeatability $= 0.0132\sqrt{a}$

Reproducibility $= 0.0406\sqrt{a}$

where: a = acid number

Specification Review

Impact Assessment:

Red Yellow Green

D3703-13	STM for Hydroperoxide Number of Aviation Turbine Fuels, Gasoline and Diesel Fuels	**Original Publication Date: 1978**
Specification Scope	Determines the amount of hydroperoxide present by reaction with potassium iodide and titrated with sodium thiosulfate.	
Published Limitations	Does not detect sterically-hindered hydroperoxides The peroxide level should be between 0 to 50 mg/kg active oxygen as H_2O_2.	
Provided Precision Information	Biodiesel samples experienced wide variation within and between labs. *Repeatability:* $r = 0.2829\ X + 0.0001^{0.6596}$ *Reproducibility:* $R = 2.3046\ X + 0.0001^{0.6596}$ Where X = the hydroperoxide number	
Referenced Research Reports	RR:D02-1630	
SME Evaluation	The method is based on the chemistry concept of reacting a peroxide with an iodide, and of titration. These are fundamental concepts that measure composition and are not directly affected by composition. As long as the chemical composition does not contain or form hindered peroxides, and any hydroperoxides that are present react with KI, there is no scientific reason to expect the test to be chemical composition sensitive. There is a caveat in that there is something about biodiesel that causes measurable variability. If there is a relationship between the fuel composition of alternatively produced jet fuel and biodiesel, then there may be a limitation to the method.	
Other	•	

Specification Review

Impact Assessment:

Red Yellow Green

D3828-16	STM for Flash Point by Small Scale Closed Cup Tester	**Original Publication Date: 1979**
Specification Scope	Measures flash point on petroleum products with a flash point of -30 ° to 300 °C (-22 ° to 572 °F) using a closed cup tester	
Published Limitations	Biodiesel requires an electronic thermal flash detector.	
Provided Precision Information	*Repeatability:* r = 0.01520 (x + 110) °C *Reproducibility:* R = 0.02561 (x = 110) °C Where x = the mean of two results	
Referenced Research Reports	Research Report IP 523/10 (Energy Institute) RR:S15-1010 (for reference materials)	
SME Evaluation	The test method is based on fundamental physical chemistry. The vapors will ignite when there is an appropriate air/vapor ratio. The instrument measures a physical property of combustion. There is no relationship between the value observed and the operation of the test. The method measures differences in chemical composition and will not be sensitive to fuel chemistry in operation. The only caveat is that depending on the composition, the electronic thermal flash detector may be required.	
Other	• Method is a measure at a single point. The tester is set to a temperature, the sample injected and a test run. For a different temperature, the instrument is cleaned and a new test is run at a new temperature. • Definition of D3828 flashpoint is when the vapors ignite as opposed to an instantaneous flame across the surface. • Data corrected for barometric pressure • Method can be used with solids and liquids.	

Specification Review

Impact Assessment:

Red Yellow Green

D4045-15	STM for Sulfur in Petroleum Products by Hydrogenolysis and Rateometric Colorimetry	**Original Publication Date: 1987**
Specification Scope	Sulfur content is determined by pyrolysis of the sample in hydrogen (hydrogenolysis) creating H_2S followed by colorimetric titration with lead acetate.	
Published Limitations	Sulfur content between 0.02 mg/kg to 10.00 mg/kg and boiling point from 30 to 371 °C (86 to 700 °F). Materials that can be analyzed include naphtha, kerosene, alcohol, steam condensate, various distillates, jet fuel, benzene and toluene.	
Provided Precision Information	*Repeatability:* $r = 0.16\sqrt{x}$ *Reproducibility:* $R = 0.26\sqrt{x}$ Where x = average of two results mg/kg	
Referenced Research Reports	RR:D02-1405	
SME Evaluation	The method is based on fundamental reaction chemistry. As long as there is nothing in the fuel composition that would also react with lead acetate, and the fuel will appropriately pyrolyze, the test should not be sensitive to fuel chemistry.	
Other	• None	

Specification Review

Impact Assessment:

Red Yellow Green

D4057-12	Standard Practice for Manual Sampling of Petroleum and Petroleum Products	**Original Publication Date: 1981**
Specification Scope	Provides general sampling guidance on all petroleum products from crude to finished petroleum products.	
Published Limitations	None	
Provided Precision Information	Not applicable	
Referenced Research Reports	Not applicable	
SME Evaluation	As long as the compatibility considerations discussed in this and ASTM D4306 & D5842 are made, there is nothing in the Practice which should be sensitive to the chemical composition of alternatively produced jet fuels.	

Other	• Document discusses all the types of sampling to be taken, how to locate the sample, and the equipment required to take the samples. It also discusses general container selection and cleaning.
	  ○ The guide is to be used in conjunction with ASTM D4306 (Cleaning cans) when sampling aviation fuel.
	  ○ The guide is to be used in conjunction with ASTM D5842 (volatile samples) when sampling for precise volatility measurements.	

Specification Review

Impact Assessment:

Red Yellow Green

D4176-04 (2014)	STM for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures	**Original Publication Date: 1982**
Specification Scope	Visual inspection for free water and particulates	
Published Limitations	Final boiling point < 400 °C ASTM color of 5 or less	
Provided Precision Information	*Repeatability:* none – Procedure 1 (pass/fail) r = 1 Procedure 2 *Reproducibility:* none – Procedure 1 (pass/fail) R = 2 Procedure 2	
Referenced Research Reports	Report on the determination is available from ASTM but no research report number is provided.	
SME Evaluation	As long as the limitations of FBP and color are not exceeded, the only other potential impact of fuel chemistry may be viscosity. If a vortex is not appropriately formed, it could be difficult to see free water or sediment. In general the method should not be sensitive to chemical composition.	
Other	• Method has two procedures: ○ 900 ml into 1L jar for visual clarity ○ 900 ml into 1L jar with a bar chart and photo standards	

Impact Assessment:

Red Yellow Green

Specification Review

D4294-16	STM for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry	**Original Publication Date: 1983**
Specification Scope	Determines the total sulfur in petroleum and petroleum products using XRF.	
Published Limitations	Petroleum or petroleum products, that are a single phase and are liquid at room temperature or liquefiable with heat or solvent, and a sulfur content between 20 mg/kg and 4.6 mass%. Specifically covered materials include diesel fuel, jet fuel, kerosine, other distillate oil, naphtha, residual oil, lubricating base oil, hydraulic oil, crude oil, unleaded gasoline, gasoline-ethanol blends, biodiesel and similar products. Evaporation of light ends affects precision. Interferences – phosphorus, zinc, barium, lead, calcium, chorine, ethanol, methanol and FAME, silicon, and halides. Water can interfere by intensifying the X-rays.	
Provided Precision Information	*Repeatability:* $r = 0.4347\ X^{0.6446}$ mg/kg $r = (0.4347\ ((Y*10000)^{0.6446})/10000$ mass % *Reproducibility:* $R = 1.9182\ X^{0.6446}$ mg/kg $R = (1.9182\ ((Y*10000)^{0.6446}) / 10000$ mass % Where X = sulfur in mg/kg and Y = sulfur in mass %	
Referenced Research Reports	RR:D02-1635	
SME Evaluation	XRF is a fundamental analytical principle. The instrument responds to materials fluorescing when bombarded by x-ray (wavelength to monitored is not provided). As long as there are no constituents in the alternatively prepared fuel which also fluoresce at the monitored wavelength, (see indicated interferences), the response is attributed to sulfur. It may be necessary to confirm there are no moieties present in the chemical composition that fluoresce in the sulfur range. The precision statements may be affected and continued compliance to the precision statements could require demonstration. If the sample has a greater propensity to hold water, the results may be skewed high. Calibration standards are created by standard analytical techniques, so as long as the matrices match, the method should not be sensitive to the chemical composition.	
Other	• Calculations and conversion to sulfur content as compared to a calibration curve is performed by instrument software as opposed toD2622.	

Specification Review

Impact Assessment:

Red Yellow Green

D4305-98a (2004)	Standard Test Method for Filter Flow of Aviation Fuels at Low Temperatures	**Original Publication Date: 1983**
Specification Scope	Determine low temperature behavior through a screen type filter.	
Published Limitations	Fluids with a higher than 5 mm^2/s (cSt) viscosity at -20°C do not give equivalent freeze point values.	
Provided Precision Information	*Repeatability* r = 0.53°C for procedure A r = 1.2°C for procedure B *Reproducibility* R = 2.21 °C for procedure A R = 2.6°C for procedure B	
Referenced Research Reports	D02-1216 D02-1385 D02-1168	
SME Evaluation	The test method is based on the physical behavior of a fluid through a screen. This part of the procedure is independent of the fuel chemistry. However, the correlations to ASTM D2386 would be dependent on the fluid chemistry and new correlations would need to be prepared.	
Other	• **Method was withdrawn in 2012** • Test method was a procedure for determining simulated freezing point for aviation fuel using a mesh screen. • Used to investigate the formation of wax crystals or cold flow properties of other products.	

Specification Review

Impact Assessment:

Red Yellow Green

D4306-15	SP for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination	**Original Publication Date: 1984**
Specification Scope	Practice for preparing sample containers for contamination sensitive tests	
Published Limitations	None	
Provided Precision Information	Not applicable	
Referenced Research Reports	RR:D02-1169, D02-1142, and D02-1504	
SME Evaluation	As long as all of the qualification tests described in the specification have been completed to demonstrate general compatibility, the practice should not be sensitive to chemical composition.	

Other	• Method developed from SAE MAP1794
	• Goal is to not add or remove any materials from the fuel sample.
	• Tests of concern –
	  ○ Water separation
	  ○ Copper corrosion
	  ○ Electrical conductivity
	  ○ Thermal stability
	  ○ Lubricity
	  ○ Trace metal content
	• Have to demonstrate epoxy coating is compatible per the specification	

Impact Assessment:

Red Yellow Green

Specification Review

D4809-13	STM for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)	**Original Publication Date: 1988**
Specification Scope	Determination of heat of combustion of hydrocarbon fuels using a bomb calorimeter at constant pressure.	
Published Limitations	Method specifically designed for aviation turbine fuels, but is applicable to gasolines, kerosines, Nos. 1 and 2 fuel oil, Nos. 1-D and 2-D diesel fuel and nos. 0-GT, 1-GT and 2-GT gas turbine fuels. Assumes the fuel contains only carbon, hydrogen, oxygen, nitrogen and sulfur. Pure compounds require thermodynamic corrections.	
Provided Precision Information	Precision statements were developed for "fuels", non-volatile and volatile. *Repeatability:* r = 0.096 MJ/kg "fuels" r = 0.099 MJ/kg non-volatile r = 0.091 MJ/kg volatile *Reproducibility:* R = 0.324 MJ/kg "fuels" R = 0.234 MJ/kg non-volatile R = 0.450 MJ/kg volatile *Bias:* Method has a bias of 0.089 MJ/kg	
Referenced Research Reports	RR:D02-1229	
SME Evaluation	Bomb calorimetry is a standard analytical method based on fundamental physical chemistry properties. As long as the entire procedure is followed, the results are what they are. There are known thermal dynamic corrections which should be considered for alternatively produced fuels with chemical compositions more like pure chemicals. In addition "foreign hydrocarbon effects" should be considered. This may be impurities in the reference. The precision statements will not be valid and may require new analyses for each class of alternative chemical compositions. For fuels to D1655, both the mass and the volumetric heat of combustion should be evaluated due to potential differences due to density differences.	
Other	• Use of better temperature controls improved D4809 over ASTM D240. • Foreign hydrocarbons can cause significant effects to the measured value.	

Specification Review

Impact Assessment:

Red Yellow Green

D4952-12	STM for Qualitative Analysis for Active Sulfur Species in Fuels and Solvents (Doctor Test)	**Original Publication Date: 1989**
Specification Scope	Detection of mercaptans by reaction with Na_2PbO_2 and sulfur. May also give information on hydrogen sulfide and elemental sulfur.	
Published Limitations	Peroxides give false positives	
Provided Precision Information	None – pass/fail test	
Referenced Research Reports	Not applicable	
SME Evaluation	This is a standard spot test based on fundamental reaction chemistry. As long as there are no peroxides or other reactive species in the fuel chemistry, the test should not be sensitive to the chemical composition of alternatively produced jet fuel.	
Other	• Sample is shaken with Na_2PbO_2 and then with elemental sulfur. If there is a color change, than mercaptans or hydrogen sulfide are present.	

Specification Review

Impact Assessment:

Red Yellow Green

D4953-15	STM for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)	**Original Publication Date: 1989**
Specification Scope	Method is a modification of the Reid vapor pressure test. It measures the vapor pressure of the sample vapors and trapped air. It is not a true vapor pressure test.	
Published Limitations	Applicable to gasolines and gasoline blends with vapor pressure 5 to 15 psi.	
Provided Precision Information	Analysis included one JP-4 sample. *Repeatability:* r = 0.53 psi Procedure A r = 0.58 psi Procedure B – gauge r = 0.31 psi Procedure B – Herzog r = 0.52 psi Procedure B – Precision Scientific *Reproducibility:* R = 0.80 psi Procedure A R = 0.78 psi Procedure B – gauge R = 0.42 psi Procedure B – Herzog R = 0.62 psi Procedure B – Precision Scientific	
Referenced Research Reports	RR:D02-1286	
SME Evaluation	Given the restrictions of the samples to be run by this method, it seems unlikely a jet fuel would meet the limitations and be tested by this method. The method is listed in D1655. With respect to the method, as long as the methodology is precisely followed, there is nothing about the method that should be affected differently based on chemical composition. There is no precision statement for traditionally produced jet fuel, so there is no precision statement to be impacted by changes in chemistry.	
Other	• Two procedures are covered, A which is manual and B which is semi-automatic (rig rotates in the bath).	

Specification Review

Impact Assessment:

Red Yellow (Green)

D5006-11 (2016)	STM for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels	**Original Publication Date: 1989**
Specification Scope	FSII, especially di-EGME is extracted into a fixed volume of water and measured by refractometry	
Published Limitations	Isopropanol interferes due to a similar refractive index to water.	
Provided Precision Information	*Repeatability:* r = 0.009 vol % refractometer r = 0.005 vol % Brix *Reproducibility:* R = 0.018 vol % refractometer R = 0.021 vol % Brix	
Referenced Research Reports	RR:D02-1251	
SME Evaluation	The test method measures the diEGME in the water by a standard analytical refractometer, so as long as there is nothing extracted that skews the result, it will measure the FSII in the water. The test method and resultant data could be affected by the fuel chemistry if there is anything else in the fuel that is extracted by water. This could be confirmed by testing with and without additive. A caveat is the consideration as to whether anything in the chemical composition affects the ability of the FSII to migrate from the fuel to the water. This would have to be evaluated as part of the compatibility testing and is not an effect on the method itself. If the FSII's ability to migrate is changed, then the measured value would be technically accurate, but might not reflect the actual concentration in the fuel.	
Other	• Several drops of extracted water are placed on the refractometer surface and the refractive index is measured. The actual concentration related to the RI is etched on the refractometer reticule. • For the Brix refractometer, a calculation from the Brix scale reading to concentration is required. The Brix reading must also be corrected for temperature. $Vol\ \%\ FSII = \frac{2 * Temp\ \ corrected\ \ \ scale\ \ reading}{100}$	

Impact Assessment:

Red Yellow Green

Specification Review

D5291-16	STM for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants	**Original Publication Date: 1992**
Specification Scope	Determines total carbon, hydrogen and nitrogen by combusting the sample and performing element specific gas chromatography	
Published Limitations	Mass % range capabilities: carbon, 75 – 87 mass %, hydrogen, 9 – 16 mass %, and nitrogen, 0-2 mass % Nitrogen < 0.75 mass % or in volatile fuels cannot be determined with this method. Not recommended for volatile fuels such as aviation gasoline or wide-cut turbine fuels	
Provided Precision Information	*Repeatability:* "Petroleum-based" C: r = (X+48.48)*0.0072 H: r = $X^{0.5}$ * 0.1162 N: r = 0.1670 Flash EA method C: r = 0.5644 % H: r = 0.5905 % N: r = 0.006897 * (X + 3) *Reproducibility:* "Petroleum-based" C: R = (X+48.48)*0.018 H: R = $X^{0.5}$ * 0.2314 N: R = 0.4456 Flash EA method C: R = 1.4671 % H: R = 1.9089 % N: R = 0.02967 * (X + 3) Where X = the mean value	
Referenced Research Reports	RR:D02-1289 RR:D02-1679	
SME Evaluation	Given experience with CHN analysis, the test method likely gives reasonable carbon, nitrogen and hydrogen values and not be sensitive to the fuel chemistry. As long as methods are carefully followed and the sample preparation is well executed, both selection of sample size and preparing the sample for the machine, results should be acceptable. The ability to give reliable values would be instrument and operator, and calibration sensitive for fuel in general.	
Other	• None	

Specification Review

Impact Assessment:

Red Yellow Green

D5304-15	STM for Assessing Middle Distillate Fuel Storage Stability by Oxygen Overpressure	**Original Publication Date: 1992**
Specification Scope	Determines the formation of deposits in an oxygen environment. For DF-1 and DF-2 this is related to storage stability	
Published Limitations	Works with additives except dispersants	
Provided Precision Information	*Repeatability:* r = 0.2 * (x + 1.3) *Reproducibility:* R = 0.9 * (x +1.3) Where x = average of 2 results in mg/100 ml	
Referenced Research Reports	RR:D02-1598	
SME Evaluation	The methodology presented is based on a fundamental expectation of thermal degradation (oxidation) being accelerated by the presence of oxygen. The test will likely create deposit formation with aviation turbine fuel and should be relatively insensitive to chemical composition. However, there is no reported relationship between the accelerated aging of aviation kerosene and storage stability. The 40 hours being similar to 40 months relationship is only for middle distillates like diesel. While the method is regularly used with kerosene, it was not designed for kerosene. The precision statement is likely to be invalid and the presence of additives or other moieties that may act as dispersants will confound the results.	
Other	• Method is useful in ranking specimens but not predictive. • Navy did testing with F-76 • 100ml of test fuel is filtered and placed in a reactor that is pressurized with oxygen. Following aging, the fuel is filtered through weighed membranes and the mass collected, aka insolubles, is reported. • 100 psig oxygen increases the insoluble formation in middle distillates approximately 10x as compared to atmosphere. ○ For middle distillates 40 hours at 40 °C has been correlated to be similar to 40 months at 20 °C.	

Specification Review

Impact Assessment:

Red Yellow Green

D5452-12	STM for Particulate Contamination in Aviation Fuels by Laboratory Filtration	**Original Publication Date: 1993**
Specification Scope	Gravimetric determination of filterable particulates. A known volume of liquid is filtered through weighed membranes	
Published Limitations	None	
Provided Precision Information	*Repeatability:* $r = 0.415 * X^{0.5}$ *Reproducibility:* $R = 0.726 * X^{0.5}$ Where X = mean of two results Repeatability ranges from 0.13 to 0.32 mg/L Reproducibility ranges from 0.23 to 0.56 mg/L	
Referenced Research Reports	RR:D02-1437 RR:D02-1145	
SME Evaluation	The gravimetric portion of the method will result in the reporting of the mass of anything filtered from the fuel onto a 0.8µ filter membrane. This portion is a physical phenomenon and not related to fuel chemistry. The color rating discussed in X.1 may or may not correlate to colors seen from traditional petroleum-based jet fuel. If there are moieties that color the filter membrane that are not related to traditional filterable solids, the color rating may not be predictive.	
Other	• Method also includes an ASTM color raging where the membrane color is compared to an ASTM color chart.	

Specification Review

Impact Assessment:

Red Yellow Green

D5453-16	STM for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel and Engine Oil by Ultraviolet Fluorescence	**Original Publication Date: 1993**
Specification Scope	Determine the total sulfur present in liquid hydrocarbon by combusting the sample and measuring the combustion gases for sulfur dioxide by UVF.	
Published Limitations	Hydrocarbon with a boiling range of 25 to 400 °C (77 to 752 °F) and viscosity between 0.2 and 20 cSt at room temperature. Must contain less than 0.35 % halides	
Provided Precision Information	*Repeatability:* $r = 0.1788 * X^{0.75}$ for S < 400 mg/kg r = 0.2 to 16.0 mg/kg $r = 0.02902 X$ for S > 400 mg/kg *Reproducibility:* $R = 0.5797 * X^{0.75}$ for S< 400 mg/kg R = 0.6 to 51.9 mg/kg $R = 0.1267 * X$ for S > 400 mg/kg	
Referenced Research Reports	RR:D02 – 1307 (1992) Original RR with multiple test matrices RR:D02-1456 (1999) UVF to X-ray comparison RR:D02-1465 (1997) Gasoline study RR:D02-1475 (1998) Gasoline, diesel, and biodiesel study RR:D02-1547 (2000-2001) Gasoline and diesel study RR:D02-1633 (2008) Biofuels	
SME Evaluation	The method is based on fundamental chemistry where sulfur is combusted to sulfur dioxide. The sulfur dioxide responds to the ultraviolet radiation and the fluorescence energy is measured. As long as there are no halides and an appropriate matrix is used for the reference, and the limitations on the hydrocarbon properties are met, there is nothing to suggest the method execution would be sensitive to chemical composition.	
Other	• ILS has confirmed method also works on jet fuel. • Concentration is determined by measuring fluorescence and converting it to concentration by calibration curve. It is assumed the test and calibration matrices are matched.	

Impact Assessment:

Red Yellow Green

Specification Review

D5842-04 (2009)	SP for Sampling and Handling of Fuels for Volatility Measurements	**Original Publication Date: 1995**
Specification Scope	Practice for preparing sample containers for volatility related measurements, i.e. vapor pressure	
Published Limitations	None	
Provided Precision Information	Not applicable	
Referenced Research Reports	None	
SME Evaluation	There is nothing in the practice that should be sensitive to chemical composition. Careful compliance to the practice is important to the procurement of valid samples no matter what the composition. If there is anything about the composition that would make procuring a representative sample unusually challenging, this should be noted.	
Other	• Practice was developed to support API MPMS Chapter 8.1 to 8.3. • Recommend demonstrating epoxy coating is compatible if lined cans are selected.	

Impact Assessment:

Red Yellow Green

Specification Review

D6045-12	STM for Color of Petroleum Products by the Automatic Tristimulus	**Original Publication Date: 1996**
Specification Scope	Automatic color reading, correlated to D156 and D1500 by instrumentation	
Published Limitations	Does not apply to samples containing dye. Cannot be used with petroleum products with extreme fluorescence. Sample cannot be cloudy. Any bubbles must be able to be dispersed before test.	
Provided Precision Information	Precision statements are equivalent to those of the related test, D156 Saybolt color or D1500 ASTM color	
Referenced Research Reports	RR:D02-1356	
SME Evaluation	The test method provides an absolute color report, that being the closest match to a color standard, and as such the reported color is composition agnostic. However, how the color value is used, especially in a comparative manner, has the potential to be specific to the chemical composition. In general, aviation turbine fuels display colors ranging from water white to straw yellow, and as such the color of the alternatively produced fuel is not likely to cause issue. If, however, the color is outside of the generally observed range, it could potentially be misinterpreted in a comparative analysis. Care is required regarding HOW the data is used.	
Other	• Method uses transmission in the visible light and develops a measurement of color in terms of the three major color stimuli (RGB). This set of values relates to a specific color. • For conversion to ASTM and Saybolt colors the instrument internally matches the tristimulus values to the tristimulus values of the color references and provides the sample data as the equivalent ASTM or Saybolt color.	

Impact Assessment:

Red Yellow Green

Specification Review

D6304-16	STM for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration	**Original Publication Date: 1998**
Specification Scope	Water content between 10 ppm to 25,000 ppm is determined directly by reaction with iodine.	
Published Limitations	Aldehydes, ketones, mercaptans and sulfides are known interferents. Additional information on interferents available in ASTM E203 volumetric Karl Fischer.	
Provided Precision Information	*Repeatability:* $r = 0.08852 * x^{0.7}$ volume % $r = 0.3813 * x^{0.6}$ mass % *Reproducibility:* $R = 0.5248 * x^{0.7}$ volume % $R = 0.4246 * x^{0.6}$ mass % Where x = mean of duplicate measurements	
Referenced Research Reports	RR:D02-1436	
SME Evaluation	The method is based on fundamental reaction chemistry between water and iodine. As long as the sample does not consist of one of the interferents or other chemical moieties that will react with iodine, or the appropriate additional procedures are employed, the method should not be sensitive to the chemical composition of alternatively produced jet fuel.	
Other	• More sensitive than ASTM D1744 which measures 50 ppm to 1000 ppm (not a referenced method in the parent documents). • Water content may be reported as by volume or by mass. • Method includes the use of pyridine-free reagents. • Aldehydes and ketones interferences are managed with the use of an oil dryer attachment. • From the ATJ Research Report:	

ATJ Research Report, March 2014, Version 1.4:

4.2.2.9 Water Solubility vs. Temperature

The amount of water dissolved in a fuel as delivered is controlled under the "contaminant" part of ASTM D4054 and tested according to Karl Fischer water test ASTM D6304. The maximum amount of water that will dissolve in a fuel is a fit-for-purpose property. The ability of a jet fuel to hold water in excess of that typically experienced has obvious logistical implications. Fuels pick up water during handling, but the issue here is the maximum amount of water a fuel could pick up when exposed to an excess of water. SwRI has developed a specialized test to look at this saturation level of dissolved water.

