SERVICE LETTER: JSL 007-7

Issue: 7

Date: 1st November 2017

Subject: Alcohol, Lead, Compression Ratio: Fuel Guidance

Release Date: 1st November 2017

Effective Date: 7th November 2017

Issue	Reason for Issue	Revision Status
1	Original Issue	CANCELLED
2	New Information Added	CANCELLED
3	Title changed, “High Lead” Avgas notes added	CANCELLED
4	New gasoline information added, UL9 1 approval added.	CANCELLED
5	Revise layout	CANCELLED
6	Mogas Storage Time Reduced	CANCELLED
7	Add notes to Mogas advisory regarding the adverse effects on fuel system and airframe	CURRENT

1 Background

1.1 Issue Notes

- Issues 1 to 6 of this Service Letter are CANCELLED and must not be referenced.
- Issue 7 is now CURRENT and has been prepared with format changes to improve clarity.

2 Certified Models

- Jabiru J160-C
- Jabiru UL-C
- Jabiru UL-D
- Jabiru LSA 55/2K
- Jabiru LSA 55/2J
- Jabiru ST
- Jabiru LSA 55/3J
- Jabiru ST3
- Jabiru 2200J Engines
- Jabiru 2200C Engines

2.1 Fuel Requirements: Certified Models

- The certified models listed above are approved to use the following fuels:

Model	Fuel
LSA 55/2K, LSA 55/2J	100/130 minimum grade aviation gasoline.
Jabiru ST, LSA 55/3J, ST3	100LL or 100/130 minimum grade aviation gasoline.
Jabiru UL-C, UL-D, J160-C.	100LL or 100/130 minimum grade aviation gasoline or Leaded or Unleaded Automotive Gasoline above 95 Octane RON
2200J Engine	100LL or 100/130 minimum grade aviation gasoline.
2200C Engine	100LL or 100/130 minimum grade aviation gasoline or Leaded or Unleaded Automotive Gasoline above 95 Octane RON

2.2 Fuel Limitations: Certified Models

- Fuels containing alcohol may not be used in certified aircraft or engines.
- Aviation gasoline may not be mixed with any other non-aviation-grade fuel.
- Fuel additives may not be used.
- Automotive gasoline is used at the operator's risk – see Section 11 for details.
- The use of any other fuel requires approval via an Engineering Order, Supplemental Type Certificate or similar.

- The use of any alternative fuels, or the mixing of fuels, is known to accelerate deterioration of the aircraft / engine fuel system. In addition the use of alternative fuels, or the mixing of fuels, is known to introduce engine wear that has been linked to a number of engine failures.

3 Light Sport Aircraft Category Models

3.1 Applicability: LSA Models

- Information for Light Sport Aircraft category models are given in Jabiru Service Notification JSN 007-7. A copy of this directive is attached within this file, below.

3.2 Fuel Requirements: LSA Models

- Information for Light Sport Aircraft category models are given in Jabiru Service Notification JSN 007-7. A copy of this directive is attached within this file, below.

4 Other Aircraft Categories

4.1 Applicability: Experimental Models

- All models and variants of Jabiru Aircraft
- All models and variants of Jabiru Engines.

5 Background Information – Advisory

- The remainder of this document contains advisory and reference information for owners, operators and maintainers. It contains fundamental knowledge that will allow operators to better understand, operate and care for their engines.
- While not a part of the airworthiness requirements of this letter it is strongly recommended that owners, operators and maintainers of Jabiru Aircraft and Engines read the information contained within as it forms the basis of current Jabiru policy on fuels.
- **Jabiru Aircraft may choose to void any warranty for aircraft or engines which have been operated outside of the recommendations contained in this letter.**

6 Gasoline General Information – Advisory

- Current Jabiru 2200 and 3300 engines are designed to use Australian Aviation Gasoline (AVGAS), unleaded AVGAS or Australian Premium Unleaded Motor Spirit – MOGAS – of at least 95 RON.
- Modern fuels are an increasingly specialised field as each gasoline blend incorporates ingredients from diverse sources. Traditional gasoline refined from crude oil is increasingly being blended with hydrocarbons from different sources – coal syngas, oil sands, shale oil, alcohols, algal and plant refineries to name a few. As with any complicated field some basic knowledge of the basic “rules of the road” are essential to operate successfully.

