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MIRCE Science approach to maintenance of microbial contamination of fuel tanks in COVID-19 grounded aircraft

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Abstract

Microbial contamination of aviation fuel tanks is a known physical phenomena to airlines that are dealing with it in accordance to manufacturer guidelines. However, as the disastrous COVID-19 pandemic has left aircraft grounded and scattered across airfields around the world there is a danger that contaminated fuel could cause undesirable consequences to a fuel system like:

clogging of fuel filters, corroding tanks, performance degrading combustion quality, as well as damaging the rubber components specific to the fuel tank, thus impacting the functionability performance of an aircraft. A full understanding of these mechanisms is essential for the determination of the most effective maintenance policy for testing the fuel of grounded aircraft. Thus, the main objective of this paper is to address microbial contamination of fuel tanks in COVID-19 grounded aircraft as a potential mechanism of the motion of an aircraft through MIRCE Space. Recommendations for the fuel contamination testing maintenance programme are presented in the paper, which should assist airlines to ensure that fuel systems of over 20,000 temporarily grounded aircraft are safe when the time comes for them to resume operations.

Key words

MIRCE Science;

microbial contamination;

aviation fuel tanks;

CODIV-19 grounded aircraft;

fuel testing maintenance programme;

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1. Introduction

The principal function of aircraft fuel tanks is to function as a wing and then as a fuel tank. Thus, the design of a wing structure does not allow a single simple sump, but it creates lots of difficult to drain water traps. While an aircraft is in regular operation, a system of specially shaped pipes is designed in the fuel tanks that mix any water back in with the fuel to prevent microbes accumulating.

Due to the global pandemic of corona virus COVID-19, around 80% of the world's fleet of commercial aircraft were grounded during most of 2020 creating conditions for the water accumulation in their tanks. The situation is even more critical during the summer months when the rising temperatures create conditions ideal for the growth of microbes. During the pandemic aircraft are on the ground all the time. Hence, the fuel system, the fuel, and the water get to an ambient temperature, which in most parts of the world in summer is over 30° C. In fleets that have not been treated with biocide the first signs of microbial growth begin to show after two to three months of storage.

The reduction in movement of aircraft during the COVID-19 outbreak has raised concerns over microbial contamination and the damage this can do to aircraft fuel systems, especially when they are in hot, humid regions that facilitate the rapid growth of micro-organisms.

Many of these aircraft have been in "active storage" with some fuel remaining in the tanks. Although that fuel is often treated with biocide, the threat of microbial contamination still exists. This is because fuel is warm for extended periods without being in flight and fuel is also static, so “hotspots” of contamination may occur that are very difficult to detect.

Experience teaches us that the storage and distribution of aviation fuel has “challenges” regarding the control and prevention of the growth ofmicrobes (bacteria and fungi) in fuel tanks. Presence of water enables microbes to grow and multiply in the fuel tank, and then to get transferred to other tanks and continue propagating. The contaminated fuel could cause undesirable consequences like: clogging of fuel filters, corroding tanks and performance degrading build up of deposits caused by the acids the microbes excrete which cause fuel to break apart and lose combustion quality. Thus, the main objective of this paper is to address microbial contamination of fuel tanks in COVID-19 grounded aircraft as a potential mechanism of the motion of an aircraft through MIRCE Space. Recommendations for the contamination testing maintenance programmes for aircraft scattered over airfields away from usual lab testing facilities are presented in the paper in order for operators to ensure that fuel systems of over 20,000 aircraft are safe when the time comes for them to resume operations.

2. MIRCE Science Fundamentals

According to MIRCE Science[1], at any instant of calendar time, a given functionable system[2] could be in one of the following two states [1]:

- Positive Functionability State (PFS), a generic name for a state in which a functionable system is able to deliver the expected function, performance and attributes.
- Negative Functionability State (NFS), a generic name for a state in which a functionable system is unable to deliver the expected function, performance or attributes.

In MIRCE Science a functionability performance of a functionable system is defined by the trajectory of its motion through MIRCE Space. Mathematically, it is three dimensional space containing functionability points. Each point is defined by:

- a functionability state that a functionable system could be found in,
- a probability of being in each of these states
- the instant of the calendar time considered.

The motion of a functionable system through MIRCE Space is generated by natural or human functionability actions, which are classified as:

- Positive Functionability Action (PFA), a generic name for any mechanism whatsoever that compels a system to move to a PFS.
- Negative Functionability Action (NFA), a generic name for any mechanism whatsoever that compels a system to move to a NFS.

