



AEROSPACE INFORMATION REPORT

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Guidance on the Impact of Fuel Properties on Fuel System Design and Operation

RATIONALE

There is a general lack of understanding across the industry of how the different properties of jet fuel may impact the design of fuel system equipment. In recent years, with the development of synthetic fuels, this has become important. This document tries to give an overview of what should be considered in the design of any new system, or when considering the impact of a new fuel pathway on an existing fuel system.

FOREWORD

This document is intended to give an overview of jet fuel properties (both specification properties and fit for purpose properties) which may impact airframe fuel system design. It discusses the properties and their impact on fuel system design. It is intended for use by fuel system designers to increase their understanding of the complexities of jet fuel.

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1. SCOPE

This document describes a number of jet fuel properties and where applicable gives the specification limits for Jet A and Jet A-1, though the properties are generally applicable to all turbine fuels. Later versions of this document will give more details on specification limits for other similar fuels, such as TS-1, where they differ from Jet A and Jet-A1. It gives details about the possible impact on airframe fuel system design.

1.1 Purpose

This document is intended to give fuel system designers a better understanding of the interaction between jet fuel properties and the design and operation of the airframe fuel system.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR5691 Guidance for the Design and Installation of Fuel Quantity Indicating Systems

2.1.2 ASTM

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D910 Standard Specification for Aviation Gasolines

ASTM D1655 Standard Specification for Aviation Turbine Fuels

ASTM D6615 Standard Specification for Jet B Wide-Cut Aviation Turbine Fuel

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

2.1.3 UK MOD

DEF-STAN-91-091 Turbine Fuel, Aviation Kerosine Type, Jet A-1 (AVTUR)

DEF STAN 91-86 Turbine Fuel, Aviation Kerosine Type: High Flash Type, Containing Fuel System Icing Inhibitor (AVCAT/FSII)

DEF STAN 91-87 Turbine Fuel, Aviation Kerosine Type, Containing Fuel System Icing Inhibitor (AVTUR/FSII)

DEF STAN 91-88 Turbine Fuel, Aviation: Wide Cut Type, Containing Fuel System Icing Inhibitor (AVTAG/FSII)

2.1.4 MIL SPECS

Copies of these documents are available online at <http://quicksearch.dla.mil>.

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

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

MIL-HDBK-510 Handbook – Aerospace Fuels Certification

MIL-STD-889 Dissimilar Metals

2.1.5 CRC

Available from Coordinating Research Council, 5755 North Point Parkway, Suite 265, Alpharetta, GA 30022, Tel: 678-795-0506, www.crao.com.

CRC Report No. 663 Handbook of Aviation Fuel Properties

CRC Report No. 647 CRC Aviation Committee - World Fuel Sampling

CRC (NAVAIR-06-5-504) Aviation handbook – Fuel and Fuel Systems (Note specific issue in May 1967 is used, now cancelled)

2.1.6 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

AC 25-981-1C Fuel Tank Ignition Source Prevention Guidelines

DOT/FAA/AR-98/26 A Review of the Flammability Hazard of Jet A Fuel Vapor in Civil Transport Aircraft Fuel Tanks

14 CFR Part 25 Code of Federal Regulation, Airworthiness Standards: Transport Category Airplanes

14 CFR Part 33 Code of Federal Regulation, Airworthiness Standards: Aircraft Engines

2.1.7 EASA Publications

Available from European Aviation Safety Agency, Ottoplatz, 1, D-50679 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu

CS25 Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes

CS-E Certification Specifications for Engines

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Aerospace Technical Report.

AIR4246 Contaminants for Aircraft Turbine Engine Fuel System Component Testing

ASTM D4054 Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives

STANAG 3747 Guide Specifications (Minimum Quality Standards) for Aviation Turbine Fuels (F-24, F-27, F-34, F-35, F-40, and F-44)

AFLP-3747	Guide Specifications (Minimum Quality Standards) for Aviation Turbine Fuels (F-24, F-27, F-34, F-35, F-40, and F-44)
GOST 10227	Jet Fuels, Specifications (Russian Fuels)
GOST 12308	Thermostable Fuels T-6 and T-8B for Jet Engines Specifications (Russian Fuels)
GB 6537-2006	No. 3 Jet Fuel (Chinese Fuel Specification)
CAN/CGSB 3.22	Wide-Cut Type Aviation Turbine Fuel (grade JET B)
CAN/CGSB 3.23	Aviation Turbine Fuel (Grades Jet A and Jet A-1)
CAN/CGSB 3-GP-24	High Flash Type Aviation Fuel

2.3 Definitions, Symbols and Terminology

ASTM	ASTM International (previously American Society for Testing & Materials, but now known just by the acronym with no specific meaning assigned to it)
BOCLE	Ball on Cylinder Lubricity Evaluator
CRC	Co-ordinating Research Council
ESD	Electro Static Dissipation
FAA	Federal Aviation Authority
FAME	Fatty Acid Methyl Esters
FQI	Fuel Quantity Indication
ICAO	International Civil Aviation Organization
IGGS	Intert Gas Generation System
MDA	Metal Deactivator Additive
MOD	Ministry of Defence (UK)
MSEP	Micro SEPARATOR
SDA	Static Dissipative Additive
TVP	True Vapor Pressure
UN	United Nations
WSD	Wear Scar Damage

3. SUMMARY OF JET FUELS

The table below gives fuel types in general usage in both commercial and military applications.

