AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/2/3/10160
Aircraft Registration	ZS-BTL	**Date of Accident**	18 May 2022	**Time of Accident**	0805Z
Type of Aircraft	Piper PA-25-235D Pawnee	**Type of Operation**	Private (Part 91)		
Pilot-in-command Licence Type	PPL (A)	**Age**	52	**Licence Valid**	Yes
Pilot-in-command Flying Experience		**Total Flying Hours**	1060.1	**Total Hours on Type**	17.6

Last Point of Departure	Potchefstroom Aerodrome (FAPS), North West Province
Next Point of Intended Landing	Bospan Airstrip, North West Province
Damage to Aircraft	Substantial
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)	
± 910 metres from the threshold of Runway 21 at FAPS (GPS co-ordinates: 26°39’45.65” South 027°05’01.94” East) at an elevation of 4 459 feet (ft)	
Meteorological Information	Surface wind: 340°/06-10kt; temperature: 19.7°C; dew Point: 7°C; visibility: 9999m

Number of People On-board	1 + 0	**Number of People Injured**	0	**Number of People Killed**	0	**Other (On Ground)**	0

Synopsis

On Wednesday, 18 May 2022, a pilot on-board Piper PA-25-235D Pawnee aircraft with registration ZS-BTL took off on a private flight from Runway (RWY) 03 at Potchefstroom Aerodrome (FAPS) in the North West province, with the intention to land at Bospan Airstrip, also in the same province.

The pilot stated that during the initial climb out at a height of approximately 300 feet (ft) above ground level (AGL) the engine revolutions per minute (RPM) dropped below 2 400 RPM when the gauge was supposed to be indicating 2 575 RPM. The pilot scanned the area and identified an open field covered with grass ahead of the aircraft’s flight path on which to conduct an emergency landing. After touchdown on the grass covered surface, the aircraft ran over a body of water, which led to the main landing gears sinking into the muddy soil. The aircraft nosed over and came to rest in an inverted position.

The aircraft sustained substantial damage during the accident sequence; however, the pilot did not sustain any injuries. She disembarked from the aircraft unassisted.

The cause of the partial power loss was attributed to fuel contamination due to the presence of water in the fuel.

Probable Cause

Water contaminated fuel led to partial engine power loss during the initial climb phase which led to the inability of the aircraft to climb. This prompted the pilot to perform a forced landing on an open area in a grass-covered wetland which led to substantial damage to the aircraft.

Contributory Factor

Draining fuel samples too soon after refuelling; not allowing time for any impurities/contaminants in the fuel to settle into the drain sump/point of each tank before draining fuel samples.

SRP Date	9 May 2023	Publication Date	10 May 2023

Occurrence Details

Reference Number	**:** CA18/2/3/10160
Occurrence Category	**:** Accident (Category 2)
Type of Operation	**:** Private (Part 91)
Operator Type	**:** Private
Aircraft Registration	**:** ZS-BTL
Aircraft Make and Model	**:** Piper Aircraft Corporation, PA-25-235D (Pawnee)
Nationality	**:** South African
Place	**:** ±910 metres from the threshold of Runway 21, Potchefstroom Aerodrome (FAPS)
Date and Time	**:** 18 May 2022 at 0805Z
Injuries	**:** None
Damage	**:** Substantial

Purpose of the Investigation

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011, this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and not to apportion blame or liability.

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Investigation Process

The Accident and Incident Investigations Division (AIID) of the South African Civil Aviation Authority (SACAA) was notified of the occurrence on 18 May 2022 at 0805Z. The occurrence was classified as an accident according to the CAR 2011 Part 12 and ICAO STD Annex 13 definitions. A notification was sent to the South African Civil Aviation Authority as the State of Registry and Operator in accordance with the CAR 2011 Part 12 and ICAO Annex 13 Chapter 4. The investigator-in-charge (IIC) did not dispatch to the accident site.

Notes:

1. *Whenever the following words are mentioned in this report, they shall mean the following:*
   Accident — this investigated accident
   Aircraft — the Piper PA-25-235 Pawnee *involved in this accident.*
   Investigation — the investigation into the circumstances of this accident
   Pilot — the pilot involved in this accident.
   Report — this accident report

2. *Photos and figures used in this report were taken from different sources and may have been adjusted from the original for the sole purpose of improving clarity of the report. Modifications to images used in this report were limited to cropping, magnification, file compression; or enhancement of colour, brightness, contrast; or addition of text boxes, arrows, or lines.*

Disclaimer

This report is produced without prejudice to the rights of the AIID, which are reserved.

Table of Contents

Abbreviation	Description
°	Degrees
°C	Degrees Celsius
±	Plus/minus (Approximately)
AIID	Accident and Incident Investigations Division
AGL	Above Ground Level
AME	Aircraft Maintenance Engineer
AMO	Aircraft Maintenance Organisation
AMSL	Above Mean Sea Level
AVGAS	Aviation Gasoline
C of A	Certificate of Airworthiness
C of R	Certificate of Registration
CRS	Certificate of Release to Service
FAPS	Potchefstroom Aerodrome
ft	Feet
hPa	Hectopascal
IAW	In Accordance With
kPa	Kilopascal
kt	Knots
L	Litres
m	Metres
METAR	Meteorological Aerodrome Report
MPI	Mandatory Periodic Inspection
MTOW	Maximum Take-off Weight
NM	Nautical Miles
OH	Owner’s Handbook
PPL	Private Pilot Licence
RPM	Revolutions per Minute
RVP	Reid Vapour Pressure
RWY	Runway
SACAA	South African Civil Aviation Authority
SAWS	South African Weather Service
QNH	Altitude Above Mean Sea Level
USG	US Gallons
VFR	Visual Flight Rules
Z	Zulu (Term for Universal Co-ordinated Time - Zero Hours Greenwich)

1. FACTUAL INFORMATION

1.1. History of Flight

1.1.1. On Wednesday, 18 May 2022, a pilot on-board a Piper PA-25-235D Pawnee aircraft with registration ZS-BTL took off on a private flight from Runway (RWY) 03 at Potchefstroom Aerodrome (FAPS) in the North West province, with the intention to land at Bospan Airstrip, also in the same province. The flight was conducted under visual flight rules (VFR) by day.

1.1.2. According to the pilot, the aircraft was refuelled to capacity from a bowser in the aircraft's hangar. The aircraft was then taxied to the parking area in front of the hangar where the pilot carried out the pre-flight checks in accordance with (IAW) the aircraft Owner's Handbook (OH) checklist before take-off. The pilot indicated that during the checks, sufficient fuel was drained from the left and right fuel tank drains, as well as the header tank drain until there was no visible water or any sign of contamination. The pilot then boarded the aircraft and started the engine. Warm-up and ground checks were carried out without any abnormal indications noted prior to taxi for take-off.

1.1.3. The pilot opted to use RWY 03 for take-off as the prevailing wind was from the north-west. The pilot stated that during the initial climb out at a height of approximately 300 feet (ft) above ground level (AGL), the aircraft had partial engine power loss, evidenced by a decay in engine revolutions per minute (RPM) from 2 575 to below 2 400 on the RPM gauge.

1.1.4. According to the pilot, the engine power loss occurred towards the end of the runway with the aircraft at a low altitude, thus cancelling out the option for the pilot to attempt a turn back to the aerodrome. The pilot continued with the flight and carried out the aircraft's emergency procedure for engine power loss during take-off; however, the engine power could not be regained. The pilot then sought out and identified an open field of grass, about 30 degrees (°) left of the aircraft's flight path, on which to conduct an emergency landing.

Figure 1: Aerial view of the accident site in proximity to FAPS. (Source: Google Earth)

1.1.5. After touchdown on a waterbed area, the aircraft ran over a body of water which caused the main gears to sink into the mud, abruptly decelerating the aircraft. As a result, the tail lifted forward which caused the aircraft to nose over before it came to rest in an inverted position.

1.1.6. The aircraft sustained substantial damage during the accident sequence; however, the pilot was not injured and disembarked from the aircraft without assistance.

1.1.7. The accident occurred during daylight at Global Positioning System (GPS) co-ordinates determined to be 26°39'45.65" South 027°05'01.94" East, at an elevation of 4 459 ft above mean sea level (AMSL).

1.2. Injuries to Persons

Injuries	Pilot	Crew	Pass.	Total On-board	Other
Fatal	-	-	-	-	-
Serious	-	-	-	-	-
Minor	-	-	-	-	-
None	1	-	-	1	-
Total	**1**	**-**	**-**	**1**	**-**

Note: Other means people on the ground.

1.3. Damage to Aircraft

1.3.1. The aircraft sustained substantial damage.

Figure 2: The aircraft after being positioned upright. (Source: AMO)

1.4. Other Damage

1.4.1. None.

1.5. Personnel Information

Pilot in command (PIC)

Nationality	South African	Gender	Female	Age	52
Licence Type	Private Pilot Licence				
Licence Issue Date	6 February 2019	Licence Expiry Date	30 June 2022		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Night				
Medical Class	Class 2				
Medical Issue Date	30 August 2021	Medical Expiry Date	30 September 2022		
Limitations	Suitable corrective lenses				
Previous Accidents	None				

Note: Previous accidents refer to past accidents the pilot was involved in, when relevant to this accident.

