Serious Incident

Aircraft Type and Registration:	ATR 42-500 (600 version), G-LMSA
No & Type of Engines:	2 Pratt & Whitney Canada PW127M turboprop engines
Year of Manufacture:	2017 (Serial no: 1213)
Date & Time (UTC):	23 July 2024 at 1230 hrs
Location:	Aberdeen International Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 30
Injuries:	Crew - None Passengers - None
Nature of Damage:	Significant damage to No 1 engine turbine assemblies and fire and heat damage to No 1 engine inside cowlings
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	40 years
Commander's Flying Experience:	2,700 hours (of which 210 were on type) Last 90 days - 181 hours Last 28 days - 62 hours
Information Source:	AAIB Field Investigation

Synopsis

Whilst in the cruise, the aircraft suffered a contained failure of the No 1 engine and a subsequent fire inside its cowlings due to a leak from the fuel return line which had become sufficiently loose following the engine failure to result in fuel leakage. The flight crew correctly followed the checklist procedures to shut down the engine, and the fire was extinguished. The aircraft landed without further incident.

Although this is the only known instance of this fuel line becoming loose, the aircraft manufacturer has commenced a safety review to identify any possible safety actions which would further reduce the likelihood of leakage from the fuel return line.

History of the flight

The crew were operating their fourth sector of the day on a return flight to Glasgow Airport from Sumburgh Airport in Shetland. The aircraft took off from Runway 27 at 1129 hrs, then turned onto a southerly track, climbing to FL180 in the Y905 airway to the Aberdeen VOR. The commander was the pilot flying while the co-pilot was the pilot monitoring.

At approximately 1201 hrs, approaching RISDU, a reporting point 28 nm north-east of Aberdeen Airport, the commander described hearing a “big thump”, or a “muffled bang”. The aircraft immediately yawed to the left, which was corrected by the rudder trim under the control of the autopilot. The commander noticed an amber HBV[1] label had replaced the digital counter on the No 1 engine torque indicator and that the torque had reduced to nearly zero. At the same time, the No 1 engine Interstage Turbine Temperature[2] (ITT) was increasing rapidly. The co-pilot announced that there was an ENG 1 OVER LIMIT caution. They cancelled the Master Caution attention getter[3] and started the relevant abnormal checklist procedure displayed on the Engine and Warning Display (EWD). However, the checklist was interrupted by an ENG 1 FIRE warning. The crew completed the emergency checklist procedure for an engine fire in flight (Figure 1). Both fire bottles had to be discharged before the ENG 1 FIRE warning extinguished.

ENG 1(2) FIRE OR SEVERE MECHANICAL DAMAGE IN FLIGHT E70.02

- ► PL (affected ENG).. FI
- ► CL (affected ENG).. FTR THEN FUEL S.O.
- ► FIRE HANDLE (affected ENG)... PULL
- ■ **If fire persists after 10 s**
  - ► AGENT 1 (affected ENG)... DISCH
  - ■ **If fire persists 30 s after AGENT 1 DISCH**
    - ► AGENT 2 (affected ENG)... DISCH
- ► **LAND ASAP**
- ► ATC.. NOTIFY
- ► ENG (affected) : DO NOT RESTART
- ► SINGLE ENG OPERATION procedure (A70.12) .... APPLY

Figure 1

Engine fire or severe mechanical damage in flight checklist

Footnote

1 Handling Bleed Valve: ensures correct operation of the low-pressure turbine stage. The amber HBV label indicates that the electronic engine control cannot control the valve.

2 ITT is the gas path temperature between the high pressure and the low-pressure turbines.

3 There is a Master Warning/Master Caution panel located above each PFD. Each panel has a Master Warning Light and Master Caution Light (the ‘attention getters’) that provide a visual indication to alert the pilot that a warning or caution has been generated. When pressed, the light will turn off and associated aural warnings will be cancelled.

