



## **OPERATING INFORMATION – UNLEADED MOGAS**

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*This information is only applicable to LAA aircraft and only those airframe/engine combinations specifically cleared by the LAA for use with unleaded fuel.*

*This document is to be attached as an addendum to the Flight Manual or Pilot's Notes of the aircraft concerned or, in the absence of these, stapled within the airframe logbook.*

### **1. Obtaining and Storing Mogas**

It is essential that the type of unleaded fuel used is to BS EN 228 and is the 95 RON 'Premium Unleaded' type. Check the markings at the fuel pump. LAA have not investigated the older BS7070 specification fuel, which is sometimes seen at the pumps although it is now superseded.

On no account use Four Star 'Lead Replacement Fuel' which may be adequate for gentle road-going use but is not suitable for aircraft, in which the engine has to run continuously at high power setting.

It is always preferable to buy Mogas for aircraft use from a supply at an airfield or a garage with a reasonably high turnover and from a reputable supplier. We have come across problems in the past with cut-price supermarket fuel of poor quality.

In recent years, due to pressures from the 'Green' lobby to use bio-fuel, some petrol supplied through the forecourts has had varying amounts of alcohol added to it. The proportion of alcohol added is gradually increasing over time and the number of outlets supplying alcohol laced petrol is also increasing. Alcohol in the fuel can damage the rubber components in the fuel system, and also cause problems through progressively absorbing water which can suddenly come out of solution later, flood the water trap and fuel sump and stop the engine in flight.

Cap 747, Section 2, Part 4, General Concession 5 makes it mandatory to check that unleaded Mogas fuel does not contain alcohol before it is used in any group A aeroplane. The test method for detecting alcohol in petrol as described in the CAA Safety Sense leaflet 4b is not sensitive to alcohol levels of 5% or less, the current maximum level likely to be found, therefore a test kit has been developed that enables the detection of alcohol down to around 1%. Alcohol detection test kits are available from Airworld UK Ltd.

Always store fuel in suitable clean containers. CAA requires that fuel containers may be either metal, of up to 23 litres capacity and fitted with a secure leak-proof cap (Jerry can) labelled 'Petroleum Spirit, highly inflammable' or if plastic, it must be made for the purpose (complex regulations refer) and of no more than 5 litres capacity.

We are advised that the Road Traffic regulations normally applicable to carriage of petrol by road do not apply if the fuel is being carried for recreational purposes. No more than four containers, which must be made specifically for the carriage of petrol and have a maximum capacity of 20 litres each, may be carried.

If fuel is kept only for leisure purposes, we understand that up to 270 litres may be stored in one premises before having to apply to the County Council Petroleum Officer for a license. Nevertheless if more than 15 litres is stored then there is a legal obligation to inform the Petroleum Officer who must inspect and approve the premises. He will require the fuel store to be adequate for the job and to be equipped with a suitable nearby 6 Kg dry powder fire extinguisher.

On the other hand, there is no requirement to contact the Petroleum Officer if the fuel is stored in the fuel tank of the aircraft itself. Nevertheless you should use common sense and also consider the implications regarding buildings insurance etc.

Apart from the obvious safety considerations, due to the short 'shelf life' of Mogas fuel you are advised not to store large quantities. You are far better off purchasing small quantities of fuel as and when required, which will ensure that you always use fresh fuel blended appropriately for the time of year – see section 7 below.

## 2. Records of Purchase

Find a reasonably substantial envelope and write the aircraft's registration and the year on it. Each time you buy unleaded fuel for your aircraft put the receipt in the envelope. At the start of the next year, treat yourself to a new envelope and put the old one into store for at least a further year. After that year has elapsed you can then throw the old one away.

The above procedure has been agreed by the CAA to meet the intent of the Airworthiness Notices.

## 3. Quality Checks

Despite the lack of aviation-type quality control measures, over the years that four-star Mogas was being used in aircraft there were few reports of problems due to contaminated fuel from garage forecourts. It is likely that this record will continue to improve due to more stringent standards of underground tank installations and special tank connections to preclude the possibility of the underground storage tanks being filled with the wrong type of fuel. Nevertheless this is no excuse for lesser vigilance on the part of the pilot, and all Mogas fuel should be poured into the aircraft via a fine-mesh or chamois leather filter, and carefully sampled in the normal way. Watch out for flakes of paint in the fuel from the insides of metal 'Jerry cans'. *(When fuelling and de-fuelling, guard against 'flash fires' by electrically grounding the tank, funnel and can before transferring the fuel, and avoid a brimming funnel. If the stream of fuel from the 'source' encounters the fuel in the 'receiver' inside a closed container, the fuel/air mixture will almost certainly be too saturated to cause a fire should a spark occur. If, on the other hand, the fuel stream encounters a brimming funnel in free air then the petrol vapour in the vicinity may well be in the critical region where the tiniest spark will cause a flash fire).*