6.1 Fuel Basics:

- Gasoline, technically is a *"Refined petroleum used as fuel for internal combustion engines"* – petroleum being *"A liquid mixture of hydrocarbons that is present in certain rock strata and can be extracted and refined to produce fuels including gasoline, kerosene, and diesel oil".* So under these definitions any liquid containing carbon and hydrogen, refined from crude oil, can be a gasoline. Obviously this is a very broad definition and which includes many different chemical compounds.
- When burning a fuel in a piston engine one of the most important characteristics of the fuel is how much load it can take without "knocking". Knock is a complicated mechanism which is also known as pinging or detonation; pre-ignition is a similar and related issue. The important thing to know is that knock – by whatever name – is bad news for a piston engine. It causes excess temperature and pressure in the engine and in extreme cases can break pistons or cause other damage very quickly.
- An automotive fuel's anti-knock performance is usually measured in Australia using RON (Research Octane Number). RON describes how early a fuel will start to knock – the higher the RON the less susceptible the fuel is to knock. The same is also true for the other knock ratings discussed below: higher numbers indicate a fuel less likely to knock.
- The RON for a fuel is obtained by running the fuel in a special calibrated engine under strictly controlled conditions. The fuel being tested is compared to a special fuel made by blending iso-octane with heptane. Iso-octane has a RON value of 100 while helptane has a value of 0. A 90 octane RON fuel is a fuel which behaves the same as a mixture of 90% iso-octane and 10% heptane. If the test fuel behaves the same way as a mixture of 90% iso-octane & 10% heptane it will be given a RON of 90. RON is a good performance indicator for a fuel but it has some important limitations – mainly that the testing method is not particularly realistic when compared with real world conditions.
- A MON is calculated using a similar test to RON but in this case the temperature of the intake mixture to the test engine is increased and ignition timing is altered. This is a better real-world indication of how a fuel will behave when under load in service – which is why AVGAS octane ratings are given in MON. Actually, MON is also sometimes known as the Aviation Lean Octane Rating as the test was invented with high-powered aircraft engines in mind. Again however, the MON is a controlled test and does not completely reflect how a fuel will perform in the real world.
- AKI (Anti-Knock Index) is also commonly used in some countries. AKI is the average of a fuel's RON and MON. RON is always a higher number than both MON and AKI. As a general rule, RON can be estimated by adding 5 to a fuel's AKI (i.e. a fuel with an AKI of 89 will have a RON of approximately 94, and so must not be used.).
- AVGAS 100LL generally has a MON (lean) of around 100-101. Depending on the composition of the fuel, the MON of a modern gasoline will be about 8 to 10 points lower than the RON, however there is no direct link between RON and MON. Using this estimation AVGAS 100LL would have a RON of about 110.
- Octane ratings are not a direct measure of how "powerful" a fuel is. A fuel with a higher octane number will not usually produce more power in a given engine unless that engine is mechanically altered to take advantage of the fuel. However, a higher octane number

should – all else being equal – allow an engine to safely operate under higher loads at a lower RPM.

- Additional details, including a useful table which shows the RON, MON and AKI ratings for various fuels are available online at http://en.wikipedia.org/wiki/Octane_rating .

6.2 Fuels In Service:

- All of the Octane tests described above are carried out under controlled conditions of temperature, RPM etc. Obviously in service these conditions are not controlled – temperatures, engine loads, rpm etc all vary. To try to cater for all these variations the hydrocarbon blend of a given fuel is constantly being adjusted by the fuel supplier. So Brand X 95 Octane (RON) gasoline purchased in a hot, arid area will contain a different chemical blend to the same fuel bought in a cool, low-altitude area. Both fuels have the same RON but their composition can be very different
- **It is important to realise that having the same RON, MON, AKI etc does not make different fuels the same or even compatible.**
- It follows from this that if you take a fuel blend away from the environment it was designed for then it may not perform as you would expect.
- In comparison, AVGAS is blended for use in aircraft engines which operate using relatively crude mixture control and widely varying conditions of engine load, RPM, temperature, altitude etc – it is specifically designed to suit as wide a range of conditions as possible.
- While modern cars monitor the engine constantly and use computer controls to ensure that the engine operates as it should on any given fuel, engines which use a carburettor (or similar) do not have this ability and can be more vulnerable to changes in fuel blends.

6.3 Shandies

- A “shandy” is a mix - for the purposes of this letter it is a mix of any 2 or more different fuels.
- In some areas it has become popular to operate Jabiru engines on a shandy of AVGAS and MOGAS. This might be done to reduce the cost of fuel, to reduce lead buildup in the combustion chamber, to “beef up” the octane rating of a sub-standard fuel or other reasons.
- **This practice is unsafe. Jabiru Aircraft do not endorse it and may void any warranty of an engine or aircraft which has been operated using such a fuel. This position is based on data received directly from gasoline producers.**
- In terms of chemical composition AVGAS is totally different to MOGAS. A petroleum company representative described mixing the two as “mixing Gin with Beer”. Clearly, mixing these drinks is a bad idea – it tastes bad and the after affects can be messy & expensive. There is potential for elements in the fuels to react to each other and the finished blend would have unknown knock resistance – because the fuels are so complex you cannot assume that mixing 110 RON AVGAS with 91 RON MOGAS – at almost any mixing proportion – will result in a fuel with acceptable knock resistance for a Jabiru aero engine.

7 Alcohol – Advisory

7.1 General

- Worldwide, debate on using Ethanol as an aircraft fuel continues. The problem is that while it can be a good fuel for the engine, it is a significant operational, maintenance and storage issue for the rest of the aircraft. These issues must be addressed if an aircraft is to operate safely on a fuel containing alcohol.
- Note that different Jabiru Airframes can have different maintenance requirements. For example, the CASA-Certified J160-C must be operated and maintained in accordance with the CASA-Approved procedures given in its Flight and Maintenance manuals – which do not allow the use of fuels containing alcohol (but do approve the use of suitable MOGAS).
- Operators using Octane Boosters and wishing to avoid introducing alcohol to their fuel systems must ensure that their chosen octane booster does not contain alcohol. Jabiru Aircraft do not endorse the use of octane boosters.

7.2 Alcohol – Good Points

- Alcohol is a renewable fuel which (arguably) produces less carbon dioxide than fossil fuel.
- Alcohol burns cleanly and has an octane boosting effect.

