Australian Government
Civil Aviation Safety Authority

AIRWORTHINESS BULLETIN

Water Contamination of Aviation Fuel (AVGAS / MOGAS)	**AWB** 28-008	**Issue** : 2
	Date : 8 March 2016	

1. Effectivity

Aircraft using AVGAS or MOGAS fuel.

2. Purpose

To alert operators, pilots and maintainers with updated and more comprehensive information regarding the main causes for the fuel system becoming contaminated by water which typically results in loss of power, rough running and engine failure.

3. Background

An analysis of defect reports and accident investigations shows that there are five main causes of loss of power and engine failure due to water in the fuel; water entering the fuel tank via faulty fuel cap sealing; water contaminated fuel being pumped into the aircraft fuel tank during re-fuelling, and poorly executed post-refuelling / pre-flight water checks, compounded by unintended water retaining ridges in the bottom of fuel tanks, and flawed water drain location. The wreckage pictured below is the direct result of not identifying one or more of these causal factors and taking appropriate action.

Figure1.

Source: Australian Transport Safety Bureau (ATSB Report AO-2012-083)

Shortly after take-off, the aircraft pictured opposite (Figure 1) lost power and clipped a tree during the subsequent forced landing.

The day before this flight, the aircraft was re-fuelled with 20L of AVGAS from a previously opened 200L (44 gallon) drum.

Despite the pilot taking fuel samples to test for water contamination, the accident investigation team found a considerable amount of water in fuel samples taken from a number of locations in the aircraft fuel system - and in the drum of AVGAS.

The hand pump used to transfer the fuel from the drum of AVGAS to the aircraft tanks was not fitted with a filter.

This AWB will discuss each of the key causal factors and seeks to show how a failure in one of the following components of the fuel system can have an unanticipated, unsafe effect on another.

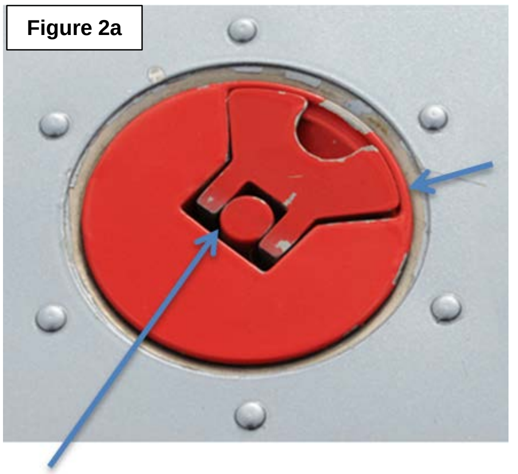
Filler Caps & Receptacle

Reports of engine failure due to abnormal amounts of water contamination in small piston powered aircraft fuel tanks typically follow heavy rainfalls, where the aircraft has been parked outside, or after washing. Investigations usually find that water has entered the fuel tanks via poor fitting or unapproved fuel caps, incorrectly adjusted fuel tank cap latches, failed fuel tank cap seals and / or damaged and distorted tank filler necks and caps.

Flush fuel caps

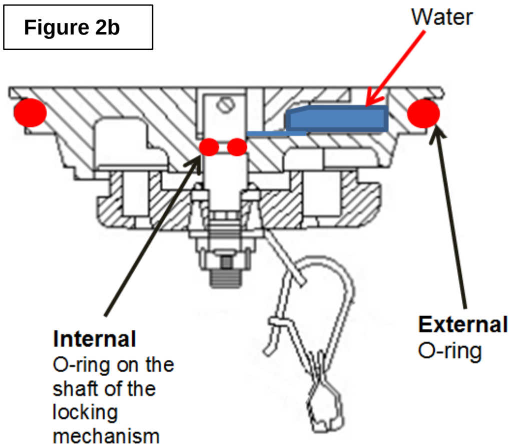
A deficient seal between the cap and tank filler neck permits water to enter the fuel tank, and allows fuel to be siphoned overboard via the cap in flight. Internal and external O ring seals can lose elasticity, perish and fail (Figures 2a and 2b). The final latch action should clamp the cap firmly into the filler neck and 'snap' fully flush on closing without any 'spring back'. The latch cannot be 'adjusted' to compensate for adverse wear on the latch cam or bearing plates (Figure 3).

