

## SHELL AVIATION FUELS

Shell Aviation fuels may be classified into two basic groups: aviation gasoline, for use in spark ignition piston engines; aviation turbine fuels (jet fuels), for use in turbo-fan, turbo jet and turbo-prop engines. Jet fuels are also certified by Aviation Authorities for use in compression ignition piston (diesel) engines, although the jet fuel specifications do not designed for this purpose. The various grades of each type available are described in this section.

All Shell Aviation fuels are produced to meet the stringent manufacturing requirements set out in the relevant specifications. At key stages between refinery and aircraft tank, fuel quality is checked by sampling and on-site or laboratory testing, to ensure that the fuel conforms to the requirements specified for the grade when it is delivered to the aircraft. The Shell Aviation Quality Assurance System is organised on a worldwide basis, made easier because Shell Aviation Service is provided directly in many countries of the world.

### Aviation Turbine Fuel (Jet Fuel)

Today's kerosine 'Jet' fuels have been developed from the illuminating kerosine used in the early gas turbine engines. These engines needed a fuel with good combustion characteristics and a high energy content. The kerosine type fuels used in civil aviation nowadays are mainly Jet A-1 and Jet A. The latter has a higher freezing point (minimum  $-40^{\circ}\text{C}$  instead of minimum  $-47^{\circ}\text{C}$ ) and is available only in the U.S.A.

### Major Civil Jet Fuel grades

#### Jet A-1

Jet A-1 is a kerosine grade of fuel suitable for most turbine engine aircraft. It has a flash point minimum of  $38^{\circ}\text{C}$  ( $100^{\circ}\text{F}$ ) and a freeze point minimum of  $-47^{\circ}\text{C}$ . It is widely available outside the U.S.A. The main specifications for Jet A-1 grade (see below) are the UK specification DEF STAN 91-91 (Jet A-1) NATO code F-35, (formerly DERD 2494) and the ASTM specification D 1655 (Jet A-1).

#### Jet A

Jet A is a kerosine grade fuel, normally only available in the U.S.A. It has the same flash point as Jet A-1 but a higher freeze point minimum ( $-40^{\circ}\text{C}$ ). It is supplied against the ASTM D 1655 (Jet A) specification. Jet A is used within the United States by domestic and international airlines.

#### Jet B

Jet B is a distillate comprising naphtha and kerosine fractions. It can be used as an alternative to Jet A-1, but because it is more difficult to handle (higher flammability), there is minimal demand and availability for this grade of fuel. The only significant area of use is in very cold climates, like northern Canada, where its better cold weather performance is important. Jet B is specified by ASTM D 6615, but in Canada it is supplied against the Canadian Specification CAN/CGSB 3.23

**TS-1**

TS-1 is the main jet fuel grade available in Russia and the Commonwealth of Independent States. It is a kerosine type fuel with slightly higher volatility (flash point is 28 °C minimum) and lower freeze point (<-50 °C) compared with Jet A-1. It is supplied against the GOST 10227 specification.

**No.3 Jet Fuel**

No.3 Jet Fuel is the main Chinese grade which is essentially identical to Jet A-1.

**American Civil Jet Fuels**

The basic civil jet fuel specification used in the United States of America is ASTM Specification for Aviation Turbine Fuels D 1655, which defines the requirements for the two grades of fuel – Jet A and Jet A-1 (Note: ASTM D 1655 formerly included Jet B but this grade is now covered by a separate specification ASTM D 6615).

**Alternative Fuels**

A recent development for jet fuels is the approval of alternative blend components. Unconventional blend components, including those derived from Fischer-Tropsch synthesis or some renewable bio-routes, are covered by a new specification, ASTM D7566. In this specification, blend components are defined and controlled in the Annex section, along with the blending limits. Once blended, the finished fuels must meet the test requirements in the main table of ASTM D7566, which includes all of the testing requirements of ASTM D1655 plus some additional parameters. Once a finished fuel is certified to ASTM D7566 it can be recertified as ASTM D1655, thereby allowing the fuel to be handled and mixed with conventional jet fuel batches and, furthermore, not requiring any change in the certification of either aircraft or engines.

Research and testing continues to prove the suitability of new processes and source materials for use in jet fuel and, as this work progresses, the scope of ASTM D7566 will continue to be expanded to accommodate these changes.

