AIRCRAFT SERIOUS INCIDENT REPORT AND EXECUTIVE SUMMARY

			Reference:			**CA18/3/2/1385**	
Aircraft Registration	**A2-ABK**	**Date of Incident**	30 December 2021			**Time of Incident**	1027Z
Type of Aircraft	ATR 72-600		**Type of Operation**			Air Transport Operation (Part 121)	
Pilot-in-command Licence Type	Airline Transport Pilot Licence (ATPL) Aeroplane		**Age**	57		**Licence Valid**	Yes
Pilot-in-command Flying Experience	**Total Flying Hours**		17 510			**Hours on Type**	14 155
First Officer Licence Type	Airline Transport Pilot Licence (ATPL) Aeroplane		**Age**	32		**Licence Valid**	Yes
First Officer Flying Experience	**Total Flying Hours**		3 972			**Hours on Type**	3 466
Last Point of Departure	O.R. Tambo International Airport (FAOR), South Africa						
Next Point of Intended Landing	Sir Seretse Khama International Airport (FBSK), Botswana						
Damage to Aircraft	Minor						
Location of the incident site with reference to easily defined geographical points (GPS readings if possible)							
On a climb phase from FAOR at Global Positioning System (GPS) co-ordinates determined to be 25°59'21.86" South, 028°8'22.55" East, at an elevation of 8 000 feet (ft)							
Meteorological Information	FAOR 301030Z 30015KT CAVOK 26/14 Q1020 NOSIG=						
Number of People On-board	2+2+70	**Number of People Injured**	0	**Number of People Killed**	0	**Other (On Ground)**	0
Synopsis							

On 30 December 2021 at 1027Z, an ATR 72-600 aircraft with registration A2-ABK operated by Air Botswana was involved in a serious incident during the climb phase from O.R. Tambo International Airport (FAOR) whilst en route to Sir Seretse Khama International Airport (FBSK) in Botswana. Visual meteorological conditions (VMC) prevailed at the time of the flight. The instrument flight rules (IFR) plan was filed for this flight, which was conducted under the provisions of Part 121 of Botswana Civil Aviation Regulations (BCAR).

Whilst at approximately flight level 87 (FL87), the crew observed the engine number 2 (ENG 2) torque indication fluctuate and the Interstage Turbine Temperature (ITT) increase by approximately 40°C. At FL140, the ENG 2 fire warning light illuminated, and the crew shut it down. The crew made an air turn back to FAOR and landed safely on Runway 03L. The crew members and the occupants were not injured during the serious incident; however, the aircraft sustained damage to the right engine.

Probable Cause/s and/or Contributory Factors			
During the climb phase, three PT2 blades of the hot section were fractured on the chromium-coated section; this led to the failure of all three blades in-flight which subsequently caused other component failures in the engine and, thus, the crew's decision to shut down the engine. **Contributory Factor:** The three chromium plated PT2 blades were subjected to sulphidation which led to the fracture during operation.			
SRP Date	9 May 2023	Publication Date	10 May 2023

Occurrence Details

Reference Number	**:** CA18/3/2/1385
Occurrence Category	: Category 1
Type of Operation	**:** Air Transport Operations (Part 121)
Name of Operator	**:** Air Botswana
Aircraft Make and Model	**:** Aerospatiale/Alenia Avion, ATR 72-600
Nationality	**:** Botswana
Registration	**:** A2-ABK
Place	**:** During the climb after passing FL87
Date and Time	**:** 30 December 2021 at 1027Z
Injuries	**:** None
Damage	**:** Minor

Purpose of the Investigation:

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

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

Investigation Process:

The Accident and Incident Investigations Division (AIID) of the South African Civil Aviation Authority (SACAA) was notified of the occurrence via the AIID Inbox on 31 December 2021. The occurrence was classified as a serious incident according to the CAR 2011 Part 12 and ICAO STD Annex 13 definitions. The notifications were sent to the State of Registry, Operator, Design and Manufacturer in accordance with CAR 2011 Part 12 and ICAO Annex 13 Chapter 4. The State of Design appointed an accredited representative and advisor.

Notes:
1. Whenever the following words are mentioned in this report, they shall mean the following:

Serious Incident — this investigated serious incident.
Aircraft — the ATR 72-600 involved in this serious incident.
Investigation — the investigation into the circumstances of this serious incident
Pilot — the pilot involved in this serious incident.
Report — this serious incident report

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

Disclaimer:

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

Table of Contents

Abbreviation	Description
°	Degrees
°C	Degrees Celsius
AFM	Airplane Flight Manual
AGB	Accessory Gearbox
AGL	Above Ground Level
AIID	Accident and Incident Investigations Division
AMO	Aircraft Maintenance Organisation
AMSL	Above Mean Sea Level
AOC	Air Operator Certificate
ATC	Air Traffic Control
ATPCS	Automatic Take-off Power Control System
ATPL	Airline Transport Pilot Licence
BCAR	Botswana Civil Aviation Regulation
˚C	Degrees Celsius
CAAB	Civil Aviation Authority Botswana
CAR	Civil Aviation Regulations
CAVOK	Cloud and Visibility OK
CVR	Cockpit Voice Recorder
ECI	Eddy Current Inspection
EEC	Electronic Engine Control
ENG	Engine
FAOR	O.R. Tambo International Airport
FBSK	Sir Seretse Khama International Airport
FI	Flight idle
FL	Flight Level
FDR	Flight Data Recorder
FO	First Officer
ft	Feet
GPS	Global Positioning System
HBV	Handling Bleed Valve
HMU	Hydromechanical Unit
hPa	Hectopascal
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
ITT	Interstage Turbine Temperature
IAW	In Accordance With
KG/H	Kilogram per hour
kts	knots
m	Metre
METAR	Meteorological Aerodrome Report
MHz	Megahertz
MM	Maintenance Manual
NL2	Rotation speed
PF	Pilot Flying
PIC	Pilot-in-command
PL	Power Lever
PM	Pilot Monitoring
QAR	Quick Access Recorder
QNH	Barometric Pressure Adjusted to Sea Level (Query Nautical Height)
RGB	Reduction Gearbox
SACAA	South African Civil Aviation Authority

SAWS	South African Weather Service
TBO	Time Between Overhaul
UTC	Co-ordinated Universal Time
VFR	Visual Flight Rules
VHF	Very High Frequency
Z	Zulu (Term for Universal Coordinated Time – Zero Hours Greenwich)

1. FACTUAL INFORMATION

1.1. History of Flight

1.1.1 On 30 December 2021, an ATR 72-600 aircraft with registration A2-ABK and a call sign BP206 was on a scheduled international commercial flight from O.R. Tambo International Airport (FAOR) to Sir Seretse Khama International Airport (FBSK) in Botswana. On-board the aircraft were two (2) flight deck crew, two (2) cabin crew members and seventy (70) passengers. The aircraft was operated under the provisions of Part 121 of Botswana Civil Aviation Regulations (BCAR).

1.1.2 The pilot-in-command (PIC) who was the pilot flying (PF) and the first officer (FO) who was the pilot monitoring (PM) stated that whilst on the climb phase, approximately 40 nautical miles (nm) north-west of FAOR and passing FL87, they observed engine number 2 (ENG 2) (right-hand) torque indications fluctuate and the Interstage Turbine Temperature (ITT) increase by approximately 40°C. The ENG 2 parameters stabilised after passing FL110. However, as they reached FL130, the master caution light and the engine electronic control (EEC) fault indication lights illuminated on both the local alert and flight warning systems. The crew made a request to the air traffic control (ATC) to climb higher and level off at FL140, which was granted, before going through the checklist and conducting the technical fault-finding procedure. Whilst engaged in fault-finding procedure, the ENG 2 fire warning light illuminated. The crew complied with the in-flight engine fire checklist recommendation and shut down ENG 2; the fire alert indication was reset without discharging the fire extinguishing bottles. The crew notified the ATC that they had shut down ENG 2 and requested to return to FAOR. The PIC was able to land the aircraft safely on Runway 03L; thereafter, taxied to parking bay B09. Post-incident inspection of the ENG 2 revealed that the exhaust pipe, turbine blades, exit vanes and handling bleed valve (HBV) electrical connector were damaged. Moreover, the inspection revealed that there were exhaust pipe metal pieces on the bottom cowling.