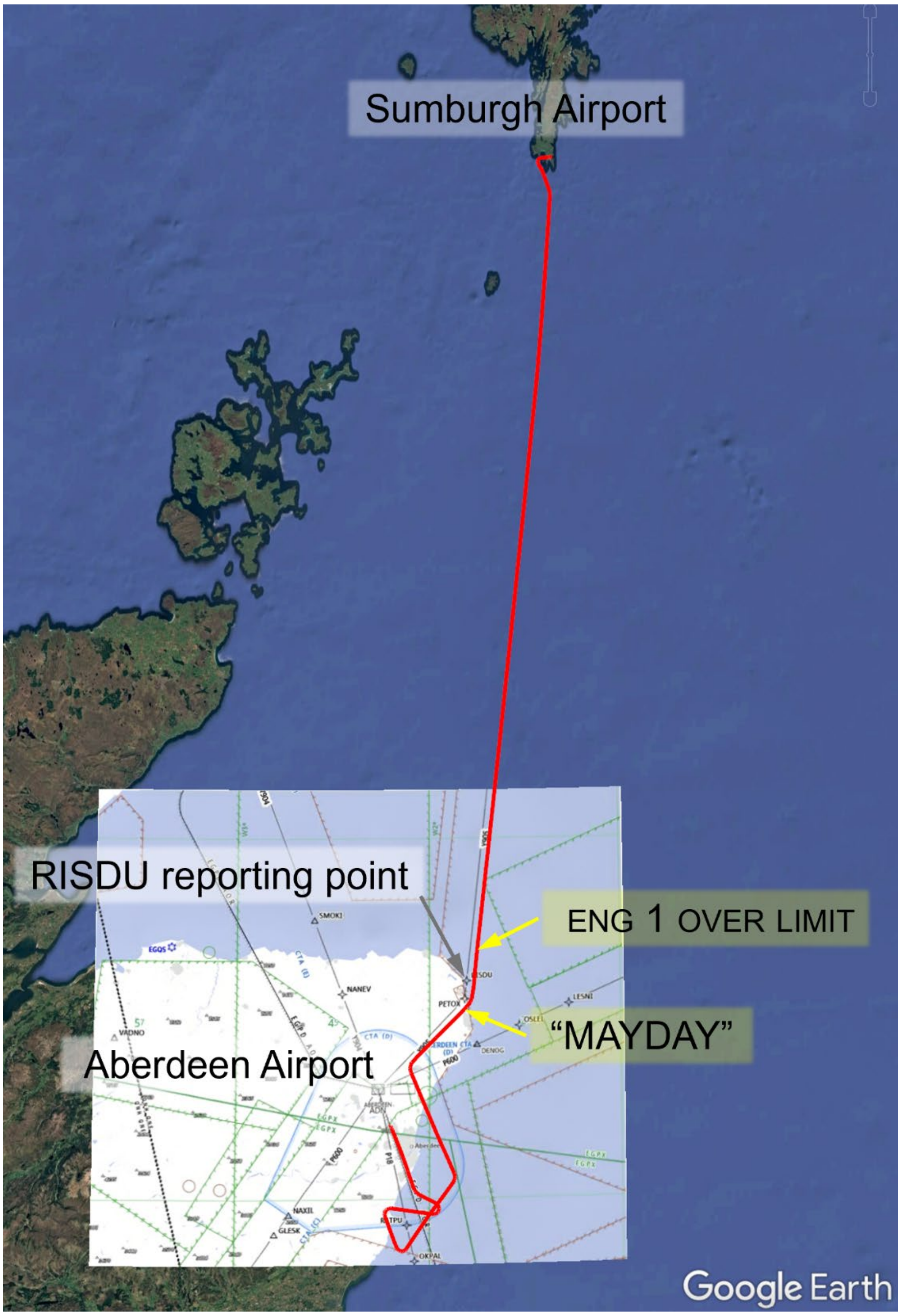

Figure 2

Reporting points near Aberdeen Airport
(Map data: Google, Jeppesen)

The co-pilot declared a MAYDAY to Scottish Control while the commander initiated a descent and called the cabin crew to stations. The commander indicated to ATC that they intended to divert to Aberdeen, now approximately 24 nm to the south-west (Figure 2). Scottish Control instructed a descent to FL130 and transferred control to Aberdeen Radar. Concurrently, the co-pilot carried out the Single Engine Operations checklist (Figure 3).

A70.12 SINGLE ENG OPERATION

- ▶ PWR MGT .... MCT
- ▶ **LAND ASAP**
- ▶ FUEL PUMP (affected ENG).. OFF
- ▶ DC GEN (affected side).. OFF
- ▶ ACW GEN (affected side).. OFF
- ▶ PACK VALVE (affected side)...................................... OFF
- ▶ BLEED VALVE (affected side).................................... OFF
- ▶ APM .... OFF
- ▶ TCAS .... TA ONLY

Note

Refer to Single Engine Gross Ceiling to determine single engine gross ceiling.

■ **If icing conditions**

- ▶ FLAPS... 15

TO IMPROVE DRIFT DOWN PERFORMANCES & SINGLE ENGINE CEILING.

- ▶ FUEL BALANCE : MONITOR

MAXIMUM RECOMMENDED FUEL UNBALANCE IS 200 kg (440 lb).

● **When FUEL X FEED is required**

- ▶ FUEL PUMP (affected ENG).. ON
- ▶ FUEL X FEED.. ON
- ▶ FUEL PUMP (operating ENG)...................................... OFF

● **For approach**

Note

Refer to STEEP SLOPE APPROACH to check steep slope approach limitation applicable to your aircraft.

- ▶ BLEED VALVE (operating side).................................. OFF
- ▶ CL (operating ENG).................................. 100 % OVRD
- ▶ V_{APP} .... NOT LESS THAN V_{GA}

■ **If affected engine NP above 10 %**

- ▶ V_{APP} .... NOT LESS THAN V_{REF} + 10 kt

● **When V_{APP} is increased**

- ▶ LDG DISTANCE................................ MULTIPLY BY 1.15

- ▶ ILS CAT 2 : PROHIBITED

● **At touchdown, until nosewheel touches the ground**

- ▶ PL : MAINTAIN AT OR ABOVE FI

Figure 3

Single engine operation checklist

Given the proximity of the aircraft to Aberdeen at the time of the engine malfunction there was no requirement to cross-feed fuel. On contact with Aberdeen, the commander downgraded the emergency to a PAN and the aircraft was vectored to an approach on Runway 34. While being vectored, the crew noticed a FUEL FEED LO PR master caution, accompanied by a FEED LO PR light[4] on the fuel panel for the No 2 engine. The engine was running normally so the crew decided to prioritise the One Engine Inoperative (OEI) landing, which was accomplished at 1228 hrs without further incident.