**UK Jet Fuels**

Although developed originally as a military jet fuel specification by the UK Ministry of Defence, DEF STAN 91-91 (originally DERD 2494) has been adopted as the standard UK civil jet fuel specification. It defines the requirements for a kerosine type fuel (Jet A-1 grade) having a minimum freeze point of -47 °C.

Jet A-1 according to the DEF STAN 91-91 specification is essentially the same as Jet A-1 defined by the ASTM D 1655.

**Russian and East European Jet Fuels**

Russian kerosine type jet fuels are covered by a wide range of specification grades reflecting different crude sources and processing treatments used. The grade designation is T-1 to T-8, TS-1 or RT. The grades are covered either by a State Standard (GOST) number, or a Technical Condition (TU) number. The limiting property values, detailed fuel composition and test methods differ quite considerably in some cases from the Western equivalents.

The principle grade available in Russia and other members of the Commonwealth of Independent States (CIS) is TS-1 (written as TC-1 in Russian script).

The main differences in characteristics are that Russian fuels have a low freeze point (equivalent to about -57 °C by Western test methods) but also a low flash point (a minimum of 28 °C compared with 38 °C for western fuel). RT fuel (written as PT in Russian script) is the superior grade (a hydrotreated product) but is not produced widely. TS-1 (regular grade) is considered to be on a par with Jet A-1 and is approved by most aircraft manufacturers.

In some locations in Russia and for exports, product may be supplied against the Russian Jet A-1 specification GOST 52050-2006 which is aligned with DEF STAN 91-91.

Eastern European countries have their own national standards with their own nomenclature. Many are very similar to the Russian standards, but others reflect the requirements of visiting international airlines and are similar to Jet A-1 in properties and test methods.

**Chinese Jet Fuels**

Five types of jet fuel are covered by current Chinese specifications. Previously, each grade was numbered with a prefix RP; however, they are now renamed No.1 Jet Fuel, No.2 Jet Fuel, etc.. RP-1 and RP-2 are kerosines which are similar to Russian TS-1. They both have low flash points (minimum 28 °C). RP-1 freeze point is -60 °C and RP-2 is -50 °C.

RP-3 is essentially the same as Jet A-1. RP-4 is a wide-cut type fuel similar to Jet B and Russian T-2. RP-5 is a high flash point kerosine similar to that used in the west by naval aircraft operating on aircraft carriers. Virtually all jet fuel produced in China is now RP-3 (renamed No.3 Jet Fuel).

### International Specifications - AFQRJOS Check List

As jet fuel supply arrangements have become more complex in the 1970s, involving co-mingling of product in joint storage facilities, a number of fuel suppliers developed a document which became known as the Aviation Fuel Quality Requirements for Jointly Operated Systems, or AFQRJOS, Joint Fuelling System Check List. The "Check List" embodies the most stringent requirements of the DEF STAN 91-91 and ASTM D 1655 specifications for JET A-1. By definition, any product meeting Check List requirements will also meet either DEF STAN or ASTM specifications.

The Check List is recognised by eight of the major aviation fuel suppliers - BP, Chevron, ENI, ExxonMobil, Kuwait Petroleum, Shell, Statoil and Total.

### Military Jet Fuel grades

#### JP-4

JP-4 used to be the primary jet fuel for the US Air Force but was phased out in the 1990s because of safety problems. A few airforces around the world still use it but there is very little production.

JP-4 is the military equivalent of Jet B with the addition of corrosion inhibitor and anti-icing additives; it meets the requirements of the U.S. Military Specification MIL-DTL-5624U Grade JP-4. The UK Military specification for this grade is DEF STAN 91-88 AVTAG/FSII (formerly DERD 2454), where FSII stands for Fuel System Icing Inhibitor. NATO Code F-40.

#### JP-5

JP-5 is a high flash point kerosine meeting the requirements of the U.S. Military Specification MIL-DTL-5624U Grade JP-5. The UK Military specification for this grade is DEF STAN 91-86 AVCAT/FSII (formerly DERD 2452). This is primarily jet fuel for use in aircraft carriers. NATO Code F-44.

#### JP-8

JP-8 is the military equivalent of Jet A-1 with the addition of corrosion inhibitor and anti-icing additives; it meets the requirements of the U.S. Military Specification MIL-DTL-83133G. It is the dominant military jet fuel grade for NATO airforces. The UK also has a specification for this grade namely DEF STAN 91-87 AVTUR/FSII (formerly DERD 2453). NATO Code F-34.