1.1.3 The occupants on-board the aircraft were not injured. The aircraft sustained damage to ENG 2 during the serious incident.

1.1.4 The serious incident occurred during day light whilst on a climb phase from FAOR at Global Positioning System (GPS) co-ordinates determined to be 25°59'21.86" South, 028°8'22.55" East, at an elevation of 8 000 feet (ft).

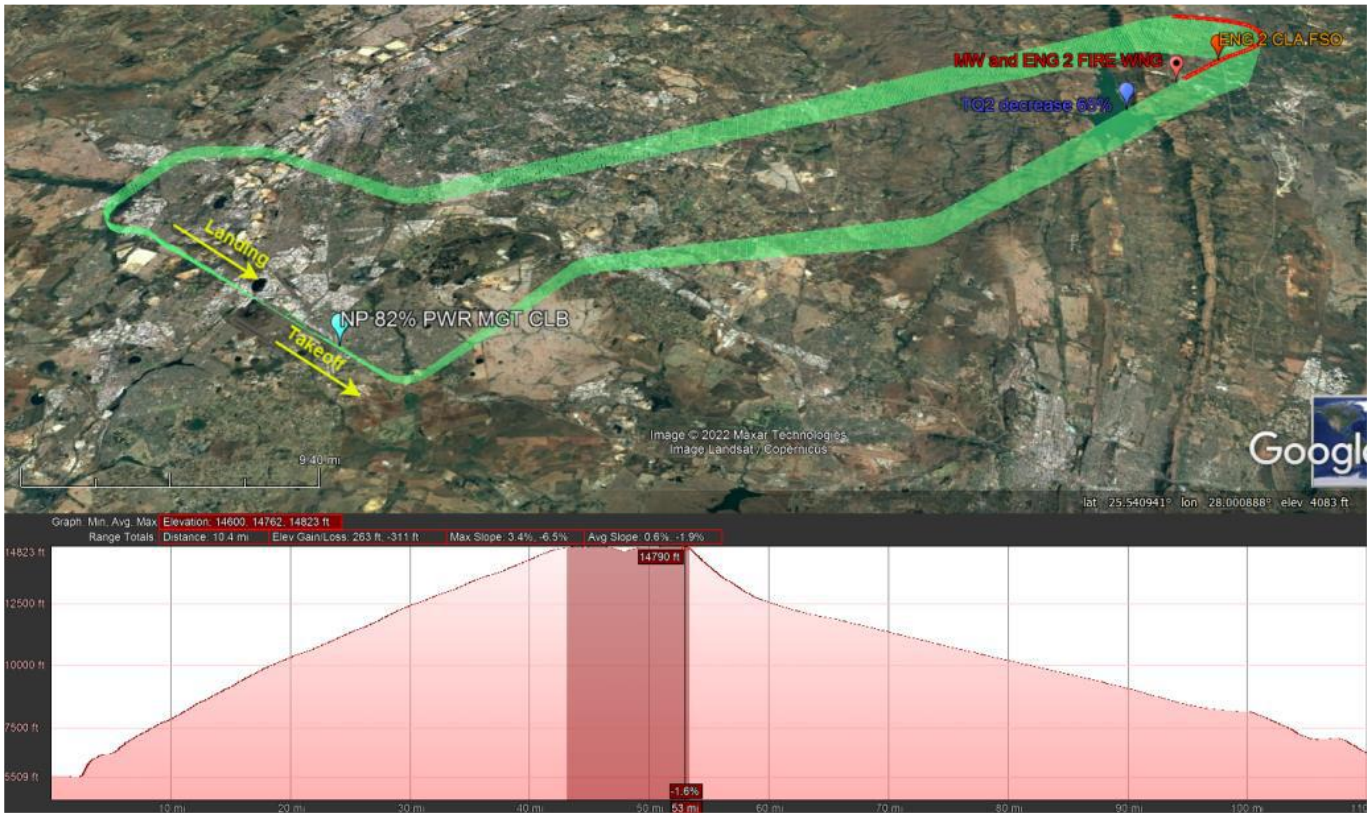


Figure 1: Flight track from FAOR and back to FAOR. (Source: Google Earth)

1.2. Injuries to Persons

Injuries	Pilot	Crew	Pass.	Total On-board	Other
Fatal	-	-	-	-	-
Serious	-	-	-	-	-
Minor	-	-	-	-	-
None	2	2	70	74	-
Total	**2**	**2**	**70**	**74**	-

Note: Other means people on the ground.

1.3. Damage to Aircraft

1.3.1 ENG 2 sustained damage during the incident.

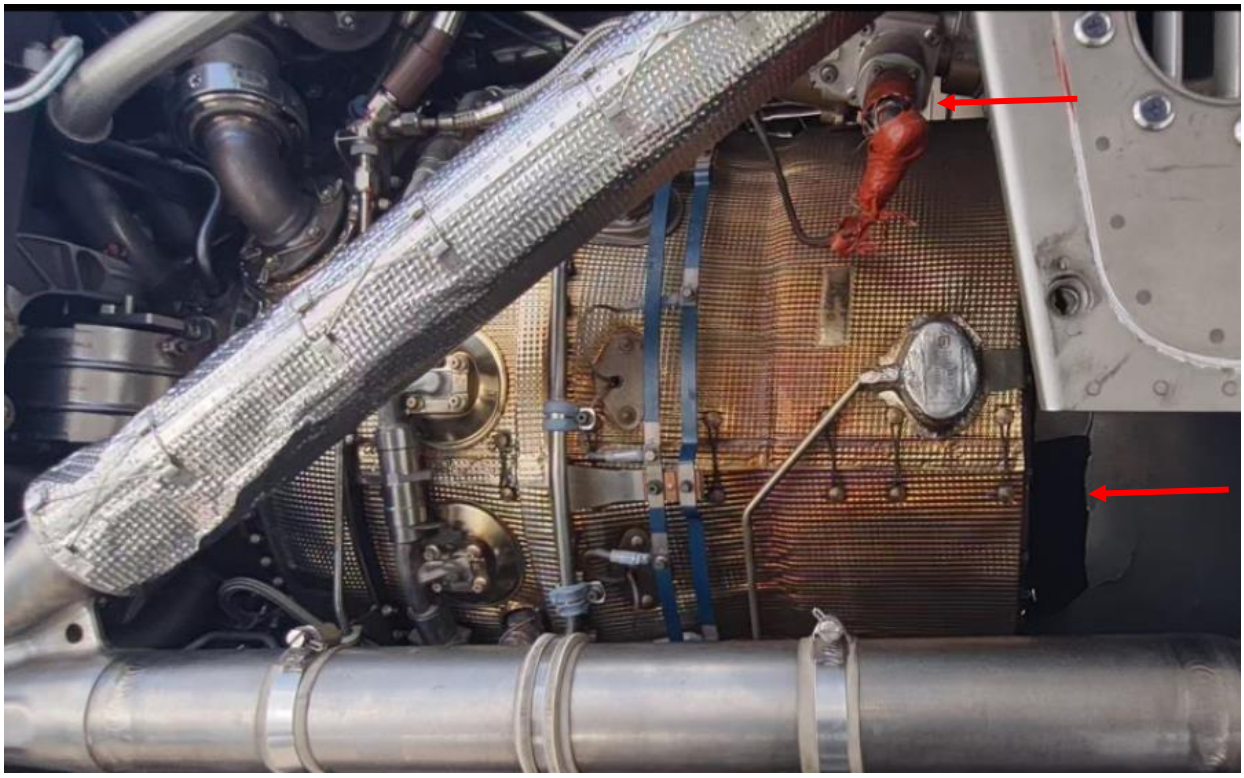


Figure 2: Exhaust pipe and P10 connector sustained damage due to the sheared exit guide vanes.

