SOUTH AFRICAN CIVIL AVIATION AUTHORITY

*Section/division* **Accident and Incident Investigations Division** Form Number: CA 12-12a

# AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | **Reference:** | CA18/2/3/10087 | | |
| **Aircraft Registration** | ZS-EZM | **Date of Accident** | 7 December 2021 | | **Time of Accident** | 0635Z | |
| **Type of Aircraft** | Cessna 177 Cardinal | | **Type of Operation** | | Private (Part 91) | | |
| **Pilot-in-command Licence Type** | CPL (A) | | **Age** | 23 | **Licence Valid** | Yes | |
| **Pilot-in-command Flying Experience** | | **Total Flying Hours** | | 724.1 | **Hours on Type** | 36.4 | |
| **Last Point of Departure** | Grand Central Airport (FAGC), Gauteng Province | | | | | | |
| **Next Point of Intended Landing** | Grand Central Airport (FAGC), Gauteng Province | | | | | | |
| **Damage to Aircraft** | Substantial | | | | | | |
| **Location of the accident site with reference to easily defined geographical points (GPS readings if possible)** | | | | | | | |
| Approximately 300 metres from the threshold of RWY 31 at Baragwanath Aerodrome (FASY), at GPS co-ordinates determined to be 26°21'05.2" South 027°47'10.8" East at 5439 ft AMSL | | | | | | | |
| **Meteorological Information** | Surface wind: 360°/10kt; temperature: 21°C; dew Point: 15°C; CAVOK; visibility: 9999m; QNH: 1025hPA | | | | | | |
| **Number of People On-board** | 1 + 1 | **Number of People Injured** | 0 | **Number of People Killed** | 0 | **Other (On Ground)** | 0 |

**Synopsis**

On Tuesday morning, 7 December 2021, a pilot, and a passenger on-board a Cessna 177 Cardinal aircraft with registration ZS-EZM were on a private flight from Grand Central Airport (FAGC) in Midrand, Gauteng province, to Johannesburg South General Flying Area (GFA) with the intention to land back at FAGC. Visual meteorological conditions (VMC) by day prevailed at the time of the flight, and no flight plan was filed. The flight was conducted under the provisions of Part 91 of the Civil Aviation Regulations (CAR) 2011 as amended.

According to the pilot, after approximately 1 hour 5 minutes (1.09 hours) of total flight time whilst cruising at an altitude of 7 000 feet (ft) overhead Lawley residential area in the south of Lenasia, Johannesburg, the engine started to run rough, and it eventually stopped. Whilst conducting fault-finding and engine restart procedures in accordance with the aircraft Owner's Manual (OM), the pilot noted that the fuel gauges displayed empty (denoting there was no fuel) and presumed that the engine had stopped due to fuel exhaustion.

The pilot then glided the aircraft towards Baragwanath Aerodrome (FASY) which was approximately 7 nautical miles (NM) from his position. However, the aircraft lost height rapidly which resulted in the aircraft undershooting Runway 31 (RWY 31) by approximately 300 metres (m). During the forced landing, the nose landing gear wheel impacted the hard rugged terrain, bringing the aircraft to an abrupt halt. The aircraft was substantially damaged; however, the occupants did not sustain any injuries during the accident sequence.

Post-accident, the pilot reported that both fuel tanks were found empty and fuel residue was observed underneath the left fuel tank and along the roof of the cabin. According to the aircraft maintenance engineer (AME) who recovered the ZS-EZM aircraft from the accident site, approximately 150 millilitres (ml) of fuel was drained from both tanks, and there was no smell of fuel at the accident site.

| Probable Cause and Contributory Factors | | | |
|---|---|---|---|
| **Probable Cause**<br>Engine stoppage in-flight due to fuel exhaustion, which prompted the pilot to perform a forced landing on an open area of grassland, resulting in substantial damage to the aircraft.<br>**Contributory Factor**<br>There was insufficient evidence to determine the cause of the fuel exhaustion. However, based on fuel calculations, it is likely that the fuel exhaustion resulted due to a lack of consideration of higher fuel consumption rates during cruise due to wind conditions, different flying techniques, insufficient fuel mixture leaning, to list a few factors.<br>Inadequate in-flight fuel management. | | | |
| SRP Date | 14 March 2023 | Publication Date | 30 March 2023 |

## Occurrence Details

| | |
|---|---|
| **Reference Number** | **:** CA18/2/3/10087 |
| **Occurrence Category** | **:** Category 2 |
| **Type of Operation** | **:** Private |
| **Aircraft Registration** | **:** ZS-EZM |
| **Aircraft Make and Model** | **:** Cessna Aircraft Company, Cessna 177, Cardinal |
| **Nationality** | **:** South African |
| **Place** | **:** 300 m from the threshold of Runway (RWY) 31 at FASY, South of Baragwanath Aerodrome (FASY), Gauteng Province |
| **Date and Time** | **:** 7 December 2021 at 0635Z |
| **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 7 December 2021 at 0645Z. The occurrence was classified as an accident according to the CAR 2011 Part 12 and ICAO Annex 13 definition. Notifications were sent to the State of Registry (South Africa – SACAA) and State of Manufacturer (United States of America – NTSB) in accordance with the CAR 2011 Part 12 and ICAO Annex 13 Chapter 4. The NTSB appointed a non-travelling accredited representative and advisor. The investigator was not dispatched 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* Cessna 177 Cardinal *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 various 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


Executive Summary ........ 1
Occurrence Details ........ 3
Purpose of the Investigation ........ 3
Investigation Process ........ 3
Disclaimer ........ 3
Table of Contents ........ 4
Abbreviations ........ 5
1. FACTUAL INFORMATION ........ 6
1.1. History of Flight ........ 6
1.2. Injuries to Persons ........ 7
1.3. Damage to Aircraft ........ 7
1.4. Other Damage ........ 8
1.5. Personnel Information ........ 8
1.6. Aircraft Information ........ 8
1.7. Meteorological Information ........ 11
1.8. Aids to Navigation ........ 12
1.9. Communication ........ 12
1.10. Aerodrome Information ........ 12
1.11. Flight Recorders ........ 12
1.12. Wreckage and Impact Information ........ 12
1.13. Medical and Pathological Information ........ 15
1.14. Fire ........ 15
1.15. Survival Aspects ........ 15
1.16. Tests and Research ........ 16
1.17. Organisational and Management Information ........ 20
1.18. Additional Information ........ 20
1.19. Useful or Effective Investigation Techniques ........ 21
2. ANALYSIS ........ 21
3. CONCLUSION ........ 28
3.2. Findings ........ 29
3.3. Probable Cause ........ 30
3.4. Contributory Factors ........ 30
4. SAFETY RECOMMENDATIONS ........ 31
5. APPENDICES ........ 31

| Abbreviation | Description |
| --- | --- |
| ° | Degrees |
| °C | Degrees Celsius |
| AIID | Accident and Incident Investigations Division |
| AMSL | Above Mean Sea Level |
| ATC | Air Traffic Control |
| ATCO | Air Traffic Control Officer |
| AVGAS | Aviation gasoline |
| CAR | Civil Aviation Regulations |
| CASA | Australian Civil Aviation Safety Authority |
| C of A | Certificate of Airworthiness |
| C of R | Certificate of Registration |
| CPL | Commercial Pilot Licence |
| CRS | Certificate of Release to Service |
| E | East |
| FAGC | Grand Central Airport |
| FAOR | O.R. Tambo Airport |
| FASY | Baragwanath Aerodrome |
| ft | Feet |
| GFA | General Flying Area |
| GPH | Gallons per hour |
| GPS | Global Positioning System |
| hp | Horsepower |
| hPa | Hectopascal |
| hr | Hour |
| JHB | Johannesburg |
| kg | Kilograms |
| km | Kilometres |
| kt | Knots |
| L | Litres |
| L/hr | Litres per hour |
| m | Metres |
| METAR | Meteorological Routine Aerodrome Report |
| MHz | Megahertz |
| ml | Millilitres |
| MPI | Mandatory Periodic Inspection |
| NM | Nautical mile(s) |
| OM | Owner’s Manual |
| PIC | Pilot-in-command |
| RPM | Revolutions per minute |
| RWY | Runway |
| QNH | Barometric pressure setting to indicate elevation Above Mean Sea Level |
| S | South |
| SACAA | South African Civil Aviation Authority |
| SAWS | South African Weather Service |
| SB | Service Bulletin |
| TBO | Time Between Overhaul |
| USG | US Gallons |
| VMC | Visual Meteorological Conditions |
| Z | Zulu (Term for Universal Co-ordinated Time - Zero Hours Greenwich) |

# 1. FACTUAL INFORMATION

## 1.1. History of Flight

1.1.1. On 7 December 2021, a pilot, and a passenger on-board a Cessna 177 Cardinal aircraft with registration ZS-EZM took off on a private flight from Grand Central Airport (FAGC) in Midrand, Gauteng province, to the Johannesburg South General Flying Area (GFA) with the intention to land back at FAGC. Visual meteorological conditions (VMC) by day prevailed at the time of the flight, and no flight plan was filed. The flight was conducted under the provisions of Part 91 of the Civil Aviation Regulations (CAR) 2011 as amended.

1.1.2. According to the pilot, during the pre-flight inspection, the aircraft had a total (both tanks) of approximately 91 litres (L) (24 US gallons (USG)) of usable fuel with a flight endurance of approximately 3.0 hours at take-off. After engine start, the aircraft was held on the ground for approximately 22 minutes due to other movements in the circuit.

1.1.3. Later, the pair took off using Runway 35 (RWY 35) at 0559Z with an estimated flight duration of 1 hour 30 minutes (1.5 hours). According to the pilot, a fuel quantity check was done at the point where ZS-EZM left FAGC airspace, and a subsequent fuel quantity check was done during the re-leaning of the fuel mixture after reaching a cruise altitude of 7 000 feet (ft) above mean sea level (AMSL) en route to the GFA. The pilot had deduced that the fuel levels were adequate for the remainder of the planned flight and, therefore, continued with the flight.

1.1.4. Whilst routing back to FAGC, the aircraft climbed to 7 500 feet (ft) above mean sea level (AMSL) but shortly after that, conflicting oncoming traffic in the area reported that they were at the same position and altitude as the ZS-EZM. Because the reporting traffic could not be visually detected by the pilot of ZS-EZM, the pilot (ZS-EZM) descended to 7 000ft AMSL for vertical separation while continuing to look out for the traffic.

1.1.5. As the ZS-EZM was flying overhead Lawley residential area (northerly direction en route to FAGC) in the south of Lenasia, Johannesburg, the pilot stated that the engine started to run rough. This was after 1 hour 21 minutes (1.35 hours) of total operating time (with the airborne time being unknown) while flying at an altitude of 7 000 ft AMSL.

1.1.6. The pilot conducted the fault-finding procedure in accordance with the aircraft Owner's Manual (OM) but could not identify the faults. The engine continued to run rough and, eventually, stopped while the fuel setting was selected to both fuel tanks. The pilot noted that the fuel gauges, the fuel flow gauge, and the fuel pressure gauge, all displayed empty/zero readings (denoting there was no fuel). He then deduced that the most probable cause of the engine stoppage was due to fuel exhaustion.