If the aircraft has been standing for 24 hours or longer, check that the fuel has not become contaminated with water before flight. It is generally preferable to keep tanks full whenever possible to minimise water condensation – the only exception being in hot weather when there may be a risk of the fuel becoming heat soaked and causing vapourisation problems – see section 7 below.

Only use fresh supplies of fuel and after a period of protracted storage, drain out any old fuel from the tank before filling up with fresh. Over a long period of time the fuel in the tank will evaporate away the more volatile 'fractions' through the tank vents, leaving a residue of low-volatility fuel which will cause poor starting, reduced performance and possibly engine damage through detonation or over-heating.

When in storage, Mogas fuel has a much greater tendency to form gum deposits than Avgas, so it has a much more limited 'shelf life' of just a few weeks. Avgas on the other hand can be kept in sealed drums for several years. Gum deposits can block carburettor jets and cause moving parts to 'stick'. Even if your engine appears to start and run well on last season's fuel, you should drain it off and replace with fresh.

Mogas fuel is also blended differently in the summer to that in the winter, to promote easy starting and driveability. Using summer fuel in winter may cause difficulty in starting, while using winter fuel in summer will increase the likelihood of vapour problems (see section 7. below)

#### 4. In Use

Except as described below, you should find no difference in operation when you transfer from four-star to unleaded, except perhaps a slight change in the colour of the grey exhaust pipe deposits and less tendency toward plug fouling.

#### 5. Operating Limitations

Unleaded Mogas fuel is restricted by Cap 747, Section 2, Part 4, General Concession 5 to operation with a fuel not exceeding 20° C and an altitude not exceeding 6000 ft. These additional limitations must be displayed in the cockpit using a suitable placard (see section 6 below).

Special steps may be needed to prevent the fuel tank temperature exceeding 20° C, especially during summer. Avoid letting the aircraft heat soak in the sun for long periods before flight, especially if the part containing the tank is painted a dark colour. On a hot sunny day, avoid parking the fuelled-up aircraft on dark tarmac surfaces. Consider instead filling the tank with cold fuel shortly before take-off, or better still, leave in the cool of morning rather than after a prolonged soak in the midday sun.

Assuming that your aircraft is cleared for use with both unleaded Mogas and with Avgas 100LL, there is no problem with mixing fuel of both types in your tank. Note however that even with just a small proportion of Mogas in the tank, the vapour pressure of the mixture will be almost as high as that of pure Mogas, so all running on a mixture containing Mogas must be carried out observing the operating limitations for unleaded Mogas alone.

#### 6. Placards

A placard must be fitted alongside each fuel filler stating as follows:

**UNLEADED MOGAS**  
BS EN228, 95 RON

A placard must be fitted on the instrument panel, or other location in clear view of the pilot in flight, stating:

#### **USE OF UNLEADED MOGAS**

(see CAP 747, Section 2, Part 4, General Concession 5)  
-only legal in aircraft specifically approved for the purpose  
-fuel to be fresh, clean, water and alcohol free  
-verify take-off power prior to committing to take-off  
-tank temperature not above 20° C  
-fly below 6000 ft  
CARB ICING AND VAPOUR-LOCK MORE LIKELY

Placards as above are available from LAA Engineering, free of charge to LAA members.

#### 7. What about Vapour Lock ?

Unleaded Mogas, like the obsolete four-star Mogas fuel, has a much higher vapour pressure than 100LL or 80/87 Avgas. The initial boiling point of the fuel is only slightly above ambient temperature, so it takes only a slight raise in temperature or drop in pressure to make it start to vapourise. This unfortunate property of Mogas makes it much more likely to suffer vapour-lock or vapourisation problems than Avgas, especially in hot weather or at high altitude. Hence the limitations to 20° C and 6000 ft altitude which apply to Mogas use, and the requirement to check

that full engine power is available before committing to a take-off. These special power checks should not be rushed, as they also serve to burn off the fuel which may have become pre-warmed in the fuel pump and gascolator while the engine has been idling, and drawing fresh, cool fuel through from the tank which will be less likely to cause vapour problems on take-off.

