Australian Government
Civil Aviation Safety Authority

AIRWORTHINESS BULLETIN

Aircraft Fuel

AWB 28-003 **Issue** : 1
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1. Applicability

All aircraft.

2. Purpose

This AWB provides a summary of regulations related to aviation fuel and provides answers to many frequently asked questions (FAQ).

3. Background

CASA receives frequent enquiries from the general public on regulations related to aviation fuel and aircraft refuelling. This AWB summarises the major CASA regulations governing aircraft refuelling.

Requirement	***Reference Regulation***
CASA requires an operator / pilot in command of an aircraft to ensure that the aircraft does not commence a flight unless it is carrying sufficient quantity of fuel and oil to complete the flight safely.	*Civil Aviation Regulations (CAR) 234*
CASA may give directions on the loading of fuel on aircraft.	*CAR 235 (7).*
CASA requires the pilot in command of an aircraft to ensure that the aircraft is not flown unless fuel / oil complies with the specification approved by CASA.	*Civil Aviation Order (CAO) 20.9*
CASA requires that the aircraft is operated on fuel that conforms to the specification nominated in the flight manual or approved maintenance data.	*CAR 36A*
The pilot in command of the aircraft must comply with a requirement, instruction, procedure or limitation set out in the aircraft flight manual.	*CAR 138*
If applicable, CASA requires all commercial aircraft operators to have Operations Manual that includes a section on fuel management.	*Civil Aviation Advisory Publication 215-1(0).*
CASA may approve Flight Manual Supplements after an aircraft switches from one specification of fuel to another after incorporating Australian STC modification.	*Civil Aviation Safety Regulations – Part 21.*

4. Recommendation

In view of the regulations cited above, CASA recommends that:

A. The Pilot in command of an aircraft should ensure that the aircraft fuel tanks are replenished with a fuel that meets the specifications referenced in the aircraft flight manual (AFM) or AFM supplement.

Fuel specifications for an aircraft may change from one type (avgas, for example) to another (motor gasoline, diesel or ethanol blend, for example) only if the change is approved by CASA under the regulations (an STC, for example) and the change is reflected through an approved AFM supplement.

B. If applicable, commercial operators should review their Operations Manual and ensure adequate policies and procedure are in place for all phases of fuel management.

Random internal audits of its own refuelling operations may help an operator to ensure that all policies are being followed to the intent.

C. Fuel held in drum stocks beyond shelf life may lose a portion of aromatics, affecting fuel octane rating. Similarly, inadequate or inappropriate storage facilities may allow fuel to be contaminated. Pilots using drum stocks or using fuel distribution networks with a very low turnover should ensure that the use of fuel meets the prescribed specifications.

5. Frequently Asked Questions

Q - What is Avgas (Aviation Gasoline)?

A - Aviation Gasoline (Avgas) comes from the petroleum fraction (mainly alkylates) and is designed to fuel the aircraft that uses the reciprocating piston engine with spark ignition. Grades of aviation gasoline are identified with names based on their antiknock quality (as measured by Octane Number):

- Grade 80 / Grade 91 - No longer available in Australia; and
- Grade 100/130; and
- Grade 100LL (Low Lead).

Different colours, obtained by the use of specific dyes, are used to differentiate the fuel grades.

Grades 100/130 and 100LL are identical in antiknock quality but differ in maximum lead content.

The most common specification for Avgas is ASTM D910 and determines the various properties of aviation gasoline such as performance (Knock Value / Octane rating), concentration of lead (addition of tetraethyl lead or TEL), appearance, colour (blue, yellow and red), volatility, vapour pressure, residue/ precipitate, density, sulphur content, freezing point, corrosion, oxidation stability and conductivity.

For avgas, the maximum vapour pressure (measured by Reid Vapour Pressure or RVP) is 7 psi and the minimum is 5.5 psi. The maximum reduces vapour lock problems. The minimum is to ensure the vapour in the tank is always above the rich explosive limit.

These properties ensure a satisfactory performance of aircraft piston engines over a wide range of operating conditions.

Requirements common for all grades either prescribe a balance of properties to ensure satisfactory engine performance, or limit the concentration of components that could have an adverse effect on engine performance.

Q - What is AvTur (Aviation Turbine) Fuel?

A – Aviation Turbine Fuel (Avtur) comes from the petroleum fraction distillation and is designed to fuel aircraft powered by gas turbine engines.

Aviation Turbine Fuels (Jet A and Jet A-1) are kerosene based and may contain additives such as icing inhibitors, corrosion inhibitors, lubricants, and antistatic agents. The primary physical difference between the two is freeze point. Jet A (mainly used in the USA) has a freeze point of -40 ºC or below, while Jet A-1 must have a freeze point of -47 ºC or below. Jet A does not normally contain a static dissipater additive, while Jet A-1 often requires this additive. There are some other key differences too between the manufacturing specifications within the United States and Europe/ Africa/ Middle East and Asia Pacific.