MIRCE Science focuses on the scientific understanding of the mechanisms that generate functionability actions, positive and negative, which govern the motion of functionable systems through MIRCE Space [1]. The understanding of these processes, in MIRCE Science, is placed within the physical scale that provides the necessary level of understanding. That scale is ranging from the size of 10^{-10} m (Atomic System) to 10^{10} m (Solar System). Analysis and research performed in any “smaller scale” would not give sufficient granularity of observations, which could lead to the prediction errors.

Microbial contamination impacts the functionability of aviation systems through mechanisms such as microbiologically influenced corrosion (MIC), clogging of fuel filtration components, fuel deterioration, failure of aircraft fuel system instrumentation, and even stopping the fuel supply to the engines during flight. The study conducted by Hu, D., et al [3], concluded that, “the aircraft fuel tanks harboured various micro organisms, which utilised the aviation fuel as a source of carbon and energy.”

Microbial contaminated aviation fuel, if left untreated, can lead to costly damage to structures, potentially cost millions of dollars or a complete write-off in extreme cases. In normal operation, unscheduled aircraft downtime equates to loss of precious revenue, but also the possible additional pay-out for passenger compensation if flights are significantly delayed or cancelled.

3. Types of aviation fuel contamination

The three main types of contamination are:

- Water
- Particulate
- Microbial growth

Each of the above will be briefly addressed below.

3.1. Water

The chemical composition of aviation fuel allows water to be absorbed and held in suspension, either as suspended particles or in liquid form. The amount of suspended particles varies with the temperature of the fuel. Physical processes draw out some of the

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[1] MIRCE Science is a body of knowledge that computs the time evolution of opertionally defined functionable systems by subjecting natural and human actions to the laws of mathematics. www.mirceakademy.com (assessed 18.09.2020)

[2] According to Knezevic, a functionable system is “a set of mutually related entities required for delivering work that is considered done when a measurable function is performed through time.” [1]

water molecules that are suspended in the fuel and slowly accumulate them in the bottom of the fuel tank, whenever the temperature of the fuel decreases. However, whenever the temperature of the fuel increases, it draws moisture from the atmosphere to maintain a saturated solution. Consequently, temperature changes result in a continuous accumulation of water.

Water promotes corrosion in some components of a fuel system. If enough water is present, it can form ice crystals in low temperatures and clog fuel lines, filters, or components. This could interrupt or even stop the fuel supply to the engine. To prevent this, some aircraft fuel systems employ heated fuel filters or fuel heaters to eliminate the problem of ice crystal accumulation and others rely on anti-icing fuel additives.

3.2. Particulates

Almost anything can cause particulate contamination from rags and bugs to deterioration of fuel system components like corroded metal parts or deteriorated rubber of fuel cells and lines. Dust and sand can be introduced through openings in tanks and from the use of fuelling equipment that is not clean. Rust can be introduced through pipelines, storage tanks, fuel trucks and drum containers.

Other sources of particulates include airborne solids that enter through tank vents or slip past the seals of floating roof tanks, like pollen or solids entering through damaged hoses and filters (rubber particles and fibres).

3.3. Microbial growth

A microbial contamination of fuel could be caused by numerous different types and species of microorganisms. However, the following three are the main categories:

- bacteria that are typically small (1–5 microns) rod shaped or spherical cells; some can produce slimy extra cellular polymers;
- moulds that are filamentous micro-organisms that produce mats of growth at the fuel/water interface and on surfaces: they also produce resistant spores that enable the spread of contamination in the fuel phase;
- yeasts that are either filamentous or ovoid cells (typically 5 -10 microns across).

Moulds and yeasts belong to a group of microorganisms collectively known as fungi. All of these organisms are present in the natural environment and therefore can easily access the whole fuel supply chain. The microorganisms grow in water and feed off the hydrocarbons in the fuel.

The essential constituents that are necessary for the existence of microbes are:

- water, as essential surrounding for living
- fuel, as essential food source
- oxygen, as essential element for growth

Certain bacteria and fungi are capable of existing in water where it interfaces with the fuel. These micro-organisms use alkanes[3] and additives in fuel as food. They can propagate rapidly, while generating a sludge-like substance as a by-product.

The most destructive of the microbes that grow in the aircraft fuel environment is the fungus Hormoconis resinae[4], due to its size. Compared to single-cell yeasts and moulds, it produces far more biomass. It is the most common cause of microbial corrosion in aircraft fuel tanks.