1.1.7. The pilot then glided the aircraft towards Baragwanath Aerodrome (FASY); however, it lost height rapidly, resulting in the aircraft undershooting RWY 31 by approximately 300 metres (m). During touchdown, the nose landing gear collapsed, and the aircraft came to an abrupt stop. The aircraft was substantially damaged; however, the occupants did not sustain any injuries; they disembarked from the aircraft unassisted.

1.1.8. The accident occurred on an open field approximately 300m before the threshold of RWY 31 at FASY at Global Positioning System (GPS) co-ordinates determined to be 26°21'05.2" S 027°47'10.8" E, at 5 439 ft AMSL.

**Figure 1:** A view from inside the cockpit with the runway visible in the 12 o'clock position. (Source: Accident Claim Accessor)

## 1.2. Injuries to Persons

| Injuries | Pilot | Crew | Pass. | Total On-board | Other |
|---|---|---|---|---|---|
| Fatal | - | - | - | - | - |
| Serious | - | - | - | - | - |
| Minor | - | - | - | - | - |
| None | 1 | - | 1 | 2 | - |
| **Total** | **1** | **-** | **1** | **2** | **-** |

Note: Other means people on the ground.

## 1.3. Damage to Aircraft

1.3.1. The aircraft was substantially damaged.

**Figure 2:** The aircraft post-accident. (Source: Pilot)

## 1.4. Other Damage

1.4.1. None.

## 1.5. Personnel Information

| | | | | | |
|---|---|---|---|---|---|
| Nationality | South African | Gender | Male | Age | 23 |
| Licence Type | Commercial Pilot Licence (CPL) Aeroplane | | | | |
| Licence Valid | Yes | Type Endorsed | Yes | | |
| Ratings | Instrument, Instructor Grade 2 | | | | |
| Medical Class | Class 1 | | | | |
| Medical Issue Date | 27 January 2021 | Medical Expiry Date | 31 January 2022 | | |
| Restrictions | 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 Hours | 724.1 |
| Total Past 90 Days | 48.5 |
| Total on Type Past 90 Days | 16.8 |
| Total on Type | 36.4 |

1.5.1. The pilot had a Commercial Pilot Licence (CPL) that was issued on 6 February 2021 with an expiry date of 28 February 2022. According to the pilot questionnaire, the pilot had flown a total of 724.1 hours, of which 36.4 were on the aircraft type.

1.5.2 The pilot was issued a Class 1 aviation medical certificate on 27 January 2021 with an expiry date of 31 January 2022, with the restriction to wear suitable corrective lenses.

## 1.6. Aircraft Information

1.6.1. *The Cessna 177 Cardinal is a four-seat, high-wing, fixed-tricycle-gear aircraft manufactured in 1968 and is powered by a four-cylinder Lycoming IO-360-B1B piston engine with 180-rated horsepower (hp) at a rated speed of 2700 revolutions per minute (RPM), equipped with a three-blade, variable-pitch, Hartzell propeller*.
(Source: Cessna 177 Cardinal Owners' Manual)

**Airframe:**

| | | |
|---|---|---|
| Manufacturer/Model | Cessna Aircraft Company / 177 Cardinal | |
| Serial Number | 177-00296 | |
| Year of Manufacture | 1968 | |
| Total Airframe Hours (At Time of Accident) | 3 082.84 | |
| Last MPI & CRS (Date & Hours) | 11 December 2020 | 3 047.99 |
| Airframe Hours Since Last MPI | 34.85 | |
| C of A (Original Issue Date & Expiry Date) | 8 September 1988 | 30 April 2022 |
| C of R (Issue Date) (Present Owner) | 10 March 2021 | |
| Operating Category | Part 91 | |
| Type of Fuel Used | Avgas 100 LL | |
| Previous Accidents | None | |

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

**Engine:**

| | |
|---|---|
| Manufacturer/Model | Lycoming IO-360-B1B |
| Serial Number | L-5698-58A |
| Hours Since New | 2957.41 |
| Date of overhaul | 3 July 2003 |
| Hours Since Overhaul | 300.78 |

**Propeller:**

| | |
|---|---|
| Manufacturer/Model | Hartzell HC-C3YR-1RF |
| Serial Number | DY4609B |
| Hours Since New | 348.29 |
| Date of Midlife Inspection | 4 December 2017 |
| Hours Since Overhaul | 52.34 |

1.6.2. According to the aircraft's airframe logbook, the Service Bulletin (SB) 99-18 which requires that the fuel quantity indication system be bench-tested or inspected every 12 months was complied with during the aircraft's last mandatory periodic inspection (MPI) that was conducted on 11 December 2020. Furthermore, there had not been prior defects reported that related to the fuel system.

1.6.3. According to the certificate relating to maintenance of the ZS-EZM record, during the aircraft's last MPI, repair of the right-side fuel tank leak was conducted.

1.6.4. There were no technical defects with the engine that were recorded in the engine logbook and flight folio. Also, there were no technical defects with the propeller that were recorded in the propeller logbook and flight folio.

1.6.5. <u>Aircraft's Operation History</u>

1.6.5.1. According to the pilot, the aircraft had approximately 91 litres (L) (24 US gallons [USG]) of usable fuel in both tanks prior to start – 53 L (14 USG) in the right fuel tank and 38 L (10

USG) in the left fuel tank. The pilot stated that the fuel quantity was checked using a Fuel Hawk Universal 14 Inch Fuel Gauge pipette.

1.6.5.2. Based on the pilot questionnaire, on 7 December 2021, the engine was operated at 2 300 revolutions per minute (RPM) while cruising at 7 000ft. According to the pilot, the fuel on-board the aircraft would have been enough for a flight endurance of approximately 2.8 hours at 65% or 2.2 hours at 75% cruise power.

1.6.6. Boost Fuel Pump History

1.6.6.1. The ZS-EZM owner submitted Job card 18001, according to the job card the aircraft's boost fuel pump (S/N: 4079) stopped working and was sent to an electrical AMO for a full repair and overhaul on 23 September 2021. According to the owner there was an estimated fuel loss of around 40.7 L (10.7 USG) when the fuel pump failed. The pump was received back and was installed to the aircraft as required. Operation checks were carried out and found satisfactory. There is no indication on Job card of when the installation was carried out, however, the job card was printed on 29 October 2021. According to the owner, the pump was overhauled between 23 September 2021 and 18 October 2021.

1.6.6.2. According to the aircraft's engine component record, the fuel pump (S/N: AA15950) was installed newly overhauled on 17 April 2003. There were no records to be determined when the fuel pump referred to in 1.6.6.1. was installed on the aircraft.

1.6.6.3. There were no logbook entries to record the overhaul carried out on 27 September 2021 in the either the aircraft or engine logbooks.

1.6.6.4. The owner of the aircraft further stated that the electronic fuel pump experienced an issue on 2 November 2021, and the issue was discussed with the AME who installed the pump previously. According to the owner, the aircraft was returned to service on 8 November 2021. The owner estimates that 90 L (24 USG) of fuel was lost during the removal, reinstallation and testing of the fuel pump. However, no evidence of this was provided or found, the pilot in control on 2 November 2021 did not record a defect with the fuel pump in the defect log nor was this repair recorded in the aircraft's logbooks by the AMO.

1.6.6.5. During the review of the aircraft's logbooks there was no entry of the fuel pump defect rectification recorded.

According to the South African Civil Aviation Regulations (CAR) of 2011 (as amended) requirements for Rectification of unsatisfactory items in terms of subpart 43.02.4 are as follows:

*(1) When during any maintenance or at any other time any part, product, component, equipment, or item is found to be unserviceable or is unlikely to remain serviceable under normal operating conditions during the period preceding the next inspection, such rectification action as considered necessary shall be taken to ensure the continued serviceability of the part, component, or item prior to releasing the aircraft to service.*

*(2) (a) Deferred defects shall be transferred from the flight folio onto a work sheet.*
*(b) Any maintenance carried out to restore the serviceability of any part, component, equipment, or item shall be clearly recorded in the relevant logbook or other*

*approved recording system and be certified by an appropriately rated licence or approval holder prior to releasing the aircraft to service.*

*(3) A person certifying the entry referred to in sub-regulation (2) shall furthermore certify in the relevant flight folio that the deferred defect has been rectified, and he or she shall sign and date the entry accordingly.*

According to the South African Civil Aviation Regulations (CAR) of 2011 (as amended) requirements for Overhaul, Repair and Substitution of Major Components in terms of subpart 43.02.5 are as follows:

***1.Overhauls: General***

*(1) Any overhaul must be carried out in accordance with the manufacturer's current overhaul manuals. Airworthiness Directives, mandatory Service Bulletins, mandatory Service Letters, and mandatory Service Instructions must be embodied as directed. Refer to technical standard 43.02.8 section A 3(5)(b).*

*(3) Overhauls shall be recorded and certified in the appropriate logbook(s) by the holder of an appropriately rated licence or approval.*

1.6.6.6. During the review of the flight folio details, no record of the fuel pump defect was logged for rectification.

According to the CAR of 2011 as amended, *Duties of the PIC regarding flight operations* in terms of subpart 91.02.8 are as follows:

*(4) A PIC of an aircraft shall—*

*(j) record any technical defect and the exceeding of any technical limitation which occurred while he or she was responsible for such flight, in the flight folio.*

## 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) on 7 December 2021 at 0500Z, recorded at O.R Tambo International Airport (FAOR) which is located 10 nautical miles (nm) from FAGC (point of departure).

| | | | | | |
|---|---|---|---|---|---|
| Wind Direction | 360 ° | Wind Speed | 07 kt | Visibility | 9 999 m |
| Temperature | 19 °C | Cloud Cover | CAVOK | Cloud Base | CAVOK |
| Dew Point | 14 °C | QNH | 1 024 hPa | | |

1.7.2. The weather information below was obtained from the METAR that was issued by the SAWS on 7 December 2021 at 0630Z, recorded at FAOR which is located 27nm from the accident site.

| | | | | | |
|---|---|---|---|---|---|
| Wind Direction | 340 ° | Wind Speed | 12 kt | Visibility | 9 999 m |
| Temperature | 22 °C | Cloud Cover | CAVOK | Cloud Base | CAVOK |
| Dew Point | 15 °C | QNH | 1 025 hPa | | |

## 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 navigation system 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 (SACAA). There were no recorded defects with the communication system prior to the accident. According to the pilot's statement, the pilot did not broadcast a distress call.

## 1.10. Aerodrome Information

1.10.1. The aircraft touched down approximately 300m short of the threshold of RWY 31 on an open grass field.

| | |
|---|---|
| Aerodrome Location | Baragwanath Aerodrome (FASY), Westonaria, Gauteng Province |
| Aerodrome Status | Unlicensed |
| Aerodrome GPS coordinates | 26°20'47" South 027°46'31" East |
| Aerodrome Elevation | 5 393 ft |
| Runway Designations | 13/31 |
| Dimensions of Runway Used | 11 13 m x 11 m |
| Runway Used | 31 |
| Runway Surface | Asphalt |
| Approach Facilities | None |
| Radio Frequency | 122.35 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. According to the pilot, after the engine had stopped, the aircraft was glided towards FASY; however, the aircraft lost height rapidly, resulting in the aircraft touching down approximately 300m short of the threshold of RWY 31, on an open grassland.

