Air Accident Investigation Unit Ireland

FORMAL REPORT

ACCIDENT
Partenavia P68, F-HIRD
Near Carnsore Point, Co. Wexford

23 September 2021

An Roinn Iompair
Department of Transport

Foreword

This safety investigation is exclusively of a technical nature and the Final Report reflects the determination of the AAIU regarding the circumstances of this occurrence and its probable causes.

In accordance with the provisions of Annex 13[1] to the Convention on International Civil Aviation, Regulation (EU) No 996/2010[2] and Statutory Instrument No. 460 of 2009[3], safety investigations are in no case concerned with apportioning blame or liability. They are independent of, separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability. The sole objective of this safety investigation and Final Report is the prevention of accidents and incidents.

Accordingly, it is inappropriate that AAIU Reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

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[1] **Annex 13**: International Civil Aviation Organization (ICAO), Annex 13, Aircraft Accident and Incident Investigation.

[2] **Regulation (EU) No 996/2010** of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.

[3] **Statutory Instrument (SI) No. 460 of 2009**: Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulations 2009.

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In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and the provisions of SI 460 of 2009, on 23 September 2021 the Chief Inspector of Air Accidents, appointed Kate Fitzgerald as the Investigator-in-Charge to carry out an Investigation into this Accident and prepare a Formal Report.

Operator:	**Action Communication (Commercial Name: Action Air Environnement)**
Manufacturer:	**Partenavia**
Model:	**P68 Victor**
State of Registry:	**France**
Registration	**F-HIRD**
Serial Number:	**14**
Location:	**Near Carnsore Point, Co. Wexford, Ireland**
Date/Time (UTC)[4]	**23 September 2021 / 16.10 hrs**

SYNOPSIS

The Partenavia P68 Victor aircraft, with one Pilot and three Task Specialists on board, took off from Waterford Airport, Ireland, and was operating a marine wildlife survey flight off the south-east coast of Ireland when the right engine stopped. The Pilot commenced a return to Waterford Airport and a few minutes later, the left engine lost power repeatedly. The Pilot carried out a forced landing on a beach close to Carnsore Point, Co. Wexford. The Pilot and all three Task Specialists exited the aircraft and summoned assistance. The Pilot and one Task Specialist sustained serious injuries. The two other Task Specialists sustained minor injuries. The aircraft was destroyed. There was no fire.

The Investigation concluded that the probable cause of the accident was separate interruptions to the fuel supply of each engine, while operating at or below a quarter of the aircraft's fuel tank capacity, which ultimately resulted in a forced landing. Contributory causes were:

1. **A lack of clarity in the Aircraft Flight Manual limitations section regarding operations at less than ¼ tank fuel.**
2. **The configuration of the fuel selector panel was potentially misleading, and its operation was not intuitive.**

Three Safety Recommendations are made as a result of this Investigation.

[4] **UTC**: Coordinated Universal Time. All timings in this Report are quoted in UTC. Local time was UTC + 1 hour at the time of the accident.

TABLE OF CONTENTS

NOTIFICATION AND RESPONSE

The AAIU Inspector On-Call (IOC) was notified of the accident by Shannon Air Traffic Control (ATC) at 17:30 hrs on 23 September 2021. Three Inspectors of Air Accidents deployed to the accident site which was in an intertidal zone of the beach near Carnsore Point, Co. Wexford. Gardaí, with the assistance of local people, secured the aircraft prior to the AAIU's arrival. During the night of 23 September, the AAIU conducted an initial examination of the aircraft insofar as light and tidal conditions permitted. When the tide receded, the aircraft was moved to a position above the high-water mark. The following morning, a further examination of the aircraft and accident site was completed, before the aircraft was recovered to the AAIU's secure wreckage examination facility at Gormanston, Co. Meath.

1. FACTUAL INFORMATION

1.1 History of the Flight

The twin-engine aircraft, a Partenavia P68 Victor, with one Pilot and three Task Specialists[5] on board, departed Waterford Airport (EIWF) at 11:08 hrs on 23 September 2021. The three Task Specialists were members of an environmental research team. The flight was part of a series of survey flights, the purpose of which was to record sightings of marine wildlife in the waters off the coast of Ireland. The aircraft seating layout was two rows of two seats and a bench-type seat in the rear of the aircraft. During the occurrence flight, one Task Specialist was seated in the front right seat next to the Pilot, and the two other Task Specialists were seated in the row directly behind. The rear bench seat was unoccupied.

The plan for the flight was to fly over the sea along 16 pre-defined survey lines at a height of approximately 250 – 300 feet (ft) and a speed of approximately 100 knots (kt). Each line was approximately 45 km (24.3 NM) in length and the lines were spaced approximately 4 km (2.2 NM) apart. The planned 16 survey lines were completed in approximately 4 hours and 30 minutes. Following a discussion with the Task Specialists, and after assessing the remaining fuel, the Pilot determined that there was enough fuel to complete two more survey lines before returning to EIWF with his fuel reserves intact.

Shortly after commencing the second of the two additional survey lines, the right engine stopped. At the time, the aircraft was reportedly travelling at a speed of approximately 105 kts and was at a height of approximately 300 ft. Recorded data shows that the aircraft then climbed to approximately 500 ft. The Pilot reported that the aircraft climbed more slowly than expected whilst operating on the left engine only.

At approximately 500 ft whilst still in the climb, the left engine exhibited a significant loss of power but did not completely stop. The Task Specialists later reported that the aircraft dropped in height and turned to the left. The left engine power recovered but the power loss re-occurred. This sequence of climbing slightly, losing power, losing height, and recovering engine power when descending repeated several times.

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[5] **Task Specialists:** Annex I of Commission Regulation (EU) 965/2012 '*laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council'* gives the following definition of a Task Specialist: '*'task specialist' means a person assigned by the operator or a third party, or acting as an undertaking, who performs tasks on the ground directly associated with a specialised task or performs specialised tasks on board or from the aircraft.'*

The Pilot then routed directly towards land and as the aircraft approached the shore, the left engine lost power again. The Pilot banked the aircraft to the left and carried out a forced landing on the beach during which the nose of the aircraft impacted with the loose shale surface. The aircraft sustained significant structural damage to the forward cabin area. The three Task Specialists exited the aircraft through the door on the left side. The Pilot and Task Specialists reported that when the aircraft was on the beach, the left engine ran briefly at what the Pilot said appeared to be full power. The Pilot pulled back the fuel mixture lever to shut down the engine. The Pilot exited the aircraft through the broken windscreen which had shattered during the impact. Two Coastguard helicopters attended the scene. The Pilot and the Task Specialist seated in the front right seat sustained serious injuries during the impact sequence and were airlifted to hospital. The two other Task Specialists sustained minor injuries and were taken to hospital by road ambulance.

1.1.1 Witness Information

1.1.1.1 Pilot

During three separate interviews, the Pilot, who had been seriously injured in the accident, provided the Investigation with detailed information about the accident flight and the survey operations being conducted to the best of his recollection. The summary below is the sequence of events from the start of the final two survey lines as described to the Investigation by the Pilot.

The Pilot informed the Investigation that when conducting this type of survey flight, he ensured that all the required turns were coordinated turns[6], as this ensured the comfort of the Task Specialists and a stable interception of the next survey line. Before starting the final two survey lines, the Pilot made a check of the fuel, the engine parameters, and the time (on the date of the accident there was a NOTAM[7] in place informing pilots that EIWF closed at 18:00 hrs). He told the Task Specialists that there was approximately one hour, and 45 minutes of fuel left in the tanks. This meant that they could fly for 30 more minutes conducting the survey, then fly back to EIWF and land with a planned one hour of reserve fuel. The Pilot and the Task Specialists agreed to carry out two more survey lines. The Pilot stated that he checked the parameters for each engine two more times before continuing.

Several minutes later, the right engine ran roughly and stopped. The Pilot said that the symptoms being exhibited by the engine were like those experienced when there is air in the fuel. He said he looked at the fuel gauge for the right-hand tank. Initially he observed that it was indicating between one quarter and one half full but then it began to show an abnormally low indication, and he suspected a fuel leak (a fuel leak had prompted the Pilot to shut down the right engine five days earlier – **Section 1.1.2**). He switched on the auxiliary fuel pump and pushed all the engine controls (fuel mixture, propeller, and throttle) to their fully forward positions, but the engine did not recover.

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[6] **Coordinated turn:** A turn where all the forces acting on the aircraft are balanced, i.e. there is no slipping or skidding.

[7] **NOTAM:** NOtice To AirMen – A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.

The Pilot reported that within a few minutes of the engine stoppage, the fuel gauge reading for the right-hand tank had dropped to zero. This drop in fuel quantity supported the Pilot's belief that the aircraft had a significant fuel leak, and due to the low altitude at which they were flying no further attempt was made to re-start the right engine. The Pilot described how he secured the right engine by pulling back the fuel mixture lever to idle cut-off, feathering the propeller, pulling back the throttle and selecting the right tank fuel selector to '*TANK OFF*' (**Section 1.6.2.1**). The Pilot transmitted a MAYDAY call to ATC at EIWF informing them of the situation and that he was routing direct to EIWF. The Pilot then briefed the Task Specialists that the aircraft had sufficient fuel and the capability to perform a single engine landing without any problems.

The Pilot initiated a climb; however, he did not believe that the left engine was delivering full power despite the engine control levers being in their fully forward positions. The Pilot observed that the fuel gauge for the left-hand tank was indicating between one quarter and one half full, and that the aircraft was unable to climb while maintaining the blue line speed[8]. He said that he switched on the auxiliary fuel pump for the left engine and then moved the fuel selector knobs so that fuel was being fed from the right tank to the left engine (**Figure No. 3**). The Pilot was aware of previous occurrences involving the incorrect configuration of the crossfeed system of this aircraft type and his reasoning for moving the fuel selector knobs was to be sure that the knobs were in their correct positions. The Pilot said that after waiting a little time and observing no change, he moved the fuel selector knobs back to their original positions. The Pilot also observed that to move the left fuel selector knob from the '*ON*' position to the '*CROSSFEED*' position it had to pass through the '*TANK OFF*' and '*ENGINE SHUT OFF*' positions. The Pilot decided to route closer to the shore so that if a forced landing became necessary the aircraft would be close to the shore or over land.

The left engine then lost power suddenly. The engine power then recovered before power was lost again. At this point, the aircraft was flying at approximately 250 ft above the sea and the Pilot made the decision to fly directly towards the shore. The Pilot noted that there was close to a quarter tank of fuel remaining in the left tank.

The left engine power recovered again. The Pilot said he tried again to crossfeed fuel from the right tank but without any apparent effect and he then repositioned the fuel selector knobs to their original position. The left engine lost power again and recovered several times, but each time the engine recovered it did not produce sufficient power to maintain aircraft speed and altitude. The Pilot could not recall exactly what method he used when attempting to recover the left engine during the numerous power losses but believed that he may have used both the windmilling propeller and the starter. He also recalled trying to position the left wing to a good position for feeding fuel to the engine.

As the aircraft approached the shoreline, the left engine lost power again. At this point, the aircraft was approximately 70 ft above the sea. The Pilot turned the aircraft so that it was parallel to the shore and performed a forced landing on the beach. The aircraft touched down on the main landing gear, on a soft shale surface, and decelerated rapidly. The nose undercarriage leg and nose structure impacted hard with the beach surface. The aircraft came to rest in a nose-down attitude.

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[8] **Blue line speed:** A speed indicated on the aircraft airspeed indicator of a twin-engine aircraft, which shows the best rate of climb speed with one engine inoperative.

Due to the severity of the impact, one of the Pilot's legs was trapped and he was unable to exit the aircraft immediately. The Task Specialist sitting next to him also found it difficult to exit the aircraft. The Pilot asked the other Task Specialists seated in the middle row of the aircraft to assist the Task Specialist seated in the front. They did this and all three Task Specialists exited the aircraft. The Pilot was able to free himself and exit through the broken front windscreen.

The Pilot informed the Investigation that soon after the impact the left engine appeared to spontaneously run to full power, and he pulled back the fuel mixture levers to shut it down.

Prior to the engine problems on the accident flight, the Pilot had noted different cockpit indications for each engine. The Pilot asked the Task Specialist sitting in the front right seat to take a photograph of the aircraft's instrument panel. The Pilot explained to the Investigation that the reason for taking the photograph was to show the Operator's engineering department that there appeared to be a problem with the rigging of the throttle levers. The Pilot informed the Investigation that the photograph was taken when both engine throttles were at the same setting. The photograph showed both engines were operating at the same rotational speed (in revolutions per minute), but the left engine had a lower fuel flow (by approximately 1.5 Gallons per hour) and the left engine had a lower manifold pressure (by approximately four inches of mercury).

1.1.1.2 Task Specialists

The Investigation interviewed the three Task Specialists who were on board the aircraft during the accident flight. The Task Specialists were interviewed individually and the information they provided regarding the accident flight has been consolidated and summarised below.

The Task Specialists described the roles that they had on board the aircraft. Two of the Task Specialists, seated in the middle row of the aircraft, were observers sighting seabirds and cetaceans[9]. The third Task Specialist carried out the role of data logger and was seated in the front right seat beside the Pilot. All the Task Specialists had been involved in the survey project for some time. They had carried out multiple flights as a team working with the same Pilot, flying in the subject aircraft and another similar aircraft used by the Operator.

The Task Specialists described how at the end of the planned survey work they had a discussion with the Pilot, and after checking fuel quantities, it was agreed that two further survey lines would be carried out. Two of the Task Specialists observed the fuel gauges at around that point in the flight; one Task Specialist estimated that the tanks were just less than half full and the other estimated that they were at about one quarter full. The third Task Specialist recalled the Pilot commenting on the fuel consumption during an earlier part of the flight and saying that they were '*doing great*'.

The Task Specialists estimated that the engine problems started when they were between half and three quarters of the way through the final additional survey line. The Task Specialists heard unusual noises described as *'stuttering'.* One Task Specialist observed that the aircraft then climbed. The Task Specialists recalled that soon after this, the Pilot secured the right engine as it had stopped. The Pilot briefed them that they could not continue the final line of the survey but that there should be no problem returning to Waterford Airport using the left engine only.

[9] **Cetaceans:** A family of large aquatic mammals including whales, dolphins, and porpoises.

The Task Specialists recalled that the problems with the left engine began almost immediately after the right engine was secured by the Pilot. They heard a similar stuttering sound and the aircraft dropped in height and turned to the left. The Task Specialists described the Pilot repeatedly trying to recover the left engine and moving the fuel selector knobs. Each time the engine recovered the aircraft would climb. The engine would then stutter again, and the aircraft dropped in altitude. This cycle of losing power during climb and recovering during descent happened several times. The Pilot then informed the Task Specialists that he was going to attempt to land on the beach and transmitted a MAYDAY. The Task Specialists stated that during this time the Pilot was extremely busy and that they [the Task Specialists] knew that their role was to stay calm and prepare for either a ditching or a forced landing. They prepared for this by ensuring their immersion suits were properly fastened, ensuring their lap belts were secure, gathering up loose personal items and safety equipment, and adopting the brace position.

One of the Task Specialists recalled hearing what they thought was the stall warning alarm just before the impact on the beach. The Task Specialist who was sitting in the right seat in the middle row described being thrown diagonally across the cabin and into the back of the Pilot's seat. The Task Specialist sitting in the left seat in the middle row explained that their ankle was initially trapped below the seat, but that with the assistance of another Task Specialist, they were able to free it and exit the aircraft soon after impact. The Task Specialist seated in the front seat sustained more serious injuries to one arm and one leg but was able to unfasten their seatbelt and exit the aircraft with the assistance of the other Task Specialists. At around the same time, the Pilot, who had serious injuries, had climbed out through the now-shattered front windscreen.

The Task Specialists then sat down on the beach away from the aircraft. They were assisted by local fishermen and the emergency services were alerted. All three Task Specialists recalled that the left engine ran briefly whilst they were sitting on the beach. Emergency medical assistance arrived shortly thereafter.

1.1.2 Previous Flights

The aircraft had flown from Rennes, France, to Ireland on 18 September 2021. During that earlier flight, when the aircraft was in the cruise phase, at approximately 8,700 feet and 140 kts, the pilot (who was also the Pilot on the accident flight) reported that he had an issue with the right engine. Waterford ATC assisted the Pilot with relevant flight information, put the Airport Fire Service on a '*Local Standby*[10]' and notified the Waterford Coastguard Search and Rescue base. The Pilot continued the flight and landed at EIWF with only the left engine operating. The Pilot subsequently informed the Investigation that during this previous occurrence, the aircraft lost approximately 130 litres of fuel in 10 minutes. Following the single-engine landing, a local engineer examined the right engine and identified the cause of the fuel leak as a loose connection on the fuel supply hose to the mechanical fuel pump. The fuel hose connection was tightened, a successful maintenance check flight was carried out by the Pilot, and the aircraft was returned to service.