4. Mechanisms of attack by microorganisms

Hendey [4] coined the name 'kerosene fungus' for the fungus that had been known as the 'creosote fungus' because of its association with creosoted timbers. It is usually referred to as Cladosporium resinae because this is the state in which it normally occurs in kerosene and soil. Interest in this fungus was first aroused, in the early 1960's, by reports of its occurrence in storage and aircraft fuel tanks containing aviation fuel. [5]

Lansdown [6] has specified problems related to the microbial growth in aviation fuel. These include filter clogging, fuel tank corrosion and failures of fuel pumps due to corrosion. Even, at that time, he concluded that, "It has now become apparent that microbial contamination is widespread in aircraft fuel supply systems, both on land and in aircraft carriers, where serious clogging of fuel system filters has occurred." The observed problems were spread worldwide, although the worse cases were experienced in the tropics.

Hazzard [7] reported that in 78% of all fuel samples from aircraft tanks tested in Australia the 'kerosene fungus' is the organism most frequently observed, whereas Engel and Swatek [8] stated that it was in 80% of all fuel samples examined in California, USA.

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[3] Alkanes are functional saturated hydrocarbons that form a chain with single bonds between atoms.

[4] Commonly known as the kerosene fungus. It utilises aliphatic and aromatic hydrocarbons, as well as alcohols and acids. Its growth can lead to serious bio deterioration of the fuel quality, the formation of sludge, and deterioration of pipe work and storage tanks, both in the refinery and at the end-user facility. [4]

Aviation fuel is mainly composed of hydrocarbons[5] with some traces of contaminants and additives. The major additive, found in high-octane aviation fuel, is a lead compound. Typically, it is a lead tetraethyl with an organic bromide used to prevent lead fouling. Other additives that are present in aviation fuel, but in much smaller quantities, are:

- anti-oxidants, which extend storage life and protect fuel systems by increasing resistance to oxidation
- anti-icing, which prevents icing of water in non heated aircraft fuel systems
- anti-static, which ensures that aviation fuel will not become charged.

Jet aircraft today use aviation turbine kerosene that in its natural state can dissolve up to 75 ppm of water, which extracts constituents from the fuel and might, for example, contain a few ppm of hydrocarbons and several per cent of anti-icing additive. These water extracts constituents from the fuel might contain a few ppm of hydrocarbons and several per cent of anti-icing additive, for example. Due to condensation, the actual amount of water present in fuel depends on variations of temperature and atmospheric humidity.

Different classes of hydrocarbons attack different microorganisms. For example, the 'kerosene fungus' can use kerosene as its sole carbon source. Between 20 and 50 percent of the carbon assimilated by bacteria and fungi is converted into cell substance, whereas the remainder of the carbon is converted to more highly oxidised compounds including carbon dioxide, organic acids, alcohols and esters. These compounds modify the environment. For example:

- the lowering molecular weight fatty acids would lower the pH of the aqueous phase making it more corrosive to metals.
- alcohols and esters increase the solubility of fuel in the aqueous phase., resulting in extension of the zone for optimum microbial growth. Consequently, micro-organisms that meanwhile had remained dormant, may now find conditions suitable for their growth, which is now rapid and oxygen is all consumed leading to anaerobic conditions.
- the presence of sulphate creates favourable conditions for the growth of sulphate-reducing bacteria, which produce fuel-soluble corrosive sulphide that can be carried with the fuel and cause corrosion of components of an aircraft fuel system.

Microbial attack is also manifested by the formation of sludge or solid matter that may clog downstream parts of the fuel system, particularly filters and screens. Although there is some doubt as to whether bacterial slime has sufficient mechanical strength to block filters, there is a little doubt that fungal mycelium can block filters, screens and even the drain points of fuel tanks.

Fungal growth may also become attached to the fuel tank walls and prove difficult to remove during cleaning maintenance tasks. Some rust inhibitors appear to function as nutrients for bacteria. The surface-active rust inhibitors reduce the interfacial tension of water and hydrocarbon, and thus increase the availability of hydrocarbon to bacteria that encourage rust and make slimes. Slimes generated hold rust in suspension that encourages bacteria, which encourage rust to make more slime.

5. Impact of Microbial Growth of Aircraft fuel system

The wide variety of environments and microbes means that every infestation is different and can cause a wide range of problems. For example:

- Bacterial films can interfere with sensors,
- Microbial mats can clog filters and pumps,
- Microbial growth can extract the plasticiser contained in seals, making them less flexible and leading to leaks,
- Fungi can spread filaments below the epoxy layer that lines the bottom of some fuel tanks, breaking it apart and creating debris that can block fuel filters.

