

A review of phase separation issues in aviation gasoline fuel and motor gasoline fuels in aviation

K Thanikasalam¹, M Rahmat¹, A G Mohammad Fahmi², A M Zulkifli¹, N Noor Shawal¹, K Ilanchelvi³, M Ananth³, R Elayarasan

¹Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia (UTM), 81310 Skudai, Johor, Malaysia

²Department of Aeronautical Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), 86400 Batu Pahat, Johor, Malaysia

³Department of Chemical Engineering, Universiti Malaysia Sabah (UMS), 88400 Kota Kinabalu, Sabah, Malaysia

*Corresponding author: insp466@hotmail.com

Abstract. In an attempt to bring in sustainable energy resources into the current combustibles mix, recent European legislations make obligatory the addition of biogenic fuels into traditional fossil gasoline. The preferred biogenic fuel, for economic reasons, is predominantly ethanol. Even though likened to fossil gasoline constituents, ethanol has a dissimilar chemical formulation that may lead to a potentially hazardous physicochemical phenomenon, particularly in the presence of water. Owing to increased financially driven propensity to utilize motor vehicle gasoline as aviation gasoline fuel, this may result in potentially hazardous situations, specifically in running smaller or compact General Aviation aircraft. The potential risks posed by ethanol admixtures in aircraft are phase separation and carburettor icing. Gasoline mixed with ethanol is also prone to an increased vulnerability to vapor lock that happens when fuel turns into vapor in the fuel pumps due to high temperatures and lessened ambient pressure at high altitudes. This article provides a literature review on phase separation issues in aviation gasoline fuel and motor gasoline fuels in aviation.

1. Introduction

Esch et al. (2010) suggest that, currently, over 90% of all gasoline fuel sold in the European Union comprises a blend of ethanol. According to Esch et al. (2010), the usage of blended fuels increases the likelihood for a phenomenon called phase separation. Phase separation takes place when water gets into a tank that houses an ethanol-gasoline mixed fuel. Esch et al. (2010) claim that ethanol soaks up water and when gasoline becomes soaked, a film of water and ethanol, called phase separation, forms in the tank. The water-ethanol mixture has a heavier density compared with the gasoline phase, thus the mixture patches up at the base of the tank [2]. The mixture is not combustible and would result in an immediate starvation of the aviation engine if it were sucked in.

2. How Phase Separation Occurs

Boichenko and Lejda (2015) argue that the risk posed by a phase separation, although always reliant on the availability of water in the fuel tank, is a complex one. They suggest that as long as the water quantity does not surpass specific limits it is bearable. Numerous boundary circumstances investigated



based on their significance in numerous tests influences this limit [1]. When an aircraft begins its service, the fuel's ceiling becomes frosty. The water carrying capacity depends on the fuel's temperature. Thus, flight experiment assists in the exploration of the cool-down effect. Boichenko and Lejda (2015) argue that, even if at the beginning of a flight there is a lack of adequate water content in the fuel tank to prompt a phase separation, an aircraft might gather additional water during the aerial navigation if it flies through chilly water vapour like fog or clouds. The aircraft may also cause the condensed water vapour to flow out of the ingested tank into the gasoline tank when descending from a freezing service height. Boichenko and Lejda (2015) also allege that when an aircraft is unused for a prolonged period the custom is to fill up its tanks to avoid corrosion. Since ethanol-admixed gasoline fuel is to some extent hygroscopic, this can result in a slow but progressive intake of environmental water.

Esch et al (2010) conducted an experiment to assess phase separation on a MORANE aircraft. The findings indicated that even though MORANE's tank is more thermally insulated likened to a wet wing system, the aircraft cools down considerably in a long flight. Owing to this, there is a real risk of phase separation if the gasoline encounters a considerable amount of water. This water, though not present when MORANE begins to fly, may flow into the fuel tank through the venting gap [2]. This threat exists in spite of the fact that minimal rates of water intake exists during rainy conditions, even when the aircraft passes through clouds or rains. Esch et al. (2010) argue that scientists should investigate further the quantity of potential humidity condensation in the descent stage from dry and cold heights to moist warm air in lower stratum. Esch et al. (2010) concluded that the risk of phase separation depends on the quantity of air ingested by the fuel tank's venting system, the particular crossover temperature gap bumped into during the last stage of descent, and the amount of moisture in the air.