1.4. Other Damage

1.4.1 None.

1.5. Personnel Information

Pilot-in-command (PIC) – Pilot Flying

Nationality	Motswana	Gender	Male	Age	57
Licence Type	Airline Transport Pilot Licence (ATPL) Aeroplane				
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Night and Instrument				
Medical Expiry Date	30 March 2022				
Restrictions	Corrective Lenses				
Previous Incidents	None				

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

Flying Experience:

Total Hours	17 510
Total Past 90 Days	149
Total on Type Past 90 Days	149
Total on Type	14 155

1.5.1 The PIC was initially issued an Airline Transport Pilot Licence (ATPL) on 30 August 1999 in accordance with (IAW) the Civil Aviation Authority of Botswana. The PIC's last licence revalidation was carried out on 26 March 2021 with an expiry date of 31 March 2022. The

PIC's hours in the above table are as per the hours submitted by him through the pilot questionnaire.

1.5.2 The PIC was issued a Class 1 medical certificate on 30 August 2021 with an expiry date of 30 March 2022 with a restriction to wear corrective lenses.

1.5.3 The PIC was issued an ATR 72 type rating on 9 October 2015 to act as pilot-in-command or co-pilot.

First Officer (FO) – Pilot monitoring

Nationality	Motswana	Gender	Male	Age	32
Licence Type	Airline Transport Pilot Licence (ATPL) Aeroplane				
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Night, Instrument, and Instructor				
Medical Expiry Date	30 March 2022				
Restrictions	None				
Previous Incidents	None				

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

Flying Experience:

Total Hours	3972
Total Past 90 Days	141
Total on Type Past 90 Days	141
Total on Type	3466

1.5.4 The FO was initially issued an ATPL on 6 February 2017 in accordance with the Civil Aviation Authority of Botswana. The FO's last licence revalidation was issued on 26 March 2021 with an expiry date of 28 March 2022. The FO's hours in the above table are as per the hours submitted by him through the pilot questionnaire.

1.5.5 The FO was issued a Class 1 medical certificate on 11 March 2021 with an expiry date of 30 March 2022.

1.5.6 The FO was issued an ATR 72 type rating on 6 February 2017 to act as co-pilot.

1.6. Aircraft Information (Source: ATR Operating Manual)

1.6.1 *The ATR 72 is a turboprop-powered regional airliner, capable of accommodating a maximum of 72 passengers. It is powered by a pair of Pratt & Whitney Canada PW100 turboprop engines, which drive an arrangement of four or six-bladed propellers supplied by Hamilton Standard. Earlier models of the ATR 72 are equipped with the older PW124B engine, rated at 2,400 shaft horsepower (shp), whilst later-built aircraft are powered by the newer PW127 engine, rated at a maximum of 2,750*

shp to achieve improved "hot and high" takeoff performance. It can land and takeoff in high airports with short runways like the Andorra Airport. It employs carbon fibers for 30% of the wing by weight, for a 20% weight reduction.

In a standard configuration, the aircraft does not have an auxiliary power unit; when present it is installed within the C4 cargo section. Most operators of the ATR 72 equip their aircraft with a propeller brake (referred to as "Hotel Mode") that stops the propeller on the No. 2 (right) engine, allowing the turbine to continue running and provide both airflow and electrical power to the aircraft while on the ground.

Figure 3: Picture of A2-ABK taken at the AMO facility after the incident.

Airframe:

Manufacturer/Model	ATR 72-600	
Serial Number	1433	
Year of Manufacture	2018	
Total Airframe Hours (At Time of Incident)	4405.3	
Last A Check Inspection (Hours & Date)	4047.0	12 October 2021
Airframe Hours Since Last Inspection	326.3	
CRS (Issue Date)	12 October 2021	
C of A (Initial Issue & Expiry Date)	2 November 2018	31 October 2022
C of R (Issue Date) Present Owner	1 November 2018	
Operating Category	Air Transport Operations (Part 121)	
Type of Fuel Used	Jet A1	
Previous Serious Incidents	None	

Note: Previous serious incidents refer to past serious incidents the aircraft was involved in, when relevant to this incident.

1.6.2 According to available information, the aircraft was first registered to the present owner on 1 November 2018. The aircraft was re-issued a Certificate of Release to Service (CRS) on 12 October 2021.

1.6.3 Based on the aircraft maintenance records, the last maintenance inspection was an A-Check which was carried out on 12 October 2021 at 4079.0 airframe hours. The aircraft had accumulated an additional 326.3 airframe hours in operation since the last inspection, and no major defects were recorded.

1.6.4 The aircraft had 1900 kilograms (kg) of Jet A1 fuel on-board during take-off at FAOR. Approximately 1380kg of fuel remained in the tanks after an air turn back to FAOR.

1.6.5 **Propeller No. 1:**

Manufacturer/Model	Hamilton Sundstrand 568F-1
Serial Number	FR2017050012
Hours Since New	4405.3
Hours Since Overhaul	TBO not reached

Propeller No. 2:

Manufacturer/Model	Hamilton Sundstrand 568F-1
Serial Number	FR2017050013
Hours Since New	4405.3
Hours Since Overhaul	TBO not reached

1.6.6 **Engine No. 1:**

Type	Pratt and Whitney 127N
Serial Number	ED 1417
Hours Since New	4405.3
Hours Since Overhaul	TBO not reached

Engine No. 2:

Type	Pratt and Whitney 127N
Serial Number	ED 1419
Hours Since New	4405.3
Hours Since Overhaul	TBO not reached

ENG 2 was manufactured in November 2016. It had logged 4405.3 hours since new at the time of the serious incident.

1.6.7 *Pratt and Whitney 100 engine series have the ability to be on an on-condition program. This means that the engine parameters trending is leveraging to elaborate and plan shop visit. This will vary from one operator to another based on its proactive maintenance, environmental factor, type of mission profile amongst other factors. Should the operator elect not to be on the on-condition maintenance the PW127N have a recommended overhaul interval of 7000 hours for both modules, the reduction gear box and the turbomachinery with a midlife inspection of the hot section components should the engine not being on a trending program.* (Source: Engine Manufacturer)

1.6.8 The ATR 72-600 Quick Reference Handbook (QRH) in-flight warnings:

Abnormal engine parameters in-flight

ABNORMAL ENG PARAMETERS IN FLIGHT A70.13

- **If Intermittent fluctuations or unrealistic steady indication**
  - ► ATPCS ..... OFF
  - • **When flight conditions permit**
    - ► PL (affected ENG)..... FI
    - ► EEC (affected ENG)..... OFF
    - **If normal engine operations recovered**
      - ► EEC 1(2) FAULT procedure (A70.03) .....APPLY
    - **If abnormal fluctuations or indications persist**

      -OR-
    - **If TQ = 0 % and NP < 77 %**
      - ► PL (affected ENG)..... FI
      - ► CL (affected ENG)..... FUEL S.O.
      - ► **LAND ASAP**
      - ► SINGLE ENG OPERATION procedure (A70.12) ..... APPLY
- **If "HBV" indication on display**
  - ► PL (affected ENG)..... MOVE WITH CARE

Automatic take-off power control system (ATPCS) status for the incident flight was not part of the recording list of parameters and the actions on this system cannot be confirmed by QAR analysis. The power lever (PL2) was moved to flight idle (FI), but the engine electronic control (EEC2) remained on initially.