Jet fuel specifications determine the composition (such as appearance, acidity, total aromatics and sulphur content), volatility (distillation temperature, residue, flash Point and density), fluidity (freezing point and viscosity), net heat of combustion, corrosion, thermal satiability and conductivity.

The volatility of avtur is much lower than avgas to ensure that the vapour in the tank is always too lean to explode.

Q – What would happen if avtur and avgas get mixed up by mistake?

Because of the difference in volatility values, any combination of avgas and avtur is dangerous, because the mixture:

(i) may detonate in hot engines; and
(ii) may make the fuel explosive in the tank in avtur powered aircraft.

That may be the reason why we see no fuel with volatility ranged between that of avgas and that of avtur.

Q – What sort of additives is mixed in the aviation fuel?

A – All aviation fuels are manufactured to a specification. It's the specification that determines what additives will be blended into the fuel and in what ratio. The following additives are either required or added by agreement for use in aviation fuel.

- **Static Dissipater:** Refinery processing can remove naturally present polar species and as a result fuel becomes poor in conductivity. It may seem trivial but a fuel that's poor in conduction will have an increased risk of charge generation and ultimately static discharge, especially during loading or as the fuel passes through filters. To eliminate this risk, a static dissipater additive is widely used in jet kerosene.

- **Metal Deactivators:** Metal ions in fuel can catalyse oxidation reactions that contribute to poor thermal stability and give rise to gum. Copper and zinc are the two most common metal contaminants found in jet fuel. Metal deactivator additive (MDA) is a chelating agent that binds metal ions and prevents fuel degradation.

- **Antioxidants:** Hydro-processing of aviation fuels removes naturally occurring antioxidants that provide protection from per-oxidation. Peroxides are known to attack elastomers causing embrittlement while also contributing to gum and particulate formation. The use of antioxidants prevents per-oxidation from occurring.

- **Corrosion Inhibitors (Lubricity Improvers):** Many aircraft fuel system components, especially pumps, rely on the fuel to lubricate moving parts. Corrosion inhibitors protect the fuel distribution system and aircraft engines from corrosion and provide required lubricity.

- **Fuel System Icing Inhibitors (FSII):** Water dissolved in fuel can come out of solution at low temperatures in the form of very fine droplets. Although the amounts are small, the droplets formed can freeze at altitude and cause filter plugging. Fuel system icing inhibitors protect the system from this problem. The most widely used additive is diethylene glycol monomethyl ether (DiEGME). FSII is sometimes referred to by the generic trademark "Prist®".

  Small aircraft that do not incorporate a fuel heating system need icing inhibitors (Check the AFM if FSII is required for your aircraft). Even if the aircraft is equipped with electric fuel line heaters and if the fuel heaters are inoperable, the aircraft may be still be declared fit to fly if FSII is added to the fuel.

  In aircraft that require it, FSII must be injected into the fuel as it is pumped into the tank; otherwise the concentration will not be consistent throughout the entire fuel supply.

  Most of the icing inhibitors are highly toxic in nature and should be handled very carefully.

- **Thermal Stability Additive:** Military jet engines require aviation fuel that has a higher thermal stability and heat sink capacity than is currently available and thermal stability additive provides these benefits. The additive is not compatible with current commercially available filter/water separators and accordingly, is not approved for use in Jet A or Jet A-1. Manufacturers are currently looking at alternative filter/water separator designs that will overcome this problem.

- **Tracing Additive:** Tracer A (Sulphur hexafluoride, SF_6) is used as a part of a tracer system for fuel system leak detection at major airports. Airports occasionally run leak detection testing of hydrants, which may be carried out monthly or quarterly.

- **Biocides:** Biocides are permitted by engine and airframe manufacturers for intermittent use during maintenance turnaround. The aircraft are refilled and fully dosed and, as a general rule, will fly on the treated fuel until it is fully used up. Fuel System Icing Inhibitor may also serve to inhibit fungal and bacterial growth in aircraft fuel systems, but may not do so reliably.

Remember that most of the above mentioned additives are optional and are added by agreement between the user and the fuel supplier.

Q – All of the above additives seem to be great and I want all of them but how do I get an assurance that the aviation fuel that I am buying contains the additives that I want?

A – In order to determine what additives are present in the fuel, the first step would be to know the fuel specification. The specification will dictate what additives must be present and in what ratio. There are many additives that are optional and are added by the fuel manufacturer to improve upon the formulation or by agreement between the user and the supplier. Accordingly, it is always beneficial to consult the fuel supplier for advice.