7.3 Alcohol – Bad Points

- Ethanol is hygroscopic (i.e. it will mix with water). This can be water vapour from the air, condensation inside tanks or free water. While very small amounts of water can be absorbed without significantly affecting combustion, at higher levels the mixture will not be combustible. In addition, because this incombustible fuel is formed from a mixture of the Ethanol in the fuel and the water it can have a large volume – so a small amount of water will result in a much larger amount of incombustible Ethanol/water mix. This may give false readings in the fuel tank sumps or exceed the volume of the sump altogether.
- As noted above, Ethanol is an Octane booster and can be absorbed by water. Because of this, mixing a fuel with water can effectively wash the Ethanol out of the fuel resulting in a significant drop to the remaining fuel's Octane rating.
- If an Octane Booster containing alcohol is used the operator must ensure that the maximum alcohol content of the resulting fuel / booster mix does not exceed the limits given below. Due to the fact that their composition varies widely between brands Jabiru Aircraft do not endorse the use of octane boosters.
- The engine will use slightly more fuel as the percentage of added alcohol increases. As an approximate rule of thumb the engine must burn 3% more fuel to give the same power output if the fuel contains 10% Ethanol.
- Ethanol mixed with water is somewhat corrosive and may attack parts of the fuel system.
- In long-term storage, Ethanol may oxidise with exposure to air. This process produces a mild acid solution (effectively vinegar – the effect is the same as when the seal fails on a bottle of wine) which can attack fuel system components.
- Long term exposure to Ethanol damages some types of plastics. The flexible fuel lines used by Jabiru Aircraft have been chosen with Ethanol use in mind and are designed to be

safe when replaced at the intervals specified in the aircraft Maintenance Manuals. However increased monitoring during servicing is recommended when using an Ethanol blend.

- **Note** that flexible fuel lines are available in a wide range of colours. Generally the colour of the line is a dye only and has no bearing on the line's ability to operate in contact with alcohol – though some fuel line manufacturers use different colours to designate different products. Jabiru Aircraft have used blue fuel lines and (at the time of writing) orange lines. Both are acceptable for use with fuels containing alcohol when maintained as specified.
- Some fuel testers (including the type supplied by Jabiru Aircraft at the time of writing) have a scale on their side which allows the Ethanol content of a fuel to be checked & assessed.
- Several Australian Civil Aviation Safety Authority (CASA) documents discuss Ethanol use in aircraft. Jabiru Aircraft strongly recommend that owners considering using an Ethanol fuel blend read and understand this information before using a fuel of this type. The following CASA document is current at the time of writing: Airworthiness Bulletin AWB 28-003 (Document dated 4th Jan 2007)
- **Due to the issues listed above, OPERATORS WHO USE GASOLINE CONTAINING ALCOHOL DO SO AT THEIR OWN RISK.**
- **Important Note For Jabiru Aircraft:** Only aircraft with white coloured fuel tank sealant can use fuel containing alcohol. Earlier tanks use a caramel coloured sealant – this sealant is soluble in alcohol & must not be used with an alcohol blend fuel. Fuel tanks with caramel-coloured sealant may be re-sealed with white sealant – contact Jabiru Aircraft or our local representative for details. Figure 1 shows the sealant colour as seen through the filler.

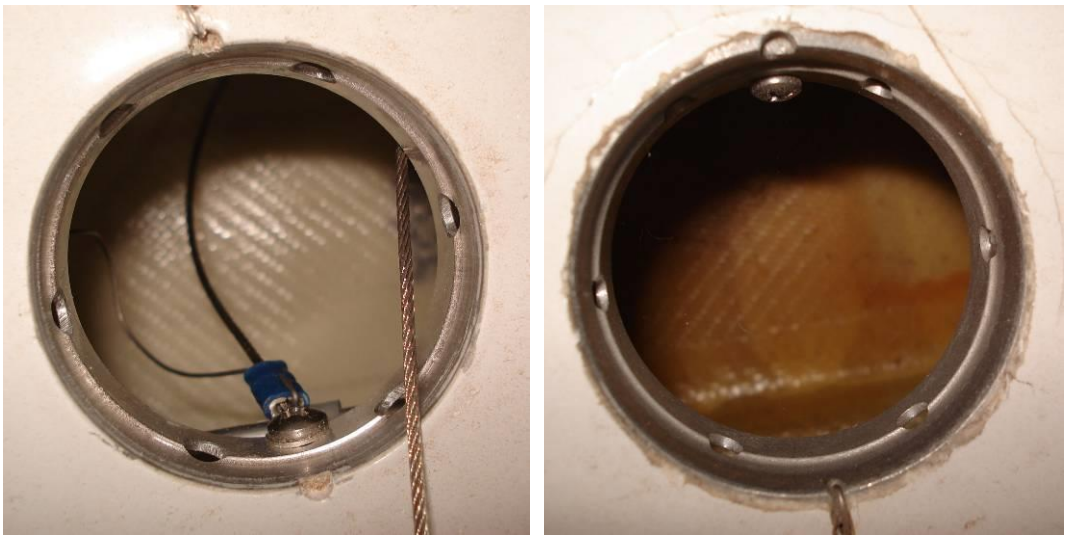

Figure 1 – Fuel Tank Sealant Colours (White on Left)

7.4 Individual Items[1]:

- **Carburettor:** Suitable for use with fuels containing alcohol.
- Carburettor inspection recommended after 200hrs (or 6 months) using fuel containing alcohol

[1] Details applicable for OEM parts from Jabiru Aircraft Australia only

- **Mechanical Fuel Pump**: Suitable for use with fuels containing alcohol.
- No additional maintenance required for up to 10% alcohol
- The pump manufacturer does not recommended using fuels containing more than 10%.
- Operational experience with fuels containing higher percentages has shown that the mechanical fuel pump is tolerant of higher levels of alcohol.
- **Carburettor Connection:** Suitable for use with fuels containing alcohol.
- **Electronic Fuel Pump:** Suitable for use with fuels containing alcohol.
- **O-Rings:** Suitable for use with fuels containing alcohol.
- **Black Fuel Hose:** Suitable for use with fuels containing alcohol.
- **Blue Fuel Hose:** Suitable for use with fuels containing alcohol.
- Maintenance & inspection requirements increased for fuel containing more than 10% alcohol.
- **White Coloured Fuel Tank Sealant:** Suitable for use with fuels containing alcohol.
- **Caramel Coloured Fuel Tank Sealant:** Unsuitable for use with fuels containing alcohol.
- **Combustion Chamber Shape:** All combustion chamber shapes are compatible with fuels containing alcohol. However, the Octane rating of the fuel used must be selected to suit the combustion chamber design.