[10] **Local Standby:** The term used for a situation where an aircraft is approaching an aerodrome with a known or suspected defect, but the issue is not expected to prevent the aircraft from making a safe landing. In such cases aerodrome emergency services would be alerted to a state of readiness.

Following the subject accident, the Investigation examined the connection in question and determined that it was securely attached. The Investigation also examined the Journey Log for the aircraft. The Journey Log contained a copy of paperwork signed by a French maintenance organisation certifying that the leak had been repaired and that the aircraft could return to service.

1.2 Injuries to Persons

The Pilot and one Task Specialist were seriously injured in the accident. The other two Task Specialists sustained minor injuries (**Table No. 1**).

Injuries	Pilot	Task Specialists	Others
Fatal	0	0	0
Serious	1	1	0
Minor /None	0	2	

Table No. 1: Injuries to Persons

1.3 Damage to Aircraft

The aircraft was destroyed.

1.4 Other Damage

There was no damage to the accident site. However, some items of wreckage were washed away by the tide and were not recovered.

1.5 Pilot Information

The Pilot held a European Union (EU) Commercial Pilot Licence (CPL), Aeroplane (A), which was initially issued in November 2014 and most recently re-validated in January 2020 by the Direction Générale de l'Aviation Civile (DGAC), France. The Pilot's licence contained a number of ratings: a Single-Engine Piston rating, a Multi-Engine Piston rating, a Multi-Engine Instrument rating, and a Flight Instructor (Aeroplane) certificate.

The Pilot also held a Class 1 medical certificate issued by a DGAC-approved aero medical examiner on 12 May 2021.

1.5.1 Flying Experience

The Pilot's Flying Experience is outlined in **Table No.2**.

Total all types:	2,112 hours
Total on type:	325 hours
Last 90 days:	204 hours
Last 30 days:	64 hours
Last 24 hours:	5 Hours

Table No. 2: Pilot's Flying Experience

1.6 Aircraft Information

1.6.1 General

The aircraft was a Partenavia P68 Victor which was manufactured in Italy in 1973. It was powered by two Lycoming IO-360-A1B engines, each of which was fitted with an MTV-12, three-bladed, variable pitch, constant speed propeller rotating in a clockwise direction (when viewed from the rear). The aircraft cabin could accommodate a maximum of six people (one pilot plus five others) with seating arranged in two rows of two seats and a bench-type seat in the rear of the aircraft. Each seat was fitted with a '*lap-strap*' style seatbelt. The two front seats were also fitted with a single shoulder strap. Cabin access and egress was provided by a door on the left side of the aircraft. The Aircraft Flight Manual (AFM) states that the maximum take-off and landing weight was 4,100 pounds (1,860 kg). The original aircraft manufacturer, Partenavia, no longer exists. The type certificate holder for the P68 aircraft is now Vulcanair, referred to in this report as the Type Certificate Holder.

The aircraft was equipped with a Century IIIB autopilot system.

The aircraft had a Certificate of Airworthiness issued by the DGAC on 11 April 2018. The most recent Airworthiness Review Certificate was dated 29 October 2020 and had an expiry date of 2 December 2021.

The Certificate of Airworthiness for the aircraft stated that:

> *'This Certificate of airworthiness is issued pursuant to the Convention on International Civil Aviation dated 7 December* 1944 *and Regulation (EC) No 216/2008*[11]*, Article 5(2)(c) […]'*

Regulation (EC) No 216/2008, Article 5(2)(c) states:

> *'c)* […] *The certificate shall be issued when the applicant has shown that the aircraft conforms to the type design approved in its type-certificate and that relevant documentation, inspections and tests demonstrate that the aircraft is in condition for safe operation.* […]*'*

And Regulation (EC) No 216/2008, Article 5(2)(a) states:

> '[…] *The type-certificate shall cover the product, including all parts and appliances fitted thereon;'*

[11] Regulation (EC) No 216/2008 (Basic Regulation) on the '*common rules in the field of civil aviation and establishing a European Aviation Safety Agency* […]') was repealed and replaced by Regulation (EU) 2018/1139 which contains similar articles with regards to Airworthiness Certification.

1.6.2 Fuel System

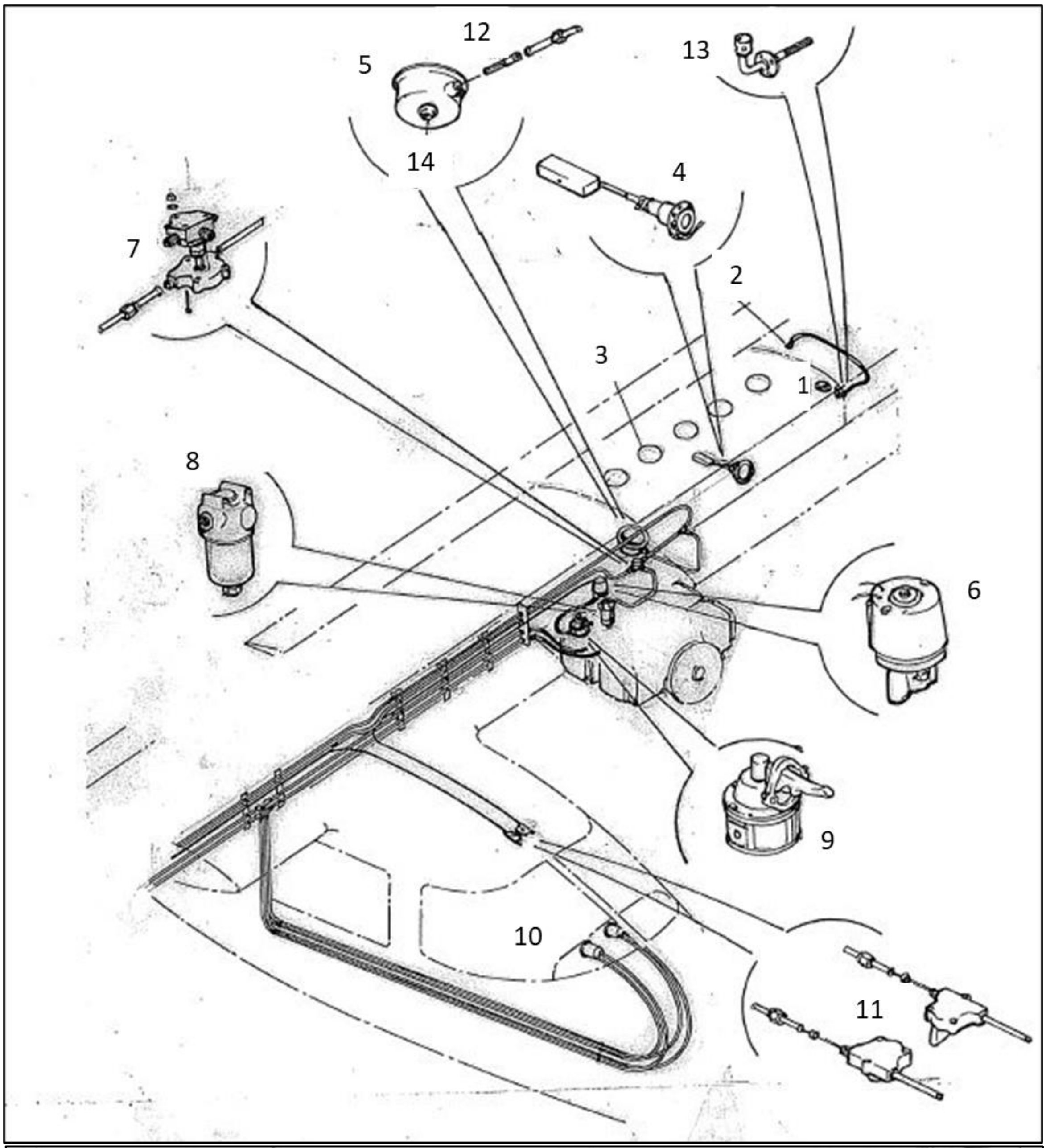
Each wing contains an integral fuel tank. The fuel tank capacity is shown in **Table No. 3**.

Total Fuel Capacity Per Tank	54 US Gallons (204.4 litres)
Unusable Fuel Per Tank	2.5 US Gallons (9.5 litres)
Total Useable Fuel Per Tank	51.5 US Gallons (194.9 litres)
Total Fuel Capacity (Both Tanks)	108 US Gallons (408.8 litres)
Total Unusable Fuel Capacity (Both Tanks)	5 US Gallons (19 litres)

Table No. 3: Stated Aircraft Fuel Tank Capacity

With reference to **Figure No. 1**, for each side of the aircraft, fuel is drawn from the fuel tank into the engine by a mechanical fuel pump mounted on the engine (Item 9) which operates when the engine is running. An auxiliary electrical fuel pump is installed on each side (Item 6) which is used for starting the engines and as a backup in case of a mechanical fuel pump failure. During normal operation, the left engine draws fuel from the left-wing tank and similarly, the right engine draws fuel from the right-wing tank. The emergency procedures section of the aircraft Flight Manual (AFM) contains a fuel crossfeed procedure whereby, if necessary, the fuel system can be configured such that an individual fuel tank can provide fuel to the engine on its own side, the engine on the opposite side, or both (**Section 1.6.2.1**).

Fuel dockets from the AVGAS refuelling station at EIWF state that on 22 September 2021, 271 litres (L) of AVGAS fuel were uplifted to the aircraft fuel tanks prior to a short test flight being undertaken. The following day, a further 43 L of fuel was added to replenish the tanks after the short test flight. The refueller at EIWF informed the Investigation that the Pilot's preference was to fuel the aircraft himself. The Pilot informed the Investigation that the fuel tanks were full prior to departure of the accident flight and that he used a fuel consumption value of 62 L per hour (16.38 US gallons per hour) for flight planning purposes. He said that in his experience, the fuel gauges on the subject aircraft were reliable.



1) Fuel Filler
2) Breather Pipe
3) Inspection Door
4) Fuel Level Transmitter
5) Fuel Sump
6) Auxiliary Fuel Pump
7) Fuel Selector Valve
8) Fuel Filter
9) Fuel Pump, Diaphragm Type
10) Instrument Panel
11) Fuel Selector Control Lever
12) Fuel Inlet Filter
13) Fuel Vent Pipe Connector
14) Fuel Drain Valve

Figure No. 1: Aircraft Fuel System (*Manufacturer's Maintenance Manual*)

1.6.2.1 Fuel Tank Selection

Manipulation of the aircraft fuel selector knobs, mounted overhead in the cockpit, alters, via cables, the position of the fuel selector valves located in the roots of each wing (item no. 7 in **Figure No. 1**). This allows or blocks the supply of fuel to an engine as required. **Figure No. 2** shows the logic scheme schematic of the fuel system and **Figure No. 3** shows the fuel selector from the occurrence aircraft. The upper part of **Figure No. 3** shows the fuel selectors as found. However, the Investigation was informed that the selectors may have been moved by emergency responders post-accident.

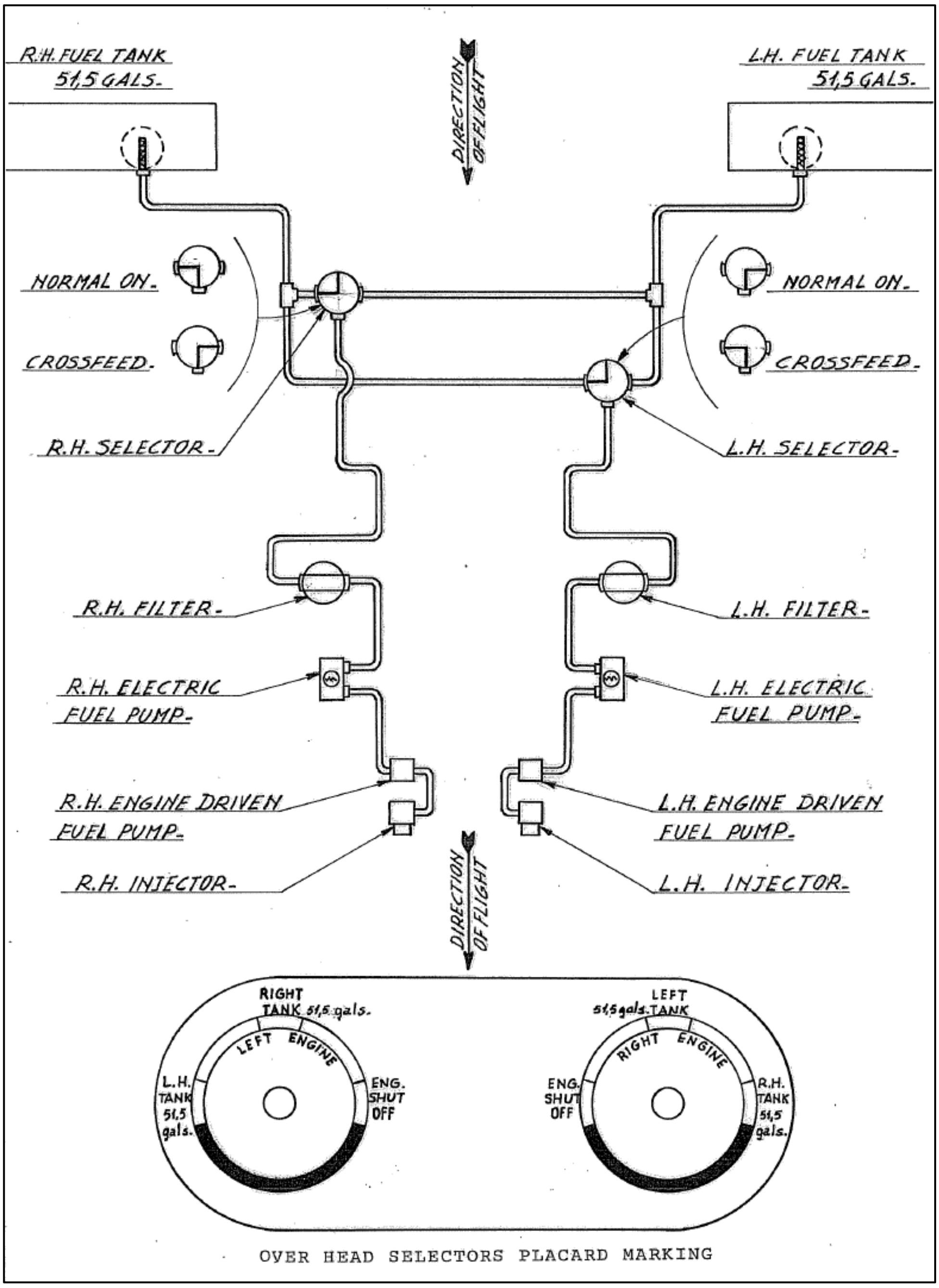


Figure No. 2: Fuel system Schematic (Manufacturer's Maintenance Manual)[12]

[12] The Manufacturer informed the Investigation that this figure represents the '*logic scheme*' of the fuel systems for several of the P.68 aircraft types. Therefore, it does not fully represent the fuel system installed in the subject aircraft.