After shutting down the aircraft, the crew were informed by a ground engineer that fuel was leaking from the area of the No 1 engine.

Footnote

4 Fuel feed low pressure: in case of fuel delivery pressure below 4 psi, the light illuminates amber. This indicates a fuel pump failure or fuel starvation.

Recorded information

Following the event, the aircraft's FDR and CVR were removed from the aircraft to be downloaded at the AAIB. A copy of the quick access recorder (QAR) data (containing the same data recorded by the FDR) for the event flight was also provided by the operator. Data for the event is plotted in Figure 4.

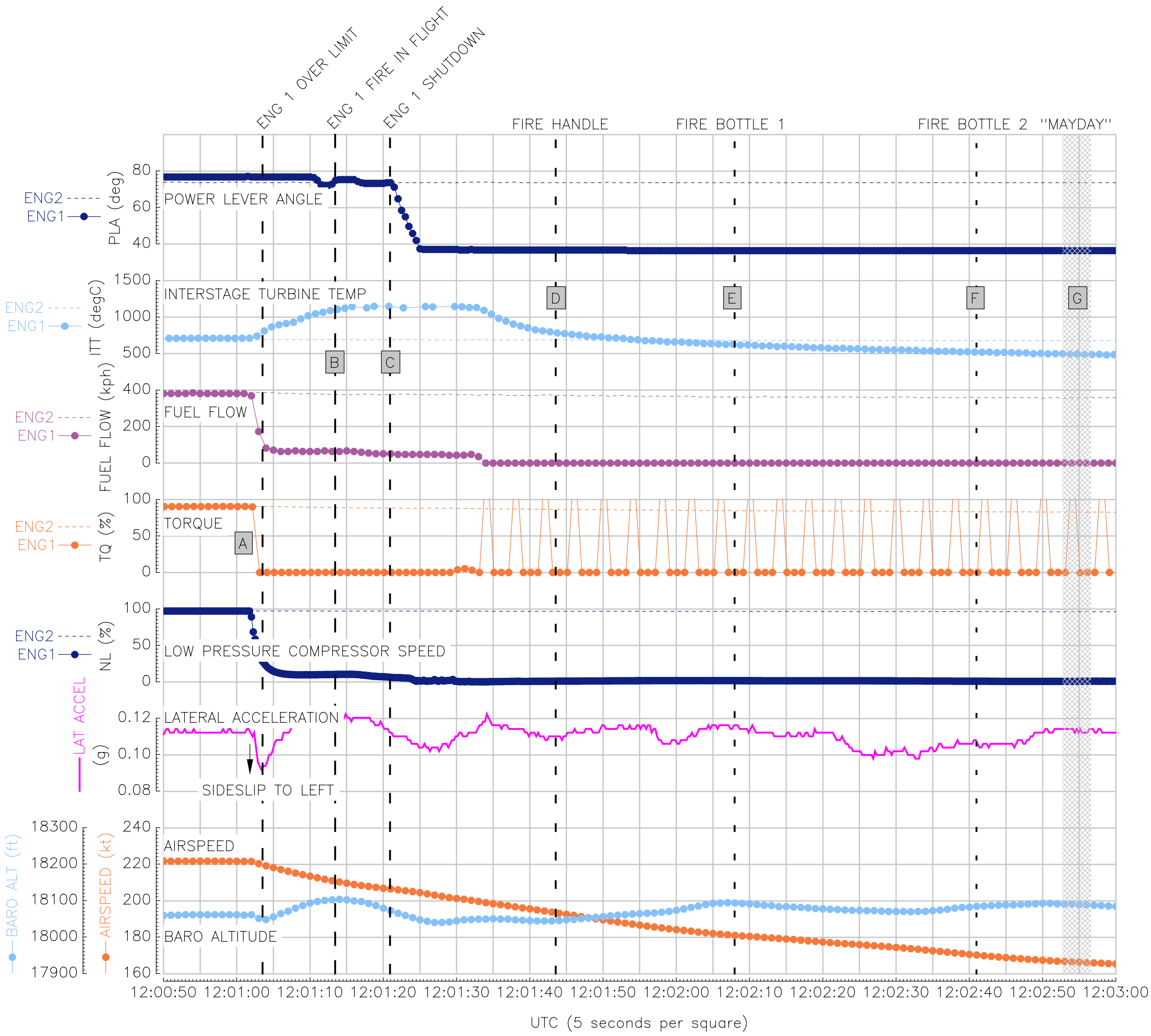

Figure 4

Recorded data for the event

The key points from Figure 4 are:

[A] 12:01:02 (t0) – The torque on No 1 engine reduced from 90 to 0% within one second, with corresponding drops in fuel flow and N_L, a rise in No 1 engine ITT, and aircraft sideslip to the left. This was followed by a master warning and ENG 1 OVER LIMIT message just over one second later.