#### JP-8 +100

JP-8 +100 is JP-8 fuel to which has been added an approved thermal stability improver additive. It meets the requirements of the U.S. Military Specification MIL-DTL-83133G and is widely used by the USAF in their fighter and trainer wings. NATO Code F-37.

### Aviation Gasoline (Avgas)

Aviation Gasoline (Avgas) is used in small piston engine powered aircraft within the General Aviation community, e.g. private pilots, flight training, flying clubs and crop spraying. Piston engines operate using the same basic principles as spark ignition engines in cars, but they have a much higher performance requirement. In today's General Aviation community there are only two main Avgas grades (100 and 100LL low lead) - a rationalisation that has enabled fuel companies to continue supplying a market that would otherwise have become uneconomic. Worldwide, total Avgas volumes are low, since Avgas-fuelled aircraft, although they outnumber jet-fuelled aircraft, are generally much smaller.

### Avgas grades

#### Avgas 100

This was the standard high octane fuel for aviation piston engines and has a high lead content. There are two major specifications for Avgas 100. The ASTM D 910 and UK DEF STAN 91-90. These two specifications are essentially the same, but differ over antioxidant content, oxidation stability requirements and max lead content.

Avgas 100 is dyed green and is now only produced in a few refineries in the world.

#### Avgas 100LL

This grade is the lower lead version of Avgas 100. Low lead is a relative term. There is still up to 0.56 g/litre of lead in Avgas 100LL. This grade is listed in the same specifications as Avgas 100, namely ASTM D 910 and UK DEF STAN 91-90.

Avgas 100LL is dyed blue and is the main grade of Avgas used worldwide.

#### Avgas 100VLL

This grade is the very low lead version of Avgas 100LL, containing a maximum lead concentration of 0.45 g/litre. It is effectively a variant of Avgas 100LL with a restraint on the max lead content. It could be made available as an interim measure prior to the introduction of an unleaded high octane fuel, should it be necessary to address environmental concerns about leaded fuels. This grade is listed in ASTM D 910 and, other than the lower lead content, is constrained by the same specification requirements as Avgas 100LL. It therefore meets the same aircraft approvals and operating limitation requirements as Avgas 100LL meeting ASTM D910.

Avgas 100VLL is dyed blue.

**Avgas UL82**

This grade is intended to comply with the same aircraft approvals as the original motor gasoline (mogas) Supplementary Type Certificate (STC) approvals, but with better compositional and performance control. It is aimed at the low compression ratio engines which do not need the high octane of Avgas 100 and could be designed to run on unleaded fuel. Avgas UL82 is specified in ASTM D 6227. Unlike other Avgas specifications, ASTM D6227 allows the use of some non-hydrocarbon components used in mogas, such as ethers, but, unlike mogas specifications, alcohols are not permitted.

Avgas UL82 is dyed purple.

**Avgas UL87**

This is a relatively new grade added to ASTM D6227, driven by the need for some light sport engines to have a higher octane fuel than Avgas UL82.

Avgas UL82 is dyed yellow.

**Avgas UL91**

Compositionally this grade is somewhat comparable with Avgas 100LL but with a zero lead content, which results in a lower octane rating of 91MON. Avgas UL91 is specified in ASTM D7547. Avgas UL91 differs principally from both Avgas UL87 and UL82 not only in the higher octane rating, but in lower vapour pressure (49kPa max compared with 60kPa max in ASTM D6227) and that oxygenates such as ethers are not permitted. In common with all other current Avgas specifications, ASTM D7547 does not permit the use of alcohols such as ethanol.

Avgas UL91 is dyed orange.

**History of Avgas Grades**

Avgas is gasoline fuel for reciprocating piston engined aircraft. As with all gasolines, avgas is very volatile and is extremely flammable at normal operating temperatures. Procedures and equipment for safe handling of this product must therefore be of the highest order.

Avgas grades are defined primarily by their octane rating. Two ratings are applied to aviation gasolines (the lean mixture rating and the rich mixture rating) which results in a multiple numbering system e.g. Avgas 100/130 (in this case the lean mixture performance rating is 100 and the rich mixture rating is 130).