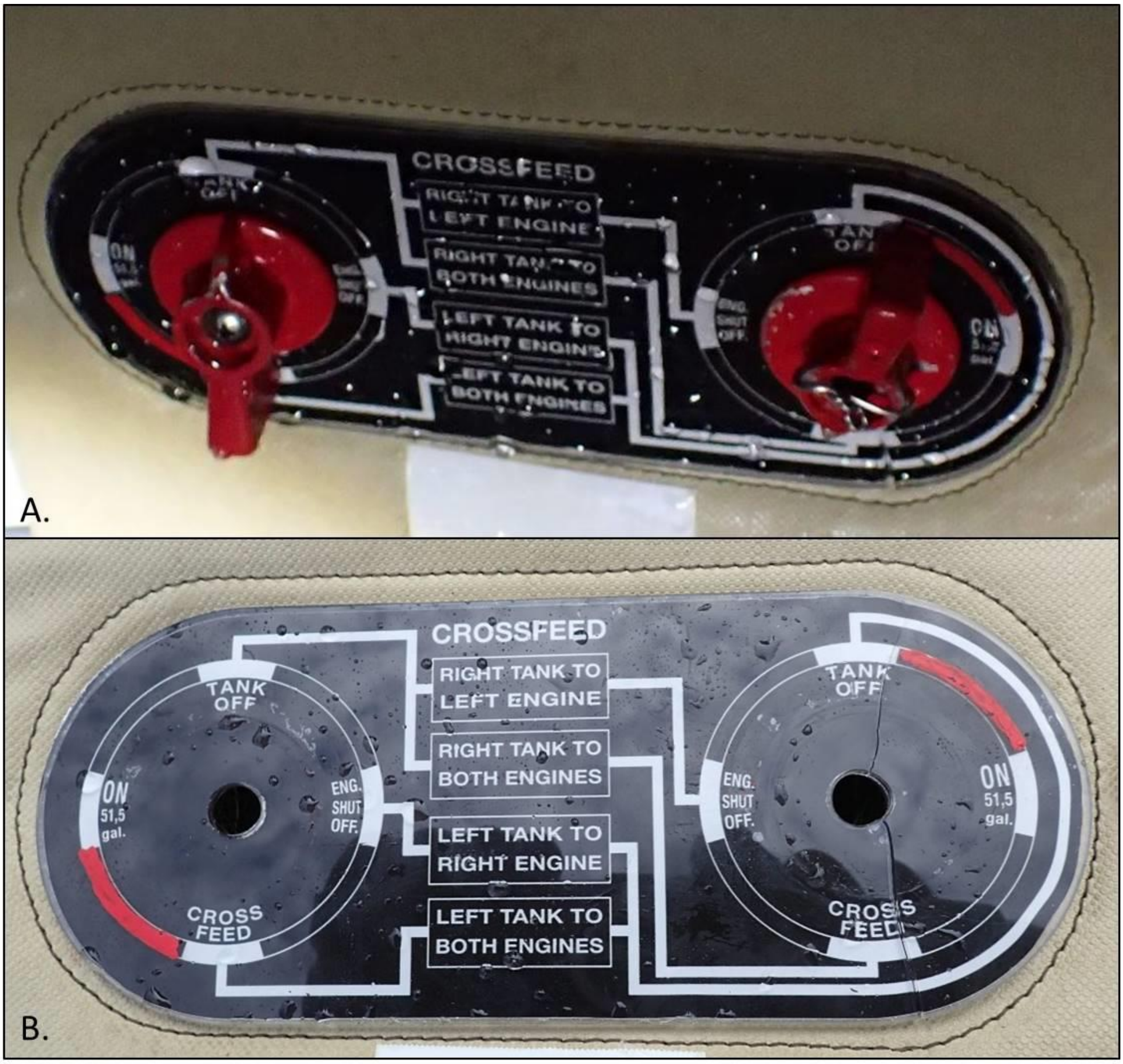


Figure No. 3: Fuel Selectors - A. Showing Fuel Selector Panel with fuel selector knobs installed and B. with Fuel Selector knobs removed.

Red quadrants indicate the positions through which the fuel selector knob cannot pass. However, the Investigation found that the red quadrant for the right engine was incorrectly marked. The red marking was between the 'TANK OFF' and the 'ON' positions but when checked after the accident, the Investigation found that it was not possible to move the fuel selector knob between the 'ENG. SHUT OFF' and 'TANK OFF' positions. The Investigation also observed that the inaccessible positions were different for the left engine. In the case of the left engine, it was not possible to move the fuel selector knob between the 'CROSSFEED' and 'ON' positions. This was consistent with the red quadrant.

The crossfeed system is such that when an engine is being supplied from the fuel tank on the opposite side, it can no longer be supplied with fuel from the tank on its own side. More recent versions of this aircraft type have a re-designed (simplified) fuel selector panel.

1.6.2.2 Fuel Gauges

A fuel gauge for each wing tank was installed in the aircraft instrument panel (**Photo No. 1**).

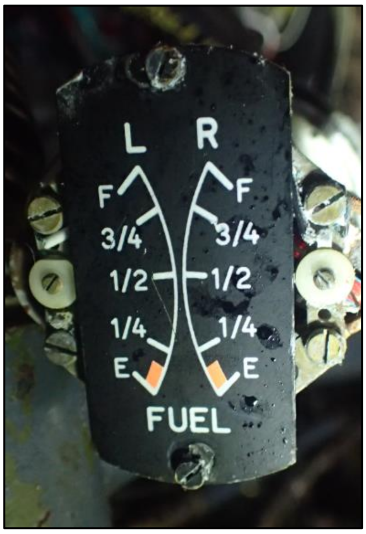


Photo No. 1: Fuel Gauge (post-accident)

1.6.2.3 Aircraft Flight Manual Limitations

The limitations section of the AFM states:

> '*Avoid rapid taxi turns before take-off or excessive nose-up attitude with ¼ fuel or less in each tank.*'

1.6.3 Single Engine Performance

The AFM contains data indicating the expected rate of climb that should be achieved by the aircraft at maximum weight (1,860 kg) with the left engine inoperative[13]. The air temperature at the surface on the day of the occurrence was 19 ^{o}C and the Mean Sea Level (MSL) pressure was 1019 hectopascals (hPa) (**Section 1.7**). This indicates that the aircraft may have achieved a gross[14] climb rate of approximately 325 feet/min.

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[13] **Left Engine Inoperative:** In twin-engine aircraft with clockwise rotating propellers the consequences of a left engine failure are more severe than a right engine failure. Therefore, it is common for manufacturers to quote performance data for a left engine failure as this is the worst case.

[14] **Gross climb:** The actual demonstrated performance achieved by the manufacturer during certification.

1.6.4 Procedures for Engine Failure During Flight

Section III, I. D of the AFM is a '*Procedure for Best Performance After Engine Failure during Cruise Flight*' which states:

1. *Inoperative Engine - SECURE*
2. *Operative Engine – ADJUST*
3. *Trim Tabs – ADJUST*
4. *Fuel valves position: inoperative engine – OFF*
   Operative engine – ON or CROSSFEED
5. *Electrical load – DECREASE to minimum required*
6. *As soon as practicable – LAND*

The Investigation notes that the fuel selector valves in this aircraft had two potential '*OFF*' positions; '*ENGINE SHUT-OFF* and '*TANK OFF*'.

Section III, I. G of the AFM is a procedure for '*Engine Restart in Flight*' which states:

a. *Fuel Selectors – BOTH ON*
b. *Magneto Switches – ON*
c. *Throttle – FORWARD approximately one inch*
d. *Propeller FORWARD*
e. *Starter – OPRESS* [sic] *and hold until engine is windmilling*
f. *Mixture – FULL RICH*

Section III, I. H of the AFM gives the following instructions to feed fuel from the right tank to the left engine when the right engine is shut off:

'Right tank to left engine: L/H Fuel Sel. – TANK OFF
(Right engine shut off): R/H Fuel Sel. – ENG. SHUT OFF'

1.6.5 Instrument Panel

During the inspection of the aircraft, the Investigation observed that the RPM gauge[15] (tachometer) for the engines was from another aircraft manufacturer. The RPM gauge indicated green and amber running ranges and a red RPM limit (**Figure No. 4**). However, these ranges and the limit were different, and were higher than those specified in the AFM for the subject aircraft (**Figure No. 5**). Further information is contained in **Section 1.17.4.3**.

[15] The one tachometer fitted to the subject aircraft utilised two indicator needles – one for each engine.

Figure No. 4: RPM Gauge from the Subject Aircraft

Tachometer	
Green Arc (Normal)	550 RPM to 2700 RPM
Red Arc, concentric with Green Arc (avoid continuous operations)	2100 RPM to 2350 RPM
Red Radial (Maximum)	2700 RPM

Figure No. 5: Extract from Aircraft Flight Manual, Section 1 – Operating Limitations

The Pilot stated that the normal engine power setting that he used for flying survey lines was between 16- and 18-inches manifold pressure and between 2,050 and 2,200 rpm. This engine speed setting is in the green band on the tachometer fitted to the aircraft but in a band labelled '*Avoid Continuous Operation*' on the tachometer that is approved for installation in this aircraft. The Operator informed the Investigation that the configuration of the aircraft at the time of the accident was the same as the configuration of the aircraft when the Operator purchased it.

1.6.6 Airworthiness Publications

In 2002, in response to a number of reports of malfunctions or improper fuel selector valve control rigging, the Italian Airworthiness Authority, *Ente Nazionale per l'Aviazione Civile* (ENAC) issued Airworthiness Directive 2002-415 mandating that all owners and operators of the P68 aircraft type carry out initial and repetitive checks of the fuel selector control system as detailed in the aircraft Type Certificate Holder's Service Bulletin (SB) 113. This SB includes an operational check of the fuel selector system with both engines running at a number of different fuel selector positions.

Prior to the issuance of SB 113, checks of the fuel selector control system were described in Service Instruction 107. Service Instruction 107 contained instructions for checking the correct correspondence between the position of the handle on the fuel selector placard and the position of the fuel selector valve located within the wing root structure. It was originally published as an attachment to the aircraft Maintenance Manual but was incorporated into the Maintenance Manual in September 2017. SB 113 provided more detailed instructions for this check.

1.6.7 Maintenance History

According to the aircraft Journey Log, the most recent scheduled maintenance performed was a 200-hour check carried out by an approved maintenance organisation on 13 September 2021. The documentation for the 200-hour check states that Vulcanair Airworthiness Instruction F-2002-480 had been carried out. This instruction required the application of ENAC Airworthiness Directive 2002-415 and accordingly SB 113. The maintenance documentation also stated that the following tasks were included in the 200-hour check:

- *FUEL SELECTOR TRANSMITTER – Check for condition and operation*
- *FUEL SELECTOR RECEIVER – Check for condition and operation*
- *FUEL SYSTEM – Inspect plumbing and component mounting for condition, security; system for leaks.*
- *FLEXIBLE FUEL LINES – Check for leaks and condition*
- *FUEL INJECTION NOZZLE AND FUEL LINES – check fuel injector nozzles for looseness […]. Check fuel lines for dye stains at connection indicating leakage and security of line*

1.7 Meteorological Information

Met Éireann, the Irish meteorological service, was asked to provide details of the estimated meteorological conditions prevailing in the area of the accident, at the time of the accident. Details from the report received are reproduced in **Table No. 4**.

Meteorological Situation:	A moderate westerly airflow covers Ireland with a high of 1031 hectopascals (hPa) to the southwest and a low of 986 hPa to the south-west of Iceland.
Surface Wind: **Wind at 2,000 ft:** **Between surface and 300 ft:**	West-northwest 5 – 8 kts North-west 10 -12 kts Similar to surface
Visibility:	30 km
Weather:	Dry and sunny
Cloud:	Largely clear skies, isolated fair weather cumulus with bases around 2,500 ft
Surface Temperature / Dew Point:	19/12 degrees Celsius
Mean Sea Level (MSL) Pressure:	1019 hectoPascals (hPa)
Freezing Level:	11,000 feet

Table No. 4: Estimated Meteorological conditions in the area at the time of the occurrence

1.8 Aids to Navigation

See **Section 1.11.2**.

1.9 Communications

The Investigation was provided with a recording of the MAYDAY call made by the Pilot after the reported failure of the right engine. The call was received by Waterford ATC at 16:07 hrs but the quality of the received signal was poor. The Air Traffic Controller heard the aircraft callsign and that the aircraft was reporting a MAYDAY. He immediately cleared the aircraft to enter the Waterford Control Zone, but when he asked the Pilot to confirm that the problem was an engine failure, the received transmissions were unreadable. The pilots of two other aircraft who were listening on the same frequency provided communication assistance and were able to confirm that the Pilot was reporting a single engine failure and was flying at 300 ft. The sound of a running engine could be heard in the background of the MAYDAY recording.

1.10 Aerodrome Information

Not applicable

1.11 Recorded Data

1.11.1 Flight Recorders

Flight data or cockpit voice recorders were not installed on the aircraft, nor were they required to be.

1.11.2 Other On-Board Recording Devices

The following recording devices were carried on board the aircraft during the accident flight:

- Garmin Aera 796 GNSS[16] navigation device – recovered in a damaged condition
- Spidertracks device – recovered in a damaged condition
- Bad Elf GPS device – recovered in a damaged condition
- Zoom H1 Handy Voice Recorder – not recovered

A Garmin GNS430 navigation device was also installed on the aircraft. However, this did not have the capability to record the flight track.

1.11.2.1 Garmin Data

The damaged Garmin Aera 796 GPS device was sent to the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA), the National Air Safety Investigation Authority of France. The BEA successfully downloaded the flight path data recorded on the device which included time, position, and altitude for the occurrence flight. **Figure No. 6** shows the final fifteen minutes of altitude data recorded by the Garmin device.

[16] **GNSS:** Global Navigation Satellite System

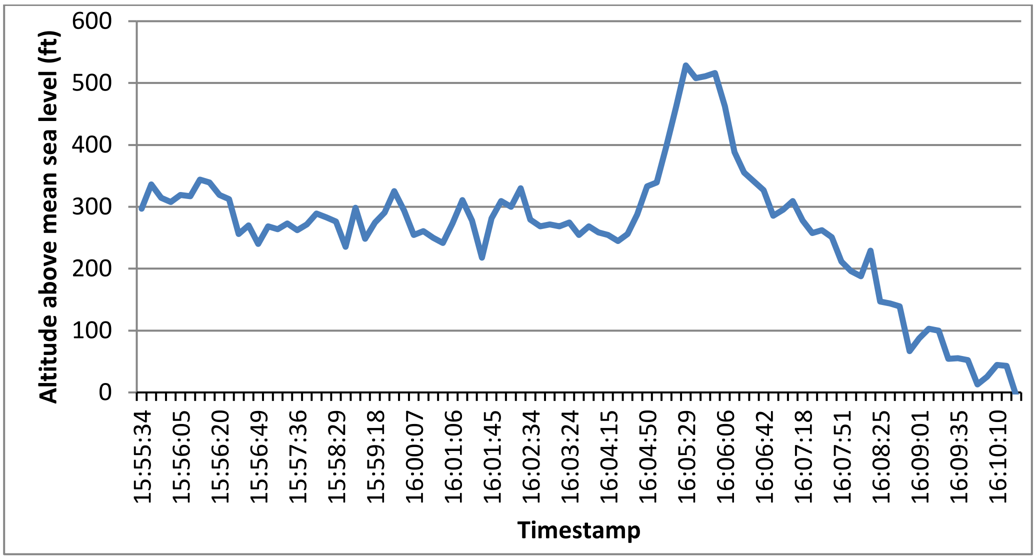

Figure No. 6: Calculated Altitude Data[17] Recorded by the aircraft Garmin Aera 796

1.11.2.2 Spidertracks Data

The Investigation downloaded flight path data (**Figure No. 7**) that had been uploaded from the Spidertracks device to the service provider's website. This device recorded and transmitted the position, altitude, speed (over ground) and bearing of the device at 15 second intervals using a GNSS position fix. The first recorded data point was on the ground at EIWF prior to the flight and the final data point was recorded approximately 2.5 km south-south-east (SSE) of the accident site.

Figure No. 7: Aircraft Track (Spidertracks and Google Earth)

[17] Altitude Data on GPS device is calculated using satellite data and a model of the earth as a terrestrial geoid.

The Investigation contacted the manufacturer of the Spidertracks device to understand the accuracy of the data. The manufacturer of the device was able to review their historic system data and confirmed that the PDOP[18] for the data of the accident flight was '*one*'. This is the highest level of precision possible and indicates that the accuracy of the data was in the order of a few metres. The manufacturer of the device also provided documentation which described the possible sources of errors. From this information, the Investigation was satisfied that any errors in the data were likely to be systematic, i.e. apply to all data points equally. Therefore, any comparisons of successive data points were likely to be reasonably accurate.

The manufacturer of the Spidertracks device also provided the Investigation with an additional set of data recorded during the accident flight. This data was recorded at one second intervals and was transmitted when a cellular network was available. This data included parameters that were sourced from satellite data (time, position, altitude, vertical speed, ground speed, speed) and parameters that were sourced from sensors on the device itself (roll, pitch, and yaw). However, the Investigation was informed by the Pilot that the Spidertracks device was carried loose in the cockpit rather than fixed in place using a bracket as recommended by the manufacturer. This meant that the data that was sourced from the sensors on the Spidertracks device (roll, pitch, and yaw) was not reliable and was discounted by the Investigation.

The final fifteen minutes (approximately) of altitude data recorded by the Spidertracks device at a sample rate of one second is shown in **Figure No. 8**. The altitude data in this case is relative to WGS84[19]. It should be noted that the altitude data recorded by the Garmin device is relative to mean sea level and therefore shows different recorded altitude values. **Figure No. 9** and **No. 10** show an extract of the aircraft ground speed and vertical speed data respectively.

For clarity, the approximate time is shown in red boxes below each figure.