[B] 12:01:13 (t0+11) – Master warning and ENG 1 FIRE IN FLIGHT message.

[C] 1201:21 (t0+19) – Master warning and ENG 1 SHUTDOWN message.

[D] 1201:43 (t0+41) – (From CVR) crew stated fire handle 1 pulled.

[E] 1202:08 (t0+66) – (From CVR) crew stated engine fire bottle 1 discharged.

[F] 1202:41 (t0+99) – (From CVR) crew stated engine fire bottle 2 discharged.

[G] 1202:53 (t0+111) – (From CVR) crew declare a MAYDAY.

Also, from the CVR, the crew are heard actioning the Single Engine Operation checklist about four minutes after the first (No 1 engine) fire bottle was discharged. 20 seconds later, the co-pilot confirmed the No 1 engine fuel pump was OFF.

Aircraft information

The ATR 42-500 (600 version) is a twin-engine turboprop, short-haul regional airliner seating up to 48 passengers.

Engine

The Pratt & Whitney Canada PW127M turboprop engine is a two-spool gas turbine engine with two stage centrifugal compressors (also known as impellers) each driven by a separate turbine. A separate two stage power turbine powers the propeller via a reduction gearbox (Figure 5). Each of the rotating assemblies is supported and located by sets of roller and ball bearings. The No 1 engine was installed in the aircraft in February 2024. The fuel return line was installed at this time and had not been disturbed since.

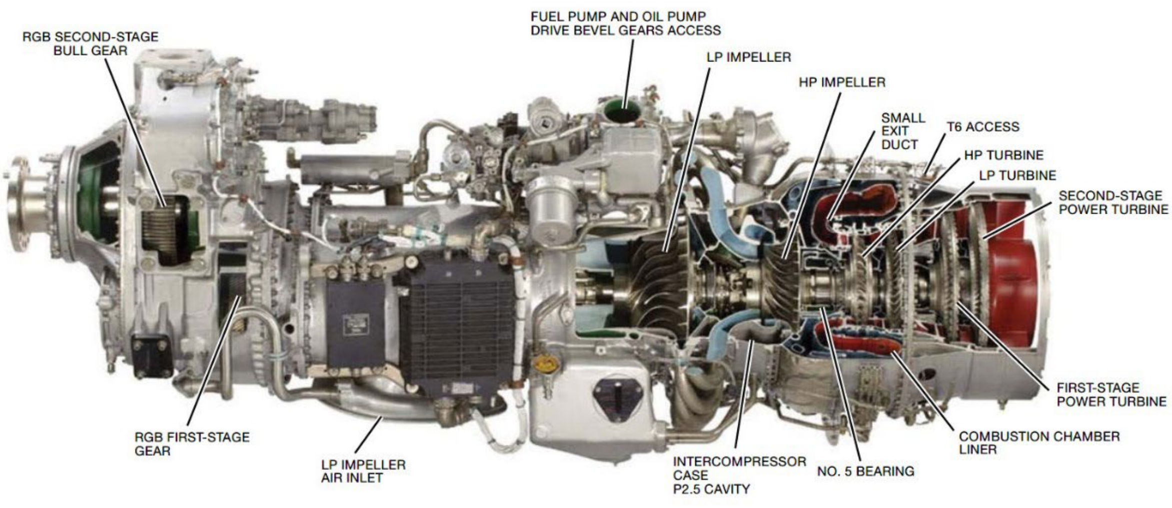

Figure 5

Cut away view of general engine arrangement
(used with permission)

Engine fire detection and extinguishing

The fire detection controls and indications are located in the flight deck.

Each engine has a fire detection system which consists of two continuous loops in parallel connected to an electronic control unit. Each loop consists of five sensing elements connected in series. The elements are made of coaxial cable whose properties are sensitive to temperature. The fire detection control unit processes signals from the sensing elements and, if required, triggers corresponding indications in the flight deck.

A fire extinguishing system is installed on each engine and the extinguishant[5] is stored in two sealed bottles, one in each wing fairing. Each bottle's contents can be directed to either engine depending on selections made by the flight crew.

Fuel system

Fuel is contained in a main tank and a feeder compartment in each wing. Each main tank is vented to atmosphere through a vent surge tank.

Fuel is supplied to the engine from the feeder compartment which is continually replenished with fuel from the main tank either by the feeder tank jet pump[6] or through flap valves in the tank wall.

An electric fuel pump is used for engine starting but the engine feed jet pump takes over once a motive flow of fuel is established at sufficient pressure from the hydro-mechanical unit[7] (HMU) via the motive flow valve. The electric fuel pump is then automatically shut down and the engine feed jet pump supplies fuel to the engine.