Flying Experience:

Total Flying Hours	1 060.1
Total Hours Past 24 Hours	2.5
Total Hours Past 7 Days	8.1
Total Hours Past 90 Days	31.9
Total Hours on Type Past 90 Days	17.3
Total Hours on Type	17.6

1.5.1. According to the pilot's logbook endorsement section, the Piper PA-25-235 Pawnee aircraft type conversion training was completed and endorsed on the pilot's licence on 24 November 2021. The pilot completed a Private Pilot Licence (PPL) skills test on 27 February 2022, which was endorsed by an instructor in the pilot's logbook.

1.6. Aircraft Information (Source: Piper Pawnee D Owner's Handbook)

1.6.1. *The Piper PA-25 Pawnee was manufactured by Piper Aircraft as an agricultural aircraft and introduced in August 1959. The Pawnee was produced from 1959 to 1981 and continues to serve its purpose in agricultural spraying. It was also utilised as a tow plane, or tug, used for launching gliders or for towing banners.*

In the same year, two pre-production models were built and in May 1959, aircraft production began. In 1962, the PA-25-235 Pawnee B was built. It was powered by a Lycoming O-540-B2B5 engine rated at 235 brake horsepower and showcased a larger hopper, enhanced dispersal gear, and increased payload of 540 kg. In 1967, the PA-25-235 and PA-25-260 Pawnee C were introduced. It was an enhanced variant of the previous Pawnee B fitted with *a 235 horsepower or 260 horsepower high-compression type of the Lycoming O-540 engine. It also featured a fixed-pitch or a constant-speed propeller. The PA-25-235 and PA-25-260 Pawnee D with fuel tanks located in the outer wings were also built.*

Airframe:

Manufacturer/Model	Piper Aircraft Corp., PA-25-235-D (Pawnee)	
Serial Number	25-7656016	
Year of Manufacture	1976	
Total Airframe Hours (At Time of Accident)	7963.30	
Last MPI (Date & Hours)	17 March 2022	7937.00
Hours Since Last Inspection	26.30	
CRS Issue Date	17 March 2022	
C of A (Original Date of Issue & Expiry Date)	5 November 2004	30 November 2022
C of R (Issue Date) (Present Owner)	25 July 2014	
Type of Fuel Used	AVGAS	
Operating Category	Private (Part 91)	
Previous Accidents	None	

Note: Previous accidents refer to past accidents the aircraft was involved in, when relevant to this accident.

Engine:

Manufacturer/Model	Lycoming, O-540-B2B5
Serial Number	L-13409-40
Hours Since New	1836.9
Date of Last Overhaul	TBO not yet reached
Hours Since Overhaul	TBO not yet reached

Propeller:

Manufacturer/Model	McCauley, 1A200FA8452
Serial Number	104523
Hours Since New	Unknown
Date of Last Overhaul	1 November 2019
Hours Since Overhaul	178.6

1.6.2. The investigation found no technical defects with the airframe or installed systems and components that were recorded in the logbook or defect reports which may have led to the accident.

1.6.3. Mass and Balance

1.6.3.1. The mass and balance at take-off was as follows:

Table 1: Mass and Balance Information

Item	Mass (kg)
Aircraft Empty Mass	763.4
Pilot	70
Fuel	106
Hopper	0
Take-off Weight	**939.4**

1.6.3.2. According to the Mass and Balance Report, the aircraft was last weighed on 26 September 2018, and the recorded empty mass was 763.4 kilograms (kg) (1683 pounds (lb]). According to the Pawnee Owner's Handbook (OH), the aircraft's certified maximum take-off mass (MTOM) is 1315 kg (2900 lb). Therefore, the aircraft's take-off mass of 939.4 kg for the flight was within the limit of the certified MTOM by 376kg.

1.6.4. Fuel Information

1.6.4.1. The fuel upload records of the aircraft revealed that the aircraft was refuelled at FAPS' fuel bay with 68 litres (L) (18 gallons [USG]) of aviation gasoline (AVGAS) to full capacity prior to the flight on 18 May 2022. According to the Pawnee OH, the aircraft's full capacity is 146 L (38.5 USG) with roughly 136 L (36 USG) being usable fuel.

1.6.4.2. A description and schematics of the fuel system are shown in Appendix A – Piper PA-25-235D Fuel System.

1.6.5. Carburettor Information

1.6.5.1. According to the Lycoming Operator's Manual, *the O-540 series engine type, fitted to the ZS-BTL aircraft, is a six-cylinder, direct drive, horizontally opposed, air cooled engine. The oil sump incorporates an oil drain plug, oil suction screen, mounting pad for carburettor, the intake riser and intake pipe connections*.

The induction system of a Lycoming O-540 series engine is equipped with a Marvel-Schebler MA-4-5 carburettor. Good distribution of the fuel-air mixture to each cylinder is obtained through the centre zone induction system, which is integral with the oil sump and is submerged in oil, insuring a more uniform vaporisation of fuel, and aiding in cooling the oil in the sump. From the riser the fuel-air mixture is distributed to each cylinder by individual intake pipes.

The Marvel-Schebler MA-4-5 carburettor is of the single barrel float type and is equipped with a manual mixture control and an idle cut-off.

1.6.5.2. According to the Precision Airmotive® MSA Float Carburettor Handbook (Formally Marvel-Schebler/Facet), the MA-4-5 model is an updraft carburettor used on Continental, Franklin, and Lycoming engines. It is also a plain tube, fixed jet type.

The general description of some of the carburettor components:

- *ACCELERATOR PUMP – This pump, if provided with a discharge jet, discharges fuel into the mixing chamber to provide smooth acceleration under all operating conditions.*

- *MANUAL MIXTURE CONTROL – The carburettor has a manual mixture control which adjusts the carburettor for all throttle positions and loads. It is not normally employed under 5 000 ft mean sea level (MSL).*
- *IDLE SYSTEM – Both primary and secondary idle air vents ensure proper air and fuel emulsion for starting and idling.*
- *FUEL INLET STRAINER AND SCREEN – This screen prevents the entry of dirt or foreign matter apt to cause failure.*
- *VENTS – All air vents open into the main air entrance which ensures against the entry of dirt into the carburettor passages or fuel bowl when an efficient air cleaner is used.*
- *BOWL DRAIN PLUG – The bowl drain plug is located at the lowest point in the fuel bowl and is used to drain water.*

Details of the principles of operation of the carburettor are provided in Appendix B.

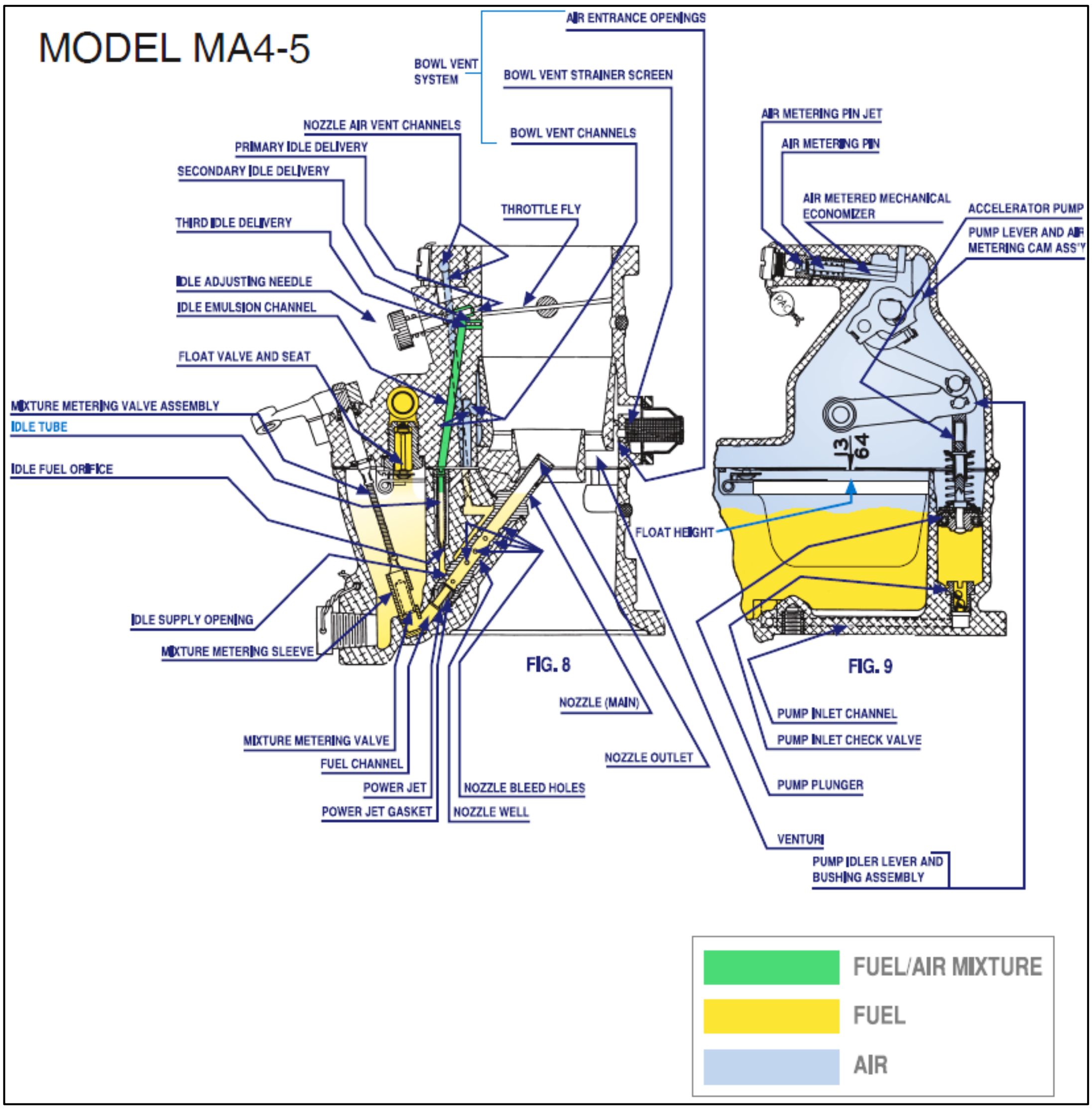


Diagram 1: Schematic of the MA-4-5 carburettor model. (Source: Precision Airmotive® MSA Float Carburettor Handbook)