7.5 Testing for Alcohol

- Using a clear jar of about 100-200 ml capacity (ideally a long and narrow jar) add about 10% by volume of water and mark the level of the water on the jar.
- Add a sample of the fuel to be tested to the jar so that the relative volumes are about 10% water/90% fuel
- Shake the sample vigorously and then allow the sample to settle
- Check the level of the "water"
- If the level is the same as previously marked on the jar, no alcohol is present in the fuel.
- If the level of "water" increases, alcohol is present in the fuel

7.6 Alcohol Usage Recommendations

7.6.1 Use of Gasoline Containing Up to 10% Alcohol:

- Due to QA considerations plus the technical points listed above, operators who use gasoline containing alcohol do so at their own risk.
- Jabiru Aircraft has no objection to operators using gasoline containing up to 10% alcohol in Jabiru Aircraft or Jabiru Engines except as limited by the aircraft's certification basis. For most engines the use of fuel with RON of 95 or above is adequate, however older engines must use a fuel which meets the Octane rating requirements of their combustion chamber (See Section 13.1).
- **Only those Jabiru Aircraft with white coloured fuel tank sealant can use fuel containing alcohol.**
- No modifications are required for Jabiru Engines to use fuel containing 10% alcohol.

- Where a Jabiru Engine is installed in a non-Jabiru airframe the operator must comply with the airframe manufacturer's approved fuel recommendations.
- Fuel hose should be monitored for hardness, brittleness and loss of colour. Lines must be inspected regularly and renewed if any sign of deterioration (such as brittleness or cracking) is found. In addition, at the time of writing Jabiru Aircraft recommend that all flexible fuel lines be replaced at intervals (see the aircraft Technical Manual). While this maintenance system is considered adequate while using a fuel containing alcohol, operators choosing to use these fuels are encouraged to be especially pro-active and exacting in their fuel system maintenance.
- It is recommended that after the first 200hrs (or 6 months) of operation on fuel containing alcohol the carburettor be disassembled for a one-off inspection. Components must be checked for damage, i.e. excessively soft or hard rubber parts, swelling of rubber components, corrosion of metal components. Replace parts if damaged or in doubt.

7.6.2 Use of Gasoline Containing Between 10% and 20% Alcohol:

- Due to QA considerations plus the technical points listed above, operators who use gasoline containing alcohol do so at their own risk.
- Jabiru Aircraft does not recommend that operators use any fuel containing between 10% and 20% alcohol in Jabiru Aircraft or Jabiru Engines.
- Operational experience has shown that operating Jabiru Aircraft and Engines with a fuel containing 10% – 20% alcohol is safe and does not introduce excessive maintenance requirements. However, formal testing has not been carried out and this level of alcohol content exceeds the maximum safe recommendations for some fuel system components.
- Operators using such fuel must understand that they operate entirely at their own risk. Clearly such operations can only occur in categories such as the "Experimental" category where all aircraft occupants & operators fly at their own risk.
- **Only those Jabiru Aircraft with white coloured fuel tank sealant can use fuel containing alcohol.**
- No modifications are required for Jabiru Engines run using fuel with 10% - 20% alcohol.
- Where a Jabiru Engine is installed in a non-Jabiru airframe the operator must comply with the airframe manufacturer's approved fuel recommendations.
- The ongoing maintenance requirements of a Jabiru aircraft or engine using this level of alcohol are currently unknown. The following points are recommended, however they are intended as a basic guide for operators and may not address all issues found when operating on these fuels. Operators must develop their own ongoing maintenance and inspection scheme suitable to their fuel and usage.
    i. Fuel hose should be monitored for hardness, brittleness and loss of colour. Lines must be inspected regularly and renewed if any sign of deterioration (such as brittleness or cracking) is found. It is recommended that all flexible fuel lines be replaced at 1 year intervals when using fuels containing 10% – 20% alcohol.

ii. At every 200hrs (or 6 months) of operation the carburettor be disassembled & all components checked for damage, i.e. excessively soft or hard rubber parts, swelling of rubber components, corrosion of metal components. Replace if damaged or in doubt.

iii. At every 200 hours (or 6 months) of operation the mechanical fuel pump be disassembled and all components checked for damage, i.e. excessively soft or hard rubber parts, swelling of rubber components, corrosion of metal components. Replace component if damaged or in doubt.

7.6.3 Use of Gasoline Containing More Than 20% Alcohol

- Use of fuel containing more than 20% alcohol is not recommended.

7.7 Checks When Changing to a Fuel Containing Alcohol

- Fuel filter & carby bowl - check for sediment & clogging after 10 hrs (or 1 month) of use.
- It is recommended that fuel lines be renewed before switching to a fuel containing alcohol.

8 Gasoline Containing Tetraethyl-Lead (TEL) – Advisory

8.1 General

- In most countries worldwide AVGAS is the only gasoline available which still contains TEL. Of the AVGAS family, AVGAS 100LL is the most common grade available. The "LL" designation indicates that the fuel contains a "Low Lead" level when compared to AVGAS 100 (which may also be known as AVGAS 100/130). AVGAS 100LL contains less than 0.56grams/litre while AVGAS 100 contains less than 0.85g/L. AVGAS 100LL is dyed blue while AVGAS 100 is dyed green. However, in some countries MOGAS containing TEL is also available which contains more lead than even AVGAS 100/130.

