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SERVICE LETTER 00078 REV 1

Date Released:	May 10, 2023 – Rev 1 (Expanded affected models) April 25, 2023 (Initial Release)
Date Effective:	April 25, 2023
Subject:	Vapor Lock
Affected Models:	All RV Aircraft using MOGAS
Required Action:	Information Only
Time of Compliance:	Not Applicable
Supersedes Notice:	None

Labor Required / SLSA Warranty Allowance: Not Applicable

Level of Certification: Not Applicable

Synopsis:

Although this document is mainly focused on the Rotax powered RV-12 and RV-12iS, the concepts presented here are applicable to other RV aircraft using any powerplant capable of running MOGAS.

Recent changes to ASTM F2245 requirements, which govern the design and performance of Light Sport Aircraft (LSA), require that additional fuel system vapor lock testing be performed, and that related information be added to LSA Pilot Operator Handbook (POH) and Flight Training Supplement (FTS) documents. This vapor-lock related information has been included in numerous areas throughout those aircraft documents. This service letter summarizes that information in one location and is intended to help inform the reader about the causes of vapor lock, and how to detect and avoid vapor lock. This service letter is provided in addition to, and does not replace, the POH and FTS documents.

What is vapor lock? ASTM standards define the term "vapor lock," when used in reference to liquid fuel systems, as when the liquid fuel, while still in the fuel delivery system, changes state from liquid to gas (i.e., vaporizes), that causes either: a) fuel feed pressure to the propulsion unit to decrease below manufacturers specifications, b) transient loss of power, or c) complete stalling of the propulsion unit. That is a straightforward definition, but let's unpack that a little further.

Vapor lock is most commonly associated with:

1. High Operating Temperature. The ASTM standard associates vapor lock with temperatures at or above 80 deg F (26 deg C). High outside air temperature and/or a heat-soaked engine or cockpit can raise the temperature of the fuel until components of that fuel begin to vaporize.
2. High vapor pressure fuel (high RVP)
3. Low atmospheric pressure (high density altitude)

As the temperature increases and/or the pressure decreases, fuel will change from a liquid to a gas (vaporize). Fuel that transitions to a vaporized state will flow through the fuel line as small bubbles or may form as a large bubble that blocks all or part of the cross-sectional area of a fuel line. As a result, fuel flow rates will decrease, which will result in power loss and/or a rough running engine. If a bubble forms across the entire cross section of a fuel line the bubble may grow and stretch allowing no fuel to pass, stopping all fuel supply to the engine (true vapor lock). Certain areas of the fuel system may lower the local pressure causing vapor to form, such as filters, vanes or diaphragms of a pump, partially open fuel valves, sharp bends (90 deg elbows or bends sharper than specified in the plans) and fuel lines that have been improperly bent (many times by hand) having a reduced cross section. Always use the recommended fuel tubing bending tool and proper centerline radius. RV's use 3/8 diameter tubing for fuel lines with a minimum 1-inch centerline radius.

Some fuels use additives that vaporize more easily. These are most commonly found in fuels used in cold northern climates. At lower temperatures, normal gasoline will not combust as easily. To help combustion in cold temperatures, more combustible volatile liquids that vaporize more easily are added to the fuel (most commonly butane). While this fuel is stable in cold conditions, these additives will vaporize in warmer conditions. Additionally, these additives create more pollution during combustion. For these reasons, different summer and winter blend fuels are produced. This winter/summer difference in fuel combustibility (volatility) is directly proportional to the propensity of the fuel to vaporize and is communicated to consumers as a value known as the Reid Vapor Pressure, or RVP.

Think of RVP as a measure of volatility. The higher the RVP the more volatile the fuel. AvGAS RVP ranges from 5.5 to 7.1 psi while MOGAS RVP ranges from 7 to 14 psi depending on the location and season.