Figure 2a



Water can enter the fuel tank via a defective external or internal O-ring. Water collects in the handle cavity of flush mounted fuel caps and can enter the fuel tank via a defective internal O-ring.

Figure 2b



(Adapted from the Beechcraft Baron 55 and 58 Maintenance Manual 28-10-00-201.)

Beechcraft require a periodic fuel cap latch opening pull test. If excessive force is required to operate the latch, this may also be an indication that the locking shaft is binding due to corrosion following failure of the internal O-ring. (Figure 3).

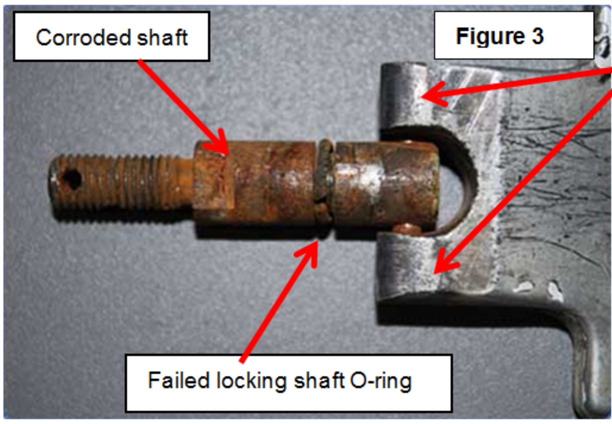


Figure 3

Note the corroded shaft and worn latch handle bearing plates (or cams).

When the handle bearing plates become excessively worn, the cap latch will not ‘lock’ and sit flush, and the cap is not adequately sealed against fuel or water - or for flight.

Fuel tank caps are aircraft components and are required to be installed and maintained in accordance with approved data. Some aircraft manufacturer’s data may list part numbers for filler cap O-ring seals, but may not provide any approved data for repairing and adjusting the cap. *“The lack of specific original equipment manufacturer inspection and maintenance guidelines for flush-mounted fuel caps can result in discrepancies such as deteriorated cap seals (O-rings) to remain undetected, thereby increasing the risk of water entering aircraft fuel cells, which can ultimately contribute to loss of engine power”* (Safety Information Letter 4/2009 Transport Safety Board of Canada).

The aircraft manufacturer’s maintenance instructions typically require an inspection of the fuel cap external seal every 100 hours/12 months, but usually there is no inspection to determine the condition of the internal seal on the shaft. (Refer Figures 2 and 3). Cessna have developed detailed guidelines for inspection and maintenance of flush mounted fuel caps (Service Information Letters SE80-59 and SE82-34, which are mandated in the CASA Cessna 100 and 200 Series Airworthiness Directives (AD). Some fuel cap OEMs consider their fuel caps to be a return item if repair, including O-ring replacement or overhaul is required.

Expanding 'plug' fuel caps.

This type of cap sits in a depressed aluminium ring (Scupper) under a hinged fuel cell filler access cover which, when closed, is flush with the top wing skin to reduce drag. As the latch on the top of the tank fuel cap locks down, it shortens the length of the assembly and in so doing, expands the rubber plug section into the fuel tank filler neck for security and sealing. (Figure 4)

While slight wear on the cam (circled) may be compensated for by "larger" adjustment, the over-centre cam latching and locking function can be lost due to adverse cam wear.

The temptation is to adjust the cap for cam wear so that the latch will go 'down' and allow the outer hinged cover door to close.

Such action can result in a loose tank cap. The latch should always have a clearly defined over-centre lock action with the cap firmly sealing the fuel tank filler neck.