Some of the additives are approved under a Supplemental Type Certificate (STC) as well.

An add-on fuel additive may be used only if it is approved for the purpose and is added / maintained in accordance with the approved procedures.

Q - What is ethanol? Why is ethanol used in fuels and what are advantages and disadvantages?

A – Ethanol is a liquid alcohol obtained from fermenting sugar or starch converted to sugar. Grains such as corn, wheat and barley are used for commercial production of Ethanol. Ethanol is used either as a blending ingredient in fuels or as a main fuel. 5% and 10% Ethanol blended automotive gasoline is commonly available in Australia.

Benefits of Ethanol include:

a) Adding ethanol to gasoline increases the octane number.

b) Ethanol also contains oxygen, which allows for cleaner and more complete combustion, helping the environment. Ethanol fuels reduce greenhouse gas emissions. Fuel blends with 85 percent ethanol (such as E-85) can reduce emissions by 60-80 percent.

c) Ethanol-gasoline can be used all year-round. In fact, ethanol-gasoline can serve as a gasoline anti-freeze.

The problems associated with Ethanol include:

d) Increased probability of vapour lock.

e) Ethanol is hygroscopic in nature and has a great affinity for water. If water builds up in the aircraft fuel tank, the potential for phase separation increases. Phase separation occurs when the alcohol dissolves the water in the tank and then that (water/alcohol) mixture separates out as a discrete phase. This phase has a higher density than the raw petroleum phase, and settles at the bottom of the tank. The volume of the water/alcohol mixture can exceed the capacity of the fuel tank sumps and gascolators.

   If moisture in ethanol gets separated, it may initiate corrosion and even worse, if an alcohol gets oxidised over time it becomes acidic (vinegar) and this will enhance corrosion with/without water.

f) Compatibility of ethanol with elastomers is yet another area of concern. A few of the elastomers used in old aircraft models and which are otherwise compatible with Avgas may deteriorate on contact with Ethanol.

Q - What is E-85 and what is AGE-85 Fuel. What is the difference?

A - E-85 is a new type of fuel blend having 85% percent ethanol and 15% ordinary unleaded motor gasoline. E-85 fuel is an alternate fuel primarily aimed at cars and flexible fuel vehicles (FFVs).

AGE 85 on the other hand is Aviation Grade Ethanol (AGE) for use in piston engine aircraft. This fuel is unleaded and contains 85 percent ethanol along with light hydrocarbons and bio-diesel fuel. Proponents of AGE-85 claim better cold starting, good mixture balance, prevention of carburettor and fuel line icing, excellent detonation margins, cleaner combustion and lower exhaust emissions.

STC's for the use of AGE-85 are currently under development. Switching to AGE85 is possible only after incorporating the appropriate STC as it will involve new jets or injection settings and reversion to avgas on an intermittent basis will not be possible.

Q - What are the common differences between aviation gasoline and motor (automotive) gasoline?

A – Some of the differences are as follows:

- The distillation characteristics of motor gasoline (mogas) are different than those of aviation gasoline. Mogas includes wider-cut petroleum fractions that tend to include hydrocarbons less stable to oxidation, less clean-burning and more prone to form combustion chamber and induction system deposits if run in an over-rich mode.

- The properties considered critical for aviation use (for example, vapour pressure and cleanliness) may not be important for Mogas applications and accordingly the final end product mogas (along with its additives) may differ from supplier to supplier, from season to season and from one geographical location to another.

- Mogas normally has a much higher vapour pressure, which varies seasonally. With a high Reid Vapour Pressure (RVP) fuel the risk of vapour lock during take-off and climb increases, particularly if the aircraft had been parked in high ambient temperatures and does not have a gravity-fed fuel system.

  Invented by an Australian, Dr. Ray Hodges' Fuel Volatility Tester is small enough to be carried in the airplane and will tell you at a glance whether or not the fuel has any serious vapour lock potential, given the current outside air temperature. It confirms if the fuel could cause vapour lock, regardless of contributing factors such as, temperature, altitude, seasonal blend, weathering history, or blends with avgas or ethanol. The operation of the tester is fail safe since air leaks cause low ("unsafe") readings.

In view of the above, unless your aircraft is specifically approved for the use of a fuel alternative to avgas, don't use it!

Q - My aircraft is certified to use mogas. I frequently hear in the news that Ethanol blending may be mandated in Australia. Is it OK to use 5-10% ethanol blended mogas in my aircraft? Pure mogas is more difficult to find now.

