Product specifications
Turbine Fuel, Kerosene Type, Jet A-1

Table 1. Test Requirements

PROPERTY	UNITS	LIMITS		TEST METHODS	
				ASTM STANDARDS	IP STANDARDS
Visual Appearance	-	Clear, bright, and visually free from solid matter and undissolved water at ambient fuel temperature.		Visual	
Saybolt colour (1)	-	Report		D156 D6045	
Contamination (2) or	mg/l	Max 1.0		D5452	IP 423
Cumulative channel particle counts (2)(3)	Individual channel counts & ISO code	Channel counts	ISO Code		IP 565 IP 577
≥ 4 µm(c)		Report	Max 19		
≥ 6 µm(c)		Report	Max 17		
≥ 14 µm(c)		Report	Max 14		
≥ 21 µm(c)		Report	Report		
≥ 25 µm(c)		Report	Report		
≥ 30 µm(c)		Report	Max 13		
Total acidity	mg KOH/g	Max 0.015		D3242	IP 354
Aromatic hydrocarbon types					
Aromatics or	% v/v	Max 25.0		D1319 (4)	IP 156 (4)
Total Aromatics	% v/v	Max 26.5		D6379 (5)	IP 436 (5)
Sulfur, Total	% m/m	Max 0.30			IP 336
Sulfur, Mercaptan (6) or	% m/m	Max 0.0030		D3227	IP 342
Doctor Test		Doctor Negative			IP 30
Refining components, at point of manufacture (7)					
Non-Hydroprocessed Components	% v/v	Report			
Severely Hydroprocessed Components	% v/v	Report			
Synthetic Components (8)	% v/v	Report			
Distillation (9)				D86	IP 123
Initial Boiling Point	ºC	Report			
10 % Recovery	ºC	Max 205.0			
50 % Recovery	ºC	Report			
90 % Recovery	ºC	Report			
End Point	ºC	Max 300.0			
Residue	% v/v	Max 1.5			
Loss	% v/v	Max 1.5			
Flash Point	ºC	Min 38.0			IP 170
Density at 15 ºC	kg/m³	Min 775.0; Max 840.0		D4052	IP 365
Freezing Point (10)	ºC	Max minus 47.0		D2386	IP 16
Viscosity at minus 20 ºC	mm²/s	Max 8.000		D445	IP 71
Smoke Point (11) or	mm	Min 25.0		D1322	IP 598
Smoke Point (11) and	mm	Min 18.0		D1322	IP 598
Naphthalenes	% v/v	Max 3.00		D1840	
Specific Energy	MJ/kg	Min 42.80		(12)	
Copper Strip (13)	Class	Max 1		D130	IP 154

Table 1. Test Requirements

PROPERTY	UNITS	LIMITS	TEST METHODS	
			ASTM STANDARDS	IP STANDARDS
Thermal Stability (JFTOT) (14) Test Temperature Tube Rating (one of the following requirements shall be met) (15) 1) VTR 2) ITR or ETR, average over area of 2.5 mm^2 Pressure Differential	 °C - nm mm Hg	 Min 260 Less than 3. No Peacock (P) or Abnormal (A) Max 85 Max 25	D3241	IP 323
Existent Gum	mg/100 ml	Max 7		IP 540
Water separation Characteristics Microseparometer at Point of Manufacture (one of the following requirements shall be met) (16) MSEP Without SDA MSEP With SDA MSEP	 Rating Rating Rating	 Min 85 Min 70 Min 88	 D3948 D3948 D8073	
Water separation Characteristics Microseparometer downstream of the point of manufacture (16) MSEP MSEP	 Rating Rating	 Min 85 Min 88	 D7224 D8073	 IP 624
Electrical Conductivity (17)	pS/m	Min 50; Max 600	D2624	IP 274
Lubricity Wear Scar Diameter (18)	 mm	 Max 0.85	 D5001	
FAME Content (19) (20)	mg/kg	Less than 5.0		IP 585 IP 590 IP 599
DRA Content (20) (21)	µg/L	Nil	D7872	
Additives	-	(22)		

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THE TEST METHODS TO BE APPLIED WILL BE THOSE CORRESPONDING TO THE LATEST PUBLISHED VERSION. ALTERNATIVE METHODS ARE INCLUDED IN ANNEX E OF DEF STAN 91-091 ISSUE 16. SEE NOTES OF THIS TABLE ON PAGE 5 OF THIS DOCUMENT. IF THERE IS A MODIFICATION ON THE OFFICIAL SPECIFICATION THIS DOCUMENT WILL BE REVIEWED TO UPDATE IT.	