EEC fault:

EEC 1(2) FAULT A70.03

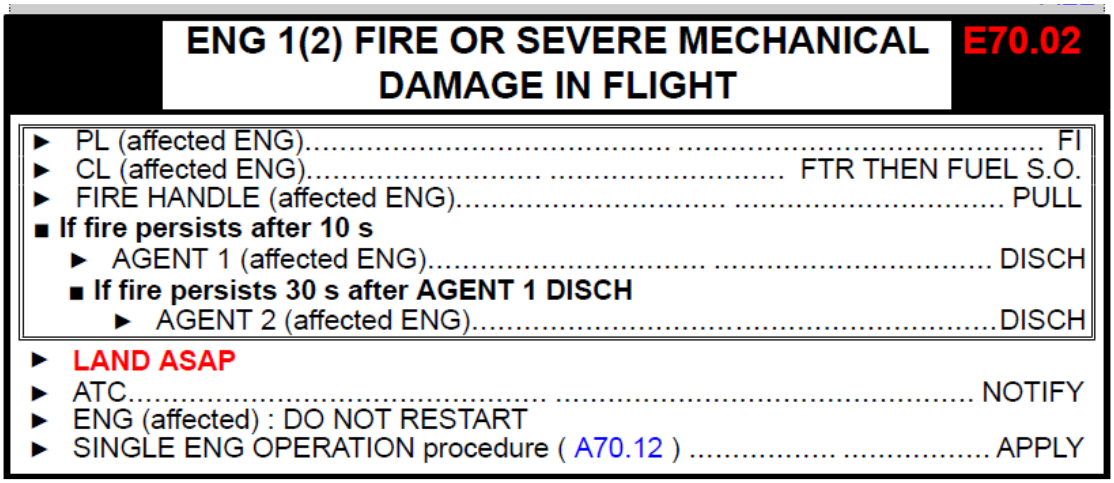
► ATPCS ..... OFF

CAUTION

Do not reset EEC Flashing

- **When flight conditions permit**
  - ► PL (affected ENG).....RETARD IN GREEN SECTOR
  - ► EEC (affected ENG).....RESET
  - **If EEC recovered**
    - ► ATPCS .....ON
    - ► PL (affected ENG).....RESTORE POWER
  - **If EEC fault persists**
    - ► EEC (affected ENG)..... OFF
    - ► PL (affected ENG).....MOVE WITH CARE
    - ► PL (affected ENG).....RESTORE POWER
    - **In the following cases : icing conditions, engine(s) flame out, emergency descent, severe turbulence, heavy rain**
      - ► MAN IGN .....ON
    - • **In final approach**
      - ► CL 1 + 2..... 100 % OVRD
      - ► V_{APP} ..... NOT LESS THAN V_{REF} +10 kt
      - ► SPD TGT ..... MAN SEL
      - ► LDG DIST (Refer to Landing Distance)..... MULTIPLY BY 1.15
      - **If engine failure during go-around**
        - ► PL : DO NOT REDUCE BELOW 45 ° BEFORE FEATHERING
    - • **After landing**
      - ► TAXI : ENG (affected) FEATHERED
      - ► ACW BTC .....CHECK CLOSED

Engine fire in-flight:



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

The PIC shut down the affected engine by setting the condition lever (CL2) to the fuel shut-off (Fuel S.O.) position and the power lever (PL) was already in in-flight idle (FI) mode. The ENG 2 fire warning indication activated automatically and, therefore, there was no need for the crew to discharge the fire extinguishing agent to the affected engine. The crew alerted the ATC at FAOR and requested an air turn back to land as soon as possible with one engine operating.

1.7 Meteorological Information

1.7.1 The meteorological aerodrome report (METAR) for FAOR on 30 December 2021 at 1030Z was as follow: FAOR 301030Z 30015KT CAVOK 26/14 Q1020 NOSIG=

Wind Direction	300˚	Wind Speed	15kts	Visibility	9999m
Temperature	26˚C	Cloud Cover	CAVOK	Cloud Base	CAVOK
Dew Point	14˚C	QNH	1020hPa		

1.8 Aids to Navigation

1.8.1 The aircraft was equipped with standard navigational equipment as approved by the Civil Aviation Authority of Botswana. There were no records indicating that the navigational equipment was unserviceable prior to the flight.

1.9 Communication

1.9.1 The aircraft was equipped with a standard communication system as approved by the Civil Aviation Authority of Botswana. No defects that could render the communication system unserviceable were recorded before the flight.

1.10 Aerodrome Information

1.10.1 The incident occurred during the climb phase from FAOR.

Aerodrome Location	Kempton Park, Gauteng province	
Aerodrome Status	Licensed	
Aerodrome Co-ordinates	26°08'01.30" South 028°14'32.34" East	
Aerodrome Elevation	5 558ft	
Runway Headings	03L/21R	03R/21L
Runway Dimension	4 421m x 60m	3 405m x 60m
Runway Used	03L	
Runway Surface	Asphalt	
Approach Facilities	Runway lights, PAPI, DVOR / DME (JSV), ILS LOC and ILS GP for both runways	
Tower Frequency (West)	118.10 MHz	
Tower Frequency (East)	118.60 MHz	

1.11 Flight Recorders

1.11.1 The ATR 72-600 (incident aircraft) is equipped with two flight recorders:

1. The flight data recorder (FDR) system that records all mandatory flight data parameters on:
    - The flight data recorder (FDR)
    - The quick access recorder (QAR)

2. The cockpit voice recorder (CVR) system records:
    - All voice communications to and from the flight deck between the aircraft and any other station.
    - All voice communications between the cockpit crewmembers.
    - All aural warnings and the cockpit environment and Datalink communication.

1.11.2 The aircraft is fitted with a L3 Harris FDR, L3 Harris CVR and a QAR.

	FDR	CVR	QAR
Type	Solid State	Solid State	Solid State
Part Number	2100-4245-60	2100-1225-22	261065723-3000
Serial Number	001213245	001140075	2610657231100

1.11.3 The reviewed QAR data: (Source: Aircraft Manufacturer)

10.26.34Z: *Take-off power was set with PL in the notch (75° HMU). Take-off was performed with both bleed valves closed. During take-off, the speed target was recorded at 132kt. Super Boost was selected. While in-flight, Flight Director engaged modes were LNAV / IAS and YD was engaged.*

***10.27.37Z**: At 790ft AGL*

- *Power Management was changed from Take-Off to Climb position.*
- *Both engine bleed valves opened, and both packs valves opened.*
- *Indicated Air Speed target changed from 132kt to 170kt.*

And several engine 2 parameters started to fluctuate, as follows:

- Torque 2: variations of around +/-5% around the torque 1 average value

- OIL pressure 2: variations of around +/-10 PSI

- Fuel flow: variations up to +/-25 KG/H

- High-Pressure Spool Rotation Speed (NH2) and Low-Pressure Spool Rotation Speed (NL2) also varied.

Engine Electronic Control (EEC2) remained ON.

Crossing 1120ft AGL, Autopilot was engaged, vertical mode changed to PITCH HOLD, and IAS target changed to 160kt.

***10.29.42Z:** While still climbing*

Power Lever (PL) 2 then PL1 were moved from the notch = 75°Hydromechenical Unit (HMU) to ~70° HMU.

***10.30.52Z:** Flight Level 85*

High Pressure bleed 2 valve and pack valve 2 closed during ~40 seconds then re-opened.

<u>BLEED VALVE 2 FAULT</u> procedure was displayed.

Torque 2 objective increased and, after ~30 seconds of more stable engine 2 parameters, their variations increased again, for example torque 2 varied between 67% and 81% during the next 2 minutes.

***10.31.54Z:** Flight Level 93*

PL1&2 were moved again backward to ~63°HMU, with a minimum of Torque 2 recorded at 67%, then they were both moved close to the notch.

The difference between fuel flows 1&2 was around 30 KG/H in average (FF2 > FF1) and difference between inter turbine temperature (ITT) 1&2 was around 30°C in average (ITT2>ITT1).

EEC2 remained ON.

10.32.53Z:

Fluctuations were no more visible on most of the engine 2 parameters, only OIL pressure 2 remained fluctuating. ITT2 remained around 35°C above ITT1.

