THE GAMGRAM

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DEALING WITH WATER IN AIRCRAFT JET FUEL

NOTE: To clarify and address comments received after the publication of the original GamGram 71, we have revised this GamGram and changed the number to avoid confusion.

It is not the purpose of this GamGram to determine the choice you make as an operator, but to illustrate the present situation, the pluses and the minuses, the reality of the situation.

This GamGram is intended to present the current situation our industry faces in regard to dealing with water in jet fuel as of the date of publication: September 2020. We suggest that before you read this GamGram, you review GamGram 63, "**Detecting Water in Aviation Fuel Systems**." The two may sound similar, but they are quite different.

Jet fuel can have water in two forms: free and dissolved. Just as with humidity in air, water can be dissolved into the fuel. As the fuel temperature changes, it can hold more or less water dissolved into it. At higher temperatures, jet fuel can hold as much as 100 ppm (parts per million) of dissolved water. At low temperatures (high altitude), much or all of this water can condense out much as water condenses out of air, as haze (fog) or as liquid water.

This dissolved water, coming out of solution in the fuel and becoming free water, can be enough to cause, and has caused, a variety of problems. One being a recurring problem in drain valves freezing on a number of aircraft in recent years and, debatably, even the crash on one Boeing 777.

The two sides of the 777 crash debate are:

A. A commonly discussed theory is that the 777 in question had been refueled with a considerable amount of free water from a poorly maintained filter separator and that this water is what clogged the parts of the fuel system that caused both engines on the 777 to not perform properly just before landing.

B. The other position is based on the Official AAIB accident report. This report concludes that the water came out of solution due to the flight being a long one in very cold air. From the Page 176:

   "Ice had formed within the fuel system, from water that occurred naturally in the fuel, whilst the aircraft operated with low fuel flows over a long period and the local fuel temperatures were in an area described as the "sticky range."

   The report goes on to say: *"Further, the likelihood of a separate restriction mechanism occurring within seven seconds of that for the right engine was determined to be very low."*

   So the investigators were confident that the water, which became ice and clogged the fuel systems of both engines, came out of solution in the fuel, and refueling filtration was not the cause of the problem.

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The report also showed that fuel removed from the damaged aircraft showed 35-40 ppm of TOTAL (free and dissolved) water present, which would be within the normally expected range for dissolved water and which was similar to that found on other aircraft that had flown similar routes. So there was no evidence to indicate that gross water was present as far as the investigation could find.

IMPORTANT! The problem component on that particular engine model was identified and corrective action on all similar models was taken to prevent the same issue from recurring.

Jet (or turbine type) engines themselves can handle quite a bit of free (liquid) water, but that aircraft fuel systems are sensitive to water and ice is a particular concern. We cannot remove the dissolved water because filters cannot do so. Our job has always been to keep free water levels as low as possible.

The primary means to remove free water, from the refinery to the terminal, all the way to aircraft is the filter separator. These vessels filter out dirt and separate free water. Water, being heavier than the fuel, falls to the bottom of the vessel. The first stage filter element type is the “coalescer element.” These elements remove dirt and “coalesce” (gather together) tiny water drops into larger ones, which then cannot pass through the second stage of the vessel, which has “separator elements.”

This free water collects in a low point of a filter separator vessel, called the “sump” - where a float or probe senses if excessive water collects - and stops the fuel system flow until that water is drained.

For decades, most refueler trucks (with tanks) have used filter separators while most hydrant carts (or “hydrant servicers”) have used monitors. Hydrant systems pump fuel underground to the airport gate and the hydrant cart simply dispenses the fuel directly to the aircraft.

Modern filter separators, properly equipped and operated, have never put significant amounts of water into an aircraft, as far as we know. They rarely pass more than 3-4 ppm of water. They are resistant to surfactants (surface active agents such as soaps and detergents).