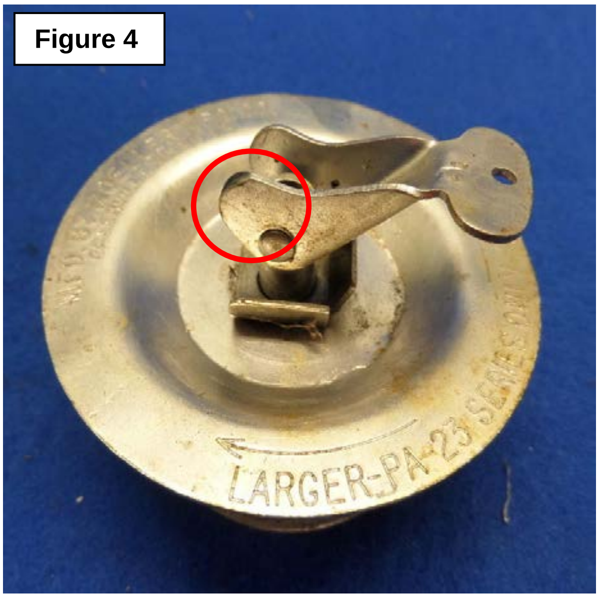
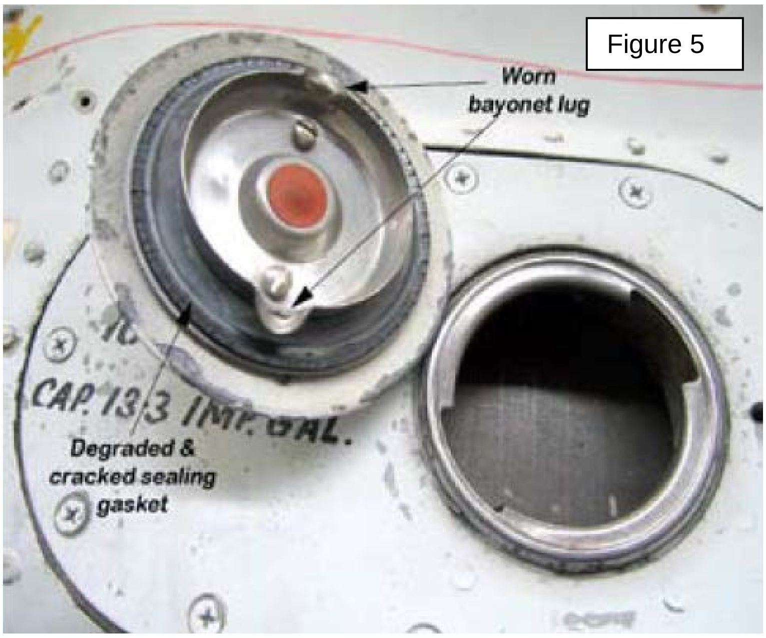


Figure 4

The hinged door which covers this type of fuel cap has a gasket to help prevent water entering the cavity between the cover and the recessed fuel cap. Such designs also incorporate a scupper drain, to drain any water which may collect in the cavity around the cap. Should the fuel cell access cover seal be in poor condition and the scupper drain become blocked (e.g. by a wasp nest) or otherwise unable to cope with the volume of water in the event of a sudden downpour, water will collect in the scupper and cover the fuel cap. Any water sitting at the edge or on the cap can enter the tank.

Protruding style fuel caps

A fatal accident in the UK involving a Piper PA-38-112 Tomahawk aircraft where the engine failed during initial take-off, has been attributed by the UK Aircraft Accident Investigation Board (AAIB) to the fuel tanks being contaminated by water due to defective fuel cap seals. AAIB Bulletin 11/2006 G-BYLE EW/C2005/10/04



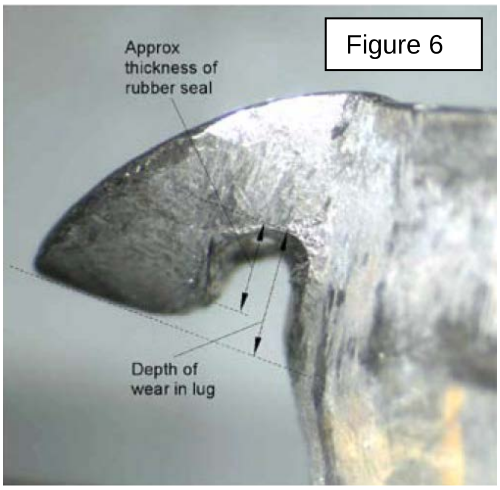
The defective Piper PA-38-112 Tomahawk Fuel Cap. Note the wear on the bayonet lugs. See figure 6.