To better understand why higher RVP fuel is more volatile, let's take a simplified (several details are left out here) look at how RVP is measured. Figure 1 shows the test setup. Two chambers are connected. The smaller chamber (shown in green) contains the test fuel. The larger vapor chamber (shown in orange/red) is four times larger than the fuel container. A pressure meter is attached to the top of the vapor chamber. These two chambers are connected and placed in a 100 deg F bath. As the fuel vaporizes the pressure in the vapor chamber increases. After some time, this pressure stabilizes and is recorded as the fuel's Reid Vapor Pressure. If a fuel is more prone to vaporizing (is

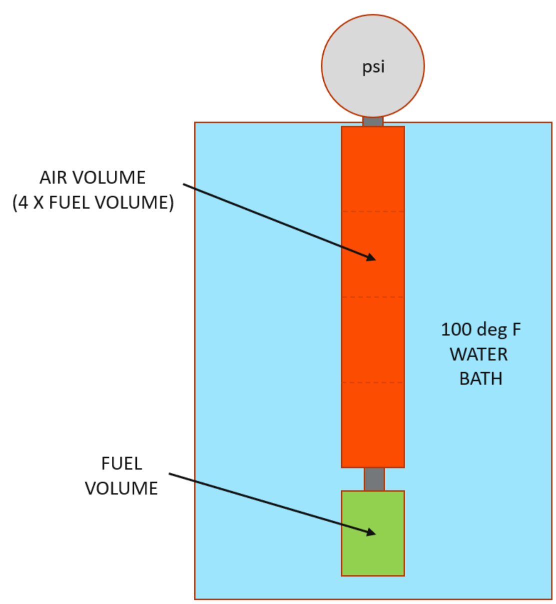

FIGURE 1 - RVP TEST SETUP

more volatile – such as winter blend fuels that contain butane) more vapor will be produced and the pressure will be higher. Higher RVP fuels are therefore more prone to releasing vapor and therefore have a much higher chance of forming vapor lock within the fuel system.

NOTE: The most important factor in avoiding vapor lock is to use an approved fuel for the flight conditions. The use of volatile fuels (with high RVP, such as wintertime blend MOGAS) will greatly increase the risk of vapor lock!

NOTE: Beware of fuel that may have been transported from a cold location to a warm area (trailered aircraft for example moved during the winter to a winter home in a warmer climate).

In the United States, some warmer states such as California keep the same summer blend (low RVP) fuel in use year-round. However, northern states may use fuels with a stated RVP value as high as 15 psi. By March or April refineries tend to begin to produce summer blends. On May 1st fuel terminals are required to sell only summer blend. By June 1st gas stations must complete the changeover to summer blend gasoline. In August refineries begin to produce winter blend gasoline and September 15th is the last day the EPA requires summer gasoline. The “danger-zone” time period is in late spring when the OAT is high and fuel stations may still be selling winter-blend high RVP gas. Some fuel stations with large volume tanks and low sales rates may still be selling winter blend gasoline into the summer months (one reported case was near the end of June at an airport selling “clear” MOGAS). Note that since winter blend fuel tends to be cheaper than summer blend fuel, stations will buy a large quantity of winter blend to fill their tanks just before the spring EPA deadline. Fuel stations may also mix winter or summer blends with each other. In short, do not trust that a fuel station will supply summer blend gasoline even though you may be well past the May 1st deadline.