1.12.2. The nose landing gear strut impacted the hard rugged soil and collapsed backwards shortly after touchdown, which brought the aircraft to an abrupt halt.

1.12.3. The engine separated from the cradle and firewall. The firewall was damaged, whilst the nose landing gear strut collapsed backwards.

**Figure 3:** The nose landing gear strut that collapsed.
(Source: Pilot)

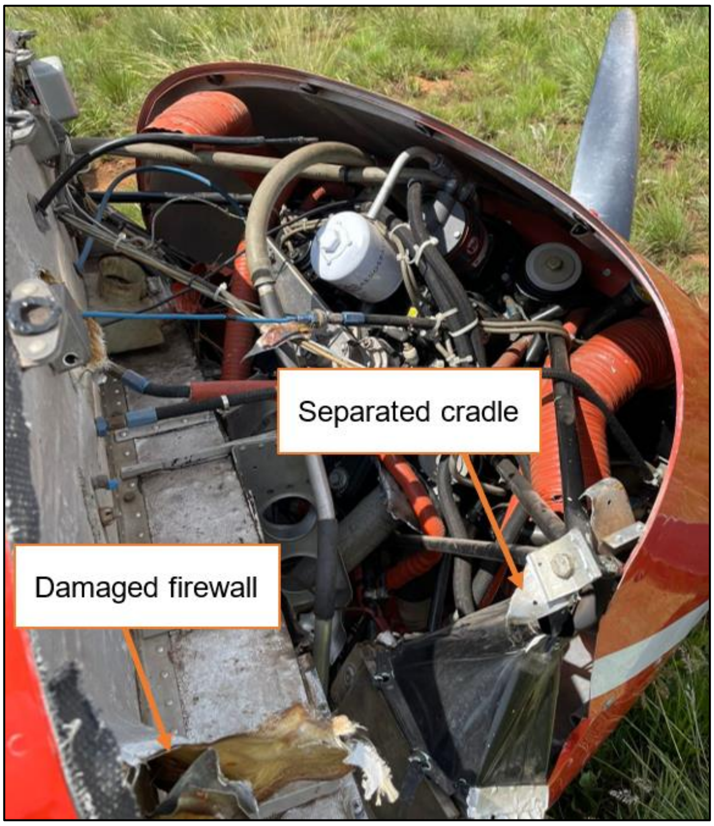


**Figure 4:** Damaged firewall and separated engine cradle.
(Source: AMO)

1.12.4. Based on the appearance of the propeller blade in Figure 5, the lack of visible damage or twisting is consistent with the engine not producing power at impact.

**Figure 5:** Appearance of propeller blades post the accident. (Source: Pilot)

1.12.5. Post-accident, the pilot noticed fuel residue, characterised by its blue colour, underneath the left-wing fuel tank and along the roof of the cabin.


**Figure 6:** Streaks of AVGAS underneath the left fuel tank (left image) and along the roof of the cabin (right image). (Source: Pilot)

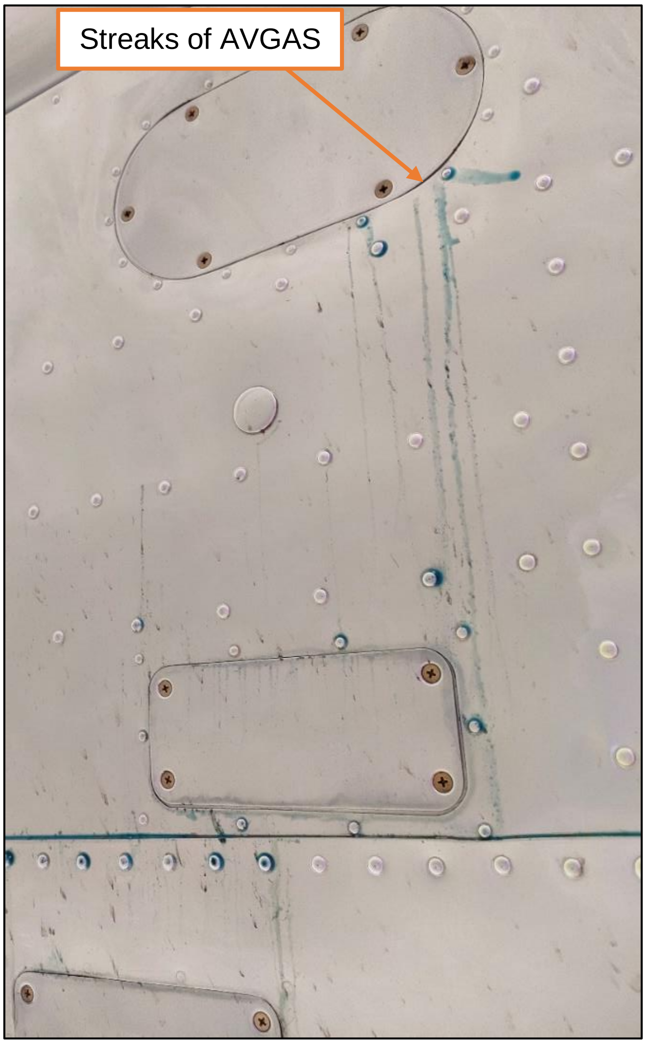


**Figure 7:** The photograph was taken on site of the lower left wing. (Source: Pilot)

1.12.6. According to the pilot, there were no mechanical anomalies with the fuel selector or the fuel indication system prior to the accident flight.

## 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 during the accident sequence. Both occupants were properly restrained with the aircraft equipped safety harnesses and did not sustain any injuries during the accident sequence.

## 1.16. Tests and Research

1.16.1. Observations made during recovery of the aircraft from the accident site:

1.16.1.1. According to the aircraft maintenance engineer (AME) who recovered the ZS-EZM aircraft from the accident site, the following observations regarding the fuel system were made:

- There was no fuel smell at the accident site, which could have been an indication of fuel leaking out due to damage caused by impact. Additionally, there was no indication of fuel streaks or residue visible on the lower aircraft fuselage that would have indicated a fuel leak from the fuel strainer drain.
- There were no fuel streaks on top of the wings which would have been attributed to leaking fuel caps. The fuel caps were found properly latched.
- Before draining fuel from the aircraft, the fuel quantity gauges were checked, and both indicated zero gallons (0 L) when the aircraft's battery power was applied (turned on).
- A 5-litre container was used to drain the remaining fuel in the fuel tanks before the wings of the aircraft were removed for transportation. Approximately 200 millilitres (ml) of fuel was drained from both the left- and the right-wing tanks, of which 50ml was water sediment.
- There was little fuel in the fuel pipes leading to the engine.

**Figure 8:** Fuel drained from wing tanks during recovery.
(Source: AME)

1.16.2. Fuel Leak Test Observations

1.16.2.1. On 19 January 2022, a fuel leak test was conducted at an aircraft maintenance organisation (AMO) facility by adding 50L in the detached left-wing tank while positioned horizontally. According to the AME who conducted the test, only small stains and minor seepage were evident (as described in section 12-11 – Fuel Bay Leaks of the Cessna 177 and Cardinal Series, 1968-1975, Service Manual).

*Classification of fuel leaks*

*Fuel leaks which do not constitute a flight hazard are stains, seeps, and heavy seeps NOT in an enclosed area. However, they should be repaired when the aircraft is grounded for other maintenance.*

*Fuel leaks which constitute a flight hazard are running leaks in any area, seeps, heavy seeps, or stains in an enclosed area, such as the wing leading edge, the sections of wing inboard and outboard of the fuel bay and the area between the rear fuel spar and the main spar. These leaks must be repaired before that bay is used for another flight.*

*The wet or stained spot on the wing in the bay is an indication of the intensity of the leak. Fuel leak classifications are shown in Figure 7.*

*NOTE*

*Stains and seeps that are not considered a flight hazard must be inspected after each flight to ensure that they have not grown in intensity to the point of causing a flight hazard.*

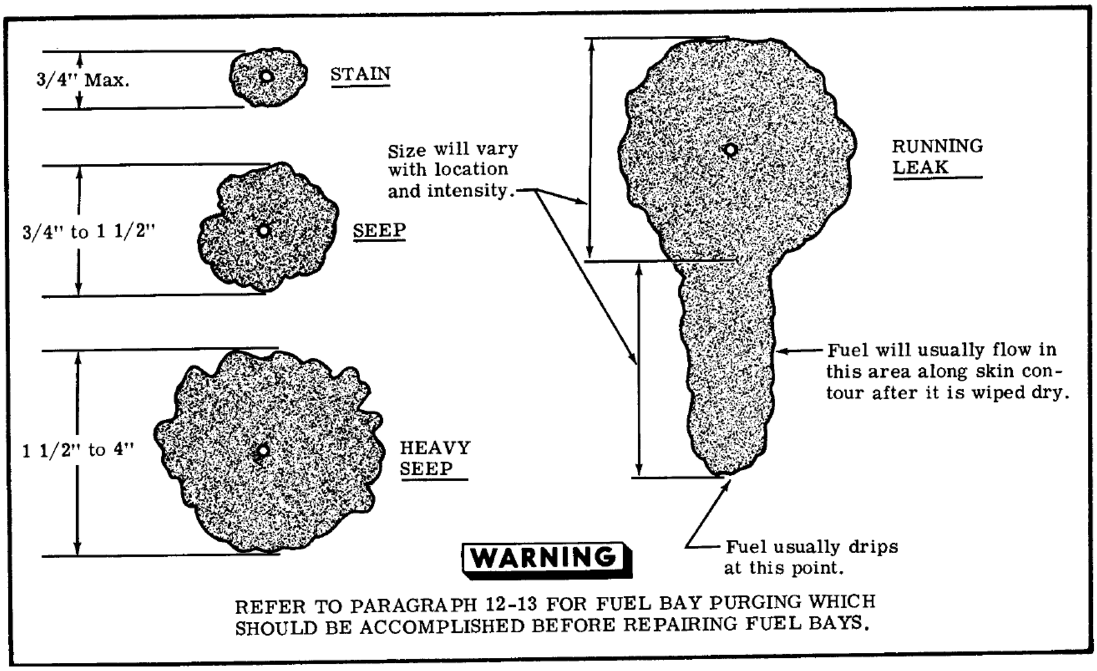


**Figure 9:** Classification of Fuel Leaks. (Source: Cessna 177 1968-1975, Service Manual)

1.16.2.2. According to the service manual, there was no evidence of a heavy seep or running leak at the time of the fuel leak test after the aircraft's wings were detached, which would have prohibited further flights.

1.16.2.3. According to the AMO, following the initial fuel leak test, the left fuel tank was repaired and reinstalled on the fuselage, and all fuel lines reconnected. Upon refuelling, a system leak test was conducted, and a minor fuel drip was observed on the forward (FWD) inboard and outboard end ribs of the left fuel tank. The leak was still not of a measurable quantity and was classified as a heavy seepage.

The fuel was drained, and the fuel tank cleaned and resealed. Pressure tests were performed with no further leaks observed.