Even when disarmed, filter separators tend to remove most of the water and this water collects in the sump, with the water float or probe stopping flow. Later in this GamGram we will explain why we are confident in this opinion. But early filter separators were not as highly reliable and so a secondary filter was devised, the “monitor” type filter. Early monitors were also called “Go-NoGo” or “Fuse” type filters.

Then a new material became available, Super Absorbent Polymer, or “SAP”. This material is commonly used in baby diapers but also removes water from fuel effectively. By adding layers of filter media, these monitor vessels were deemed good enough to replace filter separators. Due to being reliable, small, light-weight and inexpensive, they were often used in place of filter separators when flowing into plane, especially on hydrant carts.

So this is how things were done up until recently. A few years ago, some SAP material got into aircraft and caused engine control problems. As a result, the industry has been working on an alternative to SAP monitors.

It is not practical to replace monitor vessels with filter separators on most hydrant carts. The problems are space and weight. So two alternatives to retrofitting these carts with filter separators have been pursued:

1. Drop in replacements for SAP monitors
2. Using a dirt-only filter elements in the monitor housing and adding an electronic probe to detect water.

The advantage of a filter that removes water over a dirt-only filter and a sensor (which shuts you down if there is excessive water) are obvious. With a water removal filter, you get (virtually) no free water into the aircraft. With a sensor, you can pass free water to the aircraft if the quantity/volume of water is relatively low. These sensors do not sense water accurately under 15-20 ppm. In the real world, water droplet sizes vary and an optical sensor cannot accurately tell the difference.

If a filter separator fails, it will still stop most of the water but if an inline water sensor fails, any and all of the water in the fuel goes to the aircraft.

The great thing about SAP filters is that, unlike filter separators, they could not be disarmed by surfactants. Like filter separators, they never put more than 3-4 ppm into an aircraft if properly maintained and operated. So if water is present, virtually no free water reaches the aircraft.

The bad thing is that it is possible for some SAP can go downstream and potentially cause a problem with fuel flow controls to the engines. Although this is rare, NO engine or aircraft manufacturer approves the presence of SAP in the fuel, at any level. It is a contaminant. This is why the industry requires a 15 psid shutoff on monitor vessels.

The MOST important point we want to make in the GamGram is that it is our job to stop as much FREE water as possible from reaching the aircraft.

If you do use a water sensor in place of a filter separator or monitor, the electronic water probe is designed to warn you if 15 ppm of free water or more is getting to the aircraft and stops fueling at 30 ppm or more.

But recently, the JIG standard has been changed to shut down at 15 ppm and if a check of the fuel seems fine, to restart fueling. We believe this is because the higher level of water may be a temporary condition. If the sensor goes off again, then they become concerned. The A4A-ATA103 does not have this exclusion.

When you exceed the set limit, you have to stop fueling and then flush the water from the hydrant system (or truck) before fueling can continue. This may not be simple.

But remember, all the dissolved water is going to the aircraft, plus as much as 10-25 ppm more than would pass through a properly working filter separator or monitor. Is this extra free water a risk? We simply have no idea if this potential for extra free water reaching the aircraft can be a significant problem and that is why some people in the industry are concerned. It is a good idea for the JIG standard to reduce the investigation level from 30 to 15 ppm, certainly.

Others say that this trace water being a problem is unlikely. They believe that most hydrant systems are dry and systems that aren't dry - simply need to be maintained better. People who operate systems that are not dry (we hate to say "wet") disagree. They say that other factors cause systems to generate free water, such as system design, humidity and temperature change. Fuel changes temperature constantly with atmospheric change and ground temperature.

Historically, to detect if free water was in fuel flowing to the aircraft, Chemical Water detectors were used. These simple, inexpensive devices detected free water at 20-30 ppm. The accepted limit was 30 ppm. The most common CWDs today are the Shell Water Detector and the Velcon Hydrokit. Several more manufacturers are listed in JIG and ASTM Manual 5 including the AutoDis and Casri.