8.2 Tetraethyl Lead – Good Points

- TEL is an additive which is traditionally included in fuels to help suppress knock. Knock produces very high pressures inside the engine which can cause severe damage. Aircraft engines are vulnerable to knock because they operate at higher power settings and temperatures than most other engines – this is one reason why AVGAS still contains TEL.
- TEL has some lubrication properties which help to reduce wear to valve guides etc.

8.3 Tetraethyl Lead – Bad Points

- Lead is a well known pollutant.
- TEL in a fuel produces combustion chamber deposits. These deposits can affect piston ring sealing, valve sealing and also inhibit heat transfer from the combustion chamber to the head. They can also cause pre-ignition – small pieces can become very hot and act like a glowing ember inside the combustion chamber. This "ember" then ignites the fuel before the spark plug has discharged.
- Modern, high-octane unleaded MOGAS burns very cleanly. It leaves no or minimal deposits inside the combustion chamber. In comparison, a fuel containing TEL will leave deposits approximately proportional to its lead content – i.e. higher lead equals more deposits. Compared to AVGAS 100/130, AVGAS 100LL produces around 25% less combustion chamber deposits. This can significantly improve overhaul life in certain engines by reducing valve & cylinder head deposits as well as reduce spark plug fouling. There is however a maximum practical limit for the thickness of lead deposits inside a combustion chamber – they do not keep on growing thicker and thicker indefinitely. This means that when using AVGAS 100 the deposits reach this thickness and then stabilise more quickly than when using AVGAS 100LL.
- Lead can find its way into the oil of the engine where it tends to form a sludge which impedes the correct function of the lubrication and cooling system.
- Because of these points, an engine using a fuel containing TEL is likely to require more maintenance (spark plug and valve cleaning, more frequent oil changes etc) than one using a fuel which does not.

8.4 Leaded Gasoline Usage Recommendations

- Jabiru Aircraft have no objection to operators using a fuel containing TEL.

8.5 Leaded Gasoline Storage Recommendations

- Store as indicated for AVGAS or MOGAS (whichever is appropriate to the fuel being used).

9 AVGAS Containing TEL – Advisory

9.1 AVGAS – Good Points

- Excellent octane levels and knock resistance.
- AVGAS is readily available at airports in Australia and many other countries.
- AVGAS contains TEL which has some beneficial effects as discussed in Section 8. The combination of benefits given by TEL have proven to be hard to produce any other way which has made it difficult to develop a replacement fuel which will operate correctly in aircraft engines – particularly older types or high-powered turbo types.
- AVGAS has far superior quality control compared to MOGAS. Chemical composition is tightly controlled.
- Alcohols are not used in traditional leaded AVGAS.
- As a rule AVGAS fares better in storage. Due the lower designed volatility it tends to evaporate less and be less reactive.

9.2 AVGAS – Bad Points

- Leaded AVGAS contains TEL which can cause operational issues due to combustion chamber deposits. Using a fuel containing TEL is also becoming environmentally unacceptable.
- AVGAS is more expensive than MOGAS.

9.3 AVGAS Usage Recommendations

- Use fuel which is as fresh as possible.
- Be aware of the potential maintenance issues arising from using a leaded AVGAS
- Follow the storage recommendations given below.

9.4 AVGAS Storage recommendations:

- Use fuel which is as fresh as possible.
- Avoid long term storage, especially in vented tanks.

10 Unleaded Aviation Gasoline (AVGAS) – Advisory

- In some countries unleaded AVGAS is becoming available. In particular, in Europe UL 91 fuel is available.

10.1 Unleaded AVGAS – Good Points

- These fuels must comply with AVGAS QA standards.
- MON of 91 (RON 96) is acceptable for Jabiru engines & is higher than most MOGAS.
- This type of fuel is becoming more available at many airports.
- No alcohol.
- No lead.
- Cleaner exhaust emissions.

10.2 Unleaded AVGAS – Bad Points

- Lower octane ratings when compared with traditional AVGAS (though this is not an issue with most Jabiru Engines).
- Availability poor in many countries

10.3 Unleaded AVGAS – Usage Recommendations

- Use fuel which is as fresh as possible.
- Follow the storage recommendations given below.

10.4 Unleaded AVGAS - Storage

- Use fuel which is as fresh as possible.
- Do not store for long periods of time, particularly in vented tanks.

11 MOGAS - Advisory

11.1 MOGAS – Good Points

- MOGAS is cheaper than AVGAS & more widely available – though not usually at airports.
- MOGAS burns cleanly & produces minimal combustion chamber deposits.
- Fresh MOGAS of the correct octane rating produces the same engine power as AVGAS.