1.7. Meteorological Information

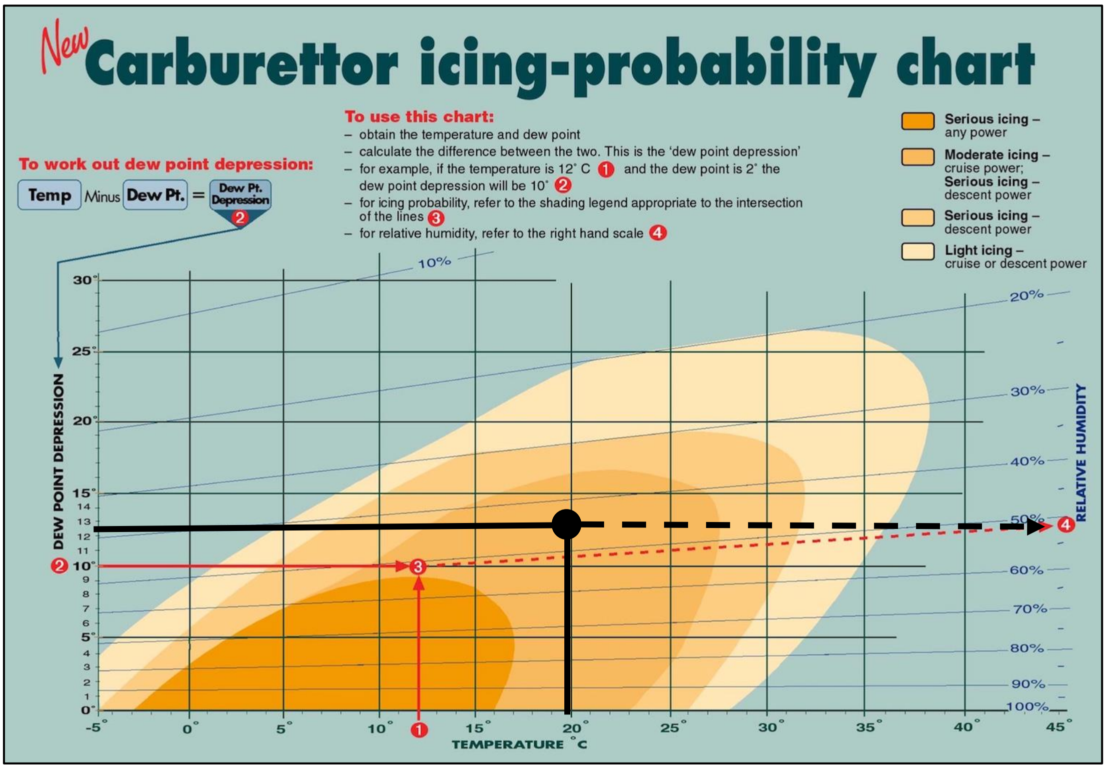
1.7.1. The weather information below was obtained from the Meteorological Aerodrome Report (METAR) that was issued by the South African Weather Service (SAWS) and recorded on 18 May 2022 at 1005Z at the Potchefstroom Automatic Weather Station (AWS). The AWS is located approximately 2 nautical miles (NM) from the accident site.

Wind Direction	340 °	Wind Speed	06-10 kt	Visibility	9999 m
Temperature	19.7 °C	Cloud Cover	None	Cloud Base	None
Dew Point	7 °C	QNH	872.1 hPa		

1.7.2. According to the SAWS reported weather conditions, the wind component that was prevalent at the time of the accident was a headwind of 6.43 knots (kt) with a crosswind of 7.66 kt. According to the aircraft's OH, the maximum crosswind component allowable for the aircraft is 15 kt.

1.7.3. The carburettor icing chart below shows that the weather conditions were conducive for moderate icing at cruise power or serious icing at descent power, and no probability of carburettor icing during climb power (refer to the black solid and dotted lines, as well as the round spot on the graph below).

Temperature	19.7 °C
Dewpoint	7 °C
Dewpoint depression	12.7 °C
Relative humidity	51.0 %



Graph 1: The Carburettor icing-probability chart.

1.8. Aids to Navigation

1.8.1. The aircraft was equipped with standard navigational equipment as approved by the Regulator (SACAA). There were no records indicating that the navigational equipment was unserviceable prior to the accident.

1.9. Communication

1.9.1. The aircraft was equipped with a standard communication system as approved by the Regulator. There were no recorded defects with the communication system prior to the accident.

1.10. Aerodrome Information

1.10.1. The aircraft touched down approximately 910m from the threshold of RWY 21 on an open grass-covered field.

Aerodrome Location	Potchefstroom Aerodrome (FAPS), North West Province
Aerodrome Status	Licensed
Aerodrome GPS coordinates	26°40’13.16” South, 27°04’44.66” East
Aerodrome Elevation	4 520 feet
Runway Numbers	03/21
Dimensions of Runway Used	1765m x 30m
Heading of Runway Used	032°
Surface of Runway Used	Asphalt
Approach Facilities	None
Radio Frequency	115.50 MHz

1.11. Flight Recorders

1.11.1. The aircraft was neither equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), nor was it required by regulation to be fitted to the aircraft type.

1.12. Wreckage and Impact Information

1.12.1. The aircraft landed on a waterbed after touchdown and rolled over a body of water which led to the main wheels sinking into the muddy soil and bringing the aircraft to an abrupt stop. The aircraft nosed over and came to rest in an inverted position, with the engine compartment resting in the waterbed.

Figure 3: The wreckage location. The picture was taken by a pilot on-board another aircraft. (Source: Pilot)

1.12.2. The aircraft's wings and vertical stabiliser were damaged.

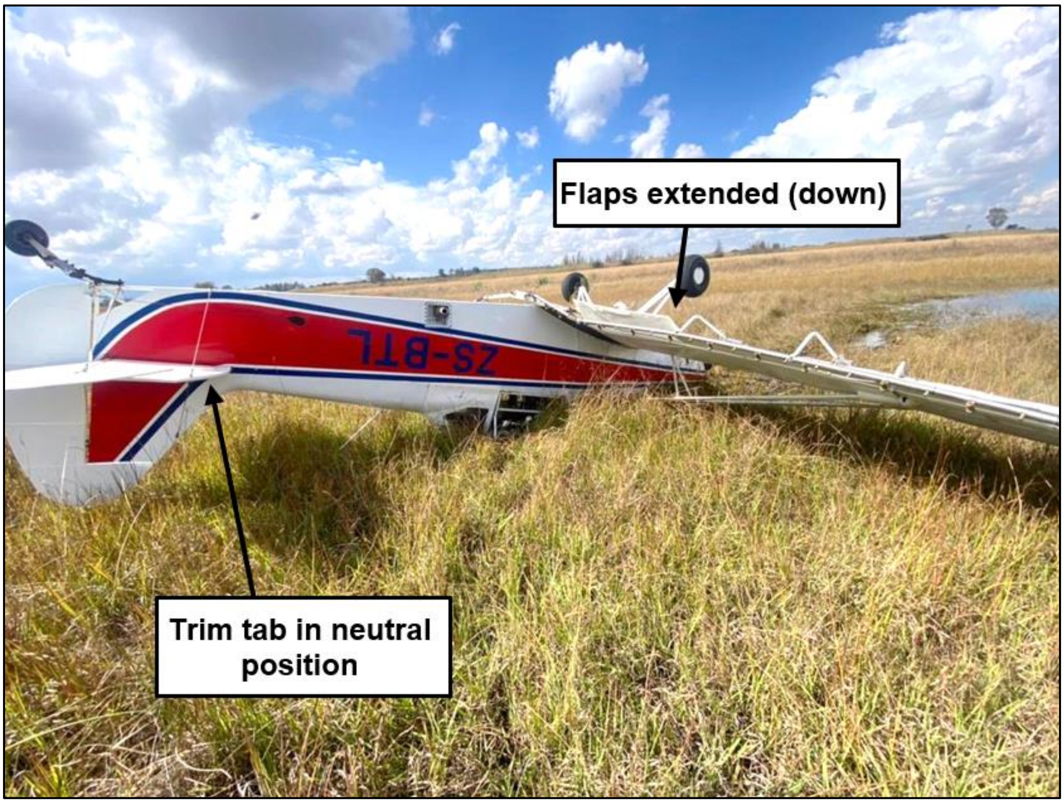


Figure 4: The aircraft as it came to rest on the grass-covered field. (Source: Pilot)

1.12.3. Damage observed on the propeller blades indicated that the engine was not producing power on impact and that the propeller blades were probably wind milling during the landing roll. One of the propeller blades was bent slightly backwards, whilst the other blade was deeply lodged into the soft ground with the third of its length above ground and still intact.