What is octane rating and how does octane affect vapor lock, if at all? Octane is the name of the molecule (made from a chain of carbon and hydrogen atoms) that fuels are made of. There are many isomers (arrangement of the atoms) of this molecule. Some arrangements are more resistant to combustion than others. The Octane rating is based on the pressure at which the fuel will spontaneously combust. The higher the number, the higher pressure at which spontaneous combustion will occur. As the cylinder compresses the fuel/gas mixture, the pressure increases. Low octane fuels running in an engine with high compression will combust under pressure before the ignition system ignites the mixture. This sharp rise in pressure is called pre-ignition, detonation, or engine knock. If the fuel detonates early, the upward moving piston is fighting against the now ignited and expanding combustion. This robs power and can cause significant internal damage to the engine. Higher octane rated fuels allow engines to have higher compression. Higher compression is what yields higher power output. Compression (usually quantified as the compression ratio) is generating the power, not the octane of the fuel. The octane is simply allowing the fuel to be compressed further before ignition. If an automobile will run on 87 octane and 100 octane fuel is used instead, the engine will generate the same amount of power with both fuels. Higher octane does not mean more power (even though the highest octanes at your local service station will be advertised as “power” fuels. It should be noted here that there are a variety of octane rating scales and averages of those scales (RON, MON, AKI etc.) and that they are all measured differently. When thinking of a fuel’s tendency to vaporize and cause vapor lock, it is the additives and RVP of the fuel that matter – not the octane rating. Any fuel, regardless of octane rating, will vaporize - and even more so if it contains volatile additives. Do not fall into the trap that buying higher octane fuel at your local fuel station will prevent vapor lock. 100LL is resistant to vapor lock not because of its octane rating but rather because it does not contain the volatile additives present in winter MOGAS.

If you are unsure what fuel is in the aircraft or if the fuel is old (fuel degrades over time), drain the fuel. If you know or suspect that the fuel is a winter blend, possibly (see the note below) mix the fuel with 100LL as described in the fuel limitations section of the Pilot’s Operating Handbook (POH).

NOTE: At this time Van’s Aircraft has not tested the worst-case 15 psi RVP fuel mixed with 100LL. Until that testing is complete Van’s cannot officially recommend mixed fuels. Van’s has had success so far mixing 100LL with fuels that have a slightly higher RVP using a 50/50 mix ratio.

The RV-12 equipped with a Rotax 912ULS engine uses an auxiliary pump located as close to the fuel tank as possible. This pump should remain turned on for the entire flight. The pump is inexpensive and the argument of turning it off to save money will only result in saving pennies per hour. Typically, the cost per year will be less than the price of a gallon of milk, a dozen eggs or a flavored latte at your favorite coffee shop. Why risk engine failure or increase the chance of vapor lock for so little savings? Typically, we turn this pump off in a Lycoming as well. Why? Because we were taught to do so during flight instruction. Before you turn the aux pump off in your Lycoming ask yourself why.

In the RV-12iS using a Rotax 912iS, both fuel pumps are located behind the baggage compartment. These pumps increase the pressure in the fuel lines and help push fuel to the engine. This helps prevent the onset of vapor lock. These pumps must remain on for the entire flight.

Some have also asked why we do not locate the fuel pumps for the RV-12 and RV-12iS inside the fuel tank. At this time, Rotax does not provide a good option for this. Possibly such a design will be available in the future. Even if the fuel pump was located in the tank, remember there are several other locations where vapor lock could occur as stated previously, such as in a filter or gascolator, a partially-open fuel valve, or in the vanes or diaphragm of the pump itself. A pump inside the fuel tank, although potentially slightly better, would not eliminate vapor lock. In cases where the vapor lock is happening elsewhere in the system (another pump, filter, etc.) placing the pump in the tank will have no effect. If a fuel is above its critical temperature and under a low enough pressure, it will vaporize. When these conditions are met there will be vapor to some extent in any fuel system.

It seems to be a common belief that vapor lock is associated with ethanol fuels. While ethanol fuel may be legally supplied at an RVP 1 psi higher than “clear” gasoline in the United States, ethanol alone does not contribute significantly to vapor lock. Rotax engines have been operated (against Rotax recommendations) on fuels with much higher concentrations of ethanol than 10% without reported occurrences of vapor lock. Additives in winter fuels (especially in northern climates with extreme cold) are the greatest contributors. Do not believe that if “clear” ethanol-free fuel is used you will be free from vapor lock.