When the fuel turns to vapour in the fuel system, this can cause a number of different problems and it is important for Mogas users to understand the implications. If the vapour collects and forms a large bubble which becomes entrapped at a high point or constriction in the fuel pipe, this can form a 'vapour lock', effectively preventing the passage of fuel to the engine and causing a 'dead cut' similar to what would happen if you were to turn off the fuel cock. If this should occur, FLY THE AEROPLANE, lower the nose, and if sufficient height is available in which to experiment, turn on an auxiliary fuel pump if you are fortunate enough to have one, and select another fuel tank. If the auxiliary fuel pump is already on, you might try turning it off.

If on the other hand the fuel vapourises from some hot spot or low pressure area in the fuel system but does not become entrapped, a stream of vapour bubbles will enter the carburettor along with the fuel, causing raised EGTs, lean running and reduced power, which in the typical fixed pitch propeller installation is evidenced by a loss in indicated rpm and possibly puffs of white smoke in the exhaust. With Mogas, when carrying out the special power check prior to committing to take off you should be looking and listening not only for signs of uneven running but also an rpm which is less than normal on the tachometer, either during the run-up or during the initial stages of the take-off run. If either of these signs of vapourisation occur, you MUST abandon the take-off as the symptoms may well worsen as the engine heats up, and the power level may fall away to nothing during the climb-out.

If vapourisation is suspected in flight, FLY THE AEROPLANE, lower the nose to maintain airspeed, reduce the throttle setting so that the airflow into the engine is reduced to correspond with the enfeebled fuel flow, and richen the mixture control (if fitted) which should at least restore the fuel mixture strength, smooth running and possibly yield a few extra rpm. Since the symptoms may also resemble those associated with carburettor icing, carburettor heat may be required although this may have an adverse effect on fuel vapourisation problems and you will need to experiment to identify the cause of the problem before you can cure it.

Vapour problems are most likely to occur in aircraft fitted with engine-driven mechanical fuel pumps, and are rarely experienced with a purely gravity-fed system or those with an electric fuel pump situated at the tank outlet or, better still, submerged in fuel within the tank itself as in modern automotive practise. Unfortunately, in the typical aircraft system the fuel pump is located above the fuel tank, so the fuel pressure on the upstream side of the fuel pump is reduced below atmospheric by the action of the pump sucking up the fuel, making it very vulnerable to fuel vapour formation on the inlet side of the pump, with symptoms as described above.

If the engine is fitted with a mechanical pump, bolted to the engine crankcase, then heat conducted into the pump from the engine block will raise the temperature of the pump body significantly and only the flow of cool fuel through the pump keeps the pump temperature moderate. When the engine is shut down after a flight, the cooling airflow through the engine compartment ceases along with the flow of cool fuel through a mechanical engine-driven pump. As a result the pump body temperature can rise alarmingly and particularly when using the more volatile Mogas, you may hear the fuel in the pump boiling. You may then notice the engine dripping fuel from the intake drain onto the ground, due to the vapour pressure of the boiling fuel pushing the contents of the carb float chamber past the float valve and into the venturi.

To cool the engine compartment after shut-down it may help to open cowling hatches and prop them open to promote convective airflow through the engine compartment. Remember to latch them down before flight though.

If the fuel should vapourise within the fuel pump due to elevated pump temperature, the fuel vapour generated inside the pump body cannot escape back into the fuel system upstream, because of the one-way valve on the intake side of the pump. So instead, the vapour expands past the outlet valve of the mechanical pump, in so doing pressurising the fuel in the fuel pipe and carburettor float chamber, causing a so-called 'pneumatic lock'. The vapour pressure of the

boiling fuel is enough to push the fuel past the carburettor float valve and the engine suffers a rich cut, with raised fuel pressure indications, rough running and characteristic sporadic black puffs of exhaust smoke. The most likely time this will occur is when the aircraft is flown, landed, parked for a short time and then a second take-off is made. If this should occur in flight, FLY THE AEROPLANE, lower the nose to maintain airspeed, reduce the throttle setting to that appropriate to level flight and attempt to restore smooth running by leaning the mixture.

If your aircraft has a mechanical pump with a back-up electric pump connected in parallel, then it is important not to switch the electric pump off too early after take-off, especially with Mogas, as there is a risk that the fuel in the mechanical pump may have been stagnant and vapourised away while running on the electric pump, in which case the engine will stop as soon as the electric pump is switched off.