1.16.2.4. According to the owner of the ZS-EZM, the fuel leak was substantial and is related to the cause of the fuel exhaustion. However, according to the AMO, the fuel leak observed would not have resulted in substantial loss of fuel. The fuel tank repairs were conducted in the absence of the investigator.

1.16.2.5. According to the repair and maintenance work pack documents there were no tests done on the fuel system components, as they were not suspected to have contributed to the fuel exhaustion as no fuel system related issues were identified during the repair and maintenance.

1.16.2.6. After ZS-EZM was released to service on 15 August 2022, a test flight was conducted on 18 August 2022. Post repair and maintenance test flight, and the aircraft was found to be serviceable.

1.16.3. **Fuel Consumption Calculation**

1.16.3.1. Table 1 shows the flight times and fuel upliftment used to determine the actual average fuel consumption for the ZS-EZM aircraft over time. An average fuel consumption of 39.1 litres/per hour (L/hr) (10.3 GPH), was derived from previous information captured in the aircraft's flight folio from 6 August 2021 to 13 November 2021, which was reported as the date of the last fuel upliftment to full capacity.

1.16.3.2. It should be noted that the Tachometer hour readings were used as the aircraft was not fitted with a Hobbs meter. This device does not display the actual flight time as it is dependent on engine RPM. To convert the Tachometer hours entered in the flight folio to indicate the flight duration, the recorded Tachometer hours per flight were multiplied by a factor of 1.3 as given by the pilot and owner of the aircraft.

1.16.3.3. Table 1 also shows the flight times and fuel burn rates per flight leading to the day of the accident. The data was derived from flight information captured in the aircraft's flight folio from 6 August 2021, for a three-month period.

**Table 1:** Fuel burn rates leading to the day of the accident.

| Date | Journey (From-To) | Tach Start | Tach Stop | Tach FLT Duration (Hr) | Hobbs FLT Duration (Hr) | Fuel Uplift (Litres) | Fuel CONSMP (L/Hr) | Fuel Burned (Litres) | Fuel for next FLT (Litres) |
|---|---|---|---|---|---|---|---|---|---|
| 06 08 2021 | | | | | | 128,0 | 34,0 | - | 182,0 |
| 06 08 2021 | FAGC-FAGC | 3060,57 | 3061,74 | 1,17 | 1,52 | | | 37,0 | 145,0 |
| 09 08 2021 | FAGC-FAGC | 3061,74 | 3063,17 | 1,43 | 1,86 | | | 45,3 | 99,7 |
| 12 08 2021 | FAGC-FAGC | 3063,17 | 3064,33 | 1,16 | 1,51 | | | 36,7 | 63,0 |
| 12 08 2021 | | | | | | 119,0 | 24,3 | - | 182,0 |
| 25 08 2021 | FAGC-FAGC | 3064,33 | 3065,26 | 0,93 | 1,21 | | | 39,2 | 142,8 |
| 31 08 2021 | FAGC-FAGC | 3065,26 | 3066,29 | 1,03 | 1,34 | | | 43,4 | 99,5 |
| 01 09 2021 | FAGC-FAGC | 3066,29 | 3066,99 | 0,70 | 0,91 | | | 29,5 | 70,0 |
| 01 09 2021 | | | | | | 112,0 | 32,4 | - | 182,0 |
| 05 09 2021 | FAGC-FAGC | 3066,99 | 3067,80 | 0,81 | 1,05 | | | 34,7 | 147,3 |
| 11 09 2021 | FAGC-FAGC | 3067,80 | 3069,49 | 1,69 | 2,20 | | | 72,3 | 75,0 |
| 11 09 2021 | | | | | | 107,0 | 32,9 | - | 182,0 |
| 12 09 2021 | FAGC-FAGC | 3069,49 | 3070,27 | 0,78 | 1,01 | | | 26,9 | 155,1 |
| 13 09 2021 | FAGC-FAGC | 3070,27 | 3071,60 | 1,33 | 1,73 | | | 45,8 | 109,3 |
| 16 09 2021 | FAGC-FAGC | 3071,60 | 3072,50 | 0,90 | 1,17 | | | 31,0 | 78,3 |
| 21 09 2021 | FAGC-FAGC | 3072,50 | 3073,70 | 1,20 | 1,56 | | | 41,3 | 37,0 |
| 21 09 2021 | | | | | | 145,0 | 26,5 | - | 182,0 |
| 19 10 2021 | FAGC-FAGC | 3073,70 | 3074,97 | 1,27 | 1,65 | | | 78,4 | 103,6 |
| 23 10 2021 | FAGC-FAGC | 3074,97 | 3075,92 | 0,95 | 1,24 | | | 58,6 | 45,0 |
| 23 10 2021 | | | | | | 137,0 | 47,5 | - | 182,0 |
| 29 10 2021 | FAGC-FAGC | 3075,92 | 3076,25 | 0,33 | 0,43 | | | 55,9 | 126,1 |
| 08-11-2021 | FAGC-FAGC | 3076,25 | 3076,64 | 0,39 | 0,51 | | | 66,1 | 60,0 |
| 11-11-2021 | | | | | | 122,0 | 130,3 | - | 182,0 |
| 11-11-2021 | FAGC-FAGC | 3076,64 | 3078,34 | 1,70 | 2,21 | | | 65,4 | 116,6 |
| 12-11-2021 | FAGC-FAGC | 3078,34 | 3079,63 | 1,29 | 1,68 | | | 49,6 | 67,0 |
| 13-11-2021 | | | | | | 115,0 | 29,6 | - | 182,0 |
| 13-11-2021 | FAGC-FAGC | 3079,63 | 3081,28 | 1,65 | 2,15 | | | 93,6 | 88,4 |
| 23-11-2021 | FAGC-FAGC | 3081,28 | 3081,80 | 0,52 | 0,68 | | | 29,5 | 59,0 |
| 02-12-2021 | FAGC-FAGC | 3081,80 | 3082,00 | 0,20 | 0,26 | | | 11,3 | 47,6 |
| 07-12-2021 | FAGC-FASY | 3082,00 | 3082,84 | 0,84 | 1,09 | 182,0 | 43,6 | 47,6 | 0,0 |
| **Average fuel consumption gal/hr = l/hr / 3,78** | | | | | | | | | |
| **Hobbs=Tach*1,3** | | **1,3** | | | | | | | |

Interpretation of Table 1:

- The aircraft was last refuelled on 13 November 2021, which was verified with the fuel bay attendant at FAGC. According to the fuel attendant and pilot, the aircraft was refuelled with 115 L aviation gasoline (AVGAS), which was confirmed to have been a top-up to full capacity of 182 L (42 USG) of the aircraft.
- According to the Cessna Model 177 & Cardinal Owner’s Manual, the total (both tanks) unusable fuel for the Cessna 177, manufactured in 1968, is 4 L (1 USG).
- Because the approximate fuel consumption per segment, was calculated based on the next fuel uplifted divided by the number of hours flown since the last uplift. This was not possible for the segment from 13 November 2021 to 7 December 2021 when the fuel exhaustion occurred.
- To determine the approximate fuel consumption of the aircraft between 13 November 2021 and 7 December 2021, to determine the approximate fuel consumption for each flight in the segment leading to the fuel exhaustion the 4.17 hours flown up to the date of the fuel exhaustion were added and divided by the known amount of 182 L (42 USG) were used to get an average fuel consumption of 43.6 L/hr (11.5 GPH).

## 1.17. Organisational and Management Information

1.17.1. The AMO which conducted the last mandatory periodic inspection (MPI) prior to the accident flight was issued an AMO certificate by the SACAA on 18 June 2021 with an expiry date of 31 May 2022.

1.17.2. The ZS-EZM aircraft is used for pilot training. The owner of the aircraft is in position of a student pilot licence and utilises the aircraft for pilot training.

1.17.3. The flight on 7 December 2021 was conducted under the provisions of Part 91 of the CAR 2011 as amended.

## 1.18. Additional Information

1.18.1. FAGC Air Traffic Control (ATC) Flight Strip

1.18.1.1. According to the FAGC ATC flight strip for ZS-EZM, recorded on 7 December 2021, the air traffic control officer (ATCO) was provided with the following information before departure:

- Destination: FAGC-South-FAGC
- Altitude to be maintained: 6500 ft.
- Fuel endurance: 3.00 hours
- Estimated flight duration: 1 hour 30 minutes (1.5 hours)
- The aircraft departed FAGC at 0559Z and reported outbound at 0604Z.

1.18.2. According to the Cessna 177 Cardinal Owner's Manual – Forced Landing Without Engine Power, the procedure should be conducted as follows:

**FORCED LANDINGS.**

**EMERGENCY LANDING WITHOUT ENGINE POWER.**

If all attempts to restart the engine fail and a forced landing is imminent, select a suitable field and prepare for the landing as follows:

(1) Airspeed -- 85 MPH (flaps UP).
75 MPH (flaps DOWN).
(2) Mixture -- IDLE CUT-OFF.
(3) Fuel Selector Valve -- OFF.
(4) Ignition Switch -- OFF.
(5) Landing Gear -- DOWN (UP if terrain is rough or soft).
(6) Wing Flaps -- AS REQUIRED (30° recommended).
(7) Master Switch -- OFF.
(8) Doors -- UNLATCH PRIOR TO TOUCHDOWN.
(9) Touchdown -- SLIGHTLY TAIL LOW.
(10) Brakes -- APPLY HEAVILY.

1.18.3. According to the Australian Civil Aviation Advisory Publication (CAAP) 234-1(2) – Guidelines for aircraft fuel requirements:

*6.3 In-flight fuel quantity checks*

*6.3.1 The pilot-in-command must ensure that fuel quantity checks are conducted in-flight at regular intervals. The established quantity of usable fuel remaining is evaluated to:*

- *compare actual fuel consumption with planned fuel consumption,*
- *determine that the usable fuel remaining is sufficient to complete the planned flight,*
- *determine the expected usable fuel remaining on landing at the destination aerodrome.*

*6.3.2 The interval between in-flight fuel quantity checks should be sufficient to allow the pilot-in-command to remain aware of the aircraft fuel state. In addition to periodic fuel quantity checks, there are specific instances where an additional fuel check is needed to ensure that in-flight decisions are supported by accurate fuel state awareness. For example, specific checks are needed before passing a critical point (i.e., ETP/PNR/CP).*

*6.3.3 Whenever possible, the in-flight fuel quantity checks should include a reconciliation of the fuel remaining indicated from the available aircraft fuel quantity indication systems, such as debit meters. Raw data information, such as fuel quantity gauges, should also be checked to confirm fuel balance and fuel tank quantity against known fuel usage to minimise the possibility of an undetected fuel leak. The maximum efficiency for fuel quantity checks is achieved when conducted at regular intervals and follow a consistently applied methodology.*

*6.3.4 The relevant fuel quantity data must be recorded after the specific in-flight fuel quantity checks are completed*.