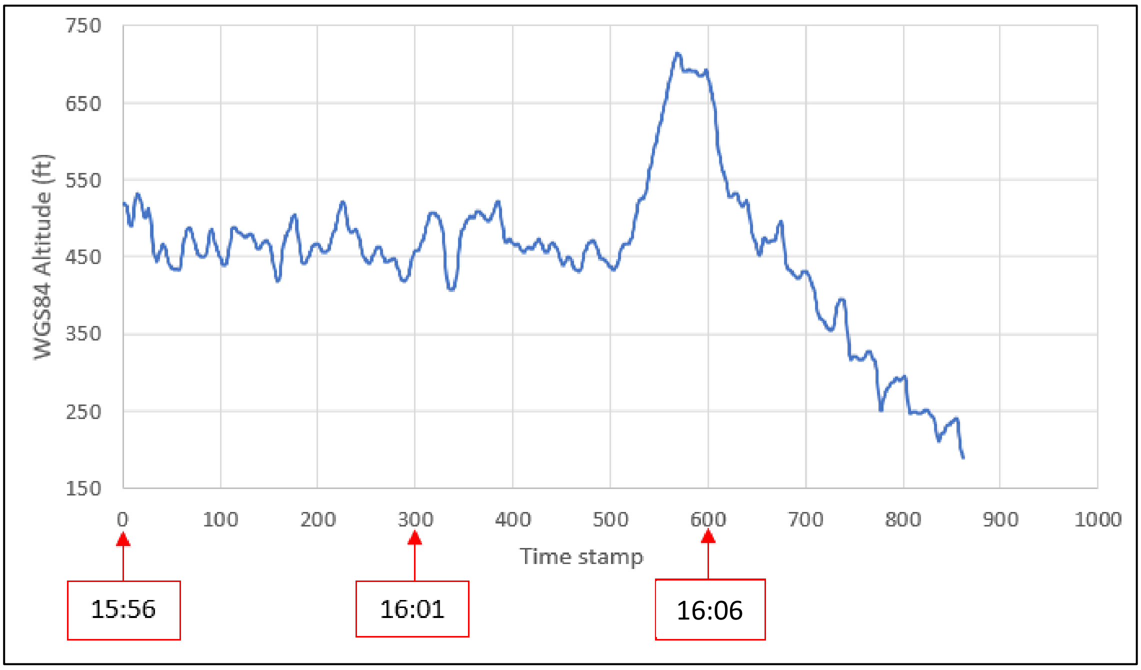

Figure No. 8: Altitude data from 15:56 hrs to end of recording (Spidertracks)

[18] **PDOP:** Position dilution of precision. A measure of the real-time accuracy of a GNSS/GPS system taking into account, *inter alia*, the number of satellites visible to an antenna and their relative geometric positions in the sky.

[19] **WGS84:** The World Geodetic System 1984 (WGS84) is a global datum used for determining positions on the Earth's surface.

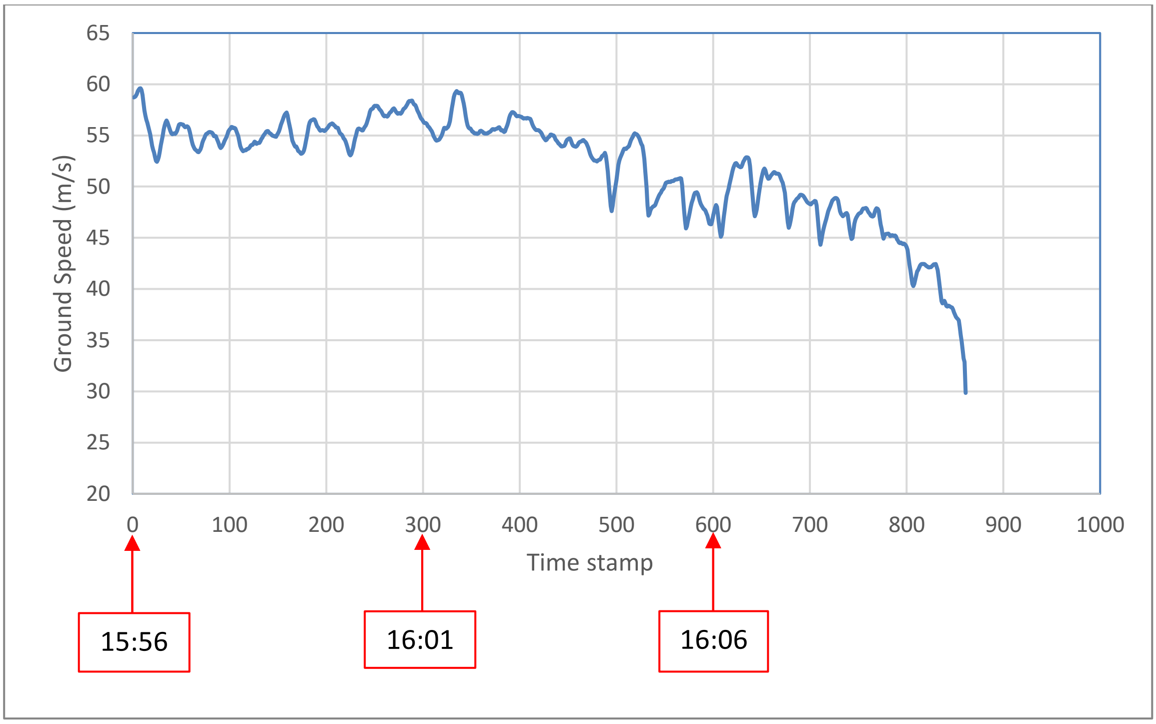

Figure No. 9: Ground Speed data from 15:56 hrs to end of recording (Spidertracks)

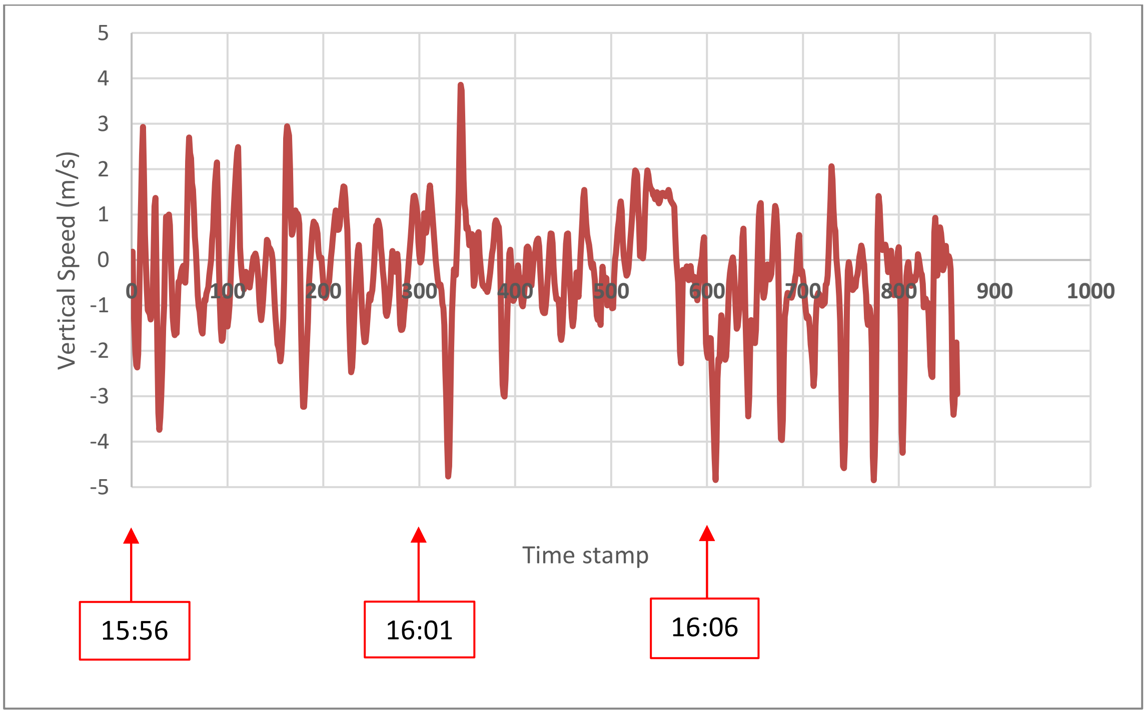

Figure No. 10: Vertical Speed data from 15:56 hrs to end of recording (Spidertracks)

1.11.3 Irish Coastguard Helicopter Recordings

The Irish Coastguard provided a number of video recordings that were taken by one of the helicopters that was dispatched to the scene shortly after the accident. These recordings were taken at approximately 16:30 hrs and show the left side of the aircraft being buffeted by waves. However, the left wing and engine appear to remain above water at that time. Part of the recording, lasting just over one second, shows the left propeller moving slowly, whilst the right propeller appears to be stationary. Images taken by the helicopter's Forward Looking InfraRed (FLIR) camera at around the same time show a heat source in the location of the left engine. After approximately three seconds the recording changes to show a normal, i.e. not thermal image and the heat source can no longer be seen.

1.12 Wreckage and Impact Information

The forced landing was performed on a beach near Carnsore Point, Co. Wexford. The surface of the beach consisted of loose shale which was sloped towards the sea. The accident site was compact with the aircraft remaining largely intact, albeit substantially damaged. Some items that had been loose in the cabin were washed away by the sea but were retrieved from the shoreline of the beach. Other items were washed out and were not recovered. When the Investigation team arrived at the site, the aircraft was partially submerged and could not be safely accessed. This limited the level of inspection that could be carried out immediately. Once the tide receded, the aircraft was moved to a position on the beach above the high-water mark to enable a more detailed inspection.

The forward section of the aircraft was destroyed, having been crushed upwards and rearwards, which pushed the instrument panel, rudder pedals and control yoke rearwards towards the first row of seats. The nose landing gear had detached from the aircraft, and the main landing gear sustained minor damage. Video footage taken by the Irish Coastguard showed the aircraft exit door attached to the aircraft and intact. However, the incoming tide subsequently damaged the door, and it was washed away prior to the wreckage recovery. Part of the door was found over a year later by a member of the public at another beach in the area.

On the left propeller, one propeller blade was broken at approximately one-half span from the propeller hub and one propeller blade was split at the tip. The right propeller had one blade that was split at approximately one-third span from the propeller hub. All six propeller blades had minor damage on their leading edges close to the hub.

One of the Task Specialists on board the aircraft took a photograph (**Photo No. 2**) immediately after the accident. **Photo No. 3**, which was taken by the Investigation team on arrival at the accident site several hours later, indicates the extent of damage that was caused by the incoming tide.

Photo No. 2: Aircraft wreckage immediately after impact

Photo No. 3: Aircraft wreckage several hours after the Accident

1.13 Medical and Pathological Information

The Pilot and one of the Task Specialists sustained serious injuries in the accident sequence. The remaining two Task Specialists sustained minor injuries (**Section 1.2**).

1.14 Fire

There was no fire.

1.15 Survival Aspects

The two front seats of the occurrence aircraft were fitted with lap belts and an additional diagonal shoulder strap that could be connected to the lap belt. The rear seats were fitted with lap belts.

Table No. 5 describes the disposition of the aircraft seatbelts and the condition of the seat belt attachment points following the accident.

Front left seat	Lap belt intact and unbuckled, mounting bracket for the lap belt attached to aircraft structure. Shoulder strap intact and mounting bracket for shoulder strap attached to aircraft structure. Shoulder strap was not connected to lap strap.
Front right seat	Lap belt intact, attached to aircraft structure and unbuckled. Shoulder strap intact and attached to aircraft structure. Shoulder strap was not connected to lap strap.
Middle left seat	Lap belt intact and buckled but right-hand attachment point had separated from aircraft floor.
Middle right seat	Lap belt intact and buckled but attachment points had separated from aircraft floor on both sides of the seat.
Rear left seat[20]	Lap belt intact, attached to aircraft structure and unbuckled.
Rear right seat	Lap belt intact, attached to aircraft structure and unbuckled.

Table No. 5: Condition of aircraft seatbelts post-accident

As outlined in **Table No. 5**, some of the seatbelt attachment brackets had separated from the floor area during the accident sequence. The aircraft Type Certificate Holder advised that the lap strap style seatbelts should be attached to the aircraft floor and that the location of the attachment points was designed such that the seat belts would be anchored to aircraft structure underneath the floor. However, a review of the original drawings for the aircraft did not show the detail of this attachment. The attachment points of the seatbelts that had separated in the accident were secured to sheet metal floor panels rather than aircraft structure. In some cases, the mounting brackets and associated rivets had been pulled away from the sheet metal panels during the accident sequence. Examples of an attached and detached seatbelt are shown in **Figure No. 11.**

[20] The rear seats were unoccupied during the accident flight.

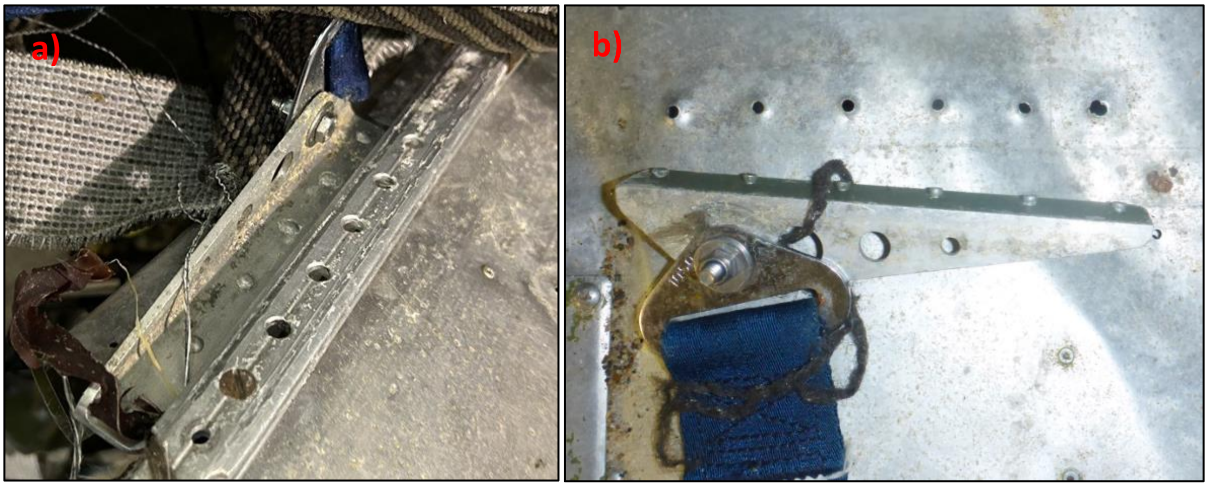

Figure No. 11: Seatbelt attachment brackets ((a) attached, and (b) detached)

The Task Specialists stated that they were wearing the lap strap seatbelts provided in the aircraft as well as life jackets and immersion suits. A life raft, an axe and a diving knife were also carried on board. The Task Specialists informed the Investigation that the Pilot regularly carried out safety drills and that they had been briefed by the Pilot about various aircraft procedures. This included procedures related to ensuring that the aircraft stayed within weight and balance limitations, as well as emergency procedures such as ditching. The Task Specialists were allocated different responsibilities in the event of a ditching: One Task Specialist was responsible for the life raft, and another was responsible for opening the aircraft door prior to ditching and wedging it open with the axe. The Task Specialists also informed the Investigation that prior to the start of the research project, they had completed a course of training in aircraft underwater emergency egress at a centre for maritime safety training.

Examination of the aircraft wreckage showed that the front of the aircraft absorbed most of the energy during the forced landing. This caused significant crush damage to the front of the aircraft cabin, pushing the instrument panel rearwards towards the front row of seats, reducing the liveable space[21] substantially in that area. The middle and rear of the cabin containing the second and third rows of seats sustained considerably less damage and the liveable space in that area was not significantly reduced by the impact.

The aircraft is of a high-wing design with all potential aircraft exit routes below the level of the wings. The aircraft had one exit door used for normal and emergency access and egress. This was located behind the front row of seats and partially under the left wing of the aircraft. In addition, one of the windows on the right side of the cabin was an emergency exit. The window emergency exit was not used in this case. The aircraft also has one small cargo door which is located behind the cabin bulkhead.

The Task Specialist, who had been seated in the right seat of the middle row, informed the Investigation that they were thrown out of their seat towards the front left seat when the impact occurred. This Task Specialist sustained a head injury. The Task Specialist seated in the left seat of the middle row required assistance to exit the aircraft as their ankle had become trapped below the seat during the accident.

[21] **Liveable space:** The cabin space where humans can safely reside. An accident often significantly changes the size and shape of an aircraft's liveable space.

Both the Pilot and the Task Specialist seated in the front row sustained serious injuries during the accident sequence. The Pilot asked the Task Specialists who had been seated in the middle row of the aircraft to assist the Task Specialist in the front row to egress the aircraft. The Task Specialists seated in the middle row informed the investigation that they were able to slide their colleague backwards and out of the aircraft door. The Pilot was able to egress the aircraft through the front windscreen.