Morgan (2014) suggests that an affinity to a buildup of water, even in powerful ethanol-admixed petrol (E-10, 10% of ethanol containing gasoline), is only identifiable once exposed fuel tank. When parked in a temperature-adjustable equilibrating hangar, the impact is significantly less. Morgan (2014) notes that experimentally established water bearing capabilities are larger compared to those indicated in existing literature, even though these pieces of literatures fail to provide principal clearance, and the concern by itself remains significant. Morgan (2014) also alleges that a phase separation in gasoline mixed with water may happen during the cool-down of the tank ingredients in the mid-flight. According to Morgan (2014), additional problems may emerge in the future if aircraft operators use automotive petrol without any direct pre-flight water content management. Given that currently there are no standardizing upper limits of water quantity for the ever-increasing ethanol-admixed gasoline, it would not be long before some competitive retailers are tempted to make the most of this boundary situation to a tip where motor vehicles with their almost stable fuel tank temperature would not endure any obvious drawback. A number of experiments using hydrous E-15 (E-15, 15% of ethanol containing gasoline) intended at saving the cost of making super-azeotropic ethanol before gasoline admixing process are already in this direction [4]. If such fuels with moderately high water content serve as aviation fuel, then the powerful cool-down in uncovered aircraft tanks might trigger the phase separation effect. Given that the absolute temperature reliance on the water tolerance rises considerably with increasing ethanol content, this phenomenon would progress considerably if aircraft operators exploit "non-disturbing water content" for commercial purposes.

Gramajo de Doz, Bonatti, and Sólamo (2004) assert that there is a limit to the quantity of water absorbed by ethanol-gasoline mixed fuel. According to Gramajo de Doz et al. (2004), this limit is reliant on the temperature and quantity of ethanol in the admixed fuel. If the water soaked up by ethanol-gasoline mixed fuel separates, a film of ethanol and water forms underneath the fuel tank. The film of ethanol and water blend is not an ideal fuel for the airplane, thus a fractional, if not absolute, power loss occurs. Gramajo de Doz et al. (2004) suggest that at 60°F, a one-gallon mixture of 90% gasoline and 10% ethanol absorb around 0.60 ounces of water before experiencing phase separation. If the temperature decreases to 32°F, 20% of the whole water contained in the fuel will phase separate.

Gramajo de Doz et al. (2004) note that with a 48-gallon fuel tank, around 6 ounces of water would amass and possibly flow through the pipe system. According to Gramajo de Doz et al. (2004), certification requirements only need 1 ounce per 20 gallons.

3. Effects of Phase Separation

Mukhopadhyay and Datta (2008) suggest that phase separation can cause harm to aviation petroleum infrastructure. Phase separation comprises a larger percentage of ethanol, some percentage of water, and a small percentage of gasoline. Mukhopadhyay and Datta (2008) allege that this mixture is very corrosive even compared with E-10 or pure water. There are some claims that phase separation might be even highly abrasive than 100% ethanol [5]. Some aviation petroleum tanks are incompatible to this ethanol-blended and corrosive liquid. Based on the content of the tank, phase separation soaked may gradually depreciate the integrity of aviation tank walls and increase the threat of a leakage into the environment [5]. Other than the fuel tanks, other components of delivery and storage systems like pipes, dispensers, and submersible turbine pumps may also be in jeopardy when the level of phase separation rises to the position where pumping system can pick it up. Each of these concerns presents financial and environmental issues, as their substitute may be costly and harmful to the ecosystem if not detected [5]. Ideally, the aviation petroleum owner would want to identify any incidence of phase separation as quick as possible to allow them to speedily remediate and lessen the exposure to potential corrosion.

Other than damaging the aviation petroleum infrastructure, phase separation also has the potential to damage aircraft applications. Nakama, Kusaka, and Daisho, (2008) suggest that when using ethanol-gasoline mixed fuel like E10 in aircraft applications, possible problems exist. The more the concentration of ethanol, the higher the chances that the aircraft will experience issues that comprise;

- harm to fused gasoline tanks and rubber gaskets. Ethanol-gasoline mixed fuel is not as compatible as pure gasoline to these apparatuses [6].
- Phase separation also causes corrosion issues with metal gasoline tanks, electric fuel siphons, and other fuel system apparatuses. Ethanol, contained in the fuel, readily soaks up water.