Figure 5: The propeller blades after the accident. (Source: AMO)

1.12.4. The throttle control lever was found in the “idle cut-off” position and the fuel selector valve was in the “off” position. The carburettor lever was found in the “cold” position.

1.13. Medical and Pathological Information

1.13.1. Not applicable to this occurrence.

1.14. Fire

1.14.1. There was no evidence of a pre- or post-impact fire.

1.15. Survival Aspects

1.15.1. The accident was considered survivable as the cockpit and cabin structure remained intact. The pilot had made use of the aircraft's equipped safety harnesses during the flight.

1.16. Tests and Research

1.16.1. Post-accident Inspections

1.16.1.1. On the day of the accident, a post-accident inspection was carried out by the aircraft maintenance engineer (AME) during which the engine compression test was conducted by turning the propeller by hand in the direction of rotation, and it rotated freely without obstruction. The owner requested that the AME take fuel samples on the same day as there was a suspicion that the engine power loss could have been due to the fuel which was uploaded before the flight.

1.16.1.2. A few days after the accident, the aircraft was recovered to the owner's hangar for engine and propeller examination. During the examination, the engine's crankshaft was rotated and it did not rotate as expected. A decision to conduct a teardown of the engine was taken and arrangements were made to send the engine and its components to an approved Lycoming engine aircraft maintenance organisation (AMO) for the procedure.

1.16.2. Engine Teardown Inspection

1.16.2.1. On 3 August 2022, an engine teardown inspection was conducted in the presence of the investigators. The purpose of the procedure was to determine signs of mechanical anomalies not related to the impact during the accident. The following observations were made:

- The teardown inspection of the engine did not reveal any pre-impact mechanical failures. The findings showed that the engine and its attachments were in good condition and did not exhibit any impact damage because of the accident.
- Visual examination of the engine-driven fuel pump did not identify any anomalies that may have affected its operation. Disassembly and examination of the magnetos, vacuum pump, oil pump and associated oil system components similarly did not identify any failure or condition that may have affected engine operation.
- No obvious external anomaly was found on the crankcase. All spark plugs were found in good condition; they had a light brown tint, an indication that no mechanical internal failure had occurred in the combustion chamber of the cylinders, which also ruled out the possibility of the valve failure.
- There was evidence of sufficient oil in the engine. However, the oil had turned into a slurry (milky liquid). It was deduced that the fuel had mixed with water which had seeped into the engine during the time the engine was submerged in the waterbed for a few days after the accident. The thick slurry had migrated into the engine components and restricted the free movement of the crankshaft, cylinders, pistons and valve assemblies. The water also caused rust to form on the crankcase.

1.16.3. <u>Contamination of the carburettor by water</u>

1.16.3.1. Disassembly and inspection of the carburettor bowl did not reveal any failure or blockage. Because the engine was stored in an inverted orientation for months before it could be subjected to a teardown inspection, there were very little remnants of fuel found in the carburettor bowl.

1.16.3.2. All seals were observed to be in good condition, which ruled out a possibility of an internal leak in the carburettor.

1.16.3.3. After disassembly, observation of discolouration due to rust was noted on the idle fuel tube vent, accelerator pump, pump plunger and the walls of the accelerator pump chamber.

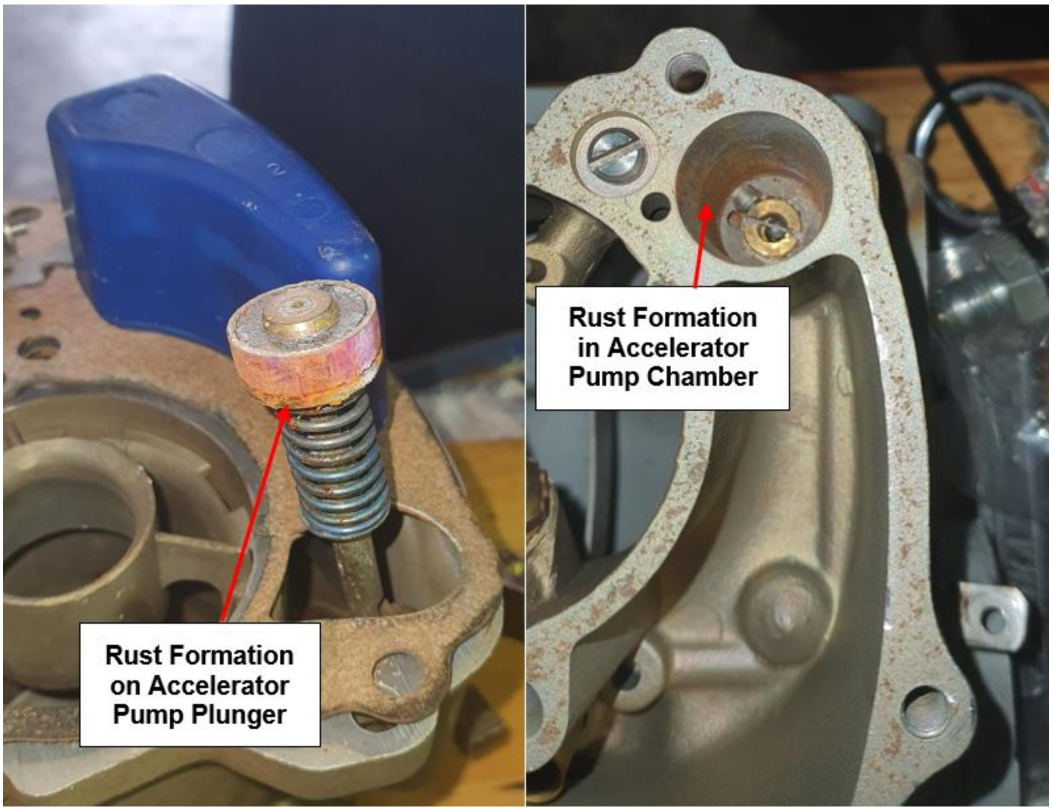


Figure 6: Rusted accelerator pump plunger and chamber.

1.16.4. <u>Fuel Quality and Fuel Checking Process</u>

1.16.4.1. According to the pilot, it is likely that the power loss experienced on the day of the accident could have been due to fuel contamination, with high water sediments found even after adequate draining of fuel samples.

1.16.4.2. The ZS-BTL aircraft was refuelled from a bowser which was in the owner's hangar.

1.16.4.3. The owner of ZS-BTL had a fuel sample taken to test for contamination at SGS Aviation Compliance. According to the owner, fuel was drained from both the left and right fuel tank drains and the header tank drain.

1.16.4.4. According to the fuel contamination test results for ZS-BTL (refuelled from the owner's bowser) and ZU-DUI (another aircraft which was refuelled from the main SV main tanks), on the aviation fuel quality and fuelling process for their aviation activities at FAPS and at the remote helicopter hangar in the North West province, the following details on the possible issues and risks were provided:

- *Fuelling processes conducted by the fuel supplier at FAPS.*
- *Fuel quality from the main supplier tank facility at FAPS.*
- *Fuelling processes conducted by the owner from their own bowser fuel.*
- *Fuel quality of bowser fuel owned and operated by owner.*
- *Aircraft fuel checking processes.*
- *Aircraft fuel quality*.

According to the report, on 27 May 2022, the first batch of fuel samples were taken for ZU-DUI and ZS-BTL. Samples from the first batch were also sent for verification by a third party.

On 1 June 2022, a site inspection was carried out by an SGS inspector, and the processes used for fuelling were reviewed. A second batch of 3L of fuel samples were taken for testing. Fuel was drained from both the left and right fuel tank drains and the header tank drain, as well as from the bowsers and SV Aviation's main tanks (SV Aviation is the fuel supplier at FAPS). Samples from the second batch were also sent for verification by a third party.