Table 1 - Jet fuel types

Designation Grade (Specification)	Kerosene Type			High Flash Kerosene Type	Wide Cut Type
Freeze Point Max °C	-60 (-50 for some TS-1)	-47	-40	-46	-50
British Joint Services		JET A-1/AVTUR (DEF-STAN-91-091, F-35) AVTUR/FSII (DEF-STAN-91-87, F-34)		AVCAT/FSI I (DEF-STAN 91-86)	AVTAG/FSII (DEF-STAN 91-88)
USA Civil (ASTM)		JET A-1 (F-35) (ASTM D1655)	JET A (F-4) (ASTM D1655)		JET B (ASTM D6155)
USA Military		JP-8 (F-34) (MIL-DTL-83133) JP-8+100 (F-37)	F-24 (Jet-A + Military additives) F-27 (Jet A + Military additives + thermal stability additive)	JP-5 (F-44) (MIL-DTL-5624)	JP-4 (F-40) (MIL-DTL-5624)
Canadian		JET A-1 (CAN/CGSB3.23)	JET A (CAN/CGSB3.23)	(3-GP-24)	JET B (CAN/CGSB3.22)
Chinese		No.3 Jet Fuel (GB 6537-2006)			
Russian	TS-1*, RT (PT) (GOST 10227)				

*The TS-1 Specification actually refers to this as the "chilling point", which is 3 °C lower than the freeze point, so the TS-1 -50 °C chilling point is equivalent to Jet A-1 -47 °C freeze point.

As can be seen from the table, Jet Fuel is controlled by a number of specifications. Many countries also have their own specifications for Jet A and Jet A-1, but virtually all of these are based on ASTM D1655 and/or DEF-STAN-91-091. There are ongoing worldwide efforts to harmonize ASTM D1655 and DEF-STAN-91-091, as well bring the Chinese No.3 Jet fuel specification and TS-1 specification into line with these specifications.

A common approach with all of the jet fuel specifications is that they are largely performance based, not compositional. They are based on Empirical data, collected over a number of years, and focused around parameters important to engine operation. This means that a range of values for each parameter are considered acceptable – for example density at 15 °C is specified as being between 775 kg/m³ and 840 kg/m³. The specifications only give a limited number of parameters against which jet fuel is certified as acceptable, but as part of the activity to standardize the clearance of additives and synthetic fuels, a large number of additional fit for purpose parameters have been identified, which are applicable to any synthetic fuel, or fuel containing new additives. These are considered to be implicitly achieved by fuel derived from crude oil (though changes in processes at the refinery may impact this), but need to be explicitly tested for a synthetic component or new additive. For example, permittivity of fuel is not a specification parameter, but any synthetic fuel blend which is to be certified as Jet A or Jet A-1 fuel must lie within the data presented within the CRC Handbook for the normal permittivity range. The testing against these fit-for-purpose characteristics is performed as part of the ASTM approval process, in order for a new synthetic fuel blending component or additive to be added to ASTM D7566.

NOTE: Although much of the data in the CRC handbook is based on measured values, some parameters are based on calculation or historic data, so the margin of error should be considered. The detail of each measured fuel, and therefore the spread of data represented by the average curves shown in CRC Handbook 663 can be found in CRC Report No. 647 CRC Aviation Committee - World Fuel Sampling Program.

3.1 Jet Fuel Chemistry

The chemistry of jet fuel is complex, with more than 500 different components. It primarily consists of a blend of hydrocarbon molecules, with 8 to 16 carbon atoms per molecule (C8 through C16). Around 60% of the molecules are paraffins, 20% are naphthenes and 20% are aromatics, though the proportions may vary. If there is a synthetic component (i.e., a fuel not made from a crude oil source), then the final fuel must contain a minimum of 8% aromatics. There are also trace amounts of olefins, sulfur, nitrogen and oxygen compounds. The different hydrocarbon molecular types are depicted in Figure 1.