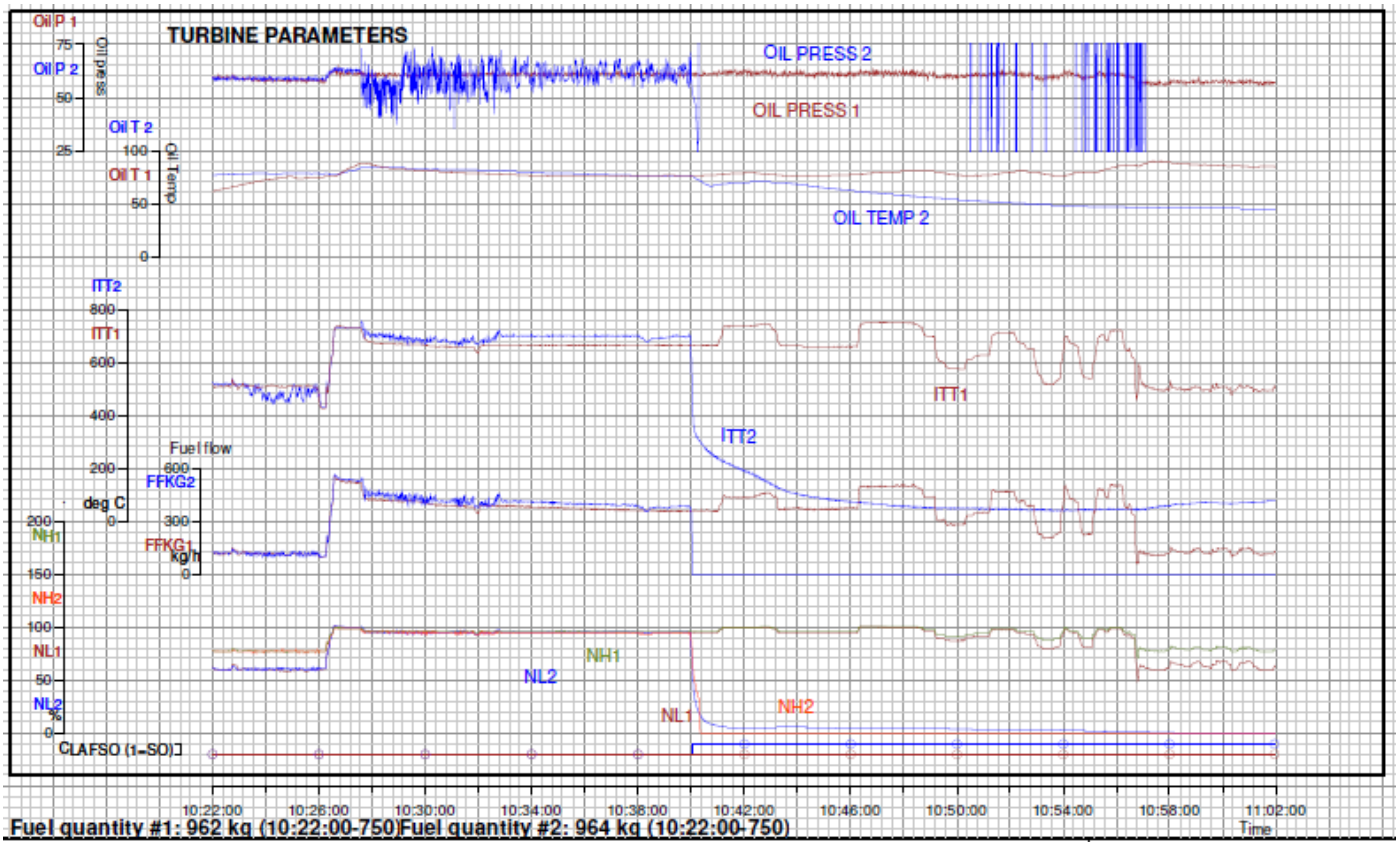


Figure 4: Engine parameters (Oil, ITT, Fuel flow, NH and NL) from take-off until FL 93. (Source: QAR)

10.37.28Z: *Flight Level 129*

EEC 2 was recorded FAULT or OFF until the end of the flight.

EEC 1 (2) FAULT procedure was displayed.

PL remained in the notch positions (75° HMU).

10.38.03Z - 10.39.17Z *(duration 1 minute 15 seconds):*

Torque 2 decreased below torque 1 (TQ2=65% vs TQ1=72%) while both PL remained close to the notch. Both NH remained constant (+/- 1%, resolution = 1%).

A decrease on the average value on other engine 2 parameters was also observed (ITT2 by 20°C, FF2 by 35KG/H, NL2 by 1.5%).

10.39.03Z: *Flight Level 138*

Vertical mode changed to vertical speed with a target at +200ft/min while aircraft was climbing towards FL140. Altitude target was changed from FL160 to FL140.

10.39.16Z: *Reaching Flight Level 140*

Torque 2 was close to torque 1. Master warning and Engine fire warning triggered.

ENG 2 FIRE IN FLIGHT procedure was displayed.

Then Altitude mode engaged, and aircraft levelled off at FL140.

10.39.53Z: *36 seconds after Master Warning triggered*

NH remained at 95%, beta2 started to increase, NP2 decreased towards 35% and torque 2 started to increase to 100%. Both PL remained in the notch.

10.40.01Z:

Condition Lever 2 was set on fuel shut off position. PL2 remained in the notch.
Engine 2 parameters (NL2, NH2, NP2, FF2, ITT2, OILP2, OIL temperature 2) decreased.
Engine 2 bleed valve and pack 2 control valve closed.

10.40.14Z:

ENG2 Fire warning was no more triggered.
SINGLE ENGINE OPERATION procedure was displayed.
Then aircraft started a left turn to perform an inflight turn back to FAOR.

10.40.37Z:

Autopilot and Yaw Damper were re-engaged. Rudder trim moved to +11.8° (nose left) while Indicated Air Speed (IAS) was decreasing toward 146kt (IAS target = 160kt).

10.41.01Z:

Both PL were moved forward above the notch, then were pulled back to the notch. PWR MGT was set to maximum continuous. NP1 increased to 100%.
Then PL2 was moved to FI position.

10.42.10Z: *Level off at Flight Level 140*
Aircraft started its descent in VS mode with selected altitude at FL100. IAS increased from 146kt (IAS target was 160kt).
Then, selected altitude was lowered to 8000ft and later to 7000ft.

10.45.10Z: *Flight Level 100 and descending*
TCAS status changed to Traffic Advisory only and APM was set to OFF.