11.2 MOGAS – Bad Points

- The vast majority of MOGAS blends have lower octane ratings and therefore less resistance to knock than AVGAS blends.
- The single biggest drawback with MOGAS is Quality Control – quality control for MOGAS is very much poorer than for AVGAS. Fuel sold from automotive service stations can contain a bigger range of components and may be stale, contaminated or diluted. The busiest service station in town is most likely to have fresh, clean fuel and getting to know the station operators is also a good idea.
- **It is important to realise that due to the lower QA standards, even following best practice it is still possible for a particular tank-full of MOGAS to be unsuitable or unsafe for use in a Jabiru Aircraft or Engine. Jabiru Aircraft may choose to void any warranty for aircraft or engines which have been damaged due to "bad" MOGAS. OPERATORS USE MOGAS AT THEIR OWN RISK.**
- Many automotive MOGAS blends rely on highly volatile components. During storage these volatiles can be lost rapidly and the fuel's performance can degrade significantly in a relatively short period of time. This needs to be stressed to operators as it is entirely possible for MOGAS loose several points from its Octane rating while stored, leaving the engine vulnerable to detonation. In addition, long-term storage of MOGAS in an open-vented fuel system like a Jabiru's can encourage the formation of gums, varnishes or solids which can then block the lines or filters.
- Several different fuel blends are sold at the bowser throughout the year. "Winter" fuel, "Summer" fuel and "Alpine" fuel (and many other sub-divisions) are sold depending on the time of year and the location of the fuel station. These fuels all have different recipes designed to provide the right vaporization, octane number etc for an engine operating in the given environment. Fuel bought at the top of a snow-covered mountain in winter is not ideal for use at sea level during a summer heat wave. This is another reason why long-term storage of MOGAS is not recommended.
- Automotive fuels are generally more prone to vapour-lock than AVGAS. Testing has shown that Jabiru Aircraft meet certification requirements for the prevention of vapour-lock when using MOGAS, however issues can be provoked by poor operational procedures. The following are recommended when operating on MOGAS:
  i. Avoid running the engine for extended periods on the ground – this causes heat-soak into the engine bay which increases vapour-lock risk.
  ii. Use the back-up electric fuel pump for all critical modes of flight – generally any time the aircraft is on the ground or within 1500 feet of the ground. Jabiru Aircraft have no objection to operators running the electric boost pump continuously.

11.3 Adverse effects to the fuel system and airframe

- As has been mentioned previously the exact composition of MOGAS varies due to a multitude of factors including:
  - The specific manufacturer
  - Country or region of origin (Cold climates versus warmer climates will have vastly different exact fuel blends available)
  - Seasonal variability (again the exact blend available will depend on the specific time of year at which a given batch of MOGAS is obtained)
- Since all fuel blends are proprietary knowledge to the relevant manufacturer no information is available to Jabiru Aircraft on the exact nature of composition of any of the multitude of MOGAS fuel blends available worldwide.
- For this reason it is therefore impossible to predict the effects of any single tank of MOGAS on the fuel system or the airframe at large. Volatile aromatics and other compounds within the fuel can have the potential to cause damage to the following:
  - Fuel system components including the fuel lines, filters, pumps (both mechanical and electric boost pumps), taps and fittings
  - The fuel tank sealant and the structure of the fuel tank itself
  - The airframe as a whole, particularly where vapour or liquid components of fuel come into contact with the airframe either during handle or through damage or leaks to the fuel system itself. This may include (but by no means be limited to) windscreens, wing and fuselage skins and external paint work.

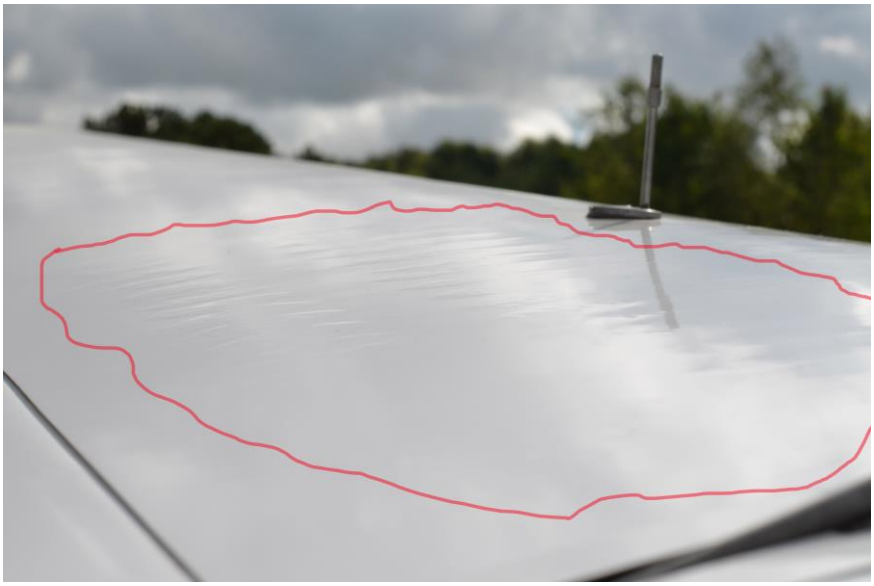

Figure 2 - 'Bubbling' in exterior paintwork due to adverse chemical reaction with unknown MOGAS aromatics

11.4 MOGAS Usage Recommendations

- Due to QA considerations and the reasons listed above, **operators who use MOGAS do so at their own risk**. Operators must accept that this risk exists both in terms of potential engine damage as well as damage to all fuel system related components and the airframe as a whole. The risk accepted in using MOGAS extends to all financial responsibility in rectifying damage caused by the use of MOGAS. As well as any liability claims that may be incurred as a consequence of MOGAS related engine or airframe damage.
- Use fuel which is as fresh as possible.
- Be aware of the potential issues arising from using MOGAS
- Follow the storage recommendations given below.
- Operators wishing to use automotive gasoline but wishing to avoid using alcohol should obtain Technical Data Sheets for the Gasoline they are using. Regular testing as detailed above should also be carried out to ensure the fuel does not contain alcohol.

11.5 MOGAS - Storage

- Due to the storage issues of MOGAS discussed above it is recommended that MOGAS is stored in the aircraft for **no more than 14 days (2 weeks)**
- Storage outside the aircraft depends on the ambient conditions, how the tank is vented and many other factors. Again, due to the issues discussed above Jabiru recommend not using any fuel which has been stored for 2 weeks or longer in anything other than industry approved gasoline tanks. Drums, jerry cans and above-ground tanks are not considered approved tanks.
- If you drain the tanks, take care to also drain the MOGAS from the carburettor – otherwise, as the fuel evaporates from the carburettor it may form a varnish which will block jets etc.
- Do not block the tank vents to prevent evaporation: as the temperature around the aircraft rises and falls during the day and night the contents of the tank expand, contract and give off gases. If the vents are blocked these effects can easily rupture the tank.