NOTES

If it cannot be assured that the product will be shipped exclusively as Jet A-1 (civil aviation fuel), the specifications that apply to it will be the most restrictive of the latest issue of DEF STAN 91-091 and NME-3004.

The following table contains the properties and their limits for compliance as JP-8. The test methods to be applied will be those corresponding to the latest published version:

Table 2. Properties and limits for compliance as JP-8

PROPERTY	UNITS	LIMITS	TEST METHODS	
			ASTM STANDARDS	IP STANDARDS
Hydrogen Content *(I)*	% m/m	Min 13.4	D3343 D3701 D5291 D7171	
Calculated Cetane Index	-	Report	D976 D4737	
Filtration Time	minutes	Max 15	*(II)*	
Components and additives *(III)*	-	(22)		

(I) The referee test method is ASTM D7171.

(II) A minimum sample quantity of 3.785 litres (1 gallon) will be filtered. The filtration time will be determined according to appendix A of the latest published version of MIL-DTL-83133 standard. This procedure may also be used to determine particulate matter as an alternative method to ASTM D2276 or ASTM D5452.

(III) Antioxidants

Immediately after manufacturing and before the fuel is exposed to the atmosphere, an approved antioxidant additive or a mixture of them may be added to prevent peroxidation and gum formation. The addition in the supply chain will also be permitted subject to prior agreement between supplier and contractor or user. The final concentration of antioxidant, in either case, will be included in the corresponding certificate and will not exceed 24.0 mg/l of active material.

Corrosion Inhibitor/Lubricity Improver (CI/LI) or Lubricity Improver Additive (LIA)

This additive is incorporated into the fuel in the EXOLUM system.

Fuel System Icing Inhibitor (FSII)

This additive is incorporated into the fuel in the EXOLUM system.

Components

Aviation turbine fuel can only contain as synthetic fuel up to 5% by volume of co-processed from esters and fatty acids or Fisher-Tropsch hydrocarbons.

For compliance, as specified in DEF STAN 91-091 Issue 16, table 3 includes the additional properties and their limits as included in annex B.4 of DEF STAN 91-091 Issue 16:

Table 3. Extended Requirements of Aviation Turbine Fuels Containing Co-hydroprocessed Fatty Acid Esters and Fatty Acids or Fisher-Tropsch hydrocarbons (a)(b)

PROPERTY	UNITS	LIMITS	TEST METHODS	
			ASTM STANDARDS	IP STANDARDS
Thermal stability (JFTOT) Test temperature for 2.5hr (c)	ºC	Min 280	D3241	IP 323
Tube Rating (one of the following requirements shall be met): 1) VTR	-	Less than 3. No Peacock (P) or Abnormal (A)		
2) ITR or ETR, average over area of 2.5 mm^2	nm	Max 85		
Pressure differential	mm Hg	Max 25		
Freezing Point	ºC	Max minus 47.0	D5972 (d) D7153 D7154	IP 435 (d) IP529 IP 528
Viscosity at minus 40ºC (e)	mm^2/s	Max. 12.0	D445 (f) D7945	IP 71 (f)
Unconverted fatty acid esters and fatty acids	mg/kg	Max 15	D7797 (g)	IP 583 (g)

(a) Applies at the point of manufacture only.

(b) Applies for the finished batch of jet fuel.

(c) An IP323 / ASTM D3241 test temperature of 280°C has been selected to help ensure that reactive compounds introduced through co-hydroprocessing of fatty acid esters and fatty acids are limited. Metal Deactivator (MDA), as described in annex A of DEF STAN 91-091 Issue 16, may not be used to meet this requirement.

(d) IP 435 / ASTM D 5972 is the referee method.