Prior to the accident flight, the aircraft had been parked outside during heavy rainfall.

The AAIB investigation found that:

"Deteriorated fuel cap seals and inadequate locking mechanisms rendered the sealing function of the fuel cap ineffective, allowing water to leak into the fuel tank".

This design relies on two very thin and stiff circumferential springs behind the thin seal to ensure the two locking tabs in the cap remain firmly engaged in the locking detents in the tank and pressure is maintained on the seal when the cap is closed. The bayonet lugs were badly worn and the seal badly degraded.



Deterioration of the seal and/or free play between the cap and the tank when the cap is installed is reason for rejection.

EASA Safety Information Notice No.: 2008-08 dated 07 February 2008 also refers.

Fuel caps – General

Fuel tank filler cap security and sealing is of critical importance, not only to stop water entering the tank, but also to prevent fuel in the wing tanks from being siphoned out of the tank in flight due to the decreased air pressure on the top of the wing (lift), relative to the ambient air pressure inside the tank. Rubber fuel cells are prone to collapsing upwards from the bottom as fuel siphons out, because in addition to the securing 'buttons' or 'snaps' the top of the rubber fuel cell is secured to the top of the wing fuel tank cavity by the ring of bolts in the access and filler cover. As the flexible tank contracts in this way, it can have at least four effects:

1. The fuel is kept at or near the top of the tank near the leaking cap, so that siphoning continues until most or all of the fuel is lost overboard.
2. The float of the fuel tank quantity gauge can come into contact with and be supported - or even raised - by the rising the tank liner bottom. The cockpit fuel quantity indicator may continue to show full or nearly full, despite the loss of fuel.
3. Loss of fuel via the fuel tank cap - particularly a fuel cell with a flexible rubber liner - is often not detected until the contents are almost, if not entirely, lost overboard and has been the cause of forced landings.
4. In the event of a safe landing, and the pilot is unaware of the fuel loss, the distorted tank can be filled up to the neck, but the tank may not re-shape itself, reducing the volume of the tank. If the fuel quantity indicator float is sitting on a high bump or wrinkle from the tank bottom, the fuel gauge also provides a false indication.

Installing a non-vented fuel cap where a vented cap is required can have the same effect on the fuel cell as a leaking cap. See "*Honey They Shrunk the Fuel Tanks*". FSA September – October 2001. A blocked vent system can cause a solid wet wing fuel tank to be crushed by differential pressure created by engine fuel pumps as they draw fuel from the tank, and local atmospheric pressure.

Whenever a defective fuel cap seal is detected on a fuel tank with a flexible rubber cell, in addition to replacing/repairing the cap, inspect the interior of the rubber tank liner to ensure that the liner conforms to the cavity, paying particular attention to the bottom of the liner to ensure there are no distortions that will reduce the capacity of the tank, and that there are no wrinkles which can act as a dam and hold water away from the drains in the tank liner.

CASA has also mandated by AD, Cessna SIL SE 84-4 and SIL SE 84-9 Rev1 (see AD/CESSNA 180/69) requiring repetitive inspection of bladder type fuel cells for wrinkles and purging water contamination from the tank. CASA has also mandated Cessna SIL SE 82-34 (see AD/CESSNA 206/39) requiring specific fuel cap inspection procedures which include functional pressure testing for certain Cessna aircraft.

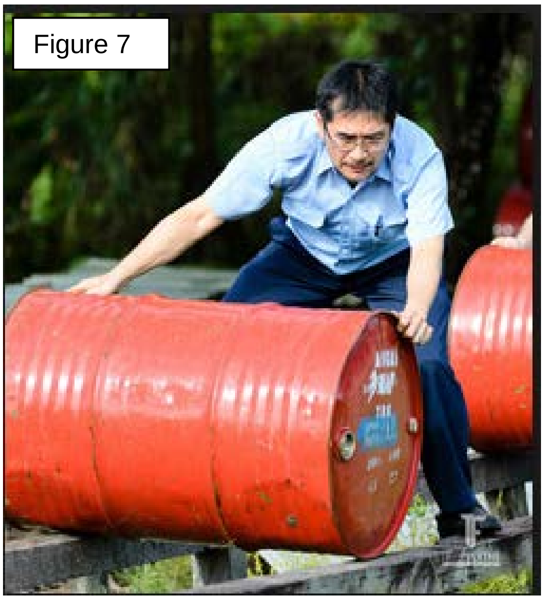
Water Contamination Caused by Refuelling