If required, a Low Pressure (LP) fuel valve can be closed, by operating the fire handle in the cockpit, to shut off the fuel supply to the engine.

For engine starting the electric fuel pump push-switch is pressed IN, causing the electric fuel pump to operate and supply fuel to the engine. The RUN caption of the push switch is illuminated, and the motive flow valve is de-energised (Figure 6).

Footnote

[5] Mono-bromo-triflouromethane (CF3 Br).

[6] A jet pump has no moving parts and consists of a venturi into which a jet of fuel under pressure is directed. This jet causes a pressure drop in the venturi which is used to draw a larger flow of fuel into the venturi and on to the outlet.

[7] The aircraft manufacturer uses the term HMU in its manuals, but the engine manufacturer refers to the unit as the manual fuel control unit (MFCU). It notes the term HMU is used on the smaller PW100 series engines and the term MFCU is used on the larger PW100 series engines such as the PW127 fitted to this aircraft; both units perform a similar function. For consistency with the aircraft manufacturers diagrams shown in this report, the term HMU is used.

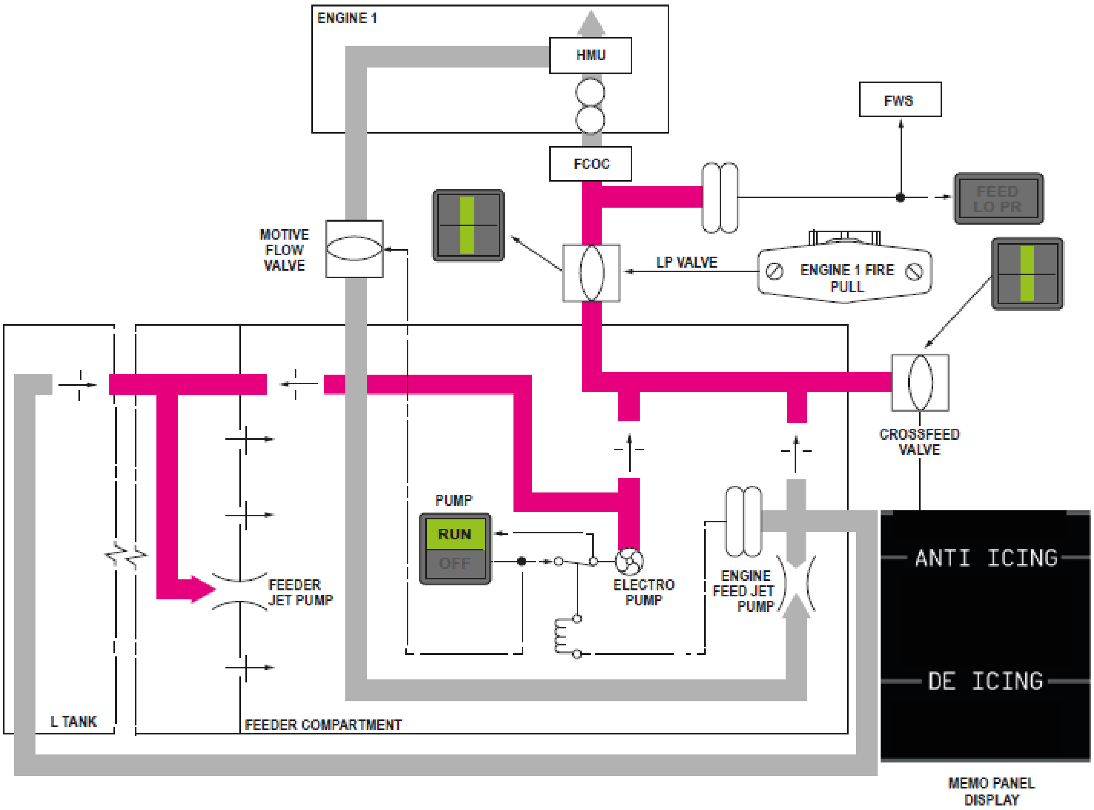

Figure 6

Schematic of No 1 engine fuel system, engine starting
(used with permission)

As the engine starts, fuel from the HMU is fed to the de-energised motive flow valve causing it to fully open and supply fuel to operate the engine feed jet pump. Once the feed from the fuel feed jet pump has sufficient pressure, the electric fuel pump is automatically switched off and the RUN caption is extinguished as the electric pump is no longer operating; the switch remains in the IN position.

In normal operation, fuel is fed to the respective engine by the engine feed jet pump which is powered by a motive flow of fuel via the motive flow valve (Figure 7). If the fuel pressure from the engine feed jet pump reduces, the electric pump will automatically restart to provide fuel flow, and its RUN caption will illuminate.