11.6 MOGAS Storage recommendations:

- Do not use MOGAS which has been stored for more than 2 weeks outside of an approved gasoline storage tank in a Jabiru engine.
- Leave the tank and carburettor full of AVGAS or
- Run the carburettor dry by turning off the fuel tap and running the engine until it stops, then drain all MOGAS from the tanks.
- Note that the storage methods currently outlined in Jabiru Technical Manuals generally presume that the aircraft is being operated on AVGAS – which suffers far less from the problems noted above.
- Commercial fuel additives and stabilizers are available which are designed to allow MOGAS to be stored for longer however Jabiru Aircraft have not tested their efficacy or their effects on other parts of the fuel system. Jabiru Aircraft does not currently endorse or approve their use.

12 Fuel Summary – Advisory

12.1 General:

- Where possible Jabiru Aircraft recommend using AVGAS. This is a fuel specifically designed for aircraft use and is subject to very strict documentation and quality assurance. This is simply the safest fuel available.
- Because it has a higher compression ratio the Jabiru 5100 engine must be operated using AVGAS or other fuel with a RON of 100 or higher.
- Where a Jabiru Engine is installed in a non-Jabiru airframe the operator must comply with the airframe manufacturer's approved fuel recommendations.

12.2 Approved Fuels

- Unleaded Aviation Gasoline (AVGAS) UL91 meeting ASTM D7547
- AVGAS 100LL
- AVGAS 100/130
- MOGAS with RON of 95 or higher and alcohol content as detailed in Section 7.

12.3 Fuel Preference Chart

★★★★★ The Perfect Fuel (mythical beast – does not exist)

★★★★☆ The State of the Art (best fuel available for Jabiru Engines)

★★★☆☆ Quite Suitable (A good fuel with some relatively minor negatives)

★★☆☆☆ Suitable (A good fuel but which has operational, maintenance and legal requirements the operator must be aware of)

★☆☆☆☆ Marginal. (Should only be used when the operator has no other suitable choice)

☆☆☆☆☆ UNSUITABLE for use with Jabiru Engines.

Fuel	Pro	Con	Rating
AVGAS 100LL	- Availability (varies) - Quality assurance - Designed for aircraft. - Ease of storage	- Availability (varies) - Lead content - Price	★★★★☆
AVGAS 100	- Availability (varies) - Quality assurance - Designed for aircraft. - Ease of storage	- Availability (varies) - Lead content - Price - Maintenance may be higher	★★★★☆

Fuel	Pro	Con	Rating
AVGAS UL91 (Unleaded AVGAS)	- Availability (varies) - Quality Assurance - Designed for Aircraft - No Lead.	- Availability (varies)	★★★★☆
Other AVGAS Blends with Higher Lead Levels	- Availability (varies) - Quality assurance - Designed for aircraft. - Ease of storage	- Availability (varies) - Lead content - Price - Maintenance may be higher	★★★☆☆
95+ Octane RON MOGAS	- Availability (varies) - No lead - Price - Clean burn - Good Octane when fresh	- Availability (varies) - Does not store well - Lower quality controls - Not designed for aircraft - Unknown effects on Engine, Fuel system and Airframe	★★★☆☆
95+ Octane RON MOGAS Containing Alcohol	- Availability (varies) - No lead - Price - Clean Burn - Good octane when fresh	- Availability (varies) - Does not store well - Lower quality controls - Extra alcohol-related maintenance required. - Not designed for aircraft - Unknown effects on Engine, Fuel system and Airframe	★★☆☆☆
Lower Octane Fuels with Octane Booster Added	- Availability (varies) - Price - No lead - Clean burn	- Availability (varies) - Unknown octane rating - Lower quality controls - Does not store well - Unknown octane booster content - Extra alcohol-related maintenance required. - Not designed for aircraft - Unknown effects on Engine, Fuel system and Airframe	★☆☆☆☆
Lower Octane fuels	- None Applicable	- Unsuitable - Will damage engines - May write engine and airframe off completely.	☆☆☆☆☆

13 Compression Ratio / Combustion Chamber Shape – Advisory

13.1 Compression Ratio

- At Manufacture the compression ratios of Jabiru Engines were as listed:
  - 1600 All S/No. 9.3:1
  - 2200 S/No. 1 – 106 9.3:1
  - 2200 S/No. 107 – 127 9.3:1
  - 2200 S/No. 128 – 831 7.8:1 or 8.3:1
  - 2200 S/No. 832 – 1003 7.8:1 or 8.3:1
  - 2200 S/No. 1004 Onwards 8:1
  - 3300 S/No. 1 – 223 7.8:1 or 8.3:1
  - 3300 S/No. 224 Onwards 8:1
  - 5100 All S/No. 8.5:1
- Where two ratios are listed those engines fitted with shims between the cylinder barrel and the crankcase have the lower ratio, engines without shims the higher.
- Note that the details given above apply to each engine as it was produced. As many of the older engines are now more than 10 years old and have been overhauled in the meantime, operators must be aware that the engine's current configuration may be different from that given here.

13.2 Combustion Chamber Shape

- Older Jabiru Engines had a combustion chamber shape which demands the use of AVGAS or 100 Octane RON fuel. Details are given below.
- Note that the details given above apply to each engine as it was produced. As many of the older engines are now more than 10 years old and have been overhauled in the meantime, operators must be aware that the engine's current configuration may be different from that given here.
- The following engines were manufactured with combustion chamber as shown in Figure 3.
  - 2200 S/No. 1 - 1003.
  - 3300 S/No. 1 - 223
  - All Jabiru 1600 engines.