Always suspect that the fuel about to be loaded into the aircraft could be coming from a container which is contaminated with water, rust, dust, paint flakes and sludge. This includes drums; jerry cans; any fuel storage tanks and delivery trucks.

Drum Stock

The major aviation fuel manufacturers provide aviation fuel storage and fuelling guides which reflect world-wide standard practice and which should be followed. CASA Civil Aviation Order (CAO) 20.9 contains basic fuelling requirements, and general drum refuelling procedures can be found at CASA Safety video – Drum refuelling**.**

Safety precautions for using fuel from drum stock typically include only using fuel from those drums which have their contents clearly identified by the fuel manufacturer's markings and with original seals intact.



Fuel drums should be stored on their side with the big and small bungs horizontal (9 o'clock & 3 o'clock position) and under shelter.

If drums are stored on end (upright) in the open there is a strong possibility that water will collect in the head of the drum and subsequently be drawn into the fuel drum via the sealed bungs during the normal day/night - hot/cold temperature fluctuation.

Source: Fuel for Life/MAF Canada

Reject fuel from any drum if the seals are broken, or if the fuel is past the displayed expiry date. Aviation fuels have a comparatively short storage life. Using fuel past the expiry date may result in unpredictable engine performance.

When fuelling from drums, tip the drum on end, chock the bottom so that the larger bung is on the high side, and allow the fuel to settle for at least 30 minutes.

Test the fuel in the drum for water at the lowest point using a draw-pipe and water detecting paste. The fuel pump used to extract fuel from the drum should be equipped with a micro-filter, preferably with a water sensitive filter element, and a drainable sump.

Manually operated fuel pumps are recommended. Replace all drum bungs & caps after refuelling to contain hazardous vapours which remain even when the drum is empty.

Jerry Cans

Fuelling aircraft from jerry cans, a common practice for remote helicopter operations, is considered completely outside the control of any fuel manufacturer's quality system, and represents a considerable risk to operators and pilots. Fuelling from jerry cans requires additional vigilance, because the container is very likely to be contaminated with water, paint flakes, dust and debris. Every effort should be made to ensure that only clean, dry fuel of the correct specification is delivered to the aircraft fuel tanks.

To avoid contaminating the aircraft fuel system, use a metal funnel equipped with an effective water and debris micro-filter/separator system. Do not use non-conducting plastic fuel containers or funnels. These items can only discharge the static electricity build-up during refuelling by arcing, even when connected to 'earth'. Arcing in the presence of the fuel and vapour typically results in fire and explosion.

Post Fuelling / Pre-flight Fuel Drain Sampling

Always suspect that there will be water in the aircraft fuel tank, particularly after re-fuelling and if the aircraft has been standing in rain or from condensation of atmospheric moisture inside the tank long-term or just overnight.

CASA CAO 20.2 Paragraph 5; Fuel System Inspection states that the operator and pilot in command must ensure the inspections and tests for the presence of water in the fuel system of the aircraft are made in accordance with approved data before the start of each day's flying, and after each refuelling, with the aircraft standing on a reasonably level surface. Reference to approved data means using the aircraft Flight Manual and Service Bulletins to correctly identify the number and location of fuel drains and sumps, and how to drain the main fuel sump/collector box/gascolator.

It is important that fuel drain sample checks for water contamination be positive in nature and not reliant solely on sensory perceptions of colour and smell, both of which can be highly deceptive. For example, if a sample taken at the fuel drain comes from a fuel tank heavily contaminated with water, the drain sample may be all water, but give the impression that it is all fuel and that there is no water in the fuel sample. For this reason, CAO 20.2.5 requires that in order to identify any water in the fuel, that a small quantity of known 'dry' fuel is put in the fuel drain sample container before taking samples from the aircraft fuel tank or filter drain points.