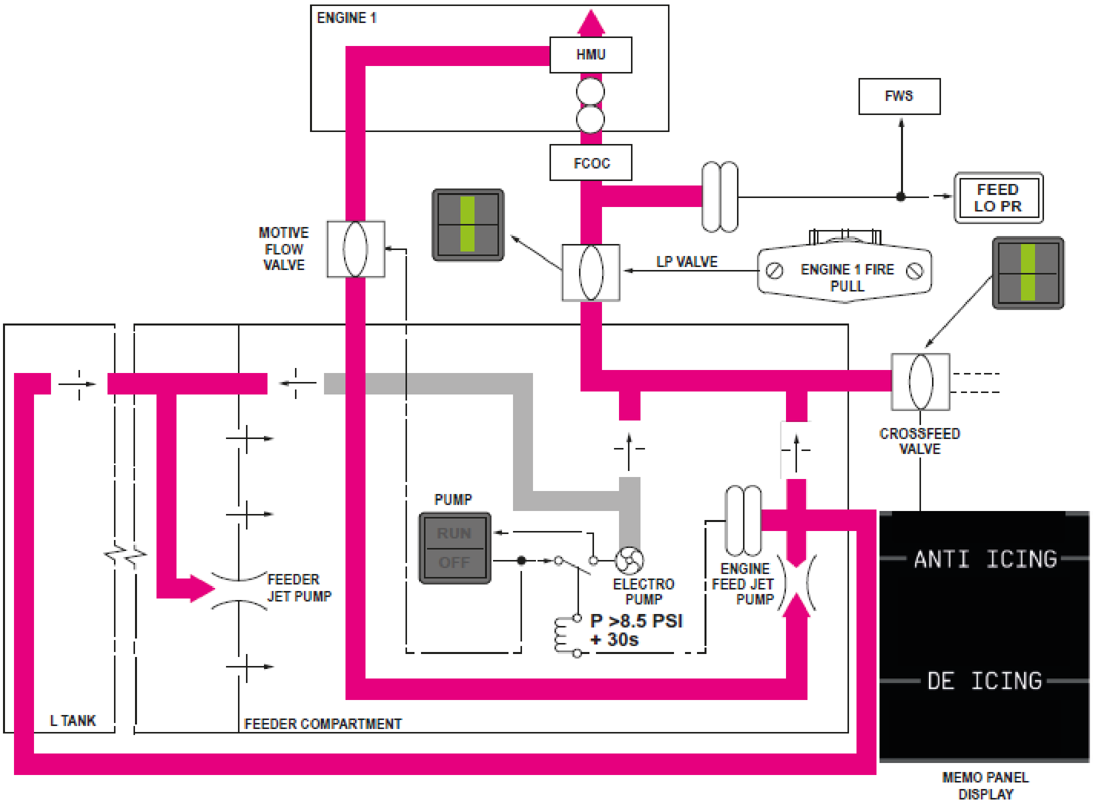

Figure 7

Schematic of No 1 engine fuel system, engine normal operation (used with permission)

The motive flow valve

The motive flow valve is used to control the motive flow of fuel from the HMU to the engine feed jet pump. The inlet is connected to the fuel return line from the HMU on the engine, and the outlet is connected to the engine feed jet pump in the header tank. The valve is controlled by an electrical solenoid and motive flow fuel pressure (Figure 8).

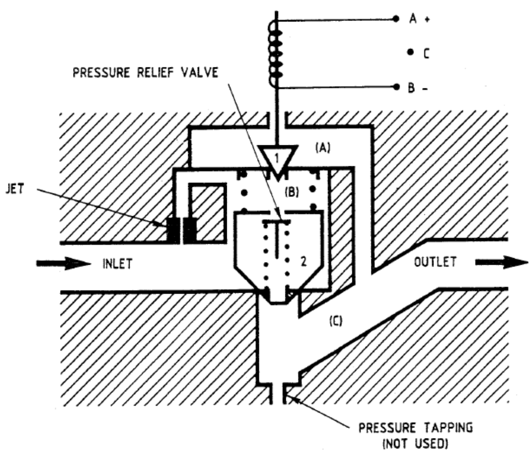

Figure 8

Schematic of the motive flow valve (used with permission)

The solenoid is de-energised when the electric fuel pump press switch is selected IN; this is the normal flight condition. In this de-energised condition, the needle valve (1) opens and allows the fuel pressure in the valve chambers to equalise. Fuel pressure from the HMU can then push up piston (2) which allows fuel to flow to the engine feed jet pump in the header tank. In this condition when there is no fuel flow from the HMU, a small flow of fuel from outlet to inlet is expected due to the valve design.

If the electric fuel pump is selected OUT (OFF), the solenoid is energised, and the needle valve (1) closes causing the motive flow valve to fully close.

Aircraft examination

There was evidence of fire around the No 1 engine cowlings and an inspection of the area inside the cowling revealed additional fire damage and sooting. The fuel return line was found loose and leaking at the HMU outlet.

With the motive flow valve de-energised, the flow of fuel leaking from the motive flow pipe when disconnected was measured at 165 ml/min. It was not possible to determine the flow rate at the time of the fire as the connection had been re-tightened to stem the leak whilst the aircraft was parked.

The end fitting had been marked with indicator material. When the fitting was re-tightened, the marks aligned, and the leak stopped.

Due to the routing of the fuel return line away from the end fitting, a 90° elbow, it was possible to use the line as a lever to manually loosen the fitting (Figure 9).