Batch sample testing outcomes were as follows:

<u>*First batch samples (sampled on 27 May 2022 – reanalysed on 8 June 2022)*</u>

- *Helicopter hangar bowser (KMG 698 NW) new fuel batch from SV Aviation – enviro condition: Clear / Product meets specifications for properties tested.*
- *OG bowser (JUR 779 NW) – enviro condition: clear / product meets specifications for properties tested.*
- *Aircraft hangar bowser (KMG 672 NW) new fuel batch from SV Aviation – enviro condition: clear / product meets specifications for properties tested.*
- *Aircraft Registration (ZU-DUI) sample ex-aircraft fuel tank drain – enviro condition: clear; sample comment: sample does not meet requirements for RVP (Reid Vapour Pressure) 35 kPa.*
- *Aircraft registration (ZU-DUI) sample ex-aircraft fuel tank drain – third party verification - sample condition: acceptable / 42 kPa RVP (Reid Vapour Pressure) within limits.*
- *Aircraft registration (ZS-BTL) sample ex-aircraft fuel tank drain – enviro condition: clear; sample comment: sample fails on appearance (fine particles and free water present) and does not meet requirements for RVP (Reid Vapour Pressure) 22 kPa.*

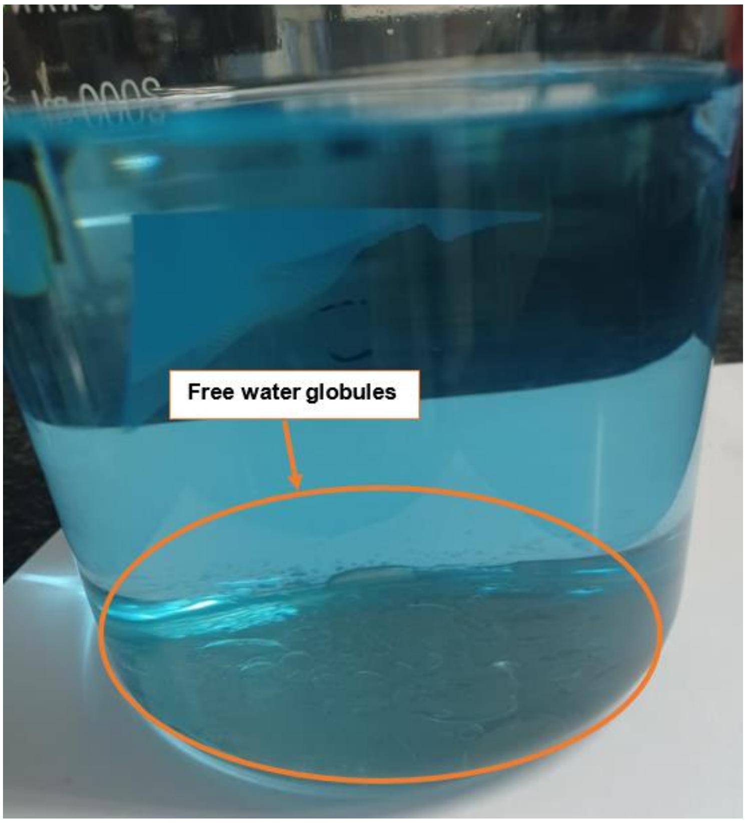


Figure 3: First fuel sample of ZS-BTL taken after the accident shows free water globules. (Source: SGS)

2nd Batch samples (Sampled 1 June 2022 – analysed 8 June 2022)

- *Aircraft hangar bowser (KMG 672 NW) new fuel batch from SV Aviation – enviro condition: clear / product meets specifications for properties tested.*
- *Aircraft hangar bowser (KMG 901 NW) old fuel batch from SV Aviation – enviro condition: clear / product meets specifications for properties tested.*
- *Helicopter hangar bowser (KMG 698 NW) new fuel batch from SV Aviation – enviro condition: clear / product meets specifications for properties tested.*
- *Helicopter hangar bowser (KMG 698 NW) new fuel batch from SV Aviation – third party verification – sample condition: acceptable.*
- *SV Aviation main tank (new fuel batch) - enviro condition: clear / product meets specifications* for properties tested.

The following recommendations were provided after the inspection of the processes followed by the owner of the ZS-BTL and ZU-DUI aircraft and the fuel supplier (SV Aviation) at FAPS:

- The *owner should conduct regular safety/quality audits of the fuel supplier (SV Aviation) at FAPS.*
- *A written agreement between the owner and SV Aviation should be drawn up outlining the individual responsibilities, safety-related services, and quality to be provided.*
- *Pilots signing for fuel uploads from SV Aviation either directly to aircraft or to bowsers are to ensure that testing of the fuel supply has been done and that copies of records are obtained and kept with each upload.*
- *Bowser fuel management is to be documented by the owner and should include, but not limited to*:
  - *Bowser cleaning procedures.*

   - *Bowser refuelling procedures.*
   - *Bowser filtration procedures.*
   - *Bowser daily water testing procedures (both visual and water paste), with samples kept as required by aviation regulations and documented accordingly.*
   - *Bowser delivery and storage procedures.*
- *Aircraft fuel management is to be documented by the owner and should include, but not limited to:*
   - *Daily fuel tank drain testing (both visual and water paste), with samples kept as required by regulations and documented accordingly.*
   - *Aircraft fuel upload from bowsers or SV Aviation main supply to include document reference of testing having taken place.*

Note: *All aviation fuels absorb moisture from the air and contain water in suspended particles and liquid form. The number of suspended particles varies with the temperature of the fuel. Whenever the temperature of the fuel is decreased, some of the suspended particles are drawn out of the solution and slowly fall to the bottom of the tank. Whenever the temperature of the fuel is increased, water is drawn from the atmosphere to maintain a saturated solution. Changes in fuel temperature, therefore, result in a continuous accumulation of water. The above procedures are recommended to reduce the risk of water contamination.*

1.17. Organisational and Management Information

1.17.1. This was a private flight conducted under the provisions of Part 91 of the CAR 2011 as amended.

1.17.2. The AMO that carried out the last mandatory periodic inspection (MPI) was issued an AMO approval certificate by the SACAA on 12 July 2021 with an expiry date of 31 July 2022.

1.18. Additional Information

1.18.1. Extract from the SACAA – Aircraft Fuel Control (CA AOC-AC-005), 18 September 2015:

1. Purpose

This Advisory Circular alerts the aviation community to the potential hazards of inadvertent mixing or contamination of turbine and piston fuels and provides recommended fuel control and servicing procedures.

3. Background

Since the introduction of jet aircraft fuel, there have been several instances of inadvertent fuelling of piston-powered aircraft with jet fuel. Aviation fuel can only serve its ultimate purpose when the proper fuel is delivered into the aircraft as free from contamination as it was the day it left the refinery. Unless care and attention are given to its handling, servicing, and storage, the many precautions taken in its manufacture and transportation are wasted. Close attention to compatibility of fuel and aircraft as well as faithful adherence to good housekeeping practices, is necessary to prevent possible disaster as well as costly contamination. A review of accidents attributed to fuel problems reveals that many power failures were due to use of improper fuel or careless servicing – fuelling aircraft from poorly filtered tanks, particularly small tanks or drums, improper mixing or *fuel additives, improper pre-flight action by the pilot, and storing aircraft with partially filled tanks, etc., which invites condensation and contamination of the fuel.*

8. Fuel Contamination

Fuel is contaminated when it contains any material that was not provided under the fuel specification. This material generally consists of water, rust, sand, dust, microbial growth, and certain additives that are not compatible with the fuel, fuel system materials and engines.

9. Causes of Fuel Contamination

a. Water. All aviation fuels absorb moisture from the air and contain water in both suspended particle and liquid form. The number of suspended particles varies with the temperature of the fuel. Whenever the temperature of the fuel is decreased, some of the suspended particles are drawn out of the solution and slowly fall to the bottom of the tank. Whenever the temperature of the fuel increases, water is drawn from the atmosphere to maintain a saturated solution. Changes in fuel temperature, therefore, result in a continuous accumulation of water. During freezing temperatures, this may turn to ice, restricting or stopping fuel flow.

10. Field Tests

Three gallons (11 litres) of water were added to a half full fuel tank of a popular make, high wing monoplane. After several minutes, the fuel strainer (gascolator) was checked for water. It was necessary to drain ten liquid ounces (295 millilitres) of fuel before any water appeared. This is considerably more than most pilots drain when checking for water.

In another test, simulating a tricycle geared model, one gallon (4 litres) of water was added to a half full fuel tank. It was necessary to drain more than a quart (946 millilitres) of fuel before any water appeared.

In both tests, about nine ounces (266 millilitres) of water remained in the fuel tank after the belly drain and the fuel strainer (gascolator) had ceased to show any trace of water. This residual water could only be removed by draining the tank sumps.

11. Contamination Control

The presence of any contamination in fuel systems is dangerous. Laboratory and field tests have demonstrated that when water was introduced into the gasoline tank, it immediately settled to the bottom. Fuel tanks are constructed with sumps to traps this water. It is practically impossible to drain all water from the tanks through the fuel lines, so it becomes necessary to regularly drain the fuel sumps to remove all water from the system. It may be necessary to gently rock the wings of some aircraft while draining the sumps to completely drain all the water. On certain tailwheel type aircraft, raising the tail to level flight attitude may result in additional flow of water to the gascolator or main fuel strainer. If left undrained, the water accumulates and will pass through the fuel line to the engine and may cause the engine to stop operating. The elimination of contaminants from aviation fuel may not be entirely possible but can control it by the application of good housekeeping habits.

b. Pre-flight action

Drain a generous sample of fuel – considerably more than just a trickle – into a transparent container from each of the fuel sumps and from the main fuel strainer or *gascolator. (Remember that it was necessary to drain ten ounces (295 millilitres) in the field tests.) On certain aircraft having fuel tanks located in each wing, positioning of the fuel tank selector valve to the "BOTH ON" position may not adequately drain the system. This is due to the fuel taking the path of least resistance. In this case, the fuel selector valve should be positioned at each tank in turn.*

Examine the fuel samples for water and dirt contamination. If present, it will collect at the bottom of the container and should be easily detected. Continue to drain fuel from the contaminated sump until certain the system is clear of all water and dirt.
"The use of quick drain valves in the sumps and gascolator makes in practical to keep free of significant quantities of water and other contaminants."

1.18.2. Civil Aviation Authority (CAA) of New Zealand – Good Aviation Practice (GAP) 2021 – Fuel Management states:

Contamination

Contaminants in the fuel, especially water, have been known to cause engine failure – usually just after the aircraft has taken off.