The presence of water may then be revealed by a visible surface of demarcation between the two fluids in the container, providing a positive indication.

Typical procedures require that a small quantity of fuel is sampled from each fuel tank drain and the main fuel sump (if fitted with a quick drain) into a clear transparent container and be visually checked for the presence of water. If the aircraft does not have a drain point at each tank, but is equipped with fuel lines from the tank to the main fuel sump / collector box or gascolator, then inspect the fuel system filters and sump in accordance with the approved data.

Check to ensure that the fuel sample is of the correct colour for the required fuel type / Octane rating, inspect for clarity and freedom from dirt and/or visible water by swirling the fuel sample in a circling motion so that any sediment, etc. will collect in the centre bottom of the container. Fuel tank drain samples may also be checked for water by chemical means such as water detecting paper or paste, where a change in colour of the detecting medium will give clear indication of the presence of water.

CASA CAO 20.2.5 states that: *If, at any time, a significant quantity of water is found to be present in an aircraft fuel system, the operator and pilot in command must ensure that all traces of it are removed from the fuel system, including the fuel filters, before further flight*. FAA Advisory Circular *AC 20-125 Water in Aviation Fuels* is another good source of information regarding water contamination in aviation gasoline and jet fuel. The AC identifies 114 aircraft accidents due to the infiltration of water in the fuel supply. The Canadian DoT comment states: *The probable cause in 85 of those accidents was due to inadequate pre-flight checks*. (Canadian Service Difficulty Advisory AV 2009-05 - Inspection & Maintenance Guidelines for Flush-Mounted Fuel Caps)

Fuel Tank Design Flaws

Fuel tank retains water

A review of accident data indicates there have been many cases where the pilot has conducted diligent post fuel / pre-flight fuel drains in accordance with approved data without detecting any water, only to suffer power loss or total engine failure during take-off and initial climb due to undetected water in the fuel system being delivered to the engine.

The USA National Transport Safety Bureau (NTSB) have investigated the high number of fatalities caused by water contaminating the fuel system in small, single engine aeroplanes, and issued *Safety Recommendations A-83-3 to 11* after finding evidence that significant quantities of water can be held in the wrinkles in the bottom of a rubber fuel tank. Many flexible fuel cells do not have any means to secure the bottom of the fuel tank to the fuel tank cavity, relying only on the weight of the fuel to hold the bottom of the tank in place.

If the bottom of the bladder tank is wrinkled due to poor installation, or has been lifted, become distorted and developed ridges as a result of siphoning due to a leaking fuel cap, or lack of venting, the folds in the rubber tank can act as dams (or a series of weirs) and hold a considerable amount of water away from the drains.

Tests by the NTSB found that even after wing rocking, lowering the tail and jacking up the aircraft to raise one wing, that residual water in the raised fuel tank could not be removed via the drains.

An internal tank inspection found that water was being held back from the drains by a wrinkle in the rubber tank running at 45 degrees between the wing root leading edge and wing trailing edge.

Accident reports indicate that this undrained water typically spills over the ridges or wrinkles in the bottom of the tank and enters the fuel system during turning, acceleration for take-off and adopting climb attitude. During such manoeuvres the water in the fuel tank migrates to the fuel tank main outlets and other low points in the fuel system which then collects at the main fuel sump. Just one flight (or many flights over an extended period) can fill the main fuel strainer / sump until the water overflows the capacity of the sump, passes to the carburettor bowl (or injector) and water instead of fuel is delivered to the engine, causing loss of power or total engine failure.