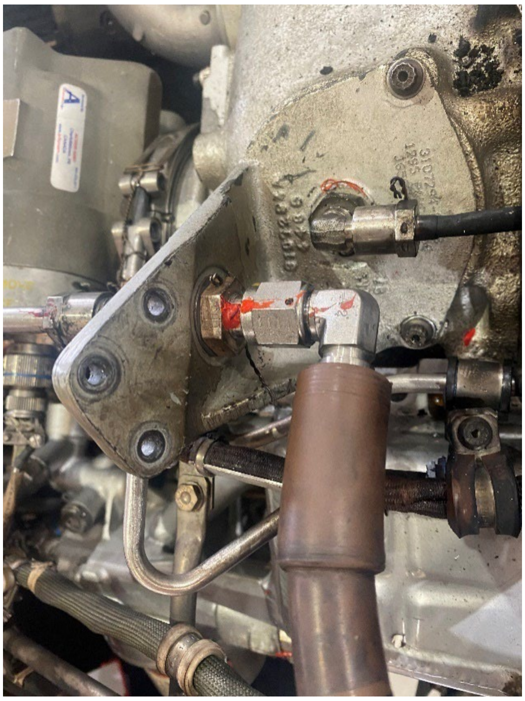

Figure 9

Fuel return line connection to HMU after engine removed from aircraft
(line temporarily fitted to show routing)

The aircraft manufacturer reported that they had no recorded in-service instances of this fuel return line fitting becoming loose.

Engine examination

Initial inspection of the engine identified that the second stage power turbine had suffered significant damage, and further damage was visible to the other turbine stages (Figure 10).

Figure 10

Damage to No 1 engine second stage power turbine, looking from exhaust outlet

The engine was removed from the aircraft and sent to the engine manufacturer's facility where it was disassembled for detailed inspection under supervision of the Transport Safety Board (TSB) Canada.

The elastomer material in the engine vibration isolation system showed signs of cracking indicating large forces had been exerted on them.

The disassembly inspection identified that the No 6 main bearing, located aft of the low-pressure turbine, had suffered significant degradation resulting in the loss of location of the turbine assembly which then contacted the surrounding parts causing the damage seen to the turbines and their casings. This bearing has been sent to the engine manufacturer's laboratories for detailed failure analysis under supervision of TSB Canada.

Fuel system indications

The crew reported that a No 2 engine FEED LO PRESS warning and that an amber box was displayed around the No 2 engine feeder tank. This was a parameter recorded by the FDR, but the recording from the event showed no change in status which would have indicated that a warning was displayed.

The amber box around the feeder tank means there was more than 160 kg in the No 2 tank, but that the No 2 feeder tank was not full. The feeder tank is normally kept topped up by a separate jet pump and, if this fails, the feeder tank is kept topped up via flap valves from the main tank when the feeder tank level falls below the main tank level to ensure fuel supply to the engine is maintained.

The crew checklist action for a FEED LO PRESS is to ensure the electrical fuel pump is ON which they did, and no issues were experienced with this engine.

The indication was not displayed on the ground, no work was done on the No 2 fuel system, and no issues were reported on return to service. The cause of the fuel indications for the No 2 engine was not determined.

Certification of engine shutoff

The aircraft manufacturer advised for the ATR 42, the applicable certification basis is JAR 25 change 13, paragraph 25.1189, *Shut-off means*. Paragraph (a) requires,

> *'Each engine installation and each fire zone specified in JAR 25.1181(a) (5) must have a means to shut off or otherwise prevent hazardous quantities of fuel, oil, de-icer, and other flammable fluids, from flowing into, within, or through any designated fire zone….'.*

The manufacturer was able to demonstrate compliance for the primary fuel supply line to the engine with the fuel shutoff valve. This valve can be used to cut off the primary fuel supply to the engine and therefore isolate it from further risk of fire.

The motive flow valve allows a small fuel leakage, when it is not energized (normal condition during flight), to the fuel return line which, when properly connected, is sealed. Compliance for this line was provided by the line being made of fire-resistant material and its integrity is guaranteed by the installation and the associated maintenance procedures to install it.

Analysis

Engine

The disassembly of the engine identified that the No 6 bearing had suffered significant degradation resulting in the loss of location of the high-pressure turbine assembly and the damage seen to the turbines and their casings.

The No 6 bearing has been sent for more detailed examination and the results of this work will be used to inform the established airworthiness and reliability processes of the engine manufacturer. If the findings of this work require it, an addendum to this report will be issued.

Motive flow valve

Testing of the motive flow valve confirmed it was operating normally and that, with the valve de-energised, a small flow from outlet to inlet is expected due to the valve design. The leak from the loose fuel return line connector to the HMU was consistent with this flow rate. In normal conditions this connector would be secure, and the fuel would remain contained in the line. In this event as the connector was loose, the fuel leaked into the cowling area and then ignited.

During this event and following the engine failure, the crew followed the relevant procedure, '*Engine Fire or Severe Mechanical Damage'*, to shut down the engine.