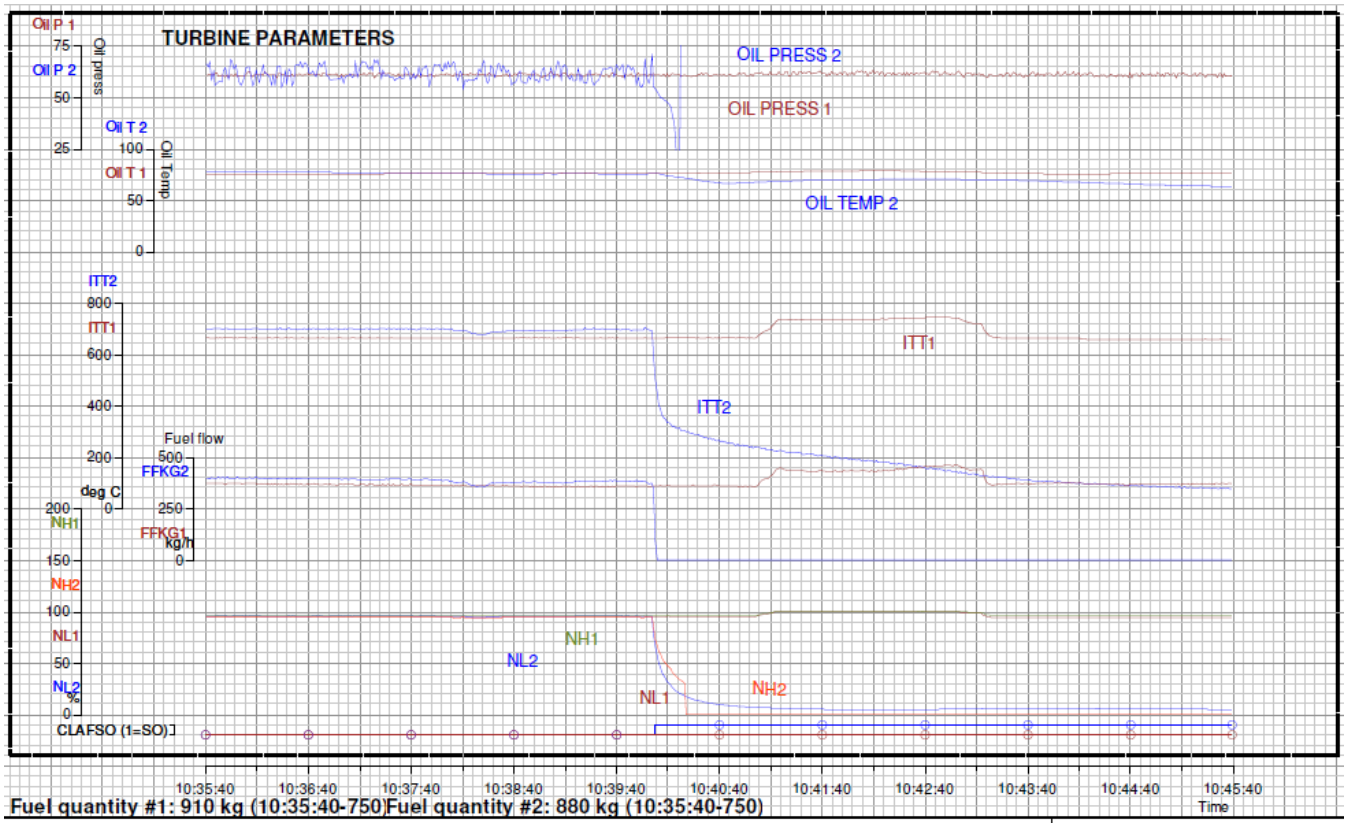


Figure 5: Engine parameters (Oil, ITT, Fuel flow, NH and NL) from engine fire warning until ENG 2 shut down. (Source: QAR)

10.55.00Z: *1400ft AGL*

Aircraft landing configuration finished to be deployed (gears down and FLAPS 30).

10.55.17Z: *1000ft AGL*

Aircraft was performing an ILS approach to runway 03L with AP engaged in LOC / GS modes. The aircraft was close to the glide path and LOC beam.

IAS was close to the IAS target, which was recorded as 123.13 kt.

Aircraft was in landing configuration (gear selected down, flaps 33 extended). Selected altitude was 8300ft.

Right rudder pedal effort was observed up to 150N while AP was engaged, rudder trim increased towards the maximum nose left position (+13.7°).

10.55.45Z: *650ft AGL*

AP then YD disengaged.

Descent rate started to reduce, and the aircraft flew above the glide path.

10.56.08Z: *450ft AGL*

Rudder trim was changed from the maximum nose left position (+13.7°) to the neutral position.

10.56.30Z: *70ft AGL*

LOC and glide deviations were close to 0mV.

Then aircraft uneventfully touched down and performed its rollout without reverses.

1.12 Wreckage and Impact Information

1.12.1 The aircraft was on the climb phase from FAOR and, whilst passing FL87 the crew noticed torque fluctuations and ITT increase by approximately 40°C on the ENG 2 parameters. At FL130, the master caution and the EEC fault warning lights illuminated. At FL140, the ENG 2 fire warning light illuminated. The crew complied with the engine fire checklist recommendations and shut down ENG 2; the fire alert was reset without discharging the fire extinguishing bottles. After shutting down the engine, they returned to FAOR and successfully landed the aircraft on Runway 03L.

Post-incident inspection of the ENG 2 revealed that the exhaust pipe, turbine blades, exit vanes and handling bleed valve (HBV) electrical connector were damaged. The inspection also revealed that there were exhaust pipe metal pieces on the bottom cowling. All engine damage was contained in the engine cowlings.

1.13 Medical and Pathological Information

1.13.1 None.

1.14 Fire

1.14.1 The ENG 2 fire warning indication illuminated but there was no evidence of fire in the engine compartment.

1.15 Survival Aspects

1.15.1 The incident was survivable as the crew was able to shut down the affected engine, return to departure airport, and land the aircraft without further damage.

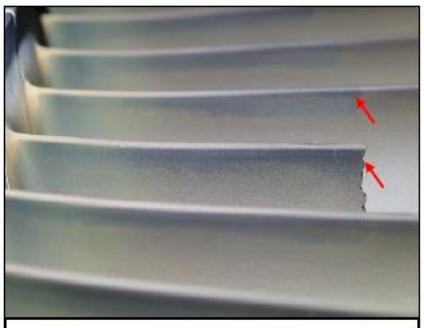
1.16 Tests and Research

1.16.1 Engine Shop Findings Report (Source: Engine Manufacturer)

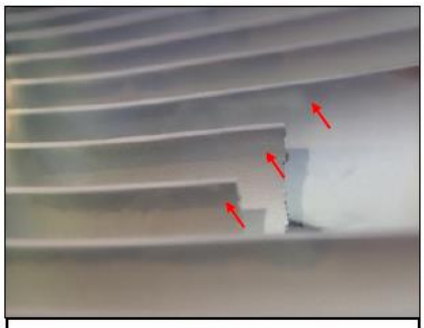
Teardown:

- *Performed modular teardown of the Hot Section module in accordance with (i.a.w) PW127N Maintenance Manual and approved DAA data for LLP access.*
- *Performed modular teardown of the Cold Section module i.a.w. PW127N Overhaul Manual and approved DAA data for LLP access.*
- *Performed borescope inspection on reduction gearbox (RGB) module in accordance with PW127N Maintenance Manual (MM), condition found satisfactory.*
- *Inspect hot section components i.a.w MM/HSI limits.*
  1. Three 2nd stage PT blades were found to have fractured off at the aerofoil coated

area about one third above the platform. Two off fractured blades and one full blade with ECI indication was sent for lab analysis on the fractured surface.

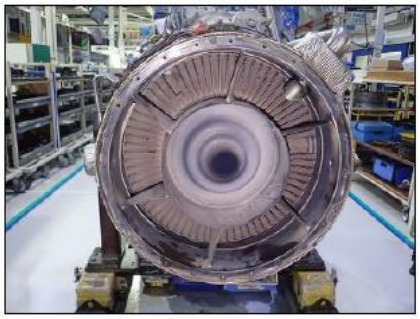


Coated area

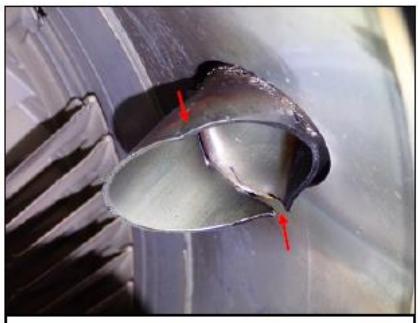


Coated area

2. Exhaust duct and the accessory gearbox (AGB) breather tube was found with impact damage.



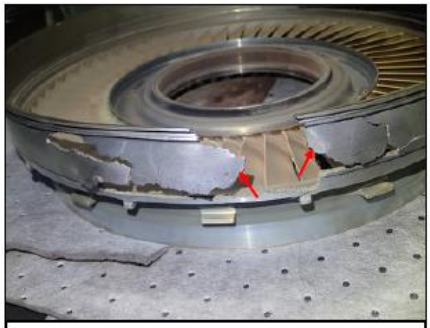
Distressed



Impact damage

Impact damage

3. PT2 stator was found with missing material on the outer shroud area.

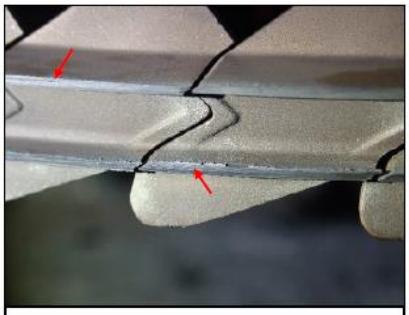


Distressed

Distressed

4. PT1 blades were found intact, severe rubbing was noticed on the outer platform shroud seal.

Nil abnormality



Rubbing

Rubbing

- *Visual inspect cold section components i.a.w CIR.*
  1. Two off GGC diffuser pipes were found fractured.
- *Complied with PW100 Master Specification, GPW100-001 Rev. 2.15 dated 17 Feb 2014.*
- *Complied with all applicable ADs.*

Conclusion:

- *Damages observed are mostly isolated to the 2nd stage power turbine (PT2) blades location and downstream. There were no signs of missing material upstream of the PT2 stator to suggest that the root cause of the blade failure could be from upstream of the PT2 blades. The three fractured blades were also noted to have fractured at the coating area.*
- *Scanning electron microscopy (SEM) analysis on the fractured PT2 blades found traces of chromium sulphide (CrS) in the coated area which suggest sulphidation on the coated area. It is highly likely that the crack initiated from the chromium coating sulphidation area and led to the eventual blade failure.*
- *The part number of the PT2 blades were 3124654-01 (post SB21876) chromium coated blades. Reliability of this PT2 blade configuration can be improved. SB 21917 was issued with category 5 recommended compliance code to replace SB21876 configuration PT2 blades. SB21959 introduced the latest configuration.* (See Appendices)
- *The blades distress probably led to unbalance in the PT rotor and induced high vibration in the engine. This could be observed from the severe rubbing noted on various parts upstream, especially on LP impeller, LP shroud segments, HP impeller, GGC diffuser pipes fracture, turbine interstage case interstage seal and 1st stage PT blades.*
- *All observed defects will be rectified at this shop visit and the engine may be released for continued service following a successful test cell run.*

1.16.2 PT2 blade Service Bulletins (Source: Engine Manufacturer)

With the objective to increase reliability of the PT2 blades installed on the PWC 100 engine series, a new configuration with a chromium coating was introduced under SB21876. Following its introduction, this newer configuration has demonstrated low time distress mechanisms, prompting the engine manufacturer to implement an eddy current inspection (ECI). Method on post SB21876 PT2 blades. While the ECI inspection method has demonstrated effectiveness, a new configuration of the PT2 blades was later introduced under SB21959.

1.17 Organisational and Management Information

1.17.1 The operator was initially issued an Air Operating Certificate (AOC) by the State of Registry and State of Operator, Botswana, on 30 March 2021 with an expiry date of 30 April 2022.

1.17.2 The operator was issued an international scheduled Air Service Licence (ASL) by the State of Registry and State of Operator, Botswana, on 8 February 2021 with an expiry date of 7 February 2022.

1.17.3 The operator was issued a Foreign Operator's Permit (FOP) by the state of occurrence to operate charter flights between 1 June 2021 and 31 March 2022 or until the International Air Services Council is appointed, whichever comes first.

1.17.4 The aircraft maintenance organisation (AMO) which carried out the last maintenance inspection (A Check) prior to the incident flight was in possession of an approved AMO certificate that was issued by the Civil Aviation Authority of Botswana on 26 April 2021 with an expiry date of 6 December 2022, unless cancelled, suspended or revoked.

1.18 Additional Information

1.18.1 Protecting your engine against sulphidation (Source: Pratt and Whitney)

[Sulphidation] can do serious damage to engines; however, there are actions you can take to minimise it. Engine sulfidation is a chemical reaction that occurs at high temperature ranges. Sulphur contained in your aircraft's fuel combines with salt and other airborne contaminants in the intake air to create a corrosive mixture that attacks metal components. Unless you take the proper maintenance actions, sulfidation could lead to major engine damage. For instance, it can attack and erode the protective surface coating of turbine blades, gradually forming blister scales and undermining their mechanical integrity.

1.19 Useful or Effective Investigation Techniques

1.19.1 None.

2. ANALYSIS

2.1. General

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

2.2. Analysis

2.2.1. Weather

The METAR for FAOR on 30 December 2021 indicated fine weather conditions at the time of the serious incident. The weather was not a contributory factor to this incident.

2.2.2. Crew

The PIC was qualified to act as a pilot-in-command and had a valid ATPL and a Class 1 medical certificate. The PIC was issued an ATR 72-600 aircraft rating to act as a pilot-in-

command or co-pilot. The FO was qualified to act as a co-pilot with a valid ATPL and a Class 1 medical certificate. The FO was issued an ATR 72-600 aircraft rating to act as a co-pilot. After the ENG 2 fire warning, the captain shut it down as per the QRH and, thereafter, returned to the departure airport.

2.2.3. Aircraft

The aircraft was on an autopilot climb phase from FAOR. As the aircraft passed FL87, there were fluctuations noted on the ENG 2 torque value, oil pressure, fuel flow, high- (NH2) and low-pressure spool rotation speed (NL2). The PIC moved the power lever (PL) down as per the QRH recommendation on abnormal engine parameters, but at this stage the EEC2 remained on. As the aircraft passed FL93, the PIC moved the PL down again, and ITT2 was approximately 35°C higher than ITT1. When the aircraft passed FL129, EEC2 fault warning light activated, and the PIC moved the PL down to the green sector (below 59° hydromechanical unit [HMU]) as per the QRH recommendation on EEC fault. The crew requested to stop the climb at FL140 and, as they reached FL140, the ENG 2 fire warning activated. The PIC set the condition lever (CL) of ENG 2 to fuel shut-off and feathered ENG 2 propellers as per the QRH recommendation on engine fire in-flight. Eight seconds later, the ENG 2 parameters (NL2, NH2, FF2, ITT2, OILP2, Oil Temp 2) and the propeller rotation speed decreased, and the PIC closed the bleed valve and pack 2 control valve. The ENG 2 fire warning activated, and the crew made a request to ATC to return to FAOR for a single engine landing.

The cause of the engine fire warning and the fluctuations of the ENG 2 parameters were attributed to the engine air intake as it was climbing. When ambient air combines with compounds such as sulphur in the engine fuel, it is transported to the high temperatures of the hot section of the turbine engine, and a chemical reaction occurs on the chromium-coated PT2 blades of the engine. This process is called sulphidation; it corroded the (chromium sulphide [CrS]) fractured part of the PT blades and, subsequently, led to the failure of the three blades in-flight. The failure of the blades caused an imbalance in the PT rotor and high vibration in the engine, this further damaged the PT2 stator outer shroud, P10 connector, AGB breather tube and exhaust duct.

Engine manufacturer mitigation action:

- Service Bulletin (SB) 21876 dated October 2017: *"Second stage PT blade resistance to corrosion caused by [sulphidation] can be improved by replacing the blades with one that has chromium coating*". ENG 2 was manufactured in November 2016, and had complied to the SB 21876 which required the replacement of the power turbine blades with ones that are chromium-coated.
- The SB 21917 dated March 2019: *"Replace the post SB21876 coated blades with ones that do not have chromium due to the chromium coating causing sulphidation in a number of engines in operation. The SB was issued by the engine manufacturer with a Category 5; recommended to be done during an engine overhaul, and access*

is available to the necessary subassembly". The engine manufacturer recommended that the engine type overhaul interval should be at 7000 hours and the hours since new of the incident engine were at 4405.3, which meant that they had not yet reached the overhaul hours. Hence, the failed PT2 blades still had the chromium coating.

- SB 21959 dated August 2022: *"There are reports of second stage (PT2) blade fractures in-service. This could be caused by sulphidation assisted fatigue. Replace the PT2 blades with ones that have a modified airfoil shape to reduce stress levels and application of a new coating for improved [sulphidation] resistance. This necessitates a modification to the power turbine vane ring, which requires additional machining to maintain the required clearance with the PT2 blade."* With the introduction of the latest SB, there has been a noticeable decrease in the number of failed PT2 blades in-service.

3. CONCLUSION

3.1. General

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

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

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

3.2. Findings

3.2.1 The PIC had an Airline Transport Pilot Licence (ATPL) that was issued on 26 March 2021 with an expiry date of 31 March 2022. According to the hours derived from the pilot questionnaire, he had flown a total of 17 510 hours, of which 14 155 hours were on the aircraft type. The PIC was issued a valid Class 1 medical certificate on 30 August 2021 with an expiry date of 30 March 2022 with a restriction to wear corrective lenses.

3.2.2 The FO had an ATPL that was issued on 26 March 2021 with an expiry date of 28 March 2022. According to the hours derived from the pilot questionnaire, he had flown a total of

3 972 hours, of which 3 466 hours were on the aircraft type. The FO was issued a Class 1 medical certificate on 11 March 2021 with an expiry date of 30 March 2022.