It may surprise you that CWD testers, while widely used around the world, have never been widely used in the USA, commercially or in the military. Simply checking filter sumps and checking differential pressure (DP or pressure drop) was all we have done here to look for water. We have a very good record, even at airports with "wet" airport fuel systems.

No device, which is only a spot check, can positively detect filter separator deterioration or failure, if water is not present at the filter vessel inlet. So it is desirable to have a sensor that detects if a filter separator is disarmed, passing over 6-10 ppm of water. Such a device is not yet available. 6ppm is 6/10,000 of 1%.

No one is certain where the 30 ppm limit for free water came from, but according to an old expert, it was the point where someone with very good vision could just begin to see haze in a large sample container. But regardless, the 30 ppm limit did not come from the aircraft manufacturers and was not based upon the normal amount of water that would pass through the filters and into the aircraft.

What are the present options and what is coming in the future? Presently, there is no simple, ideal solution. We need to make a point here, every option always carries different costs and different concerns. We do not address costs in the GamGram, we only address the technical issues. In addition, every location is different. For example, if you do find water periodically in your system, this is different from if you don't.

All the options that we have today are:

1. We can continue to use SAP filters as safely as possible for the time being. This is done by making sure a differential pressure switch stops flow if DP exceeds 10 to 15 psid. This is not in keeping with the EI standards after January 1, 2021. (EI is the Energy Institute, formerly the Institute of Petroleum. It is in London and writes several commonly used equipment standards for the petroleum industry, which used to be written by the API.)
2. We can install a Faudi EI1598 AvGuard water sensor (to EI-1598) and dirt-only filters. This is the choice Shell oil company has taken. Some companies feel this is the best solution, because they want to avoid the use of SAP filters and possible engine control issues. Others are nervous for the reasons stated above, trace water can get the the aircraft, as well as whether water in a hydrant system can shut down fueling, because if a sensor does "go off", flushing could mean downtime for a number of pits.
3. We can use filter separators (to EI-1581) for into plane refueling. This is fine if you already have filter separators on your vehicles, but in most cases it is difficult or impossible to retrofit a filter separator to a vehicle due to their size and weight. But it is a good option when buying a new vehicle.

But it isn't a bad idea to see if your vehicle can accommodate a modern filter separator if you have the room and your chassis can handle the extra weight. In the long run, this may be more cost effective as well. Not to get into the cost aspect too much, but this may be a factor.

Coming options:

1. Velcon is beginning field testing of a new approach, the "Barrier" filter. It has already passed all the laboratory testing. This new filter has the advantage of being a true drop-in filter. By that we mean that is requires no modification to the vehicle and **removes ALL of the water**. In testing so far, it has passed all of the requirements, the only issue has been shorter life on some field tests. BUT, **is it better to remove all water** and perhaps have a shorter element life? Could putting in finer (upstream) filters feeding your hydrant system lengthen the life of these elements if you do have a dirt problem? Note, the Barrier doesn't "plug-up" with water, it removes the water to be drained off. It can only plug on dirt.
2. Facet has a "Water Capture" drop-in replacement element under development which works exactly like an SAP element, but with a different technology. But EI has not yet set a standard for it to be tested to. So we have no idea when or if this new element will be available. Once a standard is established, it takes time to pass all the tests, as much as 2 years.

3. We are not aware of every project being worked on, and manufacturers working with EI and other authorities may have products in development which are not yet publicly known. We suspect that they do.

But are filter separators ideal?

What we have learned at two major airports over the past 40 years is interesting. But first, you need to know that these airports have supplied over 2 billion gallons or 7.5 billion liters a year, combined. They both receive fuel through multi-product pipelines, meaning pipelines that carry diesel, gasoline, heating oil and jet fuel. This means they are more likely to get contamination from other fuels. They are also not modern or “dry” systems. They do tend to find trace water in the system regularly.

Both airports have filter separators and monitors on all hydrant carts.