Fuel suppliers provide higher volatility fuel in winter to help cold-starting. Be particularly wary of vapour problems in spring and autumn months when winter fuel is being supplied but ambient temperatures may be moderately high.

A simple piece of test equipment is available which allows the pilot to test the volatility of his fuel and likelihood of vapour problems during the pre-flight check. This is known as a Hodges volatility tester, and is available at a modest price from Petersen Aviation Inc. in the USA, tel. 001-308-832-2050.

#### 8. Carburettor Icing

The greater volatility of Mogas compared to Avgas means that the carburettor throat temperatures are lowered more by the atomisation of Mogas at the jet than occurs with Avgas. Tests by the BGA showed that with the same ambient conditions, the carb throat temperatures of a Lycoming O-360 were typically 7° C lower with winter grade Mogas than Avgas. The result is that when using Mogas, carburettor icing will occur under higher ambient temperature conditions and lower humidity than with Avgas.

Take particular care to check the efficiency of any carburettor heating provisions and to watch out for signs of carburettor icing in flight. When using Mogas, use carb heat more frequently and for a longer period than normal especially on days when carburettor icing is likely – refer to CAA Safety Sense Leaflet on the subject. Carburettor ice remains a frequent cause of engine failures, which suggest that fitting a proprietary ice detector system to the carburettor may give a useful safety benefit.

#### 9. Chemical Compatibility

During the daily check and other routine inspections, pay particular attention to non-metallic fuel pipes, fuel valves etc for signs of leaks due to chemical attack from the fuel. There is a possibility that rubber pipes, seals, gaskets, O-rings, fuel tank sloshing sealants and even the varnish on cork fuel gauge floats may be affected by constituents within unleaded fuel. Standard MS29513 aviation O-rings swell significantly in size when in contact with unleaded Mogas, which may effect the operation of fuel valves, gascolators, fuel filler cap seals etc. All these points should be borne in mind during your pre-flight checks. You should also check filters frequently for signs of contamination either from the fuel or resulting from chemical attack on fuel system components or the fuel tank.

Viton rubber is unaffected by unleaded fuel. O-rings of Viton rubber are available from specialist seal suppliers.

#### 10. Continental and Lycoming Engines

With these engines, many of which were originally produced many decades ago, there have been a variety of different valve seat and valve materials used over the years, and there is a possibility that some combinations in the field might suffer problems with valve seat recession if

deprived of the dry-lubricating effect of tetraethyl lead in leaded fuels. To guard against this possibility it is recommended that all users of Continental and Lycoming engines cleared for unleaded Mogas use should either use a fuel mixture with 10% 100LL in it or run a tankful of 100LL through the engine at least every 75 running hours to lubricate the valves and valve seats.

If you have the engine top overhauled or 'majored', it is recommended that you run the engine on 100LL Avgas for the first 10 hours operation afterward to ensure adequate lead content during the break-in period.

Due to the likelihood of 100LL being withdrawn in the not too distant future for environmental reasons, it is recommended that when Continental or Lycoming engines come to be overhauled, the cylinder assemblies are replaced with new assemblies known to be compatible with unleaded fuel, which will not require this occasional 'doping' with leaded fuel.

Some Marvel-Schebler (latterly, Facet and now 'Precision Airmotive') carburettors may still be fitted with moulded cellular rubber floats, as introduced by FAA AD 66-05-04 (withdrawn in 1985). Some of these floats have given trouble due to soaking up fuel, losing buoyancy and dropping in level, causing rich running problems, i.e. flooding carburettor, rough running at idle speed and inconsistent shutdown. Facet Service Bulletin A1-84 refers. While the composite floats are no more likely to absorb unleaded Mogas than they are 100LL fuel, owners should be wary of this problem and if problems are experienced, consider fitting a replacement float (Precision Airmotive Service Information Letter SIL MS-4).

Some Bendix NAS-3 carburettors may still be fitted with obsolete synthetic rubber-tipped needle valves, which should have been replaced with a Delrin-tipped needle under Bendix Aircraft Carburettor Service Bulletin ACSB-84. While Bendix advise that their own original neoprene-tipped valves should not cause any trouble if used with unleaded Mogas fuel (and this seems to be confirmed by the LAA's submersion tests) a problem has been reported in the USA with bogus neoprene tipped valves which swelled up when submerged in fuel and caused excessively lean engine running.

The bogus valve tips respond equally when submerged in 100LL fuel. Nevertheless, owners should be aware of this potential problem if they suspect that the neoprene-tipped valves are still fitted.