*6.4 In-flight fuel management*

*6.4.1 After a flight has commenced, in-flight fuel management is the practical means by which the pilot-in-command ensures that fuel is used in the manner intended during pre-flight planning, or in-flight re-planning.*

*6.4.2 In-fight fuel management does not replace pre-flight planning or in-flight re-planning activities, rather it acts to ensure continual validation of planning assumptions that influence fuel usage and required fuel reserves. Such validation serves as a trigger for re-analysis and adjustment activities that ultimately ensure that each flight is safely completed with the planned fixed fuel reserve on board at an aerodrome where a safe landing can be made.*

*6.4.3 The pilot-in-command should ensure that a critical point of last diversion to the final en-route alternate is identified during the pre-flight planning stage. This is particularly important when operating to a remote island. During the flight, the critical point should be assessed and, if necessary, revised based upon actual fuel consumption and in-flight conditions.*

*6.4.4 The revised critical point then becomes the last point by which the pilot-in-command should obtain and assess updated destination information (i.e. meteorological conditions, traffic and other operational conditions at the destination aerodrome) in order to validate the destination planning assumptions and allow timely diversion to occur if necessary (i.e. the revised critical point is the final opportunity to assess options for preserving the required fuel reserves should the destination aerodrome no longer be available).*

## 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

**The pilot**

2.1.1. The pilot was in possession of a Commercial Pilot Licence (CPL) that was issued on 6 February 2021 with an expiry date of 28 February 2022. According to the pilot questionnaire, the pilot had flown a total of 724.1 hours, of which 36.4 were on the aircraft type. The Cessna 177 Cardinal aircraft type was endorsed on the pilot's licence.

2.1.2. The pilot was issued a Class 1 aviation medical certificate on 27 January 2021 with an expiry date of 31 January 2022, with the restriction to wear suitable corrective lenses.

The aircraft

2.1.3. The aircraft was issued a Certificate of Release to Service (CRS) following its last MPI which was conducted on 30 July 2021 at 3 047.99 airframe hours, and valid until 29 July 2022 or at 3 148 airframe hours, whichever occurs first unless the aircraft is involved in an accident. The aircraft had accumulated a further 34.85 airframe hours since the said inspection.

2.1.4. The AMO which conducted the last MPI prior to the accident flight was issued an AMO-approval certificate by the SACAA on 18 June 2021 with an expiry date of 31 May 2022.

2.1.5. According to the pilot, all control surfaces were accounted for and there were no mechanical issues with the aircraft leading to the accident. All damage to the aircraft was attributable to the impact forces.

2.1.6. According to the aircraft's airframe logbook, the SB 99-18 which requires that the fuel quantity indication system be inspected every 12 months was complied with during the last aircraft's MPI that was conducted on 11 December 2020. Furthermore, the aircraft was flown with calibrated fuel gauges which would have been synchronised with the fuel tanks to give accurate readings of the fuel quantities in each tank. There had not been any prior defects reported that related to any subsystem of the fuel system which could have contributed to the reported fuel exhaustion.

2.1.7. According to the aircraft's owner, the aircraft's boost fuel pump stopped working on 23 September 2021, after the aircraft was refuelled to full capacity on 21 September 2021, resulting in a fuel loss of 40.7 L (10.8 USG).

2.1.8. According to a submitted job card the boost fuel pump was sent to an electrical AMO for a full repair and overhaul on 27 September 2021 and reinstalled on the aircraft on an unknown date as there were no entries in the flight folio defect log or the engine logbook as required in terms of CAR 2011 subpart 43.02.4 and 91.02.8.

2.1.9. There was no evidence or no entries in the defect log and aircraft's logbooks, for the second electronic fuel pump failure and repair the owner reported, which was claimed to have occurred on 2 November 2021.

2.1.10. Based on sections 2.1.8 and 2.1.9, It could not be determined whether the subsequent repair was done in-line with regulatory requirements. Additionally, it could not be determined if the overhaul of the fuel pump was carried out in accordance with manufacturer's overhaul requirements. Therefore, the release of the ZS-EZM aircraft to service following the report overhaul and subsequent repair, was not in line with regulatory requirements.

Flight Operations

2.1.11. According to images submitted for the investigation, the Tachometer hours at the beginning of the flight indicated 3 082.00 and after the accident indicated 3 082.84, which is a total flight duration (aircraft operation time) of 50 minutes (0.84 hours) multiplied by 1.3 to get a total flight duration of 1 hour 5 minutes (1.09 hours).

2.1.12. According to a submitted flight authorisation, there was no correlation between the aircraft starting hours recorded compared to the hours recorded in the flight folio sheet 0004. According to the flight folio there was a ground run, recorded on 2 December 2021, which lasted 0.26 hours. However, based on the flight authorisation for 7 December 2021 the aircraft starting hours in Tachometer hours were 3081.80 signifying that there was no ground run between 23 November 2021 and 7 December 2021. As a result, this means the flight on 7 December 2021, lasted 1.04 Tachometer hours (3082.84 minus 3081.80) or 1.35 Hobbs hours, instead of the reported 1.09 Hobbs hours.

2.1.13. The aircraft was flying in a north-westerly direction when the engine stopped due to fuel exhaustion. The prevailing wind that was measured at FAOR (located 27nm from the accident site) was from the north-west at 10 knots and would have had little to no effect on the fuel consumption of the aircraft if the wind conditions were the same at FASY.

2.1.14. According to the pilot, the fuel setting was selected to both tanks for the duration of the flight. Following the engine stoppage, the pilot conducted fault-finding procedure and attempted to restart the engine by following the prescribed engine start checklist numerous times without success. The pilot then noted that both fuel gauges indicated empty. Without engine power, the pilot elected to glide the aircraft towards FASY, which was 7nm away from his position. However, the aircraft lost height rapidly and it undershot RWY 31 by approximately 300m.

2.1.15. Based on the pilot questionnaire information and photographs of the aircraft, it was configured correctly in line with the requirements of based on the Cessna 177 Cardinal Owner's Manual – Forced Landing Without Engine Power procedure.

2.1.16. The pilot stated that there were no abnormalities observed during the pre-flight checks and that the fuel available should have been enough for a 2.8-hour flight at 65% cruise power or a 2.2-hour flight at 75% cruise power. These calculations were made based on the pilot's opinion that the fuel consumption would have been 30.45 L/hr (8.1 GPH).

2.1.17. Whilst routing back to FAGC, while the aircraft was flying at an altitude of 7 500 ft when the pilot of the ZS-EZM was alerted by another aircraft that they are flying at the same altitude. This occurred as the aircraft were in an uncontrolled airspace, the pilot of the ZS-EZM had to perform avoidance manoeuvres to avoid the other aircraft. According to the pilot, the next fuel check should have been around the time just after turning around at Golf Alpha Victor (GAV) and climbing to 7 500ft. However, this check was not conducted due to the high workload in the cockpit at the time.

2.1.18. The navigation equipment did not contain the flight details as the navigation application was not prompted to record details of the accident flight. Because there was no flight details, the investigation could not determine the exact distance flown prior to the accident.

Fuel Leak Information

2.1.19. Post-accident, the pilot found both fuel tanks empty and noticed fuel residue underneath the left fuel tank and along the roof of the cabin. According to the pilot, this suggested that some fuel had leaked out from the left fuel tank. However, the two occupants did not smell the fuel running along the cabin roof.

2.1.20. Approximately 150ml of fuel was drained from both tanks during the recovery phase of the aircraft. The AMO stated that there was no smell of fuel when they arrived at the accident site.

2.1.21. A fuel leak test was conducted on the detached left wing fuel tank at an AMO facility. Small fuel stains and minor seepage were observed which, according to the Cessna 177 Service Manual, was not a concern, and that further flights could have been conducted with the provision that the fuel seepage be monitored.

2.1.22. It was, however, highly improbable that all the fuel that was stated to have been in the left tank (45 L (12 USG)) prior to take-off leaked from the fuel tank during the flight, as the fuel stains associated with the leak as well as the post-accident fuel tank leak test that was conducted displayed the contrary.

2.1.23. Following repairs to the left-wing tank, a subsequent fuel leak was conducted, and no leaks or seepage was reported. The aircraft has since been released to service and it underwent a test flight; the aircraft was found serviceable with no further defects recorded.

2.1.24. According to the owner of the aircraft a fuel pump malfunction or failure resulted in a fuel loss of 130.7 L (34.5 USG) on 23 September 2021 and 2 November 2021. However, there is no record in the aircraft documents are required by regulations detailing the overhaul of the aircrafts fuel pump.

Fuel Quantity Information

2.1.25. The aircraft was last refuelled on 13 November 2021 with a total of 115 L AVGAS. According to the fuel attendant at FAGC and pilot, the aircraft was refuelled to the maximum capacity of 182 L (48 USG). The fuel amount after refuelling was not verified by dipping the fuel tanks to establish the exact amount of fuel on board. When both the pilot and owner were asked how this was verified, both stated that refuelling with an odd fuel amount such as 115 L typically means that the aircraft was refuel to full capacity.

2.1.26. There were three notable fuel consumption and fuel on board variances between what was reported by the owner of the aircraft, the pilot and based on the flight logs leading to the day of the fuel exhaustion based on the flight folio record details from 13 November 2021 as the aircraft was refuelled to full capacity.

2.1.27. Fuel consumption and estimated fuel on board during recent flights based on the owner:

According to the aircraft owner, who was also a passenger on the day of the accident, the overall approximate fuel consumption of the aircraft is 41.6 L/hr (11 GPH), according to the Lycoming Operator's Manual operating conditions this correlates to an engine operating at normal rated performance cruise (75 % rated).

The aircraft owner reported that when the aircraft was refuelled on 13 November 2021, with 115 L, it was refuelled to full capacity 182 L (48 USG), and after the refuel the aircraft was flown for 1.56 hours at a fuel consumption of 41.6 L/hr (11 GPH) maximum, this would have required 65 L (17.2 USG) of fuel for the flight. Based on this, the owner stated that on 7 December 2021, the aircraft took off with approximately 110 L (29 USG) of fuel which was a little over ½ in both tanks and would have been sufficient for a flight duration of 2.5 hours.