3.2.3 The aircraft was first registered to the current owner on 1 November 2018. The aircraft had a valid Certificate of Airworthiness (C of A) that was initially issued on 2 November 2018. The latest C of A had an expiry date of 31 October 2022.

3.2.4 The operator was issued an Air Operating Certificate (AOC) by the State of Registry and State of Operator, Botswana, on 30 March 2021 with an expiry date of 30 April 2022.

3.2.5 The AMO had a valid AMO certificate that was issued on 26 April 2021 with an expiry date of 6 December 2022, unless cancelled, suspended or revoked.

3.2.6 The last maintenance inspection (A Check) on the aircraft was carried out on 12 October 2021 at 4079.0 airframe hours. The aircraft had accumulated an additional 326.3 airframe hours in operation since the last inspection, and no major defects were recorded.

3.2.7 The weather at the time of the serious incident did not contribute to this occurrence.

3.2.8 Shortly after take-off during climb, the master caution light and EEC fault indication lights illuminated, followed by the ENG 2 fire warning light. The crew shut down ENG 2 and returned to FAOR where the aircraft landed safely on Runway 03L.

3.2.9 The QAR data revealed that the engine parameter fluctuations were consistent with mechanical damage in the engine module. The fluctuations led to engine vibrations which caused some of the debris to cut the HBV connector and the jet pipe.

3.3. Probable Cause/s

3.3.1 During the climb phase, three PT2 blades of the hot section of ENG 2 fractured on the chromium-coated section; this led to the failure of the three blades in-flight which subsequently caused other failures in the engine and, thus, the crew's decision to shut down the engine.

3.4. Contributory Factor/s

3.4.1 The three chromium plated PT2 blades were subjected to sulphidation which led to the fracture during operation.

4. SAFETY RECOMMENDATIONS

4.1. General

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

4.2. Safety Recommendation/s

4.2.1 None.

5. APPENDICES

5.1 Appendix 1. Service Bulletin 21876
5.2 Appendix 2. Service Bulletin 21917
5.3 Appendix 2. Service Bulletin 21959

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

Appendix 1: Service Bulletin 21876

PRATT & WHITNEY CANADA

SERVICE BULLETIN

P&WC S.B. No. 21876R3

BULLETIN INDEX LOCATOR
72-50-01 / 72-53-00

TURBOPROP ENGINE
SECOND STAGE POWER TURBINE BLADES - REPLACEMENT OF

MODEL APPLICATION

PW119B, PW119C, PW123, PW123B, PW123C, PW123D, PW123E, PW123AF, PW124B, PW125B, PW126, PW126A, PW127, PW127B, PW127E, PW127F, PW127G, PW127H, PW127J, PW127M, PW127N

Commercial Support Program No: 1008617

Compliance: CATEGORY 7

Summary: Second stage PT blade resistance to corrosion caused by sulfidation can be improved. Replace the blade with one that has chromium coating.

PRATT & WHITNEY CANADA

SERVICE BULLETIN

P&WC S.B. No. 21876R3

TURBOPROP ENGINE
SECOND STAGE POWER TURBINE BLADES - REPLACEMENT OF

1. Planning Information (Cont'd)

C. Reason

(1) Problem

Second stage PT blade resistance to corrosion caused by sulfidation can be improved.

(2) Cause

No protective coating.

(3) Solution

Replace the blade with one that has chromium coating.

D. Description

Replace 2nd stage PT blades with new ones.

E. Compliance

CATEGORY 7 - You can do this service bulletin when the supply of superseded parts is fully used.

Appendix 2: Service Bulletin 21917

PRATT & WHITNEY CANADA

SERVICE BULLETIN

P&WC S.B. No. 21917R7

BULLETIN INDEX LOCATOR

72-50-01

TURBOPROP ENGINE
SECOND STAGE POWER TURBINE (PT) BLADES - REPLACEMENT/MODIFICATION OF

MODEL APPLICATION

PW119B, PW119C, PW123, PW123B, PW123C, PW123D, PW123E, PW123AF, PW124B, PW125B, PW126, PW126A, PW127, PW127B, PW127E, PW127F, PW127G, PW127H, PW127J, PW127M, PW127N

Commercial Support Program No: 1008734

Compliance: CATEGORY 5, 7

Summary: The second stage Power Turbine (PT) blade durability may be improved. Replace the serialized PT blade with one that does not have chromium coating.

PRATT & WHITNEY CANADA

SERVICE BULLETIN

P&WC S.B. No. 21917R7

TURBOPROP ENGINE
SECOND STAGE POWER TURBINE (PT) BLADES - REPLACEMENT/MODIFICATION OF

1. Planning Information (Cont'd)

(3) Solution

Replace the serialized PT blade with one that does not have a chromium coating.

D. Description

Replace the serialized PT blade with new ones.

E. Compliance

For Engines that have Post-SB21876 PT2 Blades:

CATEGORY 5 - P&WC recommends to do this service bulletin when the engine is disassembled and access is available to the necessary subassembly (i.e. module, accessories, components, or build groups)

For Engines that are Pre-SB21876 PT2 Blades:

CATEGORY 7 - You can do this service bulletin when the supply of superseded parts is fully used

Appendix 3: Service Bulletin 21959

PRATT & WHITNEY CANADA

SERVICE BULLETIN

P&WC S.B. No. 21959R4

BULLETIN INDEX LOCATOR
72-50-01 72-53-00

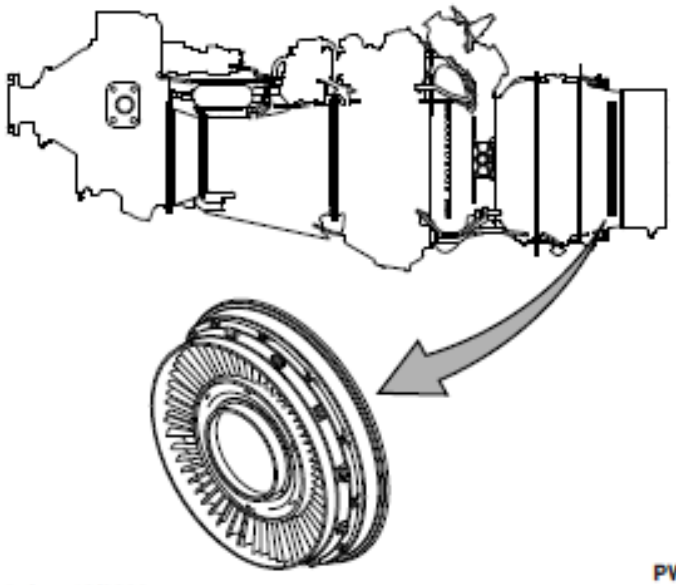
TURBOPROP ENGINE
SECOND STAGE PT STATOR BLADES - REPLACEMENT/MODIFICATION OF

MODEL APPLICATION

PW119B, PW119C, PW123, PW123B, PW123C, PW123D, PW123E, PW123AF, PW124B, PW125B, PW126, PW126A, PW127, PW127B, PW127E, PW127F, PW127G, PW127H, PW127J, PW127M, PW127N

Compliance: CATEGORY 7

Summary: There are reports of second stage power turbine (PT2) blade fractures in service. This could be caused by sulfidation assisted fatigue. Replace the PT2 blades with ones that have a modified airfoil shape to reduce stress levels and application of a new coating for improved sulfidation resistance. This necessitates a modification to the power turbine vane ring, which requires additional machining to maintain the required clearance with the PT2 blade.



Feb 25/2021
Revision No. 4: Aug 19/2022

PW100-72-21959
Cover Sheet

1. Planning Information (Cont'd)

C. Reason

(1) Problem

There are reports of second stage power turbine (PT2) blade fractures in service.

(2) Cause

This could be caused by sulfidation assisted fatigue.

(3) Solution

Replace the PT2 blades with ones that have a modified airfoil shape to reduce stress levels and application of a new coating for improved sulfidation resistance.

D. Description

Replace the PT stator assembly with a new or modified one.

E. Compliance

Deleted

CATEGORY 7 - Do this service bulletin when the supply of superseded parts is fully used.