(e) The kinematic viscosity specification of 12.0 mm^2 /s at minus 40°C maximum mitigates the potential risk of increased viscosity due to n-paraffin enrichment. Compared to conventional hydrocarbons, a co-hydroprocessed esters and fatty acids stream may contain a higher concentration of n-paraffins.

(f) IP 71 / ASTM D445 allows measuring the viscosity at minus 40°C, however, the precision values were determined down to minus 20°C. A revision to test method IP 71 and ASTM D445 to specify measurement precision at minus 40°C is in process.

(g) Applies only to co-processing esters and fatty acids. The ability of IP 583 / D7797 to identify carbonyl containing compounds in addition to FAMEs is acknowledged. The reported value may be corrected for a local sample-specific bias related to trace carbonyl species inherent in aviation turbine fuel derived from conventional sources. Corrected values shall be identified as such.

(1) The requirement to report Saybolt colour shall apply at point of manufacture, thus enabling a colour change during distribution to be quantified. Where the colour of the fuel precludes the use of the Saybolt colour test method, then the visual colour shall be reported. Unusual or atypical colours should also be noted. For further information on the significance of colour see Annex F.4 of DEF STAN 91-091 Issue 16.

(2) This limit shall apply at point of manufacture only. To meet the requirements of this standard the limits of either particulate contamination or particle counts shall be met, and it is only necessary to report whichever property is being used to support release of the fuel. For more information on particulate contamination or particle counting refer to annex F of DEF STAN 91-091 Issue 16. For JP-8 military fuel, the ASTM D5452 method is the reference method in accordance with NME-3004 specification.

(3) If limits are exceeded annex B of IP 565 or IP 577 may be applied to eliminate trace free water, and cleanliness re-determined. In such cases, results before and after application of the annex shall be reported.

(4) Due to technical issues, dyes with lot numbers 3000000975 through to 3000000982 are unacceptable for use and shall not be used in conjunction with these test methods. The lot number of the dye shall be reported on the test certificate.

(5) Inter laboratory studies have demonstrated the correlation between total aromatics content measured by IP 156 / ASTM D1319 and IP 436 / ASTM D6379. Bias between the two methods necessitates different equivalence limits as shown. In cases of dispute IP 156 will be the referee method.

(6) Doctor Test is an alternative requirement to Sulfur Mercaptan. If the Doctor Test result is Positive, the Sulfur Mercaptan Test shall be carried out and reported. In case of conflict, the determination of mercaptan sulfur prevails.

(7) Blend components used in the make-up of the batch shall be reported on the Certificate of Quality as a percentage by volume of the total fuel in the batch. Severely hydroprocessed components are defined as those petroleum derived hydrocarbons that have been subjected to a hydrogen partial pressure of greater than 7000 kPa (70 bar or 1015 psi) during manufacture. Note that the sum of the reported composition may be less than 100% if the batch includes a mildly hydroprocessed component.

(8) The semi-synthetic jet fuel CoQ at point of batch origination shall include a listing of the quality documents relating to the conventional and synthetic blend component (SBC) batches in the blend and their respective volumes to show compliance with the blending limits set out in the annexes to ASTM D7566. The SBC producer's CoQ, COA or RT number shall be available for each SBC at the point of batch origination including number, antioxidant concentration (as the concentration of active material reported on originator's CoQ) and corresponding formulation Qualification reference per annex A.2.4 of DEF STAN 91-091 Issue 16. In the specific case of co-processing, the CoQ must inform that the batch can incorporate up to 5% v/v of co-hydroprocessed synthetic kerosene.

(9) In methods IP 123 and ASTM D86 all fuels certified to this Standard shall be classed as group 4, with a condenser temperature of zero to 4°C.

(10) During downstream distribution if the freezing point of the fuel is very low and cannot be determined within the IP 16 lowest achievable temperature of minus 65 degrees C, if no crystals appear during cooling of the fuel and when the thermometer indicates a temperature of minus 65°C, the freezing point shall be recorded as below minus 65°C. This limit does not apply if the freezing point is measured by the alternative test methods listed in table 5 of DEF STAN 91-091 Issue 16.

(11) IP 598 / ASTM D1322 includes both a manual and an automated method. The automated method is the referee method.

(12) Specific Energy by one of the methods listed in Annex E of DEF STAN 91-091 Issue 16 is acceptable.