This test utilizes a standard coulometric Karl Fischer water titrator but the sample preparation is unique. Unaware of any standard procedure to perform this test, SwRI developed the following method and employed it in previous studies. The volumes used in this effort were doubled from previous testing to provide more sample volume for analysis.

Impact Assessment:

Red Yellow Green

Specification Review

D6378-10	**STM for Determination of Vapor Pressure (VP_x) of Petroleum Products, Hydrocarbons and Hydrocarbon-Oxygenate Mixtures (Triple Expansion Method)**	**Original Publication Date: 1999**
Specification Scope	Determine the vapor pressure in a vacuum.	
Published Limitations	Boiling point must be greater than 0 °C (32 °F) and the vapor pressure between 1 to 21 psi (7 to 150 kPa) at 37.8 °C (100 °F). Vapor pressure for aviation turbine fuels cannot be converted to DVPE from this data.	
Provided Precision Information	**TABLE 3 Repeatability (aviation turbine fuel)** Temperature, °C | Repeatability (kPa) | Effective Range (kPa) 25 | 0.6 | 0.1–11.0 37.8 | 0.06(Y + 4) | 0.3–17.0 50 | 0.035(Y + 15) | 0.5–26.0 100 | 1.70 | 5.4–107.5 where: $Y = VP_4$ kPa **TABLE 5 Reproducibility (aviation turbine fuel)** Temperature, °C | Reproducibility (R) kPa | Effective Range (kPa) 25 | 1.0 | 0.1–11.0 37.8 | 0.11(Y + 4) | 0.3–17.0 50 | 0.065(Y + 15) | 0.5–26.0 100 | 2.2 | 5.4–107.5 where: $Y = VP_4$ kPa	
Referenced Research Reports	RR:D02-1651 for aviation turbine fuel RR:D02-1619 for gasoline and oxygenates	
SME Evaluation	This method has no correlations or calculations to convert to the vapor pressure value of the sample, other than to determine the partial pressure of air. This is based on fundamental physics of the behavior of compounds in a vacuum. As long as the chemical composition does not include high vapor pressure materials, the method for determining the vapor pressure should not be sensitive to the chemical composition of an alternatively produced jet fuel. Furthermore, the method specifically prohibits the use of this data for conversion to DVPE on jet fuel, precluding an issue of sensitivity	

	between the chemical composition of traditionally prepared petroleum jet fuel and alternatively produced jet fuel.
Other	• This method does three separate expansions and determines the partial pressure from dissolved air. If there are low levels of high vapor pressure materials present in the fuel, they will be included in the partial pressure of air in the error correction. • This method eliminates the need to saturate the sample with air.

Impact Assessment:

Red Yellow Green

Specification Review

D6732-04 (2015)	STM for Determination of Copper in Jet Fuels by Graphite Furnace Atomic Absorption Spectrometry	**Original Publication Date: 2001**
Specification Scope	Determine copper content in jet fuel by AA graphite furnace.	
Published Limitations	5 to 100 ppb of copper in jet fuel Above 100 ppb, dilute and the precision statement will not apply. Interference can occur but this is usually caused by poor technique.	
Provided Precision Information	*Repeatability:* $r = (x + 1)^{0.5}$ *Reproducibility:* $R = 4.5 (x+1)^{0.5}$ Where x = average of two results in µg/kg	
Referenced Research Reports	RR:D02-1512	
SME Evaluation	The method is based on a fundamental analytical instrument in which a sample is combusted and subjected to energy at known wavelengths. A detector measures the energy absorbed. A calibration curve of known copper concentration is prepared and the resulting absorption value correlated to a concentration value. As long as good analytical techniques by an experienced operator are used and there is good correlation between the sample matrix and that of the blank / standards, the results should be unaffected by chemical composition.	
Other	• The bland and calibration standards should be prepared using a kerosene matrix.	

Impact Assessment:

Red Yellow Green

Specification Review

D6793-02 (2012)	STM for Determination of Isothermal Secant and Tangent Bulk Modulus	Original Publication Date: 2002
Specification Scope	Determination of the isothermal static bulk modulus	
Published Limitations	Liquids that are stable and compatible with stainless steel	
Provided Precision Information	None	
Referenced Research Reports	None	
SME Evaluation	The test is an analytical method based on physics. As long as the equipment is functional, it should not be affected by the fluid chemical composition.	
Other	• The test method can be run from -40 to 200 °C, from ambient to 68.95 MPa (10K psig). The upper pressure is determined by the bulk modulus of the fluid. • Secant bulk modulus is the original fluid volume * secant slope. The secant slope is the line drawn from the origin to a desired point on the plot of pressure vs $\frac{\Delta V}{V}$ • Tangent bulk modulus is the fluid volume at the desired pressure P * $\int_{volume}^{pressure}$ at temperature T • Each instrument has a system constant $\frac{V}{\Delta V}$ and is determined with a standard of known bulk modulus • Isothermal secant bulk modulus (ISBM) is the static bulk modulus; a fluid's compressibility. The larger the value, the less compressible the fluid. • ISBM is measured as a function of pressure and can be used to determine Isothermal Tangent bulk modulus (ITBM) and density as a function of pressure at a fixed temperature. • This data cannot be used to calculate dynamic bulk modulus. • The pressure is a system pressure provided by a piston which results in a change in system volume. • Explanation: Bulk modulus is $B = -V\frac{dP}{dV}$ and $\rho\frac{dP}{d\rho}$ V = function(P, V_o , K) and specific volume $\frac{(V-V_o)}{V}$ In a fluid, the bulk modulus and density determine the speed of sound, $C = \sqrt{\frac{B}{\rho}}$	

	Bulk modulus is the reciprocal of compressibility. A steep slope indicates incompressibility. The plot is not linear, so two different mathematical methods are used to define the slope, Secant B and Tangent B

Specification Review

Impact Assessment:

Red Yellow Green

D6866-16	STM for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis	**Original Publication Date: 2004**
Specification Scope	Basic radiocarbon dating	
Published Limitations	Can be used with any carbon-containing compound that is combustible. Should only be run in laboratories with no other source of artificial ^{14}C Inorganic carbonates must be addressed.	
Provided Precision Information	The process of carbon dating has an intrinsic indeterminate error based on the value attributed to modern carbon based on the year.	
Referenced Research Reports	None	
SME Evaluation	There is nothing about this procedure that would limit its use on alternatively produced jet fuel. The method provides a value which is what it is and by specification, no comment on the resulting value can be made. As long as the sample does not contain chemical quenching components and the presence of any inorganic carbonates are addressed per the method, the method should not be affected by the chemical composition.	
Other	• None	

Impact Assessment:

Red Yellow Green

Specification Review

D7042-16	STM for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)	**Original Publication Date: 2004**
Specification Scope	Measures both the dynamic viscosity, η, and the density, ρ.	
Published Limitations	Fluid must be Newtonian	
Provided Precision Information	Repeatability and reproducibility are determined for specific materials at specific temperatures. Reported below are for jet fuel and biodiesel. *Repeatability:* Jet fuel ρ @ -20 °C; r = 0.001 g/cm^3 η; r = 0.06477 mPa.s, ν; r = 0.0856 mm^2/ sec Biodiesel ρ @ 40 °C; r = 0.0002 g/cm^3 η; r = 0.0004 mPa.s, ν; r = 0.004647 mm^2/ sec *Reproducibility:* Jet fuel ρ @ -20 °C; R = 0.0027 g/cm^3 η; R = 0.1085 mPa.s, ν; R = 0.1485 mm^2/ sec Biodiesel ρ @ 40 °C; R = 0.0008 g/cm^3 η; R = 0.009595 * (0.96%) mPa.s, ν; R = 0.009603 * (0.96%) mm^2/ sec	
Referenced Research Reports	RR:D02-1773, 1741, 1742, 1750, 1776, 1837, and 1555	
SME Evaluation	The test measures fundamental physical behaviors in a fluid and should be unaffected by the chemical composition. The precision statement may need to be validated as the chemical composition moves away from traditional petroleum-based chemistry.	
Other	• Values are essentially equivalent to the values obtained using ASTM D445. • Kinematic viscosity, ν, can be mathematically determined from η and ρ by the equation $\nu_T = \eta_T/\rho_T$ Dynamic viscosity η is the resistance to flow under external shear. Kinematic viscosity, ν, is the resistance to flow under gravity. • Stabinger uses rotating cylinders to measure η and an oscillating U-tube to measure ρ at a controlled temperature.	

Impact Assessment:

Red Yellow Green

Specification Review

D7111-15a	**STM for Determination of Trace Elements in Middle Distillate Fuels by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)**	**Original Publication Date: 2005**
Specification Scope	Determines the concentration of trace elements in middle distillates.	
Published Limitations	Range 0.1 mg/kg to 2.0 mg/kg. Outside of that range, the method will work but it will exceed the precision statement. Boiling range between 150 to 390 °C (302 to 734 °F). Trace elements present as volatile compounds result in biased high results.	
Provided Precision Information	The precision statement is element and concentration range dependent. **TABLE 3 Repeatability** **TABLE 4 Reproducibility**	
Referenced Research Reports	RR:D02-1569 RR:D02-1778	
SME Evaluation	Assuming the method is executed by an experienced operator, with experience to recognize spectral interferences and volatile compounds, the method is a fundamental analytical technique. The method makes no assessment on limits or impacts. There is no technical reason to expect the method to be sensitive to chemical composition beyond the limitation statement. It is possible for a target metal to be present outside the range prepared for the precision statement. This would require the preparation of a new precision statement.	

Other	• Method measures content as a spectral response correlated to a calibration curve. The standards are prepared as organometallics dissolved in kerosene. • There are 27 target metals in the precision statement list. • Method listed as an alternative to ASTM D3605 (not a parent document). • The method notes that it is possible for there to be spectral interferences in the suggested wavelengths, but no further information was provided.

Specification Review

Impact Assessment:

Red Yellow Green

D7171-05 (2016)	STM for Hydrogen Content of Middle Distillate Petroleum Products by Low-Resolution Pulsed Nuclear Magnetic Resonance Spectroscopy	**Original Publication Date: 2005**
Specification Scope	Determine hydrogen content in middle distillates by low res NMR.	
Published Limitations	Boiling range 150 to 390 °C (302 to 734 °C). Outside of this range may work but negates the precision statements.	
Provided Precision Information	Accuracy is operator dependent. *Repeatability:* @ 35 °C r = 0.009352 (X + 1.7000) @ 40°C r = 0.006409 (X + 5.0000) *Reproducibility:* @ 35 °C R = 0.01769 (X + 1.7000) @ 40 °C R = 0.01580 (X + 5.0000) Where X = mass % hydrogen content.	
Referenced Research Reports	RR:D02-1577	
SME Evaluation	NMR magnetizes and aligns protons, so the method is an analytical method based on a fundamental physical property. As long as the operator is experienced and accurate standards have been prepared, the results will be what they will be. No information on hydrogen bonding (for example the connected chemistry) is provided or suggested. As long as the test is run in the temperature range of the precision statement, the method should not be sensitive to chemical composition.	
Other	• Similar to D3701 (in the parent documents) and D4808 (not in the parent documents) but pulsed instead of continuous. • Reports hydrogen as a mass percent.	

Specification Review

Impact Assessment:

Red Yellow Green

D7345-16	**STM for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure (Micro Distillation Method)**	**Original Publication Date: 2007**
Specification Scope	Determining the distillation range of light and middle distillates at atmospheric pressure	
Published Limitations	Applicable to light and middle distillates, auto fuels, ethanol, aviation gasoline, aviation turbine fuel, regular and low sulfur diesel, B100, B20, spirits, naphtha, white spirits, kerosene, burner fuels, marine fuels, organic solvents of narrow boiling range, and oxygenated compounds. Not applicable to resid oil or wet samples.	
Provided Precision Information	Method does not require the use of group numbers, but they are used to maintain read across to ASTM D86. Groups 1, 2, and 3 are grouped together as Not 4. *Repeatability:* Group NOT4: IBP: r = 3.3 valid range: 20 °C – 50 °C E5: r = 1.1 valid range: 25 °C – 60 °C E10: r = 1.1 valid range: 30 °C – 65 °C E20: r = 1.2 valid range: 40 °C – 70 °C E30: r = 1.8 valid range: 50 °C – 85 °C E40: r = 2.7 valid range: 55 °C – 100 °C E50: r = 2.4 valid range: 60 °C – 120 °C E60: r = 2.4 valid range: 75 °C – 125 °C E70: r = 1.8 valid range: 100 °C – 140 °C E80: r = 2.1 valid range: 115 °C – 160 °C E90: r = 1.9 valid range: 140 °C – 180 °C E95: r = 2.0 valid range: 150 °C – 200 °C FBP: r = 3.0 valid range: 140 °C – 260 °C where: E = evaporated temperature at x percent within valid range prescribed (°C) T = recovered temperature at x percent within valid range prescribed (°C) *Reproducibility:*	

	Group NOT4: IBP: R = 5.9 valid range: 20 °C – 50 °C E5: R = 2.5 valid range: 25 °C – 60 °C E10: R = 2.1 valid range: 30 °C – 65 °C E20: R = 2.2 valid range: 40 °C – 70 °C E30: R = 2.6 valid range: 50 °C – 85 °C E40: R = 3.6 valid range: 55 °C – 100 °C E50: R = 4.1 valid range: 60 °C – 120 °C E60: R = 4.5 valid range: 75 °C – 125 °C E70: R = 3.5 valid range: 100 °C – 140 °C E80: R = 3.7 valid range: 115 °C – 160 °C E90: R = 5.8 valid range: 140 °C – 180 °C E95: R = 5.4 valid range: 150 °C – 200 °C FBP: R = 5.7 valid range: 175 °C – 220 °C where: E = evaporated temperature at x percent within valid range prescribed (°C) T = recovered temperature at x percent within valid range prescribed (°C) *Between Method Bias* The bias between the predicted value and D7345, Y = X + 1.42 °C where X = is the result from D7345. In addition there are data point specific bias corrections covering 3 pages. There is another 5 pages of discussing instrument accuracy and precision by sample type.
Referenced Research Reports	RR:D02-1621 RR:D02-1831 RR:D02-1794 (biodiesel)
SME Evaluation	The instrument is based on the fundamental principle of distillation and the results are just that. There are some result biases due to the mechanics of where and how the temperature and volumes are measured as compared to D86. The method is a measure of chemical composition and as such should not be affected by chemical composition. The method does contain a measurable amount of bias correction information which may suggest a need to perform validation of the precision statements and the bias statements. This makes no comment on how the distillation range and differences in results between compositions relate to the use of the limits of use.
Other	• Runs similar to D86 and corrects for barometric pressure.

Impact Assessment:

Red Yellow Green

Specification Review

D7359-14a	STM for Total Fluorine, Chorine and Sulfur in Aromatic Hydrocarbons and Their Mixtures by Oxidative Pyrohydrolytic Combustion followed by Ion Chromatography Detection (Combustion Ion Chromatography-CIC)	**Original Publication Date: 2008**
Specification Scope	Determines the total F, Cl, and S in aromatic hydrocarbons and their mixtures in ppm.	
Published Limitations	Content range 0.10 to 10 mg/kg. Sample may be brought in range by dilution. Interferences – any substance that co-elutes with fluorine, chlorine or sulfur ions during ion chromatography. No specific examples provided.	
Provided Precision Information	Precision statement was element and content dependent, but the highest values corresponded to the highest content. Fluorine r = 0.013 to 0.449 mg/kg R = 0.168 to 1.195 mg/kg Chlorine r = 0.009 to 0.796 mg/kg R = 0.093 to 1.190 mg/kg Sulfur r = 0.017 to 0.198 mg/kg R = 0.061 to 2.126 mg/kg Ten labs ran seven samples and one quality control sample.	
Referenced Research Reports	RR:D02-1052	
SME Evaluation	It is likely this method would only be used on high aromatic blend components. The method involves the use of general analytical test methods, combustion and ion chromatography. No modifications are employed specific to aviation turbine fuel or petroleum distillates, so there is nothing about the method that should be sensitive to the chemical composition of alternatively produced jet fuel.	
Other	• CIC Discussion - The sample is combusted in an oxygen and water rich atmosphere to create CO_2, H_2O, hydrogen halides, sulfur sulfates and elemental oxides (ash). Ion chromatography separates the halides and sulfur anions. Content is determined from a calibration curve. • Large amounts of one anion can interfere with the detection of the others if there is insufficient peak separation.	

Specification Review

Impact Assessment:

Red Yellow Green

D7872-13	STM for Determining the Concentration of Pipeline Drag Reducer Additive in Aviation Turbine Fuels	**Original Publication Date: 2013**
Specification Scope	Measure high molecular weight polymers in aviation turbine fuels at > 72µg/L. Method only identifies the presence of not the source or type. Method expects the source to be due to PDRA but it would have to be confirmed.	
Published Limitations	Interferences: any high molecular weight polymer (HMP). The assumption is that no other HMP are permitted to be added, so a positive response is attributed to PDRA.	
Provided Precision Information	*Repeatability:* r = 0.01793 * (X + 1117.6082) µg/L *Reproducibility:* R = 0.03014 * (X + 1117.6082) µg/L Specification defines these values as "poor".	
Referenced Research Reports	RR:D02-1763	
SME Evaluation	The method is based on a fundamental analytical analysis, gel permeation chromatography. Large particles do not get embedded in the pores and pass. It does not matter what the large particles are. If a material is large enough to be excluded from the column in the retention time of interest, it will generate a response. This may or may not be due to the presence of PDRA, as is noted by the method. The method is not chemistry dependent, though it could give responses not related to the PDRA. If an alternatively prepared jet fuel generated material causing a response in this time period, regardless of the source, it would be measured. It would be prudent to confirm no large material is passed by the GPC.	
Other	• The sample is evaporated in a rotovap and the concentrated fluid is analyzed by gel permeation chromatography with a refractive index detector. • Gel permeation chromatography – small particles are held up in the pores and elute last. In this method the HMP are totally excluded and will move through quickly. Biggest disadvantage is peak resolution within the test time. • The resultant detector response is compared to a calibration chart created with standards of sheared polymer in jet fuel.	

Impact Assessment:

Red Yellow Green

Specification Review

D7945-16	**STM for Determination of Dynamic Viscosity and Derived Kinematic Viscosity of Liquids by Constant Pressure Viscometer**	**Original Publication Date: 2014**
Specification Scope	Determine the dynamic viscosity (η) and density (ρ) at a known temperature and calculate the kinematic viscosity (ν).	
Published Limitations	Useful range is 0.5 mm^2 /s to 1000 mm^2/s between -40 and 120 °C (-40 to 248 °F).	
Provided Precision Information	Precision statements were only determined on fluids 2.06 to 476 mm^2 /s at 40 °C (104 °F). Jet fuels were 2.957 to 5.805 mm^2 /s at -20 °C (-4 °F) and 5.505 to 13.03 mm^2 /s at -40 °C (-40 °F) *Repeatability:* r = 0.0018*$X^{1.4}$ @-40 °C r = 0.011 @-20 °C r = 0.0020 * (X*0.50%) @ 40 °C r = 0.0075 * (X*0.75%) @ 100 °C r = 1.14 °C for 12 cSt temperature *Reproducibility:* R = 0.0021*$X^{1.4}$ @-40 °C R = 0.021 @-20 °C R = 0.0080 * (X*0.80%) @ 40 °C R = 0.0138 * (X*1.38%) @ 100 °C R = 0.17 °C for 12 cSt temperature *Bias*: There are some sample specific biases which should be checked to use the method to predict D445 values.	
Referenced Research Reports	RR:D02-1797 (at 40 and 100 °C) RR:D02-1833 (-20 and -40 °C)	
SME Evaluation	The method is based on foundational fluid mechanics and should not be dependent on chemical composition. Similarly, the conversion from η to ν is based on foundational physical chemistry. As long as the test fluid is Newtonian, the method will show changes in chemical composition and not itself be affected by composition. The instrument requires a determinability setting which must be developed if not provided. It is assumed that the determinability value for alternatively produced jet fuels will need to be developed.	

	The precision statements would likely need to be validated and possibly developed especially as the chemical composition diverged from that of traditional petroleum-based fuels. It is not expected the changes in fuel chemistry are likely to result in precision concerns given the range of materials tested in the ILS.
Other	• The method is similar to D445 except the flow through the capillary is horizontal instead of vertical. Optical sensors measure the flow and an oscillating U-tube measures the density. Impetus of motion is a constant pressure provided by air as opposed to gravity. • The instrument is programmed with a D341 (not listed in parent specifications) viscosity chart to extrapolate temperature at which a desired kinematic viscosity is achieved. You want to know when the fluid is 12 cSt and the equation determines the temperature at which it occurs.

Impact Assessment:

Red Yellow Green

Specification Review

E582-07 (2013)	STM for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures	**Original Publication Date: 2007**
Specification Scope	Determination of minimum ignition energy required to ignite a sample on a flat plate, in air, at ambient pressures. The method may be modified for other temperatures and pressures.	
Published Limitations	Specific to alkane or alkene fuels admixed with air at normal ambient temperature and pressure	
Provided Precision Information	r & R suggested to be +/-10%. Variability of the fuel composition at combustion is the limiting factor.	
Referenced Research Reports	None	
SME Evaluation	The method is based on fundamental physical combustion properties and no correlations or conversions are required to report the data. The method thus measures differences due to chemical composition and execution is not effected by the composition. Note, this evaluation makes no assessment of the validity of using this method to measure the spark ignition of aviation turbine fuels.	
Other	•	

Impact Assessment:

Red Yellow Green

Specification Review

E659-15	STM for Autoignition Temperature of Chemicals	**Original Publication Date: 1978**
Specification Scope	Determination of the hot and cool autoignition (AIT) of liquids and easily melted solids. AIT is the lowest temperature at which ignition will occur without an external ignition source, i.e. the heat from oxidation in the air is a sufficient ignition source.	
Published Limitations	Results can be impacted by the vessel size, larger vessel = lower AIT Air pressure and local oxygen content can impact test Not to be used with materials that exothermically decompose Not for materials that are liquid at the test temperature.	
Provided Precision Information	*Repeatability:* r = 2% of temperature in °C *Reproducibility*: R = 5% of temperature in °C	
Referenced Research Reports	None	
SME Evaluation	The test method is based on a fundamental physical chemistry apparatus and has no formulas or corrections. There is nothing to suggest the method should be any more sensitive to the chemical composition of the test fluid than the limits already in the specification.	
Other	• Similar to ASTM D2885 which was not referenced in the parent specifications.	

Impact Assessment:

Red Yellow Green

Specification Review

D681-09 (2015)	STM for Concentration Limits of Flammability of Chemicals (Vapors and Gases)	**Original Publication Date: 1979**
Specification Scope	Determines the upper and lower concentration limits of flammability for chemicals that have flammable mixtures at atmospheric pressure; 13 kPa (100 mm Hg) to atmospheric and a maximum temperature of 150 °C.	
Published Limitations	Interferences – materials that are readily oxidized in air - Too small a vessel will quench the flame front due to interaction with the walls.	
Provided Precision Information	Precision work was done with pentane *Repeatability:* r = 0.1 % vol LFL r = 0.15% vol UFL *Reproducibility:* R = 0.1 % vol LFL R = 0.9 % vol UFL	
Referenced Research Reports	None	
SME Evaluation	Within the limitations stated within the specification, there is nothing specific to fuel chemistry which should affect execution of the test method. The precision statement was based on a pure, flammable material so there are limits to the validity of the precision statement for petroleum-based chemistry compositions. Any composition that cause any of the provided limitations could affect the test results and any LFL/UFL should be assessed with the same considerations.	
Other	• Upper and lower flammability limits (UFL and LFL) can be are not necessarily equivalent to the upper and lower explosive limits (UEL and LEL). • Test material is put into a closed vessel, an ignition source is provided and the flame front is visually reviewed.	