Nakama et al. (2008) claim that ethanol may even soak up a noteworthy quantity of water from the environment during humid conditions. According to Nakama et al. (2008), when too much water is soaked up, phase separation occurs resulting in ethanol and water falling to the bottom of the gasoline tank. The combined water and ethanol can be caustic to metal gasoline tanks and fuel system apparatus, particularly if allowed to stay for a longer period.

Like Nakama et al. (2008), Strauss and Gonzalez (1989) claim that phase separation may damage aircraft's components. When separation occurs in the gasoline tank, there are higher chances that they will go through into the pumping system and enter the piping system, dispensers, and ultimately into an aircraft engine. Strauss and Gonzalez (1989) allege that phase separation causes many aircraft engines to stall. The affected aircraft will need maintenance leading to financial costs and losses.

4. Solutions to Address Phase Separation

Yüksel (2004) claims that if correctly installed with fuel tank sump drains, an aircraft should be able to drain off phase separation leaving only gasoline. However, Yüksel (2004) suggests that in such instances the remaining fuel will have somewhat reduced octane levels, less by 2-3 points based on the antiknock index (AKI) ranking technique. According to Yüksel (2004), the Rotax 912-ULS engine, two-stroke 618 engines, and the turbocharged 914 engines need 91-octane fuel using the AKI ranking procedure. The 912UL engine and the two-stroke 582, 503, and 447 engines operate on 87-octane.

Totten, Westbrook, and Shah (2003) note that if an aircraft's fuel tanks do not have sump drains installations and aircraft operator finds water at the gascolator, the operator should contemplate depleting a considerable quantity of fuel from every tank via the gascolator. Thereafter, the technician should assess the drained fuel for any signs of water contamination. The technician should carry on depleting the fuel up until the water is completely removed [9]. The gascolator ought to be the lowest

tip in the fuel system. Thus, an aircraft ought to be level to ensure any water in the fuel tanks positions at the fuel tank pickups. The tip in the tank where the fuel lines sketch ought to be the lowest point if gasoline tanks lack sump drains installation [9]. This is where water will amass supposing the aircraft stays leveled.

Olah, Goeppert, and Prakash (2011) suggest that since ethanol has a tendency to absorb water, aircraft operators should ensure that they utilize the freshest E10 fuel whenever possible, check their fuel tanks for any water prior adding fresh gasoline, and do not stock up E10 fuel in containers several weeks unless in a dry place or climate. In addition, Olah et al. (2011) indicate that aircraft owners should only purchase fuel when there is an intention to use it and have fuel tank sump drains or gascolator installed in their planes. These gadgets will act as water collectors and filters. Olah et al. (2011) also point out that when any water is found on the gascolator, there are higher chances that phase separation has already taken place. This implies that there is likelihood for a considerable quantity of ethanol and water mix in the aircraft's fuel system. The aircraft's engine cannot operate using the phase separation, so it ought not to be permitted to find its way into the engine [7]. In such circumstances, the technicians should investigate the fuel system for any water before trying to take off.

5. Conclusion

According to Esch et al. (2010), in their Safety Implication Of Biofuels In Aviation 2010 report, there is an actual threat of phase separation if the gasoline contains a significant amount of water. This water, even if not already present at the time of start, may enter the fuel tank by its venting opening. This danger exists despite the fact that low rates of water ingestions are observed in rain conditions, even if the aircraft traverses clouds or strong rain. The amount of potential humidity condensation during the descent phase from cold and dry heights to humid warm air in lower strata should be scrutinized more thoroughly still. It will depend on the amount of air ingested by the tank venting system, the specific crossover temperature gap encountered during the last phase of descent, and the humidity of the air Esch et al. (2010). A phase separation in a water charged gasoline may occur during the cool-down of the tank content in mid-flight. Here another potential problem may arise, especially in future years, if automotive gasoline should be used uncritically and without at least an immediate pre-flight water content control: Since at present there is no normative upper limit of water content for the increasingly ethanol-admixed gasolines, only the absence of haze is required, some very competitive vendors may be tempted to deliberately exploit this boundary condition to a point where vehicles with their almost constant gasoline temperature will not experience any obvious disadvantage Esch et al. (2010).

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