Inadequate fuel system drain configuration

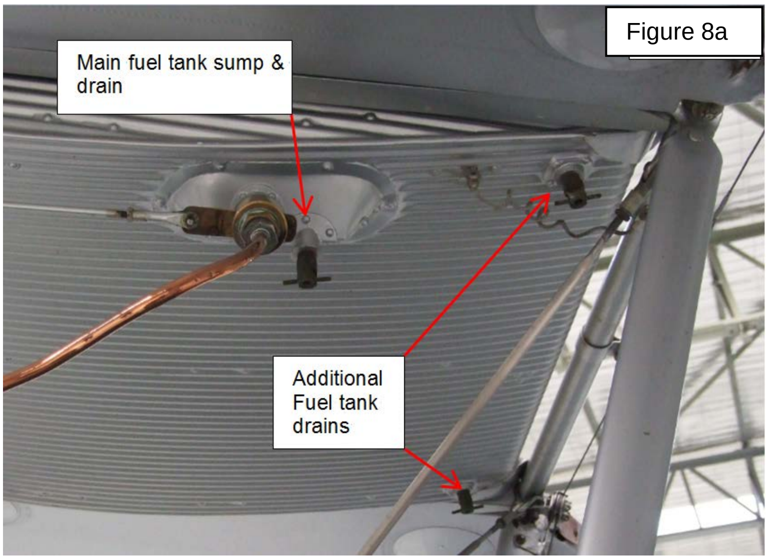
Although FAA design rules require that the fuel tanks have effective drains installed, the number and location of fuel system drains have frequently been found to be inadequate in eliminating water from an aircraft fuel system, as addressed by FAA SAIB CE-10-40R1 *Aircraft Fuel System; Water Contamination of Fuel Tank Systems on Cessna Single Engined Airplanes* which contains a list of applicable FAA ACs SAIBs and Cessna Aircraft Company Service letters and Service bulletins to address these problems in various single engine Cessna aircraft.

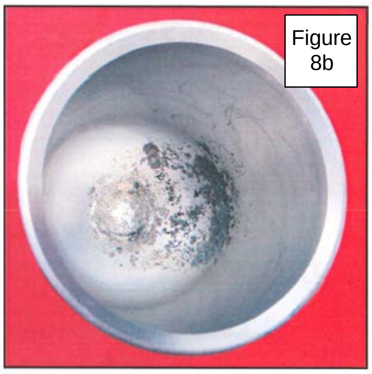
The Piper *TIPS Chapter Three Fuel Systems* provides information on similar issues which apply to Comanche and a wide range a wide range of other Piper aeroplane models. Manufacturer's Service Bulletins typically identify a service kit to retro-fit additional fuel tank drains, and which may include an additional quick drain at the main fuel sump.

Another example is the DH82 Tiger Moth, and other DH Moth aircraft which, when on the ground (tail down) the main fuel tank sump and drain are not at the lowest point of the fuel tank. A significant amount of water can collect in the aft portion of the fuel tank. A fuel sample taken at the sump drain with the aircraft sitting on the ground will not access this water. Refer: ATSB Occurrence Report 199503537 and ATSB Recommendation R19980258.

As the tail comes up during the take-off run (and the aircraft rocks from side to side a little), the angle of the floor of the tank changes and tilts toward the main sump, and overcomes the acceleration forces on any undrained water which runs forward and collects in the main sump, now the lowest point of the fuel tank. This water is delivered to the engine via the fuel bowl on the firewall. If the fuel bowl fills with water, it will overflow and water will be delivered to the engine, resulting in loss of power and engine failure.

To overcome this problem, some operators have elected to install additional fuel tank drains at the aft portion of the DH82 fuel tank. (Figure 8a).





DH82 Aluminium firewall filter cup corroded to 2/3 of the wall thickness due to water contaminated fuel - and the presence of the brass filter.

(TNS CT Moth No.44 Issue 1)

Water from the fuel system collects in the aircraft main fuel sump or gascolator which is typically made of aluminium or cadmium plated steel, and prone to corrosion, particularly in the presence of standing water. (Figure 8b) This is another reason for fuel filter gascolators/sumps to be drained, cleaned and inspected at the calendar interval as well as at the periodic inspection interval.

Aircraft converted from tricycle gear to a ‘tail dragger’ configuration, or vice-versa may inadvertently introduce a completely ineffective fuel drain configuration. In addition to manufacturers service bulletins, STCs are available for some aircraft which provide additional drain points at the lowest point of the fuel system when the aircraft is standing, parked on level ground.