Specification Review

Impact Assessment:

Red Yellow Green

E1269-11	STM for Determining Specific Heat Capacity by Differential Scanning Calorimetry	**Original Publication Date: 1990**
Specification Scope	Determines the specific heat capacity by measuring heat flow differences between target and reference specimens.	
Published Limitations	Specimen needs to be homogeneous. Operating range -100 to 600 °C No chemical or weight changes may occur during the test. Wet samples containing water result in a special case due to heat of vaporization.	
Provided Precision Information	*Repeatability:* r = 6.2 % *Reproducibility:* R = 8.4 %	
Referenced Research Reports	None ILS run with 7 labs and 3 materials	
SME Evaluation	The test is a standard analytical method based on basic physical chemistry. As long as the sample meets the requirement of the method and the test is executed per the method, there is nothing about the method that should be chemistry dependent. The ILS was based on a pure chemical, a linear polymer and indium, so the precision statement should be no more impacted than traditional jet fuel by alternatively produced fuel chemistry.	
Other	• Similar to ISO 11357-4	

Specification Review

Impact Assessment:

Red Yellow Green

E2253-16	STM for Temperature and Enthalpy Measurement Validation of Differential Scanning Calorimeter	**Original Publication Date: 2003**
Specification Scope	The test method is actually for use in validating the differential scanning calorimeter (DSC) specifically the temperature/time parameter and the enthalpy measurements. Validation is done by measuring the temperature or enthalpy of analytes. Enthalpy by DSC is a fundamental analytical process, however the test method does provide published guidance on the measurement of enthalpy.	
Published Limitations	None	
Provided Precision Information	Method is for the development of precision statements and as such does not have its own.	
Referenced Research Reports	None	
SME Evaluation	Measuring enthalpy using DSC is a fundamental analytical method. Equipment information and routine research procedures exist to use the equipment for the development of enthalpy data. The use of this method is not specifically for measuring enthalpy of analytes but rather for developing validation data on the equipment. However, it is a formal, published specification which includes information on developing and reporting enthalpy data and as such could be used as a test method to measure the enthalpy of alternatively produced aviation fuels. Because the DSC is a fundamental analytical tool, it is used to evaluate changes in chemical composition, and the execution of the method beyond typical laboratory procedural considerations would not be itself effected by the sample's chemical composition.	
Other	•	

Specification Review

Impact Assessment:

Red Yellow Green

EPA Method 8015C-2000	Nonhalogenated Organics Using GC/FID	**Original Publication Date: N/A**
Specification Scope	Determine the concentration of 27 listed non-halogenated volatile organics, trimethylamine in water, gasoline range organics and diesel range organics.	
Published Limitations	The analyst must demonstrate the method works with the specific sample. "FID is a non-selective detector. There is potential for many non-target compounds present in the samples to interfere.	
Provided Precision Information	Calibration curves must have a relative standard deviation less than 20% to assume linearity through the origin. If the RSD is greater than 20%, use an alternative calibration option. Analyte calibration standard must be +/-15% of the response obtained for the calibration. Each lab must develop a method detection limit for the matrix specific analyses.	
Referenced Research Reports	N/A	
SME Evaluation	The method is a fundamental analytical test method. It is primarily for the identification of specific VOC's in soil and water for EPA/RCRA purposes. The use of the method for the identification of VOC's in fuel samples is a modification intended use of the method. Changes in the fuel chemistry should be addressed by the requirement to develop local detection limits and demonstration of method validity. As long as the method can be validated, the method should not be affected by the chemical composition.	
Other	• Method provides the chromatographic conditions for the analysis of the analytes. • Method references a number of other EPA methods for sample preparation	

Specification Review

Impact Assessment:

Red Yellow Green

EPA Method 8260B-1996	Volatile Organic Compounds by GC/MS	**Original Publication Date: N/A**
Specification Scope	Determine the concentration of 108 listed volatile organics, in solid waste matrices. An additional 22 compounds are listed that can be analyzed when prepared as aqueous azeotropes.	
Published Limitations	Atmospheric contamination and the nature of petroleum products can result in carryover in the capillary column.	
Provided Precision Information	No precision statement. Internal reference should have a relative standard deviation ≤ 15%. The calibration check compounds should have an RSD ≤ 30%.	
Referenced Research Reports	N/A	
SME Evaluation	The method is a fundamental analytical test method. It is for the identification of specific VOC's in soil and water for EPA/RCRA purposes. The use of the method for the identification of VOC's in fuel samples is a modification intended use of the method. Changes in the fuel chemistry should be addressed by the requirement to develop local detection limits and demonstration of method validity. As long as the method can be validated, the method should not be affected by the chemical composition.	
Other	• Specimens are injected onto a GC column and separated. The separated compounds are then fed to a quadrupole mass spectrometer. The resulting spectra are compared to knowns using a five point calibration curve. • Method references a number of other EPA methods for sample preparation • It is recommended the capillary column be baked out between petroleum samples due to the presence of semi-volatile hydrocarbons. • It is possible to use the MS to identify compounds not in the list.	

Specification Review

Impact Assessment:

Red Yellow Green

EPA Method 8270D-2014	Semivolatile Organic Compounds by GC/MS	**Original Publication Date: N/A**
Specification Scope	Determine the concentration of semivolatile organics, in solid wastes, soils, air or water. The method has been validated on 145 separate RCRA listed semiVOC's provided in the method.	
Published Limitations	Assumes a trained operator In general 8270D is not be used as a quality control method; individual based methods for each of the referenced procedures are referenced. Method is not well suited for multicomponent analyses due to peak separations.	
Provided Precision Information	No precision statement.	
Referenced Research Reports	N/A	
SME Evaluation	The method is a fundamental analytical test method. It is for the identification of specific semiVOC's EPA/RCRA purposes. The use of the method for the identification of VOC's in fuel samples is a modification intended use of the method. The operator will be required to select the appropriate base procedure depending on the semi-VOC being analyzed. Changes in the fuel chemistry should be addressed by the requirement to develop local detection limits and demonstration of method validity. As long as the method can be validated, the method should not be affected by the chemical composition.	
Other	• Specimens are injected onto a GC column and separated. The separated compounds are then fed to a quadrupole mass spectrometer. • Method references a number of other EPA methods for sample preparation • No specific methodologies are included in EPA 8270D.	

Specification Review

Impact Assessment:

Red Yellow Green

ISO 20823	Petroleum and related products – Determination of the flammability characteristics of fluids in contact with hot surfaces – Manifold ignition test	**Original Publication Date: 2003**
Specification Scope	Determines if 10 ml of a fluid flashes or burns when dropped on a heated tube.	
Published Limitations	None	
Provided Precision Information	None	
Referenced Research Reports		
SME Evaluation	The method is based on physics, whether a specified drop hitting a surface will burn or flash on contact or after it drips off the tube to the collection surface. It is used to display differences in chemical composition responses and execution of the method is not affected by the chemical composition.	
Other	• Primarily used for fire resistant hydraulic fluids • The height of the drop and the temperature of the tube are defined by individual test, often 700°C.	

11.6.2 Yellow –

Specification Review

Impact Assessment:

Red (Yellow) Green

D130-12	STM for Corrosiveness to Copper from Petroleum Products by Copper Strip Test	**Original Publication Date: 1922**
Specification Scope	A copper strip is immersed in a sample of the petroleum, heated, washed and then compared to a copper color chart. The goal is to capture sulfur-based corrosion not related to the amount of sulfur present but rather to the type of sulfur present.	
Published Limitations	• Specifically lists for use with aviation gasoline, aviation turbine fuel, automotive gasoline, Stoddard solvent type II, kerosene, diesel fuel, fuel oil, lubricating oil, natural gasoline, or other hydrocarbons with vapor pressure no greater than 18 psi at 37.8°C. • Water is specifically noted as an interference.	
Provide Precision Information	There is no precision statement as the test is a pass/fail test.	
Referenced Research Reports		
SME Evaluation	There is a potential for the test method to be sensitive to fuel composition. While there is a wide variety of petroleum products on which the test is successfully used, there are three items that raise a concern. 1. The method specifically indicates that water is a interferent and provides a suggested remediation for drying the petroleum. It is possible that the filtration could be sensitive to chemistry, or some other component in the alternatively produced fuel could interfere in a similar manner. 2. The specified test times and temperatures might not be sufficient or appropriate for alternative fuel compositions 3. Because the rating is based on comparison to a color chart, it would need to be proved the colors still match appropriately. Because the test is a strictly pass/fail test based on this color comparison, this should be further investigated.	
Other	• The sample can be dried (from water) by filtering through rapid qualitative filter paper. Assumes the fuel will release the water to the filter paper. • The procedure has specified test times and temperatures that are specific to the test specimen. • The results are based on comparison to a color chart • Method replaced D89	

Impact Assessment:

Red Yellow Green

Specification Review

D240-14	**STM for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter**	**Original Publication Date: 1957**
Specification Scope	The test method is used to determine the net heat of combustion of liquid hydrocarbon fuels by measuring the test temperature before, during, and after combustion of the sample. This is constant pressure combustion. The test is designated as being applicable to liquid fuels with volatilities from light distillates to residual fuels.	
Published Limitations	The test method is directly applicable to gasolines, kerosines, Nos. 1 and 2 fuel oil, Nos. 1-E and 2-D diesel fuel and Nos. 0-GT, 1-GT, and 2-GT gas turbine fuels. The test method is limited to fuels containing only carbon, hydrogen, nitrogen and sulfur.	
Provide Precision Information	*Repeatability:* r = ± 0.13 MJ/kg *Reproducibility:* R = ± 0.40 MJ/kg	
Referenced Research Reports	RR:D02-38 This data were developed in 1957. A second analysis using data from 1957 – 1966 was also published.	
SME Evaluation	While the concept utilizes a fundamental physical chemistry test, a bomb calorimeter, the test method utilizes a number of restrictions and assumptions which could make the method fuel composition sensitive. Most notably: 1. The test method is restricted to fuels containing only carbon, hydrogen, nitrogen, and sulfur. If the fuel composition contains any other elements, the thermochemical corrections will be incomplete. 2. If the actual mass % hydrogen of the fuel has not been determined, then the method has an equation that makes use of an estimation that was developed from analyses performed in 1945 and 1953. This estimation can be affected as the chemical composition moves away from that of traditional petroleum-based fuels. 3. This method makes a correction for the amount of water vapor that is theoretically formed based on research and analysis. As the chemical composition changes the potential amount of water vapor formed, either due to changes in hydrogen content (see 2) or due to other thermal chemical reactions	

	taking place during combustion (see 1), the correction for the latent heat of vaporization of water vapor will be effected.
Other	• Test method is noted to be less repeatable and less reproducible than ASTM D4809 • The test method has correction factors based on nitric acid, sulfuric acid and gelatin/mineral oil. This is the reason for the limitation on composition. • Gross heat of combustion, Q_g is the energy released during combustion, including the condensation of the water vapor formed. Net heat of combustion, Q_n is determined by subtracting the latent heat of vaporization of the water vapor. • Samples should be filtered to remove water and insoluble material prior to testing.
Related Test Methods	➢ ASTM D3338 – Net Heat of Combustion of Aviation Fuels ➢ ASTM D4529 – Estimation of Net Heat of Combustion ➢ ASTM D4809 – Net Heat of Combustion, Precision method Bomb Calorimeter

Impact Assessment:

Red Yellow Green

Specification Review

D341-09 (2015)	**Standard Practice for Viscosity-Temperature Charts for Liquid Petroleum Products**	**Original Publication Date: 1932**
Specification Scope	Practice provides the viscosity charts and the formulae for determining the kinematic viscosity of a petroleum product at a desired temperature when the viscosity is known at a minimum of two temperatures (see discussion on definition of petroleum).	
Published Limitations	None	
Provided Precision Information	Not Applicable	
Referenced Research Reports	None	
SME Evaluation	In general the charts have been developed from a variety of petroleum data, and have a fair to low probability of being measurably affected by the chemical composition. There have been occurrences that suggest that at the extremes of low temperature, the data can show measurable deviations from linearity. It may be prudent to validate the linearity of alternatively produced aviation fuels at more than just two central temperatures. Data collected at both high and low temperature extremes should be collected to validate the linearity of kinematic viscosity of the product at both upper and lower temperatures. This is particularly true when determining the 12 cSt temperature value.	

Other	• Seven different charts with a variety of temperature and viscosity ranges are available. Selecting a chart in an appropriate range improves the precision of the interpolated/extrapolated values read from the chart.
	• Values are only accurate within the temperature range between the cloud point and initial boiling point.
	• The charts are logarithmic, the goal to take available data and plot it as a straight line.
	  ○ The first equations were developed in 1927
	  ○ There was a single constant that was developed from historical petroleum data
	  ○ Current charts are derived by computer analysis of more modern petroleum data and the equations now include two constants.	

    - The data taken from the newer charts does not exactly match data read from the 1943 charts.
    - Current calculations are an improvement in precision over the 1943 charts, especially for extrapolation to higher temperatures.
- High boiling materials show deviations from linearity at temperatures as high as 280 °C (550 °F)

Impact Assessment: Red Yellow Green

Specification Review

D445-15a	STM for Kinematic Viscosity of Transparent and Opaque Liquids	Original Publication Date: 1937
Specification Scope	Determine the kinematic viscosity and calculate a dynamic viscosity using the density. Fluid is permitted to fall under gravity through a capillary opening and the time required for a measured volume to fall is used to calculate the viscosity.	
Published Limitations	Test method assumes the sample exhibits Newtonian behavior. Residual oils, for example, are non-Newtonian. The method is valid for fluids with 0.2 to 300,000 cSt viscosity, but the provided precision statements are for a smaller subset of that range.	
Provided Precision Information	**TABLE 1 Approximate Tolerance Bands** NOTE 1—The tolerance bands were determined using Practice D6617. The calculation is documented in Research Report RR:D02-1498.[4] Viscosity of Reference Material, mm^2/s — Tolerance Band < 10 — ±0.30 % 10 to 100 — ±0.32 % 100 to 1000 — ±0.36 % 1000 to 10 000 — ±0.42 % 10 000 to 100 000 — ±0.54 % > 100 000 — ±0.73 % *Repeatability* – Additives at 100 °C[14] — $0.00192\ x^{1.1}$ Gas oils at 40 °C[15] — 0.0043 (x+1) Jet fuels at –20 °C[16] — 0.007 x — (0.7 %) Kerosine, diesel fuels, biodiesel fuels, and biodiesel fuel blends at 40 °C[17] — 0.0056 x — (0.56 %) where: x is the average of results being compared. *Reproducibility* – Additives at 100 °C[14] — $0.00862\ x^{1.1}$ Gas oils at 40 °C[15] — 0.0082 (x+1) Jet fuels at –20 °C[16] — 0.019 x — (1.9 %) Kerosine, diesel fuels, biodiesel fuels, and biodiesel fuel blends at 40 °C[17] — 0.0224 x — (2.24 %) where: x is the average of results being compared.	
Referenced Research Reports	RR:D02-1498 (throws out the historical tolerance band of ±0.35%) RR:D02-1420 (performed with 9 jet fuels) RR:D02-1421 (Reference 14) RR:D02-1422 (Reference 15)	

	RR:D02-1780 – a kerosene study that was done after the previous research reports. (Reference 17) RR:D02:1498 – Comparison of automated and manual viscometers, no difference determined. RR:D02-1820 – automated precision statements, done for biodiesel and fuel oils.
SME Evaluation	As long as the test fluid is a Newtonian fluid, the test itself should not be sensitive to the chemical composition of the test fluid. The precision statements are developed using a broad enough range of petroleum products, that the likelihood of changes to the precision statement being required appear small. The concern for the method is **not** related to the actual testing of the viscosity using the viscometer. The concern is related to the subsequent graphing of the viscosities using the viscosity chart paper described in ASTM D341. While ASTM D341 is not specifically referenced, it is typically used for the next step in the generation of kinematic viscosity data. One of two next steps is typically executed: 1) The observed viscosity at the measurement temperature is plotted on an existing logarithmic data chart and the kinematic viscosity at other temperatures is read from the chart or 2) kinematic viscosities at two temperatures are determined and plotted on the logarithmic chart paper to provide interpolation and extrapolation of the test fuel's kinematic viscosity to other temperatures. The first choice **is** sensitive to the chemical composition of the test fluid and has a measurable risk of being incorrect, especially as the difference in composition increases. The second choice may also have concerns. The charts were designed to result in straight lines over target temperature ranges. The first equations were generated in 1927 and included a constant developed from historical petroleum data. The current charts were derived by computer using more modern data and resulted in the equation having TWO constants. It was recognized that the data from the new charts were not exactly equivalent to the old viscosity chart/data. In recent times, further findings are suggesting that the kinematic viscosity of some fuels do not continue to display linear behavior based on the existing formula/charts at the lower temperatures. This divergence may become more pronounced as the composition deviates further from that of traditional jet fuel.

	While the test method for measuring kinematic viscosity is in and of itself not sensitive to the chemical composition of the jet fuel, how the data are subsequently handled IS likely to be sensitive to composition.
Other	• The equipment is calibrated with reference standards. • The method has a correction factor for the gravity constant

Impact Assessment:

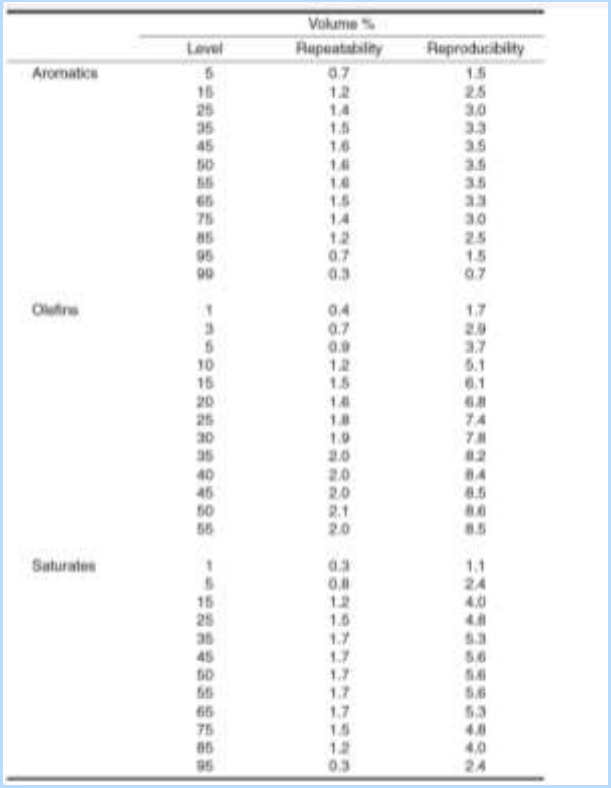
Red (Yellow) Green

Specification Review

D1298-12B	STM for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method	**Original Publication Date: 1953**
Specification Scope	Uses a glass hydrometer and calculations to determine density, relative density (SpGr) and API Gravity on petroleum, crude, and petroleum mixtures	
Published Limitations	RVP < 101.325 kPa (14.696 psi)	
Provided Precision Information	*Repeatiblity:* Density r = 0.0005 g/ml API r = 0.1 °API *Reproducibility:* Density R = 0.0012 g/ml API R = 0.3 °API	
Referenced Research Reports	No source for values available, considered historical numbers	
SME Evaluation	The specification directs the user to the D1250 Petroleum Tables for conversions to alternate temperatures. It specifically tells the analyst that the version of ASTM D1250 used defines what thermal expansion correction to perform. If it is the 2004 version, the analyst is left to determine the glass thermal expansion correction on his or her own. The method itself is a fundamental physical property and should be relatively fuel chemistry agnostic. During the conversions user should be careful if the sample has measurably different thermal expansion properties (see review of ASTM D1250 for full discussion of concerns).	
Other	• Values read from the hydrometer are just "hydrometer" values and must be converted to anything else, i.e. API or density with a calibration factor provided with the hydrometer. • Conversion accounts for meniscus effects, the glass thermal expansion correction, alternative calibration effects and then reduction to the reference temperature by calculation. • Volatile components can evaporate during the test, measurably affecting the measured density value.	

Impact Assessment: Red Yellow Green

Specification Review

D1319-15	**STM for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption**	**Original Publication Date: 1954**
Specification Scope	Determine the volume % of saturates, olefins, and aromatics in a petroleum products by separation in a silica column treated with dye and followed with UV light inspection (see comment on definition of petroleum products).	
Published Limitations	The maximum distillation temperature is 315 °C (600 °F). Dark colored fuels interfere with seeing the color bands Does not work with narrow boiling range materials near the 315 °C temperature limit. Oxygenated components may or may not be detected and their presence must be confirmed by other means.	
Provided Precision Information	"Method has not been tested on coal, shale, or tar sand based fuels and the precision statement may not apply." Precision is related to the type of hydrocarbon and the measured volume % 	
Referenced Research Reports	RR:D02-1361	

	Volume %		
	Level	Repeatability	Reproducibility
Aromatics	5	0.7	1.5
	15	1.2	2.5
	25	1.4	3.0
	35	1.5	3.3
	45	1.6	3.5
	50	1.6	3.5
	55	1.6	3.5
	65	1.5	3.3
	75	1.4	3.0
	85	1.2	2.5
	95	0.7	1.5
	99	0.3	0.7
Olefins	1	0.4	1.7
	3	0.7	2.9
	5	0.9	3.7
	10	1.2	5.1
	15	1.5	6.1
	20	1.6	6.8
	25	1.8	7.4
	30	1.9	7.8
	35	2.0	8.2
	40	2.0	8.4
	45	2.0	8.5
	50	2.1	8.6
	55	2.0	8.5
Saturates	1	0.3	1.1
	5	0.8	2.4
	15	1.2	4.0
	25	1.5	4.8
	35	1.7	5.3
	45	1.7	5.6
	50	1.7	5.6
	55	1.7	5.6
	65	1.7	5.3
	75	1.5	4.8
	85	1.2	4.0
	95	0.3	2.4

SME Evaluation	The test method has published limitations which could include the chemical composition of alternatively produced jet fuels. The method was specifically developed around petroleum-based jet fuel chemistry and the shift to cracked refinery processes did cause issues. The potential for changes to the precision statement with alternatively sourced petroleum (coal, shale, etc.) was noted but not determined. Similar issues with the precision statement for other chemical compositions should be ruled out.
Other	• Separation occurs based on the hydrocarbon type adsorption affinity for activated silica. • Volatile compounds require a special injection. • Visible color bands appear as each hydrocarbon type reacts with the dye. The distance of the band following moving down the column is measured. From the liquid front to yellow are the saturates, yellow to blue are the olefins, and blue to red are the aromatics. • Specification notes that color interpretation can be difficult in cracked fuels, due to impurities.

Specification Review

Impact Assessment:

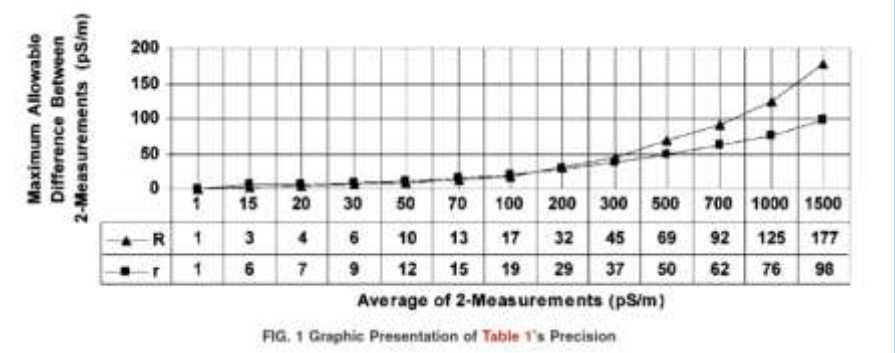
Red (Yellow) Green

D1740-01	STM for Luminometer Numbers of Aviation Turbine Fuels - WITHDRAWN	**Original Publication Date: 1960**
Specification Scope	This method was withdrawn in 2006, but was still referenced in D3701 as a traditional data, and in D7566. It was removed from D7566 in July 2016. Originally smoke point ad luminometry provided the combustion quality information on fuel. The luminometer value was essentially an emissivity measure. The radiation emitted by the flame was measured with a photocell. The value was found to correlate to smoke point and predicted temperatures in the gas turbine.	
Published Limitations	The results are impacted by the amount and type of mono aromatic and di aromatic compounds present.	
Provided Precision Information	*Repeatability:* r = 6.1 luminometer numbers *Reproducibility:* R = 8.8 luminometer numbers Precision statements prepared from data using seven laboratories, nine fuels, seven of which were D1655 and two were GT Fuel Oils.	
Referenced Research Reports	RR:D02-1180	
SME Evaluation	While the test method is no longer required, a review of the method suggests it would be sensitive to the fuel chemistry due to sensitivity to the amount and type of aromatics present. The test may then give unusual but not unexpected results based on the chemical composition of the fuel. It is likely the correlations between lamp meter reading and lamp temperature rise could be impacted by changes in fuel composition.	
Other	• The measured radiant energy was compared to the results of tetraline, L = 0, and isooctane, L = 100. • Ultimately a target hydrogen content provides the necessary control on the fuel's combustion properties.	

Impact Assessment:

Red Yellow Green

Specification Review

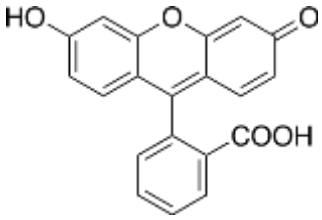
D2624-15	STM for Electrical Conductivity of Aviation and Distillate Fuels	Original Publication Date: 1967
Specification Scope	Methods to test the electrical conductivity of aviation and distillate fuels with and without SDA.	
Published Limitations	Not recommended for very low conductivity fuels Note 6: Conductivity is temperature dependent and each laboratory must establish temperature versus conductivity *for fuels of interest* (italics added).	
Provided Precision Information	Repeatability and reproducibility are a function of the value of the measurements.  FIG. 1 Graphic Presentation of Table 1's Precision	
Referenced Research Reports	RR:D02-1799, RR:D02-1235, RR:D02-1013, RR:D02-1476, RR:D02 -1161, RR:D02-1680	
SME Evaluation	The physical test method measures movement of electricity between two electrodes (current). This is a fundamental physical property and as such is not affected by the test medium. Rather it is used to measure changes to the test medium. However, any site generated correction factors would have to be reviewed for sensitivity to the fuel composition. The contributing environmental factors that impact the test method, i.e. test temperature, frequency, current type, etc. may require confirmation testing to demonstrate the environmental factors display impacts similar to those seen with traditionally prepared jet fuel. Changes to the fuel chemistry could feasibly change the correlations used to present data. It may also impact correlations between instrument types.	