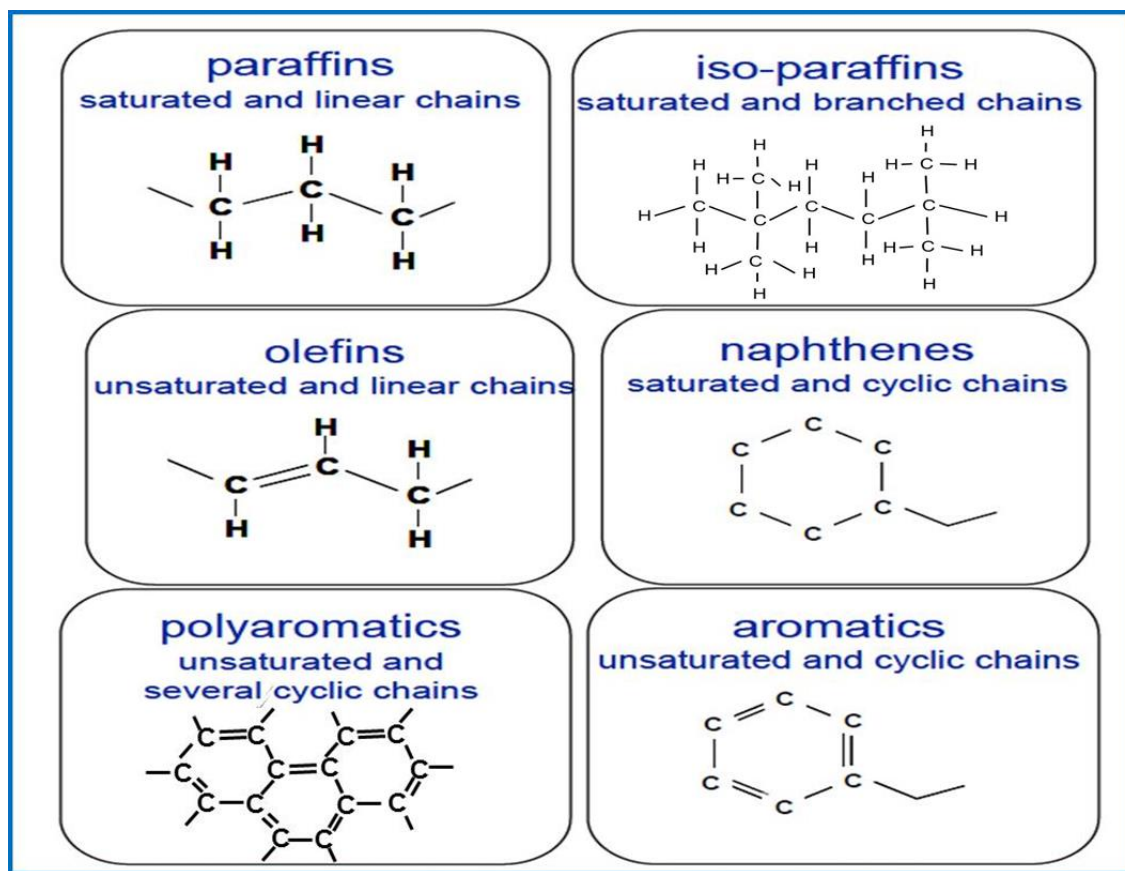


Figure 1 - Molecules present in hydrocarbon fuels

There are issues with existing jet fuel formulations, including:

- **Instability:** formation of insoluble components (residue and gums) because of reactant presence, storage or blending of two different jet fuels
- **Composition variability:** depends on oil origin/processing. This is increased by the introduction into the specification of a possibility of a synthetic component, where fuels could contain one of a number of synthetic elements (see Section 4).

4. SYNTHETIC FUELS

As part of the ongoing development of jet fuel, a number of different pathways have been developed to derive jet fuel from sources other than crude oil. This is in part driven by a need to reduce overall emissions and the push towards renewable energy sources, but also by a desire to reduce the dependence on crude oil. All these fuels are classed as “Drop-In” i.e., once approved they perform in the same way as today’s fuel, so no changes are required for the certification of the aircraft in order to use them. Although developing a fully synthetic fuel would help to address reduction in emissions, and would address the UN ICAO agreement for zero new emissions by 2030, the key driver is for a “drop-in” fuel, which means that blends of crude and synthetic fuels are likely to continue for the foreseeable future.

ASTM D4054 defines the process by which synthetic fuels from non-crude oil sources are approved. This is a guideline, and does not guarantee that a fuel will be approved. The approved synthetic fuels, and the acceptable blend percentages are given in ASTM D7566. A number of other fuels are still going through the approval process.

In order to approve these synthetic fuels, ASTM D4054 lists materials which have to be checked for compatibility, and a number of “fit-for-purpose” characteristics which must be tested, as well as the basic specification properties given in ASTM D1655.