**Table 2:** Flight folio extract – and fuel calculations for 41.6 L/hr (11 GPH)

| Date | Journey (From-To) | Tach Start | Tach Stop | Tach FLT Duration (Hr) | Hobbs FLT Duration (Hr) | Fuel Uplift (Litres) | Fuel CONSMP (L/Hr) | Fuel Burned (Litres) | Fuel for next FLT (Litres) |
|---|---|---|---|---|---|---|---|---|---|
| 13-11-2021 | | | | | | 115,0 | | - | 182,0 |
| 13-11-2021 | FAGC-FAGC | 3079,63 | 3081,28 | 1,65 | 2,15 | | | 89,2 | 92,8 |
| 23-11-2021 | FAGC-FAGC | 3081,28 | 3081,80 | 0,52 | 0,68 | | | 28,1 | 64,6 |
| 02-12-2021 | FAGC-FAGC | 3081,80 | 3082,00 | 0,20 | 0,26 | | | 10,8 | 53,8 |
| 07-12-2021 | FAGC-FASY | 3082,00 | 3082,84 | 0,84 | 1,09 | | | 45,4 | 8,4 |
| **Average fuel consumption L/hr** | | | | | | | **41,6** | | |
| **Average fuel consumption gal/hr (L/hr/3,78)** | | | | | | | **11,0** | | |
| **Hobbs=Tach*1,3** | | | **1,3** | | | | | | |

Based on the results provided in Table 2, the following discrepancies were noted:

- The fuel calculations given by the owner above did not consider that Hobbs flying hours are 1.3 more than Tach hours. For accurate flight times and fuel burned per flight, the values given should have been multiplied by a factor of 1.3. It would have been correct that a flight duration of 1.56 Tach hours would have used 65 L (17 USG) of fuel, however, using actual flight time, 65 L (17 USG) multiplied by a factor of 1.3, would have resulted in a fuel usage of about 84 L (22 USG).
- Based on the flight folio flight logs, the actual flight duration on 13 November 2021 was 1.65 Tach hours and not 1.56 Tach hours. The flight duration was 0.09 Tach hours more or 5.8 percent higher than what the owner thought it was. Resultantly, the fuel burned during that flight would have been approximately 89.2 L (23.6 USG). Therefore, the actual fuel burned would have been 24 L (6 USG) or 27 percent higher than what the owner estimated it was at the end of the flight.
- Based on the calculation, there would have been 92.8 L (24.5 USG) remaining for the next flight on 23 November 2021. On the contrary, according to the owner of the aircraft, after the flight on 13 November 2021, there would have been an estimated 110 L (29 USG). However, this is incorrect as the owner omitted to consider the flight take occurred on 23 November 2021, which according to calculations, would have used approximately 28 L (7 USG) of fuel which would have resulted in 64.6 L (17 USG) remaining for the ground run on 2 December 2021.
- Following the ground run on, based on the calculation, the remaining fuel for the flight on 7 December 2021 would have been 56.2 L (15 USG), which would have resulted in 8.4 L (2 USG) remaining after the flight. However, only 150 ml of fuel was drained from the aircraft after the accident.
- The 56.2 L (15 USG) remaining would have been 35.8 L (9.5 USG) or 39 percent less than the reported fuel of 92 L (24 USG) at the start of the flight 7 December 2021.

2.1.28. Fuel consumption and estimated fuel on board during recent flights based on the pilot's calculation:

According to the calculation submitted by the pilot, the overall approximate fuel consumption of the aircraft is 30.28 L/hr (8 GPH). This approximate was derived by excluding the fuel consumptions for periods 19 October 2021 to 12 November 2021 of 47.5 L/hr (12.5 GPH) and 130.3 L/hr (34.4 GPH), respectively.

**Table 3:** Flight folio extract – and fuel calculations for 30.45 L/hr (8.1 GPH)

| Date | Journey (From-To) | Tach Start | Tach Stop | Tach FLT Duration (Hr) | Hobbs FLT Duration (Hr) | Fuel Uplift (Litres) | Fuel CONSMP (L/Hr) | Fuel Burned (Litres) | Fuel for next FLT (Litres) |
|---|---|---|---|---|---|---|---|---|---|
| 13-11-2021 | | | | | | 115,0 | | - | 182,0 |
| 13-11-2021 | FAGC-FAGC | 3079,63 | 3081,28 | 1,65 | 2,15 | | | 65,3 | 116,7 |
| 23-11-2021 | FAGC-FAGC | 3081,28 | 3081,80 | 0,52 | 0,68 | | | 20,6 | 96,1 |
| 02-12-2021 | FAGC-FAGC | 3081,80 | 3082,00 | 0,20 | 0,26 | | | 7,9 | 88,2 |
| 07-12-2021 | FAGC-FASY | 3082,00 | 3082,84 | 0,84 | 1,09 | | | 33,3 | 62,8 |
| **Average fuel consumption L/hr** | | | | | | | **30,45** | | |
| **Average fuel consumption gal/hr (L/hr/3,78)** | | | | | | | **8,1** | | |
| **Hobbs=Tach*1,3** | | **1,3** | | | | | | | |

Based on the results provided in Table 3, the following was noted:

- According to the pilot the aircraft's approximate fuel consumption of 30.45 L/hr (8.1 GPH) is lower than the given value based on the Lycoming Operator's Manual operating conditions for an engine operated at economy cruise (65 % rated) of 32.2 L/hr (8.5 GPH) as the power setting for the flight on 7 December 2021 was reported as 2300 RPM.
- Although the pilot stated that the fuel quantity was checked using a Fuel Hawk Universal 14 Inch Fuel Gauge pipette and was confirmed to have been 92 L (24 USG) before the flight on 7 December 2021; based on the calculations in Table 2, using a fuel consumption of 30.45 L/hr (8.1 USG), the calculated fuel amount that would have been available for the flight would have been approximately 88 L (23 USG). The measured fuel available was 4 L (1 USG) or 4 % less than the measured fuel.
- With a fuel consumption of 30.45 L/hr (8.1 USG), a flight duration of 1.09 hours would have required 41.2 L (10.9 USG) of fuel, this means that a fuel loss of approximately 55 L (14.5 USG) would have occurred resulting in the fuel exhaustion. However, the fuel leak test conducted on the detached left wing fuel tank revealed a minor to major seepage which, according to the Cessna 177 Service Manual, was not a concern, and that further flights could have been conducted with the provision that the fuel seepage be monitored. Furthermore, there were no faults found with the fuel system was noted during the repair, maintenance and subsequent flight test conducted following the repairs.
- Both fuel tanks were selected for the flight, if there was 53 L (14 USG) of fuel in the right fuel tank prior to the flight as reported, presuming that all fuel from the left fuel tank was lost, there should still have been approximately 12 L (3 USG) of fuel remaining in the right fuel tank at the time of the forced landing. However, only 150 ml of fuel was drained from both fuel tanks after the accident. It is improbable that there was 92 L (24 USG) of fuel on-board the aircraft prior to take-off on 7 December 2021, as shown by the fuel calculations in Tables 1 and 2.

2.1.29. Based on overall analysis of the fuel consumption values given in Table 1 in section 1.16, the following was noted:

- From 6 August 2021 to 12 November 2021 (about a three-month period), the aircraft's actual approximate fuel consumption was 41.08 L/hr (10.8 GPH). This approximate consisted of fuel consumptions per segment, calculated from the hours flown per segment before the next uplift.
- None of the values were comparable to the Lycoming Operator's Manual operating conditions for an engine operated at economy cruise (65 % rated) which is 30.28 L/hr (8 GPH), nor at normal rated performance cruise (75 % rated) which is 41.6 L/hr (11 GPH). With 24.3 L/hr (6.4 GPH) being the least approximate fuel consumption over 4.89 flying hours; and 130.34 L/hr (34.4 GPH) being the highest approximate fuel consumption over 0.94 flying hours.

**Table 4:** Flight folio extract – and fuel calculations for 43.6 L/hr (11.5 GPH)

| Date | Journey (From-To) | Tach Start | Tach Stop | Tach FLT Duration (Hr) | Hobbs FLT Duration (Hr) | Fuel Uplift (Litres) | Fuel CONSMP (L/Hr) | Fuel Burned (Litres) | Fuel for next FLT (Litres) |
|---|---|---|---|---|---|---|---|---|---|
| 13-11-2021 | | | | | | 115,0 | | - | 182,0 |
| 13-11-2021 | FAGC-FAGC | 3079,63 | 3081,28 | 1,65 | 2,15 | | | 93,5 | 88,5 |
| 23-11-2021 | FAGC-FAGC | 3081,28 | 3081,80 | 0,52 | 0,68 | | | 29,5 | 59,0 |
| 02-12-2021 | FAGC-FAGC | 3081,80 | 3082,00 | 0,20 | 0,26 | | | 11,3 | 47,7 |
| 07-12-2021 | FAGC-FASY | 3082,00 | 3082,84 | 0,84 | 1,09 | | | 47,6 | 0,1 |
| **Average fuel consumption L/hr** | | | | | | | **43,6** | | |
| **Average fuel consumption gal/hr (L/hr/3,78)** | | | | | | | **11,5** | | |
| **Hobbs=Tach*1,3** | | **1,3** | | | | | | | |

Based on the results provided in Table 4, the following was noted:

- By considering that the last fuel uplift to full capacity of 182 L (48 USG) and the aircraft had flown a total of 4.17 hours when the fuel exhaustion occurred. The calculated approximate fuel consumption using flight logs recorded between 13 November 2021 and 7 December 2021 was 43.6 L/hr (11.5 GPH), 2.0 L/hr (0.5 GPH) or 4.5 percent higher than the owner given estimated fuel consumption rate, and 13.2 L/hr (3.5 GPH) or 43 percent higher than the pilot given estimated fuel consumption rate.
- Based on these calculated values, by using values given in the engine's operator's manual, which gives ideal operating conditions for new engines, led to the pilot and owner of the aircraft estimating the fuel consumption of the aircraft to have been lower than it was.
- Although the data present gives an overall fuel consumption based on a calculation, fuel consumption per flight could have differed substantially, which would have led to a higher fuel consumption than expected.
- By relying on ideal fuel consumption values, the high fuel consumption of the aircraft were unnoticed as the pilots of ZS-EZM did not dip the fuel tanks after flights to measure the actual fuel remaining. Although this is not mandatory, adopting this method can ensure that fuel usage for older aircraft such as ZS-EZM is monitored. Additionally, by monitoring fuel consumption, would ensure that the actual fuel burn would be used to determine the quantity of usable fuel required for a flight.
- Based on this it can be determined that, the aircraft did not have a constant fuel

consumption rate throughout its operation as it is sometimes used for training flights and is flown by different pilots. The following factors could be attributed to the varied significance in the fuel consumption of the aircraft.

2.1.30. Based on the results provided in Tables 2 and 4,

- According to the pilot's statement, the aircraft had 91 L (24 USG) before departure at FAGC. It is likely that the pilot calculated the fuel amount available based on the Lycoming Operator's Manual operating conditions for an engine operated at economy cruise (65 % rated) which was 30.28 L/hr (8 GPH). However, this meant that the fuel on board had less fuel than would have been required based on the actual fuel consumption of the engine which could have been as low as 24.35 L/hr (6.4 GPH) or as high as 130.34 L/hr (34.4 GPH) based on historical trends.
- Based on the results provided in Table 4, the approximate fuel consumption during this segment was calculated to have been 43.6 L/hr (11.5 GPH); this amount is 2.0 L/hr (0.5 GPH) or 4.5 percent higher than the manufacturer's given fuel consumption rate at normal rated performance cruise (75 % rated) of 41.6 L/hr (11 GPH), and 13.2 L/hr (3 GPH) or 43 percent higher than the pilot given estimated fuel consumption rate of 30.45 L/hr (8.1 USG).

2.1.31. In the absence of evidence indicating that a fuel leak resulted in the fuel exhaustion, a combination of the following possibilities could have led to the fuel exhaustion:

- Operating at low altitudes with the mixture fully rich can substantially increase the fuel consumption. Forgetting to lean at the appropriate time could reduce the range by 25% to 40%. That's a drastic difference even on a shorter flight.
- Taking off with less fuel on board than was thought.
- Underestimating the amount of fuel required for the flight, which can be drastically influenced by the fuel consumption.
- Insufficient monitoring of fuel quantity in-flight.
- The "dipstick" method works well for checking intermediate fuel levels. The dipstick should be calibrated to the specific aircraft. The results may vary greatly depending on the level position of the aircraft.