	NOTE: A noticeable amount of work involving instruments measuring conductivity is currently taking place. Any findings within these studies related to the differences in fuel chemistry are not immediately known. Additionally, if the fuel chemistry results in very low conductivity, then it may be necessary to use D4308 which is not currently a referenced test method for jet fuel.
Other	• Method also references ASTM D4308 which is more for low conductivity fuels. This method is not currently called out by the parent documents • Since 2006, additional equipment, methods and research reports have been added. • Performance is related to the ion content of the fuel. Anything that can change the ion concentration, i.e. handling, additives, production, have to be considered when evaluating the results.

Impact Assessment: Red (Yellow) Green

Specification Review

D3240-15	STM for Undissolved Water in Aviation Turbine Fuels (Pad Reader)	Original Publication Date: 1973
Specification Scope	Measures water present in a flowing fuel stream. Measures free water, not dissolved water.	
Published Limitations	Undissolved water between 1 -60 ppm Corrosion inhibitor, fuel system icing inhibitor, and anti-static additives may affect the calibration of the system.	
Provided Precision Information	Aqua-Glo: Repeatability, $r=0.4155 \times x^{0.8058}$ ppm Digital Aqua-Glo: Repeatability, $r = 0.3454 \times x^{0.5771}$ ppm JF-WA1: Repeatability, $r = 0.1591 \times x^{0.8784}$ ppm Aqua-Glo: Reproducibility, $R = 0.5408 \times x^{0.8058}$ ppm Digital Aqua-Glo: Reproducibility, $R = 0.4070 \times x^{0.5771}$ ppm JF-WA1: Reproducibility, $R = 0.3691 \times x^{0.4997}$ ppm Where x = average of two results in ppm volume over the range from 1 ppm to 60 ppm.	
Referenced Research Reports	RR:D02-1195 (1991) RR:D02-1824 (2015) added ILS for pad reader	
SME Evaluation	The test method is based on the free water reacting with the uranine and the reaction products' fluorescing when the pad is read. The specification specifically notes that additives may interfere with the calibration of the system. The largest concern is that an alternatively prepared fuel composition may contain other materials that react with uranine or which may also be collected on the pad and also fluoresce or which may also interfere in some way. The pH of the solution can also affect the intensity of the fluorescence. The instrument is electronically converting an intensity reading to an equivalent water content. Because this is not a direct measurement, continued validity of the correlation may be required with alternatively prepared jet fuels.	

Other	• Readings are based on the intensity of fluorescence following a reaction with uranine (sodium fluorescein or the dye D&C Yellow no. 8). • Fluoroscein is slightly soluble in alcohol • Fluoroscein structure 

Impact Assessment:

Red (Yellow) Green

Specification Review

D3241-16a	STM for Thermal Oxidation Stability of Aviation Turbine Fuels	**Original Publication Date: 1973**
Specification Scope	An aerated fuel is pumped over an aluminum tube at a defined test temperature. The surface deposits and change in pressure across a filter are evaluated.	
Published Limitations	None	
Provided Precision Information	For the method there is no precision statement because the review did not meet the statistical methods.	
Referenced Research Reports	RR:D02-1309 (Statistical review of D3241) RR:D02-1786 (VTR, statement not included in D3241) RR:D02-1786 (ITR, statement not included in D3241) RR:D02-1774 (ETR, statement not included in D3241)	
SME Evaluation	Based solely on the method, there is nothing about the physical execution of the instrument that is likely to be affected by the fuel chemistry. The formation or lack of formation of deposits is the desired data and is the output of the method. The method is not dependent on the chemical composition of the fuel, but rather reports it. Considering only at that limited scope of review, there is nothing that suggests that the execution of the method is sensitive to the chemical composition. While the method itself may not be directly sensitive to the chemical composition, the output and interpretation of the data cannot be separated from the execution of the method. Significant efforts in the industry to approve multiple evaluation techniques are currently on-going. The extent, challenges and results of those efforts exceed the scope of this assessment. This is a result of recognition of both limitations to the measurement and interpretation of the data and challenges experienced as fuel chemistry changes. Given the extent of interpretation issues being reviewed regarding the JFTOT, its applicability, and the precision of the method with respect to alternatively produced jet fuels, a true SME evaluation is beyond the scope of the program at hand. I defer to the limits, concerns, and ongoing research as to the extent and applicability of the method to chemical composition. However, the extent of the research activity is sufficient to suggest caution as to the impact chemical composition may have on the method.	
Other	• None	

Specification Review

Impact Assessment:

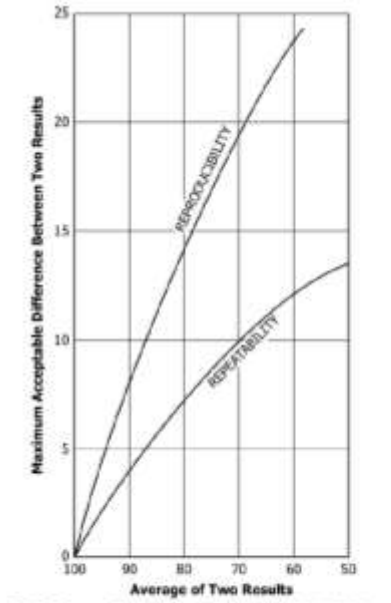
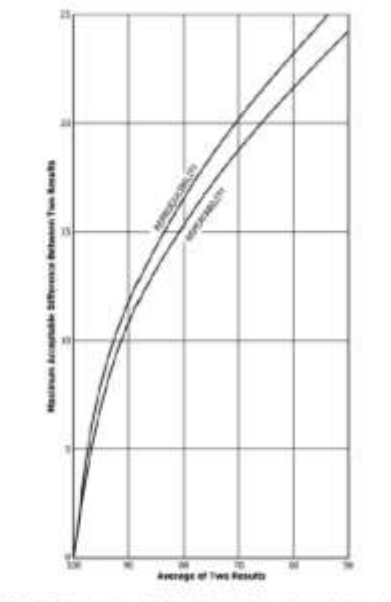
Red (Yellow) Green

D3701-01 (2012)	STM for Hydrogen Content of Aviation Turbine Fuels by Low Resolution Nuclear Magnetic Resonance Spectrometry	**Original Publication Date: 1978**
Specification Scope	Determine the hydrogen content using NMR set up specifically for analyzing jet fuel.	
Published Limitations	None	
Provided Precision Information	*Repeatability:* r = 0.09 mass % *Reproducibility:* R = 0.11 mass % *Bias:* 1977 study indicates method is bias high as compared to a pure hydrocarbon known.	
Referenced Research Reports	RR:D02-1186	
SME Evaluation	The method is based on a fundamental analytical instrument which is designed to measure the alignment of protons in a magnetic field. From that standpoint, the method is specifically designed to register hydrogen atoms. However, given that the method specifically notes that the method is biased high for pure hydrocarbons, and that the method recommends the use of D4808 for all other petroleum products, the offeror is encouraged to review the chemical composition of the alternatively produced fuel and determine if it would be better suited to one of the procedures described in ASTM D4808. This is particularly true as the chemical composition becomes more like a pure hydrocarbon, or blends of a few discrete moieties.	
Other	• Method is designed specifically for aviation turbine fuel. All other petroleum products are directed to the more global ASTM D4808 method which is not called out by the parent documents in this program. ○ Specific difference appears to be the setting of the audio frequency gain of the instrument and clearly specifying a pure hydrocarbon as the reference standard. • Method is described as providing a quick and more precise alternative to other hydrogen content determination methods involving other parameters or combustion.	

Impact Assessment: Red Yellow Green

Specification Review

D3948-14	STM for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer	Original Publication Date: 1980

Specification Scope	The ability of water to separate from a turbine fuel is evaluated by flowing fuel through a fiberglass coalescing material. Designed as a field unit.
Published Limitations	MSEP rating from 50 to 100 Method is sensitive to trace contamination
Provided Precision Information	 FIG. 9 Reference Fuels—MSEP-A (Mode A Operation) Variation of Repeatability and Reproducibility of MSEP-A Ratings Obtained for Reference Fuels (Jet A, Jet A-1, MIL JP-5, MIL JP-7, and MIL JP-8) Containing a Dispersing Agent  FIG. 10 Field Samples—MSEP-A (Mode A Operation) Variation of Repeatability and Reproducibility of MSEP-A Ratings Obtained for Field Samples (Jet A, Jet A-1, MIL JP-5, MIL JP-7, and MIL JP-8)
Referenced Research Reports	RR:D02-1647 RR:D02-1274
SME Evaluation	The test method is based on the chemistry concept that the additives interfere with the ability of the fuel to release the water. The free water is measured as turbidity after the sample is run through coalescing materials.

	There are two ways this process could potentially be affected by the fuel chemistry if it deviates too far from traditional petroleum-based composition. 1) The base fuel is seen as turbid by the machine even if the water was removed. This should be recognized as an interference during baseline runs but would likely impact instrument precision. 2) The fuel chemistry is such it is less able to release the water despite the coalescer not being disarmed. The instrument is most likely not sensitive to the chemical composition of the alternatively produced fuels, but the precision statement is likely to be sensitive to the fuel chemistry. Furthermore, appendix X3 has correlations of the MSep to the MSS. These are based on results from the two methods and reported as a formula. Because the alternatively produced fuel chemistries have not been analyzed using the withdrawn D3602 method, it would be unwise to assume continued formulaic correlation without actual data.
Other	• Mode A used for kerosene – Essentially equivalent to ASTM D2550 and D3602 • Mode A used for wide cut (JP-4/Jet B) and gasoline – Essentially equivalent to ASTM D3602 but not equivalent to ASTM D2550 • Mode B used for gasoline – Essentially equivalent to ASTM D2550 • Operation is based on turbidity

Specification Review

Impact Assessment:

Red Yellow Green

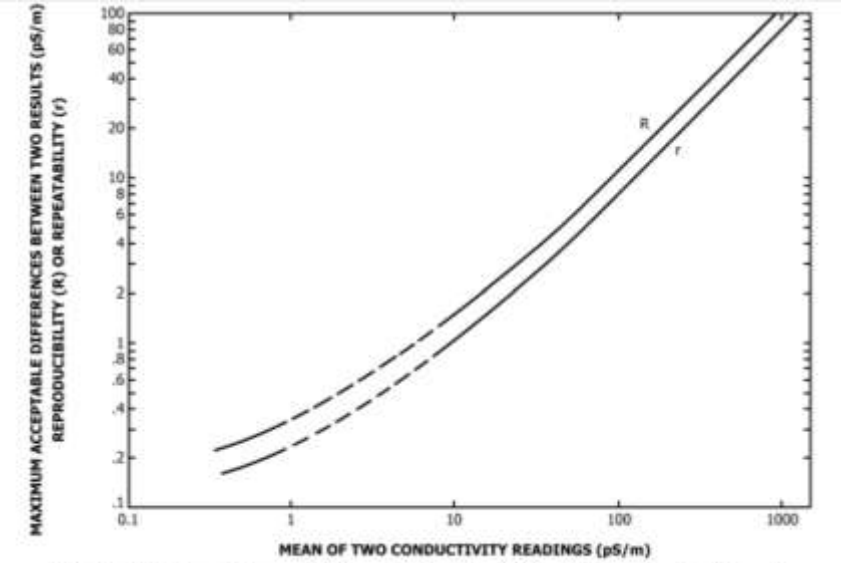
D4052-15	STM for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter	Original Publication Date: 1981

Specification Scope	Determination of density , relative density and API gravity by use of a density meter
Published Limitations	Petroleum distillates and viscous oils that are liquid (see comment on definition of petroleum products). ASTM D5191 vapor pressure less than 100 kPa and viscosity less than 15,000 mm²/s. Visually colored light enough to see bubbles.
Provided Precision Information	Precision statements are given specific to the measurement, to the type of material being measured and the type of injection. TABLE 2 Density (g/mL) and Relative Density (Repeatability) Range | Sample Types | Testing Condition | Repeatability 0.71–0.78 | Gasoline and RFG | Single Determination (Manual injection) | 0.00045 Average of 2 Determinations (Manual or automated injections) | 0.00031 0.80–0.88 | Distillates, Basestocks, and Lubricating Oils | Single Determination (Manual or automated injection) | 0.00016 Average of 2 Determinations (Manual or automated injections) | 0.00011 TABLE 3 API Gravity (Repeatability) Range | Sample Types | Testing Condition | Repeatability 51–85 | Gasoline and RFG | Single Determination (Manual injection) | 0.080 Average of 2 Determinations (Manual or automated injections) | 0.063 29–45 | Distillates, Basestocks, and Lubricating Oils | Single Determination (Manual or automated injection) | 0.032 Average of 2 Determinations (Manual or automated injections) | 0.022 TABLE 4 Density (g/mL) and Relative Density (Reproducibility) Range | Sample Types | Testing Condition | Reproducibility 0.71–0.78 | Gasoline and RFG | Single Determination (Manual injection) | 0.00160–0.0044 (D–0.75) Average of 2 Determinations (Manual or automated injections) | 0.00105–0.0015 (D–0.75) 0.80–0.88 | Distillates, Basestocks, and Lubricating Oils | Single Determination (Manual or automated injection) | 0.00352 Average of 2 Determinations (Manual or automated injections) | 0.00350 where: D = density or relative density value obtained TABLE 5 API Gravity (Reproducibility) Range | Sample Types | Testing Condition | Reproducibility 51–86 | Gasoline and RFG | Single Determination (Manual injection) | 0.60 + 0.040 (G–80) Average of 2 Determinations (Manual or automated injections) | 0.60 + 0.037 (G–80) 29–45 | Distillates, Basestocks and Lubricating Oils | Single Determination (Manual or automated injection) | 0.133 Average of 2 Determinations (Manual or automated injections) | 0.126 where: G = API Gravity value obtained ILS performed in 1996 included 11 labs and 23 samples. The samples included 4 Jet A and 1 JP-8 sample. The larger variability of the gasoline samples was attributed to the volatile nature of gasoline.

	The method has a bias as indicated by the results from pure materials. The bias is as high as 0.0006 g/ml and is related to viscosity. Newer instruments purport to have addressed this bias, but no study has been done.
Referenced Research Reports	RR:D02-1734 RR:D02-1387 (Bias to pure chemicals)
SME Evaluation	The measurement of the oscillation time is based on physical properties of fluids and should not be affected by chemical composition, (NOTE viscosity bias). API gravity is a calculated value using this method and is based on the formulae developed from the ASTM D1250 petroleum measurement tables. If the chemical composition deviates sufficiently that the formulae from D1250 are affected, then the instrument may report an inaccurate API gravity. This could be further impacted for data collected at other than standard temperatures (60 °F/60 °F) as there are additional concerns related to temperature correction calculations in D1250 (see review of ASTM D1250)
Other	• Density is determined by the change in oscillation frequency caused by the mass of the fluid in conjunction with calibration data. • Instrument is calibrated on air and water. • Density and relative density (aka specific gravity) are calculated from the oscillation period. On board software reports equivalent API gravity based on ASTM D287 (API hydrometer), D1298 (Hydrometer and conversions), and D1250 (Petroleum measurement tables) o Answers are reported to 4 significant figures, all computations use 6 significant figures.

Impact Assessment: Red Yellow Green

Specification Review

D4308-13	STM for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter	Original Publication Date: 1983
Specification Scope	Determines the "rest" electrical conductivity of aviation fuels and other low conductivity hydrocarbon liquids by applying a known voltage and measuring the voltage passing through the sample.	
Published Limitations	Conductivity range of 0.1 to 2000 pS/m Note 8: Conductivity is temperature dependent and each laboratory must establish temperature versus conductivity *for fuels of interest* (italics added).	
Provided Precision Information	 FIG. 3 Variation of Repeatability and Reproducibility with Conductivity Level No formulae provided	
Referenced Research Reports	RR:D02-1170	
SME Evaluation	The physical test method measures movement of electricity between two electrodes (current). This is a fundamental physical property and as such is not affected by the test medium. Rather it is used to measure changes to the test medium. However, any site generated correction factors would have to be reviewed for sensitivity to the fuel composition.	

	The contributing environmental factors that impact the test method, i.e. test temperature, frequency, current type, etc. may require confirmation testing to demonstrate the environmental factors display impacts similar to those seen with traditionally prepared jet fuel. Changes to the fuel chemistry could feasibly change the correlations used to present data. It may also impact correlations between instrument types. *NOTE: A noticeable amount of work involving instruments measuring conductivity is currently taking place. Any findings within these studies related to the differences in fuel chemistry are not immediately known.*
Other	• Method replaced D3114 which was withdrawn in 1985. • Method not called by parent documents, but is called out as a see also in ASTM D2624. • Uses different equipment than ASTM D2624. • Recommends the use of AC current measurements for conductivities 0.1 to 1.0 pS/m but this DC method can be used if strict cleanliness requirements are met.

Impact Assessment:

Red Yellow Green

Specification Review

D5001-10 (2014)	STM for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)	Original Publication Date: 1989
Specification Scope	A ball is placed against a spinning cylinder that is wetted with the sample at a defined temperature and relative humidity (10%). The size of the resulting wear scar is measured and used to assess the lubricating ability of the sample.	
Published Limitations	None	
Provided Precision Information	*Repeatability:* $r = 0.08311 * X^{1.5832}$ $r = 0.08580 * X^{2.5083}$ (semi) *Reproducibility:* $R = 0.01178 * X^{1.5832}$ $R = 0.09857 * X^{25083}$ (semi) Where X = the mean WSD	
Referenced Research Reports	RR:D02-1639 RR:D02-1256	
SME Evaluation	Within the limits of the test, the wear scar is a physical manifestation of the friction experienced between the rotating cylinder and the ball. The results are used to predict test fluid behavior. Executing the test method is not dependent on the chemical composition of the test fluid beyond high volatility causing evaporation of the sample before test completion. The concern is the correlations drawn between the results observed from the BOCLE and the performance in use. WSD and the BOCLE have proven useful in predicting behavior in some hardware applications but has not been an absolute. Fuels containing certain additives have been observed to have "normal" WSD results but not perform as expected. Similarly, fluids have tested that have had large WSD diameters but have not demonstrated correlating performance. The caveat is that changes to the chemical composition can have significant impact on the resulting WSD that may or may not be correlated to the actual performance.	

	Impacts to the precision statement would also need to be evaluated.
Other	• Fuel chemistry has been shown to have a measurable impact on the test results. • The data are the wear scar diameter (WSD) of the wear on the ball calculated as $\frac{M+N}{2}$ where M is the length of the major axis in mm and N is the minor axis in mm. • Highly volatile components have been observed to evaporate during the test, changing the chemical composition of the test fluid and potentially the end results.

Specification Review

Impact Assessment:

Red (Yellow) Green

D5190-07 (WD2012)	STM for Vapor Pressure of Petroleum Products (Automatic Method)	**Original Publication Date: 1991**
Specification Scope	Determine the total vapor pressure of air containing volatile petroleum products. Method is suitable for calculating the dry vapor pressure equivalent by correlation.	
Published Limitations	Suitable for liquids with boiling points above 0 °C (32 °F) and with vapor pressure between 7 and 172 kPa (1 to 25 psi) at 37.8 °C (100 °F).	
Provided Precision Information	*Repeatability:* r =2.48 kPa (0.36 psi) *Reproducibility:* R = 3.45 kPa (0.50 psi)	
Referenced Research Reports	RR:D02-1286	
SME Evaluation	The goal of Mil HBK 510 requiring D5190 is to get dry vapor pressure for use in determining the latent heat of vaporization. While the method has been withdrawn, it is still a referenced specification. This method is similar to other vapor pressure measurements in that a chilled sample is placed into a sample chamber and then forced into the expansion chamber. Because the method is based on fundamental physical behaviors, the method itself is not likely to be specifically sensitive to chemical composition. The measured vapor pressure is automatically converted to DVPE by the instrument. The method uses a bias correction to convert to DVPE equivalent to ASTM D4953. This bias correction could be sensitive to chemical composition.	
Other	• Specification was withdrawn 2012 ○ A review of the method shows it to be similar to ASTM D5482 - Mini Method, Atmospheric (referenced for the program). • Method does not account for dissolved water. • Dry vapor pressure (DVP) measured using ASTM D4953 (referenced for the program).	

Specification Review

Impact Assessment:
Red (Yellow) Green

D5191-15	STM for Vapor Pressure of Petroleum Products Mini-Method	**Original Publication Date: 1991**
Specification Scope	Measure total vapor pressure exerted in a vacuum by air containing volatile petroleum products including spark-ignition fuels.	
Published Limitations	Not recommended for crude oil measurements	
Provided Precision Information	*Repeatability:* r = 1.47 kPa (0.21 psi) *Reproducibility:* R = 2.75 kPa (0.40 psi)	
Referenced Research Reports	RR:D02-1619 RR:D02-1260	
SME Evaluation	The vapor pressure measurements are based on direct observation of a fundamental physical behavior so the method should show changes in chemical composition not be affected by them. The reported DVPE is calculated from the measured total pressure (fluid + air) but dissolved water is not considered. The DVPE equation was derived from the results of an ILS and confirmed in a second study. There is a strong suggestion the testing was only done on spark ignition fuels and fuel/oxygenates and the reference tests were performed with high vapor pressure chemicals. This raises concerns for the applicability of at least the method precision statements, and possible the correlation for lower vapor pressure fluids like jet fuel, especially as the dissolved water content increases. The instruments are undoubtedly well programmed for traditional aviation turbine fuel, but how the software handles deviations from known are unclear. While the scope would permit the method use with lower vapor pressure fuels, care should be taken in considering the DVPE correlation.	
Other	• Method correlates to DVPE (ASTM D4953), but is more precise than D4953.	

Impact Assessment:

Red (Yellow) Green

Specification Review

D5482-15	STM for Vapor Pressure of Petroleum Products (Mini-Method – Atmospheric)	**Original Publication Date: 1993**
Specification Scope	Measure total vapor pressure exerted by petroleum products with a boiling point above 0 °C (32 °F) and vapor pressure between 7 to 110 kPa (1.0 to 16 psi) at 37.8 °C (100 °F). The method is applicable to gasoline fuels. No account is made for dissolved water.	
Published Limitations	Not recommended for crude oil measurements	
Provided Precision Information	*Repeatability:* r = 0.19 psi (Herzog) R = 0.26 psi (ABB) *Reproducibility:* R = 0.39 psi (Herzog) R = 0.60 (ABB)	
Referenced Research Reports	RR:D02-1286 Study included 14 hydrocarbons with vapor pressure from 2 to 15 psi The fuels used appear to be primarily spark ignition fuels. This study is the source of the correlation factors used by the two instruments to correlate the observed vapor pressure to DVPE.	
SME Evaluation	The vapor pressure measurements are based on direct observation of a fundamental physical behavior so the method should show changes in chemical composition not be affected by them. The reported DVPE is calculated from the measured total pressure (fluid + air) but dissolved water is not considered. There are concerns regarding the correlation, especially as the dissolved water content increases. If there is reason to suspect the chemical composition is more conducive to holding dissolved water, the offeror is encouraged to confirm continued accuracy in the correlation to DVPE. There is also a potential concern related to the precision statement as the chemical composition of the fuel diverges from that of traditional spark ignition fuels. The instruments are undoubtedly well programmed for traditional aviation turbine fuel, but how the software handles deviations from known are unclear.	
Other	• This method is essentially the same as ASTM D5190 except the chamber is not evacuated but is left at atmospheric pressure. • Method correlates to DVPE (ASTM D4953), but is more precise than D4953.	

Impact Assessment:

Red Yellow Green

Specification Review

D5972-16	STM for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)	Original Publication Date: 1996
Specification Scope	Determination of the temperature below which solid hydrocarbon crystals may form in aviation turbine fuels.	
Published Limitations	Range -80 ° to 20 °C (-112 to 68 °F). Note: ILS only demonstrated-60 to -42 °C (-76 to -44 °F).	
Provided Precision Information	*Repeatability:* r = 0.5 °C *Reproducibility:* R = 0.8 °C *No Reported relative bias to ASTM D2386 (manual method):* There may be a relative bias for wide-cut fuels but there was insufficient data.	
Referenced Research Reports	RR:D02-1385 RR:D02-1572	
SME Evaluation	The following is not a condemnation of the automatic fiber optic method, and after further analyses the following concerns may be found to be non-issues. However, contemporary challenges with the use of automatic equipment suggest a sensitivity to fuel composition that warrants further investigations. (see discussion on freeze point measurements). The instrument was designed around the expected crystallization of a standard hydrocarbon fuel. There is a concern related to issues being observed in contemporary data that the instrument may register materials that melt at unreasonably high temperatures and are not representative of the actual freeze point of the fuel. If the fuel composition deviates enough from the composition used to develop the instrument and method, it is possible the instrument may generate/optically register materials that are not indicative of freeze point, or are registered erroneously as contaminate. Depending on the nature of these 'other' crystals, the instrument may report skewed results either artificially high or inappropriately low.	