In the past, there were many different grades of aviation gasoline in general use e.g. 80/87, 91/96, 100/130, 108/135 and 115/145. However, with decreasing demand these were rationalised down to one principle grade, Avgas 100/130. (To avoid confusion and to minimise errors in handling aviation gasoline, it is now common practice to designate the grade by just the lean mixture performance rating; thus Avgas 100/130 becomes Avgas 100).

Some years ago, an additional grade was introduced to allow a common fuel to be used in engines originally designed for grades with lower lead contents as well as in those engines certified for higher lead contents. This grade is called Avgas 100LL, the LL standing for 'low lead'.

All equipment and facilities handling avgas are colour coded and display prominently the API markings denoting the actual grade carried. Currently, the two major grades in use internationally are Avgas 100LL and Avgas 100. To ease identification the fuels are dyed: Avgas 100LL is coloured blue, while Avgas 100 is coloured green.

In 1999 a new Avgas grade UL82 (UL standing for unleaded) was introduced as a low octane grade suitable for low compression engines. It has a higher vapour pressure than conventional Avgas and can be manufactured from motor gasoline components, but, notably, the specification does not allow alcohols such as ethanol to be used. It is particularly applicable to those aircraft which have STCs to use automotive gasoline.

An extension of this has been the grade Avgas UL87, which was created in response to the higher octane demand of some light sport engines; notably the turbocharged Rotax<sup>®</sup> engines. UL87 is otherwise similar to UL82, using similar components, but again expressly excluding alcohols.

The relatively high vapour pressure of the ASTM D6227 specification makes UL82 and UL87 somewhat unsuitable for high altitude flight as engine failure from vapour lock can be an issue. In order to meet the demands from the military for an unleaded Avgas for use in high flying, unmanned aerial vehicles (UAVs), a new low vapour pressure UL91 grade was introduced, resulting in the requirement for a new specification, ASTM D7547. At the time of writing, this specification is approved for light sport engines, such as Rotax<sup>®</sup>, and is in the process of being considered for approval in a wider range of general aviation engines of low to mid-octane demand. However, it is clear that this will not be of high enough octane rating to be used safely in all general aviation engines and work continues in trying to find a true unleaded alternative to the almost ubiquitous Avgas 100LL.

## ACCESS TO AVIATION FUEL SPECIFICATIONS

Because it is important to refer only to the most recent issues of fuel specifications, their detailed requirements have not been tabulated in this AeroShell Book since they could quickly become out-of-date. Copies of the specifications cited above can be obtained from the following authorities:

### DEF STAN Specifications

Ministry of Defence  
Directorate of Standardisation  
Kentigern House  
65 Brown Street  
Glasgow G2 8EX  
UK

phone +44 141 224 2496  
fax +44 141 224 2503

*NOTE: DEF STAN specifications are freely available from their web site at:*  
**[www.dstan.mod.uk](http://www.dstan.mod.uk)**

### ASTM Specifications

ASTM specifications are published annually in the ASTM Book of Standards, Section 5 (on paper and CD). Copies are available from:

ASTM  
100 Barr Harbor Drive  
West Conshohocken  
PA 19428-2959  
USA

phone +1 610 832 9585  
fax +1 610 832 9555

ASTM website is: **[www.astm.org](http://www.astm.org)**

*NOTE: Specifications are available for a charge.*

### US Military Specifications

Department of Defense  
DODSSP  
Building 4/ Section D  
700 Robins Avenue  
PA 19111-5094  
USA

phone +1 215 697 2667  
fax +1 215 697 1462

*NOTE: US Military specifications are freely available from their web site at:*  
**<http://assist.daps.dla.mil/quicksearch>**

### IATA Guidance Material for Aviation Turbine Fuels Specifications

IATA issue an excellent guide covering commercial aviation fuels and additives. The latest edition can be obtained from:

Fuel Services  
IATA  
800 Place Victoria  
PO Box 113  
Montreal  
Quebec  
Canada H6Z 1M1

phone +1 514 874 0202  
fax +1 514 874 2661

IATA website is: **[www.iataonline.com](http://www.iataonline.com)**

### AFQRJOS Check List for Jet A-1

The Joint Fuelling Systems Check List for Jet A-1 is maintained by the JIG Product Quality Committee on behalf of the industry. The latest edition can be accessed on the Joint Inspection Group's website: **[www.jointinspectiongroup.org](http://www.jointinspectiongroup.org)** under the link 'fuel quality'.