2.1.32. Accurate fuel management relies on establishing a method of determining how much fuel is being burned. There are many variables that could affect the fuel burn rate such as the power setting, the effect of flying at different altitudes or levels, flying at different airspeeds, the technique used to adjust the mixture, etc. If these factors are not considered and managed by the pilot, then the pilot's awareness or knowledge of the fuel remaining on-board during the flight will be reduced.

## 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

The pilot

3.2.1. The pilot was licensed and qualified for the flight in accordance with the existing regulations.

3.2.2. The pilot provided the ATCO and investigator inaccurate information regarding the fuel amount on-board the aircraft prior to take-off.

The aircraft

3.2.3. The aircraft had a valid Certificate of Airworthiness and had been maintained in compliance with the regulations.

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

3.2.5. There was no mechanical defect with the aircraft that could have caused or contributed to the accident. Although the aircraft's owner stated that the fuel pump was overhauled before the accident, however, there are no maintenance records indicating that the aircraft component was overhauled and installed in accordance with existing regulations and approved procedures.

3.2.6. As a result of an undocumented overhaul which was not in accordance with existing regulations, the aircraft was invalidly released to service after the overhaul of the fuel pump, as the airworthiness of the aircraft leading to the accident could not be verified.

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

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

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

3.2.10. The position of the fuel selectors was set to both fuel tanks during the flight. The pilot did not observe irregular indications on the fuel quantity or fuel pressure indicators prior to the engine stoppage.

3.2.11. Post-accident, fuel residue was observed underneath the left-side fuel tank and along the roof of the cabin, suggesting a leak in the left fuel tank.

3.2.12. There was a small amount of fuel drained from both fuel tanks; additionally, there was no fuel smell at the accident site post-accident, therefore, no fuel could have been lost because of the forced landing.

3.2.13. A fuel leak test was conducted with the detached left fuel tank and only small stains and minor seepage was observed which were not major or concerning. Further flights could have been conducted with the provision that the leak be monitored. Additionally, based on the fuel leak test, it is improbable that the fuel exhaustion was caused by a fuel leakage from the left fuel tank. Although the aircraft's owner stated that since the wing was not tested in-flight, this find in invalid as the fuel leak test was not carried out with the fuel tank pressurised or in in-flight conditions.

3.2.14. According to the Lycoming Operator's Manual operating conditions for an engine operating at normal rated performance cruise (75 % rated) will have an approximate fuel consumption of 41.6 L/hr (11 GPH), whilst one operating at economy cruise (65 % rated) will have an approximate fuel consumption of 30.2 L/hr (8.5 GPH). It will not always be possible for an aircraft to be flown at economy cruise as factors such as wind conditions, pilot training and engine age, amongst other factors, may influence the fuel consumption of each flight which may result in lower and sometimes significantly higher fuel consumptions.

3.2.15. As a result of inadequate in-flight fuel quantity checks to regularly check the fuel quantity gauges, confirm fuel balance and fuel tank quantity against fuel usage, the pilot was not able to detect that the fuel required to continue with the flight was inadequate until the engine started to run rough and stopped.

## 3.3. Probable Cause

3.3.1. Engine stoppage in-flight due to fuel exhaustion which prompted the pilot to perform a forced landing on an open area of grassland, resulting in substantial damage to the aircraft.

## 3.4. Contributory Factors

3.4.1. There was insufficient evidence to determine the cause of the fuel exhaustion. However, based on fuel calculations, it is likely that the fuel exhaustion resulted due to a lack of consideration of higher fuel consumption rates during cruise due to wind conditions, different flying techniques, insufficient fuel mixture leaning, to list a few factors.

3.4.2. Inadequate in-flight fuel management.

## 4. SAFETY RECOMMENDATIONS

### 4.1. General

The safety recommendations/messages 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 three 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 Action

4.2.1. Following the accident, the owner of ZS-EZM has the following safety action:

According to the owner, *the fuel indicators, in ZS-EZM was placed behind the yoke and remained obscured for the most part from both the left and right seat. With the newly installed Garmin GI-275 this risk is removed by placing the fuel flow, fuel quantity, manifold pressure, EGT, oil temperature, oil pressure and RPM into a single instrument just below eye level and unobscured by any other flight control or instrument. This is more practical and allows both the right and left seat to have a clear view. Therefore, even if the fuel quality gauges were found to be functioning as expected its placement, in my view, by Cessna was simply not practical given the importance of the instrument.*

### 4.3. Safety Recommendation

4.3.1. None.

### 4.4. Safety Messages

4.4.1. Pilots should ensure that defects encountered during operation of aircraft are recorded in the aircrafts flight folio in accordance with existing regulations. Additionally, AMEs and AMOs, carrying out any type of maintenance should ensure that all relevant documents are completed in accordance with existing regulations.

4.4.2. The accident could have been avoided if the pilot had performed regular in-flight fuel checks. Therefore, AIID urges pilots to perform in-flight fuel management as it is a practical means by which pilots can ensure that fuel is used in the intended manner during pre-flight planning. In-fight fuel management does not replace pre-flight planning or in-flight re-planning activities; rather, it helps to ensure continual validation of planning assumptions that influence fuel usage and required fuel reserves. Such validation serves as a trigger for re-analysis and adjustment activities which ultimately ensure that each flight is safely completed with the planned fixed fuel reserve on-board at the aerodrome where a safe landing can be made.

## 5. APPENDICES

5.1. Appendix A – Fuel System (Source: Cessna 177 and Cardinal Owner's Manual, 1968)
5.2. Appendix B – CAA of New Zealand – Good Aviation Practice (GAP) 2021 – Fuel Management
5.3. Appendix C – Dissenting views of pilot and owner of ZS-EZM
5.4. Appendix D – Comprehensive Summary of Flight Data for ZS-EZM In Response to the Fuel Exhaustion Incident dated 7 December 2021 CA18/2/3/10087.

**This report is issued by:**

**Accident and Incident Investigations Division**
**South African Civil Aviation Authority**
**Republic of South Africa**

**APPENDIX A**

**Fuel System (Source: Cessna 177 and Cardinal Owner's Manual, 1968)**

*Fuel is supplied to the engine from two integral fuel bladder tanks, one in each wing. Usable fuel in each tank for all flight conditions is 24 USG (91 L) when filled (48 USG or 182 L in total).*

*A 21-USG (79 L) level marker in the form of a white line, just inside the filler neck, is provided.*

*Fuel from each wing fuel tank flows through a selector valve, small reservoir, and fuel shut-off valve, to the fuel strainer; thereafter, it is routed to an engine-driven pump which delivers fuel under pressure to the carburettor. The electric auxiliary fuel pump parallels the engine-driven pump and is used when fuel pressure drops below 2 pounds per square inch (psi).*

*It is not necessary to have the auxiliary fuel pump operating during normal take-off and landing since gravity feed will supply adequate fuel flow to the carburettor with the engine-driven pump inoperative. However, gravity flow is considerably reduced at maximum performance take-off and climb attitudes, and the auxiliary fuel pump would be required should the engine-driven pump fail during these manoeuvres.*

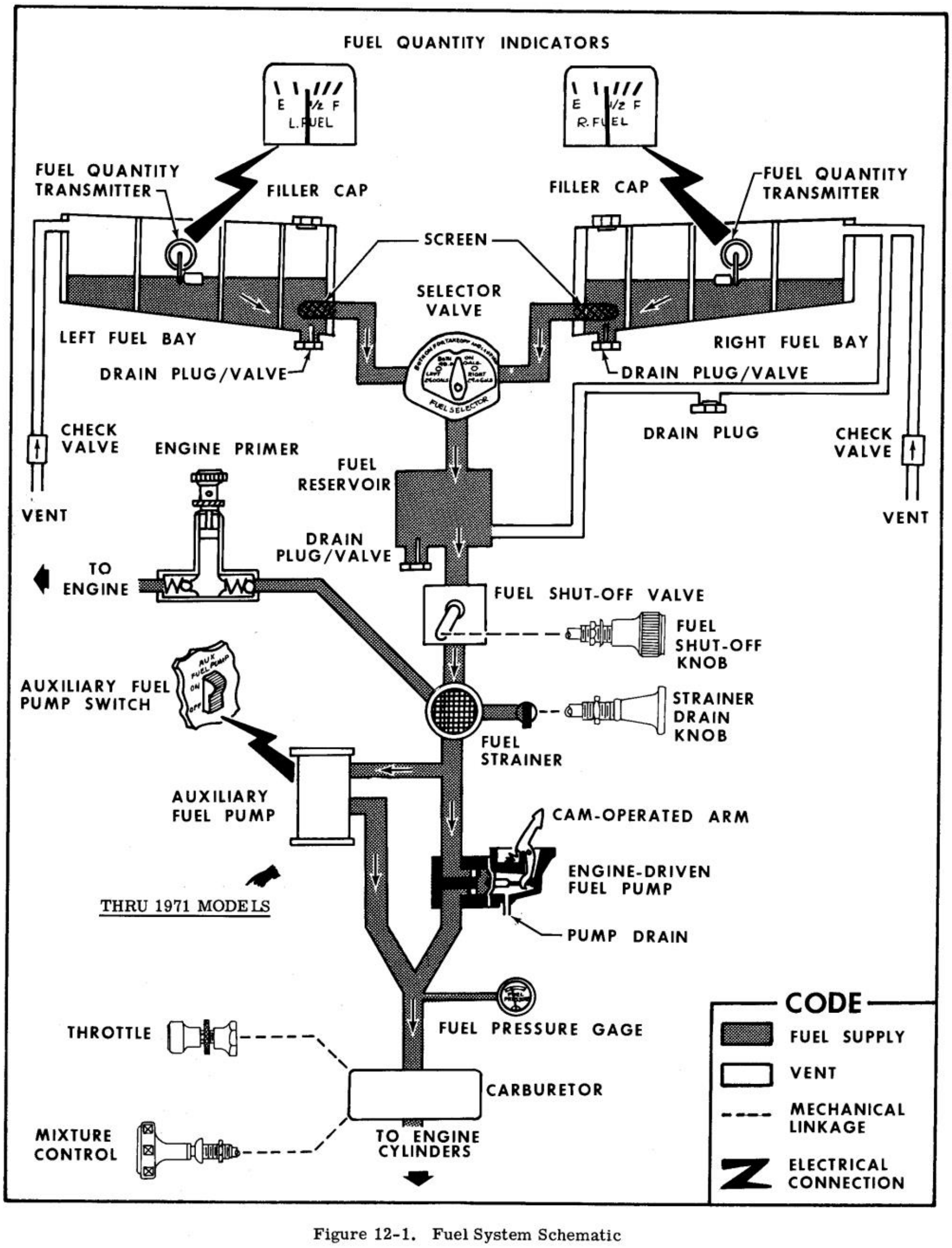


Figure 12-1. Fuel System Schematic

## APPENDIX B
## CAA of New Zealand – Good Aviation Practice (GAP) – Fuel Management

*According to this article, 40 percent of engine failures are caused by fuel exhaustion, starvation, or contamination. Of that 40 percent, starvation occurrences are the most common. The fact that most of those likely result from pilot error illustrates the need to improve pre-flight planning, inflight fuel monitoring and aircraft knowledge.*