1.16 Tests and Research

1.16.1 Engine Examination and Testing

Following examination of the aircraft at the accident site, the aircraft was recovered to the AAIU wreckage examination facility, where a preliminary examination of both engines was carried out. The initial examination found that:

- There was no evidence of a fuel leak on either engine.
- The fuel hose that had been the source of the fuel leak on 18 September 2021 was found in place, with the connection secure.
- A small amount of fuel was present in the gascolator[22] bowl for each engine.
- There was no fuel in the flow dividers on either engine (flow dividers supply fuel to the fuel injectors).
- There was no fuel in the inlet fuel hose, connected to the flow divider on either engine.

1.16.1.1 Right Engine

Dual engine failures are rare, and when they do occur, the probable causes often relate to components or systems that are common to both engines, for example, the fuel system. Prior to beginning further examinations of the fuel system, the Investigation sought to eliminate any engine-related causes. Both the Pilot and Task Specialists reported that the left engine had run following the forced landing. The Investigation was therefore satisfied that the left engine was capable of running. To demonstrate that the right engine was also capable of running, the right engine including all accessories was removed from the aircraft and shipped to an approved engine facility in the UK for testing. The fuel hose at the inlet to the mechanical fuel pump was left undisturbed (this had been the source of the reported fuel leak on the 18 September 2021). The test was witnessed on behalf of the Investigation by a Senior Inspector of Air Accidents from the UK Air Accidents Investigation Branch. The test report made the following observations:

- The engine was connected to a dynamometer to simulate the load of a propeller.
- The engine was connected to the test rig using the engine's own fuel control unit, fuel, and oil hoses.
- The engine started as normal with no issues.
- Test points from the Engine Manufacturer's engine run-in sheet were completed. Test points included 1,200, 1,500, 1,800, 2,000, 2,200, 2,400 and 2,700 rpm.

[22] **Gascolator:** A device normally found at the lowest point of an aircraft's fuel system which collects water and sediment that may be present in the fuel.

- During the test runs the engine achieved 164-172 Brake Horsepower (BHP). The engine is rated at 200 BHP and a newly overhauled engine is typically expected to achieve 182-200 BHP.
- A differential pressure test was carried out in accordance with the engine manufacturer's '*Service Instruction 1191A'*. Cylinder No. 3 was found to have lower than expected compression. The test report noted that this lower compression may have caused the low engine power output noted during engine testing.
- A Mag drop test[23] resulted in a 50 rpm drop when checked. This was considered normal.
- The engine had no oil or fuel leaks at the time of the test.

To determine the cause of the low compression in Cylinder No. 3, the Investigation subsequently dismantled the engine. Examination of Cylinder No. 3 components showed scoring on the side of the piston, and some brown marks consistent with piston blow-by[24]. The UK test facility advised that scoring and scuff marks were not unusual.

1.16.1.2 Left Engine

During the Investigation, it became apparent that the left engine may not have been delivering full power during the accident flight. To determine if this was the case, the Investigation shipped the left engine to an approved engine test facility in the UK where a full strip, examination, and rig testing of some of the critical components in accordance with the Engine Manufacturer's specifications was carried out. Due to the time elapsed between the accident and the test, it was not possible to carry out a whole engine test. The examination and testing did not identify any anomaly that would have prevented the engine from running or cause an in-flight stoppage. Specifically, the examination and testing determined that:

- The flow divider, fuel injector servo and magnetos all met the Engine Manufacturer's test requirements.
- Two of the fuel injectors met the Engine Manufacturer's test requirements.
- The remaining two fuel injectors were slightly below the Engine Manufacturer's test requirements. The approved engine test facility advised that the impact of this would be a slightly higher cylinder head temperature.
- A functional test was carried out on the mechanical fuel pump and propellor governor; both were found satisfactory.
- Cylinder No. 1 was forcibly removed as it was seized due to corrosion from the long period of inactivity. The remaining cylinders were found with moderate corrosion due to the long period of inactivity. The pistons, rings, inlet, and exhaust valves were all found satisfactory with no evidence of faults found.
- There was a quantity of debris found in Cylinders No. 1 and No. 4. This was subsequently analysed (**Section No. 1.16.1.3**)
- The crankshaft, main and big-end bearings were visually inspected and found satisfactory.

[23] **Mag Drop Test:** A check of the reduction in engine rpm when one of the engine magnetos is switched off, which identifies that a magneto is operational.
[24] **Piston blow-by:** Where combustion forces push some pressurised air, fuel, and other contaminants past the cylinder rings and into the engine crankcase.

- The conrod and piston (small end) bearings were visually inspected and found satisfactory.
- The crankshaft gear and idler gear were inspected and found satisfactory with some expected surface corrosion.
- Camshaft lobes and corresponding tappet mating surface were found worn, especially on cams one and four, which operate the number one and number four exhaust valves. The in-service effect of this wear would be that the corresponding inlet and exhaust valves would not open fully, and the power produced by the engine would be lower than expected.

1.16.1.3 Debris analysis

The debris found in Cylinders No. 1 and No. 4 was analysed by a materials laboratory. The analysis found that the sample contained aluminium, bromine (within other organic material) and lead deposits. It is possible that this was due to post-accident corrosion.

1.16.2 Fuel System Testing

1.16.2.1 Fuel Quality and Consumption

At the accident site, the Investigation removed the refuel caps from both wings and noted that there was a quantity of fuel in each fuel tank. A sample of one litre was taken from each tank. No fuel leaks from the fuel tanks or the fuel system were observed by the Investigation at the accident site. The aircraft was transported to the AAIU wreckage examination facility with the fuel system intact. The aircraft was re-examined on arrival at the facility and no fuel leaks were observed. Both fuel tanks were then drained, and the quantity of fuel was measured. The total quantity of fuel, including the samples taken previously, was 74 L approximately, which comprised of 42 L from the right tank and 32 L from the left tank. A sample of fuel drained from the occurrence aircraft was tested by a specialist laboratory. The laboratory informed the Investigation that the sample met DEFSTAN 91-090, which is an industry standard for AVGAS.

To determine if there were any impediments to the fuel that remained in the fuel tanks reaching either engine, the Investigation carried out further examination of the fuel system components.

1.16.2.2 Gascolator and Fuel Sump Filters

Both gascolator filters were inspected. They were found clean and free of debris. '*Finger*' filters located in the fuel sumps of the left and right fuel tanks were also inspected and found to be clean and free of debris.

1.16.2.3 Fuel Selector Valve

The Investigation examined the rigging of the fuel selector valves in accordance with the aircraft Type Certificate Holder's SB 113 and the aircraft Maintenance Manual.

The examination showed some free play in the fuel selector knobs. It was also observed that the inaccessible portion of the right fuel selector (shown in red at the right side of **Figure No. 3** in **Section 1.6.2.1**) was incorrectly indicated. The aircraft fuel selector showed the inaccessible (red) quadrant in the 1-3 o'clock position. The Investigation found that the inaccessible portion of the right fuel selector approximately corresponded to the fuel selector being positioned in the 10-12 o'clock arc.

The fuel selector system was then tested by introducing low pressure compressed air into the system, in between the fuel tank and the fuel transfer valve on each wing and identifying where the air exited the fuel system. This was done firstly on the left fuel system for all combinations of fuel selector valve positions and then on the right fuel system for all combinations of fuel selector valve positions. The Investigation did not identify any anomalies during this testing in terms of selected positions, but flow levels could not be accurately assessed.

During the inspection of the crossfeed system, the Investigation observed that a fitting on the crossfeed pipe (**Figure No. 1** in **Section 1.6.2**) where it connected to the right-hand fuel transfer valve, was loose, and that the pipe could move in and out along the longitudinal axis of the pipe and fitting. The Investigation disassembled the fitting and found significant damage to the olive fitting (**Figure No. 12a** and **12b**) and o-ring (**Figure No. 12c**). The damage did not appear to be recent.

Figure No. 12: Damage to Olive Fitting

1.16.2.4 Fuel Tank Unusable Fuel Level

Each fuel tank of the aircraft contained a fuel sump (Item No. 5 in **Figure No. 1** in **Section 1.6.2**) which was located towards the front edge of each fuel tank. The fuel feed from each tank was located at the bottom of the fuel sump. The aircraft Type Certificate states that the unusable fuel in each tank is 9.5 litres. The Investigation explored the possibility that the unusable fuel as stated in the aircraft Type Certificate could be incorrect and that the fuel system may have been susceptible to unporting[25].

The certification of the aircraft design was carried out in 1971 by the original aircraft manufacturer. This organisation no longer exists; therefore, the Investigation asked the current Type Certificate Holder to review the fuel tank geometry and the original certification of the aircraft unusable fuel level stated in the Type Certificate.

[25] **Unporting:** A condition where the outlet from a fuel tank to an engine is no longer submersed in fuel. This can be caused by a low fuel quantity or by aircraft manoeuvring, particularly uncoordinated manoeuvering.

The aircraft type was originally certified using FAR (Federal Aviation Regulation) certification standard CS23. The requirement relating to unusable fuel supply was CS23.959, which stated that:

'The unusable fuel supply for each tank must be established as not less than the quantity at which the first evidence of malfunctioning occurs under the conditions specified in this section. […]'

In relation to demonstrating compliance with the requirement, FAR CS23.959 stated:

'For test purposes the quantity of fuel to be used to show compliance with this section must be chosen by the applicant. In addition when establishing the unusable fuel supply, the following flight conditions must be arranged in order, from the most to the least critical:

(1) Level flight at maximum continuous power, or at the power required for level flight at V_c[26], whichever is lower.
(2) Climb at maximum continuous power at the calculated best angle of climb at minimum weight.
(3) Rapid application of power and subsequent transition to best rate of climb from a power-off glide at 1.3 V_{s0}[27].
(4) Slips and skids in level flight climb, and glide, under the applicable conditions specified in sub paragraphs (1), (2) and (3) of this paragraph, of the greatest severity likely to be encountered in normal service or turbulent air.'

The aircraft Type Certificate Holder reviewed the original flight test reports written at the time of aircraft certification relating to this requirement. These reports document a flight test campaign of 44 sorties with a total test time of 38 hours. The flight tests concluded that the most critical condition was climb at maximum continuous power at the calculated best angle of climb and the unusable fuel was determined to be 9.5 litres in each tank.

It is notable that the original certification requirements did not contain any information in relation to the how the slips and skids required for the certification tests should be performed. The Acceptable Means of Compliance relating to compliance with current EASA Certification Standard CS23.959 gives the following additional direction:

'Level flight at maximum recommended cruise –
1. Maintain straight co-ordinated flight or bank angles not exceeding 5°, until a malfunction occurs.

2. Simulate turbulent air with ± half-ball width oscillations at approximately the natural yawing frequency of the aeroplane, until a malfunction occurs.

3. Skidding turns with 1-ball skid. Hold for 30 seconds and then return to co-ordinated flight for 1 minute.'

[26] V_c: Design cruising speed.
[27] V_{s0}: Stall speed or the minimum steady flight speed in the landing configuration.

The angle of incidence[28] of the wing in the subject aircraft was 1.5 degrees and the dihedral[29] was one degree. The Investigation found 42 litres of fuel remaining in the right tank. Using computer models of the aircraft, the Type Certificate Holder determined that with 42 litres of fuel remaining in the fuel tank, an aircraft pitch angle of 11 degrees would be required to unport the fuel sump. Similarly, 32 litres, as found remaining in the left tank, would require an aircraft pitch angle of 8 degrees to unport the sump. The Investigation notes that this analysis is a geometric analysis based on a wings-level configuration and does not take account of fuel sloshing and/or acceleration Based on measurements taken, the Investigation estimated that the fuel held in the fuel sump and in the pipes between the fuel sump and the engine would amount to approximately one litre.

The Investigation was also provided with information from an experienced P68 pilot. The pilot informed the investigation that to maintain a speed of approximately 90 kts, a pilot would need to hold the aircraft at a pitch angle of approximately 11% [6.3 degrees].

The Investigation shared some of the (15 seconds interval) recorded data with the Type Certificate Holder and requested that they analyse it. The Type Certificate Holder observed that some of the turns carried out during the flight did not appear to be coordinated. The Type Certificate Holder's analysis of the final turn (a left turn from survey line 17 to the final survey line) estimated that it was likely to have a '*non-negligible lateral acceleration (slip/skid)*' and that the lateral acceleration was '*non-negligible'* for at least 45 seconds.

The Type Certificate Holder informed the Investigation that in 1978, a modified fuel sump was introduced. This was located further rearwards in the wing and was a tub-shaped stamped sheet metal construction.

1.16.2.5 Fuel Level Transmitter

A visual inspection of the fuel level transmitters in the fuel tanks was carried out. The following observations were made:

- The wiring associated with the right-hand fuel level transmitter appeared generally aged and brittle with some exposed conductors where the insulation had been damaged.
- The float-arm of the right fuel level transmitter was distorted.
- At full down deflection, the float of the right transmitter sat on the bottom stop of the transmitter rather than the bottom of the tank. The Type Certificate Holder informed the Investigation that the float should sit on the bottom of the tank when the fuel gauge reads zero.
- The wiring associated with the left fuel level transmitter looked generally less aged and newer than that on the right fuel level transmitter.
- When deflected down, the left float appeared to contact the bottom of the fuel tank before contacting the transmitter stop.
- There was evidence that when deflected upwards, the left float had repeatedly impacted with a nut located in the fuel tank access panel on the top of the wing (circled area of **Photo No. 4**)

[28] Angle of Incidence: The angle between the chord line of the wing where the wing is mounted to the fuselage, and a reference axis along the fuselage.
[29] Dihedral: The upward angle of an aircraft's wings when viewed from the front.

- The Investigation observed that it was possible for the left float to become caught on the fuel tank access panel nut and if this occurred, it would be possible for the left transmitter to read '*full*' although the fuel level was reducing.

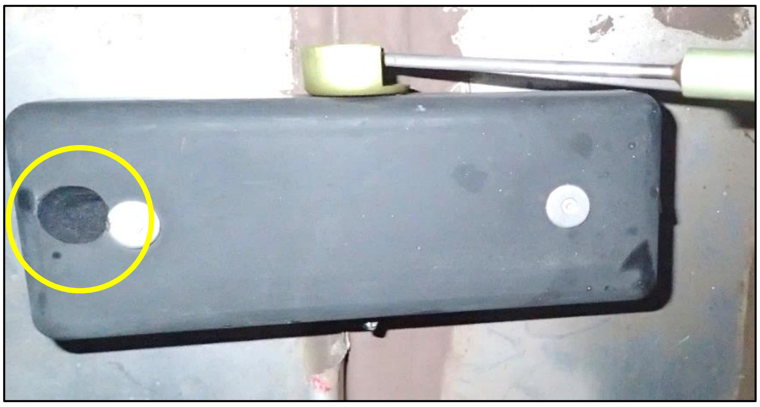

Photo No. 4: Left Fuel Tank Transmitter float (damaged area highlighted)

The Investigation also carried out electrical resistance measurements of the fuel level transmitter systems and compared the values to the values shown in the original aircraft Manufacturer's drawings (**Table No. 6**).

	Float Deflection (mm)	Resistance value from drawing (Ω)	Measured resistance left transmitter (Ω)	Measured resistance right transmitter (Ω)
Empty	0	0	10	7.5
1/2	78.5	93	110	109
Full	188	187.5	187	194

Table No. 6: Fuel level transmitter electrical resistance check

1.16.2.6 Auxiliary (electrical) Fuel Pumps

The two auxiliary fuel pumps were removed from the aircraft and tested by connecting them to a 12V[30] power supply. The fuel pumps were tested '*as fitted*', in a vertical orientation as they would be installed on the aircraft. The pumps were then separated from the motors and the motors were tested in isolation. The results of the tests are shown in **Table No. 7**.

The Investigation noted that when the fuel pumps were disassembled, the motor side of the shaft ran freely on both pumps but that the pump side of the shaft was stiff for both pumps.

	Electrical Fuel Pump	Observations
Pre-disassembly	Left	Fuel pump failed to run
	Right	Fuel pump ran
Disassembled - Motor only	Left	Motor ran but was noisy and rough
	Right	Motor ran smoothly

Table No. 7: Electric fuel pump tests

[30] The power supply in the aircraft was 24V. However, the intention of this test was simply to test if the motors ran freely.

The Type Certificate Holder informed the Investigation that the electrical fuel pump approved for use on the P68 aircraft for aircraft serial numbers 1, up to and including serial number 44 is a Weldon B-8100-D. The electrical fuel pumps installed on the accident aircraft (serial number 14) were Weldon C-8100-F which are approved for use on aircraft serial numbers 45 onwards. The Operator advised the Investigation that the configuration of the aircraft had not changed since they had purchased it on 27 November 2019. The Operator provided documentation to the Investigation which showed the configuration of the aircraft in 2017. Both electrical fuel pumps, C-8100-F, were fitted to the aircraft at that time.