You should carry out a fuel drain after each fuelling. It should also be done before every flight. You should know how many drain-points your aircraft has.

After fuelling, allow the fuel to settle for as long as possible. A minimum of 15 minutes per 30 cm depth of fuel for avgas is recommended. For Jet A-1, that recommendation is 60 minutes per 30 cm. This gives any impurities a chance to settle into the drain sump of each tank. At an intermediate stop, it's a good idea to fuel the aircraft first, before attending to other business. That will normally allow enough time for any water in suspension to settle out.

Some aircraft have long fuel lines, meaning contaminants can take some time to reach the drain point. Know what the recommended sample sizes are. Refer to the aircraft flight manual for details.

Detecting water and other contamination

By whatever method available, ensure your sample of 'fuel' is not, in fact, pure water. It has been done! The trouble is, the mild tint in avgas can be 'bleached out' if you hold the sample to the light, so trying to identify it as avgas or water can be quite difficult.

Holding the sample to the light, however, will allow you to detect small globules of water sitting on the bottom of the testing vessel.

Make sure your drain vessel is clean before taking a sample. Hold it to the light and against a white background, and look at it from the side, rather than from above. You should be able to detect any debris, and you can also see if the contents are tinted. If you're in reduced natural light, check the sample under bright lighting and against a white background, such as a fuselage. That will make it easier to identify the colour and detect any debris or contaminants.

A cautious smell of the sample may be enough to indicate the fuel is stale or contaminated.

If the sample does test positive for water – or any other contaminant – empty the tester and continue draining until you get a clean sample. Be sure to empty the sample into a fuel disposal container.

If you're using a portable fuel source, such as a jerry can, check a sample from that source before fuelling the aircraft. Truck-mounted tanks also need to be checked regularly for water or other contaminants.

Refuelling

Ideally, the aircraft should be topped up with fuel after the last flight of the day to minimise the chances of condensation forming inside the tanks, particularly if it's going to be parked outside overnight. Condensation can form inside a fuel tank when water vapour in the air trapped in the tank condenses as it cools.

1.19. Useful or Effective Investigation Techniques

1.19.1. None.

2. ANALYSIS

2.1. General

From the available evidence, the following analysis was made with respect to this accident. This shall not be read as apportioning blame or liability to any organisation or individual.

2.2. Analysis

<u>The Pilot</u>

2.2.1. The pilot had a Private Pilot Licence (PPL) that was issued on 6 February 2019 with an expiry date of 30 June 2022. According to the pilot's questionnaire, the pilot had flown a total of 1060.1 hours, of which 17.6 were on the aircraft type.

2.2.2. The pilot was issued a Class 2 aviation medical certificate on 30 August 2021 with an expiry date of 30 September 2022 with a restriction to wear suitable corrective lenses.

<u>Weather</u>

2.2.3. The wind conditions at the time of take-off were within limits, detailed in the aircraft's OH. According to the SAWS report, the crosswind component was within the maximum allowable limit.

2.2.4. The dew point calculation indicated that the weather conditions were conducive for the formation of moderate icing at cruise power or serious icing at descent power with 50% relative humidity. Accordingly, these conditions would have less likely resulted in the formation of carburettor icing during take-off (take-off power).

<u>The Aircraft</u>

2.2.5. The aircraft was issued a Certificate of Release to Service (CRS) following its last mandatory periodic inspection (MPI) that was carried out on 17 March 2022 at 7937.00 airframe hours. The aircraft had accumulated a further 26.30 airframe hours since the inspection.

2.2.6. The aircraft logbooks and maintenance history were scrutinised, and all documents were found to be in order. All applicable Service Instructions (SIs), Service Bulletins (SBs) and Airworthiness Directives (ADs) were complied with.

Flight Operations

2.2.7. After experiencing partial power loss during take-off, the pilot carried out the emergency checklist in accordance with the OH, however, the engine power could not be restored. The pilot then sought out and identified an open field of grass, about 30° left of the aircraft's flight path on which to conduct an emergency landing. Based on aerial photographs of the accident site, there was a large body of water concealed by grass. The presence of water caused the aircraft to flip over during touchdown as the aircraft's wheels locked when they encountered the body of water.

2.2.8. The take-off mass of the aircraft was within the prescribed limit and would not have affected the flight characteristics of the aircraft on take-off.

2.2.9. The amount of fuel on-board the aircraft was confirmed to have been enough, as a result, the possibility of fuel starvation or exhaustion could not have contributed to the partial power loss experienced by the aircraft's engine.

Engine Teardown

2.2.10. During post-accident inspection, the engine compression test was conducted by turning the propeller by hand in the direction of rotation, and it rotated freely without restriction or obstruction. However, after recovery the next day, the engine would not turn freely when rotated by hand, which prompted an engine strip.

2.2.11. The teardown inspection of the engine did not reveal any pre-impact mechanical failure, and the findings showed that the engine and its attachments were in good condition and did not exhibit any impact damage because of the accident.

2.2.12. There was evidence of sufficient oil in the engine. However, the oil had turned into a slurry (milky liquid). It was deduced that the oil had mixed with water which had seeped into the engine when it was submerged in the waterbed for a few days after the accident. The thick slurry had migrated into the engine components and restricted the free movement of the crankshaft, cylinders, pistons and valve assemblies experienced by the AME after recovery. The possibility of damage due to impact was eliminated as it was determined that water had caused rust to develop in the interior of the crankcase and other components, which caused restriction of the engine's internal components.

2.2.13. Disassembly and inspection carburettor bowl did not reveal any failure or blockage. Because the engine had been stored in an inverted orientation for months before it could be stripped, there were very little remnants of fuel found in the carburettor bowl. After disassembly, observation of discolouration due to rust was noted on the idle fuel tube vent, accelerator pump, pump plunger and the walls of the accelerator pump chamber of the carburettor.

2.2.14. The accelerator pump is responsible for providing the momentary additional fuel needed under heavy acceleration conditions. When the throttle is suddenly pushed to apply full power, the throttle valve will open, immediately adding additional air for increased power. The additional air requires additional fuel, especially in the precise moments after the throttle is opened, this is the fuel the accelerator pump provides. When the throttle is rapidly opened, the accelerator pump will squirt a small amount of fuel into the throat of the carburettor so that the engine can continue running smoothly under increased load. The presence of water in the fuel would have disturbed the combustion of the fuel air mixture in the combustion chambers on the cylinders, resulting in loss of power after take-off.

Fuel Quality and Fuel Testing:

2.2.15. It could not be determined how much fuel was drained during the fuel testing by the pilot, however, it is possible that not enough fuel was drained as indicated by SACAA's Aircraft Fuel Control (CA AOC-AC-005). It was necessary to drain 10 liquid ounces (295 millilitres) of fuel before any water appeared. This is considerably more than most pilots drain when checking for water.

2.2.16. Although the pilot did not take note of how long the fuel was drained after refuelling, it is possible that water was still suspended in the fuel when fuel quality checks were carried out by the pilot. By not allowing the fuel to settle for a longer period, impurities in the fuel had not settled into the drain sump of each tank before the pilot drained the fuel.

2.2.17. On 27 May 2022, fuel samples from bowsers KMG 672 NW and KMG 698 NW from which the owner refuels were taken for analysis; the fuel samples from bowsers were found acceptable and met all specifications. However, according to the results given in 1.16.4.4., the fuel sample from ZS-BTL supplied by the owner failed on appearance as there were fine particles and free water globules visible; the sample did not meet the requirements for RVP.

2.2.18. On 1 June 2022, a follow-up site inspection was carried out and processes used for fuelling were reviewed, and a second batch of fuel samples were taken for similar testing. The samples from the second batch were analysed on 1 June 2022 and were later sent for verification by the third party. All fuel samples were found to be clear and met all specifications for properties tested.

2.2.19. Fuel samples from the SV Aviation's main tank at FAPS were also taken for analysis on 27 May and 1 June 2022 and both fuel samples were found to be clear from contamination and were of acceptable standard during tests carried out on different samples.

2.2.20. Based on the significant quantity of water identified in the fuel sample taken after the accident and the absence of any other engine defect, the engine power loss was probably the result of water contamination. A possible source of water found in the fuel was considered to have seeped into the fuel tanks as the aircraft was submerged in a waterbed for a few days before the fuel sample was drawn.

2.2.21. Based on the pilot not experiencing an engine surge when the power loss occurred, this could indicate that the water droplets were still suspended in the fuel and resulted in the engine not producing enough power to maintain flight. The time between the accident and the time the fuel sample was taken (a few days after the accident) would have allowed water droplets to separate out of suspension from the fuel as found during the fuel quality examination (Figure 9).

2.2.22. Water is non-flammable and when mixed with fuel has the potential to disturb combustion. The presence of water in the fuel is the most probable cause of loss of engine power after take-off, reported by the pilot.

3. CONCLUSION

3.1. General

From the available evidence, the following findings, causes and contributing factors were made with respect to this accident. These shall not be read as apportioning blame or liability to any organisation or individual.

To serve the objective of this investigation, the following sections are included in the conclusion heading:

- **Findings —** are statements of all significant conditions, events, or circumstances in this accident. The findings are significant steps in this accident sequence, but they are not always causal or indicate deficiencies.
- **Causes —** are actions, omissions, events, conditions, or a combination thereof, which led to this accident.
- **Contributing factors —** are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided, or absent, would have reduced the probability of the accident occurring, or would have mitigated the severity of the consequences of the accident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil, or criminal liability.