All of these microbes tend to form by-products of metabolism that are generally acidic. Some of these organic acids are capable of attacking the aluminium structures aircraft are made of, whereas the other microbes can create sulphuric acid and sulphide ions capable of eating away at steel and copper.

5.1. Microbially Influenced Corrosion of Alloys used in Aircraft Fuel Tanks

Microbes have a preference to thrive on surfaces in a film of slimy growth, known as a biofilm. The action of microbes within biofilms on metal surfaces can result in Microbiologically Influenced Corrosion (MIC) of aluminium alloys in aircraft wing tanks. Typically, it is due to the accumulation of microbially produced acids, such as isocitric acid[6], within biofilms that have developed on the tank surface. MIC of aluminium alloys in aircraft wing tanks is

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[5] Compounds containing only carbon and hydrogen

[6] Isocitric acid, defined by a chemical formula $C_6H_8O_7$, is a structural isomer of citric acid, It is an intermediate in the citric acid cycle, which occurs in the metabolism of all aerobic organisms.

manifested by etching and/or pitting corrosion, both of which may progress at rapid rates.

The water permeability of epoxy-based coatings and primers, can also increase by microbially generated acids, exposing the underlying metal to corrosive attack. In the past, coatings and primers have incorporated chromates[7] to help prevent corrosion and some anti-microbial activities. Due to the current environmental consideration, chromates are not acceptable and are not used in modern aircraft.

5.2. Impact of microbial contamination on filters in the aviation fuel supply chain

Filters are used throughout the aviation fuel supply chain and on aircraft to ensure the fuel that reaches the aircraft engine is clean and dry. Filter Water Separators (FWS) are widely used in the supply and distribution of aviation fuel to remove both particulates and water. In under-used FWS units, microbes may proliferate in any water that remains on the outer sock of coalescer elements resulting in the formation of brown spots of microbial growth, commonly known as "leopard spotting". As this microbial growth develops on the downstream side of the coalescer, it can contaminate clean fuel passing through the filter. Even more, if heavy microbial growth develops on the surface of the filter, the biosurfactants produced by the microbes can impact the ability of the coalescer to remove water from fuel and thus disarm the coalescer.

Although microbial growth tends to be the most predominant at the bottom of the tanks at the interface between fuel and any water or as a slimy film of growth on tank surfaces, turbulence in a contaminated tank can disperse particles of biomass into the fuel. In severe cases this can result in unacceptable differential pressure, as filters become clogged. A major industry development was the decision of the Energy Institute[8] to withdraw EI 1583 Report[9]. A number of alternative technologies have been proposed as replacement, including FWS or Water barrier filters, combined with enhanced particulate monitoring. The long-term implications of this change on the occurrences of microbial growth and contamination remain to be seen.

5.3. Impact of microbiological contaminants on the quality of aviation fuel

Microbial growth may occur wherever any water accumulates in aviation fuel tanks and systems. The presence of water allows heavy microbial growth to take place affecting the quality of the fuel due to particulate contamination of fuel with microbial biomass, and contamination with by-products of microbial growth such as biosurfactants and sulphide.

If microbiologically contaminated fuel is loaded onto aircraft there is a possibility of serious operational problems. Consequently, industry best practices places a strong emphasis on the prevention of microbial growth in the fuel supply chain and in aircraft fuel tanks before it causes operational problems.

6. Impact of the COVID-19 on the contamination of fuel and fuel tanks in grounded aircraft

In the COVID-19 pandemic environment, thousands of aircraft are parked and the probability of fuel contamination is higher than normal. Fuel microbes thrive in heat and humidity, and if fuel becomes contaminated it can corrode fuel tanks and cause wing structure damage. Hence, fuel testing must be carried out more frequently in the current circumstances, especially on those aircraft standing idle in hot and humid places. [2]

Aircraft in tropical areas, much of Latin America, Africa, the Middle East, Southeast Asia and Australasia, are considered to be at higher risk of microbiological contamination, according to the International Air Transport Association (IATA). Tests that used to be done at least once per year now need to be done about every other week, according to Conidia Bioscience corporation[10], which develops fuel tests for various industries. In addition to increased testing, operators are ramping-up fuel tank borescope or visual inspections for aircraft in a temporary parked situation.