#### 11. Rotax 912, 912S and 914 Engines

The Rotax 912, 912S and 914 engines have been designed to run on unleaded Mogas however a vapour return line must be fitted to the fuel system in accordance with Rotax recommendations. If the aircraft is not already fitted with one of these, one must be fitted to a scheme acceptable to LAA Engineering.

#### 12. Rotax 2 Stroke Engines

Rotax 2 stroke engines are designed to use unleaded fuel and you should find no difference in operation when you transfer from four-star to unleaded, except perhaps a slight change in the colour of the grey exhaust pipe deposits and less tendency toward plug fouling.

Unleaded Mogas, like four-star fuel, has a much higher vapour pressure than 100LL Avgas. Consequently it is much more likely to suffer vapour-lock problems causing engine power failure, especially in hot weather and high altitude. Hence the limitations to 20 degrees C and 6000 ft altitude which apply to Mogas use, and the requirement to check that full engine power is available before committing to a take-off.

Fuel suppliers provide higher volatility fuel in winter to help cold-starting. Be particularly wary of vapour lock in the autumn months when winter fuel is being supplied but ambient temperatures are still high if we are lucky enough to enjoy an 'Indian summer'.

Engines running on unleaded Mogas fuel are more likely to suffer carburettor icing than when running on 100LL. Take particular care to check the efficiency of any carburettor heating provisions and to watch out for signs of carburettor icing in flight.

During the daily check and other routine inspections, pay particular attention to non-metallic fuel pipes, fuel valves etc for signs of leaks due to chemical attack from the fuel. Check filters frequently for signs of contamination either from the fuel or resulting from chemical attack on fuel system components or the fuel tank.

### 13. Jabiru Engines

Jabiru warn that although their engines may be operated on 95 UL Mogas provided the compression ratio is not more than 8.3, there is nevertheless an increased risk of detonation when unleaded is used rather than 100LL Mogas. An installation which is marginal with regard to cylinder head cooling may suffer problems with detonation and engine damage when transferred to Mogas fuel. Be particularly wary of any signs of detonation, warped or leaking heads which may be a sign of detonation occurring which, if left unchecked, are likely to result in major engine damage and in-flight engine failure.

### 14. VW and VW based Engines

VW and VW based engines are suitable for 95 UL Mogas use, provided that the engine's compression ratio does not exceed 8.0:1 although there is the possibility that engines not fitted with hardened valve seats may suffer from rapid valve seat recession if deprived of the dry-lubricating effect of tetraethyl lead in leaded fuels. To guard against this possibility it is recommended that all users of VW and VW based engines cleared for unleaded Mogas use should either use a fuel mixture with 10% 100LL in it or run a tankful of 100LL through the engine at least every 10 tankfuls to lubricate the valves and valve seats.

Checking the compressions by turning the propeller by hand should give an indication if valve seat recession has become excessive, but the valve clearances must be measured at least once every 25 hours and adjusted if the clearance is found to be on or out of limit. Excessive exhaust valve clearance will introduce the possibility of valve burning which may lead to engine failure.

If you have the engine top overhauled or 'majored', it is recommended that you run the engine on 100LL Avgas for the first 10 hours of operation afterward to ensure adequate lead content during the break-in period.

Due to the likelihood of 100LL being withdrawn in the not too distant future for environmental reasons, it is recommended that when VW and VW based engines come to be overhauled, the cylinder assemblies are replaced with new assemblies known to be compatible with unleaded fuel, which will not require this occasional 'doping' with leaded fuel.

### 15. If Problems Occur

While the foregoing is based on the best information available at the time, ultimately Mogas supply is not as tightly controlled as Avgas and there is therefore more scope for problems of contamination or mis-identity. No guarantee can be given that fuel is of the type specified on the pump, and only by constant vigilance can safety standards be maintained. Remember that the CAA continues to take the view that engine failure is always a possibility in single-engined aircraft. Consequently the pilot has a duty to operate it in such a way that engine failure would not cause a hazard either to himself, his passengers or third parties on the ground.

If engine problems occur which appear to relate to fuel type or fuel contamination, contact the CAA as described in the Airworthiness Notices along with copies of the appropriate fuel receipts.

### 16. Further Information

Much further information about the use of unleaded Mogas is available from the websites of Petersen Aviation ([www.webworksltd.com/webpub/PetersenAviation](http://www.webworksltd.com/webpub/PetersenAviation)) and the EAA ([www.eaa.org](http://www.eaa.org)).