3.2. Findings

3.2.1. The pilot was licensed and qualified for the flight in accordance with the existing regulations. Due to the pilot having low flying hours on the aircraft type, it is likely that the pilot had limited technical knowledge of the aircraft.

3.2.2. The aircraft had a valid Certificate of Airworthiness (c of A) and was maintained in compliance with the existing regulations. The aircraft was airworthy at the time of the flight.

3.2.3. The maintenance records indicated that the aircraft was equipped and maintained in accordance with the existing regulations and approved procedures.

3.2.4. There was no mechanical defect with the aircraft, engine, propeller or fuel system that could have caused or contributed to the accident.

3.2.5. The mass and centre of gravity of the aircraft were within the prescribed limits.

3.2.6. The aircraft was substantially damaged by impact forces; however, the pilot did not sustain any injuries during the accident.

3.2.7. Lack of visible damage and/or twisting of the propeller is consistent with the engine not producing power at impact.

3.2.8. The prevailing weather conditions had no bearing on the accident.

3.2.9. The loss of engine power occurred immediately after take-off. Although the engine did not stop operating, the loss of power was such that the pilot could not maintain altitude and had no other choice other than to execute a forced landing.

3.2.10. Due to the aircraft being submerged in an inverted attitude in a waterbed for a few days before being recovered, water seeped into the engine, forming a thick slurry with the engine oil and lubricants in the engine components. The slurry restricted the rotation of the engine crankshaft when turned by hand, which prompted the engine teardown.

3.2.11. The engine teardown inspection did not reveal any pre-impact mechanical failure. The findings showed that the engine and its attachments were in good condition and did not exhibit any impact damage because of the accident.

3.2.12. After disassembly, discolouration due to rust was noted on the idle fuel tube vent, accelerator pump, pump plunger and the walls of the accelerator pump chamber of the carburettor. Water can only enter these sections of the carburettor during operation.

3.2.13. The fuel sampled from ZS-BTL after the accident was of the recommended grade, however, it contained a substantial amount of water contamination. It is possible that more water could have seeped into the fuel tanks whilst the aircraft was submerged in the waterbed after the accident. However, rust observed in the carburettor indicates that there was water in the fuel before the accident, although the amount of water in the fuel prior to the accident could not be determined.

3.2.14. Because the accelerator pump is responsible for providing the momentary additional fuel needed under heavy acceleration conditions, it squirts a small amount of fuel into the throat of the carburettor so that the engine can continue running smoothly under increased load. The presence of water disturbed the combustion of the fuel air mixture in the combustion chambers on the cylinders, which resulted in the partial loss of engine power on take-off.

3.2.15. Because the engine did not surge when the power loss occurred is an indication that the water droplets were still suspended in the fuel, and this resulted in the engine not producing enough power to maintain flight.

3.3. Probable Cause/s

3.3.1. Water contaminated fuel led to partial engine power loss during the initial climb phase, which led to the inability of the engine to produce enough power to maintain flight. This prompted the pilot to perform a forced landing on an open area of the grass-covered wetland, which resulted in substantial damage to the aircraft.

3.4. Contributory Factor/s

3.4.1. Draining fuel samples too soon after refuelling; not allowing time for any impurities/contaminants in the fuel to settle into the drain sump/point of each tank before draining fuel samples.

4. SAFETY RECOMMENDATIONS

4.1. General

The safety recommendations listed in this report are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation and are based on the conclusions listed in heading 3 of this report. The AIID expects that all safety issues identified by the investigation are addressed by the receiving States and organisations.

4.2. Safety Message

4.2.1. Pilots are advised to allow sufficient time to pass before draining fuel samples. Draining fuel samples too soon after refuelling does not allow enough time for impurities/contaminants in the fuel to settle into the drain sump/purging point of each tank.

5. APPENDICES

5.1. Appendix A – Piper PA-25-235D Fuel System
5.2. Appendix C – Airworthiness Bulletin (AWB) 28-008 – Water Contamination of Aviation Fuel (AVGAS / MOGAS), Issue: 2, Date: 8 March 2016 Who have issued this AB?

This report is issued by:
Accident and Incident Investigations Division
South African Civil Aviation Authority
Republic of South Africa

FUEL SYSTEM

A 38.5 gallon fuel supply (36 gallons usable) is carried in two aluminum fuel tanks, one in each wing. An electric fuel quantity gauge, a fuel pressure gauge and a low fuel warning light are mounted on top of the center of the instrument panel. The low fuel warning illuminates when approximately 7 gallons of fuel is left on board.

The fuel shut-off valve is controlled by a "T" handle on the right side of the cockpit. In addition to the engine-driven fuel pump, there are two electric fuel pumps connected in parallel and activated by a single ON-OFF switch mounted on the sub-panel on the lower right of the instrument panel. Circuit breakers for the electric fuel pumps and fuel quantity indicator are also mounted on this sub-panel.

To facilitate starting, an engine primer pump on the left side of the instrument panel may be used to manually pump fuel directly into the engine cylinders. To prevent engine malfunction, the primer pump should be locked in at all times except when in use.

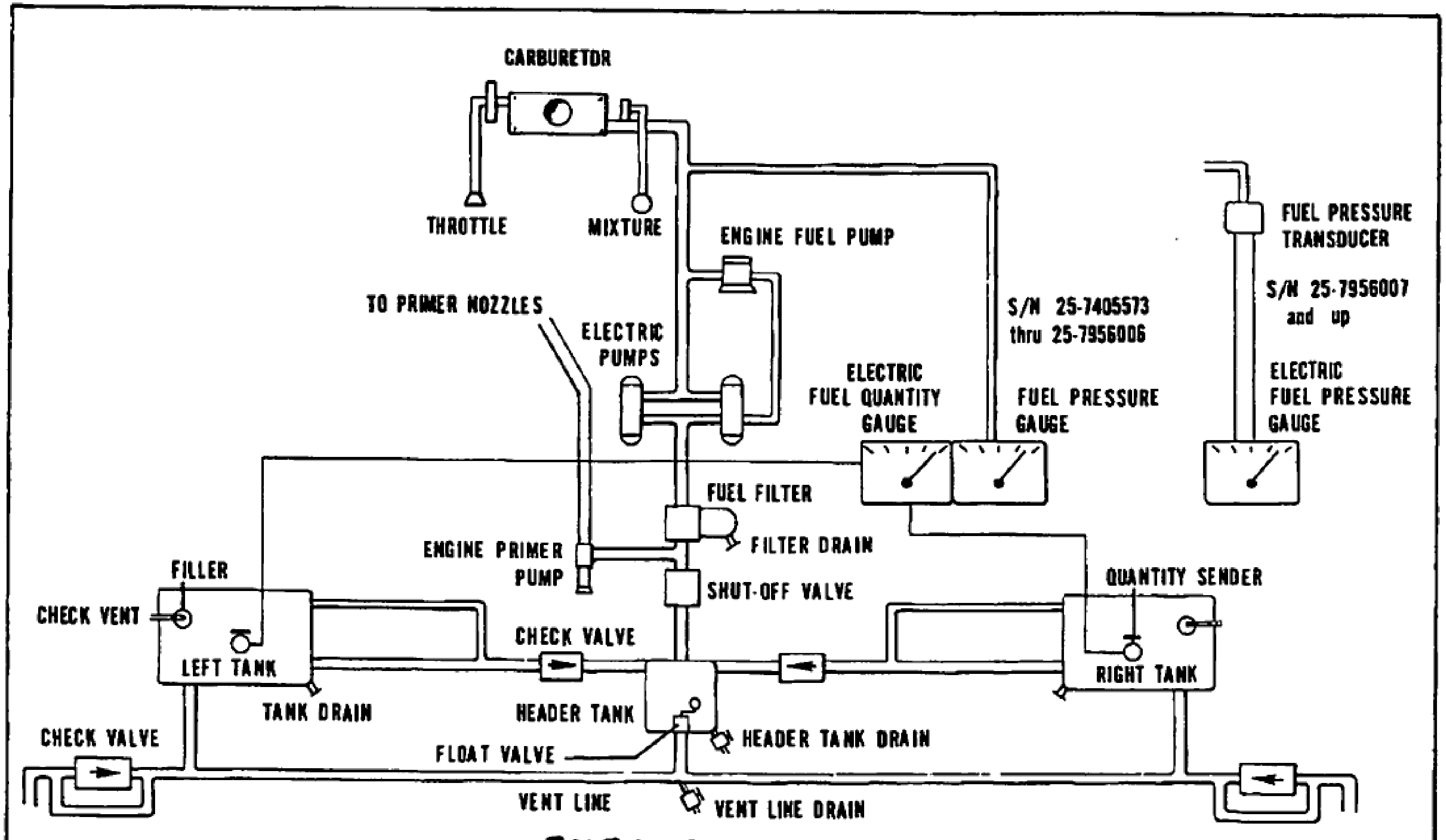
Both fuel tanks feed simultaneously into a header tank which serves to maintain a constant flow of fuel to the engine. The header tank is equipped with a quick-drain and a float valve connected to the vent line. The header tank drain and vent line drain are located aft of the wing on the underside of the fuselage. The fuel filter drain is also located on the underside of the fuselage but aft of the firewall. Each fuel tank has a drain located on the underside of the wing. Before each flight the quick-drain valves should be opened for a few seconds to remove water or sediment from the fuel system.