While operators or maintenance organisations run a grounded aircraft to make sure the systems are working, the aircraft uses some fuel. This can leave residue in the tanks, which can cause problems. Any moisture in the fuel tank, due to heat or humidity, can cause contamination, the fungi has the ability to stick to the tank, so even if the fuel is free of contamination, parked aircraft in hot or humid areas face increased microbial contamination, which requires extra inspections.

As the duration of the COVID-19 pandemic is unknown, ultimately the point could be reached where de-fuelling is required, especially if it's for

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[7] Chromates are harmful when powdered because the dust is carcinogenic.

[8] The Energy Institute is an independent professional organisation for engineers and other professionals in energy related fields established in 2003 in London, UK.

[9] EI 1583: Laboratory tests and minimum performance levels for aviation fuel monitors to be withdrawn at the end of 2020.

[10] https://conidia.com/industries/aviation/

disposal because it's been contaminated. In those cases some additional maintenance actions will be required because disposal of contaminated fuel is not something that is routinely done at airports. [2] The logistics of this process is rather challenging regarding the availability of resources like: injection carts, additives and the access to aircraft that are parked nose to tail on taxiways.

7. Microbial contamination related maintenance tasks

The best and most effective way of managing microbial contamination in aviation is prevention. Essentially, keeping fuel tanks clean is one of the best methods to avoid contamination. This prevention process can be divided into three parts namely[11]:

- Fuel monitoring program for the microbes: it involves periodic testing and sampling of the fuel, with the objective to minimise the problems through early detection of microbial growth. The appropriate industrial standards outline monitoring procedures that should be followed in test laboratories.
- Fuel system maintenance: the best way to prevent microbial growth in aviation fuel tasks is to reduce the exposure of the fuel to water. There are various ways this could be achieved9.
- Fuel treatment: a set of activities that should control the spreading of microbial growth. Removal of the biomass or the sludge that has already developed is also needed. When choosing a remover, several factors should be considered, namely:
- solubility of the fuel/water,
- compatibility with system components,
- compatibility with fuel and other additives,
- time required to kill the microbes, in accordance to regulatory approvals.

7.1. Fuel sampling

Regular fuel sampling can help reduce problems with microbial growth and freezing associated with water in the system. It also can also help identify particulate contamination.

The actual process of fuel sampling is a routine operation. Fuel is drained into a clear container filling it half way to two-thirds full. Holding it up to the light, it becomes possible to see any water or particulate contamination it contains at the bottom. Swirling the sample around to create a tornado-shaped vortex in the container can also help isolation of any contaminates. Any water or particulates will accumulate at the bottom of this vortex. A simple way to detect the water in the fuel is to add a few drops of food colouring to the sample. The food colouring will not mix with the fuel but will mix with water. If water is present, the colouring will mix with it. If no water is present, the dye will just settle in the bottom of the container. This is a good test to ensure that the whole jar is not just full of water.

Fuel samples taken should be clear and clean. A fuel sample should never be taken immediately after an aircraft is fuelled, as the fuelling action causes the water and particulates to become temporarily suspended in the fuel. A good time to take a fuel sample is prior to the first flight of the day.

7.2. Topping up fuel tanks

A good practice for operational aircraft is to top up aircraft tanks at the end of each flying day. Aviation fuel has a tendency to absorb moisture from the atmosphere. Hence, with less air in the fuel cells, the lower rate of absorption.

A good practice for grounded aircraft it to ensure for the entire parking period a fuel quantity in each tank of minimum 10% of the tank capacity. However, sometimes to prevent aircraft from leaving its parked position under the effect of high winds the weight of parked aircraft is increased by uploading a higher fuel quantity in the tanks. [11]

7.3. Inspection of fuel system screens and filters

Screens and filters within a fuel system should be inspected and cleaned on a regular basis, as this action ensures that any excessive particulate presence is investigated to the source of the contamination. Regular cleaning ensures that the filter elements do not become clogged.

The following two possibilities exist with clogged fuel filters, thus:

- In filters with a bypass system, once the filter is clogged enough to cause the differential pressure to activate the spring mechanism, the fuel will no longer be filtered, but will instead bypass the filter altogether, which could cause failures of components down the line.
- In non-bypass filters, the differential pressure that is built up could rupture the filter element and possibly generate even more particulate contamination.