Section 1.17.4.3 contains further information on the regulations relating to approval of aircraft parts.

1.16.2.7 Fuel Vents

The Investigation carried out a borescope inspection of the accessible portions of the aircraft fuel vent pipes for blockages. Both vent pipes were clear of obstructions. However, it was observed that one of four vent holes at the entry end of the left fuel vent pipe was blocked with sealant.

To ascertain if there were any obstructions in the inaccessible portion of the fuel vent pipes that were inaccessible by borescope, the Investigation introduced a gentle airflow to one end of the fuel vent pipe and observed whether there was a corresponding airflow at the opposite end of the pipe. A corresponding airflow was detected in both the left and right fuel vent pipes.

1.16.3 Throttle Lever Rigging

Due to the level of damage to the aircraft, it was not possible to check the rigging of the throttle levers after the accident. It was therefore not possible to verify if the differences between the fuel flow and lower manifold pressure, identified by the Pilot during the flight (and photographed by the Task Specialist) were due to a rigging problem or some other cause.

1.16.4 Vapour Lock

Vapour lock is a term used to describe an interruption to the flow of fuel between a fuel tank and an engine caused by bubbles of fuel vapour forming in the liquid fuel and is often associated with areas of the fuel system that are subject to localised heating.

The '*Aviation Maintenance Technician Handbook – Powerplant, Volume 1*' (FAAH-8083-32A, 2018), as published by the Federal Aviation Administration (FAA) of the United States (US), states that the three general causes of vapour lock are: lowering of the pressure on the fuel (which reduces its boiling point), high fuel temperatures, and excessive fuel turbulence (caused by movement of the fuel in the tanks, the mechanical action of the engine-driven pump, and sharp bends or rises in fuel lines). The Handbook also states that the incorporation of booster [electric] pumps in a fuel system reduces its tendency to vapour lock by keeping the fuel in the lines to the engine-driven pump under pressure.

In fuel injected engines vapour lock is most likely to occur in the fuel lines that are routed across the top of the engine. Vapour lock is also more likely to occur after the engine is shut down. This is because after shut down, residual heat in the engine rises towards the fuel lines, and in the absence of cooling airflow through the engine bay, the fuel lines and their contents can be heated. Similarly, high ambient air temperatures can be a factor in vapour lock formation.

1.16.5 Icing

Induction system icing is a phenomenon that has the potential to affect all piston engines (both carburettor and fuel injection). There are three commonly known types of icing – carburettor icing, impact icing and fuel icing. Carburettor icing affects only engines with carburettors. Impact icing is a build-up of ice on air intakes, filters, and air valves. Impact icing only occurs in snow, sleet or sub-zero cloud and can also occur in rain at sub-zero temperatures. Fuel icing is the result of water, held in suspension in the fuel, freezing in the induction piping.

1.17 Organisational and Management Information

1.17.1 Background to the Survey Project

The survey project was undertaken following a tender process run by an Irish Government Department. The project was led by an Irish academic institution and the Operator was one of the project partners. The Investigation was provided with a copy of the original Request for Tender (RFT). The RFT required the successful operator to hold an Aerial Works Permission, that was valid for the duration of the survey operations, from the IAA, in advance of the commencement of survey operations. This Aerial Works Permission had been obtained by the Operator.

1.17.2 Regulatory Information

The aircraft operation was conducted as an EASA Commercial Part-SPO[31] (Specialised Operations) in accordance with Regulation (EU) 965/2012[32], as amended. The Operator's Competent Authority[33] was the DGAC of France. However, although the competent authority for the Operator was the DGAC of France, in accordance with ORO[34].SPO.110, '*Authorisation of high risk commercial specialised operations.'* the classification of the type of operation as high risk was determined by the IAA, who were the Competent Authority in the place where the operation was to be conducted.

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[31] **SPO:** Introduced by Commission Regulation (EU) No 965/2021, Annex VIII Specialised Operations – Part-SPO.
[32] **Regulation (EU) 965/2012** laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council.
[33] **Competent Authority:** The agency within a member state that has the responsibility for ensuring effective oversight of aviation Regulatory Compliance within the member state.
[34] **ORO:** Part-ORO defines Organisational requirements for Air Operations

IAA Aeronautical Notice O.78, Issue 3, *'Notice to Air Operators Intending to Conduct High Risk Commercial Specialised Activities Including Cross-Border Operations in Ireland'* states that:

> *'When an Operator based in another EU Member State, proposes to conduct HR-SPO* [High Risk – Specialised Operations] *in Ireland, the Operator shall submit an application to their applicable competent authority for a High Risk Authorisation to conduct cross-border activities in another member state. In these cases, the High Risk Authorisation is issued by the Operator's competent authority in co-ordination with the IAA as required by ARO[35].OPS.150(f).'*

The Aeronautical Notice also includes a list of activities deemed to be high risk:

> *'Commercial specialised aircraft operations requiring a HR* [High Risk] *authorisation may include (but are not limited to) the following aircraft operations, when conducted over-congested areas of cities, towns, or settlements or over an open-assembly of persons or when operating below minimum heights where the Operator has no operational control of third parties on the ground within the area of operation:*
> […]
> - *Aeroplane survey operations including mapping*
>
> […]'

1.17.3 Aircraft Crew

At the time of the accident, one Pilot and three Task Specialists were on board the aircraft.

As outlined earlier, Annex I of Commission Regulation (EU) 965/2012 gives the following definition of a Task Specialist:

> *''task specialist' means a person assigned by the operator or a third party, or acting as an undertaking, who performs tasks on the ground directly associated with a specialised task or performs specialised tasks on board or from the aircraft.'*

The EASA website FAQ section[36] gives the following further explanation:

> *'Specialised operations (SPO) are not commercial air transport (CAT) operation; hence, passengers cannot be transported during a SPO mission flight. However, Task Specialists may be carried during such a flight.'*

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35 **ARO:** Part-ARO defines Authority requirements for Air Operations.
36 https://www.easa.europa.eu/faq/22595 (accessed 13 February 2025)

1.17.4 Aircraft Maintenance

1.17.4.1 Maintenance Organisation

The Airworthiness Review Certificate for the aircraft and associated maintenance documents indicate that the aircraft was on a maintenance programme operated in accordance with EU Part-ML (Maintenance – Light aircraft)[37]. The Operator informed the Investigation that at the time of the accident the aircraft was maintained by an approved maintenance organisation, which was a Combined Airworthiness Organisation (CAO).

Part-ML was introduced by EASA in 2020 and is applicable to operators of certain types of light aircraft. Part-ML establishes the measures to be taken to ensure that an aircraft is airworthy. It also specifies the conditions to be met by the persons or organisations involved in the activities related to the airworthiness of an aircraft. Prior to the introduction of Part-ML, Part-M (Maintenance) would have been applicable to these operators. Unlike Part-M, Part-ML includes alleviations in the aircraft maintenance programme which do not have to be approved by national competent authorities, alleviations in Airworthiness Reviews and defect deferral by pilots.

Part-ML.A.201 '*Responsibilities*' states:

> *'(a) The owner of the aircraft shall be responsible for the continuing airworthiness of the aircraft and shall ensure that no flight takes place unless all of the following requirements are met:*
> *(1) the aircraft is maintained in an airworthy condition;*
> *(2) any operational and emergency equipment fitted is correctly installed and serviceable or clearly identified as unserviceable;*
> *(3) the airworthiness certificate is valid;*
> *(4) the maintenance of the aircraft is performed in accordance with the aircraft Maintenance Program ('AMP') specified in point ML.A.302'*

Part-CAO specifies organisational requirements for organisations tasked with the maintenance of certain types of light aircraft. Part-CAO provides for a new simplified organisation, which can deal with maintenance, or continuing airworthiness management or both. It contains several alleviations to the general requirements of Regulation (EU) 1178/2011 such as simpler requirements for amendments, maintenance at unapproved locations and no man-hour requirements.

1.17.4.2 Monitoring of New Regulations

Part-ML and Part-CAO were relatively new regulations at the time of this accident. EASA informed the Investigation that the performance of new regulations is monitored using several mechanisms including the EASA standardisation process, feedback from EASA advisory bodies (Production and Continuing Airworthiness Technical Body, Maintenance Industry Group, Flight Standards Coordination for General/Non-Commercial Aviation, and the

[37] **Part-ML:** In the case of the subject aircraft Part-ML is applicable because the aircraft had a mean take-off mass of less than 2,730 kg and the operator was not required to hold a valid operating licence.

General Aviation Community Steering Group), as part of the European Safety Risk Management process, and at an individual aircraft type level through the Continued Airworthiness of Type Design process. This entails an analysis of operational feedback and occurrence reports to assess among other aspects the continued validity of applicable airworthiness limitations.

EASA stated that this monitoring focuses on the achievement of the main regulatory objectives, which in the case of Part-ML were to increase efficiency and proportionality in continuing airworthiness management for these type of General Aviation activities, without lowering the level of safety. EASA also said that since the regulations became applicable, there has been no indication that its introduction may have lowered the level of safety for the type of operations and aircraft concerned.

1.17.4.3 Installation of Aircraft Components

When an aircraft manufacturer develops a new aircraft design, the design must be certified by the relevant aviation regulatory authority before it can enter operation. When the authority is satisfied that the aircraft design meets the relevant requirements it is issued with a Type Certificate.

Once an individual aircraft enters operation, it must have a valid Certificate of Airworthiness in accordance with Regulation (EU) 2018/1139 which replaced Regulation (EC) No 216/2008. Article 5(2)(c) of Regulation (EU) 2018/1139 requires that an operational aircraft must conform '*with the type design approved in its type certificate*' in order to be issued with a Certificate of Airworthiness. The regulation also specifies that, '*The type-certificate shall cover the product, including all parts and appliances fitted thereon'.*

The Certificate of Airworthiness shall remain valid as long as the aircraft and its engines, propellers, parts, and non-installed equipment are maintained in accordance with the implementing acts related to continuing airworthiness and are maintained in a condition for safe and environmentally compatible operation.

The aircraft must then be maintained in accordance with the design configuration specified in the aircraft's Type Certificate. Regulation (EU) 1321/2014 on the continuing airworthiness of aircraft and aeronautical products, parts, and appliances states:

> *'ML.A.501 (b) Prior to the installation of a component on an aircraft, the person or approved maintenance organisation shall ensure that the particular component is eligible to be fitted if different modifications or airworthiness directive configurations are applicable.'*

In addition to the provisions of ML.A.501 (b), there are some components that may be exchanged for other equivalent standard parts subject to certain criteria being met. These criteria are documented in the '*Certification Specifications for Standard Changes and Standard Repairs*'(CS-STAN). CS-STAN includes provisions for the exchange of some powerplant instruments including tachometers in piston-engine aeroplanes with MTOMs[38] of less than 2,730 kg (The MTOM of the subject aircraft was 1,860 kg).

[38] **MTOM:** Maximum take-off mass

CS-STAN specifies, *inter-alia*, the following conditions:

> *— The instrument is authorised according to the applicable ETSO*[39] *or the equivalent.*
> *[…]*
> *— The indicators have the markings (e.g. limits, operating ranges) that were required on the original instrument.*
> *— The selection/calibration of the instrument must be such that, under the same conditions, the indications provided by the old and the new instrument are the same.*
> *— The instructions and tests defined by the instrument manufacturer have to be followed.*
> […]
> *5. Manuals*
> *Amend the AFM with an AFMS that contains or references the operating instructions for the instrument, as required.*
> *Amend the ICAs* [Instructions for Continuing Airworthiness] *to establish maintenance actions/inspections and intervals, as required.*

The Investigation asked EASA if the installation of unapproved parts would affect the Certificate of Airworthiness of an aircraft. EASA responded that if an unapproved part is installed on a certified aircraft, then that aircraft no longer conforms to the approved type design, and the Certificate of Airworthiness is invalid.

The Investigation also asked EASA how they would expect an organisation with responsibility for airworthiness reviews to carry out a survey of an aircraft to ensure complete compliance with the aircraft's Certificate of Airworthiness. EASA advised that the airworthiness review should consist of a documented review and a physical survey. Organisations approved to carry out airworthiness reviews should have a procedure which defines the sampling and level of detail that should be followed during the review. However, airworthiness review staff can exceed the level of detail required by a procedure if they deem it necessary. EASA also noted that there is currently an on-going rulemaking task (RMT.0521), which among other subjects, intends to provide guidance on how to use samples and how to perform an airworthiness review.

1.17.4.4 Aircraft Repairs away from Base

Regulation (EU) 1321/2014 (as amended) '*on continuing airworthiness'*, Annex V(d) (Part-CAO) A.040(b) states:

> […] *in unforeseen circumstances where an aircraft is grounded at a location other than the main base where no appropriate certifying staff are available, the CAO contracted to provide maintenance support may issue a one-off certification authorisation, alternatively:*
>
> […]

[39] **ETSO:** European Technical Standard Order

(2) to any person with no less than 3 years of maintenance experience and holding a valid ICAO aircraft maintenance licence rated for the aircraft type requiring certification, provided that there is no organisation approved in accordance with this Annex at that location and that the contracted CAO obtains and holds on file evidence of the experience and licence of that person.

The issuance of a one-off certification authorisation shall be reported by the CAO to the competent authority within 7 days of the issuance. The CAO issuing the one-off certification authorisation shall ensure that any such maintenance that could affect flight safety is rechecked.

The Investigation notes that in the case of the repair to the fuel hose following the flight from Rennes on 18 September 2021, the repair was completed by a local licensed engineer and the Certificate of Release to Service was completed by the contracted maintenance organisation based in France, rather than an authorisation to certify issued to the local licensed engineer.

1.17.5 Change of Ownership

The ownership of the Operator changed during the Investigation. The Operator notified the Investigation of this change and provided updated contact details for all matters relating to the Investigation.

1.18 Additional Information

1.18.1 Other Occurrences

The Operator informed the Investigation that it believed that the Accident was caused by an interruption to the fuel supply due to the pitch attitude and manoeuvres carried out by the aircraft just prior to the accident, combined with the fact that the fuel tanks were less than one quarter full. The Operator also informed the Investigation that it had consulted pilots with significant experience of the P68 aircraft and carried out a test to attempt to re-create the phenomenon. A representative from the French BEA carried out a telephone interview on behalf of the Investigation with the P68 pilot who had carried out these tests. Separately, the Investigation met with the Operator and a second experienced P68 pilot.

Regarding the Operator's testing, the Operator contacted an experienced P68 pilot who had carried out a significant amount of aerial survey work. This pilot owned a P68 aircraft which was manufactured in 1972 and had the same fuel tank configuration as the accident aircraft. The pilot described how he carried out a test flight on behalf of the Operator. He explained that he had departed for the test flight with one tank at one quarter full and the other tank at a little over one quarter full. He used the fuel selector system to reduce the level of fuel in one tank more quickly. He began to observe engine problems which he believed were due to fuel unporting when the fuel level in one tank reached one eighth full (~25 litres) and especially when skidding[40]. The pilot observed that to unport the fuel using pitch only, a significant pitch attitude was required. The pilot also tried to recreate the phenomenon in normal (coordinated) flight but was not able to do this. The pilot carried out approximately ten tests.

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[40] **Skid:** A condition where the tail of the airplane follows a path outside the path of the nose during a turn (*FAA, Airplane Flying Handbook*).

This pilot described a number of factors which he believed may have relevance to the subject accident. He stated that in this aircraft type because the stall speed is greater than the minimum control speed of the aircraft, it is possible to fly extremely pronounced skids without losing control of the aircraft. He explained that in survey work, pilots are often trying to cover a large area without gaps between the lines. In his experience, when moving from one survey line to the next, pilots sometimes try to execute a tighter turn by turning away from the survey line for 10-15 seconds, in a *teardrop* manoeuvre and turning banked at 30-35° with their full rudder on the side of the turn. This type of skidding turn can save time and allow a more accurate transition to the new survey line, but it can also adversely affect fuel supply to an engine, particularly with fuel contents between a quarter and a half tank, or less. The pilot also noted that this fuel supply issue might not always be correctly identified by a pilot as there would be a time lag between an uncoordinated manoeuvre and the onset of associated engine problems. This is because a volume of fuel would be held in the tank's fuel manifold (sump, in the bottom of the fuel tank) and associated pipe work and this would continue to supply the engine for a short time. The pilot estimated this to be about 30 seconds.