A – No. It's not OK. Aircraft should only be refuelled with the specification of fuel it is certified to use. There are approved supplemental type certificates (STC) commercially available that modify an aircraft to allow a different fuel specification (eg ethanol blend). Should mogas (free of ethanol) become unavailable, modifying an aircraft through an STC to use pure ethanol is still an option or one can switch back to avgas. Pure ethanol will significantly lower aircraft range and increase the fuel load for a full tank, and it will preclude intermittent use of avgas with the same fuel settings for the engine.

Q – How can I ensure that the fuel I am filling in my aircraft fuel tanks is good and meets the specification of fuel mentioned in aircraft flight manual?

A- The fuel companies are responsible for delivering quality fuel that meets the stated specification up to the outlet of their bowsers. After that, it is the responsibility of the pilot (or of operator, if applicable) to ensure that the aircraft tanks are refuelled with the correct quality and quantity of fuel. Simple tests like colour, water check and volatility should help but these will not detect contamination from avtur or diesel.

Q - I want to install a diesel engine into my aircraft. Can I use any type of diesel?

A – No. Before a decision for purchase / retrofit of a diesel engine is made, it is prudent to check if the diesel fuel meeting the fuel specifications specified in the AFM or engine TCDS or equivalent document is freely available. There is more than one specification for diesel fuel.

Q – Looking at the disadvantages of using Ethanol or mogas, does it mean that I should refrain from using ethanol, mogas or a blend thereof?

A - That is a matter of choice after considering initial conversion costs, maintenance costs (including possible enhanced corrosion and wear), range loss, fuel weight increase, water absorption if the aircraft is exposed to weather and availability of fuels that can be used.

Use of ethanol is perfectly legal if your aircraft has an appropriate modification incorporated. At the time of writing, there are commercially available STCs that permit the use of 100% ethanol or a blend thereof but once the conversion is made, jet or injector settings will be different to avgas and regular swapping from one fuel to the other will not be possible.

Similarly there are STCs commercially available on popular aircraft / engine combinations for conversion from avgas to mogas and here inter-changeability between avgas and mogas is allowed.

Q - Do Aircraft / Engine manufacturers approve the use of Ethanol or ethanol blended Gasoline?

A - No. Most of the aircraft type certificate data sheet (TCDS) holders explicitly prohibit use of ethanol or ethanol blended gasoline.

Q – Is it possible to know if ethanol is mixed with pure gasoline, just by 'looking' at it?

A - No. Ethanol, when blended with pure gasoline, cannot be distinguished 'just by looking' at it. However, tests for knowing if ethanol is present in the fuel are simple and do not require special equipment. (Refer to article "A Deadly cocktail" – Flight Safety Australia (FSA) – July 2003 and article "Alcohol, just say NO" – FSA – February 2006. Both of the articles are available on the CASA website).

Q - What effect does using ethanol fuels have on fuel consumption?

A – On a 'per volume' basis, ethanol has a lesser heat value than aviation gasoline, therefore the aircraft range for the 'same tank full' of 100% ethanol is significantly lower.

Q. I want to convert to alternate fuel type so what is the first step? How can I be sure that an STC is approved for the purpose?

A - First step is to check if there is an existing STC for your aircraft / engine combination. If the STC design is approved by a national aviation authority (such as the FAA) of a country designated in CASR 21.012 then no further approval is required and the STC may be incorporated by an organisation approved for the purpose.

CASA does not recommend or endorse any particular STC holder; however a search on the World Wide Web for companies holding conversion STCs returned the following results:

Petersen Aviation, Minden, Nebraska 68959, USA.	*Largest sellers of mogas STCs.*	*www.autofuelstc.com*
Experimental Aircraft Association, Oshkosh, WI 54902, USA.	*Mogas conversion STCs.*	*www.eaa.org/*
Fuller Howard Jr, Shrewsbury MD 01545 USA	*Mogas STC for rotorcraft*	*www.faa.gov/*
Dr. Maxwell E. Shauck, Waco, TX 76706, USA	*Lycoming Engines – Use of ethanol*	*www.faa.gov/*

In all other cases, contact your nearest CASA field office for discussion and formal approval of the intended changes.

Q. Will avgas disappear from the market anytime soon?

A. Avgas is likely to remain available to the general aviation users for a long time to come however the price may vary depending on the supply, demand and location. Availability of avgas should be checked as part of your planning for flights into more remote locations.

Continued production of Tetraethyl lead (TEL) cannot be guaranteed because of the environmental concerns. Research is still underway to find a true substitute of TEL which will protect valves and seats in the same way that lead can.

Q. Are STC's transferable from one airplane to another?

A. A simple answer to a simple question - NO.

6. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletins should be made via the direct link e-mail address: AirworthinessBulletin@casa.gov.au

Or in writing, to:

Manufacturing, Certification and
New Technologies Office,
GPO Box 2005, Canberra, ACT, 2601