(13) The sample shall be tested in a pressure vessel at 100 ± 1°C for 2 hours ± 5 minutes.

(14) Heater tubes other than those supplied by the original equipment manufacturer (OEM) shall not be used. Technically suitable heater tubes are PAC – Alcor or Falex.

(15) Tube rating will be measured in accordance with the indicated methods and their corresponding annexes on the visual (VTR), interferometric (ITR) or ellipsometric (ETR) method. Tube deposit ratings shall be measured by ITR or ETR, when available. If ITR device reports “N/A” for a tube’s volume measurement, the test shall be a failure and the value reported as >85 nm. VTR is not required when ITR or ETR deposit thickness measurements are reported. In case of dispute between results from visual and metrological methods, the metrological method shall be considered the referee

(16) Where SDA is added at point of manufacture the MSEP limit of 70 shall apply, except when using the alternative method ASTM D8073, when the limits of table 5 note 6 of DEF STAN 91-091 Issue 16 apply. No precision data are available for fuels containing SDA; if water separation property testing is carried out during downstream distribution no specification limits apply and the results are not to be used as the sole reason for rejection of a fuel. A protocol giving guidelines on water separation property testing can be found in the Joint Inspection Group's latest bulletin Number 142 and it shall be applicable downstream of point of manufacture. Where SDA is added downstream of point of manufacture, it is acknowledged that MSEP results using ASTM D3948 may be less than 70.

(17) The conductivity limits are mandatory for product to meet this Standard. However, it is acknowledged that in some manufacturing and distribution systems it is more practical to inject SDA further downstream. In such cases the Certificate of Quality for the batch shall be annotated thus: “Product meets requirements of Defence Standard 91-091, except for electrical conductivity”. See annex F.2 of DEF STAN 91-091 Issue 16 for more information. Deliveries to the EXOLUM system will not incorporate SDA into the fuel and therefore will not have to meet this specification. In these cases, the refineries (or plants) will deliver two litres of SDA for every thousand cubic meters of kerosene.

(18) The requirement to determine lubricity applies only to fuels whose composition is made up of:

a) less than 5% non-hydroprocessed components and at least 20% severely hydroprocessed components (see Note 7).
b) includes synthesised fuel components (see Note 8).

(19) Test method IP 585 shall be the referee method.

(20) Post manufacture each custodian shall undertake a risk assessment to quantify the potential risk of incidental material carry over. Where such assessments indicate that there could be a potential risk in jet fuel supplies, additional quality assurance procedures shall be introduced to increase control to mitigate the risk. Where the risk of incidental material carryover exists and it is not possible to control with additional quality assurance procedures, testing shall be instigated.

(21) DRA is not an approved additive for jet fuel at any concentration. Dilution of fuels with known levels of DRA is not permitted, even to levels below the detection limit. Where the level of DRA is otherwise unknown a result at or below 72 µg/l would support an assumption of nil addition.

(22) Some additives, as qualified, include a hydrocarbon diluent as a solvent and the amount to be added is calculated based on the additive as received. These include Static Dissipator Additive and Lubricity Improver Additive. Other additives are qualified based on the active ingredient content as listed. These include Antioxidant, Metal Deactivator Additive, Fuel System Icing Inhibitor (FSII), and Leak Detection Additive.

Where it is necessary to dilute an additive for handling purposes any solvent used shall be hydrocarbon derived from the sources detailed in clause 4 “Materials” of DEF STAN 91-091 Issue 16. In this case the

vendor/manufacturer shall provide directions for calculating dosage. This information shall be placed on the certificate of analysis or additive quality documentation

Anti-oxidant (AO)

AO can be used to prevent peroxidation and gum formation during storage.

The use of AO or mixtures of AO is optional for fuels manufactured from petroleum sources.

Permitted AOs are detailed in annex A of DEF STAN 91-091 Issue 16. Specific AO requirements for fuels produced to ASTM D7566 are detailed in annex B.2. Qualified formulations are detailed in A.2.4.

The concentrations in which the qualified materials shall be used are as follows:

- Synthesised fuels: refer to the appropriate annex in ASTM D7566.
- Petroleum fuels: the total concentration of active material(s) in the final batch shall not exceed 24.0 mg/l.