	The argument could be made, that it does not matter what the chemical composition of the material triggering the instrument to report a freeze point, as the formation of any type of crystal is problematic to the aircraft system. The instrument, however, is designed to maximize sample throughput and not to replicate real world cooling and warming cycles. The precision statement would also potentially be affected by the chemical composition change.
Other	• Procedures cannot be used if D2386 is required. • In use with traditional fuel, the test has produced results found to be equivalent to D2386 data, but D5972 allows reporting freeze point to the nearest 0.1 °C with improved precision. • System cools the fuel at 15 °C/min until crystals are observed by the optical sensors and then warmed at 10 °C/min until they disappear.

Impact Assessment: Red Yellow Green

Specification Review

D6379-11	STM for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates – High Performance Liquid Chromatography Method with Refractive Index Detection.	Original Publication Date: 1999

Specification Scope

Determine the mono- and di-aromatic hydrocarbon content in aviation kerosene and petroleum distillates using HPLC with RI detection.

Published Limitations

Sulfur, nitrogen, and oxygen are interferents.

Conjugated di and poly alkenes are interferents.

Provided Precision Information

Both repeatability and reproducibility are moiety specific and concentration specific.

	Range, mass %	r	R
Mono-aromatic	10.5 to 24.1	$0.129 * X^{0.667}$	$0.261 * X^{0.667}$
Di-Aromatic	0.1 to 6.64	$0.337 * X^{0.333}$	$0.514 * X^{0.333}$
Total	10.6 to 29.8	$0.147 * X^{0.667}$	$0.278 * X^{0.667}$

Where X = average of the results being compared

Referenced Research Reports

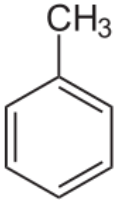
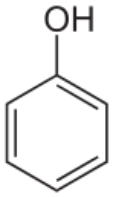
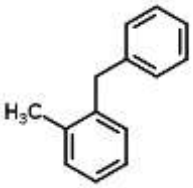
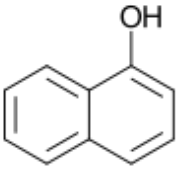
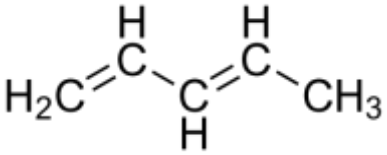
RR:D02-1446

SME Evaluation

The method will only be sensitive to chemical composition, if the chemical composition contains any of the interferents. There is nothing in the analytical method beyond the listed limitations which should be affected by the chemical composition of the alternatively produced jet fuel. In some cases, there may be fewer interferents due to the absence of nitrogen and sulfur in alternatively produced fuels which generally are present in petroleum-based fuels.

The precision statements were developed and confirmed with liquid hydrocarbons in the kerosene range, so the precision statements are not likely to be negatively impacted.

The one notable consideration is the interference by di- and polyalkenes which may be present in alternatively produced jet fuel depending on the process. It is recommended that the method be

	carefully evaluated for compositions which may contain measurable quantities of these compounds.
Other	• Examples of mono-aromatic   Toluene Phenol and di-aromatics   Benzyltoluene 1-naphthol • Example of a conjugated di-alkene  1-3 Butadiene

Specification Review

Impact Assessment:
Red Yellow Green

D7153-15	STM for Freezing Point of Aviation Fuels (Automatic Laser Method)	Original Publication Date: 2005
Specification Scope	Determination of the temperature below which solid hydrocarbon crystals may form in aviation turbine fuels.	
Published Limitations	Range -80 ° to 20 °C (-112 to 68 °F). Note: ILS only demonstrated -20 to -42 °C (-4 to -44 °F).	
Provided Precision Information	*Repeatability:* r = 0.6 °C *Reproducibility:* R = 0.9 °C *Reported relative bias to ASTM D2386 (manual method):* Manual value = X - 0.347 where X = mean of value measured by D7153 Data developed from an ILS of 13 specimens of aviation turbine fuel tested at 13 laboratories.	
Referenced Research Reports	RR:D02-1572	
SME Evaluation	The following is not a condemnation of the automatic laser method, and after further analyses the following concerns may be found to be non-issues. However, contemporary challenges with the use of the equipment suggest a sensitivity to fuel composition that warrants further investigations. (See discussion on freeze point measurements). The instrument was designed around the expected crystallization of a standard hydrocarbon fuel, thus it assumed any crystal observed 'must' be hydrocarbon. It recognized that there were cases of an additional peak (change in light signals) being observed. This was addressed by the machine as a contamination and triggered a second test cycle with alternative cooling / heating rates. The concern is related to issues being observed in contemporary data that the instrument may register materials that melt at unreasonably high temperatures and are not representative of the actual freeze point of the fuel.	

	If the fuel composition deviates enough from the composition used to develop the instrument and method, it is possible the instrument may generate/optically register materials that are not indicative of freeze point, or are registered erroneously as contaminate. Depending on the nature of these 'other' crystals, the instrument may report skewed results either artificially high or inappropriately low. The argument could be made, that it does not matter what the chemical composition of the material triggering the instrument to report a freeze point, as the formation of any type of crystal is problematic to the aircraft system. The instrument, however, is designed to maximize sample throughput and not to replicate real world cooling and warming cycles. The precision statement would also potentially be affected by the chemical composition change and a bias to D2386 with petroleum-based jet fuels has already been reported.
Other	• Cd = temperature at which optical detector sees a crystal Co = temperature at which liquid becomes opaque by optical opacity detector Do = temperature at which opacity disappears. Specimen is cooled at 10 °C/min until both detectors see hydrocarbon crystals. Then it is warmed at 3 °C/min until opacity clears and then at 12 °C/min until last hydrocarbon crystal disappears • When the specification requires ASTM D2386 (manual method), cannot substitute D7153. • If contamination is suspected as indicated by the presence of three peaks during cooling step, a different cooling/warming cycle is triggered.

Impact Assessment:

Red Yellow Green

Specification Review

D7154-15	STM for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)	Original Publication Date: 2005
Specification Scope	Determination of the temperature below which solid hydrocarbon crystals may form in aviation turbine fuels.	
Published Limitations	Range -70 ° to 0 °C (-94 to 32 °F). Note: ILS only demonstrated -60 to -42 °C (-76 to -44 °F).	
Provided Precision Information	*Repeatability:* r = 0.5 °C *Reproducibility:* R = 1.9 °C *No Reported relative bias to ASTM D2386 (manual method):* Data developed from an ILS of 13 specimens of aviation turbine fuel tested at 11 laboratories.	
Referenced Research Reports	RR:D02-1572	
SME Evaluation	The following is not a condemnation of the automatic fiber optic method, and after further analyses the following concerns may be found to be non-issues. However, contemporary challenges with the use of automatic equipment suggest a sensitivity to fuel composition that warrants further investigations. (See discussion on freeze point measurements). The instrument was designed around the expected crystallization of a standard hydrocarbon fuel. It recognized opacity at -10 °C that did not increase was due to water and was disregarded. There is a concern related to issues being observed in contemporary data that the instrument may register materials that melt at unreasonably high temperatures and are not representative of the actual freeze point of the fuel. The use of stirring is likely to reduce the formation of crystals not related to the freeze point of the fuel. If the fuel composition deviates enough from the composition used to develop the instrument and method, it is possible the instrument may generate/optically register materials that are	

	not indicative of freeze point, or are registered erroneously as contaminate. Depending on the nature of these 'other' crystals, the instrument may report skewed results either artificially high or inappropriately low. The study in which 14% of the samples were incorrectly identified as contaminated suggests the method may be sensitive to chemical composition (RR:D02-1572). The argument could be made, that it does not matter what the chemical composition of the material triggering the instrument to report a freeze point, as the formation of any type of crystal is problematic to the aircraft system. The instrument, however, is designed to maximize sample throughput and not to replicate real world cooling and warming cycles. The lack of specified cooling and heating rates may cause issues related to crystals forming related to the temperature ramp rates. The precision statement would also potentially be affected by the chemical composition change.
Other	• Procedures mimics D2386 but cannot be used if D2386 is required. • Samples are stirred throughout the test. Sample is cooled until crystals are observed and then warmed until they disappear. No rates given. • Software ignores opacity formed at -10 °C that doesn't increase in intensity as temperature drops . • Method nearly identical to ASTM D5901, only the software has been changed. D5901 is not called by parent documents.

Impact Assessment:

Red Yellow Green

Specification Review

D7524-10 (2015)	STM for Determination of Static Dissipater Additives (SDA) in Aviation Turbine Fuel and Middle Distillate Fuels – High Performance Liquid Chromatograph (HPLC) Method	Original Publication Date: 2010

Specification Scope	Determine the SDA content in aviation turbine fuel and middle distillates.
Published Limitations	Only applies to SDA containing alkyl substituted sulfonic acid, as method measures the sulfonic acid content.
Provided Precision Information	Based on DINNSA and DDBSA *Repeatability:* r = 0.5991 *Reproducibility:* R = 1.1779
Referenced Research Reports	RR:D02-1685
SME Evaluation	The method is based on the analytical principle of separation by polarity. As long as sulfonic acid SDA is the target anion, this method should perform. The solid phase extraction (SPE) step is based on polarity and assumes that there is nothing else separated from the fuel at this step. That being said, the eluate will be further separated by the HPLC and it is possible any component collected during the SPE would elute from the HPLC at a different retention time than the sulfonic acid. It would be necessary to know which peak was the sulfonic acid peak if other materials are eluted. Further method development would be required. If no other components are collected or measured during the process, there is no reason to expect any impact on the precision of measuring SDA concentration. However, until it can be demonstrated an alternative fuel preparation method does not contain either naturally occurring sulfonic acid compounds or other components that are separated by the SPE, or other compounds that will act as an interferent to the HPLC analysis, the method could be fuel chemistry sensitive.
Other	• The sulfonic acid is concentrated through the use of a solid phase extraction

The sulfonic acid is separated from the liquid phase, dependent on the polarity. The solid phase attracts one polarity and the other polarity passes.

The sulfonic acid passes through and is detected by the UV detector.

Peak area is used to determine concentration by comparison to calibration standard results.

- Alkyl substituted sulfonic acid

- DINNSA – di nonyl naphthyl sulfonic acid
- DDBSA – dodecyl benzene sulfonic acid

Impact Assessment:

Red Yellow Green

Specification Review

D7797-16	STM for Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy – Rapid Screening Method	Original Publication Date: 2012

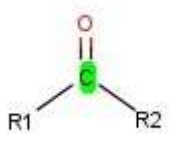
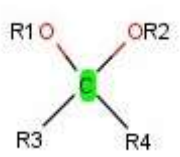
Specification Scope	Uses flow FT-IR to determine the FAME content in aviation turbine fuel at 10 to 150 mg/kg.
Published Limitations	Test detects all FAME components that respond at 1749 cm^{-1} and have C_8 to C_{22}. Additives that can be measured by the FT-IR should be removed by the flow analysis processing.
Provided Precision Information	Accuracy was developed with C_{16} to C_{18} composition. ILS was performed by Energy Institute. ILS was 8 labs, 13 turbine fuels treated with FAME. The fuels included hydrotreated, unhydrotreated and synthetic fuels. *Repeatability:* r = 4.589 mg/kg *Reproducibility:* R = 0.04967 * (X + 100) [result – 5.5 @ 10 ppm to 12.4 @ 150 ppm]
Referenced Research Reports	IP583 Round Robin Research Report IP583 FAME in Jet Worldwide Test Programme Research Report
SME Evaluation	This method uses an onboard software conversion (PLS-1 model) that was developed and frozen to report the integrated value. The user can not adjust it. The PLS-1 model would be a function of the 900 specimens used to create it. It is not beyond the realm of concern that as the chemical composition of the fuel deviates from the fuels used to create the model, the measured results may diverge from the model. The FT-IR only reports a signal response at the wave number, regardless of the source of the signal. Therefore deviation errors may occur due to the removal of a species that is not FAME, or the presence of an absorbing species that occurs at or near the wavelength of interest. This suggests there is a potential to be sensitive to the chemical composition. It

	would be prudent to validate the pre and post sorbent results of a clean fuel.
Other	• Method calls out ADJD6300. D2PP adjunct for determining precision and bias is no longer available from ASTM. It is a software program called in a number of specifications. ASTM D6300-03 describes it. • The method compares the peak area before and after being run through a sorbent material. The pre and post sorbent results are run through an on-board PLS-1 model that is fixed. It was generated from over 900 data point from Merox and hydrotreated fuels from over 20 refineries. • FAME content is calculated as mg/kg FAME = integrated value $*\frac{density\ calibrant}{density\ sample}$ • Conversations with the method developer confirmed that the test method had been developed and the ASTM controlled PLS-1 model run using an extensive array of traditional kerosene jet fuels. This testing fully validated the method on traditional kerosene. The developer did agree that compositions that deviated from traditional paraffinic, normal boiling range kerosene should be validated.

Impact Assessment:

Red (Yellow) Green

Specification Review

E411-12	STM for Trace Quantities of Carbonyl Compounds with 2,4-dintrophenylhydrazine	**Original Publication Date: 1970**
Specification Scope	Determines the total carbonyl concentration at 0.5 to 50 µg. Also detects related acetal compounds if they hydrolyze under the test conditions.	
Published Limitations	Acetals that only partially hydrolize interfere. Aldehydes and ketones in organic solvents react	
Provided Precision Information	*Repeatability:* r = 0.4 µg/g *Reproducibility:* R = 17%	
Referenced Research Reports	RR:E15-1006	
SME Evaluation	The method is based on reaction chemistry with known interferences. As long as the restrictions and warning regarding interferences are complied with, the method is routine colorimetric chemistry and measures changes in chemical composition, is not affected by them. However, given the number of potential undesirable reactions or incomplete reactions that could occur, the use of this specification should be done with consideration. In general, the method could be fuel chemistry sensitive, many of which are discussed in the specification.	
Other	• None of the related methods are listed in the parent specifications – D1089, D1612, D2119, or D2191. None were reviewed for applicability. • Sample is reacted with 2,4-dinitrophenylhydrazine to form hydrazine which reacts with potassium hydroxide and displays a color change. This is read with a photometer. The amount of color is correlated to a calibration color chart. • Carbonyls with conjugated unsaturation absorb at a different wavelength and are not seen at this method's wavelength. • Example reactive chemistries  Carbonyl  Acetal  Imine	

Specification Review

Impact Assessment:

Red Yellow Green

E2071-00 (2015)	Standard Practice for Calculating Heat of Vaporization or Sublimation from Vapor Pressure Data	**Original Publication Date: 2000**
Specification Scope	Calculates the heat of vaporization of a liquid from measured vapor pressure data.	
Published Limitations	Applicable to pure liquids and azeotropes. Method is not generally applicable to mixtures as the composition changes with vaporization.	
Provided Precision Information	None	
Referenced Research Reports	None	
SME Evaluation	All of the calculations presented in the method are based on foundational physical chemistry concepts. However, when considering the caveat on the impact of mixtures on the approximation, traditional petroleum based jet fuel is likely to have limited accuracy. When considering the impact of alternatively produced jet fuel chemical composition, the accuracy will be reflected in the amount of convergence or divergence on a single chemical moiety. In the extreme, compositions of components with measurably different heat of vaporizations, the accuracy is likely to be poor.	
Other	• Method references vapor pressure measurements different from any referenced in the program documents; ASTM D2879, ASTM E1194, ASTM E1719, or ASTM E1782. • The vapor pressure is measured and then correlated with the Antoine equation. The Antoine vapor pressure equation and graph are discussed in E1719.	

11.6.3 Red –

Specification Review

Impact Assessment: Red Yellow Green

D924-15	STM for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids	Original Publication Date: 1947
Specification Scope	Determining the dielectric constant of insulating liquids used in electrical apparatus.	
Published Limitations	The method was not developed for fuels	
Provided Precision Information	Precision statement was developed using mineral oil. *Repeatability:* r = 11% (permittivity) $r_{25C} = 0.06\ x^{0.65}$ % $r_{100C} = 0.237\ x^{0.609}$ % *Reproducibility:* R = 9% (permittivity) $R_{25C} = 0.384\ x^{0.65}$ % $R_{100C} = 0.467\ x^{0.609}$ %	
Referenced Research Reports	RR:D27-1015	
SME Evaluation	The precision statement was developed using mineral oil and as such may not be applicable to traditional aviation turbine fuel, much less to alternatively prepared fuels. Beyond the fact that the method was not developed for aviation fuels, there are two basic reasons for this test methodology to be reviewed more carefully. 1. The dielectric constant is related to density and the speed with which the atoms respond to the electric field. The first becomes part of the analysis; the second can be foundational to the results.	

	2. The method was not originally developed for measuring fuel capacitance. The data were determined to provide a useful means of measuring fuel volume and by relationship calculation, determining density, and therefore mass of fuel. As such there are a number of testing variables that are points of discussion within the industry: the K-cell vs. a 3 terminal cell; the frequency at which the test is run; the relative density terms used for calculations (vacuum or air, dry or ambient, matched temperature or ambient) While capacitance and its measurement are foundational physics properties, the testing parameters and how the data are used ARE fuel chemistry dependent and how to deal with the data calculations are chemical composition sensitive. There are enough variables and calculations involved to suggest that the test method is sensitive to chemical composition.
Other	• The method does not describe the anticipated chemistry for the fluid • Measured at 45 and 65 hz • Permittivity = dielectric constant, ratio of the fluid to air or vacuum. ε = farads/m², κ, permittivity relative to a vacuum, is dimensionless. Aircraft gauges sense ε and 'computes' ρ (density) which gives the mass, which is what the pilot uses.
References	• Maxwell, S (1970) *Aviation Fuels*. G.T. Foulis & Co. Ltd., p288. • Johnson, IB (1965) *Aviation Turbine Fuel Densities and Permittivities 1952 to 1964*, London S Smith & Sons (England) Ltd, Engineering & Research Dept., Report no. W193 • Bessee, GB; Hutzler, SA; Wilson GR (2011) *AFRL-RZ-WP-TR-2011-2084 Propulsion and Power Rapid Response R&D Support Analysis of Synthetic Aviation Fuel*

Specification Review

Impact Assessment:
Red Yellow Green

D976-06 (2016)	STM for Calculated Cetane Index of Distillate Fuels	**Original Publication Date: 1966**
Specification Scope	Estimates cetane value from API gravity and the mid boiling point.	
Published Limitations	This method is not applicable to pure hydrocarbons, synthetic fuels, alkylates or coal tar products.	
Provided Precision Information	*Repeatability:* r = +/- 2 cetane numbers, and gets worse as fuel deviates from ideal diesel fuel.	
Referenced Research Reports	None Calculation reference: ASTM Adjunct ADJD0976	
SME Evaluation	This method is NOT applicable to jet fuel and is specifically invalid by the published limitations. The results will be affected by the chemical composition of the sample.	

Other	• Method is not a replacement for measuring cetane number. It is used by the EPA to control diesel fuel aromatics concentration.
	  ○ Recommends ASTM D4737 for estimating diesel cetane (not referenced).
	• Method uses a formula, originally developed by CRC, in which the API gravity or density and the mid point boiling temperature are used to estimate a calculated cetane index.
	  ○ The formula is represented by a series of graphs, off of which a value is read.	

Specification Review

Impact Assessment: Red Yellow Green

D1250-08 (2013)	Standard Guide for Use of the Petroleum Measurement Tables	Original Publication Date: 1952
Specification Scope	The document is used for temperature and pressure volume correction factors for petroleum products and provides the algorithm and implementation procedure for the correction of temperature and pressure effects on density and volume.	
Published Limitations		
Provided Precision Information	None	
Referenced Research Reports	None	
SME Evaluation	Originally the measurement tables were the output of equations created from a great deal of petroleum product data. From the manual in 1954, API gravity = (141.5/specific gravity) – 131.5 at 60 °F. Specific gravity = the ratio of the weight of given volume of oil at 60 °F to the weight of the same volume of water at 60°F. The tables related the effect of temperature on volume, gravity or density based on actual oil data from 1912 – 1915 and the relationships were corroborated in the 1940s and 50s. The basic assumption was that all oils had a uniform coefficient of expansion. In 1942, volatile gasoline and LP relationships were added. These were based on the determined values from pure C3, C4, and C5 hydrocarbons. All of the original tables assumed the use of a hydrometer with the glass thermal expansion coefficient, "K", incorporated. Conversion of °API @60 °F to specific gravity 60/60 and density at 15 °C is a direct mathematical calculation. In the 1954 Table 5, converting API hydrometer reading at a test temperature to the API value at 60 °F the K and the change in	

volume is already accounted for in the table. To move between the temperatures requires interpolation.

Table 2.3 for converting observed specific gravity to specific gravity at 60/60, takes into account the changes in volume of the oil.

In 1980, the tables were given a full scale renovation. The hydrocarbons were separated into classes: Crude "A"; Refined products "B"; Special Applications "C"; Lubricating oils "D" and Very light (LPG & NGL) "E". The renovation also changed the measurement tables from a set of tables to pure mathematical equations which were suitable for calculations on computers.

During 1980 to 1990, while the renovations were underway, the standard value for the specific gravity @ 60 °F of water was changed slightly. A new preparation of software was required because the technology, including available software platforms, changed and the software could no longer be run on newer computers. During this same period, the real time density meters required pressure and temperature corrections before going into the VCF formulae.

The equations were changed again and replaced the tables entirely, so that the conversions between gravities, between values at different temperatures, and relationships between volumes and weights are all performed mathematically and only as inputs into a computer program.

Additionally, the equations are no longer based on hydrometer readings. If a hydrometer is used, the operator must correct the hydrometer values BEFORE inputting the numbers into the program, specifically corrections for the glass "K". Originally typical "K" values were provided as part of the D1250 measurement tables. They are no longer provided and the operator must determine the values from alternative sources.

To use the software, the hydrocarbon class must be chosen. The class chosen must be made on the actual density of the test fluid, not on the descriptor.

A study was performed for pure chemicals or homogeneous blends of pure chemicals using class "C" to confirm the

	expansion properties currently in the equations. Data has not yet been released. In summary, the use of the Petroleum Tables is no longer in the hands of the analyst. It is completely a software exercise requiring inputting the "correct" values. It assumes that all petroleum products follow the same correlations, and it assumes that the analyst selects the appropriate class to access the correct equation. Given the dependence on data from naturally occurring petroleum products, there is a concern that the correlations may not be the same for synthetically or alternatively produced hydrocarbon fuels. These variations may actually be small; however, there is a natural predilection to ascribe inappropriate accuracy and precision to a value reported from computer-based output that may be at odds with the precision and accuracy of the actual correlations. Given that the conversion between °API at 60 °F and specific gravity at 60 °F (subsequently changed to relative density) is a direct calculation this direct conversion is likely unaffected by the fuel composition. However, because volume changes are part of the calculations to convert from °API or relative density at one temperature to another, especially with the use of a hydrometer, there is a potential for diversion from historical data. These diversions from historical are potentially even more problematic for other outputs of the Petroleum Tables, such as volume vs weight calculations, and thermal expansion calculations used by the fuel handling and distribution industries.
Other	• °API Gravity = (141.5/SpGr) – 131.5 @ 60 °F • Hydrometer ≠ pycnometer • Conversions of °API Gravity at a temperature to °API Gravity @ 60 °F must account for both the hydrometer glass expansion "K" and the change in volume with temperature. These were already accounted for in the 1954 D1250 tables.

- Table 2.3 for conversion of observed specific gravity to specific gravity 60/60 accounted for the change in volume with temperature.

Specification Review

Impact Assessment:

Red Yellow Green

D1405-08 (2013)	STM for Estimation of Net Het of Combustion of Aviation Fuels	**Original Publication Date:1956**
Specification Scope	Estimation of net heat of combustion of aviation fuels based on correlation calculations from aniline-gravity	
Published Limitations	This method specifies it is only valid for liquid hydrocarbon fuels derived by normal refining processes from conventional crude oil. Method is not applicable to pure hydrocarbons. Should not substitute this method for experimental test methods.	
Provided Precision Information	*Repeatability:* r = 0.012 MJ/kg (5 BTU/lb) *Reproducibility:* R = 0.035 MJ/kg (15 BTU/lb)	
Referenced Research Reports	Values developed from the precision of the data from test methods supporting the estimation. No RR referenced.	
SME Evaluation	This specification is not applicable to alternatively developed fuels by limitations of the specification. The reported limitations on the method's ability to estimate the net heat of combustion of pure hydrocarbon means the estimation will be incorrect for fuel chemistries based on pure hydrocarbons. At best the test is +/- 15 BTU when used as intended. It is predicted to be even less precise as the chemistry deviates from conventional jet fuel chemistry.	
Other	• Other methods listed include D4529 and D240, both of which are listed in D1655 and D7566 • Correlation formulas were created in 1954 and 1958.	