*Fuel exhaustion is where the aircraft has completely run out of fuel. This could be due to:*

- *taking off with less fuel on board than was thought,*
- *underestimating the amount of fuel required for the flight,*
- *losing fuel in flight (e.g., from a stuck-open drain cock).*

***Consumption rates***

*Fuel consumption rates can vary considerably between different aircraft of the same type. That is due to their condition, age, and the way they are flown. An increase of just 100 rpm for a fixed-pitch propeller aircraft, for example, can increase fuel flow by 10 percent or more. There goes your contingency.*

*Similarly, operating at low altitudes with the mixture fully rich also substantially increases fuel burn. The cruise altitude and power setting required for the flight should therefore be decided early in the flight planning phase, and the flight manual consulted to determine the fuel flow rate for that altitude/power combination. A conservative fuel consumption rate should then be used, making a further allowance for the age and condition of the engine concerned. Engines near the end of their operational life will sometimes burn more fuel.*

***Leaning***

*Several fuel exhaustion accidents have highlighted that an important part of inflight fuel management is correctly leaning the mixture. Planned fuel consumption rates, and therefore range, will not be achieved if the mixture is not correctly leaned.*

*The mixture should always be leaned during the cruise (provided the desired altitude will be maintained for a reasonable period). Most aircraft engines can be leaned at any altitude provided the power set is 75 percent or less. (The often-quoted figure of 5000 feet is based on the engine being unable to produce more than 75 percent power, even at full throttle, at that altitude.)*

*On some aircraft, a properly leaned engine, at say 4500 feet, can increase your still-air range by as much as 20 percent compared with not leaning at all at the same altitude.*

*A more specific example: a Piper Cherokee 140 normally uses 32 litres per hour when correctly leaned with 65 percent power set, giving it an endurance of more than five hours.*

*A combination of increased rpm and incorrect leaning, however, could increase consumption by as much as 15 percent. That equates to a 45-minute reduction in endurance – there goes your reserve, and then some.*

*Leaning procedures vary considerably between aircraft. Some engines have extremely basic instrumentation and require the pilot to lean the mixture by ear and reference to rpm. Others have exhaust gas temperature and fuel flow gauges, which allow a far greater degree of accuracy. It is important you are familiar with the correct flight manual leaning procedure for the aircraft you are flying.*

***Monitoring fuel quantity***

*You should keep an accurate fuel log, and regularly cross-check the figures with fuel gauge readings. After the first landing, compare usage figures with the planned figures. At any stop on a cross-country flight, re-check the tanks with the dipstick.*

*You should not rely on a fuel log, alone, for monitoring fuel status. Fuel log calculations may not consider such factors as:*

- *higher than expected fuel consumption (because of changed power settings, non-standard fuel leaning, or flying at different cruising levels from those planned)*
- *inaccurate flying*
- *loss of fuel in flight (e.g., a leaking fuel drain, cap, or fuel vent)*
- *under-fuelling before the flight.*

*Your fuel log calculations will also be out if your calculations are flawed. Total reliance on inadequate fuel logs has led to some aircraft running out of fuel.*

*If you can estimate fuel remaining from reading the gauge(s), then recording such a figure in a fuel log gives a direct comparison, even if only an approximate one. It may give you a feel for what the fuel gauge is telling you, or it might be that higher-than-expected fuel consumption can be spotted early.*

*The bottom line is that you should use every method and aid you monitor fuel quantity.*

*Keep a close eye on the fuel gauge. Some pilots dismiss gauges as unreliable. That is possibly unwise, considering the number of fuel starvation or exhaustion incidents where pilots have pressed on with low gauge readings.*

*Make regular reading of fuel gauges an integral part of your fuel management strategy.*

***To minimise the chances of unexpectedly running out of fuel pilots should:***

- *become thoroughly familiar with the fuel systems of the aircraft you fly,*
- *know the fuel consumption rates for different altitude and rpm combinations,*
- *know the manifold pressure and rpm for maximum range,*
- *plan your flight carefully and ensure your fuel-required calculations allow for forecast headwinds, possible diversions, legal reserves, and a contingency,*
- *always plan for en-route refuelling stops and use them to ensure safe margins of fuel are always maintained,*
- *be thoroughly familiar with the usable and unusable fuel quantities for all the aircraft types you fly. Be sure to dip the tanks accurately with the aircraft's own dipstick before every flight. Always know exactly how much fuel is on board before getting airborne,*
- *do your pre-take-off checks thoroughly,*
- *know the correct mixture leaning procedure for the aircraft and lean the mixture in the cruise whenever possible,*
- *keep an accurate inflight fuel log, and regularly cross-check it with fuel gauge readings,*
- *do not hesitate to divert or conduct a precautionary landing should you become uncertain about the state of your fuel,*
- *you must always plan to land with your legal reserve intact,*
- *be familiar with the trouble checks and know how to prioritise your actions if the engine fails, and*
- *regularly dip the tanks after flight to determine the aircraft's actual fuel consumption rate.*

## Appendix C
## Dissenting views of pilot and owner of ZS-EZM

Dissenting view from pilot submitted 15 February 2023:

*The Excel calculations appear to be rectified and the uplifts now match the burns.*

*Regarding the last calculations following the uplift of 115 L, I can only provide so much further information:*

*In my previous emails I have shown that using 30.45 L/hr results in the fuel on board as 88 L prior to the flight on 07/12/2021. I have since looked at the historical mass and balance data on the authorisations for the flights on 13/11/2021, 23/11/2021 and 07/12/2021. Using these records, we can correlate the difference in weights between each flight to determine the approximate fuel burn off following the last refuel of 115 L.*

*These are the values as determined during each pre-flight and entered onto the flight authorisation page on Book a flight.*

*On 13/11/2021 the records show fuel on board as 288 lbs (48 USG/182 L)*
*On 23/11/2021 the records show fuel on board as 192 lbs (32 USG/121 L)*
*On 07/12/2021 the records show fuel on board as 144 lbs (24 USG/91 L)*

*The ground run in the folio dated 02/12/2021 has no data considering no mass and balance existed, so its burn off has to be combined with the flight on 23/11/2021.*

*So, using the above values, we can see that for the flight on 13/11/2021 the aircraft consumed 96 lbs (61 L) of fuel. For the flight on 23/11/2021 as well as the ground run on 02/12/2021, the aircraft consumed 48 lbs (30 L) of fuel. Entering these values into the Excel sheet allows us to calculate two more rates prior to the last flight on 07/12/2021. I have attached this Excel with comments.*

*Following these calculations, the average for these two trips works out to 30.2 L/hr for the final flight, which is 0.25 L from my original calculation of 30.45 L.*

*Using this average, it leaves two questions: firstly, there is 58 L that is unaccounted for? And therefore secondly, as implied by your draft, by not confirming that the aircraft was indeed full during the pre-flight after the refuelling of 115 L, it means the fuelling attendant under- fuelled the aircraft by 58 L on its last refuel?*

*An alternative way to consider the consumption after the last refuel is to say that the aircraft flew 4.17 hours on 182 L. This gives a consumption rate of 43.6 L/hr which is more than the engine is capable of.*

*For me this means that a fuel loss must have occurred. Whether it was from the wing fuel tank or not, I am not able to speculate this.*

The link to the *Dissenting views of the PIC*: https://caacoza-my.sharepoint.com/:b:/g/personal/mathebulat_caa_co_za/EejCmuhIc_ILvWI5WPI19XEBE5P4Xz5_4njQa5MHnaw0Og?e=kabU24

Dissenting view from aircraft owner submitted 15 February 2023:

*The SACAA report states that "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.*

*It is my opinion that the SACAA did not meet this responsibility. The recommendations are based upon subjectively interpreting subsets of data in a very skewed way without trying to explain the incident as a single interaction of all the dynamics at play. No true effort was made to understand the extent of the minor seepage in real flight conditions, even if it was just to eliminate it as a possible cause.*

*The report did appoint blame by implying that the PIC did not do adequate pre-flight planning, did not conduct a thorough pre-flight inspection, and did not do adequate in-flight monitoring of the fuel levels. Such statements could easily lead to liability. As the author of this report, and passenger at the time, and the owner of ZS-EZM, I am present to tell what transpired on the day. What is evident in my response is that I am presenting facts which the SACAA neglected to consider. Ultimately, the question is, what if we died during the incident. Who would tell the truth on our behalf, or would the PIC be considered negligent and by default guilty, this could easily lead to a claim on his estate.*

*My expectation is that the SACAA's investigators would make every effort to be the voice of those. who may not be able to speak for themselves after an incident.*

*In conclusion the SACAA investigation found that:*

- *The fuel tanks were empty before ZS-EZM was landed,*
- *There is no evidence that the fuel could have leaked from either the strainers or the fuel caps,*
- *The left fuel tank had a minor fuel drip that was observed on the 19th of January 2022 which was repaired and re-repaired before the leak was stopped.*

*In this presentation I demonstrated from various perspectives that:*

- *The fuel consumption is not irregular,*
- *Based upon the oil consumption the indication is that ZS-EZM was not constantly operated at the performance side (75%) of operation but more towards the economy side (65%) with a fuel consumption somewhere between the two extremes,*
- *That based upon the Fuel hawk dip, there was sufficient fuel to conduct the flight of the 7th of December 2021,*
- *That by using various methods of data interpretation that, based upon, the historical fuel consumption rate that there was sufficient fuel to conduct the flight of the 7th of December 2021, and*
- *That at the time of the fuel exhaustion there should have been close to an hours' worth of fuel left at the very least, and the level could have been as high as 1 hour 9 minutes which would have meant that EZM could have reached Grand Central with 30 minutes of reserve remaining.*

*Therefore, if the evidence presented are objectively entertained, it must be concluded that there was sufficient fuel for the flight and that the only deficiency observed during the investigation was the fuel leak identified on the 19th of January 2022. Irrespective of how minor the fuel leak may have presented itself during the static test, it must be considered as a possible cause. It is a pity that the tests were not conducted under realistic flight conditions which may have provided better insights.*

*It is my suggestion that the final report be amended to state:*

- *That the cause could not be determined, since there was sufficient fuel available for the flight, and that at the time of the exhaustion there should have been additional fuel left in the tanks, but these were found to be empty,*
- *It must be made clear that the fuel leak test conducted on the 19th of January 2022 was done with the wing at rest, not under pressure and that the minor leak observed was not further investigated to observe its potential effect under realistic flight conditions,*
- *That owners of Cessna 177 Cardinals and possibly 210's be made aware of the possibility that small leaks may result in fuel loss, and that this should be attended to during MPI's as a precautionary action.*

The link to the *Comprehensive Summary of Flight Data for ZS-EZM In Response to the Fuel Exhaustion Incident dated 7 December 2021 CA18/2/3/10087*:
https://caacoza-my.sharepoint.com/:b:/g/personal/mathebulat_caa_co_za/EVxUgzEjPuNLnAdXL1hB2CUBTyKsrLDkafnQ1anIGXX_NA?e=3YPU9f