The pilot was also aware of other occasions where this phenomenon may have occurred, and he described an occurrence that had been experienced by a flight instructor during an instructional flight. The student was flying a circuit, and the instructor simulated an engine failure at the beginning of the downwind leg. The remaining engine shut down unexpectedly at the end of the downwind leg. It was surmised that this was because the aircraft was skidding, and the fuel level was low. In that case, the aircraft was a more recent P68 Observer which has a different fuel sump design to the subject aircraft.

The second P68 pilot, who attended the Investigation meeting, described an occurrence where, during final approach to Le Touquet airport, France and with fuel tanks one quarter full, a go-around was performed. The aircraft was travelling at 90 kt in a steep left hand turn whilst climbing with left rudder applied. During the turn and climb the pilot experienced engine issues but found that the engine recovered when he levelled the wings and stopped the climb/turn manoeuvre.

1.18.2 Safety Action

1.18.2.1 Safety Actions Taken By the aircraft Type Certificate Holder

The Investigation informed the Type Certificate Holder of the findings of the Operator (**Section 1.18.1**). The Type Certificate Holder initiated their own investigation (some of which is described in **Section No. 1.16.2.4**) and whilst this was on-going, issued *Service Letter No. 69* advising Operators that:

'until further notice recommends to assume ¼ fuel in each tank as unusable fuel quantity.'

The Type Certificate Holder also informed the Investigation that they intend to update the applicable AFM with additional information in relation to uncoordinated flight at less than **50 litres of fuel in each tank** (~**¼ full**) and checking the crossfeed system prior to take-off. The Type Certificate Holder informed the Investigation that further work to fully understand this issue is on-going.

1.18.2.2 Safety Actions Taken by the Operator

As a result of the occurrences and informal testing carried out (**Section 1.18.1**), the Operator amended their Standard Operating Procedures ('*MANEX Edition 1 Rev 8 Section A08*') to require pilots to have a total fuel quantity of not less than 100 L (i.e. each tank approximately one quarter full) at all times for high-risk flight. This amendment was accepted by the DGAC (*DGAC reference no. 837016*).

On 2 October 2023, the Operator also issued Safety Information Aircraft Operating Instruction N°11 which implemented the Type Certificate Holder's *Service Letter No. 69 regarding recommended minimum fuel levels* (**Section 1.18.2.1**).

1.19 Useful Investigative Techniques

Not applicable

2. ANALYSIS

2.1 Accident Sequence

On the day of the accident, the Pilot and Task Specialists had planned to complete 16 pre-defined survey lines. The survey lines were completed after approximately four hours and 30 minutes of flying. The Pilot then carried out an assessment of the fuel levels and advised the Task Specialists that it would be possible to complete two further survey lines whilst allowing enough fuel to return to EIWF with fuel reserves intact.

During the final additional survey line, the right engine stopped suddenly. Recorded data shows that the aircraft then climbed to approximately 500 ft. However, the Pilot found that the aircraft struggled to climb whilst operating on the left engine only. A short time later the left engine began to lose power. It lost power and recovered several times, but each time it lost power again. The Pilot then routed directly towards land and elected to perform a forced landing on the beach. During the forced landing the nose of the aircraft impacted with the loose shale surface and decelerated rapidly, causing substantial structural damage to the forward cabin area. The Pilot and one of the Task Specialists sustained serious injuries. The Pilot reported that the left engine ran briefly at full power when the aircraft was on the beach before the Pilot pulled back the fuel mixture lever, shutting down the engine.

2.2 Engine Failures

2.2.1 Right Engine

Post-accident testing of the right engine showed that it started, ran, and did not reveal any anomalies that would have caused the engine failure. Furthermore, the Investigation did not identify any aircraft mechanical failure, or combination of mechanical failures that were likely to have caused the right engine symptoms experienced during the accident flight. However, when tested, the power output of the right engine was lower than that of a newly overhauled engine. A compression test identified low compression on the engine's Cylinder No. 3. The engine was subsequently dismantled, and the Investigation deemed that the most likely cause of the low compression was cylinder blow-by.

However, this low compression in Cylinder No. 3 would not explain the right engine stoppage experienced during the accident flight. As no apparent mechanical failures were identified, the Investigation considered if icing or vapour lock could have caused the symptoms. The types of icing that can occur on a fuel injected engine are impact ice and fuel ice. Both these forms of icing require temperatures of 0 ^{o}C, and as the ambient temperature was 19 ^{o}C (according to the meteorological aftercast), icing was unlikely to have occurred.

The '*Aviation Maintenance Technician Handbook – Powerplant, Volume 1*' (FAAH-8083-32A, 2018), as published by the Federal Aviation Administration (FAA) of the United States (US), cites three general causes of vapour lock: lowering of fuel pressure, high fuel temperature and excessive fuel turbulence. In the subject aircraft, the fuel outlet from the fuel tank was located above the mechanical fuel pump meaning that gravity would assist the flow of fuel and making it unlikely that fuel pressure was an issue. Given that the subject aircraft had operated for more than four hours in the prevailing conditions, the Investigation therefore considers vapour lock to be unlikely.

The Investigation then considered the possibility that aircraft manoeuvres prior to the engine failure could result in engine fuel supply interruption(s). The Investigation noted that the Manufacturer's AFM included the warning:

> *'Avoid rapid taxi turns before take-off or excessive nose-up attitude with ¼ fuel or less in each tank.'*

If a manoeuvre is not coordinated, there will be a net lateral force on the aircraft (a slip or a skid). It is possible for the net forces acting on the fuel during an uncoordinated manoeuvre to displace the fuel in the tank away from the fuel sump. If this happened, the fuel quantity available to the engine would be restricted to the fuel held in the pipes between the fuel sump and the engine, and the fuel held in the fuel sump itself. The Investigation estimated that this would amount to approximately one litre of fuel. The Investigation also estimated that the actual fuel consumption rate for the aircraft during the accident flight was approximately 67 l/hr[41] (approximately 33.5 L per engine per hour). Therefore, it would be possible for an engine to be starved of fuel within two minutes after a manoeuvre that directed fuel away from the fuel sump.

Examination of the recorded data by the Type Certificate Holder estimated that some of the turns carried out during the flight, including the final turn (a left turn from survey line 17 to the final survey line were uncoordinated. However, if this final turn was the cause of the right engine failure, then the symptoms of engine failure would have occurred less than two minutes after the turn. The Pilot and the Task Specialists recalled that the engine symptoms began when the aircraft was approximately half-way through the final survey line.

[41] The total capacity of the fuel tanks was 408.8 litres. The aircraft was found with 74 litres remaining having flown for approximately five hours. The fuel consumption would be reduced for the last approximately 10 minutes of the flight after the right engine was shut down.

Figures No. 6 and **8**, show altitude data recorded by the Garmin and Spidertracks devices during the final survey line. Both plots indicate that there was some variability in the altitude of the aircraft during the survey line, but the most significant change occurs at approximately 16:04 hrs when the aircraft initiates a significant climb. The aircraft speed just prior to the climb was approximately 105 kt. The Pilot also recalled that the aircraft was flying at 105 kt when the right engine symptoms started, after which he commenced a climb.

In this case, there was no recorded engine data and no voice recorder, and it is therefore not possible to be definitive about when the engine symptoms started. However, the Pilot reported that a climb was initiated after the right engine failed and the data shows that this occurred seven minutes after the turn. Therefore, the Investigation believes that the right engine symptoms were not related to the turn.

Data recorded by the Spidertracks device (**Figures No. 9** and **10**) showed that throughout the flight there was variability in the recorded parameters when the aircraft was established on a survey line. This is not unexpected as the flight was flown using manual control for many hours which would have required the Pilot to make constant flight control inputs. However, in this scenario, it may be possible for the flight to briefly become uncoordinated, which at lower fuel levels has the potential to cause temporary interruption(s) to engine fuel supply. Even a short interruption to engine fuel supply could introduce air into the fuel and cause problems with engine operation. When interviewed after the accident, the Pilot described the right engine symptoms as '*like when there is air in the fuel*'.

In addition to the potential for air to disrupt engine fuel supply, testimonies provided to the Investigation by other pilots experienced in operating this aircraft type indicated that when flying in an uncoordinated manner with less than one quarter tank of fuel, it is possible to induce fuel supply interruptions.

At the time of the right engine failure, the aircraft had been flying for approximately five hours. Examination of the aircraft journey log indicated that a flight of this length had only been carried out on one previous occasion since it was purchased by the Operator. However, on the previous longest flight, the last phase of the flight was the transit back to the airport, i.e. at higher speed and altitude, and in a relatively stable, lower pitch attitude. The aircraft technical log indicates that all the flights undertaken since the Operator purchased the aircraft were also carried out with fuel tanks that were initially full or nearly full. It is therefore possible that the accident flight was the first time the Operator had experience of this aircraft being flown at less than one quarter tank of fuel and at relatively low speed, and low altitude.

2.2.2 Left Engine

The Pilot reported that when the aircraft was operating on the left engine only, the engine did not seem to be producing full power and the aircraft struggled to climb. Disassembly and inspection of the engine following the accident revealed wear on several of the engine's camshaft lobes and tappets which would have caused a reduction in the power produced by the engine.

The Pilot informed the Investigation that he tried to hold the aircraft at a low bank angle to ensure the fuel was in the best position to feed the engine. However, the Pilot would have had to manage the asymmetric force on the aircraft caused by the failed right engine, whilst climbing and therefore it is probable the aircraft was in uncoordinated flight at this time. Uncoordinated flight at a time when there was less than one quarter tank of fuel remaining may have the potential to result in fuel supply interruptions to the engine.

The Pilot stated that he was aware of previous occurrences involving the crossfeed system of this aircraft type. The Pilot observed that the aircraft was unable to climb while maintaining the blue line speed. He said that he switched on the auxiliary fuel pump for the left engine and then moved the fuel selector knobs so that fuel was being fed from the right tank to the left engine. The Investigation notes that this action, which is prescribed in the AFM, would turn off the fuel from the left tank to the left engine. Also, the Investigation found damage to the fitting on the crossfeed line, which would have adversely affected any supply from the right tank or could have allowed air into the fuel system. The Pilot informed the Investigation that he moved the fuel selector knobs to ensure their correct location in the detents. After waiting a little time, he moved the fuel selectors back to their original positions.

Witness testimonies from the Pilot and Task Specialists provide supporting evidence for a fuel supply interruption. The witnesses describe the left engine losing power at the same time as the aircraft climbed, before briefly recovering as it descended, then losing power as it climbed again. This testimony is consistent with the recorded altitude data, which shows climbing (implying engine power available) followed by descending (loss of engine power).

The Pilot reported that after the aircraft came to rest on the beach, the left engine spontaneously ran to full power. It is not possible to determine exactly why this occurred. However, although, the engine had lost power before landing, the Pilot did not secure the engine. Electrical power and fuel were being supplied to the engine, and the throttle was forward, making the engine '*live*' i.e. capable of running. Recordings that were taken slightly later by the Irish Coastguard when they arrived on scene, show the propeller moving slowly. The possibility exists that such a propeller movement on a hot, live engine could have caused the engine to re-start. The sudden change in aircraft attitude on landing could have resulted in an improved fuel supply causing the engine to run to full power as reported by the Pilot.

2.2.3 Type Certificate Holder Guidance

The caution given in the Type Certificate Holder's AFM limitations section when operating with less than one quarter tanks of fuel does not define what is meant by '*excessive nose-up attitude*', and the Investigation is of opinion that this caution should be expanded to give pilots additional information when making in-flight decisions. Subsequent to the accident, the Investigation was also made aware of other occurrences (some of which were deliberate tests) where fuel supply to the engines on the subject engine type was interrupted at a fuel level greater than the certified unusable fuel (**Section 1.18.1**). The Investigation communicated this information to the aircraft Type Certificate Holder which initiated its own investigations (**Section 1.18.2.1**). These investigations are on-going, but in the interim, the Type Certificate Holder has issued *Service Letter No. 69* which advised Operators that:

> *'until further notice recommends to assume ¼ fuel in each tank as unusable fuel quantity'.*

The Type Certificate Holder also informed the Investigation that it intends to update the applicable AFM with additional information in relation to uncoordinated flight at less than ¼ tank of fuel and checking the crossfeed system prior to take-off. The Investigation considers that it is critical that the Type Certificate holder develops a full understanding of this issue and the limitations of the aircraft design at less than ¼ tank of fuel. Therefore, the Investigation makes the following Safety Recommendation:

Safety Recommendation No. 1

Vulcanair, as the Type Certificate Holder, should define the flight scenarios that may lead to inadvertent interruptions to the fuel supply, promulgate this information, and ensure that any cautions or relevant checklists in flight documentation give clear guidance to pilots.

(**IRLD2025001**).

2.2.4 Fuel Selector Valve

The inaccessible portion of the right fuel selector was incorrectly marked, and no evidence was provided to the Investigation to indicate that this issue had been identified or reported. There was some play identified in the fuel selectors, but when checked, the rigging of the fuel selectors appeared to be correct. The Investigation observed that the layout of the fuel selector system would not facilitate intuitive use, and mistakes could easily be made, particularly during times of high workload. In this case, the Pilot had been manually flying the aircraft at low height above the sea for almost five hours. During interviews after the accident, the Pilot informed the Investigation that he was aware of previous investigation reports relating to the fuel selectors of this aircraft type. The Pilot described the sequence of movements that he made to the fuel selectors to crossfeed fuel to the left engine, and these descriptions correlated with procedures described in the AFM. However, as outlined earlier, attempting to crossfeed from the right tank, cuts-off the fuel supply from the left tank to the left engine. In a high workload environment such as a loss of engine power scenario at low altitude, it is also possible that a fuel selector knob could be moved to an incorrect position due to distractions caused by the high workload. The Investigation notes that more recent versions of this aircraft type have a different fuel selector panel.

2.2.5 Fuel Remaining in Aircraft Tanks

Following the accident, the Investigation drained both fuel tanks and found 42 litres of fuel remaining in the right tank and 32 litres remaining in the left tank. This was enough fuel to return to Waterford Airport which the Pilot estimated was 20 minutes away. The discrepancy between the fuel levels in the two tanks was likely because the right engine had stopped several minutes before the accident, whereas the left engine continued to run, albeit with power losses, and was briefly operated at a higher power setting in order to climb following the right engine stoppage. This would have contributed to the 10 litres discrepancy observed between the tanks.

The quality of the fuel that remained in the tanks was found to meet industry standards.

2.2.6 Fuel Level Transmitter Anomalies

The testimony given by the Pilot and Task Specialists after the accident indicates that during the flight, and particularly around the time the engine problems began, the fuel gauges may have been giving erroneous indications. One Task specialist recalled that during the flight the Pilot commented that they were '*doing great'* with regards to fuel consumption. Prior to starting the final two survey lines, the Pilot believed that there was one hour and forty-five minutes of fuel left (just over one quarter of a tank on each side), however 20 minutes later (when the right engine symptoms started) the Pilot recalled that the fuel level was between one quarter and half a tank. The Pilot then described how within a few minutes of the right engine stoppage, the indicated fuel level on the right tank dropped to zero. The indications on the left tank were reported to be between one quarter and half a tank at the time the left engine symptoms started but reducing slowly.

When inspecting the fuel level transmitters after the accident, the Investigation found several anomalies (**Section 1.16.2.5**) and therefore believes it is possible that the fuel level transmitters were intermittently misreading during the flight. This means that when the Pilot made the decision to continue with the extra two survey lines, the indicated fuel levels may have been incorrect. The fuel consumption rate used by the Pilot of 62 l/hr was also slightly lower than the actual fuel consumption rate (67 l/hr). If a fuel consumption rate of 62 l/hr was applied to the time flown since refuelling, the calculated fuel remaining would be 99 litres, whereas the actual fuel remaining was 74 litres.

The Investigation also noted that the graduated scale of the fuel gauge installed in the Aircraft (**Section 1.6.2.2**) was marked in ¼ tank increments. The Investigation is of the opinion that this fuel gauge would not facilitate a sufficiently accurate in-flight assessment of fuel levels to make in-flight decisions with regards to extending the flight, particularly when the flight being undertaken was classified as high risk.

2.2.7 Left Engine Performance

The Pilot reported to the Investigation that after the failure of the right engine, the aircraft struggled to climb, and he did not believe that the left engine was delivering full power. While noting that the engine had reportedly run to '*full power*' on the beach immediately after the accident, to determine the potential cause of the lower-than-expected power, the Investigation shipped the left engine to an EASA-approved engine test facility in the UK where a full disassembly, examination and rig testing of some of the critical components in accordance with the Engine Manufacturer's specifications was carried out. The examination and testing did not identify any anomaly that would have prevented the engine from running or cause an in-flight stoppage. However, the probable cause of the reduced power was determined to be wear of several of the camshaft lobes and corresponding tappet mating surfaces. The in-service effect of this wear would be that the corresponding inlet and exhaust valves would not open fully, and the power produced by the engine would be lower than expected.