Impact Assessment:

Red Yellow Green

Specification Review

D2425-04	STM for Hydrocarbon Types in Middle Distillates by Mass Spectroscopy	Original Publication Date: 1965

Specification Scope

Method is an "analytical scheme" using mass spectrometry data to designate hydrocarbon types present in "virgin middle distillates".

Published Limitations

Sample is a virgin middle distillate with a boing range of 204 to 343 °C (400 to 650 °F).

Composition should be paraffins C_{10} to C_{18} with the average carbon number between C_{12} to C_{16}.

Sulfur and nitrogen interfere if present in significant amounts.

Provided Precision Information

Precision statements are type and the mean mass % specific

Method precision is essentially composition dependent.

TABLE 7 Precision of Test Method

Compound	Concentration Mass, %	Repeatability	Reproducibility
Saturate Fraction:			
Paraffins	40 to 50	0.5	4.0
Monocycloparaffins	18 to 25	1.1	5.2
Dicycloparaffins	6 to 12	0.7	4.4
Tricycloparaffins	1 to 5	0.3	2.0
Alkylbenzenes	0 to 3	0.2	0.3
Aromatic Fraction:			
Paraffins	0 to 2	0.4	0.6
Cycloparaffins	0 to 2	0.5	0.9
Alkylbenzenes	3 to 8	0.3	1.4
Indan and/or tetralins	2 to 5	0.3	0.5
C_nH2n-10	0 to 4	0.3	0.7
Naphthalenes	3 to 8	0.3	1.0
C_nH2n-14	0 to 3	0.1	0.9
C_nH2n-16	0 to 3	0.3	0.7
C_nH2n-18	0 to 3	0.1	0.4

Referenced Research Reports

None

Statistical analysis of ILS, no study

SME Evaluation

A great deal of development work was done on this method regarding sensitivities, but in general the method doesn't care from where the hydrocarbon types came. Mass spectroscopy cannot tell what the source for a hydrocarbon was, only what the mass fragments making it to the detector are.

	It is noted that traditional jet fuel is just in the boiling point range limitation, and slightly outside of the carbon number distribution limitation, making use of the method as scoped, marginal for traditional fuels. As the alternatively prepared jet fuel sources result in more skewed, narrowed, or limited carbon number ranges, and less traditional composition, concerns for the applicability of the method as developed and described increase. The work developing the summation scheme may be impacted by the chemical composition of the sample. Moving to new sources may require changes to the scheme due to shifts in the carbon number distributions. The way this method is designed, an analyst has to have at least some knowledge of from where one is starting to confirm a) samples are in the target carbon number range, with the expected average carbon number, and b) expected carbon mass fragments that may or should be seen. In addition, testing to date has shown that reproducibility error increases as the paraffinic content increases. This means it is not a good choice of method for alternatively produced fuels, many of which have a very high paraffinic composition.
Other	• Method uses the summation of characteristic mass fragments to identify the hydrocarbon types present. • Eleven hydrocarbon types are determined by the method. • Samples are separated into saturate and aromatic fractions prior to running this test method by using ASTM D2549 separation techniques. NOTE: D2549 is not applicable to jet fuel since it is impossible to evaporate the solvent used in the separation without losing the light ends of the jet fuel. • The calculations used were changed between 1999 and 2004. • Industry shows indications of moving away from mass spectroscopy analyses to GC x GC – MS analyses. No ASTM test method for this type of analysis is currently available. • There are indications that the method gives incorrect results when synfuel is analyzed.
References	(2010) Significance of Test for Petroleum Products, ASTM Manual 1, Rand, SJ ed., 8th ed., ASTM International, p.318

Specification Review

Impact Assessment:
Red Yellow Green

D3338-09 (2014)	STM for Estimation of Net Heat of Combustion of Aviation Fuels	**Original Publication Date: 1974**
Specification Scope	Covers estimating net heat of combustion in aviation gasoline and aviation turbine fuel in the range of 40.19 to 44.73 MJ/kg.	
Published Limitations	Method is limited to Jet A, Jet A-1, Jet B, JP-4, JP5, JP7 and JP8	
Provided Precision Information	*Repeatability:* r = 0.021 MJ/kg (9 BTU/lb) *Reproducibility:* R = 0.046 MJ/kg (20 BTU/lb) Precision built on the precision statements of the feeding data's test methods.	
Referenced Research Reports	RR:D02-1183	
SME Evaluation	Synthetic fuels of a similar composition to the traditional petroleum fuel composition are likely to comply sufficient with the formulas to be within the broad precision of the specification. The estimation is based on correlations between four physical properties created from actual data. The further from norm the chemical composition moves, the more risk involved in using the formulas. This method has the potential to be significantly affected by the fuel composition because of the number of assumptions of correlations between physical properties and heat of combustion.	
Other	• Method developed using actual data and created correlations based on density, aromatics, sulfur and distillation. Six references were used to generate the equation.	

Impact Assessment: Red Yellow Green

Specification Review

D3343-16	STM for Estimation of Hydrogen Content of Aviation Fuels	Original Publication Date: 1974
Specification Scope	Method is an empirical estimation of hydrogen content "applicable to liquid hydrocarbon fuels that conform to the requirements of specifications for aviation gasolines or aircraft turbine and jet engine fuels of types Jet A, Jet A-1, Jet B, JP-4, JP-5, JP-7 and JP-8.	
Published Limitations	In 1998 a hydrocarbon range of C_6 – C_{10} was sited.	
Provided Precision Information	*Repeatability:* r = 0.03% *Reproducibility:* R = 0.10% Analysis used data from 331 fuels, 247 were aviation fuels and 84 were pure hydrocarbons.	
Referenced Research Reports	None provided.	
SME Evaluation	• The relationships in this method were developed for the listed jet fuels at the time of the method development and likely would not contain jet fuel chemical compositions that diverged from traditional petroleum-based jet fuel. • The analysis of determining API gravity is discussed in the review of ASTM D287. The potential issues with conversion between API gravity at one temperature to the API gravity at another are discussed in the review of ASTM D1250. • The results are reported to the nearest 0.01% hydrogen. This suggests a level of sensitivity in the method that is likely to be affected by changes chemical composition. The empirical formulae are from known hydrocarbon behavior based on expected types and ratios of aromatics, cyclics, and olefins. If an alternatively produced fuel has a chemical composition that significantly deviates in these ratios or types of hydrocarbons, the formulae may no longer be valid at least to the reported level of significance. Furthermore, the precision statements may no longer be valid. Demonstration	

	of continued compliance to the formulae in the method is recommended.
Other	• Method is based on experimentally determined relationships between API gravity, distillation range, aromatic content, and relative density. • "The estimation of the hydrogen content of a hydrocarbon fuel is justifiable only when the fuel belongs to a well-defined class for which a relationship among the hydrogen content and the distillation range, density, and aromatic content has been derived from accurate experimental measurements on representative samples of that class. Even in this case, the possibility that the estimates may be in error by large amounts for individual fuels should be recognized." • Experimental determination of hydrogen content is referenced in ASTM D1018, D3701, D5291, and D7171. All except D1018 are referenced methods in this program. • Hydrogen content is used to correct heat of combustion. • From the specification:

3.1 A correlation[4] has been established between the hydrogen content of a fuel and its distillation range, API gravity, and aromatic content. This relationship is given by the following equations:

Type fuel—All aviation gasolines and aircraft turbine fuels

$$\%\,H = 0.063\,17G - 0.041\,089A + 0.000\,072\,135AV + 0.000\,056\,84GV - 0.000\,496\,0GA + 10.56 \quad (1)$$

or in SI Units,[5]

$$\%\,H = (9201.2 + 14.49T - 70.22A)/D + 0.026\,52A + 0.000\,129\,8AT - 0.013\,47T + 2.003 \quad (2)$$

where:

% H	=	mass percent hydrogen;
G	=	gravity, °API;
A	=	volume percent aromatics;
V	=	average of 10 %, 50 %, and 90 % distillation data, °F (using Test Method D86);
T	=	average of 10 %, 50 %, and 90 % distillation data, °C; and
D	=	density in kg/m^3 at 15 °C.

Specification Review

Impact Assessment:
Red Yellow Green

D4529-01 (2011)	STM for Estimation of Net Heat of Combustion of Aviation Fuels	**Original Publication Date: 1985**
Specification Scope	Estimates the net heat of combustion at constant pressure	
Published Limitations	"Method is purely empirical, and is applicable only to liquid hydrocarbon fuels derived by normal refining processes from conventional crude oil which conform to the requirements of specifications for aviation gasolines or aircraft turbine and jet engine fuels of limited boiling ranges and compositions."	
Provided Precision Information	Estimations are not experimental, so the results are not necessarily accurate or precise. *Repeatability:* r = 0.012 MJ/kg (5 BTU/lb) *Reproducibility:* R = 0.035 MJ/kg (14 BTU/lb)	
Referenced Research Reports	No research report	
SME Evaluation	Even before reviewing the impacts of chemical composition on the method, the scope and limitations make the method inapplicable to non-traditionally prepared jet fuel. Alternatively produced jet fuels do not meet the requirement that the fuel be derived by normal refining processes, nor do they meet the requirement they be from conventional crude oil. Unless the alternatively produced fuel's chemical composition is shown to meet the requirements of a well-defined class, the method will NOT be insensitive to the chemical composition. Given the caveats on the method with traditional petroleum-based chemistries, full demonstration of the correlations is recommended.	
Other	• "The estimation of the net heat of combustion of a hydrocarbon fuel from its aniline point temperature and density is justifiable only when the fuel belongs to a well-defined class for which a relationship between these quantities has been derived from accurate experimental measurement on representative samples of that class." • The aniline point, density and sulfur contents are determined experimentally and correlations are based on articles from the 1950s and 60s. • ASTM D1405 has four equations, depending on the fuel type with the precision statements being equal. D4529 has one equation for all the fuels with a precision statement based on the test method.	

11.7 Individual Review Sheets – Def Stan 91-091.

Note: References to "Precision Statements" refers to any provided precision, bias, repeatability or reproducibility statements provided in the reviewed document. This is in contrast to an analysis of the statistical variation or accuracy (correctness) of a result.

Note: Specific items leading to a yellow or red assessment are colored within the review sheets. The text describing items that contributed to a concern are highlighted in yellow while text describing items contributing to assessment of red are colored red. This is done to facilitate locating specific items of concern within the review document.

11.7.1 Green-

Standard Review

Impact Assessment:

Red Yellow Green

ARP 1797A	Aircraft and Aircraft Engine Fuel Pump Low Lubricity Fluid Endurance Test	**AKA**
Specification Scope	Procedure for testing fuel pumps and aircraft hardware for low lubricity wear	
Published Limitations		
Provided Precision Information		
SME Evaluation	The goal of the procedure is to demonstrate the pumps' ability to function with a low lubricity fuel. It can also be used to test an unknown fuel with known hardware. The purpose is support of hardware design. Typically it is a 100 hour test using MIL-PRF_7024 Type II (SSII). The test used with an unknown fluid then becomes the indicator identifying issues due to fluid composition as opposed to being limited by the composition. As such the sensitivity to composition BECOMES the goal.	
Other	•	

Impact Assessment:

Red Yellow Green

Standard Review

IP 12/79 2001	Determination of specific energy	**AKA BSi:2000:Part 12: 1993**
Specification Scope	Liquid fuels but not specific to aviation	
Published Limitations	None	
Provided Precision Information	r = ± 276 J/g R = ± 773 J/g	
SME Evaluation	Method is not equivalent to the ASTM methods (D240 Bomb, D1405 Aniline estimate, D3338 density estimate, D4529 aniline/density/sulfur estimate, or D4809 Precision bomb) Test method is similar to D240 and D4809 with noted differences in the materials and methods of execution. D240 was assessed as yellow and D4809 was not reviewed. Calculations for heat capacity correct for the acid formation, the firing cotton, and variations in temperature. Footnote 2: "In any comparison of measurements on pure compounds with those cited in these compilations, the user of this method should realise that impurities of various kinds, including water and foreign hydrocarbons, may cause significant effects on the values obtained from particular samples of material." This warning and the method presentation all combine to indicate variations in results due to changes in composition should be considered, but it is an analytical method that gives the results it gives. Furthermore there are no considerations or corrections for aviation fuel involved. Unlike the ASTM methods which involve measureable estimations that are based on composition assumptions, this method just measures the joules (energy) released.	
Other	•	

Standard Review

Impact Assessment:

Red Yellow (Green)

IP 16-15	Determination of the freezing point of aviation fuels – Manual method	AKA
Specification Scope	Aviation turbine fuel and aviation gasoline	
Published Limitations	None	
Provided Precision Information	r = 1.5 °C R = 2.5 °C	
SME Evaluation	Listed as equivalent to D2386 – Assessed as green	
Other	• Section 9.5 "Contamination with other petroleum products can cause crystals to appear at much higher temperatures than normally expected for aviation fuel freeze points."	

Standard Review

Impact Assessment:

Red Yellow Green

IP 123/11 (2014)	Petroleum products – Determination of distillation characteristics at atmospheric pressure	**AKA ISO 3405:2011 BSi 2000: Part 123:2011**
Specification Scope	Manual or automated distillation for all petroleum products. Generally automotive petrols, petrols with ethanol, aviation petrol, aviation turbine, kerosene, diesel, bio diesel, burner fuels and marine fuels without appreciable residue.	
Published Limitations	Light and middle distillates from petroleum with IBP > 0 °C and FBP <400 °C Hazy or wet samples are not suitable	
Provided Precision Information	Table 7 — Precision for groups 2,3 and 4 — Manual Percentage recovered % (V/V) / Repeatability °C / Reproducibility °C IBP: 0,35 (ΔC/ΔV) + 1,0 / 0,93 (ΔC/ΔV) + 2,8 5 to 95: 0,41 (ΔC/ΔV) + 1,0 / 1,33 (ΔC/ΔV) + 1,8 FBP: 0,36 (ΔC/ΔV) +0,7 / 0,42 (ΔC/ΔV) + 3,1 % (V/V) at T °C: 1,00 (ΔC/ΔV) + 0,5 / 1,89 (ΔC/ΔV) + 1,3 NOTE This table is derived from the nomograph representing this set of precision data published in all previous editions of this International Standard as well as in other, parallel, standards. Table 8 — Precision for groups 1, 2, and 3 — Automated Percentage evaporated % (V/V) / Repeatability °C / Reproducibility °C / Valid range °C IBP: 0,029 5(E + 51,19) / 0,059 5(E + 51,19) / 20 - 70 10: 1,33 / 3,20 / 35-95 50: 0,74 / 1,88 / 65-220 90: 0,007 55(E + 59,77) / 0,019(E + 59,77) / 110 - 245 FBP: 3,33 / 6,78 / 135-260 E is the temperature at the percentage evaporated within the prescribed valid range. IP 123 is referenced in D86	
SME Evaluation	Method is essentially equivalent by review to D86. Differences include a slightly different barometric correction (IP method includes a correction for latitude) and a slight difference in r and R. Uses the same research report as D86. Method sorts the fluids into 1 of 4 groups to select the set up conditions. They are the same groups as defined by D86	
Other	• Uses dry point if FBP not repeatable.	

Standard Review

Impact Assessment:

Red Yellow Green

IP 160/99	Crude petroleum and liquid petroleum products – Laboratory determination of density – Hydrometer method	**AKA ISO3675:1998 BSi:2000: Part 160: 1998**
Specification Scope		
Published Limitations		
Provided Precision Information		
	Equivalent to D1298-99 (2005) by IP reference. Current ASTM revision is D1298-12a, a two revision difference. The changes were the addition of a thermal glass correction and updates/corrections to the procedure, the precision and reporting, and the addition of a discussion on the terminology of hydrometer reading which did not exist and discussion on opaque liquid testing. NOTE: the IP method is only the hydrometer portion of D1298, which was not where the ASTM methods were.	
SME Evaluation	See D1298 evaluation (yellow) None of these updates fundamentally change the fuel SME evaluation, particularly the challenge in identifying the hydrometer thermal correction value. The IP160 standard does not refer to the correction factor beyond a statement to "apply any hydrometer correction factor to the observed hydrometer reading…" The method indicates the standard means of converting to density is the use of the computer procedure contained in ISO91-1:1992 which includes a subroutine into which the correction should be incorporated.	
Other	• The concern related to the thermal correction factor is a general concern, not specific to fuel chemistry	

Standard Review

Impact Assessment:

Red Yellow Green

IP 170/14	Determination of flash point – Abel closed-cup method	**AKA ISO 13736:2013 BSi 2000-170:2013**
Specification Scope	Determination of manual and automated closed cup flash points of combustible liquids	
Published Limitations	Liquids with flash point -30 to 75 °C, precision statement only for -8.5 to 75 °C. Not applicable for water borne paint Halogenated compounds give anomalous results Manual method limited to 70 °C max due to the thermometer.	
Provided Precision Information	r = 1.4 °C R = 3.2 °C	
SME Evaluation	"Flash point values are not a constant physical chemical property of materials tested. They are a function of the apparatus design, the condition of the apparatus used, and the operational procedure carried out. Flash point can therefore be defined only in terms of the standard test method and no general valid correlation can be guaranteed between methods." This means that a Pensky-Martin flashpoint value does not necessarily correspond to an Abel flashpoint. However, the measured result within the apparatus is what it is. The chemistry of the fluid being tested is essentially what the method tests. Therefore, as long as the method is followed, and volatility concerns are addressed, the test method is composition agnostic.	
Other	• Abel flashpoint is primarily a European test choice, but it is run by Intertek.	

Impact Assessment:

Red Yellow Green

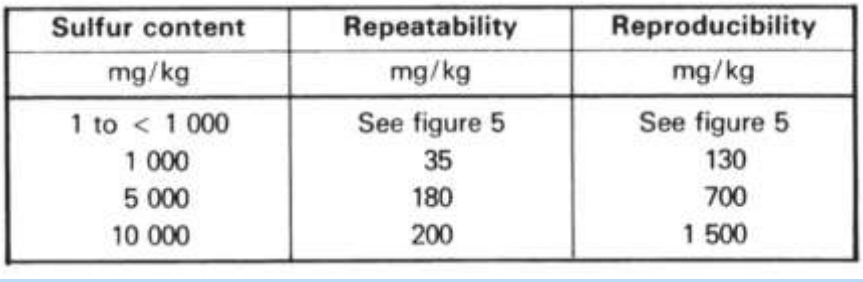
Standard Review

IP 225/76 (2014)	Determination of copper in light petroleum distillates – Spectrophotometric method	**AKA** None
Specification Scope	Determine the copper content from 10 to 250 µg/kg (ppb)	
Published Limitations	Aviation turbine fuels or similar boiling distillates. A contaminated atmosphere will prevent reaching lower limits.	
Provided Precision Information	r = ± 20 ppb No reproducibility has been determined.	
	No equivalent ASTM	
SME Evaluation	The sample is treated with sodium hypochlorite and the copper is extracted with hydrochloric acid. Ammonium citrate and EDTA are used to eliminate interferences. The copper is then complexed with sodium diethylcarbamate and the complex is extracted with chloroform. The resultant color correlates to the copper content. The color is measured using a UV-Vis machine at 435 nm. A correlation graph is prepared using standards. This is a fundamental analytical technique measuring the absorbance of a sample at 435 nm. If there were other chemical moieties present that also absorbed at 435 nm, they could confound the results. However, given the chelation of the copper followed by the extraction, there is a low probability that changes in the chemical composition of the fuel would affect the method.	
Other	• Copper can precipitate onto the walls of the sample container over time	

Standard Review

Impact Assessment:

Red Yellow Green

IP 243-94 (2013)	Petroleum products and hydrocarbons – Determination of sulfur content – Wickbold combustion method	**AKA ISO 4260:1987 EN 24260: 1994 BSi 2000:Part 243:1984**
Specification Scope	Determine the sulfur content in petroleum products, natural gas and olefins	
Published Limitations	Sulfur content from 1 to 10,000 mg/kg, particularly suitable for < 300 mg/kg Highly viscous samples must be diluted with sulfur free solvent Not suitable for heavy duty engine oils Inorganic bound chlorine must be removed prior to test. Potential issues with lead if the concentration is not accurately known	
Provided Precision Information		

Sulfur content	Repeatability	Reproducibility
mg/kg	mg/kg	mg/kg
1 to < 1 000	See figure 5	See figure 5
1 000	35	130
5 000	180	700
10 000	200	1 500

Figure 5 Below

Standard Review

Impact Assessment:

Red Yellow Green

IP 336/2004 (2014)	Petroleum products - Determination of sulfur content - Energy-dispersive X-ray fluorescence spectrometry	AKA ISO 8754:2003 BSi 2000:Part 336:2003
Specification Scope	Determining sulfur content of hydrocarbon fuels such as naphthas, distillates, fuel oils, residues, lube base oils, and unleaded gasolines.	
Published Limitations	Range of sulfur content 0.03 to 5.0% m/m Heavy metal additives, lead alkyls etc. interfere with the method. Silicon, phosphorous, calcium, potassium and halides will interfere if present at more than 100 mg/kg	
Provided Precision Information	$r = 0{,}045\,4\,(X + 0{,}05)$, for values ≥ 0,03 % (*m/m*) and ≤ 0,05 % (*m/m*); $r = 0{,}021\,5\,(X + 0{,}15)$, for values > 0,05 % (*m/m*) and ≤ 5,00 % (*m/m*); $R = 0{,}178\,1\,(X + 0{,}05)$, for values ≥ 0,03 % (*m/m*) and ≤ 0,05 % (*m/m*); $R = 0{,}081\,2\,(X + 0{,}15)$, for values > 0,05 % (*m/m*) and ≤ 5,00 % (*m/m*); where X is the average of the results being compared, in % (*m/m*).	
	Equivalent to ASTM D4294 by ASTM Manual 44. Assessed as green. The ASTM method has a useable range of 20mg/kg to 4.6 % m/m, slightly shifted compared to the IP method. Minor variations in what and how calibration reference standards Different precision statements.	
SME Evaluation	XRF is a fundamental analytical principle. The instrument responds to materials fluorescing when bombarded by x-ray. As long as there are no constituents in the alternatively prepared fuel which also fluoresce at the monitored wavelength, the response is attributed to S. Per the IP method, changes in carbon/hydrogen ratio (C/H) may interfere if the ratio varies more than one as compared to the calibration reference material. Care must be taken to match the reference's C/H to that of the sample. It may be necessary to confirm there are no moieties present in the chemical composition that fluoresce in the sulfur range.	
Other	•	

Standard Review

Impact Assessment:

Red Yellow Green

IP 365/97 (2004)	Crude petroleum and petroleum products – Determination of density – Oscillating U-tube method	**AKA** **ISO 12185: 1996** **BSi 2000:Part 365:1996**
Specification Scope	Determining density of liquids using an oscillating tube	
Published Limitations	Crude petroleum 600 to 1000 Kg/m^3 Single phase liquids of any vapor pressure as long as they stay single phase. To convert using measurement tables, run at as close to desired temperature as possible. Not for use in calibrating on-line density meters.	
Provided Precision Information	r = 0.2 Kg/m^3 R = 0.5 Kg/m^3	
	Listed as equivalent in ASTM Manual 44 to ASTM D4052 digital density meter; D4052 has a restricted vapor pressure to below 100 kPa and viscosity < 15,000 mm^2/s Assessed as green R and r were fluid specific for ASTM D4052 and only two distinctions in IP365. Resultant values measurably different.	
SME Evaluation	There does not appear to be any corrections, only a conversion of the frequency of the vibration to a density. The instrument is calibrated to the viscosity range of the test fluid and corrected to hydrometer readings.	
Other	• Oscillation can have up to 1 Kg/m^3 bias due to viscosity effects.	

Impact Assessment:

Red Yellow Green

Standard Review

IP 367/07	Petroleum products – Determination and application of precision data in relation to methods of test	**AKA** ISO 4259:2006 BSi 2000:Part 367:2006
Specification Scope	Procedures for setting up an ILS to generate statistical data	
Published Limitations		
Provided Precision Information		
	Similar to but not equivalent to ASTM D6300.	
SME Evaluation	The standard covers the preparation and execution of an ILS. This is not directly related to the composition of the petroleum product but takes into account the homogeneity of a petroleum product and thus the natural variation in test results. The only time the composition would become an issue is if the fluid was inhomogeneous, which would have such wide ranging implications for fuel use as to be a non-risk. By definition, the limits are selected to be 2R of the maximum value and of the minimum values achievable by the method.	
Other	• The IP method uses/references the software D2PP for Petroleum by DMG Lawrey. This is not referenced in D6300.	