1. Never has an aircraft at either airport been contaminated with water from the fuel. So the filter separators in the fuel farms, hydrant systems and hydrant carts (plus the monitors) have stopped the water. Periodic checks were run with the AquaGlo and have confirmed this for over 4 decades.
2. On these hydrant carts with monitor vessels mounted downstream of the filter separators , they have never had to change elements in a single monitor vessel due to water collecting and creating high differential pressure (15 psi pressure drop)

From this we conclude that this shows that filter separators stopped all of the water, all of the time. The monitors were not needed. So we conclude that modern filter separators are very resistant to surfactants.

The important point here is that for decades, aircraft at all airports with filter separators and/or with SAP filters virtually never saw even 5 parts per million of free water over the course of a refueling, except in very rare cases. There have been events, when the water controls did not work due to poor maintenance and free water got onto aircraft, but even those cases were very rare.

In our opinion and that of many people in the industry, using a water sensor and not using a water removing filter of some kind will result in more free water getting into aircraft when water is present, but we simply do not know how much. At very dry airports, this is less likely to happen, but at “wet” airports, many people believe that it is to be expected.

This part of the fuel community feels that it stands to reason that in wet systems, or dry systems that experience water for some unusual reason, water can be present in the flow going to the aircraft and an electronic water sensor which warns at 15 ppm and alarms at 30 ppm will allow 1-15 ppm of water through to the aircraft, if that water is present. Even if the electronic water sensor alarm is set for 15 ppm, more free water can reach the aircraft than before.

But what about the continued use of SAP monitors? Is there more risk in this than in getting more water into the aircraft? This risk is greatly lessened by the use of a 15 psi DP switch as is required today by JIG, A4A, and IATA. We must leave this question to the aircraft manufacturers and operators. So there is debate, as there should be when no clearly ideal solution is available.

It is also important to mention that the industry standards apply not only at large hydrant systems at major airports, but to ALL refueling locations from large ones all the way down to tiny systems for fueling helicopters from small tanks or even drums. What are they to do?

As of January 2021, the EI “oversight and the approval program” for the EI1583 SAP monitor standard (for SAP filter monitors) will end. At that time, what to do is up to “the operators.”

Continued use of SAP filters is necessary. Why? It is impossible for every location with SAP filters to replace them with dirt filters and sensors or with filter separators in the time allowed. Even if you choose to use Barrier elements, which are not yet approved, getting enough of them made will be impossible in the time allotted. So operators will have to continue to use SAP filters into the future, at least in most locations.

Especially at the smaller locations, the electronic water sensors are not a viable alternative for everyone. Barrier type elements, or other alternatives such as converting to filter separators, may be a better choice. Barrier elements did pass all the EI laboratory tests and passed no water in those tests or in preliminary field testing. So element life in regard to dirt holding capacity does not appear to be a safety issue. Even if they do not last 12 months in high though-put locations, it appears that, at least for small locations, the Barrier filter may be a better future solution.

There is some small risk in using SAP filtration, even with a 15 psi DP switch to stop flow. SAP is not approved to be in the fuel reaching the aircraft. But there is also an unknown risk of using dirt-only filters and water sensors and passing more water to the aircraft. Others can debate based on the costs of the different approaches, company policies and opinions.

So where is the industry now? On vehicles with filter separators, there seems to be no concern.

Another concern is that these electronic sensors are not capable of being tested or calibrated in the field. This is highly unusual for our industry. Quality control related equipment is usually capable of field calibration or at least of checking operation. We have just been advised that Faudi is working on this, but we have no details.

We will update this GamGram as changes take place.

But the important point to be made here is that WE MUST NEVER RELY ON EQUIPMENT. If excessive free water reaches an aircraft, it is not only a problem with equipment, IT IS THE RESPONSIBILITY OF THE PEOPLE OPERATING THE EQUIPMENT.

It is human nature to rely on equipment, WE MUST NOT DO THIS! All of your periodic checks MUST be done and every effort made to keep free water out (rain, condensation and ground water).

EQUIPMENT FAILS. We must be forever diligent and NEVER rely on the equipment.