The Pilot and Task Specialists also described repeated significant reductions in the power of the left engine after the right engine stopped. Each time this occurred, the engine power recovered when the aircraft descended and ran normally for a short time before the power reduced again when a climb was attempted. When interviewed after the accident, the Pilot could not recall exactly the actions taken to recover the engine but believed it may have been a combination of windmilling the propeller and using the starter.

Analysis of the recorded data for the period immediately after the failure of the right engine indicates that the average climb rate was 244 ft/min. This is lower than the minimum gross single engine performance of 325 ft/min quoted in the AFM. However, the aircraft was able to climb, and flew for approximately 11 NM after the right engine shut down; indicating that the left engine was running and providing some power until the end of the flight.

2.3 Survivability

During the accident sequence, the Pilot was able to maintain control of the aircraft until the point of impact, executing a forced landing rather than an uncontrolled impact with terrain. Unfortunately, the shale surface of the beach meant that the main wheels of the aircraft sank on touchdown causing the nose to impact the shale resulting in significant damage to the front of the aircraft. The impact forces were survivable, but the damage caused to the front of the aircraft during the impact sequence reduced the liveable space in the front row of the cabin and resulted in serious injuries to the occupants of the front seats.

By contrast, the occupants in the middle row of seats sustained less serious injuries. However, both seatbelt attachment brackets in the middle row separated from the aircraft which likely contributed to the injuries sustained by the occupants of these seats. During inspections of the aircraft, the Investigation found that the attachment brackets of the seatbelts for the front and middle row of seats were attached to aircraft floor panels rather than aircraft structure underneath the floor as advised by the Type Certificate Holder. Had the seatbelts been more securely anchored, it is likely that they would have been able to withstand much greater loads and may have reduced the level of injury experienced by the occupants. Due to the limited detail shown on the original aircraft Manufacturer's drawings it was not possible to ascertain exactly how the original aircraft Manufacturer intended the seatbelts to be anchored.

Accordingly, the Investigation makes the following Safety Recommendation:

Safety Recommendation No. 2

Vulcanair, as the current Type Certificate Holder, should initiate a review of other P68 aircraft in use to ensure that seatbelt attachment points are suitably robust.

(**IRLD2025002**).

The Task Specialists on board the aircraft informed the Investigation that the Pilot carried out regular safety briefings and drills. For each flight, the Pilot also ensured that each Task Specialist understood the duties assigned to them in the event of an emergency. These duties included responsibility for opening doors, carrying the life raft etc. In addition, the Task Specialist's employer mandated that all Task Specialists must wear immersion suits and life jackets for all survey fights, and prior to the survey project, each Task Specialist completed bespoke training in underwater aircraft evacuation. In summary, the Task Specialists were appropriately trained and equipped, and appropriately briefed by the Pilot for the flights that they were due to undertake.

2.4 Aircraft Certification

When aircraft are certified, flight tests are carried out to determine how a fuel system behaves during a range of aircraft manoeuvres. This ensures that an aircraft can carry out the full range of normal operations without any interruptions to the fuel supply. One of the outcomes of such flight tests is the determination of an unusable fuel level for the aircraft type. The original certification tests for the subject aircraft type were carried out in 1971. The certification requirements relating to unusable fuel that were extant at that time specified the following:

> *'For test purposes the quantity of fuel to be used to show compliance with this section must be chosen by the applicant. In addition when establishing the unusable fuel supply, the following flight conditions must be arranged in order, from the most to the least critical:*
>
> *(5) Level flight at maximum continuous power, or at the power required for level flight at V_c, whichever is lower.*
>
> *(6) Climb at maximum continuous power at the calculated best angle of climb at minimum weight.*
>
> *(7) Rapid application of power and subsequent transition to best rate of climb from a power-off glide at 1.3 V_{s0}.*
>
> *(8) Slips and skids in level flight climb, and glide, under the applicable conditions specified in sub paragraphs (1), (2) and (3) of this paragraph, of the greatest severity likely to be encountered in normal service or turbulent air.'*

The certification requirements did not include any further guidance as to how the slips or skids should be performed, and flight test reports written by the Manufacturer at the time of certification do not include details as to how the slips and skids were performed. It is notable that the current Acceptable Means of Compliance relating to EASA Certification Standard CS23.959 gives the following additional direction:

> *'Level flight at maximum recommended cruise –*
>
> *1. Maintain straight co-ordinated flight or bank angles not exceeding 5°, until a malfunction occurs.*
>
> *2. Simulate turbulent air with ± half-ball width oscillations at approximately the natural yawing frequency of the aeroplane, until a malfunction occurs.*
>
> *3. Skidding turns with 1-ball skid. Hold for 30 seconds and then return to co-ordinated flight for 1 minute. '*

Notwithstanding the fact that the Pilot reported that a climb was initiated after the right engine failed, and the data shows that this occurred seven minutes after the turn, it is possible that the final turn was uncoordinated for approximately 45 seconds which is longer than the uncoordinated turns required by current certification standards. Therefore, it is possible that the aircraft was inadvertently flown in a manner that had not been tested during the original certification programme and was not specifically prohibited by the Aircraft Flight Manual.

2.5 Regulatory Environment

From a regulatory perspective, the Operation was categorised as a commercial Part-SPO. As the Operator was based in France, the Competent Authority tasked with approving the Operator's Survey Operations was the DGAC of France. However, as the location of the survey operations was Ireland, the IAA was responsible for determining the classification of the operation. In accordance with IAA Aeronautical Notice O.78, *'Notice to aircraft operators intending to conduct high risk commercial specialised activities including cross-border operations in Ireland'*, the IAA determined the operation to be high risk.

Part-SPO Operators are not permitted to carry passengers but can carry Task Specialists. The definition of a Task Specialist given in Annex I of Regulation (EU) 965/2012 is *'a person assigned by the operator or a third party, or acting as an undertaking, who performs tasks on the ground directly associated with a specialised task or performs specialised tasks on board or from the aircraft.'* In many cases, Task Specialists are not aviation professionals. They are often specialists in other fields, or simply members of the public who are on board an aircraft to take part in a particular activity (e.g. skydiving). Therefore, Task Specialists, like most other members of the flying public, are reliant on the aviation regulation system to ensure the safety of their flight.

In this case, the required regulatory processes were followed, and the required approvals were in place. However, the Investigation notes that some aspects of Part-SPO regulation are less stringent than the equivalent commercial air transport regulation. A consequence of this is that an operator carrying out commercial passenger flights in small twin-engine aircraft is subject to more stringent regulation than a commercial survey operator in a similarly sized aircraft, even though both operators may carry similar numbers of personnel.

For example, Part-SPO allows an Operator to maintain an aircraft under Part-ML and Part-CAO which is a less stringent maintenance and airworthiness regime than that which would be applied if the operation was classed as commercial air transport.

The Investigation recognises that Part-ML and Part-CAO maintenance arrangements allow greater flexibility and are less onerous for small operators, but this flexibility has the potential to increase the safety risks. Information provided to the Investigation by EASA (**Section 1.17.4.2**) described the mechanisms that are in place to monitor the effectiveness of such new regulations. EASA also informed the Investigation that to date, there has been no indication that the introduction of the regulations may have lowered the level of safety for the type of operations and aircraft concerned. Therefore, considering EASA's ongoing monitoring of the effects of these regulations, the Investigation does not make a Safety Recommendation in this regard.

2.6 Aircraft Configuration

During inspections of the aircraft, the Investigation observed some anomalies regarding configuration. This included installation of a tachometer that was not approved for the aircraft and had incorrect limits marked on it, installation of auxiliary fuel pumps that were not an approved part number and incorrect markings on the fuel selection panel. The Certificate of Airworthiness for the aircraft was issued pursuant to Regulation (EC) No 216/2008, Article 5(2)(c) which requires that an aircraft must conform '*with the type design approved in its type certificate*' to be issued with a Certificate of Airworthiness. The regulation also specifies that, '*The type-certificate shall cover the product, including all parts and appliances fitted thereon'*. This means that the Certificate of Airworthiness is only valid if all the aircraft parts that are installed on the aircraft were included in the original type certificate of the aircraft or have a supplemental type certificate approving their installation. This was confirmed by EASA.

In this case, the unapproved parts were not causal to the accident. However, the installation of any unapproved part is a potential safety issue because the part has not been certified for that aircraft. For example, the incorrect tachometer installation misled the Pilot who flew the aircraft at a power setting which was in the green band of the installed tachometer but would have been in a band marked '*AVOID CONTINUOUS OPERATION*' on the tachometer that was approved for installation in the aircraft.

An aircraft is a large and complex system. The Investigation recognises the difficulty in ensuring that every component on an aircraft is approved, particularly when an Operator purchases an older aircraft which may have been subject to configuration changes and modifications. The Investigation also notes EASA's current work under Rulemaking Task 0521 to provide guidance on how to use samples and how to perform an airworthiness review. However, the anomalies that were found on the subject aircraft, indicate that the Operator's continuing airworthiness and maintenance arrangements could be strengthened. Accordingly, the Investigation makes the following Safety Recommendation to the Operator:

Safety Recommendation No. 3

Action Communication/Action Air Environnement (affiliated to Sabena Technics Group since 5 July 2024), should review its Maintenance and Continuing Airworthiness arrangements, procedures, resources, and expertise to ensure that the aircraft it operates are configured and maintained in accordance with their respective Type and Airworthiness Certificates.
(**IRLD2025003**).

2.7 Human Factors

The type of survey work that was being undertaken at the time of this accident required an aircraft to be flown for long periods and at low altitude. This introduces risks and increases pilot workload, compared to higher altitude flights, particularly if an aircraft is flown manually by a single pilot. At low altitude, a pilot has significantly less time to consider options and make decisions following a malfunction. In addition, after an engine failure in a twin piston-engine aircraft, the available climb rate may at times be marginal at best.

During interview with the Investigation, the Pilot said that he did not attempt to re-start the right engine after the initial problems. The Pilot said that this was due to the low altitude at which the right engine problem occurred, and the fact that he had observed a reduction in fuel level in the right tank. He believed that the problem was a recurrence of the fuel leak that he had experienced only a few days earlier. From this experience, he was confident that he could fly the aircraft with one engine[42]. Therefore, he secured the right engine, and turned the aircraft back towards Waterford Airport. As no re-start of the engine was attempted, it is not possible to determine if the engine would have restarted at that time.

The Pilot informed the Investigation that when the left engine problems occurred, he tried to position the left wing at an angle that would ensure adequate fuel supply to the left engine. This indicates that the Pilot had a tacit understanding that a fuel supply interruption was a possibility in the circumstances. The Pilot also decided that he would fly close to the shoreline which would be better if a forced landing became necessary because he would be able to bring the aircraft over land rather than be forced to ditch in the sea. When it then became apparent that a forced landing was required, the Pilot turned the aircraft directly towards shore and executed a forced landing on the beach.

The decision that the Pilot made regarding securing the right engine demonstrated that his focus was on the continued safe flight of the aircraft. His decision to route closer to land demonstrated that he was cognisant of minimising the risks to the aircraft occupants in the event of a forced landing.

During the accident sequence, the Pilot also moved the position of the fuel selector knobs and returned them to the original position. The testimony given by the Pilot after the accident indicates that the actions taken to crossfeed fuel correctly correlated with procedures described in the AFM. However, as stated in **Section 2.1.2** the design of the fuel selector panel was not intuitive and could be susceptible to human error being made, particularly at times of high workload.

[42] The Investigation notes that this fuel leak occurred while the aircraft was at altitude, and therefore an immediate climb was not required. Furthermore, the aircraft at that time was likely operating at a lower weight and a higher fuel quantity than was the case for the accident aircraft at the time of the right-hand engine stoppage.

2.8 Summary

An in-flight loss of power from both engines of a twin-engine aircraft is a very uncommon occurrence. Aircraft design and maintenance practices attempt to minimise the risk of dual engine failure scenarios. In such occurrences, a common mode of failure must be considered. Fuel exhaustion or fuel supply interruption are the most probable causes of concurrent engine problems. In this case, the Investigation found that the aircraft had 42 litres of fuel in the right tank and 32 litres in the left tank after the accident, which was enough fuel for the aircraft to complete the planned flight. Therefore, the Investigation discounted fuel exhaustion as a cause of the accident.

While it was not possible to be definitive about the mechanism by which the right engine stopped, the Investigation is of the opinion that the most likely cause was a fuel supply interruption. As no restart was attempted, it is unknown if such an interruption to the right engine fuel supply was temporary.

When the left engine appeared to be developing lower than expected power, the Pilot manipulated the fuel selectors to crossfeed fuel from the right tank to the left engine which may have interrupted the fuel supply to the left engine, particularly given the anomalies identified with the crossfeed pipework. The aircraft descended and climbed several times following the stoppage of the right engine. It is also possible that climbing (pitch up) adversely affected the fuel supply to the left engine and once the aircraft pitched down, the supply recovered.

The Investigations acknowledges the Safety Action taken by the aircraft Operator to update their Standard Operating Procedures to provide a greater margin of safety during flight operations. The Investigation also acknowledges the Safety Action taken by the aircraft Type Certificate Holder to provide clarity on the minimum fuel levels for safe operations.

3. CONCLUSIONS

3.1 Findings

1. The Operator held appropriate approvals for the work being undertaken.

2. The Operation was subject to Part-SPO approval.

3. The aircraft was maintained under Part-ML and Part-CAO regulations.

4. The Pilot held a valid licence and medical certificate.

5. Following the failure of the right engine, a re-start was not attempted; the Pilot secured the engine and routed back to shore.

6. The aircraft climb performance was lower than expected when operating on the left engine.

7. The fuel selectors were manipulated when the aircraft did not appear to be climbing as expected following the stoppage of the right engine, which may have adversely affected the fuel supply to the left engine.

8. The Task Specialists had undertaken relevant emergency evacuation training prior to commencing survey operations.

9. The Pilot conducted a forced landing on a shale beach.

10. The Pilot and the Task Specialist seated in the front right seat sustained serious injuries.

11. The occupants of the aircraft wore immersion suits and life jackets during the flight.

12. Several items of safety equipment including a life raft and an axe were carried on board the aircraft, although their use was not required in this case.

13. The Pilot carried out regular safety briefings and drills with the Task Specialists.

14. All of the seats in the aircraft were fitted with lap belt restraints.

15. Some of the lap belt attachment points had been secured to aircraft floor panels rather than stronger aircraft structure.

16. The attachment points for the lap belts at two of the seats used by the task specialists separated from the aircraft floor panels.

17. The liveable space in the front of the cabin was significantly reduced during the accident sequence.

18. The left engine was reported to have spontaneously run to full power on the beach in the immediate aftermath of the accident.

19. The right engine operated successfully on a test bed after the accident.

20. Both fuel tanks likely had less than ¼ tank fuel at the time of the engine problems.

21. The aircraft was recovered with a total of 74 litres of fuel in the fuel tanks.

22. The aircraft was found with pre-existing damage to the fuel level transmitters which may have resulted in intermittent anomalous fuel level readings during the flight.

23. The aircraft was found with suspected pre-existing damage to an olive fitting on the fuel crossfeed pipe between the right tank and the left engine.

24. The installation of an unapproved tachometer and unapproved auxiliary fuel pumps although not considered factors in the engine problems, rendered the Certificate of Airworthiness for the aircraft invalid.

3.2 Probable Cause

Separate interruptions to the fuel supply of each engine, while operating at or below a quarter of the aircraft's fuel tank capacity, ultimately resulting in a forced landing.

3.3 Contributory Cause

1. A lack of clarity in the aircraft Flight Manual limitations section regarding operations at less than ¼ tank fuel.

2. The configuration of the fuel selector panel was potentially misleading and its operation was not intuitive.

4. SAFETY RECOMMENDATIONS

No.	It is Recommended that:	Recommendation Ref.
1.	Vulcanair, as the Type Certificate Holder, should define the flight scenarios that may lead to inadvertent interruptions to the fuel supply, promulgate this information and ensure that any cautions or relevant checklists in flight documentation give clear guidance to pilots.	IRLD2025001
2.	Vulcanair, as the current Type Certificate Holder, should initiate a review of other P68 aircraft in use to ensure that seatbelt attachment points are suitably robust.	IRLD2025002
3.	Action Communication/Action Air Environnement (affiliated to Sabena Technics Group since 5 July 2024), should review its Maintenance and Continuing Airworthiness arrangements, procedures, resources, and expertise to ensure that the aircraft it operates are configured and maintained in accordance with their respective Type and Airworthiness Certificates.	IRLD2025003
	View Safety Recommendations for Report 2025-001	

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