Operating the fire handle closed the LP fuel valve and thereby shutoff the main fuel supply to the engine. Once the engine was shut down, there was no motive flow from the HMU, and the motive flow valve piston would drop closing off the valve. However, in this de-energised condition, fuel would still flow from the outlet to the inlet of the valve and leak through the loose fuel return line connection due to gravity as the fuel tank is higher than the loose connection.

It was only later in the crew procedures, and after the fire had been extinguished, the crew moved on to the Single Engine Operation checklist. This checklist requires the crew to select the fuel pump push switch OFF. This selection energised the motive flow valve solenoid causing it to fully close the motive flow valve and stop the flow of fuel from the loosened fuel return line.

The fuel flow would be stopped for the remainder of the flight providing the fuel pump switch remained OFF.

If the crew had subsequently needed to cross-feed fuel to maintain lateral balance, the fuel pump for the failed engine would need to be selected ON to feed fuel from that tank. This selection would de-energise the motive flow valve and allow the leak to recommence. It would stop again when the electrical fuel pump press switch was selected OFF after the completion of fuel transfer.

The time taken from the fire warning until the electrical fuel pump being selected OFF was approximately five minutes.

The crew completed the required checklists in a timely and accurate manner and successfully extinguished the fire using both fire bottles at the required intervals. The crew remained unaware of the leaking fuel until after the aircraft was parked. Their prompt completion of the Single Engine Operation checklist ensured the fuel leak in flight was stemmed and prevented a potential escalation of the emergency. Due to the proximity of the diversion airport, fuel transfer was not required.

Later, when the aircraft was parked and electrical power removed, the motive flow valve solenoid became de-energised, and the leak recommenced. Maintenance staff were able to stem the leak by re-tightening the connection.

The motive flow valve will only be fully closed when it is energised following flight crew selection of the electric fuel pump to OFF. Should the crew need to cross-feed to maintain lateral balance the electric fuel pump would need to be selected ON again and then motive flow valve would be no longer shut-off.

Fuel return line

The engine failure was violent as witnessed by the rapid reduction in torque and tears in the elastomer anti-vibration mounts and it is considered possible that the reaction to this sudden reduction in torque could have caused the fuel return line to ‘whip’ and loosen the connection and for consequent engine vibrations to have loosened it further. There is no secondary locking on the connection and the line leaves the HMU via a 90° elbow which would add leverage to any loosening forces.

It is also possible that the connection was not correctly torqued during installation, but maintenance records indicated it had been and there were no reports of leakage before the event. The operator had also conducted a check of its fleet of similar aircraft and found all the fuel return lines had been correctly installed.

The design of the fuel return line installation complied with the certification standards in place at the time of certification. However, as was seen in this event, loosening of the fuel return line was not identified as a risk as the integrity of the line was assured by the use of fire-resistant materials, the installation and associated maintenance procedures.

The aircraft manufacturer confirmed that they were not aware of any events where the motive flow fuel line had become loose and leaked. Interviews with maintenance staff, checks of maintenance documentation and inspection of the connection, confirmed that it was likely this connection had been correctly installed and tightened when the engine was installed in the aircraft in February 2024.

Conclusion

The No 1 engine suffered a contained failure. This was due to significant degradation of its No 6 main bearing which resulted in the rotating high-pressure turbine being no longer correctly located. This allowed the rotating parts to contact adjacent parts causing significant damage to the turbine stages.

There was an under-cowling fire which was due to leaking fuel igniting on hot engine parts. It was detected and extinguished by the crew using onboard systems; both fire bottles were discharged.

The fuel leak was from the connection between the HMU and the fuel return line which had become loose. The reason for this could have been either that the connection had not been tightened correctly when it was installed or that it had become loose due to the forces of the engine failure ‘whipping’ the fuel return line. Maintenance records, interviews with the maintenance staff and indicator markings appeared to confirm that it had been tightened correctly, and the aircraft manufacturer was not aware of any other cases where this connection had become loose.

Due to the fuel system design, specifically that of the motive flow valve, fuel continued to leak from the loosened fuel return line after the crew, as part of the Engine fire or Severe Mechanical Damage checklist, operated the fire handle to shut down the engine. It continued to leak until the crew selected the No 1 engine electrical fuel pump OFF as part of the Single Engine Operation checklist, as it was this selection to OFF that fully closed the motive flow valve. The fuel leak would have recommenced if the crew had needed to cross feed fuel to maintain the lateral balance of the aircraft as this process requires the electrical fuel pump to be selected ON, thereby allowing the motive flow valve solenoid operated needle valve to open which would then allow fuel to leak through it from the feeder tank and out of the loose connection.

Safety action

The aircraft met certification requirements in place at the time of certification, and there have been no other similar events in the history of the aircraft. However, the aircraft manufacturer has initiated the following safety action:

> The aircraft manufacturer has commenced a safety review to identify any possible safety actions which would further reduce the likelihood of leakage from the fuel return line. This review will be completed by the end of 2025.

Published: 19 June 2025.