Although manufacturers have generally moved away from using rubber fuel cells to ‘wet’ wings, there are still problems with some wet wing fuel tanks and drain locations. In some cases the internal structure of the tank retains water and the tank corrodes. In order to remove all the water from these fuel tanks, in addition to adding drains, it may be necessary to drain the fuel, gain access to the interior of the tank and sop up the water using lint free rags and sponges.

4. Recommendations

CASA recommends constant vigilance shared between fuel suppliers; the pilots involved in the day to day operation of the aircraft; and the maintainers responsible for detailed inspections to ensure the fuel does not become contaminated with water. CASA recommends, in conjunction with the recommendations contained in this AWB, that with regard to:

1. Operations

a) Fuel Caps:

(i) During a pre-flight inspection, and after every re-fuel, verify that fuel cap locks and latches operate correctly and the cap is tight and secure when closed/locked. Any loose, unlocked or 'rocking' fuel cap should be corrected before flight. Check fuel filler cap gaskets, seals and O-rings are in place and not obviously damaged; no evidence of inflight leakage. Vents and scupper drains of recessed fuel filler compartments are clear.

b) Fuelling:

(i) Aircraft fuelling is to be carried out in accordance with CAO 20.9.

(ii) Only introduce clean dry fuel of the correct specification into the aircraft fuel system. Check drum expiry dates.

(iii) Use a manually operated pump equipped with a filter when refuelling from drums, and

(iv) Use an electrically conducting funnel equipped with a serviceable with a micro filter when refuelling from jerry cans.

c) Water drains sumps and gascolator:

(i) Drain fuel samples from the fuel tanks and fuel sump before the first flight of the day, after refuelling, and after precipitation (if parked outside) before flight in accordance with CASA CAO 20.2 Paragraph 5, Fuel System Inspection.

(ii) Drain samples of fuel from the tanks in accordance with the approved data. 'Become familiar with all drain locations on a specific model of airplane. From model to model in a series of airplanes, the number, type, and location of drains may not be the same. There is no single point of drainage that can be used to check for all fuel system contaminants simultaneously. Take the time to properly check all drain locations, all of the time'. (FAA SAIB CE-10-40R1)

(iii) Dismantle, clean and inspect the fuel gascolator at the calendar periods as well as the flight hours time in service frequencies specified in the aircraft manufacturer's data.

d) Fuel Tanks:

(i) Check there are no obvious traces of fuel on the top of the wing or fuel seeping evident on or under the wing, and no smell of fuel in the cabin.

(ii) Tank capacities match the manufacturer's specifications.

(iii) Research manufacturer's data for optional fuel drain configurations.

2. Maintenance

In addition to the above checks carried out while operating the aircraft, during periodic maintenance, do the following in accordance with the approved data:

(i) Check the fuel cap is the correct part number for the aircraft system and tank configuration.
(ii) Inspect the filler neck for damage, and that fuel filler cover seals are serviceable, scupper drains allow water to drain, and vents are clear.
(iii) Inspect the fuel cap for correct operation and seals for obvious deterioration in accordance with approved data. This may require a pressure check.
(iv) Inspect the interior of metal fuel tanks for water and signs of corrosion, which may indicate water contamination.
(v) Inspect the interior of bladder tanks for water, including the bottom of the tank for wrinkles, signs of broken or missing hangers, etc.
(vi) Dismantle, clean and inspect all aircraft fuel system filters and the main sump/gascolator for water contamination and corrosion by dismantling and inspecting at the calendar periods provided by the aircraft manufacturer, as well as the flight hours time in service frequencies specified in the aircraft manufacturer's data.
(vii) Drain and flush the carburettor / fuel servo fuel strainer and bowl completely.
(viii) Research manufacturer's data for optional fuel drain configurations.

If additional fuel drains are available for the aircraft, or if signs of fuel system contamination or component deterioration are found during these inspections, alert the owner to your findings for corrective action. Any discrepancies which compromise the fuel system should be rectified before the aircraft is returned to service.

5. Reporting

Report fuel system defects to CASA via the SDR reporting system.

6. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletin should be made via the direct link e-mail address:

AirworthinessBulletin@casa.gov.au

or in writing, to:

Airworthiness and Engineering Standards Branch
Standards Division
Civil Aviation Safety Authority
GPO Box 2005, Canberra, ACT, 2601