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[11] https://fuelandfriction.com/trucking-pro/microbial-growth-in-fuel-prevent/#:~:text=%E2%80%9C%20Fuel%20tanks%20and%20other%20storage%20systems%20are,can%20also%20cause%20tank%20corrosion%20and%20fuel%20spoiling (accessed 5.8.2020)

8. Frequency of fuel testing for microbial contamination

In normal operation, aircraft may fly up to eight times per day. At altitude, temperatures way below 20 degrees C stop microbiological growth. However, the frequency of flights during the COVID-19 outbreak has dropped significantly and subsequently, the risk of microbial contamination has greatly increased for aircraft in active storage with some fuel still in their tanks.

Accurate testing at the regular intervals enables maintenance engineers to determine the correct testing frequencies, with the objective of being able to intervene at the earliest and least costly opportunity, well before the contamination is classified as "heavy" and requires intensive remedial actions. [10]

According to [11], if heavy contamination levels are reached, a full clean of a three-tank aircraft can cost in excess of $100,000 plus three or four days of lost revenue while the aircraft is on the ground. In total this could be anywhere up to around $2 million.

Airlines manage the risk of contamination through periodic testing of fuel. The interval between tests will depend on the aircraft manufacturer's guidelines and a risk assessment carried out by the airline. The risk is higher for aircraft located in hot, humid regions where the micro-organisms can really thrive.

In the Asia-Pacific region, for example, the time from cleaning a fuel tank to heavy contamination can be as little as three months. Therefore, testing every month is not uncommon. At the same time, in colder regions, such as Scandinavia, the risk assessment may mean testing once every 12 to 18 months may be sufficient.

Normally, EasyJet is testing aircraft fuel for microbial contamination once per year, but that frequency for the COVID-19 grounded aircraft has been increased to once every 14 days, for each of the 21 currently grounded locations instead of one. For all operators, the COVID-19 grounded aircraft require more frequent testing that means more samples to be sent to well established laboratories, which is where many test providers test fuel samples. To take fuel test samples, send them to labs, and wait for the results typically takes 4-10 days. Today, in the COVID-19 driven environment forces aircraft to be scattered around airfields away from home bases, the process inevitably takes longer and requires more resources. Also, it is a logistical problem, as these samples also need to be transported in a controlled environment so that micro organisms present in the sample are not compromised, leading to a false test result. Even further this is compounded by travel restrictions in various countries due to the pandemic.

In summary, many airlines are finding that the increased frequency of testing the fuel of grounded aircraft across multiple airfields very difficult or even physically or financially impossible. Even if fuel has been treated with biocide, the biocide is only effective on the amount of fuel actually in the tank, which may be only 10 percent of full payload, contamination levels still need to be monitored to ensure it is still working.

9. Conclusions

Microbial contamination of aviation fuel tanks is a known physical phenomenon to airlines that are dealing with it in accordance to manufacturer guidelines. However, as the disastrous COVID-19 pandemic has left aircraft grounded and scattered across airfields around the world there is danger that contaminated fuel could cause undesirable consequences for a fuel system. Thus, a full understanding of these mechanisms is essential for the determination of the most effective maintenance policy for testing the fuel of grounded aircraft.

Microbiological contamination of fuels can cause operational problems, such as corrosion of metallic structures, fuel quantity indication problems, and blocking of the scavenge systems and fuel filters during flight. There are a number of signs that will indicate that fuel tanks are contaminated such as evidence of contamination of fuel filters, discoloration of sump sample, blocking of fuel injectors, erratic/inaccurate fuel level readings. For example, erratic behaviour of the fuel quantity gauging system can be a sign of microbiological contamination, as most gauging systems are capacitance based and the microorganisms have a different capacitance than fuel.

While aircraft fuel contaminants can prove difficult to control, employing a solid fuel quality monitoring system through a series of tests will ensure that aircraft fuel stays clean. Whether in the aircraft or stored in a long-term facility, it is important to understand the potential of microbial growth, taking appropriate measures to search for it, and then removing any sludge, thereby keeping the fuel microbial free is an integral part of preventive maintenance process of any airline. As the duration of the COVID-19 pandemic is unknown, ultimately the point could be reached where de-fuelling is required, especially if it's for disposal because it's been contaminated. In those cases some additional maintenance actions will be required because disposal of contaminated fuel is not something that is routinely done at temporal storage facilities. The logistics of this process is rather challenging regarding the availability of additional resources, like: injection carts, availability of the additives and also simple things like being able to access aircraft that are parked nose to tail on airports runways.

Recommendations for the fuel contamination testing maintenance programme are presented in the paper, which should assist airlines to ensure that fuel systems of over 20,000 temporarily grounded aircraft are safe when the time comes for them to resume operations.

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