One way check valves are used in the vent line to prevent excess fuel overflow during taxi turns or uncoordinated flight. These check valves have two pressure release holes which bypass the check valves and will allow slight overflow during thermal expansion of a full tank.

An idle cut-off is incorporated in the mixture control - the engine should be stopped with the idle cut-off.

NOTE

To insure lateral stability, fuel tanks must not be filled asymmetrically.


CARBURETOR
THROTTLE
MIXTURE
ENGINE FUEL PUMP
FUEL PRESSURE
TRANSDUCER
S/N 25-7956007
and up
TO PRIMER NOZZLES
ELECTRIC
PUMPS
S/N 25-7405573
thru 25-7956006
ELECTRIC
FUEL QUANTITY
GAUGE
FUEL PRESSURE
GAUGE
ELECTRIC
FUEL PRESSURE
GAUGE
FUEL FILTER
FILTER DRAIN
ENGINE PRIMER
PUMP
FILLER
SHUT-OFF VALVE
QUANTITY SENDER
CHECK VENT
CHECK VALVE
LEFT TANK
RIGHT TANK
TANK DRAIN
HEADER TANK
CHECK VALVE
HEADER TANK DRAIN
FLOAT VALVE
VENT LINE
VENT LINE DRAIN

FUEL SYSTEM

Appendix B
Marvel-Schebler MA-4-5 Carburettor Principles of Operation

SECTION III
OPERATION

1. **PRINCIPLES OF OPERATION**.

   a. IDLE SYSTEM, (Ref. appropriate figure for a particular model). – With the throttle fly slightly open to permit idling, the suction or vacuum above the throttle on the manifold side is very high. Very little air passes through the venturi at this time, and hence, with very low suction on the main nozzle, it does not discharge fuel. This high suction beyond the throttle, however, causes the idle system to function as the primary idle delivers into the high suction zone above the throttle. Fuel from the fuel bowl passes through the mixture metering sleeve, fuel channel, power jet, and into the main nozzle bore, where it passes through the idle supply opening in main nozzle, through the idle fuel orifice in idle tube, where it is mixed with air which is allowed to enter idle tube through the primary idle air vent and secondary idle air vent. The resultant rich emulsion of fuel and air passes upward through the emulsion channel, where it is finally drawn into the throttle body through the primary idle delivery opening, subject to regulation of the idle adjusting needle, where a small amount of air passing the throttle fly mixes with it, forming a combustible mixture for idling the engine. The idle adjustment needle controls the quantity of rich emulsion supplied to the throttle barrel, and therefore controls the quality of the idle mixture. Turning the needle counter-clockwise away from its seat richens the idle mixture to the engine, and turning the needle clockwise towards its seat leans the idle mixture. On idle, some air is drawn from the throttle barrel below the throttle fly through the secondary idle delivery opening and blends with the idling mixture to the engine as the throttle is opened, coming into play progressively and blending with the primary idle delivery to prevent the mixture from beginning too lean as the throttle is opened and before the main nozzle starts to feed. These Carburetors are provided with a third and, possibly a fourth idle delivery in addition to the secondary idle delivery, depending on the application to cover the broader idle range in these Carburetors.

   b. METERING, (Ref. appropriate figure for a particular model). – All fuel delivery on idle, and also as steady propeller speeds up to approx. 1,000 rpm, is from the idle system. At approx. 1,000 rpm the suction from the increasing amount of air now passing through primary and secondary venturi causes the main nozzle to start delivering, and the idle system delivery diminishes due to lowered suction on the idle delivery openings as the throttle fly is opened for increasing propeller speeds, until at approx. 1,400 rpm the idle delivery is practically nil, and most of the fuel delivery from that point onto the highest speed is from the main nozzle. However, the fuel feed of any full throttle operation is entirely from the main nozzle. The idle system and main nozzle are connected with each other by the idle supply opening. The amount of fuel delivered from either the idle system or main nozzle is dependent on the whether the suction is greater on the idle system or main nozzle, the suction being governed by throttle valve position and engine load. The main nozzle feeds at any speed if the throttle is open sufficiently to place the engine under load, which drops the manifold suction. Under such conditions of low manifold suction at the throttle fly, the main nozzle feeds in preference to the idle system because the suction is multiplied on the main nozzle by the restriction of the venturi.

   c. ACCELERATOR PUMP, (Ref. appropriate figure for a particular model). – The accelerator pump discharges fuel only when the throttle fly is moved towards the open position, and provides additional fuel to keep in step with the sudden inrush of air into the manifold when the throttle is opened. By means of an accelerator pump lever connected to the throttle shaft, the accelerator pump plunger is moved downward when the throttle is opened, thus forcing fuel past the carburetor pump discharge check valve into the accelerator pump discharge tube which delivers accelerating fuel through the primary venturi into the mixing chamber of the carburetor. Upon closing the throttle, the accelerator pump plunger moves upward, thus refilling the accelerator pump chamber by drawing fuel from the fuel bowl through pump inlet screen and pump inlet check valve. On any quick opening of the throttle the pump follow-up spring yields and thus prolongs the pump discharge sufficiently to prevent "slugging" the engine with fuel. As a precaution to prevent fuel from being drawn into the mixing chamber when the accelerator pump is inoperative, (any constant throttle position), accelerator pump discharge check valve assembly mounted in the Carburetor is provided with an accelerator pump discharge check valve loaded by an accelerator pump discharge check valve spring.

d. POWER ENRICHMENT, (ECONOMIZER), SYSTEM, (Ref. appropriate figure for a particular model).-Aircraft engines are designed to produce a maximum amount of power consistent with their weight. But since they are not designed to dissipate all of the heat the fuel is capable of releasing, provisions must be made to remove some of this heat. This is done by enriching the fuel - air mixture at full throttle. The additional fuel absorbs this heat as it changes into a vapor. Power enrichment systems are often called economizer systems because they allow the engine to operate with a relatively lean and economical mixture for all conditions other than full power.

e. MECHANICAL AIRBLEED ENRICHMENT SYSTEM, (Large MA-4-5, HA-6 Carburetors, Ref. appropriate figure for a particular model).–When we increase the air velocity through the main venturi, we get an increased pressure drop that enriches the mixture, and to prevent this enrichment, an air bleed of a very precise size is used between the float bowl and the discharge nozzle. If we increase the size of this air bleed, we lean the mixture, and if we decrease it, more fuel is pulled from the discharge nozzle and the mixture becomes richer. The air for the air bleed comes from the float chamber and passes through the air bleed metering valve. The needle for this valve is held off of its seat by a spring and is closed by an operating lever attached to the throttle shaft. When the throttle is wide open, the lever closes the air bleed valve and enriches the fuel – air mixture.

f. BACK-SUCTION TYPE ENRICHMENT SYSTEM, (Small MA-3, MA-4 Carburetors, Ref. appropriate figure for a particular model). – The back-suction mixture control varies the pressure in the float chamber between atmospheric pressure and a pressure slightly below atmospheric. This pressure variation is accomplished by using a control valve located in the float chamber vent line. The float chamber is vented to the low-pressure area near the venturi through a back suction channel. This lowers the pressure in the float bowl. When then mixture control is in the rich position, the vent valve is open and the pressure in the float bowl is raised to essentially the atmospheric pressure, and a differential pressure exists across the main metering jet. This causes fuel to flow out of the discharge nozzle. When the mixture control is moved to lean, it closes the vent valve, and pressure in the float chamber is decreased to a pressure that is essentially the same as that of the discharge nozzle. This decreased pressure differential decreases the flow of fuel.

g. MIXTURE CONTROL, (Ref. appropriate figure for a particular model). – The mixture control consists of mixture control lever which is attached the mixture metering valve assembly. The mixture metering valve assembly is provided at its lower end with mixture metering valve, which rotates in stationary mixture sleeve. Mixture metering sleeve is provided with a transverse slot through which the fuel enters and fuel metering is accomplished by the relative position between one edge of the longitudinal flat on the mixture metering valve and one edge of the slot in the mixture metering sleeve. When the mixture control lever is in toward the carburetor throttle flange, a full rich mixture is provided for takeoff. With the mixture control lever in the "FULL RICH" position, metering is controlled by the power jet, but in other than "FULL RICH" position, metering is accomplished by the relative position of the respective edges of the mixture metering sleeve and mixture metering valve as described above. To make the mixture leaner for altitude compensation, move the mixture control lever away from the carburetor throttle flange. With the mixture control lever in the full lean position, (with mixture control lever in a position farthest from the carburetor throttle flange), no fuel is allowed to enter the nozzle and idle system, thus providing what is known as "IDLE CUT OFF" to prevent accidents when working around a hot engine. This cut off is accomplished by the fact that the angular opening between the metering edge of the mixture metering valve and the metering edge of the mixture metering sleeve in the "FULL RICH" position is narrower than the total angular travel of the mixture metering valve.

Appendix C
Airworthiness Bulletin (AWB) 28-008 – Water Contamination of Aviation Fuel (AVGAS / MOGAS), Issue: 2, Date: 8 March 2016

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.

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.

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 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)

(Source: https://www.legislation.gov.au/Details/F2006C00266)