Figure 3 – Early "High Octane" Combustion Chamber

- The "High Octane" chamber can be modified as shown in Figure 4.

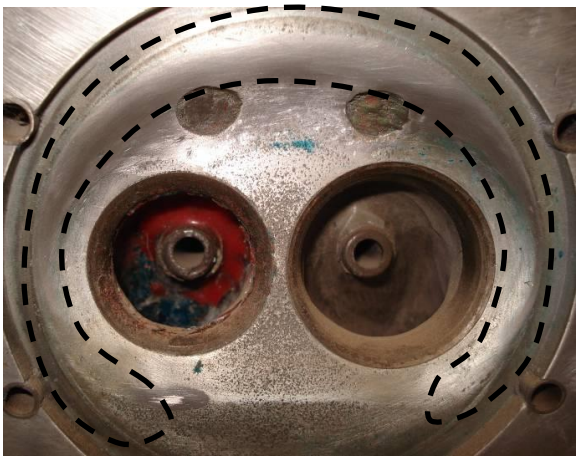

Figure 4 – Re-Worked "High Octane" Combustion Chamber

- Engines with Serial Numbers higher than the range listed above were manufactured using variations of the combustion chamber shown in Figure 5.

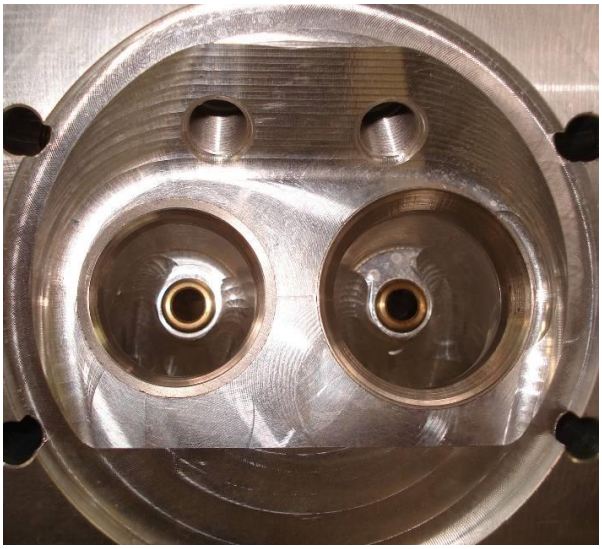

Figure 5 – Current "Wedge" Combustion Chamber

13.3 Fuel Octane Rating Requirements

- All 2200B, 2200C and 3300L engines may be operated using 95 Octane RON (or higher) MOGAS or AVGAS fuels. The fuels may contain alcohol to the limits listed in Section 7.6.
- Table 1 can be used to find which fuels should be used for a given engine. Example: 2200 engine, S/No. 800 with no shims fitted and therefore compression ratio of 8.3:1. Combustion chambers have been re-worked to Figure 4. Read the table as marked with the arrows, to the grey-shaded cell: the engine may use 95 Octane MOGAS.

Table 1 – Chamber / Compression Matrix

Compression Ratio:	"High Octane" Chamber	Modified "High Octane" Chamber	"Wedge" Chamber
9.3:1	100 RON or higher	100 RON or higher	N/A
8.5:1	N/A	N/A	100 RON or higher
8.3:1	100 RON or Higher	95 RON or higher	N/A
8:1	N/A	N/A	95 RON or higher
7.8:1	95 RON or Higher	95 RON or higher	N/A

- Any of these engines may use fuels containing alcohol up to the limits given in Section 7.6.

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LSA Service Notification: JSN 007-7

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Applicability:

The following excludes “Experimental-LSA” aircraft and engines. For these models refer to the general applicability section of Jabiru Service Letter JSL007-6.

- Jabiru J160-D
- Jabiru J170-C, J170-D
- Jabiru J230-C, J230-D
- Jabiru J120-C
- 2200 & 3300 engines used in LSA aircraft

Requirements:

- The models listed above are approved to use the following fuels:

Model	Fuel
J160-D	Avgas 100LL Avgas 100/130 MOGAS with minimum Octane Rating of 95 RON Fuels with alcohol content up to a maximum of 10%
J170-C, J230-C, J120-C, J230-D.	Avgas 100LL Avgas 100/130 MOGAS with minimum Octane Rating of 95 RON may be used
J170-D	Avgas 100LL Avgas 100/130 MOGAS with minimum Octane Rating of 95 RON Ethanol blend fuels may be used but are not recommended

Jabiru 2200 Engines Jabiru 3300 Engines	Avgas 100LL Avgas 100/130 MOGAS with minimum Octane Rating of 95 RON

Limitations

- Fuels containing alcohol must not be used in CASA-registered models.
- Aviation gasoline must not be mixed with Automotive Gasoline
- Fuel additives may not be used.
- Automotive gasoline is used at the operator's risk – see Section 11 of Jabiru Service Letter JSL007-7 for details.
- Fuel containing alcohol is used at the operator's risk – see Section 7 of Jabiru Service Letter JSL007-7 for details.
- **The use of any alternative fuels, or the mixing of fuels, is known to accelerate deterioration of the aircraft / engine fuel system. In addition the use of alternative fuels, or the mixing of fuels, is known to introduce engine wear that has been linked to a number of engine failures.**

Reference Information

- Jabiru Service Letter JSL007 contains detailed information on fuels and should be referenced by anyone seeking an understanding of fuels and these operating limitations.