The propensity for vapor lock can be reduced by preventing a rise in the temperature of the fuel.

1. Before shutdown, run the engine for 2 mins at low power to flush as much heat out of the engine compartment as possible.
2. Most importantly, open the oil door after shutdown. The oil door is purposefully located above the oil tank (which post-flight will contain latent heat) and also next to the right carburetor on a ULS engine. Vents in the cowling (such as the louvers above the ignition coils) or the NACA inlet cooling Regulator B along with the lower cowling exit area, form a chimney effect after engine shutdown. Hot air venting from the top openings draws fresh, cool air in through the lower outlet of the cowling. This beneficial effect is greatly increased when the oil door is left open.
3. Since air is flowing in through the cowl exit, the chimney effect of cooling is most efficient if the tail of the aircraft is oriented into the wind. The next best option would be to point the aircraft nose into the wind.
4. Leave the canopy in the partially-open position to allow heat to escape from the cabin. Open the canopy and let the cockpit area cool off before flight.
5. Run the fuel pump(s) for 5 mins as you do your walk around. This will push fresh fuel through the system and flush out as much vapor as possible.
6. Pay attention to fuel pump tone or noise. A fuel pump moving air instead of fuel will generate a distinctly different sound.
7. If temperatures build in the runup area, remember to increase RPM in order to force more air through the coolant and oil coolers as well as the engine compartment. This may be counterintuitive. The EFIS will prompt you to increase RPM under these conditions if RPM is low and engine temperatures rise.
8. After takeoff, reduce climb angle and increase forward speed to maximize in-flight cooling.

For aircraft with multiple fuel tanks, it is common practice to run 100LL in one tank and MOGAS in the other. When switching tanks with the mixture leaned there is an increased risk of vapor lock occurring.

It is important to not misdiagnose vapor lock. Loss of fuel pressure can also be caused by other factors such as a clogged fuel filter or gascolator. Overlooking these possibilities can lead to power loss or engine failure! Fatalities have occurred because clogged filters were assumed to be vapor lock even when the OAT was lower than that at which vapor lock would occur. Stop, check your fuel filters, and verify that the fuel return line orifice openings are clean.

In flight, recognize that the signs of vapor lock will typically be: a rough running engine, loss of power, and a loss of fuel pressure as you gain altitude. You may also hear a change in pitch and volume of fuel pump noise as air is pumped through them. If you have drained the fuel system and turned on the pumps, the pumps will initially only be pumping air. The sound will be similar. If you notice these signs, reduce altitude. If fuel pressure increases and power returns as the altitude is decreased, it is likely you are experiencing vapor lock. If you experience these conditions, do not continue to climb as this will only further reduce the fuel pressure. This pressure reduction may result in a complete powerplant failure.

Most importantly, use of the correct fuel is the best way to prevent vapor lock.

Further Reading:

1) AVGAS/AUTOGAS Comparison: Winter Fuels, DOT/FAA/CT-86/21, Augusto M. Ferrara, July 1986
2) OPERATING INFORMATION – UNLEADED MOGAS, Light Aircraft Association (LAA), May 26, 2009
3) AC 23.1521-1A, Certification of Non-Oxygenated Automobile Gasoline (Autogas) instead of Aviation Gasoline (Avgas) in Part 23 Airplanes with Reciprocating Engines, Federal Aviation Administration, January 2, 1991.
4) AC 23.1521-1B, Type Certification of Automobile Gasoline in Part 23 Airplanes with Reciprocating Engines, March 2, 1995
5) AC 23.1521-2, Type Certification of Oxygenates and oxygenated Gasoline Fuels in Part 23 Airplanes with Reciprocating Engines, dated January 21, 1993
6) AC 23.961-1, Procedures for Conducting Fuel System Hot weather Operation Tests, dated January 14, 1987
7) AC 23-16A, Powerplant Guide for Certification of Part 23 Airplanes and Airships, February 23, 2004

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