If AO is added to the fuel, report the AO concentration as a total active material in the final batched fuel.

If AO is added post manufacture, report the total active material concentration in the final batched fuel on the Certificate of Analysis and the Release Certificate.

Metal Deactivator Additive (MDA)

Permitted MDA are detailed in annex A of DEF STAN 91-091 Issue 16. MDA may be added to fuel under the following conditions:

- At Point of Manufacture

    a) No more than 5 % of the jet fuel batches produced in a 12-month period may be treated with MDA to meet table 1 thermal oxidative stability requirements (260 °C test temperature).

    b) The batch of fuel shall pass table 1 thermal oxidative stability requirements at a test temperature of 245 °C prior to any MDA addition.

    c) The fuel batch after MDA addition (2.0 mg/L maximum MDA) shall pass table 1 thermal oxidative stability requirements at a test temperature of 275 °C.

    d) The thermal oxidative stability test result at 245 °C prior to MDA addition, the original test result at 260 °C and the test result at 275 °C (post MDA addition) and the concentration of MDA added shall be reported on the Refinery Certificate of Quality.

- During Distribution

    a) MDA may be added to jet fuel in the distribution system to recover thermal oxidative stability performance lost during distribution (after release from point of manufacture). The Certificate of Analysis shall show the initial thermal oxidative stability test result, the result after the addition of the MDA and the concentration of MDA added.

Initial addition of more than 2 mg/l MDA, to jet fuel that meets table 1 thermal oxidative stability requirements (260ºC test temperature) prior to MDA addition is permitted when fuel will be transported in supply chains where copper contamination can occur: the maximum cumulative addition still applies.

Qualified material is detailed in A.3.3 of DEF STAN 91-091 Issue 16. The concentration of active material used on initial doping of the fuel shall not exceed 2.0 mg/l. Cumulative addition of MDA when redoping the fuel shall not exceed 5.7 mg/l. The requirements of A.3.1 shall be met when doping or redoping.

Static Dissipator Additive (SDA)

Where necessary to meet the conductivity requirements an SDA shall be added to the fuel to impart electrical conductivity in accordance with Table 1.

Qualified materials are detailed in A.4.2 of DEF STAN 91-091 Issue 16.

The concentration of SDA to be used in newly manufactured, or on first doping of fuel, is 3.0 mg/l maximum. It is permitted to add additional SDA downstream of the point of manufacture. In such circumstances the maximum total SDA concentration, including initial doping, shall not exceed 5.0 mg/l.

A suitable method for the determination of SDA concentration at the point of manufacture is IP 568 or ASTM D7524.

In deliveries to the EXOLUM system this additive shall not be incorporated.

Lubricity Improver Additive (LIA)

A LIA may be added to impart improved lubricity to the fuel. Further information on Aviation Turbine Fuel Lubricity is available at annex of DEF STAN 91-091 Issue 16.

Qualified materials at the specified concentrations are detailed in A.5.4 of DEF STAN 91-0911 Issue 16.

Fuel System Icing Inhibitor (FSII)

An FSII may be added to the fuel by agreement between purchaser and supplier. Concentrations of less than 0.02% by volume can be considered negligible and do not require agreement/notification.

Under no circumstances shall fuels containing FSII be delivered through a filter monitor.

Qualified materials are detailed in A.6.3 of DEF STAN 91-0911 Issue 16.

Suitable methods for determining the additive concentration are IP 424 and ASTM D5006.

Leak Detection Additive

Where necessary a leak detection additive may be added to the fuel to assist in detecting and locating leaks in ground-based fuel storage, delivery, and dispensing systems. It should be recognized that other leak detection techniques may have less environmental impact than Tracer A. The additive should only be used when other options have been considered.

Qualified materials are detailed in A.8.2 of DEF STAN 91-0911 Issue 16.

The concentration of Tracer A shall not exceed 1.0 mg/kg.

The refinery Certificate of Quality CoQ (RCQ) shall include all the information relating to the additives incorporated into the fuel, both type and concentration of each of them. The names and codes of the additives listed in Annex A of DEF STAN 91-091 Issue 16 shall also be noted on the point-of-manufacture quality certificates.