Impact Assessment:

Red Yellow Green

Standard Review

IP 373/11	Petroleum products – Determination of sulfur content – Oxidative microcoulometry method	**AKA** **ISO 16591:2010** **BSi 2000:Part 373:2011**
Specification Scope	Determining sulfur content b oxidative microcoulometry Sulfur content 1 < S > 100 mg/Kg	
Published Limitations	Petroleum and light middle distillates Final boiling point < 400 °C Nitrogen interferes at concentration > 0.1% Chlorine interferes at concentration > 1.0% Bromine interferes at concentration > 500 mg/Kg Diesel can leave carbonaceous deposits	
Provided Precision Information	r = 0.063x where x = sulfur R = 0.147x where x = sulfur In ASTM D3120 precision statements are specific to the test fluids in addition to a simple r & R. The simple r & R raises sulfur content to a power.	
	Similar to ASTM D3120 reviewed previously. Greatest differences between methods are the measurement range and the precision statements.	
SME Evaluation	Within the limitations of the method, the method is based on basic combustion and titrations. Because matching of standards to test are not considered, variability may be higher as compared to ASTM D3120. But the basic chemistry of the method should be composition agnostic.	
Other	Comparative review to ASTM D3120 • Smaller range of sulfur concentration • Similar interferents at slight different amounts • Same apparatus drawing • Calibration standards not provided • Mathematically equivalent calculations	

Impact Assessment:

Red Yellow Green

Standard Review

IP 379/88 (2017)	Determination of organically bound trace nitrogen – Oxidative combustion and chemiluminescence method	**AKA**
Specification Scope	Determine trace total nitrogen naturally occurring in liquid hydrocarbons	
Published Limitations	Boiling range of 0.2 to 400 °C, viscosity between 0.2 and 10 cSt, and nitrogen content 0.3 to 100 mg/kg total nitrogen	
Provided Precision Information	$r = 0.1825\ x^{0.5149}$ $R = 0.8094\ x^{0.5149}$ Where x is the average of the results being compared.	
	Equivalent to ASTM D4629-12 (Not reviewed in Phase 1)	
SME Evaluation	Sample is injected into a gas stream and combusted in an oxygen environment. The nitrogen is converted to NO. NO reacts with ozone and is converted to NO_2 (excited). The excited NO_2 relaxes and the decay is measured by a photomultiplier tube. $NO + O_3 \rightarrow NO_2^* + O_2 \quad NO_2^* \rightarrow NO_2 + h\nu \quad \lambda = 600 - 2800$ nm The method is based on the assumption that any radiation observed is from the reaction of the analyte and reagent. This is a fundamental analytical chemistry reaction that has been used for decades. The method has been successfully used to monitor nitrogen in multiple industries. Research identified no interferents to the method. Therefore, it is assessed that the method should not be sensitive to the chemical composition of the test fuel.	
Other	• Method has been used successfully on biofuels	

Impact Assessment:

Red Yellow Green

Standard Review

IP 424/96 (2010)	Determination of fuel system icing inhibitor content of aviation turbine kerosines by high performance liquid chromatography
Specification Scope	Determine the FSII content of aviation turbine fuel within the range of 0 to 0.2 v/v % using HPLC
Published Limitations	Use a pulse free pump on the HPLC or it interferes with the refractometer
Provided Precision Information	r = 0.01% v/v R = 0.01% v/v
	No ASTM equivalent. ASTM D5006 is FSII by water extraction and Brix refractometer.
SME Evaluation	The sample is injected onto the HPLC and then the separated effluent is measured with a refractometer. The column is either 5 or 10 µm nitrile (cyano) bonded silica. 100 µl of sample and of calibration solutions is used. The area under the peak is measured and compared to a reference. As long as there are no components that would either co-elute or elute at nearly the same time as the FSII and there are no components that would react with the column packing, the test method should be composition agnostic. It is assumed testing would have already determined that there are no components that would react with the FSII itself.
Other	• Document to be reviewed when existing supplies of ethylene glycol monomethyl ether (EGME) are depleted

Impact Assessment:

Red Yellow Green

Standard Review

IP 438/01 (2013)	Petroleum products – Determination of water – Coulometric Karl Fischer titration method	**AKA ISO12937:2000** **BSi 2000-438:2001**
Specification Scope	Determine water in petroleum products with boiling point <390 °C at a level of 0.003% to 0.100% m/m	
Published Limitations	No ketones, no residual oil, no sulfides, no mercaptan sulfur	
Provided Precision Information	$r = 0.01874 * x^{0.5}$ $R = 0.06877 * x^{0.5}$ Where x is the average measured value	
	No ASTM equivalence – similar to D6304	
SME Evaluation	The method is based on fundamental reaction chemistry between water and iodine. As long as the sample does not consist of one of the interferents or other chemical moieties that will react with iodine the method should not be sensitive to the chemical composition of alternatively produced jet fuel.	
Other	Comparative analysis with D6304 • Volumetric method in D6304 is located in Annex B in IP438 • IP method does not have an evaporator drier method • IP method has a clear and bright check with an addition of sodium dioctylsulfosuccinate solution not used in D6304 • ASTM precision statements are for volumetric and for mass. Neither is the same as the IP precision statement • IP method leaves instrument specific methodologies to the instruments' instructions	

Impact Assessment:

Red Yellow Green

Standard Review

IP 447/08 (2013)	Petroleum products – Determination of sulfur content – Wavelength-dispersive X-ray fluorescence spectrometry	**AKA** ISO 14596:2007 BSi 2000: Part 447:2007
Specification Scope	Determination of sulfur content in liquid petroleum products and solid/semi solids that can be made liquid	
Published Limitations	Products with 0.001 to 2.5 % sulfur. Other elements do not interfere but concentrations of P or Cl >3% can cause bias. Increased molybdenum can cause an increase in the background	
Provided Precision Information	SULFUR BY WDXRF, IP 447 Table 2 — Precision data	

Sulfur content % (m/m)	Repeatability limit	Reproducibility limit
0,001 0 to 0,002 9	0,000 3	0,000 5
0,003 0 to 0,004 9	0,000 6	0,001 0
0,005 0 to 0,009 9	0,001 0	0,002 0
0,010 0 to 0,029 9	0,002	0,003
0,030 0 to 0,049 9	0,003	0,005
0,050 0 to 0,099 9	0,005	0,010
0,10 to 0,99	0,01	0,02
1,00 to 2,50	0,02	0,04

	Method similar to ASTM D4294 but not equivalent
SME Evaluation	The method describes an analytical test method that is what it is. There are considerations for matrix matching, but it is assumed the operator is familiar and complies with the considerations. As long as the interferents are not present in the test material, the test method should be composition agnostic.
Other	A comparative review as compared to ASTM D4294 was performed. • Slightly smaller range of sulfur content • Method uses an internal reference of zirconium • There is no matrix guidance • Method uses different calibrants • Different precision data • Method fundamentally the same

Impact Assessment:

Red Yellow Green

Standard Review

IP 475/05	Petroleum liquids – Manual sampling	**AKA** ISO 3170:2004 BSi 2000:Part 475:2004
Specification Scope	Procedures for collecting liquid/semi-liquid petroleum samples for testing.	
Published Limitations	Not intended for special petroleum products covered by other standards such as electrical insulating oils.	
Provided Precision Information		
	Similar to but not equivalent to ASTM D4057	
SME Evaluation	The standard covers the standard sampling procedures for liquid/semi-liquid hydrocarbons from tanks, drums, or pipelines by manual means. Fluids are at or near atmospheric pressure. As long as the alternative fuel is compatible with the sample containers and equipment, the method just instructs in collection methods which are not composition related.	
Other	•	

Impact Assessment:

Red Yellow Green

Standard Review

IP 523/15	Determination of flash no-flash and flash point – Rapid equilibrium closed up method	**AKA ISO3679:2015** **BSi 2000: Part 523:2015**
Specification Scope	Flash point tests in the range of -30 to 300 °C on paints, varnishes, solvents, petroleum products, and related products. With a detector can also measure FAMEs	
Published Limitations	Halogens can give anomalous results and water borne paints can give elevated results when an electric ignitor is used.	
Provided Precision Information	Table 3 — Calculated repeatability and reproducibility for petroleum and related products, excluding paints, and varnishes Temperature, °C: 20 40 60 80 100 120 140 160 180 200 220 Repeatability, °C: 2,0 2,3 2,6 2,9 3,2 3,5 3,8 4,1 4,4 4,7 5,0 Reproducibility, °C: 3,3 3,8 4,4 4,9 5,4 5,9 6,4 6,9 7,4 7,9 8,5	
	Not linked but essentially equivalent to D3828 assessed green	
SME Evaluation	Same discussion on flashpoint being apparatus specific. Procedure A is a flash/no-flash at a specified temperature test Procedure B is a determination of a flash points; uses multiple test portions at multiple test temperatures Corrects to barometric pressure of 101.3 kPa. Within the caveats of flashpoint apparatus, the method measures what it measures. Fundamentally it would see changes in chemistry not be affected by them.	
Other	• ISO 1516 and ISO 1523 are also closed cup flash point tests	

Impact Assessment:

Red Yellow Green

Standard Review

IP 524/05	Determination of flash no-flash and flash point – Rapid equilibrium closed up method	**AKA ISO3680:2004** **BSi 2000: Part 524: 2004**

Specification Scope

Flash point tests in the range of -30 to 300 °C on paints, varnishes, solvents, petroleum products, and related products. With a detector can also measure FAMEs

Published Limitations

Provided Precision Information

Table 1 - Precision values

Range	Repeatability °C	Reproducibility °C
Petroleum and related products 20 °C to 70 °C Above 70 °C	0,5 $0,022X^{0,5}$	$0,03(X + 29)$ $0,063X^{0,5}$
Paints, enamels, lacquers and varnishes 5,8 mm^2/s at 37,8 °C and below Above 5,8 mm^2/s at 37, 8 °C	1,7 3,3	3,3 6,0
Fatty acid methyl esters (FAME)	1,0	15,0
NOTE where X is the average of the results being compared.		

NOTE - The following values have been calculated from the precision values given in Table 1 for petroleum and related products.

Temperature °C	Repeatability °C	Reproducibility °C
20	0,5	1,4
70	0,6	2,9
93	1,3	4,9
150	2,0	7,5
200	2,6	9,9
260	3,3	12,4

Not linked but essentially equivalent to D3828 assessed green

SME Evaluation

Same discussion on flashpoint being apparatus specific.

Procedure is a flash/no-flash at a specified temperature test

Corrects to barometric pressure of 101.3 kPa.

Within the caveats of flashpoint apparatus, the method measures what it measures. Fundamentally it would see changes in chemistry not be affected by them.

Other

- This method appears to be identical to IP 523 except for the use of a 5 ml syringe where IP523 uses a 2 ml syringe or 2 x 2ml for sample injection.
- Apparatus verification actually sends the user to IP 523.
- This method only has the flash/no flash procedure where IP 523 has both procedures.
- The precision statements are different
- ASTMD3828 refers to IP 524 for method A, flash/no flash

Impact Assessment:

Red Yellow Green

Standard Review

IP 540/08 (2014)	Determination of the existent gum content of aviation turbine fuel – Jet evaporation method **AKA**
Specification Scope	Determine the existent gum content in aviation turbine fuel using either air or steam to vaporize the sample
Published Limitations	Aviation gasoline and other volatile distillates may be determined using IP 131
Provided Precision Information	$r = 2.1161\ x^{0.6}$ where x = average of the results $R = 2.5046\ x^{0.6}$ where x = average of the results
	Not linked but essentially equivalent to ASTM D381 assessed green
SME Evaluation	The test is based on the fundamental principle of evaporation and will generate the results it generates. Because the existent gum is not analyzed for composition, the result of obtaining gum may be composition related but the impact would need further correlation to performance in use.
Other	Comparative analysis to ASTM D381 • Procedure only for aviation fuel • Same equipment • Same calibration • Different precision statement

Standard Review

Impact Assessment:

Red Yellow Green

IP 564/13	Determination of the level of cleanliness of aviation turbine fuel – Laboratory automatic particle counter method	**AKA**
Specification Scope	Determine the dirt and water in avtur in the range of 4 µm to 30 µm up to a maximum concentration of 40000 cumulative counts per ml. A method is provided to eliminate water.	
Published Limitations		
Provided Precision Information	CLEANLINESS OF AVTUR/APC, IP 564 Table 1 Parameter / Range of results / r / R ≥ 4 µm(c) / 200 - 34140 / 0,1278(x + 1 000) / 0,1788(x + 1 000) ≥ 6 µm(c) / 70 - 18610 / 0,1780(x + 300) / 0,2877(x + 300) ≥ 14 µm(c) / 8 - 3355 / 0,3438(x + 25) / 0,4505(x + 25) ≥ 21 µm(c) (see note 1 under 13.3) / 2 - 580 / 1,017x / 1,268x ≥ 25 µm(c) (see note 1 under 13.3) / 1 – 256 / 1,042x / 1,339x ≥ 30 µm(c) (see note 1 under 13.3) / 1 – 81 / 1,288x / 1,655x Where x is the average cumulative counts per ml.	
	Similar to ASTM D7619 which has a smaller sample chamber and which is not referenced in ASTM D1655 et.al.	
SME Evaluation	Sample is mixed and a sub-specimen is drawn into the testing chamber. As long as the viscosity of the fluid is not such thst there is measurable entrained air and the chemistry of the test fluid does not react with any of the equipment hardware, there should be no issues beyond those endemic to the method itself due to the sample composition. The one caveat is if the method for removing water is used, then the compatibility of the fluid composition with propan-2-ol or the proprietary chemical used to 'dry' the sample should be confirmed.	
Other	• The precision statement was generated in a 2007 round robin	

Standard Review

Impact Assessment:

Red Yellow Green

IP 565/13	Determination of the level of cleanliness of aviation turbine fuel – Portable automatic particle counter method	**AKA**
Specification Scope	Determine the dirt and water in avtur in the range of 4 µm to 30 µm up to a maximum concentration of 60,000 cumulative counts per ml. A method is provided to eliminate water.	
Published Limitations		
Provided Precision Information	Table 1 Where x is the average cumulative counts per ml.	
	Source of the text used to prepare ASTM D7619. Not a method in D1655	
SME Evaluation	Sample is mixed and a sub-specimen is drawn into the testing chamber. Instrument is slightly larger than equipment in IP 564. As long as the viscosity of the fluid is not such that there is measurable entrained air and the chemistry of the test fluid does not react with any of the equipment hardware, there should be no issues beyond those endemic to the method itself due to the sample composition. The one caveat is if the method for removing water is used, then the compatibility of the fluid composition with propan-2-ol or the proprietary chemical used to 'dry' the sample should be confirmed.	
Other	• The precision statement was generated in a 2007 round robin	

Parameter	Range of results	*r*	*R*
≥ 4 $\mu m_{(c)}$	216 - 45 061	0,07861(x + 2 000)	0,09959(x + 2 000)
≥ 6 $\mu m_{(c)}$	74 - 22 483	0,1545(x + 500)	0,1993(x + 500)
≥ 14 $\mu m_{(c)}$	9 - 4 105	0,3485(x + 40)	0,4567(x + 40)
≥ 21 $\mu m_{(c)}$ (see note 1 under 13.3)	2 - 1 444	0,5202(x + 5)	0,7272(x + 5)
≥ 25 $\mu m_{(c)}$ (see note 1 under 13.3)	1 - 776	0,6023(x + 2)	0,9096(x + 2)
≥ 30 $\mu m_{(c)}$ (see note 1 under 13.3)	1 - 365	0,7937(x + 0,5)	1,2781(x + 0,5)

Standard Review

Impact Assessment:

Red Yellow Green

IP 577/13	Determination of the level of cleanliness of aviation turbine fuel – Automatic particle counter method using light extinction	**AKA**
Specification Scope	Determine the dirt and water in avtur in the range of 4 µm to 70 µm up to a maximum concentration of 60,000 cumulative counts per ml. A method is provided to eliminate water.	
Published Limitations		
Provided Precision Information	Table 1	

Parameter	Range of results	Repeatability, *r*	Reproducibility, *R*
>4 µm(c)	192 - 38770	0,1897(X + 2 000)	0,2097(X + 2 000)
>6 µm(c)	92 - 24686	0,1552(X + 2 000)	0,1408(X + 2 000)
>10 µm(c)	44 - 11324	0,1150(X + 1 500)	0,1191(X + 1 500)
>14 µm(c)	16 - 6396	0,1172(X + 500)	0,1051(X + 500)
>21 µm(c)	7 - 2632	0,1614(X + 150)	0,1493(X + 150)
>25 µm(c)	5 - 1484	0,1860(X + 80)	0,1717(X + 80)
>30 µm(c)	3 - 604	0,2771(X + 30)	0,2751(X + 30)
>70 µm(c)	1 - 4	0,7831X	1,5261X
where X is the average cumulative counts/ml.			

SME Evaluation	As long as the viscosity of the fluid is not such that there is measurable entrained air and the chemistry of the test fluid does not react with any of the equipment hardware, there should be no issues beyond those endemic to the method itself due to the sample composition. The one caveat is if the method for removing water is used, then the compatibility of the fluid composition with propan-2-ol or the proprietary chemical used to 'dry' the sample should be confirmed.
Other	• The precision statement was generated in a 2009 round robin • Results from a highly contaminated sample resulted in the addition of an instruction for flushing the equipment with filtered heptane after an sample giving more than 20,000 counts of 4 µm.

11.7.2 Yellow –

Standard Review

Impact Assessment:

Red Yellow Green

IP 156/08	Petroleum products and related materials – Determination of hydrocarbon types – Fluorescent indicator adsorption method	**AKA EN 15553 BSi 20000-156: 2007**
Specification Scope		
Published Limitations		
Provided Precision Information		
	Equivalent to D1319 by review	
SME Evaluation	See D1319 evaluation – assessed yellow. Primarily concerns with precision statements based on existing petroleum chemistry and stated concerns related to alternatively sourced chemistries. Same scope, same dye, same equipment.	
Other	•	

Standard Review

Impact Assessment:

Red Yellow Green

IP 323/16	Determination of thermal oxidation stability of gas turbine fuels	**AKA**
Specification Scope	Procedure for rating the tendencies of gas turbine fuels to deposit decomposition products.	
Published Limitations	Applicable to middle distillate and wide cut fuels, and is particularly specified for aviation gas turbine fuels	
Provided Precision Information	Not possible to specify a precision statement	
	Lists equivalence to ASTM D3241-16a	
SME Evaluation	See evaluation of D3241 (yellow) for discussion	
Other	•	

Impact Assessment:

Red (Yellow) Green

Standard Review

IP 585/10	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	**AKA**
Specification Scope	Measure from 4.5 to 150 mg/Kg of select FAMEs in aviation turbine fuel	
Published Limitations	Only designed to measure C-16 – C18 FAME High molecular weight naphtha components mask low FAME content. Low molecular weight FAME cannot be seen due to the jet fuel responses.	
Provided Precision Information	r = 0.1632 (X + 3) where X is the average of two results R = 0.2579 (X + 3) where X is the average of two results	
SME Evaluation	The method runs a neat sample with a known internal standard. The difference between the response of what went in and what came out is the FAME content. Because of the nature of GC-MS and the specificity of the analysis, as the chemical composition of the test fluid diverges from the traditional petroleum used to develop the method, the potential for deviations in the ability of the method to distinguish the FAME components from the fuel components increases. It is recommended the precision and accuracy of the method be confirmed as the fuel chemistry becomes less like the traditional petroleum used to develop the method.	
Other	• In a round robin study that included three Merox treated fuels, no bias was observed	

Impact Assessment:

Red Yellow Green

Standard Review

IP 590/10	Determination of fatty acid methyl esters (FAME), derived from bio-diesel fuel, in aviation turbine fuel – HPLC evaporative light scattering detector method	**AKA**
Specification Scope	Measure from 3 to 140 mg/kg of select FAMEs in aviation turbine fuel using HPLC	
Published Limitations	Cannot be used to assess coconut FAMEs as they are too volatile	
Provided Precision Information	r = 0.1512 (X + 4) where X is the average of two results R = 0.2022 (X + 4) where X is the average of two results	
SME Evaluation	Aviation turbine fuel is run across a standard silica column to separate the fuel components from any FAME. The FAME collected is identified by comparison to a standard reference of FAME. The reference is comprised of C16 and C-18, three isomers at 20%. While the risk is believed to be low, as the chemical composition of a test fluid diverges from traditional petroleum, the ability of the silica column to separate sufficiently the fuel matrix from the FAME matrix may need to be validated to confirm adequate and correct separation. Because the precision statement was developed with traditional petroleum and existing synthetic fuels, continued accuracy and precision of the method may need to be confirmed.	
Other	• Because some types of jet fuel cause high noise levels on the detector, the method allows for the diverting of the hydrocarbon fraction ahead of the FAME fraction.	

Standard Review

Impact Assessment:

Red Yellow Green

IP 590/10	Determination of fatty acid methyl esters (FAME), derived from bio-diesel fuel, in aviation turbine fuel – Gas Chromatography using heart-cut and refocusing	**AKA**
Specification Scope	Measure from 3 to 116 mg/kg of select FAMEs in aviation turbine fuel using GC x GC	
Published Limitations	Aviation turbine fuels can have high molecular weight components that interfere. The three isomers of C18 FAME's may not fully separate	
Provided Precision Information	r = 0.00980 (x + 40) mg/kg where x is the average of the results R = 0.09163 (x + 2) mg/kg where x is the average of the results	
SME Evaluation	Aviation turbine fuel is run through a non-polar GC column, then a temperature trap for FAME and then a polar column to separate the FAME isomers. Method uses FAME calibration standards. The cutting times for a setup are determined by the calibration standards. Response factors are determined for an individual experiment using a reference standard. The areas under the peaks are compared to quantify the amount of a component. While the risk is believed to be low, as the chemical composition of a test fluid diverges from traditional petroleum, the ability of the GC x GC to separate the petroleum fraction (non-polar) from the FAME (polar) should be confirmed, especially if any of the components of the alternative fluid are more polar than traditionally encountered.	
Other	•	

11.7.3 Red –

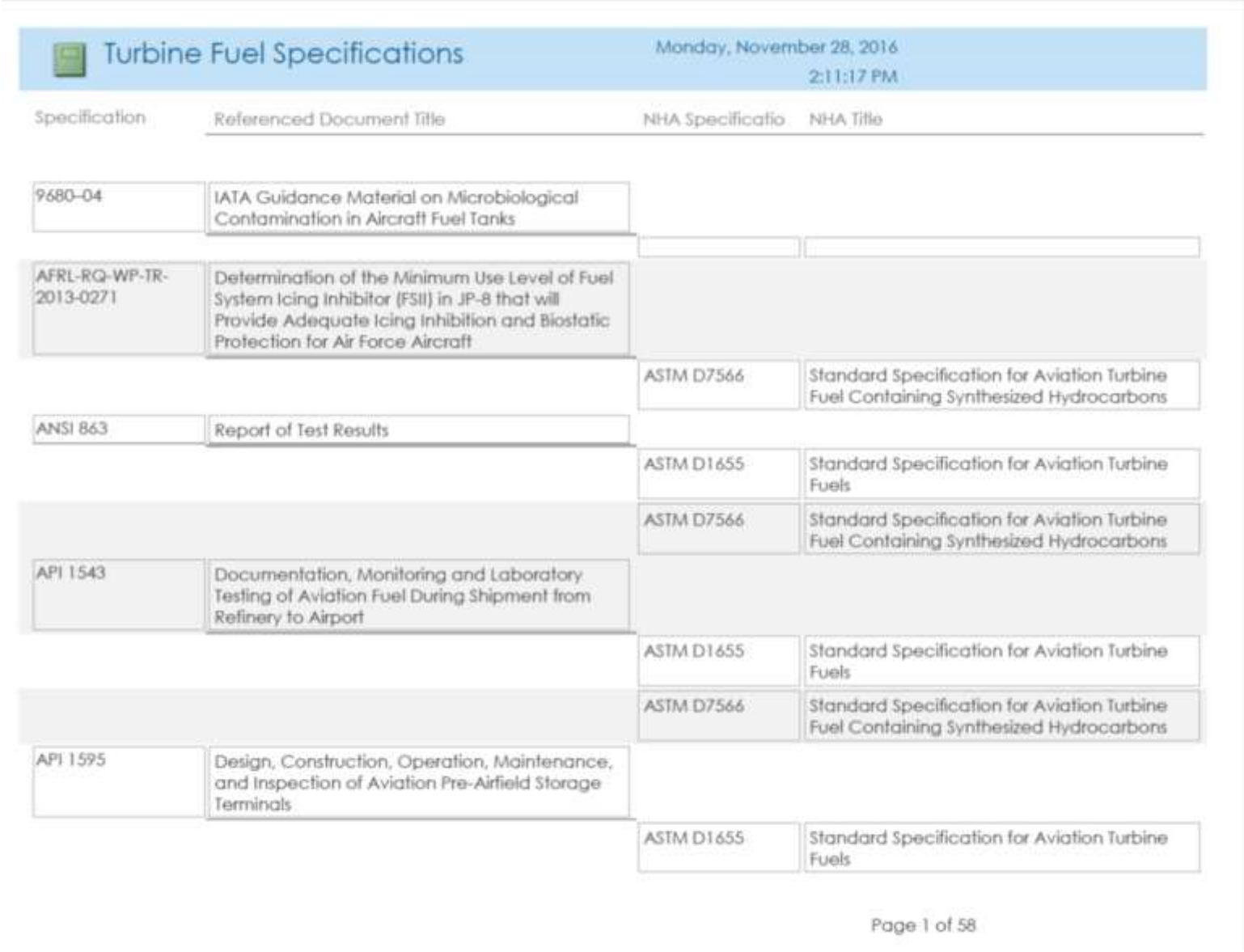
Standard Review

Impact Assessment:

Red Yellow Green

IP 381/97 (2014)	Aviation Fuels – Estimation of net specific energy	**AKA** **ISO 3648:1994** **BSi 2000:Part 381:1997** **ASTM D4529-02**
Specification Scope	Estimate net specific energy of aviation fuels from their aniline point, density, and sulfur.	
Published Limitations	Not applicable to pure hydrocarbons	
Provided Precision Information		
	References the ASTM CD/ROM "… using either the API/ASTM/EI compact disc or printed table 53B, referenced in ISO 91." Current revision of D4529 is -17. Reviewed version was -02.	
SME Evaluation	The documents are equivalent including the caveats on the standard's use and reference to defined classes. This means all of the concerns raised in the original review remain	
Other	•	

11.8 U.S. Specification Source



Turbine Fuel Specifications

Monday, November 28, 2016
2:11:17 PM

Specification	Referenced Document Title	NHA Specificatio	NHA Title
9680-04	IATA Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks		
AFRL-RQ-WP-TR-2013-0271	Determination of the Minimum Use Level of Fuel System Icing Inhibitor (FSII) in JP-8 that will Provide Adequate Icing Inhibition and Biostatic Protection for Air Force Aircraft		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ANSI 863	Report of Test Results		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
API 1543	Documentation, Monitoring and Laboratory Testing of Aviation Fuel During Shipment from Refinery to Airport		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
API 1595	Design, Construction, Operation, Maintenance, and Inspection of Aviation Pre-Airfield Storage Terminals		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Page 1 of 58

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM A240/A240M	Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM B36/B36M	Specification for Brass Plate, Sheet, Strip, and Rolled Bar		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM B93/B93M	Specification for Magnesium Alloys in Ingot Form for Sand Castings, Permanent Mold Castings, and Die Castings		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D1002	Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D1094	Water Reaction Interface Rating		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D1266	Sulfur, Total		

Page 2 of 58

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D129	Sulfur, Total		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D1298	Density (versus Temperature – Subset 1, Thermal Expansion – Subset 2)		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D130	Copper Strip Corrosion		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D1319	Aromatics		

Page 3 of 58

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D1322	Smoke Point		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D1331	Test Methods for Surface and Interfacial Tension of Solutions of Paints, Solvents, Solutions of Surface-Active Agents, and Related Materials		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D1405	Test Method for Estimation of Net Heat of Combustion of Aviation Fuels		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Page 4 of 58

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D1414	Test Methods for Rubber O-Rings		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D156	Saybolt Color		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D1655	Standard Specification for Aviation Turbine Fuels		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		prime	n/a
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D1660	Method of Test for Thermal Stability of Aviation Turbine Fuels (Withdrawn 1992)3		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Page 5 of 58

Specification	Referenced Document Title	NHA Specificatio	NHA Title
ASTM D1840	Napthalenes		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D1903	Density (versus Temperature – Subset 1, Thermal Expansion – Subset 2)		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D2240	Test Method for Rubber Property—Durometer Hardness		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D2276	Particulate Matter		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D2386	Freezing Point		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Page 6 of 58

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D240	Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D2425	Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D257	Test Methods for DC Resistance or Conductance of Insulating Materials		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D2622	Sulfur, Total		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D2624	Electrical Conductivity at Standard Temp.		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D2710	Test Method for Bromine Index of Petroleum Hydrocarbons by Electrometric Titration		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D2717	Test Method for Thermal Conductivity of Liquids		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D2779	Ostwald Coefficient/ Gas Solubility		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D2887	Distillation Curve		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification

Page 8 of 58

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D2892	Test Method for Distillation of Crude Petroleum (15-Theoretical Plate Column)		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D3114	Method of Test for D-C Electrical Conductivity of Hydrocarbon Fuels (Withdrawn 1985)3		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D3120	Sulfur, Total		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D3227	Sulfur, Mercaptan		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D323	Test Method for Vapor Pressure of Petroleum Products (Reid Method)		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D3240	Test Method for Undissolved Water In Aviation Turbine Fuels		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D3241	Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D3242	Acid Number, Total		

Page 10 of 58

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D3338	Test Method for Estimation of Net Heat of Combustion of Aviation Fuels		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D3343	Hydrogen Content		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D3359	Test Methods for Measuring Adhesion by Tape Test		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D3363	Test Method for Film Hardness by Pencil Test		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D3701	Hydrogen Content		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D3703	Test Method for Hydroperoxide Number of Aviation Turbine Fuels, Gasoline and Diesel Fuels		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D381	Existent Gum		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

Specification	Referenced Document Title	NHA Specificatio	NHA Title
ASTM D3828	Test Methods for Flash Point by Small Scale Closed Cup Tester		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D3948	Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D395	Test Methods for Rubber Property—Compression Set		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D4045	Standard Test Method for Sulfur in Petroleum Products by Hydrogenolysis and Rateometric Colorimetry		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		prime	n/a
ASTM D4052	Density (versus Temperature – Subset 1, Thermal Expansion – Subset 2)		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D4054	Additive Compatibility		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D4057	Practice for Manual Sampling of Petroleum and Petroleum Products		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D4066	Classification System for Nylon Injection and Extrusion Materials (PA)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
ASTM D412	Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D4171	Specification for Fuel System Icing Inhibitors		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D4176	Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D4294	Sulfur, Total		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D4306	Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D445	Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D4529	Heat of Combustion, Net		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D471	Test Method for Rubber Property—Effect of Liquids		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
ASTM D4809	Heat of Combustion, Net		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D4865	Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D4952	Sulfur, Mercaptan		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D4953	Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D5001	Lubricity		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D5006	Fuel System Icing Inhibitor		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D5190	Test Method for Vapor Pressure of Petroleum Products (Automatic Method) (Withdrawn 2012)3		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D5191	Test Method for Vapor Pressure of Petroleum Products (Mini Method)		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D5291	Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D5304	Test Method for Assessing Middle Distillate Fuel Storage Stability by Oxygen Overpressure		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D5363	Specification for Anaerobic Single-Component Adhesives (AN)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D5452	Particulate Matter		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D5453	Sulfur, Total		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D56	Flash Point		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D5972	Freezing Point		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D6045	Test Method for Color of Petroleum Products by the Automatic Tristimulus Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D613	Cetane Number		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D6304	Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D6378	Test Method for Determination of Vapor Pressure (VPX) of Petroleum Products, Hydrocarbons, and Hydrocarbon-Oxygenate Mixtures (Triple Expansion Method)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
ASTM D6379	Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D6469	Guide for Microbial Contamination in Fuels and Fuel Systems		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D6615	Specification for Jet B Wide-Cut Aviation Turbine Fuel		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D6732	Test Method for Determination of Copper in Jet Fuels by Graphite Furnace Atomic Absorption Spectrometry		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D6751	Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D6793	Bulk Modulus		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D6866	Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D7042	Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D7111	Test Method for Determination of Trace Elements in Middle Distillate Fuels by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D7153	Test Method for Freezing Point of Aviation Fuels (Automatic Laser Method)		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D7154	Test Method for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D7171	Test Method for Hydrogen Content of Middle Distillate Petroleum Products by Low-Resolution Pulsed Nuclear Magnetic Resonance Spectroscopy		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D7345	Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure (Micro Distillation Method)		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Specification	Referenced Document Title	NHA Specificatio	NHA Title
ASTM 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)		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D7524	Test Method for Determination of Static Dissipater Additives (SDA) in Aviation Turbine Fuel and Middle Distillate Fuels—High Performance Liquid Chromatograph (HPLC) Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons		
		prime	n/a
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D7797	Test Method for Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy—Rapid Screening Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Specification	Referenced Document Title	NHA Specificatio	NHA Title
ASTM D7872	Test Method for Determining the Concentration of Pipeline Drag Reducer Additive in Aviation Turbine Fuels		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D790	Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D7945	Test Method for Determination of Dynamic Viscosity and Derived Kinematic Viscosity of Liquids by Constant Pressure Viscomete		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM D7974	Test Method for Determination of Farnesane, Saturated Hydrocarbons, and Hexahydrofarnesol Content of Synthesized Iso-Paraffins (SIP) Fuel for Blending with Jet Fuel by Gas Chromatography		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D86	Distillation Curve		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
ASTM D924	Dielectric Constant versus Density versus Temperature		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D93	Flash Point		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM D97	Pour Point		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM D971	Surface Tension versus Temperature		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification

Specification	Referenced Document Title	NHA Specificatio	NHA Title
ASTM D976	Calculated Cetane Index		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
ASTM E1269	Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM E29	Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ASTM E411	Test Method for Trace Quantities of Carbonyl Compounds with 2,4-Dinitrophenylhydrazine		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM E659	Autoignition Temperature		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ASTM E681	Flammability Limits		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
ATA-103	Standard for Jet Fuel Quality Control at Airports11		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
AWS C3.4	Specification for Torch Brazing		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
AWS C3.5	Specification for Induction Brazing		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
AWS C3.6	Specification for Furnace Brazing		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
AWS C3.7	Specification for Aluminum Brazing		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
BMS 10-20	Corrosion Resistant Finish for Integral Fuel Tanks		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
BMS 10-39	Fuel and Moisture Resistant Finish for Fuel Tanks		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
BMS 5-267	Fuel Tank Coating		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
Bulletin Number 65	MSEP Protocol11		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
CRC Handbook	Thermal Conductivity versus Temperature		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
Defence Standard	Turbine Fuel, Aviation Kerosine Type, Jet A-1		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
DOD-L-85645	Lubricant, Dry Film, Molecular Bonded		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
EI 1550	Handbook on Equipment Used for the Maintenance and Delivery of Clean Aviation Fuel		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
EI 1583	Laboratory Tests and Minimum Performance Levels for Aviation Fuel Filter Monitors		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
EI/JIG 1530	Quality Assurance Requirements for the Manufacture, Storage and Distribution of Aviation Fuels to Airports		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
EN14214	Automotive Fuels—Fatty Acid Methyl Esters (FAME) for Diesel Engines—Requirements and Test Methods10		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
Fed Test Std 791C	Hot Surface Ignition		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
FED-STD-791	Testing Method of Lubricants, Liquid Fuels, and Related Products		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
IATA Guidance Mat	Ref. No: 9680-029		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
ICAO 9977	Manual on Civil Aviation Jet Fuel Supply13		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 107/26	Determination of sulfur - Lamp Method		
IP 12	Determination of Specific Energy		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
IP 123	Petroleum Products—Determination of Distillation Characteristics at Atmospheric Pressure		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
IP 154	Petroleum Products—Corrosiveness to Copper—Copper Strip Test		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 156	Petroleum Products and Related Materials—Determination of Hydrocarbon Types—Fluorescent Indicator Adsorption Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 16	Determination of Freezing Point of Aviation Fuels—Manual Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 160	Crude Petroleum and Liquid Petroleum Products—Laboratory Determination of Density—Hydrometer Method		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
IP 170	Determination of Flash Point—Abel Closed-Cup Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

Specification	Referenced Document Title	NHA Specificatio	NHA Title
IP 216	Particulate Contaminant in Aviation Fuel		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 225	Determination of Copper in Light Petroleum Distillates—Spectrophotometric Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 227	Corrosiveness to Silver of Aviation Turbine Fuels—Silver Strip Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 274	Determination of Electrical Conductivity of Aviation and Distillate Fuels		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
IP 299	Determination of Bromine Index—Electrometric Titration Method		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

Specification	Referenced Document Title	NHA Specificatio	NHA Title
IP 30	Detection of Mercaptans, Hydrogen Sulfide, Elemental Sulfur and Peroxides—Doctor Test Method		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 323	Determination of Thermal Oxidation Stability of Gas Turbine Fuels		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 336	Petroleum Products—Determination of Sulfur Content—Energy-Dispersive X-ray Fluorescence Spectrometry		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 34	Determination of Flash Point—Pensky-Martens Closed Cup Method		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 342	Petroleum Products—Determination of Thiol (Mercaptan) Sulfur in Light and Middle Distillate Fuels—Potentiometric Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

Specification	Referenced Document Title	NHA Specificatio	NHA Title
IP 354	Determination of the Acid Number of Aviation Fuels-Colour-Indicator Titration Method		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
IP 365	Crude Petroleum and Petroleum Products—Determination of Density—Oscillating U-tube Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 379	Determination of Organically Bound Trace Nitrogen—Oxidative Combustion and Chemiluminescence Method		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 394	Liquid Petroleum Products—Vapour Pressure—Part 1: Determination of Air Saturated Vapour Pressure (ASVP) and Calculated Dry Vapour Pressure Equivalent (DVPE)		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 406	Petroleum Products—Determination of Boiling Range Distribution by Gas Chromatography		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 423	Determination of Particulate Contaminant in Aviation Turbine Fuels by Laboratory Filtration		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 435	Determination of the Freezing Point of Aviation Turbine Fuels by the Automatic Phase Transition Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 436	Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 438	Determination of Water—Coulometric Karl Fischer Titration Method		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 475	Petroleum Liquids—Manual Sampling		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 523	Determination of Flash Point—Rapid Equilibrium Closed Cup Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 524	Determination of Flash/No Flash—Rapid Equilibrium Closed Cup Method		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 528	Determination for the Freezing Point of Aviation Turbine Fuels—Automatic Fibre Optic Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 529	Determination of the Freezing Point of Aviation Turbine Fuels—Automatic Laser Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 540	Determination of the Existent Gum Content of Aviation Turbine Fuel—Jet Evaporation Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 583	Determination of the Fatty Acid Methyl Esters Content of Aviation Turbine Fuel Using Flow Analysis by Fourier Transform Infrared Spectroscopy—Rapid Screening Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
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		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 590	Determination of Fatty Acid Methyl Esters (FAME) in Aviation Turbine Fuel—HPLC Evaporative Light Scattering Detector Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 598	Petroleum Products—Determination of the Smoke Point of Kerosine, Manual and Automated Method		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

Specification	Referenced Document Title	NHA Specificatio	NHA Title
IP 599	Determination of Fatty Acid Methyl Esters (FAME) in Aviation Turbine Fuel by Gas Chromatography using Heart-cut and Refocusing		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
IP 61	Determination of sulfur - High pressure combustion method		
IP 69	Vapour Pressure-Reid Method (St-B-9)		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP 71, Section 1	Petroleum Products—Transparent and Opaque Liquids—Determination of Kinematic Viscosity and Calculation of Dynamic Viscosity		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
IP200	Guidelines for the use of the Petroleum Measurement Tables		
		ASTM D4052	
ISO 20823	Hot Surface Ignition		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
JIG 1	Aviation Fuel Quality Control & Operating Standards for Into-Plane Fueling Services		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
JIG 2	Aviation Fuel Quality Control & Operating Standards for Airport Depots & Hydrants		
		ASTM D1655	Standard Specification for Aviation Turbine Fuels
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
J-STD-004	Requirements for Soldering Fluxes		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
J-STD-005	Requirements for Soldering Pastes		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
J-STD-006	Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
Method 8015	Nonhalogenated Organics by Gas Chromatography		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
Method 8260	Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
Method 8270	Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-C-83019	Coating, Polyurethane, for Protection of Integral Fuel Tank Sealing Compound		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-DTL- 83133	Filtration Time		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
MIL-DTL-17902	Hose, End Fittings and Hose Assemblies, Synthetic Rubber, Aircraft Fuels		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-DTL-24441	Paint, Epoxy-Polyamide, General Specification for		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-DTL-25988	Rubber, Fluorosilicone Elastomer, Oiland Fuel-Resistant, Sheets, Strips, Molded Parts, and Extruded Shapes		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-DTL-26521	Hose Assembly, Nonmetallic, Fuel, Collapsible, Low Temperature with Non-Reusable Couplings		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-DTL-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-DTL-5578	Tanks, Fuel, Aircraft, Self-Sealing		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-DTL-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-DTL-83054	Baffle and Inerting Material, Aircraft Fuel Tank		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-DTL-83133	Turbine Fuel, Aviation, Kerosene Type, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-H-4495	Hose Assembly, Rubber, Aerial Refueling		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-HDBK-510	Aerospace Fuels Certification		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-P-25732	Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Limited Service at 275 °F (135 °C)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-PRF-25017	Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons
MIL-PRF-370	Hose and Hose Assemblies, Nonmetallic: Elastomeric, Liquid Fuel		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-PRF-46010	Lubricant, Solid Film, Heat Cured, Corrosion Inhibiting, NATO Code S-1738		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-PRF-6855	Rubber, Synthetic, Sheets, Strips, Molded or Extruded Shapes, General Specification for		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-PRF-81298	Dye, Liquid for the Detection of Leaks in Aircraft Fuel Systems		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-PRF-81733	Sealing and Coating Compound, Corrosion Inhibitive		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
MIL-PRF-8516	Sealing Compound, Synthetic Rubber, Electric Connectors and Electric Systems, Chemically Cured		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-PRF-87260	Foam Material, Explosion Suppression, Inherently Electrostatically Conductive, for Aircraft Fuel Tanks		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-S-85334	Sealing Compound, Noncuring, Low Consistency, Silicone, Groove Injection, for Integral Fuel Tanks		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
MIL-STD- 3004	Storage Stability		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
MMM-A-132	Adhesives, Heat Resistant, Airframe Structural, Metal to Metal		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
QDS-25017	Qualified Data Set for MIL-PRF-25017 (Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble)		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

Specification	Referenced Document Title	NHA Specificatio	NHA Title
QPL-25017	Qualified Products List for MIL-PRF-25017 (Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE AMS-I-7444	Insulation Sleeving, Electrical, Flexible		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE AS5127/1	Aerospace Standard Test Methods for Aerospace Sealants Two-Component Synthetic Rubber Compounds		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-2410	Plating, Silver Nickel Strike, High Bake		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-2427	Aluminum Coating, Ion Vapor Deposition		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-3215	Acrylonitrile Butadiene (NBR) Rubber Aromatic Fuel Resistant 65–75		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
SAE-AMS-3265	Sealing Compound, Polysulfide (T) Rubber, Fuel Resistant, Non-Chromated Corrosion Inhibiting for Intermittent Use to 360 °F (182 °C)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-3276	Sealing Compound, Integral Fuel Tanks and General Purpose, Intermittent Use to 360 °F (182 °C)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-3277	Sealing Compound, Polythioether Rubber Fast Curing Integral Fuel Tanks and General Purpose, Intermittent Use to 360 °F (182 °C)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-3278	Sealing and Coating Compound: Polyurethane (PUR) Fuel Resistant High Tensile Strength/Elongation for Integral Fuel Tanks/Fuel Cavities/General Purpose		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-3279	Sealing Compound, Sprayable, for Integral Fuel Tanks and Fuel Cell Cavities, for Intermittent Use to 350 °F (177 °C)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
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)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-3283	Sealing Compound, Polysulfide Non- Curing, Groove Injection Temperature and Fuel Resistant		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-3361	Silicone Potting Compound, Elastomeric, Two-Part, General Purpose, 150 to 400 Poise (15 to 40Pa·s) Viscosity		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-3375	Adhesive/Sealant, Fluorosilicone, Aromatic Fuel Resistant, One-Part Room Temperature Vulcanizing		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-3376	Sealing Compound, Non-Curing, Groove Injection Temperature and Fuel Resistant		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
SAE-AMS-4017	Aluminum Alloy Sheet and Plate, 2.5Mg –0.25Cr (5052–H34) Strain-Hardened, Half-Hard, and Stabilized		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
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		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
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		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-4037	Aluminum Alloy, Sheet and Plate 4.4Cu –1.5Mg – 0.60 Mn (2024; –T3 Flat Sheet, –T351 Plate) Solution Heat Treated		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-4107	Aluminum Alloy, Die Forgings (7050–T74) Solution Heat Treated and Overaged		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
SAE-AMS-4260	Aluminum Alloy, Investment Castings 7.0Si – 0.32Mg (356.0–T6) Solution and Precipitation Heat Treated		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-4750	Solder, Tin–Lead 45Sn – 55Pb		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-4751	Tin–Lead Eutectic 63Sn – 37Pb		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-4901	Titanium Sheet, Strip, and Plate Commercially Pure Annealed, 70.0 ksi (485 MPa)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-4915	Titanium Alloy Sheet, Strip, and Plate 8Al–1V – IMo Single Annealed		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-5330	Steel Castings, Investment, 0.80Cr – 1.8Ni–0.35Mo (0.38–0.46C) (SAE 4340 Modified) Annealed		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
SAE-AMS-5338	Steel, Investment Castings 0.95Cr – 0.20Mo (0.35–0.45C) (SAE 4140 Mod) Normalized or Normalized and Tempered		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-5504	Steel, Corrosion and Heat–Resistant, Sheet, Strip, and Plate 12.5Cr (SAE 51410) Annealed		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
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		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-5604	Steel, Corrosion Resistant, Sheet, Strip, and Plate 16.5Cr – 4.0Ni – 4.0Cu – 0.30 Solution Heat Treated, Precipitation Hardenable		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-5613	Steel, Corrosion and Heat Resistant, Bars, Wire, Forgings, Tubing, and Rings 12.5Cr (SAE 51410) Annealed		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
SAE-AMS-5643	Steel, Corrosion Resistant, Bars, Wire, Forgings, Tubing, and Rings 16Cr – 4.0Ni – 0.30Cb –4.0Cu Solution Heat Treated, Precipitation Hardenable		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-5688	Steel, Corrosion–Resistant, Wire 18Cr–9.0Ni (SAE 30302) Spring Temper		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
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		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
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		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-6345	Steel, Sheet, Strip and Plate 0.95Cr –0.20Mo (0.28–0.33C) (SAE 4130) Normalized or Otherwise Heat Treated		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
SAE-AMS-6415	Steel, Bars, Forgings, and Tubing, 0.80Cr – 1.8Ni –0.25Mo (0.38–0.43C) (SAE 4340)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-6444	Steel, Bars, Forgings, and Tubing 1.45Cr (0.93–1.05C) (SAE 52100) Premium Aircraft-Quality, Consumable Electrode Vacuum Remelted		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-6470	Steel, Nitriding, Bars, Forgings, and Tubing 1.6Cr – 0.35Mo – 1.13Al (0.38–0.43C)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
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		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-7257	Rings, Sealing, Perfluorocarbon (FFKM) Rubber High Temperature Fluid Resistant 70 – 80		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

Specification	Referenced Document Title	NHA Specificatio	NHA Title
SAE-AMS-7271	Rings, Sealing, Butadiene-Acrylonitrile (NBR) Rubber Fuel and Low Temperature Resistant 60 –70		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-7276	Rings, Sealing, Fluorocarbon (FKM) Rubber High-Temperature-Fluid Resistant Low Compression Set 70–80		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-7902	Beryllium, Sheet and Plate, 98Be		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-C-27725	Coating, Corrosion Preventative, Polyurethane for Aircraft Integral Fuel Tanks for Use to 250 °F (121 °C)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-DTL-23053/5	Insulation Sleeving, Electrical, Heat Shrinkable, Polyolefin, Flexible, Crosslinked		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-P-5315	Butadiene–Acrylonitrile (NBR) Rubber for Fuel-Resistant Seals 60 to 70		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-P-83461	Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Improved Performance at 275 °F (135 °C)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-QQ-A-250	Aluminum Alloy 7075, Plate and Sheet		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-QQ-P-416	Plating, Cadmium (Electrodeposited)		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-R-25988	Rubber, Fluorosilicone Elastomer, Oiland-Fuel-Resistant, Sheets, Strips, Molded Parts, and Extruded Shapes		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-R-83485	Rubber, Fluorocarbon Elastomer, Improved Performance at Low Temperatures		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-S-4383	Sealing Compound, Topcoat, Fuel Tank, Buna-N Type		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
SAE-AMS-S-8802	Sealing Compound, Temperature Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High Adhesion		
		ASTM D4054	Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives
TBD - Enthalpy	Enthalpy versus Temperature		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
TBD - Flame Speed	Flame Speed		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
TBD - Heat Vaporization	Heat of Vaporization, Latent – see ASTM D323 or ASTM D5191 Vapor Pressure		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
TBD - Spark Ignition Energy	Minimum Spark Ignition Energy (The criterion is defined as "no easier to ignite than Jet A/JP- 8.")		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
TBD - Specific Heat	Specific Heat (as a Function of Temperature) (currently calculated)		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
TBD - Thermal Expansion	Thermal Expansion see ASTM D1298, D4052, D1903 Density (Thermal Expansion)		

Specification	Referenced Document Title	NHA Specificatio	NHA Title
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
TBD - Velocity of So	Velocity of Sound		
		MIL-HDBK-510	Department of Defense Handbook Aerospace Fuels Certification
UOP 389	Trace Metals in Oils by Wet Ash/ICP-AES		
		ASTM D7566	Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

11.9 Specification Review Databases

See Excel Spreadsheets for U.S. and Def Stan 91-091 Available from Coordinating Research Council